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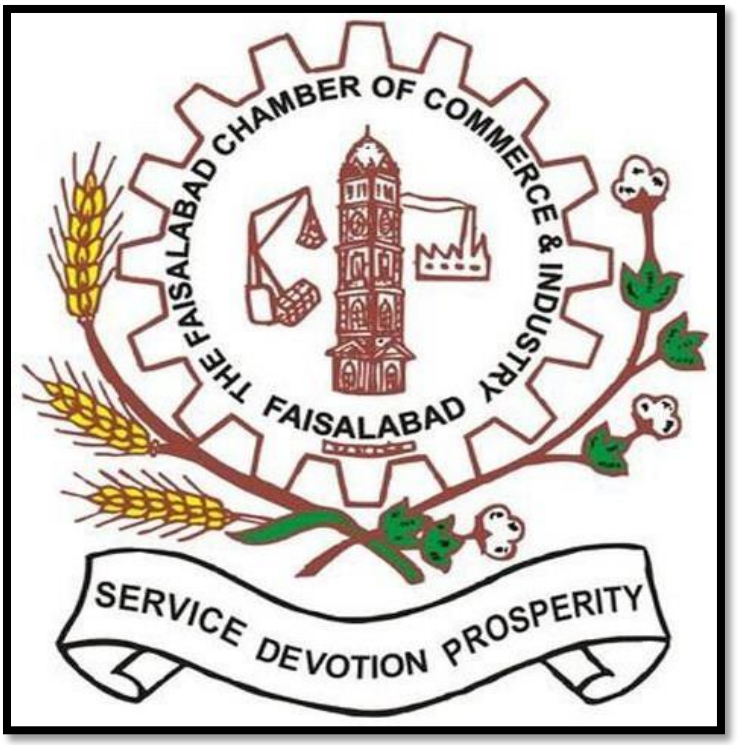

Title

Nuclear Energy in Today's World

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Nuclear Power in the World Today

(Updated January 2022)

1. Introduction

- In the 1950s, the first operation of industrial nuclear power plants started**.**
- With 440 power reactors, nuclear energy today produces around 10% of the world's electricity.
- Nuclear energy is the world's second-largest low carbon electricity source (28 percent of the total in 2019).
- Nuclear power is used in around 220 nuclear reactions in over 50 nations. Such reactors are used for a variety of purposes, including research, medicinal and commercial radioisotope synthesis, and teaching.

Atomic technologies make use of the energy generated when specific materials' atoms are separated. It was first created in the 1940s, with research projects focusing on the production of bombs throughout the Second World War. In the 1950s, the focus shifted to the safe and controlled use of fission reactors for electricity generation. **[1]**

- From 1895 to 1945, research in nuclear physics, atomic transformation, and nuclear technology was conducted, with the latter six years accounting for most of that time.
- The nuclear bomb was the target of most of the work between 1939 and 1945.
- Since 1945, researchers have focused on exploiting this power in a regulated manner for naval propulsion and electrical generation.
- From 1956, the primary concentration was on the advancement of technology for safe atomic energy stations.

Nuclear energy facilities are already active in 32 nations throughout the globe, with more than 18,000 reactors and decades of work experience. Several more nations, in fact, rely on conventional nuclear power to some extent thanks to regional distribution systems; Italy and Denmark, for example, import almost 10% of their electricity. There were significant divisions between the Northern and Southern sectors whenever the nuclear power generation business started in the 1960s. The distinct U.S. and Soviet domains of influence are no longer relevant, and the nuclear sector is now defined by international trade. Materials for a reactor being built in Asia nowadays might come from South Korea, Canada, Japan, France, Germany, Russia, and other nations. Radium from Australia or Namibia, for example, may wind up in a UAE reactor after being transformed in France, enhanced in the Netherlands, reconverted in the UK, and manufactured in South Korea. Atomic power has several applications besides providing reduced electricity. It aids in the management of illness, aids physicians in the diagnosis and management of diseases, and fuels our most adventurous space endeavors. Atomic technology is at the core of the world's largest efforts to achieve environmental sustainability because of its many applications **[2]**

2. Defining Sustainable Development

"Sustainable growth" is defined as "advancement that fulfills current demands while jeopardizing coming generations' capacity to satisfy their current demands." As a result, sustainable advancement is the path to long-term conservation. To become sustainable, an action, resource, or institution must find a balance between ecological, economic, and social sustainability; the three "pillars."

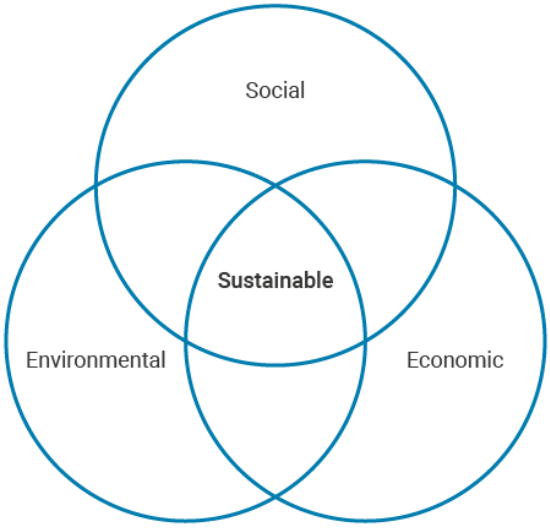

Figure 1: The three 'pillars' of sustainability

The United Nations' 193 participating countries approved the 2030 Agenda for Sustainability Advancement in 2015, which is an operation program for humans, the world, and commerce based on the three pillars of sustainability. The United Nations decided on 17 Sustainability Development Goals (SDGs) to lead and measure success in implementing the 2030 Agenda's lofty objectives.

Figure 2: The UN's Sustainable Development Goals

Approximately 440 nuclear energy plants generate approximately 10% of the world's electricity. About 50 additional reactors are being built, which will account for around 15% of the current capability. Nuclear power stations produced 2553 TWh in 2020, decreasing from 2657 TWh in 2019. From 2010 to 2020, nuclear power and new electronic energy power have climbed for seven years in a row. **[3]**

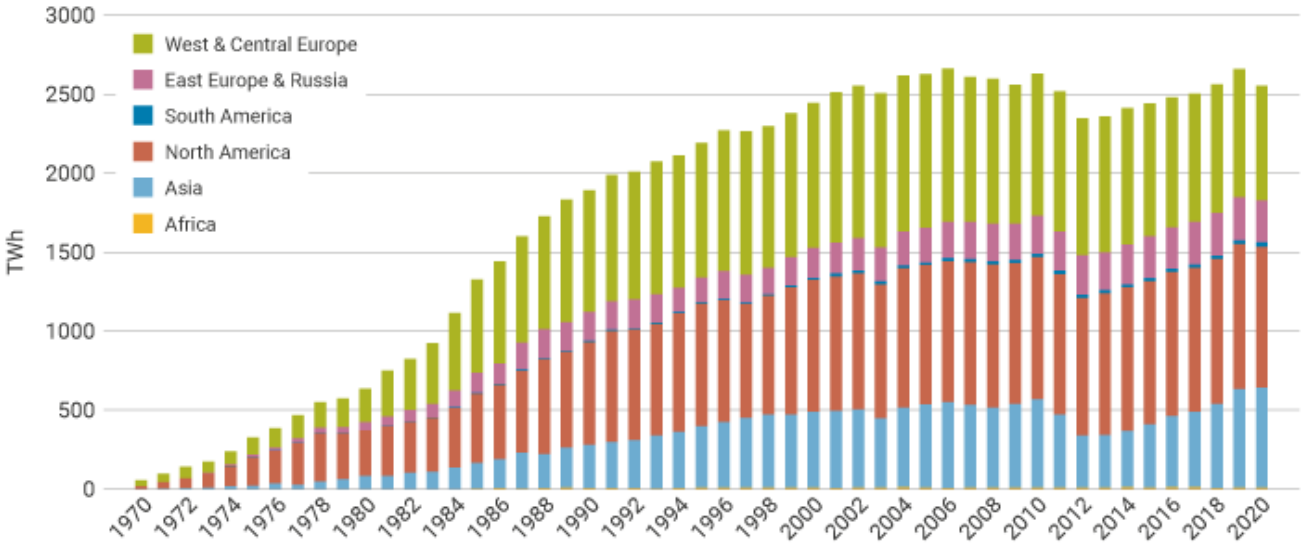

Figure 3: Nuclear electricity production (source: World Nuclear Association, IAEA PRIS)

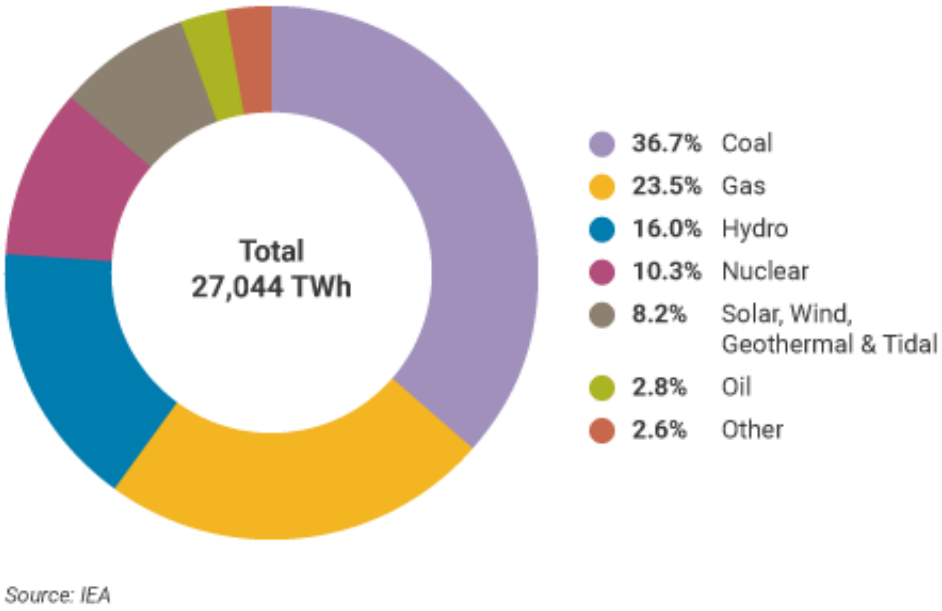

Figure 4: World electricity production by source 2019 (source: International Energy Agency)

13 nations generated at least a quarter of their electricity from nuclear power in 2020. Atomic power provides almost three-quarters of France's power, over 50% of Slovakia's and Ukraine's, and one or more of Hungary, Belgium, Slovenia, Bulgaria, Finland, and the Czech Republic. Atomic power provides over 30% of the energy in South Korea, whereas atomic power provides roughly one-fifth of the electricity in the United States, the United Kingdom, Spain, Romania, and Russia. Japan was accustomed to depending on nuclear energy for more than 25% of its electricity generation and is projected to recover to that degree.

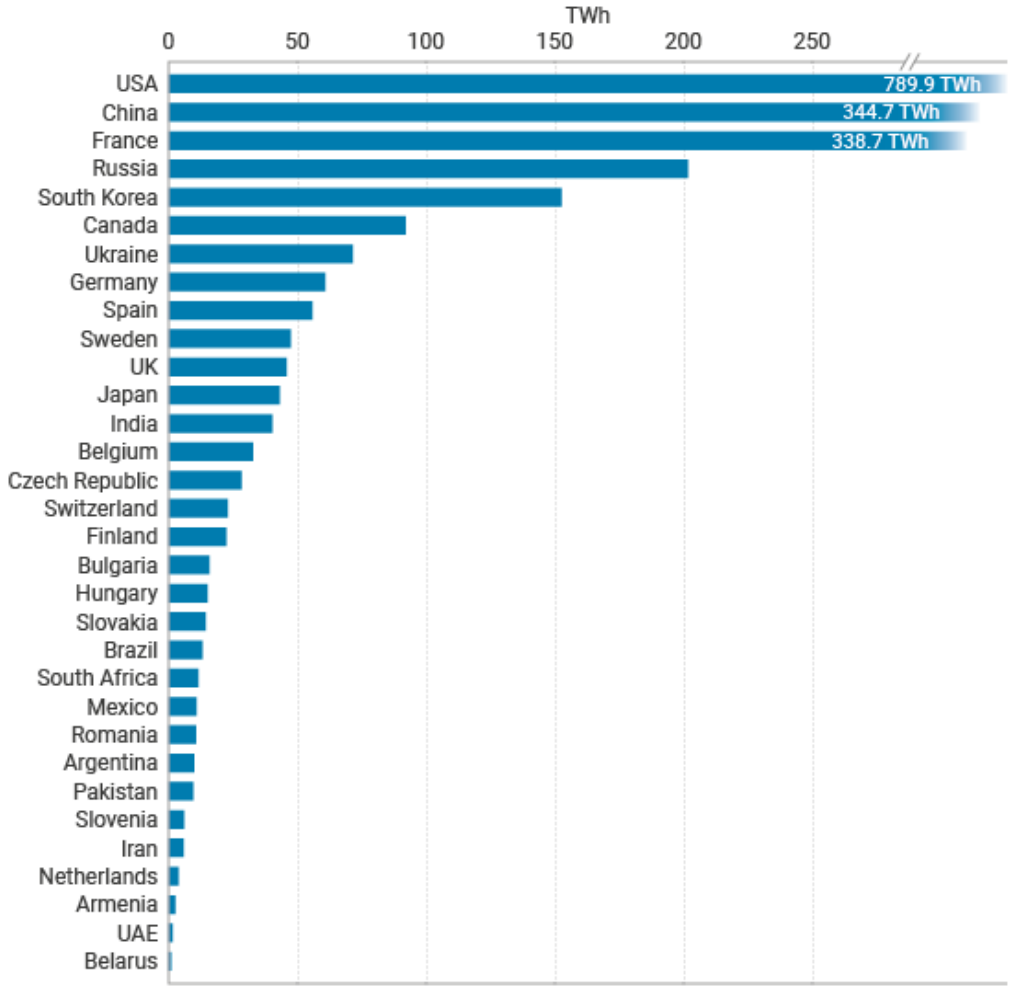

Figure 5: Nuclear generation by country 2020 (source: IAEA PRIS)

3. Nuclear energy and Covid-19

Coronavirus disease 2019 (Covid-19) is an infection illness produced by a coronavirus that causes severe acute respiratory syndrome (SARS-CoV-2). The spread of the new coronavirus has

necessitated drastic measures in many sectors of life throughout the planet. It is critical to have a steady source of energy. Atomic power generates around 10% of the electricity in the world, so atomic plants play a significant role. Nuclear technicians have taken precautions to preserve their employees and have created business continuity strategies to guarantee that critical components of their activities keep functioning **[4].**

Atomic technology offers medicinal implications that will aid in the fight against COVID-19, in addition to electricity production. The International Atomic Energy Agency (IAEA) is supplying test tools, technology, and instruction in nuclear-derived detection methods to countries seeking help in combating the worldwide spread of COVID-19, a new coronavirus.

4. Need for new generating capacity

The additional generated power is clearly needed across the globe to both replace aging fossil fuel plants, particularly coal-fired units, which release a lot of CO_2, and to satisfy the rising demand for power in several nations. In 2019, energy sources accounted for 63% of total power production. Despite the current massive support for and development of volatile renewable energy resources, the fossil fuel proportion of energy production has remained relatively constant over the previous 15 years (66.5 percent in 2005).

Annual power situations are published by the OECD International Energy Agency. There is an optimistic "sustainable development situation" in the International Energy Outlook 2021 that is compatible with the production of clean and dependable power and the reduction of air pollution, among other goals. By 2050, atomic power production will have increased by nearly 75%, to 4714 TWh, and ability will have increased by 669 GWe, according to this decarbonization scenario. The World Nuclear Association has proposed a much more optimistic scenario: the Harmony program proposes adding 1000 GWe of new atomic capability by 2050, with 1250 GWe of capacity providing 25% of power generation (roughly 10,000 TWh) (after allowing for retirements). **[5]** This would necessitate producing 25 GWe annually starting in 2021 and increasing to 33 GWe each year by 2025, which is comparable to the 31 GWe added in 1984 or the total record of 201 GWe set in the 1980s. Using nuclear power to provide a quarter of the world's electricity might significantly cut carbon dioxide emissions and improve air quality.

5. World overview

Atomic energy research is taking place all around the globe, as seen in the instances under. See the table of Globe Nuclear Energy Reactors & Uranium Requirement for the most a go information on operational, ongoing building, and projected reactors throughout the globe. **[6].** Have seen the Countries Profiling Area of the International Energy Institution's Resource Library for extensive country-level data. **[7]**

5.1. North America

Canada maintains 19 power plants in operation, with a total net capability of 13.6 GWe. Nuclear power produced 14.6% of the total electricity generated in 2020. Ontario is home to all but one of the country's 19 atomic power plants. Ten of those apartments will be refurbished, six in Bruce and four in Darlington. The operating lifespan will be extended by 30–35 years because of the initiative. Ontario was able to transition off coal in 2014 because of similar refurbishing efforts, resulting in one of the cleanest energy blends in the globe.**[8]**

Mexico maintains 2 nuclear plants in operation, with a total net capability of 1.6 GWe. In 2020, nuclear energy will account for 4.9 percent of total electrical generation. **[9]**

The **United States** has 93 atomic plants in operation, with a total net capability of 95.5 GWe. Atomic power produced 19.7% of the total electricity generated in 2020. Two of the four AP1000reactors that were under development have been canceled. The extraordinarily effective development of management tactics is one of the explanations for the halt in new construction in the United States to date. Improvements in operating efficiency have expanded the use of nuclear energy plants across the country during the previous 15 years, resulting in the construction of 19 additional 1000 MWe units. In 2016, the country's first existing atomic energy nuclear power station in twenty years went online. Considering this, from a high of 104 in 2012, the number of operational plants has decreased in previous years. A combined effect of circumstances, which include inexpensive energy, financial deepening, over-subsidization of renewable sources of energy, and political campaigning, has resulted in early closures. **[10]**

5.2. South America

Argentina has three nuclear plants with a total net capacity of 1.6 gigawatts (GW). In 2020, atomic power generated 7.5 percent of total electricity generated **[11]**

Brazil has two nuclear plants with a total net capacity of 1.9 gigawatts. Atomic power will provide 2.1 percent of the country's electricity in 2020. **[12]**

5.3. West & Central Europe

Belgium has seven nuclear plants are in operation, with a total net capability of 5.9 GWe. Nuclear power generated 39.1% of the country's electricity in 2020. **[13]**

Finland has four nuclear plants in operation, with a total net potential of 2.8 GWe. Nuclear power will produce 33.9 percent of the country's electricity in 2020. A fifth reactor, a 1720 MWe EPR, is now under development, and a Russian VVER-1200 unit is being built at a new location (Hanhikivi). [14]

France has 56 nuclear plants in operation, with a total net potential of 61.4 GWe. In 2020, nuclear power will generate 70.6 percent of total electricity generated. By 2025, a 2015 energy plan is intended to lower the nation's nuclear power generation contribution by 50%. This deadline has been pushed out until 2035. According to the country's power ministry, the objective is unrealistic and will raise greenhouse gas emissions, jeopardize the ability to fulfill the requirements, and jeopardize jobs. In France, one reactor, a 1750 MWe EPR at Flaman Ville, is currently in production. **[15]**

In **Germany**, three nuclear power reactors are still operational, with a total net capability of 4.1 GWe. In 2020, nuclear power will account for 11.3 percent of renewable energy sources. Underparts of its Evergreened agenda, Germany plans to phase out nuclear power by 2022. Energy Wende, largely regarded as its most effective national environmental impact mitigating program, has failed to achieve a significant decrease in CO2 emissions. In 2011, Germany released 731 Mt CO2 from fuel-burning 2011, the year after the program was implemented; in 2018, the nation released 677 Mt CO2, making it the world's seventh-largest CO2 emission. 2. The German government wants to fall well short of its aim of a 40% decrease in emissions compared to 1990 levels **[16]**

The **Netherlands** has a solitary atomic power station with a total capability of 0.5 GWe that is operational. Atomic power will produce 3.9% of the sources of renewable energy in 2020. **[17]**

Spain has seven atomic power stations in operation, with a total net potential of 7.1 GWe. Atomic power produced 22.2% of the sources of renewable energy in 2020. **[18]**

Sweden has six nuclear plants in operation, with a total net capacity of 6.9 GWe. Nuclear power produced 29.8% of the power generated in 2020. Some ancient plants are being shut off, but the nation has spent considerably on functioning lifespan extensions and uprates **[19]**

Switzerland has four atomic plants in operation, with a total net potential of 3.0 GWe. Atomic power will produce 32.9% of the total electricity generated in 2020 **[20]**.

The **United Kingdom** has 12 atomic power stations in operation, with a total net capability of 7.3 GWe. In 2020, atomic energy will account for 14.5% of renewable energy sources. In mid-2006, a UK government energy report recommended the replacement of the nation's existing nuclear plant network with future reactor construction. The first of a younger breed of reactors have growth and expansion. **[21]**

5.4. Central and East Europe, Russia

Armenia has a solitary nuclear power plant with a 0.4 MW net capability. In 2020, atomic energy will account for 34.5 percent of renewable energy sources **[22]**

Belarus has one operational atomic power reactor, which will be linked to the grid in November 2020, and is constructing a new nuclear power plant. Natural gas is used to generate plenty of the rest of the country's power. **[23]**

Bulgaria has two nuclear power stations in operation, with a total net capacity of 2.0 GWE. Nuclear power produced 40.8 percent of the country's electricity in 2020 **[24]**

The **Czech Republic** has six nuclear power stations in operation, with a total net performance of 3.9 GWe. In 2020, nuclear power will account for 37.3 percent of renewable energy sources. **[25]**

Hungary has four nuclear plants in operation, with a total net capability of 1.9 GWe. In 2020, nuclear power will account for 48.0 percent of renewable energy sources **[26]**

Romania has two nuclear power stations in operation, with a total net potential of 1.3 GWe. Nuclear power produced 19.9% of the sources of renewable energy in 2020**. [27]**

Russia has 37 nuclear power stations in operation, with a total net performance of 27.7 GWe. In 2020, nuclear power generated 20.6 percent of total electricity generated. In 2016, the administration issued a decree mandating the building of 11 more nuclear power stations by 2030, in comparison to the regular ones already under development. Russia has four facilities undergoing development at the beginning of 2020, with an overall capacity of 4.8 GWe. Russia's nuclear industry in terms of strength is mirrored in its domination of nuclear plant export industries. The country's nuclear sector is now participating in new reactor developments in Belarus, China, Hungary, India, Iran, and Turkey, as well as in Algeria, Bangladesh, Bolivia, Indonesia, Jordan, Kazakhstan, Nigeria, South Africa, Tajikistan, and Uzbekistan to various degrees as a shareholder. https://world-nuclear.org/information-library/country-profiles/countries-o-s/russia-nuclear-power.aspx. **[28]**

Slovakia has four atomic power stations in operation, with a total operating capability of 1.8 GWe. In 2020, atomic energy will account for 53.1 percent of renewable energy sources. Two more flats are now being built **[29]**

Slovenia has a solitary atomic power station with a net capability of 0.7 GWe that is currently operational. Slovenia produced 37.8% of its electricity from nuclear energy in 2020. **[30]**

Ukraine has 15 nuclear plants in operation, with a total net capacity of 13.1 GWe. In 2020, nuclear power will account for 51.2 percent of renewable energy sources. **[31]**

Turkey started building its first atomic energy station in April 2018, with a projected launch date of 2023. **[32]**

5.5. Asia

In 2017, **Bangladesh** began work on the first of two projected Russian VVER-1200 reactors. The second began development in 2018. By 2023, it hopes to have the first operational unit. Currently, coal and oil provide almost all the nation's energy needs. **[33]**

China has 53 nuclear power stations in operation, with a total net capacity of 50.8 GW. In 2020, atomic energy will generate 4.9 percent of total electricity generated. The country continues to lead in the future reactor construction sector. At the beginning of 2022, China was home to 18 of the 57 reactors currently under development throughout the world. China was the first nation to order two major models in 2018: the AP1000 and the EPR. The Hualong One, a primarily domestic nuclear design, is now being marketed for export. The necessity to enhance city environmental performance and reduce carbon emissions is driving China's development of new nuclear energy. The federal government's declared lengthy goal, as described in its Energy Improvement Program Implementation Strategy 2014-2020, is to have 58 GWe of capability operational by 2020, with another 30 GWe undergoing production. **[34]**

India has 23 nuclear power stations in operation, with a total net potential of 6.9 GWe. Nuclear power will provide 3.3 percent of the country's electricity in 2020. As part of its huge construction development agenda, the Indian country’s commitment to increasing nuclear-generating capacity. In 2010, the government established a lofty goal of bringing 14.6 gigawatts of nuclear power online by 2024. In India, seven reactors were undergoing development at the beginning of 2020, with an overall capacity of 750 MW. **[35]**

Japan has 33 nuclear plants in operation, with a total net performance of 31.7 GWe. Despite the Fukushima disaster in 2011, ten plants had already come back online as of June 2021, with another 15 awaiting restarting permission. Atomic energy once accounted for 30% of renewable energy sources; by 2020, that figure had fallen to only 5.1 percent. **[36]**

South Korea has 24 atomic power stations in operation, with a total net power of 23.2 GWe. Atomic power produced 29.6% of the total electricity generated in 2020. South Korea is building four nuclear plants at home, as well as four in the United Arab Emirates. It intends to build two more afterward, after which its energy strategy will be undetermined. It's also doing a great deal of research into upcoming plant models. **[37]**

Pakistan has five nuclear power stations in operation, with a total net performance of 2.2 GWe (gigawatt electrical). Atomic energy produced 7.1% of the total energy generated in 2020. There is one Chinese Hualong in Pakistan. One tower is currently being built. **[38]**

5.6. Africa

South Africa seems to be the only African country today generating energy from atomic energy, with two operational nuclear power plants with a collective net performance of 1.9 GWe. Atomic power produced 5.9% of the total electricity generated in 2020. South Africa is dedicated to expanding its capacities, but it faces substantial financial challenges. **[39]**

5.7. Middle East

Iran has a unique operational atomic power station with a total power of 0.9 GWe in the Middle East. Nuclear power will provide 1.7 percent of the country's energy in 2020. A secondary VVER-1000 unit, created by the Russians, is now being built. **[40]**

The **United Arab Emirates** has two nuclear plants with a combined energy output of 2.7 GWe in operation. At a relatively similar facility, two additional reactors are being built (Barakah). **[41]**

6. Emerging nuclear energy countries

As previously stated, Bangladesh, Belarus, Turkey, and the United Arab Emirates are all building their initial nuclear energy facilities. Many other nations are considering nuclear energy as a source of energy. **[42]**

7. Improved performance from existing reactors

Nuclear power station efficiency has significantly increased throughout time. The fraction of units attaining a large performance factor has grown dramatically during the previous 40 years. For example, in 2018, 62% of units had a total capacity greater than 80%, compared to 28% in 1978, and only 7% of plants had a performance factor of less than 50%, compared to 20% in 1978.

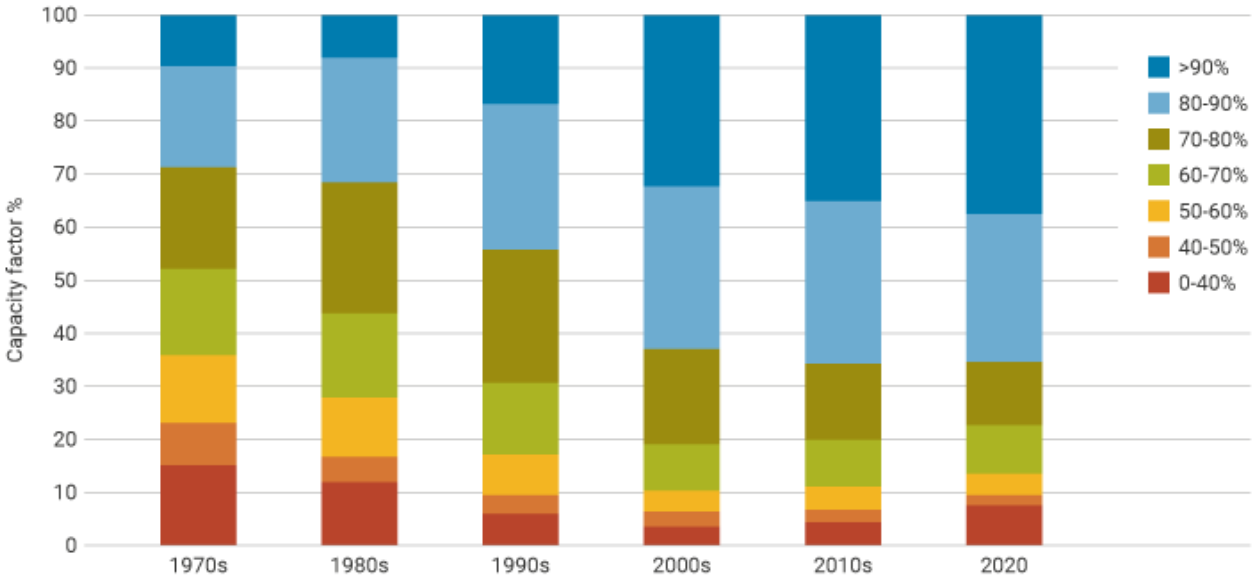

Figure 6: Long-term trends in capacity factors (Figure 5) (source: World Nuclear Association, IAEA PRIS)

It's also worth noting that the mean capacity factor for reactors has shown no significant age-related trend over the previous five years.

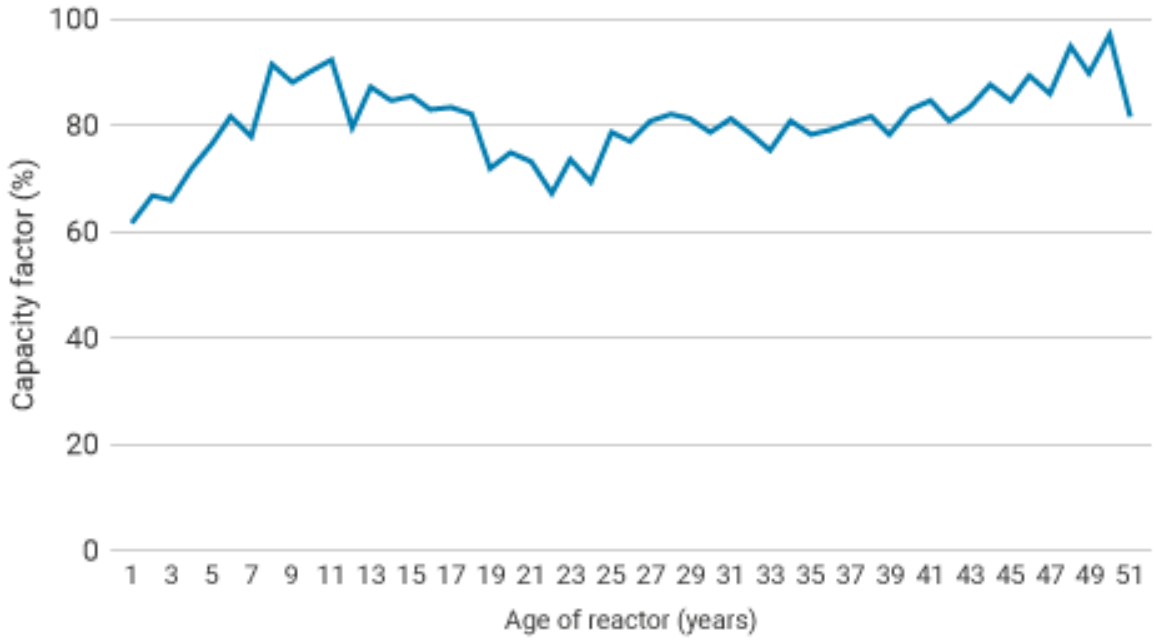

Figure 7: Mean capacity factor 2016-2020 by age of reactor (source: World Nuclear Association, IAEA PRIS)

8. Other nuclear reactors

There are currently around 220 research reactors functioning in over 50 nations, including more undergoing development, in addition to industrial atomic energy facilities. Most of these reactors produce medicinal and commercial isotopes in addition to being used for research and teaching. Reactor designs are generally used for ship propulsion in large militaries, where they have played a key role over the past five years, supplying energy for submarines and big surface warships. Over 160 ships, predominantly submarines, are driven by 200 nuclear reactors, which have accumulated over 13,000 power plants' decades of work expertise. Many of Russia's and the United States' nuclear submarines from the Cold War era have been destroyed. Russia also has a fleet of big nuclear-powered icebreakers on the way, with more on the way. In the isolated arctic location of Pevek, it has also linked a floating nuclear power station with two 32 MWe reactors to the grid. The reactors are based on those used to power icebreakers. **[43]**

References

1. https://world-nuclear.org/information-library/current-and-future-generation/outline-history-of-nuclear-energy.aspx
2. https://world-nuclear.org/information-library/energy-and-the-environment/nuclear-energy-and-sustainable-development.aspx.
3. https://world-nuclear.org/information-library/energy-and-the-environment/nuclear-energy-and-sustainable-development.aspx.
4. https://world-nuclear.org/information-library/current-and-future-generation/covid-19-coronavirus-and-nuclear-energy.aspx
5. https://world-nuclear.org/our-association/what-we-do/the-harmony-programme.aspx
6. https://world-nuclear.org/information-library/country-profiles/countries-a-f.aspx.
7. https://world-nuclear.org/information-library/country-profiles.aspx.
8. https://world-nuclear.org/information-library/country-profiles/countries-a-f/canada-nuclear-power.aspx.
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38. https://world-nuclear.org/information-library/country-profiles/countries-g-n/iran.aspx.
39. https://world-nuclear.org/information-library/country-profiles/countries-t-z/united-arab-emirates.aspx.
40. https://world-nuclear.org/information-library/country-profiles/others/emerging-nuclear-energy-countries.aspx.
41. https://world-nuclear.org/information-library/non-power-nuclear-applications/overview/the-many-uses-of-nuclear-technology.aspx.

42. https://www.iea.org/data-and-statistics.
43. https://www.world-nuclear.org/our-association/publications/global-trends-reports/world-nuclear-performance-report.aspx.