

# Energy Industry in France



## General State of the Economy

France, officially the French Republic, is a country in Western Europe. Its capital city is Paris. The mainland

borders Belgium, Germany and Luxembourg (to the north-east), Switzerland (to the east), Monaco and Italy (to the south-east), and Spain and Andorra (to the south-west).

### France / French Republic

Capital: Paris	Density: 122/km <sup>2</sup>	Currency: Euro (€) (EUR)
Official languages: French	Life expectancy at birth: 82.23 years	GDP (PPP): \$3.972 trillion (2023)
National Day: 14 July	Land area: 547,557 km <sup>2</sup>	GDP - per capita (PPP): \$58,167 (2023)
Population: 66,548,531 (2025)	Coastline: 4,853 km	Internet country code: .fr

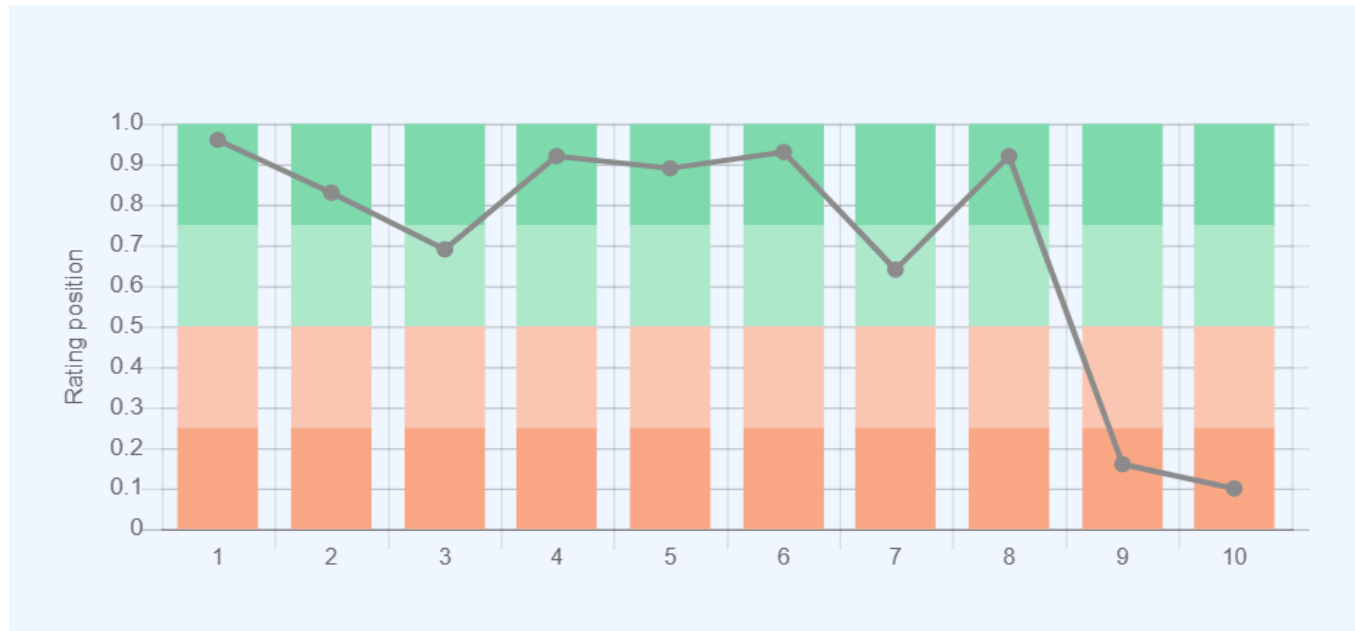
Source: [1,2,3,4,5]



Eiffel Tower landmark, view from Arc de Triomphe. Paris, France. Envato Elements. HZTFV3BSDK

To the east and north-west the country has access to the Atlantic Ocean, and the Mediterranean Sea to the south. France, is third largest country in Europe and the 48<sup>th</sup> largest in the world, and is home to around 66.5 million people as of 2025. In terms of population density the country is 97<sup>th</sup> in the world [1,2,3]. The total length

of the country's coastline is 4 853 km [3]. The political form of government is a unitary semi-presidential representative democratic republic and the official language is French. The administrative map of France is divided into 18 regions [3]. France is one of the ten strongest economies in the world, which is reflected 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
  3. Inflation rate (consumer prices), 2019 est. / The World Factbook/Library/Central Intelligence Agency \*228
  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
  5. The Global Competitiveness Index 2019 / Rankings / Reports / World Economic Forum \*141
  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 France

In almost all indices the country's positioning is markedly higher than the world average, in the upper quarter of the chart (among the top 25% of the world's countries included in the rating). Since the early 1990s the country has experienced steady growth of GDP at purchasing power parity, both in general and per capita [4,5]. GDP at purchasing power parity has increased slightly over three years for which the most recent data exist from \$3.648 trillion in 2021 to 3.764 trillion in 2023 (9<sup>th</sup> in the world) [3]. GDP at purchasing power parity per capita is somewhat lower (35<sup>th</sup> in 2023), demonstrating a positive trend: from \$53 800 in 2021 to \$55 200 in 2023 [3]. The inflation rate increased from 1.64% in 2021 to 4.88% in 2023; according to this indicator the country is 104<sup>th</sup> in the world [3]. The Global Competitiveness Report measures 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. High-technology exports in 2021 was 22% of manufactured exports.

According to the Index of Economic Freedom in 2024, which takes into account business freedom, freedom from government intervention, protection of property, and freedom from corruption, France was 62<sup>nd</sup> out of 184 countries. France's public debt as a percentage of GDP was 98.7% in 2022 [3].

## Energy resources

France does not have significant reserves of fossil fuel resources (Table 1). In terms of proven reserves of oil and natural gas, the country is 75<sup>th</sup> and 81<sup>st</sup> in the world, respectively [3]. According to [3] in 2021, proven oil re-

serves were only 61.119 million barrels. For comparison, oil reserves in other relatively resource poor countries were, for example, 115.2 million barrels in Germany at the beginning of 2021, while Poland had 113 million barrels [3].

**Table 1. Fossil energy resources of France**

Resource/ explanations	Crude oil*	Natural gas*	Coal*	Shale Gas**	Tight Oil**	Oil Shale
<b>Value</b>	62(0.004%)	8.41(0.004%)	176(0.014%)	136.7	4.7	7 000
<b>Unit</b>	million barrels	Tcf	million short tons	Tcf	billion barrels	million barrels
<b>Year</b>	2021	2021	2023	2013	2013	2008
<b>Source</b>	[6]	[6]	[6]	[7]	[7]	[8]

\*share of the country's reserves in world total is provided in brackets

\*\*unproved technically recoverable

Proven natural gas reserves in France at the beginning of 2021 were 7.787 Bcm [3]. Coal resources as of 2022 were 176 million short tons [6].

France has the largest shale gas reserves in Europe – 136.7 Tcf, and tight oil – 4.7 billion barrels [7]. The reserves of kerogen oil (oil shale) in the country, as of 2008, were 7 000 million barrels [8].

France has a great resource potential for the development of clean energy production. A selection of basic indicators of this type of resource is presented in Table 2. The level of solar horizontal radiation for the majority of the territory of the country is between 3.0–3.5 kWh/m<sup>2</sup>/day; the highest level of solar radiation of between 4.1–4.5 kWh/m<sup>2</sup>/day can be observed in Corsica island, and the southern regions of Provence-Alpes Cote d'Azur and Languedoc-Roussillon [9]. The distribution of wind resources is as follows: for the majority of the country the wind speed is 5.5–6.5 m/s, and in the southern part of

country along the coastline of the Gulf of Lion it can exceed 8 m/s at a height of 50 m [10]; the average annual duration of wind speeds in the working range of a wind turbine (usually 3–25 m/s) is more than 80%, reaching 90% in some areas. This region boasts some of the richest wind resources in the world. The economically exploitable hydropower capability as of 2013 is 70 GWh/year [11], which allows for the intensive use of hydro resources for electricity production. More than 51.7% of France is covered by agricultural land, and 31.8% is forested [12,13].

According to municipal waste generation – 530 kg per person, France is behind, for example, Germany – (601 kg per person) and other highly developed European countries. This resource is a valuable raw material for recycling or energy production, the technologies of which have reached a high level of development in France [14].

**Table 2. Renewable energy resources of France**

Resource/ explanations	Solar Potential (GHI)*	Wind Potential (50 m)*	Hydro energy Potential**	Bio Potential Agricultural area	Bio Potential Forest Area	Municipal Solid Waste
<b>Value</b>	3.0 – 3.5	5.5-6.5	70	51.7	31.8	530
<b>Unit</b>	kWh/m <sup>2</sup> /day	m/s	MW	% of land area	% of land area	kg/per capita/day
<b>Year</b>	2022	2022	2015	2022	2022	2023
<b>Source</b>	[9]	[10]	[11]	[12]	[13]	[14]

\*for most of the territory of the country

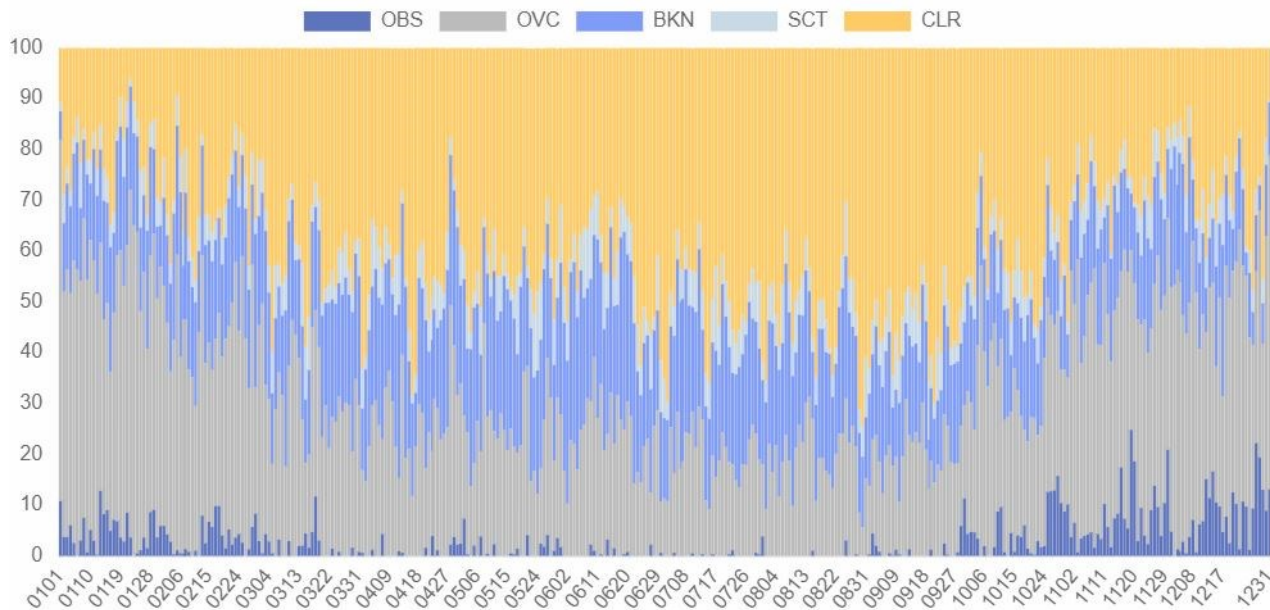
\*\*economically exploitable capability



## FRANCE, CHATEAUDUN

Latitude: 48.06, Longitude: 1.38

### Average daily sky coverage over 10 years of observations, %



CLR - clear, SCT - scattered from 1/8 TO 4/8, BKN - broken from 5/8 TO 7/8, OVC - overcast, OBS - obscured, POB - partial obscuration

Source: based on NOAA U.S. Department of Commerce

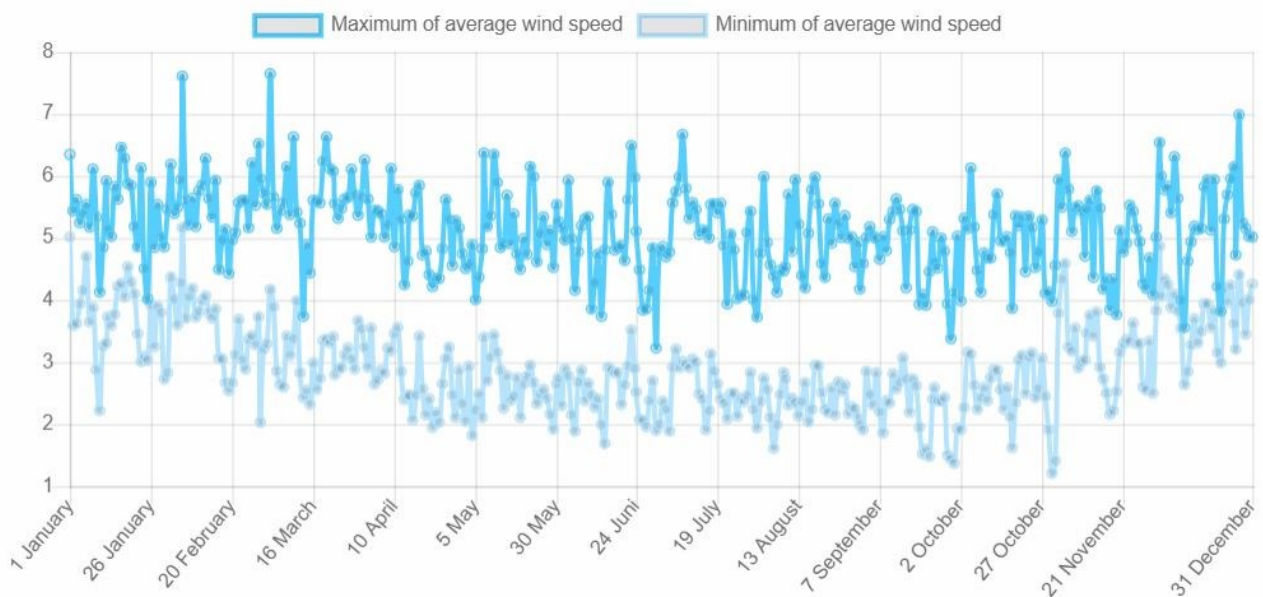
Detailed information: [Interactive map of solar resources](#)

## FRANCE, CHATEAUDUN

Latitude: 48.06, Longitude: 1.38

Average speed: 3.94 m/s, Operational share: 65%

### Average daily wind speed for 10 years of observations, m/s, 10 m above the ground



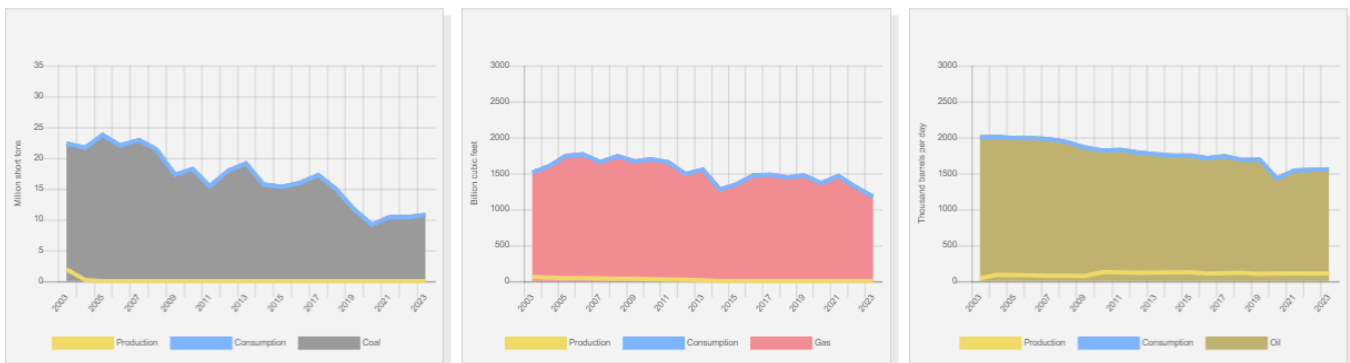
Source: based on NOAA U.S. Department of Commerce

Detailed information: [Interactive map of wind resources](#)

## Energy balance

According to the Statistical Review of World Energy 2024, primary energy consumption in France in 2023 totalled 8.66 Exajoules and was dominated by nuclear energy at 35%, followed by oil – 31.9%, natural gas – 14%, renewable energy – 11%, hydroenergy – 6%, and coal – 2.1%[15]. According to [6], in 2023 in France, the total primary energy production was 3.894 quadrillion Btu, while consumption was at 8.438 quadrillion Btu. Thus, the share of domestic production in primary energy

consumption was 46.15%. This shows that France is a country dependent on energy imports. Oil production between 2010-2023 remained relatively stable, reaching 106.5 thousand barrels/day [6]. The volume of oil consumption in the country since 2008 has been showing a decline (Fig. 2) and in 2023 amounted to 1 554 thousand barrels/day [6]. The Energy Institute reported that oil consumption in 2023 reached 1 430 thousand barrels/day [15]. Oil imports to France in 2020 were 663 thousand barrels/day [3].



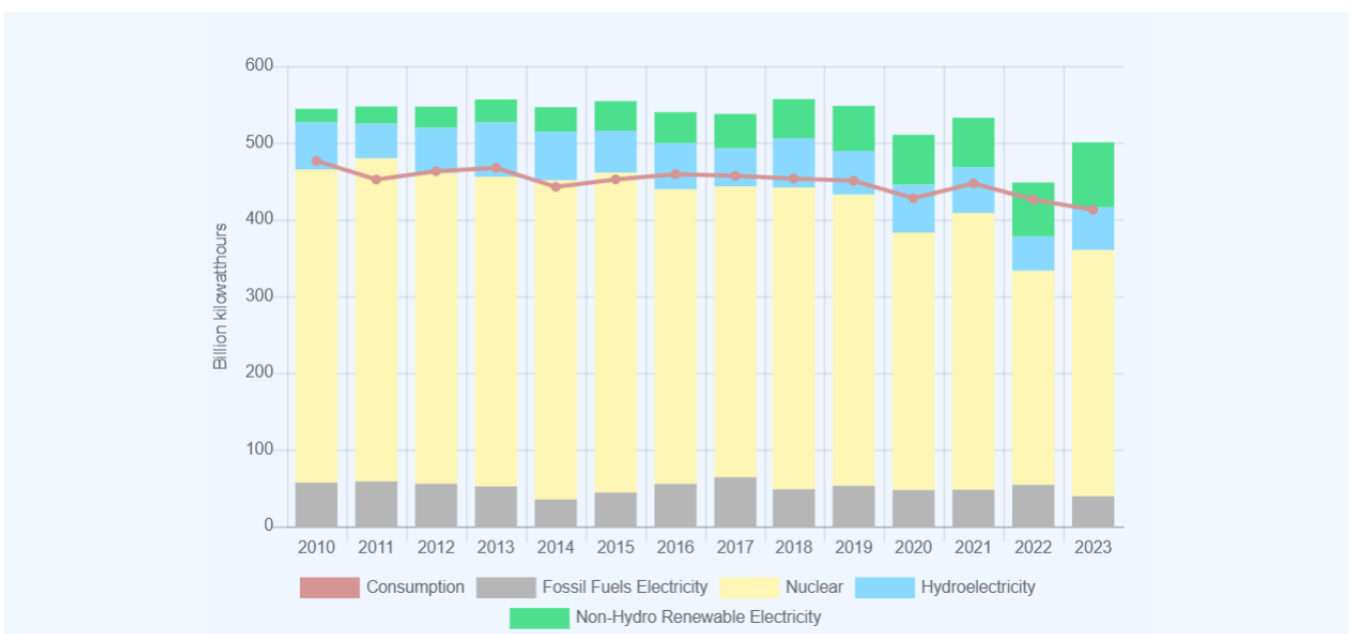
Source: U.S. Energy Information Administration (Sep 2024) / <https://www.eia.gov/>

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

Gas consumption between 2001-2017 remained relatively stable, with minor deviations, not exceeding 1 763 Bcf. However, a slight decline began in 2011 and this decline accelerated in 2021 (Fig. 2) and in 2023 natural gas consumption reached 1174 Bcf, compared with 1 552 Bcf in 2013 [6].

According to the Statistical Review of World Energy June [15] gas consumption in 2023 was estimated at 33.9

Bcm. France imported 1,657 Bcf of natural gas in 2023 [6]. Coal consumption in the country gradually decreased between 2005 - 2023, with annual fluctuations, and in 2023 was 10.74 million short tons [6] and in 2023, according to the Statistical Review of World Energy report, 0.18 Exahoules [15]. Historically, France has a high share of atomic energy electricity production (Figure 3).

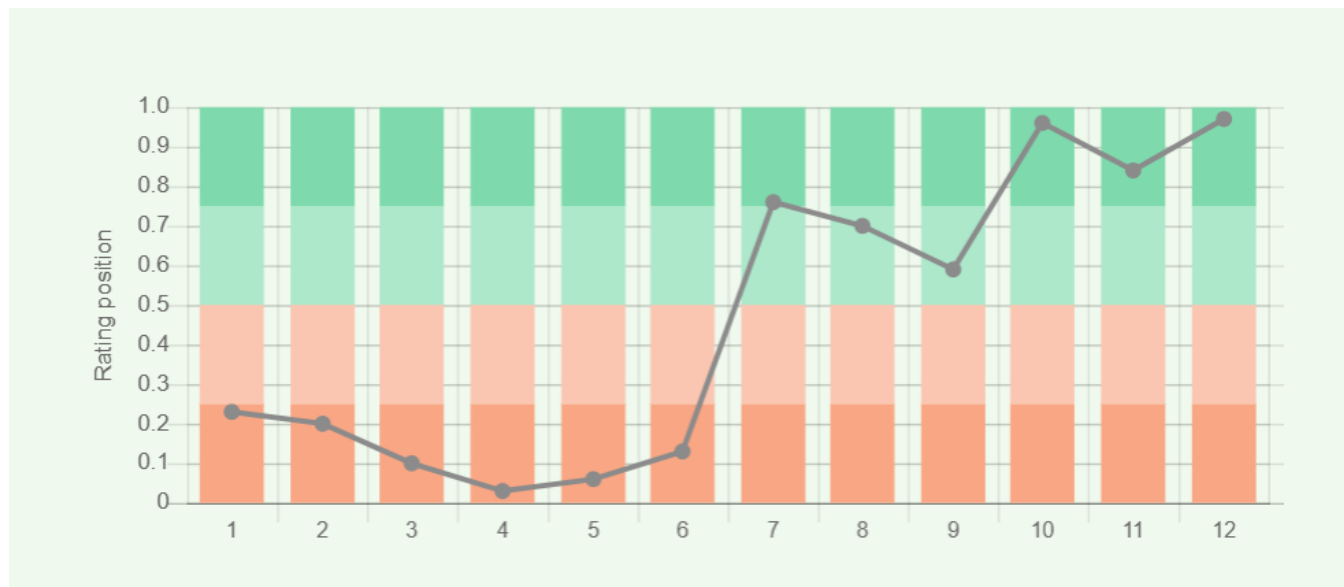


Sources: U.S. Energy Information Administration (Sep 2024) / <https://www.eia.gov/>

Figure 3. Electricity production in France

Electricity production in 2023 decreased to 501.93 TWh (10% down compared to 2018) [6]. According to the Ministère de l'Environnement, de l'Énergie et de la Mer (Ministry of the Environment, Energy and the Sea) total electricity production in 2023 was 494,3 TWh, of which 64,8% was generated by nuclear energy, 11,9% by hydroenergy, 6,6% by fossil fuels, 10,3% by wind energy,

and 6.4% by other renewable sources [16]. Slightly different data on the production of electricity from renewable sources was presented by the International Renewable Energy Agency (IRENA) (Fig. 7). France's position in the comparative diagram of energy index is shown in Figure 4.



Sources:

1. Crude oil proved reserves, 2021 / International Energy Statistic/Geography / U.S. Energy Information Administration (Nov 2021)\*98
2. Natural gas proved reserves 2021 / International Energy Statistic / Geography / U.S. Energy Information Administration (Nov 2021) \*99
3. Total recoverable coal reserves 2019 / International Energy Statistic / Geography / U.S. Energy Information Administration (Nov 2021) \*81
4. Combination production-consumption for Crude oil 2018 / International Energy Statistic / Geography / U.S. Energy Information Administration (Nov 2021) \*219
5. Combination production-consumption for Natural gas 2019 / International Energy Statistic / Geography / U.S. Energy Information Administration (Nov 2021) \*123
6. Combination production-consumption for Coal 2019 / International Energy Statistic / Geography / U.S. Energy Information Administration (Nov 2021) \*128
7. Electricity – from other renewable sources (% of total installed capacity), 2017 est. / The World Factbook / Library / Central Intelligence Agency \*170
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
10. The Global Energy Architecture Performance Index Report (EAPI) 2017 / Rankings / Reports / World Economic Forum
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 France

As previously mentioned, France does not have significant reserves of fossil resources, so the first six indices have extremely low rates. The volume of explored fossil resources is many times behind the level of their consumption in France, which has stimulated the development of energy-saving technologies and renewable energy. Other indices have high indicators and correspond to the level of energy development in France. In terms of the share of electric generation from renewable resources (excluding hydropower), France was 41<sup>st</sup>, among the 170 countries selected for consideration.

For the indicator GDP per unit of energy, France is above the world average – 20<sup>th</sup> place, the index of energy use

per capita is similar – 27<sup>th</sup>, among 66 countries considered. Despite the scarcity of its resource base, France is in the top quarter of the ranking of countries for energy consumption per capita, although considerably behind leading countries such as Qatar and Iceland. It should also be noted that in the last decade this indicator has decreased by almost 15%. In terms of electricity consumption per capita, the country is 35<sup>th</sup> in the world, however, for combined electricity production-consumption, France is 6<sup>th</sup> in the ranked list of 216 countries.



## Energy Infrastructure

A territorial map showing the distribution of the largest infrastructure projects of the fossil fuel sector in France is shown in Figure 5. In the total potential of natural resources, oil amounts to around 54.6%, and natural gas to 45.4% (Fig.5). The main oil fields are concentrated in the

region of the capital, and in the south-west of the country. The Paris Basin accounts for 62.6% of oil production, and the Aquitaine and Alsace basins account for 36.9% and 0.5%, respectively [17]. French refineries, which are mainly concentrated in the Paris and southern regions, have a total installed capacity of 1 248 million barrels/day (Fig. 5).



Chemical industry factory details at night, France. Envato Elements. DZKMCYXS2G

The country's largest refinery is in Normandy (Gonfreville l'Orcher), and is owned by Total, with an installed capacity of 350 000 barrels/day [18]. The main oil terminal is in Marseille (12 million tons), and the main oil storage facility is in Le Havre (4 000 000 m<sup>3</sup>) [19,20]. Refineries and large consumers in France are connected via pipelines for the transportation of petroleum products with a total length of 5 084 km. Crude oil is transported via oil pipelines with a total length of 2 939 km (Fig. 5). Natural

gas fields are mainly located in the region of Paris and in the south of the country. The largest gas storage facility is Trois-Fontaines (2 080 million m<sup>3</sup>) [21]. Imported gas is carried through LNG terminals, the largest of which is Fos Tonkin Elengy (620 000 m<sup>3</sup>). Dunkerque LNG Terminal, with a volume of 570 000 m<sup>3</sup> [22], is under construction, and gas is transported internally through a pipeline network of 15 322 km in length (Fig. 5).

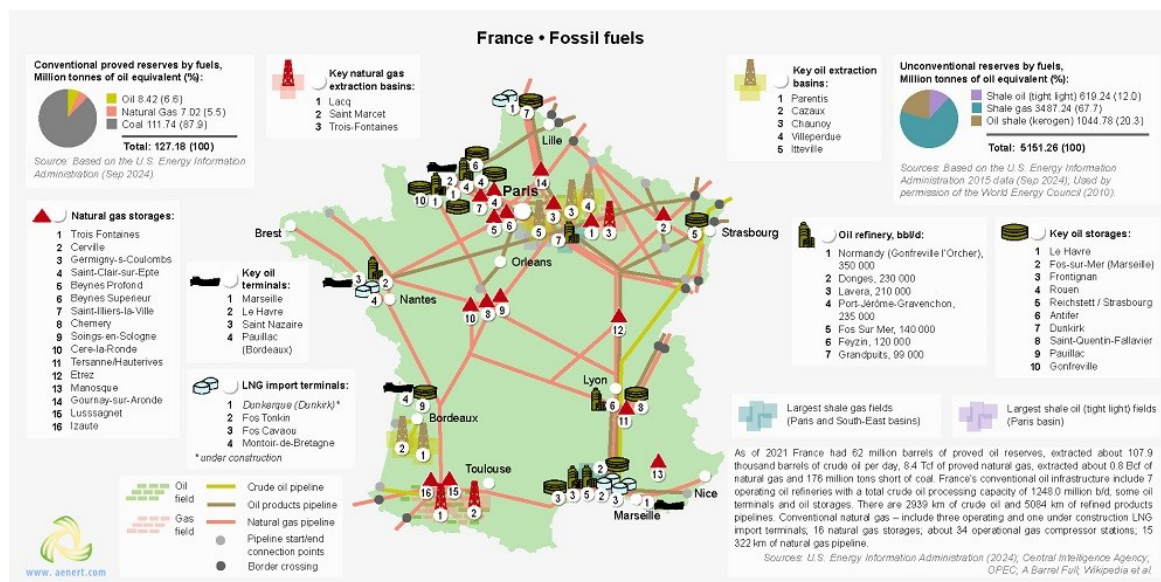


Figure 5. Basic infrastructural facilities of the fossil fuel sector in France

The shale gas reserves in the country are 67.7%, oil shale accounts for 20.3%, and the reserves of tight oil are 12% of the total potential of unconventional resources. The main fields of these types of resources are also located in the area of the capital, however, they are not being developed due to the legislative ban. Figure 6 shows the

most important facilities in France producing electrical energy. According to the Réseau de Transport d'Électricité (Electricity Transmission Network), the share of fossil fuels in electricity production in France in 2023 was only 6.6% (Fig.6).

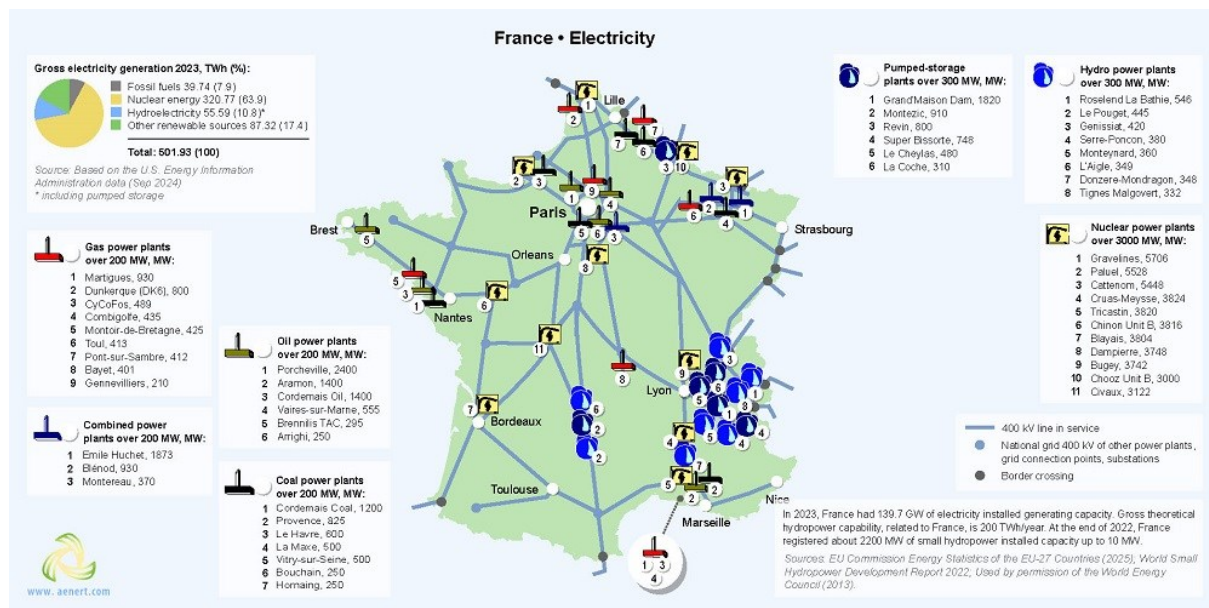


Figure 6. Electricity production in France

The country has a significant number of stations for the production of electricity from hydrocarbons, including power plants with a capacity of more than 200 MW, including six oil, nine gas and three combined-type power plants, as well as a large number of less powerful stations (Fig.6). The largest gas power plant is Martigues, with total capacity of 930 MW [23]; the largest oil power plant is Porcheville, with installed capacity of 2 400 MW; largest combined-

type – Emile Huchet with a capacity of 1 873 MW; and the largest coal – Cordemais Coal, with an installed capacity of 1 200 MW [24,25,26]. The main volume of electricity in the country is produced by nuclear power plants, including 11 large nuclear power plants with a capacity of more than 3 000 megawatts; the most powerful of them is Gravelines (5 706 MW) [27]. Hydropower in France does not have a significant share in the total generation of electricity; it is represented by

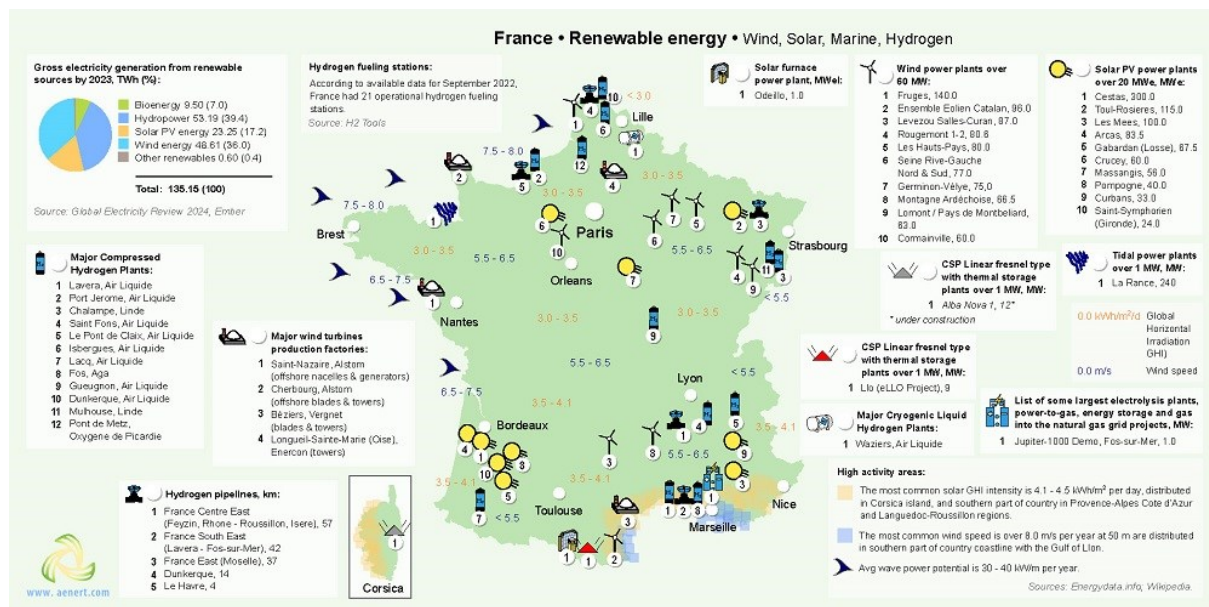


Figure 7. Renewable energy in France: wind, solar, marine, hydrogen



several hydro and pumped storage power plants, which in 2023 produced 55.6 TWh (Fig. 6). The largest hydroelectric power plant is Roselend La Bathie with an installed capacity of 546 MW [28]; and the largest pumped storage power plant is Grand Maison Dam, with an installed capacity of 1 820 MW [29].

In Figure 7, you can see the main facilities of the France infrastructure for the production of energy from renewable sources.

As noted above, with the exception of hydropower, renewable energy in France does not have a significant share in total electricity generation. The total production of electricity from renewable sources in 2023, excluding hydropower, amounted to 81.97 TWh (Fig. 7). Around the capital in the north-east of the country, in zones of relatively high wind activity, there are 10 large wind parks with a capacity of more than 60 megawatts each, as well as a large number of smaller facilities. In 2021 there were more than a thousand wind farms in France with a total installed capacity of 22 200 MW. In February 2022, the leadership of the country announced that by 2050 France should build 50 offshore wind farms with a total capacity of at least 40 GW [30]. The largest of the French wind parks is Fruges with an installed capacity of 140 MW, in which 70 Enercon E70 wind turbines are installed [31]. There are also several large factories producing wind turbines and components, among them Alstom in Saint Nazaire, which manufactures generators, gondolas and other equipment for offshore wind farms [32]. As mentioned earlier, the level of horizontal solar radiation in some areas of the country can reach 4.5 kWh/m<sup>2</sup>,

which is a low, but sufficient resource for the production of energy through photovoltaics [10]. Consequently solar energy facilities have been constructed on this territory, including 10 photovoltaic stations with a capacity of more than 20 MW each (Fig. 7). In 2015, the largest European photovoltaic park, Cestas, was opened in 2015 with an installed capacity of 300 MW, which covers an area of 250 hectares near the city of Bordeaux [33]. The Llo Solar Thermal Project has an installed capacity of 9 MW; and uses Fresnel's linear parabolic concentrators and a thermal energy storage facility that is located in an area of 35 hectares in the eastern Pyrenees [34]. In the north of France and in coastal regions, the potential of tidal energy can reach 30-40 kW/m per year (Fig. 7). At the mouth of the River Rance in Brittany, there is a 240 MW tidal La Rance hydro power station, which was built in 1966 and has 24 reversible bulb hydrounits (turbine/pump + generator/motor) and an annual generation capacity of 540 GWh [35]. France is one of the leading countries in Europe for the production and use of hydrogen as an energy source for vehicles. As of December 2019, 18 hydrogen filling stations were in operation in the country (Fig. 7). France has more than a dozen hydrogen production plants, the largest of which is Lavera (25 000 Nm<sup>3</sup>/h), Air Liquid [36]. The cryogenic plant for liquid hydrogen Waziers, also owned by Air Liquid, has an installed capacity of 4 864 Nm<sup>3</sup>/hr [37]. Hydrogen is transported through several pipelines with a total length of 140 km (Fig. 7).

Figure 8 shows the main bioenergy facilities of France for energy production.

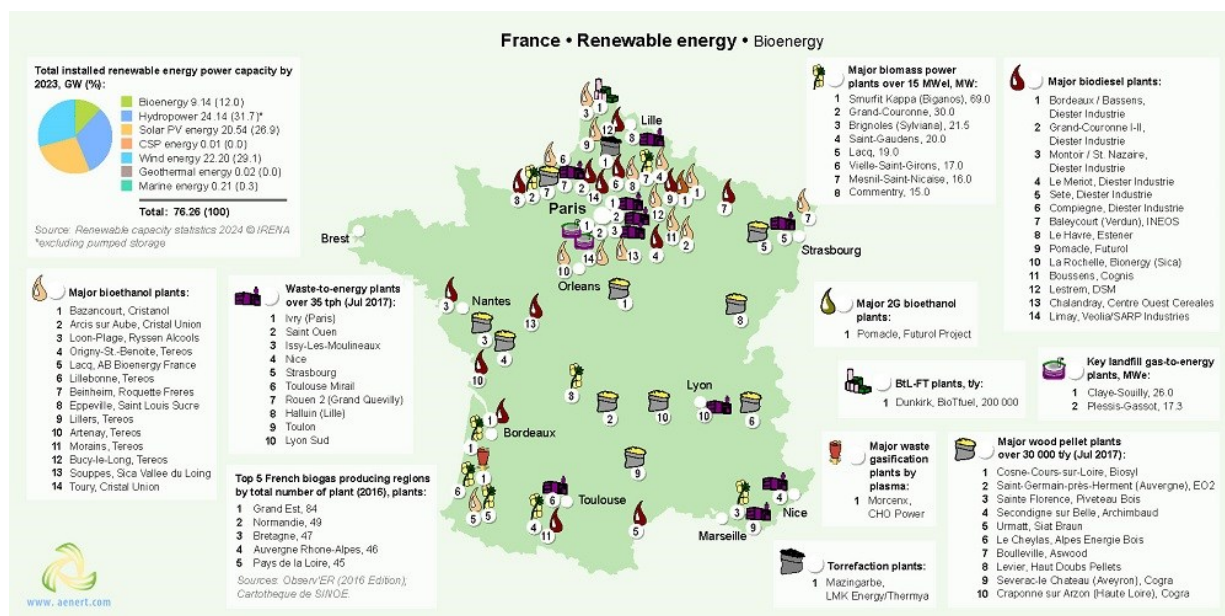


Figure 8. Renewable energy in France: bioenergy

Bioenergy is being actively developed in France and, according to 2023 data, the installed capacity of bioenergy is 9.14 GW (Fig. 8). The country has biomass and municipal waste processing plants, biogas, biodiesel, bioethanol, pellet and landfill gas. Biganos owns the largest biomass processing plant, Smurfit Kappa, with an installed capacity of more than 69 MW [38]. Claye-Souilly Landfill Gas-to-Energy Plant generates about 26 MW of electricity from landfill gas [39].

Cristanol produces 200 million tons of bioethanol annually, at the largest enterprise in the country – Bazancourt [40]. Pomacle, a second generation bioethanol production plant, produces 180 000 litres of fuel per year [41]. The main French enterprises in energy production from biomass are: Bordeaux/Bassens, which produces about 283 million tons of biodiesel annually [42]; Morcenx waste gasification plant by plasma with an installed capacity of 12 MW [43]; and Cosne-Cours-sur-Loire, which produces 120 000 tons of pellets annually [44]. The leader in the generation of electricity from municipal waste is Ivry (Paris) with an installed capacity of 100 tons per hour [45]. Mazingarbe Torrefication Plant produces about 20 000 tons, the BtL-FT Dunkirk plant with an installed capacity of 200 000 tons of biofuel/year is under construction [46,47]. France has taken the lead in negotiations on climate change, and was also one of the first countries to adopt the Energy Transition for Green Growth Act in 2014. The main priorities of France's energy policy are to reduce the share of nuclear power in the production of electricity from 70% to 50% by 2035, and to increase the share of renewable energy sources in total energy production. In this regard, French EDF, the largest energy company, will have to reduce the capacity, when its new Flamanville 3 EPR nuclear power plant, starts commercial operation, at least by 1 650 GW. In 2015, RTE began work on a 1 200-MWe underground high-voltage transmission line (HVDC line), the end point of which will be Turin in Italy [48].

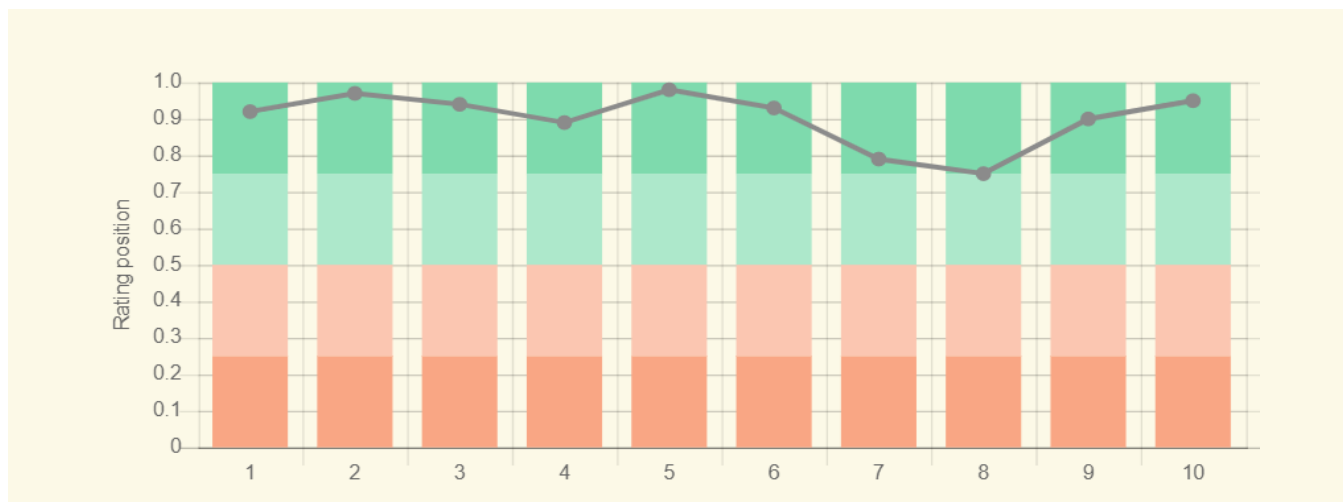
The Energy Transition for Green Growth Act is already bearing fruit – 2016 was one of the most successful years for the French wind power industry. According to the French Wind Energy Association FEE, a stable policy and legal framework resulted in 45% growth (1 560 MW) of installed wind power capacity [49]. In 2017, Nordex received orders for the construction of four wind parks in France with a total capacity of more than 40 MW [50,51]. In the field of geothermal power, it is worth noting the activities of Fonroche, which is implementing 8 projects in France.

For example, Vendenheim geothermal power plant near Strasbourg will have a capacity of 30 MW and provide heat for about 10 000 households. In addition, the company oversees two geothermal projects in the south, including a 5.5 megawatt power plant [52]. As previously mentioned, bioenergy is being actively developed in France and by 2020 the revenues from bioenergy should amount to 920 million euros, which is more than double the figure from 2015. By 2020 it was also planned to put in operation about 1 000 anaerobic stations [53]. To this end the Italian company SEBIGAS, which successfully completed the construction of the Gramat plant in 2016, has received an order for two more anaerobic plants with a capacity of 2 400 Nm<sup>3</sup>/h and 950 Nm<sup>3</sup>/h, respectively [54]. Schmack Biogas is implementing a biogas plant project that will have a capacity of 250 Nm<sup>3</sup>/h, but the plant design already has a capacity expansion project of up to 500 Nm<sup>3</sup>/h [55]. Notable in the field of hydropower is an increase in the capacity of the existing La Coche pumped storage station by 240 MW. The implementation of the project began in 2019 and its cost is estimated at 25 million euros [56]. The French Environment and Energy Management Agency (ADEME) in 2014 funded the Normandie Hydro project, which includes the installation of seven tidal turbines, with a capacity of 14 MW. The turbines are planned to be installed on the northwestern shelf of France's Cotentin peninsula in the Raz Blanchard Strait, the potential of which is estimated to be from 1 to 3 GW [57].

## Education and Innovation

The set of indices reflecting the position of France among other countries in the field of education and innovation can be seen in Figure 9. As follows from the dia-

grams presented, France is a country with a very high level of education and innovation. According to the Index of Global Innovation 2021, France is 12<sup>th</sup> out of 133 countries (see the diagram for links).



Sources:

1. The Global Innovation Index 2021, Rankings / Knowledge / World Intellectual Property Organization / Cornell University, INSEAD, and WIPO (2021): Energizing the World with Innovation. Ithaca, Fontainebleau, and Geneva \*132
  2. Patent Grants 2011-2020, resident & abroad / Statistical country profiles / World Intellectual Property Organization \*185
  3. Patents in Force 2020 / Statistical country profiles / World Intellectual Property Organization \*109
  4. QS World University Rankings 2022 \*97
  5. SCImago Country Rankings (1996-2020) / Country rankings / SCImago, (n.d.). SIR-SCImago Journal & Country Rank [Portal]. Retrieved 17 Nov 2021 \*240
  6. Internet users in 2018 / The World Factbook / Central Intelligence Agency \*229
  7. Internet users in 2018 (% Population) / The World Factbook / Central Intelligence Agency \*229
  8. Government expenditure on education, total (% of GDP), 2019 / United Nations Educational, Scientific, and Cultural Organization (UNESCO) Institute for Statistics. License: CC BY-4.0 / Data as of September 2021 \*177
  9. Research and development expenditure (% of GDP), 2018 / UNESCO Institute for Statistics. License: CC BY-4.0 / Data \*119
  10. Scientific and technical journal articles, 2018 / National Science Foundation, Science and Engineering Indicators. License: CC BY-4.0 / Data \*197
- \* Total number of countries participating in ranking

Figure 9. The indices of education and innovation in France

According to the number of patents granted to French nationals, both domestically and abroad, the country ranks 6<sup>th</sup> in the world. Similarly, by the number of patents in force, the country was 7<sup>th</sup> in the world, indicative of France's favorable conditions for innovation.

In terms of government expenditure on education as a percentage of GDP, the country demonstrates a result that is significantly higher than the world average – 45<sup>th</sup> out of 177 countries selected for consideration. 35 French universities are included in the QS University Rating 2024. It should also be noted that the country's GDP is high, therefore in absolute terms the costs of education and research are very significant. In the ranking of countries in terms of research and development expenditure, as a percentage of GDP, the country is 12<sup>th</sup> place, behind a number of European countries, including Austria and Germany. France is well positioned when considering the number of publications of specialists in scientific and technological journals and patent activities. In the Scimago ranking the country is 6<sup>th</sup>, out of the 240 participating countries; similarly in the ranking of Scien-

tific and Journal Activities France ranked 10<sup>th</sup> out of 197 countries. The country is also among the leaders in the region in terms of the number of Internet users. French universities, such as the National Graduate School of Engineering Chemistry of Lille, the National Polytechnic Institute of Toulouse, Joseph Fourier University, the Graduate Engineering School of University Montpellier, and Centrale Supélec train specialists in various fields of energy, including Mechanical Engineering, Energy, Engineering and Industrial Management Systems, Electric Energy, etc. IFP Institut Français du Pétrole, Air Liquide and IFP (École nationale supérieure du pétrole et des moteurs) actively patent their inventions in the sector of synthetic fuel technologies; Research in this area is carried out by the Université de Lille, IFP (École nationale supérieure du pétrole et des moteurs).

In the field of extraction and processing of non-traditional oil, patents for technical solutions are provided by Services Pétroliers Schlumberger, IFP Institut Français du Pétrole. Total SA, IFP (École nationale supérieure du pétrole et des moteurs) are also actively engaged in



research in this field. Services Petroliers Schlumberger is the leading patent holder in the field of coalbed methane, gas hydrates and hydrocarbon production from low permeability reservoirs, Total SA is also engaged in research in these areas. In the field of associated gas, according to the number of patents, IFP Institut Français du Pétrole is leading, and by the number of publications – Total SA and International Energy Agency.



*Air Transport - Airbus A300-600T Beluga. Envato Elements. C2FPSVR54X*

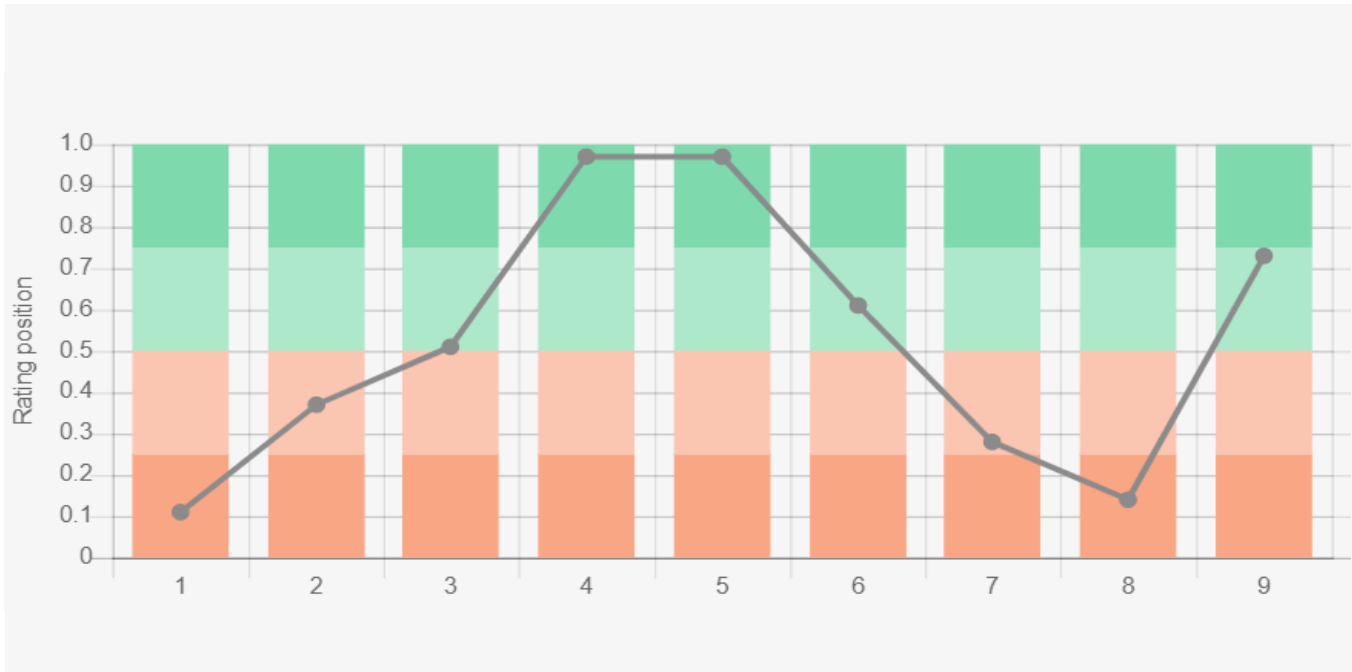
The patent holders in bioenergy technologies are IFP (École nationale supérieure du pétrole et des moteurs), Commissariat à l'énergie atomique et aux énergies alternatives, IFP Institut Français du Pétrole. Scientific research in the same field is conducted by INRA Institut national de la recherche agronomique, and Université de Lorraine. A large number of companies patent inventions and conduct research in the field of renewable energy technologies. In the field of solar energy - Commissariat à l'énergie atomique et aux énergies alternatives, Le centre national de la recherche scientifique (CNRS). Among the universities: Le national de la recherche scientifique (CNRS), the University of Perpignan, PROMES CNRS are in the lead in the number of publications in this field.

In the field of wind power, Alstom Renewable Technologies and IFP (École nationale supérieure du pétrole et des moteurs) are the leaders in the number of patents, and research is carried out by the Université de Lorraine.

## Ecology and Environment Protection

A diagram of environmental indices is shown in Figure 10.

The indices presented in the diagram, to some extent, give an opportunity to assess the ecological situation in the country. The country demonstrates a relatively high level of CO<sub>2</sub> emissions, both in general and per capita.



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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  3. Forest area 2020 (% of land area) / The Global Forest Resources Assessment 2020 / Food and Agriculture Organization of the United Nations \*234
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  5. The Environmental Performance Index (EPI) 2020 / Rankings / Yale Center for Environmental Law & Policy / Yale University \*180
  6. Annual freshwater withdrawals (m3 per capita), 2017 \*179
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  9. The Climate Change Performance Index (CCPI) 2022 / Overall Results / Jan Burck, Thea Uhlich, Christoph Bals, Niklas Höhne, Leonardo Nascimento / Germanwatch, NewClimate Institute & Climate Action Network \*60
- \* Total number of countries participating in ranking

Figure 10. France's environmental indices

In 2014, the level of CO<sub>2</sub> emissions in the process of coal mining and processing amounted to 11 mt, which is considerably less than, for example, in Poland – 129 mt and Germany – 256 mt [58]. On average, France spends more than 7 billion euros (health costs, pollution costs) and Germany 37 billion euros to eliminate the consequences of such emissions [58]. It is also necessary to note a high level of methane emissions. France ranked 37<sup>th</sup> in the list of 61 countries responsible for more than 90% of global CO<sub>2</sub> emissions related to energy in the Climate Change Performance Index (CCPI-2024). The two remaining coal-fired power plants located in Cordham and St. Avold, originally scheduled to close by the end of 2023, have

been granted permission to continue operating through the end of 2024 [59].

In terms of forest area relative to the total area of the country, France is 114<sup>th</sup> in the world, but the trend indicating its change looks very positive; according to this indicator the country is placed 8<sup>th</sup> in the world. The preservation of forests is a priority for the state. The situation is also brightened by a very high valuation of France in the Environmental Performance Index rankings (EPI-2024), which focuses primarily on assessing the environmental performance of national governments. Here, France is 12<sup>th</sup> out of 180 countries.



*Aerial beautiful view of a hill on the shore overlooking the beach and the sea in Etretat, France. Envato Elements. 2KS8TXF9ND*

The overall negative picture is highlighted by the Ecological Footprint Atlas rating, according to which France is among a number of ecological debtors. Brazil also belongs to a group of countries with very high levels of methane emissions.



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

*[For more information about the energy industry in France see here](#)*