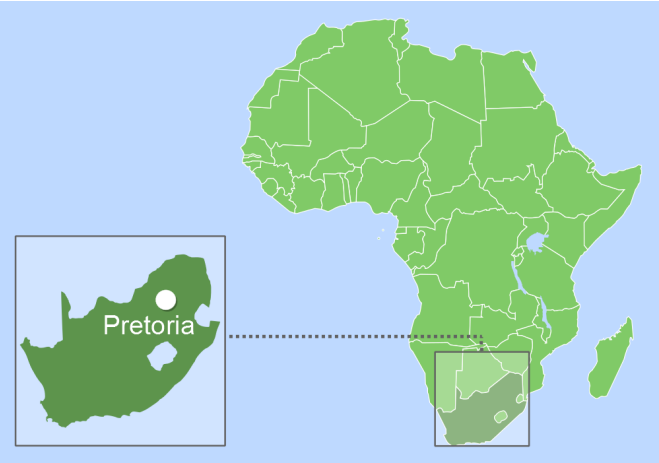
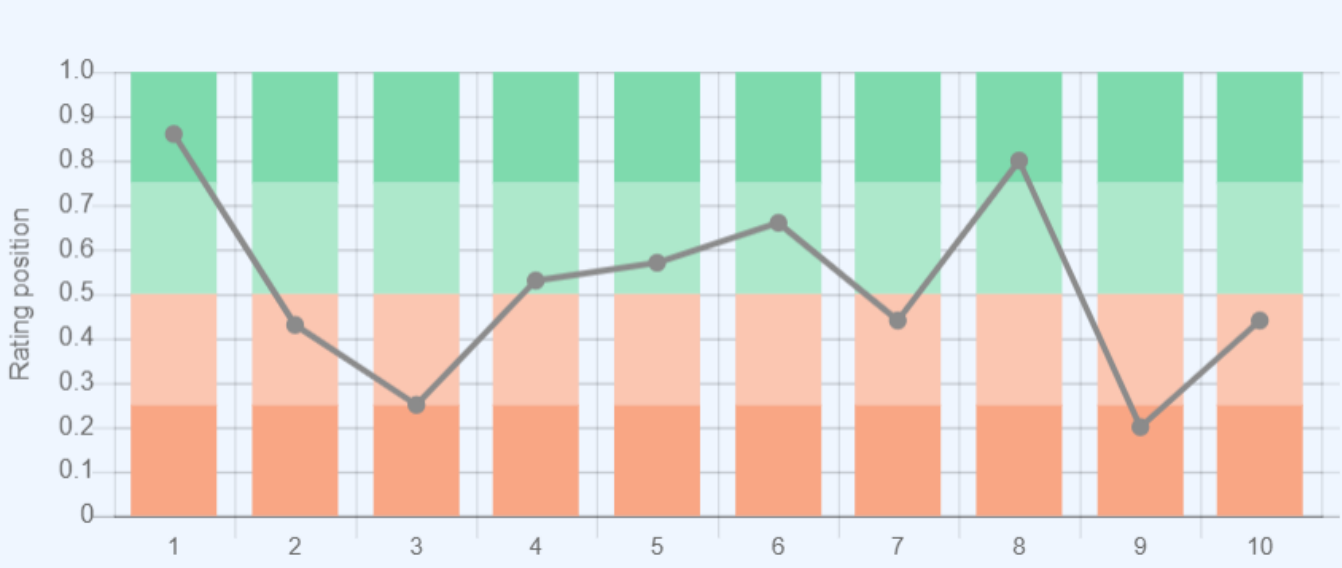


Energy Industry in **South Africa**

General State of the Economy

The Republic of South Africa (RSA), short form – South Africa, is located in the south of the continent and borders Namibia, Botswana and Zimbabwe (to the north), and Mozambique and Swaziland (in the northeast). In addition, South Africa surrounds the territory of the state of Lesotho.

According to 2018 statistics, South Africa, which is 26th in terms of the size of the territory, is home to more than 56 million people, and according to the population density the country is 80th in the world out of [1,2,3]. The total length of the country's coastline is 2 798 km [3].



Sources:
1. GDP (purchasing power parity), 2020 est. / The World Factbook/Library/Central Intelligence Agency *228
2. GDP - per capita (PPP), 2020 / The World Factbook/Library/Central Intelligence Agency *229
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4. Charges for the use of intellectual property, receipts (BoP, current US$), 2020 / International Monetary Fund, Balance of Payments Statistics Yearbook, and data files. / License: CC BY-4.0 *88
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7. 2021 Index of Economic Freedom / International Economies / The Heritage Foundation *178
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9. Annual average GDP growth in %, for the last 10 years (2011-2020) / World Bank national accounts data, and OECD National Accounts data files / License: CC BY-4.0 *206
10. Public debt (% of GDP), 2017 est. / The World Factbook / Library / Central Intelligence Agency *210
* Total number of countries participating in ranking

Figure 1. Economic indices of South Africa

The administrative capital of the country is Pretoria. The administrative map of South Africa is divided into 9 provinces; the political form of government is a parliamen-

tary republic. The national languages are English, Afrikaans, Vendian, Zulu, Spit, Southern Ndebele, Swati, Northern Soto, Sesoto, Tswana, Tsonga [3].
South Africa is one of the most economically developed countries of the continent, often competing in some respects with the leading countries of the world, which is reflected in the comparative diagram of various economic indices - Fig.1. The financial, energy and the transport srctors are at the core of the economy [3]. In the majority of cases, the Republic of South Africa is positioned above the world average, in the upper half of the chart (i.e., among the top 50% of the best countries in the world included in the rating).
Since the early 1990s, the country has high volatility in GDP (current $US), both in general and per capita [4]. GDP (current $US) increased from 323.6 billion dollars in 2016 to 404.8 billion dollars in 2018, and 335.4 in 2020 [3]. GDP (current $US) per capita is significantly lower, the current dynamics of this indicator is negative: from $8 811 in 2011 to $5 656 in 2020 [3]. The inflation was 5.2% in 2017 to 4.1% in 2019 (171st in the world) [3]. In terms of the market value of publicly traded shares in 2015 the country was 16th in the world.
According to The Global Competitiveness Report 2019, presented by the World Economic Forum, South Africa is 60th out of an estimated total of 141 countries.
This rating reflects the effectiveness of the use of the country's own resources for sustainable development. In addition to a number of economic indicators this index also takes into account such variables as education, health, level of innovation, etc. In the list of countries that exported high-tech products in 2019 – 2020, the country was 46th out of 134 countries.
According to the Index of Economic Freedom, which is based on freedom of business, freedom from government action, property protection, and freedom from corruption, the country was 99th in 2021, out of 178 countries considered.
In terms of gold reserves and foreign exchange reserves, South Africa was 39th in the world in 2017.
According to the indicator for the average GDP growth in percentage over the last 10 years, in 2021 the country was 165th out of 206 countries. In terms of public debt, calculated as a percentage of the country's GDP, South Africa was ranked 92th out of 210 countries considered in 2017.

*For more information on the South African economy, see the attached link library by clicking **here.***

Energy resources

South Africa does not possess significant reserves of oil and natural gas and relies on their import to meet domestic energy needs, however, for coal reserves the country is included in the top 10 countries with the largest resources (Table 1).
In terms of tons of oil equivalent, in 2016-2018 proved reserves of conventional hydrocarbons in South Africa were: coal - 99.8 %, oil - 0.2% (Fig.5). The unconventional natural resource matrix looks much different: shale gas - 99.6%, oil shale - 0.2%, coal mine methane utilization potential - 0.2% (Fig. 5).
According to the U.S. Energy Information Administration, the country has the world's 10th largest amount of recoverable coal reserves and possesses 75% of Africa's total coal reserve - 35 053 million short tons in 2016 [6]. In BP's report, the total proved coal reserves in the country at the end of 2020 were estimated at 9 893 million tons [7].
According to calculations, made by Advanced Energy Technologies, the methane utilization potential, according to the methodology based on methane emissions

Table 1. Fossil energy resources of South Africa

Resource/explanations	Crude oil	Natural gas	Coal	Shale Gas*	Coal mine methane	Oil Shale
Value	15	0	9 893	389.7	98–247	130
Unit	MMB	Bcm	Mt	Tcf	Bcm	MMB
Year	2018	2018	2018	2013	2017	2008
Source	[3]	[3]	[7]	[10]	[7,8]	[9]

**unproved technically recoverable*

from [8] and coal reserves from [7], amounted to about 98—247 Bcm.
Proved reserves of oil in South Africa in 2018 were estimated at 15 million barrels [3]. Source [9] notes that at the end of 2008, in-place resources of oil shale amounted to almost 130 million barrels, and according to [10] unproved technically recoverable resources of shale gas were 389.7 Tcf (Table 1).
South Africa has a great resource potential in the development of clean energy production. A selection of basic indicators of this type of resource is presented in Table 2.

Table 2. Renewable energy resources of South Africa

Resource/explanations	Solar Potential (GHI)*	Wind Potential (50 м)*	Small hydro energy potential**	Bio Potential Agricultural area	Bio Potential Forest Area	Municipal Solid Waste
Value	5.5-7.0	5.6-6.4	247	79.8	7.6	2
Unit	kWh/m^2/day	m/s	MW	% of land area	% of land area	Kg/per person/day
Year	2018	2018	2015	2016	2016	2018
Source	[11]	[12]	[13]	[15]	[16]	[17]

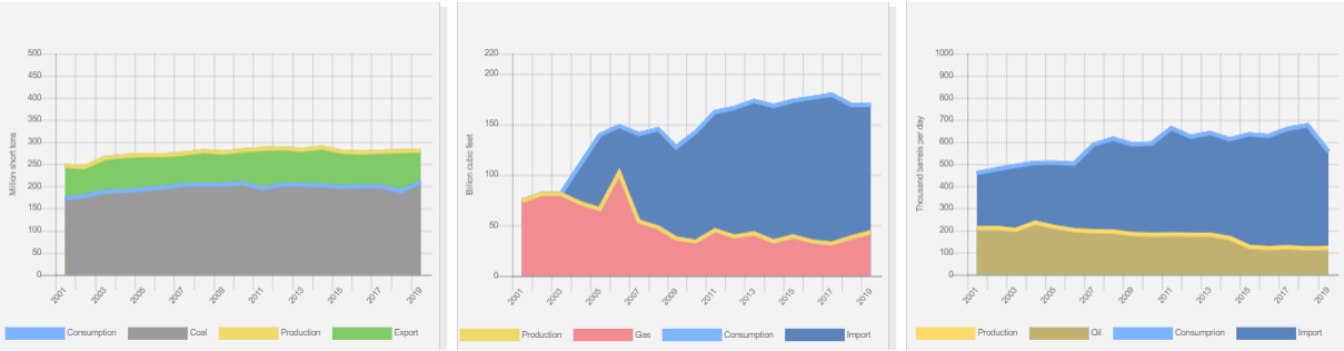
**for most of the territory of the country*

The level of global horizontal radiation in most of the country is 5.5 - 7.0 kWh/m2/day [11]. The highest level of solar radiation can be observed in the west, and in the region of Northern Cape – about 8.0 - 8.5 kWh/m2/day [11]. The distribution of wind resources is as follows: in most of the country the wind speed is 5.6-6.4 m/s [12], while in the south, south-west and south-east of the country wind speeds may exceed 9 m/sec (at a height of 90m). According to "State of Renewable Energy in South Africa 2015", the potential for a new small-scale hydropower development is estimated at 247 MW in Eastern Cape, Free State, KwaZulu-Natal, and Mpumalanga [13]. In the south and south-west of the country there is significant potential for tidal energy that can reach 60 kW / m and more [14]. According to data for 2018, 79.8% of the territory of South Africa is occupied by agricultural land, while the forest area occupies 7.6% [15,16]. The level of generation of municipal waste in South Africa (2 kg per person/day) is slightly lower than the level of highly-developed countries [17]. On one hand, municipal waste is a valuable raw material for recycling or energy production, which is actively used in South Africa, but on the other hand, long-term decomposing substances can significantly pollute the environment .

*A detailed list of sites and special reports on South Africa energy resources can be found **here.***

Energy Balance

According to the BP Statistical Review of World Energy 2021, total primary energy consumption in South Africa in 2018 was 4.9 Exajoules, about 70.8% of which was coal, 20.8% - oil, 3.0% - natural gas, 2.86% - nuclear energy, 2.2% - renewable energy [7].
Oil production between 2001-2021 was declining, and in 2021 it was 112 thousand barrels/day [18]. The volume of oil consumption in the country since 2007 has shown a growth (Fig.2), reaching the level of 555 thousand barrels/day [18]. Crude oil imports in 2017 were 404 000 bbl/day [3].
The production of natural gas in South Africa has been gradually decreasing since 2001 and reached the level of 43 Bcf in 2019 [18]. The consumption of natural gas, at the same time, has been gradually increasing and reached the level of 169 Bcf in 2019 [18].



Source: U.S. Energy Information Administration (Dec 2021) / https://www.eia.gov/

Figure 2. The production and consumption of fossil fuels in South Africa (coal-left, gas—in the center, oil-right)

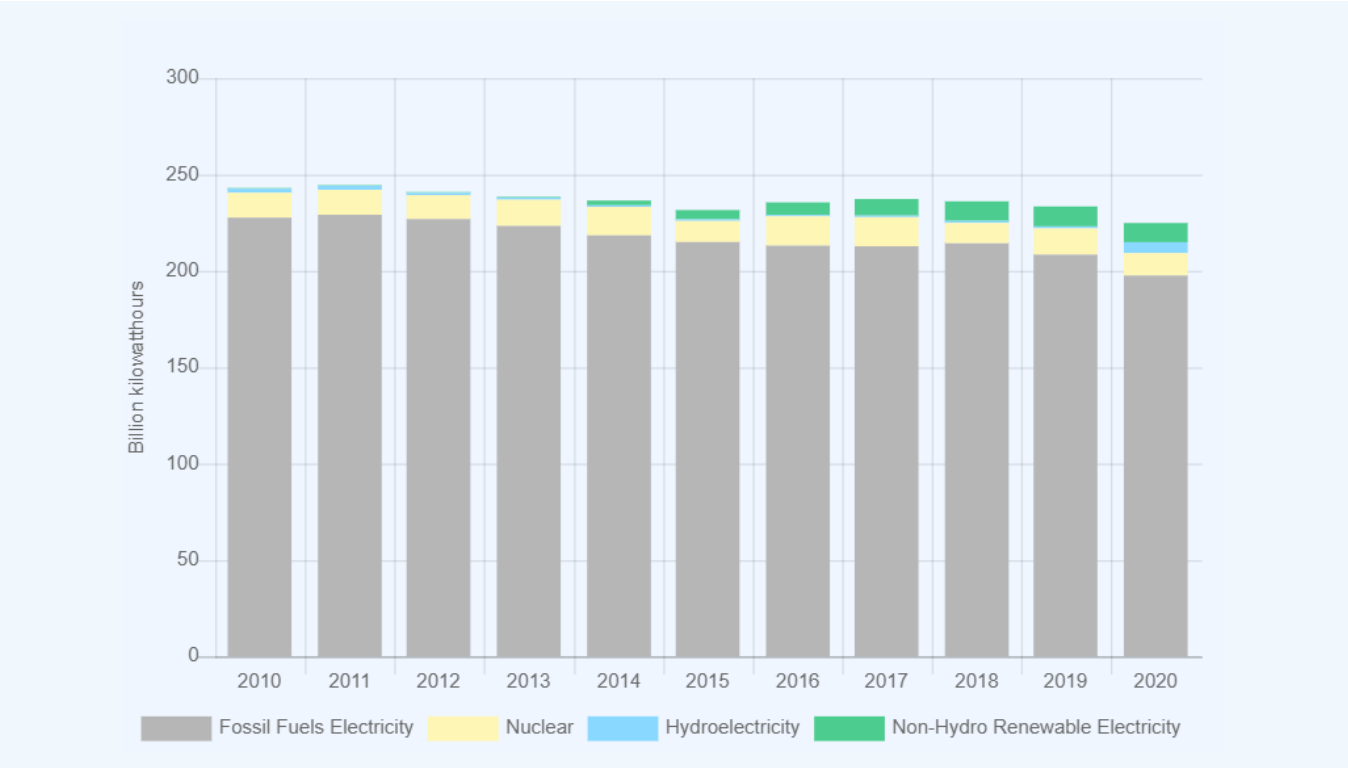
Coal production in the country has remained practically unchanged since 2001, with slight fluctuations, not exceeding 290 million short tons, and in 2020 it was 272 million short tons; coal consumption did not exceed 210 million short tons, and in 2020 it was 185 million short tons [18].

According to BP's report in 2018, coal production amounted to 143.2 million tons of oil equivalent, while consumption was estimated at 86 million tons of oil equivalent [7]. According to the U.S. Energy Information Administration, South Africa was the 5th largest coal exporter in 2017, the majority of the country's coal is being exported to Asia, primarily to India [5].

South Africa mainly relies on fossil fuels for the production of electricity, although the share of renewables has been slowly growing in the last couple of years (Fig. 3.).

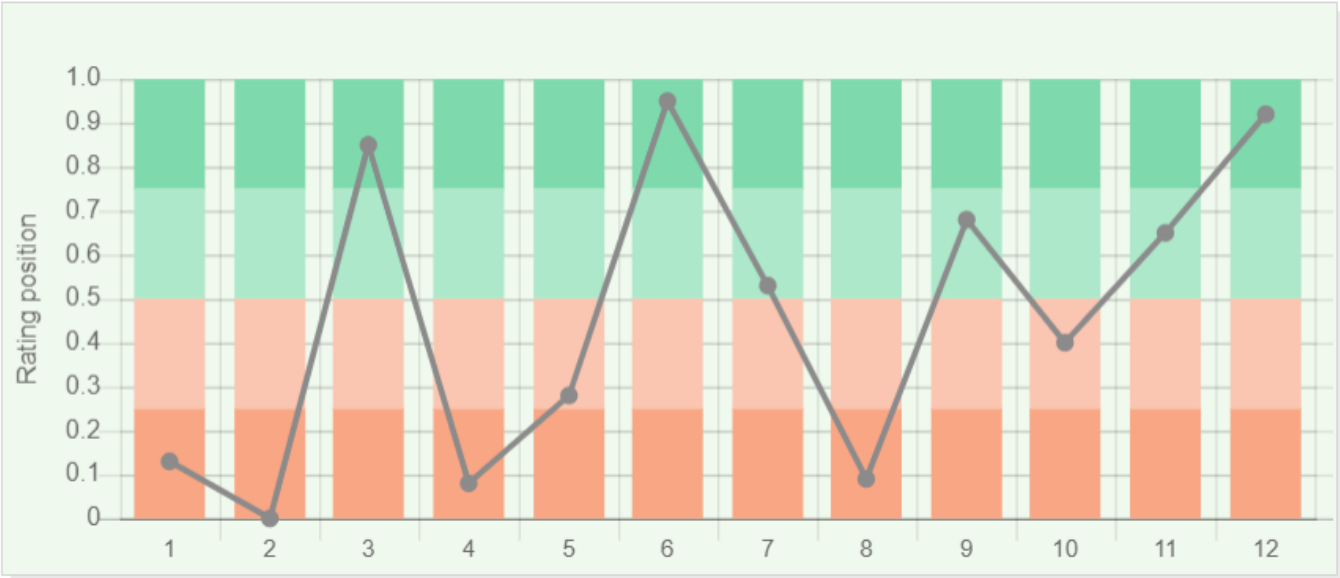
According to the U.S. Energy Information Administration, South Africa in 2017 produced 223TWh of electricity, where fossil fuels accounted for 88.8%, renewables - 7.1%, nuclear energy - 5.4%, and include hydropower 2.5% (Fig.6).

Positioning of South Africa on the diagram of energy indices is shown on Figure 4.



Sources:
U.S. Energy Information Administration (Dec 2021) / https://www.eia.gov/ ;

Figure 3. Electricity production in South Africa



Sources:
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8. GDP per unit of energy use (PPP per unit of oil equivalent), 2020 *66
Primary energy consumption - BP Statistical Review of World Energy 2021/BP;GDP (purchasing power parity) - The World Factbook/Library/Central Intelligence Agency
9. Energy use (primary energy use of oil equivalent per capita) 2020 *127
Primary energy consumption – BP Statistical Review of World Energy 2021; Population - United Nations, Department of Economic and Social Affairs, Population Division (2019). World Population Prospects 2019, custom data acquired via website. Retrieved 15 November 2021*66
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11. Electric power consumption (kWh per capita), 2016 *217
Electricity Consumption - The World Factbook / Library / Central Intelligence Agency; Population - United Nations, Department of Economic and Social Affairs, Population Division (2019). World Population Prospects 2019, custom data acquired via website. Retrieved 15 November 2021
12. Combination of electricity production-consumption (kWh)/The World Factbook/Library/Central Intelligence Agency *216
* Total number of countries participating in ranking

Figure 4. Energy indices of South Africa

Indices based on reserves of coal and export opportunities show South Africa's distinct advantage over most of the world. However, the shortage of oil and natural gas, the production of which is noticeably lower than the level of consumption, in South Africa is very tangible. In this regard, indices based on these resources are either absent or look extremely negative.

In another rating - the list of countries for the production of electricity from renewable sources (excluding hydropower) in 2017 - the country was 80th out of 213 countries selected for consideration.

In the Energy Architecture Performance Index 2017, which is based first on the level of economic growth, environmental safety, and energy independence of the country, including access to energy, South Africa was 76th; it should be noted that during the last 8 years the country has gained 10 ranking positions.

South Africa is in the middle of the graph for such indicators as GDP per unit of energy expended in 2020 - 59th; similarly, for such indicators as energy use per capita the country is 42nd.

In terms of electricity consumption per capita, the country is 76th in the world, however, for the indicator of combination of electricity production-consumption, South Africa is 17th in the ranked list of 216 countries .

More information about the energy balance of South Africa can be found in the documents from our reference library ***here.***

Energy Infrastructure

A territorial map of the distribution of the largest infrastructure projects of the fossil-fuel sector in South Africa is shown in Figure 5.

As previously mentioned, coal reserves account for 99.7% of conventional proved reserves (Fig.5).

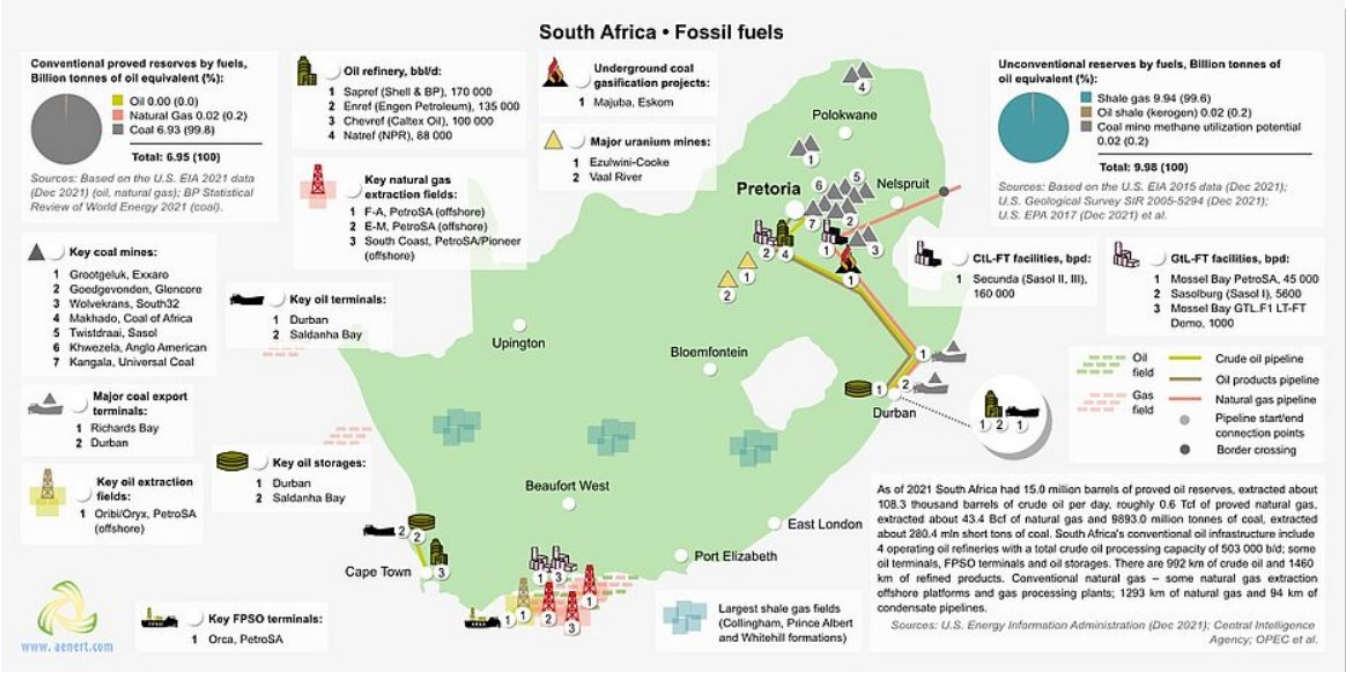


Figure 5. Basic infrastructure facilities of the fossil fuel sector in South Africa

The main coal mines are located in the northeast of the country, in the Pretoria area (Fig. 5). The largest coal mine is Grootgeluk, Exxaro Coal Mine, which, according to estimates, produces about 45.3 million tonnes per year [19].

The main coal export terminal is located in the city of Durban, and according to the information from [20] has a capacity of 250 million tons.

The largest oil fields are the Oribi / Oryx Oil Field; in June 2015 production from that field amounted to 1,800 barrels/day [21]. The refineries of South Africa have a total installed capacity of 503,000 barrels/day [5]. The country's largest refinery is Sapref (managed by BP PLC Petroleum and Shell), with an installed capacity of 170 thousand barrels/day [5]. The main oil terminal and oil storage facility is the Durban Oil Terminal, with a reservoir of 1,521,983 barrels [22].

Two types of oil pipelines connect the oil fields with the major refineries: pipelines for crude oil with a total length of 992 km, oil pipelines for the transportation of petroleum products with a length of 1460 km (Fig.5). The largest FPSO (Floating Production, Storage and Offloading) is Orca PetroSA, with an installed capacity of 30 thousand barrels/day [23].

The largest gas fields are managed by PetroSA and are located offshore (Fig. 5). The total length of gas pipeline is 1293 km, including a pipeline for the transportation of condensate - 94 km (Fig. 5). The main shale gas fields (Collingham, Prince Albert and Whitehill) are located in the south-western part of the country (Fig. 5).

The largest uranium field is the Ezulwini-Cooke Uranium Mine, the extraction from which was conducted at the level of 67 tU/year in 2016 [24].

The infrastructure of coal processing is represented by the Majuba underground gasification project, which is managed by Eskom UCG and has an installed capacity of 15,000 m^3 / hour [25], and the Secunda CTL (Coal-to-liquids) plant with an installed capacity of 160 thousand barrels/day [26]. The largest gas processing plant - Mossel Bay PetroSA GTL Plant has a capacity of 45 thousand barrels/day [27]. South Africa, and in particular Sasol, has a long tradition of producing synthetic fuels from coal and gas using the Fischer-Tropsch method, which on the one hand is associated with an excess of coal reserves and an increasing shortage of liquid fuels, but on the other hand, the country was brought to the perennial Period of economic embargo by a UN decision.

South Africa's electricity production predominantly relies on fossil fuels, and therefore gas, oil and coal-fired power plants can be found in Figure 6.

Electricity production in 2020 was at the level of 223.2 TWh, of which - 88.5% was by fossil fuels, nuclear energy - 5.2%, hydropower - 1.8%, and other renewable sources - 4.5% (Fig.6).

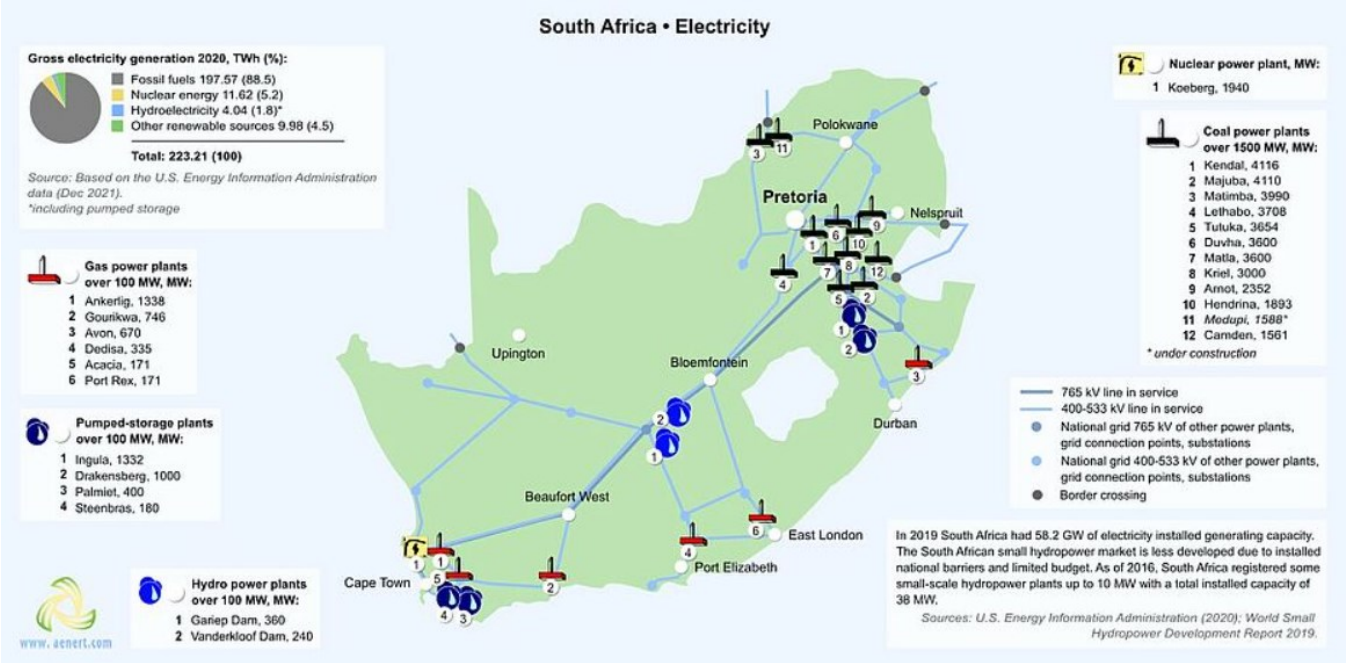


Figure 6. Electricity production in South Africa

There are about 11 coal power plants over 1500 MW, 6 large gas power plants over 500 MW and a large number of smaller stations (Fig.6).

The largest coal-fired power plant is the Kendall complex, with a total capacity of 4116 MW [28]. The largest gas station is Ankerling with an installed capacity of 1338 MW, and the most powerful nuclear power plant is a two-block Koeberg with a capacity of 1940 MW [29].

The leader in power generation among hydroelectric power plants is Gariep Dam with a total installed capacity of 360 megawatts [30], and the installed capacity of the Ingula Hydro Pumped Storage Plant is 1332 MW [31].

Figure 7 shows the main infrastructure facilities in South Africa for the production of renewable energy. As noted above, renewable energy accounts for 3.7% of electricity generation. Thus, the total production of electricity from renewable sources excluding hydropower in 2017 was 9.8 GWe (Fig. 7).

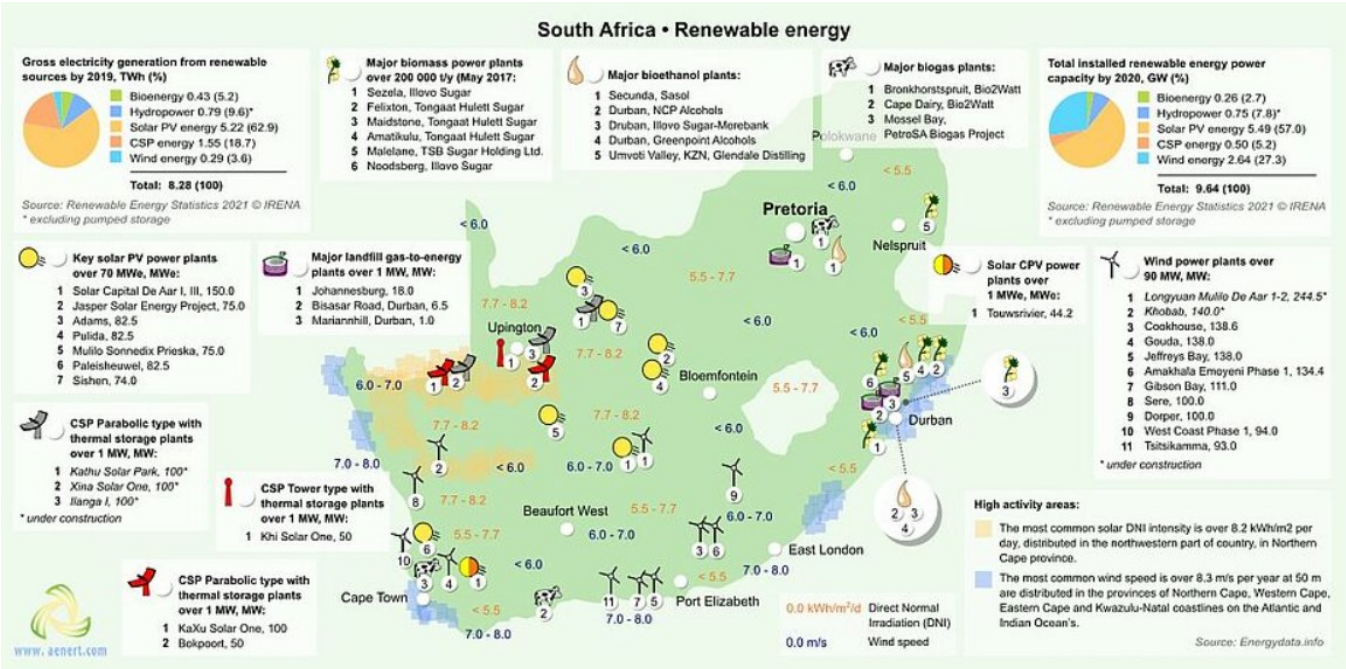


Figure 7. Renewable energy in South Africa

Along the coast, in the south-east and south-west, in zones of high wind activity, there are several large wind parks with a capacity of more than 90 MW. In total, according to 2016 data, there were 29 wind farms, with a total installed capacity of 1,471 MW [32]. The largest of these is the Cookhouse Wind Farm with an installed capacity of 138.6 MW [33].

As mentioned earlier, the level of scattered solar radiation in the most densely populated areas of the country can reach 8.5 kWh/m2/day, which is a unique resource for the production of energy through photovoltaics [11]. Nevertheless, the level of development of solar energy in South Africa is not comparable to resource opportunities. There are several different solar stations of small and medium size both on the basis of photovoltaics and solar energy concentration technologies (Fig. 7). The largest photovoltaic station is Solar Capital De Aar I, III with an installed capacity of 150 MW, the largest CSP tower plant is the Khi Solar One CSP with a storage capacity of 50 MW; the leading CSP parabolic storage type plant, KaXu Solar One CSP Parabolic Trough, has a capacity of 100 MW [34,35,36]. Also, three other parabolic storage type plants with a total capacity of more than 300 MW are under construction (Fig. 7).

Bioenergy does not have a significant share in energy production in South Africa and according to 2017 data biomass generated about 0.4 Twh or 4% of total production from renewable sources (Fig. 7). The country has biomass processing plants, biogas production, biodiesel production, landfill gas production plants. Illovo Sugar owns the largest Sezela biomass processing plant, producing about 290,000 litres of ethanol annually [37]. The landfill gas–to–energy plant in Johannesburg has an installed capacity of 18 MW [38]. Sasol annually produces about 285,000 kilolitres of bioethanol (klaa/a) at the Secunda bioethanol plant [39].

The country has a large number of biogas plants, one of which, Bronkhorstspruit, has an installed capacity of 4.6 MW and annually processes about 120 thousand tons of organic waste [40].

The modern energy policy of the country provides for a number of projects to increase existing capacities and create new enterprises, both in the field of conventional energy sources and in the field of renewable energy. So, by 2021 it is planned to increase the power of photovoltaics by 2 321 MW, and the power of concentrated solar energy by 600 MW [41]. In terms of wind power, two large stations are under construction: Longyuan Mulilo De Aar I, II Wind Park (244.5 MW) and Khobab Wind Farm (140.0 MW) [42,43]. According to estimates of experts from the Africa-EU Renewable Energy Cooperation Program, wind power capacity in the country will increase by 3,366 MW to 2020 [41].

*For current information on the development of energy in the country see **here**. More information about South African energy infrastructure is also available **here**.*

Education and Innovation

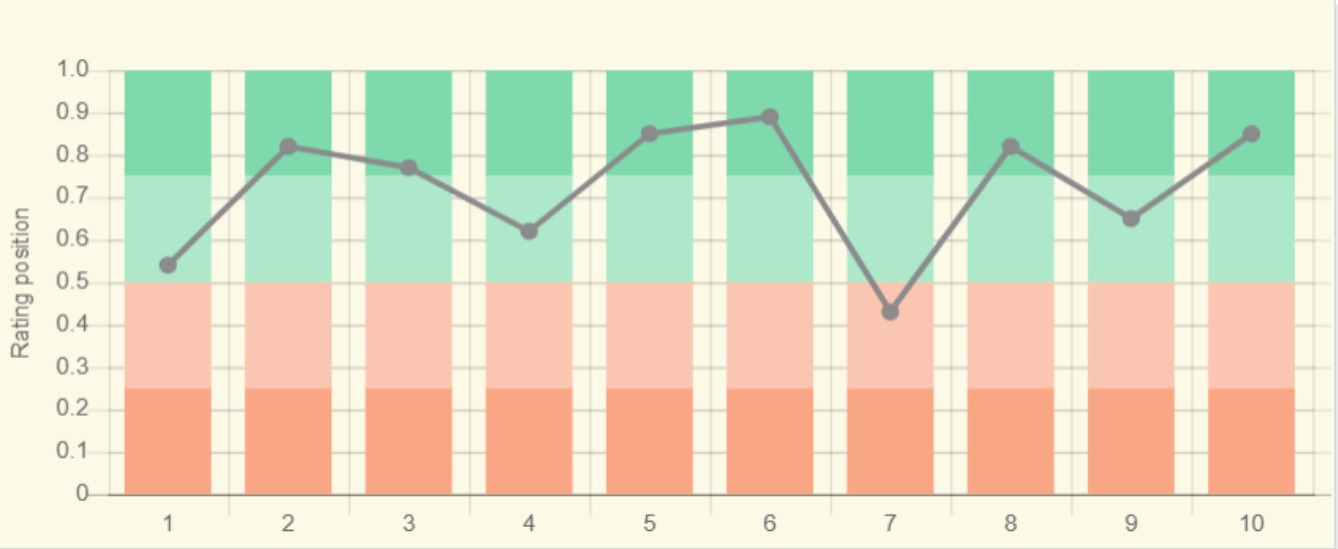
The set of indices reflecting the position of South Africa among other countries in the field of education and innovation can be seen in Figure 8. As follows from the presented diagrams, South Africa belongs to a number of countries with a high level of education and innovation, which in many ways predetermines technological development in the field of energy.

According to the number of patents granted to South African residents, both inside the country and abroad, the country ranks 33rd in the world. By the number of valid patents, the country is ranked 25th in the world, which largely characterizes the country's patent attractiveness.

South Africa is 61st out of 132 countries considered in the ranking of countries of the Global Innovation Index 2018 (see diagram). In terms of government expenditure on education as a percentage of the country's GDP, the country demonstrates a result close to the world average – 32nd out of 177 countries selected for consideration. In terms of public expenditure on research and development as a percentage of GDP, South Africa is 42nd. The country is very well positioned when considering the number of publications of specialists in scientific and technological journal and patent activities. South Africa is 35th out of 240 participating countries in the Scimago ranking, and in Scientific and Technical Journal Activities it is ranked 29th out of 197 countries. The country is also among the leaders in the region in terms of the number of Internet users.

About fifteen South African universities, including the University of Cape Town, Durban University of Technology, the University of Pretoria, and the University of the Witwatersrand train specialists in various fields of energy, such as Chemical Engineering, Environmental Engineering, Electrical Engineering, Mining Engineering, Renewable Energy Engineering.

Sasol Technology (Pty) Ltd , Petro ZA - are among the leaders of patenting among South African companies in the field of synthetic fuel production, extraction and processing of unconventional oil. Studies in this field have been conducted by the University of KwaZulu-Natal and Pebble Bed Modular Reactor (Pty) Ltd. Scientific research and development in the field of associated petroleum gas is carried out by the University of the Witwatersrand and Det Norske Veritas.



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* Total number of countries participating in ranking

Figure 8. The indices of education and innovation in South Africa

A large number of companies patent technical solutions in the field of energy production from renewable sources. In the field of bioenergy the following companies should be mentioned: Sasol Technology (Pty) Ltd and Lurgi Clean Coal Technology (Proprietary) Ltd. The University of the Witwatersrand, Stellenbosch University have the highest number of publications in this area.

Another area where South African and international companies actively conduct research is the extraction of hydrocarbons from low-permeability reservoirs, here we should mention the University of Cape Town and iThemba LABS.

Studies in the field of concentrated solar energy have been conducted by Stellenbosch University and the University of Pretoria. The University of Pretoria carries out scientific research and development in the field of wind energy.

*Additional information about education in the country can be obtained **here**, and the list of research institutes **here**.*

Ecology and Environmental Protection

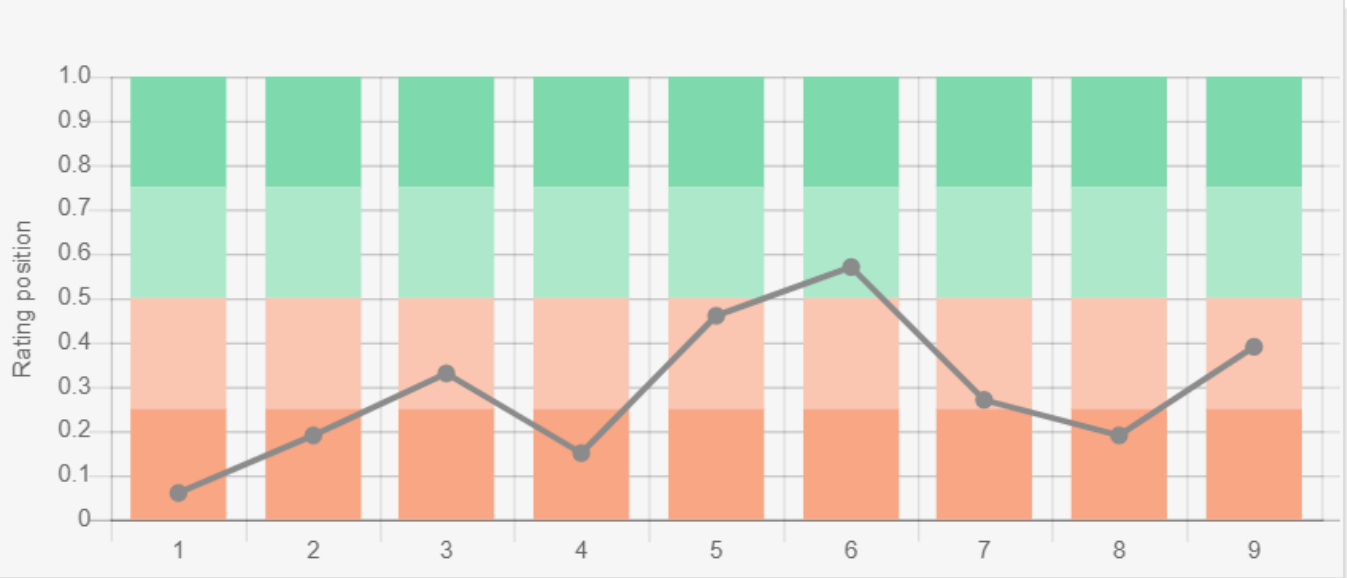
A diagram of environmental indices is shown in Figure 9. This figure shows the indices that have an indirect effect on the energy sector, but in many respects predetermine its future.

The environmental situation in the country is extremely negative. First of all, the country demonstrates a relatively high level of CO_2 emissions in general, and per capita, the level of methane emissions is also very high.

At the same time, the situation is aggravated by the fact that South Africa is 48th in the 56 countries responsible for more than 90% of global CO_2 emissions related to energy in the Climate Change Performance Index (CCPI) 2022.

In terms of forest area as a percentage of the country, South Africa was 156th in the world in 2020; at the same time, the trend associated with its change from 2010-2020 looks very negative and according to this indicator the country is 198th in the world.

The country also performed poorly in the Environmental Performance Index rankings (EPI) 2020, which focuses primarily on assessing the environmental performance of national governments. Here, South Africa was 95th out of 180 countries.



Sources:

1. CO2 total emission by countries 2020 / European Commission / Joint Research Centre (JRC) / Emission Database for Global Atmospheric Research (EDGAR)*208
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4. Forest area change 2010-2020 (1000 ha/year) / The Global Forest Resources Assessment 2020 / Food and Agriculture Organization of the United Nations *234
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* Total number of countries participating in ranking

Figure 9. South Africa's environmental indices

The overall negative picture is aggravated by the Ecological Footprint Atlas rating, according to which South Africa is among a number of ecological debtors.

*For more information on the energy complex of South Africa, see the attached link library by clicking **here**.*

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The sources of charts and curves are specified under the images.