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Nuclear Energy Needed to Fight Climate Change

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Nuclear Energy Needed to Fight Climate Change

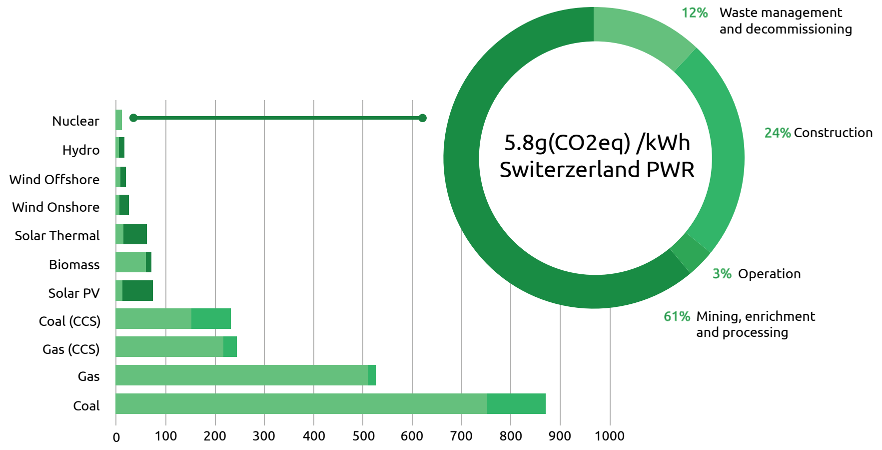
The climate change

Electricity generation is responsible for 42% of global CO_2 emissions.

With the global population and economic growth, the electrification of transportation and other sectors, global electricity demand could double by 2050. At the same time, carbon neutrality has to be reached.

FIGURE 1

Lifecycle greenhouse gas emissions per kilowatt-hour (g co2 – equivalent /kw-h)



Source: IAEA
World Energy Markets Observatory 2021

To tackle the climate emergency by 2040, over 80% of electricity should be low carbon, which is more than double current levels.

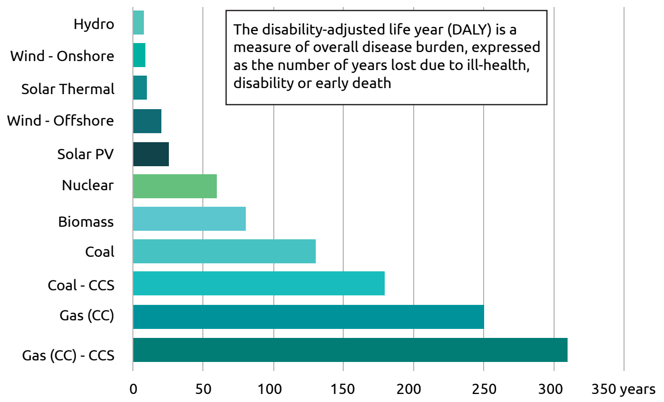
Nuclear energy development is part of the answer.

Nuclear power is one of the world's energy sources that emits the least greenhouse gas.

- Thanks to its nuclear footprint, France's electricity carbon intensity is under 50 gCO_2 per kWh, i.e. 10 times less than the G20 average.
- Nuclear energy is not currently included in the European Union taxonomies which are designed to channel sustainable investments. However, it is included in green plans for the United Kingdom, United States, and China.

FIGURE 2

Nuclear energy is safer than fossil fuels



Source: IAEA
World Energy Markets Observatory 2021

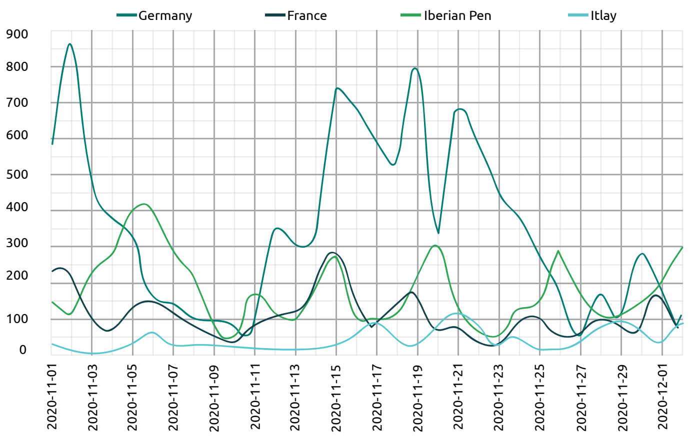
- The safest energy sources also have the smallest impact on the climate.
- Yet, these energies still account for less than 17% of primary energy (i.e. 4.3% for nuclear, 5.7% for renewables and 6.8% for hydro).

Nuclear is a 24/7 controllable electricity source

- Nuclear power contributes to balancing demand/supply on the grid with high renewables share.
- It enables a reliable and low greenhouse gas emitting electrical system.

FIGURE 3

Wind Generation



Source: AleaSoft
World Energy Markets Observatory 2021

- Nuclear power can therefore support greater deployment of intermittent solar and wind generation without the need for backup capacity from fossil fuel plants.
- "The need for flexibility in electricity generation and system management will increasingly characterize future energy systems over the medium to longer term. Improved frameworks for remunerating reliability, flexibility, and other services would favour nuclear operators," states the International Atomic Energy Agency (IAEA).

Nuclear electricity is well-suited to produce clean hydrogen, one of the energy carriers that can help decarbonize our economy

- Presently, 95% of the hydrogen consumed worldwide is produced with fossil fuel (grey hydrogen). Its production is therefore highly emissive of greenhouse gases.
- Green hydrogen produced by water electrolysis must be powered with low-carbon electricity.
- Together with renewables, nuclear is a clean electricity source.
- To reach their carbon neutrality goals, 40 countries have published a hydrogen strategy or are developing one.

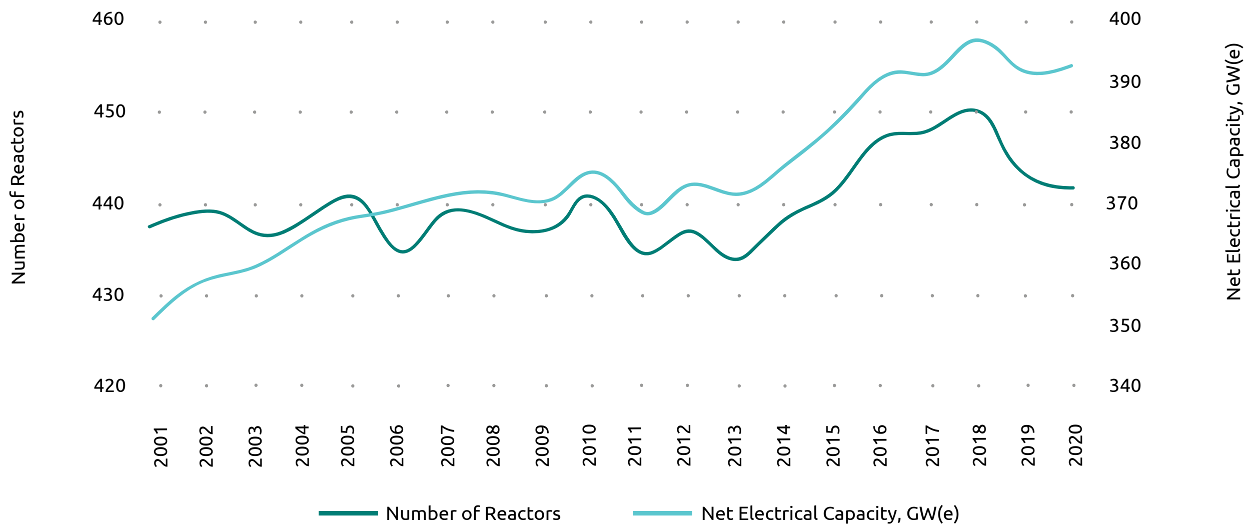
- The European Union plans to develop the low-carbon hydrogen industry:
  - It aims at building at least 40GW of electrolyzer capacity by 2030.
  - The equivalent in green electricity will have to be added, which is huge.
  - Nuclear power has to contribute to meet these goals.

Worldwide nuclear status and trends

In 2020, nuclear power provided about 10% of the world's electricity (a stable figure for many years), and 18% of electricity in OECD countries

FIGURE 4

Nuclear capacity trend



Source: IAEA PRIS (Power Reactor Information Service) Database
World Energy Markets Observatory 2021

- Global nuclear power capacity installed (443 reactors in 32 countries) was stable after a net 4.5GW decline in 2019:
  - New grid connections were offset by permanent shutdowns in Japan.
  - But increased capacity factors, notably in the United States, enabled global power generation stability.

- Nuclear energy consumption fell sharply in 2020 (-4.1%),

  driven mainly by declines in France (-0.4 %), United States (-0.2%) and Japan (-0.2%).

- However, this decline was lower than the 4.5% decrease of global primary energy consumption.

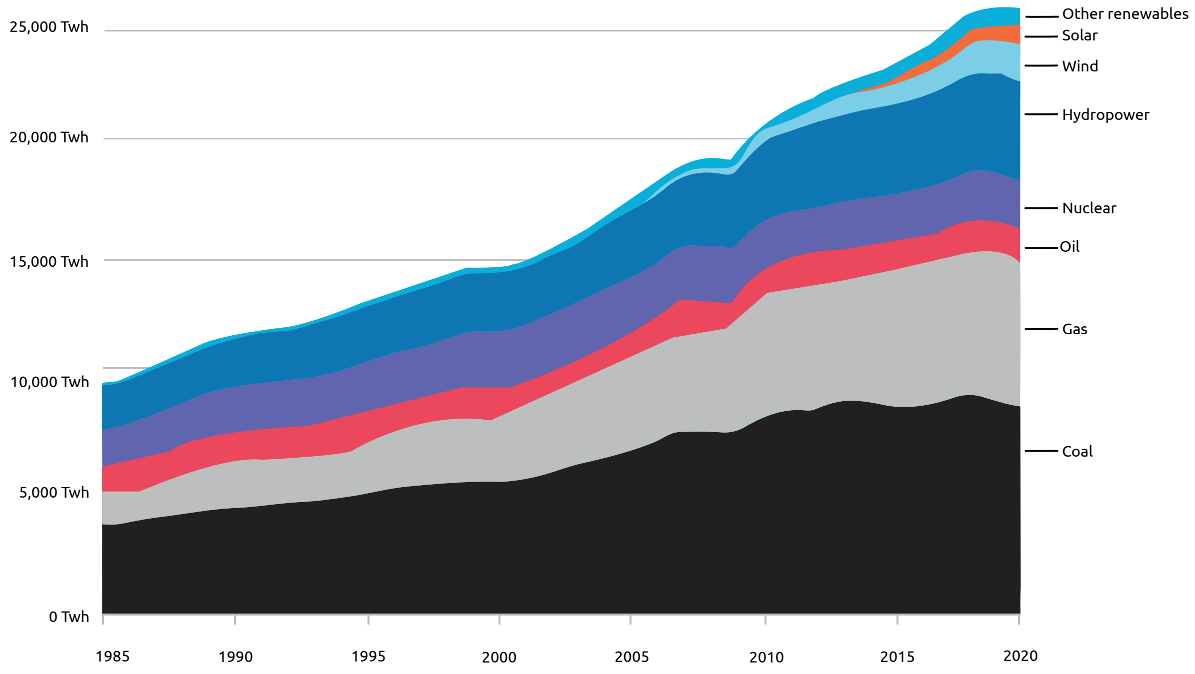
- The "big five" nuclear countries (by rank: the United States, China, France, Russia, and South Korea) generated 71% of global nuclear electricity in 2020.

- Five new reactors came online in 2020 (including locations in United Arab Emirates, China, Russia, and Belarus). Five reactors were closed, including sites in the United States, France, and Russia. Some of these closings were done for political reasons, such as the two French reactors at Fessenheim.

- Nuclear was, again, the world's second largest source of low-carbon power after renewables.

FIGURE 5

Electricity generated by fuel



Source: BP Statistical Review of World Energy – Our World in data
World Energy Markets Observatory 2021

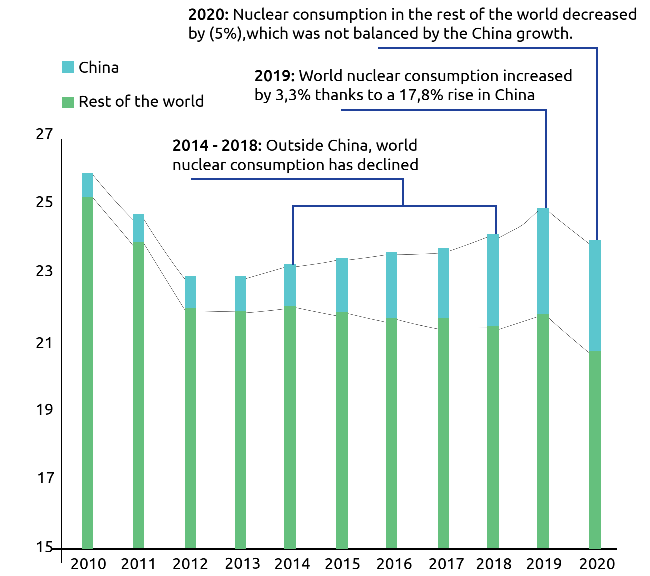
The share of Central and Eastern European, and Asian countries in global nuclear power generation has continued to increase

- The nuclear consumption of Central and Eastern Europe and Asia has been growing further in 2020, as driven by China which operates the second largest reactor fleet after the United States. China's nuclear power production surpassed that of France for the first time in 2020.

- In 2020, about 50 reactors (approximately 15% of existing capacity) were under construction, mostly in Asia. China is still leading in terms of growth, while Rosatom (Russia) ranks first for nuclear power plant construction projects abroad.

FIGURE 6

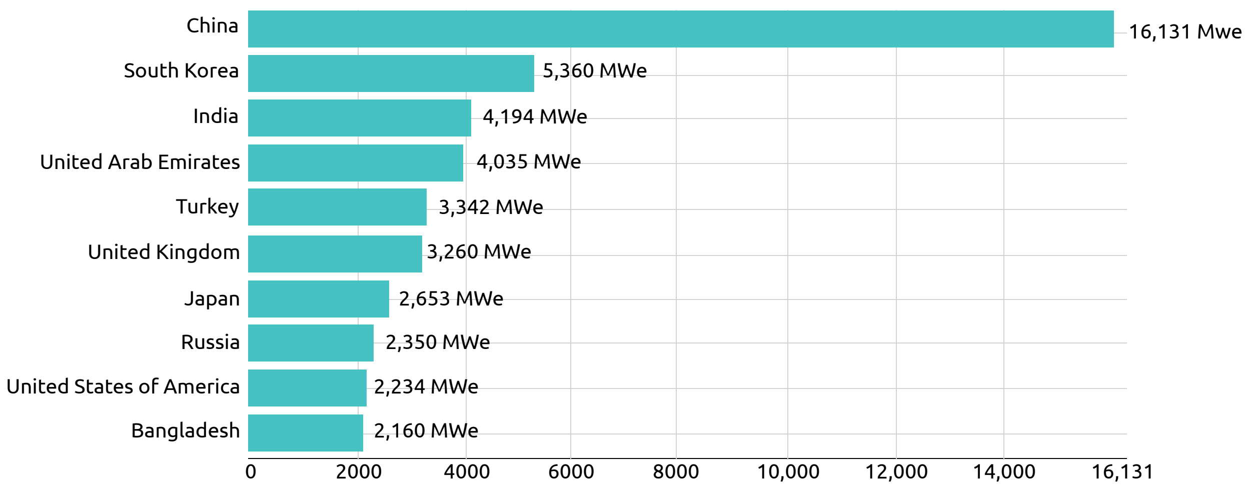
Nuclear energy consumption 2010—2020 in China and in the Rest of the World (ExaJoules – Input Equivalent)



Source: BP Statistical Review of World Energy – Our World in data, Capgemini Analysis
World Energy Markets Observatory 2021

FIGURE 7

Top 10 reactors under construction in 2020 - Net Capacity (MWe)



Source: IAEA PRIS (Power Reactor Information Service) Database
World Energy Markets Observatory 2021

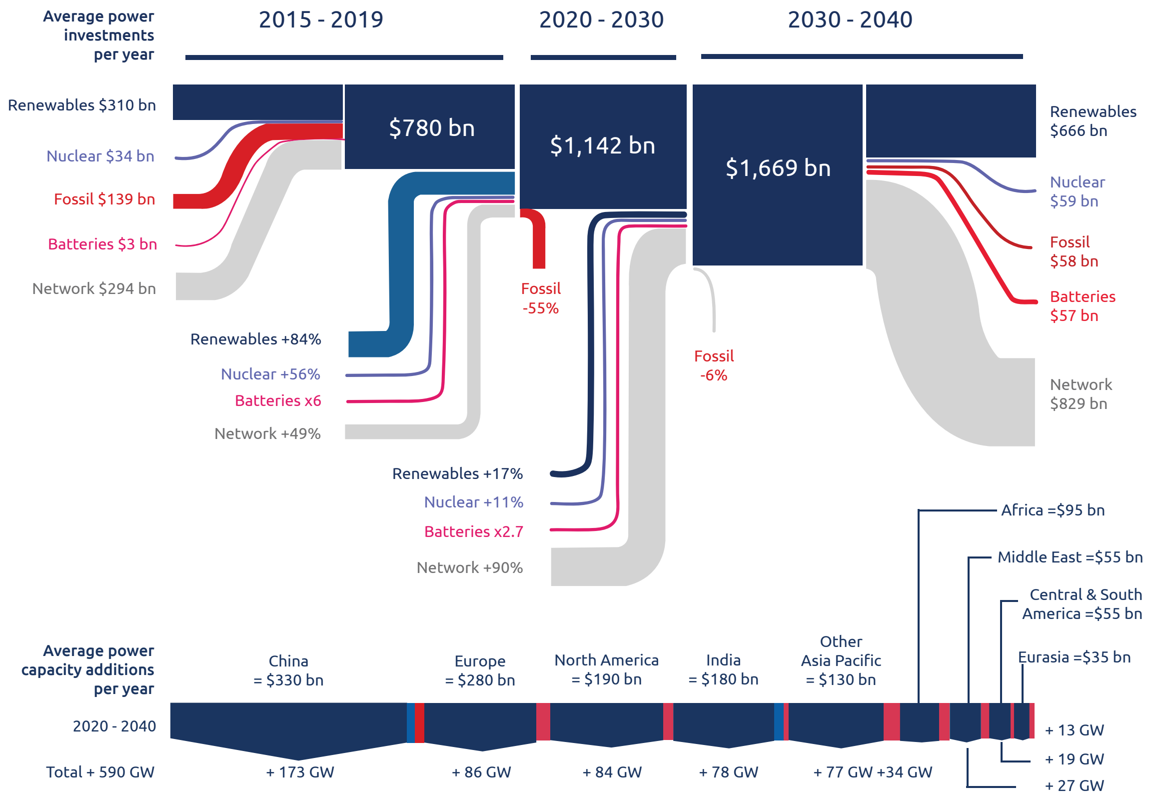
- In its net zero emissions scenario, the International Energy Agency (IEA) points out that by 2050, two-thirds of new builds (mainly large-scale reactors) will be located in developing economies.
- With plants decommissioning and few new reactors in development, the nuclear share of total electricity generation in advanced economies should fall from 18% in 2020 to 10% in 2050.

Current nuclear investment levels are far too low to respond to climate challenges

- Nuclear and renewable energy are the only sectors where investments have been maintained in 2020.
- Nuclear power investments, which accounts for about 5% of total global energy investments, grew to $42 billion in 2020 vs. $39 billion in 2019.
- Nuclear power investments are expected to increase in countries with well-defined nuclear expansion plans such as China, India, and Russia.
- Nevertheless, these yearly investment amounts are far from those required to meet the Paris Agreement objectives.

FIGURE 8

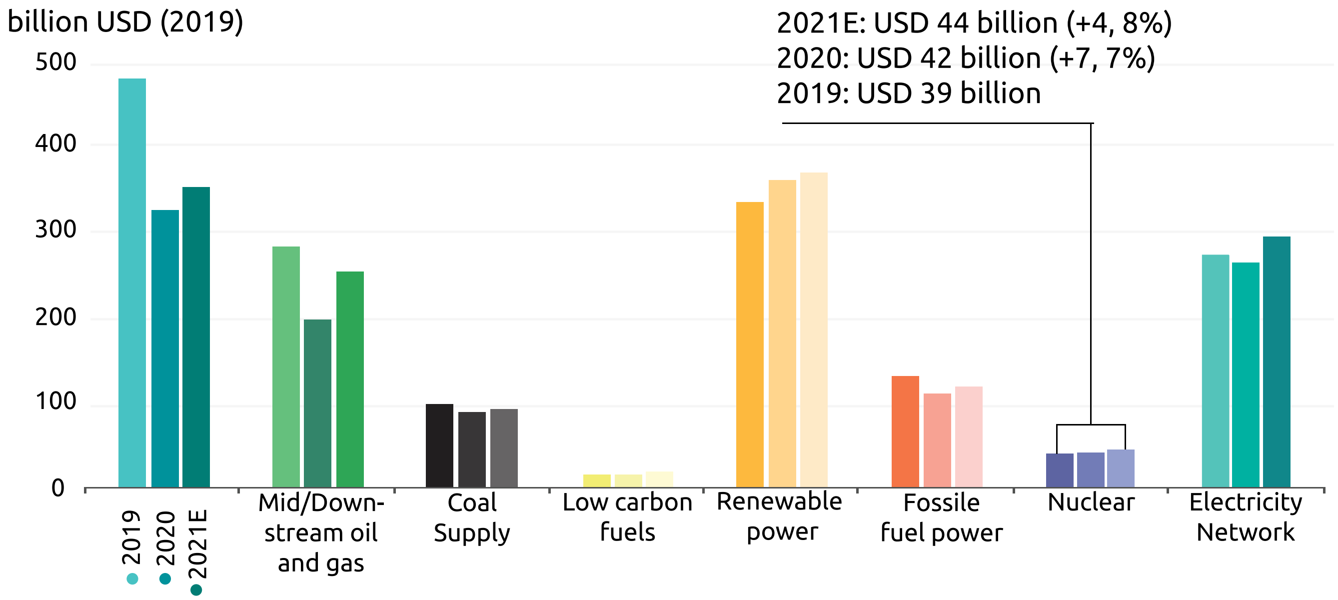
Global cumulative investments in low carbon technologies (annual average 2015-2019) and low-carbon power-sector requirements in line with the Paris Agreement (annual average 2020-2040)



Source: IEA 2021
World Energy Markets Observatory 2021

FIGURE 9

Global energy supply investment by sector, 2019-2021E



Source: IEA 2021
World Energy Markets Observatory 2021

Construction and decommissioning

Decisions are expected to be made regarding lifetime extensions and the pace of new construction

- The average age of the world's operating nuclear reactor fleet continues to increase. As of mid-2021, the average age is 31 years with 20% reaching 41 years or more.

- In most advanced economies, decisions have to be made regarding the renewal of an aging nuclear fleet and measures needed to extend the life of certain plants. Otherwise, nuclear power output in advanced economies will decline by two-thirds over the next two decades.

- EDF is investing €50 billion in the "Grand Carénage" programme, which runs from 2014 to 2025. It aims to enhance the present reactor fleet's safety and extend their lifetime beyond 40 years.

- In emerging and developing market economies, decisions are expected to be made regarding the pace of new nuclear power plant construction. The rate of 6GW per year over the last 9 years is still not high enough to match the 24GW per year expected in the IEA's Net Zero Emission pathway by 2030.

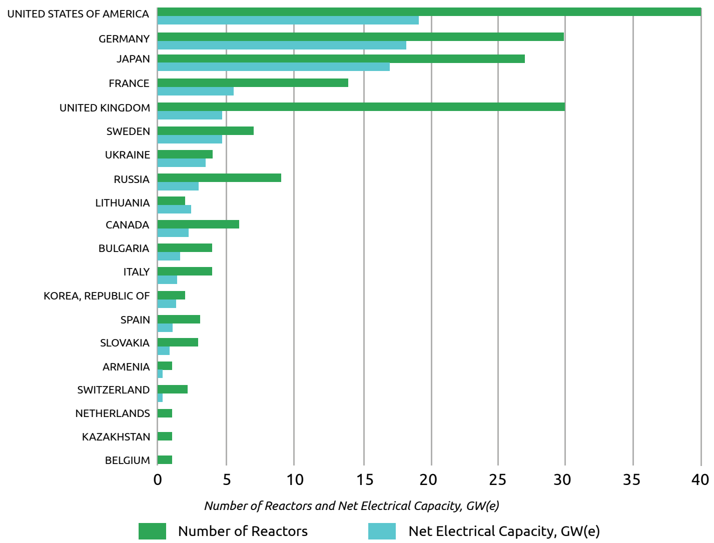
Reactor shutdowns are mainly in Europe

- 194 nuclear reactors (power and research) have been shut down worldwide since the early 1960s (totalling 89GW of capacity). More than half of these reactors are located in Europe.

- Of these 194 shutdown power reactors, 20 have been completely dismantled, but only 10 have been returned to a “greenfield” state and made available for further activity (as opposed to a “brownfield” state, which allows only industrial reuse with restrictions).

FIGURE 10

Permanent shutdown reactors



Source : IAEA PRIS (Power Reactor Information Service) Database
World Energy Markets Observatory 2021

The volume of reactors entering into decommissioning is increasing

- The pace of shutdowns has accelerated in recent years, particularly since the Fukushima nuclear accident in 2011. The rate should intensify over the next 30 years. More than 150 reactors worldwide are at the end of their lifetime.

- In Europe, 90% of the installed base will reach 40 years old by 2040 (i.e. the expected initial life of many plants). However, the lifetime of similar reactors has been extended beyond 50-60 years in the United States.

The decommissioning phase is often longer than the operating phase and requires significant expertise

- Decommissioning activities involve fuel evacuation, deconstruction of buildings, decontamination, and cutting, handling and disposal of waste.

- Dismantling operations challenges are specific to each reactor type and design.

- Dismantling of large nuclear power plants are very long-term projects with many regulatory constraints.

- The solution for very long life and very radioactive waste disposal has not yet been decided in many countries.

- Technical solutions for the treatment and disposal of certain reactor’s components (such as graphite) have to be improved.

Decommissioning stakes are large and vary according to many parameters

Parameters include:

- Series effect (in particular, the number of same design reactors to be dismantled) and the reactor’s size.
- Dismantling technologies used.
- Project ambition and scope (greenfield vs. brownfield final state, spent fuel reprocessing, etc.).
- Speed of dismantling knowing that radioactive levels decrease over time.
- Number of reactors to be dismantled per site.
- Environmental and nuclear regulatory constraints.
- Labor costs and experience level.
- Installation of the initial state and historical knowledge.

Digital transformation

The nuclear industry, like other sectors, has launched its "fourth industrial revolution"

- It affects all value chain components: design, construction, maintenance, safety, and dismantling.
- Digital transformation is powered by the high volume of data generated along the very long project lifetime: design, operation, and dismantling phases (around 100 years). In addition, regulators' studies requests and reports are very large.
- As an example, building a nuclear reactor requires the production and management of at least 4 million objects, 5 million documents and 500,000 tests.
- Digital technology has multiple roles to play in the sector: product lifecycle management, simulation, quality control, study of incidents or accidents scenarios, operator training, maintenance, etc.

Design simplification, components standardization, and data management over the lifecycle can bring major benefits

- These points can decrease costs and improve competitiveness for a sector whose levelized costs of energy have increased in recent years (while renewable energy costs have dropped considerably).
- Benefits are significant during the construction phase, wherein costs represent about 80% of the total electricity generated cost.

In several areas, the nuclear industry remains at the forefront of new technologies

- Digital twins are a major pillar to optimize the operation and maintenance of physical facilities. In January 2020, EDF launched a Digital Reactor R&D Project. From design to decommissioning, through operation and maintenance, the Digital Reactor R&D Project will provide engineers and operators with an integrated environment to improve simulations.
- The increased use of robots and drones, particularly for dismantling, is limiting the operator's exposure to radioactivity and facilitating inspections.
- Immersive 3D virtual reality rooms and helmets are used to simulate and prepare interventions.
- Some nuclear companies are developing digital platforms that will enable the various players to share project data. These platforms will enable quick digital information updates on equipment throughout their lifecycle (e.g. configurations and modifications by the various partners).

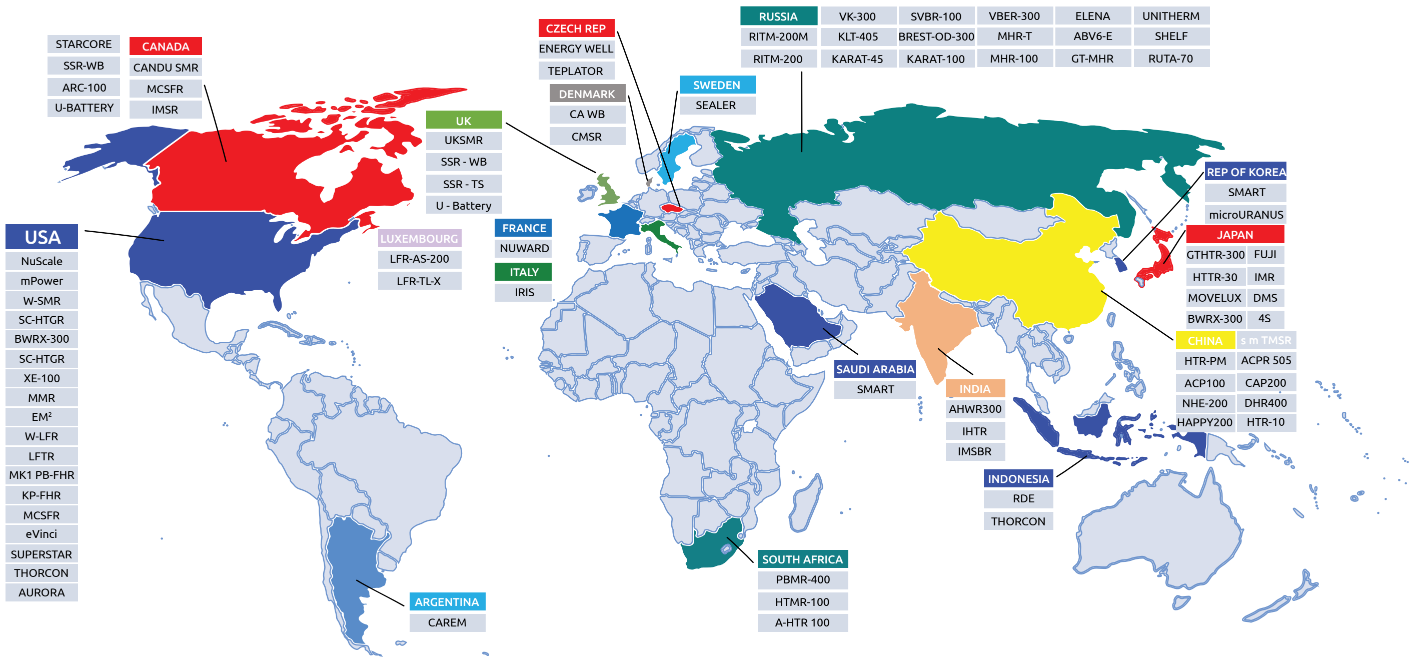
SMR

Small Modular Reactors (SMRs) are attracting the attention of many countries that want to reduce their carbon footprint and whose financial capacity is limited

- SMRs are modular reactors with a power output from 60MW to 300MW compared to more than 1,000 for conventional modern reactors. They promise significant cost reductions due to their modularity, factory manufactured components assembled on site, and simplified design. These features should help better control manufacturing costs and lead times.
- SMRs can be deployed in regions with a less developed grid. They could replace coal-fired power plants, contribute to green hydrogen production, or seawater desalination.
- Today, more than 70 SMR models of various technologies are being developed. Many countries are developing prototypes or building those reactors, including Russia, China, United States, Canada, Sweden, India, and France.

FIGURE 11

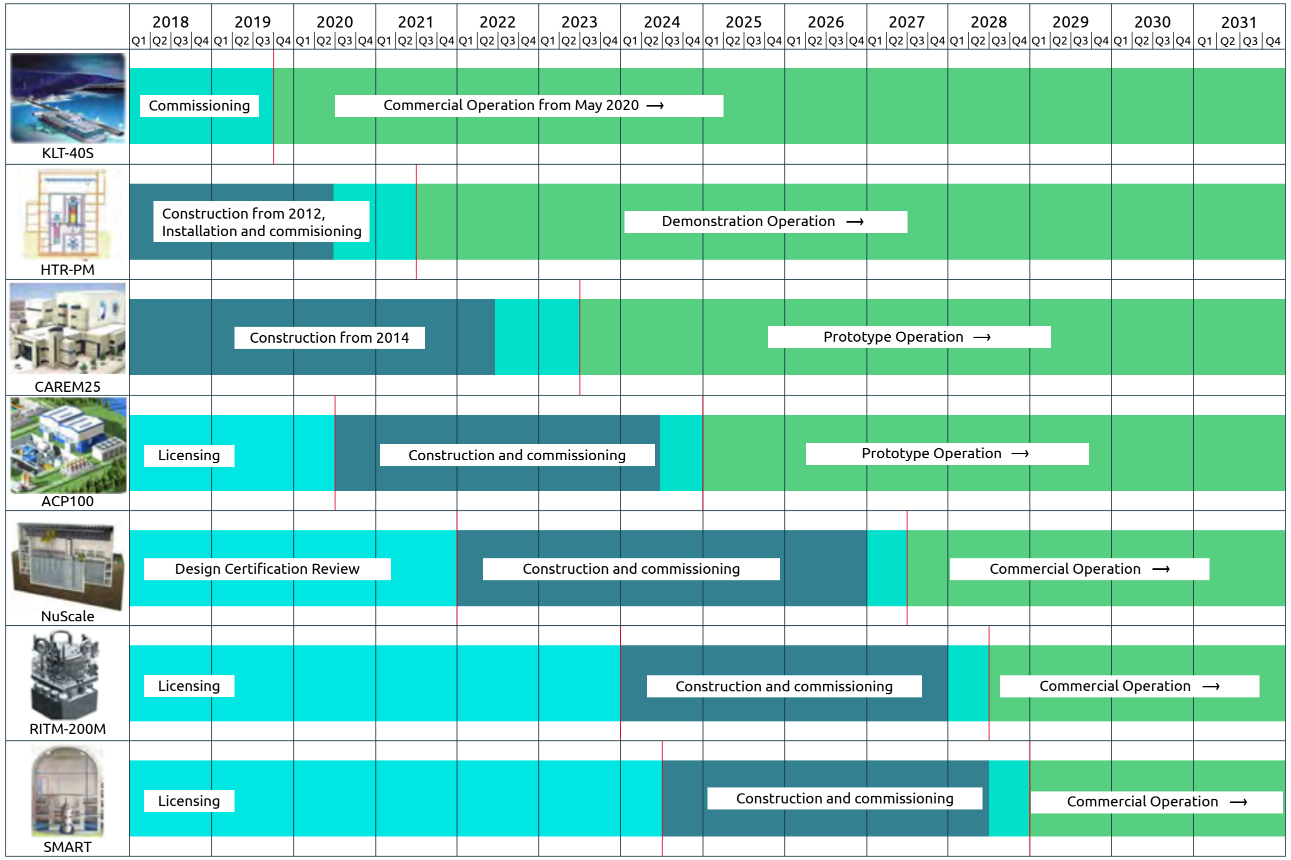
Global map of SMR technology development



Source : IAEA Advanced Reactors Information System (2020 Edition)
World Energy Markets Observatory 2021

FIGURE 12

General Timeline of deployment as of 2020



Source: IAEA Advanced Reactors Information System (2020 Edition)

- Two industrial demonstration SMRs are at an advanced stage of construction: in Argentina (CAREM, a simplified 100MW PWR) and in China (HTR-PM, a high-temperature gas-cooled reactor). They are scheduled to come on line between 2021 and 2023.
- The Akademik Lomonosov floating power generation unit in Russia, equipped with two KLT40S modules, was connected to the grid and began commercial operation in May 2020.
- In China, CNNC has begun the construction of a 125MW onshore SMRs (ACP100) that is expected to power 526,000 homes. It could be the first land-based SMR to enter into commercial service.
- Although SMRs have a lower initial investment cost per unit, their economic competitiveness remains to be proven as they require similar volume of studies and regulatory approvals than large reactors, despite having a smaller electricity output.

Conclusion

- The role of nuclear power in achieving carbon neutrality by 2050 is now recognized.
- In the context of increasing volumes of non-dispatchable electricity, nuclear is a clean schedulable electricity source and a good complement to wind and solar electricity.
- The extent to which nuclear power can enable energy transition depends on the industry's ability to drive down costs, accelerate innovation, and secure sufficient public support.
- Regarding public information, the UNSCEAR report on the Fukushima incident shows that misinformation to the public is at odds with the solid scientific evidence and facts. This is a challenge to scientists and governments around the world.
- In developed countries, nuclear reactors are aging. In the United States, Canada, United Kingdom, and France, operators are allowed to extend reactors' lifetime thanks to large investments aimed at replacing aging equipment and upgrading safety.
- Very long-term reactors decommissioning programs are growing mainly in western countries.
- The share of Central and Eastern European, and Asian countries in global nuclear power generation has continued to increase with China concentrating half of worldwide investment.
- Investment in new plants remains insufficient to reach the Paris Agreement objectives:
    - Governments should take clear decisions to renew their existing reactor fleet.
    - The absence of a timely decision could lead to real challenges as the nuclear output should double by 2050

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