ENERGY OUTLOOK AND NUCLEAR ENERGY AS OF OCTOBER 2021

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INTRODUCTION

In keeping with the tradition started in 2008, the purpose of this article is to inform about the contribution of nuclear power generation to the world energy market in 2020 and the detailed results up to October 2021. After a quick, simplified analysis of the world energy framework focused on primary energy consumption in 2020, 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 nuclear power plants, the new plants whose construction has been planned and proposed, and the CO_2 emissions they prevent. The article is rounded off with a general commentary that assesses the situation of nuclear power in the energy industry.

PRIMARY ENERGY CONSUMPTION

The Situation in the World

Primary energy consumption in the world in the 2019-2020 biennium is shown in Table 1 below broken down into the different sources, based on data from the *BP Statistical Review of World Energy* report released in June 2021.

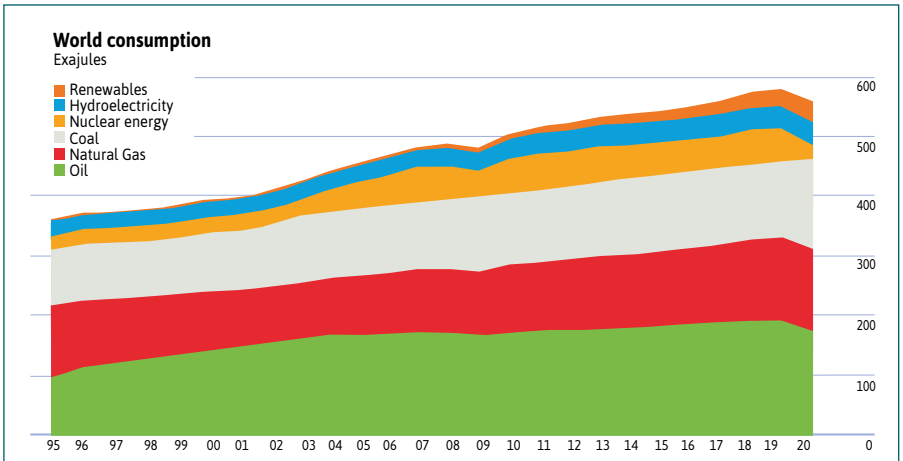
Primary energy consumption reached 556.62 EJ in 2020, there being a 24.89 EJ decrease with regard to 2019 as a result of the COVID-19 pandemic. Fossil fuels were still the major energy source (462.77 EJ, i.e. 83.1% of the total). It is worth noting that China saw significant growth (+2.1%) in the then current global economic crisis scenario. The positive renewable energy consumption rate (+9.7%) also stands out. In the global breakdown by country, the **biggest consumers** were China, with 26.1% of all energy consumed, and the U.S.A., with 15.8%, which together account for 42% of the world's energy consumption, followed at a distance by India (5.7%), Russia (5.1%) and Japan (3.1%). In the EU-28, whose countries represented 10% of the world's overall consumption, Germany accounted for 2.2%, France for 1.6%, the U.K. for 1.2%, Italy for 1.1% and Spain for 0.9%.

The growth rate had an exceptional negative value of -4.5%, the highest recorded since WWII, compared to an average value of 1.9% over the last 10 years. Oil (driven by the transportation industry) accounted for 73% of this drop in consumption, while consumption of renewable energies rose 12% and of hydroelectric energy 2%. Regarding **economic zones**, growth was negative in OECD countries (-7.7%), non-OECD countries (-2.4%) and EU-28 countries (-8.5%). As far as **geographical areas** are concerned, the largest decreases occurred in North America (-8.0%) and in Europe and Central America (-7.0% in both cases). On the other hand, the region that had the highest growth rate and best withstood the pandemic was Asia-Pacific (-1.6%), followed by the Middle East (-3.1%). The growth rates **in the five countries with the greatest consumption in the world** were as follows: China (2.1%), the U.S. (-7.7%), India (-5.9%), Russia

Year	Oil	Natural Gas	Coal	Nuclear	Hydro	Renewables	Total
2019	191,89	140,54	157,64	24,93	37,69	28,82	581,51
2020	173,73	137,62	151,42	23,98	38,16	31,71	556,62
%Δ 2020/2019	-9,7 %	-2,3 %	-4,2 %	-4,1 %	1,0 %	9,7 %	-4,5 %
***Mix* 2020**	**31,2 %**	**24,7 %**	**27,2 %**	**4,3 %**	**6,9 %**	**5,7 %**	**100 %**

Data in exajoules (EJ). 1 EJ = 1018 joules
Source: *BP Statistical Review of World Energy*, June 2021, and own calculations.

Table 1. Primary energy consumption in the world.



Source: *BP Statistical Review of World Energy. June 2021.*

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

(-5.5%) and Japan (-7.5%). In the EU-28, the figures for Germany (-7.5%), France (-10.3%), the U.K. (-11.0%), Italy (-9.3%) and Spain (-11.4%) stand out.

Fossil fuels met 83.1% of demand and had a negative growth rate of -5.6%. Oil demand, which represented 31.2% of total energy demand, had a negative growth rate of -9.7% EJ (-9.3% B/D). In OECD countries, which consumed 45.2% of all the oil consumed in the world, this rate was -13.1%, whereas it came to -6.7% in non-OECD countries and -13.8% in the EU-28. The U.S. was the world's biggest oil consumer, accounting for 18.7% of all oil consumed, followed by China (16.4%) and India (5.2%). **Coal** was second only to oil and was the source of 27.2% of all the energy consumed in the world; nevertheless, it decreased by 4.2%. In non-OECD countries, which consume 81.9% of all coal in the world, the growth rate was -1.4%, in OECD countries, -15.2%, and in the EU-28, -19.4%. China is the biggest consumer of coal in the world, accounting for 54.3% of the total, followed by India with 11.6% and the U.S. with 6.1%. **Gas**, which accounted for 24.7% of the world's energy consumption, had a negative growth rate of -2.3%. In OECD countries, which consume 46.0% of all gas in the world, the growth rate was -2.6%, whereas it shrunk by 2.1% in non-OECD countries and by 3.1% in the EU-28. The biggest consumers were the U.S. (21.8%), Russia (10.8%), China (8.6%) and Iran (6.1%).

Nuclear power supplied 4.3% of all the energy consumed in the world and experienced a -4.1% reduction. **Hydropower** grew by 1.0% and accounted for 6.9% of the world's energy consumption. The **other renewables** (wind, solar, geothermal and biomass), which satisfied 5.7% of the world's energy demand, grew by 9.7%. Regarding renewables, their growth rate was 8.6% in OECD countries, 11.2% in non-OECD countries and 6.7% in the EU-28. Figure 1 below shows the evolution of cumulative primary energy consumption over the 1995-2020 period.

The average price of a barrel of European Brent crude oil was $41.84 in 2020, plunging $22.37 from the average price in 2019 to its 2004 price; it ended the year at $51.22. The price of **uranium** in long-term contracts averaged 34.6 $/lb U3O8 in 2020, $2.8 higher than in the previous year. In long-term contracts through September 2020, it averaged 33.8 $/lb U3O8, $0.8 greater than the average value in 2019 According to the latest report from the NEA-OECD and to the IAEA-UN's Uranium 2020: Resources, Production and Demand report, the current world nuclear fleet's demand for uranium can be met with existing uranium inventories for almost 120 years at a price of 130 $/kg U.

The Situation in Spain

In 2020, **primary energy consumption** in Spain slumped by 0.70 EJ (-13.30%) to 4.58 EJ. This consumption is broken down by source in Table 2 below. The decrease in coal's share as a result of the closure of coal-fired plants within the framework of the Spanish decarbonization policy for ad-

Year	Coal	Oil	Gas	Nuclear	Renewables	Electricity balance (1)	Non-Renewable Waste	Total
2019	0,21	2,35	1,29	0,64	0,75	0,02	0,01	5,28
2020	0,08	1,90	1,17	0,64	0,77	0,01	0,01	4,58
Δ 2020/2019	-59,86 %	-19,21 %	-9,77 %	-0,14 %	1,90 %	-52,21 %	-15,54 %	-13,30 %
***Mix* 2020**	**1,80 %**	**41,50 %**	**25,50 %**	**13,90 %**	**16,80 %**	**0,26 %**	**0,24 %**	**100 %**

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

Source: Energía 2021 Foro Nuclear and own calculations using data from the Subdirectorate-General of Studies and Renewable Energies of the Ministry for the Ecological Transition and the Demographic Challenge (MITECO). The original data, which were in Mtoe (million tons of oil equivalent), were converted to EJ using a factor 1 Mtoe = 0.04187 EJ..

Table 2. Primary energy consumption in Spain.

Year	Coal	Oil	Natural Gas	Renewables	Non-Renewable Waste	Nuclear	Total
2019	0,00	0,00	0,00	0,77	0,01	0,64	1,43
2020	0,00	0,00	0,00	0,77	0,01	0,64	1,42
Self-sufficiency in 2020	**3,60 %**	**0,10 %**	**0,20 %**	**100 %**	**100 %**	**100 %**	**31,10 %**

Data in exajoules (EJ).
Source: Energía 2021 Foro Nuclear, MITECO (until 2019) and Foro Nuclear (2020 estimate with data from MITECO, Carbunión, CORES and Sedigas). AIE methodology. The original data, which where in Mtoe (million tons of oil equivalent), were converted to EJ using a factor 1 Mtoe = 0.04187 EJ.

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

dressing climate change stands out. The mix of consumed primary energy was made up of fossil fuels (68.8%) and, at a distance, clean energies (30.9%, 13.9% of which corresponded to nuclear power and the remaining 16.8% to renewables and waste). On the other hand, Spain imported 0.01 EJ of electrical energy.

Domestic primary energy production in 2020 reached 1.42 EJ, 0.37% less than in the previous year. Thus, the **degree of self-sufficiency** stood at 31.1%. This output is broken down in Table 3 below. Spain's foreign energy dependence came to 68.9%, higher than the EU-28's average figure of 57.9% in 2019.

Country	In operation in 2020				In operation as of October 2021		Under construction as of October 2021		Planned as of October 2021		Proposed as of October 2021	
	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	10,0	7,5	3	1.641	1	25	1	1.150	2	1.350
Armenia	1	375	2,6	34,5	1	415	-	-	-	-	1	1.060
Germany	6	8.113	60,9	11,3	6	8.113	-	-	-	-	-	-
Bangladhes	-	-	-	-	-	-	2	2.160	-	-	2	2.400
Belgium	7	5.930	32,8	39,1	7	5.942		-	-	-	-	-
Belarus	1	1.110	0,3	1,00	1	1.194	1	1.110	-	-	2	2.400
Brazil	2	1.884	13,2	2,1	2	1.884	1	1.340	-	-	4	4.000
Bulgaria	2	2.006	15,9	40,8	2	2.006	-	-	1	1.000	2	2.000
Canada	19	13.554	92,2	14,6	19	13.6244	-	-	-	-	2	1.500
Czech Republic	6	3.932	28,4	37,3	6	3.934	-	-	1	1.200	3	3.600
China	49	47.498	330,1	4,9	51	49.569	14	13.875	37	41.660	168	196.860
Egypt	-	-	-	-	-	-	-	-	4	4.800	-	-
Finland	4	2.794	22,4	33,9	4	2.794	1	1.600	1	1.170	-	-
France	56	61.370	338,7	70,6	56	61.370	1	1.630	-	-	-	-
Hungary	4	1.902	15,2	48,0	4	1.902	-	-	2	2.400	-	-
India	22	6.255	40,4	3,3	23	6.885	6	4.194	14	10.500	28	32.000
Iran	1	915	5,8	1,7	1	915	1	974	1	1.057	5	2.760
Japan	33	31.679	43,0	5,1	33	31.679	2	2.653	1	1.385	8	11.562
Jordan	-	-	-	-	-	-	-	-	-	-	1	1.000
Kazkhstan	-	-	-	-	-	-	-	-	-	-	2	600
Lithuania	-	-	-	-	-	-	-	-	-	-	2	2.700
Mexico	2	1.552	10,9	4,9	2	1.552	-	-	-	-	3	3.000
Netherlands	1	482	3,9	3,3	1	482	-	-	-	-	-	-
Pakistan	5	1.318	9,6	7,1	6	2.332	1	1.014	1	1.170	-	-
Poland	-	-	-	-	-	-	-	-	-	-	6	6.000
Romania	2	1.300	10,6	19,9	2	1.300	-	-	2	1.440	1	720
Russia	38	28.578	201,8	20,6	38	28.578	3	3.459	27	23.725	21	20.100
Saudi Arabia	-	-	-	-	-	-	-	-	-	-	16	17.000
Slovakia	4	1.814	14,4	53,1	4	1.837	2	880	-	-	1	1.200
Slovenia	1	688	6,0	37,8	1	688	-	-	-	-	1	1.000
South Africa	2	1.860	11,6	5,9	2	1.860	-	-	-	-	8	9.600
Corea del Sur	24	23.123	152,6	29,6	24	23.150	4	5.360	-	-	2	2.800
Spain	7	7.121	55,8	22,2	7	7.121	-	-	-	-	-	-
Sweden	7	7.740	47,4	29,8	6	6,882	-	-	-	-	-	-
Switzerland	4	2.960	23,0	32,9	4	2.960	-	-	-	-	-	-
Thailand	-	-	-	-	-	-	-	-	-	-	2	2.000
Turkey	-	-	-	-	-	-	3	3.342	1	1.200	8	9.500
U.A.E.	1	1.345	1,6	1,1	2	2.690	2	2.690	-	-	-	-
Ukraine	15	13.107	71,5	51,2	15	13.107	2	2.070	-	-	2	2.400
United Kingdom	15	8.923	45,9	14,5	13	7.833	2	3.260	2	3.340	2	2.300
U.S.A.	94	96.553	789,9	19,7	93	95.523	2	2.234	3	2.550	18	8.000
Uzbekistán	-	-	-	-	-	-	-	-	2	2.400	2	2.400
Total	**442**	**393.315**	**2.553**	**10,1 (1)**	**442**	**394.537**	**51**	**53.870**	**101**	**102.147**	**325**	**353.812**

Source: PRIS-IAEA, Foro Nuclear & World Nuclear Association. (1) % of all the electricity generated in the world (nuclear and non-nuclear).

Table 4. Nuclear reactors around the world in 2020 and as of October 1, 2021 (in operation, under construction, planned, and proposed).

GLOBAL FOOTPRINT OF NUCLEAR ENERGY

Nuclear Fleet and Nuclear Power Generation in 2020

As of December 31, 2020, **33 countries** in the world had nuclear power plants. There were 442 units in operation in all, five fewer than in 2019. The total net installed capacity stood at 393,315 MW, 2,217 MW less than in the previous year. In addition, there were 51 reactors under construction in 19 countries, 2 reactors fewer than in the previous year, for a total net capacity of 53,870 MW.

The **net electrical energy generated in 2020** came to 2,553 TWh, which was somewhat less than that generated in 2019 (2,657 TWh). This nuclear power-generated electricity accounted for 10.1% of all the electricity generated in the world in 2020. In the EU-28, the share of nuclear power in 2020 came close to 26%.

The cumulative net electrical energy of nuclear origin as of December 31, 2020, since the first nuclear reactor was connected to the grid back in 1951 stood at 85,422 TWh.

It is worth mentioning that, of the 33 countries that have nuclear power plants, in 18 the nuclear power share was greater than 15% and in 13 above 25%, France (70.6%), Slovakia (53.1%), Ukraine (51.2%), Hungary (48.0%), Sweden (29.8%) and Belgium (39.1%) standing out in this regard. The countries with the highest number of plants in operation were the U.S. (94 units), France (56), China (49), Russia (38), Japan (33), South Korea (24) and India (22).

5 reactors were connected to the grid in 2020: 1 in the United Arab Emirates (1,345 MW), 2 in China (2,000 MW), 1 in Russia (1,066 MW) and 1 in Belarus (1,100 MW). **6 reactors closed their doors for good** in the U.S. (2), France (2), Russia (1) and Sweden (1), for a total of 5,165 MW. On the other hand, 1 unit began to be built in Turkey and 3 in China, amounting to 4,473 MW.

From 2000 through the end of 2020, the total net installed capacity grew by 43.331 GW, the number of units by 7, and the electrical energy generated per year by 38 TWh (the exceptional circumstances that occurred in 2020 as a result of the Covid-19 pandemic have be taken into account).

The Situation as of October 1, 2021

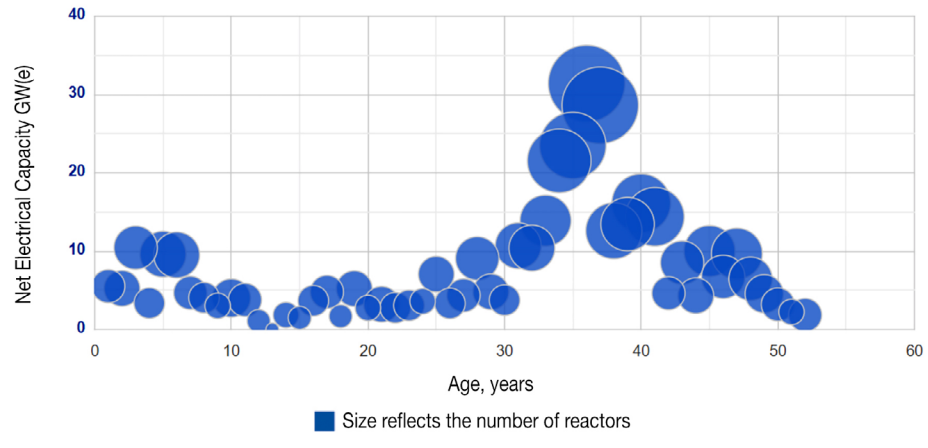
So far, **5 units have been connected to the grid** in 2021: 2 in China, 1 in India, 1 in Pakistan and 1 in the U.A.E., totaling 5,050 MW. On the other hand, **construction of 4 units started** in Turkey (1 PWR; 1,114 MW) and China (3 PWRs; 3,371 MW). Conversely, **5 reactors have ceased operations definitively** in the U.S. (1 PWR; 1,030 MW), the U.K. (2 GCRs; 1,090 MW), Pakistan (1 PHWR; 90 MW) and China (1 BWR; 985 MW).

As shown in Table 4 above, the world's nuclear fleet consists as of October 1, 2021, of 442 units in operation, 5 fewer than in October 2020, for a total net capacity of 393,315 MW. There are now 51 **reactors under construction** (3 fewer than in 2020) in 19 countries, totaling a net capacity of 53,870 MW.

The 442 reactors in operation fall into six groups by plant type (the number of units is shown in parentheses):

- PWRs (305 units): They include pressurized water reactors, pressurized heavy-water moderated and cooled reactors and PWR-VVER-type reactors, for a total net capacity of 290,474 MW.
- BWRs (62): They include boiling water reactors and advanced boiling water reactors (ABWRs) of American design (63,137 MW).
- PHWRs (48): reactors using pressurized water as coolant and heavy water as moderator (24,463 MW).
- GCRs (12): gas-cooled and graphite-moderated reactors of British origin; they include the advanced AGR design (6,635 MW).
- LWGRs (or RBMKs) (12): boiling water-cooled and graphite-moderated reactors (8,358 MW).
- FBRs (3): sodium-cooled fast breeder reactors (1,400 MW).

Figure 2 below shows the number of reactors vs. the years in operation. Two peaks can be seen at 33 and 39 years of operation, which correspond to the commissioning of a large number of reactors in the 1970s and '80s that were built in response to the well-known oil crises; there has also been an uptick in recent years.



Source: PRIS-OIEA

Figure 2. Number of nuclear reactors vs. years in operation as of October 1, 2021.

As of October 1, 2021, there were **51 units under construction** (53,870 MW) in 19 countries: China (14), India (6), South Korea (4), Turkey (3), Russia (3), Bangladesh (2), Japan (2), Slovakia (2), U.A.E. (2), U.K. (2), Ukraine (2), U.S. (2), Argentina (1), Belarus (1), Brazil (1), Finland (1), France (1), Iran (1) and Pakistan (1). Table 5 below shows the number of units **under construction by country and reactor type**.

Plant Type	Units	Total Net Capacity (MW)	Countries
PWR	43	48.015	Argentina (1), Bangladesh (2), Belarus (1), Brazil (1), China (12), Finland (1), France (1), India (2), Irán (1), Pakistan (2), Russia (3), Slovakia (2), South Korea (4), Turkey (2), U.A.E. (2), Ukraine (2), U.K. (2), U.S.A. (2)
BWR	2	2.653	Japan (2)
PHWR	3	1.890	India (3)
FBR	2	1.112	India (1), China (1)
HTGR	1	200	China (1)
Total	**51**	**53.870**	**19 countries**

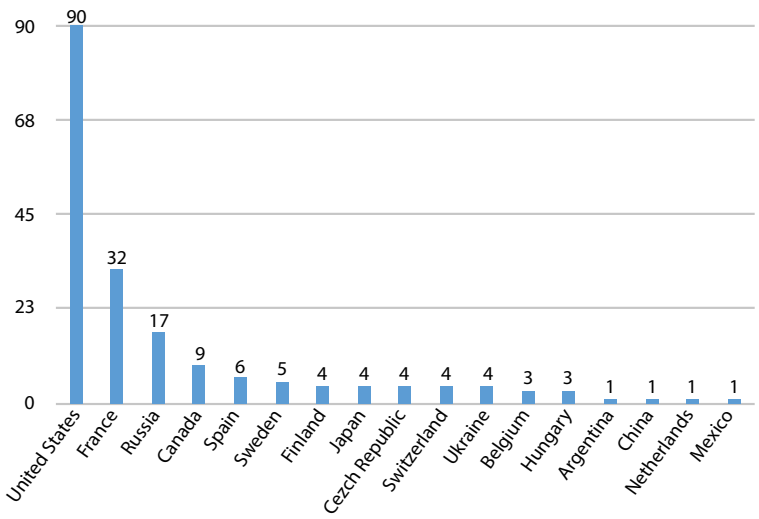
Source: PRIS-OIEA

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

Authorization for Continued Operation

According to data from the IAEA, the NRC and Foro Nuclear, different operating license granting and renewal criteria are applied at present across Europe, such as the following: the indefinite operating license of Switzerland and the Czech Republic; additional extensions ranging from 15 to 30 years in Russia and from 20 to 23 years, i.e. until 2038, in Finland, for 20 years in Hungary and for 40+ years, i.e. unspecified, in Sweden. Plants in Holland and Belgium can only operate till 2033 and 2022 respectively. In Canada, the final year is 2028. 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., 90 reactors currently in operation have been authorized to run for 60 years and 4 for 80 years, whereas 2 have submitted the application for the renewal of their operating license and 4 have planned to apply for this renewal next year.

Figure 3 below shows the status of the authorizations for the continued operation of nuclear power plants around the world. In total, 189 reactors have been authorized to operate beyond 40 years: Argentina (1 authorization until 2024), Belgium (3 authorizations until 2025), Canada (9 authorizations until 2028 and 2050), Czech Republic (4 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 an additional 20 years from the date of renewal of the corresponding operating license), Japan (4 authorizations for 60 years of operation), Mexico (1 authorization until 2050), the Netherlands (1 authorization until 2033), Russia (17 authorizations beyond their original operating license period), Spain (6 authorizations until 2027, 2028, 2030 and 2031), Sweden (5 authorizations for 40+ years of operation), Switzerland (4 authorizations for an indefinite time), Ukraine (4 authorizations for an additional 20 years from the date the renewal of the corresponding operating license was granted) and the U.S. (90 authorizations for 60 years and 6 for 80 years; and another 5 authorizations are expected to be granted).



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

Figure 3. Reactors around the world whose continued operation has been authorized as of October 1, 2021.

Year	# of Plants Operated (w/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
Comprehensive factors including all the plants that are operating and have been shut down from the start of commercial operation until the end of 2020					
Global	**589**	**-**	**76,6**	**77,7**	**5,8**
Spain	**10**	**-**	**84,9**	**85,8**	**4,0**

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

Table 6. Performance indicators for nuclear power plants worldwide.

MILESTONES IN THE LAST YEAR

Many events have occurred in the nuclear industry since October 2020. Several issues have repeatedly demanded our attention. The following is a brief summary of the most remarkable facts.

The most relevant milestone was the breakthrough made in all aspects of the design of small modular reactors (SMRs). SMRs are smaller than conventional reactors and designed to be installed and built in a modular fashion. They permit uses that conventional reactors have not been put to much so far, such as cogeneration or district heating. Their size allows them to be installed in smaller power grids or supply power to remote locations. Noteworthy initiatives launched in the last year include the Canadian government's SMR *Action Plan, the U.K. government's Net Zero Research and Innovation Framework*, and the *France 2030* Plan announced by the French President Emmanuel Macron, whose goal is the development of a French SMR design in the coming years and for which it has a budget of €1B. Countries that do not have any nuclear power plants, such as Australia, Estonia and Poland, have shown a lot of interest in this technology. On the other hand, China began construction of its first SMR—the ACP100—in July 2021.

Generation III/III+ reactors have also been commissioned over the past year, such as the APR1400 reactors at Barakah-1 and 2 NPP in the U.A.E., the VVER-1200 V-491 at Leningrad 2-2 NPP in Russia and the ACPR1000 at Hongyanhe-5 NPP in China. These reactors represent an evolution in terms of safety and operability of Generation II reactors, which make up most of the nuclear fleet currently in operation around the world. Some of the designs referred to as Generation III have opted for ramping up safety with a higher degree of redundancy in their safety systems, whereas those known as Generation III+ have decided to replace active safety systems (i.e., requiring alternating electrical current to work) with gravity-based passive systems. In the U.S.A., construction of Votgle's AP1000s is progressing at a steady pace; Unit 3 underwent hot testing in June 2021. The EPR of Olkiluoto 3 NPP in Finland, which has been under construction since 2005, announced this past summer another delay in its commissioning, which has been rescheduled for June 2022. On the other hand, the EPR reactor of Flamanville NPP in France has been scheduled for startup at the end of 2022. Finally, the construction of the EPR reactors of Hinkley Point C NPP in the U.K. is right on schedule.

All these milestones show that the development of nuclear energy, despite some undeniable difficulties, continues nonstop in economies of undoubted future prominence, thereby helping this energy source to consolidate in order to achieve international CO_2 emission reduction targets.

Performance Indicators

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

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

Plant Closures

From the outset of the commercial operation of nuclear power plants until October 2021, a total of 197 nuclear reactors in 21 countries, totaling 90,443 MW, have been shut down for good. The U.S. (40 units), the U.K. (32), Germany (30), Japan (27) and France (14) stands out in that department. They are followed by Russia (9); Canada (6); Sweden (7); Italy, 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 101 plants** around the world, for 102,147 MW of total gross capacity. On the other hand, **325 plants have been proposed**, totaling 353,812 MW. The countries with the highest expectations are China (205 units between both options), Russia (48), India (42), the U.S. (21), Saudi Arabia (16), Turkey (9), the U.K. (4), Japan (9) and Iran (6).

In the EU-27, 10 countries have announced they will build 22 plants overall, whereas 6 countries do not plan to build any new units (Belgium, France, Germany, the Netherlands, Spain and Sweden). On the other hand, 11 countries around the world (Bangladesh, Belarus, Egypt, Jordan, Kazakhstan, Lithuania, Poland, Saudi Arabia, Thailand, Turkey and Uzbekistan) intend to start their own nuclear programs, which will result in the construction of 51 additional plants.

SITUATION OF NUCLEAR POWER IN SPAIN

Nuclear Generation and the Spanish 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 251,159 GWh in 2020. This means it experienced a 3.8% decrease compared to the pre-

vious year owing to the slowdown of the country's economic activity as a result of the COVID-19 pandemic. **Conventional technologies** (nuclear, coal, hydro, combined cycle and fuel/gas) represented 55.6% of the total, i.e. 139,544 GWh, a 8.7% decline from 2019. This was due to the 60.4% drop in coal consumption and the 20.4% fall in the output of natural gas-fired combined cycle power plants, which were not offset by the 23.9% increase in hydropower generation. The other technologies (cogeneration, waste, wind, solar, pumped-storage hydroelectricity and other renewables), which experienced a 6.2% increase—mainly due to the 65.4% upsurge in solar PV power, accounted for the remaining 44.4%.

Compared with the year before, **electricity demand** fell by 5.6% to 249,819 GWh, less than the 11% decline in the country's GDP—both due to the effects of the coronavirus pandemic.

Spain's **electricity balance of trade** meant that it was a net importer for a fifth consecutive year—as opposed to the positive balance it recorded between 2004 and 2015. In other words, Spain imported 3,280 GWh in 2020, 52.2% less than in 2019, which met 1.4% of demand. The electricity transported through the link between the Spanish mainland and the Balearic Islands amounted to 1,427 GWh, representing more than 29% of the archipelago's demand.

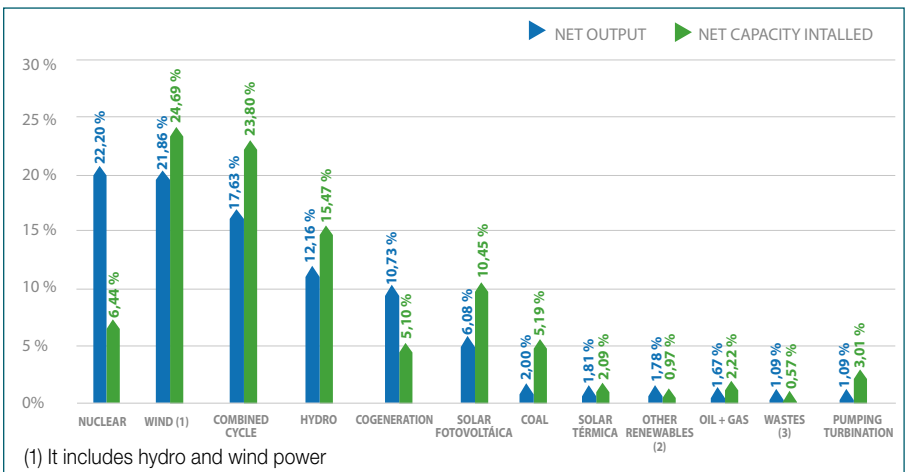
Peak demand on the peninsular grid was reached during the **winter period** on January 20 at 9:00 p.m. with 39,997 MW, 10.9% below the historical maximum experienced in December 2007.

Nuclear Power Generation

The net electrical energy generated by the Spanish nuclear fleet in 2020 was 55,757 GWh—a 0.13% decrease compared to 2019, which represented 22.2% of the country's total net production—0.79% more than in the previous year despite the fact that the four refueling outages that Almaraz I, Ascó I and II and Trillo NPPs underwent took longer than usual as a result of the extraordinary health protection measures against COVID-19 that had to be put in place and the plants operating at 70% of their rated power for many hours in March, April and May. Gross output came to 58,299.03 GWh, virtually the same value as in 2019. **Nuclear technology was, for the tenth consecutive year, the energy source which contributed the most to the national power grid**.

The **total net installed electrical capacity** as of December 31, 2020, stood at 110,449 MW—almost the same value as one year prior, of which 7,117 net MW, i.e. 6.44% of the total, corresponded to the 7 reactors that make up the Spanish nuclear fleet. The 29.5% jump in photovoltaic power stations and the 5.3% increase in wind farms offset the 3,951 MW decrease in the coal fleet.

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



(1) It includes hydro and wind power
(2) It includes biogas, biomass, marine hydro and geothermal.
(3) It includes renewable waste and non-renewable waste.
Source: Resultados nucleares de 2020 y perspectivas de futuro - Foro Nuclear (with data from REE).

Figure 4. Structure of the net capacity and production by source in the Spanish power system in 2020.

2021-2030 National Integrated Energy and Climate Plan

Based on the agreement that was reached in March 2019 among the Spanish Radioactive Waste Management Organization (ENRESA) and the companies that own the various Spanish nuclear power plants, which 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 seven nuclear reactors will remain in operation until 2027, the installed nuclear capacity being cut approximately in half in 2030, after which only three units will remain, which will be gradually phased out until 2035.

In this regard, on July 23, 2020, **MITECO renewed**—via Ministerial Order TED/773/2020—**the operating licenses** of Unit I **of Almaraz NPP** until November 1, 2027, and of its Unit II until October 31, 2028. On that same day, it also renewed the operating license of **Vandellós II NPP** until July 27, 2030 by means of Ministerial Order TED/774/2020.

Likewise, on March 27, 2020, Iberdrola Generación Nuclear, S.A.U. submitted an application for the renewal of the current operating license of Cofrentes NPP until November 30, 2030, which MITECO granted on March 18, 2021, via Ministerial Order TED/308/2021. Also on March 27, Asociación Nuclear Ascó-Vandellós II A.I.E. submitted an application for the renewal of the current operating licenses of Units I and II of Ascó NPP until October 1, 2030, and October 2nd, 2031, respectively, which MITECO granted on September 27, 2021, by means of respective Ministerial Orders TED/1084/2021 and TED/1085/2021.

The Spanish Nuclear Fleet during Storm Filomena

A historic meteorological event occurred in Spain during the sec-

Plant	Load Factor (%)	Time Availability Factor (%)	Unit Capability Factor (%)	Unplanned Capability Loss Factor (%)	Gross Output (GWh)
Almaraz I	77,69	80,42	79,58	1,34	7.161,30
Almaraz II	95,15	99,50	99,21	0,78	8.729,49
Ascó I	88,26	89,51	88,78	0,00	8.005,00
Ascó II	84,65	86,07	85,14	2,51	7.637,72
Cofrentes	96,40	100,00	99,42	0,16	9.247,36
Trillo	88,38	90,86	90,46	0,60	8.275,82
Vandellós II	96,78	99,64	98,33	7,13	9.242,35
Overall in 2020	**89,94**	**92,39**	**91,64**	**1,58**	**58.299,03**
Overall in 2019	**90,10**	**91,79**	**91,06**	**1,70**	**58.395,55**

Source: Foro Nuclear.

Table 7. Performance indicators for the Spanish nuclear fleet in 2020.

ond week of January 2021: **Storm Filomena**, which covered a large swath of the country in heavy snowfall—with depths upwards of 50 cm in the downtown of cities like Madrid—and caused temperatures to drop to historic lows—even below -30 ºC in some villages in the Pyrenees. Of course, **the demand for electricity increased proportionally** as a result of the snowstorm.

On the worst days of the storm—between January 5 and 12, nuclear power was the second largest energy source in the Spanish power grid, contributing to 21.77% of all the power generated, only behind wind power, which supplied 22.5%.

The seven Spanish nuclear reactors operated at full power, which was a decisive factor in guaranteeing the stability of the Spanish electrical grid during this period of maximum demand. In comparison, only slightly more than 26% of all installed wind power capacity operated.

Performance Indicators

In recent years, **the performance indicators of Spanish nuclear power plants have been among the best in the world**, with overall values above 90%, which is proof of their reliability and guarantees the technical operation of the Spanish grid. The values of said performance indicators in 2020 and their overall comparison with those of 2019 can be seen 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 and which the U.S. has rejoined following its withdrawal under the Trump Administration—aims to keep the increase in the global average temperature by the end of this century well below 2 °C above pre-industrial levels, although it is desirable that it remain below 1.5 °C.

For its part, in July 2021 **the European Commission released the *Fit for 55* strategy**, a package of proposals for aligning the European Union's climate, energy, land use, transport and taxation policies to achieve at least a 55% reduction in the bloc's net greenhouse gas emissions by 2030 compared to 1990 levels.

According to BP data, **global energy-related CO_2 emissions** stood in 2020 at 31,983 Mt, down 6.3% from the previous year, mainly as a result of the Covid-19 pandemic. The biggest carbon emitters include China (with 30.9% of the total), the U.S. (13.9%), India (7.2%), Russia (4.5%) and Japan (3.2%). Except in China and Iran, where emissions rose by 0.6% and 0.4% respectively, emissions dropped throughout the different regions in the world: Asia-Pacific (-2.7%), Middle East (-4.0%), Commonwealth of Independent States (-6.4%), Africa (-8.1%), South and Central America (-9.5%), North America (-12.1%) and Europe (-12.3%). This shows the extent of the economic slowdown triggered by the coronavirus.

The **442 nuclear reactors in operation around the world prevented** 2,000+ Mt CO_2 from being released into the atmosphere, which equates to more than 6% of all atmospheric emissions in 2020. Nuclear was the second lowest carbon source after hydropower.

In May 2021 the **International Energy Agency** released its ***Net Zero by 2050: A Roadmap for the Global Energy Sector*** report, according to which nuclear power will significantly contribute to the transition to a net-zero emissions energy system: "By 2050 almost 90% of the world's electricity generation will come from renewable sources; **most of the remaining 10% will be generated by nuclear power**."

In Spain, according to available data from MITECO and REE, total gross emissions from all activities (energy uses, industrial processes, agriculture and waste) in 2020 came to 299.7 Mt CO_2, a 4.7% decrease with respect to 2019. The electricity sector generated 36.1 Mt CO_2, a 27.8% drop compared to the previous year—mostly due to the 60+% reduction in coal-based energy production.

Comparatively, the Spanish nuclear fleet keeps between 20 and 30 Mt CO_2 from being released into the atmosphere every year—depending on the mix of alternative generation sources for replacing its output. In 2020, CO_2 emission-free electricity production (nuclear, hydro, solar, wind, pumped-storage hydroelectricity and other renewables) amounted to 67% of the total, 9% higher than in 2019. **The nuclear fleet generated more than 33% of Spain's clean electricity.**■