

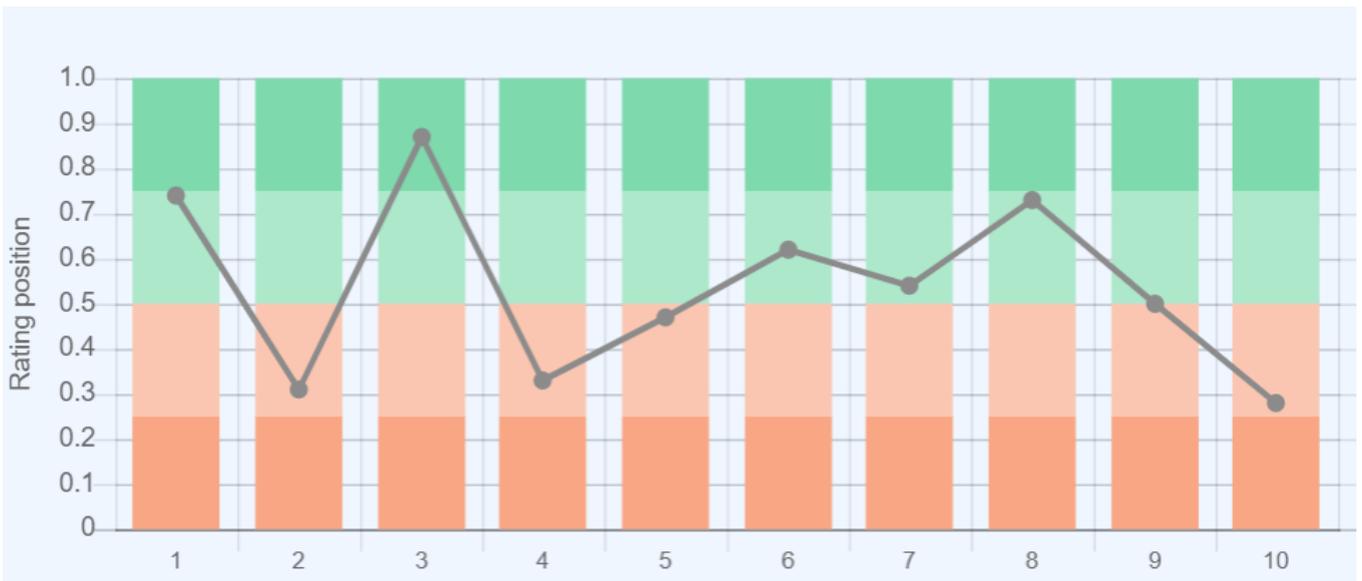
Energy Industry in Morocco



General State of the Economy

Morocco, official name - the Kingdom of Morocco, is located in North-West Africa, between Algeria and Western Sahara; in the north, the country borders Spain. Morocco is the only African country with access to both the Mediterranean Sea and the Atlantic Ocean. In terms of the size of the territory, Morocco is 57th in the world, and according to the population density, the country is 132nd [1,2].

The total length of the country's coastline is 1 835 km [3]. According to 2022 statistics, the country is home to around 36.7 million people [3]. The unique geographical position, political preferences and proximity to Europe enable Morocco to demonstrate relatively high economic performance (Fig.1) for the African region. Six out of ten indices characterizing the economic situation in the country are at the upper part of the diagram shown in Figure 1.



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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6. High-technology exports (current US\$) 2019-2020 / United Nations, Comtrade database through the WITS platform / License: CCBY-4.0 / Data *134
7. 2021 Index of Economic Freedom / International Economies / The Heritage Foundation *178
8. Reserves of foreign exchange and gold, 2017 est. / The World Factbook / Library / Central Intelligence Agency *195
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 (from smallest to largest) *210

* Total number of countries participating in ranking

Figure 1. Economic indices of Morocco

Since the year 2000, the country experienced rapid growth in GDP at purchasing power parity, amounting to \$298.6 billion in 2017, dropping slightly to \$259.42 billion in 2020 [3,4]. For this indicator, Morocco is 60th in the world [3].

According to GDP at purchasing power parity per capita, Morocco shows a figure below world average – \$6 900 in 2020 [3]. The inflation rate in 2019 was 0.2%, compared to 1.6% in 2016 [3].

According to the Global Competitiveness Report, presented by the World Economic Forum in 2019, Morocco is 75th, out of an estimated total of 141 countries, ahead of Egypt. 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 export high-tech products in 2019-2020, the country was 51st out of 134 countries.

Energy resources

Morocco doesn’t have sufficient reserves of oil, gas, and coal (see Table 1) and imports more than 91% of energy resources, including fossil fuels. In terms of tons of oil equivalent, in 2021 proved reserves of conventional hydrocarbons in Morocco were: coal – 87.5%, gas – 11.6%, oil – 0.9% (Fig.5).

The unconventional natural resource matrix looks much different: oil shale (kerogen) – 96.3%, shale gas – 3.7% (Fig. 5).

Table 1. Fossil energy resources of Morocco

Resource/explanations	Crude oil	Natural gas	Coal	Shale Gas*	Oil Shale
Value	700	1.444	15	11.9	53
Unit	thousand bbl	Bcm	million short tons	Tcf	billion bbl
Year	2021	2021	2016	2013	2008
Source	[3]	[3]	[6]	[7]	[8]

*unproved technically recoverable

Morocco has a significant potential for the development of renewable energy (Table 2).

Due to its favorable geographical location, Morocco has a feasible potential for the development of solar energy. The most typical level of direct normal irradiation is 5.5-6.6 kW/m²/day, and it can reach the level of over 6.6 kW/m²/day in Draa-Tafilelet and Souss-Massa regions [9].

According to the Index of Economic Freedom, which is based on freedom of business, freedom from government action, property protection, and freedom from corruption, Morocco was 81st in 2021, out of the 178 countries considered, behind Cabo Verde, but ahead of Uganda and Egypt. In terms of reserves of foreign exchange and gold Morocco is 53rd out of 195 countries, ahead of Angola.

According to the indicator for the average GDP growth in percentage over the last 10 years, in 2020 the country was 103rd out of 206 countries, behind Egypt. In terms of public debt, calculated as a percentage of the country’s GDP, Morocco was ranked 59th out of 210 countries considered in 2017.

For more information on the Moroccan economy click [here](#).

According to information presented in [3], as of the beginning of 2021, oil reserves in the country amounted to 700.000 barrels, and gas reserves were 1.444 Bcm. According to the U.S. Energy Information Administration, coal reserves were estimated at 15 million short tons in 2021 [6].

Morocco has small reserves of shale gas – about 11.9 Tcf, according to 2013 data [7]. The country also has reserves of oil shale (kerogen), which amounted to 53 billion bbl in 2008 [8].

Wind speed in most parts of Morocco is 5.0-7.0 m/s, and in coastal areas, and in Guelmim-Oued Noun and Laayoune-Sakia El Hamra regions, can reach over 7.0 m/s [10].

The country’s technically exploitable hydropower potential is 5 TWh/yr [12].

Table 2. Renewable energy resources of Morocco

Resource/ explanations	Solar Potential (DNI)*	Wind Potential (50 m)*	Hydro energy Potential**	Bio Potential Agricultural area	Bio Potential Forest Area	Municipal Solid Waste
Value	5.5 - 6.6	5.0 - 7.0	5	68.1	12.9	0.55
Unit	kWh/m ² /day	m/s	TWh/yr	% of land area	% of land area	Kg/per capita/day
Year	2018	2018	2008	2020	2020	2016
Source	[9]	[10]	[11]	[12]	[13]	[14]

*for most of the territory of the country

**technically exploitable hydropower potential

Around 68.1% of the country is covered by agricultural land and 12.9% of the county is forested, which determines the country's potential for the production of bio-energy [13,14].

Morocco shows the highest numbers in the region in terms of production of municipal solid waste –0.55 Kg/

capita/day, and by 2025 it can reach the level of 1.85 Kg/ per capita/day [14].

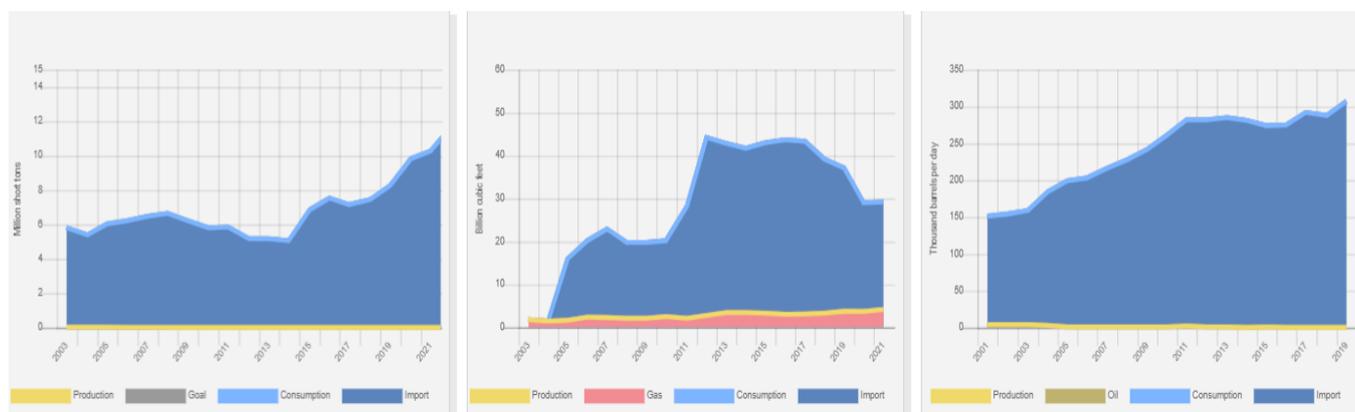
For more information about energy resources in Morocco click [here](#).

Energy balance

According to BP's report, total primary energy consumption in Morocco in 2018 amounted to 0.96 exajoules, about 57.3% of which was oil, 32.3% – coal, 7.3% – renewables, 3.1% – natural gas, 1% – hydroelectricity [15]. The volume of consumption of crude oil in Morocco demonstrated a stable growth between 2001 and 2019 (Fig. 2), then it started decreasing and in 2019 reached the level of 307 thousand barrels/day, compared to 285 thousand barrels/day in 2013 [16]. According to BP in 2021 this number was 286 thousand barrels/day [15].

As reported in [3], the volume of oil imports to Morocco in 2018 amounted to 0 bbl/d.

Internal gas production remained stable for the last decade and in 2021 was 4.2 Bcf [16]. Gas consumption in Morocco has been growing since 2004, but in 2012 it became stagnated not exceeding the level of 42 Bcf, and reaching 29 Bcf in 2021 [16]. In 2019, the country imported 950.765 million cubic meters of natural gas [3]. Coal consumption in the country has been increasing over the last few years, and in 2021 it reached the level of 11.637 million short tons [16].

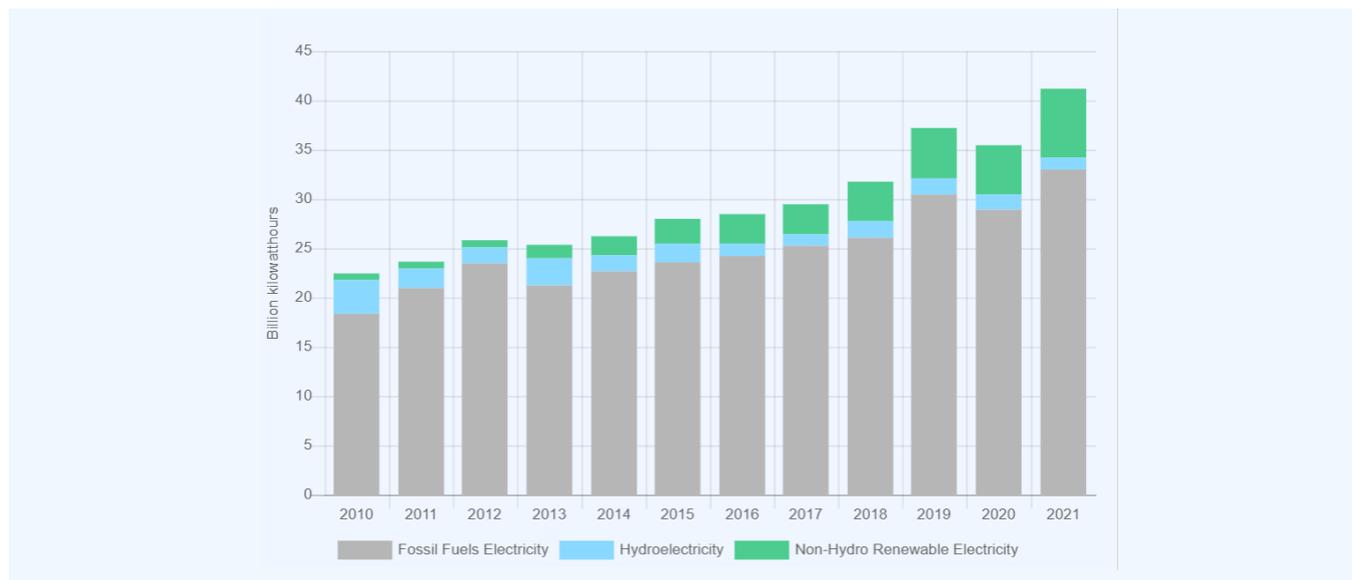


Source: U.S. Energy Information Administration (Oct 2022) / <https://www.eia.gov/>

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

Historically, Morocco has a high share of fossil fuels in electricity production (Fig. 3).

In 2021 Morocco produced about 41.20 TWh of electricity, of which 80% was by fossil fuels, 3% by hydropower, and 17% by other renewable sources (Fig. 6).



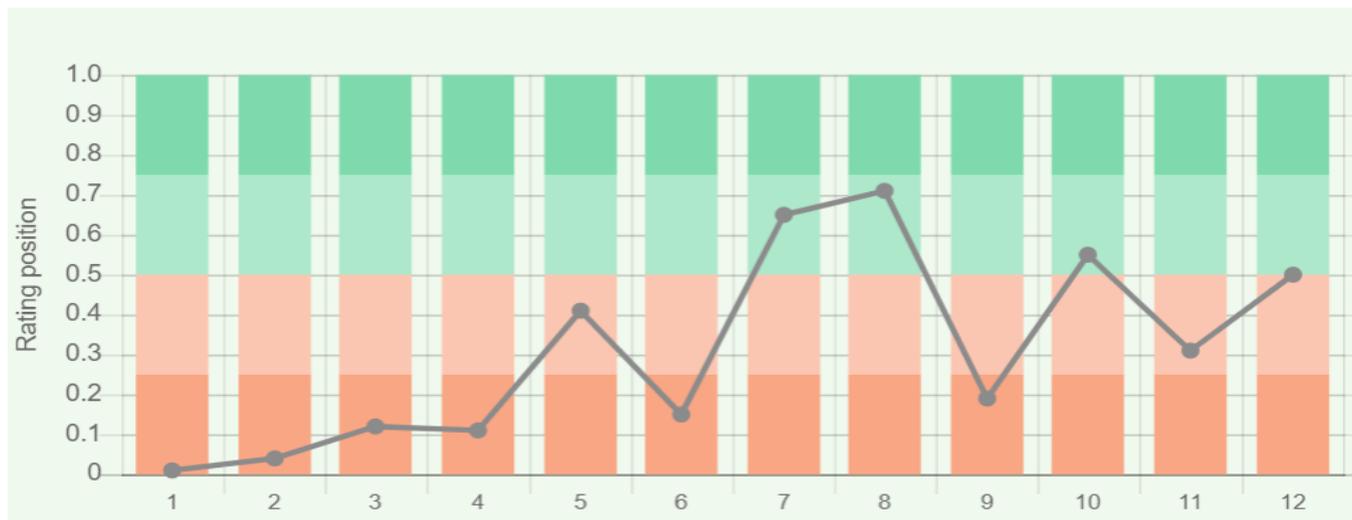
Source: U.S. Energy Information Administration (Oct 2022) / <https://www.eia.gov/>

Figure 3. Electricity production in Morocco

Morocco's position in the comparative diagram of energy index is shown in Fig. 4.

As mentioned previously, Morocco has a small potential of traditional fossil resources, which provides a low level

of indices associated with them. At the same time, the country simultaneously shows extremely low indicators of the production-consumption combination for these resources.



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 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 Morocco

However GDP per unit of energy use is above the world average – 24th place out of 66 countries considered, while energy consumption per capita is much lower – 61st out of 66 countries.

The share of renewable energy in electricity production in Morocco is about 14%, and in 2017 the country was 59th out of 170 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, Morocco gained 14 ranking positions over the previous year, and is 57th in the world, ahead of Egypt, Algeria and Libya. In terms of electricity consumption per capita, the country is 149th in the world, however, for the indicator of combination of electricity production-consumption, Morocco is 107th in the ranked list of 216 countries.

More information about the energy balance of Morocco can be found [here](#).

Energy Infrastructure

Fossil fuel production is represented by several small oil and gas fields in the central part of the country and on the coast of the Atlantic Ocean (Fig. 5).

The largest oil field is Sidi Rhalem, discovered in 1961 in the Essaouira Basin [17]. The most important gas field is Charb Basin [18].

The main oil shale fields are Tarfaya and Timahdit, with the potential of 22.7 billion barrels and 16.1 billion barrels, respectively [19].

Energy facilities in Morocco are mainly located in the vicinity of fields or on the Atlantic coast. In the north of the country Morocco Horizon Tanger has the largest oil storage, with a capacity of up to 3.35 million barrels [20]. There are also two major oil terminals: Tanger-Med and Mohammedia. Installed capacity of the Tanger-Med terminal is 532 000 m³ [21]. The Maghreb-Europe Gas Pipeline from Algeria to Spain passes through Morocco. There are two large gas compressor stations in the north, Ain

Beni Mathar and Tanger, which also form part of this pipeline (Figure 5).

The Oil refining industry in Morocco is represented by two refineries Mohammedia and SidiKacem, owned by SAMIR (which was closed in 2008 and now serves as an oil terminal). The installed capacity of the Samir Mohammedia Refinery has recently increased to 8.5 million tons / year [22].

Research in the field of production and processing of oil shale in Morocco is being conducted by ONHYM [23]. This organization has successfully implemented a pilot oil shale pyrolysis project using a vertical retort design. However, following the recent global decline in oil prices, it is difficult to talk about the serious prospects of oil shale, because of high production costs.

As mentioned previously, electricity generation relies purely on fossil fuels (Figure 6). Moroccan fossil fuel infrastructure is represented by oil and coal power plants and combined power plants.

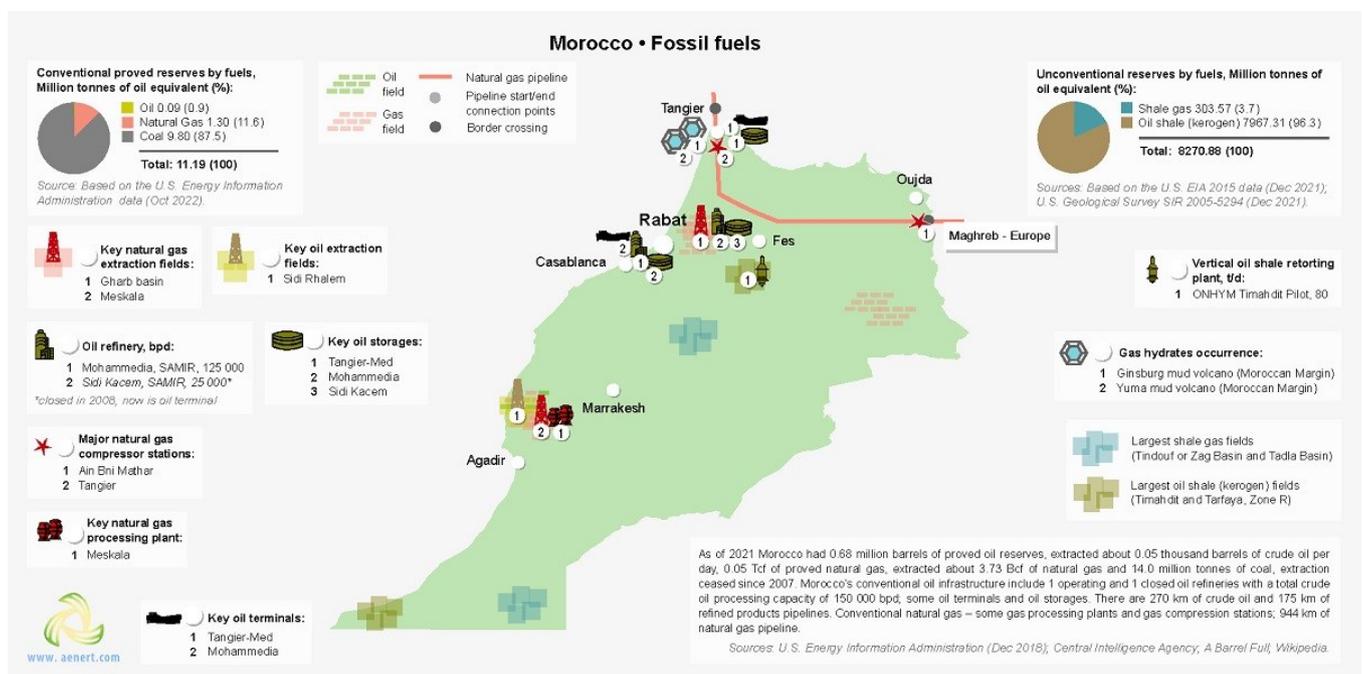


Figure 5. Basic infrastructural facilities of the fossil fuel sector in Morocco

The largest gas power plant is the Ain Beni Mathar power plant, with an installed capacity of 472 MW. The engineers of this enterprise were one of the first in the world to use an integrated solar collector field to boost output from the steam turbine [24]. The largest combined power plant is Tetouan with an installed capacity of 145 MW [25]. There are also 3 existing coal power plants

and one power plant is under construction, the largest being Jorf Lasfar with the installed capacity of 2056 MW [26]. Key oil power plant is Mohammedia Oil with the installed capacity of 300 MW [27]. Morocco also has four large hydropower plants, each with a capacity of over 100 MW. Hydroelectric Allal el Fassi, with three blocks of 80 MW, being the largest [28].

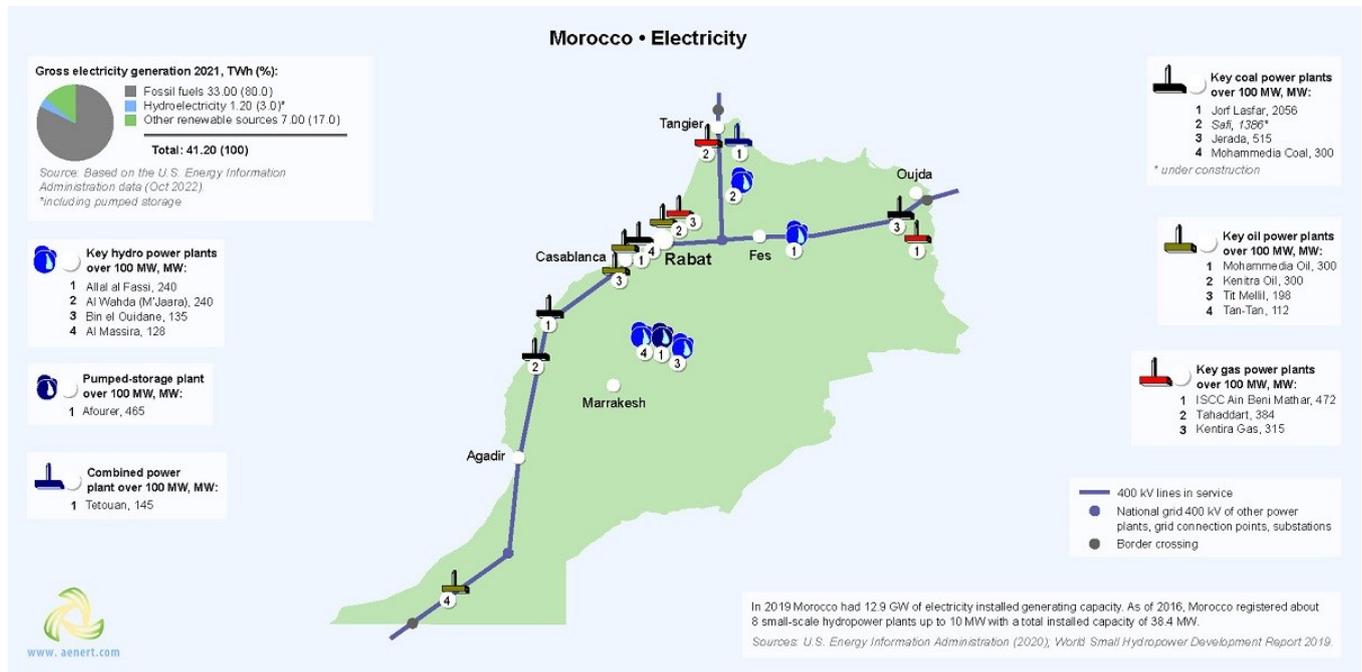


Figure 6. Electricity production in Morocco

The main Moroccan renewable energy facilities are to be found below (Fig.7). The total installed capacity of wind

power in the last ten years has increased almost ten-fold and is 1017 MW [29]. One of the biggest stations is

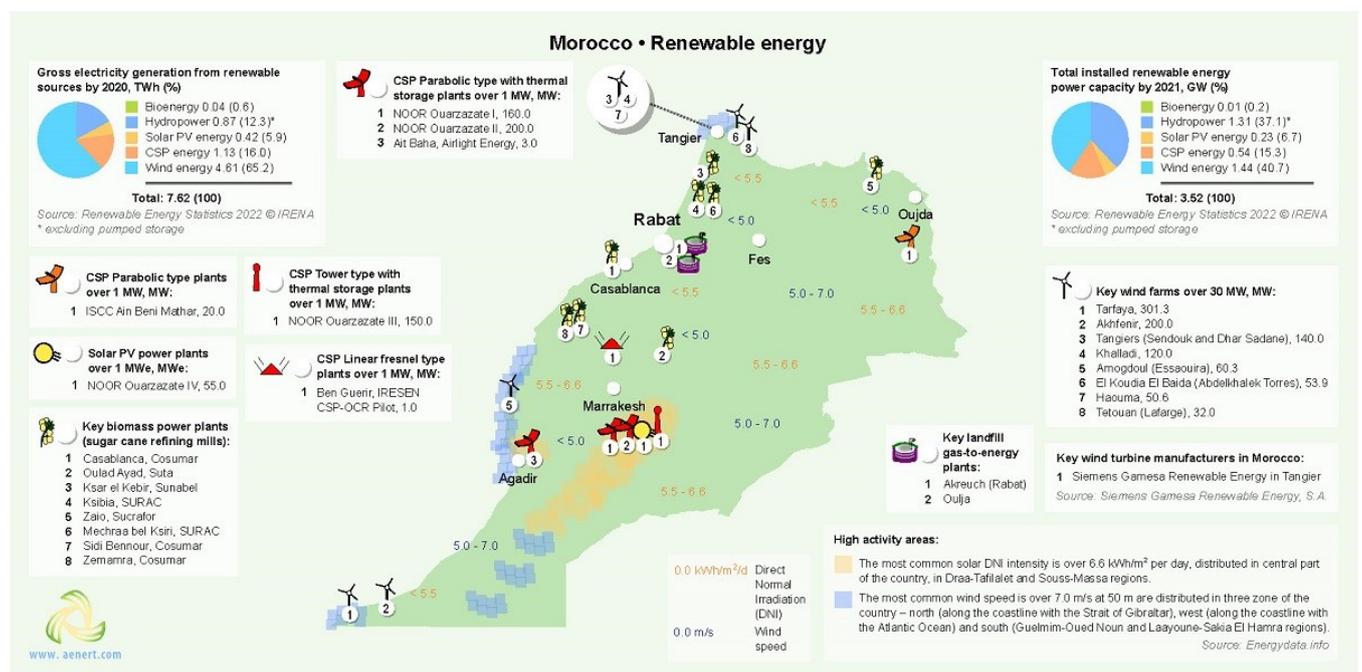


Figure 7. Renewable energy in Morocco

Tarfaya with an installed capacity of 301 MW [30]. Solar energy, with a total installed capacity of 1MW, is playing only a minor role in the production of electricity, nowadays. The only existing solar power plant is NOOR Ouarzazate IV, with a total capacity of 55 MW [31]. CSP on the other hand has installed capacity of 7.1 MW, and is represented by different types of power plant—CSP parabolic type power plant ISCC Ain Beni Mathar (20 MW), CSP tower type power plant with thermal storage NOOR Ouarzazate III (150 MW), CSP linear fresnel type Ben

Guerir (1 MW)[24,32,33]. The largest CSP parabolic type power plant with thermal storage is NOOR Ouarzazate II has an installed capacity of 200 MW [24].

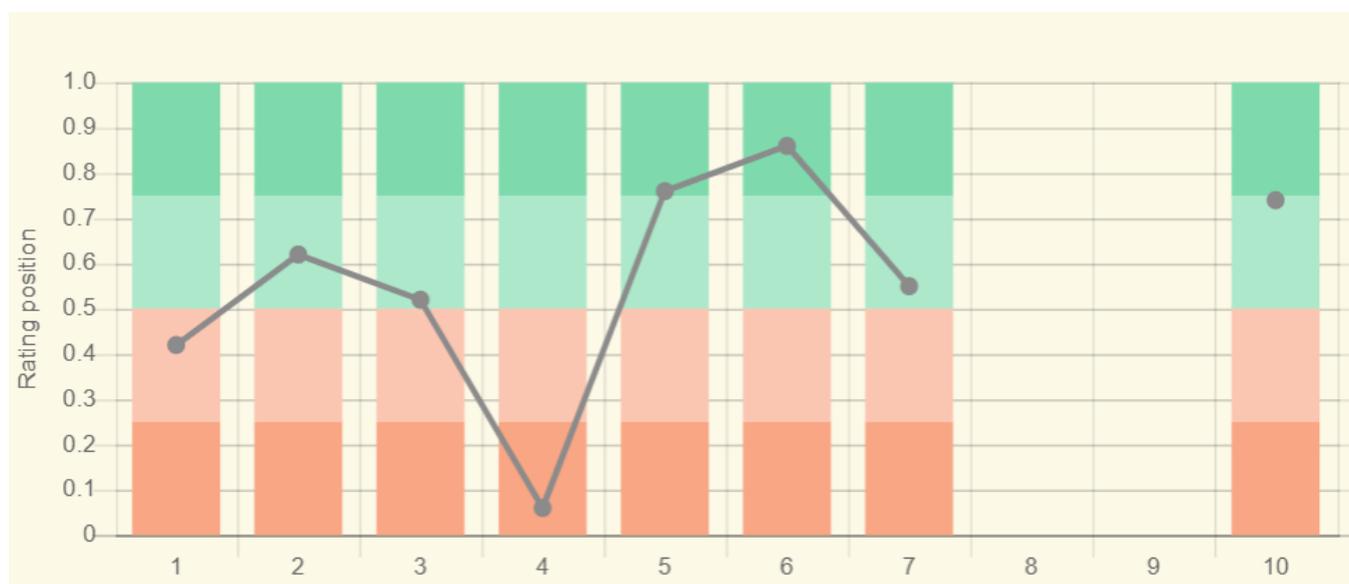
Biomass does not play a decisive role in the electricity production, and is represented by 8 sugar cane refining mills (Figure 7).

Detailed information about energy infrastructure of Morocco can be found [here](#).

Education and Innovation

The set of indices reflecting the position of Morocco among other countries in the field of education and innovation can be seen in Figure 8. In the country ranking in accordance with The the Global Innovation Index in 2021, Morocco was 77th, ahead of Algeria and Egypt. According to the number of patents granted to Moroccan residents, both inside the country and abroad, the coun-

try ranks 71st in the world. By the number of patents in force, Morocco ranks 52nd out of 109 countries. Morocco is well positioned when considering the number of publications of specialists in scientific and technological journals – 52nd place out of 197 countries considered. It is also regarded highly by the Scimago Journal and Country Rank (58th place).



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 2. Patent Grants 2011-2020, resident & abroad / Statistical country profiles / World Intellectual Property Organization *185
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 9. Research and development expenditure (% of GDP), 2018 / UNESCO Institute for Statistics. License: CCBY-4.0 / Data *119
 10. Scientific and technical journal articles, 2018 / National Science Foundation, Science and Engineering Indicators. License: CCBY-4.0 / Data *197
- * Total number of countries participating in ranking

Figure 8. The indices of education and innovation in Morocco

Cadi Ayaad University, Mohammed V University and Université Sultan Moulay Slimane are actively involved in the research in the field of unconventional oil. Abdelmalek Essaadi University is conducting research in the field of gas hydrates and synthetic fuels.

Research and development in the field of bioenergy is being carried out by Université Chouaib Doukkali and Abdelmalek Essaadi University .

A large number of Moroccan universities conduct research in the field of energy production from renewable sources. The main patent-holders in the field of solar energy are Cabinet Chardy and L'École nationale supéri-

eure des arts et métiers. Mohammed V University, Moroccan foundation for Advanced Science Innovation and research MAScIR, Moulay Ismail University and L'École nationale supérieure des arts et métiers have the largest number of scientific publications in this field.

In the field of wind energy– Mohammed V University, Sidi Mohammed Ben Abdellah University and Abdelmalek Essaadi University.

Detailed information about energy education and research in Morocco is to be found [here](#).

Ecology and Environment Protection

A diagram of environmental indices is shown in Figure 9. Half of the indicators of Morocco are located in the lower part of the chart. Morocco has a high level of methane emissions, CO₂ emissions in general, but per capita it is significantly lower. There is no positive trend in forest area change, and in terms of the ecological footprint on a global scale, Morocco is a debtor.

The situation is slightly brightened, however, by the Environmental Performance Index rankings (EPI) 2020, which focuses primarily on assessing the environmental performance of national governments. In this rating Morocco is 100th out of 180 member countries, ahead of Egypt and Lebanon.



Sources:

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- * Total number of countries participating in ranking

Figure 9. Environmental indices of Morocco

At the same time, the situation is aggravated by the fact that Morocco is 5th in the Climate Change Performance Index (CCPI) 2022, which consists of 64 positions and includes 61 countries responsible for more than 90% of global energy-related CO² emissions. The authors of the rating underline the fact that the country could install

new renewable energy capacities and has very ambitious emission targets by 2030.

For more information on Morocco's energy industry, please click [here](#).

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