# ENERGY OUTLOOK & NUCLEAR ENERGY AS OF OCTOBER 2022

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## INTRODUCTION

In keeping with the tradition started in 2008, this article informs about the contribution of nuclear power generation to the world energy market in 2021 and the detailed results up to October 2022. After a quick, simplified analysis of the world energy framework focused on primary energy consumption in 2021, nuclear power production both in the world and in Spain is discussed in greater detail. This article details the results of the world nuclear fleet by country and by reactor type, the continued operation of those plants, the new plants that have been planned and proposed, and the emissions they prevent. Everything is rounded off with a general commentary that assesses the situation of nuclear energy in the energy field.

## PRIMARY ENERGY CONSUMPTION

### The Situation in the World

Based on data from the June *2022 BP Statistical Review of World Energy* report, world primary energy consumption in the 2020-2021 biennium is shown in Table 1 broken down into the different sources.

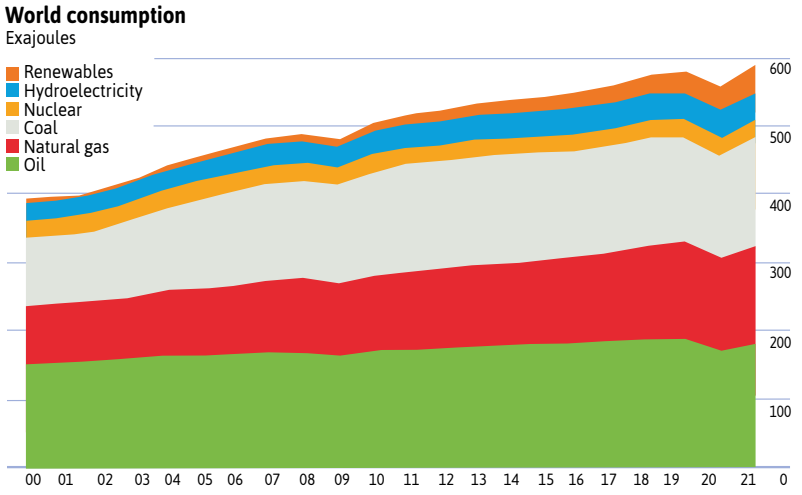
In 2021, primary energy **consumption reached 595.15 EJ**, which represents a 31.14 EJ increase compared to the year before, something which is explained by the economic recovery that took place after the Covid-19 pandemic. Fossil fuels continue to play a leading role (489.66 EJ and 82.28% of the energy mix), the growth rates of China (+7.1%) and of the consumption of renewable energy (+15.0%) standing out. In the global breakdown by country, the **biggest consumers** were China, with 26.5% of total consumption, and the U.S.A., with 15.6%; together they accounted for 42% of the world's energy consumption, followed at a distance by India (6.0%), Russia (5.3%) and Japan (3.0%). In the EU-27, whose countries were responsible for 10.1% of total consumption, Germany accounted for 2.1%, France for 1.6%, Italy for 1.1% and Spain for 0.9%. On the other hand, the UK's consumption represented 1.2% of the total.

The **growth rate was 5.8%**, i.e. there was a recovery after the impact of Covid-19; the annualized value for the last 10 years was 1.3%. The leading role of renewables, with a 15% share, is worth noting. By **economic zone**, growth rates were again positive in OECD countries (4.7%), non-OECD

| Year | Oil | Natural gas | Coal | Nuclear | Hydro | Renewables | Total |
|---|---|---|---|---|---|---|---|
| 2020 | 174.17 | 138.44 | 151.07 | 24.44 | 41.09 | 34.80 | 564.01 |
| 2021 | 184.21 | 145.35 | 160.10 | 25.31 | 40.26 | 39.91 | 595.15 |
| Δ 2021/2020 | 6,1 % | 5.3 % | 6.3 % | 3.8 % | -1.8 % | 15.0 % | 5.8 % |
| ***Mix* 2021** | **31.0 %** | **24.4 %** | **26.9 %** | **4.3 %** | **6.8 %** | **6.7 %** | **100 %** |

Data in exajoules (EJ). 1 EJ = $10^{18}$ joules
Source: *BP Statistical Review of World Energy* June 2022 and own calculations.

**Table 1.** Primary energy consumption in the world.




Source: *BP Statistical Review of World Energy. June 2022.*

**Figure 1.** Evolution of the cumulative primary energy consumption in the world by source.

countries (6.5%) and EU-27 countries (5.6%). By **geographical area**, this index experienced similar growth in North America (4.8%) and Europe (4.7%), whereas in the CIS it was 7.9% and in Central and South America 7.0%. Similar values were seen in the Asia-Pacific and Africa (6.4% and 6.2% respectively), while the Middle East grew 3.7%. **In the five countries with the greatest consumption in the world**, the rates were as follows: China (7.1%), the U.S. (5.3%), India (10.4%), Russia (8.7%) and Japan (3.8%). In the EU-27, the figures for Germany (2.6%), France (6.5%), Italy (7.6%) and Spain (8.2%) are worth mentioning. On the other hand, the UK had a 2.0% consumption rate.

**Fossil fuels** met **82.3% of demand and grew 5.6%. Oil** demand, which represented 31.0% of the total energy demand, had a growth rate of 6.1% EJ (2.56 B/day). In OECD countries, which account for 45.4% of all the oil consumed in the world, this rate was 6.5%, whereas it stood at 5.7% in non-OECD countries and 5.6% in the EU-27. The U.S. was the world's biggest energy consumer, with 19.2% of the total, followed by China (16.6%) and India (5.1%). **Coal** was second only to oil, it being the source of 26.9% of all energy consumed in the world; however, it saw a 6.3% increase. In non-OECD countries, which consume 81.5% of all coal in the world, the growth rate was 5.8%, in OECD countries, 8.3%, and in the EU-27, 13.2%. China is the world's biggest consumer of coal, with 53.8% of the total, followed by India with 12.5% and the U.S. with 6.6%. **Gas**, which accounted for 24.4% of global energy consumption, grew 5.3%. In OECD countries, which consume 44.5% of all the gas in the world, the growth rate was 2.3%, whereas consumption rose 7.8% in non-OECD countries and 4.6% in the EU-27. The biggest gas consumers were the U.S. (20.5%), Russia (11.8%), China (9.4%) and Iran (6.0%).

**Nuclear** provided 4.3% of the energy consumed in the world and experienced a 3.8% increase. **Hydropower** shrunk by 1.8% and accounted for 6.8% of the world's energy consumption. The **other renewables** (wind, solar, geothermal and biomass), which met 6.7% of the world's energy demand, grew by 15%. With respect to renewables, the growth rate was 7.9% in OECD countries (52.9% of consumption), 24.2% in non-OECD countries and 2.9% in EU-27 countries (19.8% of consumption). Figure 1 shows the evolution of cumulative primary energy consumption in the 2000-2021 period.

The average price of a barrel of European Brent crude oil in 2021 was $70.91, up $29.07 from the average price in 2020. It was the second highest price since 2015. It ended the year at $77.24. The price of **uranium** in long-term contracts aver-

| Year | Coal | Oil | Gas | Nuclear | Renewables | Electricity export/import balance (1) | Non-Renewable Waste | Total |
|---|---|---|---|---|---|---|---|---|
| 2020 | 0.13 | 1.91 | 1.17 | 0.66 | 0.67 | 0.01 | 0.01 | 4.64 |
| 2021 | 0.14 | 2.08 | 1.23 | 0.62 | 0.81 | 0.00 | 0.02 | 4.90 |
| Δ 2021/2020 | 9.42 % | 8.81 % | 5.40 % | -5.89 % | 20.64 % | -73.05 % | 120.75 % | 5.70 % |
| ***Mix* 2021** | **2.9 %** | **42.3 %** | **25.0 %** | **12.6 %** | **16.6 %** | **0.06 %** | **0.5 %** | **100 %** |

Data in exajoules (EJ). (1) Electricity imports minus exports.

Source: Energía 2022 Foro Nuclear with data from MITERD (data from 1990-2019 balance sheets), the Enerclub seminar of 3/31/2022, Foro Nuclear (estimation of non-renewable waste) and own data. The original data expressed in Mtoe (million tons of oil equivalent) were converted to EJ using a factor of 1 Mtoe = 0.04187 EJ.

**Table 2.** Primary energy consumption in Spain.

| Year | Coal | Oil | Natural gas | Renewables | Non-Renewable Waste | Nuclear | Total |
|---|---|---|---|---|---|---|---|
| 2020 | 0.003 | 0.001 | 0.002 | 0.77 | 0.01 | 0.66 | 1.44 |
| 2021 | 0.000 | 0.000 | 0.002 | 0.81 | 0.02 | 0.62 | 1.46 |
| **Self-sufficiency in 2021** | **0.00 %** | **0.00 %** | **0.10 %** | **100 %** | **100 %** | **100 %** | **29.70 %** |

Data in exajoules (EJ).

Source: Energía 2022 Foro Nuclear [MITERD (until 2019) and own data (2020 and 2021, with data from MITERD, Carbunión and other sources)] and own data. A.I.E. Methodology. The original data expressed in Mtoe (million tons of oil equivalent) were converted to EJ using a factor of 1 Mtoe = 0.04187 EJ.

**Table 3.** Primary energy production in Spain and degree of self-sufficiency.

aged 36.8 $/lb $U_3O_8$ in 2021, $2.2 higher than in the previous year. In long-term contracts through September 2022, it averaged 48.9 $/lb $U_3O_8$, $12.1 above the average value in 2021. This huge increase was largely due to Russia's invasion of Ukraine, which greatly disrupted uranium markets.

According to the latest available report from NEA-OECD and the IAEA-UN's *Uranium 2020: Resources, Production and Demand* report, current uranium inventories can meet the demand of the current world nuclear fleet for almost 120 years, taking a price of 130 $/kg U as a point of reference.

## The Situation in Spain

**Primary energy consumption** in Spain grew 0.3 EJ (5.7%) in 2021, up to 4.90 EJ. This consumption is broken down by source in Table 2. The growth of renewables (20.6%) and non-renewable waste (120.7%) is noteworthy. The consumed primary energy mix was comprised of fossil fuels (70.28%) and, at a distance, clean energies (29.65%) nuclear (12.58%) and renewables and waste (17.0%). Spain imported 0.0032 EJ of electricity.

**Domestic primary energy production** in 2021 reached 1.46 EJ, growing 0.98%, and the degree of **self-sufficiency** was 29.70%. This output is broken down in Table 3. Spain's dependence on foreign energy came to 70.30%, higher than the EU-27's average of 57.5% in 2020.

# GLOBAL FOOTPRINT OF NUCLEAR ENERGY

## Nuclear Fleet and Nuclear Power Generation in 2021

As of December 31, 2021, there were **32 countries** in the world where there were nuclear power plants. There were **437 units in operation** in all, five less than in 2020. The total net installed capacity stood at 389,174 MW, 4,141 MW less than the year before. In addition, there were 58 reactors **under construction** in 19 countries —seven more than in the previous year—, representing a total net capacity of 64,483 MW.

2,653 TWh of **net electricity were generated** in 2021, a figure greater than in 2020 (2,553 TWh). This generation accounted for 10.3% of all the electricity generated in the world. In the EU-27, the share of nuclear power in 2020 was close to 25%.

As of December 31, 2021, the net nuclear electric power that had accumulated since the first nuclear reactor was connected to the grid back in 1951 stood at 88,075 TWh.

It is worth mentioning that, of the 32 countries with nuclear power plants, the nuclear power share exceeded 15% in 17 of them and 25% in 13. France (69%), Ukraine (55%), Slovakia (52.3%), Belgium (50.8%), Hungary (46.8%), Slovenia (36.9%) and Sweden (30.8%) stood out among them. The countries with the highest number of plants in operation were the U.S. (92 units), France (56), China (54), Russia (37), Japan (33), South Korea (25) and India (22).

6 reactors **were connected to the grid** in 2021: 1 in the United Arab Emirates (1,345 MW), 2 LWRs and 1 HTR-PM in China (2,261 MW), 1 in India (630 MW) and 1 in Pakistan (1,014 MW). 8 reactors were shut down **once and for all** (3 in the UK, 3 in Germany, 1 in the U.S. and 1 in Pakistan), amounting to 6,758 MW. On the other hand, construction of 10 units (8,836 MW in total) began in four countries: Turkey (1), Russia (1), India (2) and China (6).

From 2000 till the end of 2021 the total net installed capacity increased by 48.581 GW, the number of units by 5 and the electricity generated per year by 40.6 TWh (the exceptional circumstances experienced in 2020 as a result of the Covid-19 pandemic should be taken into account).

## The Situation as of October 1, 2022

So far, 6 units have been **connected to the grid** in 2022, totaling 7,260 MW: 2 in China, 1 in Finland, 1 in South Korea, 1 in Pakistan and 1 in the U.A.E. On the other hand, **6 reactors have started to be built** in Turkey (1 PWR; 1,114 MW) Egypt (1 PWR; 1,194 MW) and China (4 PWRs; 4,695 MW). Conversely, 4 reactors have **ceased operating definitively**: 1 PWR (805 MW) in the U.S. and 3 GCRs (1,460 MW) the UK.

As shown in Table 4, the world's nuclear fleet as of October 1, 2022, consists of 427 units **in operation**, 9 fewer than in October 2021, for a total net capacity of 382,796 MW. This amounts to a decrease of 11,741 MW compared to the same date of the previous year. There are now 56 reactors **under construction** (5 more than the year before) in nineteen countries, adding up to a net capacity of 57,664 MW.

The 427 reactors in operation are divided into six groups by type (the number of units is shown in parentheses):

- PWRs (304 units): They include pressurized water reactors, pressurized heavy-water moderated and cooled reactors and PWR-VVER-type reactors, with a total net capacity of 291,723 MW.
- BWRs (53): They include boiling water reactors and advanced boiling water reactors (ABWRs) of American origin (53,041 MW).
- PHWRs (47): Reactors using pressurized water as coolant and heavy water as moderator (24,314 MW).
- GCRs (8): Gas-cooled and graphite-moderated reactors of British origin; they include the advanced AGR type (4,685 MW).
- LWGRs (or RBMKs) (11): Boiling water-cooled and graphite-moderated reactors (7,433 MW).
- FBRs (3): Sodium-cooled fast breeder reactors (1,400 MW).

Figure 2 shows the number of reactors by years of operation. Two peaks can be seen at 33 and 38 years of operation, which correspond to the entry into operation of a large number of reactors in the 1970s and 1980s, which were built in response to the well-known oil price crises; there has also been an uptick in recent years.

As of October 1, 2022, there were 56 units **under construction** (57,664 MW) in 18 countries: China (18), India (8), Russia (4), Turkey (4), South Korea (3), Bangladesh (2), Japan (2), Slovakia (2), Ukraine (2), the U.S. (2), the UK (2), the U.A.E. (1), Belarus (1), Iran (1), Argentina (1), Egypt (1), Brazil (1) and France (1). Table 5 shows the number of units **under construction by country and reactor type**.

| Country | In operation in 2021 | | | | In operation as of October 2022 | | Under construction as of October 2022 | | Planned as of October 2022 | | Proposed As of October 2022 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Units | Net Capacity (MW) | Net Output (TWh) | % of total | Units | Net Capacity (MW) | Units | Net Capacity (MW) | Units | Gross Capacity (MW) | Units | Gross Capacity (MW) |
| Argentina | 3 | 1,641 | 10.2 | 7.2 | 3 | 1,641 | 1 | 25 | 1 | 1,150 | 2 | 1,350 |
| Armenia | 1 | 415 | 1.9 | 25.3 | 1 | 448 | - | - | - | - | 1 | 1,060 |
| Bangladesh | - | - | - | - | - | - | 2 | 2,160 | - | - | 2 | 2,400 |
| Belarus | 1 | 1,110 | 5.4 | 14.1 | 1 | 1,110 | 1 | 1,100 | - | - | 2 | 2,400 |
| Belgium | 7 | 5,942 | 48.0 | 50.8 | 7 | 5,942 | - | - | - | - | - | - |
| Brazil | 2 | 1,884 | 13.9 | 2.4 | 2 | 1,884 | 1 | 1,340 | - | - | 4 | 4,000 |
| Bulgaria | 2 | 2,006 | 15.8 | 34.6 | 2 | 2,006 | - | - | 1 | 1,000 | 2 | 2,000 |
| Canada | 19 | 13,624 | 86.8 | 14.3 | 19 | 13,624 | - | - | - | - | 2 | 1,500 |
| China | 53 | 50,754 | 383.2 | 5.0 | 55 | 52,170 | 18 | 18,526 | 38 | 42,810 | 158 | 182,500 |
| Czech Republic | 6 | 3,934 | 29.0 | 36.6 | 6 | 3,934 | - | - | 1 | 1,200 | 3 | 3,600 |
| Egypt | - | - | - | - | - | - | 1 | 1,194 | 3 | 3,600 | - | - |
| Finland | 4 | 2,794 | 22.6 | 32.8 | 5 | 4,394 | - | - | 1 | 1,170 | - | - |
| France | 56 | 61,370 | 363.4 | 69.0 | 56 | 61,370 | 1 | 1,630 | - | - | - | - |
| Germany | 6 | 8,113 | 65.4 | 11.9 | 3 | 4,055 | - | - | - | - | - | - |
| Hungary | 4 | 1,902 | 15.1 | 46.8 | 4 | 1,916 | - | - | 2 | 2,400 | - | - |
| India | 23 | 6,885 | 39.8 | 3.2 | 22 | 6,795 | 8 | 6,028 | 12 | 8,400 | 28 | 32,000 |
| Iran | 1 | 915 | 3.2 | 1.0 | 1 | 915 | 1 | 974 | 1 | 1,057 | 5 | 2,760 |
| Japan | 33 | 31,679 | 61.3 | 7.2 | 21 | 19,797 | 2 | 2,653 | 1 | 1,385 | 8 | 11,562 |
| Jordan | - | - | - | - | - | - | - | - | - | - | 1 | 100 |
| Kazakshtan | - | - | - | - | - | - | - | - | - | - | 2 | 600 |
| Lithuania | - | - | - | - | - | - | - | - | - | - | 2 | 2,700 |
| Mexico | 2 | 1,552 | 11.6 | 5.3 | 2 | 1,552 | - | - | - | - | 3 | 3,000 |
| Pakistan | 5 | 2,332 | 15.8 | 10.6 | 6 | 3,256 | - | - | 1 | 1,170 | - | - |
| Poland | - | - | - | - | - | - | - | - | - | - | 6 | 6,000 |
| Romania | 2 | 1,300 | 10.4 | 18.5 | 2 | 1,300 | - | - | 2 | 1,440 | 1 | 720 |
| Russia | 38 | 27,653 | 208.4 | 20.0 | 37 | 27,727 | 4 | 3,759 | 25 | 23,525 | 21 | 20,100 |
| Saudi Arabia | - | - | - | - | - | - | - | - | - | - | 16 | 17,000 |
| Slovakia | 4 | 1,837 | 14.6 | 52.3 | 4 | 1,868 | 2 | 880 | - | - | 1 | 1,200 |
| Slovenia | 1 | 688 | 5.4 | 36.9 | 1 | 688 | - | - | - | - | 1 | 1,000 |
| South Africa | 2 | 1,860 | 12.2 | 6.0 | 2 | 1,854 | - | - | - | - | 8 | 9,600 |
| South Korea | 24 | 23,150 | 152.6 | 29.6 | 25 | 24,431 | 3 | 4,020 | - | - | 2 | 2,800 |
| Spain | 7 | 7,121 | 54.2 | 20.8 | 7 | 7,121 | - | - | - | - | - | - |
| Sweden | 7 | 7,740 | 51.4 | 30.8 | 6 | 6,882 | - | - | - | - | - | - |
| Switzerland | 4 | 2,960 | 23.0 | 32.9 | 4 | 2,960 | - | - | - | - | - | - |
| Thailand | - | - | - | - | - | - | - | - | - | - | 2 | 2,000 |
| The Netherlands | 1 | 482 | 3.6 | 3.1 | 1 | 482 | - | - | - | - | 2 | 2,000 |
| Turkey | - | - | - | - | - | - | 4 | 4,456 | - | - | 8 | 9,500 |
| U.A. E. | 2 | 2,690 | 10.1 | 7.0 | 3 | 4,107 | 1 | 1,345 | - | - | - | - |
| U.S.A. | 94 | 96,553 | 771.6 | 19.6 | 92 | 94,718 | 2 | 2,234 | 3 | 2,550 | 18 | 8,000 |
| UK | 15 | 8,923 | 41.8 | 14.8 | 9 | 5,883 | 2 | 3,260 | 2 | 3,340 | 10 | 17,000 |
| Ukraine | 15 | 13,107 | 81.1 | 55.0 | 15 | 13,107 | 2 | 2,070 | - | - | 7 | 8,750 |
| Uzbekistan | - | - | - | - | - | - | - | - | 2 | 2,400 | 2 | 2,400 |
| **Total** | **444** | **394,916** | **2,653** | **10.3 (1)** | **427** | **382,796** | **56** | **57,664** | **96** | **98,597** | **330** | **361,602** |

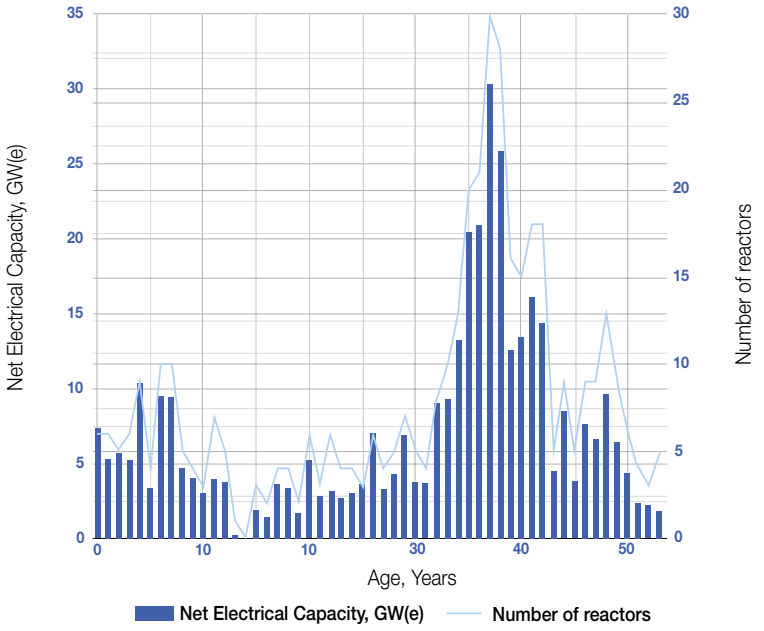
Source: PRIS-OIEA, Foro Nuclear & World Nuclear Association. (1) % of total world electricity generated (nuclear and non-nuclear).

**Table 4.** Nuclear reactors in the world in 2021 and as of October 1, 2022 (in operation, under construction, planned, and proposed).

## Authorization for Continued Operation

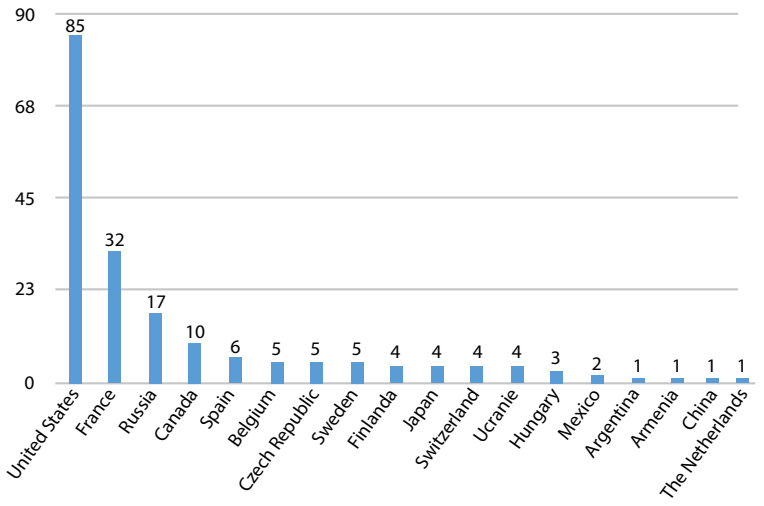
According to data from the IAEA, the NRC and Foro Nuclear, different authorization criteria are applied at present across Europe, such as: the indefinite operating license of Switzerland and the Czech Republic; additional authorizations ranging from 5 to 30 years in Russia and from 20 to 23 years, i.e. until 2038, in Finland; for 20 years in Hungary; for 40+ years, i.e. unspecified, in Sweden; till 2033 and 2035 in the Netherlands and Belgium respectively; or until 2050 in Canada. Japan authorizes plants to operate up to 60 years, whereas Argentina has authorized one of its plants to operate for 50 years. In the U.S., 85 reactors in operation have been authorized to operate for 60 years and 6 for 80 years.

Figure 3 shows the status of the authorizations for continued operation around the world. In total, 190 reactors have been authorized to operate beyond 40 years: Argentina (1 authorization until 2024), Armenia (1 authorization until 2026), Belgium (5 authorizations until 2025 and 2035), Canada (10 authorizations until 2028 and 2050), the Czech Republic (5 authorizations for an indefinite time), China (1 authorization until 2041), Finland (4 authorizations until 2038), France (32 authorizations for 50 years of operation), Hungary (3 authorizations for 20 additional years from the date the renewal was granted), Japan (4 authorizations for 60 years of operation), Mexico (2 authorizations until 2050), the Netherlands (1 authorization until 2033), Russia (17 authorizations beyond their initial operating license period), Spain (6 authorizations until 2027, 2028, 2030 and 2031), Sweden (5 authorizations beyond 40 years of operation), Switzerland (4 authorizations for an indefinite time), Ukraine (4 authorizations for an additional 20 years from the date of the corresponding operating license was granted) and the U.S. (85 authorizations for 60 years, 6 of which for 80 years).




Source: PRIS-OIEA

**Figure 2.** Number of nuclear reactors by years of operation as of October 1, 2022.




Source: Foro Nuclear with data from PRIS-IAEA, the NRC, ASN, Rostechnadzor/Rosatom, CNSC, MITECO, FANC, SÚJB, SSM, STUK, NRA/Jaif, ENSI, SNRIU, HAEA, SENER/Gobierno de México, ARN, ANNP, CNNC and ANVS.

**Figure 3.** Reactors around the world whose operating license allows them to continue operating as of October 1, 2022.

## Performance Indicators

One of the great advantages of nuclear power plants is their **high availability**. Table 6 shows the performance indicators, averaged by year and comprehensive over time, of the world's nuclear power plants since they were connected to the electricity grid for the first time up to the present day. Comprehensive values take into account all plants (operating, shut down and decommissioned) from the beginning of their commercial operation.

The historical evolution in the past few years following the disruption caused by the Fukushima accident in 2011 shows the general improvement of plant performance indicators on a global scale. In Spain, the results are manifestly better than the global average in terms of both yearly and comprehensive values, thanks to which it ranks among the top eight countries in this respect.

## Plant Closures

A total of 203 nuclear reactors in 21 countries —totaling 98 MW of power— have been shut down permanently from the start of the commercial operation of nuclear power plants until October 2022. The U.S. (41 units), the UK (36), Germany (30), Japan (27) and France (14) stands out in this regard. They are followed by Russia (10), Sweden (7) and Canada (6); Ita-

| Plant Type | Units | Total Net Capacity (MW) | Countries |
|---|---|---|---|
| PWR | 48 | 51,709 | Argentina (1), Bangladesh (2), Belarus (1), Brazil (1), China (17), France (1), India (4), Iran (1), Russia (3), Slovakia (2), South Korea (4), Turkey (4), U.A.E. (1), Ukraine (2), UK (2), U.S.A. (2). |
| BWR | 2 | 2,653 | Japan (2) |
| PHWR | 3 | 1,890 | India (3) |
| FBR | 6 | 1,412 | India (1), China (1), Russia (1) |
| **Total** | **56** | **57,664** | **18 countries** |

Source: PRIS-OIEA

**Table 5.** Reactors under construction in the world as of October 1, 2021.

| Year | No. of stations run with data | Load Factor (%) | Time Availability Factor (%) | Unit Capability Factor (%) | Unplanned Capability Loss Factor (%) |
|---|---|---|---|---|---|
| 2015 | 442 | 73.6 | 75.7 | 75.0 | 3.2 |
| 2016 | 447 | 73.3 | 76.3 | 75.0 | 4.1 |
| 2017 | 449 | 73.0 | 75.2 | 74.2 | 4.8 |
| 2018 | 454 | 74.5 | 76.2 | 75.2 | 3.7 |
| 2019 | 444 | 73.6 | 77.5 | 76.6 | 4.3 |
| 2020 | 442 | 74.3 | 75.7 | 77.6 | 4.6 |
| 2021 | 430 | 79.4 | 81.1 | 80.0 | 4.3 |
| **Comprehensive factors including all operating and shutdown plants from the beginning of their commercial operation until the end of 2021** | | | | | |
| **Global** | **594** | **-** | **77.4** | **78.5** | **5.7** |
| **Spain** | **10** | **-** | **85.0** | **85.8** | **3.9** |

Source: PRIS-OIEA, Foro Nuclear and own calculations.

**Table 6.** Performance indicators for nuclear power plants worldwide.

ly, Bulgaria and Ukraine (4 each); Spain and Slovakia (3 each); Lithuania, Switzerland and South Korea (2 each); and Armenia, Belgium, Kazakhstan, Pakistan and the Netherlands (1 each).

## Planned and Proposed Nuclear Power Plants

According to the World Nuclear Association (Table 4), there are **plans** to build 96 plants around the world, for a total gross capacity of 98,597 MW, and the construction of 330 plants, totaling 361,602 MW, **has been proposed**. The countries with the highest expectations are China (196 units between both options), Russia (46), India (40), the U.S. (21), Saudi Arabia (16), Japan (9), Turkey (9), the UK (12) and Iran (6).

In the EU-27, ten countries have announced the construction of 24 plants, whereas four countries do not plan to build any new units (Belgium Germany, Spain and Sweden). On the other hand, eleven countries around the world (Bangladesh, Belarus, Egypt, Jordan, Kazakhstan, Lithuania, Poland, Saudi Arabia, Thailand, Turkey and Uzbekistan) wish to have their own nuclear programs, which will result in the construction of 51 additional plants.

# SITUATION OF NUCLEAR POWER IN SPAIN

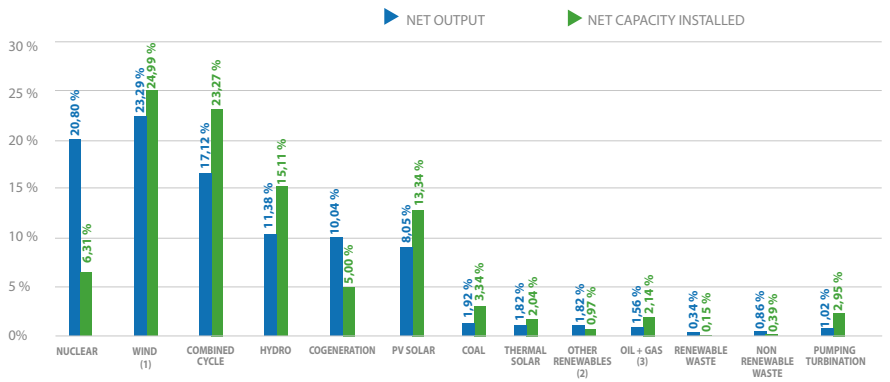
## Generation in the Power Grid

According to data from Red Eléctrica de España (REE) —the partly state-owned and public limited Spanish corporation which operates the Spanish electricity grid—, **net electricity production** in Spain came to 259,849 GWh in 2021, experiencing a 3.5% increase relative to the previous year due to the economic activity picking up after the Covid-19 pandemic. **Conventional technologies** (nuclear, coal, hydro, combined cycle and fuel/gas) represented 52.7% of the total, i.e. 137,151 GWh, 1.8% less than in 2020. The output from the **other technologies** (cogeneration, waste, wind, solar, pumped-storage turbine and other renewables) grew 9.9%, for a total of 122,698 GWh, a 37% increase in photovoltaic solar and 10% in wind standing out.

**Electricity demand** increased by 2.7% relative to the previous year —less than the 5.1% growth in GDP, reaching 233,940 GWh. This confirms the decoupling between the two variables in recent years.

The **peak demand of the peninsular grid** was reached during the winter period on January 8 at 2:00 p.m. —coinciding with Storm Filomena, when temperatures dropped to historic lows in some areas of the country— with 41,483 MW, 7.6% below the historical maximum reached in December 2007.

Spain's **electricity balance of trade** in 2021 meant that the country was a net importer for a sixth consecutive year —as opposed to the positive balance it recorded between 2004 and 2015—. In other words, Spain imported 884 net GWh in 2021, a 73.1% drop compared to 2020, which went to meeting 0.4% of peninsular demand. 890 GWh were transported through the link between the mainland and the Balearic Islands, representing more than 16% of the archipelago's demand.




(1) It includes hydro & wind power.
(2) It includes biogas, biomass, marine hydro and geothermal.
(3) It includes diesel engines, gas turbines and steam turbines.
Source: *Resultados nucleares de 2021* y perspectivas de futuro - Foro Nuclear (with data from REE).

**Figure 4.** Structure of net capacity and production by source in the Spanish power grid in 2021.

## Nuclear Power Generation

In 2021, t**he Spanish nuclear fleet produced 54,040 GWh of net electric power** —3.1% less than in 2020, which accounted for 20.8% of the country's total net production—1.4% less than the year before. Gross output stood at 56,564.26 GWh —2.8% less than in the previous year— because six reactors underwent scheduled refueling outages, some of which lasted considerably longer than usual due to the Covid-19 pandemic. **Nuclear power has been producing in excess of 20% of all**

# NUCLEAR POWER IN THE CURRENT ENERGY AND POLITICAL CONTEXT

Since mid-2021, the economic recovery following the Covid-19 pandemic has resulted in a global increase in the consumption of energy raw materials —especially natural gas—, which has since caused **prices to escalate on the international markets**. **This situation has led to higher prices in the electricity markets**—natural gas is the main fuel for electricity generation in many countries and/or the fuel that sets the marginal price in the markets so organized— and these high prices are injecting significant uncertainty into the global economy.

This state of affairs has been exacerbated since the end of February 2022, when Russia invaded Ukraine. Generally speaking, but especially in Europe, **there is no longer only alarm about the extraordinary price increases**, which have caused strong inflationary pressures, **but even greater concern about the security of supply in the short, medium and long terms**. This is due to Russia's threat to reduce —as it has already done— and even to completely cut its supply of natural gas to the EU, particularly to the Central and Eastern European countries.

This is why, as an answer to the difficulties and disruptions that the Russian invasion was causing in the global energy market, **the European Commission presented its *REPowerEU* Plan in May 2022**. There is a twofold urgency to transform the European energy system: **Putting an end to the EU's dependence on Russian fossil fuels**, which are being used as an economic and political weapon by Russia and cost European taxpayers almost €100B a year, and **addressing the climate crisis**.

Among the measures included in the *REPowerEU* Plan are those for increasing energy savings and efficiency, diversifying the supply of energy raw materials, and rapidly deploying renewable energies to replace fossil fuels in households, across the industry and for electricity production.

**This Plan also acknowledges that nuclear energy will have an important role to play in ensuring the security of supply in EU countries.**

**In addition, during the first half of 2022**, the European Parliament and Commission agreed that **nuclear energy is a necessary source of generation during the energy transition** —it is essential for the regulation, stability and balance of the power grids and for guaranteeing the security of supply— and thus **included it in the mechanisms of the EU taxonomy**, which will come into effect in January 2023.

This will not only be a boost for nuclear power but will also **give access to more advantageous financing** both for new projects and for investments for the long-term operation of existing reactors. This especially applies to countries with a clear commitment to nuclear power such as Belgium, Bulgaria, the Czech Republic, Finland, France, Hungary, the Netherlands, Poland, Romania, Slovakia and Sweden.

**There is also growing interest in nuclear power in other parts of the world**. Hence, two new countries —Belarus and the United Arab Emirates— incorporated nuclear technology into their electricity systems in 2020 with the commissioning of their first units. Turkey, on the other hand, has three reactors under construction, and another new entrant (Egypt) begun construction of its first nuclear reactor in July 2022. In addition, Bangladesh expects to commission a first unit at the Rooppur N.P.P. in 2023, and the government of Japan plans to restart up to 17 reactors, such that, by 2030, nuclear power will account for around 20 percent of all the electricity consumed in the country. Even Germany has announced that it will keep its last three reactors running—at least until April 2023.

**However**, and despite the circumstances and approach in our neighboring countries, the **incumbent Spanish Government still maintains its stance regarding the observance of the schedule for the gradual closure** of the seven units comprising the Spanish nuclear fleet between 2027 and 2035.

**the electricity consumed in Spain for 10+ years in a row**.

The **total net installed electrical capacity** as of December 31, 2021, was 112,801 MW —a 2.1% relative to the same date of the year before—, of which 7,117 net MW, that is, 6.31% of the total capacity, corresponded to the seven reactors that make up the Spanish nuclear fleet. The 3,501 MW increase in photovoltaic power more than offset the 1,969 MW decrease in the number of coal-powered stations.

The contribution in terms of net installed capacity and net electricity production of the different energy sources that make up the Spanish electric system is shown in Figure 4.

## 2021-2030 National Integrated Energy and Climate Plan

Based on the agreement that was reached in March 2019 between the Spanish Radioactive Waste Management Organization (ENRESA) and the companies that own the Spanish nuclear power plants and was sponsored by the Ministry for Ecological Transition and the Demographic Challenge (MITECO), **in March 2021 the Government of Spain approved the 2021-2030 National Integrated Energy and Climate Plan (PNIEC)**, which sets a target scenario according to which the 7 Spanish nuclear reactors will remain in operation until 2027 and the installed nuclear capacity will

| Plant | Load Factor (%) | Time Availability Factor (%) | Unit Capability Factor (%) | Unplanned Capability Loss Factor (%) | Gross Output (GWh) |
|---|---|---|---|---|---|
| Almaraz I | 87.12 | 89.04 | 88.96 | 0.68 | 8,008.86 |
| Almaraz II | 85.57 | 88.17 | 86.91 | 2.31 | 7,828.81 |
| Ascó I | 81.25 | 83.71 | 81.78 | 7.25 | 7,348.48 |
| Ascó II | 98.72 | 99.33 | 99.03 | 0.85 | 8,884.33 |
| Cofrentes | 87.70 | 90.03 | 88.84 | 1.31 | 8,389.36 |
| Trillo | 84.91 | 86.47 | 86.10 | 5.80 | 7,929.09 |
| Vandellós II | 85.85 | 88.55 | 87.39 | 1.87 | 8,175.32 |
| **Global in 2021** | **87.27** | **89.30** | **88.41** | **2.86** | **56,564.26** |
| **Global in 2020** | **89.94** | **92.39** | **91.64** | **1.58** | **58,299.03** |

Source: Foro Nuclear.

**Table 7.** Table 7. Performance indicators for the Spanish nuclear fleet in 2021

be cut approximately in half by 2030, after which only 3 units will remain in operation and will be gradually phased out until 2035.

In this regard, on March 18, 2021, MITECO granted, through Ministerial Order TED/308/2021, **the renewal of the operating license of Cofrentes N.P.P.** until November 30, 2030.

Likewise, on September 27, 2021, MITECO approved Ministerial Orders TED/1084/2021 and TED/1085/2021 granting **the renewal of the operating licenses of Units I and II of Ascó N.P.P.** until October 2, 2030, and October 2, 2031, respectively.

## The International Energy Agency. Spain 2021: Energy Policy Review

In May 2021, the International Energy Agency (IEA) published the ***Spain 2021: Energy Policy Review*** report, in which it went over the entire Spanish energy system and its evolution since the previous report from 2015.

This report says that **Spain has developed an efficient, well-integrated nuclear structure over the past 50 years**, including the 7 reactors which are currently in operation, a fuel manufacturing facility, radioactive waste management solutions and efficient regulatory bodies.

The IEA made a series of **specific recommendations** to the Spanish Government in connection with nuclear energy, namely, that it should **closely monitor the financial situation** of the stations in order to prevent their sudden or unforeseen definitive closure, which could significantly deteriorate the security of the electricity supply, promote the timely implementation of the **strategy for the final management and final storage of irradiated fuel**, develop projects that facilitate the **effective transfer** of knowledge and operating experience, and consider the **usefulness** of nuclear energy to achieve **climate neutrality** by 2050.

## Performance Indicators

In recent years, **the performance indicators of Spanish nuclear power plants have been among the best in the world**, with overall values around 90%, which illustrates their reliability and guarantees the technical operation of the Spanish power grid. The values of said performance indicators in 2021 and their overall comparison with those of 2020 are shown in Table 7.

## $CO_2$ emissions and climate change

The **Paris Agreement of the United Nations Framework Convention on Climate Change adopted at COP 21 on December 2015** —which came into effect in November 2016— aims to keep the rise in the global average temperature by the end of this century well below 2 °C above pre-industrial levels, it being desirable that it remain below 1.5 °C.

On the other hand, the **European Commission presented in May 2022 the *REPowerEU*** plan in response to the energy issues created in Europe by the Russian invasion of Ukraine in February of this year. This plan expresses greater ambition in terms of both guaranteeing the energy supply by reducing imports of fossil fuels from Russia and dealing with the climate crisis. The goal of reducing net greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels and achieving a net-zero balance by 2050 remains unchanged.

According to BP data, **global energy-related emissions of $CO_2$** rebounded sharply in 2021 to near pre-Covid 2019 levels as a result of the recovery of the global economy. Thus, 33,884 Mt were emitted, a 5.9% increase compared to 2020. The biggest carbon emitters include China (with 31.1% of the total), the U.S. (13.9%), India (7.6%), Russia (4.7%) and Japan (3.1%). Emissions also increased in the different regions of the world, South and Central America, with 11.1% of the emissions, and the Commonwealth of Independent States, with 7.7%, standing out. Despite the EU's medium- and long-term reduction targets, Europe saw a 5.4% increase.

The **444 nuclear reactors in operation around the world prevented** 2,000+ Mt $CO_2$ from being released into the atmosphere, which equates to almost 6% of all emissions into the atmosphere in 2021. Nuclear was the second lowest carbon source after hydropower.

The **United Nations Economic Commission for Europe (UNECE)** published its **Life Cycle Assessment of Electricity Generation Options** report in November 2021. This report concluded that nuclear power generates fewer $CO_2$ emissions over its entire life cycle —ranging from 5.1 to 6.4 g of $CO_2$ per kWh produced— than any other source of electric power. Nuclear power and renewables do not emit greenhouse gases during their electricity production processes but each of them has a carbon footprint at various stages throughout its entire life cycle: fuel fabrication, the construction of facilities, the

operating life thereof, and the decommissioning thereof at the end of their operating life.

According to data from MITECO and REE, **in Spain** total gross emissions from all activities (energy uses, industrial processes, agriculture and waste) in 2021 amounted to 275 Mt $CO_2$, a 4.7% decrease with respect to 2020. The electricity sector generated 35.9 Mt $CO_2$, a historic low at the national level.

**In comparison, the Spanish nuclear fleet keeps 20+ Mt $CO_2$ from being released into the atmosphere each year** depending on the alternative generation mix to replace its production. In 2021, $CO_2$ emissions-free electricity production (nuclear, hydro, solar, wind, pumped-storage hydroelectricity and other renewables) amounted to 68.5% of all electricity generated, a 1.5% increase relative to the year before. **Nuclear power stations generated more than 30% of all clean electricity in Spain.**