CAREC ENERGY OUTLOOK 2030

DECEMBER 2022

CAREC
Central Asia Regional Economic Cooperation Program

ADB

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ISBN 978-92-9269-954-3 (print); 978-92-9269-955-0 (electronic); 978-92-9269-956-7 (ebook)
Publication Stock No. TCS220577-2
DOI: http://dx.doi.org/10.22617/TCS220577-2

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Notes:
In this publication, "$" refers to United States dollars and "CNY" refers to yuan.
ADB recognizes "China" as the People's Republic of China and "Kyrgyzstan" as the Kyrgyz Republic.

Cover design by Francis Joseph Manio.

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ABBREVIATIONS

ADB	Asian Development Bank
BAU	business-as-usual
bcm	billion cubic meters
bcma	billion cubic meters per annum
BESS	battery energy storage system
Btu	British thermal unit
CAGR	compound annual growth rate
CAPS	Central Asian Power System
CAREC	Central Asia Regional Economic Cooperation
CCUS	carbon capture, utilization, and storage
CHP	combined heat and power
CO_2	carbon dioxide
COP26	26th United Nations Climate Change Conference of the Parties
COVID-19	coronavirus disease
CSP	concentrated solar power
DSO	distribution system operator
EBRD	European Bank for Reconstruction and Development
ETS	emissions trading scheme
EU	European Union
EV	electric vehicle
GDP	gross domestic product
GHG	greenhouse gas
GNERC	Georgian National Energy and Water Supply Regulatory Commission
GW	gigawatt
HPP	hydropower plant
IBRD	International Bank for Reconstruction and Development
IEA	International Energy Agency
IFC	International Finance Corporation
IFI	international financial institution
IRENA	International Renewable Energy Agency
kV	kilovolt

kWh	kilowatt-hour
LNG	liquefied natural gas
m^2	square meter
mtpa	million tons per annum
MVA	megavolt-ampere
MW	megawatt
MWh	megawatt-hour
NDC	Nationally Determined Contribution
NSMP	North–South Main Gas Pipeline
PPA	power purchasing agreement
PPP	public–private partnership
PRC	People's Republic of China
PV	photovoltaic
R&D	research and development
SAIDI	system average interruption duration index
SAIFI	system average interruption frequency index
SCADA	supervisory control and data acquisition system
SCP	South Caucasus Pipeline
SGCC	State Grid Corporation of China
T&D	transmission and distribution
toe	ton of oil equivalent
TSO	transmission system operator
TW	terawatt
TWh	terawatt-hour
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
US EIA	United States Energy Information Administration

EXECUTIVE SUMMARY

CAREC Energy Outlook 2030: A Strategic Decision-Making Tool

Energy systems globally are undergoing major transformation, and member countries of the Central Asia Regional Economic Cooperation (CAREC) program are no exception. The region faces a wide range of potential directions it can take in shaping its future energy systems. Choosing a direction requires investors, policy makers, and other stakeholders to make important strategic decisions that will impact the future design, functioning, and sustainability of the regional energy sector.

CAREC Energy Outlook 2030 comprehensively analyzes options for future energy market development in CAREC countries and is one of the flagship projects under the CAREC Energy Strategy 2030.

The principal goal of this report is to facilitate sustainable investments in energy infrastructure by equipping stakeholders with critical insights and assessments of regional energy market trends. The intention is to support investors and policy makers in identifying potential investment opportunities that will improve the quality of energy services and reduce carbon emissions across CAREC countries.

CAREC Energy Outlook 2030 covers a time horizon through 2030. Although forecasting market trends and investment needs are an important part of the analysis, the purpose of these forecasts is not to predict the future (i.e., the exact level of energy supply, demand, or related emissions). The purpose rather is to show potential outcomes of certain actions from private investors and the government under different scenarios.

CAREC brings together countries with vibrantly growing economies that are projected to rebound swiftly from pandemic-induced adversities. Coupled with a rapid increase in population expected in most CAREC countries, economic growth is certain to drive up demand for energy. Yet increase in demand for energy can be significantly tempered if countries improve efficiency of energy consumption. Multiple CAREC countries are currently ranked among the 20 least energy-efficient economies of the world, underlining the vast potential for energy savings and more rational use of resources, which can also contribute to mitigation of financial and environmental challenges in the energy sector.

Consequently, a central theme addressed in *CAREC Energy Outlook 2030* is climate change. This not only reflects the rising environmental pressure faced by stakeholders globally, but also commitments that CAREC member countries have made in recent years to transition to more sustainable energy systems and practices. Several CAREC countries submitted renewed and stricter Nationally Determined Contributions (NDCs) during the 26th United Nations Climate Change Conference of the Parties (COP26) held in Glasgow in 2021, which are reflected in this report.

The report consists of four key elements:

(i) **Supply and Demand Outlook** investigates future energy balances focusing on supply and demand as well as energy efficiency;
(ii) **Technology Outlook** sheds light on global trends in energy technology and outlines priority technologies for the region to achieve energy security and sustainability goals;
(iii) **Investment Outlook** estimates investment requirements in the region as well as global trends in energy investments, complemented by private investment case studies and the role of international financial institutions; and
(iv) **Carbon Emissions Outlook** assesses the carbon footprint resulting from combustion of energy sources and implications toward meeting various climate change targets.

All forecasts have been conducted for each individual CAREC country as well as on an aggregate regional level. This Executive Summary provides a brief overview of the main conclusions at both regional and country levels.

Major Regional Energy Market Dynamics Through 2030

Electricity is set to be one of the most rapidly growing sources of energy through 2030.

Energy demand within CAREC countries is expected to demonstrate double-digit growth until 2030. The implementation of energy efficiency measures will determine the ultimate level by which demand growth may be constrained. Electricity will be one of the most rapidly growing sources of energy through 2030, and so will be the transition fuel natural gas, partly at the expense of coal.

Energy efficiency investments are one of the most potent tools to introduce technology shifts and accelerate decarbonization.

CAREC countries have significant scope to improve efficiency by advancing energy management systems and rehabilitating infrastructure and equipment. High transmission and distribution (T&D) losses remain an important challenge.

The massive technical potential of renewables can significantly contribute to phasing out fossil fuels.

Significant technical potential of renewables in many CAREC member countries remains open for exploitation. Several renewable energy projects have been realized in recent years across CAREC as part of government efforts to mitigate greenhouse gas (GHG) emissions and diversify energy supply.

Development of hydrogen technologies can contribute to climate change mitigation and become a key lever of energy sector decarbonization.

Hydrogen is becoming an increasingly important technology for the energy sector's decarbonization efforts. Hydrogen and battery energy storage systems can play a significant role in the integration of renewable energy sources and phasing out of fossil fuels. At-scale deployment of these technologies will require government efforts to support innovation and technology transfer between countries.

Development of cross-border infrastructure can increase energy supply security.
Development of cross-border infrastructure and increasing interconnectivity of energy systems can help boost regional energy security by stabilizing energy supply and demand, expanding energy trade, and strengthening economic cooperation between CAREC countries.

Cumulative emissions have the potential to decrease under certain scenarios.
CAREC countries commit to act on climate change by individually submitting their NDCs (pre- and post-COP26) with varying targets across countries. The analysis in this report shows a potential pathway to achieve global climate change targets by limiting increases in energy-related emissions across CAREC countries (without the People's Republic of China [PRC]) or even decreasing such cumulative emissions if the PRC is included in the forecast group.

Modernization of energy grids and renewable energy development require the most urgent investments until 2030.
CAREC countries offer substantial opportunities for investment in their energy sectors, stemming from significant potential in three main areas: (i) tremendous technical potential of renewable energy sources, (ii) an urgent need for modernization of upstream and midstream infrastructure, and (iii) large potential for energy savings via increased efficiency in energy consumption.

Developments in Individual CAREC Countries

CAREC countries can be split into several groups depending on their prevailing type of fuel and energy system background. CAREC brings together countries possessing large portfolios of natural resources, including water resources (hydropower), hydrocarbon reserves (natural gas and oil), coal, and biomass. In addition, several CAREC countries share a legacy of inherited energy infrastructure from the Soviet Union era.

Countries with a high share of hydropower: Georgia, Kyrgyz Republic, and Tajikistan
Despite extensive access to emissions-free hydropower, its seasonality poses several challenges for year-round energy security in Georgia, the Kyrgyz Republic, and Tajikistan. To balance seasonal fluctuations, these countries require backup systems that include fossil-based power generation in the short- to medium-term, given that other technologies are yet to be developed. These backup systems may ideally give preference to natural gas due to its lower environmental impact than coal. These countries can also promote cross-border trade in energy to ensure the effective use of natural resources across the region.

Countries with a high share of hydrocarbons: Azerbaijan, Kazakhstan, Turkmenistan, and Uzbekistan
Hydrocarbon-rich economies historically benefited from vast energy production and exports. Yet, growing environmental pressure requires these economies to change course and reduce their consumption while accelerating the adoption of clean energy sources. Extensive oil and gas pipeline networks produce high losses due to aging infrastructure, so they require significant upgrades to reduce overall hydrocarbon consumption.

Countries with a high share of coal: Kazakhstan, Mongolia, and the People's Republic of China

Countries relying heavily on coal face the greatest challenges to decarbonize their energy sectors. Development of clean energy sources is key, especially considering the massive renewable potential in these countries. Integrating renewables requires modernizing network infrastructure, including T&D, as well as battery energy storage systems. Switching to transitional fuels, such as natural gas, and other clean fuels, such as hydrogen, are medium-term options to reduce the harmful effects of coal.

Country with a high share of biomass: Pakistan

Pakistan has a high share of biomass in its energy consumption, which is expected to gradually reduce as the share of natural gas increases. While Pakistan has a well-diversified energy supply overall, with availability of oil, natural gas, coal, nuclear, and hydropower, it is expected to promote the use of renewables considering future cost efficiencies and high technical potential.

Countries with historically inherited energy infrastructure: Azerbaijan, Georgia, Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan, and Uzbekistan

CAREC countries formerly part of the Soviet Union are today characterized by high access to power and natural gas due to the extensive T&D infrastructure built during that period. Given that this infrastructure is now significantly aging, it produces financial losses due to high leakage levels and requires modernization and significant energy efficiency upgrades.

Estimated Investment Needs by 2030

CAREC Energy Outlook 2030 estimates that CAREC countries, excluding the PRC, will have energy-related investment needs of $136 billion–$339 billion by 2030, depending on the scenario. The range rises to $2.9 trillion–$3.8 trillion if the total includes the PRC. The sheer magnitude of energy investment needs across CAREC countries implies that the private sector has a fundamental role to play in the transformation of regional energy systems. Several governments have made initial steps toward establishing competitive and liberalized energy markets, and there is a growing number of examples of successful private sector participation. Relevant case studies are incorporated in this report to illustrate success stories.

The development of modern energy systems across CAREC countries will involve a multitude of stakeholders, including investors, governments, and financiers. *CAREC Energy Outlook 2030* aims to facilitate strategic decision-making and collaboration among all stakeholders to achieve a sustainable CAREC energy sector in the long term.

The authors wish to express their sincere gratitude to CAREC governments for their support and transparency in preparing this publication. The CAREC Energy Outlook was prepared before February 2022, hence, major events and impacts occurring after this date are not reflected in this publication.

METHODOLOGY

CAREC Energy Outlook 2030 presents an analysis of trends that may determine energy sector development within the Central Asia Regional Economic Cooperation (CAREC) countries. For this purpose, CAREC countries are assessed individually in country outlooks and the findings are then synthesized into a regional overview. This CAREC-level overview provides assessments that both include and exclude the People's Republic of China (PRC) in order to show a more precise picture, given the relative size differentials between the PRC and other CAREC countries across most metrics.

To depict possible energy sector trends in the CAREC region, various assumptions were made, considering each country's individual consumer preferences, regulatory frameworks, technological development, and related investment opportunities.

The data presented in *CAREC Energy Outlook 2030* required scenario building and data modeling. This section describes the methodology used to establish the 2030 forecasts as well as data sources.

Scenarios for 2030 Projections

CAREC Energy Outlook 2030 comprises separate outlook sections for supply and demand, technology, carbon emissions, and investment for the region, and for each country individually based on three scenarios:

(i) **Business-as-usual scenario** assumes no major changes in energy systems and policies, electricity mix, and energy efficiency, resulting in substantial carbon emissions.
(ii) **Government Commitments scenario** considers the targets and priorities of CAREC governments—e.g., Nationally Determined Contributions (NDCs)—leading to moderate shifts in power generation mix and energy efficiency gains.
(iii) **Green Growth scenario** considers enhanced sustainable energy and environmental policies and accelerated economic growth, leading to increased energy efficiency and reduced carbon footprint.

These scenarios are not projections of what is likely to happen in the future. They rather explore potential implications of different energy policies and inform judgment about possible outcomes.

Sources

The forecasting methods and input figures used in *CAREC Energy Outlook 2030* were informed by analyses of reputable sources including

(i) **National stakeholders,** such as the ministries of energy and statistical committees of CAREC member countries;
(ii) **Publications by major institutions**, such as British Petroleum, Enerdata, Equinor, Fitch Solutions, and the International Energy Agency; and
(iii) **Inputs from regional and national experts**, including questionnaires answered by representatives of CAREC member countries.

Supply and Demand Modeling

Modeling of energy supply and demand in CAREC countries constitutes the heart of the analysis. The modeling approach is based on historical evolution of demand adjusted for expected efficiency gains by the consumption sector, in addition to multiple other factors. For instance, forecast of residential supply and demand also considers gross domestic product (GDP) growth per household, change in number of households, and degree of access to electricity and natural gas grids. Similarly, modeling of the transportation sector considers GDP growth per capita and change in population, in addition to usage trends and fuel shifts. Modeling supply and demand of energy for the industry, service, and agriculture sectors considers factors such as GDP evolution, historical usage trends, and expected fuel shifts amid technological improvements. Evolution of energy use by other sectors is based on analysis of historical developments.

As a rule, final energy demand is normally lower than the primary energy supply. This discrepancy varies from country to country and is dependent on the scenario. The difference is largely due to the process involved in transforming fuels into electricity. For example, 1 million tons of oil equivalent (toe) of thermal coal will translate to nearly 0.3 million toe in produced electric power (this ratio may differ from country to country). In several countries, this difference is exacerbated by transmission and distribution losses.

Greenhouse Gas Emission Modeling and Countries’ Commitments

The top-down greenhouse gas emission estimation in this report directly correlates with the modeling of energy supply and demand. Using supply and demand forecasts by fuel type and international emission factors per fuel, the model allows the calculation of carbon emissions for each scenario. Efficiency improvements are reflected as lower energy demand, lower technical and financial losses, and higher efficiency in electricity generation.

Several CAREC countries submitted renewed and stricter NDCs during the 26th United Nations Climate Change Conference of the Parties (COP26) in 2021. The models and forecasts related to carbon emissions are, however, based on NDCs made under the Paris Agreement, adopted in 2015, because they provide an all-inclusive basis for comparing CAREC countries, as not all countries submitted renewed NDCs.

In addition, many new NDCs focus on longer time horizons (e.g., 2050 or 2060) than the 2030 limit of this report. Where applicable, the renewed NDCs are still mentioned to ensure complete information and to highlight the importance of international cooperation to address climate change.

Modeling of Investment Needs

The modeling of investment needs is based on analysis of third-party publications as well as recent investments made in modernizing existing infrastructure. Investment requirements for 2030 were calculated subsequently, following the demand and supply forecast. These investments generally include only those in infrastructure required for the domestic market, not exports. The main reason is that export volumes are subject to multiple contingencies in global markets, so are harder to predict, therefore falling outside the scope of this report. The investment needs modeling is conducted for three main categories: new power generation capacities, grid modernization and expansion, and energy efficiency measures. The energy efficiency measures category is calculated separately based on national plans and programs, or benchmark investment needs required to achieve energy savings as per scenario assumptions.

Transmission towers. Total primary energy supplies among CAREC countries, excluding the People's Republic of China, are expected to increase by 30% on average by 2030 (photo by yelantsevv/Adobe Stock©).

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REGIONAL OUTLOOK 2030

Supply and Demand Outlook

The impact of the coronavirus disease (COVID-19) pandemic on the Central Asia Regional Economic Cooperation (CAREC) countries has been varied, with moderate impacts across member countries.[1] Excluding the People's Republic of China (PRC), this has resulted in a cumulative decline in nominal gross domestic product (GDP) growth of –2.0% in 2020. In an optimistic scenario, CAREC countries, excluding the PRC, are expected to gradually recover and achieve a strong rebound of 10.3% annual growth by 2030, also leading to increased future energy consumption.

Primary Energy Supply Trends in CAREC Countries, excluding the People's Republic of China

Overall, total primary energy supplies among CAREC countries, excluding the PRC, are expected to increase by 30% on average by 2030—from 280 million tons of oil equivalent (toe) in 2020 to 334–402 million toe in 2030, depending on the scenario. Under the Green Growth scenario, which assumes intensive energy efficiency measures, increases in primary energy supplies are expected to be most constrained (1.9% annually to 2030). Under the Government Commitments scenario, supplies are expected to grow at a slightly higher rate (2.4% annually), resulting in a primary energy supply of 356 million toe by 2030. In contrast, under the Business-as-Usual (BAU) scenario, energy supplies will grow more rapidly (3.5% annually) by 2030, given more limited energy efficiency measures.

From the fuel mix perspective, the total primary energy supply in CAREC, excluding the PRC, is projected to remain highly reliant on natural gas until 2030. Across all scenarios, the share of natural gas in the energy mix is projected to increase, reaching 43%–48% by 2030, reflecting its dominance as a fuel in the power generation mix as well as the large direct consumption of natural gas in the residential and industrial sectors. As governments set more ambitious climate targets, renewable and nuclear energy sources will be gradually introduced into the primary energy mix as replacements for conventional fuels, with a combined share that will almost triple by 2030 under the Government Commitments scenario (Figure 1).

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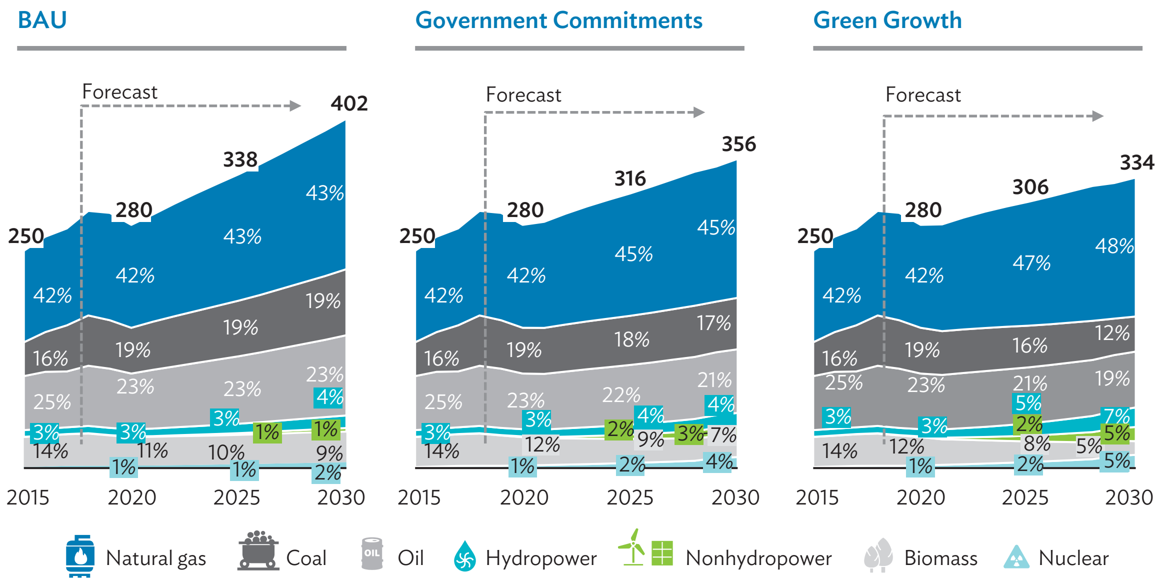
[1] The CAREC program has a membership of 11 countries, with the original eight members being Afghanistan, Azerbaijan, the People's Republic of China (Xinjiang Uygur Autonomous Region joined in 1997; Inner Mongolia Autonomous Region in 2008), Kazakhstan, the Kyrgyz Republic, Mongolia, Tajikistan, and Uzbekistan. Pakistan and Turkmenistan joined in 2010, followed by Georgia in 2016. This Outlook does not contain a chapter on Afghanistan as ADB placed its assistance in Afghanistan on hold effective 15 August 2021 (ADB. 2021. ADB Statement on Afghanistan. News release. 10 November. https://www.adb.org/news/adb-statement-afghanistan).

Figure 1: Primary Energy Supply Forecast—CAREC, excluding the People's Republic of China
(million toe)



BAU = business-as-usual, CAREC = Central Asia Regional Economic Cooperation, toe = ton of oil equivalent.

Note: The forecasts are based on the Roland Berger methodology described in the Methodology section.

Sources of historical data: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 5 August 2021); and various national statistics.

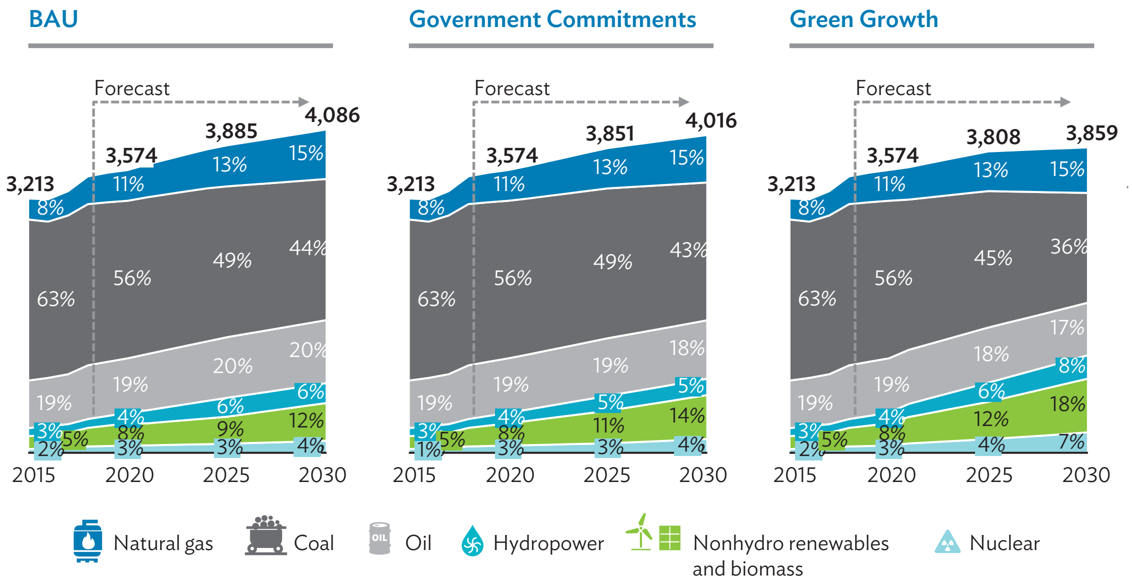
Primary Energy Supply Trends in CAREC Countries, including the People's Republic of China

Overall, the cumulative economic growth in CAREC countries, including the PRC, is not affected mostly because of the strong economic position of the PRC. Numerically, this results in an annual GDP growth of 3.3% in 2020 (comparing to 2.6% in 2019). Continuous economic growth (8.5% per annum in an optimistic scenario) is expected until 2030, leading to increased energy consumption.

The primary energy supply within CAREC countries, including the PRC, is projected to increase by 12% on average and reach 3,859–4,086 million toe by 2030 compared to 3,574 million toe in 2020, depending on the scenario. From an annual growth perspective, primary energy demand is expected to grow by 2030 under each scenario: 0.8% per annum in the Green Growth scenario, 1.2% in the Government Commitments scenario, and 1.3% in the BAU scenario.

Total primary energy supply within CAREC countries, including the PRC, is projected to remain highly reliant on coal through 2030. However, the share of coal in the supply of primary energy is projected to decrease across all scenarios, reaching 36%–44% due to the transition to renewables. Moreover, the combined share of renewable and nuclear energy sources is projected to increase from 15% in 2020 to 22%–33% in 2030, depending on the scenario (Figure 2).

Figure 2: Primary Energy Supply Forecast—CAREC, including the People's Republic of China
(million toe)



BAU = business-as-usual, CAREC = Central Asia Regional Economic Cooperation, toe = ton of oil equivalent.

Note: The forecasts are based on the Roland Berger methodology described in the Methodology section.

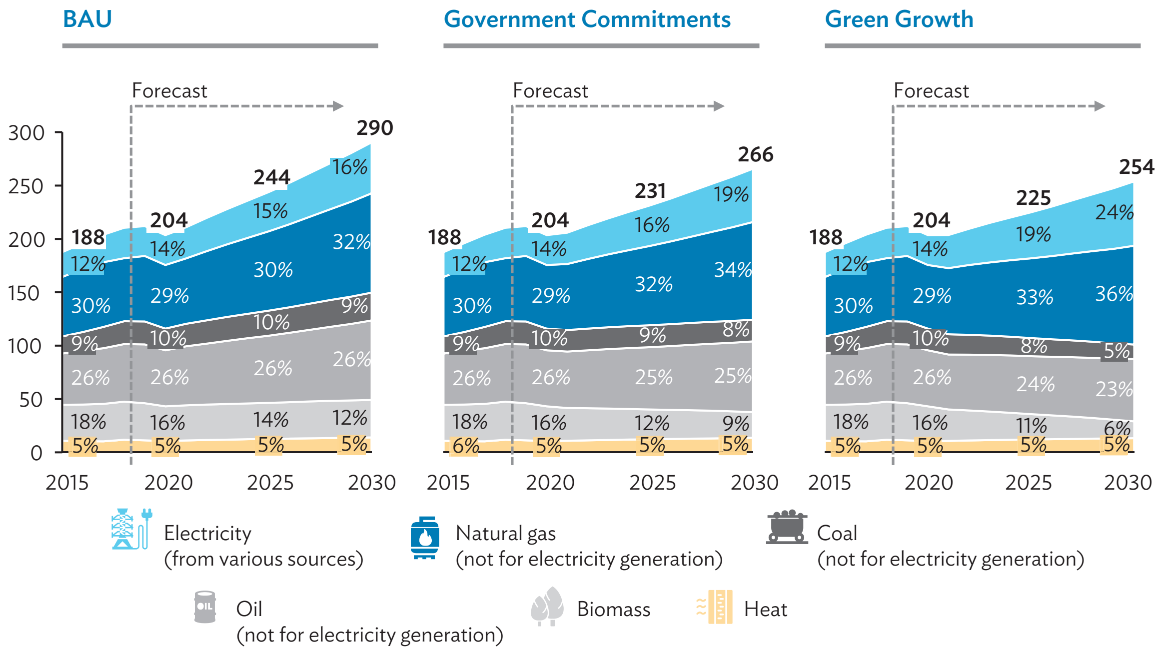
Sources of historical data: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 5 August 2021); and various national statistics.

Final Energy Demand by Fuel in CAREC Countries, excluding the People's Republic of China

The final energy demand within CAREC countries, excluding the PRC, is expected to increase by approximately 32% on average from 204 million toe in 2020 to 254–290 million toe by 2030. The implementation of energy efficiency measures will determine the ultimate level by which demand growth may be constrained within the given margins. Electricity will be one of the most rapidly growing sources of consumption through 2030. Furthermore, the consumption of natural gas is forecasted to grow across all scenarios due to the increasing energy demand in the residential and industrial sectors. The share of coal and oil will remain relatively stable under the BAU scenario (9% for coal and 26% for oil), and will decline slightly under the Government Commitments scenario (from 10% in 2020 to 8% in 2030 for coal, and from 26% to 25% for oil) and under the Green Growth scenario (from 10% to 5% for coal, and from 26% to 23% for oil). However, in terms of nominal value (million toe), coal consumption will continue to grow from 21 million toe to 26 million toe under the BAU scenario, assuming efforts to limit its consumption prove difficult and provided that there is a significant overall increase in demand. Under the Government Commitments scenario, the final energy demand for coal is expected to remain stable, while it will decline under the Green Growth scenario due mostly to its replacement with natural gas for industrial purposes (Figure 3).

Figure 3: Final Energy Demand Forecast by Fuel—CAREC, excluding the People's Republic of China

(million toe)



BAU = business-as-usual, CAREC = Central Asia Regional Economic Cooperation, toe = ton of oil equivalent.

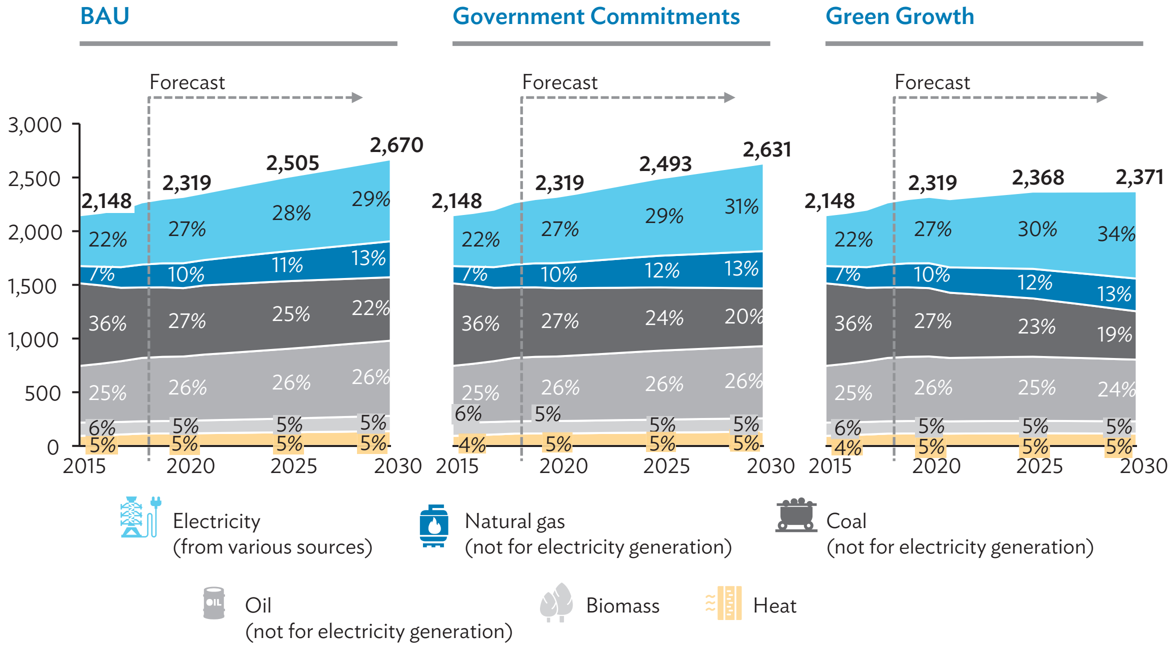
Note: The forecasts are based on the Roland Berger methodology described in the Methodology section.

Sources of historical data: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 5 August 2021); and various national statistics.

Final Energy Demand by Fuel in CAREC Countries, including the People's Republic of China

The final energy demand within CAREC, including the PRC, is projected to increase by approximately 10% on average by 2030 (from 2.3 billion toe in 2020 to 2.4 billion–2.7 billion toe in 2030, depending on the scenario). Natural gas is expected to have the most rapid consumption growth (with estimated annual growth of 3%–4% between 2020 and 2030, and with a 10%–13% share of final energy demand, depending on the scenario). This growth is expected to reflect the transition from coal to gas as well as the increase in energy demand within the residential and industrial sectors. Furthermore, the share of electricity within final energy demand is also forecasted to grow across all scenarios. The share of oil and oil products is expected to remain largely unchanged, with total consumption expected to grow under both the BAU and Government Commitments scenarios, owing to increasing energy demand in the transport sector. Finally, coal consumption is projected to decline across all scenarios, mostly driven by the PRC's stated efforts to limit its consumption, though recognizing that part of electricity generation in the PRC is expected to come from coal through 2030 (Figure 4).

Figure 4: Final Energy Demand Forecast by Fuel—CAREC, including the People's Republic of China
(million toe)



BAU = business-as-usual, CAREC = Central Asia Regional Economic Cooperation, toe = ton of oil equivalent.

Note: The forecasts are based on the Roland Berger methodology described in the Methodology section.

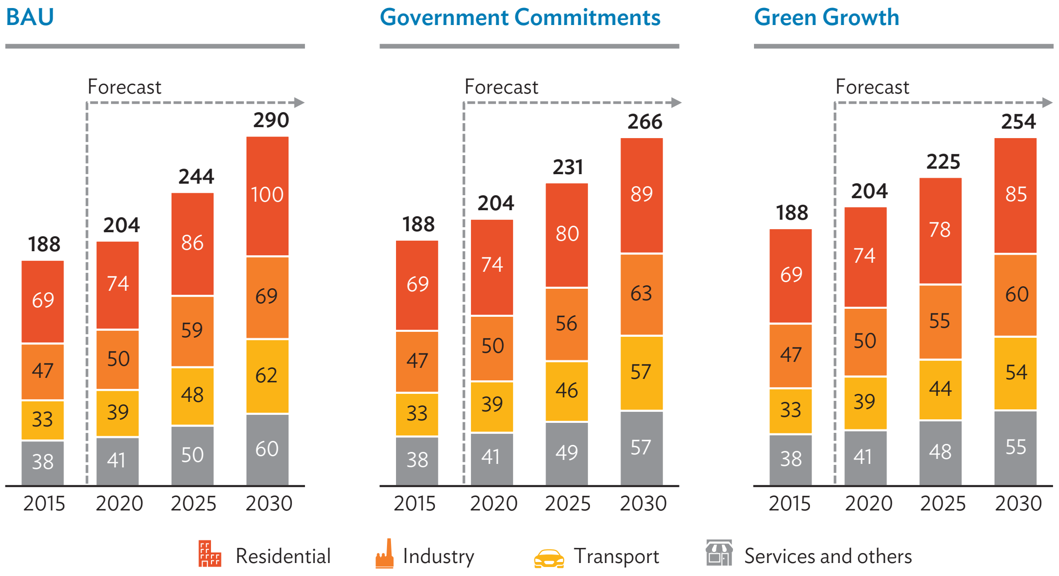
Sources of historical data: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 5 August 2021); and various national statistics.

Final Energy Demand by Sector in CAREC Countries, excluding the People's Republic of China

In terms of specific sectors, transport is projected to be the most rapidly growing sector within the CAREC region, excluding the PRC. Specifically, energy demand within the transport sector is expected to grow at a compound annual growth rate (CAGR) of 3%–4% by 2030, depending on the scenario. The residential and industrial sectors are expected to benefit from additional energy efficiency measures, leading to a relatively slow growth of 2%–3% per annum, depending on the scenario (Figure 5).

Figure 5: Final Energy Demand Forecast by Sector—CAREC, excluding the People's Republic of China

(million toe)



BAU = business-as-usual, CAREC = Central Asia Regional Economic Cooperation, toe = ton of oil equivalent.

Note: The forecasts are based on the Roland Berger methodology described in the Methodology section.

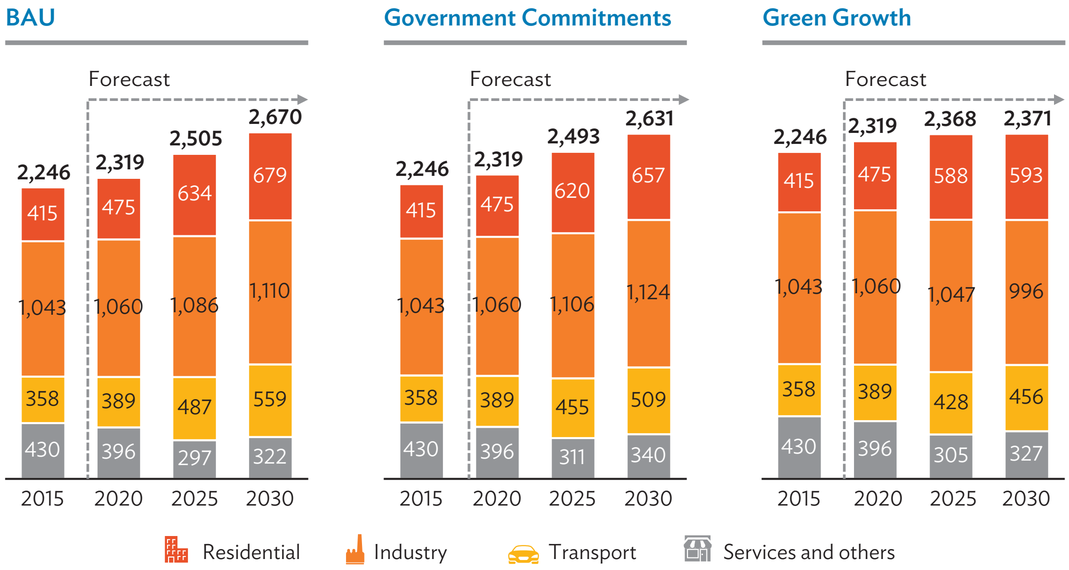
Sources of historical data: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 5 August 2021); and various national statistics.

Final Energy Demand by Sector in CAREC Countries, including the People's Republic of China

Among the CAREC countries, including the PRC, transport and residential are the two most rapidly growing sectors. Energy demand in the transport sector is expected to grow at a CAGR of 2%–3% by 2030, and the residential sector at an annual rate of 2%–4%, depending on the scenario. Under the BAU and Government Commitments scenarios, energy demand in the industrial sector is projected to grow at CAGR of 0.5%–0.6%, while under the Green Growth scenario, energy demand in the industrial sector is expected to decline at an annual rate of 0.5% (Figure 6).

Figure 6: Final Energy Demand Forecast by Sector—CAREC, including the People's Republic of China

(million toe)



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Solar and wind power plants. The global energy industry is facing a crucial turning point in its transition to a low-carbon future (photo by hrui/Adobe Stock©).

Technology Outlook

Highlights

- The global energy industry is facing a crucial turning point in its transition to a low-carbon future. This involves a gradual phase-out of mature technologies involving thermal power generation that continue to provide the bulk of energy supplies. Replacement of these technologies with low-carbon technologies, primarily renewable energy, lies at the heart of the energy transition.
- Power generation technologies based on fossil fuel combustion are likely to see additional incremental improvements in efficiency. Yet long-term use of carbon-based technologies can only be enabled in conjunction with the development of carbon capture technologies.
- Renewable energy technologies continue to gain momentum as generation costs are further reduced and efficiency and utilization rates are enhanced. The massive technical potential of renewables, in particular wind and solar, remains largely unexploited in many Central Asia Regional Economic Cooperation (CAREC) member countries.
- A key challenge of the energy transition is safe and reliable grid operation amid a growing share of intermittent renewable energy. The modernization of power systems using smart grids and wider use of demand management practices will be crucial for upgrading existing and developing future infrastructure (Axpo 2018). Yet, in many emerging countries, including within the CAREC region, large transmission and distribution (T&D) losses remain an important challenge and will require rehabilitation and expansion measures.
- Hydrogen and battery energy storage systems (BESS) can also play a significant role in the integration of renewable energy sources into the overall energy mix and in the phasing out of fossil fuels. Despite the early stage of technological maturity, both hydrogen and storage technologies have significant potential and are already in multiple pilots and early-stage commercial projects, including in CAREC member countries. In order to realize large-scale application of hydrogen, its safety and feasibility of conservation and transportation need to be ensured by advanced technologies. To apply storage technologies, the profitability of BESS should be ensured by certain trading schemes within the electricity market, for example, providing services of adjusting grid frequency.
- The outlook for consumption-side technologies largely focuses on increasing efficiency and limiting consumption. This process is enabled by a broad use of energy management systems and smart metering to facilitate consumption monitoring and implementation of various measures. CAREC member countries have significant scope to improve efficiency by advancing energy management systems and rehabilitating infrastructure and equipment.
- Another important trend in energy consumption is a gradual shift from conventional to alternative fuels and toward electrification of energy consumption. The transport sector is a prime example, with the rapid development of electric vehicles (EVs) globally. Most CAREC countries, except for the People's Republic of China (PRC), are not yet on track with this trend.

Power Generation

The analysis below focuses mainly on low-carbon energy technologies that can support global efforts to combat climate change and decarbonize the energy systems. In power generation, this includes not only renewable energy (having no greenhouse gas [GHG] emissions), but measures targeted to improve efficiency in the thermal power generation based on conventional fuels.

Renewable Energy Sources

Hydropower

Hydropower is the most mature power generation technology and uses kinetic energy embedded in flowing water. The two main types of hydropower are run-of-river and reservoir plants. Run-of-river plants depend on water flow availability in a river. With no storage capacities, run-of-river plants cannot respond to demand and are highly dependent upon natural variations in flow. Run-of-river plants are typically deployed at micro to small scales, with capacity of up to 20 megawatts (MW).

In contrast, reservoir hydropower plants (HPPs) can reach larger scales, with capacity of several gigawatts (GW). Technically, they are more complex because they involve the construction of a dam to create artificial lakes next to the plants. The water within the dam acts as storage capacity, with the power plant regulating the inflow of water and, in turn, power generation volume. As a result, reservoir HPPs provide a flexible source of power generation, which is very valuable in the context of rapidly expanding intermittent wind and solar power generation. Reservoir HPPs are optimally located in mountainous regions with large water resources.

One of the methods of load balancing during periods of high-power demand is pumped storage hydropower. This type of hydroelectric energy storage is a configuration of a lower elevation reservoir and a higher elevation reservoir that can generate power as water is discharged from one to the other, passing through a turbine (US Department of Energy).

As hydropower is already a mature technology (with over 90% of conversion efficiency), it has limited room for improvement (Canadian Hydropower Association). While incremental improvements are possible, they are unlikely to significantly lower the cost of hydropower or its efficiency.

Hydropower is currently the most important source of renewable energy in the CAREC region, with more than 380 GW of generation capacity installed as of 2019. This includes 356 GW in the PRC and 28 GW in other CAREC member countries. Several countries, including Tajikistan, Kyrgyz Republic, and Georgia, rely upon hydropower to generate most of their electricity. A key advantage of hydropower is its potential to provide flexible power generation, reacting rapidly to any changes in supply and demand. Amid rising intermittent power generation, the role of hydropower within the CAREC region is likely to grow; although, hydropower's potential to replacing fossil fuels is limited to those countries possessing the required natural resources to utilize it.

Solar

The generation of electricity from solar energy has enormous potential given unlimited and stable availability of sunshine in most of the world. Two technologies are prevalent for harnessing solar energy: photovoltaic (PV) and concentrated solar power (CSP). Solar PV utilizes the photovoltaic effect of silicon to generate power when exposed to sunlight. The most mature type of solar PV technology, with more than 90% of market share, is wafer-based silicon cells that are constituted from monocrystalline or polycrystalline. Polycrystalline PV cells are cheaper but have lower efficiency. The next generation PV technology is likely to be based on thin film technology that is currently at an early commercial stage. Other emerging PV technologies include organic solar cells and concentrated PV. But while these have a high potential to provide higher efficiency when compared to available materials, they are currently only at a precommercial stage.

CSP technologies consist of collector systems and different kinds of mirrors that direct sunlight to a receiving medium. Resulting thermodynamic processes lead to generation of electricity by means of a steam turbine and generator similar to thermal power generation at conventional power plants. CSP, however, requires direct sunlight as opposed to PV systems, which can operate under cloudy weather conditions, albeit at lower efficiency. CSP has higher technical and commercial potential for energy generation in geographic areas with stable sunshine and annual direct normal irradiance levels above 2,000 kilowatt-hours per square meter (kWh/m^2). CSP technologies vary in the type and structure of their mirror systems.

Research and pilot implementation have significantly advanced solar technology, lowering production costs and increasing efficiency and capacity factors.[2] As a result, solar energy has established itself as one of the cheapest sources of energy in many parts of the world, for instance, in parts of the Middle East and Asia. Incremental technological progress is expected to continue this decade. The use of off-grid solar energy also has high potential for improving access to energy in geographically remote areas. At the same time, the nature of solar power generation presents persistent challenges including intermittent generation, a limited capacity factor (around 15%–20%), and inconsistency in matching peak generation to peak demand periods during the day.

Solar energy is still relatively new to CAREC member countries, some of which are yet to have utility-scale solar plants. At the same time, off- and small-grid applications have been installed in most member countries and set a good basis for further technological development. As of 2019, CAREC member countries, excluding the PRC, have nearly 2 GWs of installed solar capacity, mostly PV. The PRC has progressed further in the deployment of solar energy with more than 200 GWs of capacity, making it one of the leading countries in the world in installed capacity. Improved cost competitiveness of solar energy paves the way for its rapid development across CAREC countries. Uzbekistan is a prime example, with solar PV projects totalling more than 1 GW combined capacity in the development pipeline. Further technological advancements and improved know-how and awareness should all contribute to a greater role for solar energy within the energy systems of CAREC member countries in the coming years, making it central to the region's decarbonization efforts.

Wind

Wind energy has experienced a similar development path to that of solar energy. Its commercial feasibility in recent years has increased massively due to technological advancements and higher competition in supply chains. In general, wind farms consist of multiple turbines mounted on towers with a height of 50–100 meters. The wind turns the turbine blades, creating kinetic energy that is converted into electricity.

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[2] Capacity factor is the ratio between the capacity of generation facility and the actual amount of energy produced.

Wind farms can be located either onshore or offshore. Since air flows are more rapid and stable at sea, offshore farm efficiency is significantly higher at 40%–45%, compared to around 30%–35% for onshore farms. The installation and maintenance costs for onshore farms are, however, significantly lower.

The outlook for wind energy is also positive since generated power is free of carbon emissions. Further technological improvements are likely to bring down the cost of wind energy further, through more efficient blade design (e.g., smart blades with heating for de-icing) or improved placement of the farms. Another development with high potential is predictive maintenance, especially for offshore farms, where challenging access to the turbines makes maintenance and breakdowns a more pressing issue.

Except for the PRC, wind energy in the CAREC region is only starting to gain traction. In 2019, total installed capacity reached 2 GW, compared to the PRC's 210 GW of capacity. Due to lack of relevant technological knowledge among state-owned companies, most wind farms were established as private sector investments. With energy sector reforms and market liberalization, deployment of wind energy is projected to grow at an increased pace. Wind energy can already be cost-competitive with conventional sources of energy and is superior in terms of its low environmental impact. As many CAREC member countries are landlocked, onshore farms are the prevailing type of wind energy in the region.

Other Renewable Energy Sources

The other main renewable energy sources are geothermal, waste-to-energy, and biomass. Geothermal plants generate electricity from the earth's natural subsurface heat. Waste-to-energy technology involves the combustion of municipal or industrial waste using special filters for flue gases. Biomass can be turned into electricity through biogas or via direct combustion. These energy sources can provide co-generation, meaning generation of both electricity and heating, but are not yet cost-competitive when compared to other types of renewable energy, limiting their use to niche applications.

As of 2019, installed capacity of other renewable energy sources in the CAREC region is below 1 GW, excluding the PRC (at 27 GW). Outside the PRC, a waste-to-energy plant is operating in Azerbaijan's capital city of Baku, while small-scale geothermal plants operate in Georgia. Overall, other renewable energy sources are not expected to play a significant role in future energy systems in the CAREC member countries.

Conventional Power Sources

Nuclear

Nuclear power generation technologies are based on energy released by uranium fission reactions, occurring when atoms are split into two or more smaller atoms. This process entails the generation of extensive thermal energy, which is used to steam power a turbine to generate electricity. Despite zero GHG emissions, nuclear energy poses other environmental hazards and challenges related to the safe disposal of nuclear waste and acute security risks, in case of malfunction. Nuclear power continues to be a highly divisive topic globally, with some governments viewing it as a zero-carbon and cheap alternative to power generation derived from fossil fuels, while other governments are decommissioning existing plants due to safety concerns in the wake of the Fukushima incident.

Only two CAREC member countries currently operate nuclear power plants—Pakistan (1 GW of installed capacity) and the PRC (48 GW). Both countries view nuclear power as a key part of their national energy systems that provides a stable baseload of electricity. Two other members, Kazakhstan and Uzbekistan, have initiated large-scale nuclear power plant projects, with commissioning planned prior to 2030. Both countries are major producers of uranium, a key fuel for nuclear power plants, with Kazakhstan being the largest producer of uranium globally. While nuclear power can offer significant advantages in terms of scale and reliable power generation, a comprehensive system of security safeguards should be in place to prevent malfunction and guarantee safe management of nuclear waste while respecting international non-proliferation agreements.

Natural Gas

The generation of electricity from thermal energy obtained through natural gas combustion is one of the primary sources of energy worldwide. Key advantages to gas-fired power generation include generation efficiency and moderate environmental impact, making it superior to coal-fired power generation. Two major types of natural gas power generation are simple-cycle gas turbine (a single steam generation unit) and combined-cycle gas turbine, where exhaust heat is utilized via a second turbine (heat recovery steam generator) (US Department of Energy). The combined-cycle gas turbine is significantly more efficient, with 55% efficiency on average and up to 60% efficiency in the most advanced systems. The simple-cycle turbine, in turn, can reach a maximum of 40%–45% efficiency.

Both technologies are relatively mature and commonly used globally. Future advancements are likely to be limited to incremental increases in efficiency, for instance, via enhanced cooling systems or advanced materials in turbine design (Proctor 2018). Another key area for improvement is fast-starting turbine technology, which can potentially allow turbines to ramp up operation more rapidly and efficiently, an advantage in the process of integrating larger capacities of intermittent renewable power and allowing for a more rapid response to fluctuations in supply or demand.

Two technological options are considered for full removal of GHG emissions from natural gas power generation assets. The first one involves installation of additional equipment for carbon capture, utilization, and storage (CCUS) (IEA n.d.). This technology is already feasible, although it remains costly to deploy on a significant scale. The other pathway involves replacing natural gas with hydrogen in power generation processes. These two pathways can extend the relevance of natural gas assets for multiple decades, including after the completion of the energy transition to environmentally sustainable practices.

Energy sector stakeholders across the globe are looking for sustainable ways to generate power. Even though countries are increasing their share of renewables, conventional fuels are required to ensure security of supply and balance electricity generation. The environmental footprint of natural gas can be improved by adding modern power plants. The introduction of modern gas-fired power plants can lead to significant efficiency gains and reduce environmental impacts in the short-to-medium term. Modernization and replacement of inefficient gas-fired power plants is especially relevant for many post-Soviet natural gas-rich countries with similar infrastructural challenges (e.g., Kazakhstan, Turkmenistan).

Natural gas is a key source of electricity in the CAREC region overall. Installed capacity in 2019 reached 36 GW, excluding 90 GW of capacity in the PRC, where natural gas plays a relatively lesser role in the power mix (The Oxford Institute for Energy Studies 2020). A primary reason for the central role of natural gas is the large reserve base and production volumes within multiple CAREC member countries, namely Azerbaijan, Kazakhstan, Turkmenistan, and Uzbekistan. Other reasons include high efficiency and reliability as well as a more moderate environmental impact. Given the large scope for technological improvement, including switching from simple to combined-cycle gas turbine technology, natural gas power generation infrastructure can be expected to expand even further. Considering the consistently rising demand for electricity and the large availability of natural gas in the region, natural gas is expected to continue to play a key role in the energy systems of the CAREC region in both the short- and medium-term future. Its long-term use is likely to depend on the success of the CCUS and hydrogen technologies that can significantly extend the lifespan of natural gas power generation infrastructure.

Coal

Almost 200 nations agreed to phase down coal-fired power plants at the 26th United Nations Climate Change Conference of the Parties (COP26) in Glasgow in 2021, aiming to meet the global warming target of the 2015 Paris Agreement. Forty-six nations supported the global coal-to-clean-energy transition statement and pledged to phase out coal-fired power generation and only build new plants if they are equipped with the CCUS technology. Despite the severe environmental impact of coal combustion and global efforts to phase out coal, it still accounts for a large share of the power generation mix. The relatively low price of coal and growing energy demand in emerging countries are key drivers for the use of coal. Technologically, the generation of power from coal is very similar to other conventional sources. The combustion of coal generates thermal energy that powers turbines and generates electricity. The most frequently used technology is a pulverized coal-fired plant, with efficiency ranging from subcritical (~36%) to ultra-supercritical (~46%) levels, depending on the pressure applied to the water within the system. There is a large potential for significantly decreasing GHG emissions by upgrading subcritical and supercritical plants. Other levers include advanced monitoring and control techniques as well as the treatment of flue gas. Currently, only one technological pathway can neutralize carbon dioxide (CO_2) emissions from coal-fired power generation—i.e., the CCUS technology.

Excluding the PRC, coal is the second-largest power generation source in CAREC countries, with 22 GW of installed capacity as of 2019. Key consumers are countries with large domestic coal production, mainly Kazakhstan and Mongolia. In the PRC, coal is the most important part of the power generation mix, with almost 1.1 terawatt of installed capacity as of 2019. Reliance on coal-fired power generation will pose considerable challenges in the future, given commitments by governments to reduce their carbon footprints. However, due to social and economic concerns, coal-fired power generation will continue to remain a key source in the CAREC region in the short and medium terms. Nevertheless, investors should carefully consider the long-term implications of expanding coal-fired power capacities due to the significant lifetime of such assets, often spanning more than 5 decades.

Transmission, Distribution, and Storage

Grid Modernization

Grid infrastructure in CAREC member countries will require significant modernization considering ambitious plans to increase renewable energy capacity. This shift will be especially important for countries such as Mongolia, Kazakhstan, and the PRC, which aim to rapidly switch from coal to renewable energy. Countries will increasingly focus on the installation of advanced smart metering infrastructure and larger-scale grid digitization (M. Yáñez et al. 2018). Short-term actions are likely to focus more on the rehabilitation of existing T&D infrastructure, considering the high T&D losses prevalent within CAREC. Countries with difficult geographic conditions and remote grid locations will benefit from prioritizing and developing predictive maintenance.

Battery Energy Storage

Battery energy storage is a technology that can support the integration of intermittent renewables in the overall electricity mix (IEA 2021). The primary function of battery storage is to store renewable-sourced electricity and dispatch it at peak times. Apart from limiting curtailment of renewable power, multiple benefits in terms of ancillary services can also be achieved, such as frequency control and reserves regulation (IRENA 2019). Furthermore, battery storage can replace peak capacities that are typically more costly due to low utilization factors. An important advantage is also unlimited geographic flexibility as battery storage systems can operate at any location and can be rapidly scaled.

Battery storage remains at an early stage of development. Lithium-ion batteries currently dominate the market; however, other prominent options include flow battery-vanadium and flow battery-zinc bromide. Battery storage continues to be costly but retains strong cost-reduction potential, considering significant progress of adjacent technologies, such as electric vehicle (EV) batteries. Both utility-scale and behind-the-meter systems are projected to see strong uptake in the coming decade given their role in integrating renewables.

Among CAREC member countries, only the PRC has utility-scale battery energy storage with more than 1 GW installed capacity. Other regional examples include Mongolia and Kazakhstan, which plan to introduce large-scale battery energy projects. Two primary success factors for rapid expansion of battery energy storage in the CAREC region include further cost reduction and successful pilot projects in emerging markets.

Hydrogen

Hydrogen energy has the potential to significantly accelerate the transition to a less carbon-intensive economy. As hydrogen is not a naturally occurring gas, the sources of hydrogen production vary and include fossil fuels such as natural gas (resulting in "blue" hydrogen), renewable energy via electrolysis ("green" hydrogen), nuclear energy via electrolysis ("pink" hydrogen), or variations of these (Figure 7). Green hydrogen technology draws significant interest, with the private sector perceiving it as a lucrative business opportunity, and the public sector considering it as an instrument to reduce carbon emissions and increase energy security. Many electrolysis installations are in the pilot or development stage, so the implementing stakeholders should take into consideration respective costs for research and development (R&D), construction, and hydrogen transportation.

Figure 7: Overview of Hydrogen Types

	"Grey" Hydrogen	"Blue" Hydrogen	"Green" Hydrogen
Description	"Grey" hydrogen is produced with fossil fuels (**coal or gas**); thus, the generation of this type of hydrogen entails **considerable carbon dioxide emissions.**	"Blue" hydrogen is a **cleaner version of grey hydrogen** as all the processes remain the same, while generated **carbon dioxide is captured, and stored or reused.**	"Green" hydrogen is the most suitable type for a sustainable energy transition as it **does not produce carbon emissions,** being produced using **renewable energy.**
Production Process	Steam methane reforming or gasification	Steam methane reforming or gasification with carbon capture (85%–95%)	Electrolysis
Source	Methane or coal	Methane or coal	Renewable electricity

Sources: International Energy Agency. 2019. *The Future of Hydrogen: Seizing Today's Opportunities*. Paris; and International Renewable Energy Agency. 2020. *Green Hydrogen: A Guide to Policy Making*. Abu Dhabi.

Importantly, hydrogen can be used as a fuel with zero carbon emissions in high-temperature processes that cannot be electrified, most commonly for industrial processes such as steel and cement production. Hydrogen can also be combusted to generate electricity at thermal power plants, including at natural gas-fired power plants without much retrofitting. Apart from high costs, one of the main challenges for the use of hydrogen is its difficulty to transport: being one of the lightest materials on earth, it must be pressurized, compressed, or liquified to be transported. There is a strong possibility to repurpose existing natural gas infrastructure to transport hydrogen, but it will require technical upgrades to increase pressure. Nevertheless, as environmental concerns mount, further research and government support are likely to result in significant reduction in the cost of hydrogen production as an energy source.

The potential of hydrogen in the CAREC region is significant in terms of both production and consumption. Some member countries, such as Azerbaijan, Kazakhstan, Turkmenistan, and Uzbekistan, have large reserves of natural gas, which are suitable for producing blue hydrogen. Hydrogen carries potential for countries that currently heavily rely on coal and are looking into improving the sustainability of their energy sectors. Advances in pilot projects and technical knowledge can position CAREC member countries to lead in the development of commercially scalable hydrogen energy technologies.

Consumption

Industry

The industrial sector is a key area for potential energy savings via efficiency measures. Considering the large variety of technology within various industrial subsectors, implementing an industrial energy management system (EMS) is essential to achieving optimal efficiency in an industrial plant. In general, an EMS aims to monitor, control, and optimize energy performance to detect overconsumption or leaks. In addition to compliance with international standards for energy management, an EMS oversees completion of plant-specific energy audits, continuous monitoring of energy performance, and deployment of best available practices. For instance, this can include adoption of waste heat recovery and cogeneration technologies. A next generation EMS will advance smart energy management by introducing greater data transparency and identifying additional potential efficiency measures (e.g., real-time price analysis and off-peak demand purchase) as well as predictive maintenance.

Another technological trend in industrial energy consumption involves switching from fossil fuels to more sustainable electricity or alternative fuels, such as using biofuels and waste either fully or in mix with fossil fuels.

Alternative ways to enhance the environmental sustainability of industrial energy consumption involves use of the CCUS technology (IEA 2020). Progress is already significant, with prototype stages being reached in chemical and steel industries. Advancements in CCUS are largely due to the spillover effects from mature technologies in other sectors. Wide adoption of CCUS can potentially start by 2030, assuming further technological development and cost declines.

Efficiency in energy consumption, particularly in the industrial sector, of CAREC member countries is relatively low. For instance, seven CAREC member countries are among the top 30 most energy-intensive economies globally. Insufficient development of energy services markets, limited adoption of industrial energy systems, and a lack of requirements for energy performance monitoring are among the key causes. Another important factor is the existence of subsidized energy prices that disincentivize energy efficiency. Thus, the CAREC region has large potential to improve energy efficiency in industrial consumption by using best available techniques and improving monitoring of energy performance. Provided that the CCUS technology can be used for different types of fuels (natural gas, coal, and biomass) and combustion capture type (pre-combustion and post-combustion), CCUS can be potentially attractive for CAREC gas-rich countries (Azerbaijan, Turkmenistan, and Uzbekistan) and coal-reliant countries (the PRC, Kazakhstan, and Mongolia) (UNECE 2021). Yet, it is also worth noting that the technology is largely in a development stage, with pilot and demonstration tests running throughout the world. To implement CCUS, countries need to be ready to provide necessary investments and arrange required CO_2 transportation methods and suitable storage sites (e.g., depleted oil and gas fields). Alternatively, technology improvement and wider implementation of carbon pricing can lead to greater commercial viability of CCUS in the future, implying potential interest from private investors.

Transport

Energy consumption within the transport sector has large scope for efficiency improvement, especially considering the sector's reliance on fossil fuels, specifically oil products. An important technological trend is continuous efficiency improvement in the consumption of conventional fuels. Advances in the design of road, aviation, and maritime transport, partly in response to increasingly tight emission standards, continues to be a key driver. Examples include downsizing of road vehicles, new engine core concepts in aviation, and further efficiencies of scale in maritime transport.

Another trend involves a switch to sustainable fuels, which will have a significantly larger impact on energy consumption in transport. Alternative fuels are already well established in road transport and are widely seen as a suitable low-carbon option for aviation and maritime. In maritime transport, evolving technology and fuel prices imply strong potential for liquefied natural gas (LNG) application. There is an even larger potential for the electrification of transport via battery systems. Expected improvements in battery density and cost reductions can unlock opportunities for electric transportation across all modes. The largest potential is within road transport, where battery vehicles are already in an early adoption phase. In aviation and maritime, further advancements of batteries can open opportunities for short trips and, especially, urban mobility. Rail transport is already electrified to a large extent and catenary technologies significantly outperform diesel locomotives in terms of efficiency. Use of hydrogen fuel cells is another promising technology, especially for long-distance rail and road transport and freight transportation via rail and road.

A key issue of energy consumption within the CAREC region's transport sector is the age of vehicles, specifically in road transport. With an average vehicle age of above 10 years and, in many cases, 15 years, energy efficiency is low because of outdated vehicle designs. Market penetration of EVs is very low in CAREC member countries, except the PRC. Thus, key developments should involve increased efficiency with a growing use of newer vehicles as well as electrification of the railway network. The number of EVs in all countries is projected to grow substantially, reflecting a global trend. Decarbonization of other transport modes (aviation and maritime) remains a long-term target because of low technological maturity.

Buildings

Energy consumption in buildings includes both residential and service sectors, thus representing an important lever for energy savings via efficiency measures. Similar to industrial consumption, monitoring energy performance on a granular basis at the level of individual buildings is key to efficiency improvement. This is covered by a building energy management system, an automated monitoring and control system for building management functions (e.g., heating, lighting, ventilation, and air-conditioning). Real-time analysis of energy data can significantly boost efficiency and reduce overconsumption.

An important technology is collective and district heating, which, in its modern applications, can be a solution for efficient heating in densely populated urban areas. Several new trends, such as the integration of renewable energy sources in heating (e.g., waste or solar thermal heating) and addition of heat pumps, are emerging. Heat pumps are an emerging heating and cooling technology that is projected to play a leading role in energy consumption in buildings by 2040 but has not reached commercial viability yet. Early adoption in Europe shows that heat pumps are feasible in different geographic and climate conditions and are more suitable for rollout in suburban and rural areas. A potential development is also the use of geothermal heat pumps, which can offer reliable energy for the whole year and additional seasonal storage.

Energy consumption in buildings in many CAREC member countries reaches above 300 kWh/m^2, i.e., well above international benchmarks. This is caused by a lack of basic energy management measures, such as individual metering equipment, modern and efficient insulation, energy-efficient windows, and thermostats. Several CAREC member countries utilize district heating systems with average efficiency levels below 60%, compared to 90% for modern systems. Effective rehabilitation of these systems and upgrading of existing buildings as well as more stringent energy performance requirements are high priorities for the next several years.

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Electricity pylon. One of the key challenges of the global energy transition is enabling the required financing to implement low-carbon technologies (photo by Lukasz Pajor/Adobe Stock©).

Investment Outlook

Highlights

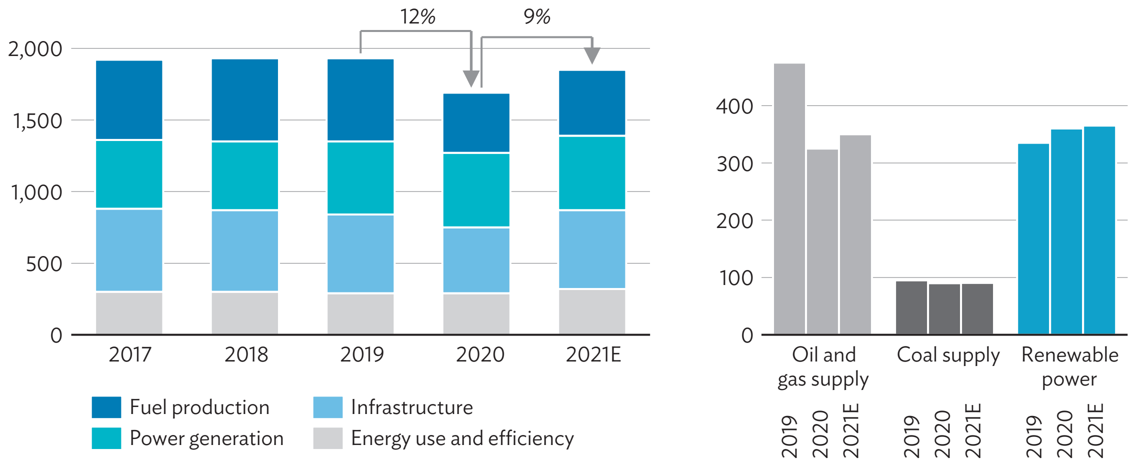
- As a result of major innovations and cost reductions, wind and solar energy are on track to become highly competitive sources of renewable energy globally.
- Nonhydropower renewables are projected to constitute the majority of newly commissioned power generation capacity in the upcoming decade. With a relatively low baseline of wind and solar power generation capacities, except for the People's Republic of China (PRC), Central Asia Regional Economic Cooperation (CAREC) members have an opportunity to rapidly scale up investments in renewables.
- One of the key challenges of the global energy transition is enabling the required financing to implement low-carbon technologies. Participation of the private sector is an integral factor of the successful decarbonization of energy.
- Most investments are balance-sheet-financed, with a share of debt instruments at around 50%. New mechanisms, such as green bonds and sustainable bonds, hold large potential to support energy infrastructure investment but continue to be underexploited in many parts of the CAREC region and the rest of the world.
- Recent policy trends in energy infrastructure include large-scale public investment plans to stimulate the energy transition.
- Another important development is the rapid spread of carbon pricing mechanisms, specifically carbon taxes and emissions trading schemes (ETS). Several CAREC members already promote efficient energy use via the ETS.
- By 2030, energy-related investment needs in CAREC countries will stem mostly from generation, representing $76 billion–$213 billion until 2030 for CAREC countries without the PRC, and $1.25 trillion–$1.92 trillion for all CAREC member countries, depending on the scenario. Energy efficiency measures are expected to constitute $35 billion–$77 billion for CAREC countries without the PRC, and $913 billion–$1.02 trillion for all CAREC countries.
- Investments in energy transmission and distribution (T&D) facilities are also projected to grow. Electricity and natural gas network modernization and expansion, and installation of metering equipment and other remote monitoring systems are projected to require investments of $25 billion–$49 billion for CAREC countries without the PRC, and $768 billion–$897 billion across all CAREC members, depending on the scenario.
- In terms of primary energy fuels, requirements of CAREC member countries (without the PRC) are projected to be dominated by natural gas, wind, and nuclear, reflecting their gradual transition to less carbon-intensive fuels. As for the total CAREC level, investment needs are expected to be primarily led by electricity T&D, reflecting the PRC's installations of ultra-high voltage lines. This is followed by wind, solar photovoltaic (PV), and nuclear power plants, indicating the transition toward more sustainable fuels.
- The CAREC region has substantial opportunities for investment in (i) its energy sector, primarily originating from the tremendous technical potential of renewable energy sources at nearly 20 terawatts; (ii) natural gas production, which could be used as fuel for "peaking plants"; and (iii) the development of blue hydrogen.

- CAREC countries benefit from extensive project experience with both international financial institutions (IFIs) and private companies like Total, BP and ACWA Power. Other factors that can stimulate investment include strong research and development (R&D) capabilities in the region, pilot projects for key modern technologies—e.g., battery energy storage systems (BESS), carbon capture, utilization, and storage (CCUS)—and growing cross-border cooperation.
- CAREC countries are taking measures for improving their energy markets, such as changing their energy subsidy systems, unbundling the energy markets, and others, which can have an impact on investments in the coming decade.

Overview of Global Investment under COVID-19

The coronavirus disease (COVID-19) pandemic and related economic uncertainty hit the global energy sector particularly hard, with global energy investments falling in 2020 by 12% to below $1.7 trillion (Figure 8).

Figure 8: Global Energy Investments
($ billion)



E = estimate.

Source: International Energy Agency. 2021. *World Energy Investment 2021.* Paris.

The COVID-19 pandemic has affected segments of the energy sector unevenly. For instance, tumbling energy prices and unprecedented decrease in demand led to a nearly 30% decline in investments in oil and natural gas supply in 2020. In contrast, a reduction of investments in coal supplies has been moderate, driven by the fact that coal is mostly produced in Asia and was impacted less by the pandemic when compared to other parts of the world. Despite environmental awareness among investors and increasingly stringent climate action regulations, investments in coal supplies increased by 4.5% globally in 2021.

At the same time, the pandemic has not slowed down investment in low-carbon energy transition, as demonstrated by the addition of 260 gigawatts (GW) of global renewable energy capacity in 2020, exceeding expansion in 2019 by nearly 50% (Figure 8).

In 2020, the first year of the pandemic, CAREC countries followed the global trend of lower energy investments. For example, the PRC suspended a large share of its natural gas imports in the first half of 2020, leading to temporary halts at natural gas production facilities in Kazakhstan and Uzbekistan.

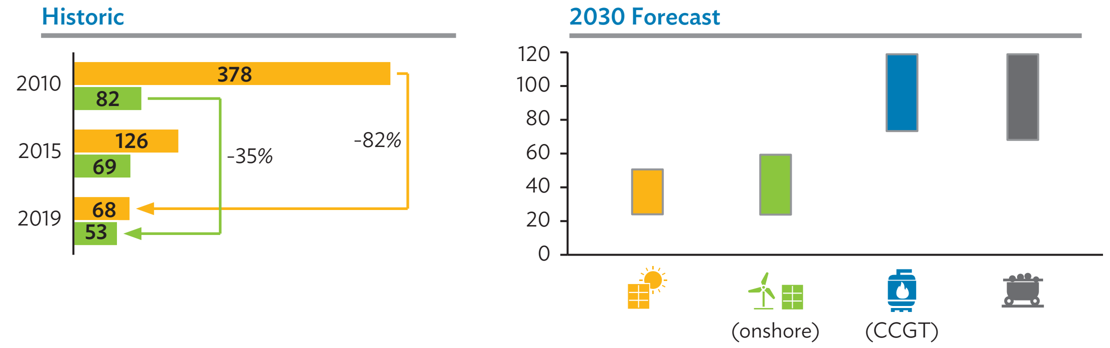
The trend of caution in coal-related investments is already evident in CAREC countries. In Georgia, for instance, coal production was temporarily halted for safety reasons in 2018 and investment in coal-fired power plants delayed (OC Media 2018).

Investment Trends: Technology

The declining cost of renewable energy has been a defining trend in energy sector investments over the last decade. This trend is amplified by the development of solar energy, the cost of which has decreased by more than 80% since 2010 because of advancements in technology. Wind energy is a more mature technology and has shown a somewhat lower cost decline of 35% (Figure 9). The development of renewables has been uneven across the globe, as generation levels and the cost of energy are highly geographically dependent. For instance, in the Middle East and Central Asia, numerous solar projects were announced with power generation prices below $20 per megawatt-hour (MWh). By 2030, renewable energy—particularly solar—is expected to be among the most competitive sources of energy in most countries due to further gains in cost efficiency. At the same time, natural gas- and coal-fired power generation costs are not expected to project a sufficient signal to significantly improve efficiency because of their high technological maturity and ongoing operating and maintenance cost requirements. Moreover, the cost of fossil-based power might increase by 2030 because of increasingly stringent climate action regulations and broader adoption of carbon pricing mechanisms (Figure 9).

Figure 9: Global Levelized Cost of Energy for Solar Photovoltaic, Onshore Wind, Combined-Cycle Gas Turbines, and Coal

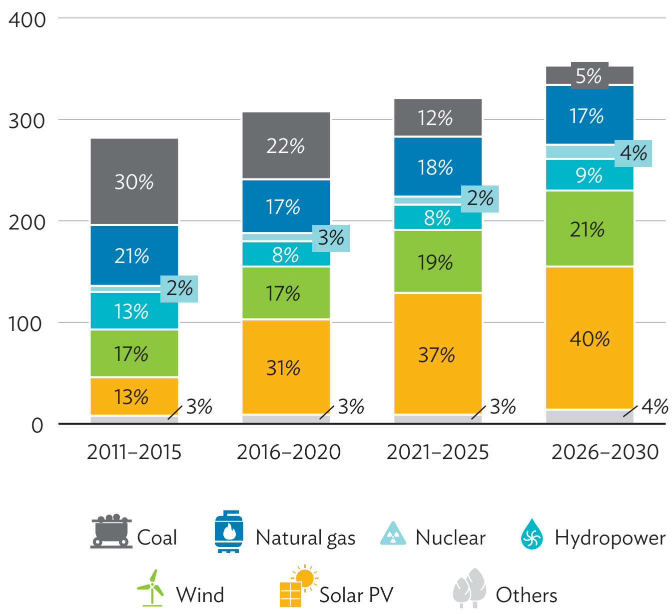
($/MWh)



CCGT = combined-cycle gas turbine, MWh = megawatt-hour.

Sources: Bloomberg; and International Renewable Energy Agency. Global LCOE and Auction Values. https://www.irena.org/Statistics/View-Data-by-Topic/Costs/Global-LCOE-and-Auction-values (accessed 27 August 2021).

Figure 10: Global Annual Power Generation Capacity Addition
(GW)

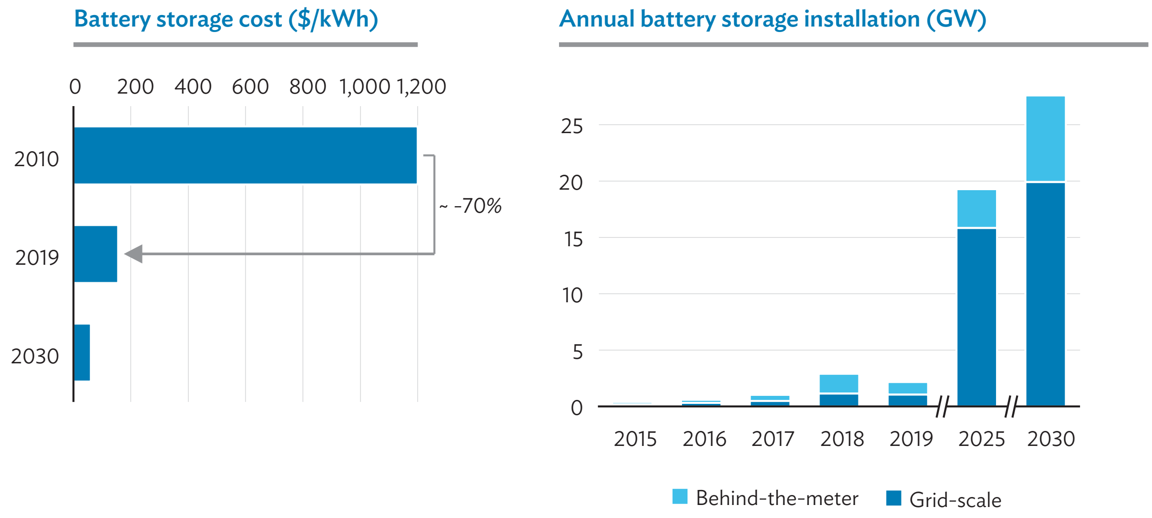


GW = gigawatt, PV = photovoltaic.
Source: International Energy Agency. 2020. *World Energy Outlook 2020*. Paris.

The tumbling cost of renewables and growing environmental awareness are driving changes in the power generation mix. While, at the start of the 2010s, fossil-fuel-fired power generation capacity additions prevailed (30% coal-fired power and 21% gas-fired), the trend is already reversing. Between 2021 and 2025, the majority of newly built power generation capacity (56%) is projected to be nonhydropower renewables (solar and wind). By 2030, the share of nonhydropower renewables in new power plant capacity will climb further to 61%. New-build coal-fired power, which was the main type of commissioned power plant between 2011 and 2015 (30%), is expected to diminish to 5% by 2030 (Figure 10).

Another important technological trend is the growing role of BESS. The integration of large capacities of intermittent renewable power generation requires additional BESS infrastructure to ensure security of supply. BESS is a potential lever to facilitate integration of renewables to mitigate intermittency by accumulating renewable energy and discharging it at peak demand periods. A critical hurdle preventing investments in battery storage systems has been their extremely high costs. However, R&D advances have helped bring down storage costs by nearly 70% since 2010, allowing commercial development. Further efficiency improvements are expected to lead to exponential growth in battery storage installations, from 2–3 GW annually to more than 25 GW annually by 2030. This includes both utility-scale systems and behind-the-meter batteries for decentralized renewable capacities (Figure 11).

Figure 11: Trends in Battery Storage



KWh = kilowatt-hour, GW = gigawatt.

Sources: Bloomberg; and International Energy Agency. 2021. *World Energy Investment 2021*. Paris.

CAREC countries are projected to follow global trends in energy technology, highlighted by wider uptake of renewables. Most CAREC countries have only recently started to develop renewable energy because of low private sector participation in the sector. But uptake of renewables may grow rapidly in the next decade, considering the relatively low baseline from which it is starting. Most CAREC members established a target share for renewable energy that requires large additions to the energy mix. Development of renewables will also be facilitated by a lower cost of energy. An example is solar energy in Uzbekistan, which has already broken record prices several times in recent years—$27/MWh in 2019 and $18/MWh in 2021. BESS is at an earlier development phase in CAREC countries, and broad uptake will require an improved regulatory framework, success of demonstration projects, and a further decrease in costs. The potential for BESS technology is already evident in the CAREC region. Mongolia is implementing a BESS project, which may serve as a reference for the whole region when it is commissioned in 2024. Other successful projects in Mongolia, demonstrating the country's technology transfer, are the Sainshand wind farm project and the Sermsang Khushig Khundii solar project (Boxes 1 and 2).

Box 1: Sainshand Wind Farm Project, Mongolia

The mining industry is the largest contributor to Mongolia's gross domestic product (90%). In 2017, around 89% of electricity generated was coal-fired using combined-heat power plants. However, most plants were built between 1960 and 1980 and currently operate with outdated technology and decreased capacity. To ensure that growing demand will be met while reducing the country's carbon footprint and diversifying its power generation capacity, the Government of Mongolia has adopted several policies targeted to introducing a share of renewable energy into installed capacity.

Mongolia's wind resources are substantial (equivalent to 1,100 gigawatts) and, consequently, the country has attracted significant investments in the wind energy sector. The latest investment is the Sainshand wind farm. Sainshand is the third privately financed wind farm in the country and was built by ENGIE Group, the largest independent electricity producer in the world. Currently, the project provides electricity for about 100,000 households and reduces carbon dioxide emissions by 200,000 tons annually.

The Sainshand project involved construction, maintenance, and operation of the wind farm, with installed capacity reaching 55 megawatts. The total project cost was $120 million, with the European Bank for Reconstruction and Development and the European Investment Bank providing long-term financing of $78.5 million, with other financial costs distributed as equity.

Key Stakeholders

Several stakeholders were involved and successfully delivered the project:

(i) **Company responsible for construction and operation:** Sainshand Salkhin Park LLC, established as a joint venture between ENGIE, FerroStaal, the Danish Climate Investment Fund, and local investors.
(ii) **Electricity off-taker:** National Power Transmission Grid, a state-owned entity focused on the transmission of electricity from generation companies to distribution networks.
(iii) **Co-financiers:** European Bank for Reconstruction and Development and European Investment Bank, providing $78.5 million in total.

Regulatory Enablers

The 2021 Law of Mongolia on Energy (E-Law) was the first major regulatory document for the Mongolian electricity sector, governing relationships in generation, transmission, distribution, and construction of new facilities. In addition, the E-Law established the Energy Regulatory Commission, the primary body establishing pricing and tariff systems, as well as setting terms and conditions for license obtainment.

The Law of Mongolia on Renewable Energy, adopted in 2007, was a first step toward regulating renewable energy power generation. Together with the E-Law, it defined the requirements to power purchasing agreements in renewable energy and set feed-in tariffs at $0.08–$0.095 per kilowatt-hour (kWh) generated and delivered by wind power. A big influx of renewable energy projects and foreign direct investments in these sectors after 2007 was likely due to the feed-in tariffs. However, this will prove costly to the government in the long run, because while the cost of technologies will go down, the price to the government remains the same.

To mitigate this problem, amendments to the renewable energy law were proposed in 2019 to provide a cap applicable only to renewable energy tariffs, setting the new wind energy tariff at up to $0.08 per kWh. The amendments also introduced the concept of renewable energy auctions for new projects procured based on tariff proposals and technical specifications. Lastly, to ensure the timely completion of the investment projects, license applicants now need to have project implementation guarantees, in the form of bank guarantees or cash deposits.

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Box 1 *continued*

Lessons Learned

Clearly defined goals for replacing traditional sources with renewables and long-lasting support from international financial institutions have established Mongolia as a frontrunner in renewable energy projects in the Central Asian region. In addition, Mongolia offers a valuable lesson to other Central Asia Regional Economic Cooperation (CAREC) countries regarding the development of the energy market and attraction of investment. Although reduction of feed-in tariffs might have introduced uncertainty in investment in recent years (with the adoption of the renewable energy law), it has proven successful in attracting early investments before transition to the new system of energy auctions.

Sources: NS Energy. Sainshand Wind Farm Project. https://www.nsenergybusiness.com/projects/sainshand-wind-farm/; S. Pyrkalo. 2017. US$ 120 Million Deal for Sainshand Wind Farm in Mongolia Reaches Financial Close. *European Bank for Reconstruction and Development*. 23 August; and Sainshand Salkhin Park LLC.

Box 2: Sermsang Khushig Khundii Solar Project, Mongolia

In Mongolia, coal-fired combined heat and power plants were responsible for around 90% of power generation and 63% of greenhouse gas emissions in 2020. The combined heat and power plants were built in the 1960s and 1970s. That plus a lack of new generating capacity resulted in a dependency on expensive electricity imports from neighboring countries, with about 20% of electricity consumed domestically being imported. Mongolia has potential renewable energy resources of 2,600 gigawatts or 5,457 terawatt-hours per year, which is sufficient to cover Mongolia's total electricity demand. Currently, the total installed capacity in Mongolia is 1,265 megawatts (MW), including around 100 MW of wind power and 20 MW of solar photovoltaic.

The Asian Development Bank (ADB) has supported the government's efforts to decarbonize the energy system and bolster energy security. The government targets raising the share of renewable energy capacity to 20% by 2023, and 30% by 2030, up from 12% in 2017. To meet these targets, renewable energy capacity has to reach 274 MW by 2023, and 595 MW by 2030.

The Sermsang Khushig Khundii Solar Project entails the construction, operation, and maintenance of a solar power plant, with a capacity of 15 MW, in the Khushig valley in Tuv Province, Mongolia. It also involves the construction of the interconnection facilities for connection to the existing Khushig substation at the new international airport, including a substation on the site of the power plant, a 14-kilometer power transmission line, and the expansion of the Khushig substation. The Sermsang Khushig Khundii Solar Project was commissioned in 2019.

Key Stakeholders

(i) **ADB provided a direct loan** and a parallel loan from Leading Asia's Private Infrastructure Fund of $18.7 million in total.

(ii) The **project investor** is Sermsang Power Corporation Public Company Limited, founded in Thailand in 2015. The company is a renewable energy developer, selecting projects based on their financial viability, considering findings from extensive due diligence.

(iii) The **operating company** is represented by Tenuun Gerel Construction LLC. The company will be in charge of the construction, operation, and maintenance of the solar power plant.

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Box 2 *continued*

Regulatory Enablers

The implementation of the project is regulated by the Law on Renewable Energy, adopted in 2007 and amended in 2015. The law creates a framework for the generation and distribution of renewable energy, sets dollar-denominated feed-in tariffs for electricity from renewable sources, and requires the generator to conclude a power purchasing agreement directly with the National Dispatch Center. In order to move closer to best practice, further amendments to the law in 2019 introduced an auction scheme for renewable energy projects and project implementation guarantees from developers.

Lessons Learned

The experience of establishing this project, ADB's first private sector infrastructure investment in Mongolia, can be helpful to Central Asia Regional Economic Cooperation (CAREC) member countries that are starting to attract private sector investments into their renewable power sector. The project benefited from technical and operational expertise from Japan and Thailand. In 2020, electricity delivered to off-taker reached 22.3 gigawatt-hours for the year, and annual emission reductions of 26,400 tons of carbon dioxide were achieved.

Sources: ADB. 2021. *Environmental and Social Monitoring Report: Sermsang Khushig Kundii Solar Project (January–December 2020)*. Manila; ADB. 2019. *Loan and Administration of Loan: Sermsang Khushig Khundii Solar Project*. Manila; *NS Energy*. 2019. ADB to Support Solar Power in Mongolia And Tonga. 20 March; and World Bank. Sermsang Khushig Khundii Solar PV Power Plant.

Investment Trends: Private versus Public Investments

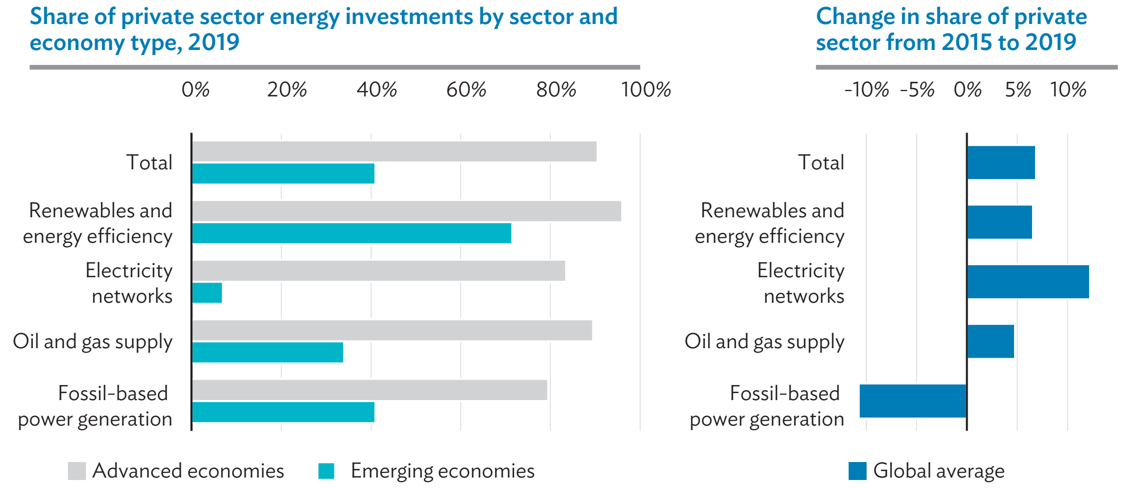
Private sector investments in the energy sector prevail in advanced economies, accounting for around 90% of the total, but still play a lesser role in emerging markets with a share of 40% (Figure 12). A key driver is the perception of risk, which is significantly higher in emerging economies because of political, legislative, and financing factors. Moreover, regulatory frameworks in emerging markets are often more restrictive for private sector projects, in contrast to advanced economies.

On average, the share of private sector investments in the energy sector is expanding globally and has increased by about 5% since 2015 to 2019. The share of private sector investments has also increased across all segments, except for fossil fuel-based power generation, which decreased by almost 10% (Figure 12). This highlights the growing importance of environmental, social, and governance issues in energy sector investments, to which the private sector is quicker to react by focusing on renewable energy and other low-carbon technologies.

The energy transition can be commercially viable, as underscored by the fact that more than 70% of total investments through 2030 in clean energy, including electricity grids, is projected to come from the private sector. The private sector is expected to play an especially prominent role in energy efficiency by investing in measures within the transport and buildings sectors with a share of more than 90%. Nearly two-thirds of investments in low-carbon power generation is projected to be made by the private sector due to solid know-how and commercial attractiveness. The only segment where public sector investments are projected to take up the majority is within grids and storage because of the monopolistic status of state-owned companies in this segment in many countries (Figure 13).

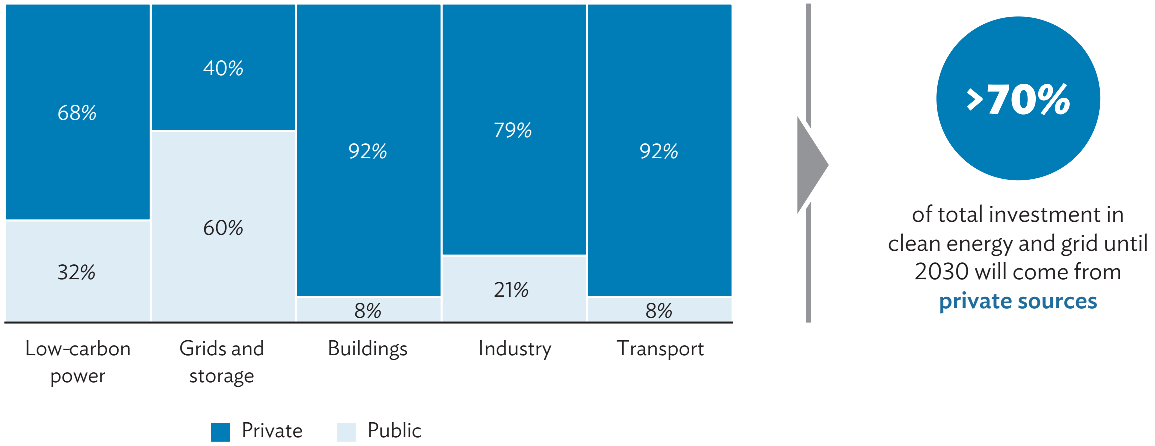
Figure 12: Share of Private Sector in Global Energy Sector Investments

(%)



Source: International Energy Agency. 2020. *World Energy Investment 2020.* Paris.

Figure 13: Share of Private Sector vs. Public Sector Energy Investments



Source: International Energy Agency. 2020. *World Energy Investment 2020.* Paris.

Public–private partnerships (PPPs) enhance private sector participation in infrastructure projects. While PPPs still lack a commonly established definition, cooperation between private and public sector players to develop an infrastructure project or deliver services is the common denominator. PPPs are especially relevant in renewable energy projects, where high one-off capital expenditure and a long payback period for investors create higher risks for the private sector. Participation of the public sector in PPP projects can reduce risks in project development and implementation, thus increasing the commercial viability of investments.

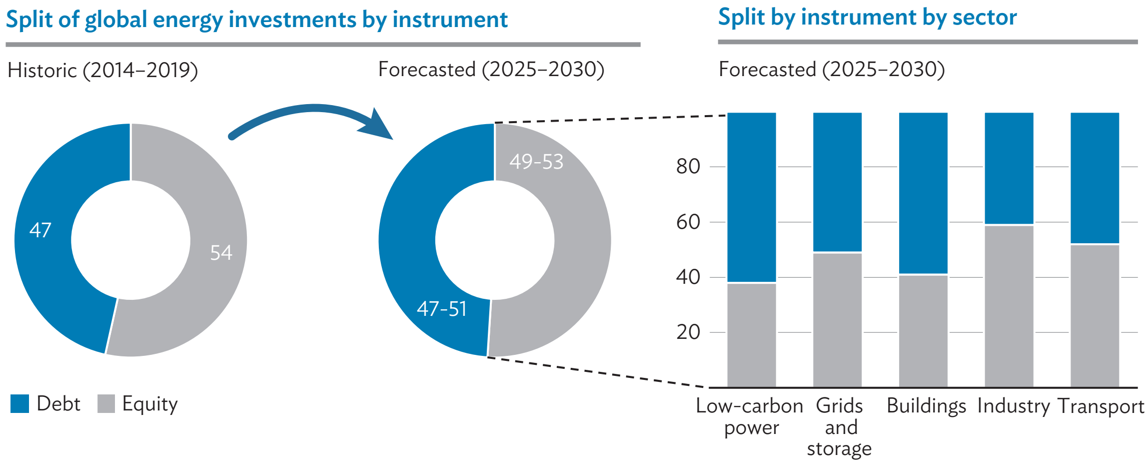
While the public sector dominates investments in CAREC countries, as in other emerging markets, improving regulations and the availability of both fossil fuel and renewable energy mean private sector investments have a positive outlook. Private investors in CAREC countries also recognize the urgent need to act on climate change and possess sufficient technological knowledge about developing clean and efficient energy systems via investments across all energy infrastructure segments. Many CAREC countries, including Georgia, Kazakhstan, and Uzbekistan, have developed PPP-specific legislation and institutions, creating an immense potential for PPPs and attractive investment opportunities for all stakeholders (Invest in Network 2020).

Investment Trends: Financing Instruments

Global energy sector investments are characterized by a large share of equity in the financing structure, at slightly above 50%. Amid a continuing decrease in borrowing costs, especially in developed economies, the International Energy Agency (IEA) projects that the share of debt will grow. Importantly, the share of debt financing is even across investment segments, within a range of 40%–60% (Figure 14).

Figure 14: Overview of Energy Investments by Instrument

(%)

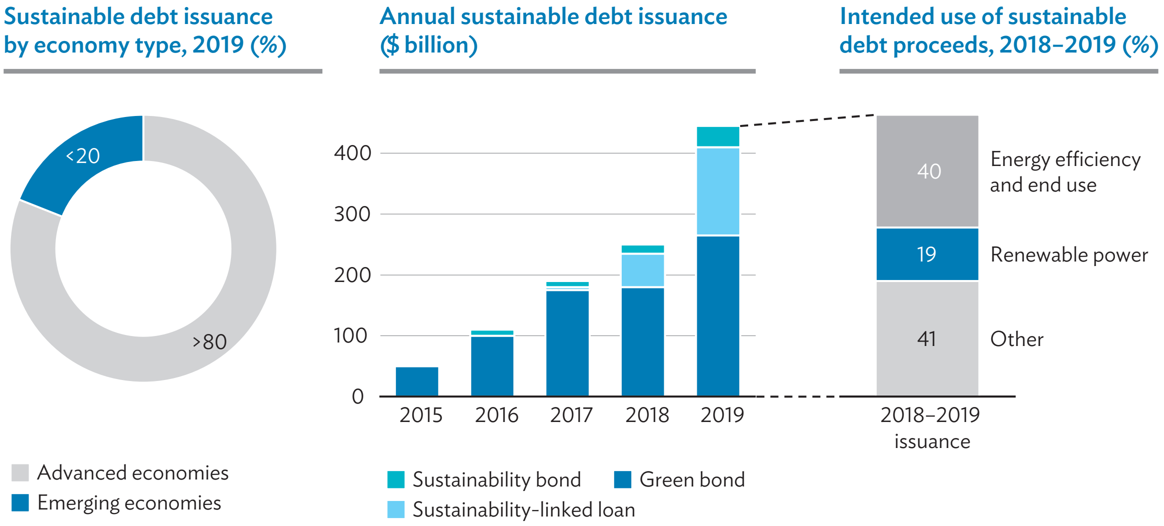


Source: International Energy Agency. 2020. *World Energy Investment 2020.* Paris.

One of the contributors to the growing share of debt in the energy sector infrastructure financing is a rise in sustainable debt, which has increased from around $50 billion in 2015 to more than $400 billion in 2019. Sustainable debt consists of such instruments as green bonds (focused, among other topics, on energy efficiency or renewables projects), sustainability-linked loans, and sustainability-linked bonds. Sustainability-linked bonds are focused not only on climate but also on broader environmental, social, and governance issues. As of 2019, approximately 80% of all green and sustainable debt is issued in developed economies (Figure 15). Emerging markets are projected to follow this trend, with a rising awareness about environmental, social, and governance issues, specifically climate challenges.

Availability of financing in most CAREC countries is rather low because of the limited capacity of local institutions. IFI support has partially compensated for insufficient financing availability. While CAREC members are yet to take advantage of the full potential of sustainable debt, some have seen it start to gain traction: the PRC was the second-largest country in terms of green bond issuance in 2020, and Georgia issued its first green bonds in 2020. Meanwhile, some recent power generation projects have been developed via special-purpose companies utilizing project finance, including M-KAT in Kazakhstan and Nur Navoi PV plant in Uzbekistan (ADB; World Bank 2020) (Box 3).

Figure 15: Sustainable Debt Overview



Source: International Energy Agency. 2020. *World Energy Investment 2020*. Paris.

Box 3: M-KAT Photovoltaic Power Plant, Kazakhstan

M-KAT is a private investment project consisting of construction, maintenance, and operation of a 100-megawatt (MW) solar photovoltaic plant in Jambyl Region, southern Kazakhstan. The plant was successfully commissioned in late 2019, and the project's total cost was around $120 million.

Kazakhstan's southern region faced power deficits and depended heavily on electricity from other regions, particularly on power generated by coal power plants in northern Kazakhstan. M-KAT helps to partially alleviate this by generating at least 154 gigawatt-hours per year of clean electricity. In addition, the project is consistent with Kazakhstan's strategic plan to achieve a 50% share of clean energy in total power generation by 2050. M-KAT helps to reduce Kazakhstan's greenhouse gas emissions by at least 82,000 tons by replacing electricity generated from coal.

Key Stakeholders

Successful project implementation has been ensured by strong cooperation across various stakeholders, including the following:

(i) The **operating company** is represented by a special-purpose entity, M-KAT Green LLP, established to obtain financing and implement the project.

(ii) The **project sponsor** is Total Eren SA, a leading French-based independent power producer with a 1,877 MW portfolio of renewable energy power plants in operation worldwide. Total Eren SA owns 100% of M-KAT Green LLP and is the primary initiator and investor in the project.

(iii) The **electricity off-taker** is the Financial Settlement Centre for Support to Renewable Energy Resources (FSC), a subsidiary of Kazakhstan Electricity Grid Operating Company designated to promote development of renewable energy. FSC signed a 15-year power purchase agreement (PPA) with the operating company.

(iv) The **co-financiers** are the Asian Development Bank (ADB) and European Bank for Reconstruction and Development (EBRD), which provided around $85 million in loans, about 70% of the total project cost. Crucially, the loans were denominated in the national currency, helping to mitigate the foreign exchange risk for the investor who is receiving revenue in tenges. The financiers offered loan terms more favorable than those available in the local market.

Regulatory Enablers

The first step for the development of renewable energy in Kazakhstan was taken in 2009, with the passage of a law supporting its use and the adoption of a policy document outlining a proposed transition toward a green economy by 2050. The law and document set the direction for development in this sector and showed the country's strong green energy ambitions. Private investments followed further adoption of secondary legislation and, specifically, the establishment of the FSC in 2013, which was mandated to sign PPAs and purchase all clean electricity generated by independent power producers. The missing regulatory piece was added in 2014, with the introduction of feed-in tariffs for renewable energy.

Under these regulatory conditions, Total Eren signed a 15-year PPA with the FSC in 2016. A Project Support Agreement negotiated between ADB, the EBRD, M-KAT, and the Ministry of Energy was signed to mitigate the regulatory risks.

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Box 3 *continued*

The M-KAT project was one of the first utility-scale solar power plants in Central Asia and serves as a reference project for the country and sector. In fact, the rapid technological advancement and improving investment climate in the country have generated higher-than-expected interest in renewable energy projects. In response, the feed-in tariff mechanism was replaced in 2018 with an auction mechanism, according to which renewable energy PPAs are awarded only via competitive tenders, where bidders with the lowest proposed electricity price are awarded a contract. As a result, the electricity price in solar PPAs decreased to nearly $40 per megawatt-hour as of December 2020.

Lessons Learned

Even though the M-KAT project was introduced via a feed-in tariff mechanism that was replaced, it provides a valuable insight into potential early-stage strategies for attracting private sector investments into renewable energy. In the case of Kazakhstan, this mechanism has served as a transition from virtually zero investment to competitive auctions. Participation of well-known companies, such as Total, and institutions, such as ADB and the EBRD, provides a solid example to stakeholders in Kazakhstan that there are trustworthy partners in renewable energy projects. This has been among the key factors leading to stronger interest in the renewable sector by private investors and has led to the introduction of an auction system, which has already resulted in significant benefits for Kazakhstan and its energy sector.

Moreover, auction mechanisms have proven to be an increasingly viable approach to mobilize large-scale investment in solar and wind energy because of their ability to reveal competitive prices as compared to feed-in tariff schemes.

This experience can be highly valuable to Central Asia Regional Economic Cooperation (CAREC) countries that are in the early stages of attracting private sector investments into their power sector. Introduction of a feed-in tariff as a transitional mechanism can provide strong assurances for investors, and the successful implementation of such projects by respectable companies and institutions can lead to greater interest from private investors and more attractive terms for governments. Another key lesson learned is that rapid addition of large-scale renewable energy will drive down system costs and PPA off-take prices, without increasing the overall risks associated with renewable energy investments.

Sources: ADB. 2019. ADB's $30 Million Loan to M-KAT Green Opens New Clean Energy Pathway in Kazakhstan. News release. 3 July; ADB. Kazakhstan: Total Eren Access M-KAT Solar Power Project; EBRD. M-KAT Green Solar Power Plant; Total Eren. 2020. M-KAT Solar Power Plant; and World Bank. M-KAT Solar PV Power Plant.

Investment Trends: Policy

Among the various trends in global energy policy is the establishment of carbon pricing mechanisms, one of the most widespread tools for gradual shifts toward low-carbon technologies. Carbon pricing is a policy instrument that captures the external costs of carbon emissions and assigns them to their source. Carbon pricing initiatives are already implemented in more than 60 countries and cities. They are formulated in two principal ways: (i) through emissions trading schemes (ETS) that establish a cap on total greenhouse gas emissions and offer trading allowances, thereby creating a market price of carbon emissions; and (ii) via a carbon tax, imposed by governments on the carbon content of fuels.

A second important trend relates to policy efforts to limit coal-fired power generation. Almost 200 nations agreed to phase down coal usage at the 26th United Nations Climate Change Conference of the Parties (COP26) in 2021. Forty-six nations stepped up their pledges to phase out coal-fired power generation and only build new plants under the condition that they are equipped with CCUS technology (Rives 2021).

A highly important development in energy policy relates to changes in support measures for renewable power generation. Feed-in tariffs have been a widely used support scheme but are now increasingly replaced by auction (tendering) schemes.

Finally, large-scale government green energy programs have emerged in several countries and regions. The European Union (EU) "Green Deal" has an overall budget of more than $1 trillion by 2030, which relies on both public spending and crowding-in of private capital. Similar programs have already been unveiled in the United States (US), where the government focuses on developing power grids, introducing energy efficiency measures, and building charging infrastructure for electric vehicle (EVs). In the PRC, the government introduced a "New Infrastructure" plan in 2020. The plan aspires to invest nearly $1.4 trillion in a wide range of programs across energy and information technology infrastructure. Key areas include ultra-high-voltage power transmission lines and charging infrastructure for EVs.

CAREC member countries are actively following global trends in energy policymaking (Box 4). For instance, two members—Kazakhstan and the PRC—have established carbon pricing mechanisms, which cover a significant share of overall emissions and promote efficient use of energy among large polluters. Other governments are expected to introduce similar carbon pricing mechanisms, most likely ETS, reacting to growing environmental pressure and international decarbonization agreements. At the same time, the phase-out of coal remains a distant goal in most emerging markets, including those in the CAREC region and especially the PRC.

Availability of support mechanisms for renewable power generation differs greatly across CAREC member countries. Several of these countries failed to implement any support mechanisms, which has led to negligible renewable energy penetration. Some countries introduced feed-in tariffs or premiums, providing an incentive for private investors to enter the market. Others have already transitioned to auction schemes, enabling a more cost-efficient expansion of renewable energy capacity. As costs in wind and solar PV energy continue to decrease, the feed-in tariffs are likely to be gradually lowered or eliminated in favor of capacity auctions.

Finally, public sector spending on infrastructure is not rising in most CAREC countries, where governments lack financial resources to undertake major investments. The major exception to this is the PRC, which has prioritized development of modern transmission and power generation infrastructure in recent government programs. Kazakhstan and Azerbaijan also have prioritized energy infrastructure investments, including large-scale domestic and cross-border natural gas transmission projects.

Box 4: Regulatory Framework in Uzbekistan

Uzbekistan's electricity sector was long dominated by one vertically integrated state-owned company, Uzbekenergo. At that time, the country's regulatory framework did not include sufficient opportunity for private sector participation, which, coupled with underinvestment in the power sector, led to aging infrastructure. The government made efforts to diversify its gas-dominated electricity mix by developing renewable energy. However, due to institutional resistance, lack of capacity, and an insufficient regulatory framework, planned renewable energy projects did not come online.

Uzbekistan then initiated a broad reform program, ranging from macroeconomic (e.g., the foreign exchange market) to sector-specific reforms. In the energy sector, this included the formation of the Ministry of Energy (MOE), the unbundling of vertically integrated state-owned companies, and improvements to the regulatory framework. Along with the government's willingness to cooperate with private investors, new mechanisms were prepared to develop renewable energy projects. Actively using support from international financial institutions, Uzbekistan managed to quickly establish a strong portfolio of renewable energy projects in the development and construction stage. These included the 100-megawatt (MW) Nur Navoi Solar plant (Masdar), 100 MW Samarkand photovoltaic (PV) plant (Total), 457 MW Sherabard PV plant (Masdar), 1.5-gigawatt (GW) Zarafshan wind farm (Masdar), and another 1.5 GW wind farm in Karakalpakstan (ACWA Power). Several additional tenders are expected to yield similar results.

Key Stakeholders

The main stakeholders in Uzbekistan's energy sector include:

(i) The MOE, which is tasked with **regulatory and policy-making functions** in energy as the main government body in the sector.

(ii) National Electric Grids of Uzbekistan (NEGU), the national state-owned electricity transmission system operator (TSO), formed as a result of the unbundling process of Uzbekenergo in 2019. NEGU also acts as a **single electricity purchaser** and signs power purchasing agreements (PPAs) with independent power producers (IPPs).

(iii) **Private investors** include such global companies as Masdar, ACWA Power, Total, and Eren. Investors can start producing and selling electricity in Uzbekistan after signing a PPA with NEGU, following direct bilateral negotiations with the government or after bidding the lowest price in competitive tenders.

(iv) International financial institutions (IFIs) not only support public and private players with financing, but also act as **transaction advisers** to the government and drive rapid and transparent establishment of energy capacity tenders.

Regulatory Enablers

The Government of Uzbekistan started energy sector reforms in 2019 with the establishment of the MOE. Previously, regulatory and policy-making responsibilities were structured across several agencies. Consolidation of these functions under the MOE creates better conditions for sound functioning of the markets. Another key decision has been the unbundling of vertically integrated companies, specifically Uzbekenergo. This has led to the establishment of NEGU, an electricity TSO with a clear set of responsibilities and operations. Discussions are ongoing to further separate a single-buyer function from the TSO and set up a separate legal entity for this function.

continued on next page

Box 4 *continued*

The most impactful legislation on private sector participation was the adoption of a Renewable Energy Law in 2019. The law affirmed key rights for private renewable energy producers, specifically a guarantee of access to the power grid and the dispatch of generated electricity. NEGU acts as a single purchaser of electricity from IPPs and is entitled to sign PPAs with private investors. Renewable projects are regulated by the existing Investment Law or by the Public–Private Partnership (PPP) Law. Such projects typically involve private sector financing, freeing up public budget for other priority expenditures.

The new regulatory framework foresees two pathways to developing renewable energy projects. The first involves bilateral agreements with investors and leaves an option of an unsolicited offer to the government for a renewable energy project. The Asian Development Bank (ADB), together with the European Bank for Reconstruction and Development (EBRD) and the World Bank, has provided policy advice for the government on the pros and cons of bilateral PPP deals. As a result, the government will prioritize tendered deals for improved transparency and price competitiveness. The procedure requires approval from the Ministry of Investments and Foreign Trade, together with a dedicated Presidential Decree. While this process can take some time, several companies are actively engaging in negotiations with the government on potential projects. For instance, the EBRD provided a loan to support the construction and operation of a 100 MW solar power plant and launch a pilot auction for solar PV in the Navoi region.

The second option involves a competitive tender of renewable energy capacity and represents an innovative approach developed by Uzbekistan jointly with IFIs. Specifically, the Government of Uzbekistan has assigned renewable energy capacity to three IFIs that will act as transaction advisors and help to prepare and hold tendering procedures according to international legal and transparency standards, as well as offer financing to the winning bidders. Specifically, the EBRD will launch tenders for 1 GW of wind power capacity, while ADB and the International Finance Corporation are in the process of launching solar power capacity tenders for 1 GW each. Multiple tenders under this procedure are in an active phase of development and continue to prove numerous advantages of this approach, including a shorter implementation period, a higher level of transparency, and lower transaction costs for bidders, thus attracting hundreds of potential investors.

Lessons Learned

The experience of Uzbekistan shows that leading international investors are eager to find investment opportunities in emerging markets, but require a supportive regulatory framework as well as clear and transparent procedures for developing renewable energy projects. Another important lesson is that Uzbekistan can benefit from the experience and knowledge of the private sector in developing wind or solar projects, which the public sector lacks. Consequently, risks of delays and cost inefficiency are minimized by involving the private sector.

Sources: ADB. 2019. Uzbekistan: Samarkand Solar Power Project; *AzerNews*. 2017. Chinese Company to Build Solar Power Plant in Uzbekistan. 14 January; EBRD. 2020. EBRD and Partners' Private Renewable Energy Project in Uzbekistan; Invest in Network and Central Asia Emerging Markets Law Firm. 2020. Uzbekistan Market Update; and V. Petrova. 2020. Total Eren Seeks EBRD Debt for 100-MW Solar Project in Uzbekistan. *Renewables Now*. 25 August.

Investment Needs in CAREC

Investment Needs in CAREC, excluding the People's Republic of China

The three scenarios established in this report evaluate different levels of energy investment needs in CAREC countries (without the PRC) until 2030, with an estimated range of $136 billion–$339 billion. Significant investments are required across the power generation, T&D, and energy efficiency sectors, considering the large market size and respective need for modernization. Investment needs for renewable energy sources are expected to reach $39 billion under the Business-as-usual (BAU) scenario, $84 billion under the Government Commitments scenario, and $133 billion under the Green Growth scenario. This illustrates both the large potential and the ambitious targets of renewable energy development. Given the expected gradual switch from coal to natural gas, and natural gas to power generation projects, significant investments in the range of $31 billion–$41 billion, depending on the scenario, will also be required. Following governments' plans to increase electricity generation from nuclear power plants, investment needs are projected to be $12 billion–$50 billion by 2030, depending on the scenario.

Assessing the relative investment needs in terms of categories, those related to generation are expected to be the largest across all scenarios—accounting for 56%–63% (or $76 billion–$213 billion) of total investment needs, depending on the scenario. Energy efficiency measures will also require significant investments amounting to $35 billion under the BAU scenario, $52 billion under the Government Commitments scenario, and $77 billion under the Green Growth scenario. Finally, energy T&D infrastructure (e.g., electricity and natural gas network modernization and expansion, installation of metering equipment and remote monitoring systems) is assumed to require a further $25 billion–$49 billion, depending on the scenario (Figure 16).

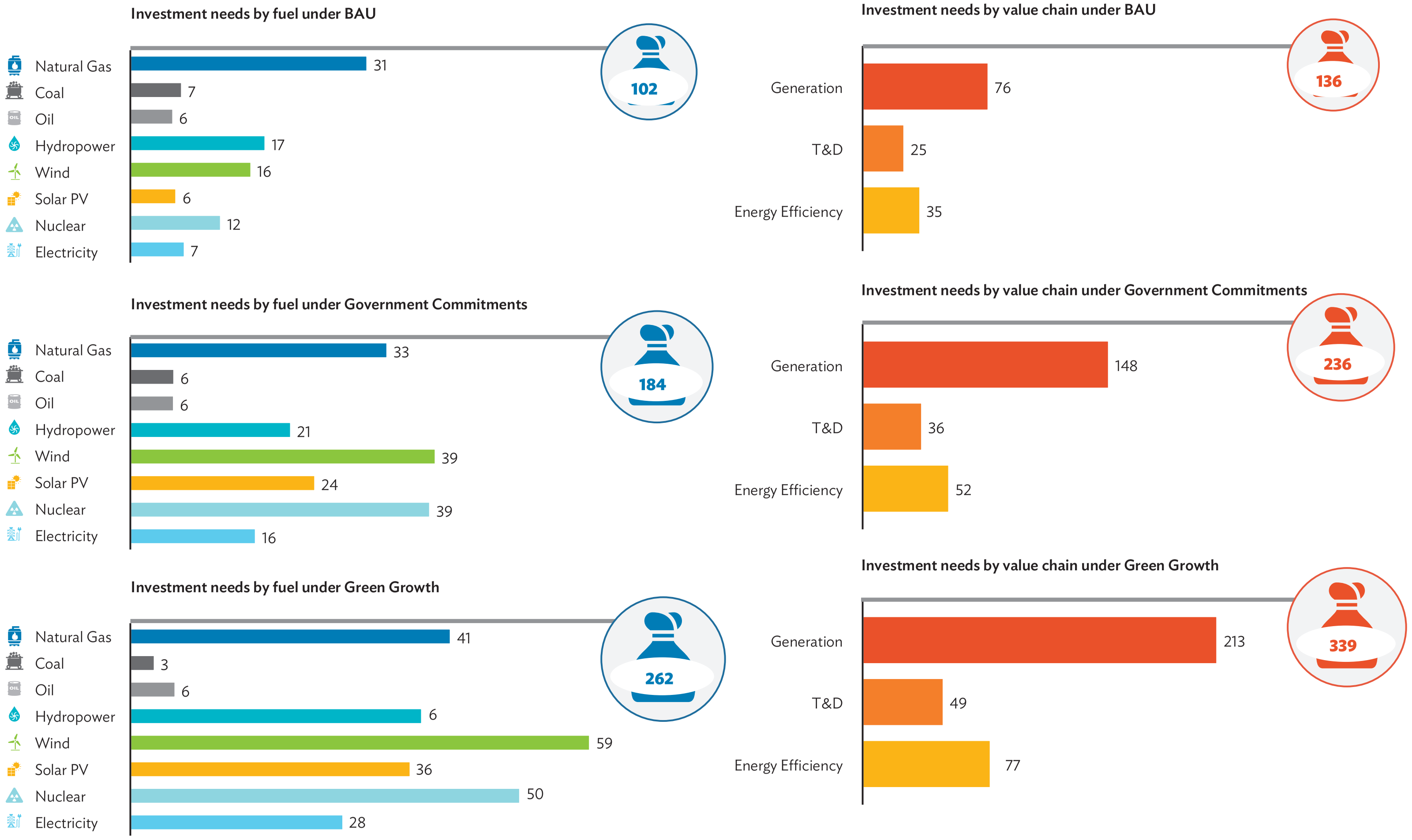
Investment Needs in CAREC, including the People's Republic of China

The three scenarios estimate different levels of energy-related investment needs in CAREC countries (including the PRC) until 2030, with the projected value between $2,934 billion and $3,836 billion, depending on the scenario. Investment needs for renewable energy sources are expected to reach $824 billion under the BAU scenario, $1,014 billion under the Government Commitments scenario, and $1,329 billion under the Green Growth scenario. Following government plans to increase electricity generation from nuclear power plants, investment needs are projected to be between $181 billion and $379 billion by 2030, depending on the scenario. Considering the expected gradual switch from coal to natural gas, natural gas power generation projects will require investments ranging between $139 billion and $178 billion, depending on the scenario. Finally, some investments are also expected to go to the rehabilitation of old coal-fired power plants, as well as construction of more efficient new plants, resulting in projected investments of between $147 billion and $172 billion by 2030, depending on the scenario.

Assessing investment needs in terms of categories, the largest investments are needed for the generation sector, reflecting the countries' target to shift to more sustainable power generation, accounting for 43%–50% of total investment needs ($1,253 billion–$1,924 billion, depending on the scenario). Energy efficiency measures will also require significant investments amounting to $913 billion under the BAU scenario, $932 billion under the Government Commitments scenario, and $1,015 billion under the Green Growth scenario. Finally, energy T&D infrastructure investment needs (e.g., electricity and natural gas network modernization and expansion, installation of metering equipment and remote monitoring systems) are assumed to require a further $768 billion–$901 billion, depending on the scenario (Figure 17).

Figure 16: Energy Infrastructure Investment Needs until 2030—CAREC, excluding the People's Republic of China

($ billion)

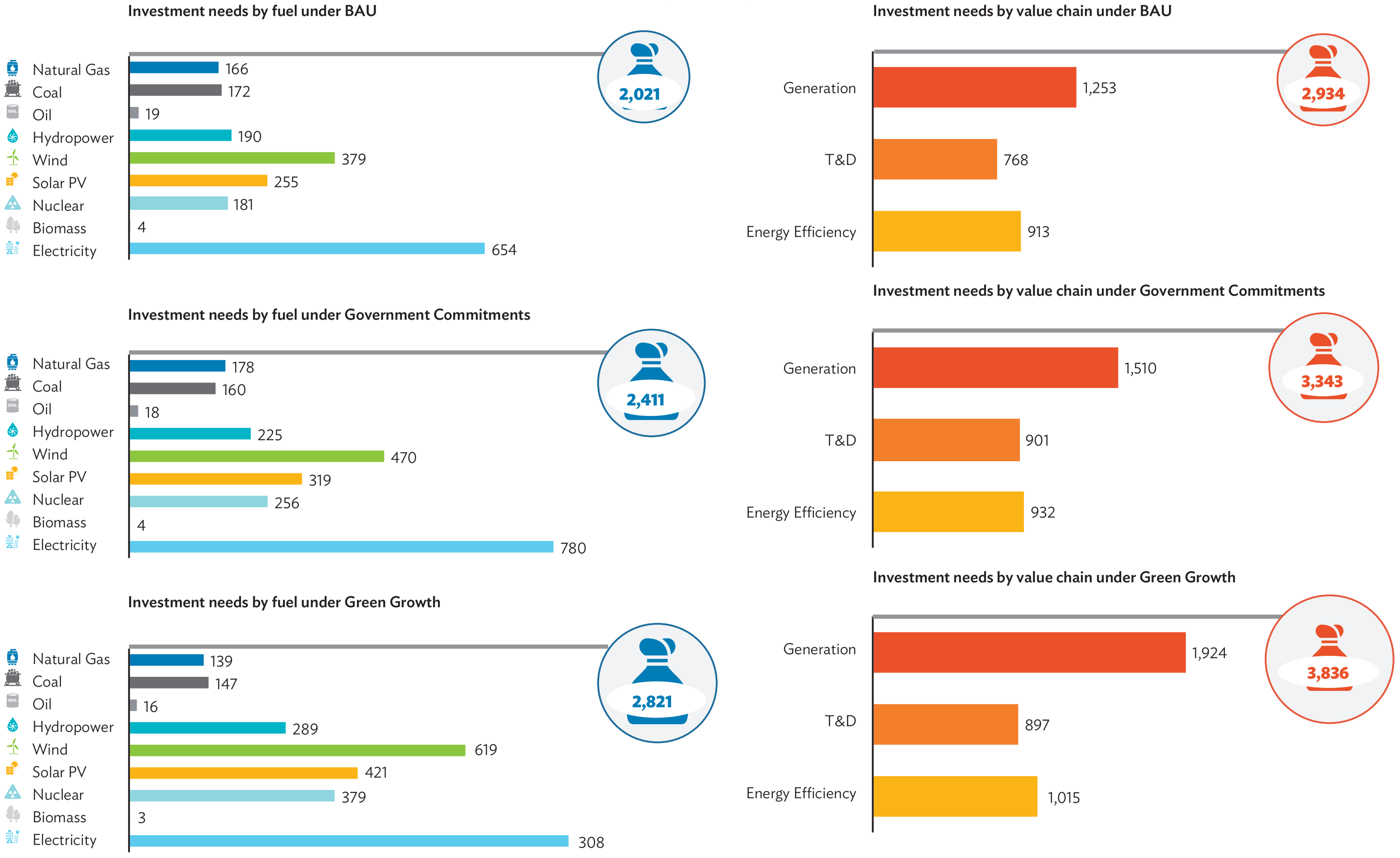


BAU = Business-as-usual, CAREC = Central Asia Regional Economic Cooperation, PV = photovoltaic, T&D = transmission and distribution.

Source: The forecasts are based on Roland Berger / ILF methodology described in the Methodology section.

Figure 17: Energy Infrastructure Investment Needs until 2030—CAREC, including the People's Republic of China

($ billion)



BAU = Business-as-usual, CAREC = Central Asia Regional Economic Cooperation, PV = photovoltaic, T&D = transmission and distribution.

Source: The forecasts are based on Roland Berger / ILF methodology described in the Methodology section.

Challenges and Opportunities in CAREC

CAREC countries are developing rapidly, with an expected annual gross domestic product (GDP) growth rate of almost 9% by 2030 for CAREC countries including the PRC, or 10% without the PRC. This will be generated by a favorable investment climate, as demonstrated by numerous international projects with private investors (such as Total, BP, and Chevron).

Yet, private investors may face a few common challenges when investing in the energy sector in CAREC countries. The first challenge stems from considerable energy subsidies in several countries, which, in some cases, constitute 3%–7% of GDP or $115–$230 per capita (2020). Sizeable energy subsidies imply prices lower than market level, which consequently has a negative impact on commercial feasibility of energy projects. In several countries, governments also intervene in market pricing mechanisms, which has a similar effect to energy subsidies.

Another challenge is that energy infrastructure (especially T&D facilities) in several CAREC countries was built decades ago and has been in use since. This is highlighted by the substantial energy losses, reaching up to 20% in the electricity sector and 12% in the natural gas sector (2020), as well as insufficient energy efficiency in consumption. However, governments are recognizing this issue and acting to address it. For instance, Uzbekistan took measures for increasing energy efficiency (including the revision of building energy codes from 2009 to 2015 and the adoption of the Presidential Decree "On additional measures to reduce the dependence of economic sectors on fuel and energy products by increasing the energy efficiency of the economy and using available resources" in 2020), and now provides support for the installation of energy-efficient equipment. Mongolia developed a new energy policy, which gives particular attention to energy savings and introduces energy audits; whereas, Azerbaijan is carrying out a program of installing smart metering systems, aimed at rehabilitation of the distribution network.

Several countries are also working on liberalizing their energy markets by shifting from vertically integrated state-owned companies to unbundled energy markets. Such market structures reduce uncertainties for private investors. For example, Tajikistan has unbundled Barqi Tojik, a vertically integrated electric utility, into three independent companies, with each in charge of a different function: electricity generation, transmission, and distribution. Georgia introduced power generation rules that were approved in 2020 in line with the principles of market liberalization, establishing a competitive electricity market. Pakistan approved a comprehensive framework and implementation plan in 2020 aimed at building a competitive wholesale power market by 2022.

Furthermore, CAREC countries present extensive investment opportunities across energy technologies. The first one stems from the very significant technical potential in renewable energy sources of around 20 terawatts. Apart from their renewable potential, CAREC countries have considerable natural gas production (e.g., the PRC ranked 4th among the world's natural gas producers in 2020, Turkmenistan was 13th, Uzbekistan 17th, Kazakhstan 23rd, and Azerbaijan 26th) (British Petroleum 2021). This is significant and holds forth the prospect for the future development of blue hydrogen, which uses natural gas as feedstocks, until green hydrogen using renewable energy sources may become part of the value chain in a more distant future.

Another investment opportunity comes from the CAREC countries' extensive investment needs in the energy sector, which are difficult to cover by state budgets only. As a result, several countries (including Kazakhstan, Kyrgyz Republic, and Mongolia) have developed PPP frameworks to facilitate private investment. Besides that, the PRC has simplified the procedures for foreign investors to enter the country's energy market. For example, investors are no longer required to form joint ventures with local companies.

In addition, the PRC has executed numerous R&D, pilot, and demonstration projects in key modern technologies such as BESS, CCUS, and green hydrogen.

The CAREC region's cross-border ties and possibilities for trade provide another opportunity for investors. For instance, the Central Asian Power System (CAPS) interconnects Central Asian countries (Kazakhstan, Kyrgyz Republic, and Uzbekistan, with Tajikistan expected to be reconnected in 2022) at different voltage levels. Some other large interconnection projects include the Trans Anatolian Natural Gas Pipeline, supplying natural gas from Azerbaijan via Georgia to Türkiye and Europe; the Turkmenistan–Afghanistan–Pakistan Power Interconnection; and the Turkmenistan–Afghanistan–Pakistan–India gas pipeline. While predictions as to whether and when the last two projects can be commissioned are difficult because of the political situation in Afghanistan, these projects highlight the solid potential of regional trade in the CAREC region.

Major Foreign Investors in CAREC

The involvement of major investors in the energy sector of CAREC countries varies depending on the country and on a mix of factors, including resource availability and the regulatory framework. The major active investors include (but are not limited to) such energy giants as BP and Chevron in the fuel supply sector, and Masdar and ACWA Power in the power sector (Figure 18). Cooperation with them has allowed CAREC member countries to absorb additional knowledge and technology and introduce more competition into their energy markets.

The Role of International Financial Institutions

IFIs play a substantial role in carrying out social and economic assistance programs in developing and emerging markets (CAREC). An overview of IFI activities across the energy sector in CAREC countries is presented below.

International Financial Institutions' Investment Trends in Renewables

IFIs have given more than $10 billion in investment funding in 2013–2017 to renewable energy projects in the CAREC region, with a compound annual growth rate (CAGR) of 25%. In terms of the types of projects, IFIs invested $5.8 billion in hydropower and $2.0 billion in solar PV in CAREC member countries, excluding the PRC, for 2013–2017 (Figure 19).

Figure 18: Major Investors Active in the Energy Sector of CAREC Member Countries

(Not Exhaustive)

Company name	Country	Sector
BP	United Kingdom	⛽
Chevron	United States	⛽
Equinor	Norway	⛽
Exxon Mobil	United States	⛽
Lukoil	Russian Federation	⛽
Total	France	⛽ ⚡
Masdar	United Arab Emirates	⚡
ACWA Power	Saudi Arabia	⚡
Engie	France	⚡

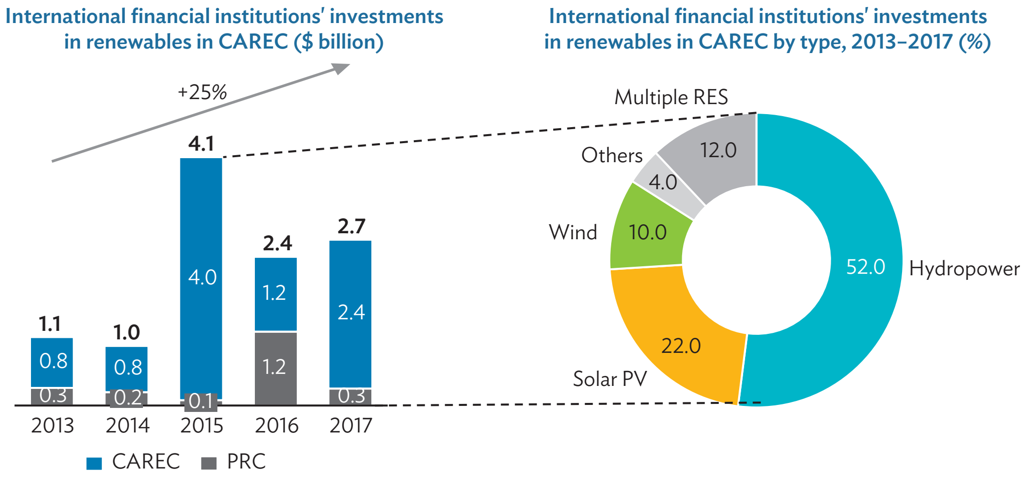
⛽ Fuel supply

⚡ Power sector

CAREC = Central Asia Regional Economic Cooperation.

Sources: Chevron. Kazakhstan: Highlights of Operations; EBRD. 2020. EBRD and Partners' Private Renewable Energy Project in Uzbekistan; Energy Industry Review. 2021. Total Eren Secures Financing of Tutly Solar Project in Uzbekistan; Fitch Solutions. 2020. *Azerbaijan Oil & Gas Report*. London; Fitch Solutions. 2020. *Kazakhstan Oil & Gas Report*. London; Fitch Solutions. 2020. *Pakistan Oil & Gas Report*. London; Fitch Solutions. 2020. *Uzbekistan Oil & Gas Report*. London; Fitch Solutions. 2020. *Uzbekistan Power Report*. London; Masdar. 100 MW Nur Navoi Solar Project; and Total Eren. 2020. Solar Tracking Bi-Facial PV Project – Tutly Uzbekistan.

Figure 19: Investments of International Financial Institutions in Renewable Energy Projects in CAREC, 2013–2017


International financial institutions' investments in renewables in CAREC ($ billion)

International financial institutions' investments in renewables in CAREC by type, 2013–2017 (%)

CAREC = Central Asia Regional Economic Cooperation (excluding the People's Republic of China), PRC = People's Republic of China, PV = photovoltaic, RES = renewable energy sources.

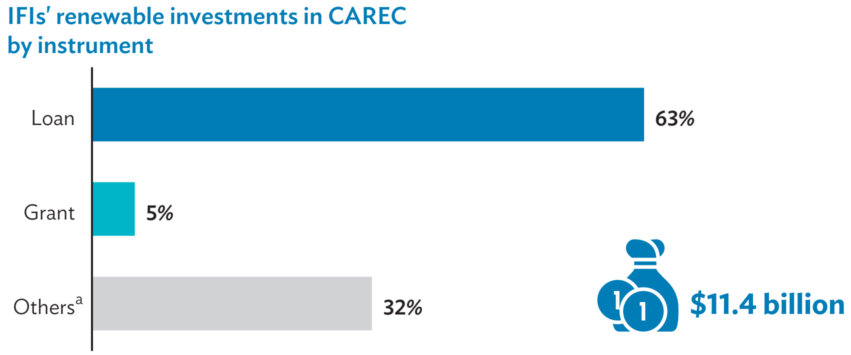
Note: Multiple RES refer to commitments that target more than one renewable energy technology. These could be equity investments, green bonds, investment funds, multiple project commitments, projects that combine technologies, and any other commitment that cannot be clearly categorized under one single technology.

Source: International Renewable Energy Agency. Renewable Energy Finance Flows. https://www.irena.org/Statistics/View-Data-by-Topic/Finance-and-Investment/Renewable-Energy-Finance-Flows.

International Financial Institutions' Instruments in Supporting Energy Projects

IFIs employ various instruments to support energy projects in the CAREC region. The most common are loans, followed by grants. Others include blended finance, private development finance, and guarantees (Figure 20). One noteworthy example where some of those instruments were deployed is the Nur Navoi Solar Project (Masdar) (Box 5).

Figure 20: Investments of International Financial Institutions in Renewable Energy Projects in CAREC by Instrument, 2013–2017



CAREC = Central Asia Regional Economic Cooperation, IFI = international financial institution.

[a] This includes other official flows (nonexport credit), guarantees, insurance, and private development finance.

Source: International Renewable Energy Agency. Renewable Energy Finance Flows. https://www.irena.org/Statistics/View-Data-by-Topic/Finance-and-Investment/Renewable-Energy-Finance-Flows.

Policy Recommendations

Several barriers prevent effective private sector involvement in the CAREC region, limiting access to much needed investment. Governments can enable broader private sector participation across energy value chains by implementing the following key measures:

(i) **Establish independent regulatory authorities.** In several CAREC member states, as of 2021, policy-making and regulatory functions are carried out by the same institution. Transforming regulating and policy-making institutions into independent authorities can facilitate competition, increase investors' confidence, and attract more investments in the energy sector, as demonstrated by global best practices.

(ii) **Reduce energy subsidies while protecting vulnerable consumers.** By reducing (and gradually eliminating) energy subsidies, CAREC governments can remove some major barriers to private sector investments. In the short-to-medium term, removing subsidies will result in higher energy bills for consumers; hence, targeted social protection measures for vulnerable and low-income households may need to be considered.

Box 5: Nur Navoi Public–Private Partnership Solar Project, Uzbekistan

Uzbekistan has vast energy potential, including both fossil fuels and renewable resources. The country has recently taken sweeping actions and reforms to create an enabling environment for private sector investments, including the adoption of the Law on Public–Private Partnership (2019), Concept Note for Ensuring Electricity Supply in Uzbekistan in 2020–2030, and the Strategy on Transition to "Green" Economy 2019–2030. A broad coalition of international financial institutions (IFIs), including the Asian Development Bank (ADB), European Bank for Reconstruction and Development (EBRD), and the International Finance Corporation (IFC), have guided Uzbek stakeholders in the development of their first competitive tender in the energy sector and by offering financing and guarantees to bidders. The tender for the Nur Navoi solar plant was held in 2019 and is widely considered a landmark success given the large number of bidders (more than 30) and the very low prices offered ($0.027 per kilowatt-hour). With expected commissioning in 2021, the project will result in the first grid-connected utility-scale solar independent power producer in Uzbekistan and the country's first power generation public–private partnership (PPP) at a total cost of $110 million.

Project Key Stakeholders

(i) The **project company**, Nur Navoi Solar Foreign Enterprise LLC, was established by the sponsor as a special-purpose vehicle.

(ii) Masdar is the project's **sponsor** and the winning bidder of the tender. Active in more than 30 countries, Masdar's portfolio includes a gross capacity of 5 gigawatts of installed or under development clean energy projects, with total value of more than $14 billion.

(iii) The **power purchaser** is the National Electric Grids of Uzbekistan (NEGU), a state-owned unbundled transmission system operator. NEGU has signed a power purchasing agreement (PPA) with Nur Navoi and will off-take power for 25 years at Masdar's bid price.

(iv) From the government side, the Ministry of Investments and Foreign Trade (MIFT) acts as the **implementing agency** and has signed a government support agreement with Nur Navoi to enhance the investment environment.

(v) The **transaction advisor** is the IFC, who provided wide technical assistance and helped the government to structure, prepare, and hold the tender.

(vi) Several reputable IFIs are project **financiers**, including ADB, EBRD, and IFC. Moreover, the International Bank for Reconstruction and Development (IBRD), the lending arm of the World Bank Group, provides a partial risk guarantee to backstop liquidity risks of electricity off-take.

(vii) The **indemnifier** is the Uzbek Ministry of Finance, which signed an indemnity agreement with the IBRD to reimburse in case of a call on the guarantee.

Modality of Assistance

Almost all instruments available to IFIs have been used to enable implementation of the Nur Navoi project:

(i) **Technical assistance** on PPP tender preparation and structuring was a key success factor. As part of the World Bank's "Scaling Solar" program, the IFC offered a full package of solutions, including prefeasibility study and documentation templates, which ensured a rapid tendering and project launch.

continued on next page

Box 5 *continued*

(ii) **Financing** is fully covered by IFIs, due to a lack of debt financing options in Uzbekistan. Only several US dollar-denominated loans were issued locally and none in the infrastructure sector. The financing package for IFIs includes loans and blended finance from the IFC totaling $40 million, as well as a $20 million loan from ADB. In addition, the EBRD has provided an equity bridge loan of $60 million to Masdar.

(iii) **Guarantees** are another crucial element of IFI support. The IBRD provided a payment guarantee of up to $5 million, which represents nearly 6 months of PPA payments. Since NEGU is a newly established entity and Uzbekistan lacks a track record in PPAs, nonpayment risk was a significant obstacle for private investors. The IBRD's support effectively mitigates this risk and signals a strong commitment to renewable energy projects and private investments by the government**.** The guarantee has also been instrumental in achieving such low tariff bids at tender because of mitigation of one of the key risks. The Ministry of Finance has signed an indemnity agreement, which ensures repayment of guarantee to the IBRD in case of its call.

Lessons Learned

The Nur Navoi project shows that a supportive regulatory framework by itself is a necessary but not sufficient condition to attract private investments and needs to be supplemented by a proven track record in adhering to obligations by the government. Building such a track record might be challenging for countries where only state-owned companies were involved in the energy sector. In this context, IFIs can play a mediation role to facilitate establishment of trust-based relationships between public and private players. Even a few such projects can have significant demonstration effects and send positive signals to private investors with high risk aversion. Thus, IFIs can be a significant lever to increase the confidence of potential investors.

Furthermore, the Nur Navoi case study proves the role of IFIs in capacity building and in sharing of best practices. With significant experience from successful and unsuccessful investments in other countries, IFIs bring a critical volume of knowledge and experience to facilitate smooth project preparation and implementation.

Sources: EBRD. 2020. EBRD and Partners' Private Renewable Energy Project in Uzbekistan; Masdar. 100 MW Nur Navoi Solar Project; and World Bank. 2020. Project Appraisal Document on a Proposed IBRD Payment Guarantee in the Amount of up to $5.1 Million to the Republic of Uzbekistan and on a Proposed IFC Financing Consisting of an IFC "A" Loan in the Amount of up to $20 Million.

(iii) **Liberalize and unbundle energy markets.** The current energy market structure in some CAREC countries is largely state-owned, with production and T&D being carried out by the same public companies. Introducing competitive trading and unbundling state utility companies into separate firms can contribute to achieving a more competitive and efficient energy sector.

(iv) **Modernize energy infrastructure.** Several CAREC countries rely on energy infrastructure that is several decades old, leading to significant losses (up to 20% for electricity, and 12% for natural gas). Governments should take a leading role in the modernization of energy assets, especially T&D facilities, in order to minimize natural gas leakages and power losses. This will have a double positive effect: improving public finances via reduced costs, while reducing the carbon footprint.

(v) **Provide stronger incentives to reduce the use of coal.** Some CAREC countries that produce and consume considerable amounts of coal have already taken initial steps to disincentivize the use of coal by setting restrictions, merging key coal companies to reduce outdated assets, and so on. Nevertheless, considerable reductions in carbon emissions can be achieved by providing more incentives for developing renewable energy as well as other low-carbon sources.

(vi) **Incentivize a transition to renewables.** Many CAREC countries have established targets for the share of renewable energy in the power mix and have started to introduce necessary regulatory frameworks. Developing support mechanisms for renewable power generation is essential for attracting private sector investments in the renewable energy sector.

Background Papers

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ADB. ASEAN Catalytic Green Finance Facility. https://www.adb.org/what-we-do/funds/asean-catalytic-green-finance-facility/terms-criteria.

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Carbon dioxide footprint reduction. The energy-related carbon emissions in CAREC countries, excluding the People's Republic of China, are expected to vary significantly, depending on the scenario (photo by Olivier Le Moal/Adobe Stock©).

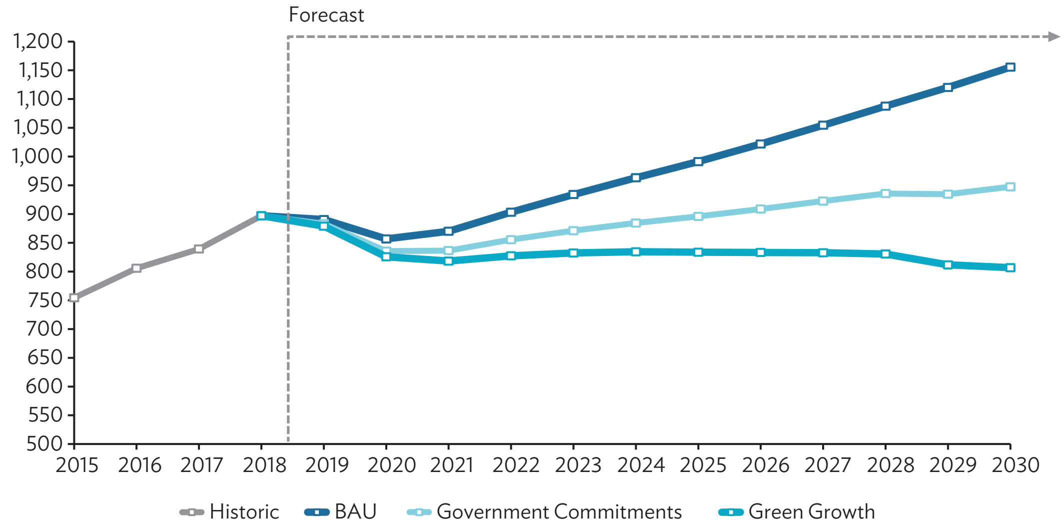
Carbon Emissions Outlook

Carbon Emissions Outlook

CAREC countries have demonstrated their commitment to act on climate change by individually submitting their Nationally Determined Contributions (NDCs). The targets vary across countries, and most of them are expected to be met, depending on the scenario.

Overall, the energy-related carbon emissions in CAREC countries, excluding the People's Republic of China (PRC), are expected to vary significantly, depending on the scenario. Under the Business-as-usual (BAU) scenario, which assumes the current energy system (with 85% of total primary energy demand satisfied by fossil fuels in 2030), energy-related carbon emissions are expected to peak at around 1,150 million tons of carbon dioxide equivalent (tCO_2e) in 2030. Under the Government Commitments scenario, emissions are projected to decrease by 18% compared to the BAU scenario, reaching approximately 950 million tCO_2e. This reduction is largely due to switching from coal-to-gas and increasing the share of renewables and nuclear energy in the primary energy mix (from 7% under the BAU scenario to 11% by 2030 under the Government Commitments scenario). Finally, under the Green Growth scenario, which assumes the largest investments, a 30% decrease to 800 million tCO_2e is expected by 2030 when compared to the

Figure 21: Energy-Related Carbon Emissions—CAREC, excluding the People's Republic of China
(million tons of carbon dioxide equivalent)



BAU = Business-as-usual, CAREC = Central Asia Regional Economic Cooperation.

Source: Historical data on carbon emissions is modelled by Roland Berger based on historical data on energy use. The forecasts are based on the Roland Berger methodology described in the Methodology section.

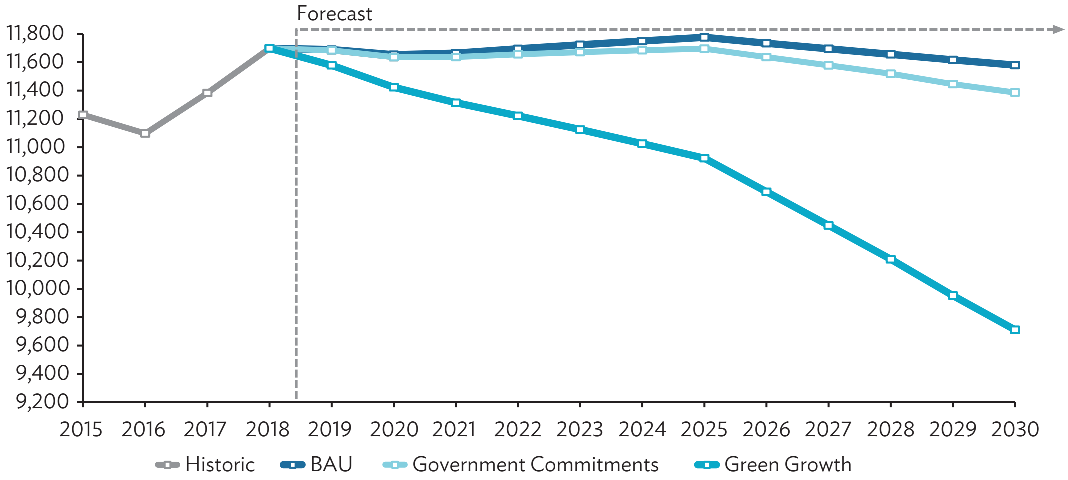
BAU scenario. This is attributed to increased renewables and nuclear energy as well as more intensive energy efficiency measures, and would bring carbon emission levels in 2030 close to the 2015 level (750 million tCO_2e) (Figure 21).

On the other hand, energy-related emissions in CAREC, including the PRC, increase gradually until 2025, followed by a more significant decrease between 2025 and 2030, under both the BAU and Government Commitments scenarios. Under the Green Growth scenario, the decline starts immediately and accelerates between 2025 and 2030. Numerically, the energy-related carbon emissions are expected to reach around 11,600 million tCO_2e under the BAU scenario and 11,400 million tCO_2e under the Government Commitments scenario by 2030. Under the Green Growth scenario, more intensive energy efficiency measures, coupled with more rapid energy transition measures, enable energy-related carbon emission levels to decline to nearly 9.70 billion tCO_2e by 2030 (Figure 22).

Almost 200 nations agreed to phase down coal usage at the 26th United Nations Climate Change Conference of the Parties (COP26) in Glasgow in 2021 to tackle climate change. Forty-six nations stepped up their pledges to phase out coal-fired power plants and only build new plants under the condition they are equipped with carbon capture, utilization, and storage (CCUS) technology (Rives 2021). The Glasgow Climate Pact calls on countries to revisit their emission reduction targets by the end of 2022 to try to keep the 1.5°C Paris Agreement target achievable. More than 100 countries signed the Global Methane Pledge announced by the US, EU, and other partners at the COP26, agreeing to reduce their overall emissions by 30% by 2030, compared to 2020 levels (Maizland 2021). Seven CAREC countries (Georgia, Kyrgyz Republic, Mongolia, Pakistan, the PRC, Tajikistan, and Uzbekistan) have submitted stronger NDCs

Figure 22: Energy-Related Carbon Emissions—CAREC, including the People's Republic of China

(million tons of carbon dioxide equivalent)



BAU = Business-as-usual, CAREC = Central Asia Regional Economic Cooperation.

Source: Historical data on carbon emissions is modelled by Roland Berger based on historical data on energy use. The forecasts are based on the Roland Berger methodology described in the Methodology section.

(UNFCCC). In particular, the PRC now aims to peak carbon dioxide (CO_2) emissions before 2030 and lower CO_2 emissions per unit of GDP by more than 65% in 2030 compared to 2005 levels. Moreover, the Glasgow Climate Pact urges countries to expedite the development and implementation of innovative technologies, as well as the adoption of sustainable energy policies, including by rapid deployment of renewables, accelerating energy efficiency measures, and escalating efforts to phase down coal-fired power plants (UNFCCC 2021).

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2

COUNTRY OUTLOOKS 2030

AZERBAIJAN

Wind generators. Azerbaijan's priority technologies and plans include developing power generation from natural gas and renewables (photo by Fokke/Adobe Stock©).

Azerbaijan Highlights

- Azerbaijan is one of the largest producers and exporters of oil and natural gas in the Central Asia Regional Economic Cooperation (CAREC) region. In 2020, 43.5 million tons of oil equivalent (toe)—72% of Azerbaijan's total energy production—were exported.
- The oil and natural gas industries are among the most important pillars of the country's economy. In 2019, oil and natural gas revenues accounted for around 40% of the country's total GDP, and for more than 90% of its total exports (IEA 2020).
- Due to the extensive availability of natural gas, 93% of electricity was generated from natural gas in 2020. While Azerbaijan has started making use of its hydropower resources, large-scale wind and solar power plants are beginning to gain ground in realizing the country's large technical renewable potential—with onshore wind, solar photovoltaic (PV), hydropower, and biomass totaling close to 27 gigawatts (GW) and offshore wind in the Azerbaijani sector of the Caspian Sea estimated at 157 GW—and to decarbonize the energy sector (Figure 23).
- Depending on the level of energy efficiency measures introduced, the country's final energy demand is projected to grow annually by nearly 3% reaching 11.9–13.3 million toe in 2030. Despite the substantial growth of its renewable energy supply, traditional fuels such as natural gas and oil will continue to play a considerable role in the overall energy supply.
- Azerbaijan's total installed capacity is around 7.6 GW. Natural gas is expected to continue dominating Azerbaijan's power generation mix until 2030, with a 65%–85% share in 2030, whereas the share of renewable energy can rise to 15%–35%, depending on the scenario. The Republic of Azerbaijan has set a target to increase its share of renewable energy capacity from 17% in 2020 to 30% by 2030 (The State Statistical Committee of the Republic of Azerbaijan 2021).
- Azerbaijan's priority technologies and plans include developing power generation from natural gas and renewables (wind and solar PV), implementing energy efficiency measures in the residential sector, and modernizing its grid infrastructure to reduce natural gas losses. Given the country's abundance of natural gas, existing infrastructure, potential demand centers, and huge offshore wind energy potential, Azerbaijan could also consider developing blue and green hydrogen in the mid-to-long term.
- Investment needs in Azerbaijan's energy system across the generation, transmission and distribution (T&D), and consumption sectors range from $10 billion to $30 billion, depending on the scenario. Ambitious renewable energy targets (1.5 GW of new installed capacity by 2030) imply that the power generation category accounts for at least two-thirds of total investment needs.
- Azerbaijan's investment opportunities stem from its solid renewable energy potential, the country's considerable track record of international energy projects (many of which involved private investors), as well as export opportunities in the short-to-medium term.
- Among the key remaining investment challenges preventing further involvement of the private sector are the country's sizeable energy subsidies, lack of a fully functional independent regulatory body, and partially bundled electricity and natural gas markets.

Figure 23: Azerbaijan—Key Figures

Renewable potential	Electricity mix	Energy exports	Carbon intensity	Energy independence
~27 GW	**94.5%**	**72%**	**111th out of 172**	**100%**
Technical potential of renewable energy in Azerbaijan is estimated at ~27 GW, with wind energy accounting for ~60% of the total potential (not including offshore wind potential estimated at 157 GW).	The share of natural gas in the electricity mix reached 94.5% in 2020.	72% of Azerbaijan's energy production was exported in 2020.	The country is ranked 111th out of 172 countries in the global ranking of carbon intensity of energy, largely due to the zero share of coal in the electricity mix.	Energy independence rate[a] in Azerbaijan is 100%.

GW = gigawatt.

[a] Energy independence rate refers to the country's self-sufficiency to fulfill its energy needs.

Sources: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 12 August 2021); K. Buljan. 2021. Floating Wind Project Unveiled in Azerbaijan. *Offshore WIND*. 15 July; State Statistical Committee of the Republic of Azerbaijan; and United States Energy Information Administration. Azerbaijan Data. https://www.eia.gov/international/data/world (accessed 12 August 2021).

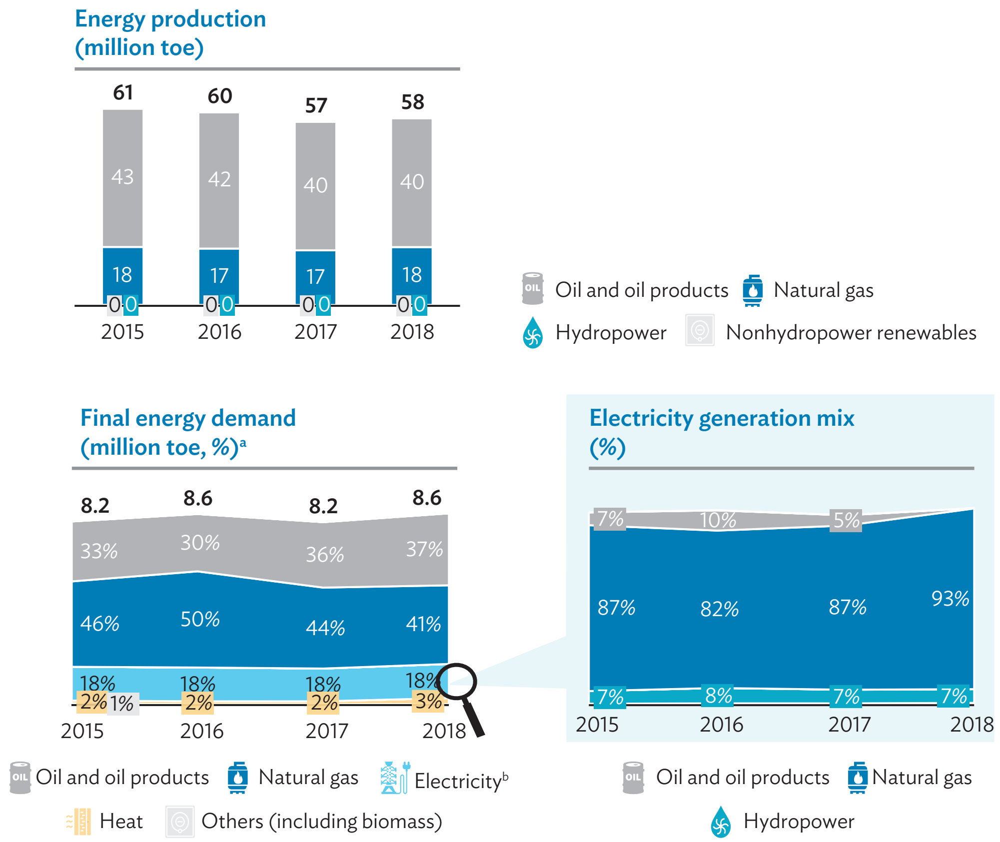
Energy Sector Profile

Country Profile

Azerbaijan is a country with a population of more than 10 million people, and a $45 billion nominal gross domestic product (GDP) as of 2020. It is also richly endowed with natural resources. The country has been gradually recovering from a 2014–2015 global decline in oil prices, with 2016–2019 annual GDP growth rate of around 8%. The coronavirus disease (COVID-19) pandemic and related restrictions affected the country's economy quite significantly, leading to an approximately 6% decline in real GDP in 2020 compared to 2019. However, due to the country's strong economic position, annual growth rates for 2020–2030 are projected at almost 6%.

Azerbaijan has one of the world's highest energy self-sufficiency ratios because of its vast production of crude oil and natural gas. The country is a major oil and natural gas exporter, exporting nearly 84% of its total domestic oil production and 31.5% of total domestic natural gas production in 2018. Due to the country's abundance of fossil fuels, natural gas and oil products dominate the country's final energy demand (almost 80% of the total in 2018) (Figure 24). Given that natural gas and oil emit less carbon dioxide (CO_2) than coal, Azerbaijan is relatively "clean" in terms of carbon intensity and energy consumption, ranking 111th out of 172 countries. In terms of energy intensity, Azerbaijan is ranked

Figure 24: Energy Profile of Azerbaijan



toe = ton of oil equivalent.

[a] Topmost numbers on the chart are in million toe.

[b] Electricity data come from various sources, including fossil fuel-based and renewables.

Sources: State Statistical Committee of the Republic of Azerbaijan; and International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 12 August 2021).

60th out of 172 countries, indicating the considerable potential for energy efficiency improvements. The government is also developing a new energy strategy that includes incentives for investing in and deploying renewable projects, thereby diversifying the country's energy mix.

Energy Sector and Technologies Assessment

Conventional Fuel Production

Azerbaijan has rich reserves of fossil fuels, with approximately 1 billion tons of oil and around 2.5 trillion cubic meters of natural gas as of 2020. Overall, although the country's oil production has been considerable (around 70% of Azerbaijan's total energy production in 2018), it declined by almost 30% between 2010 and 2019—from 51 million tons to 39 million tons. The downturn was primarily because of a natural production decline from older fields, which were developed in the early 2000s with considerable foreign investments and more than tripled the country's oil production between 2004 and 2010.

Azerbaijan International Operating Company, a consortium operated by BP, is Azerbaijan's primary producer of oil, accounting for 75% of the total. The State Oil Company of Azerbaijan Republic (SOCAR), the national oil and natural gas company, produces approximately 20% of the total.

Natural gas production has been relatively stable, with a production of 29 billion cubic meters (bcm) to 30.5 bcm annually between 2014 and 2018. Natural gas production increased from 9 bcm in 2006 to 23.4 bcm in 2008. This was due to large private investments in the Shah Deniz field project, which, as of 2020, constituted about half of the country's domestic natural gas production (total production constituted 37.1 bcm in 2020). SOCAR is another major natural gas producer, accounting for around 19% of domestic production, or around 7 billion cubic meters per annum (bcma). Azerbaijan's major oil and natural gas reserves are located in the Kura Intermontane and South Caspian depressions of the South Caspian basin. Estimates regarding the amount of remaining oil and natural gas reserves vary, but the general consensus is that a minimum of 15 years of production time remains. Azerbaijan does not have significant coal reserves or production facilities.

Electricity Generation

Azerbaijan's electricity generation has increased by 20% since 2008, reaching 26.1 terawatt-hours (TWh) in 2019. In the same year, the country's installed generation capacity amounted to almost 7.59 GW, consisting of 6.35 GW gas-fired power plants and 1.24 GW of renewable energy power plants. Renewable energy plants include 1.14 GW of hydropower plants (HPPs), all connected to reservoirs but none with pumped storage facilities; 66.15 megawatts (MW) of wind power; 37.7 MW of bioenergy and waste; and 40 MW of solar PV. With 15 natural gas-fired power plants having been constructed in the last 20 years, Azerbaijan's power plants are relatively new (17 years old on average). Therefore, no major power plant replacements are anticipated. The 2.4 GW Azerbaijan Thermal Power Plant is the only exception, with the first unit commissioned in 1981 and the last eighth unit in 1990, but it is currently undergoing rehabilitation following an accident that led to a power cut in 2018. Thus, most thermal power plants are relatively modern and operate with high efficiency, mostly using combined-cycle gas turbine technology.

The three largest HPPs are Mingachevir (424 MW, commissioned in 1955), Shamkir (380 MW, 1983), and Yenikend (150 MW, 2003), with the two older plants rehabilitated recently. Most remaining plants were commissioned during the last decade.

Transmission and Distribution

Azerbaijan's domestic oil pipeline system consists of more than 770 kilometers (km) of onshore pipelines, 1,975 km of offshore pipelines, and 9 pump stations. Its natural gas supply system comprises around 4,500 km of trunk lines and 7 compressor stations. Apart from Azerbaijan's modern export pipelines, the country's oil and natural gas infrastructure dates back to the Soviet era. Therefore, significant repairs and modernization are required. About 96% of Azerbaijan's population has access to natural gas. The grid comprises more than 36,000 km of low- and medium-pressure natural gas distribution pipelines. In 2020, natural gas losses constituted around 12% of the total supplied amount. Azerbaijan's consumption of natural gas is being metered.

The entire population has access to electricity through Azerbaijan's voltage network, which totals approximately 7,900 km (around 4,325 km of 110 kilovolts [kV]; 1,505 km of 220 kV; 31 km of 230 kV; 1,542 km of 330 kV; and 477 km of 500 kV). From 2016 to 2020, electricity transmission losses fell from

2.4% to 2.3%, and distribution losses in the electricity network fell from 10% to 8.9% of total electricity supply, which indicates the relatively satisfactory condition of the grid. To further reduce losses and modernize the system, a program is being carried out to rehabilitate the distribution grid's substations and lines, replace low-quality customer service lines, and deploy smart meters. Metering systems are compliant with international standards and owned by distribution entities.

The effective performance of Azerbaijan's electricity networks is also reflected by the relatively short duration of outages per customer in a year, with a system average interruption duration index of around 0.82 hours in 2020. This value is one of the lowest among CAREC countries. The system average interruption frequency index is also low, at 0.93 times per customer in 2020.

Azerbaijan's district heating infrastructure, however, requires modernization. Some boilers operate at low efficiency, and a substantial part of the 870 km distribution grid requires refurbishment. Meters are currently absent in the district heating chain.

Cross-Border Infrastructure

Azerbaijan has considerable transit potential, which contributes to the country's economic prosperity.

Azerbaijan has electricity interconnections with Georgia, Türkiye, the Russian Federation, and Iran. As of 2021, it exports electricity mostly to Georgia via the 500 kV Samukh–Gardabani line and the 330 kV Agstafa–Gardabani line, with a combined capacity of 700 MW (IEA 2021). Azerbaijan also has several electricity lines to Iran, with a combined capacity of 600 MW, and to the Russian Federation, with a combined capacity of 350 MW.

Owned by SOCAR, BOTAŞ and BP, the Trans Anatolian Natural Gas Pipeline is a major export pipeline (1,841 km in length) that transports natural gas from Azerbaijan to Türkiye (6 bcma) and Europe (10 bcma). The Trans Adriatic Pipeline, owned by SOCAR, BP, Snam, Fluxys, Enagas, and Axpo, exported 10 bcma to Europe via Türkiye in the 14 months since its commissioning in December 2020 (Government of Azerbaijan, Ministry of Energy 2022). Furthermore, natural gas is exported via the Southern Gas Corridor (also known as Baku–Tbilisi–Erzurum Pipeline) to Türkiye, passing through Georgia. Some 442 km of the 692 km South Caucasus Pipeline, which has a capacity of 20 bcma, passes through Azerbaijan's part of the Southern Gas Corridor.

Finally, oil constitutes around 62% of the country's energy exports (as of 2018) and is exported through three pipelines and by rail. Azerbaijan's key oil pipelines are Baku–Tbilisi–Ceyhan, Baku–Novorossiysk, and the Western Route, Baku–Supsa. Unlike some domestic T&D oil and natural gas infrastructure, export pipelines are modern and do not require additional repairs or modernization. Meanwhile, around 14 metric tons per annum of crude oil and petroleum products can be transported by rail to Georgia and Türkiye (Table 1). Capacity utilization of cross-border rail infrastructure has fallen, as pipelines are the preferred options.

Energy Consumption

Azerbaijan is an energy-intensive country but, in recent years, its energy intensity moderately decreased from 27,160 British thermal units (Btu)/$2015 gross domestic product based on purchasing power parity (PPP GDP) in 1996 to 4.280 Btu/$ 2015 PPP GDP in 2018, slightly below the global average (US EIA).

Table 1: Azerbaijan—Major Operational Cross-Border Energy Infrastructure

Energy Source	Name	Capacity	Connected Country
⚡	Samukh–Gardabani 500 kV line	700 MW	Georgia
⚡	Mugan 330 kV line, Imishli 230 kV line, Araz–Araz 132 kV line, Julfa–Julfa 132 kV line, and Astara–Astara 110 kV line	600 MW (combined)	Iran
⚡	330 kV Yashma–Derbent line and 110 kV Yalama–Bilici line	350 MW	Russian Federation
🔥	TANAP pipeline	16.0 bcma	Europe, Türkiye
🔥	TAP pipeline	10.0 bcma	Europe, Türkiye
🔥	South Caucasus pipeline	20 bcma	Türkiye
OIL	BTC pipeline	60.0 mtpa	Türkiye
OIL	Cross-border rail infrastructure	14.0 mtpa	Georgia, Türkiye
OIL	WREP pipeline	7.5 mtpa	Georgia
OIL	NREP pipeline	5.2 mtpa	Russian Federation

⚡ Electricity 🔥 Natural gas OIL Oil

bcma = billion cubic meters per annum, BTC = Baku–Tbilisi–Ceyhan, kV = kilovolt, mtpa = million tonnes per annum, MW = megawatt, NREP = North Route Export Pipeline, TANAP = Trans Anatolian Natural Gas Pipeline, TAP = Trans Adriatic Pipeline, WREP = Western Route Export Pipeline.

Sources: Fitch Solutions. 2020. *Azerbaijan Oil & Gas Report*. London; Global Energy Monitor. Trans-Anatolian Gas Pipeline; Hydrocarbons Technology. Trans Anatolian Natural Gas Pipeline Project (TANAP); International Energy Agency. 2020. *Azerbaijan Energy Profile: Country Report*. Paris; and S. Favasuli. 2020. Trans Adriatic Pipeline Begins Gas Deliveries from Azerbaijan to Italy. *S&P Global*. 31 December.

The most energy-intensive industrial sectors include food and tobacco, chemical and petrochemical, mining and metals, and construction. The largest industrial energy consumer group is chemicals and petrochemicals. The technical potential for reducing energy consumption in industry by implementing efficiency measures is estimated at 1.3 million toe.

Azerbaijan recently adopted the Law on the Rational Use of Energy Resources and Energy Efficiency, which envisages energy audits and energy management systems for business entities and buildings to identify energy efficiency and energy-saving opportunities. According to the law, business entities and nonresidential buildings subject to mandatory energy audit will be identified by criteria approved by the relevant executive authority.

Historically, the residential sector is the largest consumer group, with natural gas being the dominant source for cooking and heating. Electricity constituted around 15% of total final consumption in the residential sector for 2019, and district heating only 3%. The buildings sector is dominated by old stock, with 60% of buildings aged 50–60 years, and about 15% aged more than 60 years. As a result, the residential sector is not fully efficient in terms of energy consumption, with buildings averaging 200–280 kilowatt-hours per square meter (kWh/m^2) per year, compared to the European Union (EU) average of 180 kWh/m^2 per year (European Commission). According to the results of an energy audit conducted in Baku in 2013–2014, high-quality thermal insulation reduces the energy consumption of buildings by 50%–70%. In 2021, new energy efficiency legislation was signed and is expected to come into force in 2022. In accordance with said legislation, energy audits, energy management system, energy labeling, eco-design, the certification of buildings, and the installation of smart meters in natural gas, electricity, and heating consumption sectors should be executed.

Moreover, Azerbaijan has a large number of obsolete road vehicles. The share of vehicles older than 10 years is approximately 80% of the total (Russian Automotive Market Research 2019). Most passenger vehicles are fueled with gasoline or diesel, with gas-fueled vehicles constituting only 1% of the total in 2020 (Statistical Committee of Republic of Azerbaijan 2021). Although the car market in Azerbaijan is quite large, the number of electric vehicles (EVs) in the country remains limited. Due to a lack of proper infrastructure and the high prices of EVs, motorists still prefer traditional gasoline-powered cars (Valiyev 2021). As part of the implementation of the State Program of Road Safety in the Republic of Azerbaijan for 2019–2023, the country is expected to focus on developing EV infrastructure.

The Azerbaijan railway network (with a length of 4,285 km) is 60% electrified. The rolling stock fleet of Azerbaijan Railways, the national state-owned rail transport operator, includes 59 electric and 116 diesel locomotives (CAREC 2021).

Regulatory Framework

Following Azerbaijan's administrative reforms, the Ministry of Energy (MOE), which implements state policy and regulations in the fuel and energy sectors, was established in 2013, replacing the previous state institution with similar functions. The ministry's main functions include the preparation and implementation of state energy policy, as well as the establishment of a favorable investment environment. The State Agency for Renewable Energy Sources, which operates under the MOE, is specifically dedicated to the development of clean energy resources. The Azerbaijan Energy Regulatory Agency, which was established in 2017 and also operates under the MOE, is specifically dedicated to two tasks: (i) regulation, which includes participation in the legislative process and by-laws issues, licensing, participation in tariff setting, promotion of competition, development of incentive mechanisms to attract investment, and promotion of energy efficiency; and (ii) inspection, which includes ensuring quality of goods and services; inspection of electrical, thermal, and gas devices; participating in the investigation of accidents; handling consumer complaints; dispute resolution concerning inspections; and technical knowledge assessments (Akhundov 2019).

Azerbaijan's energy market is largely state-owned. In the electricity sector, Azerenerji OJSC is the main power producer. Operating 12 thermal power plants, 7 hydropower facilities, and 7 smaller HPPs, the company is also responsible for transmission. A few private electricity producers also own small HPPs, though their output constitutes less than 1% out of the country's total generation. Electricity distribution and supply to consumers are managed by Azerishiq OJSC. All value chain activities of heating services are conducted by Azeristiliktechizat OJSC. Finally, natural gas is produced by SOCAR, the national oil and natural gas company, which together with its subsidiaries is also responsible for processing, storing, transportation, distribution, and supply. The Gas Export Department is responsible for gas transportation. The Gas Processing Plant manages processing gas, and the Oil Processing Plant processes oil. Azeriqaz PU is a subsidiary of SOCAR and is responsible for distribution and supply. SOCAR has signed multiple agreements with international firms to explore and exploit natural gas fields. One of these agreements resulted in the Shah Deniz Consortium, which produces natural gas on the Shah Deniz field. The consortium is operated by BP, with other participants including SOCAR, Türkiye Petrolleri Anonim Ortaklığı (TPAO) (Turkish Petroleum Corporation), Petronas, Lukoil, and Naftiran Intertrade Company (NICO) (Box 6).

Box 6: Azerbaijan's Energy Market Structure—Key Players

The energy market in Azerbaijan, which is principally state-owned, is composed of three sectors: electricity, heat, and natural gas and oil. The key players in these sectors are as follows:

Electricity

Azerenerji Open Joint-Stock Company (OJSC) is a public company, the country's largest **electricity producer**, and responsible for **generation and transmission**.

Azerishiq OJSC is responsible for distribution and electricity **supply to consumers**.

Heat

Azeristiliktechizat OJSC is a key body, **responsible for heating** in the country at all stages: **production, transportation, and distribution** as well as supply to the residential sector and other facilities.

Natural gas and oil

The **State Oil Company of Azerbaijan Republic (SOCAR)** is the national oil and gas company, which **together with its subsidiaries** is also responsible for **production, processing, storage, transportation, distribution, and supply**.

Shah Deniz Consortium is a body **producing natural gas** on Shah Deniz field. The Consortium's participants include BP (operator), SOCAR, Türkiye Petrolleri Anonim Ortaklığı (TPAO) (Turkish Petroleum Corporation), Petronas, Lukoil, and Naftiran Intertrade Company (NICO).

Sources: Fitch Solutions. 2020. *Azerbaijan Oil & Gas Report*. London; International Renewable Energy Agency. 2019. *Renewables Readiness Assessment: Republic of Azerbaijan*. Abu Dhabi; and United Nations Economic Commission for Europe. 2019. *National Sustainable Energy Action Plan of Azerbaijan*. Geneva.

Azerbaijan's key legislation for the natural gas and electricity sectors include the Law on the Use of Energy Resources 1996, the Law on Energy 1998, the Law on Electricity 1998, the Law on Subsoil 1998, the Law on Gas Supply 1998, and the Law on Electrical and Thermal Power Plants 1999 (AERA 2019). These laws, which are rather currently outdated, determine the fundamentals for effective exploration, generation, transportation, and distribution of energy sources. The Law on the Use of Renewable Energy Sources in Electricity Production was adopted in 2021, and further sub-legislative documents will be prepared. The law envisages the promotion of investment activities in the field of renewables through auctions and bilateral agreements, the development of rules on the "Prosumer Support Mechanism," which allows individuals to supply energy using renewable energy sources, as well as the issuance of "green certificates," which prove the renewable source of the electricity.

Following a 2019 presidential order relating to accelerating reforms in the energy sector, new draft laws are being developed containing provisions on the transition to a liberal market. A new electricity law was also drafted, with the aim of establishing a legal framework for gradual market liberalization. This law also allows for the privatization of state power plants and the development of new ones.

The government is determined to improve energy efficiency, as reflected in the Law on the Rational Use of Energy Resources and Energy Efficiency, which was signed in 2021 and will come into force on 1 July 2022. According to the law, Azerbaijan will provide for the deployment of smart meters in the heating and natural gas consumption sectors. In addition, the law provides for the certification of buildings on energy efficiency and energy audits, including a mandatory audit every 3 years. It also provides for the establishment of an Energy Efficiency Fund, which will be formed through deductions from sales tariffs on energy resources, grants, donations, and so on (Rustambekov and Abbasova 2021; Mahmudov 2021).

Policy Framework

The Government of Azerbaijan has published several documents outlining its energy sector strategy. These include the 2016 Strategic Roadmap for Development of Utilities Services (electric energy, heating, water and gas) in the Republic of Azerbaijan, Acceleration of Reforms in the Energy Sector of the Republic of Azerbaijan (2019), Long-Term Capacity Expansion Planning with a High Share of Renewables in the Republic of Azerbaijan (2019), and Azerbaijan 2030: National Priorities for Socio-Economic Development (2021). Overall, these documents outline a general policy framework as well as short-term strategic goals, paying particular attention to the following:

(i) **Ensuring effectiveness in regulation of the energy sector.** Given that the country's regulatory and policy development institutions are the same (or directly connected), the government aims to follow global best practices by strengthening independence of a regulatory body as well as an improved and unified regulatory legal framework.

(ii) **Establishing sustainable electricity generation.** The government will work to increase the share of renewable energy sources by realizing Azerbaijan's considerable technical potential (close to 27 GW).

(iii) **Facilitating a favorable investment environment for the private sector.** The government plans to involve private investors by unbundling the electricity sector (into generation, T&D, and sales) and by liberalizing the energy market.

(iv) **Improving energy efficiency.** Azerbaijan aims to increase the efficiency of power stations by applying globally accepted quality and efficiency standards (e.g., for energy storage systems; and carbon capture, utilization, and storage [CCUS] technologies), and to decrease commercial and technical losses in the T&D sectors to European benchmark levels.

(v) **Creating effective natural gas infrastructure.** Given the importance of natural gas for the country, Azerbaijan aims to modernize its existing domestic natural gas distribution infrastructure to minimize losses (2020 natural gas losses were around 12%).

Forecast Methodology

This country study aims to conduct a detailed analysis and overview of trends that will delineate the future energy market of Azerbaijan. To achieve this, three main scenarios were developed, taking into consideration Azerbaijan's technological development, regulatory framework, consumer preferences, and other factors (Box 7). Separate outlooks for supply and demand, technology, carbon emissions, and investment were developed for each of the following three scenarios: Business-as-usual (BAU), Government Commitments, and Green Growth.

Box 7: Scenarios for Azerbaijan's Energy Sector

Business-as-usual scenario: Projected energy supply and demand, with current energy system and policies;

Government Commitments scenario: Projected energy supply and demand, considering individual priorities of the Government of Azerbaijan; and

Green Growth scenario: Projected energy and supply demand, considering enhanced energy transition and environmental policies.

Source: Roland Berger/ILF.

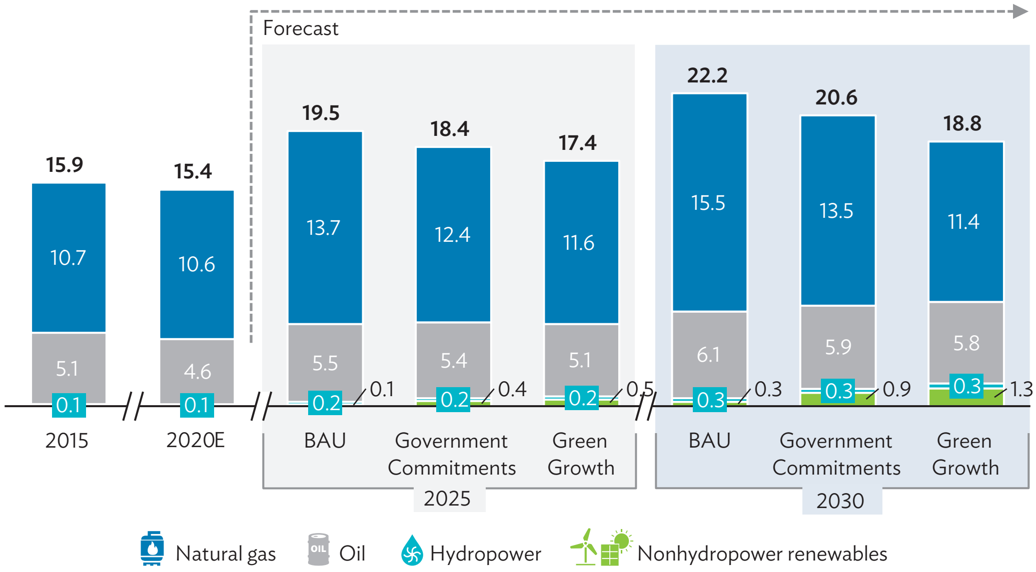
Supply and Demand Outlook

The COVID-19 pandemic resulted in a 5.9% decline in Azerbaijan's real GDP in 2020 compared to 2019, as the country depends heavily on energy exports. For instance, in 2018, energy accounted for around 90% of total exports, with 77% of energy production being exported, indicating the country's heavy dependence on oil and natural gas revenues.

The country's primary energy demand also decreased in 2020. However, as in many other CAREC countries, a strong rebound in the coming years is likely. This will lead to overall growth, including in energy consumption. Numerically, the primary energy supply is expected to reach 18.8–22.2 million toe, depending on the scenario. Under the Government Commitments scenario, annual growth from 2020 to 2030 is 3.0%, amounting to 20.6 million toe in 2030. The BAU scenario displays more rapid growth, with an annual rate of 3.2%, caused by the limited improvements in energy efficiency levels. As a result, the primary energy supply under this scenario is estimated at 22.2 million toe in 2030. In the Green Growth scenario, the estimated annual growth rate is 2.5%, with a total primary supply of 18.8 million toe in 2030, because of the implementation of efficient technologies as well as more effective energy use.

Figure 25: Azerbaijan—Primary Energy Supply Forecast

(million tons of oil equivalent)



BAU = business-as-usual, E = estimate.

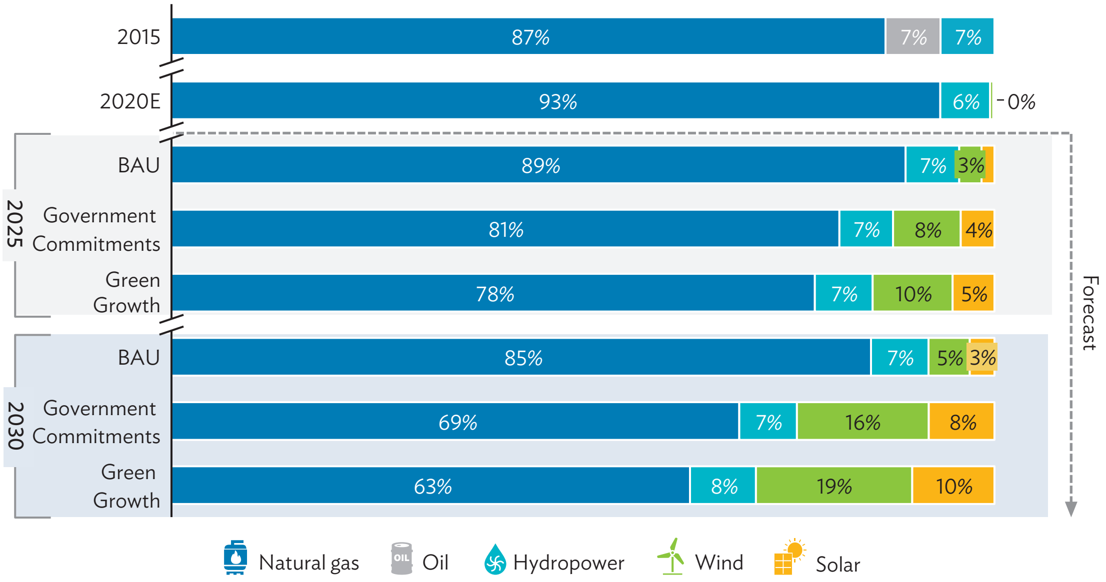
Source of historical data: State Statistical Committee of the Republic of Azerbaijan. The forecasts are based on the Roland Berger methodology described in the Methodology section.

Across all scenarios, the primary supply is dominated by natural gas and oil, which are projected to constitute approximately 97% of the total value in 2030 under the BAU scenario, 94% under the Government Commitments scenario, and 91% under the Green Growth scenario. Renewable sources of energy are gradually introduced across all scenarios, reaching 0.6 million toe in 2030 under the BAU scenario, 1.2 million toe under the Government Commitments scenario, and 1.6 million toe under the Green Growth scenario (Figure 25).

Historically, the electricity mix in Azerbaijan has been dominated by natural gas, which constituted 93% of the total in 2020. This trend will continue until 2030 across all scenarios (with a 63%–85% share of the total power generation mix). However, the share of renewable energy sources will gradually increase at rates that differ across scenarios. Hydropower is expected to grow at a consistent rate until 2030 across all scenarios, constituting 7%–8% of the total power mix. However, by 2030, wind and solar are projected to grow by up to 5% and 3% under the BAU scenario, 16% and 8% under the Government Commitments scenario, and 19% and 10% under the Green Growth scenario (Figure 26). This corresponds with the government's target to increase the share of renewables.

With the implementation of additional energy efficiency measures, final energy demand decreases, leading to a projected total demand of 13.3–11.9 million toe in 2030, depending on the scenario. Among the fastest growing sources are electricity, oil, and oil products, reflecting the growing demand for and

Figure 26: Azerbaijan—Power Generation Mix



BAU = Business-as-usual, E = estimate.

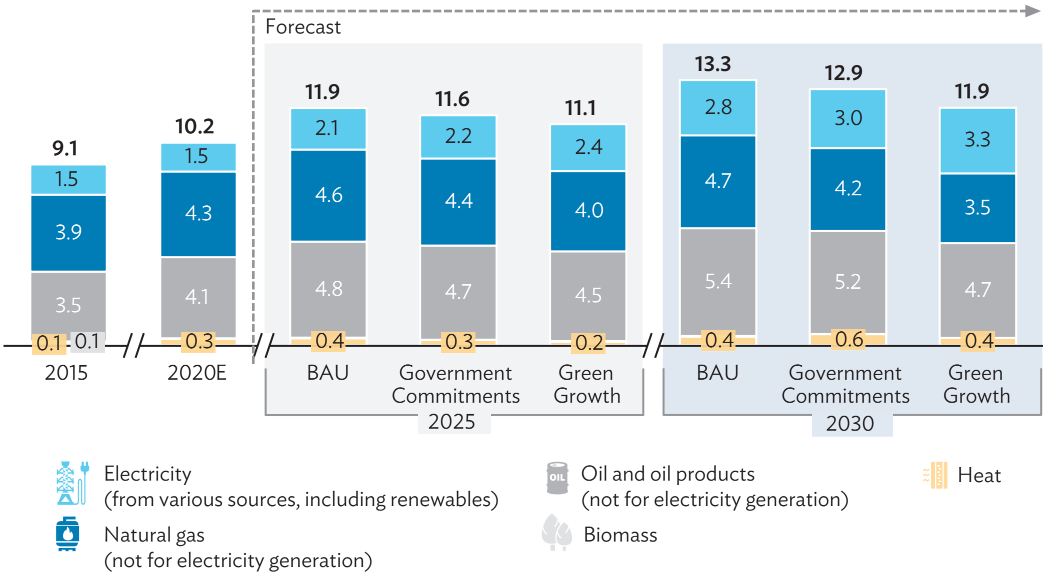
Sources of historical data: State Statistical Committee of the Republic of Azerbaijan; and International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 12 August 2021). The forecasts are based on the Roland Berger methodology described in the Methodology section.

development of the transportation sector. Natural gas, by contrast, increases slightly in the BAU scenario, and decreases in the Green Growth scenario, reflecting the government's aim to undertake infrastructure modernization and more intensive energy efficiency measures. Finally, demand for heat is also gradually increasing (compared to estimated 2020 values) in response to growing demand from the residential sector (Figure 27).

The most rapidly growing sector is agriculture, with an annual growth rate of 3.5%–3.7%, depending on the scenario. Two other rapidly growing sectors are transport, growing at 2.6%–3.1%, and services, growing at 3.1%–3.3%. This is due to GDP growth having a significant impact on these sectors, and on the baseline consumption behind the transportation sector. The residential sector is projected to grow at a moderate pace, with an annual growth rate of 1.9%–2.3%, depending on the scenario. Finally, demand from industry, with an annual growth rate of 1.7%–2.7%, depending on the scenario, is also moderately increasing (Figure 28).

Figure 27: Azerbaijan—Final Energy Demand Forecast by Fuel

(million tons of oil equivalent)

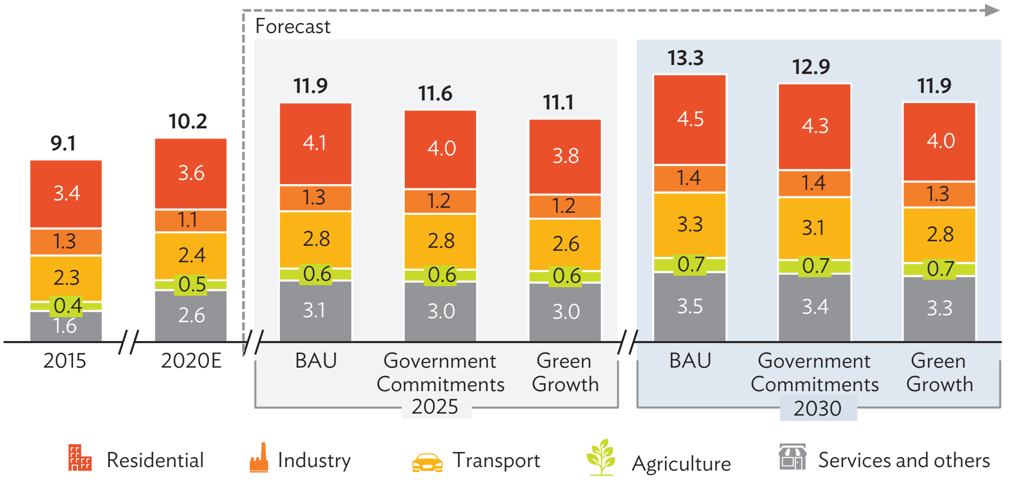


BAU = Business-as-usual, E = estimate.

Source of historical data: State Statistical Committee of the Republic of Azerbaijan. The forecasts are based on the Roland Berger methodology described in the Methodology section.

Figure 28: Azerbaijan—Final Energy Demand Forecast by Sector

(million tons of oil equivalent)



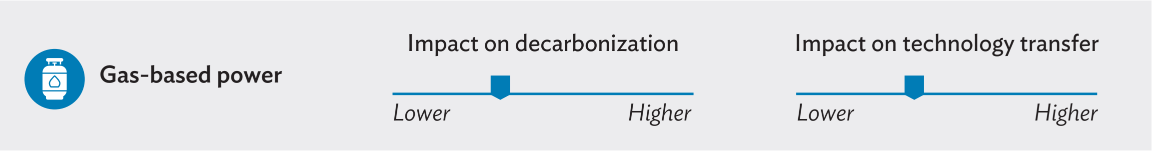
BAU = Business-as-usual, E = estimate.

Source of historical data: State Statistical Committee of the Republic of Azerbaijan. The forecasts are based on the Roland Berger methodology described in the Methodology section.

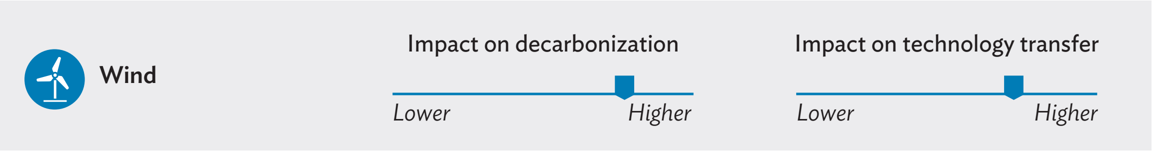
Technology Outlook

Priority Technologies: Generation

Azerbaijan's selection of priority technologies in power generation takes into account its history (i.e., the high share of natural gas in its electricity mix), the government's priorities (power from renewables and natural gas), as well as the country's resources and renewable energy potential.



Azerbaijan already has relatively modern gas-fired power plants, with the majority commissioned during the last 20 years. The exception is the 2.4 GW Azerbaijan Thermal Power Plant, commissioned in 1981, and the site of a 2018 accident. As the plant accounts for approximately 35% of the country's total installed capacity, Azerbaijan plans to rehabilitate it. The government also plans to privatize gas-fired power plants, which is expected to have a positive impact in terms of decarbonization. Finally, projects in this area should allow the government to achieve its target of increasing net fuel efficiency for combined-cycle gas turbine plants from 47% to 50% (UNECE 2019).



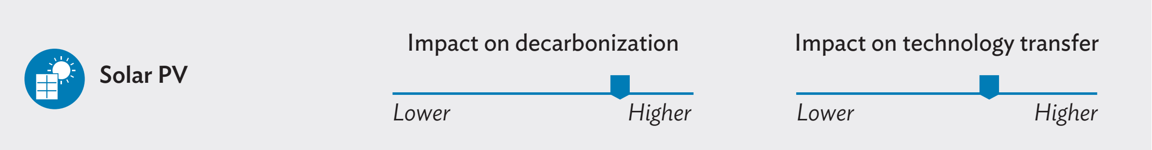
Owing to its geographical position, Azerbaijan has favorable conditions for wind farms. The average annual wind speed is estimated at around 7.9 meters per second to 8.1 meters per second, while the technical potential of wind farms is estimated at more than 15 GW. Given its significant technical potential and with sufficient investment, renewable electricity could partially displace gas-fired electric power, freeing up gas for exports. Particularly, areas such as the coastline of the Caspian Sea, the Ganja-Dashkesan zone in western Azerbaijan, the Absheron Peninsula, islands in the northwestern part of the Caspian Sea, and the Sharur-Julfa area of the Nakhchivan Autonomous Republic are of special interest. A 240 MW wind farm is currently being developed in the Absheron and Khizi districts by ACWA Power, a major power plant developer and investor of the Kingdom of Saudi Arabia. The project is expected to be commissioned in 2023 and cost approximately $300 million (ACWA Power 2021).

A significant share of Azerbaijan's wind energy potential is offshore (157 GW), including both floating wind turbines and fixed-bottom projects (Buljan 2021). Several projects aiming to exploit the offshore wind energy potential of the Caspian Sea are already underway, such as the joint project between SOCAR and Technip Energies.

On 14 April 2021, a memorandum of understanding was signed between the MOE and the International Finance Corporation (IFC), a member of the World Bank Group, on cooperation in the use of offshore wind energy for the development of renewable energy in Azerbaijan. According to the memorandum, cooperation with the IFC envisages the assessment of offshore wind energy potential in Azerbaijan and road map development.

Because increasing the share of renewable energy is among the government's key priorities, it is expected that wind farms will continue to be supported. Wind projects will have a positive impact on both decarbonization and technology transfer.

A memorandum of understanding was signed between the MOE and ACWA Power of the Kingdom of Saudi Arabia on 13 January 2022 on cooperation in the field of offshore wind energy. This memorandum envisages the assessment of offshore wind energy potential, the identification of the main principles of cooperation in the offshore wind energy sector, and the provision of necessary conditions for profitable investment in renewable energy projects in Azerbaijan.



Solar PV projects are another government priority, especially given that the country's climate provides substantial opportunities to expand solar-generated electricity. On average, Azerbaijan has 2,400–3,200 hours of sunshine per year. The country's global horizontal irradiation is 3.4–4.8 kWh/m^2, which is favorable relative to other countries, meaning it is relatively attractive for investments, too. Azerbaijan's technical solar power potential is more than 8 GW, meaning that implementing solar PV projects will have a higher impact on decarbonization. Finally, because the country currently has low installed capacities of solar PV farms (around 40 MW), their further development will have a positive impact on technology transfer. As in the case of wind energy, given the sizeable technical potential of solar power and with sufficient investment, it could partially displace gas-fired electric power in the future, making more gas available for exports.

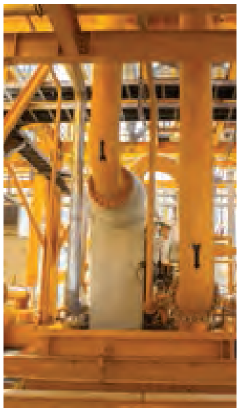
In 2021, the MOE, Azerenerji OJSC, and Masdar, a leading company in renewable energy development, signed investment, transmission, connection, and power purchase agreements for a 230 MW solar PV farm. The commission of this international project, expected in 2023, will set a positive example to attract other potential investors.

An implementation agreement was signed with BP on 3 June 2021 on the evaluation and implementation of a project to build a 240 MW solar power plant in the Zangilan/Jabrayil (Eastern Zangazur) region. Work is ongoing in this area.

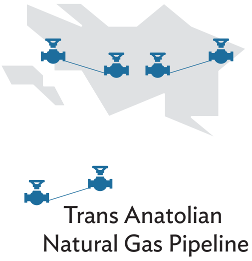
Priority Technologies: Transmission and Distribution

Azerbaijan's export pipeline infrastructure is relatively modern (Box 8). However, its domestic distribution infrastructure and, in particular, its natural gas grid, have suffered considerable losses—approximately 12% in 2020. Therefore, the modernization of Azerbaijan's natural gas grid is a government priority.

Box 8: Azerbaijan’s Flagship Energy Project—The Trans Anatolian Natural Gas Pipeline



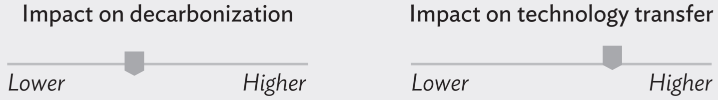
Having vast reserves of natural gas and oil, Azerbaijan has historically relied heavily on energy exports to develop its economy. After several rounds of negotiation between the governments of Azerbaijan and Türkiye, the countries started constructing a mega project, a 1,850-kilometer pipeline to export natural gas from Shah Deniz production field in Azerbaijan to Türkiye and Europe. The project is planned to occur in several phases, with an initial capacity in 2019 of 16 billion cubic meters per annum (bcma)—6 bcma to Türkiye and 10 bcma to Europe. Phase 2 is expected to start in 2023 and to increase the overall capacity to 24 bcma, while Phase 3 is expected to begin in 2026 and expand capacity to 31 bcma. The overall estimated cost is around $11 billion.



Note: Illustrative photo of pipelines is by Gozalov/Adobe Stock©.

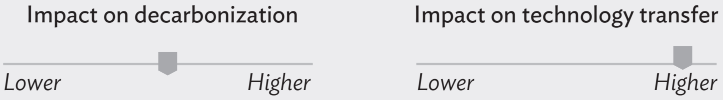
Sources: Global Energy Monitor. Trans-Anatolian Gas Pipeline; and Hydrocarbons Technology. Trans Anatolian Natural Gas Pipeline Project (TANAP).

Natural gas grid modernization



Modernizing transmission infrastructure is another government priority, as doing so will minimize natural gas-related T&D losses. Additionally, Azerbaijan plans to improve operational efficiency by installing digital meters across end-users. This will allow for more effective network tracking through detailed and direct data collection, which will, in turn, allow for informed decisions to be made regarding the implementation of further measures to improve operational efficiency, and to reduce natural gas distribution losses and the corresponding negative environmental impacts. Modernizing the grid will also have a rather significant influence on technology transfer.

Hydrogen



Hydrogen is becoming an increasingly important technology for the energy sector’s decarbonization efforts. Two distinct processes allow for sustainable hydrogen production: (i) using electrolysis with renewable energy sources to produce green hydrogen, and (ii) using natural gas with carbon capture and storage to produce blue hydrogen. Despite its limited financial viability as of the early 2020s, hydrogen has strong potential because of its projected decline in costs as well as rising environmental awareness.

The government has demonstrated its active interest in developing this technology by facilitating several studies and conducting seminars with expert companies (e.g., Equinor) (Government of Azerbaijan, Ministry of Energy 2021). While green hydrogen is seen as more sustainable, blue hydrogen is often seen as more suitable for Azerbaijan due to the country's vast reserves of natural gas and the higher maturity of its technology. In addition, the country has solid natural gas infrastructure that can be used for exports or domestic consumption. These advantages may help Azerbaijan to become less dependent on hydrocarbon price fluctuations, and to prepare for the upcoming energy transition, where hydrogen demand will be higher than demand for conventional fuels. Finally, the development of both blue and green hydrogen projects will also result in substantial technological advancements for the country.

Priority Technologies: Consumption

Achieving more efficient energy use is yet another crucial aim for Azerbaijan across all sectors. Improving energy efficiency in the residential sector is of particular importance according to recent government documents.

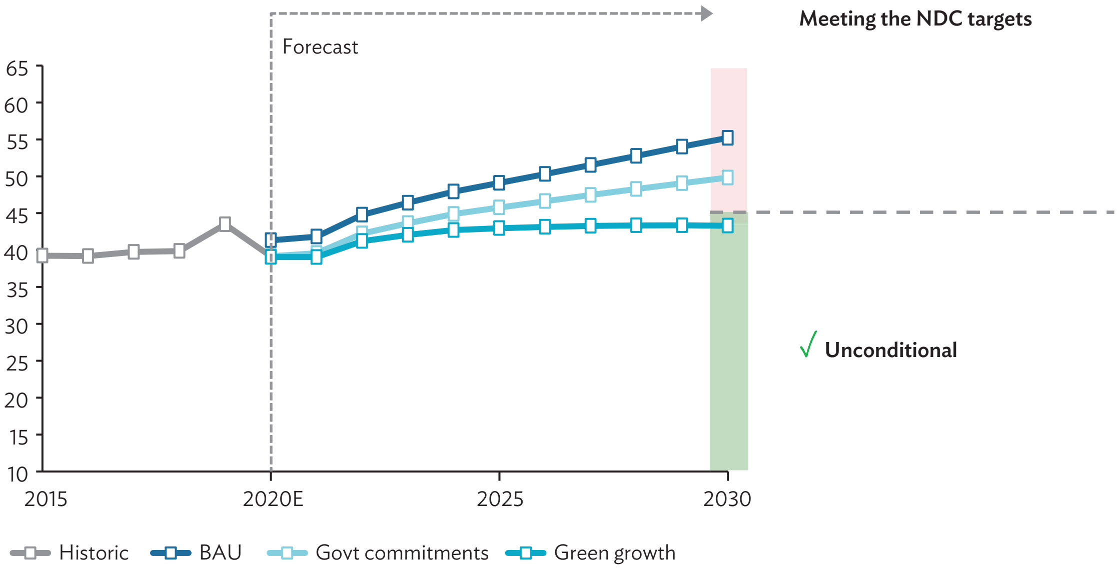
The residential sector is the largest energy consumer. It accounted for around 32% of total energy consumption in 2019 and is expected to remain the most energy-intensive sector. Given that most of Azerbaijan's buildings were built more than a half-century ago, the country's residential energy consumption is not very efficient. Azerbaijan's average energy consumption of buildings, constituting around 200–280 kWh/m^2 per year, is much higher than the average European benchmark of 180 kWh/m^2 per year. The relevant legislation for energy efficiency measures has yet to be implemented in Azerbaijan, but the government has taken an initial step by adopting a new law coming into force in 2022 that will include minimum energy performance requirements for new and renovated buildings, compulsory energy audits, an energy performance certification system, and other measures. Overall, the energy efficiency potential of the country's current building stock is estimated to be rather high, with savings of up to 50% technically feasible. To achieve them, old buildings must be renovated using modern technologies and materials with acceptable energy performance characteristics.

Carbon Emissions Outlook

By submitting a Nationally Determined Contribution (NDC), Azerbaijan demonstrated its commitment to combating climate change. Azerbaijan set an ambitious target of achieving a 35% reduction of greenhouse gas (GHG) emissions by 2030 in comparison to the 1990 level (UNFCCC 2017).

As the NDC does not provide a specific target for the energy sector, the assumption is made that the share of energy-related emissions in 2030 will be equal to average historical values. As per the Fourth National Communication to the United Nations Framework Convention on Climate Change (UNFCCC),

Figure 29: Azerbaijan—Energy-Related Carbon Emissions
(million tons of carbon dioxide equivalent)



BAU = Business-as-usual, E = estimate, NDC = Nationally Determined Contribution.

Note: Historical data on carbon emissions is modelled by Roland Berger based on historical data on energy use. The forecasts are based on the Roland Berger methodology described in the Methodology section.

Sources: Roland Berger; and United Nations Framework Convention on Climate Change. Nationally Determined Contributions Registry. https://unfccc.int/NDCREG.

the historical share of energy-related emissions was around 88% of total net emissions (UNFCCC 2021).[3] Assuming the same share for the future, the NDC target for the energy sector in 2030 would be 45 million tons of CO_2 equivalent, compared to around 43 million tons of CO_2 equivalent in 2019.

During the 26th United Nations Climate Change Conference of the Parties (COP26) in Glasgow, Azerbaijan announced enhanced ambitions on top of its NDC to reduce GHG emissions by 40% by 2050 compared to the base year (1990). The new ambitious NDC target can only be achieved under the Green Growth scenario, with the help of substantial investments as well as strong policy adjustments. The course of current actions (the BAU scenario), as well as existing official commitments (the Government Commitments scenario), are not sufficient to meet the NDC target. Numerically, the projected energy-related carbon emissions constitute approximately 55 million tons of CO_2 equivalent in 2030 under the BAU scenario, 49 million tons under the Government Commitments scenario, and 43 million tons under the Green Growth scenario (Figure 29). The results highlight a strong need for the government to act in order to improve efficiency and reduce losses, especially in the natural gas system.

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[3] Under energy-related emissions, GHG emissions from generation, transmission, and consumption of energy are considered. The assumed share of energy-related emissions is based on the historical data.

Investment Outlook

Investment Needs

Azerbaijan's energy investment needs until 2030 range from $10.1 billion to $30.1 billion, depending on the scenario. Due to the need for infrastructure modernization and the growing market size, considerable investments are needed in various sectors: power generation, T&D, and energy efficiency. In the BAU scenario, the largest investments are needed for natural gas power generation projects, while the Government Commitments and Green Growth scenarios, in line with priority technologies, imply higher investment needs in renewable energy projects. Overall, the investments in renewable sources of energy in 2030 are estimated at $3.8 billion–$17.0 billion, highlighting large differences in the expansion level of renewables across the scenarios. The investment needs are dominated by wind power, accounting for around 58%–64% of the total investments in renewables, followed by solar power, accounting for 28%–32%, depending on the scenario (Figure 30).

Generation is expected to require the most investments across all scenarios, accounting for 66%–77% of the total value, or $7.8 billion–$19.8 billion, depending on the scenario. This category is followed by the implementation of energy efficiency measures on the consumption side in the BAU scenario, constituting around 14% of the total investment needs in 2030. Under the other two scenarios, generation is followed by T&D, comprising approximately 19% of total investment needs under the Government Commitments scenario, and 22% under the Green Growth scenario, illustrating larger infrastructure modernization efforts (including the modernization and expansion of the natural gas and electricity networks, the installation of metering equipment, and remote monitoring systems).

Challenges and Opportunities

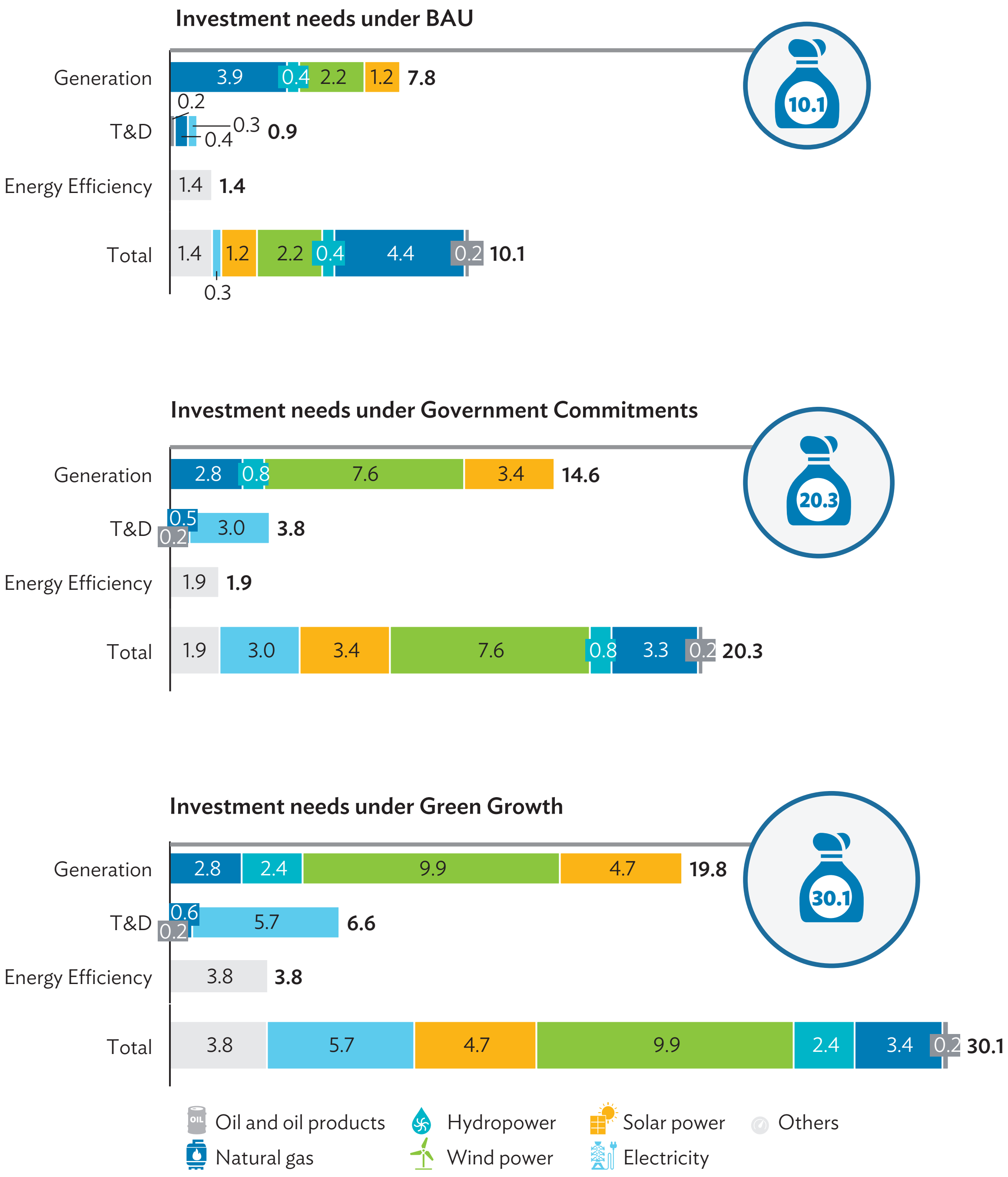
Generally, Azerbaijan's investment climate is favorable, as the country is widely recognized as a successful reformer due to improvements in investor protection legislation and in the judiciary system. The favorable climate is also reflected by Azerbaijan's proven track record in working with large private investors, with numerous large companies operating in the production segment.

However, private investors may face several challenges. The first challenge is the sizeable energy subsidies based on the government-regulated tariffs. For instance, in 2019 energy subsidies accounted for around 3.5% of the country's GDP (or $1.9 billion), with energy subsidies amounting to almost $190 per capita. Despite the establishment of a new energy regulatory authority, a Tariff Council chaired by ministers and their deputies is the main authority that decides on tariffs. The government, therefore, retains direct influence over the level of tariffs. This arrangement may pose challenges for private investors, as it may enable the public sector to provide market advantages to government-led projects.

In July 2021, the President approved the Law on Use of Renewable Energy for Electricity Production. The new law introduces auctions for renewable projects and will ensure transparency and predictability for investors and market players. Moreover, fundamental principles for a prosumer support mechanism are being developed with the support of the European Bank for Reconstruction and Development (EBRD).

In the same year, Azerbaijan also adopted the Law on the Rational Use of Energy Resources and Energy Efficiency. The draft law was jointly developed with the support of the Energy Charter Secretariat within the EU-funded EU4Energy Project (International Energy Charter 2019).

Figure 30: Energy Infrastructure Investment Needs in Azerbaijan until 2030
($ billion)



BAU = Business-as-usual, T&D = transmission and distribution.

Source: The forecasts are based on the Roland Berger / ILF methodology described in the Methodology section.

Earlier, in 2019, the President signed the Order "On Acceleration of Reforms in the Energy Sector of the Republic of Azerbaijan." This document envisages numerous reforms, including the promotion of private sector investments; the promotion of natural gas, heat, and electricity efficiency; the preparation of a long-term strategy for development of the energy sector; and the gradual opening of the electricity market to competition.

Another major obstacle for private investors is that Azerbaijan's energy market is not fully liberalized. Vertically integrated state-owned monopolies (electricity, heat, and natural gas) dominate the market. As a result, and also because of the lack of a proper public–private partnership (PPP) framework, private sector participation and competition are limited. Although the country plans to introduce competitive energy markets, limited progress has been achieved. The government is conducting the State Privatization Program, allowing private companies (including foreign ones) to participate in the privatization of enterprises and facilities in the energy sector. Nevertheless, apart from the privatization of two HPPs, no substantial activities have been executed. By facilitating a favorable environment and promoting competition, along with providing support for the private sector, the government may attract increased investments in energy projects. Private investors have the potential to focus on decarbonization efforts, from which positive environmental impacts (such as a reduction in energy-related GHG emissions) are expected to follow.

Exports also represent an attractive investment opportunity in Azerbaijan. Owing to its geographic position and existing cross-border infrastructure, Azerbaijan will continue to act as a regional hub for oil, natural gas, and electricity in the short-to-medium term, and potentially for hydrogen in the long term.

Policy Recommendations

Recent reforms and actions have laid the groundwork for increased private sector participation in Azerbaijan's energy-related projects. Nevertheless, the following actions are suggested to address some of the issues still hampering the energy sector's development:

(i) **Transform the energy regulator into an independent authority.** Currently, both policy making and regulatory functions are executed under a single umbrella, which creates a risk of biased decision-making. Transforming the recently established energy regulator into an independent authority as per the international norm may have a substantial influence on facilitating competition in Azerbaijan's energy market and attracting private investors. Global best practices have shown that well-functioning, credible independent regulators minimize overall risk levels, and thereby increase private investor confidence.

(ii) **Unbundle and liberalize energy markets.** Given that the current energy market structure is mostly monopoly state-owned, where production and transmission are mostly executed by the same state-owned company, it is crucial to facilitate unbundling and promote free competition (especially in certain segments of the value chain) to achieve high-efficiency operations. The improvement of PPP legislation can also help to attract private sector investments, especially for the expansion of generation facilities and for the modernization of the transmission or distribution infrastructure.

(iii) **Facilitate the development of renewable energy projects, particularly solar PV and wind farms.** Given Azerbaijan's considerable renewable potential (around 25 GW), the country should consider implementing additional incentives and support mechanisms to boost the development of renewable energy. Based on international best practices, potential measures may include feed-in premiums or capacity auctions, as well as net metering programs targeting off-grid installations, especially in remote and mountainous regions. Implementing this may offer more predictability to foreign investors by demonstrating the country's longer-term incentives and rules regarding renewable energy projects, thereby allowing the private sector to allocate resources.

(iv) **Continue updating key energy-related legislation.** Overall, the Government of Azerbaijan has already taken several important steps in this direction by drafting and signing new laws, yet it should also take the appropriate actions to finalize and approve them. It is also important to ensure effective implementation of laws that regulate renewable energy sources and energy efficiency.

(v) **Reform state subsidies in the energy sector and protect vulnerable consumers.** By reforming energy subsidies for residential electricity consumption and imposing targeted, transparent, and preferably time-bound tariffs, the government can attract infrastructure investments as well as overall additional investments across the energy sector. In order to achieve increased investment, the government will either need to reduce gas subsidies to allow competitive tariffs or allow incentivized residential electricity tariffs with take-or-pay, priority dispatch, or similar schemes. In the case of phasing out or reduction of subsidies, such measures will increase energy bills for consumers. It will therefore be crucial to adopt adequate social protection measures to protect low-income and vulnerable customers, ensuring their continued access to affordable energy.

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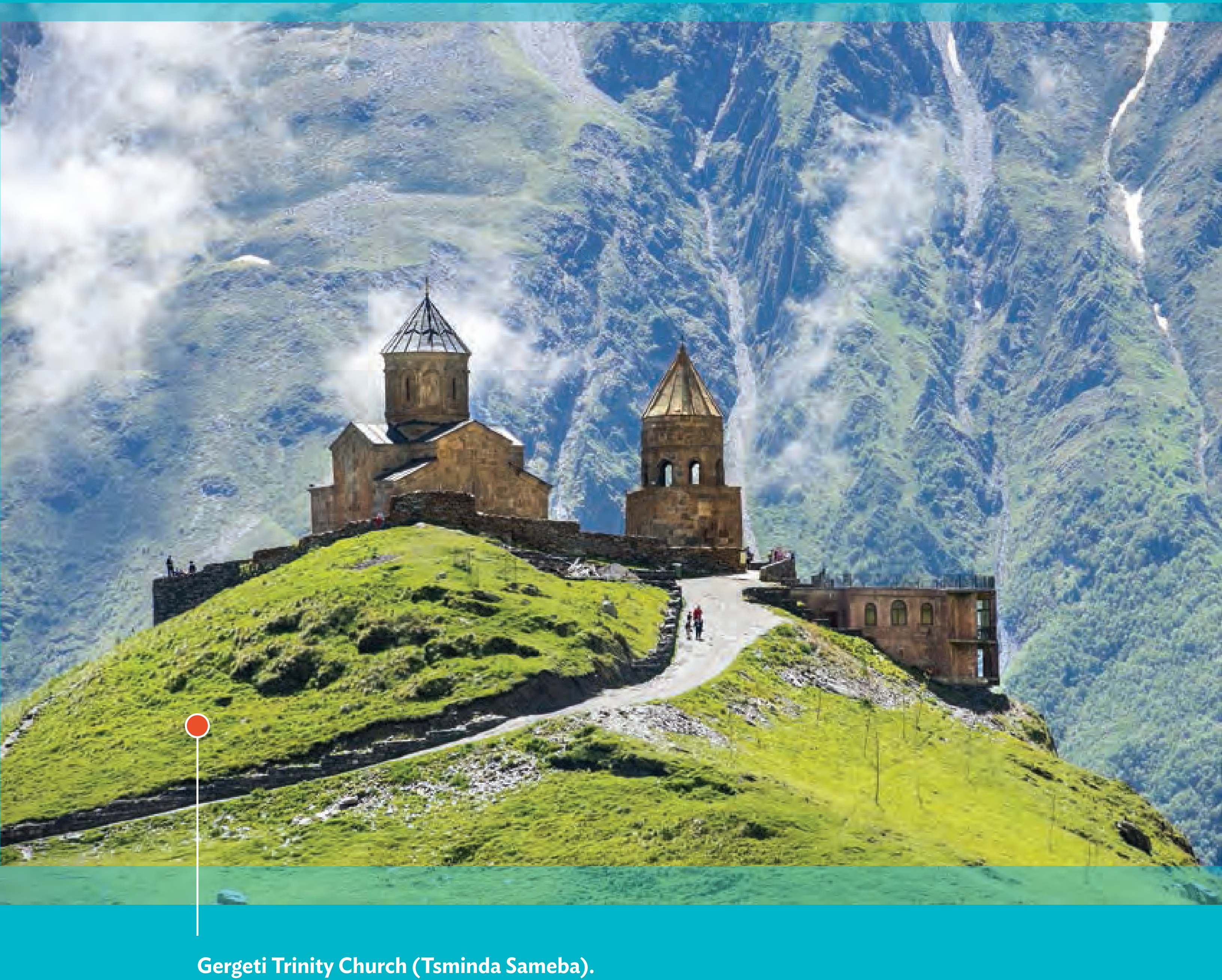
Baku. The city is a vibrant capital with a favorable investment climate (photo by Elena Petrova/ Adobe Stock©).

GEORGIA



Gergeti Trinity Church (Tsminda Sameba). The church is situated on the right bank of the river Chkheri, at an elevation of 2,170 meters, under Mount Kazbek (photo by irisphoto1/ Adobe Stock©).

Georgia Highlights

- Georgia has strong potential in renewable energy, such as hydropower, wind, solar, and an already developed hydropower infrastructure undergoing an active modernization program. The country relies on imports of fossil fuels, as it lacks its own reserves.
- Georgia has developed cross-border infrastructure for transit of natural gas, oil, and electricity. The country aspires to develop its system further, including increasing transit capacity and reverse flow on gas pipelines, to emerge as a regional transit hub.
- Significant reforms have been undertaken to fulfill Georgia's commitments under the Energy Community commitments and to establish fully liberalized competitive energy markets in line with European Union (EU) practices.
- Final energy demand in Georgia is projected to reach 5.4 million–5.9 million ton of oil equivalent (toe) in 2030, realizing an annual growth of 2.4%–3.3%, depending on the scale of adoption of energy efficiency measures. Despite large renewable energy potential, natural gas will remain the most important source of overall energy supply, considering its use for power generation and residential consumption.
- Hydropower is currently Georgia's primary mode of electricity generation, with natural gas also playing a significant role (Figure 31). However, natural gas significance is expected to decline in the coming years, while nonhydropower renewables are projected to increase their market share by up to 22% by 2030. In addition to renewable and gas-fired power generation, priority technologies and areas of intervention for Georgia include smart grid and energy efficiency measures, especially in industrial use and in residential heating.
- Total investment needs across the energy sector range from $9 billion to $19 billion depending on the scenario, reflecting significant capital investment requirements for sustainable energy transition and improved energy efficiency.
- Investment opportunities in Georgia arise from its transition to liberalized and competitive energy markets, strong investor protection regulations, and solid renewable energy potential.
- Overcoming several remaining challenges, such as energy subsidies, would encourage further private sector participation.

Energy Sector Profile

Country Profile

Georgia, a mountainous country in the Caucasus, has a population of 3.7 million people and $16 billion nominal gross domestic product (GDP) as of 2020. While the population is gradually declining, its economy has experienced solid growth as a result of profound economic reforms. Measures and restrictions related to the coronavirus disease (COVID-19) pandemic have had a significant effect on the country's economy, with a 6.2% decline in GDP in 2020. However, the Georgian economy is expected to go through a rapid recovery, with projected economic growth of almost 6% annually until 2025.

Figure 31: Georgia—Key Figures

Hydropower	Renewable energy	Carbon intensity	Energy imports	Inter-connections
40 TWh	**83%**	**157th out of 172**	**81%**	**5.2 GW**
Hydropower generation potential is estimated at 40 TWh, in addition to realized ~10 TWh.	The share of renewable sources, primarily hydropower, reached 83% in total power generation in 2018.	Georgia was ranked 157th out of 172 countries in the global ranking of carbon intensity of energy, largely due to the high share of hydropower in the electricity mix.	81% of total energy supply was provided by imports, primarily conventional fuels such as natural gas and oil products, in 2018.	Electricity interconnection capacity with neighboring countries is projected to reach 5.2 GW by 2025.

GW = gigawatt, TWh = terawatt-hour.

Sources: Geostat; Government of Georgia, Ministry of Economy and Sustainable Development. 2019. *National Renewable Energy Action Plan.* Tbilisi; Government of Georgia, Ministry of Energy. 2017. *Energy Sector of Georgia.* Tbilisi; and United States Energy Information Administration. Georgia Data. https://www.eia.gov/international/data/world (accessed 18 July 2021).

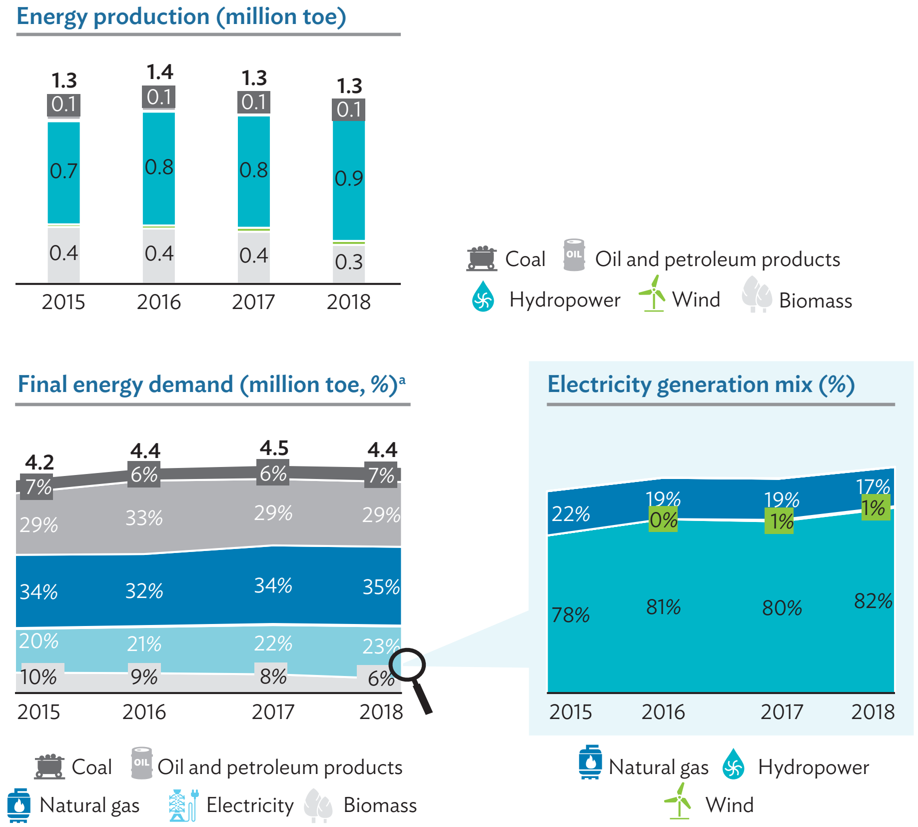
Georgia's energy sector has technology-related inefficiencies, but it also has a relatively small carbon footprint, largely attributable to the lack of exploitable fossil fuels. As a result, Georgia has historically been a net energy importer, mainly of natural gas, oil products, and coal. However, Georgia's vast water resources and developed hydropower infrastructure represent a significant opportunity. Since 2015, hydropower's share in the power generation mix ranged from 73% to 83%, helping Georgia to rank 157th out of 172 countries globally for its carbon intensity (Figure 32). Yet, Georgia has significant room for improvement in terms of energy efficiency—because of its outdated equipment and infrastructure, the country is ranked the 42nd most energy-intensive economy in the world.

Energy Sector and Technologies Assessment

Conventional Fuel Production

Georgia's domestic production of oil and natural gas is very small, each comprising 2% or less of domestic consumption. Apart from a few small onshore production wells, the country's oil and gas industry is mainly in the exploration and development stage. Production volumes have declined since the beginning of the 2000s, reflecting a general lack of capital investment, and depleting proven reserves in the country. Oil reserves are estimated at only 5 million tons, while gas reserves reach 5 billion cubic meters (bcm).

Figure 32: Energy Profile of Georgia



toe = ton of oil equivalent.

[a] Topmost numbers on the chart are in million toe.

Source: Geostat.

Coal production in Georgia takes place at two underground mines, Mindeli and Dzidziguri, with further enrichment at a plant in the town of Tkibuli. However, the safety and environmental performance of these facilities has been poor—several incidents resulted in the suspension of coal production in 2018. In addition to underground coal mining, surface coal mining takes place in Tkvarcheli, a territory not controlled by the government. Coal reserves in Georgia are estimated at around 200 million tons.

Electricity Generation

Hydropower is the most important source of electricity generation in Georgia, reaching 3,323 megawatts (MW) of installed capacity, or more than 70% of the country's total. This includes 2,381 MW of reservoir (regulated hydropower plants [HPPs] with storage) and 942 MW of run-of-river (seasonal) plants. However, most of Georgia's HPPs are outdated, having been commissioned in the 1960s and 1970s, including Enguri HPP, the country's largest plant, which is state owned and has a capacity of 1,300 MW. Modernization of infrastructure has become a priority for the government, which established a pipeline of renovation projects to improve generation capabilities.

Due to Georgia's reliance on hydropower and the seasonal variations associated with this method of generation, power supplies are inconsistent. Georgia relies on electricity imports to cover domestic demand during the winter, as most run-of-river plants do not operate at this time of the year, and the output of regulated HPPs is limited. Gas-fired power plants represent the second-largest power generation source in Georgia, with a total installed capacity of 1,189 MW across six plants. The plants include both open-cycle gas turbines as well as combined-cycle gas turbines. Two power plants were commissioned in 1963 and 1991, and hence are quite outdated. However, the recently commissioned Garbadani I and II are highly efficient, modern plants, each with 230 MW capacity (Power Technology 2016). Notably, the efficiency of these power plants is estimated at 55%, comparing favorably to international standards. All gas-fired power plants are in eastern Georgia, close to the main consumption center in Tbilisi as well as key gas import and transit pipelines from Azerbaijan.

Georgian renewable energy potential has not been fully utilized yet. Total economic potential of wind energy is estimated at about 1,330 MW while photovoltaic (PV) solar is estimated at 550 MW. Technical potential of both PV and wind is several times higher, implying even greater potential when costs decline further. The central region of Kartli is among the most attractive wind locations in terms of resource availability and proximity to consumers. Yet only one wind power plant with a capacity of 21 MW is in operation, after being commissioned in 2017. As for solar power, more than 40% of Georgia's territory has an annual global horizontal irradiance level of more than 1,400 kilowatt-hours (kWh) per square meter (m^2). While Georgia does not have utility-scale solar power plants, the Georgian Energy Development Fund announced a tender for its first, with capacity of 5 MW, in July 2021 (Schimming et al. 2020). Furthermore, decentralized generation in residential and industrial sectors demonstrated a modest growth, boosted by a net metering program.

Transmission and Distribution

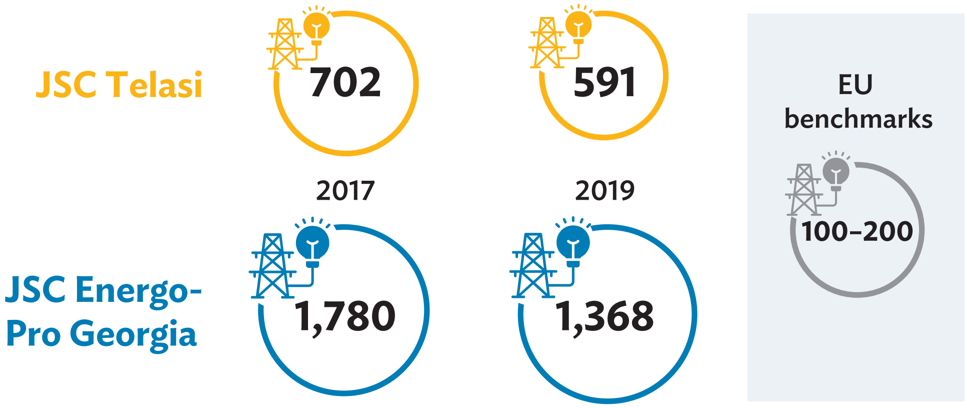
The Georgian electricity transmission and distribution (T&D) system works fairly efficiently, with 7% combined losses in 2019, and large discrepancies between grid operators in terms of losses and outages. Since 1 July 2021, and as a direct result of the unbundling of the electricity market, JSC EP Georgia Supply and Tbilisi Electricity Supply Company (Telmico) LLC are responsible for electricity supply to consumers, while distribution services are provided by JSC ENERGO-PRO Georgia and JSC Telasi.

JSC Telasi, which supplies Tbilisi, had a system average interruption duration index (SAIDI) of 590 minutes and a system average interruption frequency index (SAIFI) of six interruptions per customer in 2019. JSC ENERGO-PRO Georgia, the distribution network operator in the remaining regions, had a much larger SAIDI of 1,370 minutes and a SAIFI of 16. While average SAIDI and SAIFI have improved in recent years, they are still far from the EU benchmarks of 100–200 minutes for SAIDI and 2–3 interruptions per customer for SAIFI (Figure 33).

Geographic factors have further implications on the electricity grid infrastructure. While the main consumption centers are concentrated in the eastern regions of the country, most domestic generation facilities, including existing and prospective, are in the west. Specifically, a bottleneck occurs when the 500-kilovolt (kV) Imereti line is out of operation. To eliminate this bottleneck and to ensure the connection of new power plants with consumers, Georgian State Electrosystem (the transmission system operator) is implementing several grid reinforcement projects under a 10-year network development plan (Georgian State Electrosystem 2021). Moreover, Georgian State Electrosystem installed a supervisory

Figure 33: System Average Interruption Duration Index in Georgia and the European Union, 2017–2019

(minutes per customer)



EU = European Union, JSC = Joint-Stock Company.

Sources: Council of European Energy Regulators. 2018. Benchmarking Report 6.1 on the Continuity of Electricity and Gas Supply; and Georgian National Energy and Water Supply Regulatory Commission (GNERC) Reports on Activities.

control and data acquisition system (SCADA) in 2020 to improve infrastructure operation and quality of supply. SCADA systems consist of hardware and software components for gathering data in real time from remote locations to control system conditions (Loshin 2021). The SCADA meets European standards (Georgian State Electrosystem 2020).

In Georgia, total gas T&D system losses were 4% in 2019, measured excluding the South Caucasus Pipeline (SCP) and the North–South Main Gas Pipeline (NSMP) transit pipelines. These losses were largely caused by the technical failure of the distribution network and inefficient metering control. Out of the currently operating pipelines, more than 60% are aged 30 years or more and are substantially degraded because of corrosion. Several of the most important gas pressure regulating and metering stations are also outdated and in a critical technical condition. Poor infrastructural conditions and operations under off-specification design parameters are key challenges that also prevent the establishment of remote monitoring and management systems for the gas pipeline network (SCADA).

Cross-Border Infrastructure

Georgia plays an important transit role in the Caucasus region. Current cross-border power transmission capacity stands at 2.5 gigawatts (GW), with plans to rise to 5.2 GW by 2025. Yet, the trade and flows of electricity are restricted by acceptable operating modes of the national system, despite recent efforts to synchronize lines, e.g., with Russian and Armenian networks.

The Georgian gas transit network consists of two main gas pipelines. One is the SCP connecting Azerbaijan and Türkiye. It is owned by a consortium of international investors and is operated by the State Oil Company of Azerbaijan Republic (SOCAR). Under the project arrangements, Georgia can take 5% of annual gas flow in lieu of a tariff, in addition to purchasing 0.5 bcm at a discounted price. After expansion, the SCP's capacity will increase from 7 billion cubic meters per annum (bcma) to 22 bcma. The other is the NSMP, connecting the Russian Federation and Armenia. Operated by the Georgian Gas Transportation Company, the NSMP was rehabilitated in 2010 and has a capacity of 12 bcma.

In addition to natural gas, Georgia is also an important country for the transit of oil from Azerbaijan to the Republic of Türkiye, specifically via the Baku–Tbilisi–Ceyhan pipeline, which has a capacity of 1.2 million barrels per day and is operated by BP. Another important artery is the Baku–Supsa oil pipeline, with a capacity of up to 0.14 m barrels per day, delivering Caspian oil to international markets via Supsa terminal at the Black Sea (Table 2).

Energy Consumption

Georgian energy consumption is broadly characterized by low efficiency due to historic underinvestment and energy subsidies that discourage efficiency. Its energy intensity[4] level of 4,730 British thermal units (Btu)/$2015 gross domestic product based on purchasing power parity (PPP GDP) in 2019 is similar to the global average of 4,700 Btu/$2015 PPP GDP in 2019 (US EIA).

In industrial consumption, three subsectors dominate and occupy more than 70% of total industrial energy consumption: non-metallic minerals (including cement), chemicals (including petrochemicals), and iron and steel. Industrial enterprises in Georgia continue to use outdated and inefficient technologies. A lack of high-quality energy services, specifically energy audits, also prevents efficiency improvements. The government is taking actions to improve industrial energy efficiency, specifically by designing procedures for energy audits and developing action plans to replace outdated technologies. The groundwork for the implementation of energy audits has already been laid in legislative framework and is expected to be integrated with the construction sector in the near future.

A large share of both residential and commercial buildings in Georgia were built between 1950 and 2000 using mostly inefficient materials, leading to a low thermal resistance index (0.575 square meter degrees Celsius per watt).[5] However, over the last 15 years, most new buildings have been constructed with better quality materials and standards. Georgia introduced significantly more stringent minimum energy requirements for buildings in July 2021, so the situation is expected to improve in the mid-to-long term. The requirements are split between three construction-climate zones and are in line with modern European standards.

Similar challenges are faced by the Georgian transportation sector. Specifically, approximately 86% of vehicles are more than 10 years old. Combined with lower fuel quality standards than in Europe, the old fleet results in low efficiency and high fuel consumption. Consumption of natural gas in road transport is minor, accounting for around 13%–15% of the total, according to the latest energy balances. Considering that Georgia imports all its natural gas supply, the potential to expand the use of gas-based alternative fuels is limited. Penetration of electric vehicles (EVs) is almost negligible at less than 1%, while the share of hybrid vehicles is 5%. However, the government has shown a commitment toward expanding EV infrastructure by supporting a planned EV manufacturing plant in Kutaisi, actively expanding a network

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[4] Energy intensity is calculated as total energy consumption divided by GDP measured at purchasing power parity.

[5] Thermal resistance determines the heat insulation property of the material—the higher the thermal resistance, the lower is the heat loss.

Table 2: Georgia—Major Cross-Border Energy Infrastructure
(more than 500 MW)

Energy Source	Name	Capacity	Status	Connected Country
⚡	Kavkasioni 500 kV	570 MW	Operational	Russian Federation
⚡	Stepantsminda 500 kV	1,000 MW	Planned (2025)	Russian Federation
⚡	Mukhranis Veli 500 kV	630 MW	Operational	Azerbaijan
⚡	Gardabani 330 kV[a]	630 MW	Planned (2022)	Azerbaijan
⚡	Debeda 500 kV	700 MW	Planned (2025)	Armenia
⚡	Meskheti 400 kV[b]	1,050 MW	Operational	Republic of Türkiye
⚡	Tao 400 kV[c]	1,050 MW	Planned	Republic of Türkiye
⚡	South Caucasus	22 bcma	Operational	Azerbaijan–Republic of Türkiye
🔥	North–South (main)	12 bcma	Operational	Russian Federation–Armenia
🔥	Baku–Tbilisi–Ceyhan	1.2 m bbl/d	Operational	Azerbaijan–Republic of Türkiye
OIL	Baku–Supsa	0.1 m bbl/d	Operational	Azerbaijan

⚡ Electricity 🔥 Natural gas OIL Oil

bbl/d = barrels per day, bcma = billion cubic meters per annum, kV = kilovolt, m = million, MW = megawatt.

[a] Gardabani is existing line with transfer capacity limited to 210 MW.

[b] Overall capacity of Meskheti line is 1,500 MW, but it is limited by the capacity of the high-voltage, direct current back-to-back station in Akhaltsikhe.

[c] The Tao line will satisfy the N-1 criteria (the rule according to which elements remain in operation following a credible contingency event); however, its transfer capacity will increase from 700 MW to 1,050 MW only when new back-to-back stations will be commissioned.

Sources: Georgian Oil and Gas Corporation. 2018. *Ten-Year Development Plan for Georgian Gas Transmission Network 2019-2028.* Tbilisi; and Georgian State Electrosystem. 2021. *Ten-Year Network Development Plan of Georgia 2021–2031.* Tbilisi.

of charging stations in Tbilisi, and providing extensive tax incentives for the purchase of EVs. Several goals have been established by the country, most notably the Climate Strategy and Action Plan, which includes measures to facilitate the adoption of hybrid vehicles and EVs (Day, Gonzales-Zuñiga, and Lui 2021). The plan envisages increasing the share of EVs to 5% and hybrid vehicles to 20%. Rail transport faces similar challenges of outdated infrastructure, despite a high electrification rate of railways (around 80%).

Regulatory Framework

In signing the Association Agreement with the EU in 2014, Georgia committed itself to introducing liberalized energy market principles (European Commission 2014).[6] Since 2017, Georgia has been a Contracting Party at the Energy Community (a platform for an integrated pan-European energy market) and has made a legally binding commitment to adopt core EU energy legislation (IEA 2020). Georgia has already been well-positioned for competitive market functioning by having an independent energy regulator, the Georgian National Energy and Water Supply Regulatory Commission (GNERC). A law introduced in 2019 on energy and water supply provided for updating the national operational framework, unbundling vertically integrated companies, and creating a market-based legal framework for the generation, T&D, supply, and trade in electricity and natural gas sectors (Energy Community Secretariat 2020).

Another milestone in energy sector reforms was the adoption of a renewable energy law in the same year, which set a target share of renewables in the total final consumption of energy at 35%, and established network access rules for investors and certification of origin procedures. In 2020, another set of key laws was adopted, including specific laws on

(i) **energy labeling**, which provides for energy consumption indicators on products produced in or operated in the Georgian market;
(ii) **energy efficiency**, which sets a general framework for energy efficiency measures across all consumption sectors, as well as a framework for the installation of smart metering systems; and
(iii) **the energy efficiency of buildings**, which promotes rational use of energy resources and energy efficiency measures for all types of buildings.

These laws have created a general framework for a transition to liberalized and competitive electricity and natural gas markets. Importantly, they need to be consolidated by secondary legislation and detailed transition plans to ensure the establishment of a free and transparent market where end users can choose energy suppliers without restrictions.

GNERC has already developed concepts for electricity market rules, which were approved in 2020, and full transition of the electricity market was expected to be completed in 2021. However, adoption of secondary legislation on the gas market faces delays.

Other relevant legislation includes a law on PPPs, which sets criteria and a general framework for the establishment and operation of PPPs, as well as laws on oil and gas and the Environmental Assessment Code, which set requirements for energy-related projects and infrastructure.

Policy Framework

In recent years, Georgia has been active in energy policymaking. In 2019, Georgia issued Energy Strategy of Georgia 2020–2030, and then adopted the follow-up 2030 Climate Change Strategy and 2021–2023 Action Plan, which outlines how policy objectives will be implemented in the short term. Several further key documents are poised to be issued in the near future, including National Energy and Climate Plan

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[6] The Association Agreements aim to deepen political and economic relations between the EU and the other signatories and to gradually integrate these countries in the EU's Internal Market. This entails creating a Deep and Comprehensive Free Trade Area between the EU and each of these countries (European Commission 2014).

and Long-Term Low Emission Development Strategy. They will set a long-term framework to guide future policy decisions, integrating energy policy into a broader context of the country's economic and social development.

Key energy policy documents outline the following sector priorities for the government:

(i) **Realization of renewable energy potential.** Georgia is yet to capitalize on the significant potential of its wind, solar, biomass, and geothermal resources. Despite already high hydropower generation, the country can also advance in terms of exploiting its huge hydropower resources.
(ii) **Emergence as a regional transit hub.** As an already important transit country, Georgia aims to further strengthen its position by implementing additional east–west and north–south transit projects while also benefiting from optimized trade.
(iii) **Integrated approach to energy efficiency.** Trailing in energy intensity, Georgia aims to develop a comprehensive program to improve energy efficiency across sectors, with a key focus on industry and buildings.
(iv) **Liberalization of the energy market and trading.** One of the priorities for the country is a gradual shift toward EU legislation. The government has already introduced major legislation that follows European best practices of energy market organization. Yet further actions are planned to finalize the liberalization process and ensure competitive and transparent market conditions
(v) **Diversification and optimal use of local fossil reserves.** Highly reliant on fossil fuel imports, Georgia aims to explore its potential in oil and gas production to improve security of supply and enlarge the share of local resources in the energy balance.

Forecast Methodology

One objective of this country study is to present a detailed overview and analysis of future Georgian energy market trends. For this purpose, three scenarios were developed, taking into account the country's regulatory framework, technological development, consumer preferences, and other factors (Box 9). Outlooks for supply and demand, technology, carbon emissions, and investment were derived based on these scenarios.

Box 9: Scenarios for Georgia's Energy Sector

Business-as-usual scenario: Projected energy supply and demand, with current energy system and policies;

Government Commitments scenario: Projected energy supply and demand, considering individual priorities of the Government of Georgia; and

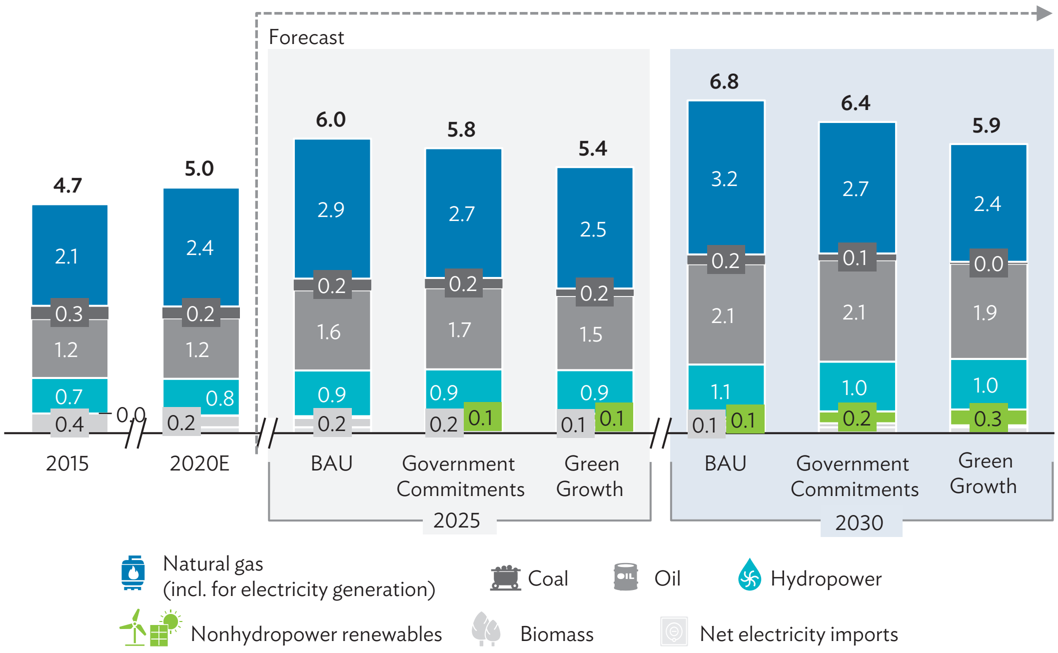
Green Growth scenario: Projected energy and supply demand, considering enhanced energy transition and environmental policies.

Source: Roland Berger/ILF.

Supply and Demand Outlook

The COVID-19 pandemic had a substantial impact on Georgia's energy demand, with an estimated 4%–5% decrease from 2019 to 2020. However, rebound of consumption in 2021 has been quite significant, reinforcing projections that energy supply and demand in Georgia will increase until 2030 in every scenario, driven by rapid economic development. The projected growth rate varies across scenarios. For instance, primary energy supply reaches 5.9–6.8 million toe in 2030 depending on the scenario, up from an estimated 5.0 million toe in 2020. Under the Government Commitments scenario, energy supply compound annual growth rate (CAGR) until 2030 is approximately 2.4%, compared to 3% under the Business-as-usual (BAU) scenario. The difference is caused by larger energy efficiency gains in consumption, reduction of losses, as well as higher power generation efficiency in the Government Commitments scenario. The Green Growth scenario assumes an even further reduction of energy intensity, driving down the growth of energy supply until 2030 to only 1.6% annually. Natural gas is projected to remain the dominant energy source until 2030 under all scenarios. Since gas is supplied not only directly to residents and industry but also for power generation, its supply level varies significantly across three scenarios along with the changes in the power generation mix (Figure 34).

Figure 34: Georgia—Primary Energy Supply Forecast
(million tons of oil equivalent)



BAU = Business-as-usual, E = estimate.

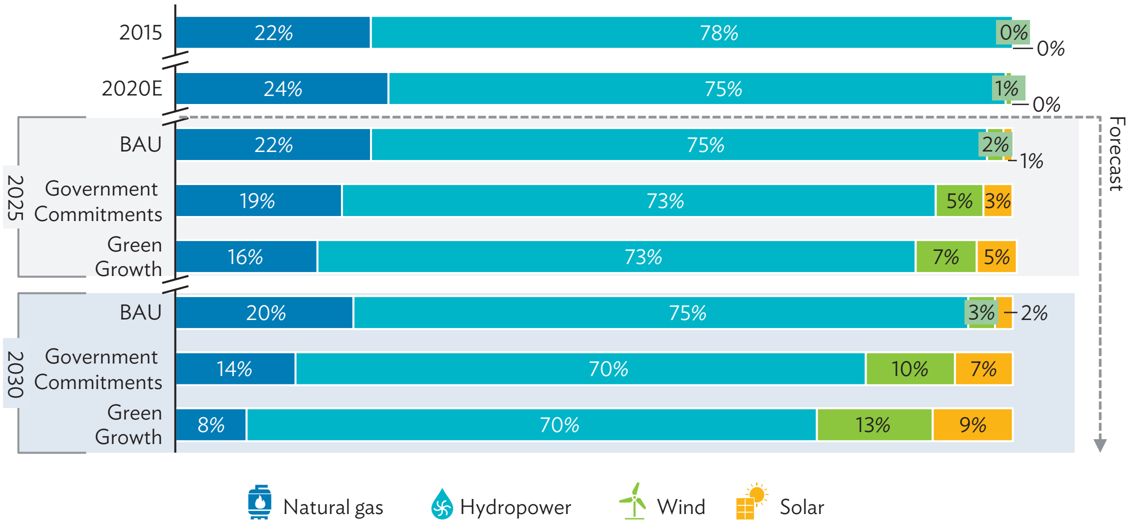
Source of historical data: Geostat. The forecasts are based on the Roland Berger methodology described in the Methodology section.

A key element in the power mix until 2030 is the development of nonhydropower renewable energy, evident across all three scenarios. Specifically, the Government Commitments scenario assumes 10% share of wind and 7% share of solar energy in the power generation mix in 2030. Under the BAU scenario, the share of nonhydropower renewables reaches only 5%. In contrast, the Green Growth scenario assumes the creation of a favorable investment climate for nonhydropower renewables, leading to a significant expansion of its share to 22% in 2030.

Importantly, all scenarios assume an expansion of hydropower capacity. Yet, the share of hydropower decreases in the Government Commitments and the Green Growth scenarios amid growing demand for electricity in the country. Considering both the large pipeline of planned hydropower projects and the highest growth in demand, the expansion of hydropower is the largest under the BAU scenario.

The recent commissioning of two modern gas-fired power plants, Gardabani I and II, brought up the share of gas in the electricity mix to 24% in 2020. However, it is projected to decline due to the prioritization of renewables in energy policy. In both the Government Commitments and Green Growth scenarios, gas-fired power plants are projected to play an auxiliary role in the energy system as outdated capacities are decommissioned. However, the BAU scenario assumes expansion of gas-fired power capacities, considering the rapid growth in consumption (Figure 35).

Figure 35: Georgia—Power Generation Mix



BAU = Business-as-usual, E = estimate.

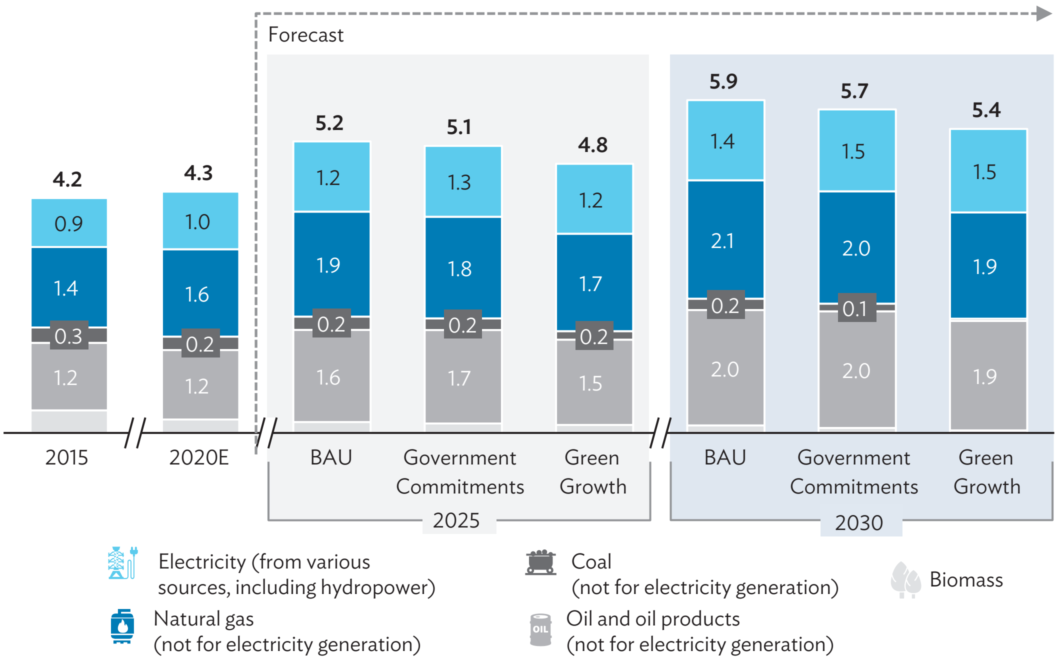
Sources: Geostat; and International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 18 July 2021). The forecasts are based on the Roland Berger methodology described in the Methodology section.

In a similar manner to primary energy supply, adoption of energy efficiency measures lowers final energy demand to varying levels, ranging between 5.4 million toe and 5.9 million toe in 2030. In all scenarios, consumption of oil and oil products outpaces overall growth in energy use because of the rapid development of the transport sector and, consequently, higher demand from vehicles. In addition, the role of electricity becomes more prominent, especially under the Green Growth scenario, as environmentally conscious consumers shift from fossil fuels to electricity. This represents a major opportunity to gradually phase out coal consumption, as illustrated by the Green Growth scenario in which coal demand is almost negligible. Similarly, the share of biomass in final energy demand declines under all scenarios, most quickly in Green Growth when it is replaced by gas and electricity (Figure 36).

Transport demonstrates the fastest growth in a sectoral split, illustrating increases of 5.2%–5.6% annually until 2030, depending on the scenario. Another rapidly growing segment is services, with a CAGR of 4.0%–4.5%. In contrast, residential and industry sectors benefit most from the energy savings as the Green Growth scenario assumes an increase of only 0.1% for residential and 1.6% CAGR for industry (Figure 37).

Figure 36: Georgia—Final Energy Demand Forecast by Fuel

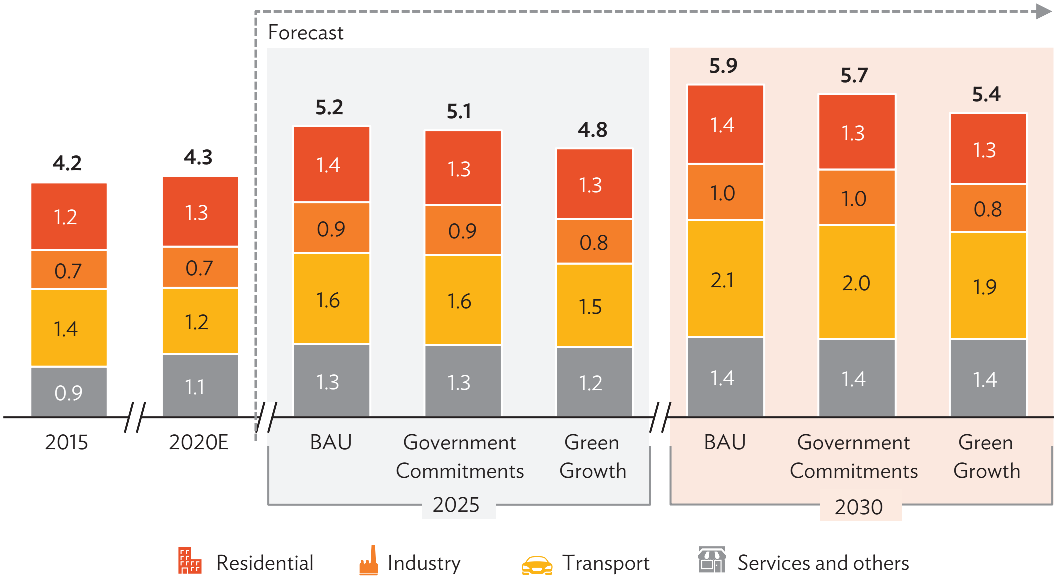
(million tons of oil equivalent)



BAU = Business-as-usual, E = estimate.

Sources: Geostat; and International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 18 July 2021). The forecasts are based on the Roland Berger methodology described in the Methodology section.

Figure 37: Georgia—Final Energy Demand Forecast by Sector
(million tons of oil equivalent)



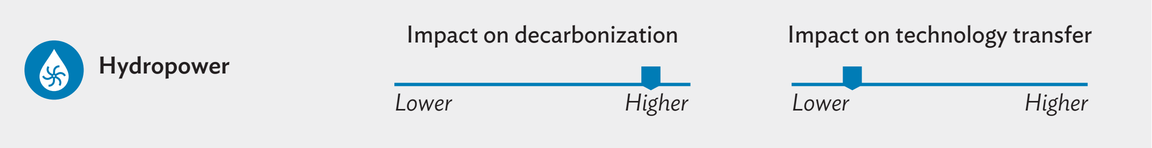
BAU = Business-as-usual, E = estimate.

Sources: Geostat; and International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 18 July 2021). The forecasts are based on the Roland Berger methodology described in the Methodology section.

Technology Outlook

Priority Technologies: Generation

The selection of priority technologies in power generation stems from Georgia's lack of fossil fuel production and substantial potential of renewables. However, the development of renewables should consider the seasonality or intermittency of its generation, thus creating a need for reliable power sources to provide flexibility.



Georgia has vast hydropower potential, with only 15%–25% of its economic potential estimated to be utilized, despite more than 3.3 GW of already installed hydropower capacity. As a cheap and clean energy source, hydropower has been a cornerstone of the Georgian electricity market and continues to attract private investments, such as for the Namakhvani plant, which is expected to become Georgia's largest energy project (Box 10). To ensure the project's proper development, the government announced a 1-year moratorium on the construction of the dam for further feasibility studies and sustainability assessments.

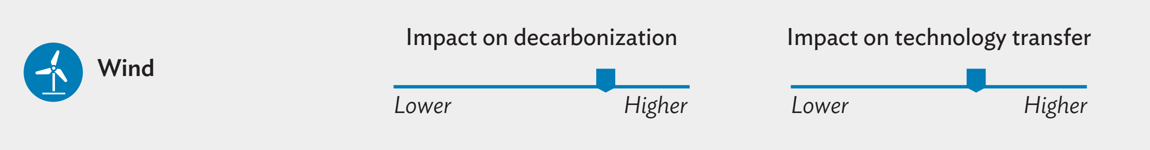
Box 10: Georgia's Flagship Energy Project

Namakhvani hydropower plant (HPP) will be the largest energy project in the history of Georgia, with foreign direct investments of up to $800 million. The construction is planned on Rioni River, with expected commissioning in 2024. The HPP's installed capacity will be 433 megawatts, with potential annual generation of nearly 1,500 gigawatt-hours. The project will enhance energy security and expand export potential, as the HPP will be able to meet 20% of peak demand and increase the country's annual power generation by 15%. The HPP will also contribute to Georgia's commitment under the Paris Agreement by reducing up to 750,000 tons of carbon dioxide emissions annually.

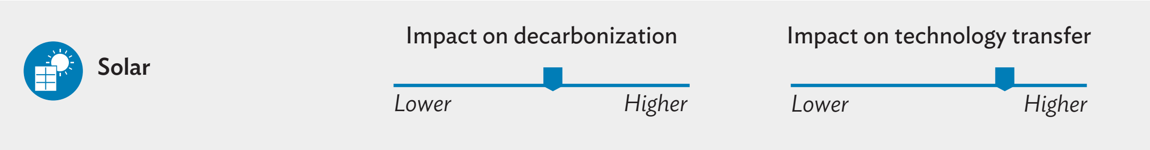
Note: Illustrative photo of transmission towers is from the Roland Berger library.

Sources: ENKA Renewables. About Namakhvani HPP; and N. Pignatti, G. Lobzhanidze, and M. Tsulukidze. 2021. Namakhvani HPP – Threat or Opportunity? *ISET Policy Institute.* 3 May.

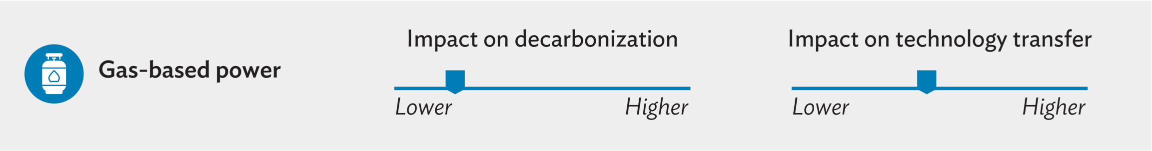
Regulated hydropower's balancing characteristics can simplify the integration of wind and solar power by flexible generation during off-peak hours. Yet, the further addition of hydropower capacities might compound the issue of seasonality. While optimal siting and sizing of pumped storage power plants can help to mitigate this issue, expansion of hydropower will not significantly improve Georgia's security of supply, as irregular electricity imports might still be required during winter to cover growing demand. Impact on technology transfer is limited since hydropower is a mature technology and Georgia already possesses ample knowledge from decades of its development.



Georgia's technical wind energy potential remains largely unutilized. Only one power plant with a capacity of 21 MW is operational, reflecting a lack of support schemes for renewable energy. As Georgia aims to diversify sources of electricity generation, wind power is a suitable option due to the high availability of this resource and continuous technological improvements resulting in falling costs. The government aims to reach approximately 1.4 GW of installed wind power capacity by 2030. This could create supply security challenges related to grid stabilization, although these would be minor considering the balancing characteristics and availability of hydropower. The impact on decarbonization is lower compared to hydropower due to lower potential; although, the development of wind energy projects will contribute significantly to technology transfer, given Georgia's limited track record.



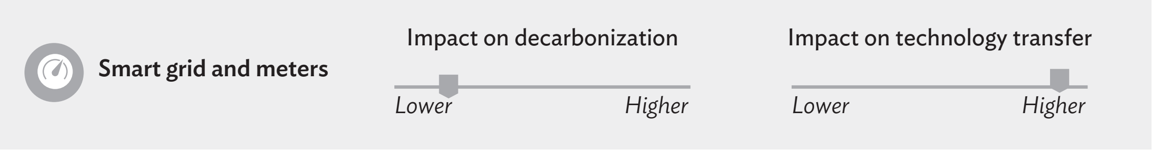
Georgia has yet to develop a solar power plant at a utility scale, despite establishing favorable conditions for the installation of decentralized solar. Launched in 2016, a net metering program was expanded in 2020 to include renewable energy installations with a capacity of up to 500 kilowatts (kW), compared to 100 kW earlier (GEFF 2020). This provides an opportunity for businesses and households to develop small-scale solar energy and sell electricity surplus to the grid. With most regions of the country having around 250–280 sunny days in a year, the technical potential of solar energy, estimated at 0.5 GW, is somewhat lower compared to wind mainly due to geographic conditions (Government of Georgia, Ministry of Economy and Sustainable Development 2019). However, as the cost of solar energy continues to decline, its attractiveness as a commercial opportunity will increase. Furthermore, a different energy generation pattern of solar energy can also enhance the security of supply via diversification and support Georgia's decarbonization efforts. The development of solar energy will also have a positive effect on technology transfer based on the lack of large-scale projects so far.



The seasonal pattern of hydropower electricity generation and the ambitious targets for expanding wind and solar capacities underline a need for stabilizing power generation sources. Natural gas is well positioned to serve as a transitional fuel, given its moderate environmental impact and the high efficiency of modern plants. For instance, new plants Gardabani I and II have high efficiency and play a crucial role in ensuring the security of power supply. However, because of the lack of domestic natural gas resources and production, natural gas needs to be imported, which weakens the potential role of gas-based power in stabilizing energy supplies. Further development also has a limited impact on technology transfer considering recent commissioning of modern power plants.

Priority Technologies: Transmission and Distribution

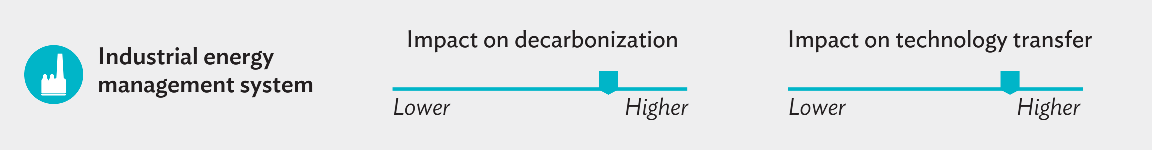
Georgian grid infrastructure is relatively well developed with moderate losses, especially in the power network controlled via remote monitoring systems. Yet, Georgia aims to further develop its grid infrastructure and has been proactively developing a strategy for smart grid and metering infrastructure.



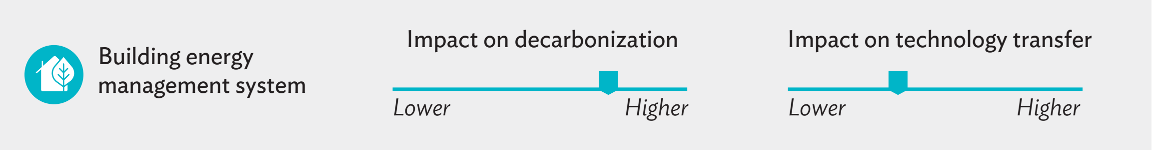
Georgia has already taken proactive steps in terms of creating a suitable environment for the introduction and development of smart metering infrastructure. GNERC has already introduced favorable net metering legislation for decentralized renewable energy systems, total capacity of which reached 10 MW in 2021. A recent increase of maximum capacity to 500 kW significantly improved viability of decentralized systems, especially for commercial consumers. GNERC has also conducted a cost–benefit analysis of a smart metering system, reiterating its positive impact on the overall energy system. Thus, extensive roll-out of smart metering devices can boost energy efficiency, enhance demand management, and reduce illegal consumption of energy. In addition, temperature sensing along the transmission cables can enable management of the current based on load, further improving reliability of supply. Given the novelty of smart grid technologies, the impact of their development on technology transfer will be significant.

Priority Technologies: Consumption

Georgia has significant potential for technological improvement in all consumption sectors. Industrial and residential sectors are prioritized in recent laws regulating energy efficiency, considering the high potential for energy savings in these sectors.



Industrial energy consumption in Georgia is highly concentrated as three enterprises are responsible for almost 60% of industrial energy consumption: Heidelberg Cement, Georgian Manganese, and Rustavi Azot (a chemical and fertilizer plant). Yet, historically energy consumption in industry was not subject to stringent regulations on efficiency. The situation changed with the recent adoption of the law on energy efficiency, which established audit and certification requirements, as well as some mandatory efficiency measures. Extensive use of an energy management system is critical to the identification of efficiency levers specific to the industry or individual plants (e.g., dry cement production methods, or solvent scrubbing in ammonia production). The emergence of energy service companies will be crucial to improving resource management efficiency in industry and to bringing modern industrial level technologies to Georgia.



Various studies demonstrate very poor efficiency in Georgia's residential and service buildings. The primary cause is a lack of roof or wall insulation (85% of buildings have no insulation) as a large share of buildings were constructed under inadequate energy performance standards. The recently adopted law on energy efficiency in buildings is an essential step toward improved efficiency, as it outlines requirements for minimum performance, certification, and inspection of heating equipment. Additional legislation in July 2021 established minimum requirements for energy performance, technical maintenance, and installation of buildings. In September 2021, the Government of Georgia adopted a national methodology for calculating the energy efficiency of buildings, which will further facilitate energy efficiency improvements in the building sector. High-impact measures can include the installation of temperature control valves, heat metering, and the modernization of gas boilers.

Carbon Emissions Outlook

Georgia demonstrated a commitment to reducing its carbon footprint with the submission of its updated Nationally Determined Contribution (NDC) before the 26th United Nations Climate Change Conference of the Parties in 2021. The country aims to diversify its renewable energy sector, specifically through expanding the share of wind and solar segments in its total energy mix, increasing the carbon-capturing capacity of Georgia's forests, and advancing climate-smart technologies. Compared to its first NDC, new targets are more ambitious, including an aim to unconditionally reduce total greenhouse gas (GHG) emissions by 35% compared to 1990 by 2030. A conditional target, which Georgia commits to reaching in case of external support (e.g., financial support), is to decrease emissions by 50%–57% relative to 1990 by 2030. Georgia's conditional target is consistent with the main goal of the Paris Agreement to limit the global temperature increase to 1.5°–2.0° Celsius. However, Georgia's target in the energy sector is less ambitious, with a 15% reduction target compared to 1990, which translates to approximately 30 million tons of carbon dioxide (CO_2) equivalent in 2030.

Georgia's GHG emissions outlook highlights that even more ambitious climate change actions are possible and attainable, as all three scenarios result in emission levels below the NDC target. Even with the COVID-19's impact on the energy sector, which reduced emissions in 2020, CO_2 emissions will maintain a steadily rising pace until 2030 under the BAU scenario. Georgia's energy-related GHG emissions reach 15 million tons of CO_2 equivalent, which is significantly below the country's NDC target for the energy sector. The Government Commitments scenario projects an even higher decrease in CO_2 emissions. With government moving toward its policy targets and long-term goals, emissions are rising at a slower pace, with almost 14 million tons being produced in 2030. Under the Green Growth scenario, which incorporates large shifts toward renewable energy technologies and stronger energy efficiency measures, CO_2 emissions are on approximately the same level as 2020, showing that an increase in demand can easily be managed with a transition to more sustainable energy generation (Figure 38).

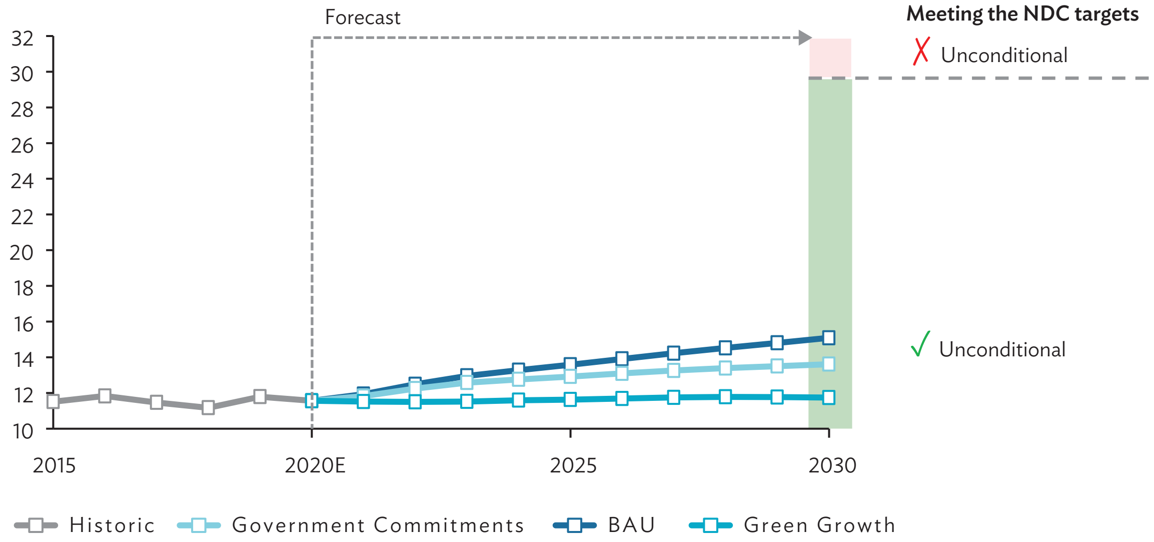
Investment Outlook

Investment Needs

Energy infrastructure investment needs until 2030 vary significantly under the three scenarios, ranging from $9 billion to $19 billion. This assessment excludes investment needs in the production of fossil fuels, considering insufficient reserves and the questionable commercial viability of production. For hydropower, investment needs are relatively stable across the scenarios at $1.4 billion–$1.7 billion. The BAU scenario also foresees an expansion of gas-fired power plants, requiring $0.5 billion in investments. Investment in nonhydropower renewables under BAU reaches only $0.4 billion, in contrast to $1.3 billion under Government Commitments and $1.5 billion under Green Growth. Most of the power generation sector investment needs are aimed at expansion, while investments into rehabilitation of old assets make up only 6% of the total under Green Growth.

Georgian energy T&D infrastructure also requires significant investments. Network modernization and expansion, installation of metering equipment, and remote monitoring systems are estimated to require $0.7 billion–$1 billion, depending on the scenario. The largest share of energy-related investment needs is concentrated on the consumption side via energy efficiency measures. As BAU assumes limited energy efficiency measures in residential, services, and industrial sectors, total investment needs reach $5.1 billion. Under the Government Commitments scenario, renovation of buildings in line with Georgia's Low Emission Development Strategy, as well as the introduction of industrial energy efficiency measures required to reach intensity targets, requires $7.3 billion. Green Growth assumes an even larger building

Figure 38: Georgia—Energy-Related Carbon Emissions
(million tons of carbon dioxide equivalent)



BAU = Business-as-usual, E = estimate, NDC = Nationally Determined Contribution.

Note: Historical data on carbon emissions is modelled by Roland Berger based on historical data on energy use. The forecasts are based on the Roland Berger methodology described in the Methodology section.

Sources: Roland Berger; and United Nations Framework Convention on Climate Change. Nationally Determined Contributions Registry. https://unfccc.int/NDCREG.

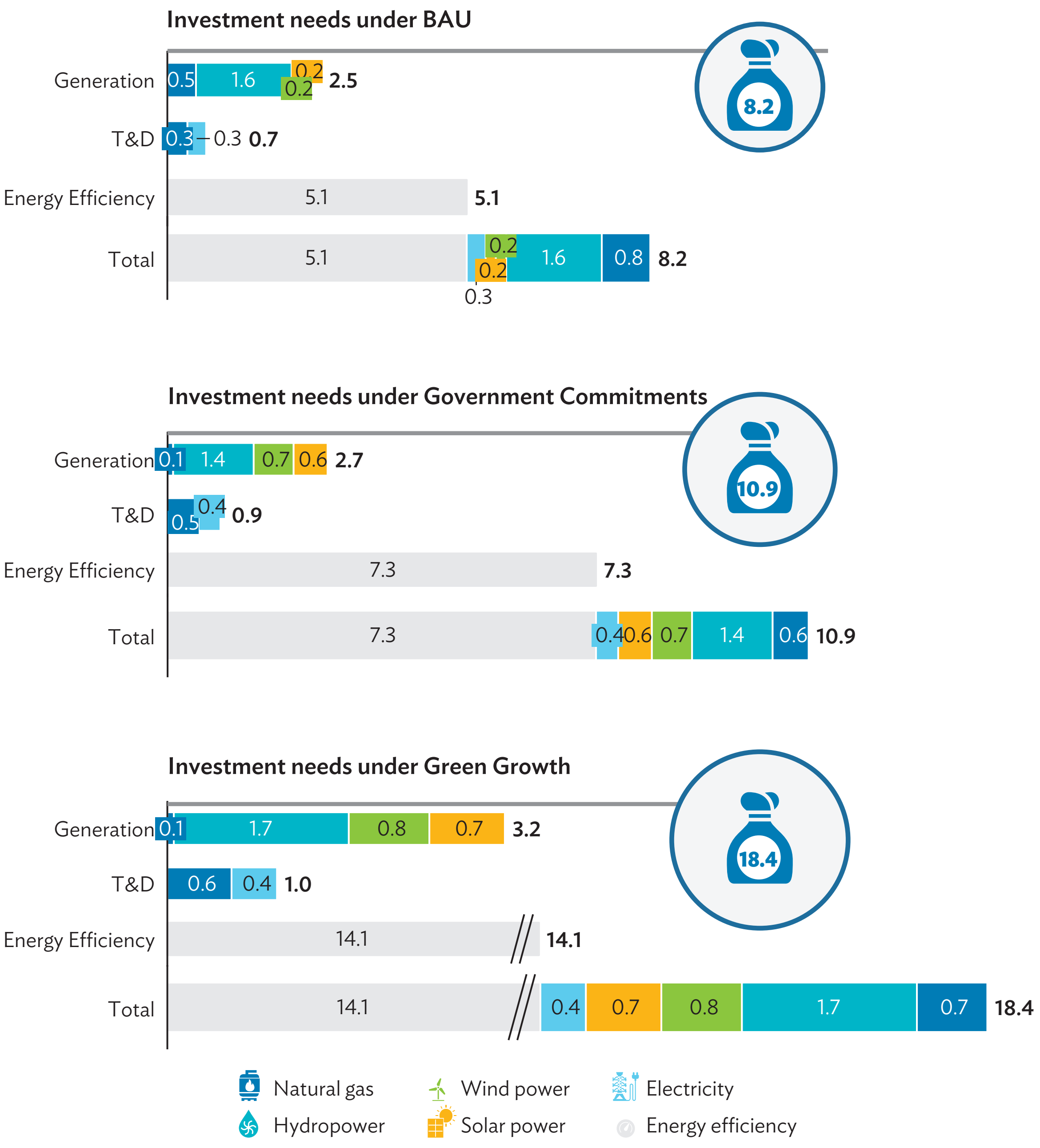
renovation program, broader measures in the industry, as well as the roll-out of EV vehicles and related infrastructure, resulting in investment needs for efficiency improvements of $14.1 billion (Figure 39).

Challenges and Opportunities

Several challenges must be addressed to further unlock the market for private companies. One of the key barriers is energy price regulation and implicit subsidies. The International Energy Agency (IEA) estimates that total subsidies for natural gas and electricity surpassed 6% of Georgia's national budget spending in 2017. This means elimination of energy subsidies will not only unlock development of energy markets via private investments but also help to reallocate public resources to other sectors. In addition, elimination of subsidies and resulting higher energy prices will raise financial viability of various energy efficiency measures. Yet, the government must also protect the most vulnerable groups via targeted support schemes to ensure stable social and economic development.

Georgia's geographical position and the context of its energy sector poses another market challenge. The lack of exploitable fossil fuel resources forced Georgia to develop abundant hydropower resources. However, high reliance on a single source of primary energy for electricity generation, in addition to distinctive seasonal patterns in hydropower generation, creates potential threats to the security of supply. Thus, a need for diversification of power generation sources, in addition to careful siting and sizing of new HPPs, should be considered by potential investors.

Figure 39: Energy Infrastructure Investment Needs in Georgia until 2030
($ billion)



BAU = Business-as-usual, T&D = transmission and distribution.

Source: The forecasts are based on the Roland Berger / ILF methodology described in the Methodology section.

Another set of challenges stem from extensive regulatory reforms undertaken by the government to encourage full transition to a liberalized energy market. This may create short-term uncertainly for potential investors as a fundamentally new market structure is introduced in 2021–2022. Recent cancellation of guaranteed off-take from mid- and large-scale HPPs via power purchase agreements (PPAs) led to cancellations and delays in multiple hydropower projects.[7] While a new regulatory framework is already established and will support private sector participation in the mid- and long-term, many secondary laws are yet to be developed and implemented. This challenge is particularly distinctive in the natural gas market, where the unbundling process faces delays and keeps constraints in place for private companies.

Another challenge is access to affordable financing. As in other emerging markets, the overall risk profile in Georgia and initial development stage of the capital markets limit the availability of low-cost long-term financing. For instance, commercial banks often require collateral double the size of the loan, making it difficult for Georgian companies and especially small and medium-sized enterprises to find resources. Importantly, long-term capital is often required for low-carbon energy projects, such as renewable energy plants or energy efficiency measures, because of the long payback period. Historically, only hydropower projects in Georgia have proven to be commercially viable without de-risking instruments, even despite the phase-out of guaranteed PPAs.

Even though Georgia has a large pipeline of hydropower projects in development and at the planning stage, virtually no large-scale solar and wind projects are being developed. Compared to many countries in Central Asia Regional Economic Cooperation (CAREC) and Eastern Europe, Georgia trails in the installation of nonhydropower renewables. This points to inadequate support schemes for wind and solar projects. As demonstrated in other CAREC countries, feed-in-tariffs or premium or capacity auctions provide strong incentives and a suitable framework for private investors to get involved.

Nevertheless, Georgia's energy sector also offers plentiful opportunities for potential investors. Georgia has introduced strong investor protection regulation and climbed to seventh position in the World Bank's Doing Business ranking, ahead of other CAREC member countries and many developed economies (World Bank). The regulatory framework specific to the energy sector also aims to create a suitable environment for private companies in the mid- and long-term via a liberalized and competitive market structure in both wholesale and retail segments, following the best practices of European legislation. This includes the unbundling of vertically integrated companies in markets for electricity (complete) and gas (ongoing). The wholesale electricity market operates based on direct contracts and deregulated prices. Importantly, the energy sector is overseen by a transparent and independent regulator, GNERC, which has proven its capability over recent years. Furthermore, recent public–private partnership (PPP) law also provides suitable conditions for energy project development under PPP.

Recognizing the potential of renewable energy sources, Georgia has developed support schemes for private operators of power plants considering a transition to market-driven mechanisms. Specifically, the government introduced a feed-in premium for all types of renewable energy power plants with a capacity of more than 5 MW. Premium is received by the producers if the power market price is below 5.5 cents per

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[7] In 2017, Georgia suspended signing new government-backed PPAs for hydropower projects following agreement with the International Monetary Fund, which was concerned about rising public debt.

kWh; however, the premium is capped at 1.5 cents per kWh. This represents a good example of targeted support for priority clean energy sources in the context of liberalized energy markets.

Moreover, the introduction of more renewable energy resources might create an opportunity to establish green hydrogen production in the country when technology is more developed, cheaper, and widely available.

Another advantage of Georgia's energy system is its strong cross-border interconnections, in both electricity and gas networks. With an operational transit capacity of 2.5 GW in electricity and 25 bcm in natural gas, Georgia is already well-positioned to become a regional transit hub, especially considering that Georgia's power generation structure is dominated by hydropower. Seasonal changes of water flow imply insufficient power generation in winter and abundant generation in summer, creating a platform for mutually beneficial energy trade with neighbors. For instance, electricity export to the Republic of Türkiye has intensified in recent years with a positive outlook for the future considering growing demand in the Republic of Türkiye, while import from Azerbaijan has been on a steady upward trend as well.

Policy Recommendations

Georgia has already substantially improved its regulatory and policy framework, thus creating a suitable environment for private sector participation. Yet several levers were identified on how Georgia can further enhance its investment climate:

(i) **Gradually phase out energy subsidies while establishing safeguards to protect vulnerable customer groups.** Regulated energy prices significantly hamper market development while also restraining additional investments in energy efficiency. However, a careful approach in the elimination of subsidies should be undertaken with targeted support of vulnerable groups, considering its potential negative short-term impact on social and economic development.

(ii) **Continue energy sector reforms to achieve a fully free, liberalized, and competitive market, and create conditions for larger private sector involvement.** Successful adoption of primary legislation in line with European best practices needs to be supplemented by rigorous secondary acts to ensure successful and timely implementation—for instance, a detailed unbundling plan for the natural gas sector. After a transition period, consumers of electricity and natural gas should be able to select energy suppliers from a competitive pool of players with adequate switching costs.

(iii) **Consider support schemes for renewable energy projects to boost development of solar and wind energy.** This can be implemented via feed-in premiums, a similar manner to how Georgia incentivizes the development of hydropower. Alternatively, Georgia can also introduce renewable energy capacity auctions, unlocking its substantial potential in wind and solar power to investors with the required know-how.

(iv) **Promote the use of innovative energy technologies by developing a legislative framework and support mechanisms.** One of the key challenges in Georgia is inadequate power generation in the winter season due to a large share of hydropower plants. Introduction of innovative energy technologies, such as the battery energy storage systems, hydrogen, or smart grids can help to manage the power network in a flexible manner while also enabling integration and use of additional solar and wind power capacities.

(v) **Ensure successful implementation of recently adopted energy efficiency legislation and targets.** Recently adopted legislation on energy efficiency has set a strong basis for improving Georgia's energy intensity. However, implementation of the related action plan and measures needs to be carefully monitored and, upon substantial progress, more stringent targets and requirements could be introduced.

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Tbilisi. The capital's history is reflected in its architecture, which is a mix of medieval, neoclassical, Beaux Art, and modern architecture (photo by monticellllo/Adobe Stock©).

KAZAKHSTAN

Energy infrastructure. Kazakhstan is a major energy producer and exporter with extensive natural resources (photo by vitmark/Adobe Stock©).

Kazakhstan Highlights

- Kazakhstan is a major energy producer and exporter with extensive natural resources—in particular, oil, natural gas, and coal reserves. Some 63% of its produced energy was exported in 2018, while oil and oil products exports accounted for around 70% of the country's total energy exports in the same year.
- Energy consumption in Kazakhstan is dominated by fossil fuels, with a large share of coal in the power generation mix and in direct consumption in the residential and industrial sectors. As a result, the country's energy sector ranks high in carbon emissions, accounting for the fourth highest carbon intensity globally (Figure 40).
- Recognizing the urgent need for decarbonization, Kazakhstan has adopted several measures to spur the development of renewable energy, in which the country has strong potential. In addition, Kazakhstan pioneered carbon pricing regulations in the region via the establishment of an emissions trading scheme (ETS), which aims at incentivizing polluters to become more efficient. To further effectively reduce emission levels, Kazakhstan should consider increasing natural gas consumption in place of coal, as well as improving the technical condition of its infrastructure to prevent grid losses.
- Final energy demand in Kazakhstan is expected to reach 49–57 million tons of oil equivalent (toe) in 2030, depending on the scale of energy efficiency measures that will be adopted. In spite of its substantial renewable energy potential, traditional fuels such as natural gas, oil, and coal will continue to play an important part in the overall energy supply.
- With a total installed capacity of 23 gigawatts (GW), the power mix is currently dominated largely by coal—estimated at 69% in 2020—and this position is projected to be sustained, with a share of 36%–64% in 2030, depending on the scenario. Meanwhile, the share of renewables in 2030 is expected to increase to 16%–28%, compared with an 11% share in 2018. Kazakhstan is also developing nuclear energy, recognizing the country's large uranium deposits and production (World Nuclear Association 2022).
- In addition to renewable and gas-fired power generation, priority technologies for Kazakhstan include energy efficiency measures, especially in industry and buildings, as well as transformation of the heating sector into a renewable technology-based heating system. Currently, the heating sector is one of the major contributors to greenhouse gas (GHG) emissions in the energy sector; hence, it has a potential to meaningfully contribute to the decarbonization process. Battery energy storage systems (BESS) are also considered among the country's important technologies, given the need to integrate a large capacity of renewables.
- Ranking 15th highest globally in energy intensity, the investment needs for Kazakhstan are primarily determined by energy efficiency improvements and a transition toward cleaner energy sources. Total investment needs range between $20 billion and $56 billion, depending on scenario.
- Investment opportunities in Kazakhstan arise from its solid renewable energy potential, its considerable track record of international energy projects—including ones with private investors—and its large and growing market size.
- Overcoming several remaining challenges, such as energy subsidies, and financial barriers, including a high interest rates and a lack of readily available financial support mechanisms, would facilitate further private sector participation.

Figure 40: Kazakhstan—Key Figures

Renewable potential	Electricity mix	Carbon intensity	Energy exports	Energy resources
4.1 TW	**30%**	**4th out of 172**	**63%**	**1st**
Technical potential of hydropower, solar, and wind generation is estimated at 4.1 TW.	Expected share of renewable sources in energy generation is 30% in 2030.	Kazakhstan is ranked 4th out of 172 countries in the global ranking of carbon intensity of energy, largely due to the high share of coal in the electricity mix.	63% of produced energy sources in Kazakhstan were exported in 2018.	The country was the world's largest producer of uranium, the 9th largest producer of coal, the 17th of crude oil, and the 24th of natural gas in 2018.

TW = terawatt.

Sources: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 25 July 2021); United Nations Development Programme. 2014. Kazakhstan: Renewable Energy Snapshot; United Nations Economic Commission for Europe. 2019. Economic and Social Commission for Asia and the Pacific. Report No. 2; United States Energy Information Administration. Kazakhstan Data. https://www.eia.gov/international/data/world (accessed 25 July 2021); and G. Zh. Zhunussova et al. 2020. Renewable Energy in Kazakhstan: Challenges and Prospects. *International Energy Journal.* 20 (3). pp. 311–324.

Energy Sector Profile

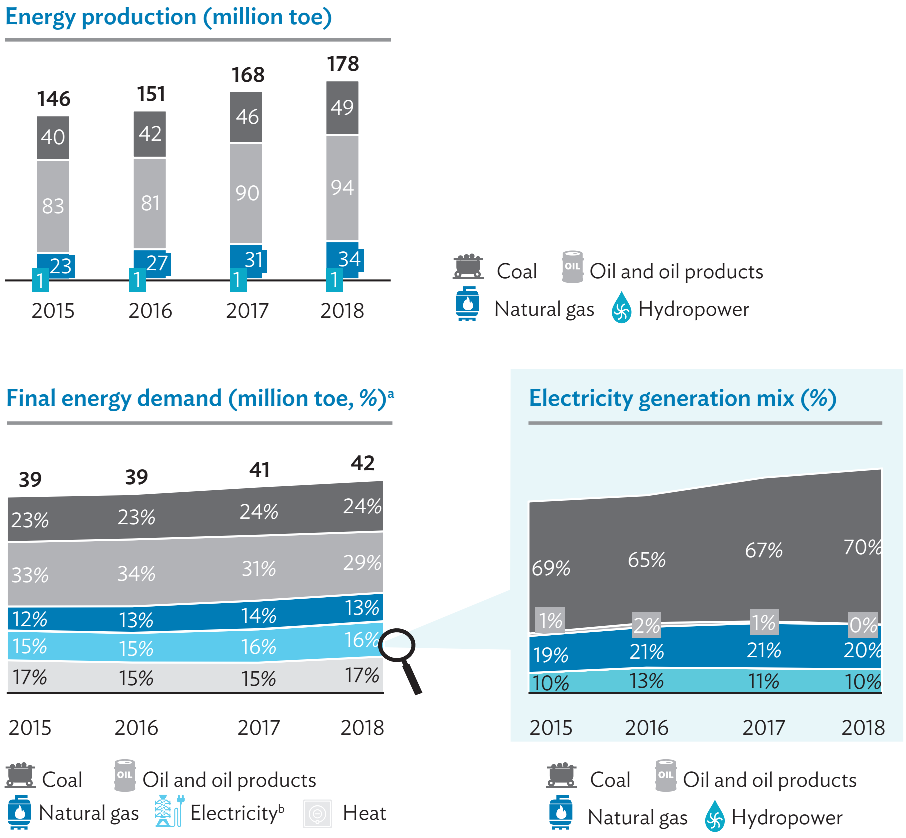
Country Profile

Kazakhstan is the largest landlocked state in the world and one of the leading economies in Central Asia. With a population of 19 million people, Kazakhstan reached a nominal gross domestic product (GDP) of around $167 billion in 2020. While the coronavirus disease (COVID-19) pandemic contributed to an estimated 3% GDP decline in 2020, Kazakhstan is expected to recover swiftly, with a forecast nominal GDP growth rate of 9% per annum until 2030.

Kazakhstan's energy sector has a significant impact on its economy. The country is a notable producer and exporter of oil, coal, and natural gas. This abundance of fossil fuels has led to an extensive carbon intensity of energy, with Kazakhstan ranking fourth highest in the world. However, the government is addressing this concern by gradually shifting its energy strategy toward alternative and green sources of energy, setting targets and plans accordingly, and opening an emissions trading market (Figure 41).

Ranking 15th highest globally in energy intensity, Kazakhstan also has considerable room for improvement in this regard. Fairly outdated infrastructure and an old fleet of vehicles are considered the primary causes.

Figure 41: Energy Profile of Kazakhstan



toe = ton of oil equivalent.

[a] Topmost numbers on the chart are in million toe.

[b] Electricity data come from various sources, including fossil fuel-based and renewables.

Source: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 25 July 2021).

Energy Sector and Technologies Assessment

Conventional Fuel Production

Kazakhstan is rich in all three conventional fuels—coal, oil, and natural gas. The country is the world's ninth largest producer of coal and has estimated coal reserves of more than 170 billion tons, with annual production reaching 120 million tons in 2020. There are 47 coal deposits, of which 5 coal mining fields and 14 deposits are currently in operation. Coal reserves are operated and maintained by several key entities, including Bogatyr Komir LLP, ArcelorMittal Temirtau Joint-Stock Company (JSC), and ERG Eurasian group, as the sector was restructured and privatized in the 1990s.

Twelve large private and state-owned coal producers in Kazakhstan are responsible for 98% of the country's coal production. Kazakhstan operates both open cast mines (Ekibastuz) and underground mines (Karaganda). Outdated mining equipment, difficult mining and geological conditions have led to a reduced techno-economic performance, and to the deterioration of the surrounding natural environment.

Kazakhstan's crude oil reserves are rather significant, being estimated in 2018 at 3.9 billion tons. The production of oil is also considerable, at around 94 million toe in 2018, after increasing at a compound annual growth rate (CAGR) of 4.4% since 2015. Kazakhstan has 271 oil fields, but more than 90% of the oil reserves are concentrated in the 15 largest fields. The five largest—Tengiz, Kashagan, Korolevskoye, Karachaganak, and Zhanazhol—account for 70% of the country's proven and probable oil and natural gas condensate reserves.

Furthermore, natural gas deposits were estimated at 1,000 billion cubic meters (bcm) at the end of 2018. Approximately 98% of the fields are in western Kazakhstan, with 85% of the volume being extracted from the large fields in Tengiz, Kashgan, Karachaganak, Zhanazhol, and Imashevskoye. In 2020, the country produced nearly 87 million toe of oil, whereas natural gas production was around 26 million toe (Agency for Strategic Planning and Reforms of the Republic of Kazakhstan, Bureau of National Statistics).

In addition, Kazakhstan has the third-largest deposits of uranium in the world (around 12% of the world's total), and is a world's largest producer of uranium, with around 20,000 tons produced in 2019 (43% of the world's total). KazAtomProm controls the production of uranium within the country.

Electricity Generation

Electricity is generated by 155 power plants, both private and state-owned, with a total installed capacity of 23 GW. Coal-fired power plants account for around 70% of power generation, mostly located in central, northern, and eastern Kazakhstan. The next largest share of total installed capacity is gas-based generation (which accounts for 19%) and hydropower (10%). Kazakhstan's renewables potential, particularly nonhydropower, has been realized to a very limited extent, yet the country is gradually expanding its portfolio. This is demonstrated by the ongoing projects and developments, particularly solar and wind power plants, which have been implemented and commissioned in the last decade. At the end of 2019, Kazakhstan had 542 megawatts (MW) of solar photovoltaic (PV) plants and 284 MW of wind power plants (IEA 2021).

Kazakhstan's electricity-generating infrastructure is aging, with approximately 65% of power-generating equipment in use for more than 20 years, and about 31% for more than 30 years. This implies that the average efficiency of power generation is rather low compared to the efficiency levels obtained by modern plants. The Government of Kazakhstan plans to address this issue by adopting various energy efficiency measures, including modernizing infrastructure.

Finally, Kazakhstan also produces a considerable amount of heat energy—as of 2018, around 17% of total final energy supply. Heat is generated by 40 co-generation plants (comprising 45% of total heat energy production), nearly 30 large boilers, and almost 900 small boilers.

Transmission and Distribution

The large size and growing population of Kazakhstan necessitates considerable energy transmission and distribution (T&D) systems. Electricity transmission in Kazakhstan is carried out by a single state-owned company, Kazakhstan Electricity Grid Operating Company. The company operates and maintains 29,000 kilometers (km) of high voltage transmission lines, and 80 high voltage substations. The national grid operates at different levels of voltage, including 220 kilovolts (kV), 500 kV, and 1,150 kV. Distribution is handled by medium and small regional electricity companies (more than

100 firms), some of which are privately owned. The 20 regional distribution companies operate at levels of 110 kV and lower. Overall, electricity networks are fairly efficient, with estimated grid losses of about 7% across T&D systems. This is also reflected by the relatively short duration of outages experienced by customers each year, with a system average interruption duration index of around 60 minutes in 2020. This value decreased by almost 6% over the 5 years' prior, and is one of the lowest among Central Asia Regional Economic Cooperation (CAREC) countries. The system average interruption frequency index is also low, at 0.91 times in 2020.

The natural gas distribution network in Kazakhstan is spread over 56,000 km, and is operated and maintained by state-owned KazTransGas Aimak. With a gasification rate of 53% in 2020, the government intends to increase the access and reach of natural gas to the northern parts of the country. The natural gas from the newly constructed Sary-Arka system will replace the use of coal for heating in buildings along the pipeline, and will support power and heat generation in Astana.

The heat in Kazakhstan is supplied by 2,427 heat producers. The supply network comprises 12,300 km of pipes. About 44% of heat pipes are above-ground and have low-quality insulation. These rather outdated, often undermaintained assets cause frequent disruptions in the supply of heat to end users. Heat system loss is estimated to be about 30%.

Cross-Border Infrastructure

Due to its favorable location in the center of Asia, Kazakhstan has considerable transit potential. Moreover, being a part of the Central Asian Power System (CAPS), which includes Kazakhstan, Kyrgyz Republic, and Uzbekistan (with Tajikistan expected to be reconnected in 2022), opens additional trade opportunities (ADB 2018). The CAPS is expected to be revived as a result of the growing significance of intercountry energy trade and improving relationships among countries. Kazakhstan also has a strong interconnection with the Russian Federation, in particular via the Ekibastuz–Kokshetau 1,150 kV line operated with capacity of 5,000 MW.

Kazakhstan's key cross-border infrastructure is relatively new, having been built after independence. One of its major infrastructure components is the Central Asia–People's Republic of China (PRC) gas pipeline, which has a capacity of 55 billion cubic meters per annum (bcma), and connects Uzbekistan and Kazakhstan to the PRC. The Beineu–Shymkent Gas Pipeline, with a capacity of 15 bcma, also connects Kazakhstan and the PRC.

Kazakhstan's major oil pipelines include (i) the Caspian Pipeline Consortium, which has a capacity of 67 million tons per annum (mtpa) and connects Kazakhstan and the Russian Federation; and (ii) the Kazakhstan–PRC oil pipeline, which has a 20 mtpa capacity and links Kazakhstan and the PRC (Table 3).

Energy Consumption

Due to most of Kazakhstan's industrial enterprises dating from the Soviet era, they use outdated technologies and are powerful sources of pollution. In the 1990s, Kazakhstan was one of the least energy-efficient economies in the world. Significant progress was made until 2001, when energy intensity reached 8.2 megajoules (MJ) per United States dollar GDP, compared to peak levels of 17.6 MJ in 1992. Yet, progress has stalled during the last 2 decades, with energy intensity reaching 7.9 MJ in 2015, well above the world average of 5.8 MJ.

Table 3: Kazakhstan—Major Operational Cross-Border Energy Infrastructure

Energy Source	Name	Capacity	Connected Country
⚡	Ekibastuz–Kokshetau 1150 kV line	5,000 MW	Russian Federation
⚡	Zhambyl–Frunzenskaya 500 kV line	870 MVA	Kyrgyz Republic
⚡	Shymkent–Tashkent 500 kV line	1,900 MVA	Uzbekistan
🔥	Central Asia–PRC	55 bcma	PRC, Turkmenistan, Uzbekistan
🔥	Beineu–Shymkent	15 bcma	PRC
OIL	Caspian Pipeline	67 mtpa	Russian Federation
OIL	Kazakhstan–PRC	20 mtpa	PRC

⚡ Electricity 🔥 Natural gas OIL Oil

bcma = billion cubic meters per annum, kV = kilovolt, mtpa = million tons per annum, MVA = megavolt-ampere, MW = megawatt, PRC = People's Republic of China.

Sources: Fitch Solutions. 2020. *Kazakhstan Oil & Gas Report.* London; Fitch Solutions. 2020. *Kazakhstan Power Report.* London; International Energy Agency. 2021. *Kazakhstan Energy Profile.* Paris.

Recognizing the urgent need for action, the government introduced an ETS in 2013 to accelerate efficiency improvements (ICAP 2022). Currently, it covers nearly 50% of total GHG emissions in Kazakhstan, including large industrial emitters (above 20,000 tons of carbon dioxide [CO_2] equivalent per year) mostly active in heavy industry. So far, the ETS has had limited impact, as the caps were set for emission stabilization or only slight decreases. Once the ETS market is expanded to a broader scale covering all GHG emissions, more ambitious emission targets should be set. The government also recently introduced energy audits for industrial enterprises, and early results have shown that the modernization of industrial technologies, including implementation of monitoring systems supporting appropriate energy efficiency measures, can lead to energy savings of 15%–40%.

Energy consumption in residential and services sectors is also characterized by low efficiency. According to various estimates, 50%–70% of buildings have thermal characteristics that do not meet modern requirements. On average, energy consumption in Kazakhstan is about 250–300 watts per square meter, which is nearly 1.5–2.0 times more than in developed countries with similar climate conditions. Root causes include outdated building codes that fail to establish adequate energy performance requirements, a limited number of contractors able to perform high-quality retrofit and construction works, and poor data availability on the performance of individual buildings because of the narrow scope of previous energy audits.

Transport energy consumption efficiency in Kazakhstan is in a similar condition to other sectors. The average age of the vehicle fleet is extremely high, at more than 20 years. Old cars are typically characterized by low energy consumption efficiency and high carbon intensity. Their problems are further compounded by poorly developed public transportation systems in large cities, where only one-third of commuters use public transport. However, public transportation has been central to Kazakhstan's efforts to switch to alternative fuels, with, for instance, more than half of buses in Almaty running on natural gas. Usage of electric vehicles (EVs) in Kazakhstan is currently limited to only a few hundred cars. However, in 2021, Kazakhstan planned to launch domestic production of EVs, including buses, which should promote a more rapid uptake of this technology. In addition, several governmental support measures helped stimulate demand for EVs, such as cancelling their recycling fee.[8] In terms of rail transport, as of 2018, 32% of rolling stock was electric, while the rest was run on diesel. Kazakhstan Temir Zholy, the national railway company, has improved its energy consumption efficiency for transportation by 15% since 2015 amid broader efforts to increase efficiency, which also include company-wide energy audits and an action plan for implementing energy efficiency measures until 2024 (Kazakhstan Temir Zholy 2021).

Regulatory Framework

Following the country's administrative reforms in 2014, Kazakhstan's energy sector is the responsibility of a single governmental body, the Ministry of Energy (MOE). The legislative base of electricity market regulation is set in the Law on Electric Power (2004), which was adjusted with amendments in 2011 and 2012. As a result, the power market has been unbundled since 2004. Generation is currently executed by multiple state-owned and private companies; transmission is carried out by the state-owned Kazakhstan Electricity Grid Operating Company; distribution occurs via regional (around 20) and small-sized (more than 100) distribution companies; and, finally, the sales process takes place via multiple standalone retail supply companies. Overall, access to the market is nondiscriminatory: power supply organizations can purchase electricity from power generation companies directly via bilateral agreements or in centralized auctions (Figure 42).

The production of conventional fuels is regulated by several key laws, such as The Law on Subsoil and Subsoil Use (2010). The law governs fuel exploration and production and establishes the state's right to preempt sale of natural gas and oil assets. The licensing regime allows private companies to administer oil and natural gas exploration and production processes mostly via concessions. Typical contract duration is 6 years for exploration, and 25–45 years for production. Contracts also typically contain a domestic obligation clause.

The Law on Gas and Gas Supply (2012) focuses on the reliability and security of natural gas supplies, and the sensible use of natural gas resources (Government of Kazakhstan 2012). Unlike the power market, Kazakhstan's natural gas market is not fully unbundled. Production occurs mostly via consortiums between state-owned companies and foreign investors or firms: Karachaganak Petroleum Operating, which is the largest producer, followed by Tengizchevroil, and others. Transmission is handled by KazTransGas, a vertically integrated transmission system operator (TSO)/distribution system operator (DSO) holding company under the direct ownership of sovereign wealth fund, Samruk-Kazyna. KazTransGas owns and operates most natural gas pipeline infrastructure (exceptions are pipelines that were built for specific

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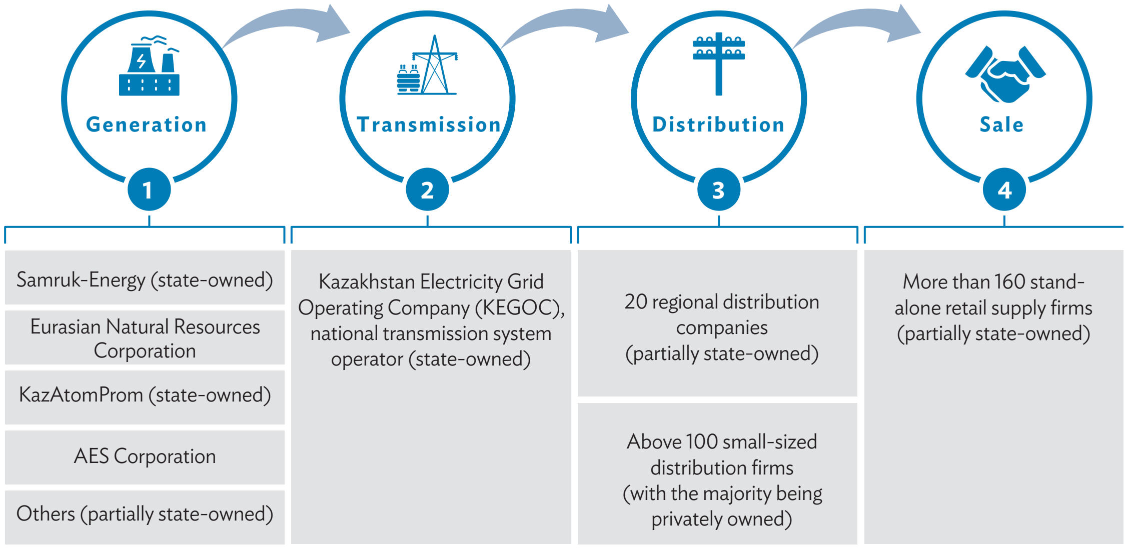
[8] This is a fixed fee that is paid by Kazakhstan's car manufacturers, official importers, and individual drivers who import automobiles into the country. This fee is paid before the initial registration of the vehicle.

Figure 42: Kazakhstan—Power Market



Sources: M. Aldayarov, I. Dobozi, and T. Nikolakakis. 2017. *Stuck in Transition: Reform Experiences and Challenges Ahead in the Kazakhstan Power Sector.* Washington, DC: World Bank; and International Energy Agency. 2021. *Kazakhstan Energy Profile.* Paris.

cross-border projects such as the Central Asia Gas Pipeline) and is responsible for natural gas supply via its affiliates.

The government has taken measures to encourage the development of renewable energy. Specifically, the Law on Support of the Use of Renewable Energy Sources (2009; amended in 2013) and the Green Economy Law (2015–2016) introduced full indexation of feed-in tariffs against inflation and established the Financial Settlement Center, tasked with purchasing energy from private companies through the establishment of power purchase agreements (PPAs) (Government of Kazakhstan 2009). In 2018, auction schemes for renewable energy were introduced as a transition to market mechanisms (Zhunussova et al. 2020). This has led to reduced electricity prices from renewables and created a substantial incentive for the further development of green energy, in line with Kazakhstan's energy strategy. Currently a draft of a new law on heating (expected to be adopted in 2022) is being prepared with the aim of increasing penetration of renewables in the heating sector.

Besides regulations facilitating the development of renewables, Kazakhstan launched its ETS (KAZ ETS) in order to mitigate the negative impact of GHG emissions and promote low-carbon technologies (World Bank 2018). The scheme was introduced gradually via four main phases. The first phase started functioning in 2013, with a permitted cap of 147 million tons of CO_2, implying that this value is the largest possible amount of GHG that can be emitted by different industries, including oil and natural gas mining, the power sector, centralized heating, and so on. The cap continues to gradually expand as additional emitters join the scheme. In the latest phase, active since 2021, the cap is set at 159.9 million tons of CO_2, a 9% increase from the initial phase.

Currently, the established caps cover approximately half of Kazakhstan's total GHG emissions value, which accounts for a sizeable but still only partial impact on emission reduction. However, once the ETS market expands to cover most GHG emissions, Kazakhstan should be closer to achieving its emission targets.

Policy Framework

Kazakhstan has developed several documents that outline its energy sector strategy, paying particular attention to the development of green energy. These include Strategy Kazakhstan 2050 (2012), Plan of Action for the Development of Alternative and Renewable Energy for 2013–2020 (2013), Concept for Transition of the Republic of Kazakhstan to Green Economy (2013), Concept of Fuel and Energy Sector Development to 2030 (2014), and Doctrine for Carbon Neutrality of Kazakhstan by 2060 (2021) (PAGE 2021; UNECE 2019). These have established a general policy framework, outlining the government's energy sector priorities as follows:

(i) **Renovate current and construct new infrastructure** for electricity and heat generation, transmission, and oil refining to balance the increasing demand for electricity and fuels.
(ii) **Develop domestic energy and power markets**, and regularly liberalize and develop market competition.
(iii) **Promote and develop modern technologies and infrastructure for greener energy sources**, including renewables, associated natural gas processing and transportation, nuclear energy, and the coal–chemical industry.
(iv) **Modernize transportation and industry by introducing modern technologies** that increase energy efficiency and minimize negative impacts on the environment.

Forecast Methodology

One of the objectives of this country study is to present a detailed overview and analysis on future energy market trends in Kazakhstan. For this purpose, three scenarios were developed, taking into account the country's regulatory framework, technological development, consumer preferences, and other factors (Box 11). Separate outlooks for supply and demand, technology, carbon emissions, and investment were derived based on these three scenarios.

Box 11: Scenarios for Kazakhstan's Energy Sector

Business-as-usual scenario: Projected energy supply and demand, with current energy system and policies;

Government Commitments scenario: Projected energy supply and demand, considering individual priorities of Government of Kazakhstan; and

Green Growth scenario: Projected energy supply and demand, considering enhanced energy transition and environmental policies.

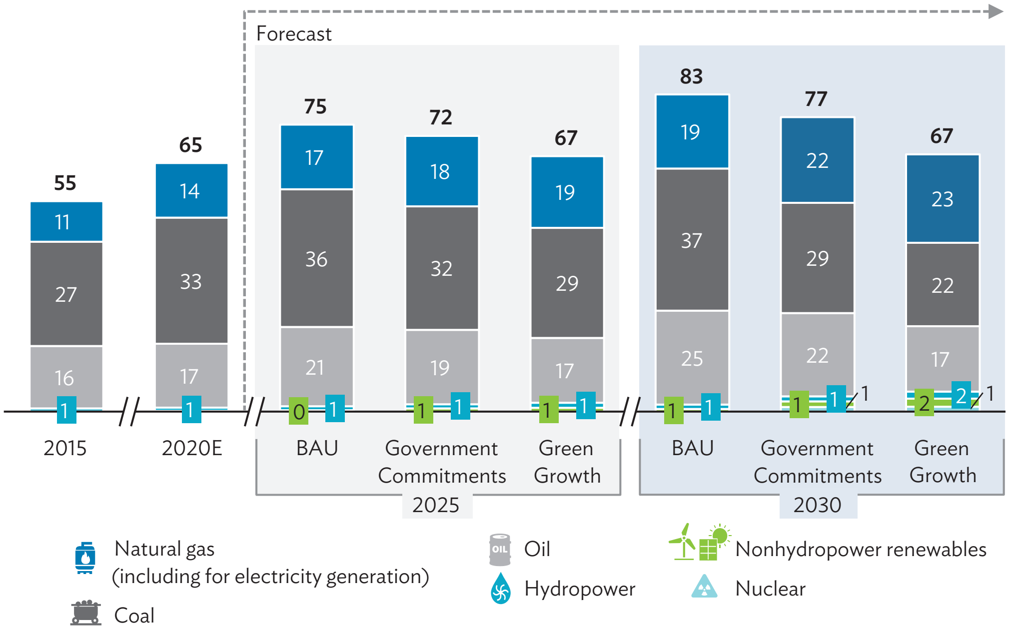
Source: Roland Berger/ILF.

Supply and Demand Outlook

The COVID-19 pandemic considerably affected Kazakhstan's energy demand, with an estimated 5% decrease in 2020 from 2019 levels. Nevertheless, the country's energy supply and demand are still expected to increase until 2030, mainly due to the impact of rapid economic development (with estimated nominal GDP growth forecast to be 9% per annum). The projected supply growth rate varies across scenarios. Primary energy supply is predicted to range from 67 million toe to 83 million toe in 2030, which reflects a CAGR of 2.4% under the Business-as-usual (BAU) scenario, while a more moderate supply growth of 1.7% is forecast under the Government Commitments scenario. The lowest supply growth is expected under the Green Growth scenario, which projects a CAGR of only 0.5% because of a significant decrease in overall energy intensity.

Kazakhstan's energy supply is projected to have a substantial share of traditional fuels, dominated by coal under the BAU and Government Commitments scenarios, and by natural gas under the Green Growth scenario. Since Kazakhstan aims to increase renewable power generation and limit its carbon emissions, coal supply is projected to gradually decrease under all three scenarios (Figure 43).

Figure 43: Kazakhstan—Primary Energy Supply Forecast
(million tons of oil equivalent)



BAU = Business-as-usual, E = estimate.

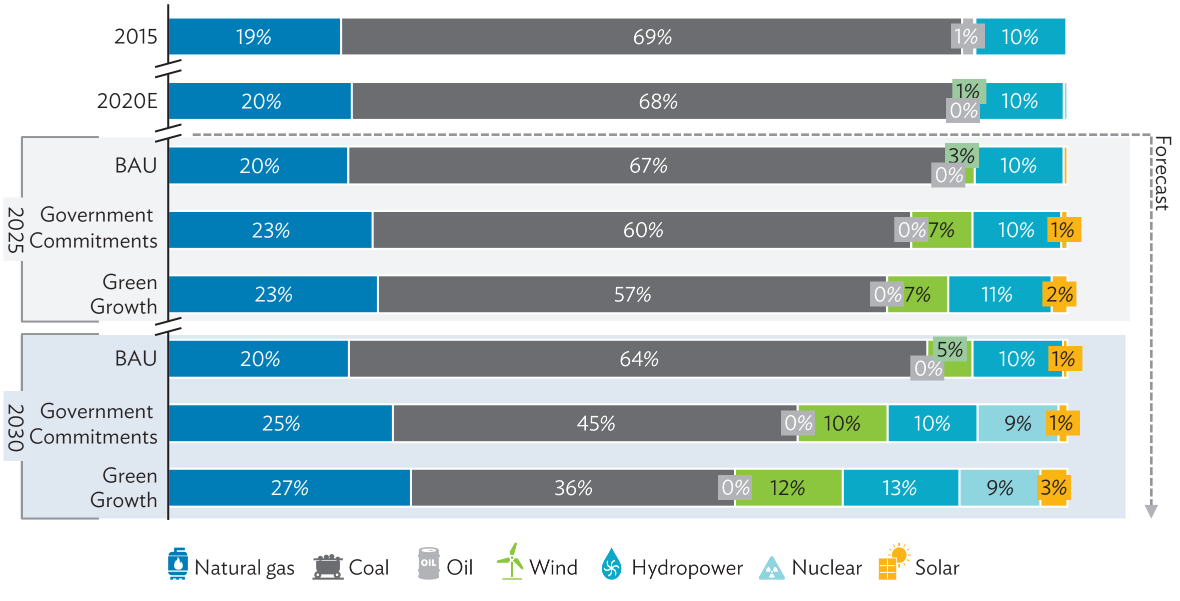
Source of historical data: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 25 July 2021). The forecasts are based on the Roland Berger methodology described in the Methodology section.

A main target of Kazakhstan regarding the power mix until 2030 is to promote low-carbon electricity generation. The Government Commitments scenario, which takes the set government targets into account, projects an increase in the use of alternative energy sources from approximately 11% in 2020 to 30% by 2030 (Katyshev 2019). The 2030 value is projected to include 10% wind and hydropower, 9% nuclear, and 1% solar power. Under the BAU scenario, the share of cleaner fuels is estimated to be around 16%. Meanwhile, the Green Growth scenario projects a share of 37% sustainable energy sources in the mix, as well as a significant decrease in coal usage and increased overall energy efficiency (Figure 44).

The final energy demand varies across the scenarios, reflecting the degree to which energy efficiency measures are implemented and losses are reduced. For example, the estimated level in 2025 is 46–49 million toe, and 49–57 million toe in 2030. In all scenarios, oil and oil products consumption is expected to have the highest share, mainly because of the considerable development of the transportation sector and the high share of internal combustion vehicles. Furthermore, the share of natural gas is expected to increase under all scenarios.

Importantly, the role of electricity becomes more evident, particularly in the Government Commitments and Green Growth scenarios. This is mostly because of the continuous consumer shift away from traditional fuels toward electricity, representing a significant opportunity to gradually decrease coal consumption. The Green Growth scenario illustrates this in a particularly emphatic way: coal consumption is considerably reduced to 7 million toe in 2030, compared with 11 million toe under the BAU scenario.

Figure 44: Kazakhstan—Projected Power Generation Mix



BAU = Business-as-usual, E = estimate.

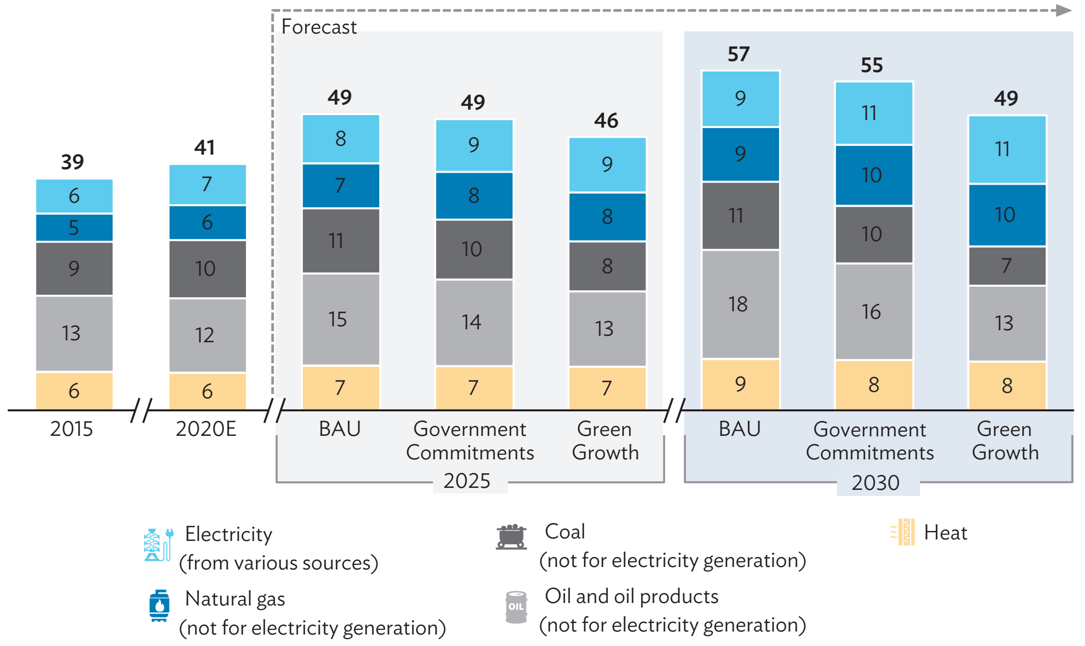
Source of historical data: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 25 July 2021). The forecasts are based on the Roland Berger methodology described in the Methodology section.

Finally, changes in heat consumption are rather similar across all scenarios, ranging between 8 million toe and 9 million toe, indicating the limited degree of energy efficiency measures expected in this area (Figure 45).

In terms of end-use sectors, the most significant demand growth is expected in the service sector: a growth rate of 4.2%–5.0% for 2020–2030 is expected, depending on the scenario. Transport is yet another rapidly growing segment, with expected growth of 2.3%–4.8% during the same period. Growth rates in the industrial and residential sectors are projected to be much lower, mostly because of energy efficiency improvements, especially under the Green Growth scenario, which assumes 1.1% growth for the industrial sector and 1.4% growth for the residential sector. Finally, agriculture is projected to have a relatively stable final energy demand (Figure 46).

Figure 45: Kazakhstan—Final Energy Demand Forecast by Fuel

(million tons of oil equivalent)

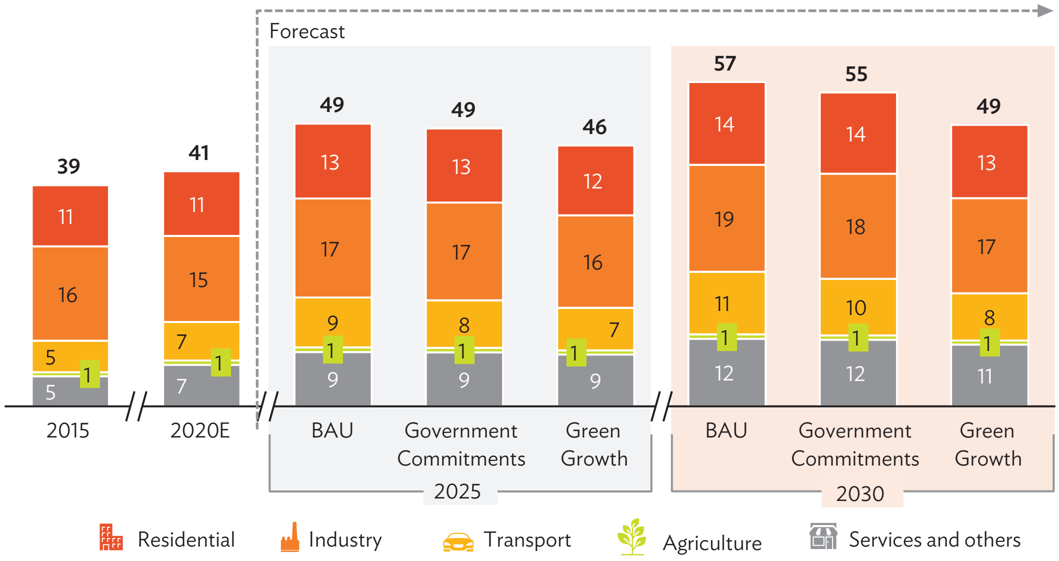


BAU = Business-as-usual, E = estimate.

Source of historical data: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 25 July 2021). The forecasts are based on the Roland Berger methodology described in the Methodology section.

Figure 46: Kazakhstan—Final Energy Demand Forecast by Sector

(million tons of oil equivalent)



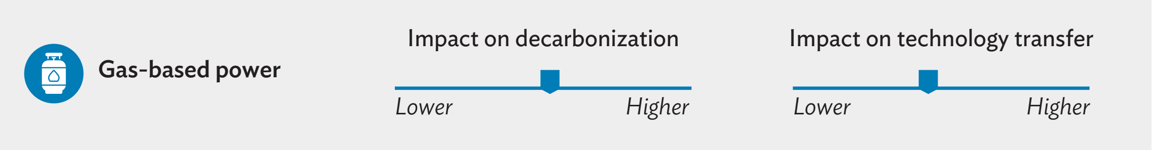
BAU = Business-as-usual, E = estimate.

Source of historical data: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 25 July 2021). The forecasts are based on the Roland Berger methodology described in the Methodology section.

Technology Outlook

Priority Technologies: Generation

The priority technologies in the generation section include gas-based power and renewable energy sources (hydropower, wind, and solar PV). Key considerations for selecting these technologies relate to Kazakhstan's limited share of "green" energy (around 11% share of renewables in electricity generation in 2018), the country's subsequent strategic targets (30% of low-carbon sources in the generation mix by 2030), and the considerable potential of renewable energy (4.1 terawatts).



Despite its historic reliance on coal, the large availability of natural gas positions Kazakhstan well to progress on its path toward improved carbon intensity and sustainability. Given the moderate environmental impact of natural gas compared to coal, it is often considered a transitional fuel to balance and ensure reliability of supply amid the expansion of the renewable energy sector. This direction is also reflected in the governmental targets of achieving a 25% share of gas-fired power in the total generation output by 2030, and a 30% share by 2050.

Hydropower

Hydropower is the most developed renewable energy source in Kazakhstan, with 2.5 GW of installed capacity already in operation. Kazakhstan has great technical potential in hydropower energy, particularly in small hydropower, where this value amounts to 4.8 GW (UNDP 2014). The potential and relatively low prices continue attracting investments in this type of power, likely helping Kazakhstan to achieve its goal of a 30% share of clean energy sources in the generation mix by 2030, and 50% by 2050. Besides, the balancing characteristics of hydropower may make the process of integrating wind and solar power considerably easier. Therefore, further exploration of hydropower is expected to have a positive effect on the state's energy transition, decarbonization, and technology transition.

Wind

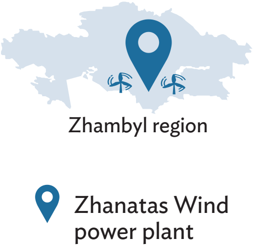
The technical potential of wind energy in Kazakhstan is substantial, at around 354 GW (UNDP 2014). Yet, it remains largely unexploited, with 284 MW of installed wind power plant capacity at the end of 2019, nearly 1% of Kazakhstan's total (IEA 2021). The expansion of wind energy is in line with Kazakhstan's energy strategy, which aims to reach a 10% share of wind power in the electricity mix by 2030, and 15% by 2050. Given that Kazakhstan plans to increase the share of renewables in the electricity mix, wind power is a suitable option for further development because of the high availability of this resource and constant technological advancement. Due to its significant technical potential, in the future, renewable electricity could partially displace coal-fired electric power with sufficient investment. Zhanatas Wind Farm is a notable example of the wind projects under development in Kazakhstan (Box 12).

Solar PV

Kazakhstan has explored only a small part of its 3,760 GW solar energy technical potential, with just 542 MW of solar PV capacity at the end of 2019 (IEA 2021; UNDP 2014). Given Kazakhstan's high potential, the government has set the target share of solar power in the electricity mix to be 1% by 2030, and 5% by 2050. Solar power is also a priority technology for Kazakhstan due to the global trend of its costs decreasing. Similar to wind power, power generated from solar PV is expected to have an auspicious effect on technology transfer and energy decarbonization. As in the case of wind energy, given the sizeable technical potential of solar power, it could partially displace coal-fired electric power with sufficient future investment.

Box 12: Kazakhstan's Flagship Energy Project

Zhanatas Wind Farm is a construction and operation project, with converging support and financing from international financial institutions, the government, and private companies. With an estimated total cost of around $140 million, the construction is planned in the Zhambyl region, and is expected to be commissioned at the end of 2021. By adding 100 megawatts of wind generation capacity, the wind farm will increase the share of renewables in Kazakhstan's electricity mix, and will thereby deliver additional climate mitigation benefits. The project is estimated to decrease greenhouse gas emissions by more than 260,000 tons of carbon dioxide per annum.

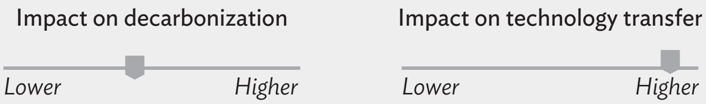


Note: Illustrative photo of a wind farm is by Vasca/Adobe Stock©.

Sources: Asian Infrastructure Investment Bank. 2019. Kazakhstan: Zhanatas 100 MW Wind Power Plant; and European Bank for Reconstruction and Development. 2020. KazRef II - Zhanatas Wind Farm.

Priority Technologies: Transportation and Storage

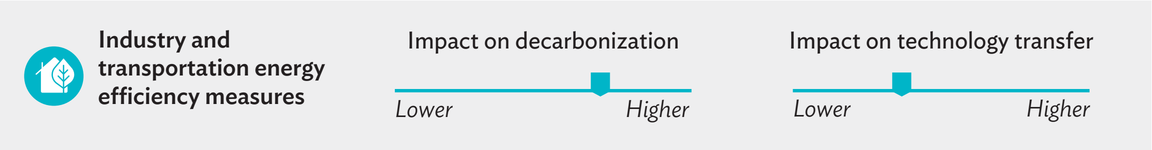
Battery energy storage systems



BESS has recently become a significant component in energy systems due to the rapid development of wind and solar generation, smart grids, and EVs. Kazakhstan is well positioned to take a leading role in the development of BESS, considering its rich supply of required minerals (including chromite, iron ore, and copper), its high potential of human resources, and its appropriate research and development base (i.e., the Institute of Batteries at Nazarbayev University). The development of BESS can play a crucial role in the integration of solar and wind power plants, as they allow for the accumulation of generated power to be discharged at peak demand periods, fully mitigating intermittency risks. In addition to their positive impact on energy security and the prevention of outages, BESS will also have a high impact on technology transfer, because this technology is relatively new in the region, and in Kazakhstan specifically.

Priority Technologies: Consumption

While Kazakhstan aims to improve energy efficiency in all consumption sectors, the industry and transportation sectors are the target sectors emphasized by the policy framework and reductions here are projected to have the largest impact.



Given that the infrastructure in Kazakhstan's industry and transportation sectors is rather outdated (most enterprises are from the Soviet era, and the vehicle fleet is on average older than 20 years), energy inefficient and, thus, produce considerable pollution, energy efficiency measures are another of the country's priorities. In line with this, Kazakhstan has started modernizing infrastructure, introducing and promoting energy audits, promoting alternative fuels, installing energy management systems, among other actions. In addition, the government plans to develop further regulations and standards for the construction of energy-efficient buildings, and to incentivize hybrid and electric car sales (for instance, via reducing tax on hybrid vehicles). The implementation of energy efficiency measures in these sectors will have a relatively lower impact on technology transfer, yet it will make a significant contribution to decarbonization efforts.

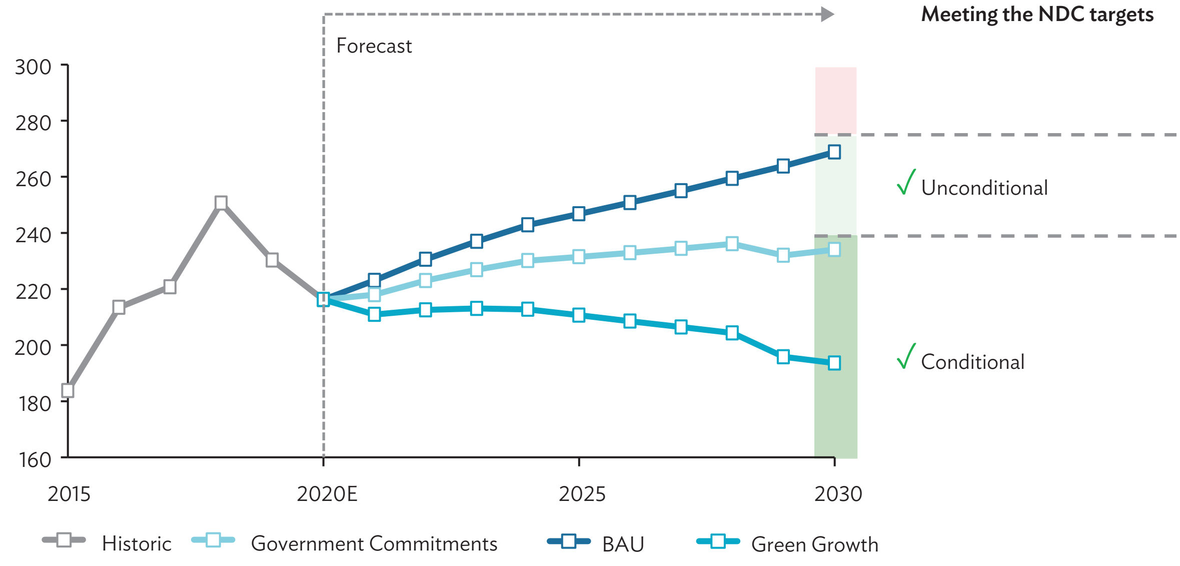
Carbon Emissions Outlook

Kazakhstan affirmed its commitment to limiting its carbon footprint when it submitted its first Nationally Determined Contribution (NDC) in 2016. Overall, Kazakhstan has set two targets: unconditional and conditional. The unconditional target entails a 15% reduction in GHG emissions by 2030 compared to 1990. In contrast, the conditional target, which assumes external financial support and access to low-carbon technology transfer, sets the goal of a 25% reduction by 2030 compared to 1990 (DIW Econ 2020). In absolute terms, the amounts are estimated at around 274 million tons of CO_2 equivalent in unconditional commitments and 242 million tons of CO_2 equivalent in conditional commitments. In 2021, the President officially presented the *Doctrine for Carbon Neutrality of Kazakhstan by 2060,* which establishes a framework for low-carbon development and energy sector transition (PAGE 2021).

In recent years, Kazakhstan has seen significant reductions in emissions from associated gas flaring. Kazakhstan is a member of the Global Gas Flaring Reduction public–private partnership launched by the World Bank in 2002.

Kazakhstan's carbon emissions outlook demonstrates that a more ambitious climate change strategy is feasible and achievable. Even though COVID-19 reduced CO_2 emissions in 2020, levels will rise continuously until 2030 under the BAU scenario. This scenario projects around 269 million tons of CO_2 equivalent, which would still meet the country's unconditional NDC target. With Kazakhstan implementing its policy targets and long-term goals as assumed under the Government Commitments scenario, emissions are expected to rise at a slower pace, reaching around 234 million tons of CO_2 equivalent, thereby achieving its conditional NDC target. However, Kazakhstan is able to contribute significantly more to combatting climate change. Implementing stronger energy efficiency measures and incentivizing a broader shift toward cleaner technologies (both preconditions under the Green Growth scenario) will allow for an even more decisive achievement of its conditional NDC target. Under this scenario, Kazakhstan is projected to reach 194 million tons of CO_2 equivalent in 2030, which is lower compared to 2020 levels (212 million tons of CO_2 equivalent) (Figure 47).

Figure 47: Kazakhstan—Energy-Related Carbon Emissions
(million tons of carbon dioxide equivalent)



BAU = Business-as-usual, E = estimate, NDC = Nationally Determined Contribution.

Note: Historical data on carbon emissions is modelled by Roland Berger based on historical data on energy use. The forecasts are based on the Roland Berger methodology described in the Methodology section.

Sources: Roland Berger; and United Nations Framework Convention on Climate Change. Nationally Determined Contributions Registry. https://unfccc.int/NDCREG.

Investment Outlook

Investment Needs

Kazakhstan's estimated investment needs until 2030 vary significantly across scenarios, ranging from $20 billion to $56 billion. Given the country's large market size and need for modernization, substantial investments are required across the power generation, T&D, and energy efficiency sectors. Given Kazakhstan's large renewable potential as well as the government's target to reach up to a 30% share of low-carbon energy sources in the electricity mix by 2030, some of the country's largest investments are expected to go into the development of nuclear power plants and renewables.

Specifically, investment needs for nuclear power plants are projected to be $9.2 billion under the Government Commitments scenario, and $9.7 billion under the Green Growth scenario. Investment needs for the development of renewable energy vary across scenarios: $3.8 billion under the BAU scenario, $7.9 billion (primarily for wind power projects) under the Government Commitments scenario, and $11.9 billion (also primarily for wind power projects) under the Green Growth scenario.

Moreover, across all scenarios, significant energy efficiency measures are expected (worth around $8 billion–$15 billion) in line with Kazakhstan's priority technologies. Furthermore, the rehabilitation of existing, and construction of new, natural gas power plants is expected to take place in coming years. This will help meet the country's decarbonization targets and aims at partially replacing coal in the power mix. Investments by 2030 of $2.9 billion–$7.8 billion, depending on the scenario, are expected for these measures.

In terms of categories, investment needs related to generation are estimated to be the largest across all scenarios, accounting for around 42%–62% of total investment needs until 2030 (or $8.5 billion–$30.6 billion), depending on the scenario. This category is followed by energy efficiency and T&D (which includes the modernization of electricity and natural gas networks, and the installation of remote monitoring systems and metering equipment). Importantly, in the T&D category, electricity is projected to require most of the investment needs: $2.1 billion, or almost 60%, under the BAU scenario; $4.2 billion, or nearly 70%, in the Government Commitments scenario; and $7.8 billion, or 74%, in the Green Growth scenario (Figure 48).

Challenges and Opportunities

Kazakhstan's low energy prices and high subsidies are among the key obstructions to larger private sector investments. Energy subsidies in Kazakhstan account for more than 3% of GDP (IEA 2022). Given that energy prices determine the financial viability of project investments, low energy prices may reduce the likelihood of investors obtaining a high enough return on energy sector projects.

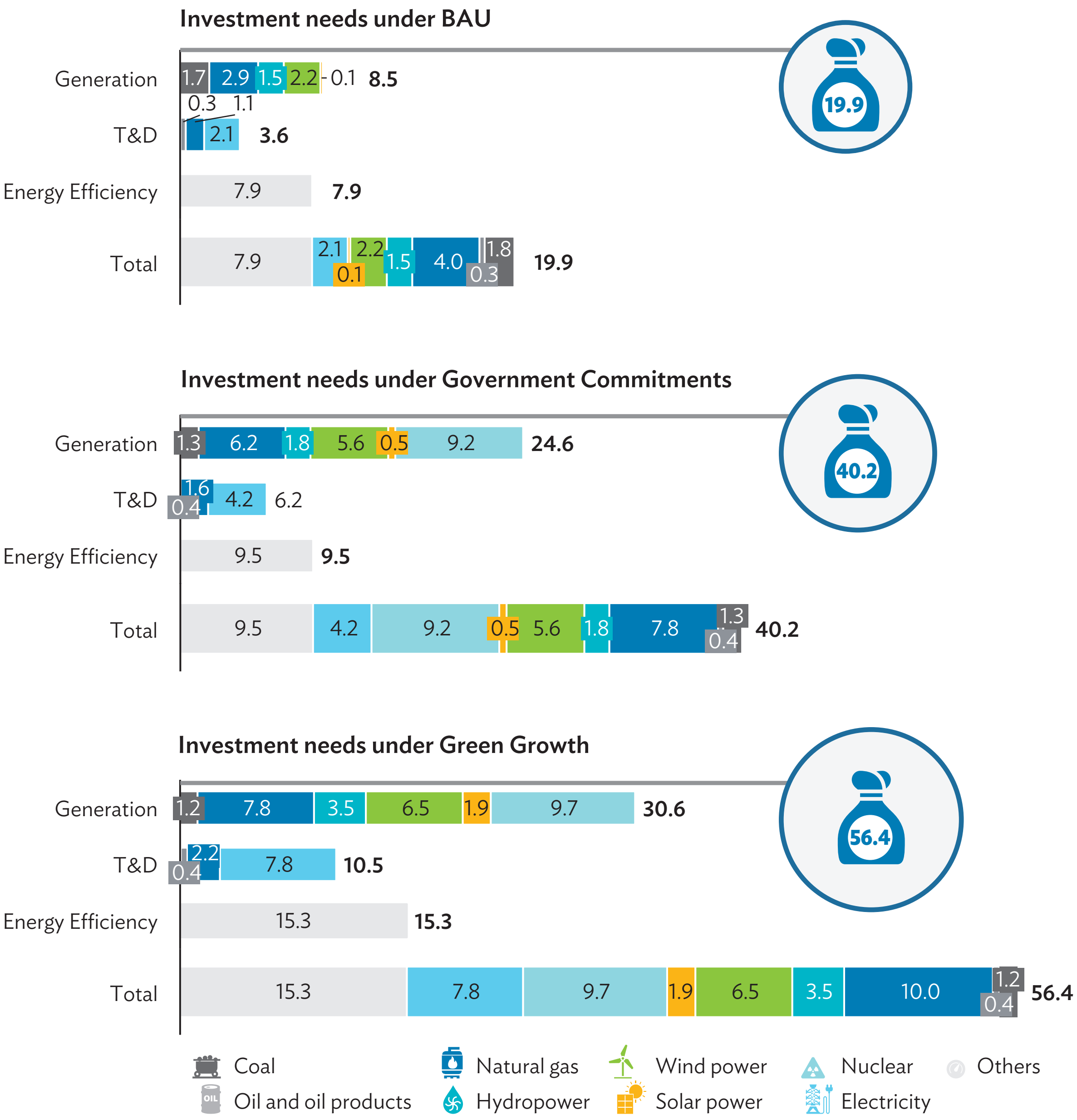
Financial barriers are another challenge, as investments in the energy sector typically require significant capital. Kazakhstan's high interest rates create financing hurdles for energy projects, and for energy efficiency measures in particular, as banks typically are not familiar with the financial and technical issues related to energy efficiency, which in turn affects their assessment of interest rates. In addition, financial mechanisms are not readily available to provide affordable long-term capital.

Another set of challenges relates to institutional barriers, such as fragmented coverage for energy efficiency regulations, administrative barriers, and bureaucracy, which may lead to delays and thus additional costs. Foreign investors have also raised concerns regarding the unequal treatment of foreign and local companies (e.g., in the procurement process). In this context, the lack of an independent regulatory body is a significant barrier to larger private sector participation. Currently, the MOE is tasked with both regulatory and policymaking functions, breaking with the international standards of practice that are intended to prevent discriminatory treatment of market participants.

The government has taken steps toward removing these barriers and establishing a favorable environment for investments in the energy sector. These include numerous state support programs, particularly for clean energy, exemptions from customs duties on imports, and state grants (including land grants). Kazakhstan also provides grants for scientific research and innovation related to the commercialization of low-carbon projects on a competitive basis. Over the last decade, the country has shown its commitment to facilitating the development of renewables by implementing various policies, targets, and green strategies, all of which serves to encourage investors' confidence.

Figure 48: Energy Infrastructure Investment Needs in Kazakhstan until 2030

($ billion)



BAU = Business-as-usual, T&D = transmission and distribution.

Source: The forecasts are based on the Roland Berger/ILF methodology described in the Methodology section.

Kazakhstan's extensive energy resource potential presents another major opportunity. In 2018, Kazakhstan was the world's 9th largest producer of coal, 17th of crude oil, and 24th of natural gas. As a result, the country's total energy production covers more than twice its demand. Kazakhstan also has significant potential in renewable energy: 354 GW of wind energy, 5 GW of small hydropower potential, and around 3,760 GW of solar power. Thus, potential investors can consider different directions in terms of fuels and applicable modern technologies. In addition, the country has well-established cross-border infrastructure and economic relations with neighboring countries. For instance, Kazakhstan, Kyrgyz Republic, and Uzbekistan are interconnected via the CAPS (ADB 2018). Plans to connect Tajikistan to the system are in place for 2022, and Turkmenistan is also exploring the possibility of reconnecting. This may provide further opportunities for trade and cooperation.

Kazakhstan also has a proven track record of working with large private investors, with many big companies operating in the production segment. For example, in 1993, Chevron gained 50% interest in Tengizchevroil, making the company the first international oil firm to penetrate Kazakhstan's market (Business for 2030 2020; Chevron 2021). Recently, other companies such as Total, Eni, China National Petroleum Corporation (CNPC), and British Petroleum (BP) entered Kazakhstan's market via numerous projects, providing yet another indication of its positive investment climate.

Finally, Kazakhstan has a large and growing market. Its population is expected to grow by around 10% by 2030, thus the market for potential customers (in both the residential and industrial sectors) is expanding. Besides that, the purchasing power in Kazakhstan is relatively high, with around $9,800 GDP per capita in 2019 (compared with the CAREC average of $4,230). Kazakhstan also plans to expand its natural gas pipeline network, and to increase the state's gasification rate to 60% by 2025. This entails a further expansion of the consumer base and the energy market size.

Policy Recommendations

Kazakhstan has been working to improve its energy investment climate by developing a favorable policy and regulatory framework. However, several additional measures may facilitate private investments even further:

(i) **Updating the *National Energy Development Strategy* and establishing a national energy efficiency action plan.** While Kazakhstan has developed several plans and strategies, they need to be updated. A national energy efficiency action plan is considered particularly important given that Kazakhstan is expected to achieve most of its energy savings and emission reductions from energy efficiency measures until 2030. These documents would provide investors with a comprehensive picture and allow them to make more informed decisions. The policy framework needs to be systematically updated to align with the *Doctrine for Carbon Neutrality of Kazakhstan by 2060*.

(ii) **Establishing an independent regulatory body.** Currently, the policymaking institution is the MOE, while committees under the Ministry of National Economy ensure compliance with regulations (particularly tariff regulations). As a result, the institutions ensuring regulatory compliance lack autonomy and are, to some extent, exposed to political interference.

Establishing an independent regulatory institution can have a substantial impact on improving competition in the energy market and attracting private investments. International experience has shown that credible, well-functioning, autonomous regulators reduce overall risk levels (especially political risks), thus enhancing investment feasibility for private companies.

(iii) **Reconsidering tariff policy.** Low energy tariffs may discourage potential investors from initiating new energy projects due to uncertainties related to financial returns or payback periods. In order to achieve increased investment, the government will need to reduce subsidies while still providing targeted support to vulnerable consumers. The establishment of an independent regulatory body may facilitate the process of reconsidering energy tariffs, which would ensure the full recovery of costs related to energy infrastructure and services.

(iv) **Developing instruments to remove financial barriers.** Establishing various instruments and additional programs (for instance, providing guarantees, insurance, and blended finance) is a crucial step in promoting private sector participation. The government could consider using the Sovereign Wealth Fund (Samruk-Kazyna JSC) as a primary investment vehicle to support large-scale renewable deployments and decarbonization investments. Enhancing such cooperation will ensure that projects in line with the country's strategic direction are initiated and executed, the amounts of capital and resources are increased, and relevant expertise is applied.

(v) **Considering reducing coal dependency.** According to the government's plans, Kazakhstan will use considerable amounts of coal, which has an acute impact on the environment, in the mid-term. Given the country's potential in other fuels, the government should consider creating disincentives for using coal in favor of natural gas or other low-carbon technologies and fuels, and establishing favorable conditions for using alternative sources of energy. For instance, Kazakhstan has a high potential for the development of both blue and green hydrogen, which could become a key lever of energy sector decarbonization in the future.

(vi) **Continuing the development of renewable sources.** As a parallel activity to reducing the country's coal dependency, the government should consider providing further incentives in executing renewable energy projects. This particularly concerns hydropower, as its balancing characteristics may make the process of integrating wind and solar power substantially easier.

(vii) **Continuing energy sector reforms to achieve a fully free, liberalized, and competitive market, and creating conditions for larger private sector involvement.** For example, a plan for the rigorous unbundling of the natural gas sector, which would allow consumers to select suppliers among different players, could be a significant step in achieving affordable natural gas to partially replace the use of coal. The government could also consider the use of green hydrogen as the "bridge fuel" to further develop solar and wind energy.

(viii) **Maximizing the use and quality of publicly available energy data.** Having official up-to-date energy-related data would allow potential investors to monitor demand, supply, and energy consumption throughout the economy, and would thus provide a more comprehensive view and analysis of the energy sector, leading to more informed decisions.

Background Papers

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Kazakhstan's capital city. Nur-Sultan, previously known as Astana, acquired its present name after the first President of Kazakhstan Nursultan Nazarbayev (photo by Diego Fiore/Adobe Stock©).

KYRGYZ REPUBLIC

Lower Naryn River Canyon in the Kyrgyz Republic. The river has significant energy resources—it has two reservoirs and five hydroelectric power stations (photo by Lukas/Adobe Stock©).

Kyrgyz Republic Highlights

- The Kyrgyz Republic's energy sector has historically relied on extensive hydropower generation, using the country's available water resources (Figure 49). As of 2021, the Kyrgyz Republic is facing difficulties in its energy sector: key energy companies are in significant debt, the country is encountering supply issues due to the deteriorating condition of its grids, and there is public resistance to proposed tariff increases.
- The Kyrgyz Republic is a net energy importer, with domestic production covering around half of the country's consumption. Besides hydropower, the country also has significant coal reserves, which it has been rapidly exploiting in recent years (production levels rose almost 4 times between 2010 and 2018). Nonhydropower renewable energy sources are not being exploited in the Kyrgyz Republic yet, despite its considerable technical potential of almost 300 gigawatts (GW).
- Given the country's rapid economic and population growth, final energy demand is projected to increase from an estimated 4.4 million tons of oil equivalent (toe) in 2020 to 4.8 million toe and 5.4 million toe in 2030, depending on the scenario. Demand for oil and oil products as well as for electricity is projected to grow. Forecasts also project coal consumption to increase unless the Kyrgyz Republic replaces coal consumption with other sources of energy.
- Hydropower plants have generated between 85% and 92% of the Kyrgyz Republic's total electricity during 2015 and 2018, with the remainder generated by coal-fired combined heat and power (CHP) plants. The share of coal in the power generation mix is expected to grow unless the Kyrgyz Republic will significantly expand the use of natural gas and nonhydropower renewable energy.
- Considering the significant environmental impact of coal combustion and the country's high energy intensity, the expansion of renewables and energy efficiency measures in buildings and transport are considered priority technologies and investment opportunities for the Kyrgyz Republic. To eliminate grid losses, the modernization of energy networks is also crucial.
- Overall, the Kyrgyz Republic is suffering from limited investments in its energy sector. Its aging infrastructure and transmission and distribution (T&D) facilities result in significant losses. The country's investment needs for power generation, for T&D energy infrastructure, and for the implementation of consumption efficiency measures range from $3 billion to $7 billion, depending on the scenario. To cover the significant investment needs, additional efforts are required to ensure the reliability of supply and the sustainable development of the energy sector.
- The Kyrgyz Republic's energy sector must overcome several challenges to attract investments. These include phasing out its energy subsidies and establishing cost-recovering energy tariffs, developing necessary secondary legislation to effectively implement existing energy policies, and establishing renewable energy targets.

Figure 49: Kyrgyz Republic—Key Figures

Renewable potential	Hydropower	Hydropower resources	Carbon intensity	Energy intensity
~300 GW	**92%**	**~10%**	**158th out of 172**	**10th out of 172**
Total potential of renewable energy is estimated at 300 GW, with solar PV accounting for almost 90% of the total potential.	The share of hydropower in the electricity generation mix reached 92% in 2018.	Utilization rate of hydropower technical potential is ~10%.	The country is ranked 158th out of 172 countries in the global ranking of carbon intensity of energy, mainly due to the high share of hydropower in the electricity mix.	Kyrgyz Republic is ranked 10th out of 172 countries in the global ranking of energy intensity.

GW = gigawatt, PV = photovoltaic.

Sources: Government of the Kyrgyz Republic; State Committee for Industry, Energy, and Subsoil Use of the Kyrgyz Republic. 2020. *Kyrgyzstan's Energy Sector.* Bishkek; United Nations Economic Commission for Europe. 2019. *Energy Sector Review in 2018.* Geneva; and United States Energy Information Administration. Kyrgyz Republic Data. https://www.eia.gov/international/data/world (accessed 8 September 2021).

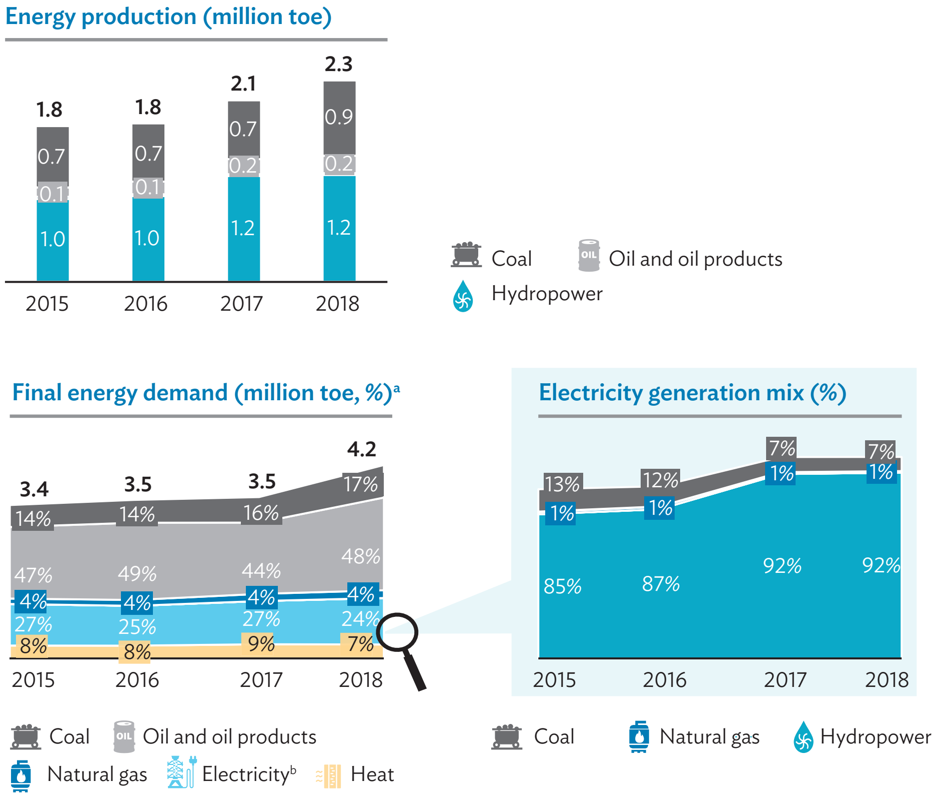
Energy Sector Profile

Country Profile

The Kyrgyz Republic is a mountainous and landlocked Central Asian country with a population of 6.5 million and a nominal gross domestic product (GDP) of over $8 billion as of 2020. The Kyrgyz Republic's economic development has been very uneven between 2010 and 2020, with periods of rapid economic growth, stagnation, and decline. The country struggles with political volatility and economic uncertainty. Public health restrictions resulting from the coronavirus disease (COVID-19) pandemic led to a 5% drop in nominal GDP in 2020. Nevertheless, the economic outlook for the coming years is positive, with expected 4%–8% nominal GDP growth annually from 2022 to 2030.

The Kyrgyz Republic's geographic position determines the current state of the country's energy sector. As a mountainous country, it has significant hydropower potential that has been exploited since the era of the former Soviet Union. In terms of fossil fuels, the country produces coal, a small volume of oil, and negligible levels of natural gas. The Kyrgyz Republic is not able to fully satisfy domestic demand through domestic sources and is thus a net importer of energy with a share of imports amounting to nearly 60% of primary energy supply, mainly driven by oil and oil products. Although the country is exporting some coal and electricity, its exports have decreased in recent years, due to fluctuations in hydropower production and deteriorating grid conditions, losses, and financial difficulties in the energy sector.

Figure 50: Energy Profile of the Kyrgyz Republic



Energy production (million toe)

Final energy demand (million toe, %)[a]

Electricity generation mix (%)

toe = ton of oil equivalent.

[a] Topmost numbers on the chart are in million toe.

[b] Electricity data come from various sources, including fossil fuel-based and renewables.

Source: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 8 September 2021).

Domestic resource availability is a major determinant of the Kyrgyz Republic's electricity generation mix and, correspondingly, of its carbon intensity. Due to the predominance of hydropower (consistently above 85% in the power mix during 2015–2018, with a recent upward trend), the Kyrgyz Republic has a low carbon footprint and is ranked 158th out of 172 countries worldwide in terms of carbon intensity (Figure 50). In contrast, the country scores high on energy intensity, as the Kyrgyz Republic is the 10th most energy-intensive country in the world—mainly due to its extremely low energy prices and outdated energy infrastructure.

Energy Sector and Technologies Assessment

Conventional Fuel Production

Coal is one of the Kyrgyz Republic's key conventional fuels, with almost 2.7 million tons produced in 2020. However, domestic production is insufficient to fully cover the country's demand. Coal production has increased by almost 4 times between 2010 and 2018, with further increases in annual production expected (National Statistical Committee of the Kyrgyz Republic 2021). Production occurs in four coal-bearing basins (Kavak, North Fergana, South Fergana, and Uzgen) across 60 underground mines and 56 open-pit mines. Coal production is a competitive business in the Kyrgyz Republic, with more than 100 active companies. Total reserves are estimated at 1.4 billion tons, which include nearly 1 billion tons of lignite, more than 0.3 billion tons of bituminous coal, and about 0.1 billion tons of coking coal.

In contrast to coal, the Kyrgyz Republic's oil and natural gas production is rather limited, despite deposits having been discovered nearly 70 years ago. Nevertheless, due to the active maintenance and restoration of existing sites, the Kyrgyz Republic has managed to increase oil production threefold since 2008—from 80,000 tons to 240,000 tons annually in 2020. As of 2021, the country has implemented a temporary ban on exports of oil products, in an attempt to stabilize oil and oil product prices in its domestic market (Xinhua 2021).

Natural gas production has been largely stable, with an output of 20–30 million cubic meters annually (National Statistical Committee of the Kyrgyz Republic 2021). Domestic production comprises only a small fraction (below 10%) of total natural gas, oil, and oil products supplies amid large imports. Overall, the situation is unlikely to change drastically in the future, considering the Kyrgyz Republic's limited available reserves (nearly 11 million tons of oil and less than 6 billion cubic meters of natural gas).

Electricity Generation

The Kyrgyz Republic's installed power generation capacity is nearly 4 GW, with hydropower plants covering more than 75% of the total (ADB 2010). Most of the power is generated in seven reservoir-type hydropower plants, with a combined capacity of more than 3 GW, and commissioning dates mostly between 1970 and 1992. One exception is the Kambar-Ata 2 Hydropower plant, which began operations in 2010. The Asian Development Bank (ADB), among others, supports rehabilitation of the country's largest power plants, Toktogul and the Uch-Kurgan hydropower plants. The Kyrgyz Republic also has more than 15 small run-of-river hydropower plants, with a combined capacity of 40 megawatts (MW). Their technical condition varies significantly since the oldest was commissioned in 1928, and the newest in 2017. Despite its large installed capacity, the Kyrgyz Republic's technical hydropower potential is estimated at nearly 26 GW, suggesting that only around 10% of this potential is currently realized.

The remaining share of the country's total installed capacity is provided by two coal-fired CHP plants. Bishkek-1 is a large subcritical CHP commissioned in 1961. Its modernization in 2017 increased the plant's capacity to 0.8 GW and improved efficiency. The second CHP is located in the southern city of Osh, with a capacity of only 40 MW—or 0.04 GW. The government's plans to construct another (natural gas-powered) CHP in Bishkek had been scrapped due to the limited availability of natural gas, but are expected to be revived in the coming years.

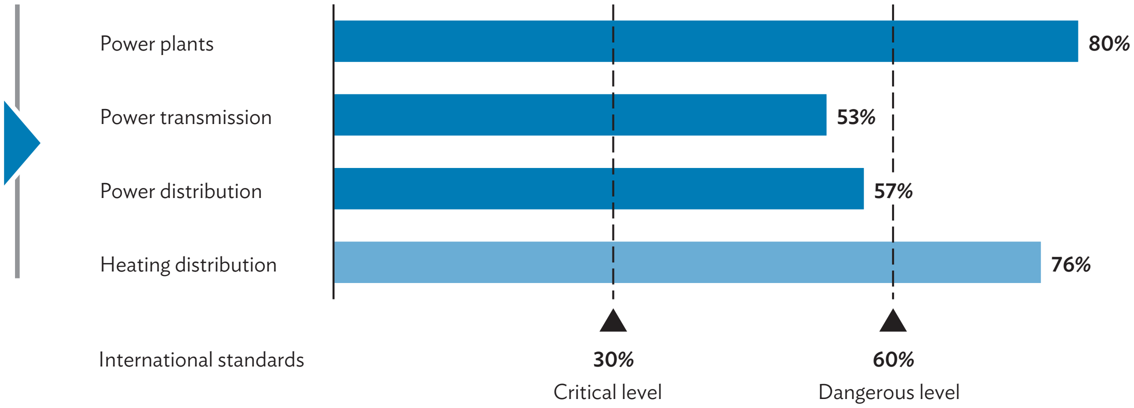
The majority (more than 90%) of the country's generation capacity is operated by the national Joint-Stock Company (JSC) Electric Power Plants (EPP) and its subsidiaries. EPP's financial position does not allow for a broad modernization program or sufficient investment in maintenance. Geographic conditions further complicate the issue, as hydropower reserves and installed capacities are primarily located along the basin of the Naryn River. This creates challenges for power transmission, as the main consumption centers are located in the northern Kyrgyz Republic. Furthermore, the country lacks reserve generation capacities, which makes outages unavoidable when generation at the main supply centers is disrupted.

The Kyrgyz Republic currently lacks major wind, solar photovoltaic (PV), geothermal, or other renewable energy facilities. The country's technical potential for nonhydropower renewables is sizeable: 267 GW of solar PV, 1.5 GW of wind, and nearly 0.2 GW of biomass (it should be noted that this is the overall theoretical amount of power that could be generated from the entire landmass of the country; it is not adjusted to cost of development or available and affordable technology, and therefore should not serve as a guide for forecasting the actual future amounts). However, market conditions prevent private operators from entering this space, while local, state-owned players lack both the technical know-how and the incentives to develop nonhydropower renewable energy projects.

Transmission and Distribution

The Kyrgyz Republic's power transmission system is operated by JSC Natsional'naya Elektricheskaya Set' Kyrgyzstana (NESK), which acts as the country's transmission system operator (TSO). While the Kyrgyz Republic's power system has been unbundled since 2000, players across the value chain are almost entirely owned by the National Energy Holding Company (NEHC), which has a strong mandate in the management of the companies (UNECE 2019). NESK operates nearly 7,500 kilometers (km) of high-voltage lines, including 550 kilovolts (kV) (~7% of total), 220 kV (~23%), and 110 kV (~70%). However, aging infrastructure and inadequate investments in maintenance and modernization have led to equipment deterioration levels of almost 70% in substations, and nearly 35% in transmission lines. Asset conditions in the distribution system are similar: 50%–60% deterioration levels in substations and 45%–68% in distribution lines across four regional distribution system operators (DSOs) that operate almost 60,000 km of low- to medium-voltage lines (Figure 51). As a result, the Kyrgyz Republic's power sector suffers from significant losses. Previously, T&D losses were reported to range between 20% and 30%. According to recently reported statistics, losses declined to nearly 18% in 2019, as a result of a grid modernization program. The government plans to continue rehabilitating and constructing power lines across all types of voltages, with a special focus on low- to medium-voltage power lines. The country also plans to introduce supervisory control and data acquisition (SCADA) systems and advanced metering

Figure 51: Deterioration Level of Energy Infrastructure in the Kyrgyz Republic



Source: Government of the Kyrgyz Republic; State Committee for Industry, Energy, and Subsoil Use of the Kyrgyz Republic.

equipment. The system average interruption duration index dropped to 714 minutes per customer in 2020, while the system average interruption frequency index dropped to 3.8 interruptions per customer in the same year. While these indicators still reflect issues with reliability of electricity supplies, the situation has improved more than twofold in recent years.

For the most part, the Kyrgyz Republic's natural gas infrastructure was constructed more than 35 years ago and is thus showing signs of aging. Nearly 3,600 km of natural gas T&D pipelines were sold to Gazprom in 2013 in exchange for taking over existing debts and committing to investing $600 million in the gas grid over a 25-year period. Only 35% of the population currently have access to the natural gas grid, but this number represents a significant improvement compared to the 2014 gasification rate of 22%. By 2030, Gazprom plans to connect 60% of the population to the natural gas infrastructure. In addition to network expansion, Gazprom is expected to renovate the existing pipelines, thereby reducing the normative losses indicator, which the government set at 11%. Thus, Gazprom acts as the Kyrgyz Republic's gas TSO.

The Kyrgyz Republic also has a centralized heating network in four main cities: Bishkek (where 85% of households have access to the network), Osh (35%), Kyzyl-Kiya (60%), and Karakol (25%). Heating energy in other cities is provided by local boiler units that cater to small neighborhoods. The boilers run largely on coal (50% of the total) and electricity (46%). Lower rates of efficiency are most evident in the heating system, where losses reach 50% in boiler houses, and 25% in the heating network. Insufficient metering equipment also impacts the achievement of higher efficiency in the heating system.

Cross-Border Infrastructure

The country's geographical conditions, particularly its mountainous terrain, make cross-border energy transportation rather challenging. For example, the Kyrgyz Republic has no oil pipelines, so oil and oil products are transported mostly by rail from Kazakhstan to the Kyrgyz Republic's local consumers and refineries. However, the Kyrgyz Republic is connected to neighboring countries via two natural gas pipelines. The first is Bukhara–Tashkent–Bishkek–Almaty, a transit pipeline that runs from Uzbekistan to Kazakhstan via the northern Kyrgyz Republic, with a total capacity of almost 4 billion cubic meters per annum, mostly for transit. An additional cross-border natural gas pipeline has a minor capacity and runs through the southern part of the country, connecting it with the natural gas system in the Fergana Valley of Uzbekistan. Both pipelines are operated by Gazprom. Natural Gas-Stream, the joint venture of Uzbekneftegaz and the Gas Project Development Central Asia (a subsidiary of Gazprom International), is conducting exploration and development of gas fields in Uzbekistan.

In addition, the Kyrgyz Republic is an integral part of the Central Asian Power System (CAPS), which interconnects Central Asian countries at all voltage levels. The Kyrgyz Republic's Toktogul hydropower plant regulates the CAPS frequency, thus providing services that ensure the stability of grid operations. Moreover, it is part of the Central Asia–South Asia (CASA-1000) project, which focuses on the construction of a 1.3 GW transmission line for power exports from the Kyrgyz Republic and Tajikistan to Afghanistan and Pakistan. It is important to note that the uncertain political situation in Afghanistan, through which the Kyrgyz Republic will transfer its electricity, has rendered any predictions as to when and if the CASA-1000 project can be successfully commissioned difficult (Table 4).

Table 4: Kyrgyz Republic—Major Cross-Border Energy Infrastructure

Energy Source	Name	Capacity	Status	Connected Country
⚡	Jambyl–Frunse 500 kV line	870 MVA	Operational	Kazakhstan
⚡	Frunse–Shu 500 kV line	870 MVA	Operational	Kazakhstan
⚡	Aigultash–Kanybadam 220 kV line	650 MVA	Operational	Tajikistan
⚡	Kzyl-Ravat–Krystal 220 kV line	550 MVA	Operational	Uzbekistan
⚡	Lochin–Toktogul 500 kV line	850 MVA	Operational	Uzbekistan
⚡	CASA-1000	1.3 GW	Planned	Afghanistan, Pakistan, Tajikistan
🔥	Bukhara–Tashkent–Bishkek–Almaty	4 bcma	Operational	Kazakhstan, Uzbekistan
🔥	Central Asia–the PRC (line D)	30 bcma	Planned	PRC

⚡ Electricity 🔥 Natural gas

bcma = billion cubic meters per annum, CASA = Central Asia–South Asia, GW = gigawatt, kV = kilovolt, MVA = megavolt-ampere, PRC = People's Republic of China.

Sources: Fitch Solutions. 2020. *Kyrgyzstan Power Report.* London; Government of the Kyrgyz Republic; State Committee for Industry, Energy, and Subsoil Use of the Kyrgyz Republic. 2020. *Kyrgyzstan's Energy Sector*. Bishkek; and International Energy Agency. 2021. *Kyrgyz Republic Energy Profile.* Paris.

Energy Consumption

The Kyrgyz Republic is the 10th most energy-intensive economy in the world, suggesting there is significant improvement potential in terms of industrial energy efficiency. With 8.7 British thermal units (Btu) per unit of GDP, the Kyrgyz Republic uses almost twice as much energy as the global average. However, the country has made significant progress since the 1990s, when energy intensity was more than 20 Btu per unit of GDP. The Kyrgyz Republic's industrial sector is dominated by mining and metals processing (including gold), which generates nearly half of the industrial output. The continued use of old equipment inherited from the Soviet era significantly impacts energy efficiency. Overall, cement production and industrial motors are the two subsectors with the largest energy-saving potential. The cement production is found to be nearly 40% less energy-efficient compared to modern analogues. However, industrial enterprises face challenges when investing in energy efficiency, given the limited availability of financing capital and the low commercial viability of implementing energy efficiency measures due to low energy prices. The Kyrgyz Republic also lacks a developed energy audit system or an energy services market since there are no requirements for energy audits.

Energy consumption in residential and commercial buildings is also rather inefficient. One of the key reasons is insufficient insulation in most buildings, with more than 75% of the stock having been built before 2004, when the country had no energy performance requirements for buildings. Another issue is the limited availability of data on energy consumption in buildings, since no comprehensive energy audits have been conducted. As a result, decision-making relies on the results of limited studies. It is estimated that energy efficiency can be improved by 40%–50% if sufficient investments in energy efficiency are undertaken—a substantial improvement considering the fact that residential consumers are the largest consumer group in the Kyrgyz Republic.

The Kyrgyz Republic's transport sector also has significant potential for energy savings, as the fleet of vehicles is mostly outdated, implying low efficiency and high emissions. According to official statistics, more than 85% of cars were manufactured 16 years ago or more. Important challenges include the lack of fuel efficiency standards for transport. If modern standards were implemented, energy efficiency in transport could increase by up to 40%. Additional emissions improvements are expected once electric vehicles (EVs) gain traction in the Kyrgyz Republic. In 2019, the government decided to promote the use of EVs by cancelling registration and tariff duties for EVs. However, the Kyrgyz Republic still has a negligible number of EVs—mostly due to limited supply, high prices, and a lack of charging infrastructure. Railway transport is also an important contributor to inefficiencies in the transport despite the limited size of the network (around 400 km in total, with two unconnected lines in the northern and southern parts of the country), as more than 90% of locomotives operate beyond their useful life and require modernization (Government of the Kyrgyz Republic 2014). The Kyrgyz Republic's railways operate only diesel locomotives, as the railway network is not electrified yet.

Regulatory Framework

The Kyrgyz Republic's regulatory framework was mostly established in the 1990s and 2000s. Its main laws include the Law on Energy Industry, the Law on Electrical Energy Industry, and the Law on Energy Saving (1998; amended in 2019). Despite some amendments adopted in subsequent years, the regulatory principles have not been changed and, for the most part, do not reflect the principles of a modern energy sector. In contrast, the energy sector's institutional framework has proven to be very volatile. The State Committee on Industry, Energy and Subsoil Use was mandated to develop and implement state policy in the energy sector in 2016 but was replaced by the Ministry of Energy and Industry in 2021. Notably, the Kyrgyz Republic has a dedicated regulatory body, The State Agency for Regulation of the Fuel-Energy Sector, which is mandated to issue licenses for energy-related activities and to develop tariff-setting methodologies. However, because the regulator is subordinated to the Ministry, it cannot be considered fully independent, potentially leading to biases and not entirely equal market conditions for state-owned players and private companies. While the vertically integrated electricity company JSC KyrgyzEnergo was unbundled in 2001, shares of energy companies were transferred to the Open Joint-Stock Company (OJSC) Energy Holding Company (EHC).

Several issues with implementing secondary legislation hamper energy efficiency improvements in the Kyrgyz Republic. For instance, the Law on Energy Saving envisions the creation of a dedicated Energy Conservation Fund that has not been created yet. In addition, the Law on Energy Efficiency in Buildings, one of the newest and most advanced pieces of energy legislation in the Kyrgyz Republic, has not been adequately implemented (International Energy Charter 2018). Developed in cooperation with international organizations, it sets modern requirements for energy performance in buildings, comparable to international best practices (IBRD 2019).

Renewable energy legislation consists of the Law on Renewable Energy Sources, adopted in 2008 and amended in 2012. The government introduced feed-in-tariffs (FITs) to spur the development of renewable energy sources, with tariffs calculated using specific coefficients depending on the type of renewables. The law also stipulates support measures to investors (e.g., guaranteed grid access, a guaranteed payback period of less than 8 years, etc.). In 2019, the law was amended again to introduce compensation for the distribution companies, which spend additional costs on purchasing sustainable electricity (UNDP 2020). These costs will be considered when approving the national power tariffs for consumers. Besides, the law modifies the FIT coefficient for all types of renewable energy to the maximum tariff at which the power will be purchased, thereby providing additional incentives for launching renewable projects. Finally, the law introduces quotas for renewable energy capacity. This will allow the establishment of full-capacity renewable energy stations, and then define which stations may receive an increased tariff based on region and type of sustainable source for a defined period of time.

Policy Framework

The National Strategy for Sustainable Development for 2018–2040 is the Kyrgyz Republic's overarching policy document (IBRD 2019). It outlines the country's intentions for its energy sector development, including increasing its energy efficiency, expanding power generation capacities, and making more extensive use of renewable energy and natural gas. This cross-sector country strategy largely overlaps with the Strategy for the Development of the Fuel and Energy Complex until 2025, the most comprehensive active policy document. Two important policy documents were recently developed and published: one concerns medium-term sector development (Concept for the Development of the Fuel and Energy Complex of the Kyrgyz Republic until 2030) and the other involves long-term sector development (Concept for the Development of the Fuel and Energy Complex of the Kyrgyz Republic until 2040).

While the new documents are mostly consistent in terms of development priorities, one stark difference relates to the establishment of competitive energy markets. While the existing Strategy for the Development of the Fuel and Energy Complex until 2025 envisions power market liberalization with the participation of the private sector, the new documents do not state the creation of conditions for broad private sector participation as a target, except for renewable power generation (Government of the Kyrgyz Republic, Ministry of Justice 2008).

The Kyrgyz Republic's tariff policies are developed by the regulator in close cooperation with the government. The Medium-Term Tariff Policy for 2020–2022 was approved in 2020, with the aim of bridging the gap toward cost-reflective tariffs, while falling short of establishing cost-recovery tariff levels in 2022 (IEA 2021).

Based on the analysis of various energy policy documents, the following sector priorities can be identified:

(i) **Reliable energy supply.** The key focus of the governmental policy is to ensure a reliable supply of energy to all groups of consumers, and to respond to projected demand growth. This also includes developing regulation or mechanism that protects vulnerable population groups.

(ii) **Energy efficiency improvements across the transmission, distribution, and consumption segments of the value chain.** The government not only aims to decrease T&D losses in electricity, natural gas, and heating networks, but also to improve energy efficiency on the consumption side.

(iii) **Support for the expansion of renewable energy generation.** The government has recently introduced changes to the Renewable Energy Law (2008; amended in 2019), including the revision of the FIT coefficients to the maximum value at which sustainable electricity can be purchased. This demonstrates the country's aim to incentivize the development of renewable energy projects, including small hydropower plants.

(iv) **Active participation in regional energy markets.** Having played a leading role in the CAPS previously, the Kyrgyz Republic is prioritizing the further integration of energy systems to benefit from complementary energy mixes and resource availability across Central Asia.

(v) **Financial recovery of the energy sector.** Additional financial resources need to be acquired to finance infrastructural modernization needs. Improvements to the tariff policy are projected to be a key lever for this policy goal, and will also help to improve the financial performance and profitability of energy sector companies.

(vi) **Regulatory framework improvement.** The government also recognizes the importance of completing the institutional and regulatory framework, which will allow for a clearer division of responsibilities as well as for the full implementation of the policy targets.

Forecast Methodology

One of the objectives of this country study is to present a detailed overview and analysis of trends that will define the future of the Kyrgyz Republic's energy sector. For this purpose, three scenarios were developed, taking into account the country's regulatory framework, technological development, consumer preferences, and other factors (Box 13). Supply and demand, technology, carbon emissions, and investment outlooks were derived based on these scenarios.

Box 13: Scenarios for the Kyrgyz Republic's Energy Sector

Business-as-usual scenario: Projected energy supply and demand, with current energy system and policies;

Government Commitments scenario: Projected energy supply and demand, considering individual priorities of the Government of the Kyrgyz Republic; and

Green Growth scenario: Projected energy and supply demand, considering enhanced energy transition and environmental policies.

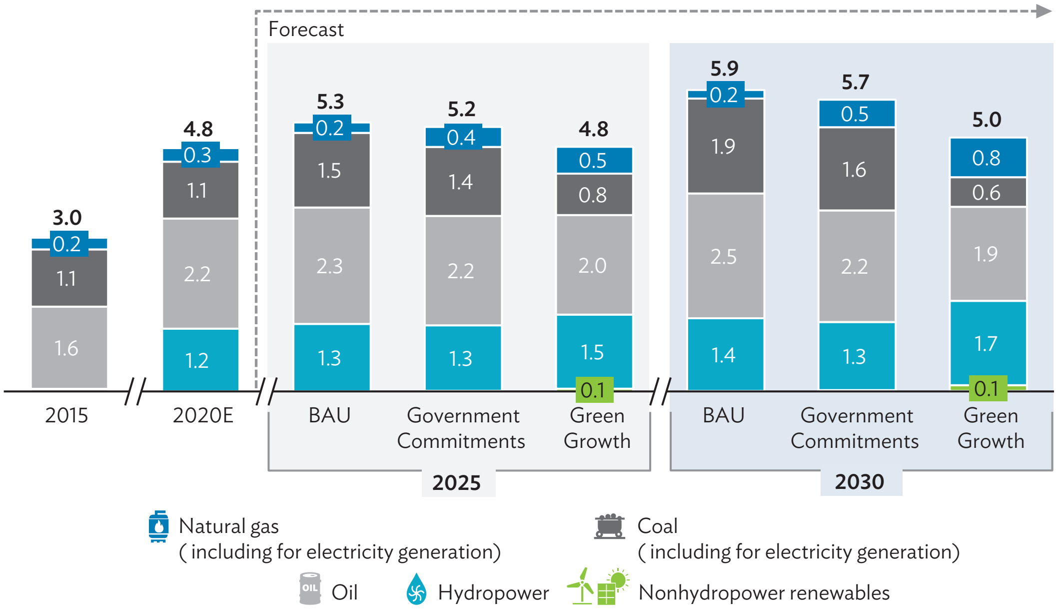
Source: Roland Berger/ILF.

Supply and Demand Outlook

The COVID-19 pandemic has had a significant impact on the Kyrgyz Republic's economy, with final energy demand declining by nearly 3% in 2020. As a result of a rapid economic rebound, demand will reach pre-crisis levels, and will continue to grow until 2030. In the Government Commitments scenario, primary energy supply is expected to reach 5.7 million toe in 2030, representing an annual growth rate of nearly 1.7%. The Business-as-usual (BAU) scenario foresees a more rapid growth rate at almost 2%, due to smaller investments in energy efficiency measures compared to the other two scenarios. In contrast, the Green Growth scenario assumes more extensive implementation of efficiency measures, leading to a growth rate of less than 1%, and a total primary energy supply of 5.0 million toe in 2030.

Driven mainly by consumption in the transport sector, oil is the largest fossil fuel in the Kyrgyz Republic's primary energy supply, with an estimated share of 45% in 2020. This share is, however, projected to decrease to 37%–41%, depending on the scenario. The share of hydropower in the total energy supply increases in each scenario because of growing electricity consumption. In contrast, coal consumption varies significantly depending on the scenario. The share of coal declines in the Green Growth scenario, which assumes that coal will be largely replaced by natural gas imports, including for power and heat generation. In the other two scenarios, final demand for coal continues to grow until 2030, with the government prioritizing the use of domestically produced fuels (Figure 52).

Figure 52: Kyrgyz Republic—Primary Energy Supply Forecast
(million tons of oil equivalent)



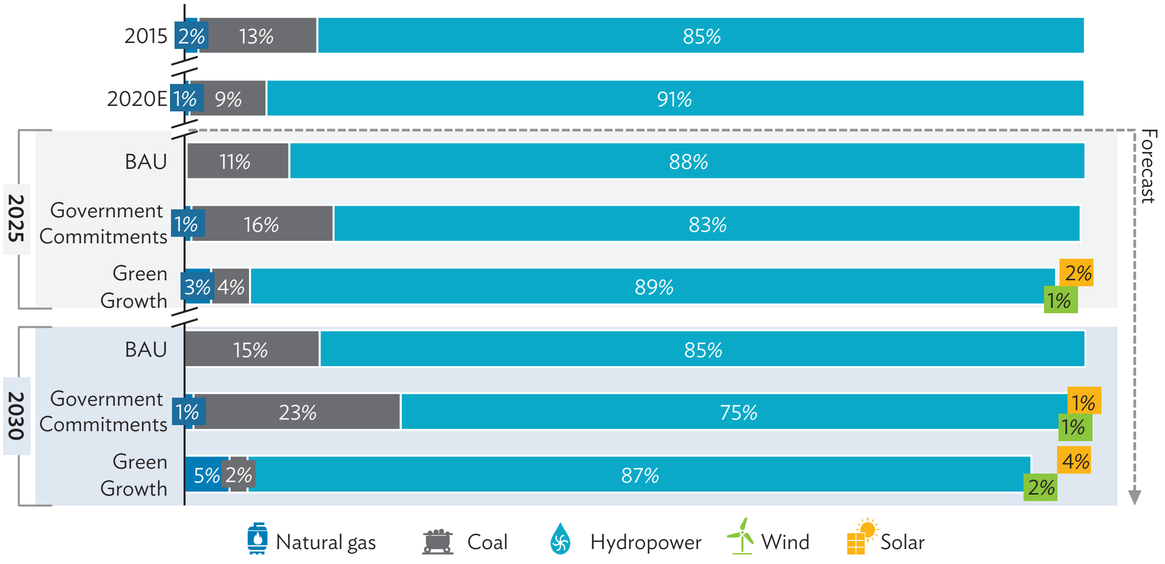
BAU = Business-as-usual, E = estimate.

Source of historical data: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 8 September 2021). The forecasts are based on the Roland Berger methodology described in the Methodology section.

The electricity mix in the Kyrgyz Republic has historically been dominated by hydropower, reflecting the country's geographic position and its large availability of water resources. The prevalence of hydropower in electricity generation is projected to last until 2030, as the Kyrgyz Republic rehabilitates old hydropower plants and constructs new ones. The power generation mix in 2030 will, however, develop into very different directions depending on the scenario. The Government Commitments scenario foresees a rapid expansion of coal-fired power generation to 23% in 2030, with minimal development of nonhydropower renewables and with the combined share of wind and solar power plants below 2%. The government has prioritized coal-fired generation in its plans given the country's significant coal reserves and considerable coal production. The BAU scenario also foresees a negligible share of wind and solar energy in the power mix, while the share of hydropower is closer to its current number, at 85% in 2030. The BAU scenario also foresees a slower expansion of coal-fired power generation, based on historic trends and the lack of projects at an advanced stage. The Green Growth scenario represents a different direction for the power sector's development, and considers the availability of natural gas import infrastructure, as well as recent efforts to modernize the grid. In this scenario, the share of natural gas-fired power generation reaches 5% in 2030, as coal is gradually phased out. The Green Growth scenario also assumes the adoption of new renewable energy policies that spur the development of wind and solar energy, leading to a combined share of 6% in 2020, and helping to diversify from hydropower generation (Figure 53).

Final energy demand depends heavily on the extent to which energy efficiency measures are implemented. In the Government Commitments scenario, final energy demand reaches 5.1 million toe in 2030—slightly lower than the 5.4 million toe forecasted by the BAU scenario, in which lower energy efficiency investments are being made. The Green Growth scenario foresees the lowest final energy demand at 4.8 million toe

Figure 53: Kyrgyz Republic—Power Generation Mix

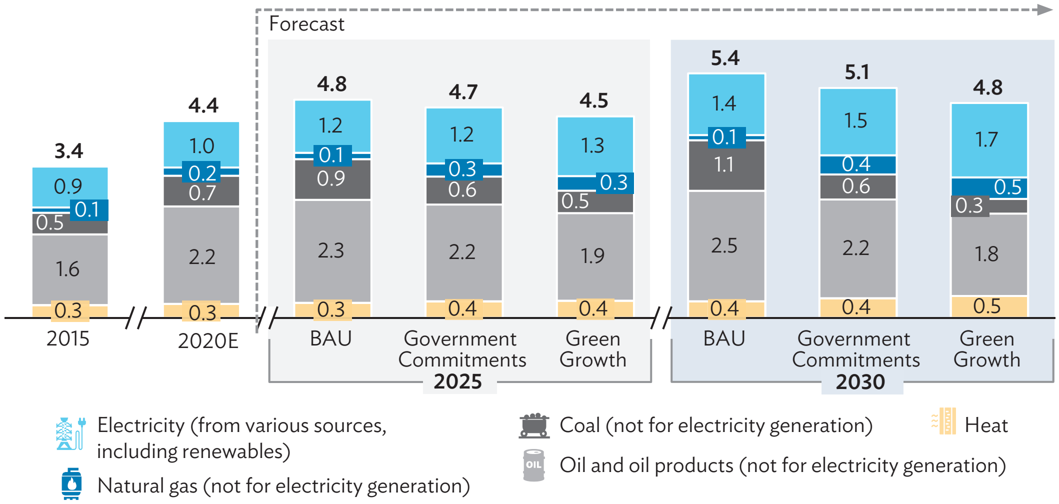


BAU = Business-as-usual, E = estimate.

Source of historical data: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 8 September 2021). The forecasts are based on the Roland Berger methodology described in the Methodology section.

Figure 54: Kyrgyz Republic—Final Energy Demand Forecast by Fuel

(million tons of oil equivalent)



BAU = Business-as-usual, E = estimate.

Source of historical data: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 8 September 2021). The forecasts are based on the Roland Berger methodology described in the Methodology section.

in 2030 because of the extensive energy efficiency measures implemented. The share of electricity in final energy demand increases fastest in the Green Growth scenario, where it partly replaces fossil fuel consumption. The Government Commitments and Green Growth scenarios assume an increase in the consumption of natural gas. Yet, final consumption of coal grows rapidly in the BAU scenario because of increased demand, mainly from industry (Figure 54).

In terms of sectors, the residential sector is the largest consumer in the Kyrgyz Republic, accounting for more than half of the final energy demand. The increase in energy consumption in the residential sector is limited, especially in the Green Growth scenario, given the large potential for savings resulting from energy efficiency measures. At the same time, industry and services demonstrate the most rapid growth across all scenarios, determining the Kyrgyz Republic's economic growth until 2030 (Figure 55).

Technology Outlook

Priority Technologies: Generation

Key considerations in the selection of priority power generation technologies include the urgent need to satisfy demand and diversify energy resources, as well as the generation potential of available resources.

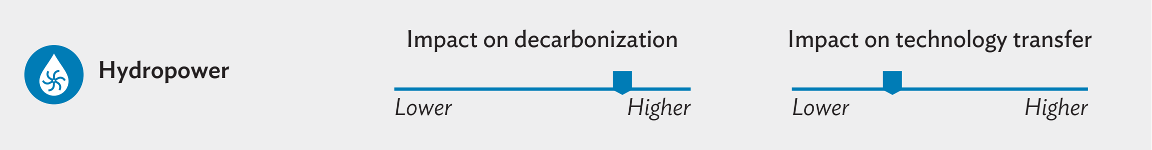
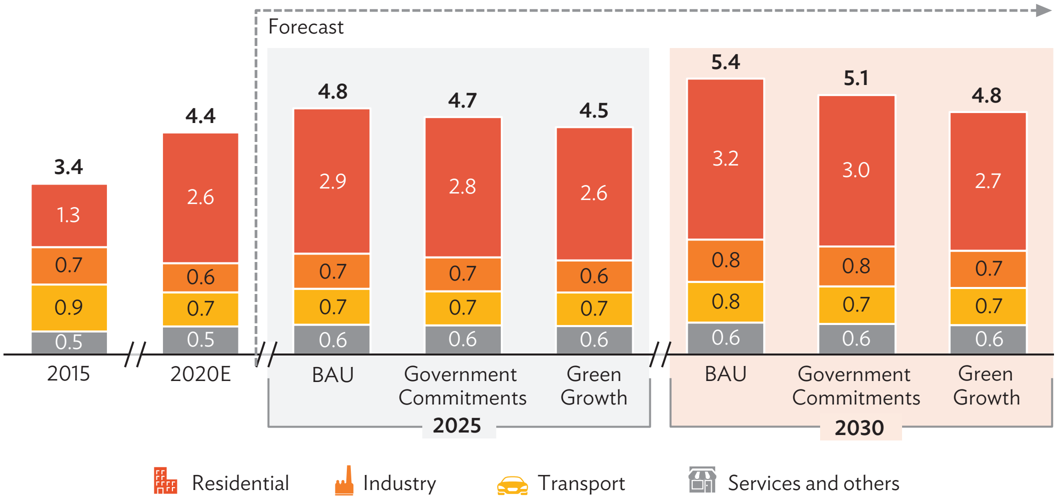


Figure 55: Kyrgyz Republic—Final Energy Demand Forecast by Sector

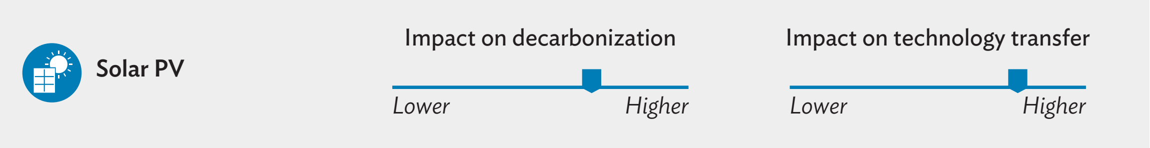
(million tons of oil equivalent)



BAU = Business-as-usual, E = estimate.

Source of historical data: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 8 September 2021). The forecasts are based on the Roland Berger methodology described in the Methodology section.

Due to its geographic conditions, the Kyrgyz Republic has unique hydropower potential, only 10% of which is currently being realized. Given the Kyrgyz Republic's extensive hydropower know-how, its further development is highly suitable for meeting the growing demand for electricity in an environmentally sustainable manner. At the same time, it is important to consider the challenges associated with adding new hydropower capacities, including seasonal patterns of generation (low output in winter) and the concentration of generation potential in a single region. Thus, careful planning and site selection will be required to ensure that new capacities will be able to meet demands at specific locations and times. The government has also prioritized the development of small hydropower plants (with an estimated total potential of 0.3 GW). Hydropower is a mature energy technology, and the Kyrgyz Republic has abundant capabilities in terms of its installation and operation.

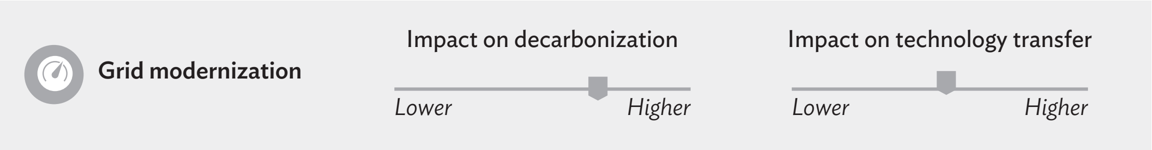


The Kyrgyz Republic still has no operational solar PV plants at utility scale, and no plants under active development. The technical potential of solar energy in the Kyrgyz Republic is estimated at around 267 GW, as the majority of the country's territory has horizontal radiational levels between 4.0 and 4.6 kilowatt-hours per square meter, which as noted above, is the overall theoretical amount of solar energy that could be generated from the entire landmass of the country; however, it should not serve as a guide for forecasting the actual future amounts generated through solar power. Solar energy use has potential to diversify the power generation mix, and to provide additional zero-carbon power generation in locations where hydropower resources are not readily available. The Kyrgyz Republic has launched some initiatives in this regard, specifically, developing floating solar installations. The technology transfer impact of developing solar energy is also considerable, as renewable energy is still nascent in the Kyrgyz Republic.

While the government has prioritized coal-fired generation in its plans due to the country's considerable coal production, the Kyrgyz Republic has to consider the environmental effects of its decisions regarding the installation of power generation assets throughout their useful life, which typically reaches several decades. It is also continuing to import coal, despite expanding its domestic production. In this context, the development of gas-fired power generation may be a more viable and cleaner alternative compared to coal-fired plants. In addition, gas-fired power plants have better balancing characteristics than coal-fired plants, which is important in light of expanding renewable generation. Furthermore, the Kyrgyz Republic has already developed cross-border infrastructure for natural gas imports, only a fraction of which is currently used (Bukhara–Tashkent–Bishkek–Almaty pipeline). As Kazakhstan continues to expand its natural gas production and develop its national transmission infrastructure, the Kyrgyz Republic's role in this pipeline can shift from transit to import. The development of gas-fired power plants is also consistent with the government's ambitious gasification and pipeline modernization plans. Moreover, with larger imports, the Kyrgyz Republic's bargaining position in terms of contract and price negotiations will be improved.

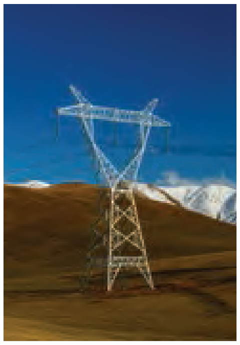
Priority Technologies: Transmission and Distribution

The Kyrgyz Republic's power and natural gas grids can benefit from modernization measures that tackle grid losses that are prone to create financial and environmental issues for energy sector players. Thus, grid modernization is one of the key priorities for infrastructure investments in the energy sector. The government has already taken actions to improve the reliability of supply, particularly through the construction of new power transmission lines (Box 14).

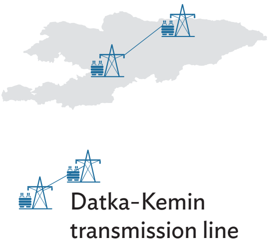


Power T&D losses have decreased from approximately 30% a decade ago to an estimated 18% in 2019. While this is a significant achievement, these losses are still considerably higher than international standards. Infrastructure that has been operating beyond its useful life is the primary cause of high losses and frequent outages. Costly grid-modernization efforts are the primary means by which the status quo may be improved, combined with a gradual application of cost-reflective tariffs. The natural gas grid suffers from similar loss issues, which, unlike power grid losses, also have a severe environmental impact due to the direct emission of methane—a highly potent greenhouse gas (GHG)—into the atmosphere. Gazprom, the Kyrgyz Republic's natural gas grid operator, committed to investing $600 million in modernizing the natural gas grid.

Box 14: Kyrgyz Republic's Flagship Energy Project



The Kyrgyz Republic has historically relied on transit through Uzbekistan and Kazakhstan to transfer power produced by hydropower plants in the Naryn basin to key consumption centers in the northern parts of the country. The construction of the 500-kilovolt Datka-Kemin transmission line, commissioned in 2015, has significantly enhanced self-sufficiency and security of supply of the Kyrgyz Republic's power network. This project has been one of the major energy infrastructure projects in the country's history, with a total cost of $ 390 million, partly financed by a long-term loan from the Import-Export Bank of China.

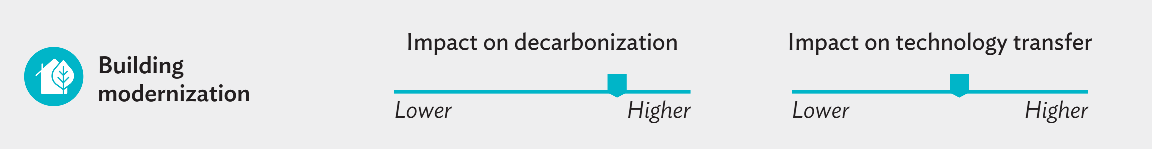


Note: Illustrative photo of a transmission line is by Mieszko9/Adobe Stock©.

Source: PwC/Asian Development Bank. 2016. *CAREC: Study for Power Sector Financing Road Map—Mobilizing Financing for Priority Projects – Kyrgyz Republic.* Final report. Manila (TA 8727-REG).

Priority Technologies: Consumption

The Kyrgyz Republic urgently needs to take action to improve technologies related to energy consumption. Commercial and residential buildings as well as transportation are identified as the sectors with the largest potential for energy savings.



The residential and services sectors are the largest consumption groups, with a combined share of nearly 70% of total final energy consumption. This fact suggests that most energy efficiency improvements can be leveraged via measures aimed at the modernization of buildings. While the government has already made some steps by adopting modern energy performance requirements for buildings, the implementation and enforcement of these regulations have been limited. In addition, no action plans for the renovation of existing buildings have been adopted yet—even though nearly 45% of all buildings in the Kyrgyz Republic were constructed before 1980, and 76% before 2004—without consideration for energy performance requirements. A starting point should be improved transparency over energy consumption in buildings by conducting extensive energy audits. The resulting information can then be used to make informed decisions about priority areas and measures for building modernization. Commercialization of renewable heat technologies can mitigate the carbon footprint of the sector largely dependent on coal, but it will require large financial support from the government and private investors.

Transport efficiency improvement

Transport in the Kyrgyz Republic is an important energy consumption group, and a significant source of emissions in urban centers. This is largely due to an old and inefficient fleet of vehicles in the country (Sputnik 2020). According to dedicated reports, efficiency in transport can be improved by up to 40% in the most optimistic scenario. While the government has declared targets to promote the use of EVs and to electrify railway networks in the Development Strategy until 2040, more impactful measures in the short-term future could include the introduction of fuel efficiency standards for vehicles and locomotives. Given the Kyrgyz Republic's green power mix, the country has strong potential to reduce its GHG emissions via the electrification of transport. Expanding the use of hybrid vehicles and developing EV infrastructure could be the first steps toward a cleaner future for transportation.

Carbon Emissions Outlook

The Kyrgyz Republic is one of the signatories of the Paris Agreement and has officially submitted its first Nationally Determined Contribution (NDC) in 2020 as part of global efforts to act on climate change. The Kyrgyz Republic submitted an updated NDC for the 26th United Nations Climate Change Conference of the Parties in 2021. The Kyrgyz Republic's NDC includes both unconditional and conditional GHG emission reduction targets. The conditional targets are dependent on international support via green financing and technology transfer. The country aims to reduce GHG emissions by 16.63% by 2025 without international financial support, and by 36.61% in case international support will be provided. By 2030, the Kyrgyz Republic aims to reduce GHG emissions by 15.97% without international support and 43.62% with international support compared to BAU levels (UNFCCC 2021). Since the Kyrgyz Republic's NDC does not contain an emissions reduction target specifically for the energy sector, an assumption of energy-related emissions in 2030 has been made for the purpose of this report.[9]

Energy-related GHG emissions under the BAU and Government Commitments scenarios are assumed to be similar, driven by the government's plans to expand coal-fired power generation. Nevertheless, slightly higher efficiency gains are expected under the Government Commitments scenario—nearly 14.5 million tons of carbon dioxide (CO_2) equivalent in 2030—as compared to the BAU scenario of 15.4 million tons of emissions. Nevertheless, slightly higher efficiency gains are expected under the Government Commitments scenario—nearly 14.5 million tons of CO_2 equivalent in 2030—as compared to the BAU scenario of 15.4 million tons of emissions. Both scenarios fall short of reaching the NDC targets because of the higher use of coal, which contradicts the Kyrgyz Republic's target of a double-digit decline in emissions. By contrast, the Green Growth scenario shows a potential pathway to reaching the unconditional NDC target of nearly 10 million tons of CO_2 equivalent in 2030 (Figure 56). Key reasons include significant improvements in energy efficiency in the generation and consumption sides, loss reductions, and a shift to cleaner fuels, specifically limiting the use of coal and diversifying the power mix with nonhydropower renewables.

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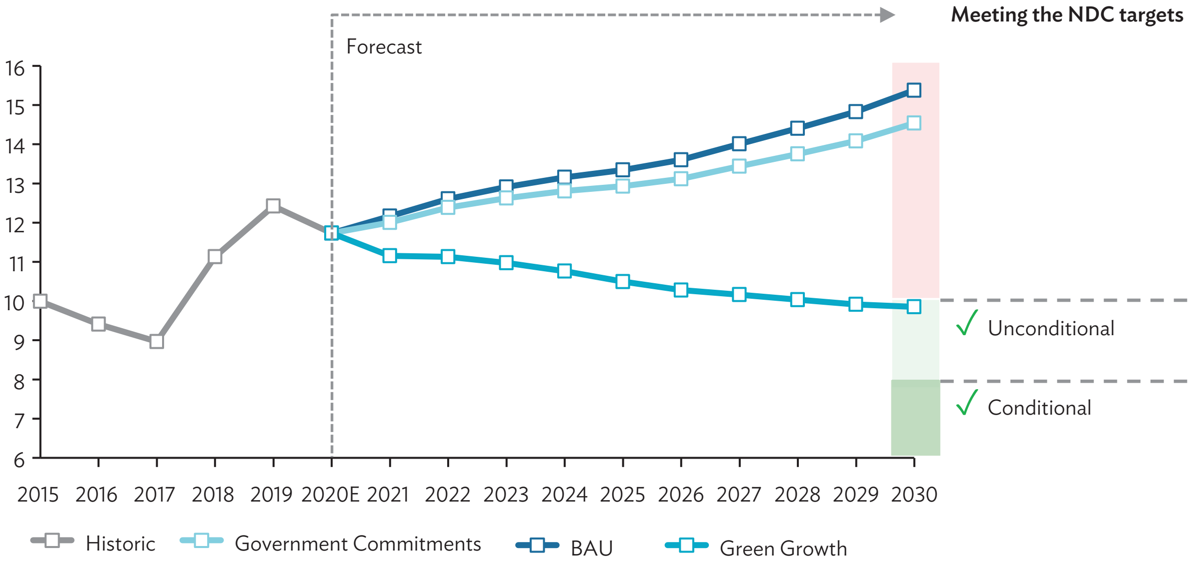
[9] Under the energy-related emissions, greenhouse gas emissions from generation, transmission, and consumption of energy are considered. Assumed share of energy-related emissions in 2030 is based on historical averages.

Figure 56: Kyrgyz Republic—Energy-Related Carbon Emissions
(million tons of carbon dioxide equivalent)



BAU = Business-as-usual, E = estimate, NDC = Nationally Determined Contribution.

Note: Historical data on carbon emissions is modelled by Roland Berger based on historical data on energy use. The forecasts are based on the Roland Berger methodology described in the Methodology section.

Sources: Roland Berger; and United Nations Framework Convention on Climate Change. Nationally Determined Contributions Registry. https://unfccc.int/NDCREG.

Investment Outlook

Investment Needs

Investment needs in power generation, T&D infrastructure, and energy efficiency measures in consumption sectors vary significantly across the scenarios, ranging from $3 billion to $7 billion until 2030. Investments in power generation infrastructure account for the majority of investment needs in each scenario, highlighting the need to rehabilitate existing capacities and build new ones in order to meet growing demand across all seasons. Investment needs in hydropower range from $0.7 billion to $1.7 billion, with the Green Growth scenario estimating the largest sum. Improving the security of supply via fossil-fuel power generation is estimated at $0.7 billion to $1.5 billion, including coal-fired power in the BAU and Government Commitments scenarios, and natural gas-fired power in the Green Growth scenario. The Green Growth scenario also assumes significant investments in nonhydropower renewables (around $0.5 billion in total), compared to the nearly negligible figures in the two other scenarios.

Investment needs in T&D infrastructure also vary significantly, reflecting considerable differences between the optimal scenario and existing trends. The BAU scenario foresees investments of only $0.3 billion, which is unlikely to significantly improve infrastructure conditions and improve the reliability of supply. By contrast, the Government Commitments scenario foresees $0.8 billion investments in T&D infrastructure, while investments in the same sector under Green Growth scenario reaches $1.2 billion. Investment needs for energy efficiency measures demonstrate similar dynamics, as spending in previous decades has not been sufficient to improve energy efficiency on the consumption side. In the Green Growth scenario, energy efficiency measures reach $2.9 billion, compared to $1.9 billion in the Government Commitments scenario and $1.2 billion in the BAU scenario (Figure 57).

Challenges and Opportunities

The root cause of most issues in the Kyrgyz Republic's energy sector is the inadequate level of tariffs. In 2019, the Kyrgyz Republic's retail electricity prices remained at the level of $8–$10 per megawatt-hour (MWh)—one of the lowest in the world, and the lowest among Commonwealth of Independent States (CIS) countries (prices in neighboring Central Asian countries are 2–6 times higher, while prices in the Russian Federation and Georgia are up to 10 times higher). The government recognizes all the implications of setting tariffs below cost-recovery level and has attempted to improve the situation. The latest development in the summer of 2021 is a good example, when the Midterm Electricity Tariff Policy for 2021–2025 developed by the Ministry of Energy and Industry was partially adopted. The proposed policy envisioned a tariff increase to $17–$27 per MWh for the residential sector (depending on consumption levels), with a lower tariff for vulnerable groups of residents at $8–$12 per MWh. For other categories, including industry and services, the tariff is planned to be set at $19–$34 per MWh, mostly in line with the cost-recovery level estimated at $17 per MWh. The policy also envisioned a further increase until 2025 to reach full cost-recovery and acquire resources for infrastructure modernization. However, the policy was amended following dissent from the public: tariffs for residents will remain at the level of $8 per MWh, while tariffs for the industrial and services sectors will be set according to the new policy.

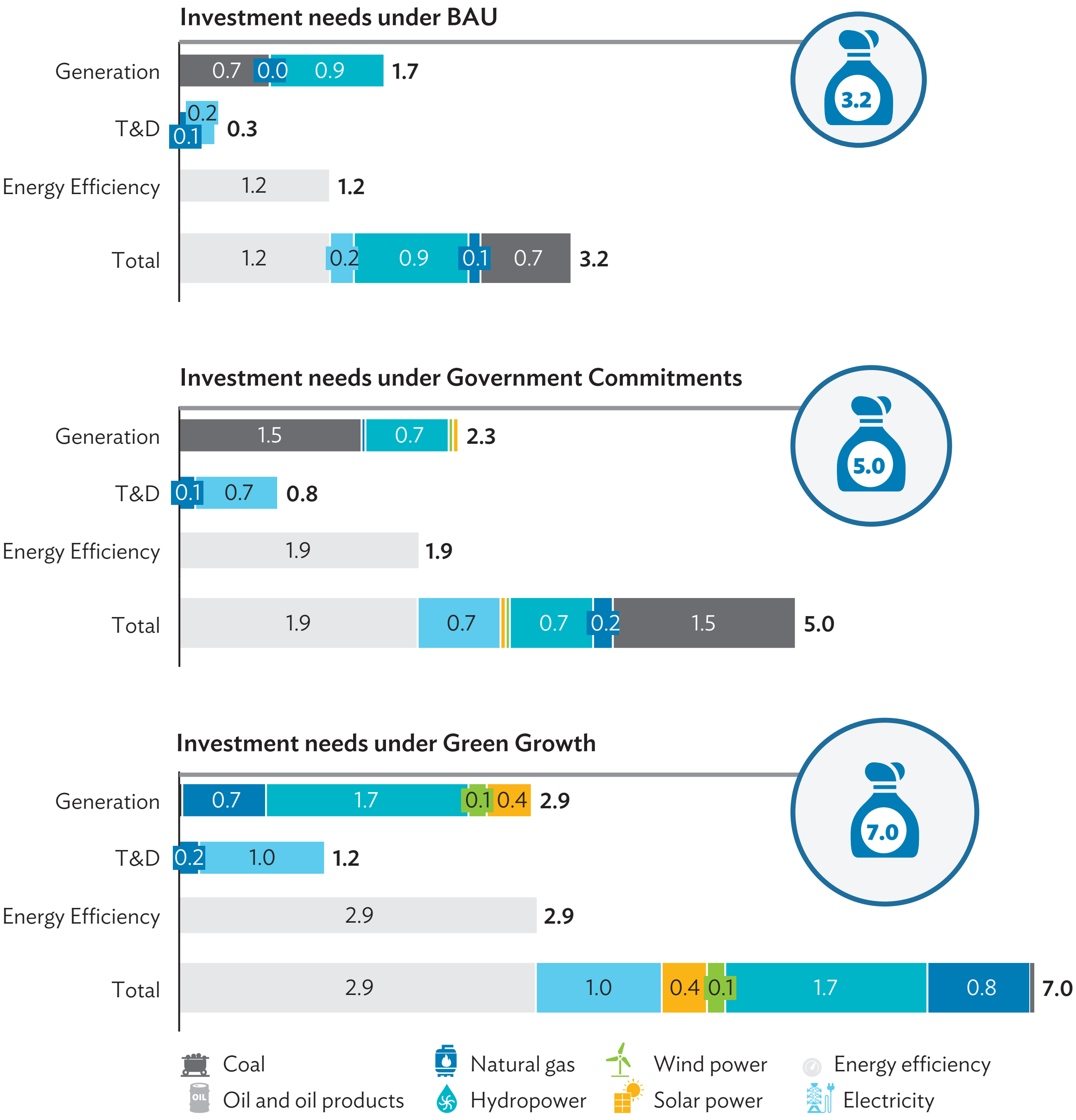
Under this new tariff regime, industrial and service consumers are likely to improve their energy efficiency levels, while residential sector consumers will not have incentives to improve energy efficiency. While the government implemented its intention to set a cost-recovery level electricity tariff across the board with only partial success, it is likely to complete the policy in several years once economic growth leads to an increase in the average income of citizens.

Other crucial energy sector challenges can also not be addressed without setting cost-recovery level tariffs. For instance, modernization of the energy infrastructure across the entire value chain (generation, transmission, distribution, and consumption) requires sufficient revenues to avoid energy companies from falling into debt and losing creditworthiness in acquiring additional loans. Moreover, low energy prices entail a low return on energy efficiency measures and limited financial impacts of high losses.

The Kyrgyz Republic faces another issue that can be mitigated by increased tariffs, namely its lack of power generation capacities. Hydropower's dominance in the generation mix does not align well with the country's energy consumption patterns, where demands during the winter can be more than two times higher than during the summer. For climate reasons, hydropower generation is lower during winter,

Figure 57: Energy Infrastructure Investment Needs in the Kyrgyz Republic until 2030

($ billion)



BAU = Business-as-usual, T&D = transmission and distribution.

Source: The forecasts are based on the Roland Berger/ILF methodology described in the Methodology section.

requiring the country to import electricity. Furthermore, the Kyrgyz Republic recently experienced low water levels in its main rivers, adding new strains to its power generation capacity. Thus, tariff increases could free up funds for the construction of new plants that could help to diversify the power generation mix.

Several challenges can, however, be addressed without changing the tariff policy. One of the key improvement areas is the development of secondary legislation and by-laws that will govern the implementation of the primary legislation. A prime illustration of this is the Law on Energy Efficiency in Buildings, which sets standards aligned with best practices in Europe, but enforcement of the law has been inadequate because of the unclear designation of responsibilities.

Another significant challenge is the rather limited development of nonhydropower renewables. While the government has established generous support measures for private investors via FITs for wind and solar energy, the mechanism is yet to be fully used due to the lack of standard power purchase agreements and licensing procedures. The government also has not communicated any targets in terms of wind and solar power capacity installments, leading to resistance from various stakeholders to approve nonhydropower plants.

Considering its sizeable technical potential in the Kyrgyz Republic, renewable energy (especially hydropower) represents a solid investment opportunity. If proper secondary legislation is developed to implement the main laws, private sector investors could benefit from extensive state support, e.g., guarantee of profitability of nonhydropower renewable energy plants for the first 8 years of operations.

When cost-recovery tariff levels are introduced in the mid-term or long-term future, the Kyrgyz Republic is likely to face steep investment needs. Support from private investors and lenders is likely to be essential to ensure the availability of capital to finance both the expansion and modernization of the infrastructure. The know-how of private players in the development of wind and solar energy, as well as in the improvement of energy efficiency in consumption, will be especially important.

Finally, the Kyrgyz Republic already has solid cross-border infrastructure in terms of power transmission lines, being interconnected to Kazakhstan, Uzbekistan, as well as Tajikistan (which is planning to reconnect in 2022) via CAPS. The Kyrgyz Republic has historically been a key part of this system, being responsible for power generation regulation and for the largest share of exports. The high seasonality of hydropower generation emphasizes the relevance of cross-border trade, as the Kyrgyz Republic can export excess electricity during the summer and, in turn, import power during peak demand seasons in the winter. Amid the gradual liberalization, larger shares of renewable energy and increased private sector participation in regional energy markets, the importance of existing and new cross-border connections will continue to grow.

Policy Recommendations

Despite facing several important challenges, the Kyrgyz Republic's energy sector has significant potential and can attract private investments if the following policy actions are adopted:

(i) **Continue tariff reforms.** The government should aim to complete electricity tariff reforms and to gradually implement the principle of cost reflectivity. This is crucial not only for improving the financial performance of energy sector companies, but also for infrastructure modernization and for the promotion of energy services. Considering the high social value of affordable energy services, low-income and vulnerable consumer groups in particular may receive subsidized energy prices following best practices. Accumulated funds can be further invested in grid and building modernization.

(ii) **Develop energy efficiency programs.** Since the Kyrgyz Republic has the second highest energy intensity indicator globally, urgent actions are needed to improve energy efficiency. While tariff reforms will also promote energy efficiency in terms of behavioral habits, outdated technology is a significant contributor to energy intensity. The government should play a leading role in driving the change by developing energy efficiency programs and promoting the use of energy audits, especially in the residential sector where the largest energy savings can be obtained.

(iii) **Develop a power infrastructure modernization action plan.** Power infrastructure across the value chain has deteriorated to dangerous levels due to constant underinvestment. A comprehensive action plan should be developed to prioritize investments once financial resources are available. It can include participation of the private sector in grid modernization. This could potentially include performance contracts, wherein the grid upgrades increase electricity throughput and increase revenue to the grid operator.

(iv) **Improve secondary legislation.** Additional legislative acts need to be adopted to guide the implementation of primary laws and targets set by the government. The establishment of a robust institutional framework should become the first priority before assigning responsibilities for implementing and monitoring policy actions.

(v) **Facilitate further renewable electricity generation, particularly nonhydropower.** While the Kyrgyz Republic has established a rather favorable investment climate in renewable energy via introducing FITs and updating the renewable energy policy and regulations, there is still ample room to further facilitate the development of solar PV or wind energy projects. Considering the financial difficulties of power sector players, a switch from FITs to a capacity auction system can ensure that the Kyrgyz Republic pays minimal market price for the diversification of its power mix toward nonhydropower renewables.

(vi) **Foster cross-border collaboration.** Central Asian countries can become prime examples of how energy can benefit all parties involved. In particular, the Kyrgyz Republic can export the cheap power it produces excessively during the summer season to Uzbekistan and Kazakhstan, while importing power, natural gas, or other fossil fuel products to ensure the reliability of supply during the winter. The existing cross-border capacity among countries is a solid foundation for developing collaboration further.

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Issyk Kul Lake. The lake is the main source of income from tourism in the Kyrgyz Republic (photo by pikoso.kz/Adobe Stock©).

MONGOLIA

Mongolian *ger* camps with solar power. Most of the camps now have access to electricity, thanks to solar panels (photo by kagemusha/Adobe Stock©).

Mongolia Highlights

- Mongolia's potential in renewable energy is massive, but exploitation is limited: coal represents the bulk of domestic power generation, with an 89% share in 2018 (Figure 58).
- With a total installed capacity of 1.3 gigawatts (GW), Mongolia primarily relies on thermal generation. However, coal power is projected to decline in the coming years, considering its high starting point and strong rollout of renewable power capacity, the share of which is projected to increase 30%–39% by 2030, depending on the scenario.
- Mongolia's power sector comprises five distinct power transmission systems. Two of them, namely the Central and Western systems, are connected to the Russian Federation for transit of electricity. Mining operations in the southern parts of the country are supplied by electricity from the People's Republic of China (PRC).
- Final energy demand is projected to reach 5.7–6.2 million tons of oil equivalent (toe) in 2030, depending on the energy efficiency measures adopted in the country under various scenarios. Oil and oil products remain the energy source with the highest share in the final demand, which can be attributed to the rapid expansion of the transport sector.
- In addition to renewable power generation, priority technologies for Mongolia include smart grid infrastructure, battery energy storage systems (BESS), and energy efficiency measures related to power generation, transport, and especially heating in the residential sector.
- Investment needs in the energy sector vary between $4 billion and $15 billion until 2030, depending on the scenario. The largest share of investments is related to modernization and expansion of the transmission and distribution (T&D) infrastructure.
- Mongolia's energy sector presents multiple investment opportunities due to the adoption of favorable legislations, such as renewable energy auctions, strong cooperation with international partners, and the government's commitment to exploit the country's massive renewable energy potential.
- Recommendations for Mongolia address several key challenges to its energy sector, including its heavy reliance on coal-powered generation, its inadequate focus on long-term development planning, and the poor condition of its heating infrastructure.

Energy Sector Profile

Country Profile

Mongolia is a land-locked country in Central Asia. It has a population of 3.3 million people and a $12.9 billion nominal gross domestic product (GDP) as of 2020. The coronavirus disease (COVID-19) pandemic has significantly impacted its economy, with nearly 8% decline in GDP in 2020. However, rapid economic recovery is expected, with an 11% annual growth rate of nominal GDP by 2030.

Mongolia's energy sector is largely dominated by coal-powered plants. Given its large coal reserves and harsh climate conditions, the country has been using combined heat and power (CHP) systems as its main source of electricity and heat. The country's electricity system is split into five energy systems, two of which rely heavily on imports from other countries (Figure 59). However, in recent years the country has started to develop its vast renewable potential, aiming at increasing renewable capacity by 30%–39%

Figure 58: Mongolia—Key Figures

Renewable potential	Electricity mix	Carbon intensity	Energy supply	Heating
2.6 TW	**30%**	**2nd out of 172**	**70%**	**60%**
Total technical potential of renewable energy resources is estimated at 2.6 TW.	Projected share of renewable sources in energy generation in 2030, according to government plans, is 30%.	Mongolia is ranked 2nd out of 172 countries in the global ranking of carbon intensity of energy, due to the significant reliance on coal.	70% of primary energy supply was provided by coal in 2018.	60% of Ulaanbaatar population lives in traditional tents (*gers*), primarily using coal stoves for heating.

TW = terawatt.

Sources: *Asian Development Bank.* 2020. Unlocking Mongolia's Rich Renewable Energy Potential. 2 June; Government of Mongolia. 2015. *Scaling-Up Renewable Energy Programme: Investment Plan for Mongolia.* Ulaanbaatar; International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 16 September 2021); International Renewable Energy Agency. 2016. *Mongolia: Renewables Readiness Assessment.* Abu Dhabi; and United States Energy Information Administration. Mongolia Data. https://www.eia.gov/international/data/world (accessed 16 September 2021).

by 2030, depending on the scenario. Although Mongolia is moving toward a "greener" energy sector, it is ranked second most carbon-intensive country out of 172 globally because of its reliance on carbon-intensive methods of power generation. The country is also one of the most energy-intensive, ranking 27th out of 172 countries, mainly because of old infrastructure and insufficient rehabilitation efforts.

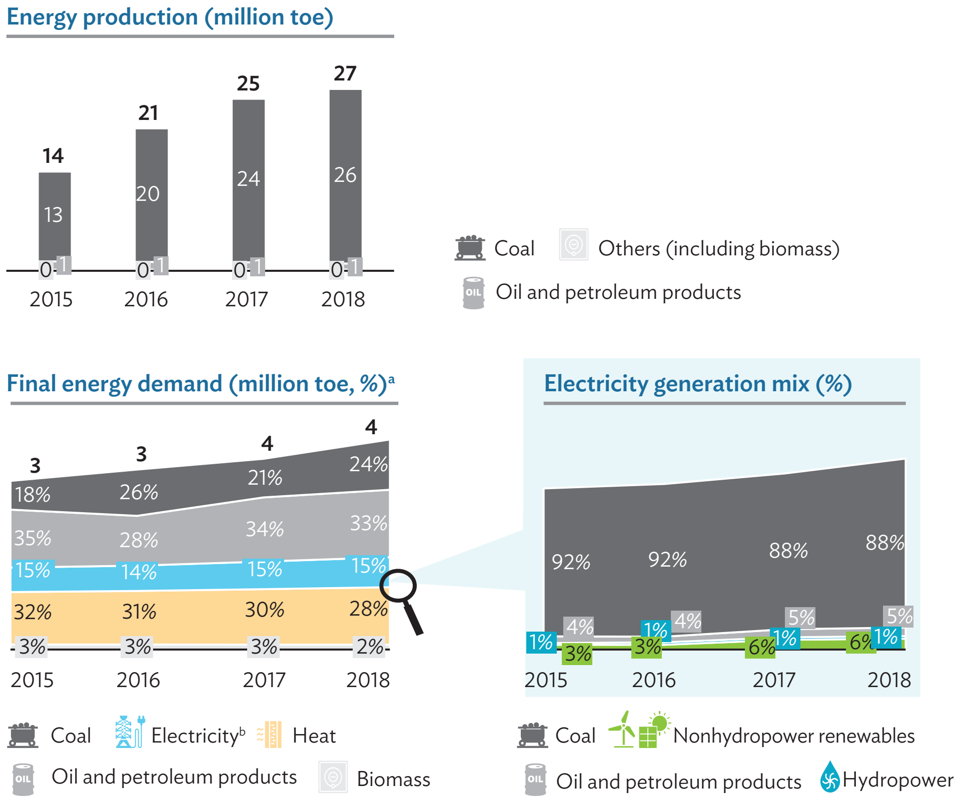
Energy Sector and Technologies Assessment

Conventional Fuel Production

Mongolia has historically been a coal-producing and, to a lesser extent, an oil-producing country. Mongolia's growing coal production is spread across nearly 160 deposits, including high-quality coking coal deposits such as Tavan Tolgoi, Ovoot Tolgoi, and Ukhaa Khugag. In 2019, Mongolia produced 57 million tons of coal, a significant increase from 24 million tons in 2015. Tavan Tolgoi is considered the world's largest undeveloped coal mine, with estimated reserves of 7.4 billion tons. Mongolia has the fourth largest combined thermal and coking coal reserves in the world, totaling more than 26 billion metric tons.

Produced oil is entirely exported as the country currently has no refining infrastructure. More than 90% of annual oil production takes place at the Tamsag basin in the eastern part of the country, where approximately 19,000 barrels of oil were produced daily in 2019. As the country currently exports all produced oil and imports all refined products, it expects to commission its first oil refinery in 2022 to decrease reliance on imports. Mongolia's oil reserves in currently producing blocks are estimated at 43 million tons (Petro Matad).

Figure 59: Energy Profile of Mongolia



toe = ton of oil equivalent.

[a] Topmost numbers on the chart are in million toe.

[b] Electricity data come from various sources, including fossil fuel-based and renewables.

Source: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 16 September 2021).

Electricity Generation

The bulk of power generation in Mongolia consists of coal-fired plants. Thermal generation reached more than 1.1 GW of installed capacity in 2019, making up almost 81% of the country's total power generation capacity, while around 16% was represented by wind and solar power, 2% by hydropower, and the remaining share by diesel stations. However, most of the thermal power plants were built in the 1960s and 1970s and run on outdated and inefficient technologies. In response to growing demand, the country has prioritized rehabilitation of CHP plants in recent years. Nevertheless, Mongolia's power generation is still lagging, and imports from the Russian Federation are required to cover peak demand.

Despite Mongolia's abundance of natural resources, the country maintains a poor environmental record, which has led to efforts to pursue renewable energy as an alternative power source. Mongolia's total renewable potential is substantial, totaling an estimated 2.6 terawatts (TW) (ADB 2020b). Solar power represents 1.5 TW of this estimated total, and the "100,000 Solar *Ger*" program was established already in the 2000s to harness its potential. Total wind energy potential is estimated at 1.1 TW, with the Gobi Desert being a particularly conducive location (Government of Mongolia 2015a). Several wind power plants are already in operation, with an aggregate capacity of 157 megawatts (MW). However, despite strong progress in recent years, Mongolia's renewable potential is far from being fully realized.

Transmission and Distribution

Efforts are needed to improve the condition of Mongolia's electricity grid, with T&D losses reaching 12% in 2018. Inefficiencies in power distribution have led to frequent outages, with a system average interruption duration index (SAIDI) across the country of approximately 1,250 minutes, and a system average interruption frequency index (SAIFI) of 12 interruptions per customer per year in 2017. While average SAIFI and SAIDI have been improving in recent years, they are still far from international SAIDI standards of 100–200 minutes and SAIFI standards of between two and three interruptions per customer.

The Mongolian electricity grid structure is highly fragmented, comprising five independently operating systems: the Western Energy System (WES), Altai-Uliastai Energy System (AuES), South Energy System (SES), Eastern Energy System (EES), and Central Energy System (CES). Although these systems are interconnected, they mostly operate independently. Most generating facilities are located in the CES, which covers more than 70% of the country's area and around 80% of its population. While the CES operates a maximum voltage of 220 kilovolts (kV), other systems connected with the CES operate mainly via 110 kV lines. Importantly, over 50% of the country's distribution lines were constructed at least 35 years ago, and one-third are 15–30 years old. Other challenges include long distances of power transmission and constrained capacity of the regional distribution systems. The combined effect of these factors leads to significant risks of shortages and load shedding, and demonstrates the critical need for rehabilitation and expansion of the midstream infrastructure. While a supervisory control and data acquisition (SCADA) system is operating in the country, it covers a limited number of stations and substations and is segmented by regions, with most of the SCADA operating in the CES.

Mongolia's heating sector is also inefficient, with T&D losses reaching 16% in centralized district systems (Agarjav 2015). Overall, more than 70% of the population still relies on individual heating. Rapid urbanization and insufficient expansion of the district heating grid have left the population with no choice but to rely on coal-fired stoves for heating and cooking, severely impacting health and quality of life (EBRD 2019).

Cross-Border Infrastructure

Only some of Mongolia's systems are interconnected with neighboring countries. For example, the WES imports electricity from the Russian Federation via 220 kV lines, which work in tandem with the Durgun Hydropower plant to supply electricity to consumers in the western provinces. The CES is also connected to the Russian Federation, enabling imports via 220 kV lines in times of peak demand. In the SES, small interconnections with the PRC are present, for instance, 10 kV transmission line from Burgasta Port to Balikun Count (Table 5).

Energy Consumption

The country's high and stable economic growth since 2008 has significantly impacted the consumption of energy, especially conventional sources such as coal, oil, and electricity. Manufacturing and mining are the two most important subsectors. The manufacturing is dominated by construction materials, such as

Table 5: Mongolia—Major Operational Cross-Border Energy Infrastructure

Energy Source	Name	Capacity	Connected Country
⚡	Gusinoozerskaya–Darkhan 220 kV line	240 MW	Russian Federation
⚡	Kharanorskaya–Choibalsan 110 kV line	<10 MW	Russian Federation
⚡	Burgasta Port–Balikun County 10 kV	<1 MW	PRC

⚡ Electricity

kV = kilovolt, MW = megawatt, PRC = People's Republic of China.

Sources: Asian Development Bank. 2020. *Strategy for Northeast Asia Power System Interconnection in Mongolia.* Consultant's report. Manila (TA 9001-MON); *and World-Energy.* 2020. Cross-Border Power Supply Lines Between China and Mongolia. 15 June.

cement, basic metals, food, and others, and has an overall energy intensity rate of 275 toe per million dollars of GDP—much higher than the mining sector at 11 toe/$ million (ERIA 2021). The metal and cement industries are the main consumers of coal for kiln heating, and hold large potential for energy savings. For instance, earlier studies have concluded that total coal consumption can be reduced by 40%–45% by replacing cement processing technologies from wet to dry. Other key measures include transitioning from oversized and badly maintained electric motor installations to modern ones, as well as the rehabilitation and modernization of steam systems. Recognizing the importance of energy efficiency, the government has targeted energy conservation as a priority in its State Policy on Energy 2015–2030 (Government of Mongolia 2015b) and Energy Conservation laws, which introduced energy audits and commitments to the cause.

The majority of buildings in the residential sector were constructed between 1970 and 1990, and have had no systematic maintenance or repairs. Poor insulation and inefficient windows have contributed to significant heat losses during the cold winter months. Earlier studies have indicated that heat consumption in Mongolia's urban buildings is about five times higher than in modern systems in Europe. Moreover, the country's rural and herder population lives mostly in *gers* (Mongolia's traditional dwellings) and relies on coal and biomass for heating. Ulaanbaatar *ger* areas have little to no levels of insulation and high ventilation heat losses. They also use highly inefficient traditional stoves. However, the government is actively pursuing the introduction of more efficient residential solutions, as shown by its joint project with the Asian Development Bank (ADB) to build 10,000 new energy efficient homes, and by its aim to reduce heat losses in residential buildings by 40% by 2030 (ADB 2019; GGGI 2019).

Similar challenges also prevail in the Mongolian transportation sector. Specifically, its road transportation is largely outdated, with more than 80% of vehicles over 10 years old. Combined with lower fuel quality standards than in Europe, the old fleet results in low efficiency and high fuel consumption. Penetration of electric vehicles (EVs) into the country's fleet is negligible, with only a few hundred cars and few public charging stations. Mongolia's rail transportation is also outdated, with most of it operating beyond its planned service life, and solely on diesel, as the railway is not electrified.

Regulatory Framework

The Energy Regulatory Commission (ERC) was established in 2001 to govern licenses and tariffs for electricity generation plants (Government of Mongolia 2015a). The National Dispatching Centre was introduced as the only player in energy imports and exports, and in the T&D of electricity. To ensure an inflow of foreign investments, regulatory framework amendments were made in 2015, which provided a more focused approach to independent energy producers by introducing incentive schemes. The Law on Renewable Energy in 2007 was another key development, introducing a clear regulatory framework for renewable energy generation and for the utilization of energy sources (ADB 2013). Generous feed-in tariffs and the establishment of the Renewable Energy Fund have also played important roles. Moving toward best practices in the sector, amendments in 2019 to the Law on Renewable Energy have introduced an auctioning scheme for renewable energy projects, as well as project implementation guarantees from developers (Odsuren and Bold 2019). Another important development is the government's growing focus on energy efficiency, with recent decrees introducing energy audit requirements and incentives for the use of energy efficient products, also expanding the ERC's mandate in energy efficiency rules and regulation.

The legal framework for fossil fuel production in Mongolia allows for broad private sector participation, particularly in coal mining. The Petroleum Law and the Minerals Law govern the exploration and development activities in their respective sectors and clarify their investment criteria (Woolley and Odkhuu 2014). The government has taken action toward preserving its environment after mining operations, developing legislation to ensure environmental rehabilitation measures. Since some energy sector projects are implemented as concessions, broader, economy-wide legislative action—such as the Concession Law and the Investment Law—is relevant in terms of energy infrastructure project development procedures and the protection of investor rights.

Policy Framework

The country has issued several documents for the development of the energy sector, including the Integrated Energy System Program and the Sustainable Energy Strategy. Renewable energy policies and development programs were issued separately. Both the renewable and the conventional generation sectors were addressed in the State Policy on Energy 2015–2030, which has become the most important document for setting a long-term policy framework and establishing a better investment climate for the country (Government of Mongolia 2015b).

Sector priorities in recent energy policy documents have been outlined as follows:

(i) **Security of energy supply amid growing demand.** The government's key priority is the expansion of energy production and generation to provide reliable energy services for consumers. Mongolia also aims to develop mutually beneficial energy trades with neighboring countries to increase exports.

(ii) **Focus on energy efficiency.** The country aims to improve energy efficiency by reducing distribution system losses and heat losses in buildings (up to 40% in 2030), as well as by introducing innovative technologies for energy production (GGGI 2019).

(iii) **Shift toward competitive market.** The introduction of a competitive energy market is stated as one of the key goals for the energy sector. The government already made several steps in this direction through projects with multilateral development banks, which aim at developing a market design and framework to support private sector investments in renewable energy, thereby stimulating a gradual transit from regulated to more market-oriented operations.

(iv) **Reduction of negative environmental impact.** The government has acknowledged Mongolia’s poor environmental record and aims to reduce greenhouse gas (GHG) emissions across the energy sector value chain. At the 26th United Nations Climate Change Conference of the Parties (COP26), the President announced that the country is going to spend at least 1% of its GDP annually to mitigate the adverse effects of climate change and desertification. Initially, the country committed to reducing GHG emissions by 14% until 2030, compared to the base year of 2010. Mongolia submitted an updated nationally determined contribution (NDC) in 2020 before the COP26 in 2021. The target stipulates a 22.7% reduction in total national GHG emissions by 2030 without international support, compared to the projected emissions under a Business-as-usual (BAU) scenario. If carbon capture and storage, as well as waste-to-energy technologies, can be implemented with international support, then Mongolia could reduce total national GHG emissions by 27.2% by 2030. If actions to remove GHG emissions through the carbon-capturing capacity of forests are implemented, in addition to the abovementioned measures, Mongolia could achieve a 44.9% reduction in total national GHG emissions by 2030. To follow the target, the government launched the “One Billion Tree” campaign and committed to plant 600 million trees.

(v) **Realization of renewable energy potential.** Mongolia’s significant renewable resource potential has yet to be realized. To ensure that the country’s future is not locked in carbon-heavy generation methods, the government has introduced ambitious targets (up to 30% of renewable energy capacity in the power mix by 2030) for its future energy sector development. In addition to renewable electricity, the other potential use of green energy is in residential heating, which is currently heavily reliant on coal. Such technologies as geothermal, solar thermal, and heat pumps driven by renewable electricity (mainly solar and wind) could potentially help to decarbonize the residential sector in Mongolia.

Forecast Methodology

One of the objectives of this country study is to present a detailed overview and analysis on future Mongolian energy market trends. For this purpose, three scenarios were developed, considering the country’s regulatory framework, technology assessment, and consumer preferences, among other factors (Box 15). Supply and demand, technology, carbon emissions, and investment outlooks were derived based on these scenarios.

Box 15: Scenarios for Mongolia’s Energy Sector

Business-as-usual scenario: Projected energy supply and demand, with current energy system and policies;

Government Commitments scenario: Projected energy supply and demand, considering individual priorities of the Government of Mongolia; and

Green Growth scenario: Projected energy and supply demand, considering enhanced energy transition and environmental policies.

Source: Roland Berger/ILF.

Supply and Demand Outlook

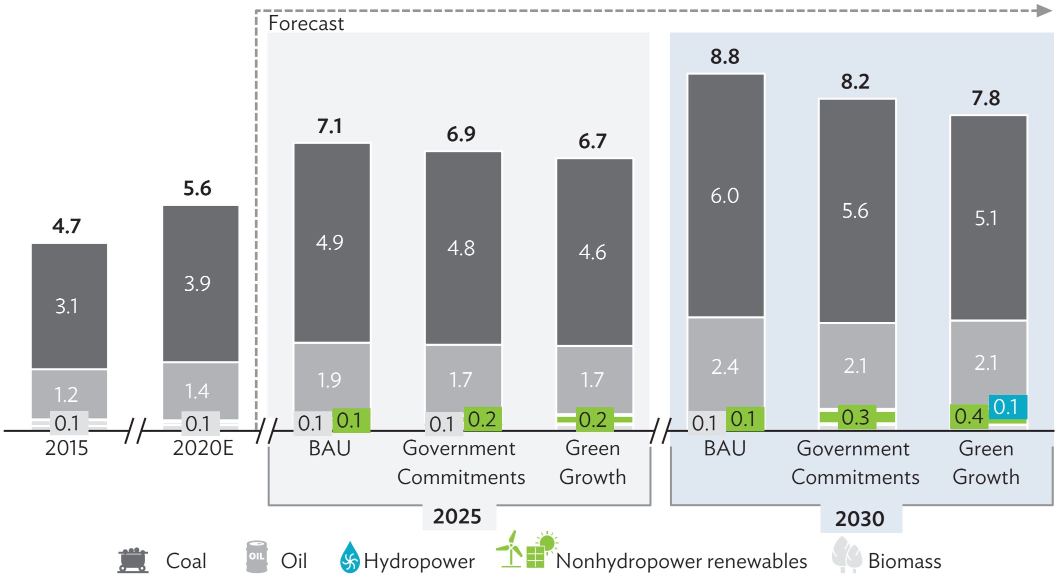
Mongolia's energy sector was significantly impacted by the COVID-19 pandemic, with an estimated 5% decrease in energy demand in 2020 compared to 2019. Nevertheless, demand is projected to increase until 2030, given the country's rapid economic and population growth. The rate of energy supply and demand growth varies across the scenarios. Primary energy supply reached 7.8–8.8 million toe in 2030 compared to 5.6 million toe in 2020. This translates into an annual supply growth rate of 4.1% in the BAU scenario, assuming current energy systems and policies. If Mongolia implements its planned energy sector policies, especially its energy efficiency and heat loss targets (40% reduction of heat losses by 2030), annual primary energy supply growth can be constrained to 3.3%. Under the Green Growth scenario, annual energy supply can be constrained even further, reaching a 2.9% annual growth rate due to more ambitious measures to reduce energy intensity.

Coal is projected to remain the most dominant energy source until 2030 in all scenarios. However, as the country is planning to introduce cleaner sources of energy into the power generation mix, its supply varies between scenarios, with the Green Growth scenario assuming the largest decrease (Figure 60).

The country's development of renewable energy sources for power generation occurs across all three scenarios, with an increasing renewable share in the power mix until 2030. Specifically, the Government Commitments scenario targets 15% share of wind and 11% share of solar energy in the power generation mix by 2030, complemented by 4% of hydropower renewables. Under the BAU scenario, the total

Figure 60: Mongolia—Primary Energy Supply Forecast

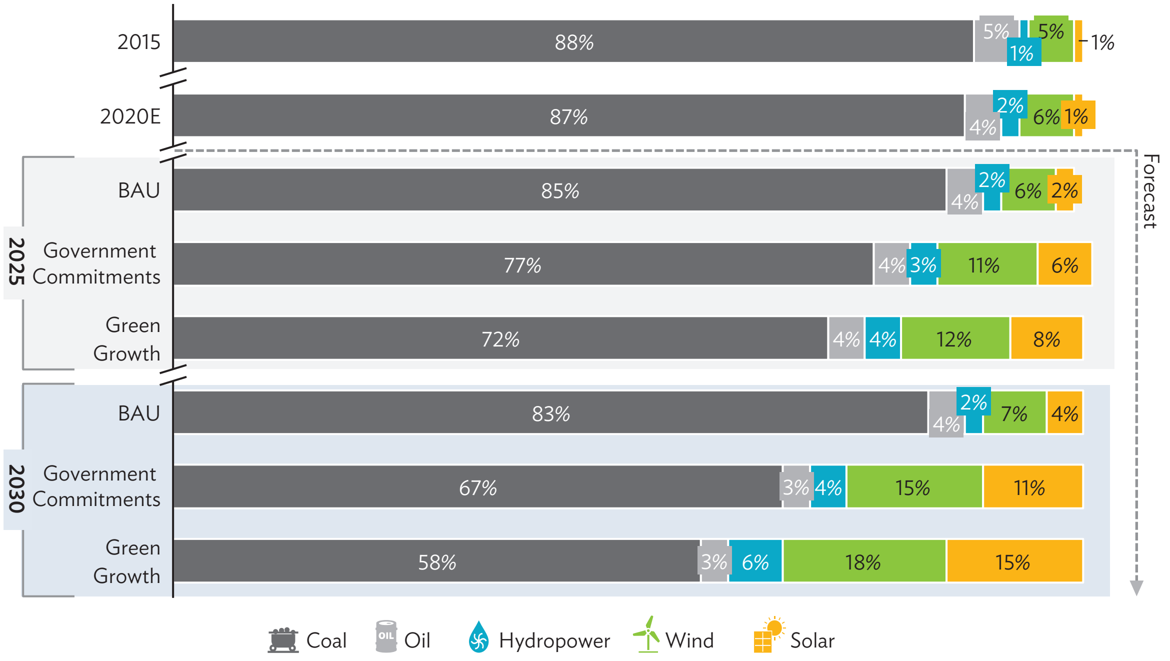
(million tons of oil equivalent)



BAU = Business-as-usual, E = estimate.

Source of historical data: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 16 September 2021). The forecasts are based on the Roland Berger methodology described in the Methodology section.

Figure 61: Mongolia—Power Generation Mix



BAU = Business-as-usual, E = estimate.

Source of historical data: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 16 September 2021). The forecasts are based on the Roland Berger methodology described in the Methodology section.

share of renewable energy generation reaches only 13%. As the Green Growth scenario assumes further development of sustainable energy sources, it leads to a significant expansion of renewable capacity, decreasing coal's share to 58% by 2030, compared to 87% in 2020. Overall, all scenarios assume decreased reliance on thermal power generation (Figure 61).

It is important to clarify that even though the share of coal in the electricity mix is decreasing, both cumulative electricity demand and coal capacity are expected to increase in absolute terms by 2030.

Final energy demand patterns will be influenced by the level of energy efficiency introduced in the generation and consumption segments. Overall, final energy demand levels will range from 5.7 million toe to 6.2 million toe in 2030 compared to 3.9 million toe in 2020.[10] The share of electricity in the energy system is expected to at least double until 2030 compared to 2020, which is attributed to a shift in consumption from fossil fuels to electricity, especially in the services, residential, and industrial sectors. At the same time, demand for oil will increase in all three scenarios due to the rising demand for vehicles. Relative demand for heating will, however, go down because of increased efficiency measures in the residential sector (Figure 62).

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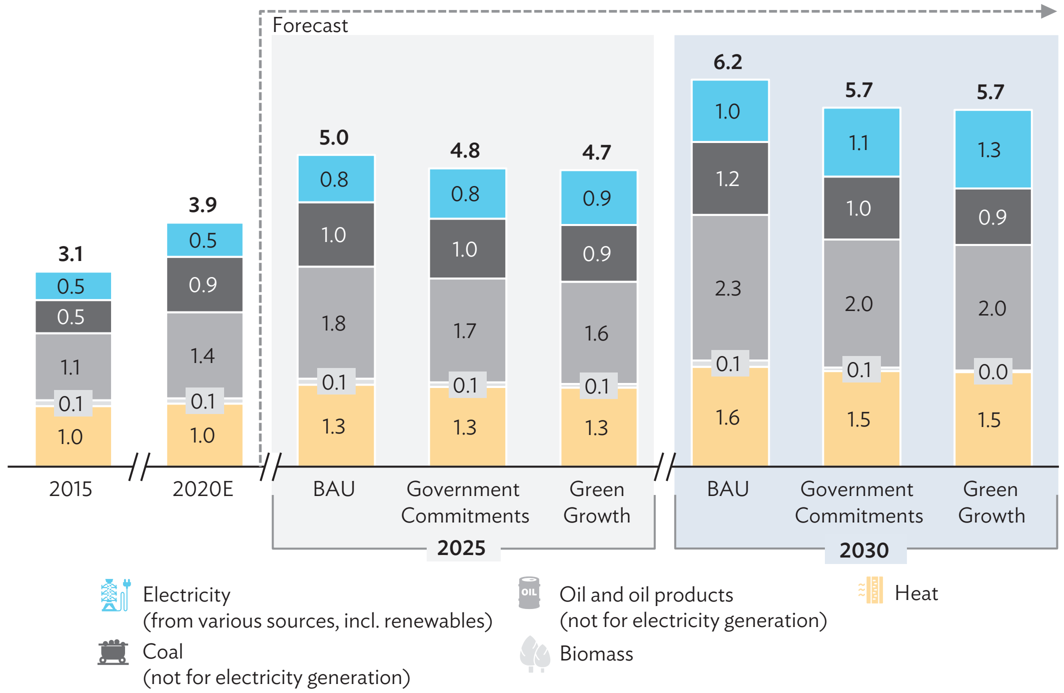
[10] The values for final energy demand in the Government Commitments and Green Growth scenarios are very similar; the difference is not visible due to the rounding effect.

Figure 62: Mongolia—Final Energy Demand Forecast by Fuel

(million tons of oil equivalent)



BAU = Business-as-usual, E = estimate.

Source of historical data: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 16 September 2021). The forecasts are based on the Roland Berger methodology described in the Methodology section.

In terms of end-use sectors, transport sector demand in Mongolia is expected to increase the fastest with a compound annual growth rate between 4.1% and 4.7% until 2030, depending on the scenario. Additionally, industry is expected to grow quickly, with increases of 4.9%–5.8% annually. Extensive energy efficiency measures, assumed in the Green Growth scenario, have the largest impact on the residential sector as efficiency limits increase of demand to 2.1% annually (Figure 63).

Technology Outlook

Priority Technologies: Generation

The selection of priority technologies in power generation is determined by Mongolia's commitments to transition to more sustainable energy generation given its current carbon-intensive energy mix.

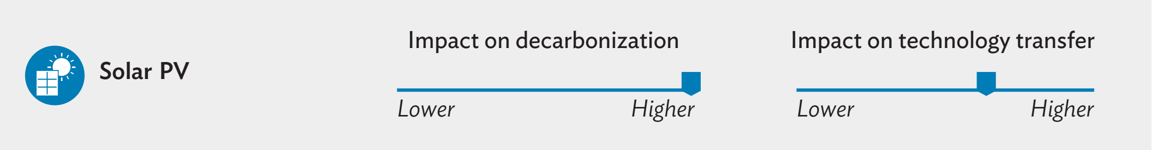
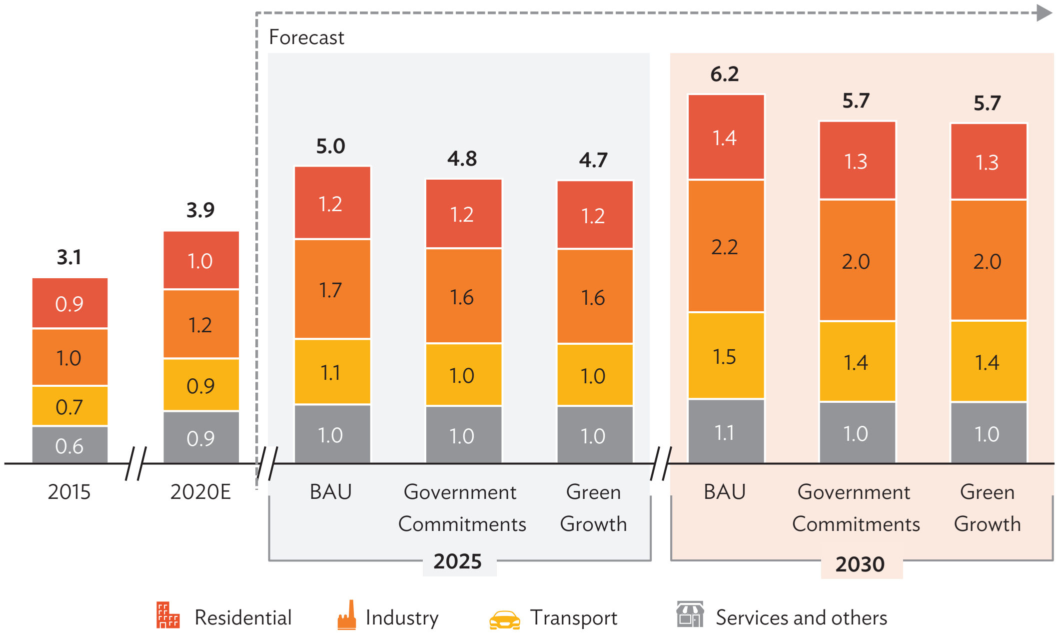


Figure 63: Mongolia—Final Energy Demand Forecast by Sector

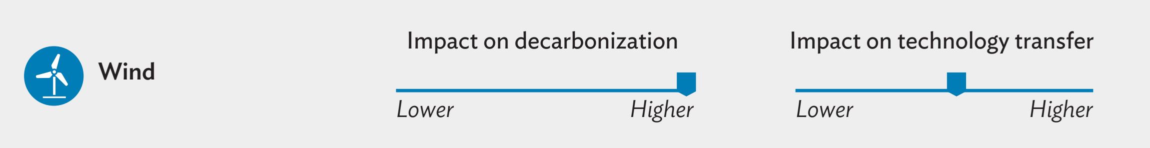
(million tons of oil equivalent)



BAU = Business-as-usual, E = estimate.

Source of historical data: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 16 September 2021). The forecasts are based on the Roland Berger methodology described in the Methodology section.

With more than 270 sunny days annually, Mongolia's solar irradiation is fairly reliable. The country's average daily solar energy potential is 3.4–5.4 kilowatt-hours per square meter (kWh/m^2), which puts its annual generation potential at around 1.5 TW, with the Gobi Desert ranking third highest of the world's deserts in terms of solar generation potential (with an average of 5.4 kWh/m^2 per day). The country has already recognized the potential of this resource, having developed off-grid village solar photovoltaic (PV) systems with an aggregated capacity of more than 1 MW, and having also increased its total installed capacity to 90 MW. To better suit the nomadic lifestyle of a significant part of Mongolia's population, more than 100,000 decentralized solar power generation systems have been provided. The large availability of the resources and the decline in the cost of solar energy will increase Mongolia's attractiveness as a commercial opportunity, including for such larger-scale developments as solar parks. Furthermore, the expansion of solar energy will help the country reach its commitments to decarbonization. The development of solar energy will also have an important effect on technology transfer because of the extensive use of the resource for different projects.

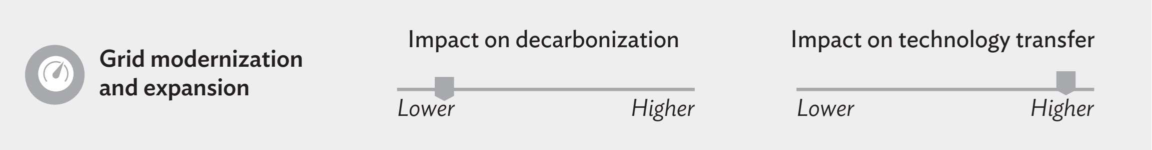


Mongolia is potentially a major wind power producer, with estimated technical capacity of more than 1.1 TW. This is greater than the total installed wind capacity in 2020 globally. However, this potential remains largely unexplored, with only 157 MW of generation capacity installed. With ambitious targets for renewable energy, falling costs for development, and the introduction of renewable energy auctions, Mongolia plans to rapidly attract investment to further harness this resource. Similar to the case of solar PV units, more than 4,000 off-grid wind systems were installed for the nomadic population to use. The potential impact on decarbonization is higher because of the ample availability of wind energy in Mongolia. The development of wind energy projects will contribute to technology transfer, considering the currently limited exploitation of the resource in the country.

The hydropower potential in Mongolia is estimated at around 2.5 GW because of geographic conditions. While the resource is cheap and clean, it is largely untapped, with only 28 MW installed capacity, and no large-scale hydropower projects built. The country had plans to build large-scale projects, and multiple related feasibility studies were conducted, for example, Orkhon hydropower plant (HPP). However, high construction costs, as well as Mongolia's landlocked location and the need to transport equipment across long distances, are among the multiple reasons for the projects' cancellation. Nevertheless, Mongolia is currently embarking on development of the 90 MW Erdenburen HPP in western Mongolia financed by the PRC. While hydropower is a seasonal resource, the development of a large-scale plant will enable usage of its balancing characteristics and could also be used as a peaking plant to help alleviate large fluctuations in day and night demand. Moreover, the introduction of large renewable solar PV and wind power projects may be subject to intermittency, which can be mitigated by the addition of hydropower to the capacity. The development of such projects would help the country to fulfill its targets for renewable energy generation and reduction of carbon emissions.

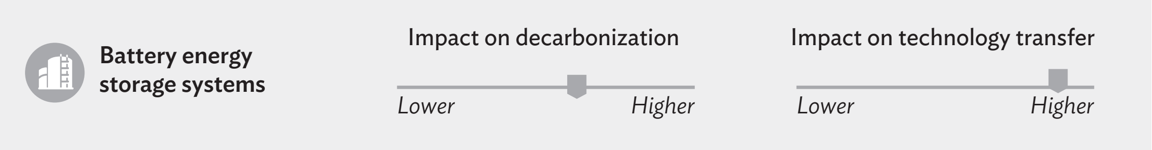
Priority Technologies: Transmission, Distribution, and Storage

Mongolia's T&D systems are split into five different grids, operating with rather high losses. The CES is the most developed, though the country is currently planning to further develop other systems and introduce a more innovative grid and metering infrastructure.



Mongolia's new energy policy has already put in place targets and plans for the development and rehabilitation of the transmission sector. Introducing new renewable energy capacity into the grid would require significant expansions to ensure proper transmission and distribution. An abundance of renewable energy resources in the southern parts of the country would provide challenges for Southern and Eastern

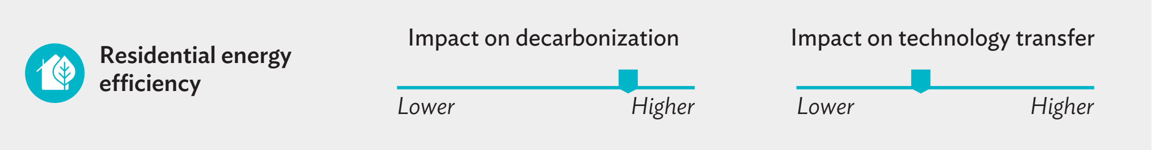
Systems, which can be mitigated through the introduction of a SCADA system. Although SCADA is primarily used in the CES currently, the government is planning to expand the system to other major grids in the country. Moreover, to measure the stress on the system due to increased demand and to manage billing, Mongolia has introduced a wide area monitoring system (WAMS) and advanced metering reading system (AMRS) to the grid. Thus, using innovative smart metering and grid technologies can boost energy efficiency and help manage the increasing demand. Given the novelty of smart grid technologies, the impact of their development on technology transfer will be significant.



Ambitious targets for the expansion of renewable generation through methods including wind and solar power would require the energy system to account for intermittency of the resource. BESS allows for the accumulation of generated power and might act as peaking plants during times where renewables are subjected to intermittency. Mongolia has already received the help of international partners to develop its first large-scale BESS (Box 16). Given that the BESS will be charged solely by renewable energy sources, it will have an important impact on decarbonization efforts in the country. Moreover, because this advanced technology is unique in Mongolia and the surrounding region, its impact on technology transfer will be high.

Priority Technologies: Consumption

In all of Mongolia's consumption sectors, there is significant room for energy efficiency and management improvements. Since the residential sector remains the second biggest energy consuming sector, energy consumption inefficiency in residential sector produces large energy losses.



With the introduction of energy conservation laws, energy audits, incentives for energy-efficient buildings, and the use of more advanced construction materials, Mongolia has made significant steps toward improved energy efficiency in buildings. The government's commitment to energy conservation is demonstrated by further policies that target a 40% reduction in heat losses by 2030. However, extensive rehabilitation efforts and investments are required to improve existing buildings. The introduction of variable flow operations for heating systems, new heat meters, and modern water heating systems are among the planned measures to ensure high energy efficiency in buildings. In addition, as mentioned above, the use of renewable heat technologies can mitigate the carbon footprint of the sector, which is currently largely dependent on coal.

Box 16: Mongolia's Flagship Project

Battery energy storage system (BESS) is a new development project in Ulaanbataar. With a planned capacity of 125 megawatts, it is scheduled for commissioning in 2024. As the first of its kind in the country, it is intended to address demand spikes, and to work in tandem with renewable energy additions to the grid. Financed by the Asian Development Bank, it is expected to release nearly 850 gigawatt-hours of renewable energy annually, and to decrease carbon dioxide energy-related emissions by around 800,000 tons annually.

Note: Illustrative photo of power sector infrastructure is by teerapon/Adobe Stock©.

Sources: *Asian Development Bank* (ADB). 2020. Unlocking Mongolia's Rich Renewable Energy Potential. 2 June; and Government of Mongolia, Ministry of Energy. 2020. *Initial Environmental Examination (Update): First Utility Scale Energy Storage Project in Mongolia* (prepared for ADB).

Carbon Emissions Outlook

Mongolia recently updated its NDC by setting new carbon footprint reduction targets. Whereas the first NDC (submitted in 2016) committed to a 14% reduction of GHG emissions by 2030, this target has now been increased to 23% (Hans et al. 2020; UNFCCC 2020). Moreover, the country has included a conditional target of 27% reductions if it is able to secure external financial support. For energy sector-related emissions,[11] targets correspond to nearly 38 million tons of carbon dioxide (CO_2) equivalent in unconditional commitments and 29 million tons of CO_2 equivalent in conditional commitments (UNFCCC 2020).

Mongolia's carbon emissions outlook shows that the government has set very realistic reduction targets. While the COVID-19 pandemic has impacted the energy sector, reducing emissions by 5%, energy-related emissions are still expected to grow at a steady pace until 2030. Under the BAU scenario, energy-related emissions reach 31 million tons of CO_2 equivalent by 2030, which meets the country's unconditional NDC target. The Government Commitments scenario projects a higher decrease in CO_2 emissions, with approximately 28 million tons of CO_2 equivalent in 2030, which would meet the unconditional target but fall short of the conditional target. The strong shift toward sustainable energy under the Green Growth scenario would allow Mongolia to meet both its conditional and unconditional targets, with 26 million tons of CO_2 equivalent by 2030, an increase of only 8 million tons from 2020 (Figure 64).

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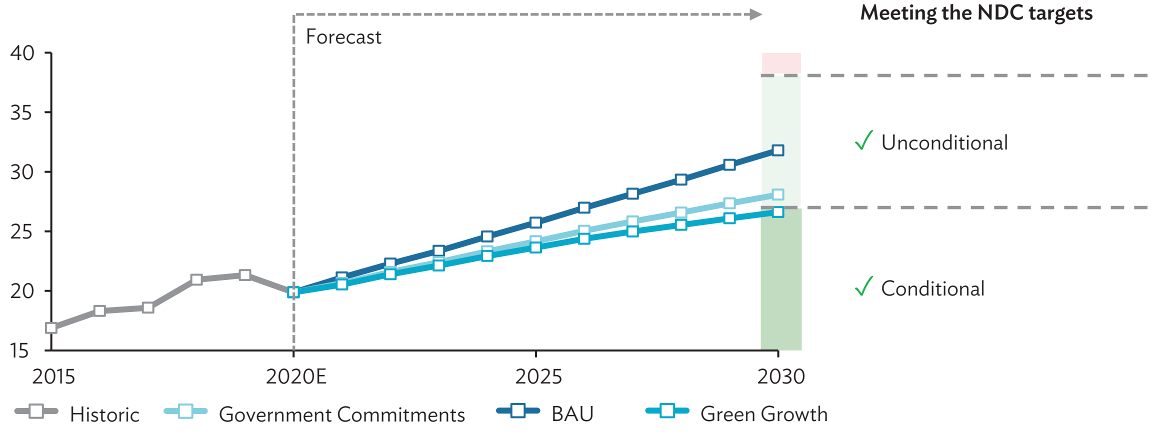
[11] Under the energy sector-related emissions, GHG emissions from generation, transmission, and consumption of energy are considered.

Figure 64: Mongolia—Energy-Related Carbon Emissions
(million tons of carbon dioxide equivalent)



BAU = Business-as-usual, E = estimate, NDC = Nationally Determined Contribution.

Note: Historical data on carbon emissions is modelled by Roland Berger based on historical data on energy use. The forecasts are based on the Roland Berger methodology described in the Methodology section.

Sources: Roland Berger; and United Nations Framework Convention on Climate Change. Nationally Determined Contributions Registry. https://unfccc.int/NDCREG.

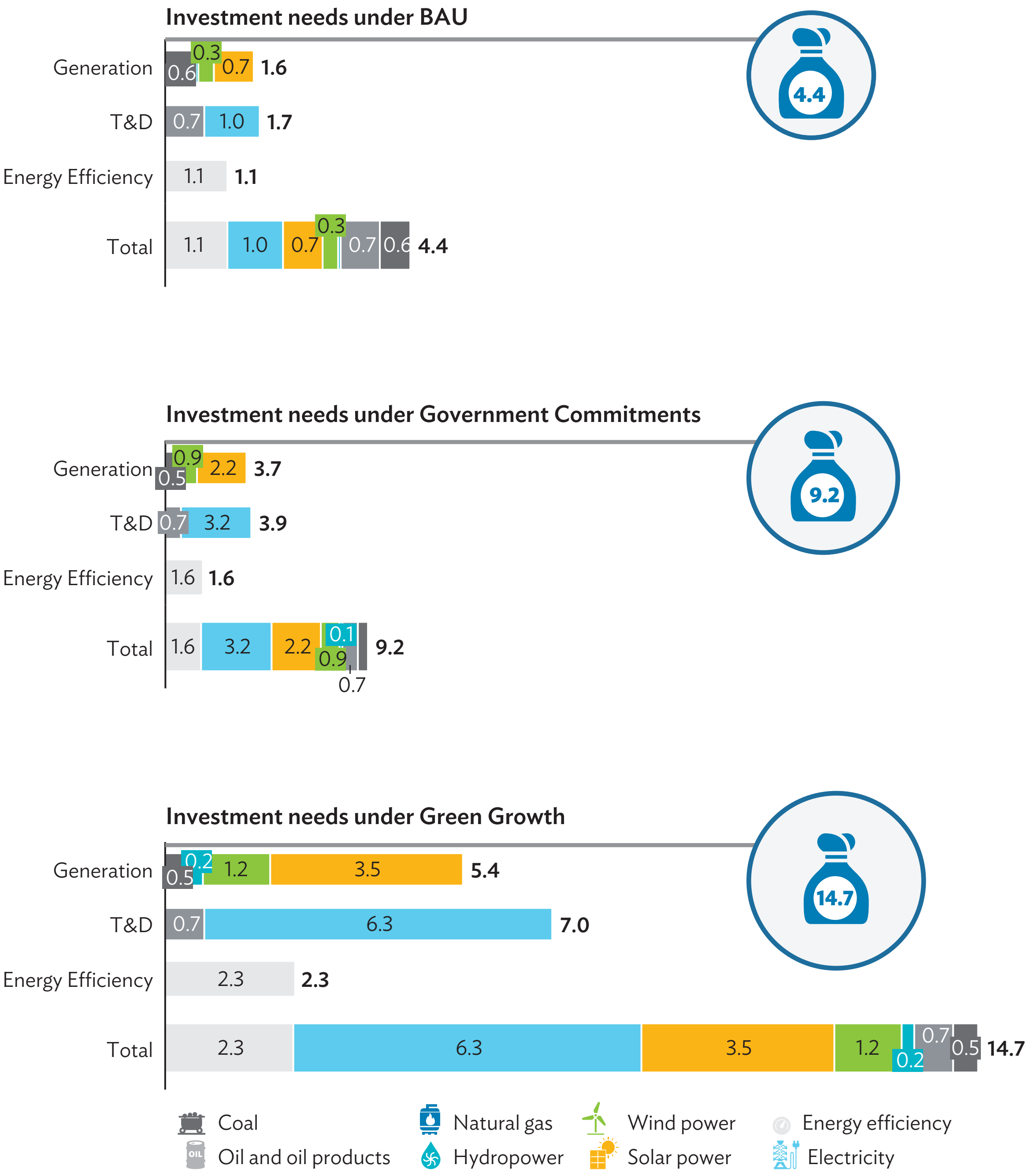
Investment Outlook

Investment Needs

All three scenarios estimate different levels of infrastructure needs in the energy sector until 2030, with $4.4 billion in the BAU scenario, $9.2 billion in the Government Commitments scenario, and $14.7 billion in the Green Growth scenario. All three scenarios assume the rehabilitation and expansion of coal-powered generation, with relatively stable investment needs across all scenarios at $0.5 billion–$0.6 billion. The Government Commitments and Green Growth scenarios, in contrast to BAU, foresee the significant expansion of the country's renewable power generation capacity, with $3.1 billion for the Government Commitments scenario and $4.9 billion for Green Growth. Yet, the largest share of investments is required for the T&D infrastructure, considering ambitious plans to interconnect power systems within the country and enhance its reliability amid a growing share of intermittent renewables. Projected investment needs for the T&D infrastructure range from $1.7 billion to $7.0 billion across the scenarios.

Significant share of investments is required for energy efficiency measures on the demand side, including in the residential, services, industrial, and transport sectors. Related investment needs in the BAU scenario are projected to reach $1.1 billion, while reaching the government's targets and reducing building energy losses would require $1.6 billion in investment. The Green Growth scenario assumes a more significant shift toward sustainable energy consumption, including the roll-out of EV vehicles and related infrastructure, more energy-efficient appliances, and larger refurbishment activities for the current building stock, which brings total investment needs for energy efficiency measures to $2.3 billion (Figure 65).

Figure 65: Energy Infrastructure Investment Needs in Mongolia until 2030
($ billion)



BAU = Business-as-usual, T&D = transmission and distribution.

Source: The forecasts are based on the Roland Berger/ILF methodology described in the Methodology section.

Challenges and Opportunities

Several challenges must be addressed to further unlock the energy market for private companies in Mongolia. The extremely harsh climate conditions of the country and heavy reliance on coal present a difficult situation. Its capital is one of the coldest and most polluted cities in the world. The country's reliance on fossil fuel generation for both heat and electricity increase health and environmental hazards, and introduce further uncertainty for a low-carbon future. As noted above, both renewable electricity and renewable residential heating (geothermal, solar thermal, and heat pumps driven by renewable electricity) could potentially help to decarbonize Mongolia's economy.

The condition of the T&D sectors presents another significant challenge. Largely outdated infrastructure is suffering from underinvestment, thus leading to significant losses in both heat and electricity distribution. Having four separate electricity systems, combined with inadequate demand management, has resulted in a heavy reliance on imports from the Russian Federation. This, combined with Ulaanbaatar's largely outdated heating system, introduces a large investment need. With growing demand, a rapid solution is required to ensure that the grid can meet increased consumption

As 45% of Mongolia's population lives in Ulaanbaatar, improving the condition of the central heating system should be prioritized. At the same time, more than 60% of Ulaanbaatar residents live in portable *gers* (tents), where households predominantly rely on coal-fired stoves for heating. As a result, the country's capital is one of the most polluted cities in the world. To ensure an adequate quality of life, heating systems must be rapidly expanded, and more sustainable alternatives must also be introduced.

The lack of long-term planning for Mongolia's energy sector development is another area for improvement. While policy documents outline the general direction of the country's energy sector, a more comprehensive approach for investment requirements, rehabilitation, and capacity development is required. The country's technological and investment needs should be clearly identified and prioritized. Feasibility assessments of specific projects would provide investors with a clearer vision of the sector.

Nevertheless, the Mongolian energy sector is moving toward increasing opportunities for potential investors. Amendments to the Renewable Energy Law have introduced more innovative practices for investors in the energy sector. The introduction of renewable energy auctions and new requirements for financial guarantees from developers has clarified the investment landscape and increased the likelihood of successful project implementation. Moreover, Mongolia's significant renewable resource potential of 2.6 TW and the government's strong commitment to attaining 30% renewable resources share of total power generating capacity by 2030 signal increased business opportunities to investors. This is particularly important given that the government will lack technical and financial resources to reach this goal without private sector participation.

Mongolia's strong track record of projects with international financial institutions and private investors also increases investment appeal. Large-scale projects have mostly been implemented with the help of foreign investment and have achieved success in the country. The recently commissioned Sainshand Wind Power Plant project with Engie—one of the largest independent power producers globally—has made the Mongolian renewable energy market particularly attractive to foreign investors.

Mongolia's abundant renewable energy resources represent strong potential for long-term investment in the development of "green" hydrogen, which is obtained using renewable energy. Despite its low technological maturity, hydrogen is projected to become an important lever in the energy sector decarbonization and to partially replace fossil fuels in high-temperature processes. Given Mongolia's lack of a natural gas transmission system, transportation presents a potential issue. However, hydrogen could help Mongolia to replace coal consumption in sectors and processes that cannot be easily electrified—particularly in densely populated centers such as Ulaanbaatar, where transportation poses less of a challenge. Moreover, establishing green hydrogen infrastructure could help Mongolia to diversify the structure of its energy exports, with the PRC primed to become a key demand center of clean hydrogen.

As of 2021, no active policies with regard to hydrogen have been put in place. However, some technological studies have been conducted to date and certain policy recommendations were published recently. Particularly, in 2021, the German development organization, GIZ, published analysis on potential policy instruments deploying green hydrogen projects in Mongolia (Nilsson et al. 2021).

The government has already committed to shifting to a competitive energy market before 2030, and to ensuring the privatization of distribution utilities. These commitments open a significant opportunity for future investors and, if implemented, are likely to result in the reduction of the distribution losses and improved quality of energy services.

Policy Recommendations

Mongolia has made significant progress in improving its regulatory and policy framework to create the best possible environment for investment. Several areas for further development are identified as follows:

(i) **Establishing a decarbonization plan to minimize coal power and heating generation.** For a country that currently relies heavily on fossil fuels, the development of a long-term decarbonization plan is crucial to reach sustainability commitments without imperiling the security of supply. While heating is mostly supplied by CHPs, feasibility studies for decarbonization projects, as well as further research on the extent to which alternative modes of heating might benefit long-term health, should be conducted.

(ii) **Ensuring the rapid rehabilitation and extension of the heating sector.** Rehabilitating existing heating infrastructure quickly and efficiently would be the most beneficial way to ensure security of supply. Suburban areas of Ulaanbaatar are dominated by *gers*, which mostly use coal-fired stoves. A combination of efforts is needed to transform heavily polluting *ger* areas into climate-resilient ecodistricts and increase access to green affordable housing.

(iii) **Continuing support for renewable energy projects and achieving policy targets.** The introduction of renewable energy auction mechanism has resulted in greater transparency for investors. While strong government targets for renewable energy generation are present, the country needs to ensure the further enhancement of the legal framework to attract investors.

(iv) **Producing a long-term capacity development action plan.** While a general policy document was produced, a more comprehensive document detailing required investments and projects across all energy sector areas (generation, transmission, distribution) would be beneficial to both the country and to investors.

(v) **Establishing clear energy efficiency targets and ensuring their attainment.** The recent policy document has set a strong target for heat loss reductions and improved energy efficiency in buildings (40% reduction in losses by 2030). However, further progress depends upon improving the legal framework to meet international standards.

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Mongolia's capital and largest city. Ulaanbaatar is the cultural, industrial, and financial heart of the country (photo by Michal/Adobe Stock©).

PAKISTAN

One of the world’s largest dams in Khyber Pakhtunkhwa Province, Pakistan. The dam regulates the flow of the Indus River, resulting in a reservoir called Tarbela Lake (photo by OoziBubble Creations/Adobe Stock©).

Pakistan Highlights

- Total installed power generation capacity in Pakistan is 34.5 gigawatts (GW), and consists mostly of thermal generation, reaching around 66% of the total. The significance of thermal generation is expected to decrease in the future, since the government has set a course to shift toward increasing renewable energy (including hydropower) generation. Pakistan's massive renewable energy potential—about 3.0 terawatts (TW)—is one of the key drivers of this shift (Figure 66).
- Pakistan's domestic energy production consists of oil, natural gas, and coal. However, insufficient investment in exploration and development activities has made the country rely heavily on imports—nearly 40% of its total primary energy supply is imported. Having insufficient cross-border infrastructure and no operating cross-border pipelines for the transit of natural gas and oil, Pakistan imports energy sources mostly via coastal terminals.
- Final energy demand in Pakistan was about 96 million tons of oil equivalent (toe) in 2018, and is projected to reach 108–126 million toe in 2030, depending on the scenario. Natural gas is expected to increase its share in the total energy supply, while reliance on biomass will decrease, leading toward a cleaner future for residential consumers.
- The country has vast renewable energy resources, with total technical potential reaching 2,900 GW for solar, 340 GW for wind, and 60 GW for hydropower (Faizi 2020; UNIDO 2016). Increasing the share of hydropower could help in terms of grid balancing, solving the issue of solar and wind intermittency.
- In addition to the development of renewable energy and alternative sources, such as nuclear power, priority investments in Pakistan include the introduction of smart metering and smart grids, as well as energy efficiency measures.
- Further development of the transmission and distribution (T&D) network is crucial for the country, as 25% of the population is not grid-connected and thus has no access to the electricity network.
- Total investment needs for the energy sector vary significantly across all three scenarios—from $62 billion to $155 billion—illustrating the significant requirements for transitioning to more sustainable sources of energy generation and implementing extensive energy efficiency measures.
- Pakistan's energy sector presents significant investment opportunities because of its efforts to transition to a more competitive energy market structure, its continued support for private projects, and the government's commitment to significantly develop renewable energy sources in the future.
- Several challenges need to be addressed to introduce a more favorable investment climate, including circular debt issues, and the overall condition and coverage of the T&D grid.

Figure 66: Pakistan—Key Figures

Renewable energy	Hydropower	Carbon intensity	Biomass	Grid losses
3.3 TW	**36%**	**95th out of 172**	**37%**	**17%**
Total technical potential of renewable energy resources is estimated at 3.3 TW, including hydropower.	Projected share of hydropower in the power mix in 2030, according to the plans of the government, is 36%.	Pakistan is ranked 95th out of 172 countries in the global ranking of carbon intensity of energy.	37% of final energy demand was provided from biomass use in 2018.	Losses in electricity transmission and distribution network accounted for 17% in 2018.

TW = terawatt.

Sources: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 17 August 2021); National Electric Power Regulatory Authority. 2020. *State of Industry Report 2020.* Islamabad; National Transmission and Despatch Company. 2020. *Indicative Generation Capacity Expansion Plan (IGCEP) 2047: Main Report.* Lahore; and United States Energy Information Administration. Pakistan Data. https://www.eia.gov/international/data/world (accessed 17 August 2021).

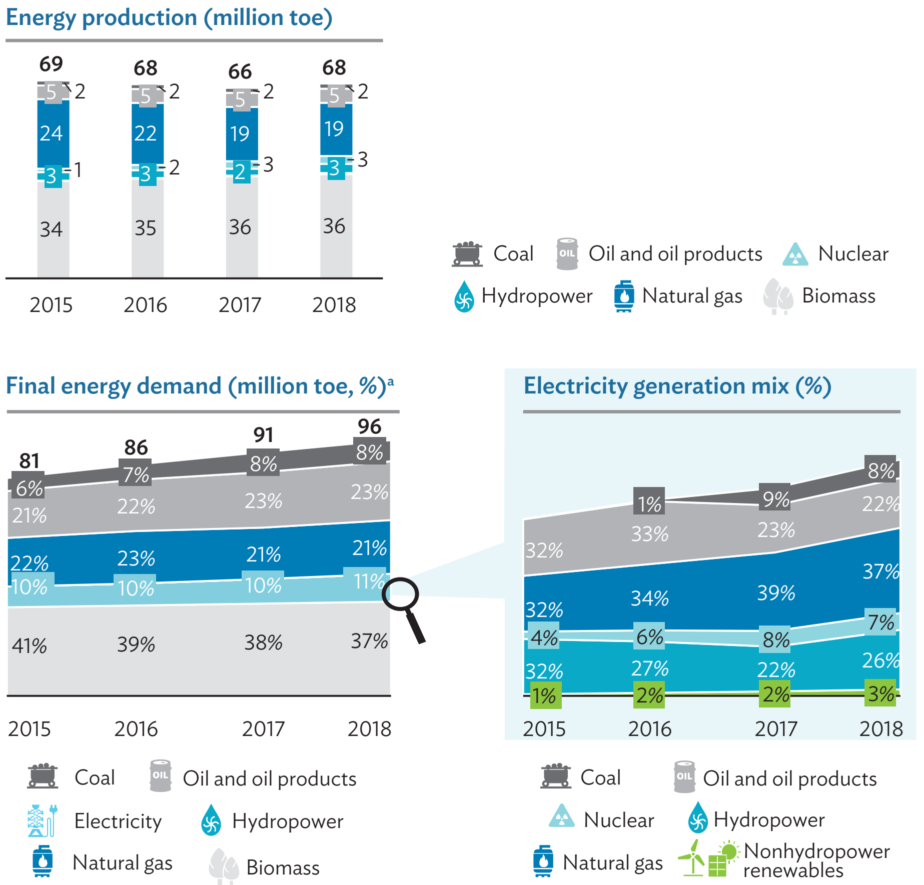
Energy Sector Profile

Country Profile

Pakistan is the world's fifth most populous country, with a population of more than 225 million people and a $264 billion nominal gross domestic product (GDP), as of 2020. Pakistan's population and economy have grown at a steady pace, with the GDP growing annually by 4%–6%, and the population by 2%, since 2015. While the coronavirus disease (COVID-19) pandemic has slowed down economic growth to 0.5% in 2020, Pakistan is expected to recover, with a projected economic annual growth rate of nearly 6% until 2025.

Pakistan's energy sector is highly dependent on fossil fuel imports. Due to insufficient exploration and development activities, the country is a major importer of fossil fuels, such as oil and coal. Moreover, issues with ever-increasing demand and an inability to meet needs with existing power generation capacities have forced consumers to use biomass as means of cooking and heating, especially in the agriculture sector, which makes up most of the GDP. On the other hand, being one of the largest countries in the region, Pakistan has vast renewable resources, such as hydropower, solar photovoltaic (PV), and wind, as well as experience in power generation from nuclear power. However, the share of electricity production from renewables has been decreasing since 2015, with fossil-fuel based generation on an upward trend in development (Figure 67). This has led to increases in carbon intensity, putting Pakistan in 95th position out of 172 countries in 2018. Energy efficiency measures in Pakistan require further development and implementation. The country was ranked the 87th most energy-intensive economy in the world in 2018.

Figure 67: Energy Profile of Pakistan



toe = ton of oil equivalent.

[a] Topmost numbers on the chart are in million toe.

Source: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 17 August 2021).

Energy Sector and Technologies Assessment

Conventional Fuel Production

Pakistan's domestic energy production consists of oil, natural gas, and coal. The country also has significant undeveloped oil and gas potential. However, insufficient investment in exploration and development activities due to pricing policies has limited Pakistan's ability to achieve security of supply through domestic energy production.

Domestic oil production in the country amounted to around 4 million tons in 2019, while total import volume was more than 10 million tons. The main production sites are located in Punjab and Sindh provinces. The country is also planning to expand its refinery capacities to meet growing demand, with a target capacity of 48 million tons per year by 2030. In 2019, total natural gas production stood at 33 billion cubic meters (bcm), slightly lower than domestic demand. The Sui Gas field is the largest natural gas field in Pakistan, accounting for 10% of total domestic production (Pakistan Petroleum Limited). However, major oil and natural gas fields in the country are in the later stages of their lifecycle, with gradually declining production volumes.

Coal in Pakistan is mainly produced in Balochistan, Punjab, and Sindh provinces. While production was only 3.3 million tons in 2015, the country expanded its production to nearly 6.8 million tons in 2019. However, the country still imported approximately 15 million tons of coal to satisfy demand. Overall, coal resources in Pakistan are estimated at more than 3 billion tons.

Electricity Generation

Pakistan's electricity sector has a total installed capacity of 34.5 GW, with thermal generation dominating the power mix, having a share of 66% (National Transmission and Despatch Company 2020). Gas-fired plants are the main source of power, having an installed capacity of almost 9.3 GW, while oil-fired power plants have 6.5 GW installed capacity and coal-fired plants have 4.6 GW. Since the regulatory framework allowed independent power producers to develop generation projects, multiple new thermal power plants were constructed. As the country's oil and natural gas reserves are diminishing, further growth in alternative energy sources is needed.

Historically, hydropower was one of the main sources of electricity generation in Pakistan. The total hydropower resource potential is estimated at 60 GW (Faizi 2020). However, with the expansion of thermal power, its share in electricity has declined significantly and currently holds a 29% share of total installed capacity. The country has 30 hydropower plants in operation, with a total installed capacity of 9.9 GW, including 17 categorized as major hydropower and 13 as small hydropower units operating mainly as a run-of-river units. The three main projects are Tarbela Dam (4.8 GW installed capacity), Ghazi–Barotha (1.4 GW), and Mangla Dam (1.1 GW). Tarbela and Mangla dams, commissioned in the 1970s, are considered the main contributors to hydropower generation. To enhance the quality and reliability of supply, Mangla Dam is planned for refurbishment, and Tarbela Dam for extension.

Pakistan's first nuclear power plant, Karachi Nuclear Power Plant (KANUPP), began operations in 1970, with a capacity of 100 megawatts (MW). Since then, nuclear power generation has experienced active growth, and current capacity is 2.5 GW. Cross-country cooperation is a cornerstone of Pakistan's strategy to reach its goal of 8,800 MW of nuclear installed capacity by 2030. Currently, one new reactor of 1,100 MW is being built.

The country's renewable energy potential has been realized to only a limited extent. The theoretical potential of total wind energy is estimated at 340 GW, with the southern wind corridors being the most auspicious—the Gharo–Keti Bandar wind corridor has over 50 GW of potential alone. However, only around 1.1 GW of wind energy capacity is currently in operation. Likewise, solar power has tremendous potential—as high as 2,900 GW, only about 0.4 GW of which is installed as of 2021. Although projects such as the Quaid-e-Azam Solar Park (0.4 GW capacity) were successfully implemented, the lack of political commitment, land availability, and the lower performance of outdated PV plants installed earlier are among the reasons for limited development of renewable energy. Additional potential solutions include offshore wind, floating solar PV in existing hydropower reservoirs, and wind farms near hydropower plants with integration into existing grid infrastructure.

Power generation during fiscal year 2020 reached 121,691 GWh: 32% by hydroelectric plants, 57% by thermal plants, 8% by nuclear plants, and 3% by renewable energy power plants.

Transmission and Distribution

Pakistan's power T&D system is suffering from significant energy losses and disruptions. In 2020, 19.8% of energy was lost during its transmission, distribution, and delivery to end consumers. Among the 10 distribution companies, losses vary greatly from 9% to 39% (NEPRA 2020). On average, the country experienced 81 interruptions (system average interruption frequency index) lasting nearly 5,300 minutes (system average interruption duration index) in 2020. The poor performance can be attributed to a variety of factors, including poor technical conditions, insufficient collection rate of accounts receivable, and issues with circular debt present in the country.

Pakistan had 7,470 kilometers (km) of 500 kilovolts (kV) and 11,281 km of 220 kV T&D lines in 2020. Distribution companies are responsible for T&D activities below 132 kV. Importantly, only 74% of Pakistan's population is connected to the power grid. With high electricity losses and frequent outages, Pakistan is planning to introduce advanced grid management infrastructure and metering. Advanced conductors and other smart grid upgrades could help reduce T&D losses.

There are two operators in Pakistan's natural gas T&D system: Sui Northern Gas Pipelines Limited (SNGPL), covering the central and northern regions of the country; and Sui Southern Gas Company Limited (SSGCL), covering the southern regions. Total grid losses accounted for nearly 17% by SSGCL and 11% by SNGPL in 2020. According to estimates, average leakage rate is 4.9 leaks per km for SSGCL, and 2.2 leaks per km for SNGPL (for comparison, this value equals 0.2 in Germany and 0.4 in Massachusetts, on average). The gas pipeline systems require a major overhaul and modernization to increase the efficiency of transportation and to reduce leakages.

Cross-Border Infrastructure

In terms of cross-border power interconnections, Pakistan has one operational line as of 2021: Mand–Jakigur, connecting Pakistan and Iran, with a capacity of 104 MW. In addition, Pakistan, Afghanistan, the Kyrgyz Republic, and Tajikistan, have launched the Central Asia–South Asia (CASA-1000) project, a mega power interconnection project of 1,300 MW. Pakistan's part of CASA-1000 is currently under construction, and is expected to transport electricity from Tajikistan and the Kyrgyz Republic. The uncertain political situation in Afghanistan, through which CASA-1000 will transit to reach Pakistan, has rendered difficult any predictions as to when and if the project can be successfully commissioned.

Natural gas is imported via sea terminals, mainly through two terminals located in the Qasim and Karachi ports, with a cumulative capacity of 12 bcm annually. As of 2021, there are no operating cross-border natural gas pipelines in Pakistan. However, in response to growing demand, the government has been planning the construction of natural gas pipelines to increase import capacity, with the Iran–Pakistan pipeline expected to be commissioned by 2025. The Turkmenistan–Afghanistan–Pakistan–India (TAPI) pipeline has been discussed since more than a decade, but its realization remains uncertain given the situation in Afghanistan and other political tensions between the participating countries. Further efforts to bridge the supply and demand gap are planned with the construction of two additional terminals, bringing total import capacity to nearly 18 bcm per annum.

Table 6: Pakistan—Major Cross-Border Energy Infrastructure

Energy Source	Name	Capacity	Status	Connected Country
⚡	Mand–Jakigur	104 MW	Operational	Iran
⚡	CASA-1000	1,300 MW	Planned	Afghanistan, Kyrgyz Republic, Tajikistan
🔥	Turkmenistan–Afghanistan–Pakistan–India Pipeline	13 bcma (Pakistan's share)	Current status and future project delivery uncertain	Afghanistan, India, Turkmenistan
🔥	Iran–Pakistan Gas Pipeline	40 bcma	Planned (2025)	Iran
🔥	Port Qasim	6 bcma	Operational	Worldwide
OIL	Port Karachi	6 bcma	Operational	Worldwide
OIL	Port Qasim	13 mtpa	Operational	Worldwide
OIL	Port Karachi	24 mtpa	Operational	Worldwide
OIL	Balochistan	14 mtpa	Operational	Worldwide

⚡ Electricity 🔥 Natural gas OIL Oil

bcma = billion cubic meters per annum, CASA = Central Asia–South Asia, mtpa = million tons per annum, MW = megawatt.

Sources: Fitch Solutions. 2020. *Pakistan Oil & Gas Report*. London; Fitch Solutions. 2020. *Pakistan Power Report*. London; and Government of Pakistan, Ministry of Energy (Petroleum Division). 2020. *Development Plan for Pakistan Oil and Gas Industry 2020*. Islamabad.

Oil is also currently imported via sea terminals. Oil terminals (the Karachi port, the Qasim port, and the Balochistan refinery single-point mooring terminal) are located near Karachi and have a total import capacity of 51 million tons per year (Table 6).

Energy Consumption

Pakistan's industry is dominated mostly by small and medium-sized enterprises in sectors such as leather, textiles, and food processing. Most entities use fossil fuels as feedstock and run on outdated and inefficient equipment. Cement and brick industries in Pakistan have historically been the two main energy consumer groups. The combined potential of energy efficiency measures for these industries represents about 40% of the total industry energy savings potential. Key levers include switching to multistage dry kilns for cement or the introduction of modern designs, such as zig-zagging for brick kilns. The National Energy Efficiency and Conservation Authority (NEECA) has been a main driver of progress, having recently implemented a mandatory energy efficiency policy for electric motors, showing the government's commitment to increasing energy savings. The NEECA also plays a prominent role in promoting energy audits in various industrial sectors. As a result of these efforts, Pakistan's energy intensity declined from 5.1 megajoules (MJ) per dollar of GDP in 2007 to 4.4 MJ per dollar of GDP in 2015. Despite these developments, the institutional framework for energy efficiency requires significant further development to achieve higher levels of efficiency across the board.

Energy efficiency measures in Pakistan often require region-specific optimization, especially in building structures (for example, buildings in southern parts require more cooling than heating). One of the key challenges is the inadequate energy performance standards of the Building Energy Code of Pakistan. The Code focuses mainly on efficiency in commercial buildings, which was last updated in 2011, and failed to introduce modern efficiency standards. For instance, the measures that might have the largest impact in terms of energy savings include building envelope insulation and efficient lighting. Some efforts to improve consumption efficiency can, however, already be observed—for example, the distribution of free compact fluorescent lamps to replace inefficient incandescent bulbs and promote more energy-efficient solutions for artificial lighting.

While the transport sector plays a leading role in the country's economic activity, it is also the biggest contributor to air pollution, with the transport sector making up more than 40% of total emissions. Importantly, Pakistan has been experiencing a rapid growth in the number of vehicles in use, as the share of households owning a car increased from 6% to 9% in 2021. Recognizing challenges related to imports of oil products, the government actively promotes the use of electric vehicles (EVs). For instance, the recently approved National Electric Vehicle Policy introduced tax incentives for imports and production, and also set ambitious EV targets for 2030 (30% of newly sold cars and trucks, and 50% of buses and two- and three-wheelers, to be EVs). In terms of railway transport, Pakistan relies solely on diesel locomotives as of 2021—the country used to have 16 electric locomotives in the early 2000s, but the government closed the lines and stopped using them after frequent copper theft incidents at different points along the tracks. Still, Pakistan has continued efforts to improve efficiency by replacing old locomotives, leading to substantial energy savings of 3.5 million liters of diesel in 2019.

Regulatory Framework

Upon obtaining independence in 1947, Pakistan introduced several authorities to regulate the energy market (Government of Pakistan 1958). The Water and Power Development Authority (WAPDA), which served as a key player in the power sector, was unbundled in the 1990s to ensure the establishment of a liberalized energy market and fair competition. As a consequence, both private operators and state-owned enterprises became eligible to participate in the generation sector via a single-buyer scheme. The Generation, Transmission and Distribution of Electric Power Act has introduced a newly established independent authority: the National Electricity and Power Regulatory Authority (NEPRA), which regulates power sector companies and sets tariffs and operational standards. One of the key laws on energy efficiency, the National Energy Efficiency and Conservation Act, established a National Energy Efficiency and Conservation Authority, with a mandate to set the strategic direction and national standards for energy efficiency measures (The Gazette of Pakistan 2016).

Two authorities, the Private Power and Infrastructure Board (PPIB) and the Alternative Energy Development Board (AEDB), were established as the main institutions, providing support to private energy project developers as well as investors (Government of Pakistan, AEDB 2006; The Gazette of

Pakistan 2012). Each board has been established for specific projects: the PPIB was created and tasked to approve conventional generation projects, while the AEDB was responsible for the approval of renewable energy projects.

Fossil fuel production in Pakistan is regulated by a set of rules for oil, natural gas, and coal, which govern the process of obtaining permission for the exploration and production of fossil fuels. The Oil and Gas Regulatory Authority (OGRA) is a primary regulator of the market and licensing authority. The Authority issues licenses for coal, oil, and natural gas through a competitive bidding process. Coal and petroleum development and production licenses are given for 25 years, with the possibility of renewal for 5 years.

With increasing market transparency and private sector participation in energy projects leading to growing investments, the country has introduced a general concept for a competitive electricity market. These new rules, already published by NEPRA and coming into force in 2022, are regulating the transfer from a single-buyer model to a competitive model in the wholesale segment (Khan 2020).

The natural gas market, in contrast, is still operating under the single-buyer scheme, and a competitive market for natural gas supply is yet to be introduced, as state-owned utilities act as single monopolies.

Policy Framework

Several governmental decrees have set the policy framework for the energy sector. The main government priorities in power generation were outlined in the Power Generation Policy and Transmission Line Policy in 2015 (Government of Pakistan, PPIB 2015). The priorities for renewable energy were set in 2019 in the Alternative and Renewable Energy Policy (Government of Pakistan 2019). The government has also published a National Energy Conservation Policy to promote the use of domestically available resources.

The following priorities were outlined in the abovementioned policy documents:

(i) **Development of renewable energy.** With the established target for renewable energy generation in the electricity mix (up to 30% of nonhydropower renewables and 30% of hydropower by 2030), Pakistan aims to attract more investment into its renewables sector (Qasim 2020). The government has already started facilitating investments in sustainable energy sources, mainly by encouraging lower tariffs via introducing competitive bidding and offering tax benefits as well as incentives for local production of renewable energy equipment, such as solar panels and wind turbines.

(ii) **Improvement in energy efficiency.** Pakistan aims to increase the energy sector's profitability and sustainability by reducing energy losses as well as increasing energy efficiency. Specifically, to realize the country's considerable energy-saving potential of, on average, 25% in key sectors (industry, residential, transport, and agriculture), the NEECA will be implementing a number of policies: developing necessary regulations, introducing the national scheme for certified energy auditors, establishing national Energy Efficiency awards, etc.

(iii) **Introduction of a competitive energy market.** As stated in the country's Power Generation Policy, Pakistan aims to provide sufficient power generation capacity and high-quality energy services at the least cost. The country plans to achieve that by enhancing fair competition and market liberalization. In 2020, NEPRA approved a detailed framework and implementation plan for a competitive trading bilateral contract market, the main goal of which is to establish the competitive wholesale electricity market with multiple sellers and buyers by 2022.

(iv) **Promotion of domestic exploration and production of oil and natural gas resources.** Through optimized pricing and licensing mechanisms, Pakistan wants to further develop its domestic production of fossil fuels to become more self-reliant and reduce its dependence on imports (the share of imports constituted around 40% of the total primary supply in 2018).

Forecast Methodology

One of the objectives of this country study is to present a detailed overview and analysis of future energy market trends in Pakistan. For this purpose, three scenarios were developed, considering the country's regulatory framework, technological development, and consumer preferences, among other factors (Box 17). Supply and demand, technology, carbon emissions, and investment outlooks were derived based on these scenarios.

Box 17: Scenarios for Pakistan's Energy Sector

Business-as-usual scenario: Projected energy supply and demand, with current energy system and policies;

Government Commitments scenario: Projected energy supply and demand, considering individual priorities of the Government of Pakistan; and

Green Growth scenario: Projected energy supply and demand, considering enhanced energy transition and environmental policies.

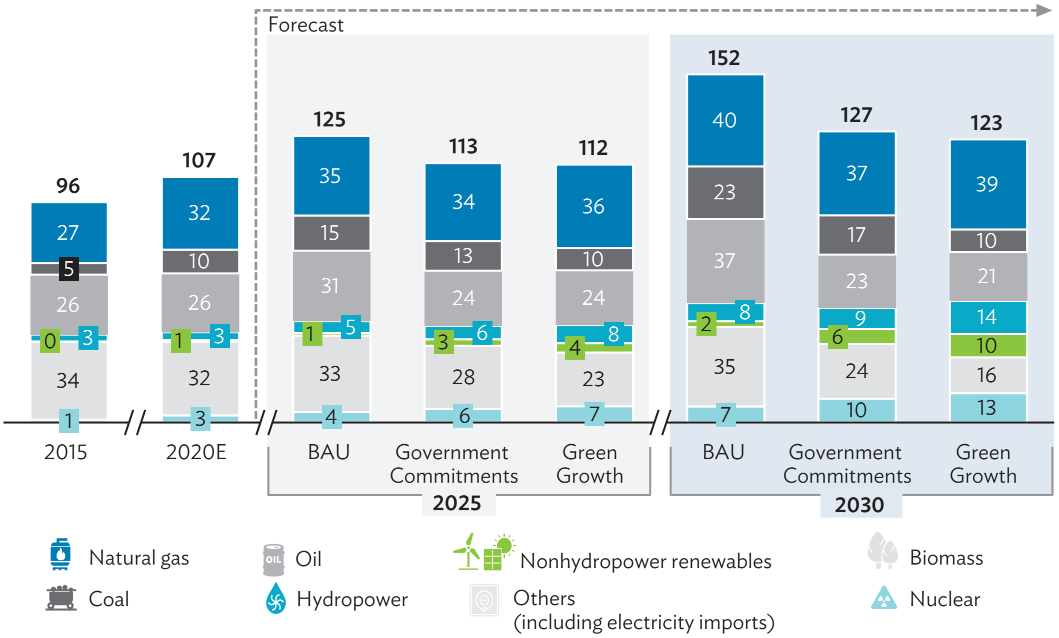
Source: Roland Berger/ILF.

Supply and Demand Outlook

Rapid economic development and population growth in Pakistan are the main drivers for growth in primary demand, which is projected to increase from 111 million toe in 2018 to 125–154 million toe in 2030, depending on the scenario. Demand has fallen during the COVID-19 pandemic, with nearly a 4% decrease from 2019 to 2020, although rapid recovery and growth in demand is expected. In the Business-as-usual (BAU) scenario, primary energy demand grows significantly at an annual rate of 3.1%, as this scenario assumes low to moderate efficiency gains and limited reductions of T&D losses. As for the Government Commitments scenario, annual growth is lower, at 1.4%, due to higher efficiency gains and lower grid losses. The Green Growth scenario shows the lowest compound annual growth rate among the three scenarios, with only 1.2% growth until 2030, assuming the greatest reduction of energy intensity (Figure 68).

In terms of energy sources, natural gas remains the most important energy resource in all three scenarios, driven by the country's large fleet of gas vehicles, and by direct consumption in the residential and industrial sectors.

Figure 68: Pakistan—Primary Energy Supply Forecast
(million tons of oil equivalent)



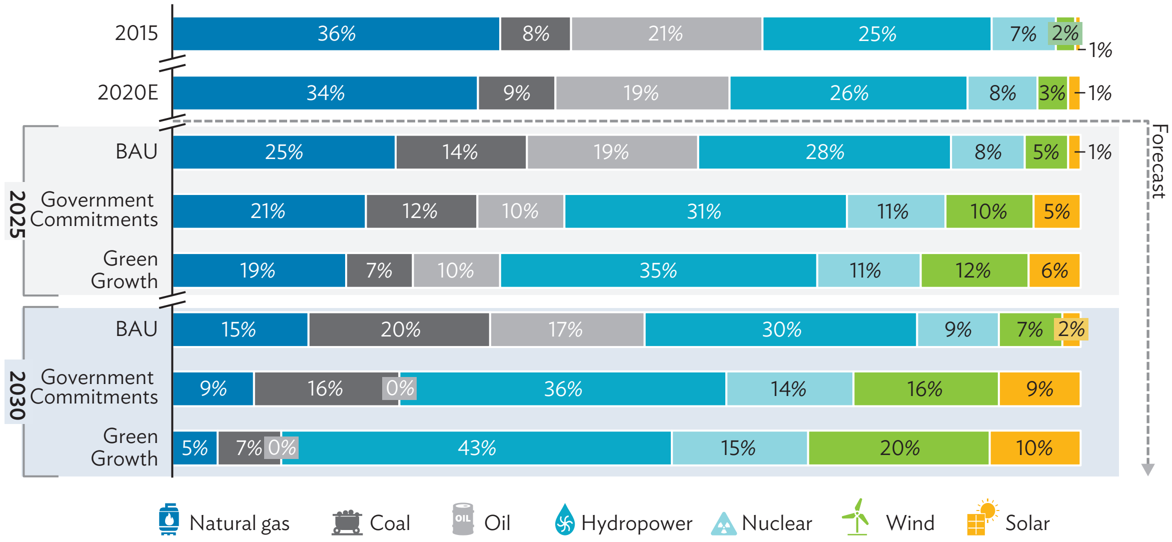
BAU = Business-as-usual, E = estimate.

Source of historical data: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 17 August 2021). The forecasts are based on the Roland Berger methodology described in the Methodology section.

Electricity generation in Pakistan is mainly dominated by fossil fuel sources, specifically natural gas and oil. Alternative energy sources in Pakistan consist mainly of hydropower and nuclear, while the share of wind and solar PV is much lower. The Government Commitments scenario assumes a large share of renewables in the mix, followed by a decrease in fossil fuel-generated power. The BAU scenario assumes a slower expansion of renewable resource generation, leading to prolonged reliance on fossil fuels in 2030. In both Government Commitments and Green Growth scenarios, many natural gas- and oil-fired power plants are decommissioned, and their capacities are replaced by renewable energy.

Nonetheless, a shift toward renewables is evident in all scenarios via the expansion of hydropower capacities and the further expansion of wind- and solar-powered plants. The Green Growth scenario assumes the most ambitious development of nonhydropower renewables, leading to a 20% share of wind and a 10% share of solar PV in 2030. Under the Government Commitments scenario, the share of wind reaches 16% and solar PV is 9%, compared to much slower developments under the BAU scenario, where wind energy reaches 7% and solar PV only 2%. Furthermore, reflecting a broad push toward the development of hydropower, the expansion of hydropower capacity is assumed in all scenarios, with the highest being in the Green Growth scenario (43% of the total generation mix) (Figure 69).

Figure 69: Pakistan—Power Generation Mix



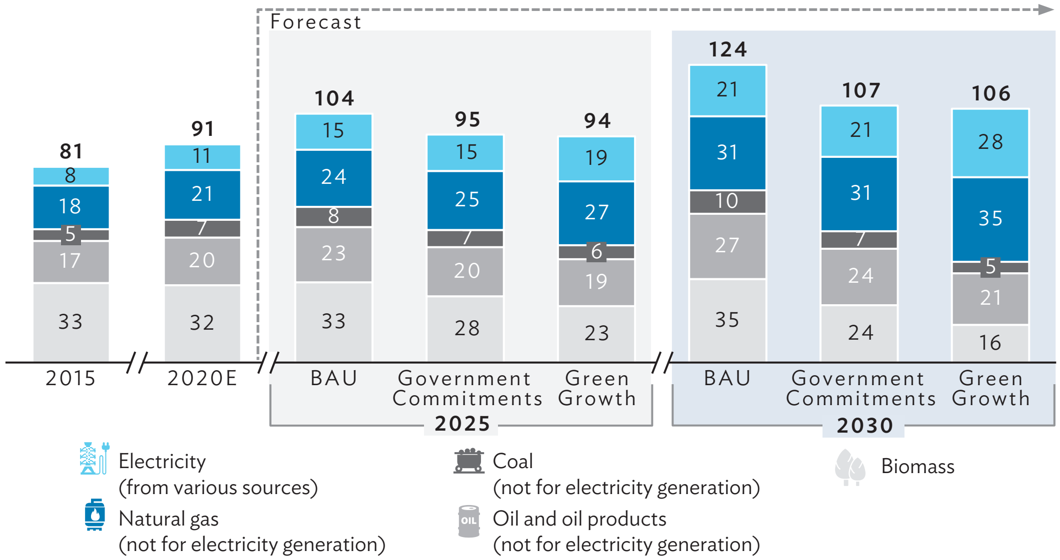
BAU = Business-as-usual, E = estimate.

Source of historical data: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 17 August 2021). The forecasts are based on the Roland Berger methodology described in the Methodology section.

Energy efficiency measures and reductions in grid losses have a direct impact on reducing final energy demand, with variation between scenarios. Final energy demand in 2030 ranges significantly, from 126 million toe to 108 million toe. All scenarios assume a rapid growth of natural gas because of significant development in the transportation sector and the high share of gas-powered vehicles. Coal consumption is only projected to grow in the BAU scenario, while the Government Commitments scenario assumes stable consumption, and the Green Growth scenario projects a decline. The role of electricity becomes even more prominent in all scenarios, as consumption shifts from biomass to electricity, thus reducing health hazards for consumers and leading to a lower carbon footprint. Biomass consumption falls drastically in all three scenarios, with mostly electricity and natural gas replacing it (Figure 70).

Transport demonstrates the fastest growth across economic sectors, increasing at an average annual growth rate of between 2.6% and 3.3% until 2030, depending on the scenario. The residential sector shows demand increase in all three scenarios, with the BAU scenario projecting an annual growth rate of 2.9%; the Government Commitments scenario, 1.4%; and the Green Growth scenario, 1.2%. Industry demand is growing between 0.1% and 2.1%, with the Green Growth scenario projecting the slowest growth (Figure 71).

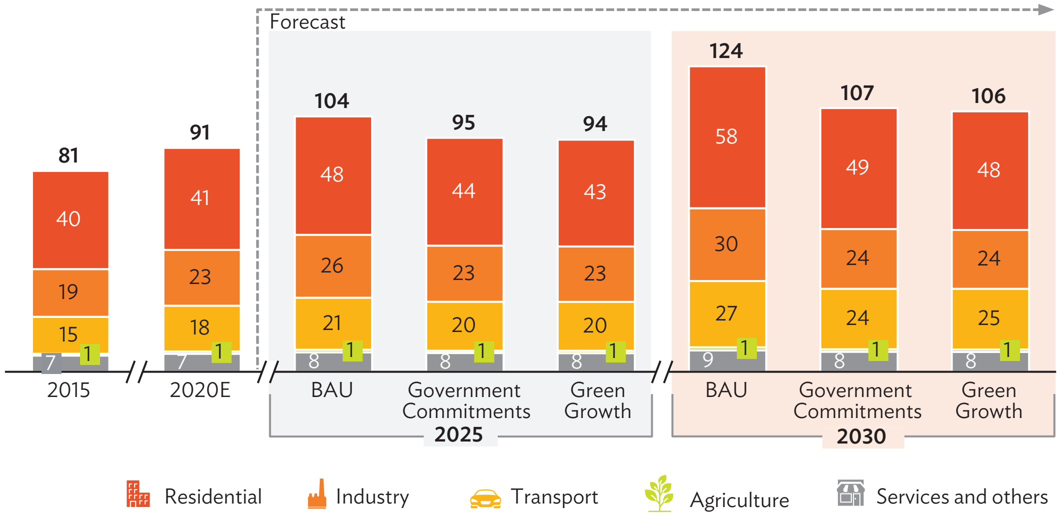
Figure 70: Pakistan—Final Energy Demand Forecast by Fuel
(million tons of oil equivalent)



BAU = Business-as-usual, E = estimate.

Source of historical data: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 17 August 2021). The forecasts are based on the Roland Berger methodology described in the Methodology section.

Figure 71: Pakistan—Final Energy Demand Forecast by Sector
(million tons of oil equivalent)



BAU = Business-as-usual, E = estimate.

Source of historical data: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 17 August 2021). The forecasts are based on the Roland Berger methodology described in the Methodology section.

Technology Outlook

Priority Technologies: Generation

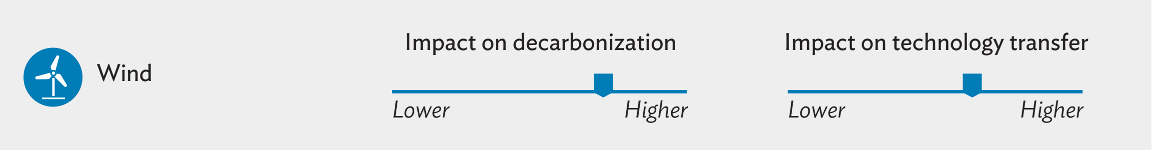
The following priority technologies in power generation are crucial for Pakistan, due to its reliance on fossil fuels in the generation mix and the government's priorities for further energy sector development.

Hydropower

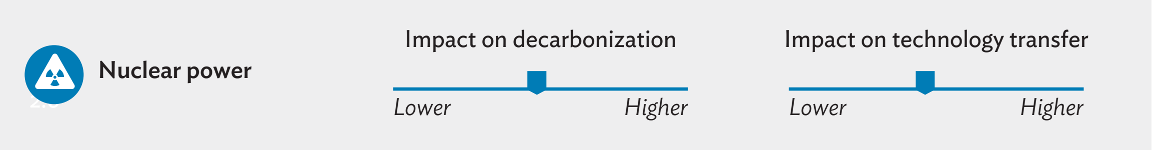
Pakistan has vast hydropower potential, with a maximum technical capacity of 60 GW across all types of plants. The Indus River Basin provides the most hydropower potential, comprising 75% of the total capacity. With around 10 GW of installed capacity, hydropower currently takes up nearly 26% of the country's generation mix. Several large-scale projects with capacities of up to 4.5 GW are planned to be put in operation by 2029, moving the share of hydropower closer toward the government target of 30% by 2030. In addition to large dams, introducing multiple smaller installations is instrumental to the rapid expansion of hydropower, thereby increasing its share in the generation mix. Hydropower has nearly negligible fuel costs and a long operational lifetime, increasing the country's energy security for many years to come. While wind- and solar-powered plants are intermittent in nature (e.g., affected by weather), large installed capacities of hydropower plants can be beneficial in terms of grid balancing, and can act as peaking plants to mitigate lower generation. Due to the high share of hydropower in Pakistan's generation mix, the country thus possesses extensive knowledge and experience in this technology.

Solar PV

Pakistan has already started harnessing the capabilities of solar PV generation, comprising 1% of the total energy generation mix in 2020. With around 300 days of sunshine each year, and solar irradiation values of more than 1,500 kilowatt-hours per square meter per year in more than 90% of its land area, Pakistan has a solar power technical potential of around 2,900 GW. The introduction of renewable energy support policies, combined with the global trend of decreasing technology costs, is expected to boost the development of solar power, which is projected to reach 9% in 2030, according to the Government Commitments scenario. As renewable energy costs go down with the scale, an important trend observed is the increasing use of auctions to reveal competitive prices. In 2017, NEPRA issued directives introducing a competitive bidding process for solicited projects (utility-scale wind and solar PV projects). A cost-plus or feed-in tariff mechanism is employed for unsolicited projects (IRENA 2018). Moreover, several provinces have introduced projects connecting rural households to off-grid solar PV installations, reducing their reliance on biomass and kerosene. Considering the government's targets and solar power's current share of the energy mix, solar PV projects will have a large impact on technology transfer and will also support Pakistan's decarbonization efforts.



The country's wind power represents nearly 120 GW of technical potential, located mostly in the southern parts of Pakistan (e.g., the Gharo–Keti Bandar wind corridor, which has over 50 GW of potential alone). While the government plans to increase the share of renewables (including wind and solar PV) by up to 30% in 2030, installed capacity of wind power plants is currently only 1 GW (or 3% of the total generation mix), reflecting the low utilization of the resource (NEPRA 2020). However, the high availability of wind energy, its low carbon footprint, and technological advancements resulting in decreasing costs, make the resource suitable for covering additional demand and for decarbonizing the energy sector. The further introduction of wind energy will provide a significant contribution to technology transfer, as Pakistan is only starting to harness this resource. Rapid addition of large-scale wind energy, combined with recently introduced competitive bidding process for utility-scale wind projects, would result in cheaper renewable power.

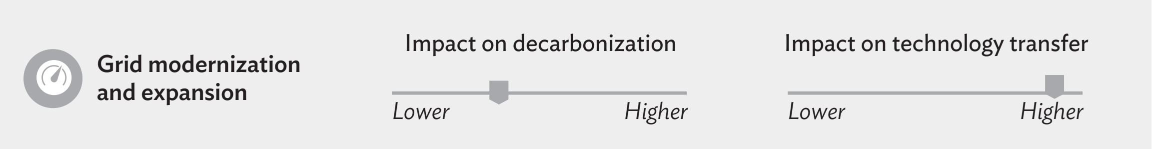


Pakistan has been making additional efforts in the exploration and development of uranium resources, as well as in nuclear energy generation. The sector started operating in 1971 with the introduction of the Karachi Nuclear Power Plant (capacity of 100 MW) (Box 18). The construction of the Chashma Nuclear Power Plant in 2000, which was further expanded with an additional four operational reactor units, increased the capacity to 1.4 GW. In 2021, Pakistan's largest nuclear power plant was commissioned, with a capacity of 1.1 GW, and the addition of a second 1.1 GW reactor is on the way.

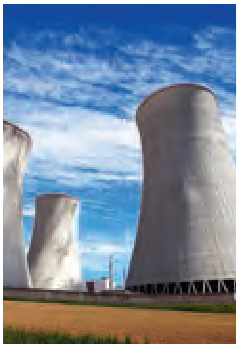
Nuclear capacity improvements correspond well with the government's plan to increase the country's nuclear power generation capacity to 8.8 GW by 2030. Despite security concerns, the further development of nuclear power is expected to positively impact energy sector decarbonization. Its impact on technology transfer is limited due to the use of similar reactor technologies in the past. Moreover, systematic efforts to upgrade physical protection and emergency systems are continuously required to alleviate any possible security issues, considering the high risks associated with nuclear power.

Priority Technologies: Transmission and Distribution

The T&D system in Pakistan is outdated and suffers from constant underinvestment. The resulting poor technical condition of the infrastructure leads to substantial losses. In response, Pakistan plans to modernize grid infrastructure and introduce initiatives to decrease losses.



Box 18: Pakistan's Flagship Energy Project



Karachi Nuclear Power Plant is the oldest commercial nuclear power plant in Pakistan, and has been operating since 1972. In 2015, the Government of the People's Republic of China signed an energy agreement to expand the power plant by adding two reactors, with investments of up to $9.5 billion. The construction of the reactors commenced in 2015 and 2016 for the K-2 and K-3 reactors, respectively. The K-2 reactor became operational in 2021, and the K-3 reactor was connected to the power grid in 2022. The project contributes to the Government of Pakistan's plan to increase nuclear energy capacity to 8.8 gigawatts by 2030.

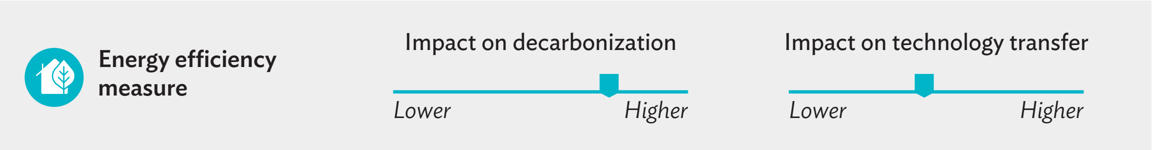
Note: Illustrative photo of a cooling tower at a nuclear power plant is by Daniel Prudek/Adobe Stock©.

Sources: A. Gul. 2021. Pakistan's China-Built Nuclear Reactor Starts Operation. *Voice of America.* 19 March; Developing Pakistan. 2022. In 2015 Government of Pakistan Signed an Energy Agreement with China. *Twitter.* 4 January; International Atomic Energy Agency. Power Reactor Information System; and *World Nuclear News.* 2022. Karachi 3 Begins Supplying Electricity. 7 March.

Pakistan's grid coverage is insufficient, with more than a quarter of the population having no access to grid electricity. Increasing quality of life and reducing biomass usage of off-grid consumers can be achieved through the expansion of the existing T&D system. Considering the government's power generation targets, new lines also need to be constructed for renewable energy capacities to operate properly. Planned expansions could place a significant stress on the system, and might reinforce the sector's existing issues. To alleviate this, Pakistan has already taken steps to address T&D sector issues through the introduction of relevant policy frameworks for development. The government is currently in the process of rehabilitating existing power lines, and introducing modern transmission systems and advanced metering infrastructure for efficient grid monitoring. These would prove beneficial to the country through improving the quality of service for consumers and the reliability of power distribution. Extensive grid modernization is crucial to meet growing demands and to monitor consumption. New technologies introduced for the transmission sector will significantly impact technology transfer.

Priority Technologies: Consumption

With a new authority for energy efficiency (NEECA), Pakistan has prioritized increasing energy efficiency across all sectors of consumption, with a focus on the industrial sector, which has the most potential for energy savings.



Pakistan has committed to implementing efficiency measures across all sectors, with a particular focus on the industry sector. Different policies (including those related to electric motors), aiming to ensure the reduction in energy intensity, have already been implemented. However, further introduction of mandatory and regular energy audits is crucial for the country in the long run. The government plans to provide frequent energy audits, and to identify mechanisms to increase production efficiency, such as electric motor systems, heat transfer, variable frequency drives, and boilers. Given Pakistan's rapid urbanization, the government is planning to introduce appliance energy labeling and modern building energy efficiency codes for ventilation, air-conditioning and heating standards. As the transport sector is one of the main contributors to emissions, the introduction of the Electric Vehicle Policy signaled government's commitment to develop a "greener" sector. Targeting 30% of vehicle sales to be electric by 2030, the government is moving closer to decreasing the transportation sector's carbon footprint.

Carbon Emissions Outlook

Pakistan committed to reducing greenhouse gas (GHG) emissions by signing its first nationally determined contribution (NDC) in 2016. The country committed to an unconditional target of 20% GHG emission reduction by 2030. Furthermore, the government specified clear reduction targets for each sector of the economy. The target level of energy sector-related emissions in 2030 is 718 million tons of carbon dioxide (CO_2) equivalent, or 48% of total emissions in 2030, compared to 898 million tons of CO_2 equivalent emissions projected in 2030 if no actions were taken.

Pakistan's carbon emissions outlook highlights that while the NDC targets are achievable, a more ambitious strategy can be implemented to tackle climate change. The COVID-19 pandemic has impacted Pakistan's energy sector, with a reduction of demand by 1.6%. However, even with relatively minor changes in the energy sector until 2030 under the BAU scenario, Pakistan's energy sector emissions will reach 427 million tons of CO_2 equivalent—well below the levels of the unconditional NDC target. The Government Commitments scenario, which assumes the achievement of policy targets and an increased share of renewables, leads to an even lower emissions level of almost 321 million tons in 2030. This is less than half of the expected target, showing the potential to introduce a more aggressive CO_2 reduction target. Through significant developments in renewable energy and a focus on energy efficiency in all demand sectors, the Green Growth scenario projects a reduction of emissions by 25% compared to 2020, also achieving the unconditional target (Figure 72).

Investment Outlook

Investment Needs

Energy investment needs until 2030 vary significantly across the three scenarios, with estimates ranging from $62 billion to $155 billion. The most significant investments are required in the power generation and energy efficiency sectors because of the rapidly growing demand and low baseline efficiency.[12] In all three scenarios, the largest investments are needed for the development of the country's hydropower capacity,

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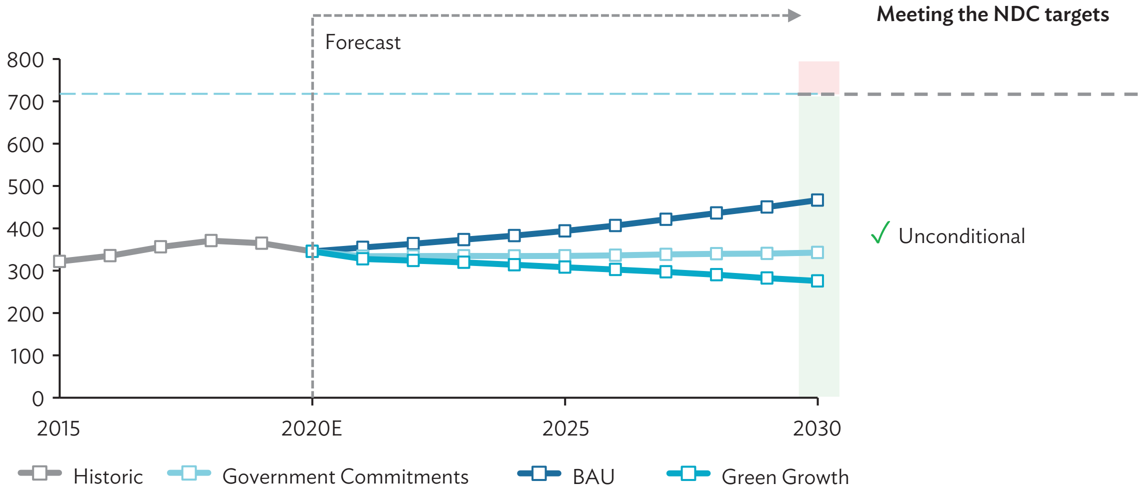
[12] Investment needs assessment excludes the fossil fuel production sector because of focus on low-carbon energy technologies.

Figure 72: Pakistan—Energy-Related Carbon Emissions

(million tons of carbon dioxide equivalent)



BAU = Business-as-usual, E = estimate, NDC = Nationally Determined Contribution.

Note: Historical data on carbon emissions is modelled by Roland Berger based on historical data on energy use. The forecasts are based on the Roland Berger methodology described in the Methodology section.

Sources: Roland Berger; and United Nations Framework Convention on Climate Change. Nationally Determined Contributions Registry. https://unfccc.int/NDCREG.

ranging from $11 billion to $26 billion. Investment needs for wind and solar energy are expected to reach nearly $12 billion in the BAU scenario, $36 billion in Government Commitments scenario, and $57 billion in the Green Growth scenario, which illustrate the country's ambitious plans for harnessing its large renewable energy potential. Moreover, in accordance with the country's targets for nuclear power generation, investments needed for the expansion and rehabilitation of nuclear facilities account for nearly $12 billion in the BAU scenario, $21 billion in the Government Commitments scenario, and $31 billion in the Green Growth scenario.

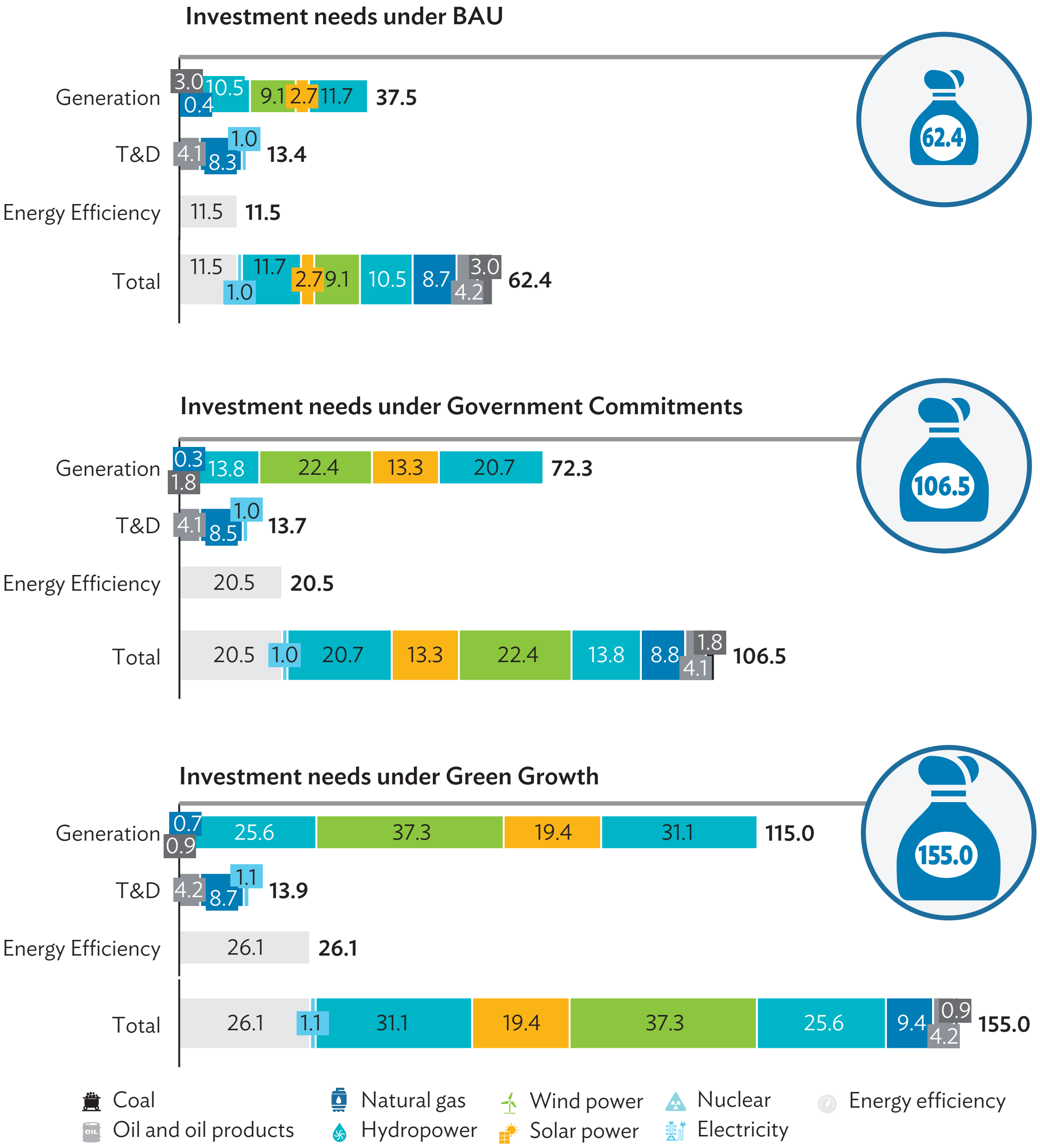
Generation rehabilitation and expansion are the investment categories estimated to require the largest share of the total—ranging from 60% to 75%, or $38 billion to $115 billion, varying across scenarios. The second biggest category is energy efficiency measures on the consumption side, requiring $12 billion in the BAU scenario, almost $21 billion in the Government Commitments scenario, and over $26 billion in the Green Growth scenario. The modernization and expansion of the power and gas grids, and the introduction of advanced metering equipment require investments of approximately $13 billion to $14 billion (Figure 73).

Challenges and Opportunities

To further unlock Pakistan's energy market for private companies, several challenges must be addressed. One of the key challenges is the lack of clarity regarding the categorization of resources. For example, although hydropower is generally considered a renewable energy resource across the world, the Alternative and Renewable Energy Policy has categorized hydropower sources as nonrenewables

Figure 73: Energy Infrastructure Investment Needs in Pakistan until 2030

($ billion)



BAU = Business-as-usual, T&D = transmission and distribution.

Source: The forecasts are based on the Roland Berger/ILF methodology described in the Methodology section.

(Government of Pakistan 2019). Considering the 30% renewable energy target in 2030, it would be hardly possible to reach this level only via wind and solar PV sources. If hydropower were to be included in the definition of renewable energy sources, it would make reaching the stated target and introducing stronger competition more realistic.

Another challenge is the lack of a detailed energy plan for the energy sector. Although the National Energy Policy has been approved, the corresponding division of roles in policymakers who would assign policy areas to all relevant stakeholders has not been completed yet. In the current framework, sector-specific policies are developed by relevant authorities. For instance, the alternative energy policy is developed by the AEDB, whereas power generation policy is drafted by NEPRA. This not only creates uncertainty regarding the long-term direction of sector development, but also leads to unnecessary bureaucracy and delays in project implementation.

With a strong focus on generation over the last several decades, T&D sectors suffered greatly from underinvestment. As a result, transmission losses in Pakistan are one of the highest in the region, with some distribution companies reaching losses of 38%. While policies, such as the Transmission Line Policy, have been established to attract private investments, a centralized Transmission Plan considering load development in the future is required to set a long-term direction for network development, and to establish realistic targets for reducing T&D losses and attracting investments (Government of Pakistan, PPIB 2015). Another challenge stems from the country's electrification rate, with more than 25% of the population having no access to electricity. With increases in rural electrification, demand will increase significantly, putting more strain on distribution companies and generation.

Finally, challenges in the T&D sector are reinforced by the issue of circular debt. With growing power generation from thermal plants, higher costs were inflicted via the import of high-priced fuels and currency devaluation. At the same time, distribution utilities tasked with energy supply face financial hurdles due to the low collection rate of tariffs and the inability to meet regulatory targets for T&D losses. As a result, distribution companies are unable to pay generation companies for purchased electricity, starting a chain of debts that reach fuel providers via power generation companies. The differential between NEPRA-approved tariffs and the uniform tariffs is paid via a tariff differential subsidy, which adds a significant financial burden on the government.

However, the government is moving toward tackling these challenges and improving the investment climate by establishing a clear and favorable environment for private investors in the energy sector. Pakistan recently approved an implementation plan for a regulatory framework that will establish a competitive market structure in the wholesale segment via a bilateral contract. Furthermore, the government plans to unbundle natural gas utilities into transportation and distribution companies and establish a competitive natural gas market, which will prove beneficial in terms of attracting private investments in the long-term.

Pakistan has already introduced specific incentives for its renewable power sector to take advantage of its substantial renewable resource potential of more than 3,000 GW (including hydropower). With feed-in tariffs for wind and solar PV technologies and a clear plan for renewable energy generation, it aims to support further development of renewable energy (Enerdata 2015). Considering the sizeable development needs in the energy sector and the government's prioritization of renewable energy, opportunities for investment are significant.

To resolve power issues and improve energy distribution capabilities, the government is considering the partial privatization of distribution companies through management contracts and concession agreements. This opens up a possibility of ensuring sufficient power supplies, mitigating losses, and increasing competitiveness in the distribution market.

Being one of the largest markets in the CAREC region, Pakistan's population is currently growing by 2% annually, with an ever-growing potential customer base. However, more than a quarter of the population does not have access to power. With suitable government priorities and regulatory frameworks, this would provide a substantial basis for investment in the energy sector, with more possibilities for return on investment and project implementation.

Policy Recommendations

Pakistan has taken steps toward introducing efficient regulatory and policy frameworks that will create more opportunities for the private sector. However, several areas that would provide further development have been identified as follows:

(i) **Gradually decrease energy subsidies for generation and distribution.** This can potentially be achieved by revising the existing tariff structure to allow higher returns for T&D companies, thereby decreasing circular debt while enabling larger infrastructure investments. The revised subsidy strategy for power consumers devised in 2021 is an important step in this direction.

(ii) **Continue the expansion of and support for the renewable energy sector.** The tremendous potential for solar PV and wind power generation should be developed rapidly. A transition away from thermal generation would reduce both emissions and supply risks, decreasing the country's dependency on imports.

(iii) **Introduce carbon pricing, specifically an emissions trading scheme.** Carbon pricing is an effective policy instrument to mitigate GHG emissions, mainly by passing the cost of emitting to the emitters and thereby giving them financial incentives to reduce their emissions. Launching the National Committee on Establishment of Carbon Markets in December 2019 was the first step in this direction.

(iv) **Introduce a detailed energy plan for the energy sector that establishes concrete actions and measures.** The successful adoption of a detailed energy plan for the energy sector will improve transparency and help guide private investors in their search for investment opportunities.

(v) **Clearly define resource categories to ensure proper development.** Categorizing hydropower as a renewable energy resource is crucial for the successful implementation of further projects, and for attracting more investment via incentives for renewable power projects.

(vi) **Continue energy sector reforms via privatization and develop competitive markets further.** The shift toward a competitive energy market for both electricity and natural gas should continue, with clearly adopted legislation to ensure efficient implementation.

(vii) **Establish development plans for the transmission sector and rural electrification.** One of the key challenges is high T&D losses, which is also a primary cause of circular debt in the market. The successful implementation of the country's transmission line development plan will provide a defined strategy toward the reduction of losses. In addition, strategy planning for the electrification of rural regions is of great importance, as it will introduce more customers to the grid and enable further economic development.

(viii) **Further introduce energy efficiency policy measures in consumption sectors via building codes and relevant legislations.** While an energy efficiency policy with a strong development goal has been established, further implementation of related rules and secondary legislation is required to ensure sufficient progress during the implementation stage.

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Islamabad. The Faisal Mosque is the sixth-largest mosque in the world and the largest within South Asia, located in the foothills of Margalla Hills in Pakistan's capital city of Islamabad (photo by Umer/Adobe Stock©).

PEOPLE'S REPUBLIC OF CHINA

Wind turbines in the mountains. The People's Republic of China is not only a global leader in renewable energy, but it also has the world's largest wind power capacity (photo by Hu/Adobe Stock©).

The People’s Republic of China Highlights

- The People’s Republic of China (PRC) is the world’s second-largest economy. It is a major energy importer (with roughly one quarter of the country’s total primary energy supply being imported). The PRC is the largest producer of coal, accounting for around half of global production. The country consumes most of its coal domestically, making the PRC the world’s largest consumer, with 54% of global coal consumption.
- However, the country also has tremendous renewable potential, with a potential capacity of wind and solar photovoltaic (PV) of more than 7.8 terawatts (TW) (Figure 74). The government has recognized the need to facilitate sustainable energy projects, and has introduced numerous incentives: feed-in tariffs (FITs), competitive auctions, quotas, etc. This resulted in an increased number of projects, and tremendous growth in wind, solar PV, and hydropower capacity—from 12 gigawatts (GW) of wind and 145 GW of hydropower in 2008, to 282 GW of wind, 254 GW of solar PV, and 369 GW of hydropower in 2020 (Statista).
- The country’s power generation mix has historically been dominated by coal. However, the share of coal in the installed power generation capacity fell below 50% (49.1%) for the first time in 2020. By 2030, coal is still expected to play a significant role in the power mix, with a share of 35%–52%, depending on the scenario. Nevertheless, the share of renewables in power generation is expected to increase from almost 30% in 2020, to up to 50% in 2030, depending on the scenario.
- By 2030, the final energy demand—between 2,117 million tons of oil equivalent (toe) and 2,380 million toe—is expected to be led by electricity consumption, accounting for 30%–36% of the total, depending on the scenario. This is largely related to the expected electrification of several different sectors. The final demand for coal is expected to decrease by 1%–3% annually, depending on the scenario. In terms of the final demand by sector, the industry sector is expected to continue to display the largest energy demand, accounting for 45% of the total value.
- Given the country’s resource potential, the PRC’s priority technologies are solar PV, wind, and nuclear power for the generation category; and ultra-high voltage (UHV) grid expansion, “green” hydrogen, battery energy storage systems (BESS), and carbon capture utilization and storage (CCUS) for the transportation, storage, and consumption categories.
- By 2030, the PRC’s investment needs in the energy sector are estimated to range between $2,799 billion and $3,497 billion, depending on the scenario. Overall, most investments are expected to come from the generation sector (especially in renewables), reflecting the country’s plan to reduce its carbon footprint. Investment needs in the transmission and distribution (T&D) sector are projected to reach between $743 billion and $865 billion, depending on the scenario, and will be led by investments in the electricity T&D networks.
- The PRC is an attractive market for private investors in the energy sector because of its continued high economic growth rates, substantial experience in modern technologies (such as CCUS, BESS, hydrogen, etc.), and availability of complete supply chain, which can reduce investment costs. In addition, investment opportunities are driven by continuous government support via subsidies, competitive auctions for renewable energy sources, programs for additional funding and grants, etc.

Figure 74: People's Republic of China—Key Figures

Renewable potential	Renewable power generation	Carbon intensity	Energy imports	Carbon emissions
7.8+ TW	**~30%**	**9th out of 172**	**~24%**	**30%**
Technical potential of solar and wind energy is estimated at 7.8+ TW, with solar PV accounting for 60% of it.	The PRC accounted for ~30% of the world's electricity generation from wind and solar PV in 2020.	The country is ranked 9th out of 172 countries in the global ranking of carbon intensity of energy, largely due to the large share of coal in the energy and power mix.	~24% of the primary energy supply was imported in 2018.	The PRC accounted for 30% of global energy-related carbon emissions in 2019.

PRC = People's Republic of China, PV = photovoltaic, TW = terawatt.

Sources: British Petroleum. 2021. *Statistical Review of World Energy 2021.* London; International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 17 August 2021); and United States Energy Information Administration. The PRC Data. https://www.eia.gov/international/data/world (accessed 17 August 2021).

- Nevertheless, a few challenges for attracting private investments still need to be addressed, mainly the government's continued regulation of energy tariffs, fully opening the market to foreign investors, and simplifying several regulatory policies.
- In 2021, record high coal and natural gas prices, coupled with power rationing and price controls, have led to renewed discussions about the need to liberalize the electricity market. The PRC's top economic planning agency announced it will allow coal-fired electricity prices to fluctuate by up to 20% from base levels, increasing previous limits.

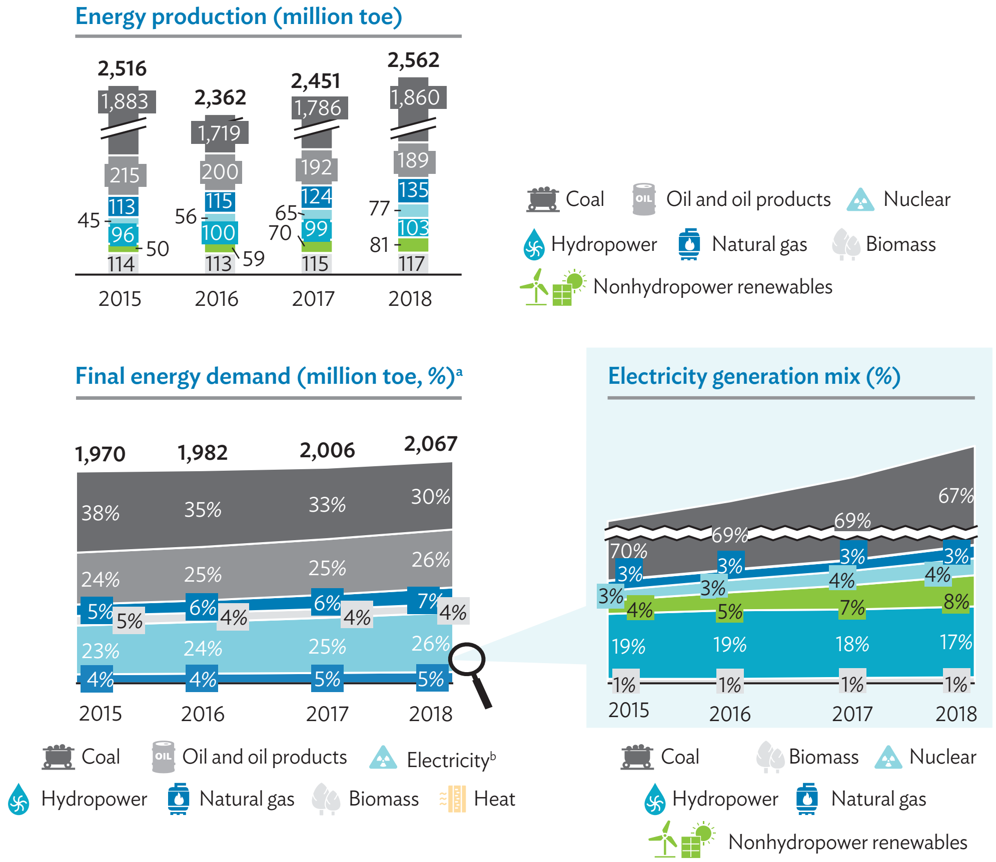
Energy Sector Profile

Country Profile

The PRC is the world's most populous country, with around 1.4 billion people in 2020. It is also the world's second-biggest economy, with a nominal gross domestic product (GDP) of $14.7 trillion in 2020. The economy has recovered very quickly from the impacts of the coronavirus disease (COVID-19) and grew by 3.5% in 2020. This growth trend is expected to continue in the coming years, with an annual growth rate of 8.4% (nominal GDP) by 2030.

The PRC is the largest producer of coal, accounting for around 50% of total global production in 2020 (British Petroleum 2021). Most of this is consumed domestically, making the PRC the world's largest coal consumer, accounting for 53% of the world's total. As a result, the PRC is ranked 9th out of 172 countries globally in terms of carbon intensity, and 25th in the world in terms of energy intensity.

Figure 75: Energy Profile of the People's Republic of China



toe = ton of oil equivalent.

[a] Topmost numbers on the chart are in million toe.

[b] Electricity data come from various sources, including fossil fuel-based and renewables.

Source: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 17 August 2021).

Despite its substantial energy production (with almost 2,600 million toe in 2018), the PRC remains a net energy importer. In 2018, the country imported almost 780 million toe, and exported around 80 million toe, resulting in a net import of around 700 million toe (Figure 75). The country imported mostly oil and oil products, accounting for 67.8% of total imports in 2018; followed by coal, with 19.7%; and natural gas, with 12.4%. The remaining share of imports was electricity.

Energy Sector and Technologies Assessment

Conventional Fuel Production

Coal is the PRC's key energy source, accounting for around 27% of the country's total final energy consumption in 2019. Overall, coal is mostly produced in the northern and northwestern regions of the country, with a total production of 3,840 metric tons (MT) in 2020. Coal production at large mines is controlled by the state-owned enterprises, while the rest are controlled by private entities. The PRC's coal reserves are estimated at 96.5 billion tons. Three-quarters of these reserves are located in the provinces of Shanxi, Shaanxi, and Inner Mongolia.

Coal mining is mostly underground, accounting for approximately 86% of production. The rest of the production is from open-pit and other methods. Overall, the mining process is reportedly plagued by outdated machinery and inefficiencies, leading to increased environmental pollution and social unrest. However, the government is working to circumvent this issue by replacing uncompetitive and outdated mine capacities, and by closing small mines in the eastern and southern regions. As of 2020, there were 4,700 coal-producing mines, with an average annual production capacity of 1.1 million tons (China Internet Information Center 2021). In 2021, production at 53 mines in Inner Mongolia and Shanxi, with a total capacity of 110 million tons, was restarted. However, the country plans to decrease the number of coal mines to around 4,000 by the end of 2025.

Oil is primarily produced by three national oil companies (NOCs) in the PRC, with 173 million tons, or 90% of the country’s total production in 2019: the China National Petroleum Corporation (CNPC), Sinopec, and China National Offshore Oil Corporation (CNOOC). In 2020, the PRC’s crude oil production reached 3.9 million barrels per day, or around 194 million tons, making the country the world’s fifth largest producer of oil and oil products (5% of global production). Overall, the PRC’s oil production decreased significantly between 2015 and 2018, with a compound annual rate of nearly −3%. After declining considerably over the years, oil production increased in 2019, as investments from the NOCs enabled extractions from tight oil reserves as well as the development of other technically challenging fields. Exploration has also led to discoveries in the Bohai Bay, Hailaer, Junggar, Ordos, Qaidam, Sichuan, Songliao and Tarimbasins. Proven oil and natural gas reserves were thereby increased by around 875 million tons for oil and 650 billion cubic meters (bcm) for natural gas. In 2020, total oil reserves amounted to 3.5 billion tons, and total natural gas reserves amounted to 8.4 trillion cubic meters (British Petroleum 2021). In the same year, natural gas production reached 186 bcm; CNPC, Sinopec, and CNOOC were responsible for 90% of this total.

Electricity Generation

The PRC’s power generation facilities have grown extensively over the last 2 decades. The installed capacity increased from 623 GW in 2006 to around 2,200 GW in 2020. Overall, in 2020, the installed capacity of power plants was dominated by conventional fuels and included approximately 1,100 GW of coal-fired plants, 97 GW of natural gas-fired power plants, 50 GW of nuclear power plants, and 2 GW of oil-powered plants. Nevertheless, the installed capacity of renewable energy sources has increased substantially during last couple of years, reaching 370 GW of hydropower in 2020 (vs. 130 GW in 2006), 281 GW of wind (vs. 1 GW in 2005), 253 GW of solar PV (vs. 3 GW in 2012), and 23 GW of biomass (vs. 1 GW in 2009).

In terms of electricity, coal-fired power generation has historically dominated the country’s power mix, reaching 62% in 2020. However, the country plans to decrease the share of coal in the electricity mix by transferring to more sustainable fuels and realizing the PRC’s renewable potential. Overall, the country’s total technical hydropower potential is estimated at 400–700 GW. As of 2020, hydropower holds a 17% share of total power generation. The technical potential of solar PV is estimated at more than 4,700 GW. As of 2021, the PRC holds the largest solar PV capacity share in the world, with the world’s largest PV systems, such as the 1.5 GW Tengger Desert Solar Park, the 1.0 GW Yanchi Ningxia Solar Park, the 1.1 GW Datong Solar Power Top Runner Base, and others (Fawthrop 2021; Power Technology 2020). The PRC aims to continue expanding solar PV systems in the coming decade. Furthermore, the technical potential of onshore wind energy is around 3,100 GW. Wind capacities have increased rapidly during the last few years, and this trend is expected to continue. The overall share of nonhydropower renewables reached 12% of total generation in 2020. The PRC accounted for 50% of the world's renewable energy capacity additions in 2020. Nuclear power accounted for almost 5% of the total electricity mix in 2020. In addition to renewables, nuclear generation is expected to expand rapidly and play a pivotal role in the decarbonization agenda of the country. Coal-to-gas switching is also one of the key government's priorities. Gas-fired generation accounted for 3% of the total power generation in 2019.

Transmission and Distribution

In December 2019, the PRC established a single entity to manage all the big three NOCs' midstream assets. The assets include pipelines, liquified natural gas (LNG) import terminals, and storage facilities. The move was made to unify the pipeline network, reduce oil and natural gas transportation costs, improve regional interconnectivity, and provide better access to third-party agencies.

As of 2020, the PRC has 98 crude oil pipelines, with a total length of 28,686 kilometers (km) and a total throughput of 7.9 million barrels per day. There are strategic oil reserves and oil storage facilities, with 1.2 billion barrels of storage for both crude oil and oil products. In addition, the PRC has 76 storage facilities for crude oil, with a capacity of 790 million barrels, and 216 facilities for oil products, with a net storage capacity of 360 million barrels.

The natural gas transmission system consists of over 64,000 km of pipelines. One of the major internal networks is the 4,380 km West–East Gas Pipeline, with natural gas supplied from Tarim Basin's gasfield to Shanghai. Another is the 8,819 km West–East Gas Pipeline, which receives natural gas from Central Asia and connects cities such as Shanghai and Hong Kong, China. The third West–East natural gas pipeline was commissioned in 2016. It is 6,480 km long and has a 30 bcm capacity. The third West–East Gas Pipeline links with the Central Asia–PRC gas pipeline network. It starts in Horgos, Xinjiang, and ends in Fuzhou, Fujian, passing through 10 provinces (Xinjiang, Gansu, Ningxia, Shaanxi, Henan, Hubei, Hunan, Jiangxi, Fujian, and Guangdong). There are interconnections between these three West–East Gas Pipelines, and they can be controlled from hubs in Zhongwei, Jingbian, Zaoyang, and Ji'an.

Most of the oil and natural gas transmission systems were developed in the past decade. In addition, with the formation of PipeChina, which integrates all midstream assets under a single organization, oil and natural gas transmission systems are expected to run more efficiently. By 2025, the PRC plans to expand its domestic pipeline network to 163,000 km for natural gas, and to 37,000 km for crude oil.

The PRC's natural gas distribution system covers 80% of all its major cities, and 20% of the entire country. The distribution of natural gas is managed entirely by the private sector, with China Resources Gas and Beijing Enterprises being the two dominant market players. It is envisaged that the natural gas distribution system will need to expand further into the country, as the shift from coal is expected to begin in 2025. Given that they are under private control, the distribution systems are expected to be monitored by advanced metering networks to maintain high efficiency levels and low losses.

The State Grid Corporation of China (SGCC) and China Southern Power Grid (CSPG) manage power T&D systems in the PRC and are responsible for different regions. Overall, the SGCC covers a population of 1.1 billion people and 80% of the country's terrain. The average urban power supply reliability is at 99.9%;

while, for rural regions, the reliability is 99.5%. Losses range from 5% to 6%. The SGCC has a transmission network consisting of UHV lines at 1,000 kilovolts (kV) alternating current (AC) and ±1,100 kV direct current (DC). As of 2021, there are 32 UHV projects in operation in the PRC, of which 15 are AC projects and 17 are DC projects. The total length of the PRC's transmission lines with 220 kV and higher voltage levels was 688,000 km at the end of 2017 (compared to 164,000 km in 2000). Extra-high voltage (EHV) and UHV lines with 500 kV and higher voltage levels reached 205,000 km at the end of 2017 (compared to 27,000 km in 2000). The 66-110 kV transmission network is 1.1 million km. On the distribution side, the total length of 6-20 kV lines is around 4.3 million km; this includes 3.4 million km of overhead lines, 0.8 million km of underground cables, and 5.2 million power distribution transformers, making the PRC's power distribution system the largest and most extensive network in the world.

The PRC's power system is at an advanced stage in the implementation of high voltage AC and DC transmission. The implementation of UHV systems is expected to dominate the technology landscape. The PRC is also a leading country in the implementation of smart grid technologies, which allow for grid stability and the seamless integration of renewables (such as solar and wind) into the grid. Smart grid systems include the presence of advanced sensors, information and communication technologies, rapid control capabilities, and energy storage. The State Grid has collaborated with charging companies to successfully integrate over 108,000 charging systems to ensure greater electric vehicle integration into the energy systems infrastructure. The Vehicle-to-Grid concept implementation is also being envisaged as the next step for managing power, with consumers being prosumers.

The district heating systems in the PRC are the largest in the world. The pipeline network spans over 371,000 km and is served by over 28 GW of combined heat and power (CHP) plants. The system also comprises 12,000 km of steam networks. The heating systems mostly use coal boilers, although some alternative solutions have also been used in recent years, such as geothermal systems for heating.

Cross-Border Infrastructure

The PRC's major cross-border power transmission infrastructure includes the PRC–Myanmar 230 kV line, the PRC–Viet Nam 110 kV line, and the Russian Federation–PRC lines of multiple voltages. The Russian Federation–PRC lines can transfer up to 7 terawatt-hours (TWh) of electrical power per year. These lines consist of three interconnections: the first (commissioned in 2011) is the 500 kV line between the Amurskaya region and the city of Heihe, with a converter station; and the other two are the 110 kV Blagoveshchenskaya–Heihe line and the 220 kV Blagoveshchenskaya–Aygun line.

In terms of natural gas, the PRC has three main import transmission routes: from Turkmenistan, the Russian Federation, and Myanmar. The Central Asia Natural Gas Pipeline connects the natural gas fields of Bagtyyarlyk in Turkmenistan to Xinjiang in the PRC. Moreover, the Central Asia Natural Gas Pipeline consists of three operational pipelines, each of which is 1,830 km long, and together has a capacity of 55 bcm. The Sino–Myanmar oil and natural gas pipelines form another major transmission route, delivering 12 million tons of crude oil per year and 12 bcm of natural gas. Furthermore, the PRC also has a natural gas pipeline network from the Russian Federation, the Power of Siberia, with 8 bcm per annum capacity. There are ongoing discussions between the PRC and the Russian Federation regarding the implementation of a 50 bcm capacity line (called the Power of Siberia 2), which is expected to greatly increase the supply of Russian natural gas to the country.

One of the major pipelines carrying oil into the PRC is the Kazakhstan–PRC oil pipeline. This 2,228 km pipeline runs from Atyrau in Kazakhstan to Alashankou in the PRCs' Xinjiang region, with a nominal capacity of 20 million tons per year. The pipeline provides for up to 5% of the country's oil energy requirements. Another pipeline is the 30-million-ton capacity Eastern Siberia–Pacific Ocean Pipeline, which carries oil into the country from the Russian Federation. It was built and is operated by Transneft. The 1,056 km pipeline provides for 6% of the PRC's oil requirements (Table 7).

Table 7: People's Republic of China—Major Cross-Border Energy Infrastructure

Energy Source	Name	Capacity	Status	Connected Country
⚡	PRC–Myanmar (Nabar–Shwebo–Ohntaw 230 kV line)	n.a.	Operational	Myanmar
⚡	PRC–Viet Nam (Yunnan Province, PRC–Thai Nguyen 110 kV line)	n.a.	Operational	Viet Nam
⚡	Russian Federation–PRC (Amurskaya Region–Heihe City 500 kV line, Blagoveshchenskaya– Heihe 110 kV line, Blagoveshchenskaya– Aygun 220 kV line)	7 TWh	Operational	Russian Federation
🔥	Myanmar–PRC (Sino-Myanmar)	12 bcma	Operational	Myanmar
🔥	Central Asia–PRC	55 bcma	Operational	Kazakhstan, Turkmenistan, Uzbekistan
🔥	Power of Siberia	30 bcma	Operational	Russian Federation
🔥	Power of Siberia 2	50 bcma	Planned	Russian Federation
OIL	Kazakhstan–PRC	20 mtpa	Operational	Kazakhstan
OIL	Eastern Siberia–Pacific Ocean Pipeline	30 mtpa	Operational	Russian Federation
OIL	Myanmar–PRC (Sino-Myanmar)	12 mtpa	Operational	Myanmar

⚡ Electricity 🔥 Natural gas OIL Oil

bcma = billion cubic meters per annum, kV = kilovolt, mtpa = million tons per annum, n.a. = not available, PRC = People's Republic of China, TWh = terawatt-hour.

Sources: Fitch Solutions. 2020. *China Oil & Gas Report*. London; Fitch Solutions. 2020. *China Power Report*. London; and United States Energy Information Administration. 2020. *China Energy Sector Overview*. Washington, DC.

Energy Consumption

The total final energy consumption reached around 87.6 million terajoules (TJ) in 2019. The share of industry in the final energy consumption was almost 49% in 2019, while the share of the transport sector was around 15.5% and the residential sector 16.8%. In 2020, the PRC's energy consumption rose by 2.1%, making it one of the few countries with increasing energy demand in 2020. This was largely driven by rapid economic recovery from the pandemic.

The PRC has demonstrated one of the largest recorded improvements in energy efficiency in the industry sector. Between 2000 and 2018, its energy efficiency improved by 20%, from 8,500 British thermal units (Btu) to 6,800 Btu per dollar of GDP. This was mostly achieved through the promotion and application of energy-saving technologies, and by reducing energy consumption in steel enterprises. One of the prime examples is the PRC's steel industry, which managed to considerably increase its efficiency and reduce its emissions by adopting modern technologies, such as top-pressure recovery turbines, coke dry quenching, coal moisture control, recycling waste heat from sintering, etc.

Overall, the PRC's industrial sector is the largest consumer of coal, accounting for 78% of the country's total coal consumption (or 495 million tons) in 2018. The largest energy consumers in the country's industrial sector are the power sector, steel, and cement production. The government is trying to address the possible climate consequences of its high coal dependency. For instance, in 2017, the government provided subsidies to the Shanghai industrial companies in the amount of CNY600 (around $95) for every ton of coal equivalent saved (up to CNY5 million, or $775,000 in total). Such financial support from the government has played an important role as "seed capital" in meeting energy conservation targets (Hao and Cuoto 2018).

In general, buildings in the PRC have a shorter lifespan and are more material-intensive than buildings in many industrialized countries. The average lifespan of urban buildings in the PRC is only 20–40 years, which is far below the standard of 50–60 years set by the government. In terms of energy efficiency in buildings, the PRC's current levels are behind European standards, with energy consumption for heating and cooling being much higher per square meter. Nevertheless, recognizing this, the PRC has also implemented a building control system at two main levels: the national and industrial level, and the regional and corporate level. The building codes at the regional and corporate level are only recommended, while those at the national and industrial level are mandatory.

The government is also focusing on retrofitting existing residential and commercial buildings to bring them in line with current construction standards. For example, in 2011, the government increased the energy reduction per square meter requirement to 10% in commercial buildings, and to 15% in buildings larger than 20,000 square meters by 2015. According to the Green Building Action Plan (2013), over 37 million square meters in residential buildings had to be modernized and repaired by the end of 2015 and all eligible commercial buildings in the northern heating zone by the end of 2020 (US EIA 2015).

Finally, the PRC has a rather new motor vehicle fleet. The average age of vehicles in the PRC is about 5 years (Ipsos Business Consulting 2016; Kaur 2020; Statista). Governmental support for the electric vehicle industry has resulted in the PRC becoming the world leader in electric vehicle production and domestic usage. The number of electric cars in the country has exceeded 5 million and is continuing to grow (Regnum 2021). The PRC also leads in the deployment of high-speed railways. The country has been electrifying its railroads at a rapid pace during the past 25 years. In 2021, railway electrification rate was around 73% (CEIC 2022). This is more than three times as much as in 1995, when the figure was only 21% (Global Sustainable Electricity Partnership). In 2021, the total length of the PRC's railway network was 150,700 km, of which 109,950 km (about 73%) are electrified (CEIC 2022). The total number of locomotives in the PRC is about 22,000, about 40% of which are diesel, although their share is gradually decreasing (Statista).

Regulatory Framework

The PRC's energy sector regulation is mostly managed by the National Development and Reform Commission (NDRC) and the National Energy Administration (NEA). The NDRC is responsible for developing and implementing energy-related policies, as well as approving investment projects in the oil and natural gas sector. Established under the NDRC, the NEA oversees drafting energy strategies, legislation, and regulations related to the administration of the energy sector. In 2013, the NDRC and the NEA also took over the regulatory function of the power sector from the State Electricity Regulatory Commission. The two institutions ensure the enforcement of the regulations, and also provide licenses to electricity companies. The nuclear sector is regulated by the State Administration for Science, Technology and Industry for National Defense through the Chinese Atomic Energy Authority.

The PRC has been improving the multilevel and unified electricity market system, and studying and promoting the establishment of a national electricity trading center in due course. In 2017, the NEA and the NDRC issued a notice with instructions and guidance for free power trading, inaugurating a gradual transition toward a market-based approach to electricity generation. Nowadays, electricity is generated by several companies, including China Energy Investment Corporation (with an installed capacity of 238 GW in 2019); China Huaneng (177 GW); China Huadian (153 GW); China Datang (149 GW); and State Power Investment Corporation (126 GW, 45% of which is clean energy), among others. These companies are controlled by the State and operate around 80% of the generation capacity.

The natural gas market is unbundled, with most of the supply function being executed by CNPC (approximately 65% of the total production in 2019), Sinopec, and CNOOC—all state-owned companies. The transmission is managed by PipeChina, which has owned and operated the natural gas transmission network since its establishment in 2019. Previously, CNPC was responsible for natural gas transmission.

The PRC's key legislative acts include the Electric Power Law (1996; amended in 2009, 2015, and 2018); the Mineral Resources Law (1986; amended in 1996 and 2009) and its Implementation Rules (1994); the Nuclear Safety Law (2018); and the Renewable Energy Law (2005; amended in 2010). Overall, the PRC government is paying particular attention to renewable energy and is providing additional incentives to facilitate the development of such projects. For instance, the country set feed-in-tariffs (FITs) for power generation from wind, solar PV, biomass, and waste, reacting to low technology maturity and lack of experience in operation, which made cost of renewable energy significantly higher than that of thermal, thus relying on support from state subsidies. Amid declining cost of solar and wind energy due to technological advancements, the government is, however, gradually shifting from the FIT scheme to auctions to further stimulate the acceleration of these technologies and achieve minimal electricity prices for consumers. The competitive auctioning mechanism for the solar PV sector was launched by the NDRC and the NEA in 2016. The first unified PV bidding round in the PRC was held in 2019, with the total capacity of solar projects amounting to 23 GW. The NEA and the NDRC plan to promote subsidy-free wind and solar projects in the future.

Furthermore, in 2019, the NEA established obligatory renewable electricity quotas in each province, requiring local grid companies to purchase a defined amount of “clean” power. The government plans to expand this initiative further by creating a green certificate quota trading scheme in 2021. A voluntary green certificate market has been operating since 2017.

Finally, the PRC also launched the national emission trading scheme (ETS), first as a pilot in five cities and two provinces in 2013–2014. The scheme was officially launched nationwide in 2017 and began operating in 2021. At this stage, the ETS only focuses on power generation companies emitting more than 26,000 tons of carbon dioxide (CO_2) per annum. As a result, the PRC’s ETS is estimated to cover more than 4 billion tons of CO_2, accounting for around 40% of the country’s carbon emissions (ICAP 2021).

Policy Framework

Several documents outline the PRC’s energy strategy. The Thirteenth Five-Year Plan, 2016–2020, which is considered the country’s first green plan, shifted the focus toward sustainability and energy security. The Consumption Revolution Strategy, 2016–2030 aims to achieve a more than 50% share of nonconventional fuels in power generation by 2030. Based on these documents and the most recent Fourteenth Five-Year Plan, 2021–2025, the priorities of the government’s energy strategy include the following (ADB 2021; Sun et al. 2022):

(i) **Reduce the country’s carbon footprint.** The PRC has been setting numerous incentives for the development of renewables (including FIT tariffs, competitive auctions, etc. for solar PV and wind farms), as well as targets to decrease the country’s emissions levels (e.g., reduce CO_2 emissions per unit of GDP by 18% by 2025 vs. 2020). Besides, the NDRC, which approves the country’s power projects and decides on subsidies, expects to considerably decrease the share of coal-fired electricity generation by limiting the number of new coal-fired electricity projects. The PRC submitted stronger nationally determined contribution (NDC) targets at the 26th United Nations Climate Change Conference of the Parties. Overall, the PRC reiterated its commitment that carbon emissions should peak before 2030 and committed to reaching carbon neutrality before 2060. The country also aims to reduce CO_2 emissions per unit of GDP by over 65% in 2030 compared to 2005 levels. The country’s updated NDCs are aligned with the so-called 1+N policy system for CO_2 peaking and carbon neutrality released in October 2021. The “1” stands for “Working guidance for CO_2 peaking and carbon neutrality in a full and faithful implementation of the new development philosophy,” and “N” stands for the Action Plan for Carbon Dioxide Peaking Before 2030 and further relevant policies and action plans for different sectors. The policy is the top-level working plan for the green and low-carbon transition until 2030 (UNDP 2021).

(ii) **Provide incentives and stimulate the development of low-carbon technologies.** The government plans to continue facilitating investments in strategic low-carbon energy technologies, such as CCUS, energy storage technologies, and “green” hydrogen, which is obtained using renewable energy, to ramp up the development of clean technologies. It has already taken some steps in this direction, such as providing capital grants to support large-scale CCUS demonstrations and CCUS construction projects, establishing various science and technology programs, taking actions to develop CO_2 transportation infrastructure, etc. The local governments of 40 cities have also presented development plans for green hydrogen equipment, as well as strategies to further expand this technology.

(iii) **Expand renewable energy generation.** The PRC set a target share of nonhydropower renewables in the power mix at 35% by 2030. This provides another direction for the country to expand sustainable power generation and will facilitate the integration of renewable energy into the grid.

(iv) **Continue to liberalize the energy market.** In 2017, the country issued guidance and instructions for free electricity trading, thereby taking an initial step toward opening the energy market to the private sector and gradually transitioning to a market-based approach, i.e., elimination of price-setting mechanisms and promotion of supply-demand mechanism. The PRC has plans to further promote competition and increase private sector participation.

Forecast Methodology

One of the objectives of this country study is to provide a comprehensive analysis and overview of the trends that could define the PRC's energy market in the coming years. To this end, three key scenarios were developed based on the regulatory and policy framework, consumer preferences, technological development, and other factors (Box 19). The supply and demand, technology, carbon emissions, and investment outlooks were derived from these scenarios. The forecasting methods for these outlooks were informed by analyses of a number of reputable sources, including British Petroleum (BP), International Energy Agency (IEA), Equinor, and others.

Box 19: Scenarios for the People's Republic of China's Energy Sector

Business-as-usual scenario: Projected energy supply and demand, with current energy system and policies;

Government Commitments scenario: Projected energy supply and demand, considering individual priorities of the Government of the People's Republic of China; and

Green Growth scenario: Projected energy and supply demand, considering enhanced energy transition and environmental policies.

Source: Roland Berger/ILF.

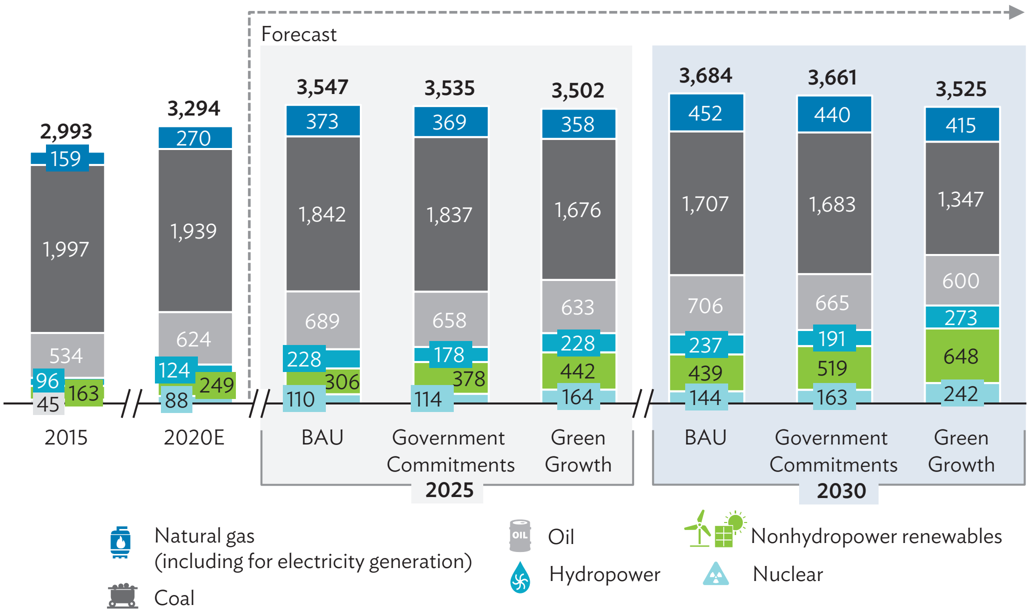
Supply and Demand Outlook

The PRC's economy has recovered very quickly from the impacts of COVID-19, resulting in a 3.5% GDP growth in 2020. A rapid growth trend (around 8.4% per annum) is expected until 2030, resulting in an increase in the primary energy supply across all three scenarios. The primary energy supply is projected to reach between 3,525 million toe and 3,684 million toe, depending on the scenario.

The PRC's fuel split is largely dominated by coal, constituting around 46% of the total in 2030 in the Business-as-usual (BAU) and Government Commitments scenarios, and 38% in the Green Growth scenario. Oil and natural gas are also expected to have a considerable share of the total value: 17%–19% for oil, and 12% for natural gas, depending on the scenario. Finally, the share of cleaner sources

Figure 76: People's Republic of China—Primary Energy Supply Forecast

(million tons of oil equivalent)



BAU = Business-as-usual, E = estimate.

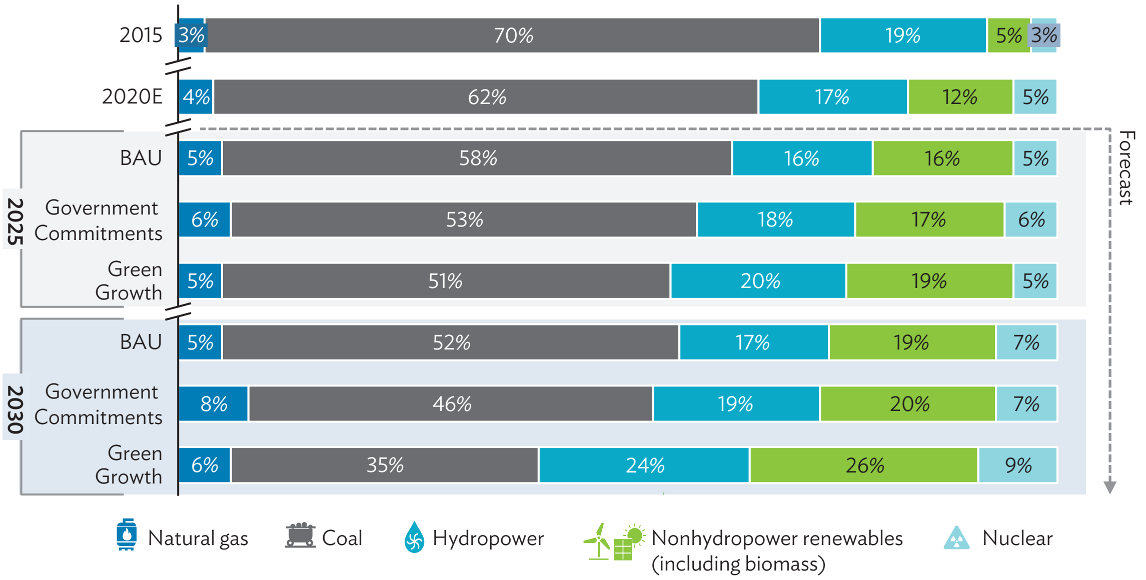
Source of historical data: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 17 August 2021). The forecasts are based on the Roland Berger methodology described in the Methodology section.

is expected to expand to 18% (dominated by nonhydropower renewables) in the BAU scenario, 19% in the Government Commitments scenario, and 26% in the Green Growth scenario. Nuclear power accounts for the remainder (Figure 76).

Coal has historically dominated the PRC's power mix, with a share of around 70% in 2015, and 62% in 2020. Recognizing the need to switch to more sustainable fuels, the PRC has launched a series of policies and regulations to promote cleaner fuels, which would result in a decreased share of coal. This share is expected to decrease to 52% by 2030 in the BAU scenario, to 46% in the Government Commitments scenario, and to 35% in the Green Growth scenario (Figure 77).

The share of renewables is estimated to reach 36% in the BAU scenario, 39% in the Government Commitments scenario, and 50% in the Green Growth scenario. Due to governmental incentives for nuclear energy, its share is also projected to increase to 7%–9%, depending on the scenario. Finally, the share of natural gas in the electricity mix is expected to increase, although it is only expected to reach around 5%–8% by 2030, depending on the scenario. The Government Commitments scenario projects the highest share, reflecting the government's plans to boost demand for natural gas (including in electricity generation).

Figure 77: People's Republic of China—Power Generation Mix



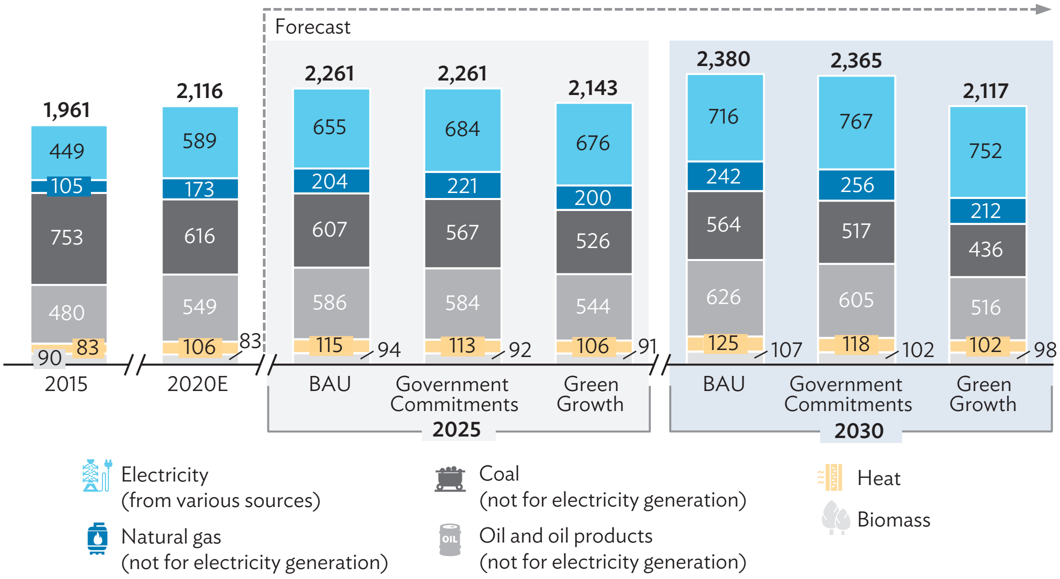
BAU = Business-as-usual, E = estimate.

Source of historical data: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 17 August 2021). The forecasts are based on the Roland Berger methodology described in the Methodology section.

Final energy demand is expected to grow by 2030 according to the BAU scenario (2,380 million toe) and the Government Commitments scenario (2,365 million toe). According to the Green Growth scenario, the final energy demand is expected to grow until 2025, but will decrease to almost 2020 levels (2,117 million toe) by 2030, reflecting more intensive energy efficiency measures. From a fuel perspective, although natural gas will constitute only 10% of the total value in 2030, its annual growth is projected to be the highest at 2%–4%, depending on the scenario. Electricity, on the other hand, is expected to have the largest share in overall demand by source between 30% and 36%, depending on the scenario. It is also expected to grow faster than other sources at around 2%–3% per annum. The 2030 final energy demand for oil is expected to rise in both the BAU and Government Commitments scenarios, but to decrease in the Green Growth scenario, reflecting its lower demand in the transportation sector. In addition, coal is expected to decrease to between 436 million toe and 564 million toe, depending on the scenario. Finally, both heat and biomass are estimated to experience higher demand by 2030 in the BAU and Government Commitments scenarios, with the demand for heat slightly decreasing under the Green Growth scenario (Figure 78).

From a sectoral perspective, industry remains the largest final energy consumer across all scenarios, with demand projected at between 936–1,041 million toe by 2030, depending on the scenario. The residential sector is projected to have the second-highest demand, with 508–579 million toe, and annual growth of 2.6%– 3.7%, depending on the scenario. The transportation sector's demand is forecasted to increase at an annual growth rate of 1.6%–3.3% (402–497 million toe), depending on the scenario. Finally, energy demand in the services sector is expected to have a decreasing trend, with annual growth of −2.3% and −2.9% (263–282 million toe), depending on the scenario (Figure 79).

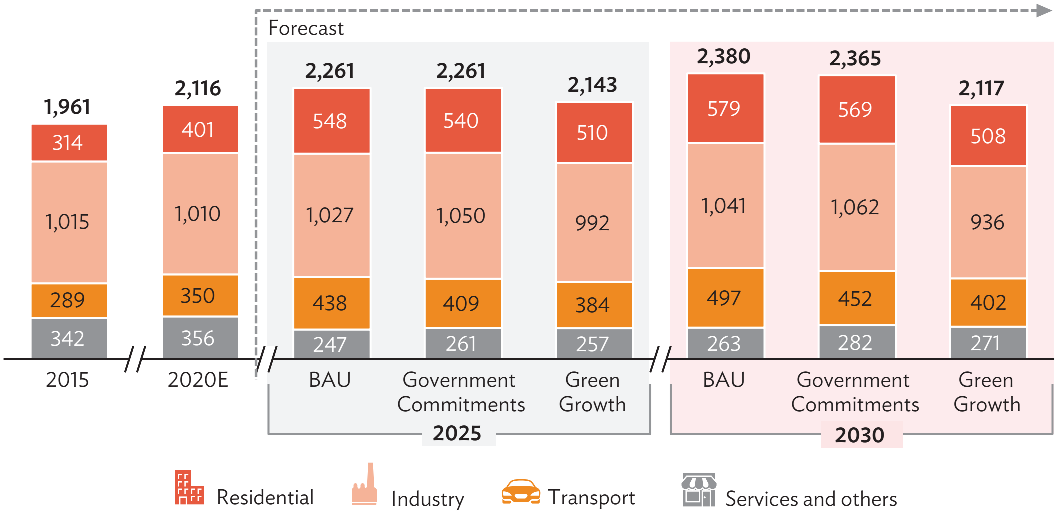
Figure 78: People's Republic of China—Final Energy Demand Forecast by Fuel
(million tons of oil equivalent)



BAU = Business-as-usual, E = estimate.

Source of historical data: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 17 August 2021). The forecasts are based on the Roland Berger methodology described in the Methodology section.

Figure 79: People's Republic of China—Final Energy Demand Forecast by Sector
(million tons of oil equivalent)



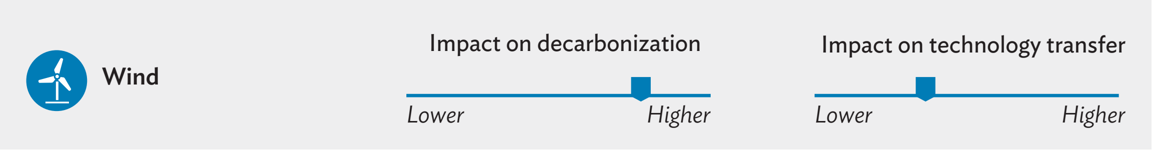
BAU = Business-as-usual, E = estimate.

Source of historical data: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 17 August 2021). The forecasts are based on the Roland Berger methodology described in the Methodology section.

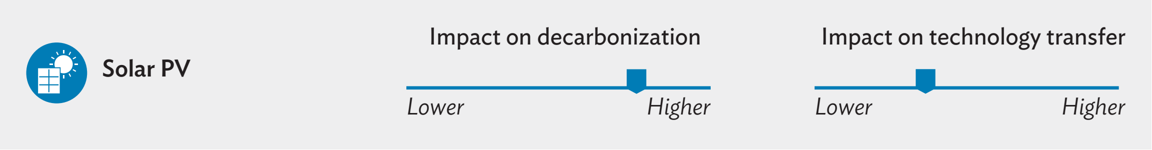
Technology Outlook

Priority Technologies: Generation

Priority technologies in power generation mainly stem from the significant potential of alternative energy sources, such as wind, solar, hydropower, and hydrogen, as well as the country's general energy strategy to increase the share of renewables and reduce the carbon footprint.

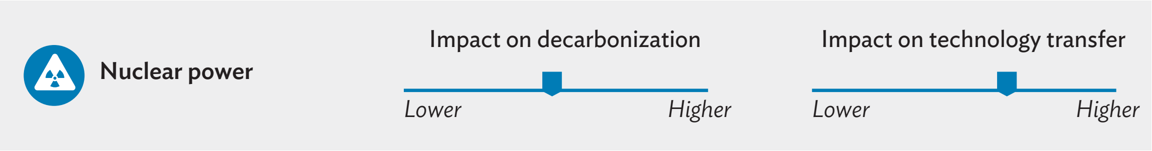


The geographic location of the PRC provides highly favorable conditions for the development of wind projects. According to estimates, the technical potential of wind power is approximately 1,000 GW at a height of 10 meters and 2,100 GW at 50 meters. In addition to this tremendous potential, the cost for wind farms has decreased due to the rapid scale-up of the technology in both the PRC and worldwide. The PRC has made significant advancements in wind energy technologies. It has operational offshore wind farms with over 7 GW in operation, and floating wind power stations that are under development. Furthermore, expanding wind power generation has a considerable impact on decarbonization and is in line with the PRC government's priorities of achieving a 35% share of renewables by 2030.



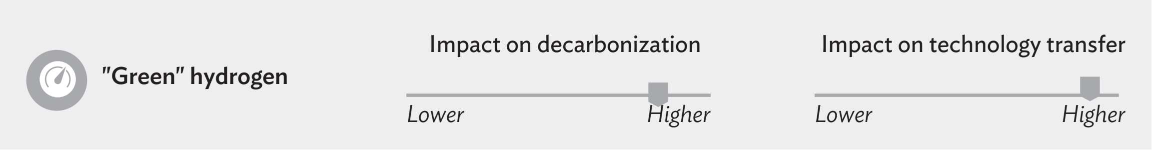
The PRC also has a very high solar energy potential—one of the highest worldwide, with a Global Horizontal Irradiation index of 2.64–5.93 kilowatt-hours per square meter and a potential capacity of more than 4,700 GW. Similar to wind energy, the rapid technological advancements of solar PV plants have led to significantly reduced costs. Overall, further development of solar PV projects will have a moderate impact on technology transfer (given the available installed solar power capacity of 253 GW in 2020), yet a rather significant impact on decarbonization. One area where technology transfer can go "outward" to other countries is offshore floating solar farms. The PRC has experience with such farms and thus can potentially transfer its expertise in floating solar, which can be considered high-end technology, to other countries.

According to various estimates, the country's total technical hydropower potential is 400–700 GW. Pumped storage hydroelectric power stations contribute to a safe and stable operation of grids by load balancing during periods of high-power demand. The PRC aims to increase its pumped storage hydropower capacity to 62 GW by 2025 and 120 GW by 2030 (Bellini 2022). The capacity of pure pumped storage hydropower in the PRC reached 30.3 GW at the end of 2020 (IRENA 2021).



To achieve the country's target to significantly decrease its carbon footprint, the PRC is reducing its coal-fired power generation and switching to cleaner sources of energy, including nuclear power. The PRC is looking to develop new nuclear technologies, particularly, pebble-bed modular high-temperature gas-cooled reactors as well as other small modular reactors' designs. In 2016, the NDRC drafted new rules for nuclear plant projects to facilitate engagement and investments from the private sector. In 2018, another draft law, the Atomic Energy Law, was announced. The law supports exports of the PRC's third-generation nuclear power technology. In addition, the NDRC introduced FIT to provide additional incentives for the development of third-generation nuclear plants for commissioning by the end of 2021. These include $6.2 per megawatt-hour (MWh) for the Sanmen Phase I Nuclear Power Plant, $6.1 per MWh for the Haiyang Phase I, etc.

Furthermore, China General Nuclear Power Corporation estimates that nuclear capacity will reach 120–150 GW by 2030, implying the construction of up to 10 new plants per year by 2025. To achieve these targets, the PRC plans to invest around $80 billion. As of now, 13 nuclear power plants are under construction, with an aggregate capacity of 11 GW. This represents 23% of the world's nuclear capacity to be commissioned by 2030.

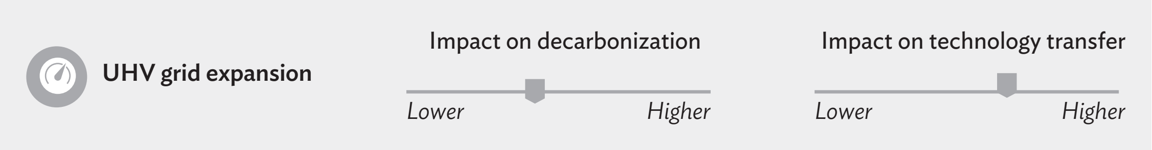


Hydrogen is widely considered among the key pathways to energy sector decarbonization. There are two methods of producing hydrogen without direct carbon emissions: one, from natural gas utilizing carbon capture or storage technology (resulting in "blue" hydrogen); and two, via electrolysis using renewable energy (labeled as "green" hydrogen). While blue hydrogen technology requires installation of efficient CCUS technologies and minimizing leakages at gas production facilities to ensure a positive environmental effect, green hydrogen holds more decarbonization potential due to its zero-carbon process. Overall, the production of green hydrogen remains expensive but is increasingly demonstrating strong potential to achieve reduced costs.

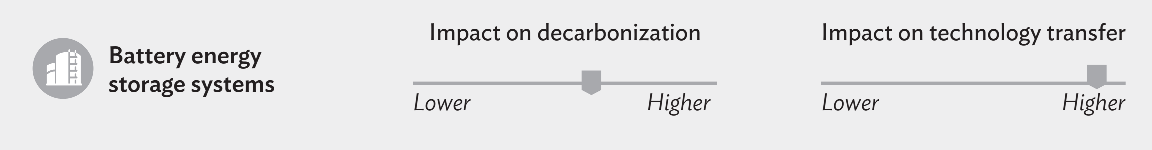
The PRC government takes a favorable stance toward green hydrogen because of its significant renewable potential as well as research, development, and technological capacities. The hydrogen sector is also expected to benefit from the support of local governments that are promoting green hydrogen companies. Overall, more than 40 cities and 20 provinces in the PRC have already published development plans for hydrogen energy production infrastructure. Furthermore, the PRC holds a great position from the infrastructure perspective and plans to develop it further. By 2022, the PRC is estimated to account for approximately two-thirds of the world's electrolyzers or green hydrogen production facilities. The value of the hydrogen industry to the PRC is projected to be $154 billion by 2025. Finally, the cost of the technology is expected to decline as green hydrogen continues to develop. A prime example is a green hydrogen project developed by Sinopec, a state energy giant expected to produce around 500,000 tons of hydrogen per annum by 2025.

Priority Technologies: Transmission and Distribution

Despite the high efficiency of the current grid infrastructure (with around 5% power losses in 2020), the PRC still faces issues of limited connectivity. Therefore, expanding UHV lines is considered to be the country's priority technologies.



Traditional transmission lines have not been very effective in the transmission process over larger distances, resulting in the need to construct additional thermal power plants (mostly coal-fired) in regions with high demand. In contrast, UHV technology will enable the country to link distant power generation plants to demand centers with limited losses. Besides, the Work Report 2020, presented during the National People's Congress, identified UHV lines as a key investment focus. In the same year, the PRC completed the construction of a UHV line (with a project cost of around $3.2 billion). The 1,600 km UHV line will only transport the electricity generated from renewables, allowing the transmission of sustainably generated energy to those regions that rely heavily on coal for power generation. This is also expected to reduce the demand for electricity from coal in the regions, where installing renewables is currently limited or difficult to implement. This initiative highlights the government's commitment to reduce carbon emissions and gradually move away from carbon-intensive electricity generation. Expanding the UHV transmission lines will have a high impact on technology transfer and will potentially enhance the profitability of renewable power generation.



BESS are expected to play an increasingly important role in the PRC's energy sector because of the rapid development of wind and solar generation, smart grids, and electric vehicles. BESS projects have a high impact on the country's technology transfer and a moderate effect on decarbonization (Box 20).

In the short term, installing BESS could significantly reduce curtailment from renewable energy sources (i.e., the purposeful reduction of electricity generation to balance the supply and transmission capabilities) until the new UHV transmission lines are deployed. In the longer term, BESS will boost the country's flexibility in terms of balancing electricity generation from intermittent renewables (wind and solar) and demand. Batteries may store and release the electricity when necessary, thereby preventing grid frequency drops or spikes. Since BESS is still an early-stage technology in the PRC, further projects can significantly boost technology transfer. At the same time, the long-term impact of BESS on decarbonization is moderate as UHV transmission infrastructure will play a central role in integrating renewables.

Box 20: People's Republic of China's Flagship Energy Project

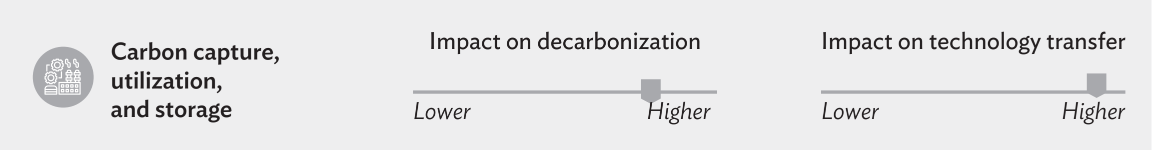
In 2020, Ming Yang Smart Energy Group—the international company specializing on clean energy integrated solutions, particularly wind and solar photovoltaic (PV)—announced its mega project, Tong Liao Hybrid Battery Energy Storage. The company signed an agreement with the local government to construct a 1.3-gigawatt (GW) renewable-battery hybrid plant in Tong Liao, Inner Mongolia. The aim of the project is to build around 1 GW in wind power and 0.3 GW in solar PV, which will be linked to a 0.3 GW lithium-ion battery storage system. The project cost is estimated around $1.3 billion.

Note: Illustrative photo of ecofriendly battery energy storage system in nature is by Malp/Adobe Stock©.

Source: *Power Technology.* 2021. Ming Yang Smart Energy-Tong Liao Hybrid Project—Battery Energy Storage System, China. 31 August.

Priority Technologies: Consumption

Despite significant improvements in energy efficiency in recent years, the industrial sector (particularly, the power, cement, and steel production sectors) remain a significant contributor to overall CO_2 emissions. This is mostly due to the sector's large consumption of coal—around 3,873 Mt or almost 80% of the country's total coal consumption in 2019. Given that the transition process from coal to more sustainable energy sources is a gradual process and will take time, CCUS could be an optimal solution to attenuate the amount of emissions.



CCUS is a crucial chapter of the PRC's climate action strategy because the consumption of energy from conventional fuels, especially coal, cannot be fully replaced in the short to medium term. CCUS technology can allow the country to continue using fossil fuels (especially in such industries as steel, cement, coal-fired power plants, and chemicals) while achieving the PRC's target of reducing its carbon footprint. While an effective regulatory framework is lacking at this stage, the government is taking initial steps in this direction.

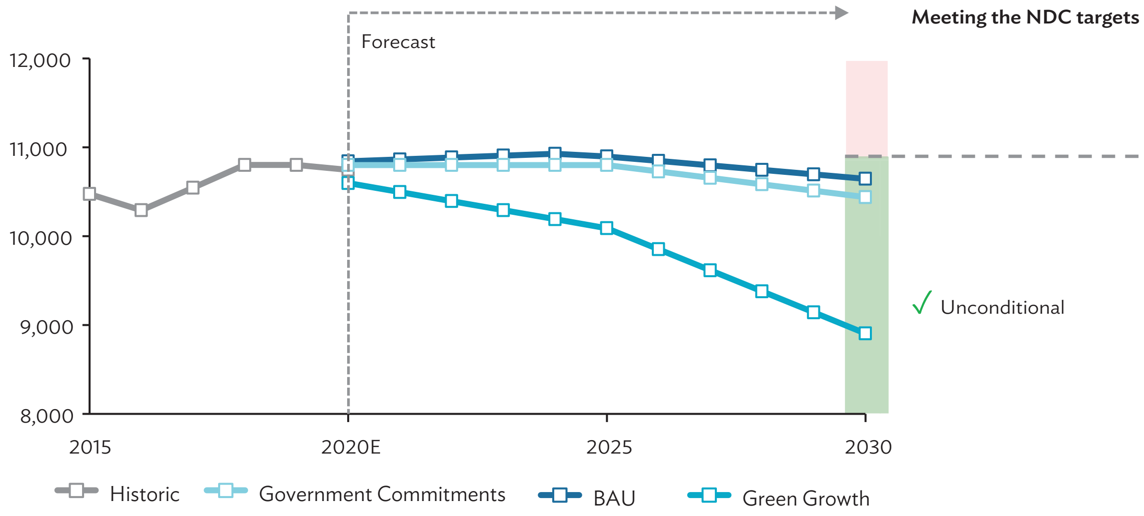
The PRC has already established considerable operational CCUS experience, based on its numerous pilot projects. Although several challenges still exist in large-scale commercial CCUS project implementation (for instance, an insufficient regulatory framework and limited engagement of the private sector), nonetheless, plentiful storage capacities, available access to financing, past project experience, as well as the government's willingness to facilitate CCUS development, generate an overall positive outlook for this type of project. The development of CCUS projects is expected to significantly enhance the country's technology transfer and accelerate decarbonization.

Carbon Emissions Outlook

By submitting its NDC in 2015, the PRC contributed to the global commitment to act on climate change. Overall, the PRC set a national target to achieve the peak of carbon emissions by 2030 and greenhouse gas emission net-zero by 2060. In addition, the PRC targets lowering the amount of emissions per unit of GDP by 60%–65% from the 2005 level, which is an overall target, without specific division for energy-related emissions (i.e., emissions from generation, transmission, and consumption of energy, recognizing that 26.8% of total emissions are from non-energy sources). To estimate the energy-specific target, the targeted amount of energy-related emissions per unit of GDP was defined (62.5% of energy-related emissions per unit of GDP in 2005) and then multiplied by the GDP forecast for 2030 from Oxford Economics, translating into an estimated energy-related target of approximately 10,900 million tons of CO_2 equivalent.

In terms of forecasted amounts, all scenarios are expected to achieve the NDC target. The emission level under the Government Commitments scenario is not much different from that under the BAU scenario, with around 10,650 million tons of CO_2 equivalent in the Government Commitments scenario and 10,450 million tons of CO_2 equivalent in the BAU scenarion. The Green Growth scenario, however, assumes the lowest emission level, with nearly 8,900 million tons of CO_2 equivalent (Figure 80).

Figure 80: People's Republic of China—Energy-Related Carbon Emissions
(million tons of carbon dioxide equivalent)



BAU = Business-as-usual, E = estimate, NDC = Nationally Determined Contribution.

Note: Historical data on carbon emissions is modelled by Roland Berger based on historical data on energy use. The forecasts are based on the Roland Berger methodology described in the Methodology section.

Sources: Roland Berger; and United Nations Framework Convention on Climate Change. Nationally Determined Contributions Registry. https://unfccc.int/NDCREG.

Even though all scenarios are expected to meet the NDC target, it would be important to strive for achieving the Green Growth emission level (or to go beyond it), given that the PRC is the largest emitter of CO_2 globally. In 2019, the PRC produced approximately 30% of global energy-related carbon emissions.

Investment Outlook

Investment Needs

Overall, the three scenarios estimate different levels of energy-related investment needs by 2030, with a projected value of between $2,799 billion and $3,497 billion, depending on the scenario. Considerable investment is required across electricity generation, T&D, and energy efficiency sectors, taking into account the large market size and plans for the energy transition.[13] The largest investments are estimated to stem from the generation sector (between $1,180 billion and $1,710 billion), reflecting the country's target to transfer to more sustainable power generation. Specifically, by 2030, the PRC's investment needs in renewable energy sources are expected to be 67%–70% out of investments for generation, depending on the scenario. Following the government plans to increase electricity generation from nuclear power plants, the respective investment needs are projected to be between $170 billion and $328 billion by 2030, depending on the scenario, representing between 14% and 19% of the generation investment needs. Besides, given the expected gradual switch from coal to natural gas, the corresponding investment needs for natural gas power plants are estimated to reach between $40 billion and $57 billion, depending on the scenario. Finally, some investments are also expected to go to the rehabilitation of the old coal-fired power plants, as well as to the construction of more efficient new plants, resulting in projected investments of between $144 billion and $165 billion by 2030, depending on the scenario.

Furthermore, the T&D investments until 2030 are estimated to range between $743 billion and $865 billion, depending on the scenario. These investments are expected to be mostly led by electricity transmission (87%–92% of T&D investments), particularly the deployment of the UHV lines. Finally, the investments in energy efficiency measures are expected to range between $879 billion and $938 billion, depending on the scenario (Figure 81).

Challenges and Opportunities

The private sector may face several challenges when investing in the PRC's energy market. One of them concerns the government's interventions in the market pricing mechanisms settings, particularly in the electricity sector. Potential price changes initiated by the state may lead to uncertainty and market risks for investors. In addition, the delays in FIT payments for renewable energy projects are an important concern of many private players already active in the market.

Market entry is another potential challenge for private investors, especially for foreign companies. Business entities face preconditions to entering the energy sector, such as forming a joint venture with a local company. However, the government declared its objective to simplify market entry for foreign companies, and has already taken the first steps toward addressing this issue. In 2019, the new foreign investment regime was introduced as part of the Foreign Investment Law. This framework provides equal

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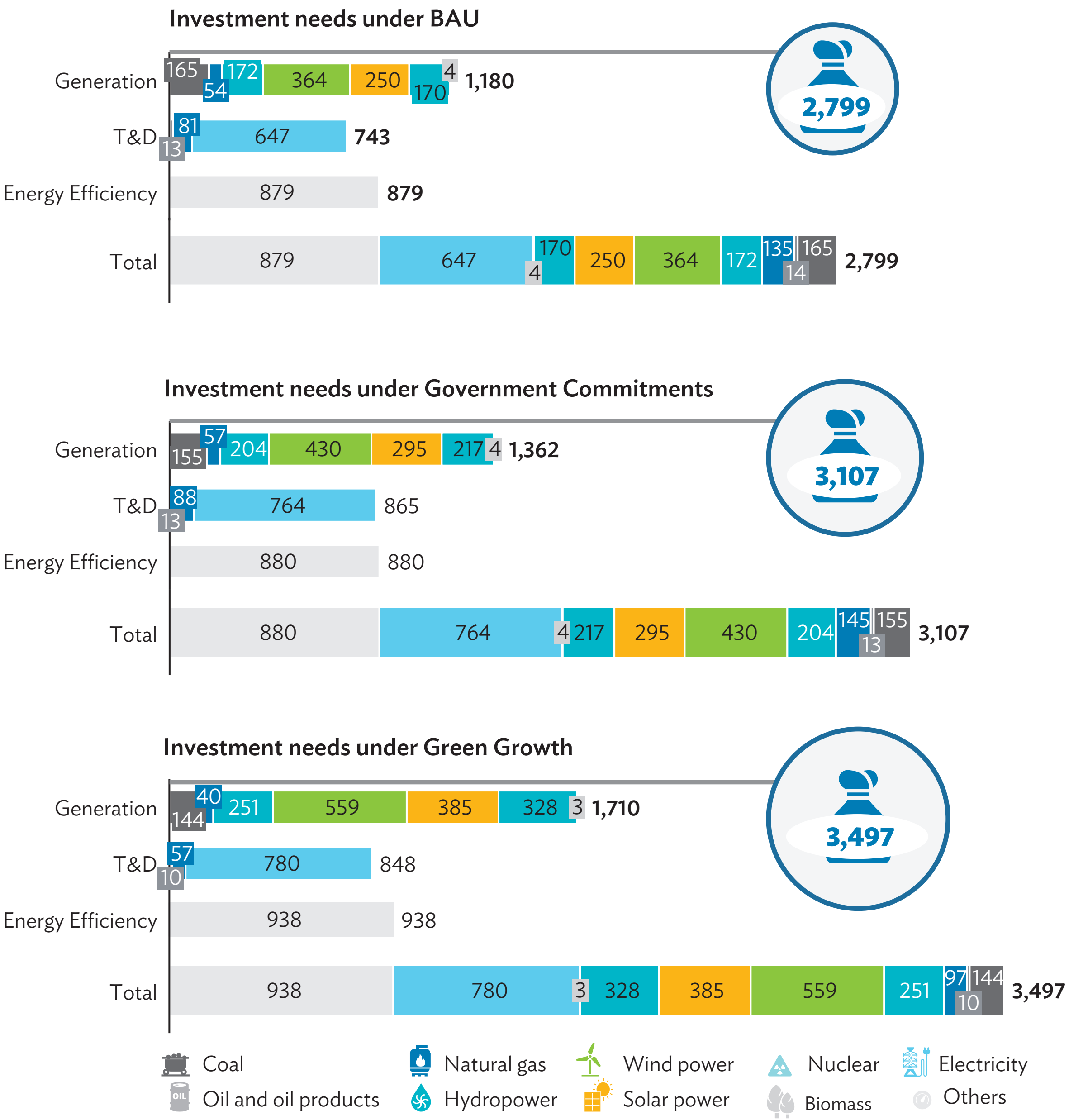
[13] Investment needs assessment excludes fossil fuel production sector because of focus on low-carbon energy technologies.

Figure 81: Energy Infrastructure Investment Needs in the People's Republic of China until 2030

($ billion)



BAU = Business-as-usual, T&D = transmission and distribution.

Source: The forecasts are based on the Roland Berger/ILF methodology described in the Methodology section.

market access for both foreign and domestic investors, with some exceptions in consolidated lists. Since 2020, the PRC has been opening the upstream natural gas and oil sectors to foreign companies, allowing them to establish and operate an entity without creating a joint venture with a local player. According to its strategy documents, the PRC will continue conducting market liberalization measures to achieve more transparent and fair market access for foreign investors.

In addition to the above referenced measures, the government is providing certain investment incentives in the energy sector, which may bring additional opportunities for private investors. Overall, the government incentives include FIT for nuclear power generation; subsidies (e.g., a subsidy program for unconventional gas aimed at boosting natural gas production); and renewable electricity quotas (by 2030, the country plans to set the minimum purchase of renewable electricity to 40% of the total value, according to the NEA draft policy), and others. Besides, the PRC has multiple programs that provide additional funding for energy projects. For instance, the China Sustainable Energy Program, which cooperates with research institutes and foundations, energy technology centers, policy groups, etc., provides grants for planning, research, and policy projects, aimed at improving energy efficiency and attenuating the country's emissions levels (Terra Viva Grants Directory 2022). Another example of such programs is the Government Science and Technology Program, which also facilitated the early-stage development of CCUS, and whose research subsidies only reached around CNY3 billion or $0.5 billion.

Finally, the PRC is leading in the majority of modern prominent technologies, such as CCUS, BESS, hydrogen, etc. Specifically, the Huaneng Group has executed one of the world's first industrial post-combustion CCUS projects. Operating for more than 10 years, the carbon capture device is based on a coal power plant, capturing up to 120,000 tons of CO_2 per annum. Besides, some of the country's CCUS technologies have already reached the commercial application stage. In terms of BESS, the PRC has already launched more than 50 energy storage projects (in 2018, the cumulative installed capacity of grid-connected energy storage was about 1 GW) and multiple projects are now in the pipeline. This includes the battery storage system in the Dalian region, with an estimated capacity of 0.2 GW and expected to be commissioned in 2022; and the Tong Liao Hybrid mega project, with 0.3 GW battery storage capacity. For hydrogen, the PRC is ranked among the world's largest hydrogen producers, accounting for around 35% of the global level, which the country aims to increase further. Specifically, the country strives to install around 100 GW of green hydrogen electrolyzers by 2030 (Collins 2021). Overall, the PRC's 23 CCUS projects are estimated to have a total carbon capture capacity of 2.1 million tons in 2021. The government aims to double its carbon capture capacity by 2025.

Finally, in addition to the PRC's substantial experience and potential, the country has considerable financial resources available, well-developed infrastructure, as well as leading research and development centers.

Policy Recommendations

The PRC has set very clear directions for the development of the energy sector, such as reducing its carbon footprint, transitioning toward more sustainable energy sources, and facilitating the participation of the private sector. To enhance their implementation and address several challenges faced by private investors, the following policy recommendations are suggested:

(i) **Providing further incentives to minimize the use of coal.** The government has achieved only minimal progress in reducing its coal consumption. In 2016, NEA announced a coal reduction policy, according to which construction of some coal-fired plants was postponed. In 2018, China Energy Corporation merged with China Guodian Corporation, driven by a push to reduce the growth of coal production in the longer term. In 2019, the government announced structural reforms via the Trial Measures for the Regional Integration of Central Government State-Owned Enterprises in the Coal-Fired Power Sector. In essence, these measures imply merging five key state-owned coal companies to eliminate outdated assets, control the new additions, and thus lower the plants' coal-fired capacity by 25%. However, the development of new coal power projects continues in certain provinces (the country commissioned 38.4 GW of new coal-fired power generation in 2020). Nevertheless, by accelerating its efforts to disincentivize the use of coal (e.g., through introduction of carbon taxes[14]) as well as to decommission antiquated facilities and facilitate the transfer toward natural gas and more sustainable energy sources, the PRC can achieve its goal of reducing its carbon footprint and promoting low-carbon technologies instead.

(ii) **Continuing the liberalization process of the energy markets.** The PRC has already taken some steps toward opening its energy sector to private investors. The country has established a new legal framework for foreign investors in 2019 (allowing nondiscriminatory market access for foreign companies without the need to create a joint venture with a local firm) and has adopted decrees on the liberalization of electricity generation market (providing guiding principles on further reform in the wholesale and retail power markets), among others. Continuing the energy market liberalization process (decreasing the government's regulation of energy tariffs, ensuring the simplified licensing and registration process of private companies, etc.) will allow equal access and market opportunities for domestic and foreign, as well as state and private companies, which will improve the competitiveness of the PRC's energy sector.

(iii) **Continuing to develop the emission trading scheme.** One of the strategic goals of the PRC is to reduce the country's carbon intensity. One activity targeted to achieve this is the country's ETS, which was started in 2021. At the first stage, the ETS focuses on power generation companies with emissions of more than 26,000 tons of CO_2 per year. This step is expected to cover more than 4 billion tons of CO_2, which is equal to around 40% of the PRC's carbon emissions. However, given that this is only a first stage of the ETS, clear consequences or penalties for noncompliance still need to be identified.

(iv) **Stabilizing the renewable energy market.** The PRC has already provided considerable stimulus for renewables in the form of FITs, competitive auctions, and quotas for purchase of renewable power, leading to the increase of renewable energy projects (the installed capacity for solar PV and wind farms increased from 1 GW in 2005 to 535 GW in 2020). Continuing to stabilize the market, expanding capacity auctions, renewable electricity quotas, and possibly introducing carbon taxes, etc. will provide further incentives for investors to launch renewable energy projects. As for hydrogen, local governments in 40 cities and 20 provinces have already published strategies and development plans for hydrogen energy equipment. By providing a green hydrogen strategy, creating a respective regulation on the national level, as well as establishing additional incentives, the government can stimulate large-scale development of hydrogen, and realize the country's potential.

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[14] Carbon tax is a fee imposed on polluting industries for every ton of CO_2 emitted.

(v) **Providing further incentives for sustainable technologies such as Battery Energy Storage System and Carbon Capture, Utilization and Storage.** The country is among the leaders in technological development, with multiple research and development studies and projects being implemented. Promoting technologies such as BESS may significantly limit the issue of curtailment, minimize electricity losses, and balance electricity generation and supply; while implementing CCUS projects may substantially help to attenuate the country's carbon intensity level. Therefore, providing a national strategy, setting up the corresponding incentives, as well as creating regulations for these technologies, can significantly facilitate the further development of large-scale projects.

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Nanchang, the capital city of Jiangxi Province. Nanchang in the People’s Republic of China blends its over 2,000 years of history and cultural interest with its magnificent natural scenery and rich tourist attractions (photo by Gui Yong Nian/Adobe Stock©).

TAJIKISTAN

Nurek Dam Spillway in Tajikistan. The 300-meter high dam had long been the world's highest dam; since 2013, it has been the second highest in the world (photo by Lukas/Adobe Stock©).

Tajikistan Highlights

- Hydropower is the foundation of Tajikistan's energy system, accounting for nearly 93% of its power generation and around 90% of its installed capacity. This reliance on hydropower is due to the country's geographic conditions and the large availability of water resources (particularly glacier-fed rivers). As a result, Tajikistan's energy sector is one of the cleanest in the world in terms of greenhouse gas (GHG) emissions.
- Tajikistan has rapidly expanded its domestic production of coal, reaching 1.7 million tons in 2017—almost 10 times more than in 2010. This translates to a 5% share of coal in the electricity mix in 2017 and 7% in 2018 (Figure 82). The country has negligible domestic production of oil and natural gas because of insignificant reserves.
- Total installed power generation capacity in the country exceeds 6 gigawatts (GW). In addition to numerous hydropower plants, Tajikistan has a coal-fired power generation capacity of nearly 0.7 GW, which is in operation during the winter to meet seasonal demands. The development of nonhydropower resources is at a very early stage, with only small-scale off- and mini-grid projects in operation.
- Tajikistan's final energy demand is expected to reach 3.5 million tons of oil equivalent (toe) to 4.1 million toe in 2030, depending on the extent of investments in energy efficiency measures under various scenarios. Electricity holds a major share of final energy demand, and is predominantly used in the industrial and residential sectors.
- Hydropower will continue to play a leading role in Tajikistan's power system until the end of the 2020s. The key challenge on the supply side is to improve hydropower reliability given seasonal variations, climate change, and the gradual disappearance of glaciers, which may significantly reduce river flows. The expansion of coal-fired generation will persist, reaching 9%–10% in 2030, with limited penetration of wind and solar energy (mostly off-grid installations in geographically remote regions), unless a combined share of nonhydropower renewables of up to 13% can be reached through enhanced policy measures.
- In addition to renewable power generation (including hydropower, wind, and solar energy), the rehabilitation and modernization of the power grid represent priority investments for Tajikistan. On the consumption side, it is crucial that measures are taken to improve efficiency in the industry and residential sectors.
- Tajikistan's energy investment needs by 2030 are estimated to range between $4.7 billion and $7.6 billion, depending on the scenario. Energy efficiency investment needs are expected to constitute the largest share—between $2.3 billion to $3.9 billion, depending on the scenario. The investment needs in the generation sector, which are the second largest (between $1.7 billion and $2.2 billion), are expected to be led by renewable power (primarily hydropower). Finally, the transmission and distribution (T&D) sector is expected to require the largest investments for electricity, which will account for 63%–87% of total T&D investments by 2030 ($0.8 billion to $1.5 billion), depending on the scenario.
- Investment opportunities in Tajikistan are linked to the government's plans to reform the sector (including unbundling measures and the introduction of cost-recovery tariffs) as well as strong opportunities for export-oriented renewable energy projects. However, further legislative work is needed to establish the right conditions for private sector participation and to mobilize resources for an infrastructure modernization program.

Figure 82: Tajikistan—Key Figures

Renewable potential	Electricity mix	Hydropower potential	Carbon intensity	Coal production
~220 GW	**93%**	**~6%**	**168th out of 172**	**>10x**
Total potential of renewable energy (excluding large-scale hydropower) is estimated at ~220 GW.	Share of hydropower in the electricity generation mix reached 93% in 2018.	Utilization rate of hydropower potential in Tajikistan is ~6%.	Tajikistan is ranked 168th out of 172 countries in the global ranking of carbon intensity, being one of the cleanest energy systems globally.	Domestic coal production increased 11 times between 2010 and 2018. The share of coal in the power mix was 7% in 2018.

GW = gigawatt.

Sources: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 3 September 2021); United Nations Development Programme. 2014. *Renewable Energy Snapshot: Tajikistan*. New York; and United States Energy Information Administration. Tajikistan Data. https://www.eia.gov/international/data/world (accessed 3 September 2021).

- Policy recommendations for Tajikistan include finalizing tariff policy reforms, continuing with support measures for nonhydropower renewables (on-grid solar photovoltaic [PV] and wind energy plants as well as off-grid solar PV systems to provide greater access to electricity in remote areas of the country), and improving the legislative framework to enable energy savings via efficiency measures.

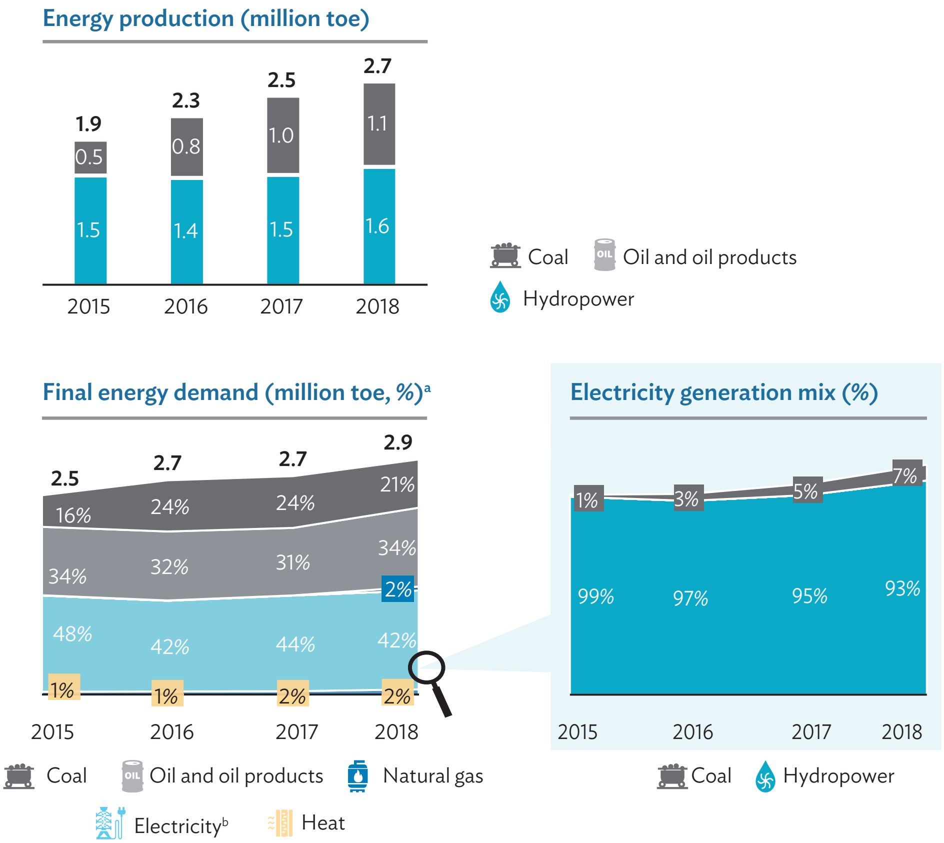
Energy Sector Profile

Country Profile

Tajikistan is a mountainous and land-locked country in the heart of Central Asia. With a population of approximately 9 million people, Tajikistan has experienced volatile gross domestic product (GDP) changes in recent years. Between 2014 and 2016, the country's nominal GDP dropped by nearly 25%, driven by economic difficulties experienced by its main trading partners—the Russian Federation and, to a lesser extent, the People's Republic of China (PRC). Economic recovery continued until 2020, when Tajikistan was seriously affected by the coronavirus disease (COVID-19) pandemic—its nominal GDP declined by 2% to slightly above $8 billion. However, Tajikistan is projected to experience a rapid economic recovery and a prolonged increase in GDP, which will almost double by the end of 2030. The population is expected to reach 11–12 million people in 2030.

Tajikistan relies on domestically available hydropower resources to cover a major share of final energy demand. The country does not only have abundant water and hydropower resources, but also legacy hydropower infrastructure from the former Soviet Union. In addition, Tajikistan has expanded coal

Figure 83: Energy Profile of Tajikistan



toe = ton of oil equivalent.

[a] Topmost numbers on the chart are in million toe.

[b] Electricity data come from various sources, including fossil fuel-based and renewables..

Source: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 3 September 2021).

production in recent years to diversify electricity production. Other energy fuels consumed in Tajikistan —mainly oil products and, to a much lesser extent, natural gas—are imported, due to the lack of domestically available resources. The country has an impressive track record in terms of carbon intensity, ranking 168th out of 172 countries in 2018. This is because of the dominance of "clean" hydropower in its power mix (Figure 83). However, the country's energy intensity performance is relatively poor —Tajikistan is the 20th most energy-intensive economy in the world, highlighting the strong potential for energy savings.

Energy Sector and Technologies Assessment

Conventional Fuel Production

Tajikistan's fossil fuel production has historically focused on coal, with oil and gas having been exploited to a lesser extent. The country's main coal deposits are concentrated at the Tajik (Gissar-Darvaz) and Fergana basins (Public Environmental Organization "Little Earth" 2017). The country has started increasing its coal production during the last 10 years, with more than 1.7 million tons of coal produced in 2017 (more than 10 times the amount produced in 2010). Total reserves are estimated to be more than 4.3 billion tons, out of which 320 million tons are industrial coal reserves of high calorific value.

Tajikistan's domestic oil and natural gas production numbers are nearly negligible. Annual production reaches less than 17 tons of oil and less than 1 billion cubic meters of natural gas. However, the government plans to modernize and conduct a technical re-equipment of its upstream infrastructure, as well as develop new oil and natural gas fields. Tajikistan also has two operational refineries, with a cumulative capacity of 150,000 tons annually.

Electricity Generation

Overall, the power system in Tajikistan is centralized, as electricity is mostly generated by large power plants that supply to the majority of the population. Historically, hydropower has been the main contributor to Tajikistan's electricity generation. The country's total power generation capacity is 6.1 GW, with hydropower covering around 90% of the total installed capacity (World Bank 2020a). Most of the hydropower plants (HPPs) in Tajikistan are over 30 years old and need rehabilitation. Several units have been rehabilitated already, and several are currently undergoing rehabilitation. The first phase of the rehabilitation of the largest HPP in the country—i.e., Nurek HPP, with an installed capacity of 3 GW, which was launched in March 2019 and is expected to continue through 2023—is cofinanced by the World Bank, Asian Infrastructure Investment Bank, and Eurasian Fund for Stabilization and Development (Asian Infrastructure Investment Bank 2017; NS Energy; World Bank 2020a). In 2020, the World Bank approved additional financing for the second phase of the Nurek Hydropower Rehabilitation Project (World Bank 2020b). Despite being Central Asia's leader in hydropower availability, Tajikistan is estimated to use only nearly 6% of its total hydropower potential.

The remaining share of the country's installed capacity is made up of thermal power plants, operating in winter to supply electricity and heat. This is due to higher demands during winter and to the seasonal patterns of hydropower generation. The country relies on three combined heat and power (CHP) plants, with a total capacity of 718 megawatts (MW), or 0.7 GW (Government of the Republic of Tajikistan, Ministry of Energy and Water Resources). In response to increasing demand and reduced gas imports, the country has prioritized the construction of new coal-fired plants, with the most recent one having been commissioned in 2014.

Although Tajikistan is currently one of the least carbon-intensive countries in the world, its energy sector's growing emphasis on coal-fired energy is making the country less environmentally sustainable. While coal-fired generation can help to mitigate hydropower seasonality, the expansion of nonhydropower renewables can also support these efforts, given Tajikistan's significant technical potential. This is one of the government's policy priorities that is supported by international financial institutions (IFIs). The most abundant nonhydropower renewable resource is solar power, which is estimated at around 195 GW, based on the country's climate and geographic conditions, as well as wind, with an estimated potential of 2 GW. The potential for small hydropower, on the other hand, constitutes around 23 GW. The country has recently started introducing more off-grid installations in remote regions such as the Gorno-Badakhshan Autonomous Region (GBAO), which recently commissioned its first utility-scale 200 kilowatt solar PV plant. Such projects offer significant potential to sustainably improve the reliability and affordability of energy supplies to remote regions.

Transmission and Distribution

Barqi Tojik, Tajikistan's electricity utility, has been under severe financial stress because of years of operating with a tariff below cost-recovery level. This presents an important challenge to Tajikistan in the form of periods of underinvestment and inadequate maintenance, resulting in significant T&D losses of about 17%. Inefficiencies in the power grid have led to outages, but the country is moving in a positive direction, with a system average interruption duration index decreasing from about 290 minutes in 2019 to 130 minutes per interruption per customer in 2020. Its system average interruption frequency index displays the same downward trend, with six interruptions per customer in 2019 and three in 2020.

While Barqi Tojik operates the main grid, Pamir Energy operates all existing electricity generation, transmission, and distribution to Tajikistan's poorest and sparsely populated mountainous region of GBAO under a 25-year concession agreement. Generation capacity in GBAO is only 44 MW, and its transmission system operates at a maximum voltage of 35 kilovolts (kV), with a total length of more than 2,600 kilometers (km) (Government of the Republic of Tajikistan, Ministry of Energy and Water Resources). By contrast, Barqi Tojik operates high-voltage lines with a maximum level of 500 kV and a total length of more than 6,700 km.

Tajikistan's natural gas T&D infrastructure is developed to a limited extent. Without any local production, consumption of natural gas has been negligible since 2013. Although Tajikistan and Uzbekistan recently reached a solution on the contractual terms for gas supplies from Uzbekistan, natural gas imports are still low and are used by a limited number of industrial off-takers. Such a gap in the natural gas system operations not only prevents detailed analysis of the T&D infrastructure, but also implies the low importance of natural gas in Tajikistan's energy sector.

District heating systems are installed only in the capital city of Dushanbe and in the region of Yavan. Financial issues have also led to a lack of systematic maintenance and to significant heat losses of 40%–50%. All these issues indicate the critical need to rehabilitate and expand existing infrastructure in a systematic manner.

Cross-Border Infrastructure

Tajikistan plays an important role in the Central Asian energy trade, as it is interconnected with all neighboring countries.

By targeting an increase in hydropower generation, the country is planning to expand its export capabilities via the Central Asian Power System (CAPS), as well as to Afghanistan and Pakistan via the Central Asia–South Asia Electricity Transmission and Trade Project (CASA-1000). Nevertheless, it is important to note that the uncertain political situation in Afghanistan, through which Tajikistan will transfer its electricity, has rendered difficult any predictions as to when and if the CASA-1000 project can be successfully commissioned.

Tajikistan started to export power to Uzbekistan through a 500 kV line on an islanded mode in 2018. Tajikistan has received financial support from the Asian Development Bank (ADB) for the reconnection to CAPS to synchronize the systems and expand regional trade in the energy sector (ADB).

Tajikistan's natural gas cross-border infrastructure is significantly limited. Muzrabad–Dushanbe is one major pipeline used to import natural gas from Uzbekistan to main consumption centers in Tajikistan, yet its capacity is only around 2 billion cubic meters per annum (Table 8).

Energy Consumption

Like other countries in Central Asia, Tajikistan underperforms in terms of energy efficiency because of its outdated and rather inefficient infrastructure across all consumption sectors. Nevertheless, Tajikistan displayed a better indicator of energy intensity in 2019 than its regional peers, with 7.340 British thermal units (Btu)/$2015 gross domestic product based on purchasing power parity (PPP GDP).

Table 8: Tajikistan—Major Cross-Border Energy Infrastructure

Energy Source	Name	Capacity	Status	Connected Country
⚡	CASA-1000	1.3 GW	Planned	Afghanistan, Kyrgyz Republic, Pakistan
⚡	Kanybadam–Aigultash 220 kV line	600 MVA	Operational	Kyrgyz Republic
⚡	Zumrat–Aigultash 110 kV line	445 MVA	Operational	Kyrgyz Republic
⚡	Proletarsk–Samat 110 kV line	450 MVA	Operational	Kyrgyz Republic
⚡	Guzar–Regar 500 kV line	2,470 MVA	Nonoperational	Uzbekistan
⚡	Surhan–Regar 500 kV line	2,070 MVA	Nonoperational	Uzbekistan
⚡	Uzlovaya–Syrdarya 220 kV line	690 MVA	Nonoperational	Uzbekistan
⚡	Geran–Afghanistan 220 kV line	600 MW	Operational	Afghanistan
⚡	Geran–Afghanistan 110 kV line	100 MW	Operational	Afghanistan
🔥	Central Asia–PRC (line D)	30 bcma	Planned	Kyrgyz Republic, PRC, Turkmenistan, Uzbekistan
🔥	Sherabad–Dushanbe	2 bcma	Operational	Uzbekistan

⚡ Electricity 🔥 Natural gas

bcma = billion cubic meters per annum, CASA = Central Asia–South Asia, GW = gigawatt, kV = kilovolt, MVA = megavolt-ampere, MW = megawatt, PRC = People's Republic of China.

Sources: Asian Development Bank. 2017. *Tajikistan: Power Sector Development Master Plan Final Report*. Manila (Grant 0213-TAJ); China National Petroleum Corporation. Flow of Natural Gas from Central Asia; and Fitch Solutions. 2022. *Tajikistan Power Report*. London.

This represents more than a three-fold improvement compared to 2000, when this indicator reached 23,076 Btu/$2015 PPP GDP. However, Tajikistan is still above the global average of 4,700 Btu/$2015 PPP GDP in 2019 (US EIA).

In terms of industrial consumption, key subsectors include mining, chemical, textile, machine-building, and metallurgical industries. Energy consumption is rather concentrated, with the Tajik Aluminium Company (TALCO) accounting for a large share of overall energy and nearly half of the industrial electricity consumption. TALCO's completion of energy audit procedures that are supported by IFIs enables an informed analysis of potential energy savings in the sector. The energy audit found that energy consumption could be reduced by 20%–30%, if specific measures are implemented—mainly the modernization of the equipment to modern energy-efficiency standards. However, since the Tajikistan's energy services market is still nascent, wider energy audits are still not conducted.

Buildings (in both the residential and services sectors) are an important consumer group and hold large potential for energy savings. Nearly 90% of buildings were constructed according to inadequate energy performance standards inherited from the Soviet era. The lack of investments in maintenance and rehabilitation, as well as the inadequate use of thermal insulation, imply a strong need for investments in energy efficiency. Existing studies estimate that the potential for energy savings in residential buildings is 30%–40%, with current energy consumption up to 350 kilowatt-hours per square meter (kWh/m^2) per year—significantly higher than in most countries with comparable climate conditions (e.g., this indicator ranges from 200 to 280 kWh/m^2 per year in Azerbaijan). Improving energy efficiency in new and existing buildings has been on the government's agenda, as evidenced by the adoption of the Residential Buildings Code in 2005. Nevertheless, the stringency of energy performance requirements, as well as the enforcement of these standards, can be improved further.

Tajikistan's transportation sector faces similar issues. While the vehicle ownership rate remains quite low (40–50 cars per 1,000 inhabitants), the average age of the car fleet is about 15–18 years. Because old vehicles are significantly less efficient than modern cars, the impact on energy demand and emissions levels is considerable. In response to decreasing compressed natural gas (CNG) and liquefied natural gas (LNG) fuel prices, many vehicle owners have switched in recent years to petrol alternatives. Still, price volatility remains high, and the share of vehicles running on diesel and LNG is constantly changing. Electric vehicle penetration is negligible amid the lack of charging infrastructure. Similarly, the railway network in Tajikistan (totaling approximately 700 km in length) is not electrified. Diesel locomotives, operated by the State Unitary Enterprise "Rohi Ohani Tojikiston," are in poor technical condition, having been commissioned in 1970–1989.

Regulatory Framework

The Ministry of Energy and Water Resources, established in 2013, is Tajikistan's key regulatory player. Although it is unusual for a single authority to manage a country's energy and water sectors, it is reasonable considering hydropower's role in Tajikistan's energy system. A separate energy sector regulatory body was created in 2019 as a unit of the Anti-Monopoly Commission. However, the government should ensure that the ministry's function is limited to policy making, entrust a separate regulator with regulating market practices, and ensure that the market functions independently of the government.

The legislative framework for Tajikistan's energy sector was established with the Law on Energy, adopted in 2000. It determines the key ownership forms for entities in the energy sector as well as the structure of tariffs, and establishes the government as the main authority for approving and offering concession rights. A separate Law on Licensing has been approved that determines the licensing process. It also establishes the government as the main authority for granting licenses for fossil fuel production (Government of the Republic of Tajikistan 2004).

Open Joint-Stock Company Barqi Tojik, the state-owned vertically integrated power utility, was unbundled into three independent companies responsible for power generation, transmission, and distribution. The new distribution company, the Open Joint-Stock Company Electric Distribution Network, or Shabakahoi Taqsimoti Barq (STB), will engage a management contractor to operate STB for 5 years starting from 2022. The unbundling of Barqi Tojik is one of the components of the Power Sector Development Program developed jointly by the Government of Tajikistan, ADB, European Bank for Reconstruction and Development (EBRD), and the World Bank (ADB 2020). Other components of the program include a new tariff methodology, debt restructuring, and central control of sector's cash resources. Another player is Pamir Energy, which is currently operating under a concession agreement to generate, transmit, and distribute in GBAO, a remote mountainous region.

The adoption of the Law on the Use of Renewable Energy Sources in 2010 was a key development, as it is specifically aimed at the country's renewable energy generation resources. It establishes principles for the development of renewable energy sources and their support mechanisms, including tax exemptions, and guaranteed access and offtake by state-owned electricity suppliers (Government of the Republic of Tajikistan 2010).

Energy efficiency is another focus area of the government's legislative work, as reflected in the adoption of the Law on Energy Efficiency and Conservation in 2013 (Energy Charter Secretariat 2013). The law establishes broad requirements for energy audits and for metering energy usage (Government of the Republic of Tajikistan 2013). However, the development of by-laws and rules to govern the implementation of this law has not been completed, leading to weak enforcement of the requirements.

While fossil fuel production in Tajikistan is governed by the Law on Subsoil, introduced in the 1990s, the Law on Coal and the Law on Oil and Gas were adopted separately in the 2010s, aiming to increase investments in exploration and development activities. Moreover, the country has approved several legal acts, namely the Concession Law and the Public–Private Partnership Law to regulate concessions agreements, and to establish tender and auction rights (Parpiev 2020).

Policy Framework

Policymaking in Tajikistan's energy sector became active in the late 2000s. Several documents have been issued for the development of the energy sector, including the Special Program for Renewable Energy Sources Use in Tajikistan, Additional Measures for the Economic Use of Energy and Energy Saving, and Sustainable Energy for All Tajikistan. An overarching policy direction for the sector was outlined with the National Development Strategy of the Republic of Tajikistan for the period up to 2030, which has identified current issues in the sector, as well as mitigation measures in the long term (Government of the Republic of Tajikistan, Ministry of Economic Development and Trade of the Republic of Tajikistan 2016).

Yet, the country still lacks a comprehensive strategy focused specifically on the energy sector, which limits clarity regarding the sector's future development.

Priority targets in the recent energy policy documents are as follows:

(i) **Unbundle the power sector.** The government is currently executing numerous reforms to facilitate the financial sustainability of Tajikistan's power sector.
(ii) **Diversify power generation to ensure security of supply in winter.** Recognizing the need for diversification to ensure reliable supply, the country aims to decrease its reliance on hydropower electricity due to the seasonal pattern of its generation.
(iii) **Continue further development of energy efficiency and grid infrastructure.** The country aims to increase its efforts to rehabilitate power and heating grids to reduce losses (overall electricity grid losses must not exceed 10% and thermal grid losses must not exceed 20% by 2030), and to develop new energy efficiency regulations.
(iv) **Increase export capabilities.** Recognizing the country's massive hydropower potential, the government aims to increase its electricity exports to neighboring countries by commissioning new large-scale cross-border infrastructure projects.
(v) **Continue regulatory reforms to improve investment climate.** Tajikistan has already taken important steps toward improving the country's investment climate, as demonstrated by the first public–private partnership between the government and Pamir Energy Company, with a view to provide reliable power supplies to geographically isolated parts of the country. Moreover, the government plans to further develop the regulatory framework (e.g., adopting necessary by-laws and a tariff methodology) to eliminate unnecessary administrative barriers, reduce investment risks for private players, and facilitate private investor engagement.

Forecast Methodology

One of the objectives of this country study is to present a detailed overview and analysis of Tajikistan's energy market trends. Therefore, three scenarios were developed, considering the country's regulatory framework, technological development, consumer preferences, and other factors (Box 21). Supply and demand, technology, carbon emissions, and investment outlooks were derived for Tajikistan based on the following scenarios.

Box 21: Scenarios for Tajikistan's Energy Sector

Business-as-usual scenario: Projected energy supply and demand, with current energy system and policies;

Government Commitments scenario: Projected energy supply and demand, considering individual priorities of the Government of Tajikistan; and

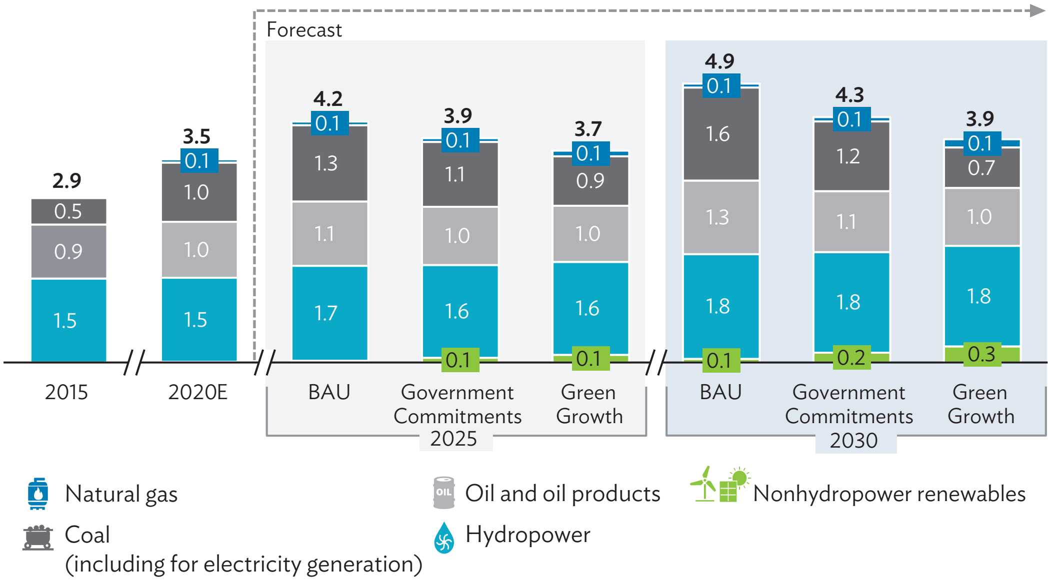
Green Growth scenario: Projected energy and supply demand, considering enhanced energy transition and environmental policies.

Source: Roland Berger/ILF.

Supply and Demand Outlook

The COVID-19 pandemic has significantly impacted Tajikistan and its energy sector. As a result of the economic uncertainty and restrictions imposed to prevent the spread of the virus, demand for energy decreased by nearly 4% in 2020. However, demand is projected to rebound quickly, exceeding prepandemic levels as early as 2022/2023. All three scenarios foresee further growth until 2030, with the actual growth rate varying depending on the extent of energy efficiency measures adopted. In terms of primary energy supply specifically, the Government Commitments scenario assumes an annual growth rate of 1.7% until 2030, reaching almost 4.3 million toe by the end of the decade. Total supply under the Business-as-usual (BAU) scenario is significantly higher at nearly 4.9 million toe in 2030, representing a compound annual growth rate of 2.8%, as this scenario assumes limited improvements in energy efficiency. In the Green Growth scenario, which is the most ambitious in terms of energy efficiency improvements, the growth rate of supply is expected to be 1.0% annually, leading to a primary energy supply of 3.9 million toe in 2030. Hydropower is currently the main source of primary energy supply in Tajikistan because of its dominance in the power generation mix. However, the rapid growth in energy supply for the industrial and transport sectors until 2030 will lead to an increase in coal and oil supply, especially in the BAU and Government Commitments scenarios (Figure 84).

Figure 84: Tajikistan—Primary Energy Supply Forecast
(million tons of oil equivalent)



BAU = Business-as-usual, E = estimate.

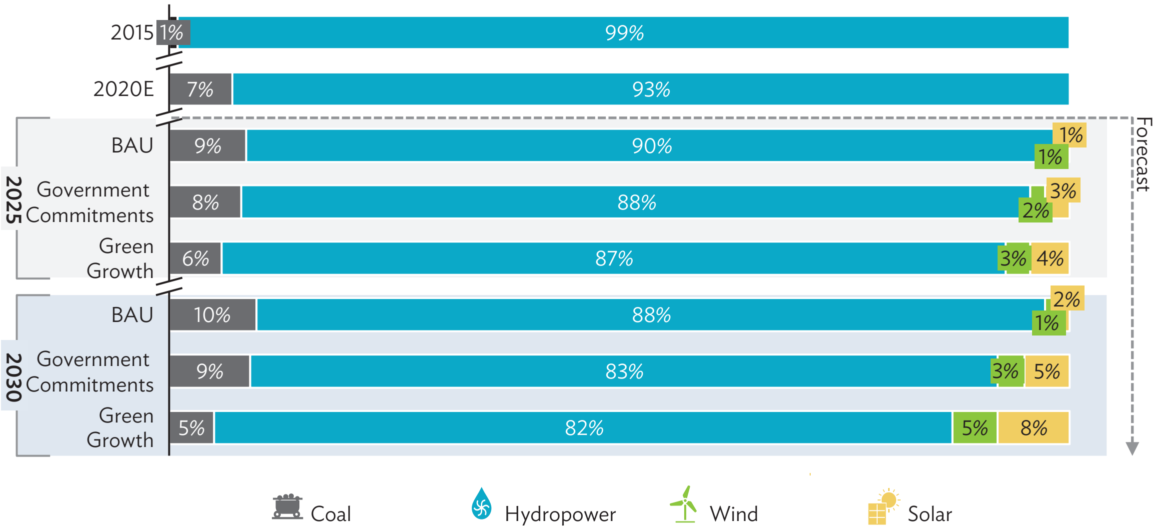
Source of historical data: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 3 September 2021). The forecasts are based on the Roland Berger methodology described in the Methodology section.

The reliance on hydropower in Tajikistan's electricity generation mix is very high; for instance, in 2015, hydropower's share reached 99% of the total (Figure 85).

While a high share of hydropower is excellent in terms of environmental sustainability, it also brings some challenges in terms of the reliability of supply because of the seasonal pattern of its generation. Specifically, HPPs have lower output in winter due to lower levels of water, which coincides with the peak energy demand season. Thus, the generation of electricity from HPPs should be supplemented with other sources to provide a reliable supply of energy to consumers across the country. The key differentiating factor among scenarios is the source of such additional supply. For instance, the BAU and Government Commitments scenarios foresee a further increase of coal-fired power generation capacities, reflecting recent trends and current government policies.

Specifically, the share of coal-fired power generation is expected to reach 10% in the BAU scenario and 9% in the Government Commitments scenario, while the combined share of nonhydropower renewables is only 3% (BAU scenario) and 8% (Government Commitments scenario) in 2030. In contrast, the sustainable energy transition foreseen in the Green Growth scenario assumes higher shares of wind energy (5%) and solar energy (8%) in 2030, and a decline in the role of coal-fired power (5% of total power generation) in 2030.

Figure 85: Tajikistan—Power Generation Mix



BAU = Business-as-usual, E = estimate.

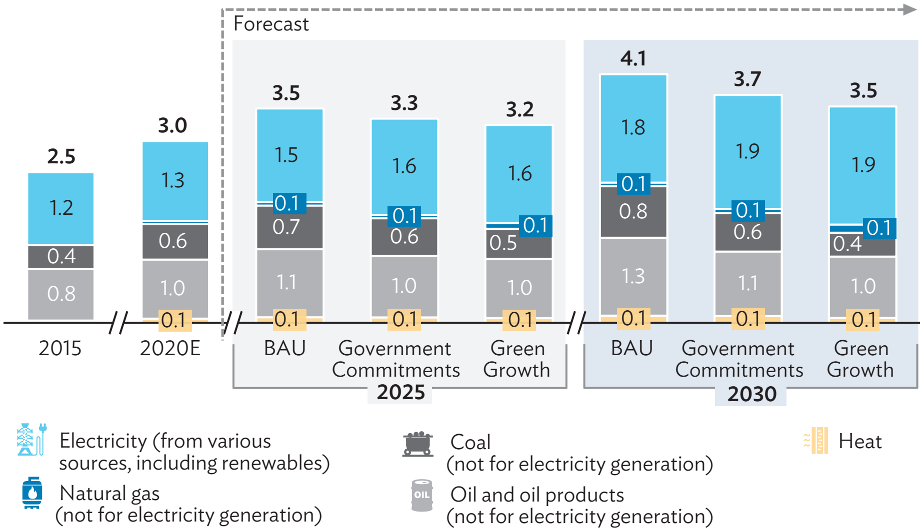
Source of historical data: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 3 September 2021). The forecasts are based on the Roland Berger methodology described in the Methodology section.

Total final energy demand in 2030 varies between 3.5 million toe and 4.1 million toe across the three scenarios, depending on the extent of energy efficiency measures in consumption. The highest growth is shown by electricity, reflecting the large availability of renewable energy in Tajikistan. In contrast, natural gas is projected to have limited growth, as the country lacks the cross-border pipeline capacity to import large volumes of gas, and has insignificant domestic reserves. At the same time, the consumption of coal increases to 0.6 million toe in the Government Commitments scenario and 0.8 million toe in the BAU scenario (Figure 86).

Primarily because of economic development, the residential, industry, and transport sectors are projected to demonstrate the highest growth until 2030. Across the three scenarios, annual growth rates in these sectors range from 1.2% to 3.0%. Final energy demand in agriculture, services, and other sectors are estimated to demonstrate slower growth, considering a high baseline in 2020, leading to annual growth rates of 0.7%–1.9% until 2030, depending on the scenario (Figure 87).

Figure 86: Tajikistan—Final Energy Demand Forecast by Fuel

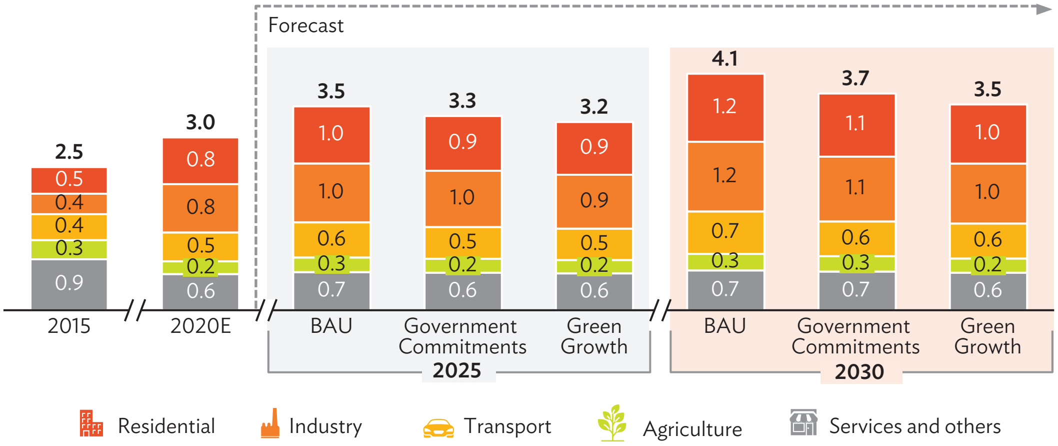
(million tons of oil equivalent)



BAU = Business-as-usual, E = estimate.

Source of historical data: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 3 September 2021). The forecasts are based on the Roland Berger methodology described in the Methodology section.

Figure 87: Tajikistan—Final Energy Demand Forecast by Sector
(million tons of oil equivalent)



BAU = Business-as-usual, E = estimate.

Source of historical data: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 3 September 2021). The forecasts are based on the Roland Berger methodology described in the Methodology section.

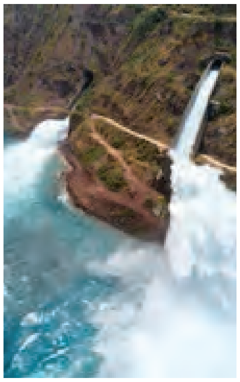
Technology Outlook

Priority Technologies: Generation

Priority technologies in the country were selected based on the country's targets and its commitment to making the power mix more sustainable. The selection was also based on the need to improve the reliability of the country's power supply, given the seasonal patterns of hydropower, Tajikistan's primary power source.

The country's climate and mountainous geographic conditions are highly favorable for the development of hydropower. Despite holding the highest rank in Central Asia and the eighth in the world in terms of hydropower resource availability, Tajikistan currently uses only around 6% of this potential. The government aims to continue developing hydropower through construction of both small- and large-scale power plants. Prominent examples of large-scale power plants include projects such as Nurek (3.0 GW), which is in operation; and Rogun (3.6 GW), which is under development (NS Energy) (Box 22). However, the seasonal pattern of hydropower generation has led to severe electricity shortages in winter, forcing the country to develop coal-fired plants. Continuing to develop hydropower projects could increase the country's export capabilities in the summer, and decrease the generation deficit in the winter. Overall, the country's strong reliance on hydropower has allowed it to significantly decrease its carbon footprint.

Box 22: Tajikistan's Flagship Energy Project



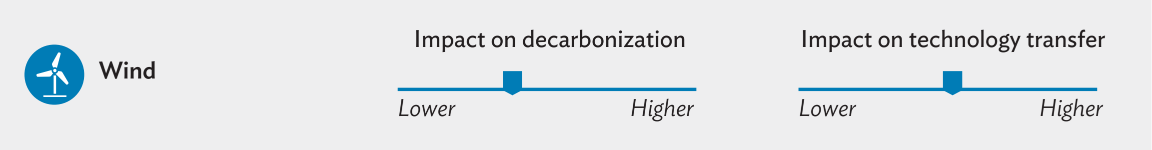
Rogun Hydropower Plant (HPP) is a project with a long history, having been initiated before the collapse of the Soviet Union. According to current plans, Rogun HPP will be the largest hydropower plant in the region, and one of the tallest dams in the world. Comprising six turbines with a combined capacity of 3.6 gigawatts, the project's total costs reach $4 billion. The project is developed in cooperation with Salini Impregilo, an Italian construction company. By generating additional 17 terawatt-hours of electricity per year, Tajikistan is planning to largely bridge the gap between supply and demand in winter and to expand export capabilities in the summer. The first turbine was launched in 2018, but the date for the project's full commission is still uncertain.

Note: Illustrative photo of a hydropower plant in Tajikistan is by Lukas/Adobe Stock©.

Sources: Asian Development Bnk. 2017. *Tajikistan: Power Sector Development Master Plan Final Report.* Manila (Grant 0213-TAJ); and NS Energy. Rogun Hydropower Project.

Solar PV

Tajikistan has more than 280 sunny days per year, making solar irradiation in the country a high-potential source of energy. The country's average daily solar irradiation ranges from 3.6 kWh/m^2 to 5.2 kWh/m^2. This puts the country's solar energy technical potential at around 195 GW. However, Tajikistan is yet to develop solar PV plants at a significant scale, despite some small off-grid and decentralized installations. The country's largest solar PV system was commissioned by Pamir Energy in 2020, but its capacity is only 0.2 MW (Asia-Plus 2020; Tetra Tech 2020; USAID 2020). In remote mountain regions, solar PV has high potential to provide access to electricity via off-grid systems. In addition, large-scale plants located near main consumption centers could help to mitigate power deficits in the winter. Due to the fact that more than 90% of Tajikistan's energy is generated by hydropower stations, floating PV projects located in existing hydropower reservoirs can make hydropower stations more efficient. With floating PV systems installed, the power density per flooded area will significantly increase and the floating solar array will enable time-shifting of hydropower output, which creates virtual pumped storage capability. Tajikistan's mountainous terrain makes the development of large utility-scale PV plants difficult. Nevertheless, solar sites in the mountains or hilly regions can undergo civil engineering to make level ground for mounting. Furthermore, given the country's proximity to the PRC (which is the largest PV producer in the area and which is willing to export solar PV technology), the key factor for implementing solar PV projects in Tajikistan is the continuous decline in the cost of solar power, which is likely to be competitive with large hydropower and coal-fired generation, even in the short term. Moreover, developing solar energy represents a significant opportunity for technology transfer in the country, which lacks relevant know-how in the development of solar PV projects. The impact on decarbonization is rather limited, given that the power generation mix is already very "green."



The country's wind power potential is estimated at 2 GW of technical capacity. However, Tajikistan currently has no large-scale wind power projects, so this potential remains largely unexplored. To diversify the country's power generation mix, wind energy can be considered as a way of balancing the current seasonal pattern of hydropower generation. Both utility-scale wind farms and off-grid installations may be suitable options, depending on the region and access to the electricity grid. For instance, they can be located close to existing HPPs, where grid installation costs are minimized. The technology transfer potential is considered significant because of the novelty of this technology for Tajikistan.

Priority Technologies: Transmission, Distribution, and Storage

Tajikistan's power T&D system is in dire technical condition, with high losses and limited systematic maintenance. Rehabilitating existing infrastructure and continuing the introduction of advanced metering systems (currently being implemented under the ADB Sector Development Program) could be important levers for improving the financial situation of the power utility.

Significant efforts are required to bring down T&D losses in the power grid, which currently stand at nearly 17%—well above internationally accepted levels. Strengthening efforts to maintain and rehabilitate existing T&D lines and substations should thus be prioritized, especially given the government's aim to reduce losses to 10%. As the government plans to expand its generation infrastructure with large-scale projects, such as the Rogun and Shurbob HPPs, grid expansion will be required to ensure the proper T&D of electricity. The country has already successfully implemented an advanced metering infrastructure project in the city of Khujand, which has had a positive impact on the collection rates and billing—another pain point in the energy sector. The Power Sector Development Program envisages the installation of smart meters in seven cities (340,000 households) by 2026. Evidently, innovative smart metering allows grids to be monitored and controlled and, with appropriate measures, can boost energy efficiency, as well as help to manage rising demand. Given the novelty of smart grid technologies, the impact of their development on technology transfer will be significant. Another opportunity to systematically upgrade the high-voltage network and decrease losses is to update conductors of the entire energy system. The shift from aluminum conductor steel-reinforced cables to high temperature log sag conductors can create a synergy effect, together with the implementation of other smart grid technologies, and benefit the system via reduction in line losses and improved climate resilience.

Priority Technologies: Consumption

Tajikistan holds large potential for energy savings if appropriate efficiency measures are implemented on the consumption side. Based on existing inefficiencies and baseline consumption figures, the industrial and residential sectors should be particularly prioritized.

The industrial sector is one of the largest energy off-takers in Tajikistan, with an estimated share in total final energy demand of 28%. This implies a strong potential for energy-saving measures, as the equipment in this industry is generally considered to be outdated. An immediate step should be the introduction of energy audit requirements for entities with the highest consumption figures. The successful completion of an energy audit at TALCO should thus be considered as a pilot project, proving the benefits of energy services. Energy audits not only clarify the status quo of energy efficiency performance, but also identify levers on how energy consumption might be improved at the level of individual plants. If the government makes energy audits a requirement across the board and supports investments in industrial energy management systems, a new service industry for energy efficiency can develop.

Residential buildings are the second largest energy consumer group in Tajikistan, with an estimated share of 27% of final energy demand. If the government takes the lead by establishing modern energy performance standards for new buildings, and develops a program for the rehabilitation of old buildings, energy efficiency measures could attract more private investors and positively affect economic development, given the spillover effects to other economic sectors that are involved in building modernization. The modernization measures should include basic elements, such as the proper insulation of walls and the installation of efficient doors and windows, which will lead to lower level of losses (including heat). At a more advanced stage, a roll-out of building management systems, smart metering, and renewable heating systems should also be considered to maximize efficiency gains, which could potentially reach 30%–40% of existing demand.

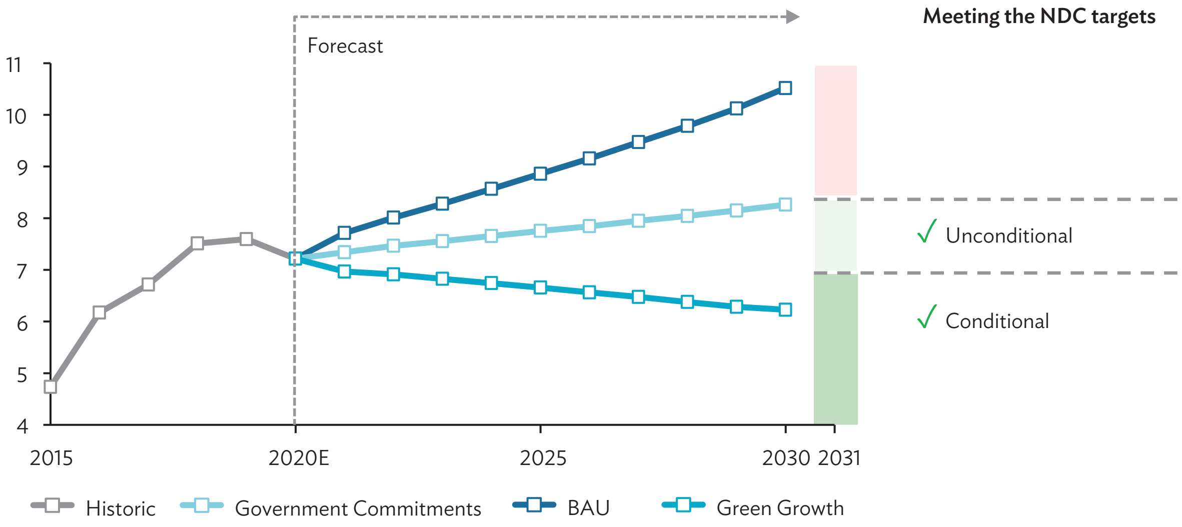
Carbon Emissions Outlook

Tajikistan has demonstrated its solidarity with global efforts to combat climate change by submitting a nationally determined contribution (NDC) in 2017 and updated NDC in 2021. Tajikistan set both conditional and unconditional targets, with the key differences between them being the availability of internal support via technology transfers and extensive international funding. If considerable support is in place, Tajikistan has committed to not exceeding 50%–60% of GHG emissions compared to 1990 levels by 2030. Tajikistan's unconditional target stipulates not to exceed 60%–70% of GHG emissions compared to 1990 levels by 2030 (UNFCCC 2021). Since this analysis only covers emissions related to the energy sector, an assumption has been made regarding the share of energy-related emissions in total GHG emissions in Tajikistan.[15]

Tajikistan's carbon emissions outlook demonstrates that both the government's conditional and unconditional targets are reasonable. Currently adopted policies, if fully implemented, will ensure that the main NDC target is achieved. In particular, the Government Commitments scenario results in the attainment of the unconditional target, but fails to achieve the conditional target, with energy-related emissions of over 8 million tons of carbon dioxide (CO_2) equivalent. However, under the BAU scenario, the targets cannot be met, with more than 10 million tons of CO_2 equivalent of GHG emissions in 2030, highlighting the fact that current trends must be adjusted to meet the targets. The Green Growth scenario shows a potential pathway to the attainment of Tajikistan's conditional target, as energy-related emissions drop to approximately 6 million tons of CO_2 equivalent in 2030 (Figure 88). Key drivers include significant investments in energy efficiency measures, additional expansions in renewable energy (including solar PV and wind), as well as shifts from coal to "cleaner" sources, such as electricity and natural gas.

Figure 88: Tajikistan—Energy-Related Carbon Emissions

(million tons of carbon dioxide equivalent)



BAU = Business-as-usual, E = estimate, NDC = Nationally Determined Contribution.

Note: Historical data on carbon emissions is modelled by Roland Berger based on historical data on energy use. The forecasts are based on the Roland Berger methodology described in the Methodology section.

Sources: Roland Berger; and United Nations Framework Convention on Climate Change. Nationally Determined Contributions Registry. https://unfccc.int/NDCREG.

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[15] Under the energy-related emissions, GHG emissions from generation, transmission, and consumption of energy are considered. The assumed share of energy-related emissions is based on historical data.

Investment Outlook

Investment Needs

The scenarios estimate different levels of investment needs until 2030, ranging between $4.7 billion in the BAU scenario, $5.8 billion in the Government Commitments scenario, and as much as $7.6 billion in the Green Growth scenario. The estimated amount of investment needs does not include further investments in the Rogun HPP because of the uncertain political and security situation along the main export corridor (including Afghanistan) of large parts of future Rogun electricity. The full completion of Rogun HPP thus remains uncertain in the short to medium term. Investment needs in energy efficiency are expected to be the largest by 2030—estimated at $2.3 billion–$3.9 billion, depending on the scenario, which is in line with the government's target to take additional measures to increase the country's energy efficiency. The generation sector is also expected to require significant investments. Across all scenarios, its investment needs stem primarily from renewable energy (particularly hydropower) generation, with $1.7 billion in the BAU scenario, $1.6 billion in the Government Commitments scenario, and $2.2 in the Green Growth scenario. Finally, investments in T&D are expected to be needed primarily for electricity, accounting for 63% of T&D investments in the BAU scenario, 82% in the Government Commitments scenario, and 87% in the Green Growth scenario (Figure 89). This reflects the country's target to reduce electricity grid losses by 2030.

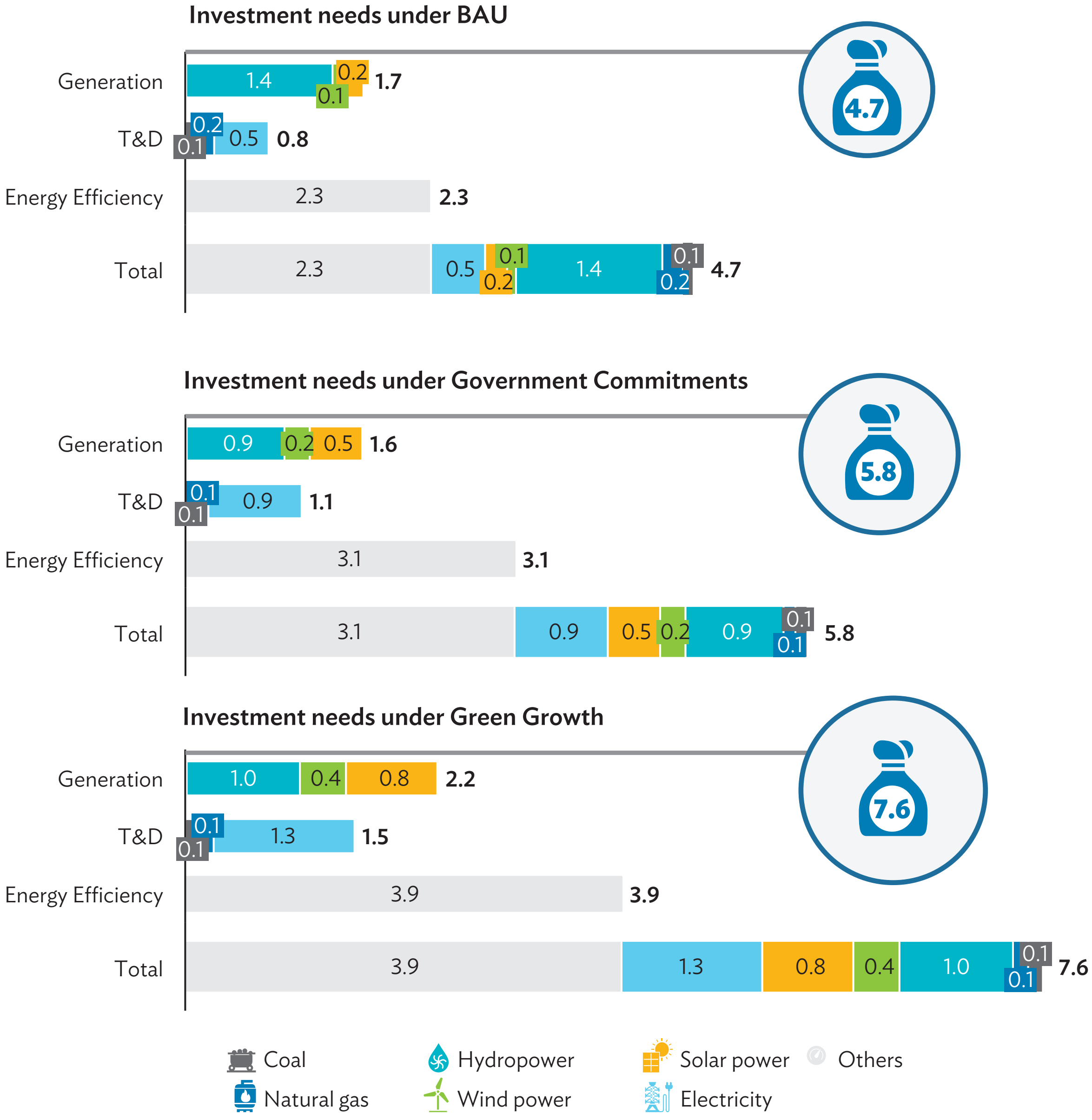
Challenges and Opportunities

Tajikistan's energy sector is facing several challenges that need to be addressed to ensure reliable supply and efficient development of the energy market. One of the challenges is insufficient generation capacity during the winter season. The country's reliance on hydropower resources for electricity generation has resulted in insufficient generation during winter, while producing a surplus in the summer. This has forced Tajikistan to expand its coal-fired generation capacities, neglecting the country's significant renewable energy potential and increasing its GHG emissions. Penetration of nonhydropower renewables has been nearly negligible, mainly due to insufficient support schemes and a prohibitive legislative framework for private sector players. The government's prioritization of thermal generation over more sustainable alternatives introduces uncertainty for investors vis-à-vis potential pathways for the sector's development. Although renewable energy sources cannot be fully relied upon to meet constant electricity supply needs due to their intermittence, solar PV and wind systems can be efficient as intermediate sources and can help reduce dependence on fossil fuels. In addition, solar PV systems require less investment per unit than other renewable sources, specifically, hydropower, which makes them less dependent on costly government programs and more attractive to private investors.

As remote and mountainous regions are not connected to the national electricity grid, the government transferred responsibility for energy supply in the GBAO region via concessions to the Pamir Energy Company. The World Bank supports the Tajikistan Rural Electrification Project, which provides financing for the development of electricity infrastructure in remote mountainous areas (including connection to the micro-grids and the centralized distribution network of the Pamir Energy Company) (World Bank). However, the further decline in the costs of solar PV and wind energy significantly enhances the viability of off-grid solutions, which can provide sustainable energy supply in an affordable manner, without large investments in T&D infrastructure expansion.

Figure 89: Energy Infrastructure Investment Needs in Tajikistan until 2030

($ billion)



BAU = Business-as-usual, T&D = transmission and distribution.

Source: The forecasts are based on the Roland Berger/ILF methodology described in the Methodology section.

Another challenge stems from the difficult state of the main power utility company in the country. As stated earlier, Barqi Tojik has been under severe financial distress due to a long period of tariffs below cost-recovery level. Without an independent energy market regulator, the tariffication process was only changed by governmental decrees, and has only started to move toward a cost-recovery methodology in recent years through joint projects with IFIs. Consistent policy-making efforts to establish a sound tariff-setting methodology would allow Barqi Tojik to fully recover its costs. It would also create conditions for the broader participation of the private sector and for an infrastructure modernization program. The Power Sector Development Program developed jointly by the Government of Tajikistan and IFIs (ADB, EBRD, and the World Bank) includes reorganization of Barqi Tojik, a new tariff methodology, debt restructuring, central control of sector's cash resources, and other initiatives.

Constant losses have caused severe financial distress to the utility, thereby leading to insufficient rehabilitation efforts. The inadequate maintenance of the key equipment has led to significant outages, decreasing the reliability of electricity supply, which is a considerable constraint to businesses, since frequent outages lead to interruptions of operations and, therefore, to potential losses in revenue. The electricity losses reach around 17% of total annual electricity generation. The rehabilitation of existing distribution infrastructure, particularly, medium- and low-voltage substations, is crucial for improving the quality and reliability of supply, which is a key element for both quality of life and economic development in Tajikistan.

Challenges in the power T&D sector can also be attributed to the insufficient investment planning in the energy sector. The long-term master plan for generation and T&D needs to be updated. An updated plan would introduce further clarity for future investors regarding the needs of the sector and the direction in which it is moving. Furthermore, regular monitoring of infrastructure needs and preventive maintenance would save costs and prevent unexpected equipment failure.

Nevertheless, the country is moving forward with the introduction of energy sector reforms that improve the investment climate and establish clear goals for the country's energy sector. Tajikistan has gained good momentum in introducing power sector reforms, namely the ongoing restructuring of Barqi Tojik into three separate entities. Moreover, the introduction of an improved methodology for tariff setting in 2019 is expected to allow for the full recovery of the electricity supply costs for Barqi Tojik. Financial recovery for the company, in turn, will free up resources for an infrastructure modernization program; it will also increase reliability of supply and reduce the frequency of equipment failures with the introduction of a routine rehabilitation program.

Another opportunity arises from the proven track record of large-scale investment projects with the participation of international donors and private companies. Private investors interested in developing large-scale projects could consider Tajikistan as a potential market. The country's willingness to improve investment climate has led to the early adoption of the Concession Law, and thus resulted in the implementation of a large project in the remote GBAO region. Moreover, the country is currently developing Rogun HPP, which will become the biggest HPP in Tajikistan, with a capacity of around 3.6 GW, highlighting the largely unexploited potential of renewable energy in Tajikistan.

One of the long-term opportunities is the country's aspirations to reinforce its position as a regional electricity exporter. The government is currently implementing two important projects for increasing its participation in the regional electricity trade (CASA-1000), and reconnecting to the CAPS. Participation in the CAPS will allow for increased exports to Uzbekistan and Kazakhstan, while CASA-1000 is expected to give access to new markets in South Asia. Amid growing energy demands throughout the Central Asia Regional Economic Cooperation (CAREC) region, existing and planned cross-border capacities in Tajikistan present a strong opportunity for developing export-oriented projects.

In the long term, Tajikistan shall also consider developing "green" hydrogen production facilities based on hydropower potential. While the production of hydrogen from hydropower is not a conventional pathway, Tajikistan may explore its potential, considering the important role that hydrogen is expected to play in future energy markets. The number of countries with policies supporting development of hydrogen technologies is increasing. Over the past few years, global investments in hydrogen energy research and development (R&D) have significantly increased. In the European Union, R&D funding has facilitated a hydrogen technology rollout. In the PRC, the low-carbon component of energy R&D grew by 10% in 2019, with a particularly large increase in R&D efforts directed at hydrogen energy. Tajikistan has not tackled this topic yet, but it could consider making early-stage R&D efforts in green hydrogen production based on hydropower.

Policy Recommendations

Tajikistan's government has made progress in the development of its regulatory and policy framework for the energy sector. However, further efforts are required to improve the conditions of its infrastructure and the reliability of supply, including the following:

(i) **Continue efforts to open the market to private players.** Recently initiated changes, for instance, the unbundling of the power utility, show Tajikistan's clear commitment to significantly reforming the energy sector. Continuing these reforms and moving toward the world's best practices, such as establishing market conditions for private sector participation in the distribution or supply of energy, would be beneficial for creating competition in the market and ensuring development in a beneficial direction for end consumers.

(ii) **Mitigate seasonality of hydropower via renewable energy.** Tajikistan has mostly focused on coal-fired power as a means to add additional generation capacity and to mitigate the seasonality of hydropower. The potential of nonhydropower renewables, especially via off-grid installations to improve access to electricity in the mountainous regions, presents a significant opportunity. ADB and other IFIs are undertaking efforts to support renewable energy development in Tajikistan. More specifically, ADB and the World Bank are working on wind and solar resource assessment and site feasibility studies in the country. The United States Agency for International Development (USAID) is helping Tajik energy utility companies to build the capacity to develop renewable energy projects. In particular, USAID supported Tajikistan with the installation of the largest solar power plant in the country, the 220-kilowatt Murghob solar power plant.

(iii) **Continue to support nonhydropower renewables with targeted measures.** The government should continue to promote the construction of on- and off-grid renewable power plants via targeted support measures; for instance, a net metering program or feed-in-tariffs. Other measures, such as the preparation of a standard power purchase agreement, creation of solar parks, and auctions, would help to attract private investors. Competition can drive investors to offer electricity generation at low prices, cheaper than coal-fired power as demonstrated in other CAREC member countries.

(iv) **Improve primary and secondary legislation for energy efficiency.** Despite setting positive requirements for a comprehensive energy audit system, recent policy documents only indicate a general direction for energy efficiency measures in the country. Further work in terms of developing detailed rules and guidelines with a clear allocation of responsibilities is needed to begin to implement the legislation effectively. The country shall take a proactive role by developing action plans for energy efficiency measures, setting stringent energy performance requirements, and promoting energy efficiency investments, for instance, by allowing public companies to retain financial savings from the energy efficiency measures.

(v) **Ensure proper planning for the development and rehabilitation of the power sector.** The rehabilitation and expansion of the power grid are among the crucial tasks for ensuring the security of supply in the coming years. Preparing a clear investment plan according to a least-cost principle is required to ensure the effective development of the sector, taking into account the expected capacity expansion.

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Hisor Fortress in Tajikistan. The fortress is over 2,500 years old and is one of the most famous historical buildings in Central Asia (photo by Leonid Andronov/Adobe Stock©).

TURKMENISTAN

Power infrastructure. Turkmenistan is a major energy exporter, as nearly half of its natural gas production is exported (photo by Lubo Ivanko/Adobe Stock©).

Turkmenistan Highlights

- Natural gas plays a dominant role in Turkmenistan's energy system. The country holds the fourth largest proven natural gas reserves in the world, with an annual production of more than 60 billion cubic meters (bcm). Gas is also the sole source of electricity generation.
- Turkmenistan is a major energy exporter, as nearly half of its natural gas production is exported (Figure 90). The country also produces oil, nearly 40% of which is exported.
- Total installed power generation capacity in the country exceeds 7 gigawatts (GW). Recently, the government committed to introducing renewable energy technologies to its generation mix.
- Final energy demand in Turkmenistan is expected to reach 27.8 million tons of oil equivalent (toe) to 30.1 million toe in 2030, depending on the extent to which energy efficiency measures are implemented across various scenarios.
- Natural gas is expected to continue being a dominant source of electricity generation until 2030. Given the government's plans to introduce renewable energy to the energy mix, the share of gas is, however, expected to decline in the long term.
- While renewable energy generation is one of the government's key priorities, there is also a need for rehabilitating and modernizing its existing grid infrastructure.
- Energy sector investment needs range between $5.5 billion and $13.1 billion, depending on the scenario. Natural gas-powered generation accounts for the largest share of investment needs, given the country's reliance on this resource.
- There are a variety of investment opportunities across Turkmenistan's energy sector, including in renewable energy generation and sustainable fossil fuel production. However, further actions are required in order to remove market-entry restrictions.
- Policy recommendations for Turkmenistan include establishing further support for renewable power generation, improving the investment climate, implementing an infrastructure modernization program, and exploring the possibility of hydrogen production.
- The data sources used to develop the supply and demand, technology, carbon emissions, and investment outlooks for Turkmenistan include a number of publications by reputed institutions, including British Petroleum, the International Energy Agency, Fitch Solutions, and others. The full list of references is available at the end of this country study.

Energy Sector Profile

Country Profile

With a population of over 6 million people, Turkmenistan is one of the least densely populated countries in Asia. The country has experienced rapid growth in the past years, with a gross domestic product (GDP) annual growth rate of approximately 9% from 2010 to 2018. The coronavirus disease (COVID-19) pandemic has impacted the country significantly, due to a decrease in exports and pandemic-related measures. Nominal GDP decreased by 3% in 2020. However, the country is set to rebound quickly as its exports resume, leading to rapid economic growth (nominal GDP is expected to grow nearly 14% per annum until 2030) (Oxford Economics).

Figure 90: Turkmenistan—Key Figures

Renewable potential	Natural gas exports	Reserves	Carbon intensity	Energy intensity
~666 GW	**~50%**	**19.5 tcm**	**103rd out of 172**	**1st out of 172**
Total potential of renewable energy is estimated at ~666 GW.	~50% of the total natural gas production was exported in 2019.	The amount of proven natural gas reserves is estimated at 19.5 tcm.	The country is ranked 103rd out of 172 countries in the global ranking of carbon intensity of energy.	Turkmenistan is ranked 1st out of 172 countries in the global ranking of energy intensity.

GW = gigawatt, tcm = trillion cubic meters.

Sources: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 3 September 2021); United Nations Development Programme. 2014. *Renewable Energy Snapshot: Tajikistan*. New York; and United States Energy Information Administration. Tajikistan Data. https://www.eia.gov/international/data/world (accessed 3 September 2021).

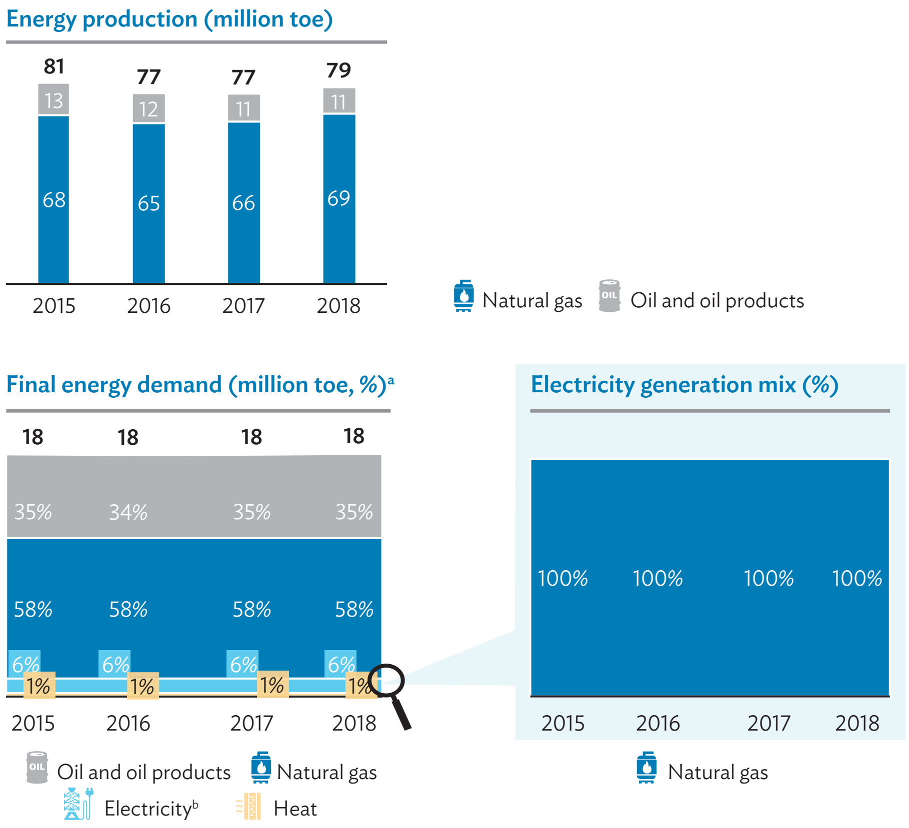
Blessed with one of the largest natural gas reserves in the world, Turkmenistan relies heavily on this resource as it covers a major part of the country's energy demand, as well as its exports. Despite abundant potential for renewable energy (e.g., roughly 300 sunny days per year), the country's sole energy generation source is natural gas (Figure 91). A long period of provision of free electricity and natural gas for a large share of the population (and low tariffs for those who pay) has led to low awareness for energy efficiency, which resulted in the country being ranked the most energy-intensive economy in 2018. However, the country is ranked 103rd out of 172 in terms of carbon intensity, due to the relatively small carbon footprint of natural gas power in comparison to other fossil fuels such as coal.

Energy Sector and Technologies Assessment

Conventional Fuel Production

Turkmenistan's fossil fuel production mainly consists of natural gas, with oil covering a much smaller share of its overall hydrocarbon production. There are numerous oil and natural gas fields spread across the country, including the Galkynysh field, which is the world's second-largest natural gas field, with reserves estimated at up to 14 trillion cubic meters (tcm). In 2019, Turkmenistan produced 70.2 bcm of natural gas, of which 32.6 bcm was consumed domestically and 37.6 bcm was exported. The country, therefore, globally ranks fourth in terms of proven gas reserves and 13th in terms of gas production. The country plans to increase its natural gas production to 250 bcm per annum by 2030. The country's proven natural gas reserves are 19.5 tcm.

Figure 91: Energy Profile of Turkmenistan



Energy production (million toe)

Final energy demand (million toe, %)[a]

Electricity generation mix (%)

toe = ton of oil equivalent.

[a] Topmost numbers on the chart are in million toe.

[b] Electricity data come from various sources, including fossil fuel-based and renewables.

Source: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 20 August 2021).

Turkmenistan produced more than 12 million tons of oil in 2019, about 60% of which was used domestically. In addition to expanding its natural gas production, Turkmenistan also aims to expand its oil production by 2030. The country's oil reserves are estimated at 82 metric tons (Mt). Its natural gas fields are owned by Turkmengaz, and its oil production fields by Turkmenneft, both of which are state-owned enterprises. The country has two oil refineries: the Turkmenbashi Oil Processing Complex (TOPC), which has a capacity of more than 10 million tons per year; and the Seidi refinery. Turkmenistan also has gas processing and other chemical plants, including a gas chemical complex in Kiyanly, with a capacity to produce up to 386,000 tons of polyethylene and 81,000 tons of polypropylene annually using 5 bcm of natural gas as feedstock. There is also the gas-to-gasoline plant at Ovadandepe, which is designed to process 1,785 million cubic meters of natural gas into 600,000 tons of ECO-93 gasoline per year (AzerNews 2019; International Trade Administration, US Department of Commerce 2020). The ammonia and urea plant in Mary has the capacity to produce 1,200 tons of ammonia and 1,925 tons of urea per day, while the Garabogazcarbamide plant in Garabogaz is designed for the annual production of 1,155,000 tons of urea (Berksan; Business Turkmenistan 2020).

Electricity Generation

Turkmenistan relies entirely on natural gas for its power generation (ADB 2018b). In 2020, installed generation capacity was about 7 GW with 14 power plants. All power plants are owned and operated by Turkmenenergo, a state-owned vertically integrated power company. Although most of its power plants were originally constructed more than 40–50 years ago, 11 power plants were rehabilitated (including the installation of new turbines) in 2003–2018 (except the Turkmenbashi Thermal Power Plant). Nevertheless, Turkmenistan has only one operational combined-cycle power plant. In 2019, Turkmenistan produced 25.4 terawatt-hours (TWh) of electricity, and exported 15% of it to neighboring countries.

Turkmenistan's government is planning to modernize two power units at the Turkmenbashi Power Plant, increasing its capacity to 645 megawatts (MW). The construction of six large energy facilities is also planned, including two power plants in the Akhal region; Gurtly, with a capacity of 508 MW; Akhal-2, with a capacity of 254 MW; and the 126 MW gas turbine power plant at the Turkmenbashi oil refinery. Total electricity generated in Turkmenistan is expected to increase in the short term as new capacity is added.

Turkmenistan has no renewable power generation apart from two hydropower plants, which do not contribute to national power generation. However, the full technical potential of renewable sources for power generation is significant and is estimated at 1.3 GW for small hydropower, 10 GW for wind energy, and as much as 655 GW for solar energy. Renewable energy generation in small and medium-sized installations in remote and sparsely populated areas is planned for the short term.

Transmission and Distribution

Although the electrification rate is 100% in the country, the electrical transmission system is characterized by inefficiencies. Operating with total power transmission and distribution (T&D) losses of 16.4%, the system has low reliability and frequent outages, particularly in the remote regions of the country due to aging infrastructure. Its main transmission lines were built in the 1970s and are in urgent need of renovation and expansion. A supervisory control and data acquisition (SCADA) system and additional metering devices are currently being implemented. Moreover, further projects in the sector are planned, including the creation of a ring between the main energy nodes. In 2021, the government inaugurated the Ahal–Balkan high-voltage transmission line, which is the first stage of the ring power transmission system.

With a combined length of over 13,000 kilometers (km), Turkmenistan's electrical transmission network operates at voltages of 35, 110, 220, and 500 kilovolts (kV). The natural gas transmission network spans the whole country through the 771 km long, 30 bcm per year East–West natural gas pipeline, which ensures a secure natural gas supply within the country. Overall, the country's natural gas pipeline network (including cross-border gas pipelines) is over 8,000 km long. Turkmenistan also has a small domestic crude oil pipeline network, linking onshore oil fields with the Turkmenbashi refinery and Caspian ports.

Cross-Border Infrastructure

Turkmenistan is interconnected with all neighboring countries and large export markets. Plans to expand its cross-border infrastructure through the Turkmenistan–Afghanistan–Pakistan–India (TAPI) pipeline for natural gas, and the Turkmenistan–Afghanistan–Pakistan (TAP) Interconnection for electricity have been launched; however, due to the scale and multitude of countries involved, these projects have not gone into operation (Table 9). It should be noted that the uncertain political situation in Afghanistan adds additional complication and renders it difficult to predict the development of these projects.

Table 9: Turkmenistan—Major Cross-Border Energy Infrastructure

Energy Source	Name	Capacity	Status	Connected Country
🔥	Central Asia–PRC	55 bcma	Operational	Kazakhstan, PRC, Uzbekistan
🔥	Dovletabat–Serakhs–Hangeran Pipeline	10 bcma	Operational	Iran
🔥	TAPI Pipeline	33 bcma	Current status and future project delivery uncertain	Afghanistan, India, Pakistan
🔥	Trans-Caspian Pipeline	10 bcma	Current status and future project delivery uncertain	Azerbaijan
🔥	Central Asia–PRC (line D)	30 bcma	Planned	Kyrgyz Republic, PRC, Tajikistan, Uzbekistan
⚡	TAP Interconnection	1,000 MW	Current status and future project delivery uncertain	Afghanistan, Pakistan
⚡	Kerki–Shebergan (the first stage of TAP Interconnection)	n. a.	Operational	Afghanistan
⚡	Mary–Herat	n. a.	Operational	Afghanistan
⚡	Mary–Andkhoy	n. a.	Operational	Afghanistan
⚡	Rabat–Kashan, Mary–Qala-e-Naw	16 MW	Operational	Afghanistan
⚡	Serdar–Karakul	400 MW	Operational	Uzbekistan
⚡	Chardzhev–Karakul	120 MVA	Operational	Uzbekistan
⚡	Balkanabad–Gonbad	300 MVA	Operational	Iran
⚡	Shatlyk–Serakhs	116 MVA	Operational	Iran

⚡ Electricity 🔥 Natural gas

bcma = billion cubic meters per annum, MVA = megavolt-ampere, MW = megawatt, n. a. = not available, PRC = People's Republic of China, TAP = Turkmenistan–Afghanistan–Pakistan, TAPI = Turkmenistan–Afghanistan–Pakistan–India.

Sources: Asian Development Bank (ADB). 2018. Power Interconnection Project to Strengthen Power Trade Between Afghanistan, Turkmenistan, Pakistan. News release. 28 February; ADB. Turkmenistan–Afghanistan–Pakistan–India Natural Gas Pipeline Project; Fitch Solutions. 2020. *Turkmenistan Oil & Gas Report*. London; Fitch Solutions. 2020. *Turkmenistan Power Report*. London; and N. Iwaszczuk, J. Wolak, and A. Iwaszczuk. 2021. Turkmenistan's Gas Sector Development Scenarios Based on Econometric and SWOT Analysis. *Energies*. 14 (10). 2740. https://doi.org/10.3390/en14102740.

Energy Consumption

In 2018, energy intensity in Turkmenistan was 19.03 British thermal units (Btu) per dollar of GDP, which is nearly 4 times higher than the global average. In terms of industrial consumption, the main consumers of energy are the oil and gas industry, chemical industry, light industry, machine-building, and metal processing. However, actions have been taken to ensure further energy savings in the industrial sector. For several years, the country has been introducing modern energy-saving technologies that meet international standards, including metering systems and natural gas meters at industrial enterprises.

As for energy consumption in the residential sector, Turkmenistan adopted new building codes in 2020. The Ministry of Construction and Architecture of Turkmenistan is working, in partnership with the United Nations Development Programme (UNDP), to update legal and regulatory mechanisms for implementing energy conservation measures in residential building design and construction. However, regulations on the rules and procedures for energy audits of residential buildings in Turkmenistan are still under consideration.

Turkmenistan's transportation fleet includes older vehicles that contribute to an increased carbon footprint. To counter this development, the importation of cars that are over 10 years old has been banned since 2011. Moreover, the import of passenger cars with engine volumes larger than 3.5 liters has also been prohibited since 2011. There are currently no charging stations for electric vehicles in Turkmenistan. The state plans to develop the local production of electric vehicles and to begin rolling out electric vehicle charging stations.

Regulatory Framework

Turkmenistan has recently been making progress in the development of its primary energy legislation, with the most active period being the 2010s. The Law on Electricity has been a stepping stone in establishing an overarching framework for the regulation of the country's electricity generation (Government of Turkmenistan 2019a). It appointed the Cabinet of Ministers and the Ministry of Energy as the electricity sector's two main regulators. Moreover, financial incentives for energy efficiency projects were introduced, and accelerating the deployment of renewable energy was set as an objective. In addition, the Law on Licensing, which determines the process for obtaining licenses across all sectors of the economy, including in the energy sector, has been approved (Government of Turkmenistan 2019b). The state remains a dominant player in the electricity market, in which generation, distribution, and transmission services are controlled by Turkmenenergo.

Recognizing the country's renewable energy potential as well as the need to transition to more sustainable methods of energy generation, the government recently adopted the Law on Renewable Energy Sources (AzerNews 2021; Government of Turkmenistan 2021). The law established several key focus areas, including ensuring environmental and energy supply protection by introducing renewable energy sources (thereby, diversifying energy generation methods), as well as major incentives for renewable energy projects (including easier land leases, and guaranteed purchase of electricity generated from renewable sources). In 2021, the government adopted the Law on Public–Private Partnership that regulates the process of preparing and implementing public–private partnership projects.

Turkmenistan is making a sizeable commitment to achieve climate neutrality. The government adopted the National Strategy on Climate Change and the National Strategy for the Development of Renewable Energy until 2030 (Academy of Sciences of Turkmenistan 2021; UNDP 2012). The country actively participated in the 26th session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) in Glasgow in 2021. Turkmenistan has expressed interest in studying the Global Methane Commitment in detail with a view to possible participation. The country aims to achieve zero growth of greenhouse gas (GHG) emissions starting in 2030, and significant reductions of emissions in the longer term. The nationally determined contribution (NDC) of Turkmenistan is a confirmation of the country's commitment to reduce GHG emissions by 2030 in key sectors of the economy.

Fossil fuel production in the country is mainly governed by the Law on Subsoil and the Law on Hydrocarbon Resources, which establish licensing rights (Government of Turkmenistan 2020). The State Agency for the Management and Use of Hydrocarbon Resources was abolished in 2016. Turkmengaz and Turkmenoil are legal successors of the State Agency for the Management and Use of Hydrocarbon Resources. Natural gas markets are dominated by Turkmengaz, which acts as the country's primary developer, supplier, and seller of natural gas. Regarding the investment framework, Turkmenistan has two separate laws on investment (the Law on Investment Activities in Turkmenistan and the Law on Foreign Investments), both of which establish the main rights and duties of investors (Government of Turkmenistan 1992, 2008).

Policy Framework

During the past several decades, a variety of legal and regulatory acts have been issued in Turkmenistan's energy sector. In recent years, the government launched initiatives to transition to a greener economy to tackle climate change. Several documents have been issued, including the National Program on Energy Conservation for 2018–2024, the National Program of Turkmenistan on Climate Change, and the Concept of Development of Energy Sector of Turkmenistan for 2013–2020. The most recent one, the National Strategy on Development of Renewable Energy in Turkmenistan for the period up to 2030, was issued in 2020 (Academy of Sciences of Turkmenistan 2021). It outlines the advantages of renewable energy for the country's future economic development, and for the transition to a "greener" economy. The main targets of these policies are outlined below:

(i) **Development of energy sector infrastructure.** The country is increasing its efforts to rehabilitate existing energy infrastructure, commission new energy infrastructure, ensure the future security of supply, and increase its export capabilities.

(ii) **Expansion of export capabilities.** The government plans to expand the country's export capabilities by increasing its efforts to establish regional interconnections, including Central Asia–PRC (line D), and others.

(iii) **Focus on energy efficiency.** Recognizing its rapid socioeconomic development and the need to decrease its energy intensity, the country plans to introduce practices that promote energy efficiency. In 2021, the government worked on developing a new Law on Energy Efficiency and Energy Saving, which the Parliament of Turkmenistan is currently considering (AzerNews 2021).

(iv) **Transfer to renewable energy sources.** Understanding the crucial need to reduce the energy sector's carbon footprint, the country aims to transfer to "greener" methods of energy generation by harnessing the significant potential of its renewable energy sources (around 666 GW). As an initial step, the government, together with international financial institutions (IFIs), has recently developed the National Strategy on Development of Renewable Energy in Turkmenistan for the period up to 2030, and is expected to continue to develop regulatory documents that will complement and enable the implementation of the strategy. As of 2021, the government is working on a total of four legal acts. There are also plans to develop seven more legal acts that will facilitate renewables in Turkmenistan.

Forecast Methodology

One of the objectives of this country study is to present a detailed overview and analysis of Turkmenistan's energy market trends. For this purpose, three scenarios were developed that take into account the country's regulatory framework, technological development, consumer preferences, and other factors (Box 23). Supply and demand, technology, carbon emissions, and investment outlooks were derived based on these scenarios.

Box 23: Scenarios for Turkmenistan's Energy Sector

Business-as-usual scenario: Projected energy supply and demand, with current energy system and policies;

Government Commitments scenario: Projected energy supply and demand, considering individual priorities of the Government of Turkmenistan; and

Green Growth scenario: Projected energy and supply demand, considering enhanced energy transition and environmental policies.

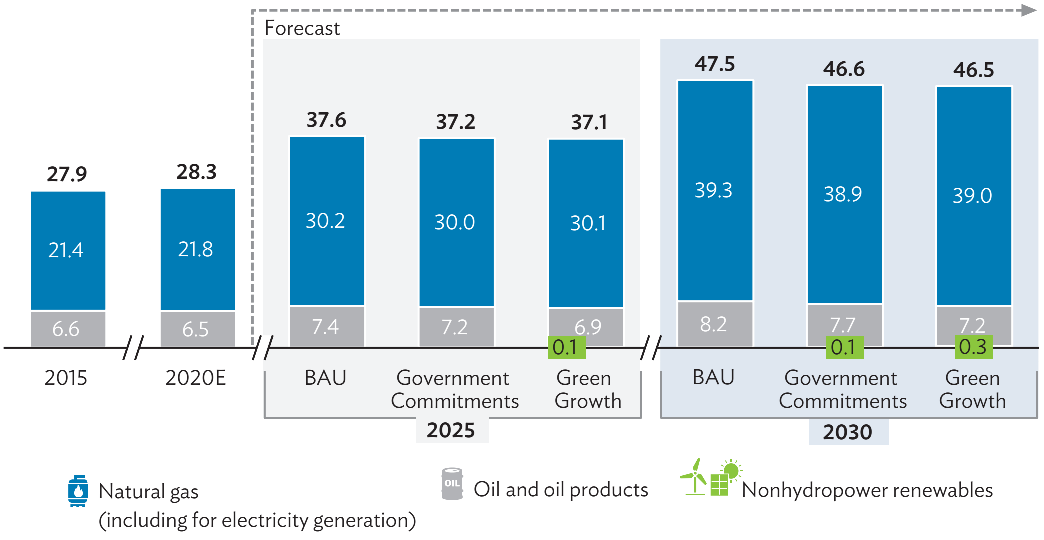
Source: Roland Berger/ILF.

Supply and Demand Outlook

Turkmenistan's energy sector has been significantly impacted by the COVID-19 pandemic. Decreased export volumes, economic uncertainty, and restrictions preventing the spread of the virus led to a nearly 5% decrease in energy demand in 2020. However, the demand is expected to rebound and to surpass prepandemic levels in 2022. Further growth of energy supply is foreseen in all three scenarios because of the expected economic growth until 2030. The Government Commitments scenario projects an annual growth rate for primary energy supply of 5.2% between 2020 and 2030, reaching almost 46.6 million toe by 2030. The Business-as-usual (BAU) scenario forecasts a higher growth rate for primary energy supply, reaching 47.5 million toe with a compound annual growth rate of 5.3% in 2030, as this scenario assumes energy efficiency measures will be limited. The Green Growth scenario, on the other hand, assumes a more intensive roll-out of energy efficiency measures and foresees a 5.1% annual growth rate for primary energy supply (the lowest of the three scenarios)—reaching almost 46.5 million toe in 2030. The differences in energy supply volumes across scenarios are insignificant, as natural gas is expected to remain the main source of primary energy supply.

Natural gas is Turkmenistan's main source of primary energy supply, considering its sole dominance of the power generation mix. All three scenarios project that it will remain in this position until 2030, with the Government Commitments and Green Growth scenarios also projecting an increase in nonhydropower renewables (Figure 92).

Figure 92: Turkmenistan—Primary Energy Supply Forecast
(million tons of oil equivalent)



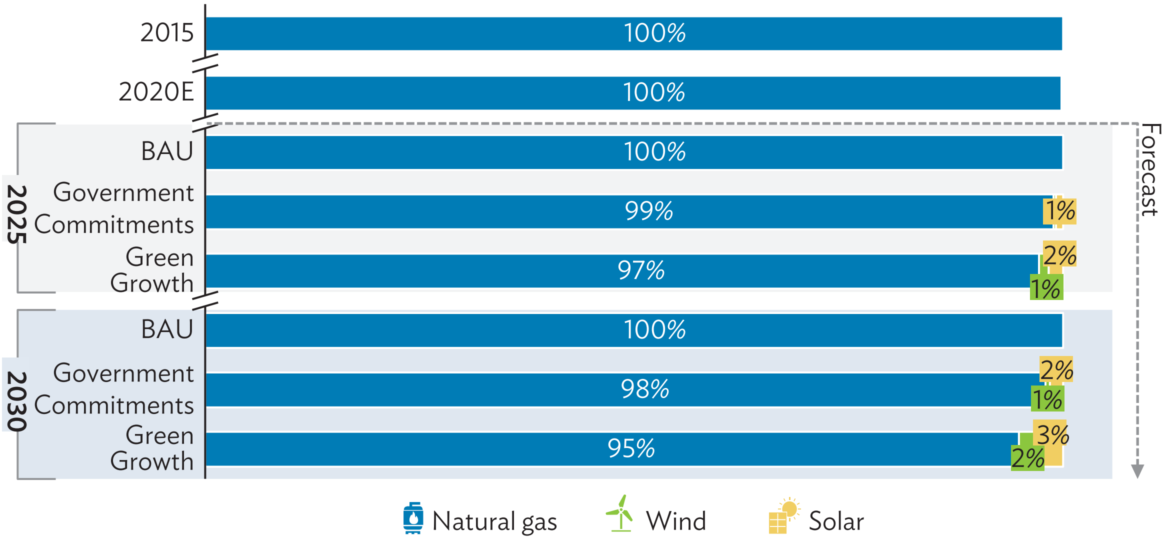
BAU = Business-as-usual, E = estimate.

Source of historical data: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 20 August 2021). The forecasts are based on the Roland Berger methodology described in the Methodology section.

While making use of its abundant reserves of natural gas benefits the country's security of supply, the government has recognized the environmental impact of natural gas power plants and has committed to introducing more renewable energy sources to the generation mix and to modernizing existing infrastructure. The key factor differentiating the three scenarios is the extent to which new renewable energy projects are developed in the country. For instance, the Government Commitments scenario projects the roll-out of solar power plants (accounting for 2% of the electricity mix) and wind power plants (1%). The BAU scenario, on the other hand, projects no change, based on historical development trends. In contrast, the transition to more sustainable methods of energy generation is most rapid under the Green Growth scenario, which projects that the share of solar power in the generation mix will reach 3% and wind power 2% (Figure 93).

In 2030, total final energy demand is forecasted to be between 27.8 million toe and 30.1 million toe, depending on the different energy efficiency improvements projected by the three scenarios (Figure 94). Electricity shows the highest growth, reflecting the growth of the economy and the market; according to Oxford Economics, real GDP is expected to grow nearly 7% per annum until 2030. This is closely followed by natural gas, which has varying growth among the scenarios, based on the extent to which energy efficiency measures are implemented. Oil consumption shows growth in all scenarios until 2030, from 6.8 million toe to 7.8 million toe.

Figure 93: Turkmenistan—Power Generation Mix

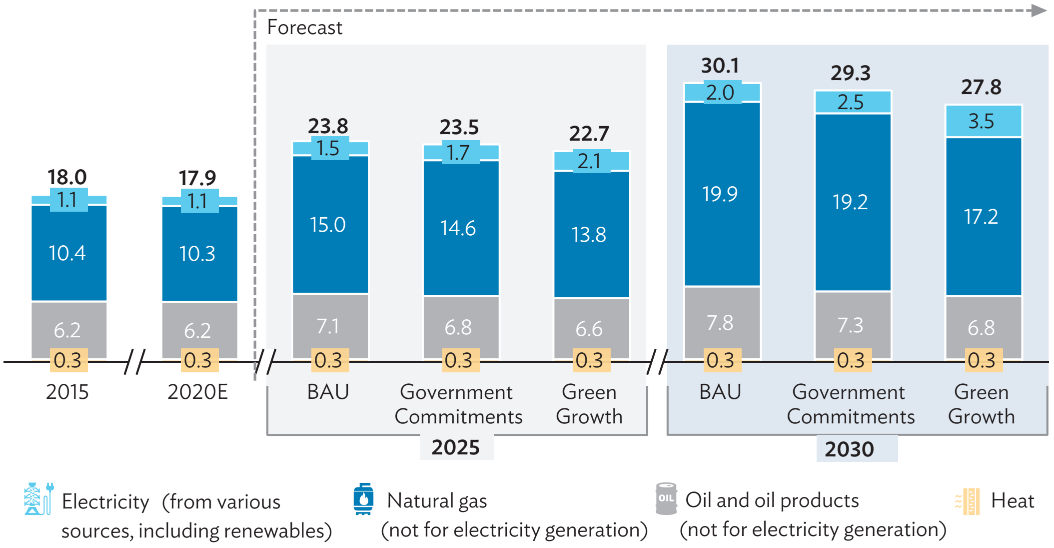


BAU = Business-as-usual, E = estimate.

Source of historical data: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 20 August 2021). The forecasts are based on the Roland Berger methodology described in the Methodology section.

Figure 94: Turkmenistan—Final Energy Demand Forecast by Fuel

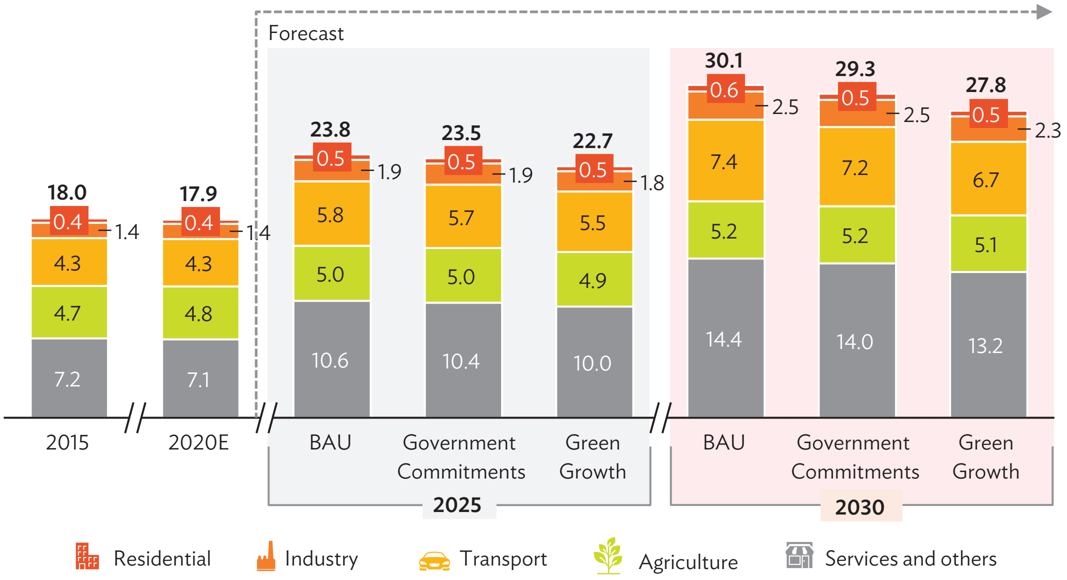
(million tons of oil equivalent)



BAU = Business-as-usual, E = estimate.

Source of historical data: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 20 August 2021). The forecasts are based on the Roland Berger methodology described in the Methodology section.

Figure 95: Turkmenistan—Final Energy Demand Forecast by Sector
(million tons of oil equivalent)



BAU = Business-as-usual, E = estimate.

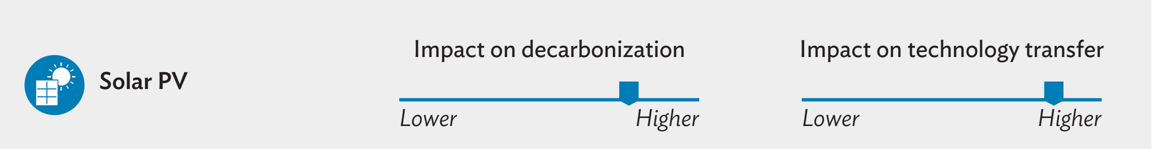
Source of historical data: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 20 August 2021). The forecasts are based on the Roland Berger methodology described in the Methodology section.

The rapid economic development of the country has impacted the services sector most significantly. It is projected to grow at a rate of 5.6%–6.5% annually, depending on the scenario (Figure 95). Transport and industry are also growing at a similar pace, with the industry sector projected to grow at a rate of 4.7%–5.6% annually, and transport at 4.0%–4.9%.

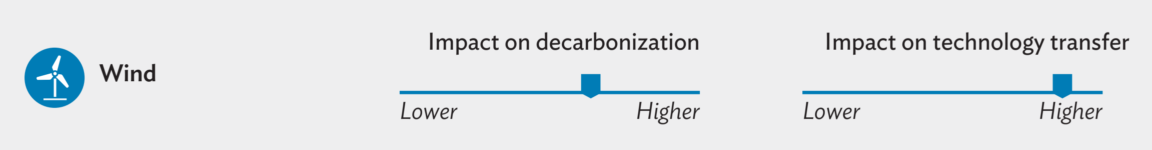
Technology Outlook

Priority Technologies: Generation

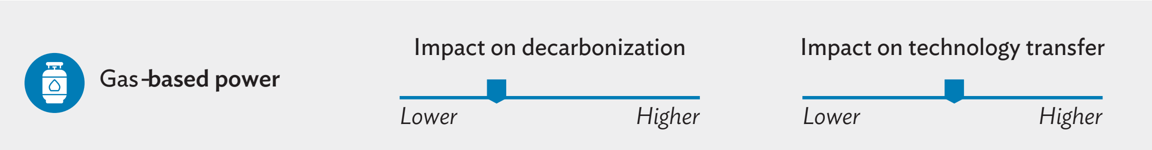
Priority technologies in Turkmenistan were selected based on the country's targets and its commitment to including more renewable energy sources in the mix. Priorities also include the modernization of the natural gas-based power system, as it has a critical role in electricity generation.



Turkmenistan has tremendous potential for harnessing solar energy. With more than 300 sunny days annually and with average annual intensity of solar radiation ranging between 700–800 watts per square meter (W/m^2), the total technical potential of solar energy amounts to 655 GW (Seitgeldiev 2018; UNDP 2014). The overall economic potential of solar energy is strengthened by the fact that the gas sector suffers from significant losses because of gas leakages; hence, diversifying the energy system to include more renewables would be a partial solution to this problem. Although the country has not yet developed any large-scale solar photovoltaic (PV) projects, companies specializing in off-grid systems are present in the market, and some remote regions are using solar installations as a substitute for diesel generators. Moreover, the government's focus on the further development of renewable energy projects, as well as the high silicon content in the sands of the Karakum Desert, might enable the country to position itself as a production center for solar PV panels. Overall, the development of solar PV represents a significant technology transfer opportunity. Because the introduction of solar PV would mitigate the country's reliance on natural gas-powered generation, it would also have a large impact on decarbonization efforts.



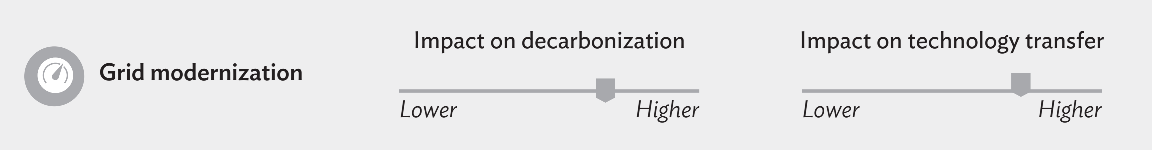
The technical potential of wind power in Turkmenistan is estimated at 10 GW of capacity. This potential remains unexploited as the country has no large-scale wind power projects to date. Together with solar PV, wind power can help the government to achieve its aim of diversifying the power mix and partly transition to renewable energy sources. The coast of the Caspian Sea is known for its strong winds and is the region with the highest potential for wind farming in the country. Due to the country's lack of a technological base, there is significant potential for technology transfer. Moreover, the decarbonization impact of this technology is significant given the absence of renewable energy generation in the country.



Turkmenistan's electricity generation mix is made up only of natural gas-fired power plants. While the country is modernizing its existing plants and adding new high-efficiency units to decrease carbon emissions, it recognizes the need to further reduce its carbon footprint as a large part of the power generation infrastructure requires modernization. As the government strategy involves the gradual expansion of renewable energy sources, natural gas-fired power plants would help to ensure a stable supply during the transition period.

Priority Technologies: Transmission, Distribution, and Storage

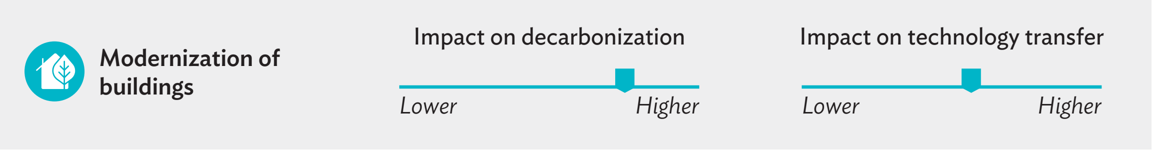
Turkmenistan's T&D system is characterized by high losses and is in need for rehabilitation and increased preventive maintenance.



Turkmenistan's electricity T&D losses are above 16%. Increasing efforts to maintain and rehabilitate the grid should be prioritized to decrease power outages, which would in turn allow for higher electricity exports. Moreover, significant expansion and modernization efforts are required to ensure the proper integration of intermittent power generation facilities, which are planned by the government. The country has already taken steps toward modernizing its current T&D infrastructure by introducing smart grids for public lighting systems in Ashgabat, and by introducing a SCADA system with the aid of international development partners. It should also consider modernizing its natural gas grid. Since natural gas is the country's primary energy supply source, introducing advanced metering infrastructure would allow for proper data collection regarding losses, and overall rehabilitation efforts would decrease leakages into the atmosphere.

Priority Technologies: Consumption

Turkmenistan has considerable potential for energy savings through the implementation of energy efficiency measures on the consumption side. Based on existing inefficiencies and baseline consumption figures, the residential and services sectors were identified as high priority. In 2019, the residential and services sectors accounted for around 42% of the total final energy consumption in Turkmenistan.



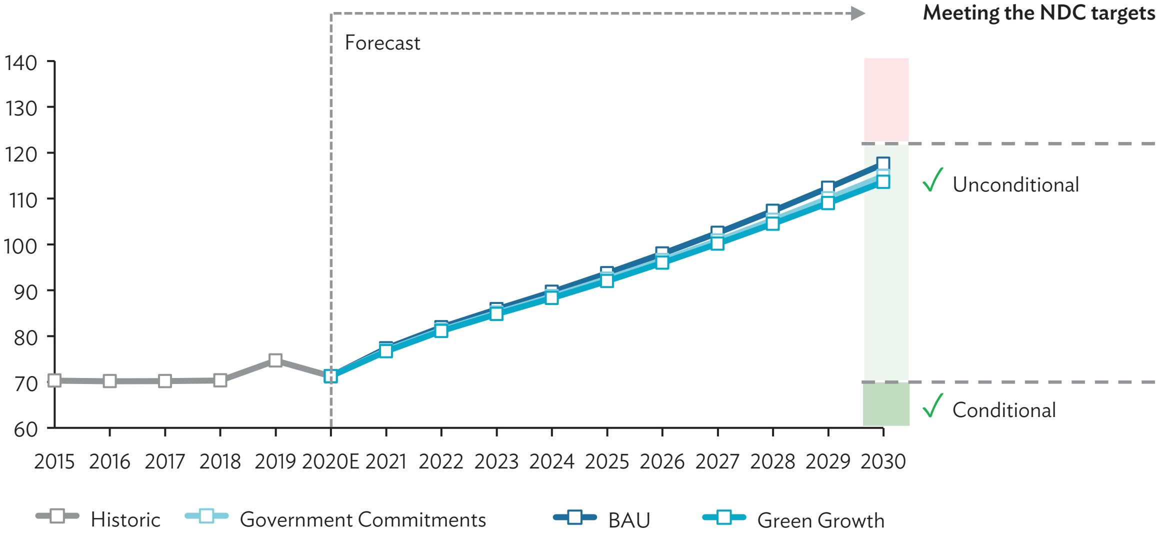
Given that energy efficiency measures in buildings would benefit both the residential and services sectors, the government as well as private investors should prioritize this area. The government has already taken an active role in launching several energy efficiency projects, including energy audits in Ashgabat, Turkmenbashi, Adaban, and other cities. These have prompted revisions to building standards and automatic temperature regulators in some homes. Moreover, modernization efforts that may be considered include basic construction elements, such as roofs, unheated cellars, and frame fillings. Implementing building energy management systems and shifting toward smart metering are other known technologies that could significantly reduce energy consumption in Turkmenistan.

Carbon Emissions Outlook

Turkmenistan demonstrated its commitment to tackling climate change in issuing the National Program on Climate Change in 2012. The country showed further commitment and solidarity with global efforts to reduce GHG emissions by submitting an intended nationally determined contribution (INDC) in 2016. Turkmenistan has established both conditional and unconditional targets, with the key difference being the provision of technological and financial support from developed countries. In case such support will be provided, Turkmenistan has committed to ensuring that GHG levels will not grow beyond 2015 levels and may even be reduced by 2030 (UNFCCC 2016). However, the country has not identified a definite target. Without external support, the government foresees that the GHG emissions rate will lag behind GDP growth, and total GHG energy-related emissions will reach about 122 million tons of carbon dioxide (CO_2) equivalent by 2030.[16]

The carbon emission outlook for Turkmenistan demonstrates that the government has set a reasonable, unconditional target. Its unconditional target is reached under all scenarios, even while assuming the steady growth of GHG emissions due to heavy use of natural gas in the primary energy supply. The Government Commitments scenario assumes an increase in renewable energy sources in the country's power generation mix and, therefore, projects about 115 million tons of CO_2 equivalent by 2030. The BAU scenario assumes that no changes in the power generation mix will occur, and that no renewable energy projects will be implemented; therefore, 117 million tons of CO_2 equivalent are projected by 2030. The Green Growth scenario projects the lowest energy-related emissions growth rate because of additional investments in energy efficiency measures and the implementation of renewable energy projects, resulting in 113 million tons of CO_2 equivalent by 2030 (Figure 96).

Figure 96: Turkmenistan—Energy-Related Carbon Emissions
(million tons of carbon dioxide equivalent)



BAU = Business-as-usual, E = estimate, NDC = Nationally Determined Contribution.

Note: Historical data on carbon emissions is modelled by Roland Berger based on historical data on energy use. The forecasts are based on the Roland Berger methodology described in the Methodology section.

Sources: Roland Berger; and United Nations Framework Convention on Climate Change. Nationally Determined Contributions Registry. https://unfccc.int/NDCREG.

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[16] Energy-related emissions include greenhouse gas emissions from the generation, transmission, and consumption of energy. The assumed share of energy-related emissions is based on historical data.

Investment Outlook

Investment Needs

Infrastructure investment needs in the energy sector until 2030 vary across the three scenarios: the BAU scenario assumes $5.5 billion; the Government Commitments scenario, $8.0 billion; and the Green Growth scenario, $13.1 billion. All three scenarios assume the expansion of natural gas-powered generation, with investments ranging from $4.4 billion in the BAU scenario to $9.2 billion in the Green Growth scenario. The Government Commitments and Green Growth scenarios both assume the expansion of renewable power generation, with investment needs of $0.4 billion (Government Commitments) and $1.2 billion (Green Growth). Investment needs in the T&D sector also vary among the scenarios, with projections ranging between $1.1 billion and $2.4 billion (Figure 97).

Challenges and Opportunities

Turkmenistan's energy sector faces a variety of challenges that need to be addressed to ensure the efficient development of the energy market and the establishment of a favorable investment climate.

Sizeable subsidies had provided Turkmen citizens with free electricity, gas, and drinking water since the 1990s. More recently, the government has started implementing gradual tariff reforms. With a view to developing a free market economy, the President of Turkmenistan signed the Decree prescribing the abolition of free supply of electricity, gas, potable water, and table salt to citizens as of 1 January 2019 (Radio Free Europe/Radio Liberty 2018). This is expected to reduce the country's high energy consumption per capita and can be considered as one of the first steps to increase recovery of costs related to energy infrastructure and services. Studies have shown that a share of major household appliances (including electrical bulbs, air conditioners, and other electrical devices) account for more than a quarter of total domestic electricity consumption, indicating a significant need for energy efficiency improvements.

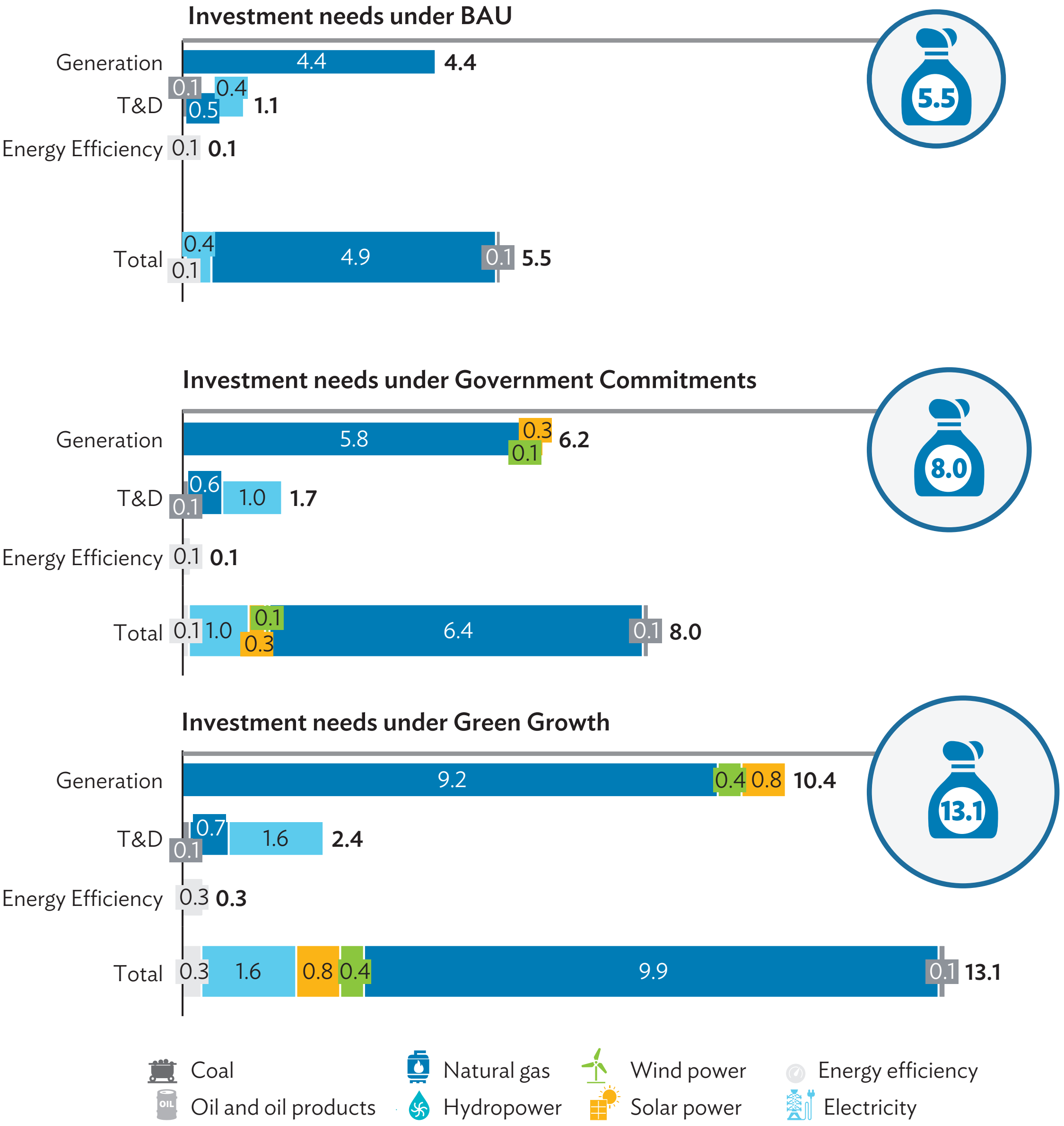
Although the development of renewable energy was identified as a government priority in the National Program on Climate Change in 2012, private sector participation in energy generation has not reached sufficient maturity to fully implement this priority. The process of registering a business requires a set of formalities, which may, in some instances, consume dedicated times such as the evaluation and approval of a new business by the interministerial commission. However, the government is currently introducing more regulations regarding the digitalization of the procedures, which demonstrates its commitment to speeding up the process in the future. With almost 670 GW of potential technical capacity, renewable energy can lead the country's climate change mitigation efforts and, in turn, increase both natural gas and electricity export capabilities.

Given the country's significant natural gas reserves, the exploration and production sectors present an investment opportunity. However, with growing ambitions in global climate targets, additional gas capacity is expected to be subject to more stringent environmental criteria in its operation and as a condition to receive financing.

Turkmenistan has significant hydrogen production potential, given its large natural gas reserves and the existence of local demand centers for hydrogen fuel (e.g., gas-fired power plants, petrochemical plants, and other industrial plants). Recognizing the considerable potential of hydrogen, the country is taking initial steps in this direction. For instance, in 2021, during a high-level United Nations Global Roundtable,

Figure 97: Energy Infrastructure Investment Needs in Turkmenistan until 2030

($ billion)



BAU = Business-as-usual, T&D = transmission and distribution.

Source: The forecasts are based on the Roland Berger/ILF methodology described in the Methodology section.

Turkmenistan's leadership identified the development of an international road map for hydrogen energy as an energy sector priority and emphasized the country's readiness to begin expert discussions on the methods and criteria for implementation. The government plans to continue exploring the possibility of hydrogen production in the country (Central Asia News 2021). While "green" hydrogen is often seen as more sustainable, the maturity of "blue" hydrogen technology is higher. The development of both blue and green hydrogen projects would result in substantial technological advancements for the country and would have positive impact on decarbonization. The success of such initiatives will largely depend on the participation of private sector players.

Policy Recommendations

While Turkmenistan's government has taken some steps toward upgrading the country's infrastructure, decarbonizing the energy sector, and introducing new legislation, further efforts are required to make tangible progress:

(i) **Implement an infrastructure modernization program.** Upgrading infrastructure (especially T&D assets), and developing action plans to reduce electricity losses and gas leakages is recommended.

(ii) **Explore options for a potential reconnection of Turkmenistan to the Central Asian Power System.** The Central Asian Power System (CAPS) was initially developed in the Soviet Union to connect Kazakhstan, the Kyrgyz Republic, Tajikistan, Turkmenistan, and Uzbekistan. In its current form, it can help expand energy trading and boost regional energy security across Central Asia. Turkmenistan disconnected from CAPS in 2003. The Asian Development Bank has approved a technical assistance grant to support an increase in regional power trade in CAPS. It also aims to study the potential reconnection of Turkmenistan to CAPS.

(iii) **Reinforce efforts to deploy renewable energy projects.** Both policy and legislation changes demonstrate Turkmenistan's clear commitment to transitioning to renewable energy generation to decarbonize the power generation sector. The establishment of special incentive schemes for renewable energy projects, such as feed-in tariffs or a capacity auction on a least-cost basis, would potentially lead to a higher investment inflow due to higher transparency in the tariff setting process.

(iv) **Improve the investment climate for the private sector.** Recently adopted legislation in renewable energy generation is a necessary step toward opening investment opportunities for the private sector. However, additional action is required to improve Turkmenistan's appeal to investors, including the establishment of a clear tariff structure, shortening the lengthy administrative processes, and opening the electricity generation market.

(v) **Study possibilities and create a regulatory framework for the decarbonization of the gas sector.** To realize Turkmenistan's hydrogen potential in the longer term, conducting feasibility studies and launching pilot projects can be crucial at this early stage. The country has taken initial steps in this direction.

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Mosque of Turkmenbashi Rukhy in Kipchak. The mosque opened in 2004 and is located about 7 kilometers away from the capital, Ashgabat (photo by kg58/Adobe Stock©).

UZBEKISTAN

Power infrastructure. Nearly 90% of Uzbekistan's electricity is generated from natural gas (photo by Mny-Jhee/Adobe Stock©).

Uzbekistan Highlights

- Uzbekistan's current energy mix is heavily dominated by natural gas. Nearly 90% of the country's electricity is generated by natural gas. The government aims to modernize old power plants to satisfy rising demand with new and more efficient units. At the same time, Uzbekistan has a vast renewable energy potential of around 600 gigawatts (GW), mainly in solar photovoltaic (PV) and wind energy (UNDP 2014) (Figure 98). As multiple projects are projected to come online during the next several years, significant business opportunities remain for additional projects.
- Uzbekistan is one of the leading producers of natural gas in the Eurasia region, with an annual production volume of 53–57 billion cubic meters per annum (bcma), and total proven reserves of 1.2 trillion cubic meters (tcm)—the 23rd largest global reserve, accounting for around 1% of the world's natural gas. Multiple foreign investors are involved in gas exploration and production in Uzbekistan's large domestic market and in some of its gas transit and export infrastructure.
- The country has taken initial steps toward liberalizing its energy market. Following the unbundling of the vertically integrated state-owned companies, Uzbekenergo and Uzbekneftegaz, in 2019, the next steps should be directed toward the establishment of competitive wholesale and retail energy markets to gradually reduce the state monopoly.
- Final energy demand in Uzbekistan is projected to grow from almost 30 million tons of oil equivalent (toe) in 2018 to 40–45 million toe by 2030, depending on the adoption of energy efficiency measures across three forecast scenarios. Despite the development of renewable and nuclear energy, natural gas will remain the key source of overall energy supply.
- The share of renewable energy in the power generation mix could reach up to 39% across hydropower, wind, and solar PV energy by 2030, depending on the scenario. Given that the government also plans to commission a large-scale nuclear power plant in 2028, the share of natural gas could decline to 45%.
- To reach its policy goals, priority energy technologies for Uzbekistan are gas-fired power plants, and solar and wind energy in the generation sector. The government should also address the high losses and overall poor technical condition of its aging midstream infrastructure, considering that the majority of greenhouse gases (GHGs) in Uzbekistan originate from the natural gas sector. Uzbekistan also has great "blue" hydrogen potential; however, in the short term, improved energy efficiency—mainly in the industrial and residential sectors—should be prioritized.
- Total investment needs in energy infrastructure of Uzbekistan are estimated at $17 billion–$36 billion, depending on the scenario. Approximately 60%–70% of the total investment is needed for power generation, driven largely by the investment size of a planned nuclear power plant.
- Uzbekistan continues to emerge as a high-potential market for private investors, given its transition to liberalized and competitive energy markets, excellent renewable energy potential, solid cross-border infrastructure, and the previous success of private companies in large-scale renewable energy projects.

Figure 98: Uzbekistan—Key Figures

Renewable potential	Renewable projects	Exports	Carbon intensity	Gas Interconnections
~600 GW	**2.8 GW**	**>12 million toe**	**114th out of 172**	**~150 bcma**
Total potential of renewable energy is estimated at ~600 GW, with 98% from solar energy.	Total capacity of renewable energy projects in the development pipeline is 2.8 GW.	Uzbekistan's natural gas exports exceeded 12 million toe in 2018.	Uzbekistan is ranked 114th out of 172 countries in the global ranking of carbon intensity of energy, largely due to the low share of coal in the electricity mix.	Cross-border natural gas export and transit capacity of Uzbekistan is ~150 bcma.

bcma = billion cubic meters per annum, GW = gigawatt, toe = ton of oil equivalent.

Sources: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 23 August 2021); United Nations Development Programme. 2014. *Renewable Energy Snapshot: Uzbekistan.* New York; and United States Energy Information Administration. Uzbekistan Data. https://www.eia.gov/international/data/world (accessed 23 August 2021).

- However, several challenges should be overcome to further improve the investment climate in the energy market. These include the phasing-out of energy subsidies, the improvement of midstream infrastructure, and the completion of market reforms. The establishment of an independent regulator, as well as the publication of a comprehensive long-term energy strategy, which brings together all existing subsector strategies under a single framework, are among the suggested levers to further improve private sector participation.

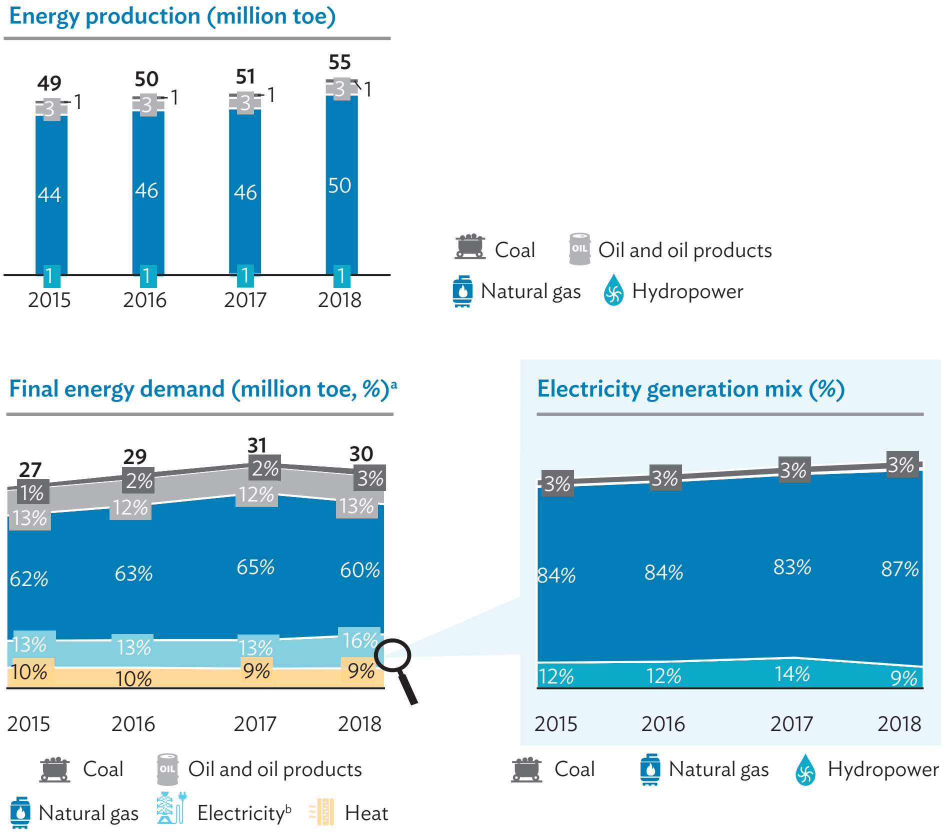
Energy Sector Profile

Country Profile

Uzbekistan has the largest population in Central Asia (over 33 million people). The country's nominal gross domestic product (GDP) reached $57 billion in 2020. While recent economic liberalization reforms triggered rapid currency devaluation and a subsequent decline of its nominal GDP, real GDP continues to grow. Despite the negative effects of the restrictions relating to the coronavirus disease (COVID-19) pandemic, the nominal GDP has stayed virtually the same since 2019. Economic recovery after the crisis is expected to result in real GDP growth of between 6%–7% annually, boosted in part by a rapid population growth.

Uzbekistan has rich natural resources, especially natural gas, which has historically been a foundation of its national economy and energy infrastructure. As a result, Uzbekistan continues to be a net energy exporter, supplying the neighboring People's Republic of China (PRC), the Russian Federation, and Central Asian countries with substantial amounts of natural gas. Availability of natural gas has also resulted in a natural gas-dominant structure of energy demand and electricity generation (Figure 99). Since natural gas has a moderate environmental impact compared to coal, Uzbekistan fares relatively well in terms of the carbon intensity of its energy consumption, ranking 114th out of 172 countries globally. In contrast, the level of energy efficiency is drastically different, with high availability of natural gas, low energy prices, and unmodernized infrastructure, contributing to Uzbekistan's position as the 22nd most energy-intensive economy in the world.

Figure 99: Energy Profile of Uzbekistan



toe = ton of oil equivalent.

[a] Topmost numbers on the chart are in million toe.

[b] Electricity data come from various sources, including fossil fuel-based and renewables.

Source: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 23 August 2021).

Energy Sector and Technologies Assessment

Conventional Fuel Production

Uzbekistan is one of the leading natural gas producers in Eurasia, with a reported 53–57 billion cubic meters (bcm) of annual production. Both private and state-owned companies participate in the market. Uzbekneftegaz, the state-owned oil and gas production giant, owns a large number of small gas fields. The majority of these fields have declining production and rely on old infrastructure amid limited exploration efforts. In contrast, private companies operate (via production-sharing agreements or joint ventures with Uzbekneftegaz) newer production fields that are increasing their production or are reaching their peak production volumes. Total proven natural gas reserves in Uzbekistan are estimated at 1.2 tcm.

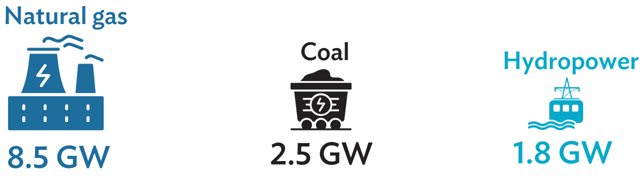
Compared to natural gas, Uzbekistan has minor oil and coal resources. Total proven oil reserves stand at 100 million tons. Output peaked at about 10 million tons in the late 1990s and has since declined rapidly to less than 1 million tons in 2019—a level insufficient to cover domestic demand, which has resulted in its reliance on oil imports from Kazakhstan. The situation regarding coal is similar—with production of around 4 million tons in 2019, Uzbekistan is unable to cover domestic demand and has to import coal from neighboring countries. Despite the limited importance in the overall energy mix, proven coal reserves stand at 1,375 million tons, and production is carried out at the Angren brown coal field and the Shargun and Baisun underground deposits (ADB 2020).

Electricity Generation

Uzbekistan's total power generation capacities reached 12.9 GW in 2019. Nearly two-thirds of total installed capacity are represented by natural gas-fired plants (8.5 GW), some of which are also combined heat and power plants. Most were commissioned during the Soviet times and use steam turbine technology. As a result, average power generation efficiency is very low, between 28% and 33%, compared to the 50%–55% efficiency averages of modern plants. However, the government has already prioritized the issue of power generation inefficiency and has started a broad modernization program. In 2020, the new Turakurgan power plant was commissioned. It has a capacity of 0.9 GW and uses a more advanced combined-cycle process. In addition, the rehabilitation and modernization of several existing power plants is planned, including the Navoi power plant. Uzbekistan also plans to decommission 5.9 GW of thermal-power generation capacity, reflecting the poor technical condition of the plants. Decommissioned capacity will be replaced by new renewable and natural gas-fired plants, some of which are already planned. The government plans to have more than 13 GW of natural gas-fired power capacity by 2030.

Other power generation sources in Uzbekistan include coal and hydropower. Uzbekistan's coal-fired power plants have a capacity of 2.5 GW, and mostly operate using technologies with low efficiency. Its coal-fired power plants are also relatively outdated, having been commissioned between 1973 and 1989. The remaining share of electricity in Uzbekistan is produced by hydropower plants that have a total capacity of 1.8 GW (Figure 100). Ten hydropower plants, with a total capacity of 1.4 GW, use reservoir technology, allowing them to provide flexible generation. The remaining 30 hydropower plants are run-of-river power plants and operate at a smaller scale (Government of Uzbekistan, Ministry of Energy 2020). Uzbekistan's hydropower plants were commissioned between 1933 and 1980 and are now moderately outdated, despite the prolonged useful life of hydropower plants.

Figure 100: Installed Power Generation Capacity in Uzbekistan, 2019



GW = gigawatt.

Source: Government of Uzbekistan, Ministry of Energy. 2020. *Concept Note for Ensuring Electricity Supply in Uzbekistan in 2020–2030.* Tashkent.

Uzbekistan's abundant renewable energy potential (a total of nearly 600 GW) has not been exploited yet (UNDP 2014). However, in cooperation with international financial institutions (IFIs), Uzbekistan has developed many potential projects that are expected to begin operating over the next few years. For instance, in 2021, a tender for two 220-megawatt (MW) solar projects in Jizzakh and Samarkand was completed; construction is expected to begin in the first quarter of 2022. Another project for 457 MW solar PV plant is planned in Sherabad. The government has also been supporting decentralized solar systems at residential buildings, covering a third of the installation costs. Yet, according to estimates, installed capacity of the solar PV systems in Uzbekistan reached only 4 MW in 2020 (IRENA 2021).

Transmission and Distribution

The large area of the country and the size of its population necessitate sizeable energy transmission and distribution (T&D) systems. The National Electric Grid of Uzbekistan is its electricity transmission system operator (TSO), operating electric grids with a voltage of 220–500 kilovolts (kV) and a total cable length of more than 9,700 kilometers (km). The electricity grids of 14 territorial distribution and sales enterprises supply consumers nationwide. They each operate in separate territories as joint-stock companies under the control of Regional Electric Grids JSC, a distribution system operator (DSO). The DSO operates power transmission lines, with a total length of more than 250,000 km, and 1,700 substations, with a voltage of up to 110 kV. The T&D lines, as well as the facilities, are operated by Regional Electric Power Networks and are severely outdated. The company estimates that around 58% of all types of overhead power transmission lines and one-third of all substations require modernization. T&D losses have grown in recent years, amounting to a combined value of 17% in 2019.

Uzbekistan's natural gas T&D network adds up to a length of around 137,350 km. Like its electricity networks, Uzbekistan's natural gas T&D infrastructure suffers from constant underinvestment and inadequate maintenance. Due to the old age of pipelines, its natural gas infrastructure also suffers from significant losses. Official statistics state that natural gas losses reached 6% in 2018; but, according to unofficial estimates, total losses are likely to be higher. Alarmingly, natural gas losses typically result in the release of methane into the atmosphere, which has a significantly higher environmental impact than natural gas combustion. With annual gas production of 55 bcm, these losses are significant and not only lead to higher GHG emissions but also sizeable loss of revenue. Another problem of Uzbekistan's midstream natural gas infrastructure is its inadequate natural gas storage capacity (a total of nearly 5 bcm) that prevents effective resource management across seasons, considering the significant difference in natural gas consumption between summer and winter as well as the significant discrepancies in weather conditions across years.

Uzbekistan's district heating system was built between the 1950s and 1970s using an open water intake scheme and dependent connections to buildings' heating system networks. Such district heating systems are not expensive to install, but they are characterized by high operating costs, short operational lifetimes, and excessive consumption of network water and thermal energy. As the district heating system has significantly deteriorated, Uzbekistan's current heat supply system does not provide optimum loading of heat sources.

Cross-Border Infrastructure

Uzbekistan has great transit potential due to its favorable location in the heart of Central Asia. It is also part of the Central Asian Power System (CAPS) that unites the electricity systems of Uzbekistan, Kazakhstan, and the Kyrgyz Republic (ADB 2018). Tajikistan is expected to be reconnected by 2022. CAPS is projected to be revived in the coming years amid improving relations among its member countries and the growing importance of the cross-country energy trade in the context of complementary availability of natural resources. Uzbekistan also exports power to Afghanistan via a line with smaller capacity, the Surkhan–Naibadad 220 kV line.

The country also has a legacy natural gas cross-border infrastructure. One of its main elements is the Central Asia–Center pipeline, with a capacity of 54 bcma that connects Turkmenistan and Uzbekistan to the natural gas grids of the Russian Federation. The Central Asia–PRC pipeline system is of a similar scale, with a total capacity of 54 bcma across three lines. Central Asia–PRC is a relatively new pipeline system (operating since 2009) and thus is in much better technical condition than infrastructure developed in Soviet times, such as the Central Asia–Center pipeline. Negotiation and early development work continue for the fourth line of the Central Asia–PRC pipeline, which could increase its capacity by an additional 30 bcma.

Two pipelines connect Uzbekistan to the Russian Federation (Bukhara–Ural), with capacity of 54 bcma, and Kazakhstan (Gazli–Shymkent), with capacity of 14 bcma. Several smaller pipelines connect Uzbekistan to the Kyrgyz Republic and Tajikistan, specifically the Bukhara–Tashkent–Bishkek–Almaty pipeline (6 bcma), the Sherabad–Dushanbe (2 bcma), and the Andijan–Osh (1.5 bcma) (Table 10).

Energy Consumption

Uzbekistan is one of the world's most energy-intensive economies, with intensity of 7.8 British thermal units (Btu) per dollar of GDP in 2018, well above the world average of nearly 4.8 Btu. However, the country's energy intensity has declined significantly from its peak levels of 33.3 Btu per dollar of GDP in 1993. The much higher level of energy intensity initially reflected the poor efficiency of the industrial sector Uzbekistan inherited from the Soviet period. This mainly included the machine-building complex, ferrous and nonferrous metallurgy, chemical, pharmaceutical, automotive, light and food industries, as well as manufacturing of building materials. Specifically, the country faces the problem of considerable physical deterioration of fixed assets, given that the depreciation level generally exceeds 40%. As a result, energy consumption in some industries is up to 2–3 times higher than the global average. In response, the government with support from international financial institutions (IFIs) has initiated investment programs by launching special credit lines for industrial energy efficiency investments (World Bank 2018). Large state-owned industrial enterprises, mainly in the oil and gas, chemical, and construction sectors, as well as small and medium-sized enterprises, have already benefited from this program by introducing energy-efficient technologies.

Table 10: Uzbekistan—Major Cross-Border Energy Infrastructure

Energy Source	Name	Capacity	Status	Connected Country
⚡	Lochin–Toktogul 500 kV line	850 MVA	Operational	Kyrgyz Republic
⚡	Lochin–Turabaev 220 kV line	450 MVA	Operational	Kyrgyz Republic
⚡	Tashkent–Shymkent 500 kV line	1,200 MVA	Operational	Kazakhstan
⚡	Surkhan–Pule Khumri 500 kV line	1,000 MVA	Planned	Afghanistan
⚡	Surkhan–Naibadad 220 kV line	150 MVA	Operational	Afghanistan
⚡	Khujand–Syrdarya 220 kV line	690 MVA	Nonoperational	Tajikistan
⚡	Guzar–Regar 500 kV line	1,000 MVA	Nonoperational	Tajikistan
⚡	Karakul–Serdar 500 kV line	1,000 MVA	Operational	Turkmenistan
🔥	Central Asia–Center	54 bcma	Operational	Russian Federation
🔥	Bukhara–Ural	54 bcma	Operational	Russian Federation
🔥	Gazli–Shymkent	14 bcma	Operational	Kazakhstan
🔥	Bukhara–Tashkent–Bishkek–Almaty	6 bcma	Operational	Kazakhstan, Kyrgyz Republic
🔥	Central Asia—PRC	55 bcma	Operational	Kazakhstan, PRC, Turkmenistan
🔥	Central Asia—PRC (line D)	30 bcma	Planned	Kyrgyz Republic, PRC, Tajikistan, Turkmenistan

⚡ Electricity 🔥 Natural gas

bcma = billion cubic meters per annum, kV = kilovolt, MVA = megavolt-ampere, PRC = People's Republic of China.

Sources: China National Petroleum Corporation. Flow of Natural Gas from Central Asia; Fitch Solutions. 2020. *Uzbekistan Oil & Gas Report*. London; Fitch Solutions. 2020. *Uzbekistan Power Report*. London; and International Energy Charter. 2018. *Uzbekistan's Energy Sector: Opportunities for International Cooperation*. A PowerPoint presentation. October.

The residential sector is the largest energy consumer group, partly due to low efficiency (Center for Energy Efficiency 2013). About 60% of apartment buildings built in Uzbekistan are at least 35 years old and have inadequate energy efficiency performance compared to modern standards. According to different estimates, specific energy consumption in buildings varies from 300 kilowatt-hours per square meter (kWh/m^2) per year to 400 kWh/m^2 per year, well above benchmark indicators in developed countries or even regional peers (UNDP Uzbekistan 2020). Inefficient insulation is a key reason for the country's poor energy efficiency record, being a primary cause of nearly 50% of heat losses. The government has already made initial steps toward improving energy efficiency in the residential sector by adopting new energy performance standards and blocking imports of equipment with low efficiency. Another recently adopted governmental program helps to cover a third of costs related to installation of energy-efficient heating equipment and decentralized solar systems.

Road transport also experiences challenges with efficiency as the average age of the vehicle fleet in Uzbekistan is 12 years, and 60% of the fleet is older than 15 years. Most cars do not meet the international Euro 4 emission standards and would be prohibited in developed countries. Considering the availability of natural gas, the government launched a program in 2019 that promotes switching from gasoline and diesel to alternative fuels, specifically natural gas. Currently, more than 800,000 vehicles (about 25%–30% of the whole fleet) use compressed natural gas and liquefied petroleum gas as fuel. Penetration of electric vehicles (EVs) is much lower, with a total number of less than 1,000 as of 2021 and less than 20 public charging stations. Yet, some growth in the number of EVs and charging stations is expected as the government has canceled import and registration fees for EVs, thus promoting their rapid expansion (Kursiv Media 2021).

The fleet of locomotives operated by Uzbekistan Railways, the national rail carrier, is also old and inefficient. Out of nearly 400 locomotives, more than 60% are over 30 years old. The total length of Uzbekistan's main railway network is about 4,700 km, with an electrification rate of about 50%; whereas, the share of electric locomotives in the fleet is only about 30%.

Regulatory Framework

Uzbekistan has undertaken an economy-wide reform and liberalization program, best illustrated by its rapid ascent in the Ease of Doing Business rankings to the 69th position in 2020, up from 141st in 2015. In addition to the overall improvement of its investment climate, energy-sector-specific reforms are also underway. Major changes were commenced with an institutional reorganization and the creation of the Ministry of Energy in 2019. While the resulting institutional framework significantly improved, the Ministry of Energy still combines policy making and regulatory functions, contrary to the best practices of energy market regulations. This gap is addressed in a draft resolution on Additional Measures to Reform the Electric Energy Industry, published in 2021, in which the creation of an independent regulator is envisioned. The new regulator will be tasked with liberalizing energy markets, setting tariff policy, as well as supporting competition and attracting private sector capital.

The same draft resolution also makes a further step in the liberalization of the power market via a planned transition to a competitive electricity market in both the wholesale and the retail power markets by 2025. This follows the unbundling of the vertically integrated Uzbekenergo (completed in 2019) into three separate companies: JSC Thermal Power Plants (power plant operator), National Electric Networks of Uzbekistan (TSOs), and JSC Regional Electric Networks (DSOs). The market will operate under a single buyer model under a newly established Guaranteed Buyer scheme expected to be in operation in early 2022.

Another important milestone has been the adoption of the Law on Renewable Energy Sources in 2019, which not only provided a guarantee of grid access for renewable energy but also tax incentives for their development. In 2019, Uzbekistan enacted a Public–Private Partnership (PPP) Law, which streamlined the process of establishing PPPs and provided guarantees and state support for projects. This structure has already been extensively used by multiple foreign investors, developing PPPs in large-scale renewable energy plants.

The natural gas market is following the path of the power market toward liberalization with some delay. Unbundling was completed in 2019, and three separate state-owned entities were established: Uzbekneftegaz (exploration and production), Uztransgaz (TSO), and Hududgazta'minot (DSO). In 2020, Hududgazta'minot was mandated to sell natural gas to consumers connected to the distribution grid, and Uzstransgaz to sell natural gas to a few larger consumers connected to the transmission system. While officials have stated aims to establish a natural gas market exchange with the competitive participation of private companies, the system is yet to be designed and implemented.

Another part of the regulatory framework is the recently updated energy efficiency regulation. Specifically, the 2019 Decree No. PP-4422 brought about a positive change through the adoption of modern construction standards and by providing support for the installation of energy-efficient equipment.

Finally, natural gas production in Uzbekistan is conducted via production-sharing agreements or joint ventures with state-owned Uzbekneftegaz. Exploration and development licenses are awarded on a project-by-project basis with limited transparency. In addition to taxes, natural gas production by private firms is subject to royalty payments of 0%–30%, depending on market prices of natural gas.

Policy Framework

A key policy document in Uzbekistan is the Strategy on Transition to "Green" Economy 2019-2030. This calls for the expansion of renewable energy for infrastructure modernization, and for increased energy efficiency by 2030 via reduced losses and improved energy management (Government of Uzbekistan, Ministry of Justice, National Legal Information Center "Adolat" 2019).

Currently, the government's objectives are scattered through multiple short-term decrees and action plans, which complicate investment decisions for private investors due to a lack of clarity regarding the long-term direction of the energy sector's development.

However, one positive exception is its power sector policy, which is laid out in the Concept Note for Ensuring Electricity Supply in Uzbekistan in 2020–2030. The document provides detailed information on targets related to electricity's share in the generation mix and its capacity by 2030, but only briefly outlines objectives related to the power sector policy. These include the elimination of energy imports to achieve energy independence, improvements in energy efficiency in the supply and demand sectors, and the development of renewable energy and an efficient electricity market model.

Based on various government documents, the following sector priorities can be identified:

(i) **Optimal use of domestic natural gas.** Uzbekistan plans to continue to make use of its abundant natural gas resources to ensure the security of its domestic energy supply and, potentially, to expand exports. To achieve this, additional efforts are required in terms of exploration activities and establishing a suitable investment climate for increased private sector participation.

(ii) **Expansion of renewable energy generation.** Uzbekistan has set ambitious targets for renewable energy generation and, with the support of IFIs, has developed an extensive pipeline of large-scale projects. Realizing renewable energy potential will not only help to diversify energy supply but will also support Uzbekistan in its decarbonization efforts.

(iii) **Improvements in energy efficiency.** Trailing in energy efficiency, Uzbekistan aims to significantly improve efficiency across all sectors, focusing on midstream infrastructure as well as consumption in the industrial and residential sectors.

(iv) **Liberalization of the energy market.** Uzbekistan has taken a firm approach toward energy market liberalization to provide high-quality energy services to domestic consumers at minimum prices. Fair competition and wide private sector participation are key levers to achieving this.

Forecast Methodology

One of the objectives of this country study is to present an overview and analysis of trends that will define the future of Uzbekistan's energy market. For this purpose, three scenarios were developed, considering the country's regulatory framework, technological development, and consumer preferences, among other factors (Box 24). Supply and demand, technology, carbon emissions, and investment outlooks were derived based on these scenarios.

Box 24: Scenarios for Uzbekistan's Energy Sector

Business-as-usual scenario: Projected energy supply and demand, with current energy system and policies;

Government Commitments scenario: Projected energy supply and demand, considering individual priorities of the Government of Uzbekistan; and

Green Growth scenario: Projected energy and supply demand, considering enhanced energy transition and environmental policies.

Source: Roland Berger/ILF.

Supply and Demand Outlook

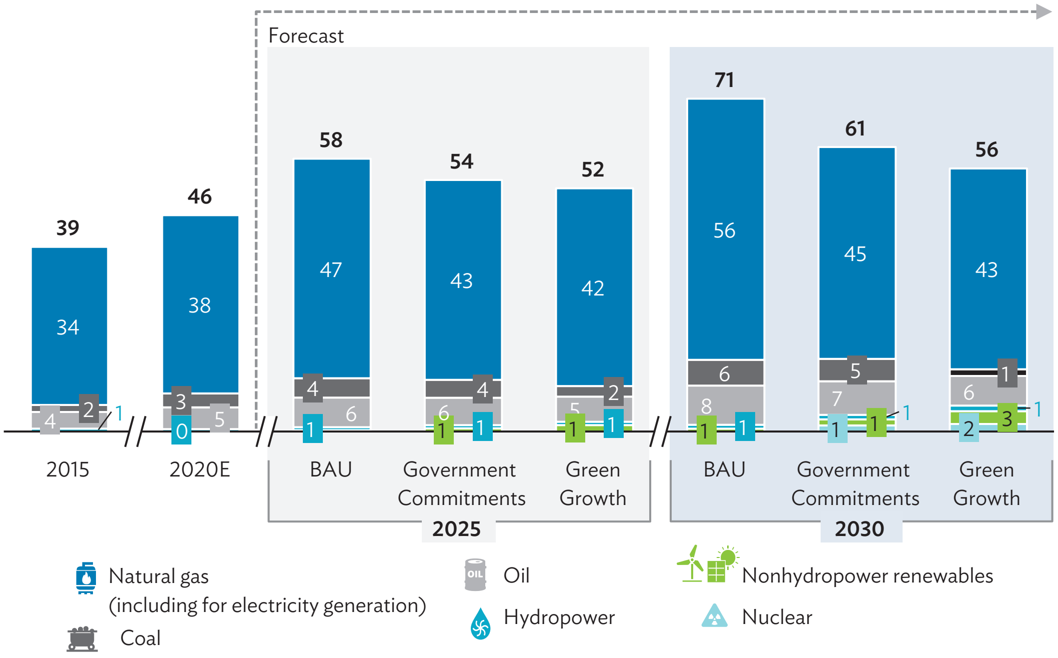
The COVID-19 pandemic had a relatively manageable impact on Uzbekistan's economy. Compared to the prepandemic growth level of real GDP of 6% in 2019, Uzbekistan's GDP stayed nearly the same in 2020. While energy demand decreased slightly from 2019 to 2020, a strong rebound is likely during the coming years, which will lead to an overall increase in energy consumption even in the short-term future.

Depending on the scenario, primary energy supply is projected to reach between 56 million toe and 71 million toe by 2030 compared to 46 million toe in 2020. In the most ambitious scenario (Green Growth scenario, which assumes a maximum of energy efficiency measures will be applied), the growth of supply can be constrained to 2.1% annually until 2030. In the Government Commitments scenario, supply is expected to grow at a slightly higher rate of 2.8% annually (2020–2030), resulting in a primary energy supply of almost 61 million toe. In contrast, energy supply will spike in 2030 in the Business-as-usual (BAU) scenario, which projects an annual supply growth rate of 4.2%, given the limited extent of energy efficiency measures applied.

Uzbekistan's energy supply is projected to remain highly reliant on natural gas. Across all scenarios, it is projected to maintain a 74%–78% share of total energy supply, reflecting its dominance in the electricity generation mix as well as the large direct consumption of natural gas in the residential and industrial sectors. Renewable and nuclear sources of energy are gradually introduced as replacements for fossil fuels, with a combined share that will increase from nearly 1% in 2020 to 2%–10% in 2030, depending on the scenario (Figure 101). This range is mostly determined by the type of investments made. If the country will build nuclear power stations and expand nonhydropower and hydropower renewable projects, the level of investment will be considerably higher as compared to a BAU situation.

Figure 101: Uzbekistan—Primary Energy Supply Forecast

(million tons of oil equivalent)



BAU = Business-as-usual, E = estimate.

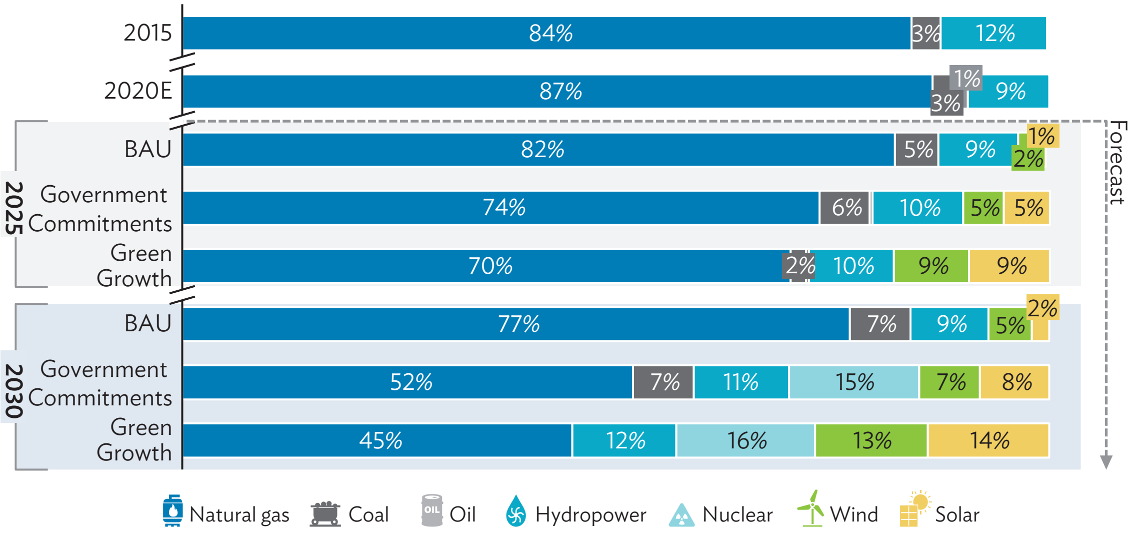
Source of historical data: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 23 August 2021). The forecasts are based on the Roland Berger methodology described in the Methodology section.

Despite Uzbekistan's expected continued reliance on natural gas to generate power, the electricity mix is projected to see significant changes by 2030. First of all, the share of wind is projected to grow rapidly (up to 7%), as well as solar energy (8%), according to the Government Commitments scenario. The BAU scenario foresees a slightly lower share of 7% combined wind and solar, while the Green Growth scenario projects 27% combined, reflecting the large potential of Uzbekistan's renewable sources (Figure 102).

An important development relates to coal-fired power, which currently has a share of only 3%. However, the Government Commitments scenario foresees the development of new coal power plants, leading to a 7% share of coal in the power generation mix by 2030. In contrast, the Green Growth scenario foresees the elimination of coal-fired power generation by 2030 because of its severe environmental impacts.

Uzbekistan has also signaled its intention to add nuclear energy to the power generation mix and has made some progress toward the development of a 2.4 GW nuclear power plant, in cooperation with RosAtom. Government plans suggest 2028 as the expected commissioning year of the nuclear power plant, which can effectively occupy 15%–16% of Uzbekistan's power generation mix. While the Green Growth scenario includes the commission of a nuclear power plant, considering its zero-carbon impact, the BAU scenario does not foresee the development of the nuclear power plant, given that Uzbekistan still needs to overcome significant technological and regulatory challenges before its commission.

Figure 102: Uzbekistan—Power Generation Mix



BAU = Business-as-usual, E = estimate.

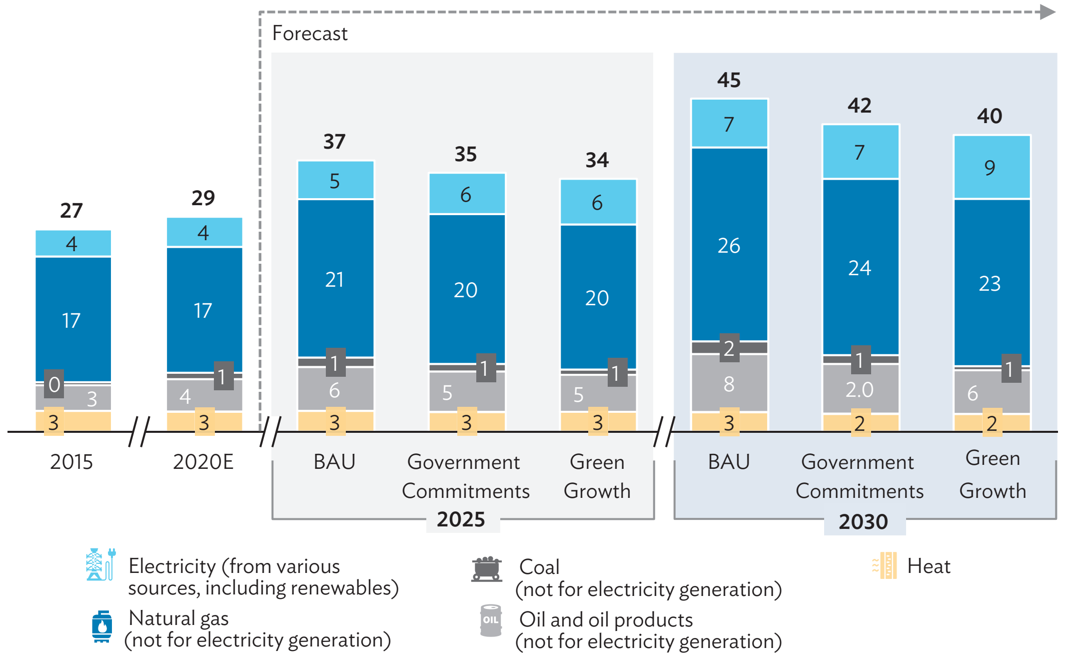
Source of historical data: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 23 August 2021). The forecasts are based on the Roland Berger methodology described in the Methodology section.

These new power generation sources will be developed partly in response to growing electricity demand and in part as a replacement for old and inefficient natural gas power plants, many of which are projected to be decommissioned during this decade. As a result, the overall share of natural gas in the power mix is projected to decline from 87% in 2020 to up to 45% in the most optimistic (Green Growth) scenario.

Final energy demand is expected to increase by approximately 40%, on average, from 29 million toe in 2020 to 40–45 million toe in 2030. The implementation of energy efficiency measures will determine the ultimate level by which demand growth can be constrained within the given margins. Electricity is one of the most rapidly growing sources of consumption until 2030. Moreover, consumption of natural gas, oil, and oil products will grow in every scenario because of the increasing energy demand in the transport, residential, and industrial sectors. In the BAU and Government Commitments scenarios, coal consumption also continues to grow, assuming that efforts to limit its consumption could prove difficult given the significant overall increase in demand. Only in the Green Growth scenario does consumption of coal decline, which is replaced mostly by natural gas for industrial consumption due to the positive environmental effects (Figure 103).

Figure 103: Uzbekistan—Final Energy Demand Forecast by Fuel

(million tons of oil equivalent)



BAU = Business-as-usual, E = estimate.

Source of historical data: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 23 August 2021). The forecasts are based on the Roland Berger methodology described in the Methodology section.

In terms of final energy demand in specific sectors, transport and industry are expected to be the two most rapidly growing sectors in Uzbekistan, given the baseline structure of energy consumption and the fact that GDP growth has the largest impact on these two sectors. In particular, energy demand in the transport sector is expected to grow at a compound annual growth rate of 5%–7% by 2030, and at an annual rate of 4%–5% in the industry sector, depending on the scenario. The residential sector also benefits from expected energy efficiency measures, leading to a relatively slow growth of 1%–3% annually, depending on the scenario (Figure 104).

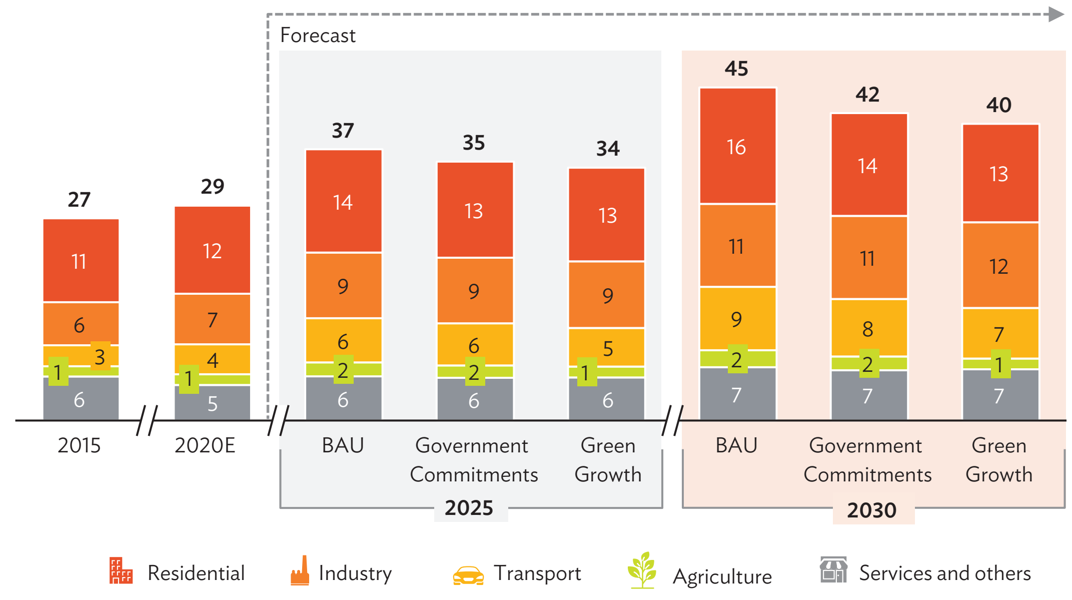
Technology Outlook

Priority Technologies: Generation

The selection of priority technologies in power generation was made considering the ample potential of renewable energy in Uzbekistan, specifically solar PV and wind. At the same time, the country should continue ensuring security of supply through readily available and reliable sources. Given its significant installed capacity, high domestic production levels, and moderate environmental impact, natural gas is highly suitable for providing the majority of supply.

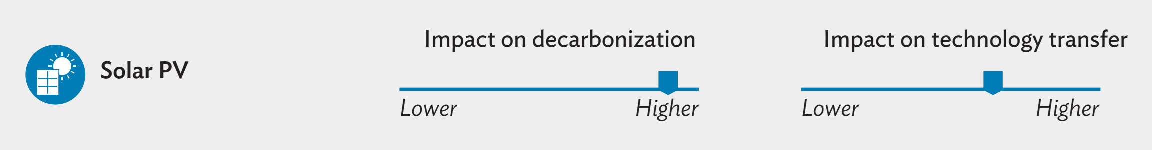
Figure 104: Uzbekistan—Final Energy Demand Forecast by Sector

(million tons of oil equivalent)

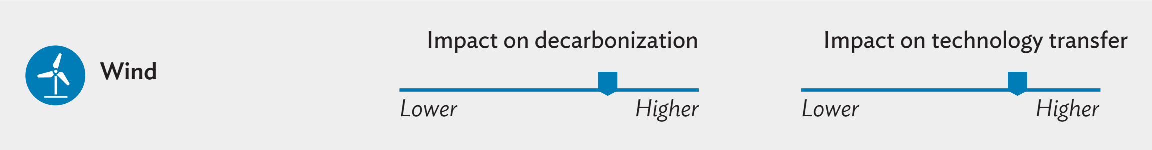


BAU = Business-as-usual, E = estimate.

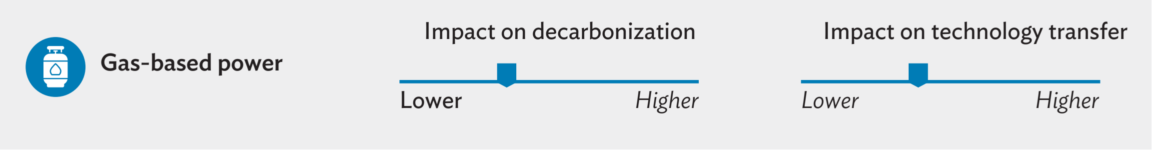
Source of historical data: International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (accessed 23 August 2021). The forecasts are based on the Roland Berger methodology described in the Methodology section.



Uzbekistan’s geographic position creates exceptional conditions for solar energy development. Much of the country has a daily cumulative solar radiation rate of 5–6 kWh/m^2. The resulting technical potential of solar energy is nearly 590 GW. The overall economic potential of solar energy is reinforced in light of the significant gas losses along the gas value chain. Therefore, besides addressing leakages in the gas system, the diversification of the energy system including solar PV can play an important role in achieving cost-effective, long-term sustainable energy security. Both the government and private investors have already identified the development of a utility-scale solar plant as a high-potential business opportunity. In addition to the diversification of the power mix, the country can also benefit from low price of solar PV electricity (Uzbekistan broke a regional record in May 2021 when Masdar won a solar PV tender, with a bidding price of $18 per megawatt-hour). A pipeline of already announced solar projects reached 1.3 GW as of 2021, after the government intensified efforts to reach its 2030 goal of 5 GW of installed solar energy. Uzbekistan commissioned its first utility-scale solar plant in 2021 (ReGlobal 2021). As renowned private investors with exceptional know-how in solar energy (e.g., Masdar, ACWA Power, Total Eren, etc.) participate in the tenders, Uzbekistan will also benefit from a significant technology transfer.



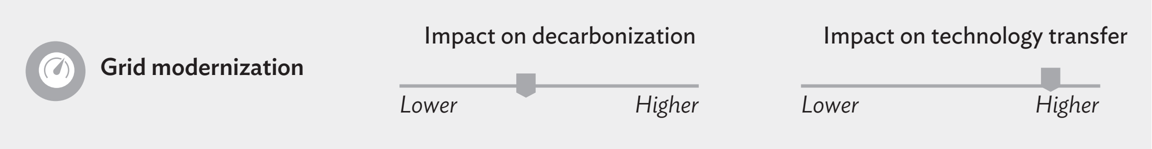
Wind energy also has high potential in Uzbekistan, despite significantly lower technical potential compared to solar at 2–3 GW. Importantly, the country has several geographic “pockets” of optimal wind speed (around 6 meters per second at 80 meters above the ground), suitably located in various parts of the country, such as in the western (Republic of Karakalpakstan); central (Navoi, Samarkand, Jizzakh regions); and eastern part (Tashkent region). Wind power farms are also under active development, with two large-scale projects already announced with a combined capacity of 1.5 GW (The Tashkent Times 2021). These important projects involve companies with ample experience in renewable energy. By 2030, the government plans to have 3 GW of wind power generation capacity installed. These projects will have a positive impact on technology transfer, and on the decarbonization of the energy sector. Careful placement of additional wind power farms near demand centers is likely to be crucial for minimizing intermittency-related grid disruptions amid growing demand.



Uzbekistan already has a legacy infrastructure of natural gas-fired power plants, which generate nearly 90% of the country’s electricity. However, the majority of these plants were constructed during Soviet times and use obsolete and inefficient technologies. Thus, modernizing existing plants and constructing new, high-efficiency plants will help to reduce the country's carbon footprint while satisfying the bulk of its electricity demands, using its vast domestic natural gas resources as feedstock. Gas-fired power plants will help to ensure security of supply amid the growing share of renewables and rapidly rising electricity demands. Furthermore, new power plants also have low "stranded assets" risks, as hydrogen might be used in the future as a feedstock to improve environmental performance once this technology matures and its infrastructure is established. In addition to incremental decarbonization, new gas-based power installations will have a positive impact on the transfer of potentially strategic technologies in Uzbekistan, given the high availability of natural gas.

Priority Technologies: Transmission and Distribution

Most of Uzbekistan's grid infrastructure is in poor technical condition and suffers from significant grid losses. The modernization of power and gas grids will require significant investments. The modernization effort should consider implementing a long-term energy transition to "blue" and "green" hydrogen infrastructure to become a regional leader in decarbonization.


Grid modernization

Transmission infrastructure has long been considered a weak point in Uzbekistan's energy sector. Both electricity and gas grids are outdated and suffer from inadequate maintenance and prolonged underinvestment. According to official statistics, combined power T&D losses amounted to 18% in recent years, while natural gas grid losses reached around 6%. Various estimates suggest that losses are likely to be even higher, particularly in the gas grid. Such high levels of losses have severe environmental impacts, especially in the case of leaking natural gas grids that result in methane emissions. Methane is a highly potent GHG that is 28–34 times more potent than carbon dioxide (CO_2) leaking into the atmosphere. In addition to the environmental threats, the poor grid infrastructure threatens the security of Uzbekistan's energy supply and is a primary cause of power and gas outages during the peak demand season in winter. Thus, grid infrastructure in Uzbekistan is in dire need of modernization and effective maintenance techniques. Further installation of remote monitoring and control systems (e.g., supervisory control and data acquisition system) and the roll-out of smart metering could also be important steps in infrastructure development and could help create greater transparency and prevent unauthorized grid access.


"Blue" hydrogen

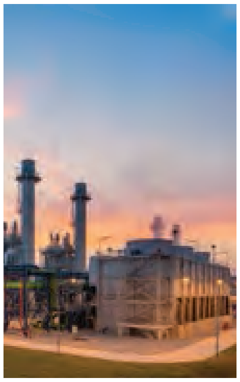
Hydrogen is widely recognized as a key pathway to the decarbonization of the energy sector. It can be created in a sustainable way through two distinct processes, either by using fossil fuels with carbon capture and storage (CCS) to produce "blue" hydrogen, or by using electrolysis with renewable energy sources to produce "green" hydrogen. Although neither of these hydrogen types are cost competitive, both show strong potential for declining costs.

Uzbekistan is in a perfect starting position for the development of blue hydrogen because of the domestic availability of natural gas and the country's potential hydrogen demand centers (e.g., gas-fired power or industrial plants). Uzbekistan also benefits from already having existing natural gas infrastructure in place, which can be used for hydrogen transportation to local demand centers as well as for exports. Using these advantages can help Uzbekistan to prepare for a future energy transition, in which demand for hydrogen will be significantly higher than demand for natural gas.

Recognizing hydrogen's potential, the government has already made initial steps toward supporting the hydrogen industry. In 2021, a Presidential Decree mandated the establishment of a hydrogen energy research center (Rödl and Partner 2021).

The advancement of blue hydrogen will also motivate a tremendous technology transfer to Uzbekistan, including that of CCS. Uzbekistan has already demonstrated its readiness to implement large-scale projects using breakthrough technologies in cooperation with the private sector, as proven by Uzbekistan's Gas-to-Liquids plant (GTL) (Box 25).

Box 25: Uzbekistan's Flagship Energy Project



Uzbekistan's gas-to-liquids (GTL) plant is only the fifth plant in the world utilizing GTL technology, and one of the largest energy infrastructure projects in the country. With a total cost of $3.6 billion, GTL plant will process nearly 3.6 billion cubic meters of gas annually, and produce 1.5 million tons of synthetic fuel, including diesel and jet fuel. The project is developed by state-owned Uzbekneftegaz, but unites a large number of international technological and engineering companies (Sasol, Hyundai, etc.), as well as a broad alliance of international lenders. The project's objective is to enhance the security of supply by reducing imports of oil products. GTL plant was officially opened in December 2021.

Note: Illustrative photo of a gas-to-liquids plant is by Bannafarsai/Adobe Stock©.

Sources: Fitch Solutions. 2020. *Uzbekistan Oil & Gas Report.* London; and Uzbekistan GTL.

Priority Technologies: Consumption

Uzbekistan has a poor track record in energy efficiency across all consumption sectors. Yet, recent governmental documents emphasize the need to prioritize the improvement of the industrial and residential sectors in this regard, reflecting the high potential for energy savings in these sectors.

Uzbekistan remains one of the least energy-efficient countries in the world, due in part to its outdated infrastructure and low energy prices. In these circumstances, industrial energy efficiency investments have a long payback period and are not commercially viable in many cases. Therefore, the government has consistently set targets to improve energy efficiency, e.g., the Green Economy Strategy has set a target of raising industrial energy efficiency by at least 20% by 2030. Several recently issued Presidential Decrees aim to implement this objective, including Degree PP-4779, which set energy audit requirements for almost 300 industrial enterprises. The development of energy services, including audits, might prove crucial for identifying key technological gaps across industrial sectors and for addressing them in a structured manner.

Another high-potential area is energy consumption in the residential and commercial sectors. Various estimates suggest that between 300 kWh and 400 KWh of energy is used for heating a square meter in Uzbekistan, compared to 170–200 kWh in developed countries. The government has already prioritized this area and initiated a program to support energy efficiency measures by individuals. Specifically, the governmental program covers 30% of expenses related to the installation of decentralized solar PV or energy-efficient thermal systems (e.g., individual gas heating units), energy-efficient gas-heating devices, as well as other kinds of energy-efficient equipment. Still, further efforts are required to renovate old buildings using modern construction materials with adequate energy performance characteristics. Most district heating systems, specifically generators and distribution systems, are also in poor technical condition, having been in operation for more than 50 years (well beyond useful life), and require significant investments to improve efficiency.

Carbon Emissions Outlook

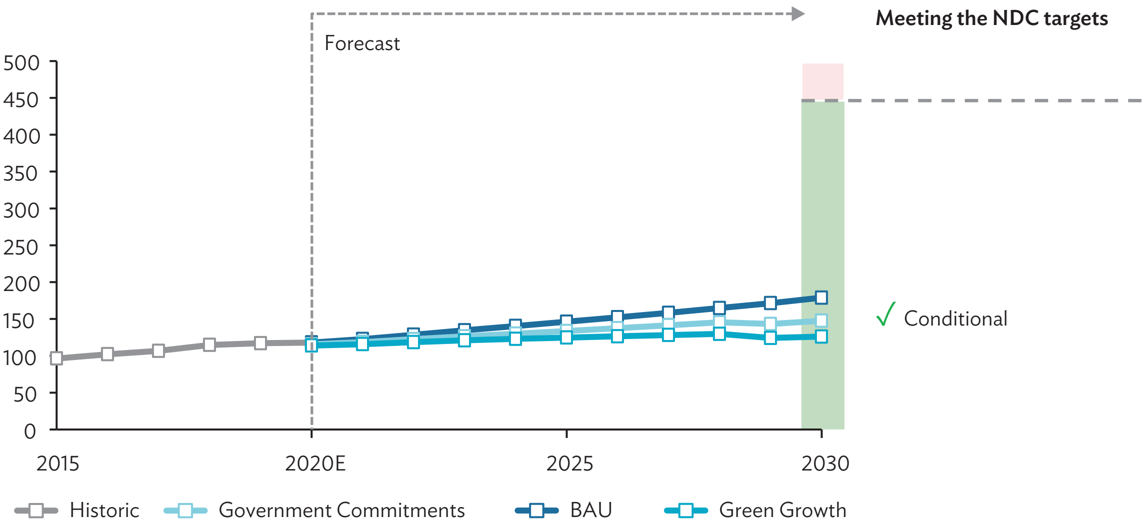
Uzbekistan has proven its commitment to respond to climate change by submitting its first nationally determined contribution (NDC) in 2017 and updated NDC in 2021. However, the country has set only a conditional target, meaning that achieving its objective depends on support from international organizations, access to low-carbon technologies, and climate financing. In accordance with the country's first NDC, the conditional target aims to decrease GHG emissions per unit of GDP by 10% by 2030 compared to 2010. In accordance with the country's updated NDC, Uzbekistan aims to reduce GHG emissions per unit of GDP by 35% by 2030 compared to 2010 (UNFCCC 2021). Given that Uzbekistan's economy is expected to more than triple in size during this period, the NDC target does not prevent the corresponding threefold increase of GHG emissions in the country by 2030.

Furthermore, Uzbekistan's NDC does not provide sector-specific targets; thus, it is assumed that carbon intensity reductions would be equal across all sectors of the economy. Historically, energy-related emissions in Uzbekistan have reached nearly 80% of the country's total GHG emissions. Assuming a comparable share in the future, the NDC's target translates to nearly 490 million tons of CO_2 equivalent energy-related emissions in 2030, compared to around 115 million tons in 2018 (Figure 105).

Uzbekistan will achieve its conditional target under all scenarios. However, given the structure of the target—which does not impose specific measures for the energy sector, the major source of carbon emissions in Uzbekistan—there is room for more ambitious carbon reduction achievements compared to the targets set in the NDC. Total energy-related GHG emissions are expected to range 125–180 million tons of CO_2 equivalent in 2030, depending on the scenario. Emissions are the lowest in the Green Growth scenario, reflecting higher efficiency gains due to larger investments and a rapid shift toward clean energy sources.

Figure 105: Uzbekistan—Energy-Related Carbon Emissions

(million tons of carbon dioxide equivalent)



BAU = Business-as-usual, E = estimate, NDC = Nationally Determined Contribution.

Note: Historical data on carbon emissions is modelled by Roland Berger based on historical data on energy use. The forecasts are based on the Roland Berger methodology described in the Methodology section.

Sources: Roland Berger; and United Nations Framework Convention on Climate Change. Nationally Determined Contributions Registry. https://unfccc.int/NDCREG.

Investment Outlook

Investment Needs

The three scenarios evaluate different levels of energy investment needs until 2030, with an estimated range of $17 billion–$36 billion. Significant investments are required across the power generation, T&D, and energy efficiency sectors,[17] considering the large market size and urgent need for modernization. The largest investments are needed for the development of the nuclear power plant (around $9 billion–$10 billion), in the Government Commitments and Green Growth scenarios. Natural gas power generation projects also require significant investments, ranging between $4.3 billion and $6.0 billion, depending on the scenario. Investment needs for renewable energy sources are expected to reach $3.5 billion in the BAU scenario, $6.2 billion in the Government Commitments scenario, and $8.4 billion in the Green Growth scenario, illustrating both the large potential and the ambitious targets of renewable energy development.

Assessing investment needs in terms of categories, those related to generation are expected to be the largest across all scenarios, accounting for 60%–70% (or $10 billion–$23 billion) of total investment needs, depending on the scenario. Energy efficiency measures will also require significant investments amounting to $3.9 billion in the BAU scenario, $6.0 billion in the Government Commitments scenario, and $8.2 billion in the Green Growth scenario. Finally, energy T&D infrastructure (electricity and gas network modernization and expansion, installation of metering equipment and remote monitoring systems, etc.) is assumed to require a further $2.7 billion–$4.4 billion (Figure 106).

Challenges and Opportunities

Despite the substantial progress in market liberalization reforms that Uzbekistan has made in recent years, much is left to be completed. The unbundling of vertically integrated Uzbekenergo and Uzbekneftegaz is a strong signal to investors that the government intends to level the playing field for public and private companies. Yet, the regulatory framework still needs to be updated to allow private players to operate as electricity and natural gas suppliers or DSOs. The creation of wholesale and retail electricity and natural gas markets is an important milestone, but significant efforts will be required to minimize switching costs for consumers and to ensure fair competition.

Another key challenge is represented by the energy subsidies. Tariffs set below cost-recovery level create significant risks for private investors, as they have to rely on the government for adequate profitability. Furthermore, cheap energy sources lead to wasteful natural resource usage and disincentivize the implementation of energy efficiency measures. Moreover, energy subsidies are a huge fiscal burden for the government and prevent more efficient allocations of the state budget. According to the International Energy Agency (IEA), Uzbekistan's energy subsidies totaled more than $4 billion in 2019, with natural gas subsidies accounting for nearly 60% and electricity subsidies for more than 30%. The inefficient tariff level structure spotlights another challenge to Uzbekistan's energy sector marked by an imperfect institutional framework. The creation of the Ministry of Energy in 2019 marked a positive development; however, its dual functioning in policy making and regulation contradicts commonly considered best practices.

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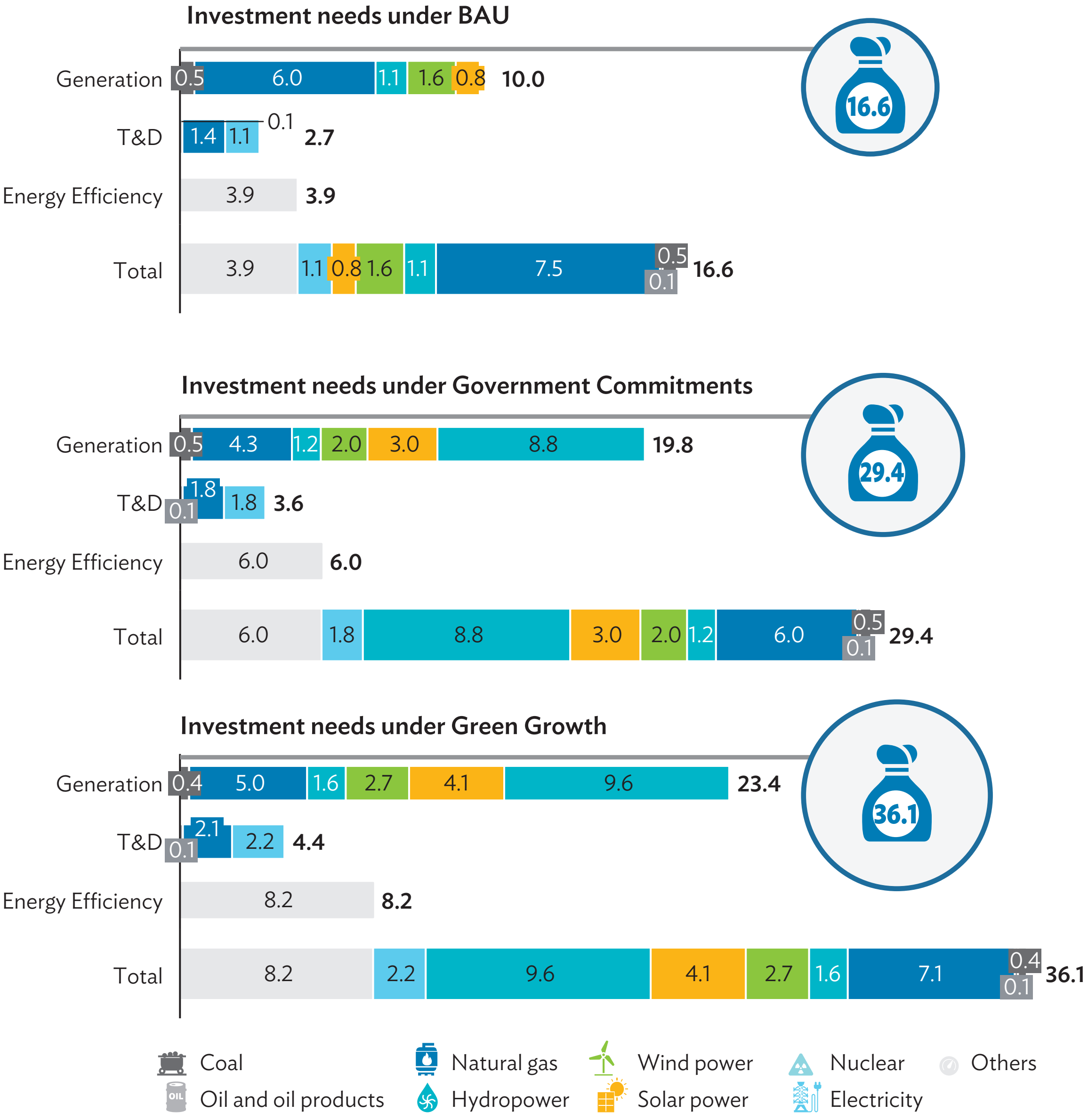
[17] Investment needs assessment excludes fossil fuel production sector because of the focus on low-carbon energy technologies.

Figure 106: Energy Infrastructure Investment Needs in Uzbekistan until 2030

($ billion)



BAU = Business-as-usual, T&D = transmission and distribution.

Source: The forecasts are based on the Roland Berger/ILF methodology described in the Methodology section.

The insufficient level of tariffs is also a primary reason for the financial difficulties experienced by the main energy sector players. In the context of subsidized operation, financial resources are lacking not only for investments in new infrastructure but also for adequate maintenance of the existing infrastructure. Given the restrictive regulations for private sector participation and the low creditworthiness of state-owned companies, the majority of investments has to be financed from the state budget. Over the decades, this has resulted in a degradation of the technical condition of the upstream and midstream energy infrastructure. This is highlighted by large losses during the production and transportation of energy sources, as well as extremely low efficiency in consumption. These factors have contributed to the low quality and reliability of supply, especially during winter, the peak demand season when consumers face frequent outages, presenting a significant setback for the economic and social well-being of the country.

Uzbekistan has taken an innovative approach to the development of renewable energy capacities by cooperating with IFIs to hold capacity auctions for large-scale projects. Important advantages of this approach include low electricity costs resulting from competition between bidders, as well as an acceleration of project development. However, an important drawback of this approach is that only large-scale renewable energy projects are developed, as the government does not currently show any interest in small- and mid-scale wind and solar plant auctions. This effectively limits the number of investors who enter the market to big players with adequate resources for projects with several hundred MW of installed capacity.

At the same time, the situation with renewable energy projects highlights Uzbekistan's large potential for private investments. With abundant solar as well as wind potential, and the government's prioritization of diversifying and decarbonizing the energy mix, an impressive pipeline of projects is expected to grow. The tender mechanism that has been developed in cooperation with IFIs is well regarded because of its relative simplicity, transparency, and speed of decision making. A good illustration is the fact that more than 50 companies showed interest and were prequalified to participate in a solar PV tender in March 2021. This demonstrable effect has been reinforced with the rapid implementation of tendered projects, the first of which is expected to come into operation by the end of 2021. This development is a positive signal to all private investors, and significantly decreases perceived risks of investing in the country.

Another encouraging development in Uzbekistan's energy sector is its progress toward market liberalization. Completing the unbundling of Uzbekneftegaz and Uzbekenergo is an important first step. It is expected that in the coming years, wholesale and retail electricity and gas markets will operate freely, enabling consumers to select their preferred suppliers. Moreover, the government has declared a privatization plan that includes energy infrastructure assets, such as the Ferghana oil refinery. While the government is unlikely to privatize key infrastructure (e.g., its transmission system) because of security of supply concerns, another potential area of private sector participation is credit markets. State-owned companies have been undergoing corporate governance reforms, aiming to reach international practices of corporate management. This includes the transition to international accounting standards, the involvement of international experts in the board of directors, and the establishment of fiscal and governmental transparency. The ultimate goal of the corporate transformation is to receive an international credit rating, which will open opportunities for receiving financing from the capital market.

Uzbekistan is also well positioned to reap the benefits of the forthcoming energy transition, since the country has an excellent foundation for the development of clean hydrogen. Green hydrogen, obtained using renewable energy, has strong potential based on the large availability of wind and solar energy in Uzbekistan. However, commercial applications of green hydrogen technology remain relatively distant, especially when compared to blue hydrogen. The large production and availability of natural gas in Uzbekistan makes blue hydrogen significantly more feasible. Moreover, existing natural gas infrastructure might be used to transport hydrogen, including for exports. Considering the decarbonization pressure that all governments currently face, Uzbekistan might be able to transition from being an exporter of natural gas to an exporter of clean hydrogen, thereby maintaining the economic and social benefits of energy exports. As hydrogen value chains are emerging across the world, Uzbekistan can potentially become an attractive location for private investors interested in hydrogen technologies.

In terms of export opportunities, Uzbekistan will continue to be a regional hub for natural gas and power trade because of its geographic position and existing cross-border infrastructure. Specifically, Uzbekistan is an integral part of the CAPS, established in the 1970s, that continues to be highly relevant in the context of complementary natural resources and electricity mixes among countries in the region. Natural gas infrastructure is also extensive as Uzbekistan is a major exporting and transit country. Total cross-border capacity of natural gas pipelines in Uzbekistan reached nearly 150 bcma in direction, connecting the country to neighboring Russian Federation, PRC, Kazakhstan, the Kyrgyz Republic, and Tajikistan.

In addition to its export opportunities, Uzbekistan also has a significant domestic market. Uzbekistan's population stands at 34 million people—the highest among Central Asian countries—and is projected to grow to more than 37 million by 2030. Furthermore, considering its rapid economic growth and growing income levels, investment opportunities in the domestic market should not be overlooked.

Policy Recommendations

Recent reforms have set a solid basis for increasing the role of the private sector in Uzbekistan's energy systems. Yet, several persistent challenges can be addressed via the following recommended policy actions:

(i) **Establishing an independent regulator.** Institutional reform of the energy sector will be completed when regulatory functions will be reassigned from the Ministry of Energy to a separate institution. This will assure potential investors that their rights will be safeguarded to the same extent as those of state-owned companies.

(ii) **Setting energy tariffs at market level to ensure cost recovery by energy companies.** Eliminating energy subsidies is an essential step toward infrastructure improvements in the energy sector. However, adequate social safeguard policies should be adopted to ensure access to energy for vulnerable groups. In the short-to-medium run, phasing-out energy subsidies will result in higher energy bills for consumers; hence, the government should also introduce targeted social protection measures for vulnerable and low-income households.

(iii) **Establishing a proper infrastructure modernization program.** While corporate governance and cost-recovery level tariffs can help to free up required investments for infrastructure modernization, especially transmission assets, the government should play a leading role in establishing transparency over critical points in infrastructure where leakages take place and in addressing them via comprehensive action plans.

(iv) **Continuing to liberalize the energy markets.** After unbundling, the next steps for Uzbekistan's government is to establish free markets for the wholesale and retail supply of power and natural gas. Moreover, the market rules should allow equal access to all players irrespective of ownership to allow for effective competition among suppliers.

(v) **Enhancing transparency over the government's long-term priorities by issuing a comprehensive energy strategy.** Since energy sector investments typically involve large capital expenditures and long payback periods, private investors require a clear understanding of the long-term policy priorities. A suitable way to ensure required transparency is to prepare an overarching energy strategy, which brings together all existing subsector strategies and action plans reinforcing them.

(vi) **Considering the introduction of carbon pricing mechanisms.** The introduction of carbon pricing aims to increase efficiency in the consumption of fossil fuels, a highly relevant initiative for Uzbekistan, considering its low efficiency. The emission trading scheme (ETS) is likely to be a more suitable pathway than carbon tax, considering the role of natural gas in Uzbekistan's economy. As in Kazakhstan, the ETS could introduce a progressive emission cap for each large emitter of GHGs. Entities that underinvest in energy efficiency would have to purchase emission credits from energy-efficient companies, or else face fines.

(vii) **Exploring possibilities for the development of "blue" hydrogen.** To realize Uzbekistan's "blue" hydrogen potential, the government should ensure suitable conditions for potential investors. First steps could include creating a blue hydrogen strategy, funding feasibility studies, and supporting first demonstration projects.

(viii) **Considering disincentivizing the use of coal.** According to government plans, the use of coal in Uzbekistan will continue growing in the mid-term future, in contrast to international practices of coal phase-outs, because of its severe environmental impacts. Following the modernization of natural gas infrastructure and the high quality of its supply, the government should consider steps to disincentivize the use of coal to promote the low-carbon development of the energy sector.

(ix) **Continuing facilitating efficiency in the heating sector.** The government has already initiated a program supporting energy efficiency measures for individuals by covering 30% of expenses related to energy-efficient thermal systems (e.g., individual gas heating units), energy-efficient gas-heating devices, decentralized solar PV, etc. However, further actions, such as decentralization of heating systems and renovation of old buildings using modern construction materials with adequate energy performance characteristics are recommended to improve efficiency and reduce heat losses.

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Bibi-Khanym Mosque in Samarkand. The mosque is one of the most famous monuments of Uzbekistan, located in Samarkand, the third most populous city in Uzbekistan (photo by bizoo_n/Adobe Stock©).

CAREC Energy Outlook 2030

This report analyzes future energy market options for Central Asia Regional Economic Cooperation (CAREC) program members. It aims to facilitate strategic decisions and sustainable investments in energy infrastructure by equipping investors and policy makers with crucial insights on regional trends. It can help identify potential investment opportunities that will improve energy services and reduce carbon emissions across CAREC countries. The report provides forecasts at both individual country and regional levels. It includes energy supply and demand scenarios, assessments of innovative technologies, estimates of investment needs in the energy sector, and possible trajectories for carbon emissions.

About the Central Asia Regional Economic Cooperation Program

The Central Asia Regional Economic Cooperation (CAREC) Program is a partnership of 11 member countries and development partners working together to promote development through cooperation, leading to accelerated economic growth and poverty reduction. It is guided by the overarching vision of "Good Neighbors, Good Partners, and Good Prospects." CAREC countries include Afghanistan, Azerbaijan, the People's Republic of China, Georgia, Kazakhstan, the Kyrgyz Republic, Mongolia, Pakistan, Tajikistan, Turkmenistan, and Uzbekistan.

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