Anthropocene Institute

# World Nuclear Investment Factbook

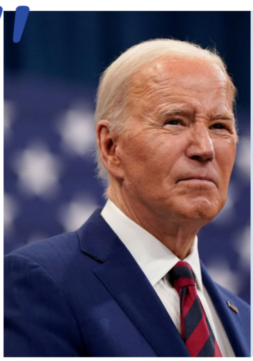
Data curated until

May 2025

# MESSAGE FROM OUR LEADERS

Bipartisan support for nuclear energy is emerging as a cornerstone of the nation's strategy to secure a reliable, low-carbon energy future. Lawmakers from both parties have consistently championed initiatives aimed at modernizing the nuclear fleet, streamlining regulatory processes, and fostering international collaboration. Recent legislative measures, such as provisions embedded in the Infrastructure Investment and Jobs Act and the Inflation Reduction Act, reflect this cross-party commitment, allocating substantial funding for advanced nuclear research and the refurbishment of existing facilities. This unified approach underscores the recognition that nuclear energy is not only critical for ensuring energy security and economic competitiveness, but also pivotal in achieving the nation's long-term climate goals.

On the global stage, bipartisan backing within the United States complements international efforts to integrate nuclear power into broader decarbonization strategies. At major climate summits, numerous countries have reiterated their commitment to expanding nuclear capacity, recognizing its essential role in reaching net-zero emissions and stabilizing energy supplies. This collective endorsement, spanning domestic and international spheres, reinforces the strategic importance of nuclear energy, positioning it as a vital component of both national energy dominance and global sustainable development. Ultimately, bipartisan support provides the political and financial impetus needed to drive innovation, secure robust supply chains, and build a resilient, diversified energy infrastructure for the future.



**"These targets are ambitious but achievable, signaling our commitment to safely expanding nuclear energy and creating related infrastructure and jobs."**

- President Biden at the Announcement of Biden–Harris Administration's framework to expand U.S. nuclear energy capacity

**"We will rapidly bring new power plants online, including nuclear, to make America the number one energy producer in the world."**

- Donald Trump at his Campaign Rally in Clinton Township, Michigan

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# EXECUTIVE SUMMARY

This updated report extends our previous analysis by incorporating the full 2023 data and insights, broadening our scope to include emerging nuclear newcomer countries alongside established nuclear powerhouses. Building on our earlier work, which detailed annual, country-wise nuclear investments (both government and private) by technology type, we have enhanced our methodology and data collection to capture the rapid evolution in the nuclear energy sector. In this edition, the Anthropocene Institute team delves deeper into the dynamics of nuclear startup ecosystems, updated funding allocations, and technological advancements, including the development of small modular reactors (SMRs) and microreactors. These innovations are poised to make nuclear installations more flexible and cost-effective, strengthening nuclear energy's role as a low-carbon, stable baseload in the global energy mix.

Against the backdrop of ambitious climate targets and the global energy transition, this report analyzes how market trends, country policies, and geopolitical events are reshaping nuclear energy investments in 2023. While established leaders like the United States, China, France, Russia, and Canada continue to drive innovation and investment, several newcomer nations (such as Poland, Serbia, and Kazakhstan) are now making significant strides, signaling a broader acceptance and strategic pivot toward nuclear power. By presenting a comprehensive, updated country profile that reflects these emerging trends and investment patterns, this report provides vital insights for governments, policymakers, industry stakeholders, and the general public. The findings highlight the critical role of nuclear energy in addressing rising global energy demands, reducing carbon emissions, and spurring economic growth through job creation in the research, development, and deployment of advanced nuclear technologies.

# INTRODUCTION

In the context of intensifying global geopolitical tensions and the urgent pursuit of decarbonization, nuclear energy has emerged as a pivotal component of national energy strategies in 2023–2024. Recent policy initiatives, notably those advanced by the Biden administration emphasizing modernization of nuclear infrastructure and the development of small modular reactors as part of a broader clean energy agenda, have reinforced nuclear power's potential role in ensuring both energy security and climate resilience [107]. Concurrently, emerging conflicts have underscored the strategic importance of nuclear assets while simultaneously exposing their vulnerabilities. For instance, the occupation of Ukraine's Zaporizhzhia nuclear power plant, where compromised safety measures have been exploited as political leverage, highlights the acute risks associated with nuclear infrastructure in conflict zones [27, 28]. Similarly, the ongoing conflict in Israel has raised concerns regarding the security of nuclear facilities in the Middle East, prompting a re-evaluation of safety protocols and risk mitigation strategies [28].

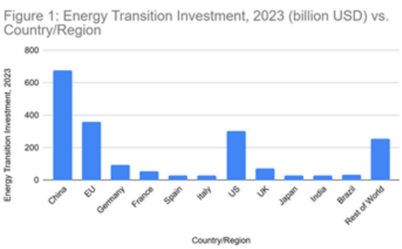
Regionally, significant policy shifts further illustrate this evolving landscape. Kazakhstan's recent national referendum on its nuclear energy strategy signals a re-assessment of the country's future energy mix in light of both domestic priorities and international security considerations [1]. Meanwhile, the Ukrainian parliament is poised to vote on the acquisition of Bulgarian nuclear reactors, a move that reflects Ukraine's determination to modernize its nuclear fleet and reduce its reliance on compromised legacy systems amid persistent geopolitical pressures [29].

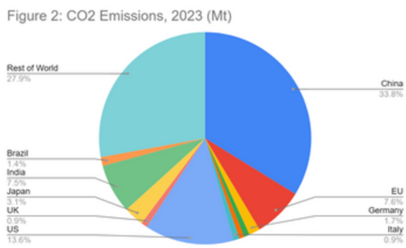
This updated report, extending our previous analysis, integrates these critical developments from 2023–2024. It offers a comprehensive overview of emerging trends, investment patterns, and policy reforms that continue to shape the nuclear energy sector globally, providing valuable insights for policymakers, industry stakeholders, and scholars engaged in the discourse on energy security and sustainable development.

The years 2023 and 2024 have marked a watershed moment for the nuclear energy sector. Advancements in reactor technology, increased public and private investment, and progressive policy frameworks have converged to drive unprecedented growth and innovation. These years have not only witnessed significant strides in nuclear reactor safety and efficiency but have also cemented nuclear energy's role as a cornerstone in the global transition toward sustainable energy. In light of these achievements, 2023–2024 can be regarded as some of the most successful and transformative years for nuclear energy to date, setting a robust foundation for future developments in the sector.

Table: Annual Energy Transition Investment and Total $CO_2$ Emissions by Country (Energy Transition Investment Trends, Bloomberg NEF 2024; IEA, 2024)

| Country/Region | Energy Transition Investment, 2023 (billion USD) | CO2 Emissions, 2023 (Mt) |
|---|---|---|
| **China** | 675.9 | 11,943 |
| **EU** | 360.5 | 2,700 |
| **Germany** | 95.4 | 600 |
| **France** | 55.5 | 300 |
| **Spain** | 32.2 | 270 |
| **Italy** | 29.7 | 330 |
| **US** | 303.1 | 4,800 |
| **UK** | 73.9 | 335 |
| **Japan** | 32.0 | 1,084 |
| **India** | 31.4 | 2,649 |
| **Brazil** | 34.8 | 479.5 |
| **Rest of World** | 257.8 | 9,844.5 |



SMRs offer the promise of reduced upfront costs and faster construction timelines owing to their simple, modular designs. Typically generating under 300 MW (in contrast to roughly 1 GW for conventional reactors), they can modulate their power output to better match fluctuating demand, making them both cost-effective and flexible [130, 131]. Their modular construction enables full factory fabrication and on-site assembly, which reduces non-recurrent costs and allows for serial production that benefits from learning effects and standardization [127].

In 2023, the development of SMRs has accelerated globally, with over 80 designs currently under development across 19 countries [130]. The NEA estimates that, under an ambitious scenario, up to 375 GW of SMR capacity could be installed by 2050, over half of the nuclear capacity needed to achieve net-zero emissions. Although widespread commercial deployment of SMRs may require over a decade to scale up, increased public and private investments are already helping to reduce these timelines and address technical challenges. In the IEA's Net Zero scenario, advanced nuclear technologies, including SMRs, are expected to contribute to half of global emissions reductions by 2050 [130].

# Country Profiles

## NEWCOMERS

The "Newcomers" section of our factbook underscores a significant global trend where countries that once rejected nuclear power are now reevaluating its role in their energy portfolios. In response to escalating energy demands, environmental concerns, and the imperative to reduce greenhouse gas emissions, these nations are lifting longstanding bans and initiating feasibility studies for new nuclear power plants. This paradigm shift is driven by a recognition that nuclear energy offers a stable, low-carbon alternative to fossil fuels, and it is increasingly seen as an essential component in achieving energy independence and enhancing grid resilience.

At the same time, these countries are actively engaging in international collaborations to share technological expertise and secure robust financing models for nuclear projects. By partnering with established industry leaders and exploring innovative reactor technologies, such as advanced light-water reactors, small modular reactors, and other next-generation designs, these emerging nuclear proponents aim to modernize their energy sectors. The collective effort not only signals a move towards diversifying national energy mixes but also highlights a broader commitment to sustainable economic growth and global decarbonization targets.

# KAZAKHSTAN

Kazakhstan has taken a major step forward in its plans for nuclear energy following a historic referendum on 7 October 2024, in which 71.12% of participants voted in favor of constructing a new nuclear power plant. Voter turnout was recorded at 63% of the electorate, reflecting keen public interest in the question: “Do you agree with the construction of a nuclear power plant in Kazakhstan?” ([1]) President Kassym-Jomart Tokayev, who announced the referendum in 2023, highlighted the country’s “dire need of reliable and environmentally-friendly sources of energy,” noting that nuclear “largely” meets Kazakhstan’s rapidly growing energy demands. In post-vote remarks, he suggested that a future plant could be built by an “international consortium of leading companies” to ensure cutting-edge technology and shared expertise. This vote not only underscores a shift in public sentiment toward nuclear but also marks a significant policy turning point: from mere discussions and feasibility studies toward a concrete, publicly supported pathway to diversify Kazakhstan’s heavily fossil fuel–based energy mix.

Kazakhstan is already the world’s leading producer of uranium, supplying a substantial portion of the global nuclear fuel cycle. Its position as the world’s largest uranium producer provides a strategic advantage in both domestic energy plans and securing nuclear fuel for international markets. Although it does not currently operate a commercial nuclear power plant, Kazakhstan has considerable experience with nuclear technology, having three research reactors and a legacy BN-350 sodium-cooled fast reactor at Aktau. Building on this nuclear heritage, the government established Kazakhstan Nuclear Power Plant (KNPP), a subsidiary of the Samruk-Kazyna National Welfare Fund, to pursue pre-project and feasibility work for new nuclear facilities. Initial studies have identified Ulken, near Lake Balkhash, as the most suitable site for the first reactor, with options to construct additional small modular reactors to replace retiring coal plants in the longer term.

In preparing for this future expansion, Kazakhstan has held preliminary discussions regarding cooperation with France, Russia, and China, with a view to sharing technological expertise and securing robust financing models. Over the longer term, the government aims for nuclear energy to account for about 5% of the national generation mix by 2035, bolstered by international partnerships and adherence to rigorous safety standards that will help solidify Kazakhstan’s position as a leading and responsible global actor in the nuclear arena. [1–2]

# SERBIA & ITALY

Serbia has officially lifted its 35-year ban on the construction of nuclear power plants, marking a significant shift in the country's energy policy [3]. The move follows President Aleksandar Vučić's calls for up to 1,200 MW of small modular reactor capacity, the signing of a memorandum of understanding among multiple ministries and academic institutions to study nuclear energy options [4], and exploratory discussions with international partners including France's EDF and engineering firm Egis [5]. While the legal change itself does not guarantee a nuclear build, it paves the way for ongoing feasibility studies and more extensive collaboration with potential partners such as Rosatom and neighboring Hungary's Paks nuclear plant. [3–5]

Italy's recent decision to reconsider its ban on nuclear energy marks a dramatic shift in national energy policy ([8][10]). Historically, Italy was at the forefront of Europe's nuclear sector, housing several reactors and pioneering advanced research in the mid-to-late 20th century. Following the 1987 referendum triggered by the Chernobyl accident, and later bolstered by a 2011 referendum in the aftermath of Fukushima, the country phased out its nuclear plants entirely, making it the only G7 member state without active nuclear power facilities. Now, under the administration of Prime Minister Giorgia Meloni, there are concrete plans to reintroduce nuclear technology. The current environment minister, Gilberto Pichetto Fratin, announced that legislation to allow the development of new nuclear technologies could be passed as early as the end of 2024, with a formal decree anticipated by 2025.

A parliamentary inquiry into nuclear energy is already underway, focusing on the viability of deploying advanced reactor technologies, including small modular reactors (SMRs), to meet an anticipated rise in energy demand and to support Italy's commitments under its National Integrated Energy and Climate Plan (NECP). Proponents view nuclear as a stable, low-emission complement to intermittent renewables like solar and wind, potentially meeting up to 11% of Italy's energy requirements by 2050. Advocates emphasize the benefits of pairing nuclear's consistent output with renewables' scalability, but concerns persist regarding protracted construction times, high capital costs, and historical reservations among the Italian public. The coming months and years will determine whether Italy can reconcile past apprehensions with the present need for reliable, low-carbon energy solutions.

The government's willingness to lift the decades-long prohibition suggests a more pragmatic stance on nuclear's role in decarbonization. Policymakers recognize that renewables alone may not suffice to replace fossil fuels at the pace required by climate targets, particularly during peak demand periods. Nevertheless, the success of any new nuclear initiative will hinge on transparent project timelines, clear risk management, and winning over a public still skeptical of large-scale reactor projects. As Italy sets out to revive a once-thriving nuclear sector, the coming months and years will determine whether the country can reconcile past apprehensions with the present need for reliable, low-carbon energy solutions.

# POLAND

Poland's pursuit of its first commercial nuclear power plant represents a pivotal shift in the country's energy strategy [14]. Long reliant on coal for the majority of its power generation, Poland has increasingly looked to nuclear technology to secure both energy independence and reduced emissions in line with European Union decarbonization targets. The leading project, earmarked for the Pomeranian region, has garnered considerable international interest. France's Bpifrance Assurance Export and Sfil have pledged financing worth PLN 15 billion (approximately USD 3.75 billion) [14], and Export Development Canada has signaled the possibility of up to CAD 2.02 billion (USD 1.45 billion) in support [15]. In parallel, the Export-Import Bank of the United States (EXIM) had previously committed a USD 3 billion letter of interest for U.S. nuclear exports to Poland [16], reflecting the broad extent of multinational cooperation underpinning the initiative.

Despite these significant commitments, estimated to total USD 10.4 billion when factoring in pledged contributions from Canada, France, the United States, and the Polish national budget [17], actual funds have yet to be disbursed. The project's overall cost could reach PLN 150 billion (around USD 38.6 billion) [17,18], leaving questions about whether these early financing gestures represent a robust foundation for a venture of this magnitude. While letters of intent offer an encouraging signal of external support, Poland's ability to transform these preliminary pledges into tangible financing agreements will determine whether the 2030 target date is achievable. Any substantial delays in capital flow could jeopardize the timeline, highlighting the urgent need for clarity in execution planning and steadfast commitment from all parties involved.

Looking ahead, Poland's success in launching its nuclear program will hinge on more than just securing adequate funding. Effective project management, transparent risk mitigation strategies, and adherence to high safety and environmental standards will be essential in translating this ambitious vision into reality. The government's drive toward energy diversification, aimed at reducing coal dependence and enhancing resilience, stands at the core of the initiative. If Warsaw can convert these financial pledges into concrete action and maintain consistent oversight and accountability, Poland's maiden nuclear power plant may well become a cornerstone of the country's future energy mix, marking a crucial step toward sustainable growth and greater autonomy in the European energy landscape.

# CHINA

**ASIA**

China's nuclear electricity generation has continued its rapid expansion, driven by the country's commitment to peaking carbon emissions before 2030 and achieving carbon neutrality by 2060 [30]. As of 2023, China operates 55 active nuclear reactors with a combined installed capacity of 53,181 MWe, while additional reactors under construction will bring an extra 21,608 MWe online [30]. These facilities include 71 pressurized water reactors, two pressurized heavy-water reactors, two fast breeder reactors, and one high-temperature gas-cooled reactor. The China National Nuclear Corporation (CNNC) has long prioritized self-reliance, spearheading numerous research endeavors to enhance domestic reactor design and engineering [31].

China's nuclear electricity output increased from 417.8 TWh in 2022 to 440.1 TWh in 2023, reflecting both the addition of new reactors and higher utilization rates [32]. In parallel, China has significantly ramped up its nuclear investment. Government planning documents indicate continued support for nuclear financing and technology demonstration in 2024, underscoring nuclear power's central role in national energy policies [31,32].

China's 14th Five-Year Plan calls for 70 GWe of nuclear operating capacity by 2025. Moreover, CNNC projects that total installed nuclear capacity could reach 180 GWe by 2035, accounting for approximately 5% of overall capacity and 10% of total electricity generation [33]. The volume of newly approved reactors further illustrates the government's sustained commitment, with ten new units sanctioned in 2022 and six more in 2023 [32].

To meet these ambitious targets, China is advancing a variety of reactor technologies. This includes the Linglong-1 small modular reactor (SMR), currently under construction and poised to become the world's first commercial land-based SMR of its kind [34]. Meanwhile, the thorium-fueled molten salt experimental reactor (TMSR-LF1), operationally approved in 2021, could lead to a 373 MWe commercial-scale unit by 2030 if the pilot project proves successful. China is also pursuing high-temperature gas-cooled reactors, floating reactors for offshore energy, and additional SMRs for both domestic and international markets [35]. This aggressive expansion, coupled with investments in international reactor projects, could reshape energy dynamics in Southeast Asia and Africa by providing countries with access to affordable, low-carbon energy and significantly contributing to international climate goals.

Looking beyond its domestic fleet, China maintains robust international collaboration with the International Atomic Energy Agency (IAEA) on reactor development, including nuclear fusion, and exports reactor technologies and expertise to several countries, notably Pakistan. It is also in discussions with emerging economies such as Argentina, Bulgaria, and Saudi Arabia [34]. These initiatives emphasize China's ambition not only to bolster its domestic nuclear sector but also to play a formative role in shaping the future of global nuclear power.

# CHINA



China's resolute commitment to expanding its nuclear capacity is reflected in both long-term policy objectives and substantial financial outlays. In 2023, the country invested approximately USD 225 billion (CNY 1.6 trillion) in nuclear power, covering operational reactors, those under construction, and newly approved units, representing a significant increase from previous years. Some estimates indicate a 20% rise in completed investment value for nuclear projects compared to 2022, underscoring China's confidence in nuclear energy as a reliable, low-carbon source.

Nevertheless, nuclear power still faces hurdles in scaling up to match the prominence of China's existing coal fleet. As of 2023, China's planned and under-construction nuclear capacity (approximately 24 GWe under construction and an additional 88 GWe planned) amounts to only about 10% of the country's current coal capacity (1,093 GWe). Further obstacles include limited public awareness of nuclear technology, insufficient legal frameworks to govern the sector's rapid growth, and lingering public perceptions shaped by past nuclear incidents. Addressing these challenges will be critical to realizing China's ambitious nuclear targets and advancing broader national goals of decarbonization and energy self-sufficiency.

Figure 3: Chinese Nuclear Electricity Output (TWh) vs. Year

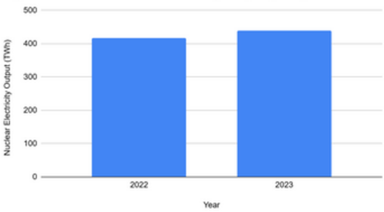
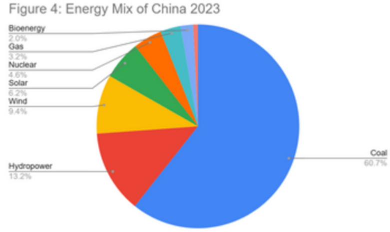



Figure 4: Energy Mix of China 2023

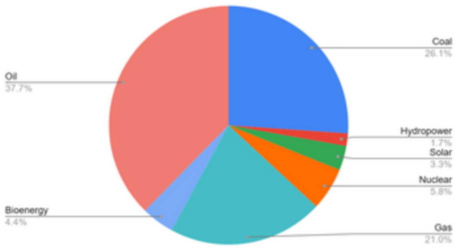


# JAPAN



Japan's energy mix in 2023 remains dominated by fossil fuels, particularly coal and natural gas, owing to longstanding concerns over energy security and the economic implications of fuel imports [37]. However, nuclear power has been making a marked comeback. Reflecting this upward trajectory, Japan's nuclear power output increased from 51.8TWh in 2022 to 81.4TWh in 2023, a rise attributed to both expanded reactor operation and higher utilization rates [38].

Figure 5: Energy Mix of Japan 2023




By late 2023, ten nuclear reactors had returned to commercial operation following stringent post-Fukushima safety reviews and upgrades [39]. These restarted reactors include:

- Sendai Units 1 & 2 (Kyushu Electric Power)
- Genkai Units 3 & 4 (Kyushu Electric Power)
- Ohi Units 3 & 4 (Kansai Electric Power)
- Takahama Units 3 & 4 (Kansai Electric Power)
- Ikata Unit 3 (Shikoku Electric Power)
- Mihama Unit 3 (Kansai Electric Power)

Government policy has played a pivotal role in facilitating these restarts [41]. Japan's nuclear strategy now aims to supply 20–22% of its electricity from nuclear power by 2030, with 10 reactors already back online as of late 2023 following extensive safety upgrades [42]. Despite the lingering impacts of the Fukushima Daiichi accident on public perception and regulatory frameworks, Japan is advancing its nuclear ambitions. The country is investing significantly in small modular reactors (SMRs), with the first expected to be operational by the mid-2030s. These SMRs are viewed as essential for meeting carbon reduction targets while addressing public concerns about nuclear safety. Their deployment is anticipated to reduce Japan's reliance on fossil fuels and enhance energy self-sufficiency, further bolstering national energy security. In parallel, Japan's Strategic Energy Plan establishes stringent safety standards for both existing facilities and next-generation nuclear technologies, including advanced light-water reactor designs, to support its net-zero goal by 2050 [41].

Public sentiment toward nuclear power remains mixed, influenced in part by the legacy of the 2011 Fukushima accident [42]. Nonetheless, the combination of recent reactor restarts and ongoing safety assessments indicates an enhanced role for nuclear energy in Japan's evolving energy mix, supported by proactive government measures to diversify the fuel portfolio, reduce greenhouse gas emissions, and strengthen energy security.

# INDIA



India's energy landscape in 2023 continues to be dominated by coal, which accounts for nearly half (49.3%) of the country's installed capacity [43]. Lignite contributes another 1.6%, while natural gas adds 6.0%, and diesel remains negligible at 0.1%. Renewables have made significant strides, with wind, solar, and other renewable sources collectively comprising 30.2% of installed capacity, and hydropower accounting for 11.2%. Nuclear power, by contrast, represents approximately 1.6% of installed capacity [43].

**Rising Demand and Continued Coal Reliance**

India's energy demand is projected to rise around 3% per year between 2021 and 2030, one of the fastest growth rates globally [46]. Historically, coal and oil have driven India's rapid industrialization, providing electricity access to tens of millions of citizens [45]. Although per capita emissions are relatively low at 1.90 t $CO_2$, the nation's large population and heavy reliance on coal make it the world's third-largest emitter of $CO_2$, at roughly 2,649 Mt per year. Even as the share of coal in the generation mix gradually declines, absolute coal-fired power is expected to increase until at least 2030, posing significant challenges to India's net-zero target for 2070 [46].

**Transition to Low-Carbon Sources**

Achieving net-zero by 2070 will require India to meet its accelerating electricity demand with greater contributions from renewables and nuclear power. Solar and wind energy already constitute around 30% of installed capacity, and the country aims to reach 500 GW of non-fossil fuel capacity by 2030 [46]. Given the high population density and extensive agricultural land use, nuclear power, with its relatively small land footprint, offers particular promise for reducing dependence on coal.

**Nuclear Power Status and Developments**

As of early 2024, India operates 22 nuclear reactors with a net capacity of 6,795 MWe, which include 18 pressurized heavy water reactors (PHWRs), 2 pressurized water reactors (PWRs), and 2 boiling water reactors (BWRs) [48]. Additionally, four reactors with a combined capacity of 595 MWe remain in suspended operation, while eight reactors totaling 6,028 MWe are under construction. Notably, India's nuclear power output experienced a slight dip, from 46.2 TWh in 2022 to 45.9 TWh in 2023, despite the broader expansion efforts [43].

The Indian government is firmly committed to nuclear expansion, targeting a tripling of installed nuclear capacity from approximately 6,780 MWe to 22,480 MWe by 2031 and aiming for nuclear power to supply about 9% of the country's electricity by 2047 [48]. To reach these ambitious goals, India has approved the construction of PHWRs in "fleet mode" to reduce lead times and costs. In parallel, initiatives by the Bhabha Atomic Research Centre (BARC) are focused on developing indigenously designed PHWRs and advanced reactor technologies, including breeder reactors fueled by thorium, to enhance the nation's self-sufficiency in nuclear technology [50].

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# SOUTH KOREA

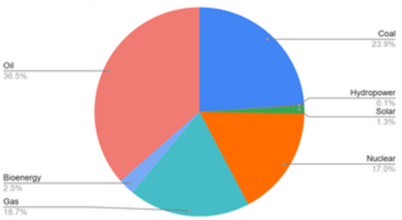


South Korea's energy mix in 2023 remains anchored by a combination of coal, liquefied natural gas (LNG), and nuclear power, although the government has recently emphasized nuclear energy as a key component of its broader decarbonization and energy security agenda [51]. Coal and LNG together still account for over half of national electricity generation, while renewables, primarily solar and wind, gradually expand through policy incentives and technological advancements [54]. Hydroelectric capacity remains limited by geographic constraints, though pumped storage contributes to overall grid stability. Amid these diverse energy streams, nuclear power has regained a particularly central role in 2023, with nuclear power plants generating a total of 168.6TWh of electricity this year, marking an uptick in nuclear's share compared to prior years [55].

Recent policy developments under the Yoon Suk-yeol administration have reinforced the nation's commitment to nuclear power. The government has advanced initiatives to prolong reactor lifespans, expedite the completion of new units, including projects like the Shin Hanul and Shin Kori reactors, and accelerate research into advanced reactor designs [51,52]. In 2023, efforts around Small Modular Reactors (SMRs), notably the indigenous SMART design, gained momentum, positioning South Korea to develop clean, exportable nuclear technologies. The Ministry of Trade, Industry and Energy (MOTIE), in collaboration with Korea Hydro & Nuclear Power (KHNP), has simultaneously invested in modernizing digital control systems, strengthening fuel supply chains, and enhancing safety protocols to meet evolving international standards [53].

Currently, South Korea operates 25 commercial nuclear reactors, with a total installed capacity of nearly 24.5GWe [55]. Building on recently completed and soon-to-be commissioned units such as Shin Hanul 1 and 2, significant government funding has been allocated to expedite construction on additional projects, including Shin Kori 5 and 6 [51].

Figure 6: Energy Mix of South Korea 2023




Meanwhile, the administration is carefully reviewing the operational lifespans of older reactors to determine whether they should undergo life-extension procedures or begin decommissioning based on safety, economic, and public acceptance considerations [54]. Reflecting a broader policy pivot toward nuclear power, MOTIE has boosted research and development budgets for advanced technologies such as SMRs and strengthened domestic supply chains to reduce reliance on external suppliers. Taken together, these initiatives are designed to fortify South Korea's nuclear sector and ensure that nuclear remains a reliable, low-carbon cornerstone of the nation's energy mix in the coming decades.

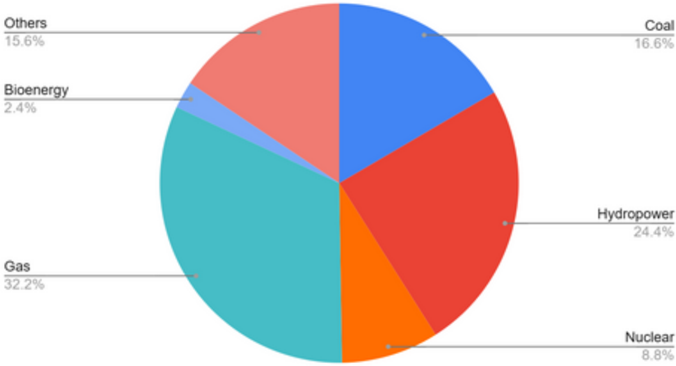
# PAKISTAN



Pakistan's electricity generation in 2023 continued to be dominated by natural gas (around one-third of the total), hydro (approximately one-quarter), and coal, which together account for over three-quarters of the national mix [56]. Nuclear power represents roughly 9% of total generation, with six operable reactors providing a combined capacity of around 3,262 MWe. These reactors—C-1, C-2, C-3, and C-4 at the Chashma Nuclear Power Plant, plus K-2 and K-3 at the Karachi Nuclear Power Plant, are all Chinese-designed pressurized water reactors. Pakistan also relies on China for enriched nuclear fuel, reflecting the deep bilateral cooperation that has shaped its nuclear sector [56].

In 2023, Pakistan generated 22.4 TWh of electricity from its nuclear fleet, an important share in light of rising energy demand and limited domestic gas reserves [57]. In July 2023, the Prime Minister inaugurated a new USD 3.5 billion Chinese-designed nuclear energy project, Chashma-V, which will add 1,200 MWe of generating capacity once completed [57]. Despite not being a signatory to the Nuclear Non-Proliferation Treaty, Pakistan has set climate objectives that include reducing its projected emissions by 50% by 2030 [58]. Expanding nuclear capacity thus forms a key component of these decarbonization efforts, as nuclear power provides a stable, low-carbon complement to the country's natural gas, coal, and hydro resources [58].

Figure 7: Energy Mix of Pakistan 2023



# UNITED KINGDOM

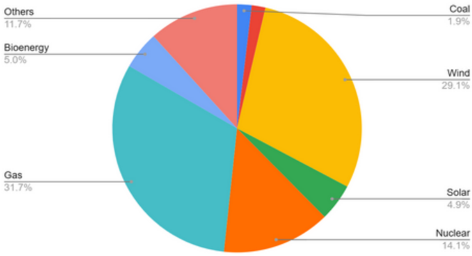


The United Kingdom's energy mix in 2023 remains largely dependent on fossil fuels, approximately 75%, while nuclear power contributes around 6% and renewables make up 19% [59]. Despite a decrease in nuclear generation from 47.7 TWh in 2022 to 40.6 TWh in 2023, nuclear power remains a crucial component for meeting the country's decarbonization goals. The UK is targeting net-zero emissions by 2050, with the electricity sector expected to be carbon-free by 2035 [61]. Recent legislative support, including the Nuclear Energy (Financing) Act (2022) and commitments for new reactors, demonstrates a strong push for nuclear growth, despite challenges such as delays and cost overruns at projects like Hinkley Point C, which is now anticipated to be completed by 2027 [64]. In addition, the UK plans to build eight more reactors by 2030, aiming to increase nuclear's share of electricity generation to 25% by 2050 [62]. In 2023, Britain's electricity generation mix comprised 32% gas, 29.4% wind, 14.2% nuclear, 5% biomass, 1.9% coal, 4.9% solar, 10.7% imports, 1.8% hydro, and 1.1% storage.

In response to these evolving dynamics, the government has bolstered its policy framework to address the inherent challenges in nuclear project development. Comprehensive measures have been introduced to streamline regulatory processes and mitigate risks associated with construction delays and escalating costs. By prioritizing robust oversight and enhanced public-private partnerships, the UK government is seeking to ensure that investments in nuclear infrastructure yield long-term benefits for energy security and economic stability. These initiatives are designed not only to fast-track new reactor projects but also to reinforce the necessary supply chains and workforce development programs that underpin a modern, resilient nuclear sector.

Furthermore, the UK's commitment to a diversified energy future is underscored by its integrated approach to low-carbon technologies. Alongside nuclear, the country continues to invest heavily in renewable energy sources, fostering synergies that enable a more flexible and balanced electricity system. International collaborations and financial instruments, such as green bonds and targeted subsidies, have been pivotal in attracting private capital and technological expertise. This multi-pronged strategy aims to position the UK as a global leader in the energy transition, ensuring that the drive towards decarbonization is both economically viable and environmentally sustainable.

Figure 8: Energy Mix of the United Kingdom 2023



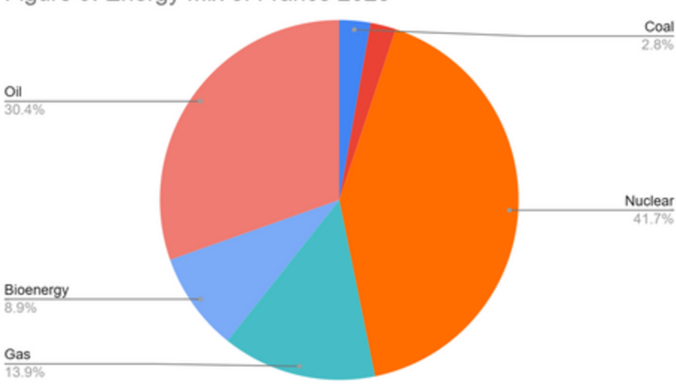
# FRANCE

**EUROPE**

As of 2023, France's total primary energy supply consists of 2.7% coal, 29.4% oil, 13.4% natural gas, 40.3% nuclear, 2.2% hydro, and 8.6% biofuels and waste [65]. While fossil fuels continue to account for a substantial share of overall energy use, nuclear power dominates France's electricity generation, with 56 reactors (total net capacity of 61,370 MWe) still producing more than half of the nation's electricity [66]. This heavy reliance on nuclear has contributed to France's comparatively low per capita emissions (4.58 t $CO_2$) among advanced economies, and the government remains committed to achieving carbon neutrality by 2050 [67]. However, the nuclear fleet's average reactor age, over 35 years, has raised concerns about maintenance, refurbishment, and unplanned outages, as evidenced by a 30% drop in nuclear output in 2022 due to stress corrosion issues at multiple reactors [68]. Although some of these units have since returned to operation, the episode underscored the risks of relying so heavily on an aging reactor fleet.

France's nuclear policy, once oriented toward reducing nuclear's electricity share to 50%, underwent significant revision when that target was pushed back from 2025 to 2035 and ultimately repealed in 2023 [68]. The government has instead proposed building at least six new reactors, potentially next-generation EPR or SMR designs, to replace or supplement existing capacity [68]. Additionally, EUR 1 billion has been allocated to advanced nuclear research, including a French-designed small modular reactor slated for demonstration by 2030 [69]. Despite these ambitious plans, France's energy transition faces challenges: slow implementation of climate policies, the recent reactivation of two coal plants amid energy security concerns, and relatively low shares of wind and solar in its electricity mix. Analysts at RTE and the IEA emphasize that extending reactor lifetimes, rapidly expanding renewables, and clarifying investment signals will be crucial to meeting France's decarbonization goals while maintaining reliable power generation.

Figure 9: Energy Mix of France 2023



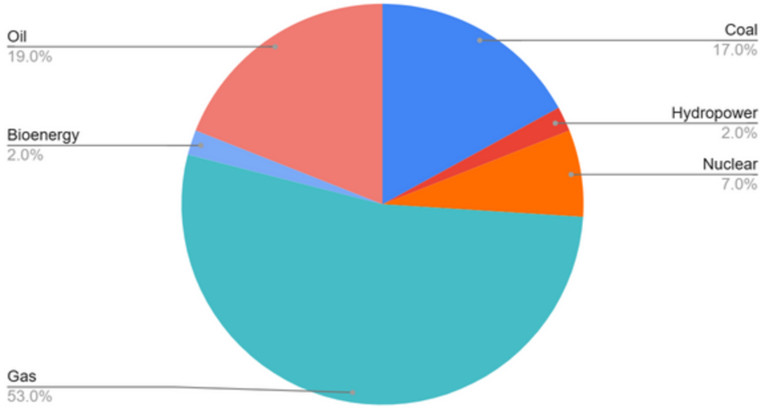
# RUSSIA



In 2023, Russia's energy mix remains heavily fossil-fuel based, with natural gas at 53%, oil at 19%, and coal at 17%, while nuclear accounts for about 7% and hydro plus biomass each contribute roughly 2% [70]. The country emitted 1,942 Mt of $CO_2$ in 2021 (13.52 t per capita), underscoring its carbon-intensive profile. Russia's nuclear sector comprises 37 reactors, including 24 pressurized water reactors (PWRs), 11 light water graphite moderated reactors (LWGRs), and 2 fast breeder reactors (FBRs), with a combined net capacity of 27,727 MWe [70]. Rosatom, the state-owned nuclear giant, plays a critical role both domestically and internationally, notably through its VVER designs and control over the nuclear fuel cycle. Rosatom's expertise in nuclear technology has enabled Russia to build strong partnerships in emerging markets like Turkey and Egypt, thereby expanding its influence on global nuclear development.

Rosatom has announced plans to build 29 new reactors by 2049 and pledged to invest at least USD 6.35 billion in nuclear development by 2025, with a significant portion of that budget allocated in 2023 to support ongoing construction and advanced R&D [73,74]. Despite these advancements, Russia's broader energy strategy remains focused on expanding fossil fuel production for export, casting doubt on its ability to achieve meaningful decarbonization. The nation's commitment to maintaining nuclear's share of domestic electricity at around 20% until 2035 is driven by ambitions for "national technological sovereignty" rather than by a comprehensive transition away from fossil fuels.

Figure 10: Energy Mix of Russia 2023



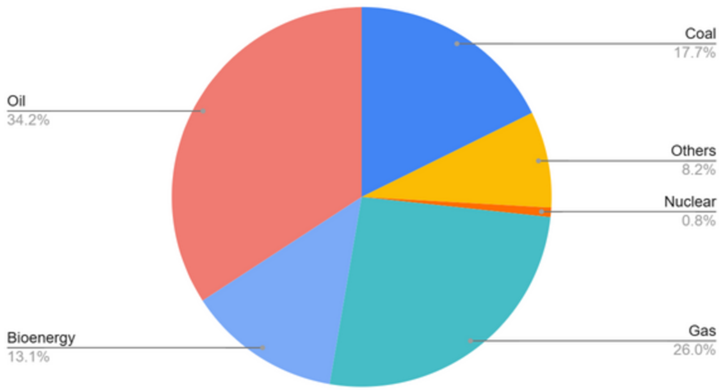
# GERMANY



Germany's energy supply in 2023 is dominated by oil (34.2%), natural gas (26.0%), and coal (17.7%), reflecting a continued reliance on fossil fuels [76]. Biofuels and waste contribute 13.1%, while nuclear power has dwindled to only 0.8%, signifying the near-completion of Germany's nuclear phase-out by mid-April 2023 [77]. Although the country once derived about one-quarter of its electricity from nuclear energy, strong public opposition, especially following the Fukushima accident, prompted a systematic shutdown of all commercial nuclear facilities. Critics contend that this move has exacerbated Germany's current energy challenges, including elevated electricity costs and a heavier reliance on fossil fuels [78].

Nonetheless, Germany is exploring alternative pathways to secure long-term energy security and meet climate objectives, notably by expanding renewable energy sources and investing in fusion research [79]. Its growing investment in fusion technologies, exemplified by startups such as Gauss Fusion, Marvel Fusion, and Proxima Fusion, which have attracted increased funding from the German Federal Agency for Disruptive Innovation, could position the country as a leader in next-generation energy solutions [80]. However, while these initiatives aim to deliver cleaner and more stable power in the future, the immediate impact of the nuclear phase-out raises concerns about the pace at which Germany can transition away from coal and natural gas without compromising energy reliability or affordability.

Figure 11: Energy Mix of Germany 2023



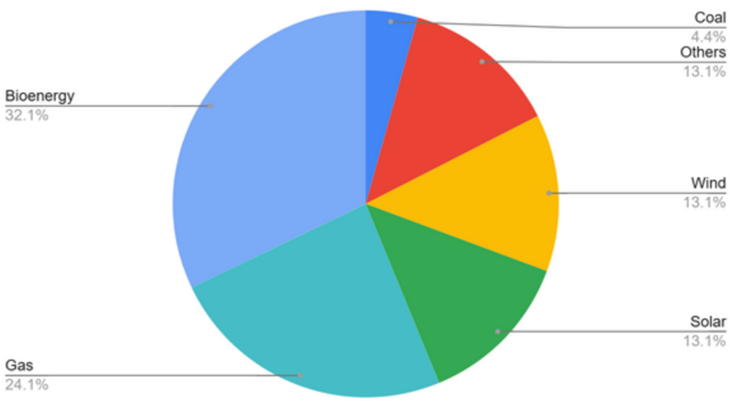
# DENMARK

## EUROPE

Denmark's total energy supply in 2023 is primarily composed of oil (37.2%) and biofuels/waste (34.7%), with coal accounting for 4.7% and geothermal, solar, wind, and other renewables together making up 14.2% [81]. Despite having some of the highest wind penetration rates in the world, with wind alone contributing nearly 57% of domestic electricity generation, Denmark has never developed commercial nuclear power. A 1985 resolution banning nuclear plant construction remains in effect, although recent polling in 2022 indicates a shift in public opinion, with 46% of respondents now in favor of nuclear power and only 39% against [82].

While there is still no direct government funding for nuclear fission projects, interest in advanced nuclear technologies is on the rise in Denmark. Two domestic startups, Seaborg Technology and Copenhagen Atomics, are independently developing molten salt reactor designs, primarily aimed at export markets. In 2023, both companies secured additional private investments from international venture capital and energy-sector partners, reflecting growing confidence in Denmark's research and development capabilities [83,84]. Nonetheless, without a formal policy reversal on the nuclear ban, the future of nuclear energy in Denmark remains contingent on evolving public sentiment and the success of these private-sector initiatives.

Figure 12: Energy Mix of Denmark 2023



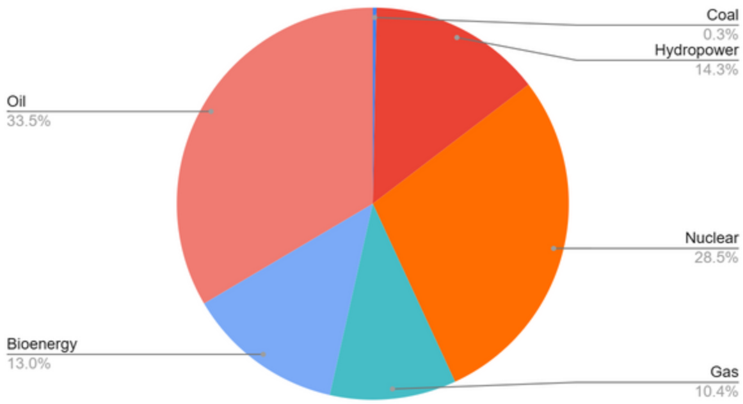
# SWITZERLAND

## EUROPE

Despite maintaining three nuclear power plants with four reactors (totaling 2,973 MWe), Switzerland has not invested in new large-scale nuclear construction projects since the Fukushima accident in 2011 [91]. The Swiss Federal Office of Energy primarily directs funds toward reactor safety, waste management, and decommissioning research rather than expanding existing facilities [92]. Meanwhile, most public and private investments focus on modernizing hydropower assets, Switzerland's principal electricity source, and increasing renewable capacity, particularly solar and wind [93].

In 2023, oil led Switzerland's total energy supply at 32.8%, followed by nuclear at 27.9%, natural gas at 10.2%, hydro at 14.0%, and biofuels/waste at 12.7%, with coal accounting for just 0.3% [94]. Nuclear power still provides around 40% of the country's electricity, second only to hydro at 57% [94]. However, nuclear output has gradually declined following a 2017 referendum that endorsed the phased shutdown of all reactors, prompting the permanent closure of one plant and solidifying Switzerland's long-term shift away from nuclear power [95].

Figure 13: Energy Mix of Switzerland 2023

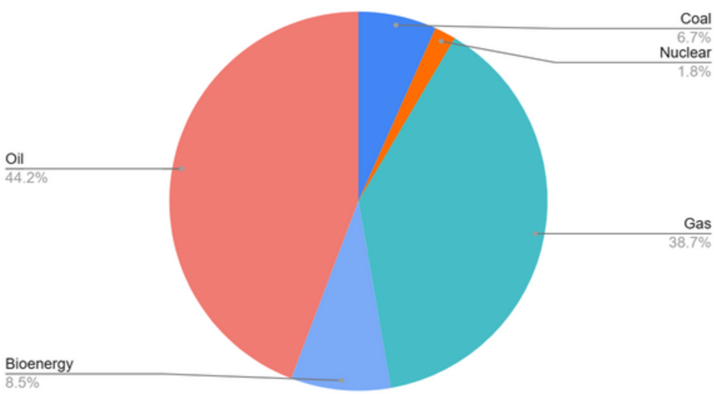


# NETHERLANDS



- As of 2023, the Netherlands' total energy supply is led by oil (41.0%) and natural gas (35.9%), with coal at 6.2%, biofuels/waste at 7.9%, and nuclear at 1.7% [85]. The lone operating nuclear reactor, the 482 MWe Borssele pressurized water reactor, accounts for roughly 3% of the nation's electricity production [85]. In recent years, the Dutch government has reversed its earlier plans to phase out nuclear power, instead designating it as a key component of long-term climate goals.
- A series of new financial commitments underscore this strategic pivot. In December 2021, the government announced an initial USD 5 billion allocation for two new reactors [86]. This initial funding has since been complemented by multiple budget allocations:
- Dutch Government (Climate Fund 2024): EUR 320 million for nuclear initiatives, including reactor R&D and workforce development.
- Dutch Government (May 2024 Update): EUR 9.5 billion earmarked for the construction of four large-scale reactors, reflecting a heightened focus on nuclear expansion.
- Dutch Government (Borssele Extension Studies): EUR 10 million directed toward feasibility studies to potentially extend the operational life of the Borssele plant beyond 2033.
- Dutch Government (New Reactors Prep Studies): EUR 117 million allocated for preparatory work on two additional nuclear reactors, with completion targeted around 2035 [87–90].

Figure 14: Energy Mix of the Netherlands 2023



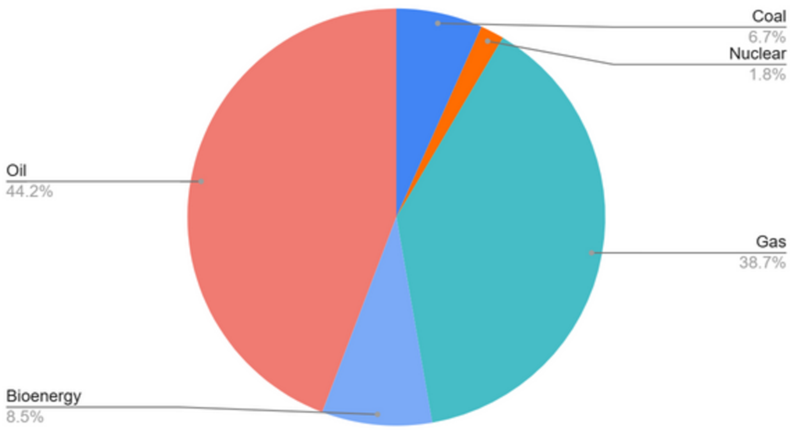
# BELGIUM



In 2023, Belgium's total energy supply is led by oil at 38.8%, natural gas at 26.0%, and nuclear at 18.3%, followed by coal (5.0%) and biofuels/waste (7.5%) [91]. Although nuclear constitutes under one-fifth of total primary energy, it provides roughly 50% of the nation's electricity via five pressurized water reactors with a total capacity of 3,928 MWe [91]. Initially set to phase out all nuclear power by 2025, Belgium postponed that deadline by 10 years in March 2022 and, in 2023, signed an agreement with Engie to extend two reactors (Doel 4 and Tihange 3), partly in response to the Russia–Ukraine war and surging fossil fuel costs [92].

Recent financial commitments reflect this renewed emphasis on nuclear. A joint venture between the Belgian government and Engie has allocated EUR 2 billion to extend Doel 4 and Tihange 3, while EUR 100 million is dedicated to advanced nuclear R&D (including SMRs) [92]. Moreover, a KPMG report estimates that achieving 8 GW of new nuclear capacity by 2050 would require an average of EUR 2 billion in annual investment [92]. These initiatives underscore Belgium's evolving energy strategy, balancing its historic reliance on nuclear with modern demands for energy security, sustainability, and cost control.

Figure 15: Energy Mix of Belgium 2023



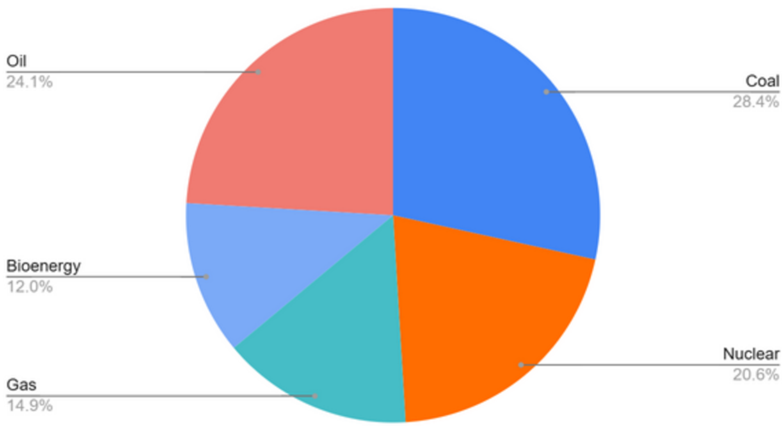
# CZECH REPUBLIC



As of 2023, the Czech Republic's total primary energy supply is led by coal (28.0%), oil (23.7%), natural gas (14.7%), and nuclear (20.3%), with biofuels and waste contributing 11.8% [95]. Despite coal's traditional prominence, nuclear power generates around 36% of the country's electricity, thanks to six pressurized water reactors with a combined capacity of 4,212 MWe that meet roughly one-third of Czech electricity demand [95]. After a dip in 2015, nuclear output has gradually increased, and the government continues to expand nuclear capacity. In May 2023, a tender was launched to add two generators to the Temelín Nuclear Power Station (2,056 MWe, comprising two VVER-1000 units), with an estimated USD 160 million investment scheduled between 2028 and 2030 [95].

Substantial new investments are also targeting the Dukovany site. The European Commission approved a EUR 7.74 billion state aid mechanism for constructing a new unit, and the Czech government signed a 200 billion CZK (approximately EUR 8.65 billion) contract with South Korea's KHNP to build two additional reactors [96]. These initiatives underscore the Czech Republic's commitment to reducing its coal reliance and maintaining nuclear power as a major pillar of its energy strategy, even as it navigates environmental concerns and geopolitical uncertainties.

Figure 16: Energy Mix of Czech Republic 2023



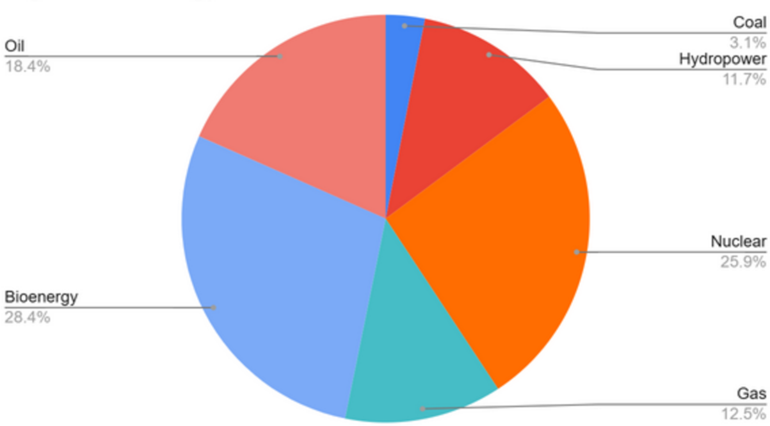
# SWEDEN



As of 2023, Sweden's total energy supply is dominated by biofuels/waste (29.4%), oil (19.0%), and natural gas (12.9%), with nuclear accounting for 26.8%, hydro for 12.1%, and coal for 3.2% [99]. Despite nuclear's fourth-place share in the overall mix, it provides about 40% of Sweden's electricity, second only to hydropower at 44% [99]. The country currently operates three nuclear power plants with six reactors (mainly BWRs with some PWRs), totaling 6,937 MWe [99]. To meet a projected doubling of electricity demand by 2040 and achieve net-zero emissions by 2045, Sweden has shifted its policy from "100% renewable" to "100% fossil free," emphasizing nuclear's central role [100].

In line with this strategy, the government's 2024 budget proposal allocates SEK 1 billion (approximately USD 97 million) for nuclear expansion in 2025, including pilot and demonstration projects [101]. A government-appointed commission estimates that an additional SEK 400 billion (around USD 38 billion) will be needed for new reactors, supported by a financing model involving government loans and guaranteed electricity prices [102]. Furthermore, Sweden has entered into a bilateral agreement with the United States to jointly develop advanced nuclear technologies, underscoring its commitment to leveraging nuclear power for a low-carbon future [103].

Figure 17: Energy Mix of Sweden 2023



# TURKEY

Turkey’s inaugural nuclear power project, the Akkuyu Nuclear Power Plant, continues to progress on schedule, signaling a transformative moment in the country’s energy transition [19]. Located in the southern Mersin province, the four-reactor facility, each a 1,200 MWe VVER-1200 unit, operates under a build–own–operate (BOO) model with Russia’s Rosatom [19]. Construction began on Unit 1 in 2018, and as of January 2025, major milestones have included the installation of the reactor pressure vessels (RPVs) for Units 1, 2, and 3, with the Unit 3 RPV being placed this month using the “open top” method [20,21,22]. Unit 2 also recently received its first batch of nuclear fuel, now stored on site in specialized containers ahead of reactor loading [24]. Once all four units are operational, targeted for completion by the end of 2028, the 4,800 MWe plant is expected to supply about 10% of Turkey’s electricity demand and diversify the nation’s energy mix [23].

The Akkuyu project carries an estimated price tag of USD 25 billion, reflecting the scale of both the investment and the technical undertakings involved [24,25]. Following years of meticulous planning and cooperation among Turkish regulators, independent auditing organizations, and Rosatom engineers, the project has remained on track, with “meticulous preparation” and “special precision at every stage” cited as integral to its success [24]. The Akkuyu Nuclear Power Plant is poised to play a pivotal role in reducing Turkey’s dependence on imported energy and enhancing its energy security. Moreover, the collaboration with Russia underscores the geopolitical significance of this project in Turkey’s broader energy strategy. This partnership has already begun to yield visible results, the arrival of nuclear fuel for Unit 2 in December 2024 officially secured Akkuyu’s status as a nuclear power plant, ensuring that Turkey moves closer to joining the ranks of nations with homegrown nuclear energy capacity [24]. If all proceeds according to plan, Akkuyu will not only provide stable baseload power but also mark a significant step in Turkey’s broader goal of strengthening energy security and reducing reliance on fossil fuel imports.

# UKRAINE



Ukraine's nuclear power sector has long been pivotal to the country's energy strategy, historically supplying more than half of its electricity. In pursuit of greater energy independence and reduced reliance on volatile fossil fuel markets, the nation has invested significantly in nuclear power, operating a fleet of 15 reactors. However, the ongoing war has dealt severe economic and infrastructural setbacks. The Russian occupation of the Zaporizhzhia Nuclear Power Plant, Europe's largest, has generated pressing concerns over safety and security, further complicating Ukraine's capacity to maintain stable power generation [27]. Despite these upheavals, the government in Kyiv remains committed to nuclear energy as a cornerstone of both its energy independence and eventual economic recovery.
In an effort to bolster capacity, diversify supply chains, and modernize aging infrastructure, Ukrainian officials are in negotiations with Bulgaria for the potential purchase of new nuclear reactor technology [28]. The Ukrainian parliament is expected to vote on this agreement, which would mark a strategic shift away from reliance on Russian designs and fuel sources [29]. Beyond simply offsetting wartime losses, the deal exemplifies Ukraine's determination to integrate advanced technologies and strengthen collaborative ties with international partners, thereby enhancing both the resilience and safety standards of its nuclear sector.

Although recent conflict has disrupted operations at several key facilities, Ukraine's underlying commitment to a nuclear-based energy mix remains firm. Nuclear power has traditionally played an outsized role in the country's electricity generation, consistently offering a reliable, low-carbon alternative to coal and gas. In 2023, the country's reactors generated 52.4 TWh of nuclear power, underscoring the enduring role of the sector in meeting critical energy demands [29]. This output demonstrates that, even under severe constraints and geopolitical uncertainties, nuclear energy remains a linchpin of Ukraine's electricity supply, as well as a foundational pillar of its long-term energy security strategy.

Despite ongoing war, Ukraine's commitment to nuclear energy remains unwavering. The country is investing in modernizing its reactors and diversifying its energy mix as part of its post-war recovery strategy, focusing on energy independence and security.

# UNITED STATES

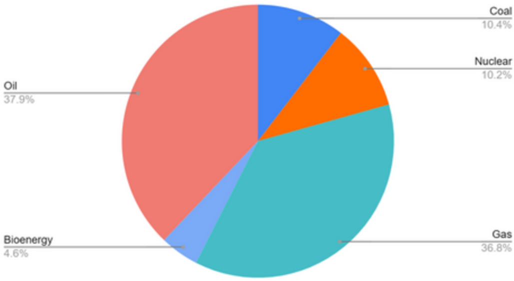
## NORTH AMERICA

In 2023, the United States' total primary energy supply comprised oil (36.3%), natural gas (35.3%), coal (10.0%), nuclear (9.8%), and biofuels/waste (4.4%) [104]. Although nuclear energy makes up less than 10% of the overall mix, it produces about 18% of U.S. electricity, securing the nation's status as the world's largest nuclear power producer and accounting for nearly 30% of global nuclear generation [104]. Presently, 93 reactors operate across 28 states with a collective capacity of 95.55 GWe, although market pressures, particularly low natural gas prices, have driven several early plant retirements, leading to a modest decline in total nuclear output.

Recent federal initiatives, such as the 2021 Infrastructure Investment and Jobs Act and the 2022 Inflation Reduction Act, have injected substantial funding into clean energy programs, including advanced nuclear R&D and support for existing nuclear plants. In 2023, the US Advanced Reactor Demonstration Program allocated $230 million (with an initial funding tranche of $160 million) to support next-generation reactor projects. Additionally, 19 states have enacted or are considering legislation offering billions of dollars in incentives, such as zero-emission credits and tax exemptions, to preserve at-risk facilities and foster new reactor development. These combined efforts have contributed nearly $20 billion in known nuclear investments this year, positioning U.S. advancements in next-generation reactors as a potential model for international partners like India and Brazil.

Despite these robust investments, significant challenges persist. The recent Vogtle expansion, for example, encountered severe cost overruns and lengthy construction delays, ultimately exceeding $30 billion [105]. High upfront expenses, complex regulatory environments, and competition from inexpensive natural gas continue to challenge the expansion potential of nuclear power. Moving forward, the trajectory of U.S. nuclear energy will hinge on sustained policy support, innovative financing models, and technological breakthroughs, especially in small modular reactors and fusion, to meet federal goals of a carbon-free electricity sector by 2035 and net-zero emissions by 2050.

Figure 18: Energy Mix of the US 2023



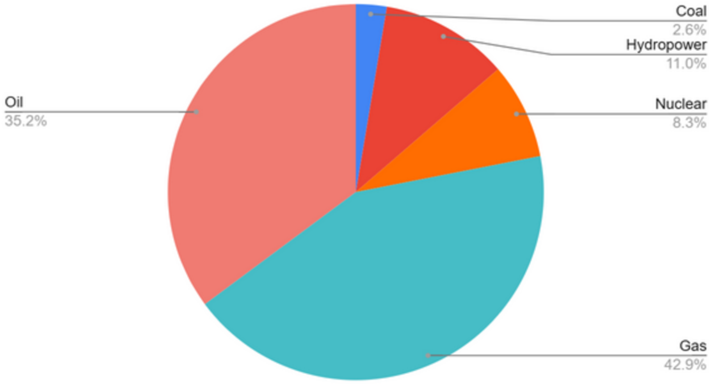
# CANADA



As of 2023, Canada's total primary energy supply is led by natural gas (40.5%) and oil (33.2%), with nuclear at 7.8%, hydro at 10.4%, and coal at 2.5% [108]. Although nuclear power constitutes only a small fraction of overall energy use, it is the second-largest source of electricity generation after hydropower, providing about 15% of Canada's electricity. Nineteen operable reactors, totaling 13,624 MWe, are located primarily in Ontario, where they supply roughly 60% of the province's power [109]. The federal government recognizes nuclear energy as a key component in achieving national climate goals, including the phase-out of coal-fired electricity by 2030 and net-zero emissions by 2050 [110].

Significant investments underscore Canada's commitment to expanding and modernizing its nuclear fleet. A total of CAD 26 billion has been allocated for refurbishing the Darlington and Bruce Nuclear Power Plants [111]. Canada is also a leader in the development of small modular reactors (SMRs). In August 2023, the federal government approved up to CAD 74 million to support SMR deployment in Saskatchewan, where SaskPower has selected GE Hitachi's BWRX-300 design for mid-2030s operation. This initiative builds on the 'Enabling Small Modular Reactors Program', launched in February 2023 with CAD 22 million to advance SMR R&D [112]. Meanwhile, multiple provinces, including Alberta, Ontario, New Brunswick, and Saskatchewan, have signed agreements to collaborate on SMR deployment, bolstering Canada's standing as a Tier 1 nuclear nation and a leading global exporter of uranium and CANDU technology [113].

Figure 19: Energy Mix of the US 2023



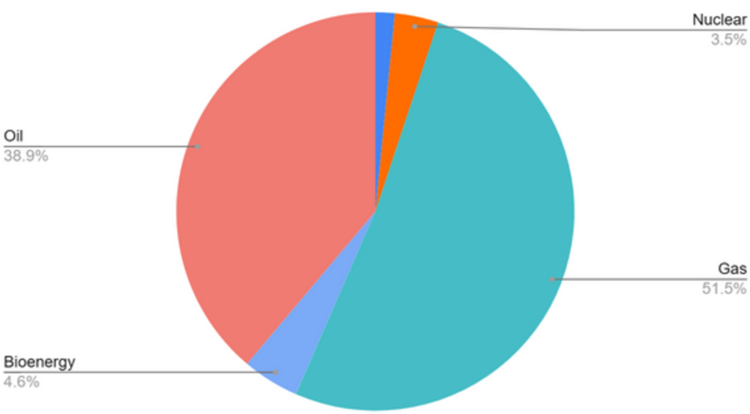
# ARGENTINA



In 2023, Argentina's primary energy supply is dominated by natural gas (49.4%) and oil (37.3%), with coal at 1.5%, biofuels and waste at 4.4%, and nuclear at 3.4% [115]. Despite its modest share in overall energy use, nuclear power provides about 5% of Argentina's electricity. The country operates three pressurized heavy water reactors (PHWRs), two at the Atucha site and one at Embalse, totaling 1,641 MWe in capacity [115]. In addition, a 25 MWe pressurized water reactor (PWR) is under construction and scheduled to start generating power by 2027, while a separate plan to build a 1,150 MWe Hualong One unit (initially envisioned as a CANDU reactor under a 2014 agreement with China) has encountered delays due to negotiations over local fuel fabrication [115].

Argentina has also made notable investments in nuclear during 2023. In April, Nucleoeléctrica Argentina SA (NA-SA) secured USD 93 million in a second funding tranche for the 20- to 25-year lifetime extension of the Atucha I reactor, with refurbishment work set to begin in 2024 and conclude by 2027 [116]. These initiatives align with Argentina's broader strategy of diversifying its energy mix, balancing abundant fossil resources with low-carbon sources like nuclear, hydropower, and renewables, to enhance both energy security and climate resilience [116].

Figure 20: Energy Mix of the Argentina 2023

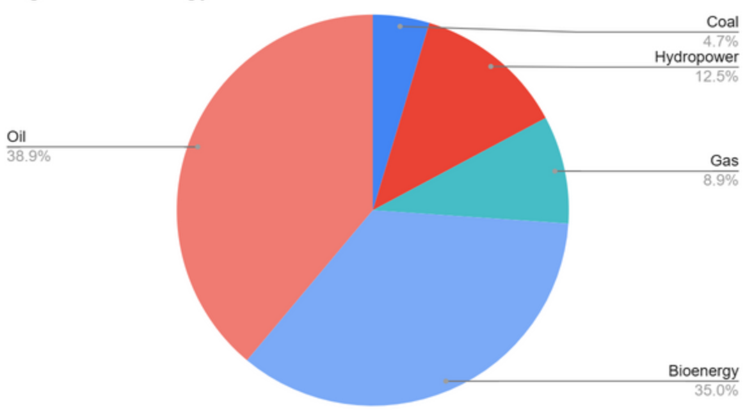


# BRAZIL

As of 2023, Brazil's primary energy supply is led by oil at 36.7% and biofuels/waste at 33.0%, followed by natural gas (8.4%), hydro (11.8%), and coal (4.4%). Nuclear power currently plays a modest role in Brazil's electricity mix, about 2.5% in 2022, with two operational pressurized water reactors at Angra (total capacity 1,884 MWe). A third reactor, Angra 3 (1,405 MWe gross), has faced repeated construction stops since its initial launch in 1984, most recently in April 2023 [118]. Nonetheless, a Joint Parliamentary Front for Nuclear Technology and Activities was formed in early 2023, pledging to expedite Angra 3's completion and explore a fourth reactor, along with the potential for small modular reactors (SMRs).

Despite these setbacks, Brazil aims to add 10 GW of nuclear capacity by 2050 under its National Energy Plan. Eletronuclear has announced a five-year investment of BRL 3.2 billion (USD 560 million) to continue work on Angra 3, with funding distributed at about BRL 720 million (USD 126 million) annually from 2023 to 2026 and BRL 320 million (USD 56 million) in 2027 [119]. This funding aligns with broader efforts to diversify away from heavy reliance on hydropower, which is vulnerable to drought, and expand baseload generation through nuclear energy, as evidenced by site selection processes that began in 2022 for future nuclear projects [119].

Figure 21: Energy Mix of the Brazil 2023

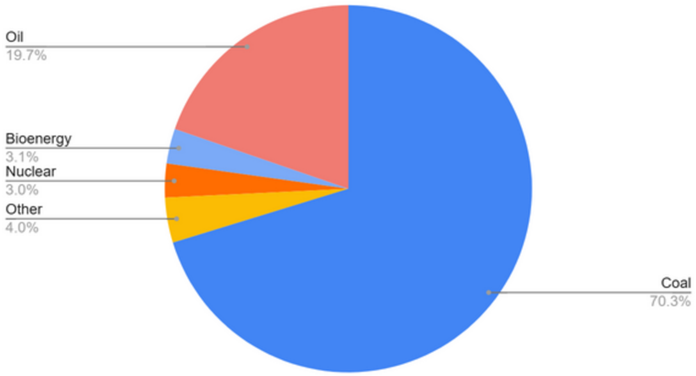


# SOUTH AFRICA

As of 2023, coal dominates South Africa's primary energy supply at about 70.9%, followed by oil at 19.9% and biofuels/waste at 3.1% [122]. Nuclear power remains modest, accounting for roughly 3% of the energy mix. Nevertheless, South Africa is the only African nation with commercial nuclear reactors, two pressurized water reactors at Koeberg with a total capacity of 1,854 MWe, which provide about 4% of the country's electricity [122]. Under the National Development Plan, the government aims to expand electricity access to over 90% of the population by 2030, relying on both renewables and additional nuclear capacity to stabilize the grid. A new multi-purpose research reactor is also slated to replace the existing facility by 2030.

In 2023, Eskom and the South African government increased funding to extend Koeberg's operational life and maintain nuclear's role in meeting rising power demands. Given the country's continued reliance on coal, extending Koeberg's lifespan until 2044 is seen as critical to maintaining grid stability while South Africa diversifies its energy mix. Although exact figures have not been publicly consolidated, local media reports indicate that billions of rand have been allocated toward reactor refurbishment, safety upgrades, and feasibility studies for future nuclear projects. These investments reflect a broader strategy to diversify South Africa's generation mix, currently vulnerable to frequent coal plant outages, while ensuring a reliable, low-carbon baseload power supply.

Figure 22: Energy Mix of the South Africa 2023



# AUSTRALIA

Despite its longstanding ban on domestic nuclear power generation, Australia plays a crucial role in the international nuclear energy landscape through its significant uranium exports. As the world's fourth-largest uranium producer, Australia produced approximately 4270 tonnes of uranium in 2023, representing around 8% of global uranium output. Virtually all domestically mined uranium is directed toward international markets, supplying nuclear reactors worldwide and positioning Australia as a vital contributor to global nuclear energy infrastructure.

In the fiscal year 2022–23, Australia's uranium exports generated substantial economic value, amounting to AUD $812 million. This highlights the considerable economic benefits derived from uranium mining and export, with potential for further growth as global interest in nuclear energy intensifies. Recent international trends, emphasizing nuclear energy's advantages such as energy security, reliability, and low carbon emissions, are expected to boost demand further, providing Australia with opportunities to strengthen its position within the global energy market.

Australia's substantial and consistent uranium exports significantly influence global energy security and sustainability. By reliably supplying countries with the fuel needed for nuclear power generation, Australia directly supports international climate commitments aimed at reducing greenhouse gas emissions. In the long run, Australia's strategic position as a key uranium exporter not only enhances its geopolitical influence but also underscores its critical role in facilitating the worldwide transition toward low-carbon and resilient energy systems.

Globally, Australia ranks third in uranium exports, behind only Kazakhstan and Canada, underscoring its strategic importance in the international nuclear fuel supply chain. This prominent position, combined with the country's extensive and high-grade uranium reserves, positions Australia as a reliable long-term partner for nations pursuing nuclear energy. By continuing to leverage its abundant resources, Australia is well-placed to maintain and expand its influential role in shaping the global nuclear energy landscape.

# NUCLEAR TECHNOLOGY TYPES (2023 UPDATED)

Modern nuclear power plants harness the heat released by splitting atoms, typically uranium, plutonium, or thorium, to generate electricity [126]. Although the first nuclear reactors were developed in the 1940s and 1950s, nuclear energy today provides about 10% of the world's electricity, with over 400 reactors operating globally [126]. Reactor designs have evolved considerably over the decades, incorporating advanced safety features, improved fuel efficiency, and more flexible operating modes. Current research and development efforts focus on next-generation reactors, such as fast neutron reactors, molten salt reactors, and small modular reactors (SMRs), which promise enhanced safety and reduced waste.

**Major Reactor Types**

- Pressurized Water Reactor (PWR):
  - The most prevalent reactor design worldwide (307 in operation as of 2023).
  - Features two water loops: a high-pressure primary loop surrounding the reactor core and a secondary loop where steam is generated to drive turbines.
  - Inherent safety is enhanced by negative feedback if the water begins to boil.
  - Widely used in the USA, France, Russia, China, Japan, and South Korea.

- Boiling Water Reactor (BWR):
  - The second most common reactor type (60 in operation as of 2023).
  - Utilizes a single water loop at lower pressure, allowing water to boil directly in the reactor core.
  - Steam generated in the core is used directly to power turbines, necessitating shielding due to potential radioactivity.
  - Primarily found in the USA, Japan, and Sweden.

- Pressurized Heavy Water Reactor (PHWR/CANDU):
  - Uses natural uranium oxide fuel and heavy water ($D_2O$) as a moderator.
  - Horizontal fuel channels enable on-load refueling without shutting down the reactor.
  - Predominantly deployed in Canada and India, with 47 PHWRs operating globally.

- Advanced Gas-Cooled Reactor (AGR):
  - Developed in the UK, using graphite as a moderator and carbon dioxide ($CO_2$) as a coolant.
  - Achieves high thermal efficiency (approximately 41%), though its use is mostly confined to the UK.

- Light Water Graphite-Moderated Reactor (LWGR):
  - Primarily used in Russia (e.g., RBMK designs).
  - Combines a graphite moderator with water coolant, with water boiling at around 290 °C.

- Fast Neutron Reactor (FNR):
  - Employs fast (unmoderated) neutrons to fission plutonium-based fuel.
  - Uses liquid sodium as a coolant, extracting significantly more energy from uranium resources.
  - Currently limited in deployment; Russia operates two commercial FNRs.

- Molten Salt Reactor (MSR):
  - Features fuel dissolved in a molten fluoride or chloride salt, operating at low pressure.
  - Offers potential for high-temperature operation and process-heat applications.
  - China leads global MSR research and demonstration projects.

**Classification by Capacity**

- Large Conventional Reactors:
  - Typically produce 700+ MWe (e.g., most current PWRs and BWRs).

- Small Modular Reactors (SMRs):
  - Generate up to approximately 300 MWe per unit; factory-built modules reduce construction times and costs.
  - As of 2023, at least three SMRs are operational (in Russia, China, and India), with many more in development [Perera, 2023].

- Micro Reactors:
  - Designed for up to 10 MWe, making them suitable for remote or off-grid applications.
  - Capable of operating for extended periods (up to 10 years) without refueling [INL, 2023].

These reactor types are increasingly central to global clean energy strategies. While large conventional reactors continue to provide bulk baseload power, SMRs and micro reactors offer new flexibility and scalability, especially in regions with smaller grids or in remote locations. Ongoing efforts aim to further improve reactor safety, reduce costs, and optimize fuel cycles to meet growing energy demands and decarbonization targets.

# ANALYSIS OF THE FUNDINGS

Global investment in nuclear energy experienced notable growth in 2023, underpinned by an expanding roster of countries embracing fission as a low-carbon, stable source of baseload power. While established nuclear powerhouses such as the United States, Canada, France, Russia, and especially China continued to inject substantial resources, China alone invested an estimated USD 225 billion into its operational fleet, new builds, and technology demonstration projects, an equally significant narrative emerges from the heightened interest among newcomer states. Poland, for instance, has garnered multinational financing commitments totaling over USD 10 billion for its first commercial nuclear power plant, and Kazakhstan's public referendum decisively endorsed constructing a new reactor. In parallel, revised energy policies in Serbia, Italy, and other European nations underscore a shift away from decades-long prohibitions, aligning nuclear initiatives with decarbonization goals and energy security objectives. These expanded funding commitments reflect not just immediate construction undertakings, but also R&D spending on advanced reactors, including small modular reactor (SMR) designs that promise greater flexibility and reduced capital risk.

Looking ahead, the landscape for nuclear funding is poised to broaden further as governments and private stakeholders seek scalable, low-carbon solutions to rising electricity demand and geopolitical uncertainties. Extensive refurbishment projects in countries like Canada and South Africa illustrate the continued emphasis on extending the life of existing assets, while substantial capital inflows in the United States, South Korea, and Japan aim to modernize reactor fleets and expedite next-generation technologies. This momentum is supported by international financing institutions and bilateral agreements, such as those signed by Czech, Swedish, and Ukrainian authorities, to promote reactor fleet expansion, collaborative R&D, and technology transfer. Although questions regarding cost overruns, extended construction timelines, and public acceptance remain salient, recent trends suggest that public and private funding channels are converging to solidify nuclear energy's place as a core contributor to global decarbonization strategies, offering a resilient power source amid mounting climate and security pressures.

# CONCLUSION

Nuclear energy stands at a pivotal junction in the global pursuit of cleaner, more resilient power systems. Bolstered by significant funding surges in 2023 and 2024, nuclear technologies, ranging from large-scale fission reactors and SMRs to advanced fusion prototypes, have garnered renewed interest from both established nuclear powerhouses and newcomer nations. This momentum reflects a broader acknowledgment that nuclear energy, as a consistently low-carbon source with relatively small land requirements, can complement intermittent renewables and meet expanding electricity demands in rapidly industrializing economies. The intensified funding landscape, underscored by strong commitments in China, the United States, India, and emerging markets across Eastern Europe and Asia, signals that nuclear power could play an even greater role in national energy portfolios over the coming decades.

However, this wave of investment also underscores persistent barriers that require sustained policy attention. Cost overruns, lengthy construction timelines, and debates over waste management and public acceptance continue to challenge new and existing projects alike. Even in nations with well-established nuclear infrastructure, market factors such as low natural gas prices or high upfront financing needs for cutting-edge technologies can derail reactor expansions. The success of SMRs, for example, hinges on robust regulatory frameworks, efficient supply chains, and clear business models that mitigate both technological and financial risks. Ultimately, bridging these gaps will determine whether nuclear energy can be scaled effectively to help meet stringent decarbonization targets while maintaining reliable baseload power.

In this landscape of renewed enthusiasm and persistent hurdles, nuclear energy's future will largely be decided by the resolve of governments, industry leaders, and international stakeholders to collaborate on technical, financial, and regulatory fronts. Increased public and private investment, supported by favorable legislation, innovative financing tools, and transparent stakeholder engagement, offers a promising path to overcoming the uncertainties that have historically plagued new builds and reactor upgrades. Together, these concerted efforts can harness nuclear power's potential as a cornerstone of a stable, decarbonized energy mix, charting a course toward more sustainable, reliable, and secure global electricity systems.

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