CLEAN ENERGY: NUCLEAR

The Nuclear Playbook for Energy Transition

Nuclear Energy has been a viable and proven technology since first being pioneered in the 1950s. But a volatile history of shifts in policy, as well as public support, in the midst of cost and safety challenges has led to inconsistent growth over time. Today, increasing momentum in innovation, investment, and policy support has nuclear technology poised to see a significant growth inflection at a time when more and more power demand globally is being driven by the need for reliable, around-the-clock, and clean sources of electricity. Nowhere is this more evident than the growing list of countries backing a COP28 declaration to triple nuclear energy capacity by 2050, with the total nuclear fleet of ~440 reactors today set to expand to ~500 by 2030 while well over 400 additional reactors are planned and proposed in the coming few decades according to the World Nuclear Association (WNA). With this as a backdrop, we highlight the broad-ranging materials, technologies and services opportunities across the nuclear value chain, with our investor roadmap for gaining leverage to the nuclear theme highlighting 14 stocks across our GS coverage, including Cameco, Mirion Technologies, Mitsubishi Heavy Industries, and Southern Company among our Buy-rated ideas with the most exposure.

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PM Summary: Nuclear Energy emerges as a key Energy Transition driver

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Exhibit 1: We highlight 14 stocks across GS coverage that we see as having the best leverage to the nuclear energy opportunity, up and down the value chain

GS nuclear stocks under coverage

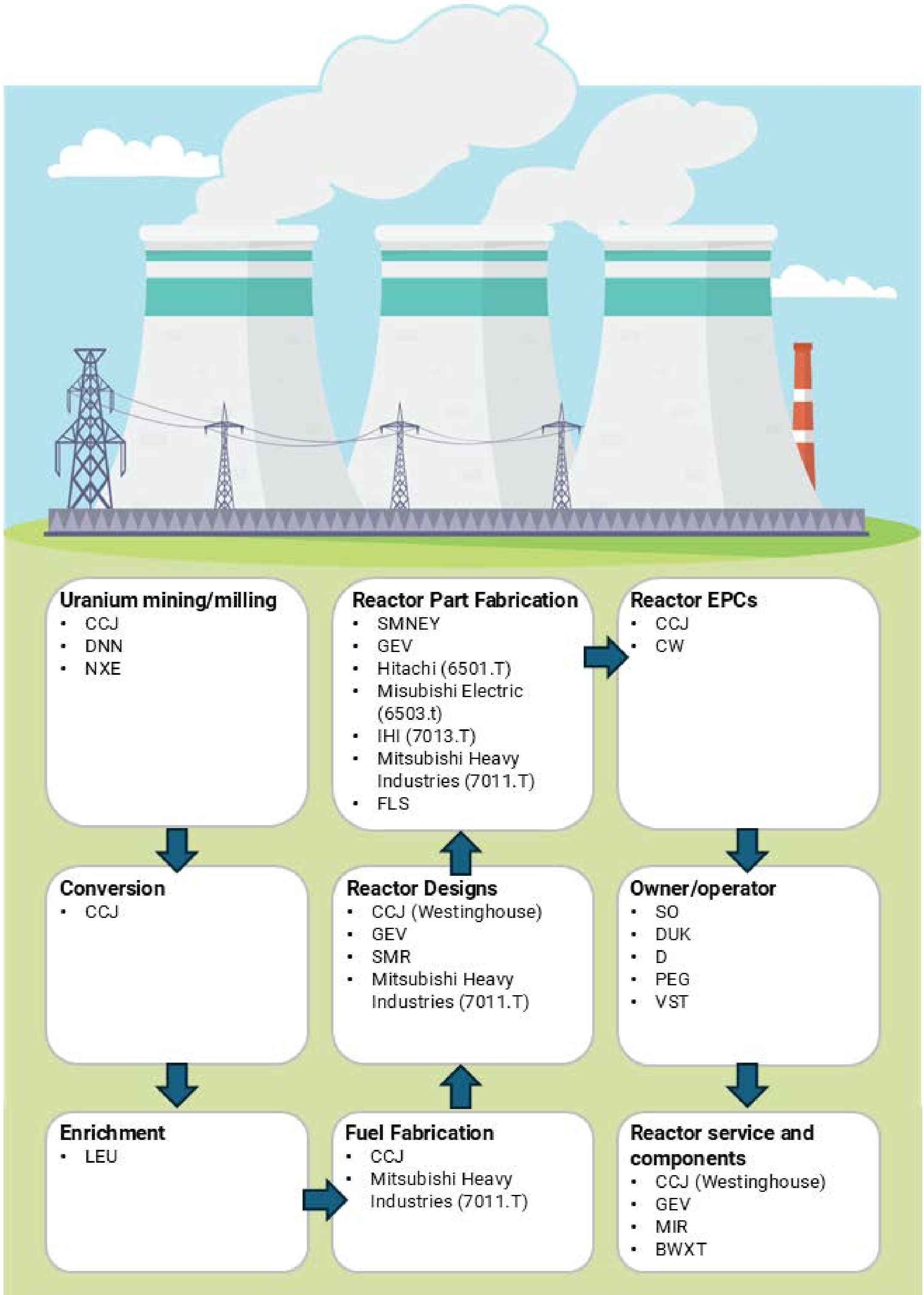
Company	Ticker	Market Cap ($bn)	Price	12-mo PT	Upside/ Downside	Analyst	Rating	Nuclear exposure
Uranium and Fuel								
Cameco Corp	CCJ	$22.5	$51.27	$65	27%	Brian Lee, CFA	Buy	●
Reactor Technology, Fabrication, and Services								
Hitachi, Ltd.	6501.T	$120.8	¥3,816	¥4,900	28%	Ryo Harada	Buy	◔
GE Vernova	GEV	$117.3	$428.06	$500	17%	Joe Ritchie	Buy	◔
Mitsubishi Heavy Industries Ltd.	7011.T	$66.1	¥2,830	¥3,000	6%	Yuichiro Isayama	Buy	◔
Mitsubishi Electric Corp	6503.T	$42.1	¥2,935	¥3,600	23%	Ryo Harada	Buy	◔
Cameco Corp	CCJ	$22.5	$51.27	$65	27%	Brian Lee, CFA	Buy	●
IHI Corp	7013.T	$13.3	¥12,930	¥13,000	1%	Yuichiro Isayama	Buy	◔
Flowserve Corp.	FLS	$6.8	$51.62	$54	5%	Joe Ritchie	Neutral	◑
NuScale Power	SMR	$6.9	$24.17	$24	-1%	Brian Lee, CFA	Neutral	●
Mirion Technologies Inc.	MIR	$3.9	$17.23	$20	16%	Joe Ritchie	Buy	◑
Owner/Operator								
Southern Co	SO	$97.4	$88.71	$102	15%	Carly Davenport	Buy	◔
Duke Energy Corp	DUK	$89.9	$116.26	$125	8%	Carly Davenport	Neutral	◑
Dominion Energy Inc	D	$46.8	$55.77	$61	9%	Carly Davenport	Neutral	◑
Public Service Enterprise Group Inc	PEG	$39.6	$79.29	$83	5%	Carly Davenport	Neutral	◔
Vistra Corp	VST	$55.2	$156.62	$134	-14%	Carly Davenport	Neutral	◔

◔ 25% or less ◑ 25% to 50% ◕ 50% to 75% ● >75%

Price as of 5/16/25

Source: Goldman Sachs Global Investment Research

Exhibit 2: Public companies across the nuclear power value chain



Source: Goldman Sachs Global Investment Research

Nuclear uses are plentiful, but Energy is the key focus and growth driver

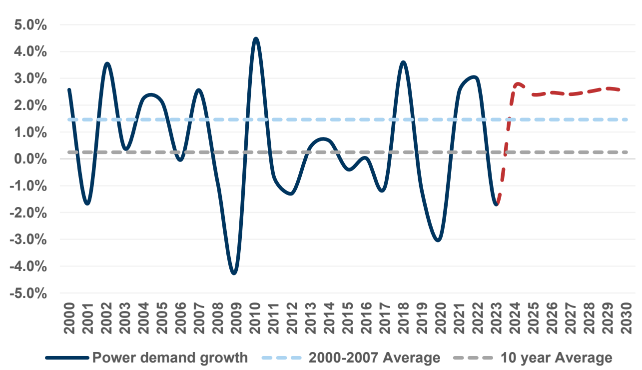
What is nuclear used for?

Nuclear's use cases span all the way from nuclear power to weapons (which use uranium-235) and radio activity/treatment/imaging (which use a different subset of isotopes). As of recent years, nuclear energy, in particular, has become a key area of focus globally as countries revisit the technology after many years of underinvestment. We highlight that nuclear power generation is one of the cleanest sources of power generation and one of the most reliable.

Current drivers of the renewed demand for nuclear in the energy complex include:

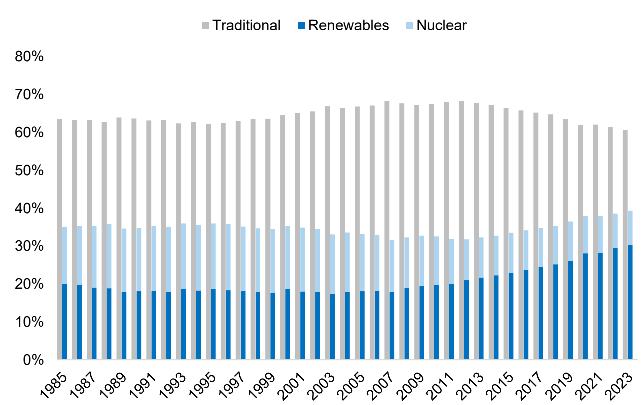
- **Increasing power consumption**, owing to expanding populations, electrification, EVs, data centers, etc.
- **Ongoing shift toward cleaner power**, as countries seek lower emissions alternatives such as renewables, battery storage, nuclear, and others.
- **Need for more baseload power**, as renewables like solar, wind and hydro are intermittent and don't run 24/7 reliably, whereas nuclear power is both emissions-free and available as a high capacity factor, baseload power generation resource akin to coal/gas.

Exhibit 3: Overall power demand growth estimates remain above the 10-year average at 2.5% through 2030
Power demand



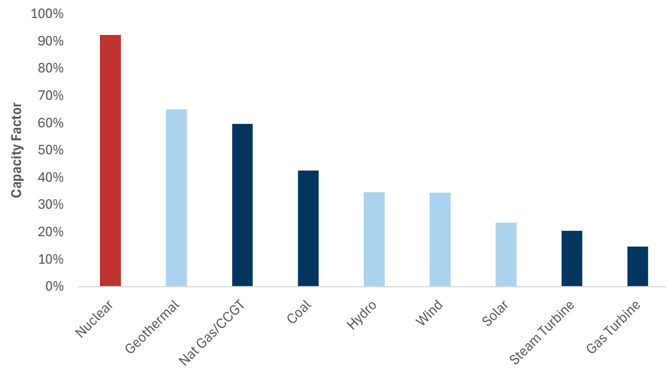
Source: EIA, Goldman Sachs Global Investment Research

Exhibit 4: Clean energy sources are contributing a greater portion of global energy
Global energy mix %, 1985-present



Source: EIA

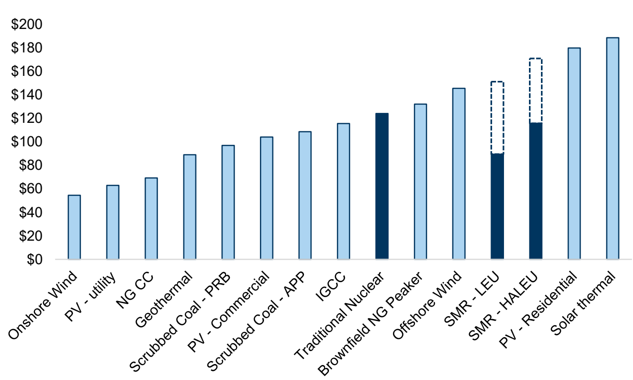
Exhibit 5: Nuclear maintains the highest capacity factor of any source of electricity
2024 annual capacity factors for different generation types



Source: EIA

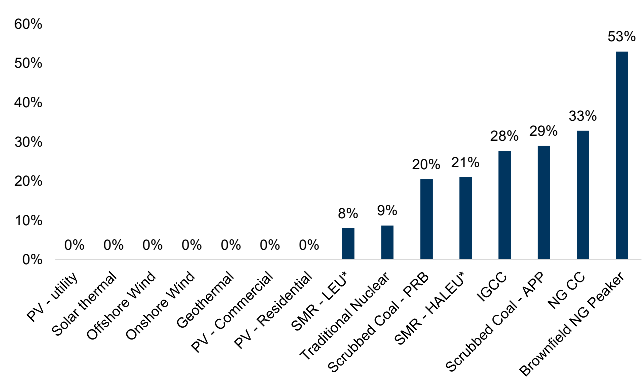
From a cost perspective, we estimate that levelized cost of electricity (LCOE) across both traditional nuclear and Small Modular Reactors (SMRs) can vary widely. Our base case assumes that traditional nuclear LCOE is roughly ~$125/MWh while SMRs, once they reach nth-of-a kind, can see LCOE in the range of ~$100/MWh or less. This will vary widely based on the actual cost to build new nuclear - where estimates are still fairly wide-ranging and differ from country to country. Notably, nuclear has higher capital costs than the majority of power generation types due to specialized construction needs for these types of power generation builds, as well as what have historically been cost overruns relative to initial projections. This causes a wide variance in construction costs for these projects, which makes them generally difficult to estimate. Compared to traditional nuclear, SMRs, especially High-Assay Low-Enriched Uranium (HALEU) fueled SMRs, have a higher fuel cost as a % of LCOE since HALEU will be more expensive than traditional fuel and SMRs maintain lower initial construction costs. We believe HALEU fuel for SMRs will be at least ~25% of the total LCOE cost, while having more general supply chain risk given lack of wide availability today.

Exhibit 6: SMRs are projected to have some of the lowest LCOEs in power generation once this technology hits steady-state
LCOE across power generation types



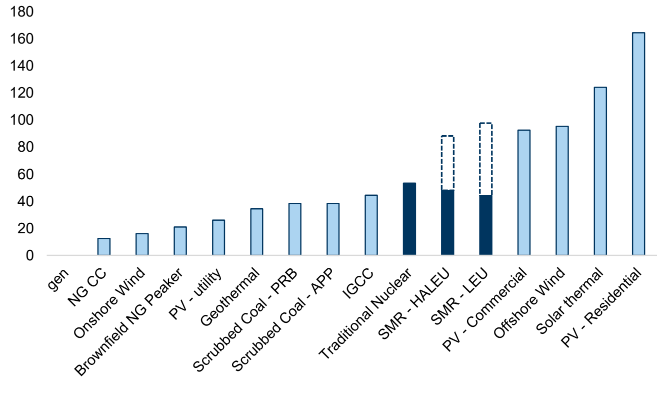
Source: Goldman Sachs Global Investment Research

Exhibit 7: Fuel costs as a % of LCOE for SMRs are in line with traditional nuclear for LEU based SMRs but much higher for HALEU
Fuel cost as a % of LCOE



Source: Goldman Sachs Global Investment Research

Exhibit 8: When SMRs reach nth-of-a-kind, we project they will have a lower capital cost than traditional nuclear
Capital costs as a portion of LCOE

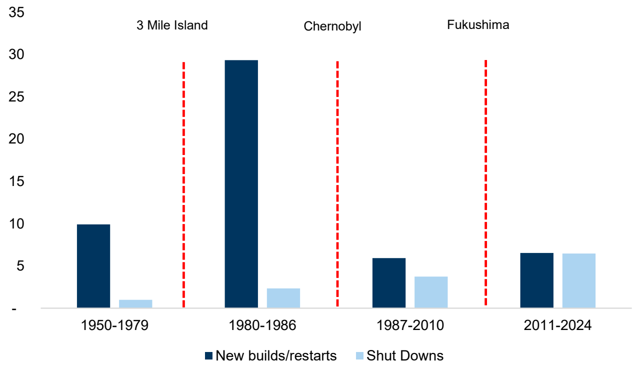


Source: Goldman Sachs Global Investment Research

Nuclear Energy - growth to stagnant back to growth again?

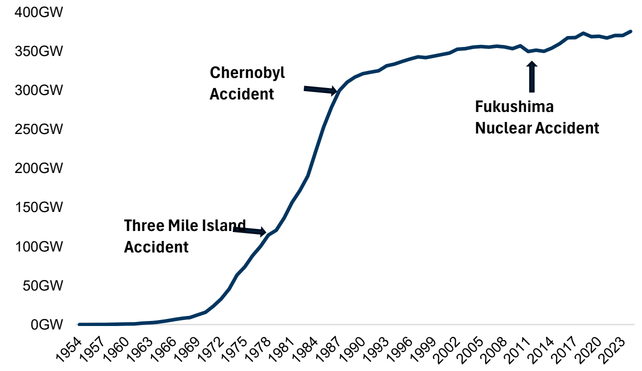
Nuclear's history in the energy complex dates back to the 1950s when the first nuclear reactor was powered on in the US. Yet, despite nuclear being one of the cleaner and more reliable power generation sources available on the grid, public perception and support for nuclear has ebbed and mostly waned after multiple high-profile accidents across the world led to doubts on the technology. Indeed, leading up to the first incident at Three Mile Island in 1979, there had been roughly 10 new nuclear reactor starts for every 1 reactor shut down over a 25-year time frame, signaling the growing importance of nuclear in the energy mix. Then Chernobyl happened in 1986, only a short seven years following Three Mile Island and the pace of nuclear build out slowed significantly with only 6 new nuclear reactors turned on per year vs. an average of 4 shutdowns per year into the early 2010s. Then the Fukushima accident occurred in 2011 and appears to have significantly hampered the global perception of nuclear technology, and its safety/reliability, with new nuclear reactor starts and shutdowns basically balancing each other out annually over the past decade and a half, and thus leading to a long period of underinvestment across the entire nuclear value chain owing to limited new growth across the nuclear energy complex.

Exhibit 9: After a period of rapid growth, new nuclear reactors have been offset by shutdowns over the past decade
Average annual new reactor builds vs. shutdowns annually



Source: PRIS, Data compiled by Goldman Sachs Global Investment Research

Exhibit 10: The buildout of nuclear power plants started in the 1950s but stagnated in the 2000s
Historical cumulative GW of nuclear power globally

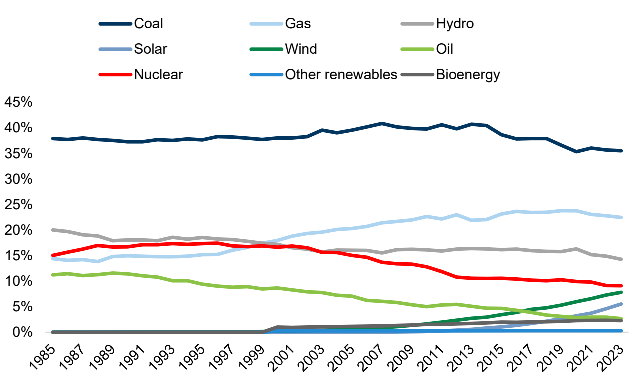


Source: PRIS, Goldman Sachs Global Investment Research

Nuclear's importance in the global power mix has waned, as has investment in the industry

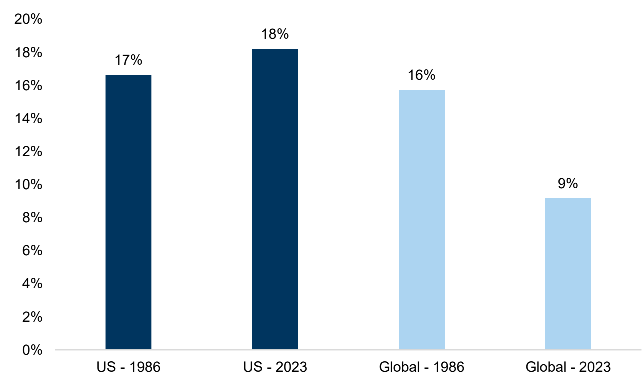
At its peak, nuclear power represented ~17% of the total global electricity generation mix in the 1980s (pre-Chernobyl) before dropping to 10% by 2010. Post-Fukishima, the generation mix represented by nuclear power generation slipped even further to roughly 9% of the global total where it currently stands. In the US, nuclear power has remained somewhat more resilient, representing 18% of today's electricity generation mix, or roughly around the same levels from three decades ago.

Exhibit 11: Nuclear power generation as a % of total global generation has declined from 17% in 1988 to 9% in 2023
Power generation by mix 1985-2023



Source: ourworldindata.org, Goldman Sachs Global Investment Research

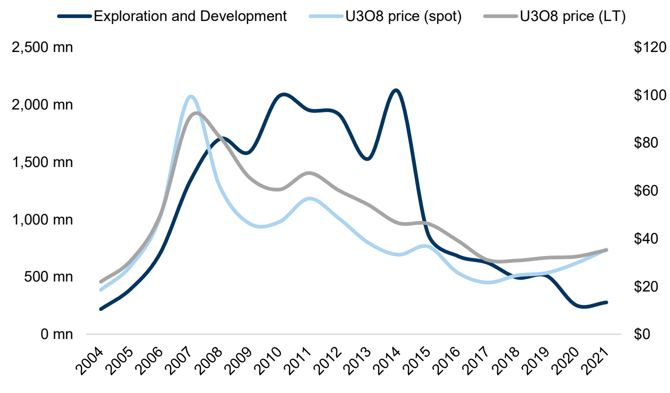
Exhibit 12: In the US, nuclear generation grew while global nuclear generation declined significantly since Chernobyl
% of total nuclear power generation US and globally



Source: EIA, Goldman Sachs Global Investment Research

The waning popularity of nuclear as an energy resource, in the face of growing safety concerns, resulted in significant underinvestment across the space in terms of new builds. As spending on development of new nuclear reactors pulled back, the effect was seen across the value chain all the way from downstream reactor builds back up to upstream materials sectors, such as uranium mining, exploration, and development. Importantly, these upstream companies require positive consumption trends to support investments such that the price of uranium - and related products - remains high enough to incentivize spending the required capital to bring more uranium supply into the market.

Exhibit 13: Declines in expectations of new reactor builds and uranium demand resulted in lower commodity prices which was followed by declines in exploration and investment spending
USD$ mn (LHS) USD$ (RHS)

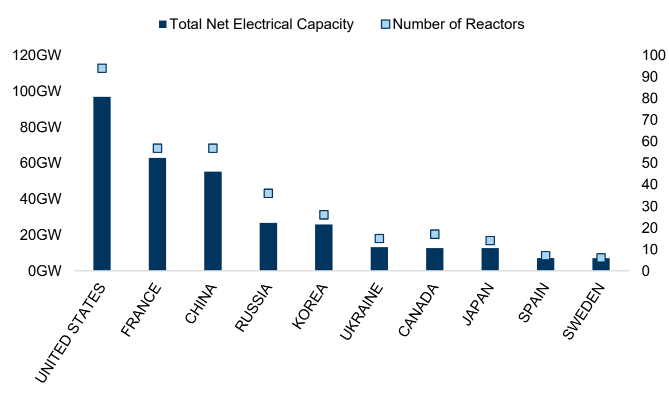


Source: Redbook, Goldman Sachs Global Investment Research, UxC

The global nuclear fleet is aging and geographically concentrated

Globally, as of 2024, there are 440 operable reactors. However, only 417 are currently operating since 19 reactors in Japan and 4 in India are suspended but still operable. While there are currently 31 countries that have operating nuclear reactors, a majority of the generation comes from the top 10 countries, which are home to roughly 80% of all global reactors and ~85% of total global nuclear generating capacity.

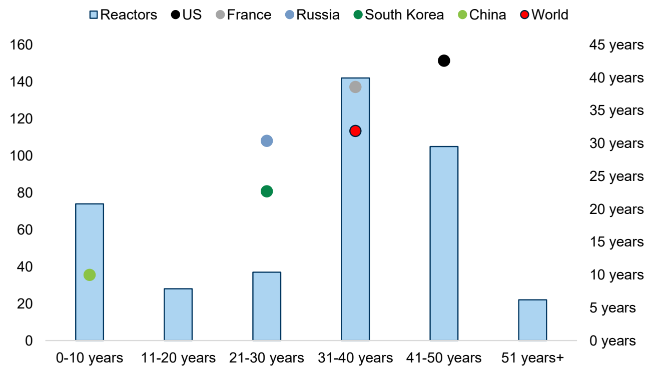
Exhibit 14: 10 countries account for ~80% of all global reactors and ~85% of all global generating capacity
Reactors and generating capacity by country, GW (LHS) # of reactors (RHS)



Source: PRIS, Goldman Sachs Global Investment Research

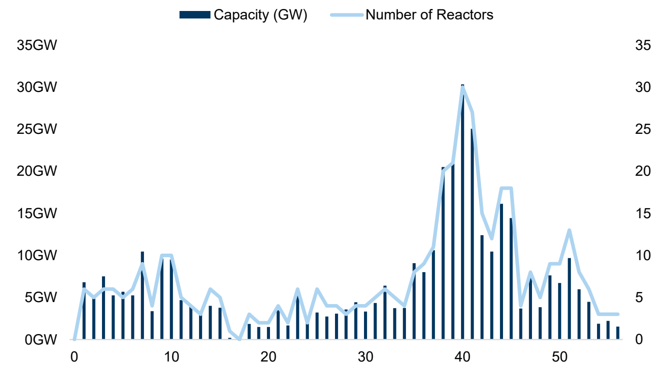
The current global nuclear reactor fleet is aging rapidly due to underinvestment and lack of interest in the technology due to fears around safety and other renewables trying to take the place of nuclear. Furthermore, the shale boom in 2008 resulted in natural gas being another source of relatively clean and substantially cheaper fuel source for power generation. The result of the decades of nuclear underinvestment is a global nuclear reactor fleet which has a median age of ~32 years, with 66% of total global reactors over 31 years old.

Exhibit 15: Median age of reactors globally is ~32 years
# of reactors (LHS) reactor age years (RHS)



Source: WorldNuclearReport, Goldman Sachs Global Investment Research

Exhibit 16: Current nuclear power in operation is aging with a majority of the nuclear infrastructure more than 30 years old
Age of nuclear reactors by number of reactors (RHS) and capacity (LHS)

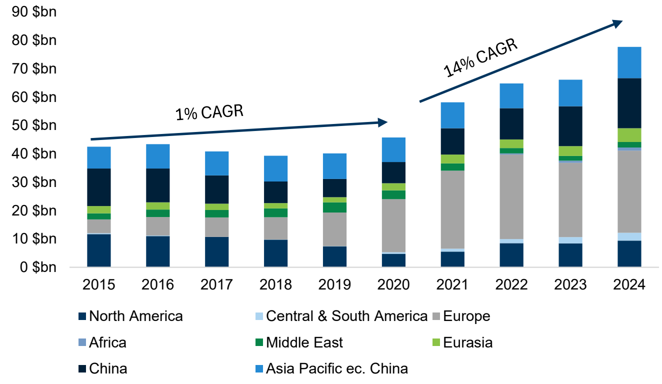


Source: PRIS, Goldman Sachs Global Investment Research

What is driving nuclear to grow again?

Recently, nuclear power has become a more front-and-center driver of current Energy Transition frameworks across the globe, with global investment in nuclear power generation having grown at a CAGR of ~14% between 2020 and 2024 after nearly a half-decade of no growth in spending. This has come on the heels of improving policy support globally, underscored by the growing demand for power and less emission-intensive alternatives in a world that is retiring coal plants at a rate much faster than it is building new ones. While nuclear power in this context would appear to be quite desirable given its large-scale capacity (e.g., most plants are 1GW or more in scale) and around-the-clock availability as long as nuclear fuel is available, years of underinvestment have left the supply chain in a challenged position to ramp quickly. Case in point: nuclear reactors take between 6-12 years on average to build and in countries that don't have existing nuclear supply chains, it can take much longer. The current solution to bridge this issue until new reactors are built is nuclear power plant life extensions for existing reactors, a dynamic that has started to see more momentum, of late. While the average nuclear power plant in the global fleet is now aged 32 years, operating licenses for nuclear plants in the US average about 40 years per the EIA, meaning many plants likely require license extensions in the coming years to continue operating. With that said, we anticipate a healthy portion of the global nuclear fleet will seek extensions, which should help bridge the gap to new reactor builds coming online.

Exhibit 17: Global investment in nuclear power generation has increased rapidly over the past 4 years
Growth in nuclear power generation investment



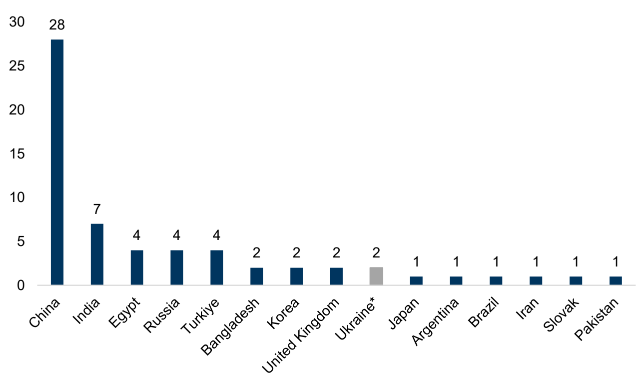
Source: IEA, Goldman Sachs Global Investment Research

The pipeline for new reactors is growing

Current data shows that there are 61 reactors under construction across 15 different countries with roughly 1/2 located in China. Importantly, 59 of 61 reactors are scheduled to come online between 2025-2032, assuming no delays. Furthermore, the 19 reactors in Japan and 4 in India that are suspended that could also be restarted during that time frame.

In addition to the 61 reactors currently under construction, there are roughly 85 reactors currently planned across the globe and another 359 proposed. While we do not anticipate all of these planned and proposed reactors to come online, we think this statistic is still noteworthy in highlighting the level of activity in the industry, as underscored by 31 countries pledging to triple global nuclear capacity 2050 at COP29.

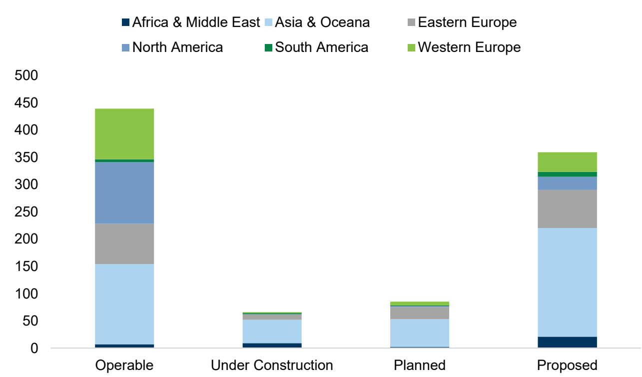
Exhibit 18: There are currently 61 nuclear reactors under construction with 59 anticipated to come online between now and 2032
Nuclear reactors under construction by country



*Ukraine reactors likely not coming online before 2032

Source: PRIS, Data compiled by Goldman Sachs Global Investment Research

Exhibit 19: The pipeline of activity for new nuclear is robust and growing
# of operable, under construction, planned, and proposed reactors



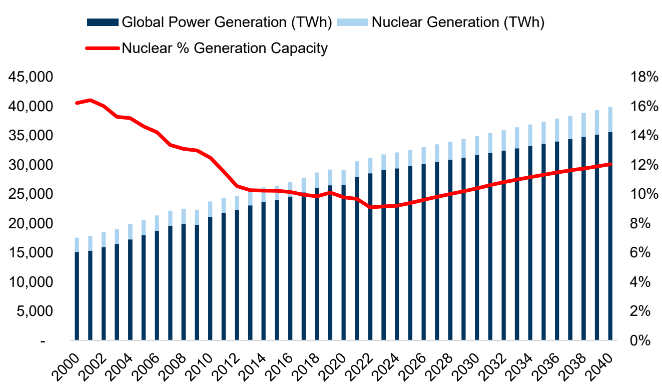
Source: World Nuclear Association, Goldman Sachs Global Investment Research

New technology coming alongside new reactors

As investment in nuclear has started to pick up globally, countries are not only looking at building out large nuclear fleets but there has also been growing investment allocated to new technologies such as SMRs. This represents a largely greenfield growth opportunity for the sector as currently there are only 2 licensed, approved, and operating small modular reactors and 1 test reactor operating across the globe. In China, the HTR-PM, which is a high-temp gas-cooled reactor, is operational with 210MWe and was connected to the grid in 2021 and entered commercial operation in 2023 according to World Nuclear News. In Russia, the KLT-40S is an operating PWR reactor with 35MWe and it is classified as a floating nuclear power plant according to the World Nuclear Association. There is also a high temperature test reactor (HTTR) in Japan that is being tested as well.

With SMR technology still years away from deploying at scale, our forecasts for nuclear generation are largely driven by life extensions, restarts, and new traditional reactors coming online that are under construction and planned. By 2040, we estimate nuclear generating capacity will grow to 575GW globally, representing 12% of the global electricity mix, up from about 9% today and representing ~200GW of incremental growth in nuclear generating capacity from today's baseline of 378GW.

Exhibit 20: We estimate nuclear as a % of total global generation will increase from ~9% today to >12% by 2040



Assumes net generation growth of other power courses grows by 1%

Source: EIA, Goldman Sachs Global Investment Research

Exhibit 21: Companies are turning to nuclear energy, particularly advanced nuclear tech, in order to deal with the growing demand for power

Summary of recent nuclear energy sector commercial activity by company

Date	Nuclear/Utility Company	Tech	Offtaker	Capacity (MWs)	Deal Type	Location	COD	Investment ($mn)
Equity Investments								
16-Oct-24	X-energy	SMR	Amazon	-	Equity Investment	-	-	500
PPAs								
10-May-23	Helion Energy	Fusion	Microsoft	>=50	PPA	-	2028	-
20-Sep-24	Constellation Energy	Traditional Reactor	Microsoft	835	PPA	PA	2028	-
15-Oct-24	Kairos Power	SMR	Google	500	PPA	CA	2030-35	-
16-Oct-24	Energy Northwest	SMR	Amazon	320	PPA	WA	2030	-
16-Oct-24	X-energy	SMR	Amazon	5,000	Partnership/PPA	-	2030-39	-
LOIs/MOUs								
17-Oct-24	Dominion Energy	SMR	Amazon	300	MOU	VA	2030	-
Purchases/Prepayments								
09-Oct-23	NuScale	SMR	Standard Power	1,848	Purchase	OH/PA	2029	-
Other								
04-Dec-24	-	Traditional/SMR	Meta	1,000-4,000	RFP	-	2030	-
17-Jan-25	GE Hitachi	SMR	TVA/Duke Energy/AEP		Coalition	TN	2033-35	
25-Feb-25	Holtec	SMR	Hyundai E&C	600-10,000	Cooperation Agreement	North America	2030s	-
01-Apr-25	GE Hitatchi/Samsung C&T	SMR	Fermi Energia	600	Teaming Agreement	Estonia	2035	-
04-Apr-25	GE Hitachi	SMR	Ontario Power Generation	300-1,200	Construction License	Ontario	2029	-
07-May-25	Elementl Power	SMR	Google	600	Development Capital/PPA	-	-	-

Source: Company data, Goldman Sachs Global Investment Research

Both policy and public support are growing for nuclear

From a policy perspective, nuclear has seen a resurgence in government support across the globe. At COP28 in December 2023, 25 countries set a goal to triple nuclear energy capacity by 2050 from 2020 levels. This group was subsequently expanded to 31 countries in November 2024. This pledge also has the support of 140 nuclear industry companies and 14 large financial institutions. Importantly, during CERAWeek in March 2025, a group of major energy users, which included Amazon, Google, Meta, Dow, Occidental, Allseas, and OSGE, also signed the pledge to support the goal of at least tripling global nuclear capacity by 2050.

We note that tripling global nuclear energy capacity suggests more than 1,100 GW of total capacity, up from ~370 GW in 2020. While this estimate is higher than the IAEA's most aggressive forecast at 890 GW, it still highlights the increasing support to expand global nuclear energy capacity.

In the US, the government set a target to triple its nuclear capacity by 2050, which implies adding ~200 GW of new capacity. Additionally, the Inflation Reduction Act (IRA) of 2022 provides several tax credits and incentives for nuclear energy. This includes a production tax credit of up to $15/MWh (assuming labor and wage requirements are met) for facilities in service in 2024, and would last through 2032. Additionally, advanced reactors can claim either a $25/MWh production tax credit or a 30% investment tax credit. Lastly, the IRA set aside $700mn to support the development of a domestic supply chain for HALEU. Importantly, in April 2025, the DOE made conditional commitments to five advanced reactor developers (Kairos Power, Radiant Industries, TerraPower, TRISO-X, and Westinghouse) to receive the first allocations of HALEU from its HALEU Availability Program. Lastly, the IRA allocated $150mn for infrastructure improvements at DOE's Idaho National Laboratory (INL) to improve nuclear energy research and development, supporting almost a dozen advanced nuclear technologies.

Exhibit 22: IRA policies support nuclear development

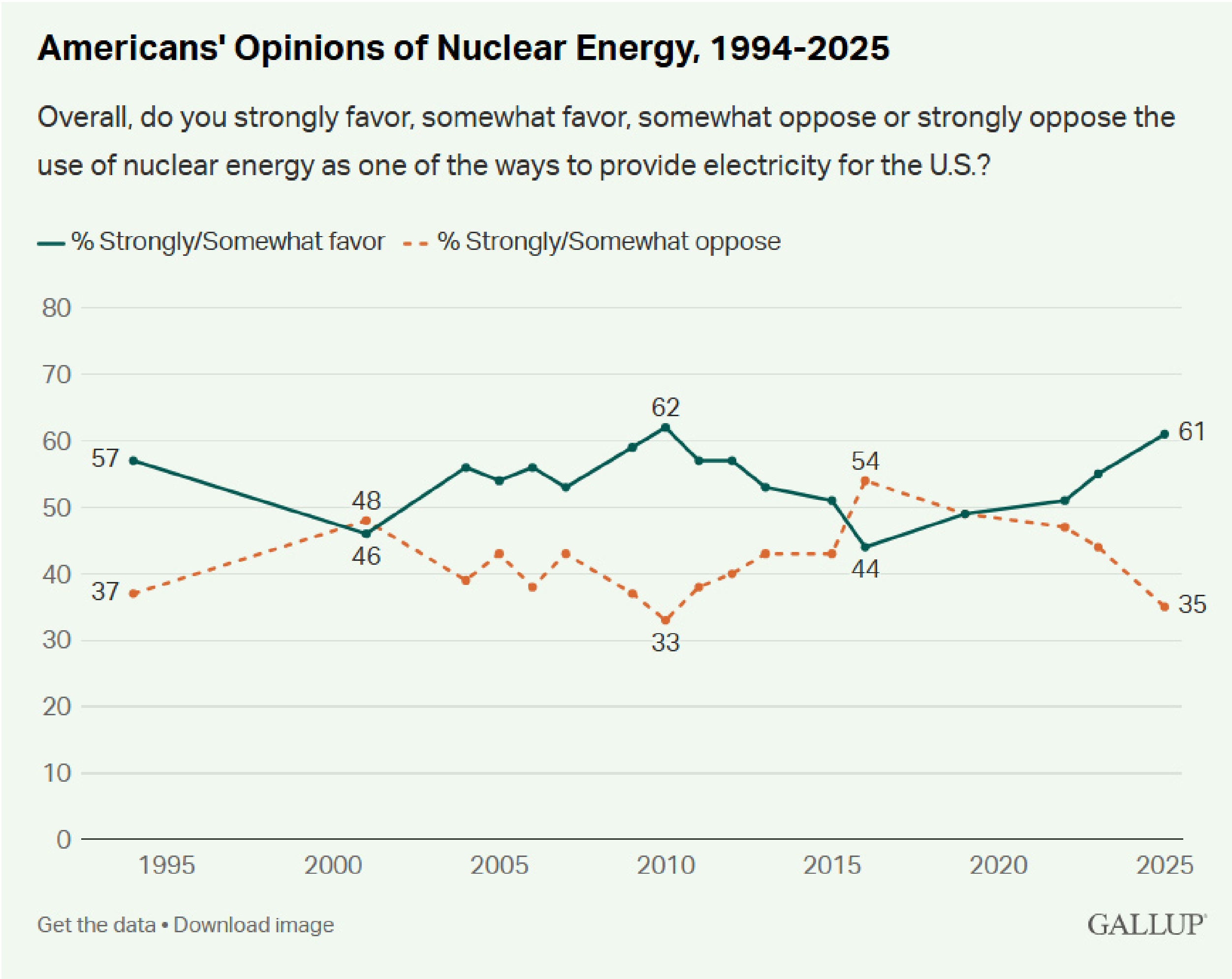
Provision	Summary	Type	Eligibility	Total Investment
Section 45Y and 48E - New Capacity	Technology-neutral production tax credit of **$25/MWh** for the first ten years of plant operation. The credit phases out in 2032 or when carbon emissions from electricity production are 25 percent below the 2022 level...	Production Tax Credit (PTC)	2025-2032	N/A
	...or a **30% investment tax credit** on new zero-carbon power plants placed into operation in 2025 or after. The ITC can rise to up to 50% if nuclear projects include sufficient domestic content and are built in former coal plant communities	Investment Tax Credit (ITC)	2025-2032	N/A
	Only one of these credits can be applied to a single facility but both do include a **10% bonus** if the power plant is built at a brown field site or a fossil energy community	-	-	-
HALEU availability for Advanced Nuclear Reactors	DOE funding - **$100M** to make HALEU fuel available for R&D, and commercial use; **$500M** to make HALEU available for the first advanced reactors, and **$100M** to assist commercial entities in the licensing and regulation of special nuclear material fuel (such as HALEU) fabrication, enrichment facilities, and transportation packages	Grant	2022-2026	$700mn
Section 48C - Advanced Energy Project Credit	The bill includes an extension of the Advanced Energy Project Credit. Base rate of 6% and **30% tax credit** if wage and apprentice requirements are met	Manufacturing Tax Credit (MTC)	2023-2032	$10bn
Nuclear R&D	Funding for infrastructure improvements at DOE's Idaho National Laboratory (INL) to enhance nuclear energy research and development	Grant	2022-2027	$150mn
Section 45U - Existing Reactors	The legislation offers a **$15/MWh** base tax credit, which gradually decreases as power prices exceed $25/MWh. Failure to meet prevailing wage requirements result in a base tax credit of **$3/MWh** and applicable corrections and penalties, if necessary	Production Tax Credit (PTC)	2024-2032	N/A

Source: US DOE, Goldman Sachs Global Investment Research

Outside of the IRA, in December 2024, the DOE announced that it selected six companies (American Centrifuge Operating, General Matter, Global Laser Enrichment, Louisiana Energy Services, Laser Isotope Separation Technologies, and Orano Federal Services) that can sign contracts to purchase low enriched uranium to support the expansion of new uranium enrichment capacity in the US. These contracts are expected to last for up to 10 years, with each company receiving a minimum contract of $2mn.

In addition to incremental government support for nuclear, public support has also been improving. As highlighted by a recent opinion survey, public support for nuclear energy has been steadily increasing since the lows experienced in 2015. In particular, a poll from Gallup shows that 61% of US citizens support nuclear energy, up meaningfully from 44% in 2016, which coincided with relatively low gas prices. Additionally, energy consultancy company Radiant Energy Group commissioned a survey through Savanta that found that support for nuclear outweighed opposition by 1.5x within 23 US states (40% supported while 27% opposed). The majority of those that support nuclear energy were Republicans (74%) and independents (64%), with 46% of Democrats supporting nuclear.

Exhibit 23: Americans' opinions of nuclear energy have become more positive in recent years
Sentiment around nuclear power



Source: Gallup

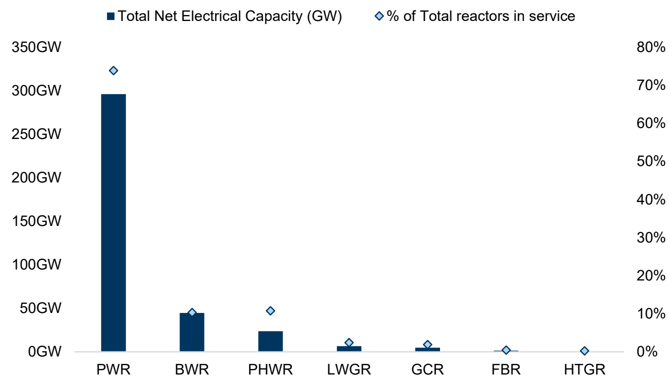
Nuclear Technology - a deep dive

Traditional nuclear overview

How do nuclear power plants work? Simplistically, nuclear reactors use heat from nuclear fission to heat water to a boiling point and produce pressurized steam. The steam is routed through a system which then spins blades of a large turbine that drive magnetic generators to produce electricity. Nuclear fission occurs when a neutron rams into a larger atom and causes it to split into 2 smaller atoms. Further neutrons are released that can start a chain reaction and large amounts of energy are produced each time one of these atoms split.

Three predominant types of traditional reactors. Globally, ~95% of all nuclear reactors fall into one of three categories: (1) PWR (pressurized-water reactor), (2) BWR (boiling-water reactor), and (3) PHWR (pressurized heavy-water reactor), with PWRs being the most popular and representing ~70% of the installed base globally.

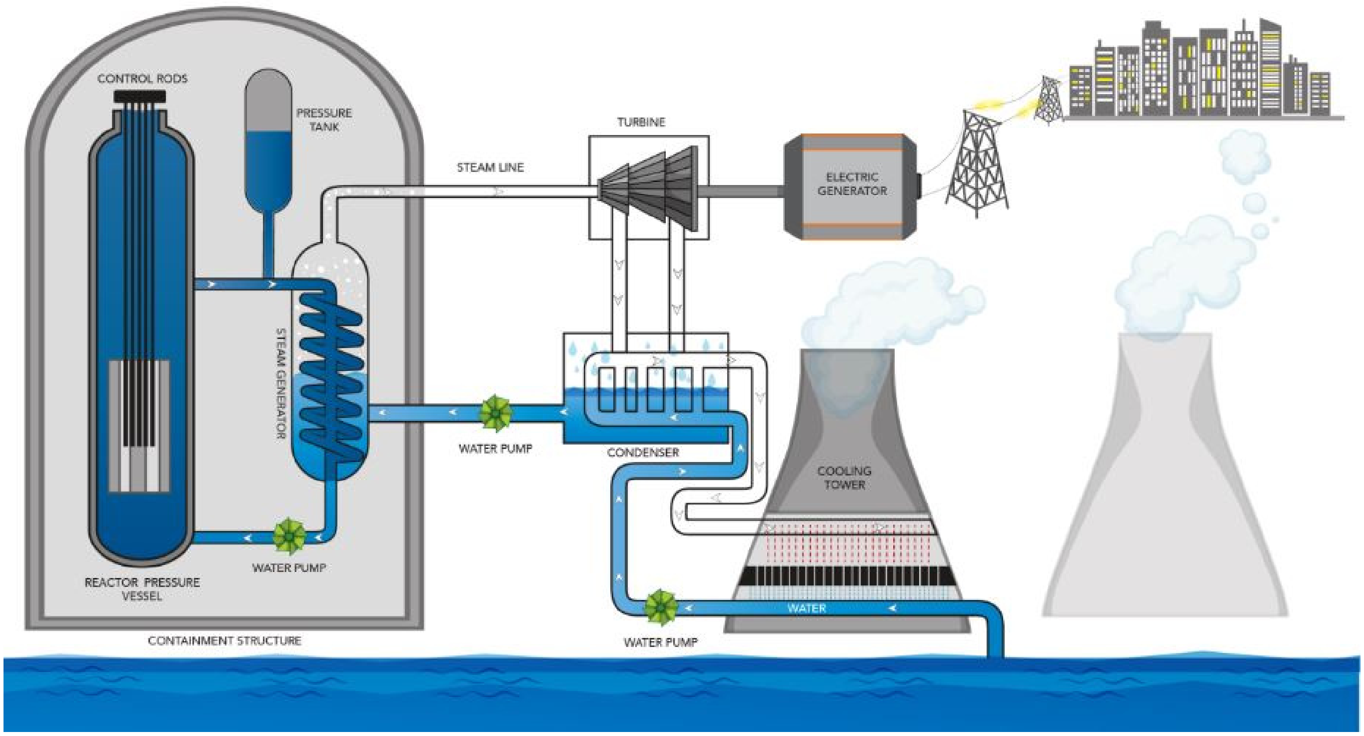
Exhibit 24: PWR is the global leader in reactor technology
Global electrical capacity per reactor technology



Source: PRIS, Goldman Sachs Global Investment Research

PWR (Pressurized-water reactor): This is the most common type of reactor with ~308 units deployed globally, making up 74% of all reactors currently in operation. In a PWR, the reactor core heats water and is able to hold the water under pressure to prevent it from turning into steam. This hot water, then flows through piping in a steam generator. The steam generator is a large cylinder full of nonradioactive (clean) water that can come from sources such as rivers, oceans, or lakes. Inside the large cylinder are thousands of tubes the radioactive hot water runs through to heat the clean water, causing it to boil and turn into steam. The radioactive water then flows back into the reactor core to be reheated and returns to the steam generator once hot again. PWRs typically require uranium to be enriched to 3%-5% to be used as fuel, meaning concentration of the fissile uranium-235 isotope needs to be increased from its natural level of 0.7%. This type of fuel is the most common for large reactors and commonly referred to as LEU (low enriched uranium). Typical PWRs need to be refueled every 18-24 months and during the refueling process, typically only 1/3 of the fuel in the reactor is replaced.

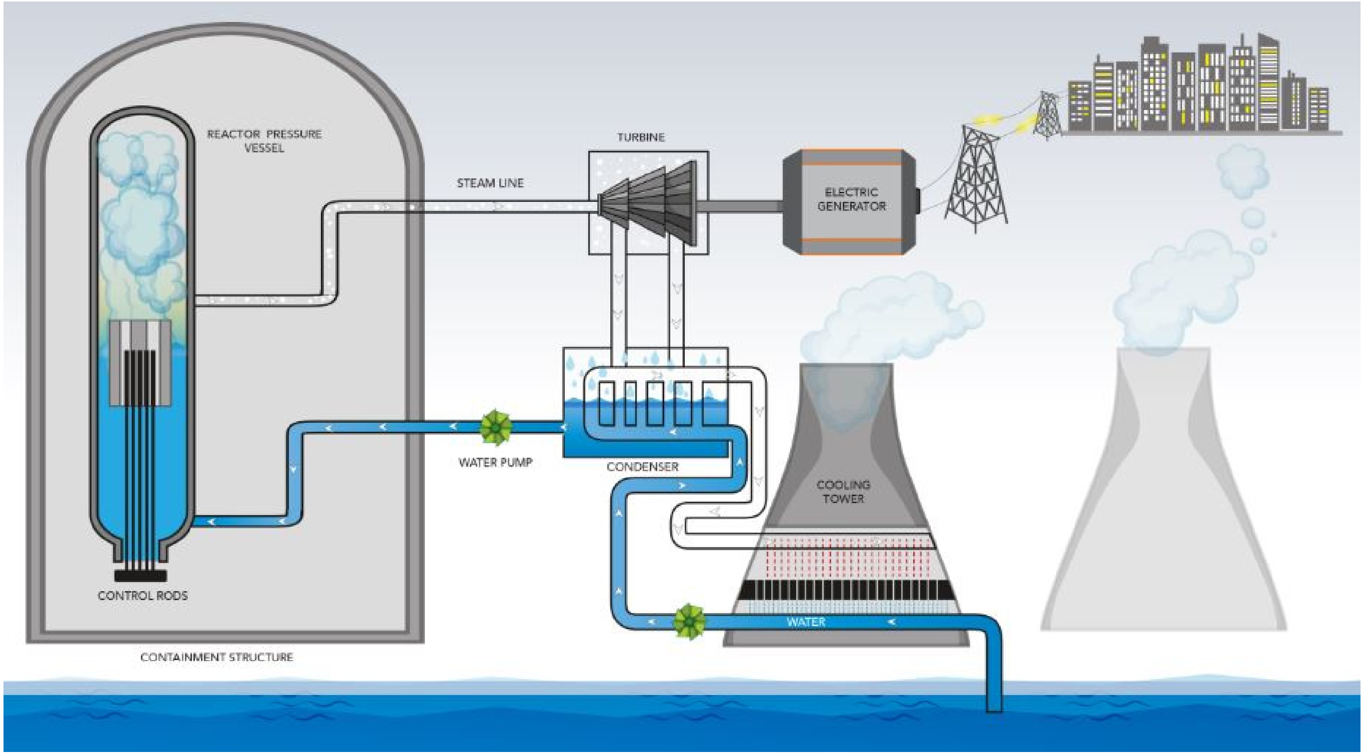
Exhibit 25: Overview of Pressurized Water Reactor



Source: US Department of Energy

BWR (Boiling-water reactor): This is the second most common type of reactor, in which the process of creating power involves the reactor core heating water, which turns directly into steam in the reactor vessel, which then the steam is used to power a turbine. Much like PWRs, BWRs also require uranium to be enriched to 3%-5% to be used as fuel.

Exhibit 26: Overview of Boiling Water Reactor



Source: US Department of Energy

PHWR (Pressurized heavy-water reactor): Basically the same as a PWR, this reactor type needs a more efficient moderator like heavy water (D2O). A PHWR produces more energy per/KG of mined uranium than a PWR but also uses a much larger amount of fuel. The pressure tube design of this system allows the reactor to be refueled progressively without shutting down as it is possible to isolate and shut down individual pressure tubes from the cooling circuit. It is also less costly but the tubes are less durable. Although PHWRs use a larger amount of fuel, they require less feed because the fuel required is natural unenriched uranium (0.7% U-235) so the fuel used does not need to go through the enrichment process. Most PHWRs are operated in Canada and India, with Canada's entire fleet operating CANDU (Canada Deuterium Uranium) reactors.

Advanced nuclear overview

What is an SMR? An SMR is a Small Modular Reactor that is a fraction of the size of a larger nuclear power plant and typically has a power capacity of between 20MWe and 300MWe vs. ~1GW for a traditional nuclear reactor like the AP-1000 PWR. We note that there are also microreactors, which are typically between 1MWe and 20MWe. Within the SMR landscape, although there are roughly ~80 different designs that have been introduced, these designs primarily operate under four different families of SMRs. Broadly speaking, almost all the SMR design applications fall under these types: (1) water cooled, (2) gas cooled, (3) liquid metal-cooled, and (4) molten salt.

- **Water-cooled SMR (Land-based & Marine-based).** Water cooled SMRs leverage established technologies from existing large-scale reactors, such as Light Water

Reactors (LWR) and Heavy Water Reactors (HWR). The advantage of this design is its ability to utilize proven technologies and fuel supply chains, enabling the creation of smaller versions of traditional large-scale reactors. Currently, there are approximately 14 land-based water-cooled SMR designs within this category. Water-cooled SMRs for marine applications are largely based on the same design, but deployed as floating power units, either barge-mounted or using other flexible deployment methods. There are currently six proposed marine-based SMR concepts. For Water-cooled SMRs, the technology typically employs enriched uranium oxide (UO2) pellets (~5% enrichment) encased in zirconium alloy tubes. This LEU fuel is similar to that used in conventional LWRs, meaning the fuel supply chain for these SMRs is already well-established. In contrast, HWR SMRs typically require HALEU fuel, which is uranium enriched to a higher concentration, typically between 5% and 20%. According to the World Nuclear Association, the global supply of HALEU is primarily controlled by the Russian company Tenex, which is currently the only commercially viable producer of HALEU at scale.

- **Gas-cooled SMRs.** Gas-Cooled SMRs are a type of nuclear reactor where gas, typically carbon dioxide (CO_2) or helium (He), serves as the primary coolant to transfer heat from the reactor core. In these reactors, nuclear fission occurs in a fuel core, often graphite-moderated, which is surrounded by the gas coolant. The coolant absorbs the heat generated during fission and carries it away to produce steam for electricity generation. CO_2 is commonly used in Magnox reactors, the first generation of gas-cooled reactors, while helium is employed in more advanced designs such as High-Temperature Gas-Cooled Reactors (HTGRs). Currently, there are 14 gas-cooled SMR designs either under development or in operation. These high-temperature, gas-cooled SMRs are primarily used for electricity generation and industrial applications. China currently operates one such reactor, while Japan has a test reactor that has been operational for over 20 years.
- **Liquid metal-cooled SMRs.** Liquid metal-cooled SMRs use liquid metals such as sodium, lead, or lead-bismuth eutectic as coolants, providing high thermal conductivity and efficient heat removal. This design allows reactors to operate at higher temperatures, improving thermal efficiency and supporting applications such as hydrogen production and desalination. The high boiling points of liquid metals reduces the risk of coolant boiling, and their low vapor pressure enables operation at near-ambient pressures, thereby enhancing safety. Notable examples include GE Hitachi's PRISM reactor, a sodium-cooled fast reactor designed for modular deployment. While challenges such as coolant reactivity and material corrosion exist, ongoing research and development efforts are focused on overcoming these issues, positioning liquid metal-cooled SMRs as a promising solution for clean and reliable electricity generation. Currently, there are 10 SMR designs utilizing fast neutrons with liquid metal coolants.
- **Molten salt SMRs.** Molten salt reactors have a history dating back to the 1960s and are now regarded as a promising technology, especially for thorium fuel cycles or the reprocessing of spent LWR fuel. A range of designs, including fast neutron reactors, are currently under development, with China leading global research efforts. Some Molten Salt Reactors (MSRs) utilize solid fuel similar to that of HTGRs,

while others innovate by dissolving the fuel directly into the molten salt coolant, a concept that improves reactor performance. These reactors typically use molten fluoride salts, such as lithium-beryllium fluoride and lithium fluoride, which remain in liquid form at high temperatures (500-1400°C) and low pressures, in contrast to PWRs. The core principle involves dissolving the fuel into the coolant as a fuel salt, which can be reprocessed continuously. Thorium, uranium, and plutonium salts can be efficiently separated for reprocessing. Although batch reprocessing is anticipated in the near-term, the typical fuel life ranges from 4 to 7 years, with graphite frequently serving as a moderator compatible with fluoride salts. Currently, there are 11 SMR designs employing molten salt cooling.

Exhibit 27: There are multiple different types of SMR technologies seeking to reach commercialization in the US

US SMR companies overview

Company	Reactor	SMR Type	Fuel	Capacity (MWe)	Refueling Cycle	Lifecycle stage	COD	First Deployment Region	Construction Time
GE-Hitachi Nuclear Energy	BWRX-300	Small modular LWR	LEU	300	1-2 years	License application submitted	2029	Canada	NOAK - 24-36 months
NuScale Power Corp.	NuScale Power Module	Small modular LWR	LEU	77	2 years	Standard Design Approval (SDA) received	2029	Romania	NOAK - 30 months
Westinghouse	AP300	Small modular LWR	LEU	330	4 years	Pre-licensing	Early 2030s	UK	NOAK - 36 months
TerraPower	Natrium	Sodium Cooled Fast Reactor	HALEU	345	2 years	Pre-licensing	2031	US	NOAK - 36 months
X-energy	Xe-100	High-Temperature Gas-cooled Reactor	TRISO	80	2 years	Pre-licensing	2030	US	NOAK - 30-48 months
Kairos Power	Hermes	Molten Fluoride Salt-Cooled High-Temp Reactor	TRISO	35	5 years	License application submitted	2027	US	NOAK - 36-48 months
Westinghouse	e-vinci Micro Reactor	Micro-Reactor	TRISO	5	>= 8 years	Pre-licensing	2029	Canada/US	-

Source: Company data, Goldman Sachs Global Investment Research

Exhibit 28: Key SMR technologies in focus fall into a few categories

Summary of major SMR technologies

	WATER-COOLED LIGHT WATER REACTORS (LWRs)	GAS-COOLED FAST REACTORS (GFRs) AND HIGH TEMP GAS COOLED REACTORS (HTGRs)	LIQUID METAL-COOLED REACTOR	MOLTEN SALT REACTORS (MSRs)
FUEL				
- Enrichment	LEU	HALEU	HALEU	LEU/HALEU
- Fuel Form	Ceramic UO2 Pellets	TRISO/UO2 in silicon carbide/ Uranium Carbide	Metallic uranium-zirconium/TRISO	Molten Flouride/Molten Chloride/Solid Fuel
- Refueling Period/Method	Usually 12-24+ months	Online 180-360 months	Online	Online
POWER OUTPUT				
- Classification	LWR-SMR	HTGR-SMR/GFR-SMR	FHR-SMR	MSR-SMR/MSR-SMR (mid-scale)/MSR-Micro
- Base Model Output (MWe)	Varies. Maximum 300MWe	Up to 300 Mwe	140 MWe	Test Reactor: 1MWth (MSR-Micro) 195-500 Mwe (MSR-SMR) 300-170-430 MWe (midscale) 780-650-910 MWe (largescale)
REACTOR: PLAYER	GE-Hitachi Westinghouse NuScale Power Corp. Holtec	X-energy General Atomics	TerraPower Ultra Safe Nuclear X-Energy	Kairos Power TerraPower Terrestrial Energy Moltex

Source: NIA, Company data, Goldman Sachs Global Investment Research

Why are SMRs seeing rapid advancement? Compared to traditional nuclear reactors, SMRs have multiple advantages, including, but not limited to:

- **Speed to market.** SMRs provide improved deployment timelines from traditional reactors. Based on various company disclosures, we estimate that leading SMR companies could see commercial deployments in as fast as 5-7 years (~36mo licensing timeline and ~18-36mo construction timeline). This compares favorably to the 10+ year time frame to build a traditional reactor in the United States, with most recent precedent at Southern Company's Vogtle plant far exceeding that timeline taking ~15 years to build.

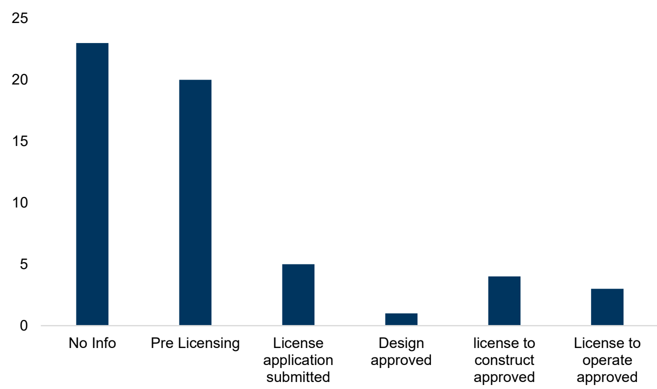
- **Modularity and flexibility.** The ability to deploy faster is founded upon the idea that SMRs can be mass-produced due to the modular parts and components, which can be manufactured in traditional facilities before being shipped to site, unlike traditional reactors which are built on-site with significantly larger and bulkier components. Also, given their smaller footprint, SMRs can be built in more locations from a siting perspective, making it possible to deploy more easily in behind-the-meter and off-grid locations.
- **Safety.** SMRs are designed to be safer than traditional reactors, including maintaining fewer failure points. Furthermore, SMRs can be fabricated and fueled in factories then sealed and transported and delivered to sites for power generation, then returned to the factory for defueling, which would minimize handling of hazardous materials.
- **Refueling.** Some SMRs, dependent on the fuel type, will be designed to operate for prolonged periods without refueling, which could be several years to tens of years compares to traditional reactors which require refueling every 18-24 months on average. This is particularly true for SMRs focused on HALEU fuel, which leverages its higher enrichment to operate for longer fueling cycles.

That said, SMRs have yet to seen significant deployment at scale, with most suppliers of the technology targeting well into the 2030s before reaching commercialization. The key bottlenecks for accelerating deployment include:

- **Regulatory and licensing timelines.** Licensing is a bottleneck to the SMR story as new designs, or even the designs based on a prior technology, need to undergo extensive review to move from design stage to construction to operating status. While the potential timelines for SMRs are shorter than for traditional reactors, the entire process is expected to take 5-7 years before turning a reactor on, according to the Canadian Nuclear Safety Commission.
- **Fuel availability.** Another obstacle remains the fuel supply chain - or lack thereof - for the type of fuel that many SMRs require to operate and is one of the more complex pieces to bring SMRs to reality. Along with the complexities that come with creating a new modular design, some companies are looking to use new/alternate fuel types in these new designs. Particularly, HALEU is one of the more common new fuel types that is being referenced in a number of new designs. The problem with HALEU is that it is highly enriched (~10%-20%) and enrichment up to these levels requires investment in enrichment facilities which currently do not have enough demand to warrant the investment. Furthermore, enrichment above 10% requires an NRC Category II facility within the US, which requires capital investment to license, build, secure, and operate. Currently, the HALEU supply and infrastructure is very limited in the US and controlled by the DOE. The only global suppliers that can produce HALEU at scale are in Russia and China.
- **Supply chains.** There are roughly ~70 SMR designs across the industry and the availability of components to be able to eventually produce these at scale, could prove to be a challenge. In this context, costs are also front and center as one of the key headwinds to the SMR industry. Out of the three operational SMRs that have

been built and the one currently under construction, at least three have experienced significant cost overruns. The Shidao Bay 1 SMR (China) and the Floating SMR (Russia) have experienced cost escalations of 300%/400% above the original cost estimates according to the Institute for Energy Economics and Financial Analysis. Currently, the CAREM 5 SMR is under construction in Argentina and although not yet complete, has experienced cost overruns of 700% to date (per IEFA). This is typical across the landscape, despite the modular component of SMRs to be more cost-efficient, they face diseconomies of scale during the earlier years of the production ramp. We note that one of the operational SMRs is High Temperature Engineering Test Reactor that was built by the Japan Atomic Energy Agency with a 30 MW capacity, which aims to support hydrogen production by 2028.

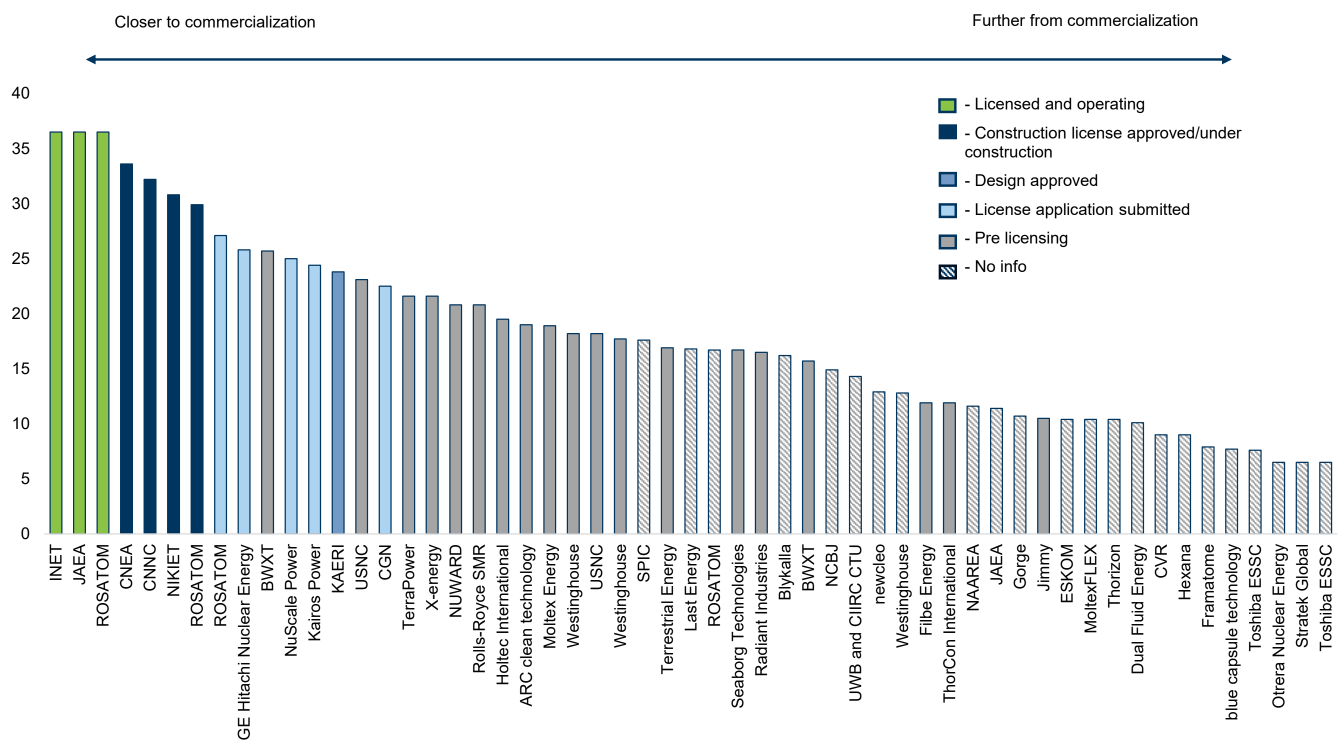
Exhibit 29: Very few SMRs have received construction or operating licenses
SMR licensing stages



Source: Nuclear Regulatory Commission, Goldman Sachs Global Investment Research

Exhibit 30: Currently, 3 SMRs are operational, 4 are under construction, 1 has design approval, and 5 have licenses submitted being reviewed

Ranking of SMR companies by order of commercialization status



Source: NEA, Goldman Sachs Global Investment Research

Nuclear Fuel Cycle - a deep dive

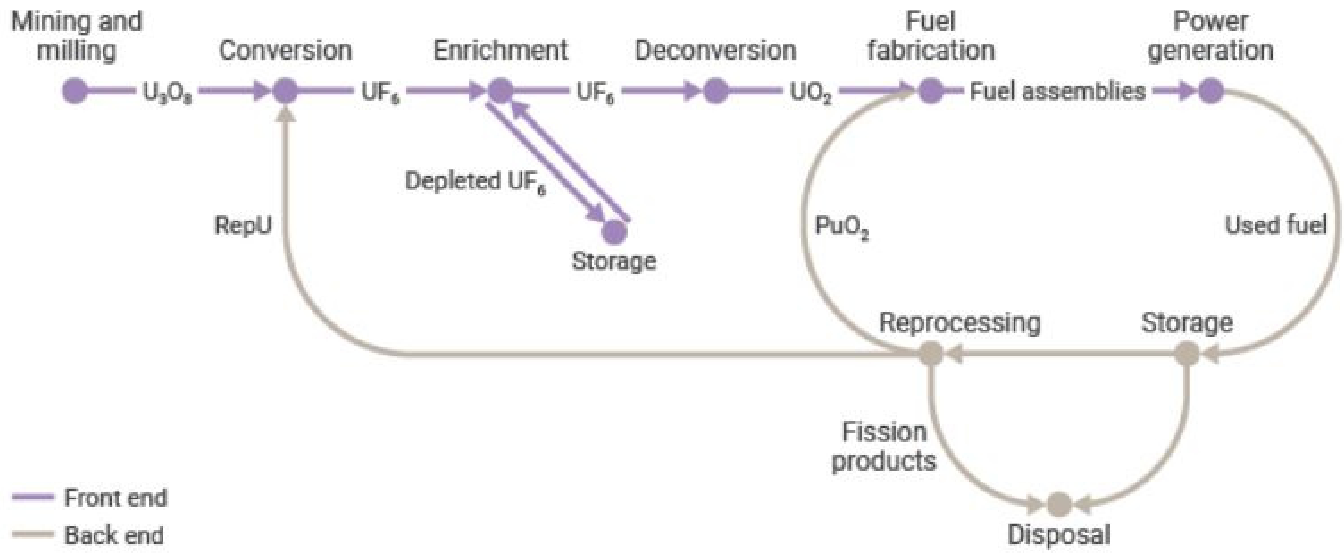
All nuclear reactors require fuel to run and traditional reactors differ vs. SMRs. Conventional nuclear reactors typically use pellets of uranium oxide (UO_2) that are inserted into thin tubes called fuel rods and then arranged into fuel assemblies. These assemblies are then placed in the reactor core. The fuel for conventional reactors is based on a uranium fuel cycle for LEU, which is uranium that is enriched to ~3%-5% Uranium-235 (U-235). U-235 is a radioactive isotope of uranium that is able to be split to create energy from nuclear fission.

However, new advanced reactors require HALEU, which is uranium enriched to 5%-20%. We note that some reactors use LEU+, which is uranium enriched to 5%-10% U-235, which can be achieved from using the same enriching facilities that enrich uranium up to 5%. However, enriching to above 10% requires a separate NRC license, which requires a meaningful amount of capex to license, build, secure and operate. For reference, the US and UK maintain naval reactors that utilize weapons-grade High Enriched Uranium (HEU), which is typically 90%+ U-235, while Russia and India use HEU above 20% U-235.

Nuclear Fuel Cycle Overview

As shown in Exhibit 31 below, the nuclear fuel cycle involves several steps across two phases. The front-end steps prepare the uranium to be used as fuel in the nuclear reactors, while the back-end steps make sure that the used/spent fuel is managed and disposed of safely as it is still highly radioactive.

Exhibit 31: Illustration of Nuclear fuel cycle

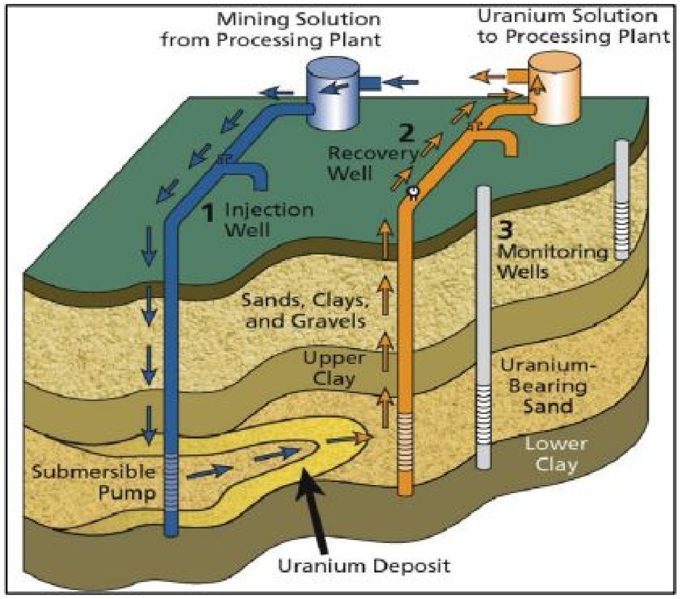


Source: World Nuclear Association

Front-end:

- Mining and milling
  - Uranium is produced through the process of either conventional mining and milling or in-situ recovery/leaching (ISR/ISL). Conventional mining is either open pit or underground mining, with the milling process leveraging a sequence of physical and chemical treatment processes to extract U_3O_8. Conversely, ISR operations involve injecting a solution of hydrogen peroxide in boreholes drilled into the ore deposit to dissolve the minerals, which is then extracted through a second borehole. We note that ~35% of uranium is mined via conventional means, while ~60% is through ISR, and ~5% is produced a byproduct from mining other minerals, mostly copper/gold.
  - Today, there are more than 30 operating uranium mines in the world that produce a total of ~160mn lbs of uranium per year (~62k tonnes), with the top 10 mines accounting for more than half of global production based on our estimates.

Exhibit 32: Overview of ISR operations



Source: NRC, Department of Energy

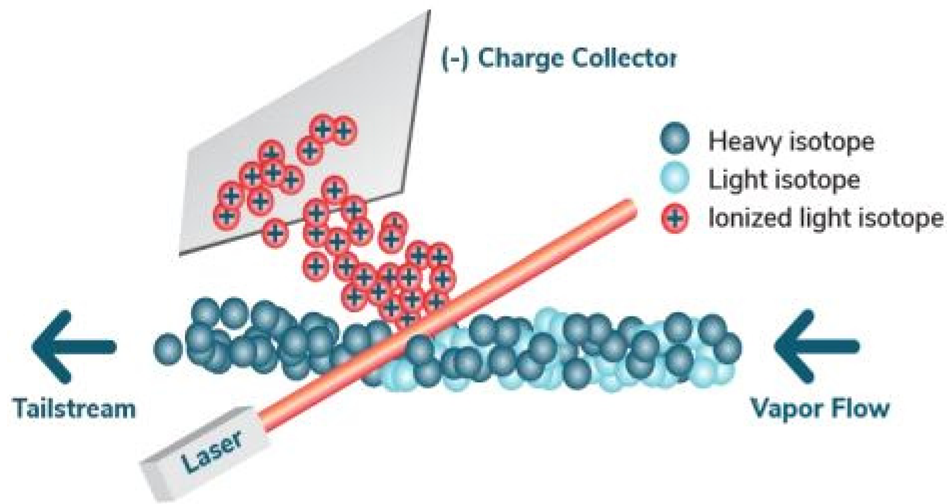
Exhibit 33: Overview of Mining Lifecycle

Source: Orano

- <u>Conversion</u>
  - The next step is the conversion of the U_3O_8 into pure uranium hexaflouride (UF_6), which is suitable for use in enrichment operations. Since fluorine has only one naturally occurring isotope, it is easier to separate from the uranium during enrichment. There are two basic conversion techniques, a "dry" process and a "wet" process. Generally speaking, the wet process is used by Cameco and Orano, among others, and involves dissolving the uranium concentrate in nitric acid and then fed through a series of processes before being reacted with fluorine to yield the UF_6. The dry process, which is mostly used in the US, involves grinding the concentrate into a fine powder that is then heated at 1,000°F+ before being interacted with hydrogen fluoride to get UF_6. In order to produce UF_6, a license is required by the NRC.

  - There is roughly 62,000 tonnes of licensed uranium conversion capacity in the world (according to the World Nuclear Association), which is mostly state owned (CNCC, Orano, Rosatom) but Cameco also maintains capacity in Canada as well as ConverDyn in the US. However, there is only 42,000 tonnes of actual conversion production, with more than half of this in Russia and China. As a result, conversion remains the main bottleneck in the upstream process of turning U_3O_8 into a usable product for the enrichment process.
- Enrichment
  - There are two main ways for enrichment, gas centrifuge enrichment, which is more commercially available today, and laser enrichment. A gas centrifuge uses a large rotating cylinder that is fed UF_6 gas, which is then rotated at high speeds to separate heavier uranium-238 (U-238) and lighter U-235, allowing for the enriched uranium-235 (U-235) to be extracted. Conversely, laser enrichment involves using lasers to separate the uranium isotopes. We note that U-235 is the only naturally occurring isotope that is thermally fissile, meaning that it can sustain a chain reaction in a reactor.
  - Importantly, enrichment up to 10% can be done through the same facilities that enrich natural uranium up to 5% under a Category III facility, but taking it to the 10%-20% level requires a Category II license and significantly more capex, according to the DOE. Taking enrichment beyond 20% requires a Category I license.
  - In the enrichment process, the key metric of convention is separative work unit (SWU), which is used to measure the effort required to separate uranium isotopes (U-235 and U-238). Basically, this quantifies how much work is necessary to increase the enrichment of U-235 from natural uranium and is not a measure of how much energy is needed. Notably, 1 SWU is equivalent to 1 kg of separative work. In order to enrich 1 kg of uranium up to 5% enrichment, a plant requires ~8 SWU if tails assay at 0.25% or ~9 SWU if tails assay at 0.20%.
  - There is ~62,000 SWU of annual enrichment capacity in the world according to the World Nuclear Association, which could enrich ~7,000 tonnes of enriched uranium product (EUP) per year from ~65,000 tonnes of U_3O_8 feed. Major enrichers include the same state-owned enterprises like CNNC, Orano, Rosatom, and Urenco. We note that while conversion remains a key bottleneck, enrichment facilities are able to overload to help drive incremental capacity and are thus not viewed as a bottleneck.

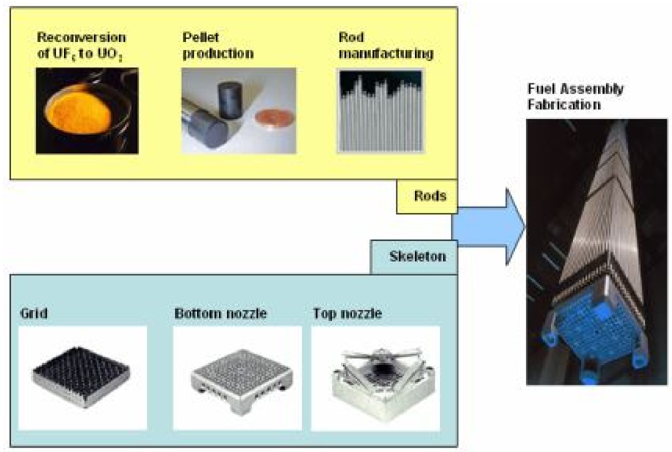
Exhibit 34: Overview of Laser Enrichment



Source: ASP Isotopes

- Deconversion
  - Since reactors don't run on UF_6, deconversion or reconversion into a uranium metal, UO_2 powder, or other suitable form for storage is required. This is technically the first step of the fuel fabrication process. Similar to conversion, there are dry and wet processes for deconversion. The wet process involves adding steam to the UF_6 vapor, adding ammonia and nitric acid, then filtering and ultimately reducing by H_2 to create the UO_2. The dry process adds steam to the UF_6 vapor to create a powder that is sent to a rotating kiln where steam and hydrogen is added to create a UO_2 powder.
  - There are currently no deconversion facilities in the US that can handle HALEU enriched to at least 19.75%. However, the DOE recently announced contracts with six companies to conduct HALEU deconversion and to transform UF_6 into other fuel forms for advanced reactors. These companies include BWXT, Centrus, Framatome, GE Vernova, Orano, and Westinghouse.
- Fuel fabrication/assemblies
  - The UO_2 powder is then pressed to form fuel pellets. These pellets are then inserted into rods that are organized into one structure called a fuel assembly. A modern reactor could have up to 10mn pellets.
  - There are numerous companies that are involved with fuel fabrication, such as Framatome, Orano, Westinghouse, TVEL, and others.

Exhibit 35: Main steps for fuel assembly fabrication



Source: International Atomic Energy Agency

- Power generation
  - A typical reactor with an output of 1,000 MWe will contain a reactor core made up of 100-200 fuel assemblies that contain ~75 tonnes of LEU. The U-235 isotopes fission or split within the reactor core, producing a large amount of heat through a process called a chain reaction. This heat is then utilized to produce steam to power a turbine and electric generator. Over a 12-18 month time frame, about one-third of the spent fuel is replaced with fresh fuel. According to the World Nuclear Association, about one tonne of natural uranium can produce 44mn kWh of electricity, or the equivalent of 20,000 tonnes of coal or 8.5mn cubic meters of gas.
  - One key metric measuring power output of nuclear reactors is called fuel burn-up, which is measured by the gigawatt-days (thermal) per tonne of uranium (GWd/tU). As fuel assemblies become more advanced and robust, it enables higher fuel burn-up rates. Historically, burn-up levels have been limited to ~40 GWd/tU with 4% enrichment, but traditional reactors today can achieve 55 GWd/tU at 5% enrichment, and there is potential to take this rate higher with higher levels of enrichment (70 GWd/tU at 6% enrichment). Importantly, the operating cycles are extended at higher burn-up rates, allowing a reduction of fuel costs. Notably, SMRs offer the potential to extend the refueling cycle to ~10 years.
  - According to the DOE, the production of 50 metric tons of HALEU requires 3,100 metric tons of UF_6, which can be produced from 2,500 metric tons of U_3O_8. This would create 2,900 metric tons of depleted UF6. Conversely, 50 metric tons of LEU requires about 550 metric tons of U_3O_8. We note this ~4x increase in required uranium is related to enriching the fuel from 5% to almost 20%.

Back-end

The back-end of the nuclear fuel cycle makes sure that used fuel, which is still highly radioactive, is managed safely, recycled, or is properly disposed of.

- Used fuel
  - Once the used fuel is removed from the reactor, it is unloaded into a storage pond, which leverages the water to shield the radiation and absorb heat. After several months and sometimes years, it can be transferred to dry storage facilities, but requires further reprocessing to be recycled or be prepared for permanent underground disposal.
  - Leftover depleted uranium that is produced during the enrichment process is also called tails, which has lower amounts of fissile U-235 isotope than enriched uranium.
- Disposal
  - The main option for used nuclear fuel is disposal. Waste from the nuclear fuel cycle is characterized as low-level, intermediate-level, and high-level waste. Most low-level radioactive waste can be disposed of once it is properly packaged for long-term management, which typically occurs in near-surface disposal facilities. These facilities are also suitable for disposing of intermediate-level radioactive waste with short-lived radioisotopes.
  - However, there are no disposal facilities to handle high-level waste or intermediate-level waste with long-lived radioisotopes. Instead, this waste is stored in solid, stable waste form either in ponds or dry casks at the reactor site or other central location. Part of the reason why there is hesitation to permanently dispose of used nuclear waste is that it still maintains usable energy to be reprocessed at a later date.
  - The preferred means of disposing of the most radioactive nuclear waste is mostly focused on deep geological disposal. This is similar to how waste from defense-related to nuclear weapons is currently disposed of, which is at the Waste Isolation Pilot Plant in New Mexico. Finland's Onkalo repository has started trial runs of disposing of spent fuel canisters in a geologic repository that is ~30 ft underground, but the final depository depth will be 1,300+ ft.
- Reprocessing
  - A secondary option for used nuclear fuel is to be reprocessed to recover materials that can be recycled back into usable fuel. This reprocessing process also helps to meaningfully reduce the amount of high-level waste. Used nuclear fuel still contains ~96% of the original uranium, but the fissionable U-235 content is reduced to less than 1%, with ~3% waste product and remaining ~1% is plutonium that was produced while in the reactor. The reprocessing involves cutting up fuel rods and dissolving them in acid to separate the uranium and plutonium from the waste. However, recycling represents a very small part of the market given the cost as well as limited recycling capacity. We note that recycled fuel is almost exclusively used as MOX fuel for MOX reactors, limiting applications to more traditional reactors.
  - According to French multi-national nuclear company Areva, roughly eight used fuel assemblies can be reprocessed into one MOX fuel assembly, two-thirds of an enriched uranium fuel assembly, about three tonnes of depleted

uranium, and ~150kg of waste. This process removes the need to purchase ~12 tonnes of mined uranium.

- Most reprocessing facilities use the PUREX (plutonium-uranium extraction) technique, which involves dissolving the waste fuel in nitric acid to chemically separate uranium and plutonium, which is then converted into powder forms of plutonium oxide (PuO_2) and uranium oxide (UO_2). This PuO_2 can be blended with the depleted UO_2 to create mixed oxide (MOX) fuel that can be used in MOX nuclear reactors.
- Reprocessed uranium (RepU) is uranium that is recovered from the reprocessing of used nuclear fuel, and is mostly U-238 and ~1% U-235. Thus, RepU needs to be converted and re-enriched to be used in reactors. Commercial capabilities of RepU is done by France, UK, Japan, and Russia, as well as some military nuclear weapons production programs.

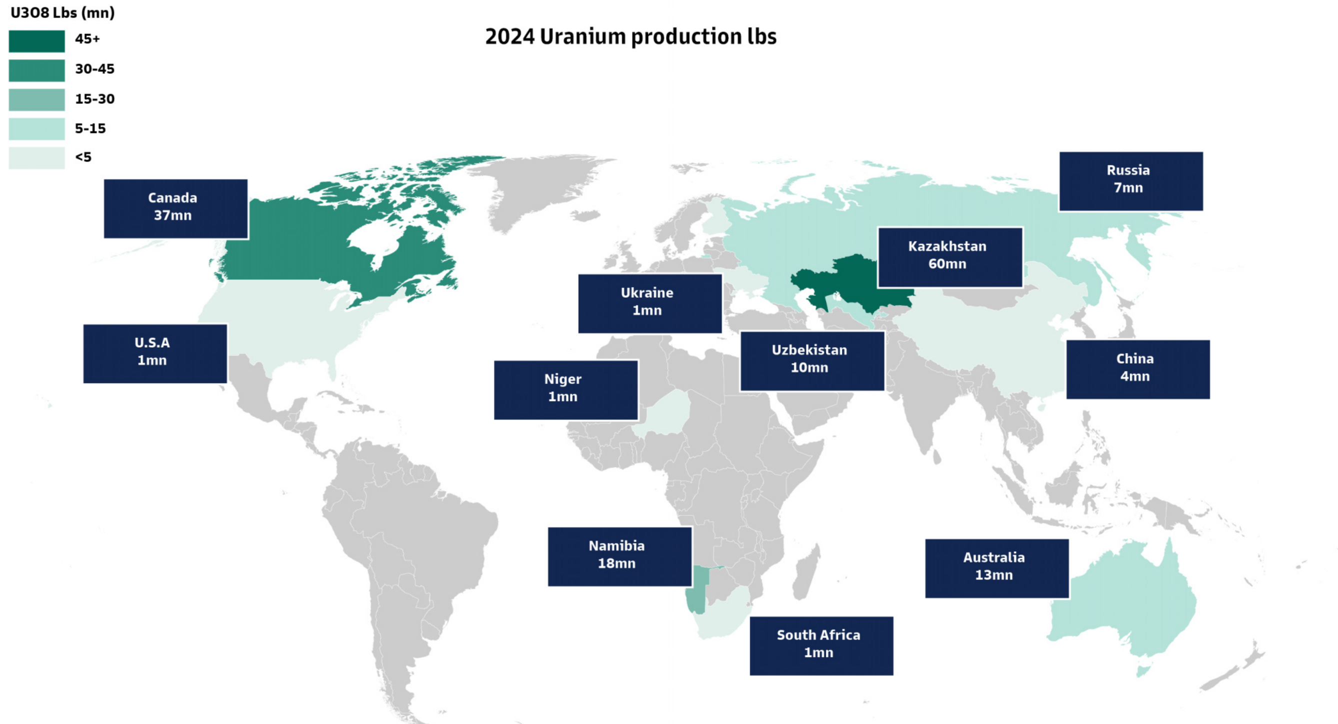
Other Nuclear Fuel Forms (SMRs)

As discussed above, most traditional nuclear reactors utilize pellets of UO2 that are arranged into fuel rods/assemblies. However, there are several kinds of fuel forms that are under consideration for advanced reactor technology, which can be created during the deconversion and fuel fabrication stage of the fuel cycle. The main fuel forms being considered for advanced reactors using HALEU are metallic alloys, different forms of ceramics (oxides, carbides, nitrides, silicides), molten salts, and tri-structural isotropic (TRISO) fuel. We include a primer on HALEU later on in this report.

Nuclear Fuel - introducing the GS uranium supply-demand model

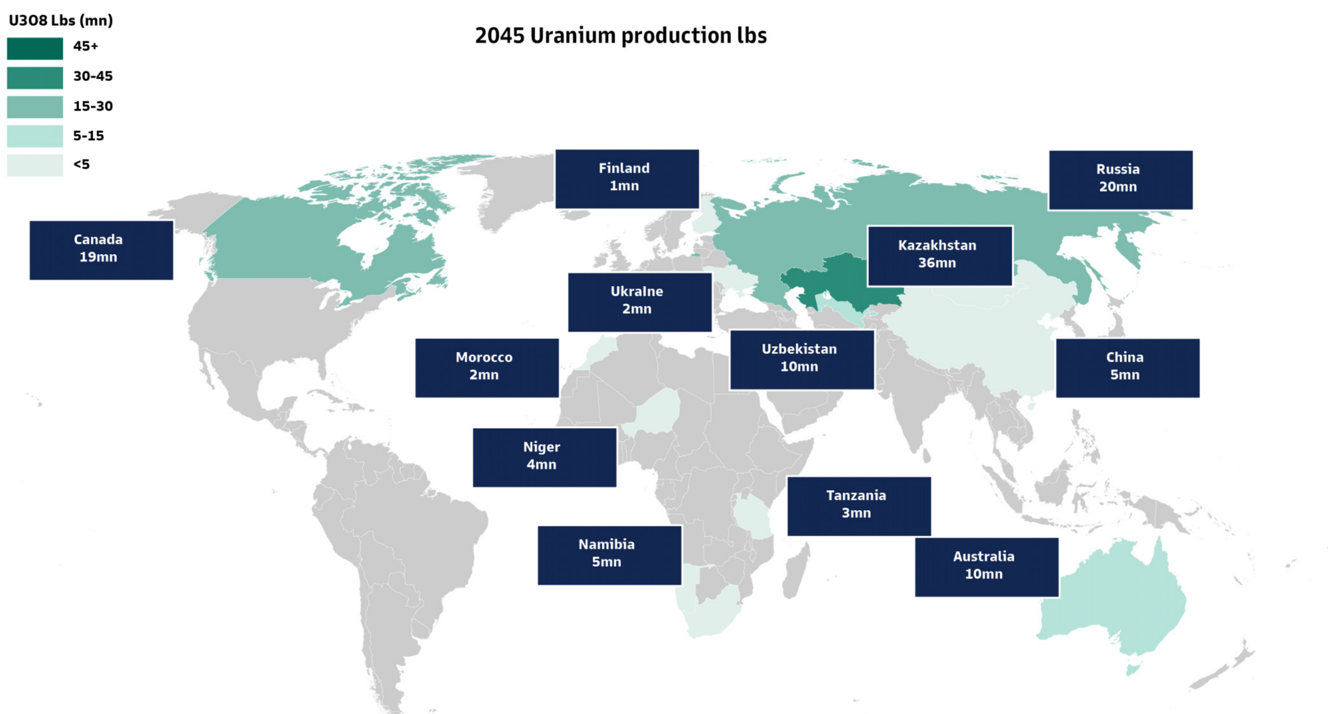
With this report, we introduce a proprietary global uranium supply-demand model that includes forecasts through 2045 by region. Our demand outlook considers the existing operating global reactor base of ~418 reactors expanding by ~258, inclusive of ~19 restarts in the coming 20 years, supporting a ~3% CAGR in uranium demand growth. On the supply side, our model tracks ~40 operating mines across the globe, in addition to specific country-wide output, and captures modest contribution from ~11 mines in current development/exploration stage that are expected to enter production through the next decade. In aggregate, we are forecasting a material structural supply deficit to occur by the 2030 timeframe, which we view as a tailwind to future uranium prices.

Exhibit 36: Uranium production spans several countries but is concentrated mostly in Canada and Kazakhstan
Overview of global uranium production



Source: Goldman Sachs Global Investment Research, Company reports, NEA, UxC

Exhibit 37: Our uranium forecast based on currently proposed mines shows a meaningful supply reduction by 2045
Overview of our forecasted uranium production in 2045



Source: Goldman Sachs Global Investment Research, UxC, Company reports

Uranium supply analysis

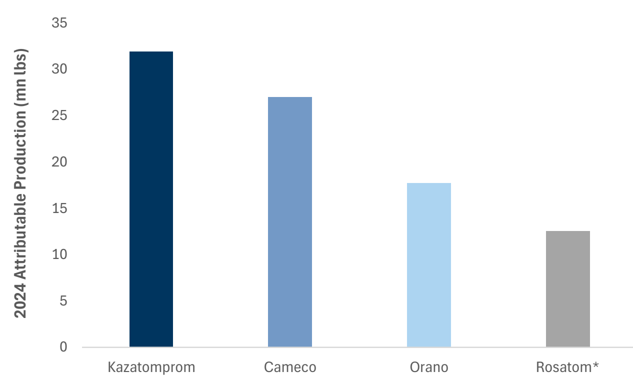
We are forecasting primary uranium production to increase to nearly ~190mn lbs of uranium in 2030 from ~160mn lbs today, and holding relatively steady through 2034, before declining to roughly ~120mn lbs by 2045. Notably, our future forecasts include a 95% utilization assumption to account for potential downtime or operational issues. Importantly, the top five largest mines represent ~40% of total uranium production, with the top 10 representing ~60% of production. We provide more details on key operating and prospective mines below.

Exhibit 38: Top 10 uranium mines represent ~60% of total uranium production in 2024
Overview of top uranium mines

Mine	Country	Ownership	2024 Production (000s lbs)	2030E Production (000s lbs)	Mining Method	Proven & Probable (000s t)	Grade (% U3O8)	Contained Uranium (mn lbs)
McArthur River	Canada	Cameco (70%)/Orano (30%)	20,300	19,000	Underground	2,491	6.55%	359.5
Cigar Lake	Canada	Cameco (54.5%)/Orano (40.5%)	16,900	18,000	Underground	551	15.87%	192.9
Husab	Namibia	Swakop (China (90%)/Namibia (10%)	11,000	11,000	Open Pit	280,000	0.05%	319.9
Budenovskoye 2	Kazakhstan	Kazatomprom (50%)/ Uranium One (50%)	8,577	8,100	ISR	29,200	0.10%	78.5
Inkai	Kazakhstan	Cameco (40%)/ Kazatomprom 60%	7,779	10,300	ISR	368,084	0.03%	251.0
Olympic Dam	Australia	BHP	8,288	10,000	Open Pit	210,000	0.06%	314.9
Muyunkum	Kazakhstan	Orano (51%)/ Kazatomprom (49%)	6,208	10,000	ISR	41,400	0.12%	124.5
Rossing	Namibia	CNUC (69%)/Iran (15%)/South Africa (10%)/Namibia (6%)	6,000	5,500	Open Pit	80,000	0.04%	49.4
N Kharasan 1	Kazakhstan	Kazatomprom (50%)/Uranium One (30%)/Energy Asia (20%)	5,278	6,500	ISR	28,900	0.11%	79.8
Budenovskoye 1,3,4	Kazakhstan	Kazatomprom (50%)/ Uranium One (50%)	5,202	4,800	ISR	36,400	0.09%	83.2
Total			**95,532**	**103,200**		**1,077,026**		**1,854**

Source: Company data, Goldman Sachs Global Investment Research

Exhibit 39: Kazatomprom is the largest uranium producer in the world
Top uranium producers based on attributable production



*represents 2023 production

Source: Company reports, Goldman Sachs Global Investment Research

- **Largest mining companies**
  - Kazatomprom (NATKY) (Kazakhstan) is majority-owned by the government of Kazakhstan but is also publicly traded, and is the world's largest producer of uranium. The company operates 14 mining assets across 27 uranium deposits within Kazakhstan, which are mined using ISR methods. Kazatomprom's ownership in these assets equates to ~12,500 tonnes or 32.5mn lbs per the company.
    - In 2024, Kazatomprom reported attributable production of 12,300 tonnes or 31.9mn lbs. However, on a 100% basis, Kazatomprom produced 23,270 tonnes of uranium (60.5mn lbs), up from 21,112 tonnes in 2023, which equates to ~35% of the world's uranium.

- In 2024, Kazatomprom's major mines/JVs included JV Inkai (60% ownership, JV with Cameco), which produced 2,992 tonnes, Karatau (50% ownership), which produced 3,299 tonnes, and the JV South Mining Chemical Company (30% ownership), which produced 2,803 tonnes per the company.
- As of the end of 2024, the company held Proven and Probable Reserves of 300,000 tonnes of uranium per its filings.
- The company transports uranium to conversion facilities owned by Honeywell, Cameco, and Orano.
- The company reported an all-in sustaining cost of $27.65/lb in 2024, up from $21.37/lb in 2023, and $16.19/lb in 2022. The company guided for AISC of $29.00-$30.50 in 2025.

- Cameco (CCJ) (Canada) is the world's largest non-state owned publicly traded uranium company. The company is the operator of some of the largest mines in the world, including Cigar Lake (54.5% ownership), which produced 16.9mn lbs in 2024 (100%-basis), and McArthur River (70% ownership), which produced an annual record of 20.3mn lbs in 2024 (100%-basis) per CCJ. The company also maintains a 40% interest in the Inkai mine in Kazakhstan, as well as suspended mining assets in the US (Crow Butte and Smith Ranch-Highland).
  - In 2024, Cameco reported attributable production of 27.0mn lbs, which includes 3.6mn lbs from its ownership in Inkai. On a 100% basis, Cameco produced 37.2mn lbs of uranium (excluding Inkai), up ~33% yoy from 2023 production of ~28.0mn lbs, and includes total output from its McArthur River and Cigar Lake assets.
  - Cameco reported total production costs in 2024 of $31.35/lb, down from $35.72 in 2023.
  - McArthur River is the largest uranium mine in the world and maintains a proven and probable reserves of 2.5mn tonnes at an average grade of 6.55%, providing 360mn lbs of uranium (100% basis) per the company.
  - Cigar Lake is the second largest operating uranium mine in the world but boasts the highest grades of uranium. Cigar Lake has proven and probable reserves of 0.6mn tonnes of uranium at an average grade of 15.87%, providing 193mn lbs of uranium (100% basis) per the company.
  - Ore from Cigar Lake is processed at the McClean Lake mill, which is majority owned and operated by Orano, while ore from McArthur River is processed at the Key Lake mill, which is majority owned and operated by Cameco.

- Orano (France) is a 100% state-owned by the government of France and is the third largest uranium producer. Orano has ownership in four operating global assets, across Canada (McArthur River and Cigar Lake), Niger (SOMAÏR), Kazakhstan (KATCO).

        - In 2024, Orano reported attributable production of ~6,800 tones or 17.7mn lbs. On a 100% basis, Orano's assets produced ~17,700 tonnes or 45.9mn lbs.
        - As of the end of 2024, Orano's assets held proven and probable reserves of ~230,000 tonnes of uranium at an average grade of 4.53% per the company. However, its share equated to ~80,000 tonnes of uranium.
        - Importantly, Orano owns conversion and enrichment plants that can enrich uranium to 3%-5%. This includes the Malvési plant, which converts uranium to uranium tetrafluoride (UF4) with a 14,000 tonne capacity, and then the Philippe Coste plant, which converts the UF4 to UF6, which also has a 14,000 tonne capacity. We note Orano maintains ~40% of western conversion capacity. Then the Georges Besse II plant, which is the largest enrichment plant in Europe with an annual capacity of 7.5mn SWU, enriches the U-235 content to 3%-5%. The company also has operations to recycle uranium as well as other services.
    - Rosatom, which is the Russia state-owned nuclear energy company, was previously the 4th largest uranium producer, with its interests in several assets owned by Kazatomprom producing 4,831 tonnes (12.6mn lbs) in 2023 per Uranium One. However, in December 2024, Kazatomprom announced that Rosatom was selling its stakes to Chinese-owned companies.
    - <u>Other important operating mines:</u>
        - Husab - located in Namibia, the Husab mine is owned by Swakop Uranium, which is a 10%/90% partnership between Namibian state-owned Epangelo Mining company and Taurus Minerals Ltd (owned by Chinese government). The mine has an annual capacity of 6,000 tonnes per company reports.
        - Olympic Dam, is an underground mine located in Australia, Olympic Dam is owned by BHP and is one of the world's largest deposits of copper, gold, and uranium. Uranium production is technically a by-product of the copper and gold production. In 2024, Olympic Dam produced 3,600 tonnes of uranium per company reports.

- **Prospective mines**
    - Rook/Arrow - The Rook I Project, which hosts the Arrow deposit, is the largest development-stage uranium project in Canada. The project is 100% owned by NexGen Energy, and is anticipated by the company to have an average annual production rate of 19.8mn pounds of uranium over an almost 12-year mine life, with a max annual capacity of nearly 30mn lbs. We note that the project maintains an average operating cost of $10/lb per its technical report.
    - Wheeler River (Phoenix/Gryphon) - The Wheeler River Project, which hosts the Phoenix and Gryphon deposits, is located in the Athabasca Basin in Canada. The project is majority owned by Denison Mines, which anticipates using ISR mining to develop the Phoenix deposit, and conventional underground mining

for the Gryphon deposit. Per its technical report, the Phoenix deposit is expected to produce 55mn lbs over a 10-year mine life, while Gryphon is forecasted to produce 50mn lbs over a 7-year mine-life.

- Patterson Lake South (Triple R) - The Patterson Lake South project is located in the Athabasca Basin in Canada, and is owned by Paladin Energy (acquired Fission Uranium in December 2024). Per its technical report, the project is forecasted to produce ~90mn lbs of uranium over a 10-year mine life.
- Elkon - The Elkon project is located in East Russia and is one of the world's largest known, undeveloped uranium deposits. The project is owned by ARMZ Uranium Holding, which is the mining division of Rosatom State Atomic Energy Corp, which has estimated an annual production rate of ~5,000 tonnes once it achieves full capacity per its technical report. The resource is estimated to be 344,000 tonnes of uranium, with an average grade of 0.146% uranium.

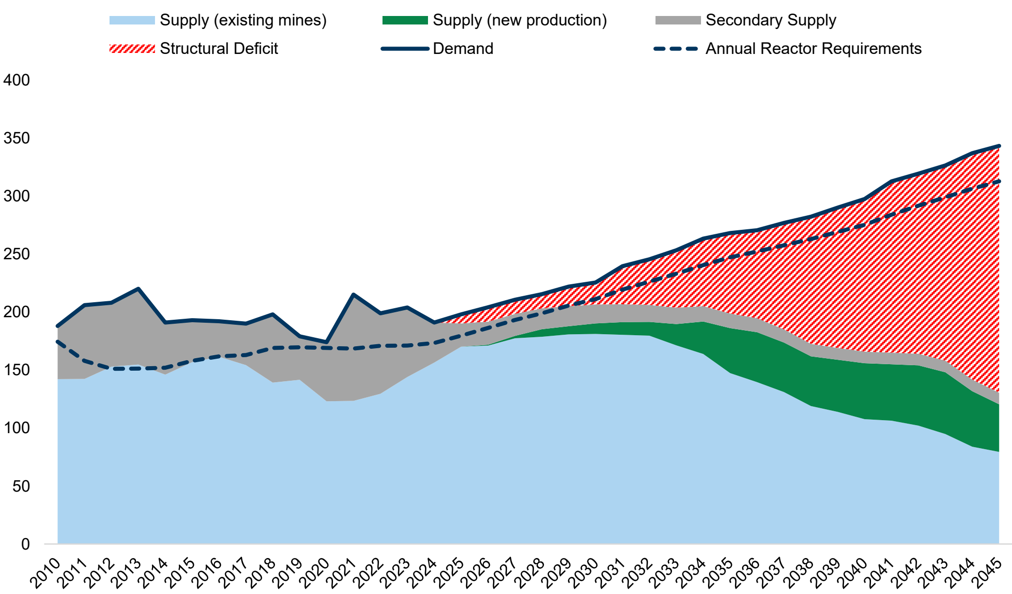
- **Inventories**
  - As a result of historical uranium production exceeding civil demand, market participants have held inventories of uranium as a secondary resources. Some governments have also discussed the creation of strategic uranium stockpiles. Additionally, there has been excess fuel from utilities that decommissioned plants in areas like Germany, Japan, and Sweden. There is a broad range of secondary sources of uranium, which includes commercial inventories, government and contractor inventories (i.e., military materials, depleted uranium, other uranic material), international fuel banks, unused fuel assemblies, depleted uranium tails (enrichers or governments), and recycled materials.

Uranium demand analysis

We are forecasting primary uranium production to increase to nearly ~190mn lbs of uranium in 2030 from ~160mn lbs today, and holding relatively steady through 2034, before declining to roughly ~120mn lbs by 2045. Notably, our future forecasts include a 95% utilization assumption to account for potential downtime. This compares to roughly 226mn lbs of uranium demand we anticipate in 2030, which represents a roughly ~35mn structural deficit between production and demand. We anticipate this deficit to grow to roughly ~205mn lbs by 2045 as new reactors come online and first time fuel loading to accelerate the structural deficit that we currently see. As of the most recent COP29 meeting in November 2024, 31 countries pledged to triple the world's global nuclear generation by 2050. This ranged from established nuclear countries which have current generation capacity to developing countries that do not have any nuclear power generation to date. Separately, China plans to build 150 nuclear reactors over the next 15 years, adding 6-8 new reactors annually with the near term target of reaching 200 GW of nuclear power by 2035 according to China's 14th Five-Year Plan. We anticipate new power generation combined with life extensions of existing nuclear power plants globally as well as uprates, will result in increased demand for uranium over the next 20+ years.

Exhibit 40: We anticipate inventory drawdowns and new supply coming online will not be enough to meet the rapidly growing demand for U3O8

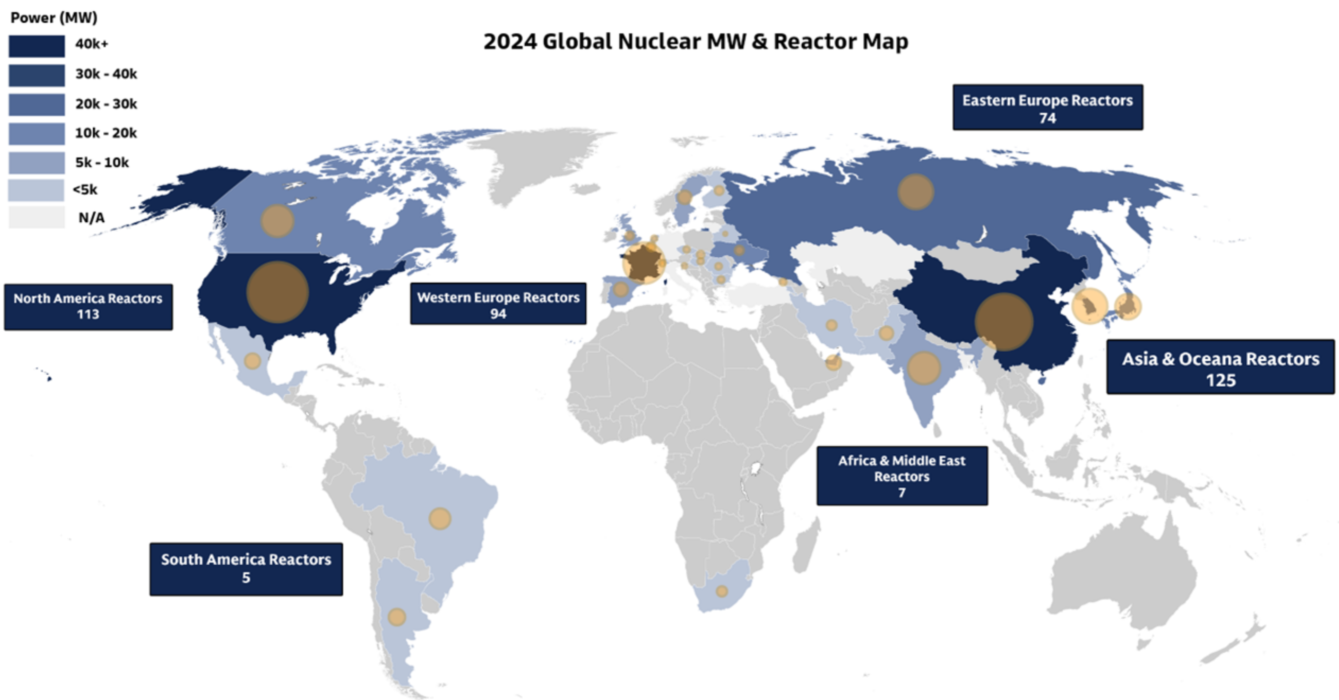
Uranium supply/demand forecast through 2045



Source: NEA, Goldman Sachs Global Investment Research, UXC

Currently, we estimate that 2024 U_3O_8 demand, estimated by operating reactor requirements plus increased fuel requirements for reactors that are being fueled for the first time, is roughly ~180mn lbs. In our demand assumptions, we assume incremental life extensions to currently operating reactors, new builds aligning with country specific nuclear generation targets by 2050, and no SMR demand in our base case. We also only count operating reactors that are consuming fuel which means we do not include the 4 suspended reactors in India and the 19 suspended reactors in Japan, although we do expect these reactors to come back online over the next 10 years. For our 2024 assumption we base this on 418 operating reactors, which excludes the 19 operable but suspended Japanese reactors and the 4 suspended but operable reactors in India, which brings the total operable reactors to 441 globally as of the end of 2024.

Exhibit 41: Current global reactor count and MW generation by country
Current global reactor count and MW generation by country

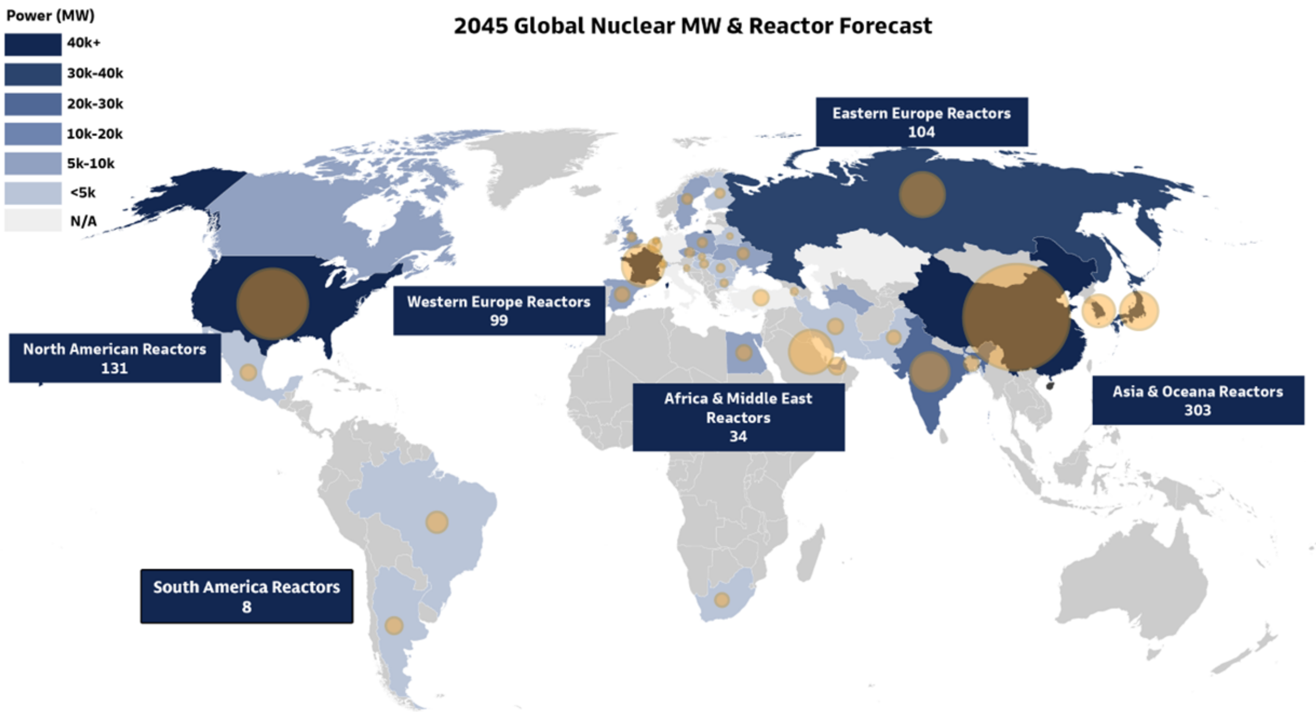


North America		South America		Western Europe		Eastern Europe		Africa & Middle East		Asia & Oceana	
Canada	17	Argentina	3	Belgium	5	Armenia	1	Egypt	-	Bangladesh	-
Mexico	2	Brazil	2	Finland	5	Belarus	2	Iran	1	China	58
United States	94			France	57	Bulgaria	2	South Africa	2	India	20
				Netherlands	1	Czech Republic	6	Turkey	-	Japan	15
				Spain	7	Hungary	4	United Arab Emirates	4	Korea	26
				Sweden	6	Romania	2			Pakistan	6
				Switzerland	4	Russia	36				
				United Kingdom	9	Slovakia	5				
						Slovenia	1				
						Ukraine	15				
Total	**113**	**Total**	**5**	**Total**	**94**	**Total**	**74**	**Total**	**7**	**Total**	**125**
World Total	**418**										

Source: PRIS, Goldman Sachs Global Investment Research

Exhibit 42: We forecast significant growth in nuclear power generation and reactor growth

2045 nuclear power generation and reactor count forecast

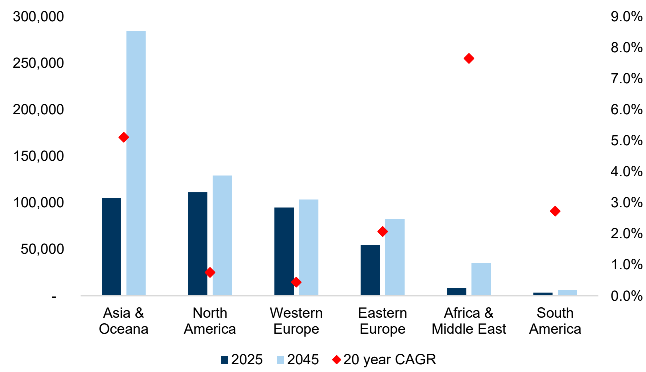


North America		South America		Western Europe		Eastern Europe		Africa & Middle East		Asia & Oceana	
Canada	26	Argentina	5	Belgium	5	Armenia	1	Egypt	5	Bangladesh	4
Mexico	2	Brazil	3	Finland	5	Belarus	2	Iran	5	China	183
United States	99			France	57	Bulgaria	4	South Africa	4	India	39
Additional	4			Netherlands	1	Czech Republic	9	Turkey	5	Japan	34
				Spain	7	Hungary	6	United Arab Emirates	6	Korea	30
				Sweden	8	Romania	5	Additional	9	Pakistan	7
				Switzerland	3	Russia	47			Additional	6
				United Kingdom	13	Slovakia	6				
						Slovenia	1				
						Ukraine	17				
						Poland	6				
Total	**131**	**Total**	**8**	**Total**	**99**	**Total**	**104**	**Total**	**34**	**Total**	**303**
World Total	**679**										

Source: PRIS, Goldman Sachs Global Investment Research

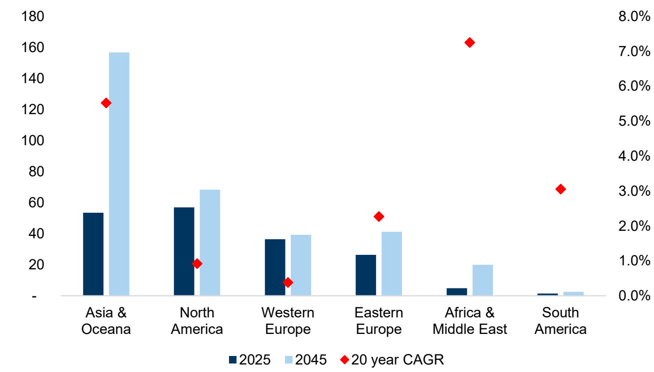
We anticipate China will drive most of the growth in new builds over the next 20 years and incremental new builds will be coming on line from additional countries. In the outer years we assume more efficiency per reactor which implies less fuel consumption. We expect annual reactor requirements to increase to ~328mn lbs of U3O8 by 2045 and this demand does not account for secondary demand from utilities buying to stockpile inventories, governments, or individual purchasers.

Exhibit 43: We estimate nuclear power generation growth in every region, with the largest growth increase in generation in Asia & oceana
MW



Source: Goldman Sachs Global Investment Research, PRIS, WNA

Exhibit 44: We expect U3O8 annual reactor requirements to increase by ~150mn lbs. by 2045
lbs. U3O8



Source: Goldman Sachs Global Investment Research, PRIS, WNA

Supply-demand considerations. Uranium maintains unique conversion rates that are different from traditional mining. In particular, a metric tonne of uranium is equivalent to ~2,600 lbs of U_3O_8, as opposed to the more traditional conversion rate of 2,204 lbs for other metals.

Key assumptions for demand model

- **Current operating reactors.** We model every reactor globally and do not account for demand from inoperable or suspended reactors. We use the latest reported MWe to back into EUP needed per reactor.
- **Burn-up rates.** We model burn up rates on a reactor by reactor basis, using lower rates for older, less efficient reactors and higher rates to account for newer more efficient reactors.
- **Capacity factor.** We model a baseline of 90% capacity factor across the global nuclear reactor fleet, which equates to roughly the average capacity factor of nuclear reactors.
- **Efficiency.** We model efficiency by reactor type, which is about 33% for PWRs/BWRs for example.
- **Product assay.** We model product assays of 4.3% for PWR/BWR reactors, which make up a majority of operating reactors installed globally.
- **Tails assay.** We use an average tails assay of 0.25% for all countries except Russia, where we use a 0.13% tails assay as Russian centrifuges are designed to run at ~0.10%. We view this tails assay assumption as conservative over the totality of the model as using a 0.25% tails assay implies the world has enough enrichment capacity through 2033. After 2033, we estimate that unless new enrichment capacity comes online, there will be a deficit which implies enrichers will need to overfeed to be able to reach desired enrichment levels using less SWU requirements. If tails assays go up, this will increase demand for U3O8 higher than current levels we project.
- **Initial loading requirements.** We model the full fuel load to be on average 3x

average annual reactor requirements.

- **Projected reactors online.** Our model assumes current reactors under construction come online within the next 10 years and beyond that, we incorporate planned reactor builds. Beyond that, we incorporate some, but not all, of the proposed reactors.
- **Reactor life.** We use an average reactor life of 75 years to account for life extensions.

Exhibit 45: We sensitized our demand forecast to get a better picture of how key variables impact estimates
Sensitivity analysis of key variables in GSe Uranium demand forecast

Baseline	Sensitivity	Demand 2040	SWU Requirements 2040
0.25%	Tails +/- 0.05%	+/- 27mn lbs.	+/- 8mn SWU
4.3%	PWR/BWR Enrichment +/- .3%	+/- 20mn lbs.	+/- 7mn SWU
33%	PWR/BWR Efficiency +/- 2%	+/- 16mn lbs.	+/- 4mn SWU
90%	Capacity Factor +/- 5%	+/- 12mn lbs.	+/- 3mn SWU

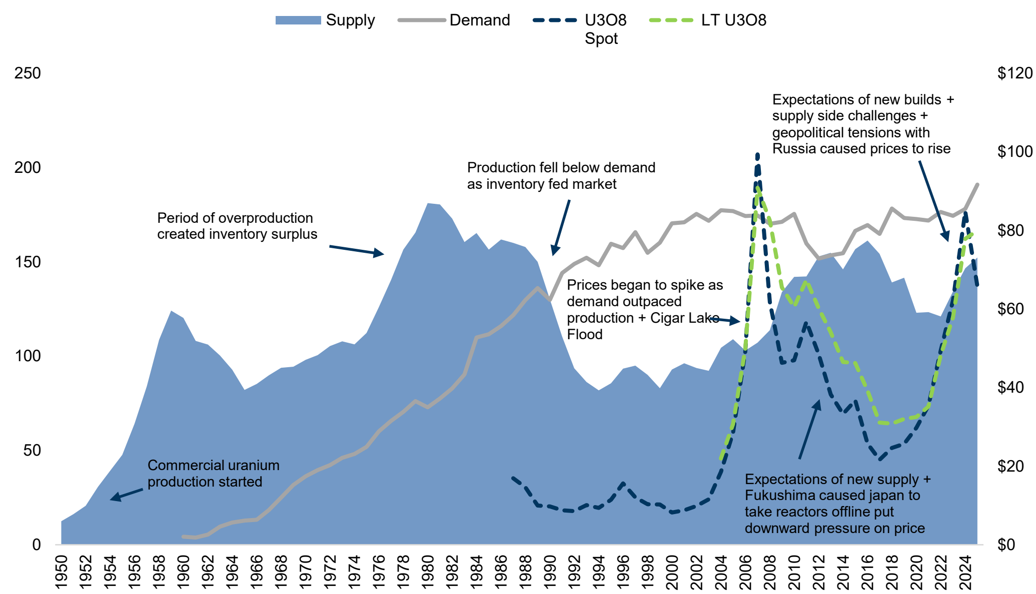
Source: Goldman Sachs Global Investment Research

Pricing and Contracting

With respect to pricing and contracting for nuclear, the key commodity and beginning part of the value chain is clearly uranium, or more specifically U_3O_8. Prices tend to move on supply and demand expectations in forward years as utilities - the key buyers - make decisions based upon viewpoints of whether there will be more supply coming online vs. additional demand which could potentially push prices down and vice versa. Furthermore, utilities typically contract backwards through the fuel cycle and focus on contracting enrichment and conversion capacity before contracting U_3O_8, as the inability to convert uranium into a usable nuclear fuel source - which includes downstream processing - would render having uranium stock as somewhat irrelevant.

Exhibit 46: Uranium pricing tends to move on expectations of demand and supply with prices movements exhibiting volatility in periods of imbalance

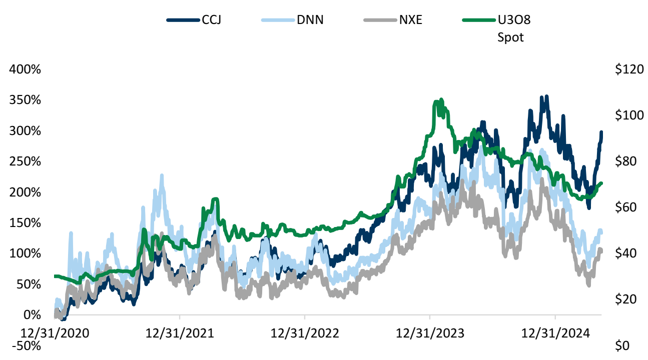
Historical supply and demand vs. price (LHS - mn lbs.) (RHS - $USD)



Source: Goldman Sachs Global Investment Research, NEA, UXC

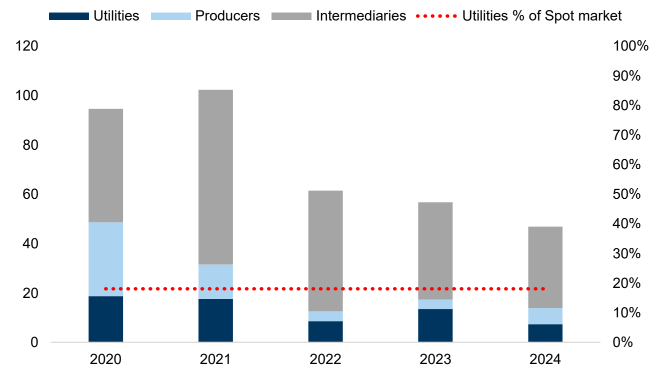
While there is a strong correlation to spot prices and uranium stock performance, the vast majority (~80%) of uranium spot movements is due to intermediaries and producers trading pounds back and forth. Utilities typically contract fuel deliveries 3-10 years in advance as they like to build in some margin of error throughout the supply chain as well as 2-3 years of inventory on hand. These contracts are usually executed in the term market, which is where 87% of utility volumes are contracted. Driving this dynamic is the fuel life cycle of a fuel for a reactor, for example, if a utility contracts U3O8 for delivery in 3 years, it could take another 1-3 years for this delivery to work its way through conversion, enrichment, and fabrication, before it is ready be placed in inventory then there is likely another 2 years before that fabricated fuel is placed into a reactor. Thus, it is quite rare for utilities to step into the spot market for purchases, (roughly 13% of procurement for utilities is done in the spot market) unless they see it as opportunistic given pricing levels to hold more inventories on hand, despite likely not needing them in the near future.

Exhibit 47: Nuclear Uranium mining stocks are highly correlated with spot price movements...
LHS - % increase in stock price vs. RHS $ spot price



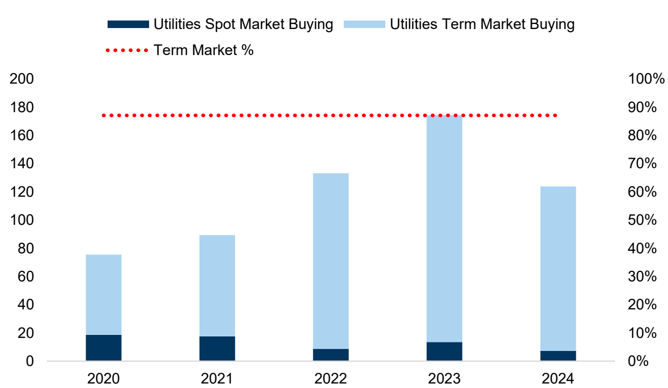
Source: FactSet, Goldman Sachs Global Investment Research, UxC

Exhibit 48: ...which are driven primarily by intermediaries and producerss, as utilities account for less than 20% of spot market volumes...
Spot market volumes by buyer



Source: UXC, Goldman Sachs Global Investment Research

Exhibit 49: ...despite utilities contracting ~87% of volumes in the long term markets
Utilities volume purchased in spot vs. term market



Source: UXC, Goldman Sachs Global Investment Research

Pricing in the uranium market is more opaque than other commodities due to lack of volume and transparency within the sector. There are two primary price indicators within the uranium market which are **spot pricing**, reported once a day, and **term pricing**, which is reported once a month. We estimate that on average, the spot market only represents 20%-30% of overall uranium volume, while the remaining 70%-80% is contracted through long-term contracts.

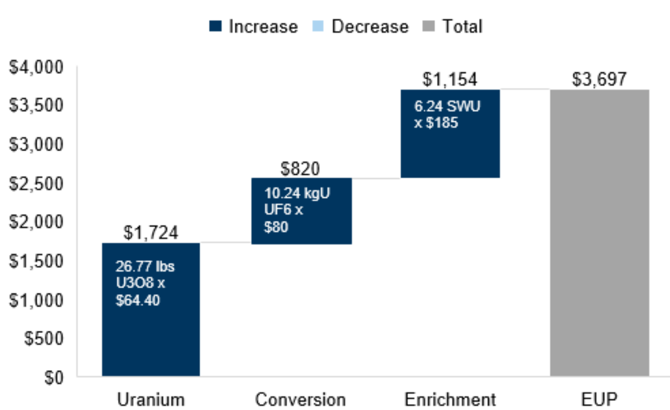
Spot pricing is a retail dominated space driven primarily by trading houses and given the lack of volume and liquidity in this market, small amounts of pounds hitting the market can move spot pricing meaningfully. Within the spot market, intermediaries/others accounted for 93% of spot volumes in 2024 per UxC which is relatively consistent with the past 20 years, while utilities accounted for 3% or roughly 1.3mn lbs of U_3O_8 in 2024, which is also relatively consistent with historical years. The spot market typically serves as an excess disposal market or a last resort market if utilities need U_3O_8 and there was an issue with the producer who they likely contracted with, and they were unable to procure supply.

Term pricing is where utilities operate and where most of the lbs. of U_3O_8 are contracted by utilities to be fed into nuclear reactors are purchased. Typically, purchases in the term market are multi year contracts and first delivery is typically 3 years out as most U_3O_8 that will be made into nuclear fuel to fuel reactors for the next 2-3 years have already been contracted years in advance. This market is much more opaque and pricing is only reported once a month, thus it is less volatile than spot price and more indicative of what producers, like Cameco, will realize in terms of their contractual agreements.

Contracting. Utilities typically sign fixed or market-related contracts for delivery and contracts are typically 5-7 year contracts that are signed 2-3 years before first delivery. **Fixed price contracts** are typically fixed at the time contracts are signed and have an escalator which is usually 2-3%. These contracts are typically signed at the long-term price. For example, if a utility signs a 5-year contract today and the long-term price is $80 with a 2% escalator, for first delivery in 3 years, by the time that utility takes its first delivery the utility will be paying roughly $85/lb. This will increase annually due to the escalator through the remainder of the contract and in year 7, the final delivery year, the utility will be paying roughly $92/lb.

The other type of contract utilities sign are **market-related contracts**. These contracts have floors and ceilings which dictate amounts the utility will pay no less or no more than and these are based on long term or spot prices. Besides the floors and ceilings, the other key difference in these contracts is that they are priced at time of delivery. For example, if a utility signs a contract today with the long term price at $80/lb., for delivery in 3 years, with a floor of $60/lb. and a ceiling of $130/lb., there can be a wide range of prices the utility will pay dependent on where prices are at time of delivery. If the long term price is $110/lb. at time of delivery, the utility will pay $110/lb. If the long term price is $50/lb. at time of delivery, since the floor agreed upon at the signing of the contract was $60/lb., the utility will pay $60/lb. If the long term price is $200/lb. at time of delivery, the utility will only pay $130/lb. since the ceiling at the time the contract was signed was $130/lb.

Exhibit 50: Bridge from U3O8 to EUP
Input costs into making EUP



Source: UxC, Goldman Sachs Global Investment Research

Nuclear Stocks in Focus

Cameco Corp (CCJ/CCO.TO; Buy - covered by Brian Lee)

What the company does: CCJ is a $16bn market cap uranium mining company with a vertically integrated model giving it 100% exposure to the nuclear value chain. The company's core sales are 85% uranium sales and 15% fuel services as of 2024. The company operates mines, mills, conversion facilities, fuel fabrication facilities and also owns Westinghouse, which is a nuclear reactor service provider that provides engineering and procurement services as well.

What impact does nuclear have on the business model? The largest portion of CCJ's business is uranium mining, as the company owns stakes in two fully operating Canadian mines and one Kazakh mine, providing control of ~15% of total global production. CCJ is one of the lowest cost producers globally, which gives the company significant operating leverage. The company's largest customers are utilities across the United States, Europe, and Asia, which typically contract both natural uranium and conversion 3-9 years out, giving CCJ visibility on demand. CCJ also has leverage to the downstream portion of the nuclear value chain via a 49% stake in Westinghouse, which contributed to ~30% of the company's EBITDA in 2024. CCJ's stake in Westinghouse adds value to the business model by providing CCJ direct exposure to the nuclear technology and OEM/services segment as Westinghouse's business model covers 40-50% of all reactors currently in service according to the company. This provides CCJ revenue to the growing nuclear theme and will benefit from not only a large installed base of between ~180-200 reactors it services, but also new builds which will come online over the next decade.

Price targets and risks. Our 12-month price targets for CCJ/CCO.TO of US$65/C$89 are based on a sum of the parts valuation on segment level adj. EBITDA. We assign a 14X multiple the Uranium business, a 21X multiple to the Fuel Services Business, and a 25X multiple to Westinghouse. Key risks include operational execution relating to lower than expected production volumes, timing of deliveries and sales occurring later than expected, lower than expected commodity prices, higher than expected operating costs, and longer than expected construction times for nuclear reactors.

NuScale Power Corp (SMR; Neutral - covered by Brian Lee)

What the company does: SMR is a ~$5bn market cap company which is building small modular reactors globally to make nuclear power cheaper and more rapidly deployable. SMR is the only company to be with an active application under review by the NRC in the US. We expect the company to have 100% revenue exposure to the nuclear theme.

What impact does nuclear have on the business model? SMR is tied to the deployment of nuclear power globally and aims to be a key player in the SMR end market in the years to come. The company is the owner of the only SMR technology in the US with a design application submitted to the NRC and is set for a final design certification ruling in 2025. The company has supply chain agreements already in place and is already manufacturing power modules slated for delivery around ~2030.

Price target and risks. Our 12-month price target of $24 is based on a 50%/50% weighting of DCF and EV/sales multiple based valuation. We use a 10-year DCF, which is based on GAAP revenues and GAAP margins to arrive at our 12-month DCF based valuation. For the EV/Sales portion of our valuation, we apply a 7x multiple to our 2030 GAAP revenue estimate. Key risks include customer and execution risk, greater cash burn and capital needs, higher costs to reach Nth of a kind capabilities, growing competition, and securing licensing.

Mirion Technologies (MIR; Buy – covered by Joe Ritchie)

What the company does: Mirion Technologies (MIR) is a ~$3bn market cap company that is a leader in ionizing radiation detection and measurement technologies. MIR sells detection, measurement, analysis and monitoring solutions for nuclear, defense, medical and research end markets. MIR is made up of two reporting business segments referred to as Medical and Nuclear & Safety. Commercial nuclear power is 38% of revenue, and MIR expects their Nuclear Power business to grow +HSD in FY25.

What impact does nuclear have on the business model? MIR has had strong momentum on the nuclear front over the past 12-18 months. There have been significant announcements recently with hyperscalers investing to secure Nuclear power for their data centers needs (e.g., MSFT with Constellation on Three Mile Island, GOOG with Kairos Power, AMZN with Energy Northwest, etc) and we expect the positive headlines to continue. ~75% of MIR's backlog is tied to Nuclear measurement/detection equipment and there are very few ways to invest in Nuclear across the industrial space. They have called out an order pipeline of $300-$400mn in Nuclear, which they expect to be awarded largely by 2025.

Price target and risks. Our 12-month PT of $20 is based on 18.5x Q5-Q8 EBITDA. Key risks include weaker organic growth, prolonged margin pressures, dilutive M&A.

GE Vernova (GEV; Buy - covered by Joe Ritchie)

What the company does: GE Vernova (GEV) is a ~$89bn market cap global leader in the electric power industry providing products and services that generate, transfer, convert and store electricity. It is a purpose-built company with decarbonization at the forefront, with its installed base generating nearly 25% of the world's electricity. GEV has three reporting segments: Power, Wind and Electrification. Nuclear Power is a smaller piece of the total company, contributing ~5% of the revenue of the Power segment in FY24. GEV currently has ~65 nuclear plants utilizing their technology across 10 countries. The nuclear power arm of the power segment operates through a joint venture with Hitachi, Ltd.

What impact does nuclear have on the business model? GEV is firm on investing in nuclear. GEV stated it sees an opportunity to add nearly 3-5 GW of nuclear power in the US through the end of the decade. The company expects nuclear to contribute to services growth this decade with nuclear becoming a more material contributor towards equipment revenue growth in the next decade. GEV also stated that its nuclear technology is proven and that having the fuel infrastructure already licensed and supply chain ready, is going to allow it to deliver faster. GE Hitachi also has small modular reactor (SMR) technology called BMRX-300 which significantly cuts down on capital cost per MW of power generated when compared with a typical water-cooled SMR.

Price target and risks. Our 12-month PT of $500 is based on 25.0x Q5-Q8 EBITDA. Key risks include slower growth due to regulatory/geopolitical changes, project delays from supply chain disruptions and execution risk.

Flowserve Corp (FLS; Neutral – covered by Joe Ritchie)

What the company does: Flowserve Corporation (FLS) is a ~$5bn market cap U.S. based global manufacturer of precision-engineered flow control systems. Operating through two segments — Flowserve Pump Division (FPD) and Flow Control Division (FCD) — the company offers pumps, valves, mechanical sales, and automation equipment, as well as diagnostic and maintenance services. These products serve critical infrastructure markets, including Oil & Gas (37% of 2024 bookings), Chemicals (19%), power generation (13%), water management (5%), and general industries (26%) such as mining and food & beverage. FLS supports both original equipment manufacturing (OEM) and aftermarket services. FLS expects to benefit from the global energy transition and increasing investments in decarbonization infrastructure.

What impact does nuclear have on the business model? Nuclear is a high-margin, long-cycle growth driver within Flowserve's decarbonization strategy. FLS has seen two consecutive quarters of strong demand with nuclear bookings >$100mn in both 3Q24 and 4Q24. Flowserve supports both new construction and life extension projects across Europe, Asia, and North America, with its portfolio of certified components, including N-stamped equipment, positioned for nuclear-grade reliability. Given the rise in global electricity demand driven by AI, energy security priorities, and the growing installed base of aging nuclear reactors, Flowserve expects its nuclear business to provide durable aftermarket pull-through and enhance recurring revenue visibility.

Price target and risks. Our 12-month of $54 is based on a 10.0x Q5-Q8 EBITDA. Key upside risks include improved execution, higher oil prices, stronger than expected orders, industry consolidation, while downside risks include 80/20 margin initiatives fall short, lackluster OE orders, dilutive M&A.

Southern Co. (SO; Buy – covered by Carly Davenport)

What the company does: Southern Company is a $98 bn market cap regulated utility operating the Southeastern US. It has over 8.7 million electric and gas customers. The company has three single state regulated electric utilities in Alabama, Georgia, and Mississippi which are relatively favorable regulatory environments, and four regulated natural gas utilities. SO also has a competitive power business, Southern Power with a 13 GW fleet, and technology and telecommunications subsidiaries, PowerSecure and Southern Telecom.

What impact does nuclear have on the business model? SO has around 4.8 GW of regulated nuclear generation and nuclear made up about 19% of its energy mix in 2024. In addition to other assets, GA power is the partial owner (45.7%) of the Vogtle nuclear power plant, which is the largest nuclear plant in the US. Its Units 1 & 2 were built in

1976 and construction began on Units 3 & 4 in 2009. After over a decade of construction and challenges, SO brought Vogtle Unit 4, which was originally expected to be placed in service in 2017, into commercial operation and was placed into service on 4/29/24 and services customers in the state of Georgia. Unit 3 went into service in July 2023. This marked the end of a decade plus long overhang on this stock given the execution issues associated with the project.

Price target and risks. Our 12-month P/E based price target of $102 is based on a 21x P/E on our Q5-Q8 estimates. Key risks relate to negative developments on the regulatory front, slower than anticipated rate base/earnings growth, negative revisions to load growth and the balance sheet.

Duke Energy Corp. (DUK; Neutral – covered by Carly Davenport)

What the company does: Duke Energy is a $93 bn market cap electric and gas utility serving the Carolinas, Florida, Indiana, Ohio, Kentucky, and Tennessee. DUK is a pure play regulated utility, with 8.2mn electric customers and 1.6mn gas customers, that invests in power generation, transmission, and distribution.

What impact does nuclear have on the business model? Nuclear accounted for ~28% of DUK's generation in 2024 and the company owns 11 operating nuclear reactors in six operating stations. The plants are owned by Duke Energy Carolinas, Duke Energy Progress, and Duke Energy Florida with combined capacity of ~9 GW+. DUK stated it plans on investing $3.9bn of its $83bn capital plan on nuclear fuel from 2025-2029 with the intention to expand initiatives on advanced nuclear. This would include the company's plans to submit an early site permit application in 4Q25 in North Carolina, continued engagement with industry task forces and nuclear vendors for technology evaluation, and participation in an application for the DoE's US Gen III+ small modular reactor technology grant. The company views nuclear as a reliable and clean energy source with tax incentives aiding in reducing costs for customers. Overall, DUK views nuclear as part of the solution to an all-of-the-above generation strategy with initiatives emerging across the country.

Price target and risks. Our 12-month price target of $125 is based on an 18x P/E multiple on our Q5-Q8 EPS estimates. Key upside/downside risks relate to the balance sheet, earnings execution, regulatory outcomes, and cost management.

Public Service Enterprise Group (PEG; Neutral - covered by Carly Davenport)

What the company does: PEG is a $40bn market cap utility company with a regulated transmission and distribution only business in New Jersey and a merchant generation business with a 4 GW nuclear fleet. The company also has subsidiary called PSEG Long Island which operates the Long Island Power Authority's electric transmission and distribution system.

What impact does nuclear have on the business model? PEG's unregulated generation business, PSEG Power, houses its nuclear generation assets, contributes roughly 10% of earnings to the overall business as of 2024. All of its generation capacity is in New Jersey and Pennsylvania. Its plants in New Jersey are located on

"Artificial Island," which has drawn investor interest for a potential co-located data center deal and other nuclear PPAs. This would include Hope Creek, which it owns 100% of and has capacity of 1.1 GW and Salem Units 1 and 2 which it owns 57% of each unit and combined capacity of 1.3 GW. Additionally, PSEG Power owns 50% of both Peach Bottom Units 2 and 3 with combined capacity of 1.3 GW. Overall, its merchant nuclear business has provided PEG with predictable cash flows and downside price protection because of PTCs providing stability for its long term growth outlook. The company is investing in uprates at its plants on Artificial Island, to extend its nuclear fuel cycle, and extend its operating licenses.

Price target and risks. Our 12-month SOTP based price target is $83. Key upside/downside risks for PEG include 1) a contract with a data center accelerates earnings at Power, 2) lack of clarity around the nuclear PTC, 3) potential for upside to current capital plan.

Vistra Corp. (VST; Neutral – covered by Carly Davenport)

What the company does: Vistra is a $36bn market cap electric power generator and a retail power provider that is headquartered in Texas. VST both sells power directly to consumers through its Retail segment, and into the wholesale market. VST has assets across the US in 20 states, and owns a generation portfolio of 41 GWs, and a retail book of 5 mn customers. Vistra's generation portfolio consists of 23 GWs of natural gas, 8.4 GWs of coal, 6.5 GWs of nuclear, 464 MWs of solar, and 1 GW of storage. VST has been one of the primary beneficiaries from the theme of data center growth and rising power demand in the US, outperforming the XLU by 50% over the past year.

What impact does nuclear have on the business model? While VST has a diverse generation fleet, the company has a nuclear fleet of ~6.5 GW which is all unregulated, with about 4 GW in the PJM market and the remaining 2.4 GWs in ERCOT. These power plants have significant value given nuclear's high capacity factor and earnings stability due to the nuclear PTC, but the main potential upside for these assets is the possibility of signing a PPA with a data center or other large load customer at an elevated PPA price. Nuclear is favored by data center operators as it is clean and reliable, providing baseload generation.

Price target and risks. Our 12-month, SOTP based price target is $134. Key upside/downside risks relate to potential data center deals, PJM capacity auction, lower than anticipated power prices, and the future of the power demand theme.

Dominion Energy (D; Neutral – covered by Carly Davenport)

What the company does: Dominion is a $44 bn market cap diversified utility company, which serves 4.1 mn customers in Virginia, North Carolina and South Carolina. The company was founded in 1909 and has a portfolio of assets including 30.3 GW of generation capacity, 10,600 miles of transmission and 79,700 miles of distribution. D is the largest utility serving the state of Virginia, which hosts the federal government along with a number of tech companies aiding growth. 70% of its contracted energy is from Millstone, the only nuclear power plant in CT, which provides over 90% of states carbon free power. The remainder of earnings from contracted energy segment comes from

Solar with 1.3 GWs, RNG, and Charybdis, the first offshore wind turbine installation vessel.

What impact does nuclear have on the business model? D operates a nuclear plant in Connecticut through its contracted assets segment, Millstone which has 2 GW of capacity and, it also has ~4 GW of regulated nuclear generation and earns a return based on the allowed return as prescribed by its jurisdiction. While it is challenging to attribute earnings to the regulated nuclear assets given its reporting structure as well as the fact that the reactors were built in the 1970s and are heavily depreciated, overall, ~20% of D's generating assets are nuclear as of 2024. On the unregulated side, the Millstone plant has almost half of its output sold under the Millstone 2019 power purchase agreement to provide nine million MWh of electricity per year to the service territories of Eversource Energy through 2029. The rest is sold through a competitive bidding process in the wholesale market.

Price target and risks. Our 12-month price target of $61 is based on a SOTP. We apply a 17.5x P/E to DEV, 17.0x to DESC and 11.0x EV/EBITDA to contracted assets. Key upside/downside risks include 1) above average power demand in Virginia, 2) regulatory uncertainty, 3) execution risk around permitting and construction.

Hitachi, Ltd. (6501.T; Buy – covered by Ryo Harada):

What the company does: Japanese company Hitachi has a market cap of US$115 bn and is regarded as one of Japan's leading conglomerates. However, over the past decade or so, it has been prioritizing businesses centered on digital infrastructure and actively selling non-core businesses. Currently, it focuses on three business segments: (1) DDS (Digital Systems & Services), (2) GEM (Green Energy & Mobility), and (3) CI (Connective Industries). In the GEM segment, the company is engaged in the nuclear power generation business through a joint venture with GE (GE Hitachi Nuclear Energy). Sales in this business in FY3/24 were ¥171.1 bn (2% of total company sales).

What impact does nuclear have on the business model? Hitachi is not currently working on any new construction projects for nuclear power plants, but it is conducting maintenance on existing plants. We believe that if nuclear power plants are restarted in Japan, Hitachi's role in engineering work for the restart would increase. The company also has technologies related to next-generation nuclear reactors, including small modular reactors (SMRs). Although it is unclear whether Hitachi will be actively involved in the construction of such reactors in the future, we believe its importance is high in terms of technical cooperation and patent utilization.

Price target and risks. Our 12-month target price of ¥4,900 is based on an EV/EBITDA of 13X on average of FY3/26E-FY3/27E. Risks: Digital systems & services: delays and losses generated on large projects, weaker IT capex sentiment at customers accompanying a macroeconomic downturn, reemergence of supply disruptions for servers and other products, slower standalone growth at GlobalLogic, slower-than-expected realization of synergies between Hitachi and GlobalLogic; Green energy & mobility (Hitachi Energy): delays on power transmission/distribution projects, a sharp rise in input costs; Connective industries: weaker new construction demand in

China, losing out on new repair/maintenance orders to competitors in Japan, semiconductor production equipment (SPE) prices not improving over the long term a risk for the measurement and analysis systems business (Hitachi High-Tech); Companywide: Forex swings (¥1 appreciation vs. USD likely has a negative impact of ¥12 bn on sales and ¥1.2 bn on adjusted EBITA) and an increase in purchase price allocation (PPA) amortization due to forex swings.

Mitsubishi Electric Corporation (6503.T; Buy – covered by Ryo Harada):

What the company does: Mitsubishi Electric (MELCO) is a Japanese company with a market cap of US$38 bn. The company has a diverse range of business areas, with its main businesses being factory automation (FA) and HVAC. Recently, its defense and space systems business and power infrastructure business have also been attracting attention given customer agreements and order intake. The company is currently restructuring part of its automotive equipment business. MELCO also manufactures a wide range of core products for nuclear power plants. These range from cooling pump motors and control rod drive coils used in reactor containment vessels, to central control panels, major transformers, and gas-insulated switchgears (GIS).

What impact does nuclear have on the business model? We estimate that MELCO's nuclear-related business accounted for a low-single-digit percentage of sales in FY3/24. However, against a backdrop of rising electricity demand, the company could benefit if domestic nuclear power plants are restarted. In the field of nuclear fusion, Mitsubishi Electric has helped supply toroidal field coils (TF coils) for the ITER, as well as central solenoid coils (CS coils) and equilibrium field coils (EF coils) for the JT-60SA joint fusion project between Japan and the EU. If the practical application of nuclear fusion advances, attention is likely to increase on these products, which the company already has a track record of delivering.

Price target and risks. Our 12-month target price of ¥3,600 is based on an EV/EBITDA of 8.5X on average of FY3/26E-FY3/27E. Key downside risks: Industrial automation systems (FA): Marginal profit growth on top-line expansion failing to offset higher depreciation from the company's new production facilities if the slowdown in orders is prolonged. Industrial automation systems (automotive equipment): A lack of progress exiting from the car multi-media business, challenges finding partners in the CASE business, or a sharp slowdown in production at client automakers. Home appliances (HVAC): Challenges achieving production scale due to difficulties procuring components and other factors, or deteriorating margins in the ATW business in a stronger competitive landscape. Power semiconductors: Inability to secure sufficient sales/orders to cover new capex, or more intense price competition on significant investment by Chinese companies and other rivals. Elevator & escalator business: Stalled new construction demand in China and other markets, or the outflow to third parties of high-margin maintenance contracts in the domestic business. Infrastructure systems: Project delays or larger-than-expected losses generated in the defense & space systems business. Companywide: Weaker prospects for synergies realized between businesses, and yen appreciation.

Mitsubishi Heavy Industries (7011.T; Buy – covered by Yuichiro Isayama):

What the company does: Mitsubishi Heavy Industries (MHI) is a $60 bn market cap Japanese heavy industries company. Nuclear Power is one of the key business areas along with Gas Turbine Combined Cycle in MHI's Energy Systems segment, accounting for approx. 5% of the consolidated revenue. As of FY3/24, the company's nuclear sales are 50% maintenance and restart for reactors in Japan, 40% nuclear fuel cycle, and 10% exports etc. Nuclear Power is one of MHI's three core focus growing businesses in their "2024 Medium-Term Business Plan".

What impact does nuclear have on the business model? MHI has played a pivotal role in Japan's nuclear power value chain. The main customer base of this business segment is Japanese power utility companies. So far MHI has focused on restarting PWR plants in Japan, and they will further take on the restart of BWR plants as well. One key aspect of MHI's competitive moat is its design and certification know-hows around the specialized safety facility (SSF), a new requirement for Japanese nuclear power plants after the Great Earthquake in 2011. More nuclear plants restart, and maintenance work will benefit MHI in the foreseeable future on the back of the Japanese government's latest Basic Energy Plan in which Japan is to leverage nuclear energy further.

Price target and risks. Our 12-month target price of ¥3,000 is based on our FY3/28 estimates and an EV/EBITDA of 9X. Key downside risks include a stronger yen versus our assumptions, lower profitability in the GTCC business due to a concentration of low-margin projects or large one-time costs, and a decline in overall returns due to setbacks in portfolio reforms.

IHI (7013.T; Buy – covered by Yuichiro Isayama):

What the company does: IHI is a $10 bn market cap Japanese heavy industries company. Revenue contribution of the Nuclear Energy business has been around 5% over the past couple of years. IHI's main revenue and profit drivers are civil aero-engines and defense businesses. The Nuclear business is positioned as one of its conventional core businesses in the "Group Management Policies 2023".

What impact does nuclear have on the business model? IHI has contributed to containment and pressure vessels for nuclear reactors and relevant maintenance works. IHI seeks to secure steady revenue from nuclear business around reactor restart and maintenance work. IHI invested in NuScale Power Corporation in 2021 and has been participated in the development of SMR.

Price target and risks. Our 12-month target price of ¥13,000 is based on our FY3/27E estimates and an EV/EBITDA of 9X, applying a 0% sector-relative discount. Key risks include a stronger yen, lower-than-expected margins in the civil aero engine business, and a widening of the discount due to a slowdown in portfolio reform.

Appendix: Nuclear value chain - upstream to downstream

Understanding the nuclear value chain, which includes the key steps and players involved, is important to set the stage for the development of nuclear energy. Importantly, the value chain for nuclear is similar to other renewable sources such as solar, as it is a network of suppliers and activities that supports the production of clean energy. A resource or mineral is mined and transformed into a usable material that is enhanced by technology providers, equipment is manufactured to leverage this technology, and developers/engineering, procurement, and construction (EPC) companies build sites that use the technology, and customers then buy the output of that technology, in this case energy. In the case of solar, the mineral is silicon/quartz and in the case of nuclear, it is uranium.

Exhibit 51: Overview of Nuclear Value Chain

Company	Mining & Conversion	Enrichment	EPC	Heavy Component Manufacturer	Basic Components	Fuel Fabrication	O&M	Advanced Reactor Design & Manufacturing	Transportation	Decommissioning and Waste Management
Bechtel			✓							✓
BWXT				✓		✓	✓	✓		✓
Cameco	✓	✓				✓				
Centrus		✓				✓		✓		
Curtiss-Wright				✓			✓	✓		
Doosan Enerbility			✓	✓	✓		✓			
Fluor			✓				✓			✓
Framatome				✓	✓	✓	✓	✓		
GE Hitachi						✓	✓	✓		
NANO Nuclear						✓		✓	✓	
Orano	✓	✓				✓			✓	✓
Rosatom	✓	✓	✓			✓				✓
Urenco USA		✓								
Westinghouse				✓		✓		✓		

Source: Goldman Sachs Global Investment Research

Uranium production and enrichment

As discussed above, the nuclear fuel cycle provides an overview of the first step of the nuclear value chain, mining/extracting uranium and converting/enriching/fabricating it into a usable form of fuel for nuclear reactors.

- Major uranium producers: Kazatomprom, Cameco, Orano.
- Main conversion companies: Cameco, CNNC, ConverDyn, Orano, Rosatom.
- Main enrichment companies: CNNC, Orano, Rosatom, Urenco.
  - Prospective enrichers: Centrus, Global Laser Enrichment, ASP Isotopes, NANO Nuclear.
- Main fuel fabrication companies: TVEL (Russia), Westinghouse, Framatome, Orano, Mitsubishi Nuclear Fuel.

Power plant development - manufacturing, construction, service and maintenance

The process of constructing a nuclear power plant requires heavy industrial manufacturing given the intense operating conditions to produce nuclear energy. These equipment manufacturers includes large global conglomerates that are involved in every process across the nuclear plant construction process including the servicing and maintenance (i.e., Doosan Enerbility, Framatome, Westinghouse, etc.), as well as companies that may produce a single component. Most of these companies are not coming up with their own technology, but will typically partner with a technology provider (discussed in more detail below) to help get the project from paper to reality. Component manufacturers, especially for the larger, heavy-duty equipment like pressure vessels or steam turbines, are likely to invest in specific manufacturing lines for specific technology providers.

- **Nuclear equipment manufacturers include (but not limited to):**
  - Doosan Enerbility (034020.KRX) is one the largest suppliers of nuclear power plant components, including the nuclear reactors and internal structures, steam generators, coolant pumps, pressurizers, pressure vessels and more. The company works with traditional nuclear companies and energy companies like Westinghouse, CNNC, Candu Energy and Meralco, and also supplies SMR parts to TerraPower and NuScale.
  - Framatome's subsidiary Creusot Forge fabricates heavy mechanical components like reactor pressure vessels and steam generators, and supplies all the French power reactors as well as some reactors in the US. Framatome is working with Nuscale, Holtec, General Atomics, among other companies advancing SMR technologies.
  - Westinghouse, which is 51% owned by Brookfield Renewable (BEP) and 49% by Cameco (CCJ), manufactures large components, such as reactor vessel internals, control rod drive mechanisms, and reactor coolant pumps, as well as smaller parts and components. The company services traditional reactors, is advancing its own AP300 SMR design, and is working with Rolls Royce on fuel development.
  - Mitsubishi Heavy Industries (7011.T) manufactures pressure vessels as well as other large nuclear components, as well as replacement components, services and technologies for pressurized water reactors. Mitsubishi Heavy Industries is working with TerraPower to advance its SMR design.
  - BWX Technologies (BWXT) manufactures steam generators, reactor pressure vessels (for GE-Hitachi BWRX-300 SMR), as well as other nuclear components. The company is the sole manufacturer of naval nuclear reactors for submarines and aircraft carriers. While it primarily works with governments, ~25% of its business is related to commercial/medical. The company is a supplier to GE Vernova's SMR supplier group as well as the Department of Defense's Project Pele, which is a prototype mobile nuclear reactor.
  - GE Hitachi (JV with GE Vernova and Hitachi)
  - Siemens Energy (ENR1n.DE) provides steam turbines and generators. The company is supplying Rolls Royce.
  - Curtiss-Wright Nuclear, a subsidiary of Curtiss-Wright (CW) offers a comprehensive range of nuclear products and is a supplier to X-energy and TerraPower.

- Other nuclear component manufacturers include United Heavy Machinery, Atomenergomash, Flowserve (FLS), and AtkinsRéalis (ATRL).

Who helps build nuclear power facilities

As with the development of utility-scale solar, construction companies or EPCs are typically responsible for the actual construction of the nuclear plant. This includes engineering/design services, equipment procurement, site permitting, construction, and commissioning.

- **Main nuclear construction/EPC companies:**
  - Fluor Corp (FLR) is a major nuclear EPC company, and was involved in the construction of the Farley Nuclear Station in Alabama and is the lead partner in Savannah River Nuclear Solutions. FLR also has a contract with the Naval Nuclear Propulsion Program and won a $45bn nuclear cleanup award from the DOE. Importantly, FLR spun out NuScale in 2021, and is working with NuScale/RoPower to advance SMRs in Romania.
  - Bechtel (BC8.DE) took over construction of Vogtle new build in USA in 2017, replacing Fluor. Additionally, the company secured a contract with Westinghouse for three AP1000's in Poland, and is also the EPC for TerraPower.
  - Aecon is working with Kiewit to build the Darlington New Nuclear Project for Ontario Power Generation, which is deploying BWRX-300 SMRs.
  - Others include: Doosan Enerbility (034020-KRX), Siemens Energy (ETR), KEPCO E&C, PCL Construction, Hyundai, and Aecon.

Owners/Operators - who operates/buys nuclear power plants

- Utilities: Southern Co (SO), Duke Energy Corp (DUK), Dominion Energy (D), Public Service Enterprise Group (PEG), Vistra (VST).
- Hyperscalers: Amazon (AMZN), Meta (META), Alphabet (GOOG), Microsoft (MSFT)

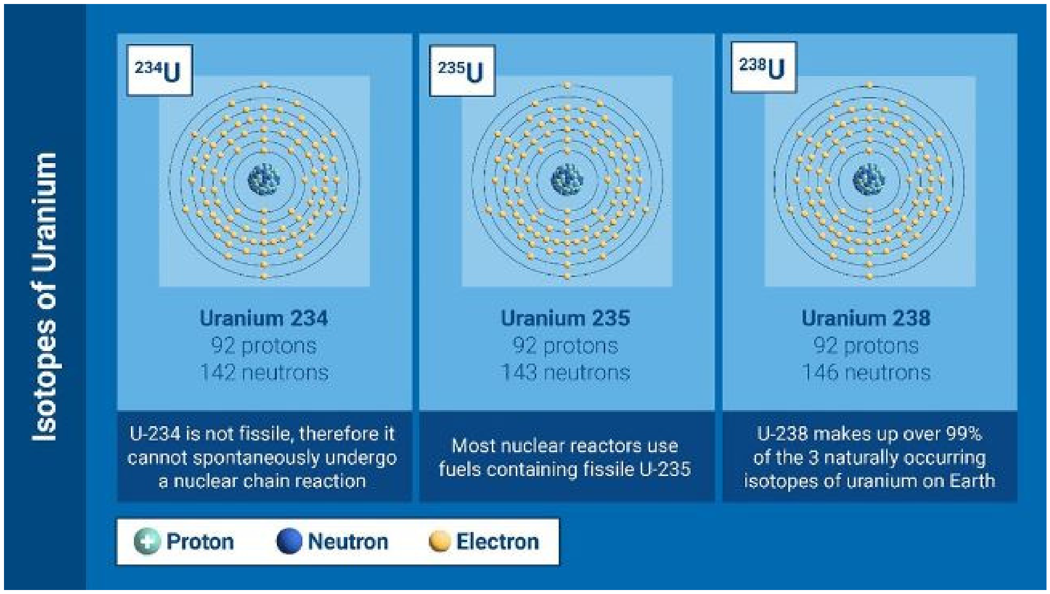
Appendix: Uranium Mining 101

What is uranium?

Uranium is a naturally occurring radioactive element that is primarily used for generating electricity for nuclear power plants, but also has applications in medicine, defense, and industrial uses. Uranium has the highest atomic weight of naturally occurring elements, and is more abundant than gold, silver, and mercury, but slightly less abundant than lead.

There are three natural isotopes of uranium, U-234, U-235, and U-238, but U-238 represents ~99% of the earth's natural uranium. However, U-235 is the main uranium isotope used in nuclear reactors, but represents less than 1% of natural uranium globally.

Exhibit 52: Overview of uranium isotopes
U-235 is the main uranium isotope for nuclear reactors



Source: IAEA

How are uranium deposits formed?

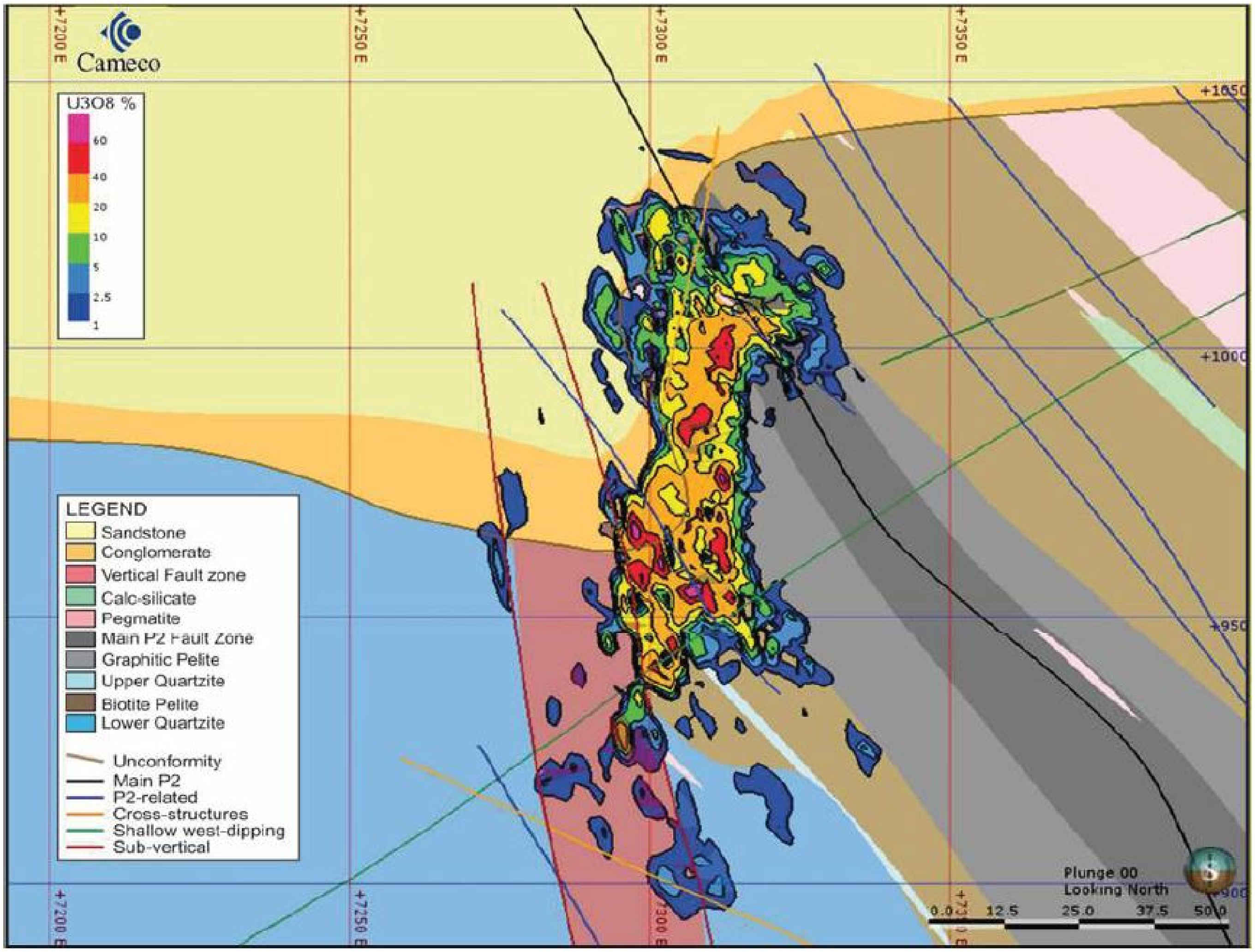
The International Atomic Energy Agency recognizes 15 main types of deposits, as well as ~40 subtypes. These deposits include unconformity-related deposits, sandstone, quartz-pebble congolomerate, breccia complex, vein, intrusive, phosphorite, and more. However, the deposits that boast the most economical amounts of uranium are sandstone/sedimentary deposits (Wyoming basin, Texas, Kazakhstan, Russia, Australia, and Niger), polymetallic iron-oxide breccia complex (Olympic Dam), and Proterozoic unconformity (Athabasca Basin).

Sandstone deposits represent ~18% of the world's measured and indicated resources according to the World Nuclear Association, and are typically low to medium grade (0.05%-0.35% U) with relatively small to medium size deposits. The sandstone uranium deposits typically occur in medium- to coarse-grained sandstones in a continental fluvial or marginal marine zones (salt marshes, tidal flats, lagoons, etc.) with impermeable shale or mudstone immediate above or below the mineralized zone. These features make sandstone deposits more amenable to ISR mining methods.

Polymetallic iron-oxide breccia complexes typically host uranium as a by-product to other ores like copper, gold, iron, and silver, such as Olympic Dam in Australia. The uranium is hosted within hematite-quartz breccias, which are comprised of large angular rock fragments cemented together in a matrix. These deposits are believed to have been formed from hydraulic fracturing or tectonic faulting during volcanic eruptions that caused explosive interactions with water and magma.

Proterozoic unconformity deposits, such as those in the Athabasca Basin, are structurally controlled and usually located within a few hundred meters of a prominent regional unconformity, which is essentially a boundary between two rock units that reflects a time gap caused by erosion or pause in sediment accumulation. This means that the rocks below the unconformity are typically older than the rocks above it. The deposits are typically controlled by faults or fracture zones. During the Proterozoic period, the low oxygen levels of the atmosphere allowed uranium to be slowly dissolved in fluids within large sedimentary basins. These fluids then encounter the unconformity, causing a change in conditions that triggers the deposition of uranium-oxide minerals. These are typically higher grade deposits that are extracted using traditional mining methods (underground or open-pit).

Exhibit 53: Geological section of Zone 2 mineralization at McArthur River deposit

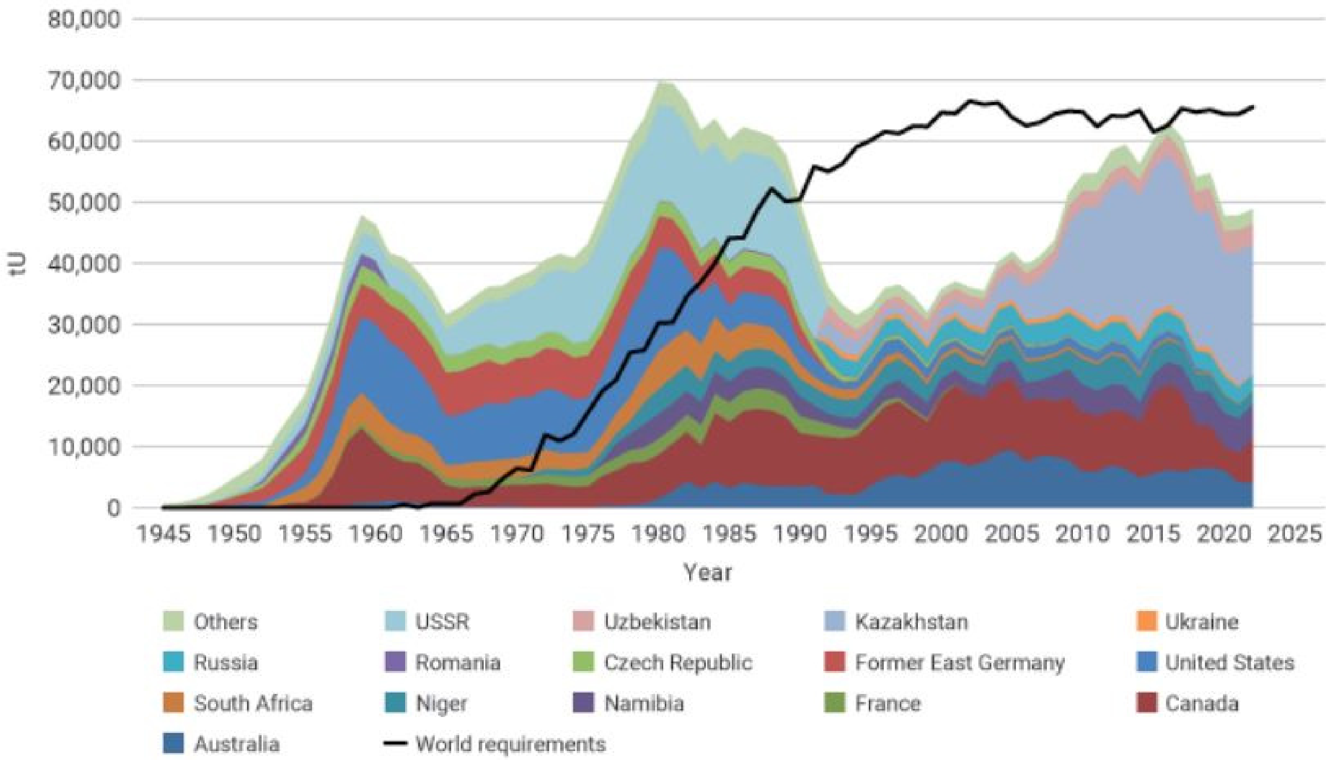


Source: Cameco

History of uranium mining

Uranium was first discovered in 1789 and was initially used as coloring in glass production. Uranium mining started in the mid-1800s but wasn't until the mid-1900s when it was more widely mined particularly as countries advanced research into atomic bombs during WW2 and the Cold War. We note that the industry experienced peak uranium production in the 1980s before declining into the 1990s driven by changing public sentiment and national energy policy as well as lower uranium prices. Mining of uranium currently occurs in 20+ countries but ~60% of the world's uranium production comes from Canada and Kazakhstan according to our estimates.

Exhibit 54: Global uranium production and reactor demand (tonnes)
Uranium production peaked in the 1980s

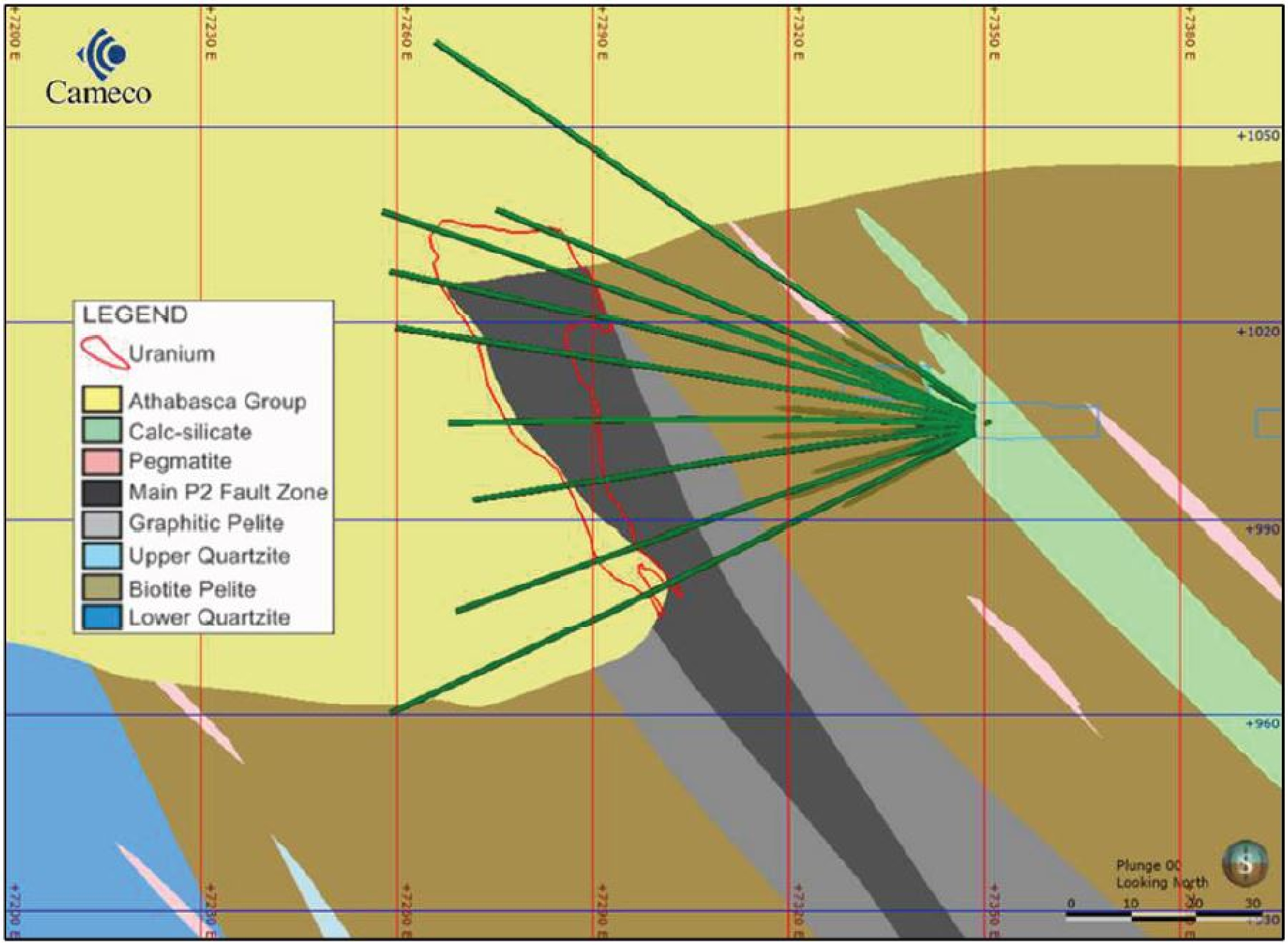


Source: World Nuclear Association, OECD-NEA, IAEA

Delineating deposits

Discovering and defining a uranium deposit is similar for other metals, and can actually be slightly easier given the radioactive decay that allows deposits to be identified from the air through airborne gamma-ray spectometry and magnetic data. Once a deposit is located, drilling programs are conducted to test potential target zones as well as more accurately define the deposit size and grade to assess whether it can economically be extracted. Drilling assay results will typically be presented as an average grade over a certain deposit length.

Exhibit 55: Typical underground drill spacing



Source: Cameco

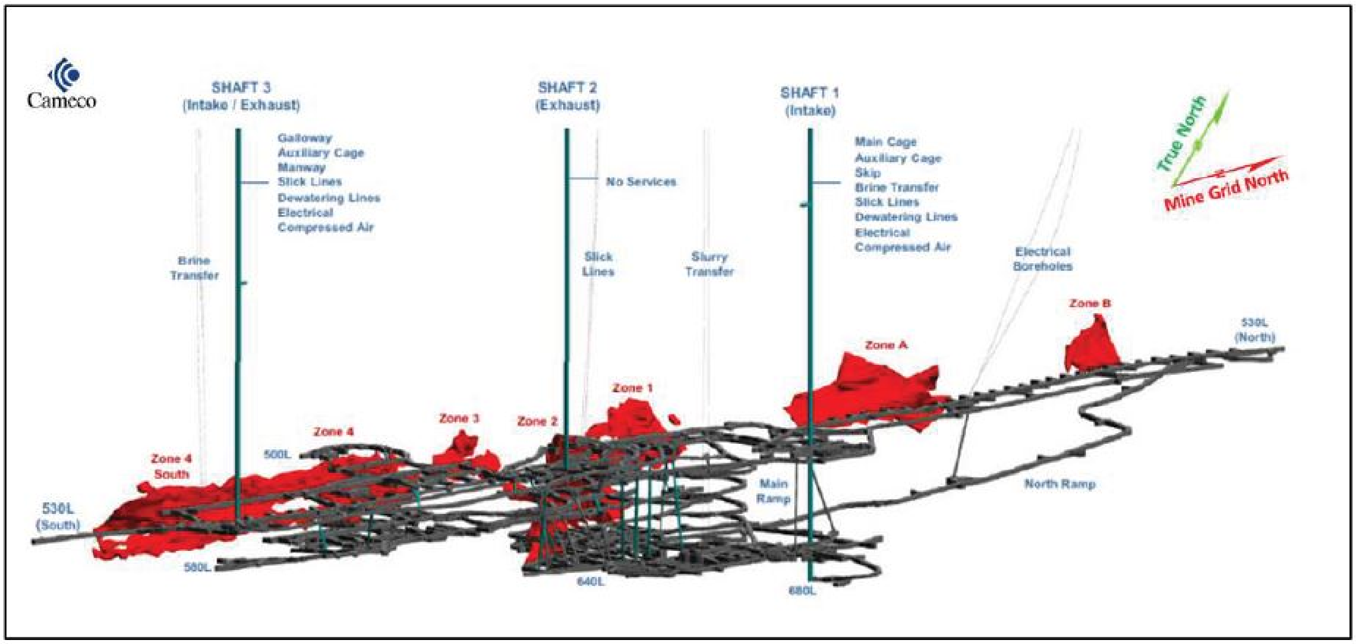
Once a deposit has been sufficiently drilled, a resource estimate can be formed that summarizes the quantity, grade, quality, density, shape, and physical characteristics. A mineral resource is usually distinguished between measured resource, which is the highest confidence level, followed by an indicated resource (measured and indicated resources are typically combined to a Measured and Indicated Resource amount), and lastly an inferred resource. These resources could be further converted to a Proven mineral resource and a Probable resource based on confidence in economically mining the resource (proven has a higher confidence level). These resource estimates must be supported by a Preliminary Economic Assessment (PEA), Pre-Feasibility Study (PFS) or a Feasibility Study (FS), which typically provides an overview of mining logistics, capital requirements, and potential challenges. We note that PEAs are referred to as scoping studies and provide an initial assessment of potential project economics, but are more preliminary than PFS and FS reports, with FS reports requiring the most engineering work that provides the most accurate assumptions of project costs and economics.

Most uranium deposits maintain average uranium grands of 0.10%+ (1,000 parts per million), with some projects offering grades of ~20%, such as Cigar Lake's average grade of ~16%. These higher grade deposits are typically more amenable to traditional mining operations like open pit or underground operations.

Mining Methods

Mining uranium is similar to other ores, but may require special techniques such as dust suppression to reduce exposure to radiation. There are two main types of uranium mining, conventional mining and ISR or ISL. We note that ~35% of uranium is mined via conventional means, while ~60% is through ISR, and ~5% is produced a byproduct from mining other minerals, mostly copper/gold. Conventional mining is either open pit or underground mining, with the milling process using a sequence of physical and chemical treatment processes to extract U3O8. Open pit mining is typically done with deposits are within a few hundred meters from the surface and overburden can be easily removed, while underground mining is used when the deposit is deep underground or covered by hard rock.

Exhibit 56: Underground workings at McArthur River



Source: Cameco

ISR operations involves injecting a solution of hydrogen peroxide in boreholes drilled into the ore deposit to dissolve the minerals, which is then extracted through a second borehole. Key characteristics include:

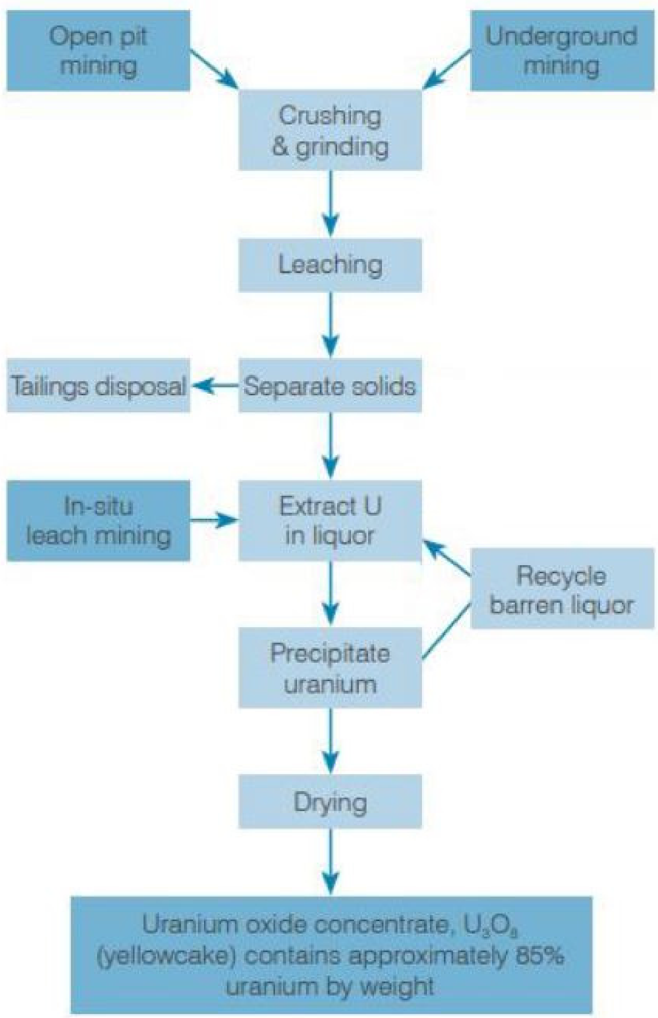
- Typically, ISR mining offers lower upfront capital costs, quicker commissioning timelines, and fewer environmental risks. However, ISR has the potential to contaminate ground-water, is only suitable on certain deposits, is usually for lower grade, and can encounter technical issues with the extraction process.
- Conventional mining is more well understood, offers potentially higher recovery rates and is mostly used on higher grade deposits. However, it has higher upfront capital costs, lengthier commissioning times, and potential environmental consequences of the removal and management of waste materials.

We note that some uranium is recovered as a by-product to other metals, such as with copper at Olympic Damn in Australia, or with gold in South Africa.

Milling/Recovery methods

Traditional mining methods and ISR mining both require leaching with sulfuric acid to dissolve the uranium oxides, which is then processed to recover the uranium. However, traditional mining requires use of a mill to crush and grind the ore to free the mineral particles so that they can be suitable for leaching. Minerals that are not dissolved are separated from the uranium-rich solution in the form of "tailings". The uranium is then recovered through an ion exchange (IX) or solvent extraction (SX) system, and the uranium is subsequently removed by using an acid or chloride solution before adding ammonia, hydrogen peroxide, or caustic soda to precipitate the uranium or cause the solids to be removed from the solution. These solids are then dried to covert the materials to U_3O_8.

Exhibit 57: Overview of steps in uranium milling and extraction process



Source: World Nuclear Association

Mineral classifications

As mining companies explore uranium deposits, they will classify the uranium resource based on the confidence level of its exploration efforts. That resource will be subdivided based on the geological confidence, which includes:

- Measured resources represents the highest confidence level of resource (not reserve) and maintains sufficient geological evidence from exploration, sampling, and other testing to provide a quantity, grade/quality, density, shape, and other physical characteristics of a deposit.
- Indicated resources represents estimated characteristics of a deposit based on adequate exploration and testing efforts to assume a resource estimate. Indicated resources have a lower confidence level than a measured resource, and can only be converted to a Probable mineral reserve.
  - Measured and indicated resources are often combined into a total measured and indicated or M&I resource.
- Inferred resources provides the lowest confidence level of resources and is typically based on limited geological evidence that is sufficient to imply a resource grade or quality. These resources need to be upgraded to indicated before being converted to a mineral reserve.
- Proven reserves represents the economically mineable portion of the measured mineral resource. These represent the highest confidence level resource, with a ~90%+ likelihood of commercial extraction.
- Probable reserves represent the economically mineable portion of an indicated resource (and sometimes measured resource), and has a lower confidence level than Proven reserves.
- We note that mineral reserves are supported by a pre-feasibility study or a feasibility study, which provides information to support mining methods, where ore will be processed, and economic data.

Economics of Uranium Mining

Economics of uranium mining vary based on country, grade, nature of the ore, as well as infrastructure. All countries have degrees of risk which determines the attractiveness of the investment, royalty, tax regimes etc. The quality of the ore is also fundamental as the quantity, geology, grade, depth, among other factors, determine the required capital to process the material.

Uranium mining costs can be broken down into capital costs, operating costs, and indirect costs. Capital costs including the upfront capex for site preparation, construction and commissioning, while ongoing capital costs are required to sustain the operation, also called sustaining capex. Operating costs represent the cost of extracting the ore and preparing it for sale, and often includes royalty payments. Operating costs, or cash costs, are typically reported as a $/lb or $/kg U, and exclude non-cash items such as depreciation. Indirect costs include depreciation and amortization of the asset, as well as interest payments, an uncapitalized sustaining capex related to exploration or mine development.

Typical reporting metrics for costs:

1. Cash operating costs
2. Total production cost (includes depreciation)
3. All-in sustaining costs (AISC), includes all costs related to sustaining future production efforts.
4. Fully allocated cost, includes all direct and indirect costs for the mining operations

Health hazards and concerns

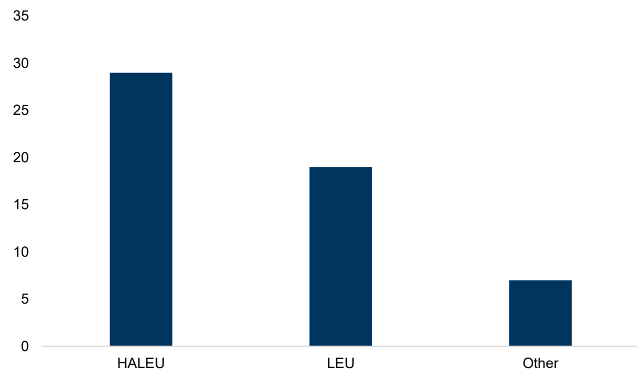
While uranium alone is only slightly radioactive, when ore is mined and crushed, it releases small quantities of radon, which is a radioactive inert gas, into the atmosphere. Open-pit mining operations are naturally ventilated, but underground mining operations require proper ventilation to limit exposure of mine workers. Importantly, radon levels can be measured to maintain certain safety levels. Additionally, ISR operations maintain limited exposure to radiation since there is no physical mining of the ore but protectionist measures are still used to minimize radon release.

Appendix: HALEU 101

Natural uranium consists of approximately 0.7% U-235, which is the fissile isotope crucial for most commercial nuclear fuels. Through the enrichment process, the concentration of U-235 can be increased to varying levels. Low-Enriched Uranium (LEU), which is used for traditional reactor fuel, is typically enriched to 3%-5% U-235. For higher concentrations, uranium can be enriched to levels exceeding 20% U-235, which is considered High-Enriched Uranium (HEU).

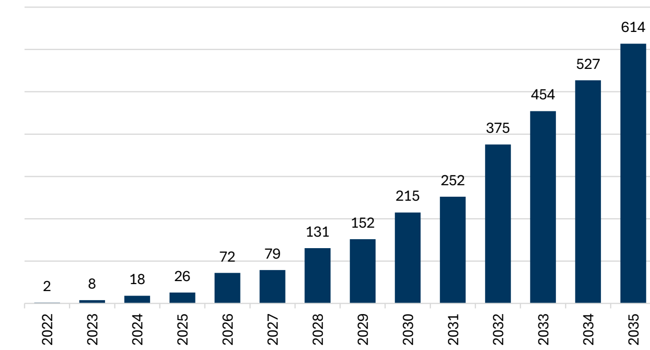
Enrichment levels between LEU and HEU, or between 5% and 20%, is considered High-Assay Low-Enriched Uranium (HALEU). HALEU fuel offers significant advantages over LEU, including higher burn-ups and greater power extraction from the same amount of fuel. These properties enhance fuel efficiency, improve fuel utilization, and extend the operational life of reactor cores. As a result, HALEU is becoming the preferred choice for advance reactor designs, where these benefits are critical for achieving the desired performance and sustainability.

Exhibit 58: We view that SMRs that use LEU fuel have an easier path toward commercialization as the HALEU supply chain is uncertain
Number of SMRs per fuel requirement



Source: NEA, Goldman Sachs Global Investment Research

Exhibit 59: Estimated annual requirements for High-Assay Low Enriched Uranium through 2035
MT/Yr



Source: NEI Survey of HALEU Requirements (2021)

HALEU

HALEU can be produced through either traditional gas centrifuge enrichment techniques or by down-blending HEU with LEU. In the US, Centrus Energy and URENCO USA are currently licensed by the Nuclear Regulatory Commission (NRC) to produce HALEU. However, the development of a reliable domestic supply chain for HALEU presents significant challenges pertaining to the "chicken-and-egg" problem in the nuclear industry. While the US possessed the technological capability to build HALEU production facilities, the market remains in a nascent stage given the current lack of demand. With advanced reactor designs still under development and demand projections yet to be fully realized, potential producers face high risks associated with the substantial upfront capital costs required for HALEU production. Reactor developers are reluctant to commit to a particular design until they can secure a stable fuel supply, but the lack of a clear customer base makes it difficult for fuel cycle companies to firm up demand projections. Within the US, the government plays a pivotal role in de-risking these investments by acting as an initial buyer of HALEU, which can later be sold back into the market as demand for advanced reactors become more predictable. This government support would enable companies to establish a more robust supply chain without bearing the full financial burden.

In the private sector, BWXT is the only company that has demonstrated the capability to down-blend HEU into HALEU fuel. Additionally, TRISO-X, a subsidiary of X-energy LLC, has applied for an NRC license to fabricate TRISO-based fuel at a new facility in Tennessee. While these efforts are important, we believe they may be insufficient on their own to support the creation of a fully functional domestic commercial HALEU fuel cycle or to meet the growing demand for HALEU in the near term. The Department of Energy (DOE) is mindful of balancing the commercialization of the HALEU fuel cycle with the need to maintain the existing baseline uranium production capacity that supports the US nuclear industry. As such, the future trajectory of HALEU development remains uncertain, and its commercialization is likely to evolve gradually.

The majority of HALEU-based SMR developers have based their design concepts to use imported HALEU from Russia. However, geopolitical tensions have effectively closed that supply channel, especially following the Uranium Import Ban that became effective in August 2024. As a result, the US government has taken decisive steps in developing a domestic HALEU supply chain, such as allocating $700mn within the IRA to support the development of a domestic supply chain for HALEU as well as a $3.4bn program from the DOE that selected six companies that can sign contracts to procure LEU. These strategic moves are critical for the continued growth of SMRs and provides greater upstream certainty for the US nuclear industry.

TRISO

Tri-structural Isotropic (TRISO) fuel is a high-performance nuclear fuel particle specifically designed for advance reactors, offering enhanced safety and durability. Composed of a uranium, carbon, and oxygen fuel kernel, TRISO particles are encased in a triple-layer protective coating, making them capable of withstanding extreme temperatures and radiation. This structure gives TRISO its remarkable strength, ensuring it retains fission products under all reactor conditions, effectively eliminating the risk of a meltdown. TRISO is considered by the DOE the safest form of uranium fuel, with its superior structural integrity and thermal performance enhancing fuel efficiency. Ongoing research and development of TRISO is supported through the U.S. Department of Energy's Advanced Reactor Technologies (ART) program, with companies like Kairos Power and X-energy noting plans to implement TRISO in their advanced reactor designs. While TRISO focuses on fuel integrity and safety, HALEU enhances reactor performance through increased fuel utilizaton and reduced refueling needs. Kairos Power and X-Energy are advancing SMRs that use TRISO fuel.

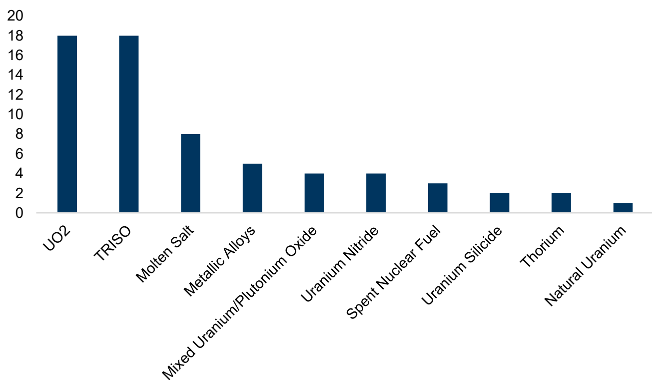
Exhibit 60: There are dozens of reactor types trying to come to market

Overview of reactor types

Name	Company	Country	Fuel Type	Fuel (LEU/HALEU/HEU)
MoveluX	Toshiba Energy Systems & Solutions corp.	Japan	Uranium Silicide	LEU
Sealer - 55	Blykalla	Sweden	Uranium Nitride	HALEU
Westinghouse LFR	**Westinghouse**	**United States**	**UO2 pellets or MOX; then UN pellets**	**HALEU for UO2 pellets, otherwise plutonium-uranium oxide for MOX**
KLT-40S	ROSATOM	Russia	UO2 pellets	HALEU
CAREM	CNEA	Argentina	UO2 pellets	LEU
ACP100	CNNC	China	UO2 pellets	LEU
RITM-200N	ROSATOM	Russia	UO2 pellets	HALEU
RITM-200S	ROSATOM	Russia	UO2 pellets	HALEU
BWRX-300	**GE Hitachi Nuclear Energy**	**United States**	**UO2 pellets**	**LEU**
VOYGR	**NuScale Power**	**United States**	**UO2 pellets**	**LEU**
SMART	KAERI	Korea	UO2 pellets	LEU
ACPR50S	CGN	China	UO2 pellets	LEU
Nuward SMR	NUWARD	France	UO2 pellets	LEU
RR SMR	Rolls-Royce SMR	UK	UO2 pellets	LEU
SMR-300	**Holtec International**	**United States**	**UO2 pellets**	**LEU**
HAPPY200	SPIC	China	UO2 pellets	LEU
PWR-20	**Last Energy**	**United States**	**UO2 pellets**	**LEU**
RITM-200m	ROSATOM	Russia	UO2 pellets	HALEU
AP300 SMR	**Westinghouse**	**United States**	**UO2 pellets**	**LEU**
Calogena	Gorge	France	UO2 or uranium silicide	LEU
Jimmy CMR	Jimmy	France	UCO TRISO Prismatic	HALEU
BANR	**BWXT**	**United States**	**UCO TRISO and UN TRISO prismatic**	**HALEU**
Xe-100	**X-energy**	**United States**	**TRISO-X pebble**	**HALEU**
eVinci Micro Reactor	**Westinghouse**	**United States**	**TRISO-X pebble**	**HALEU**
HTTR	JAEA	Japan	Triso prismatic	LEU, HALEU
MMR	**USNC**	**United States**	**TRISO Prismatic**	**HALEU**
Pylon D1	**USNC**	**United States**	**TRISO Prismatic**	**HALEU**
Kaleidos	**Radiant Industries**	**United States**	**TRISO Prismatic**	**HALEU**
HTGR-POLA	NCBJ	Poland	TRISO Prismatic	HALEU
GTHTR300	JAEA	Japan	Triso prismatic	HALEU
Energy Well	CVR	Czechia	Triso prismatic	HALEU
SC-HTGR	**Framatome**	**United States**	**TRISO prismatic**	**HALEU**
Blue Capsule	blue capsule technology	France	TRISO Prismatic	LEU or HALEU
HTR-PM	INET	China	TRISO Pebble	HALEU
Hermes	**Kairos Power**	**United States**	**TRISO pebble**	**HALEU**
A-HTR-100	ESKOM	South Africa	TRISO Pebble	HALEU
HTMR-100	Stratek Global	South Africa	TRISO Pebble	HALEU
Project Pele	**BWXT**	**United States**	**TRISO**	**HALEU**
Teplator	UWB and CIIRC CTU	Czechia	SNF from LWRs or Natural Uranium	SNF or natural uranium
LFR-AS-200	newcleo	UK	MOX	Uranium oxide and plutonium
HEXANA	Hexana	France	MOX	Depleted Uranium and Plutonium
Otrera 300	Otrera Nuclear Energy	France	MOX	MOX
SSR-W	Moltex Energy	Canada	Molten Salt	Recycled spent fuel
IMSR	Terrestrial Energy	Canada	Molten Salt	LEU
CMSR	Seaborg Technologies	Denmark	Molten Salt	LEU
LFTR	**Filbe Energy**	**United States**	**Molten Salt**	**LEU, Thorium**
ThorCon 500	ThorCon International	UAE	Molten Salt	LEU
XAMR	NAAREA	France	Molten Salt	Undisclosed
FLEX	MoltexFLEX	UK	Molten Salt	LEU
Thorizon One	Thorizon	Netherlands	Molten Salt	SNF and thorium
BREST-OD-300	NIKIET	Russia	MNUP Fuel	Natural or depleted uranium and plutonium
Natrium Reactor Plant	**TerraPower**	**United States**	**Metallic U-Zr alloy**	**HALEU**
ARC - 100	**ARC clean technology**	**United States**	**Metallic U-Zr alloy**	**HALEU**
4S	Toshiba Energy Systems & Solutions corp.	Japan	Metallic U-Zr alloy	HALEU
DF300	Dual Fluid Energy	Canada	Liquid metallic U-Cr alloy	HALEU

Source: NEA, Goldman Sachs Global Investment Research

Exhibit 61:
Number of SMRs by fuel type



Source: NEA, Goldman Sachs Global Investment Research

Additional Fuel Types

Metallic alloys include different amounts of uranium-zirconium (U-Zr) or uranium-plutonium (U-Pu-Zr) with other alloys such as aluminum or silicium. We note that companies like TerraPower are pursuing metallic U-Zr alloys.

Molten salts based on chloride or fluoride are also being considered for nuclear fuel since they can be used in very high temperatures but low pressure environments. Molten salts offer several benefits to traditional fuel, including improved safety features and efficiencies. Additionally, since the salt is liquid, it is easy to introduce new fuel as well as clean/filter in-use fuel, reducing the need for refueling down time. We note that the molten salts can act as the fuel as well as the coolant. Companies such as Terrestrial Energy, Moltex Energy, and Filbe Energy are leveraging molten salt fuels.

Appendix: Nuclear licensing

Licensing

The licensing process for a nuclear reactor is one of the most time-intensive and complex stages in nuclear development. This is the nuclear life-cycle stage where design concepts are validated and authorization is granted to proceed with implementation In the U.S., the **Nuclear Regulatory Commission (NRC)** is responsible for the licensing of nuclear reactors and conducts a comprehensive review of all stages of nuclear power operations, from initial site selection and nuclear materials handling to decommissioning. The licensing and regulation of nuclear reactors at the NRC are overseen by the **Office of Nuclear Reactor Regulation (NRR)**. NRR is “responsible for accomplishing key components of the NRC’s nuclear reactor safety mission” and focuses on regulatory areas such as licensing, operational oversight, and rule-making. The NRC separates its licensing, oversight, and regulation activities for light-water power reactors from those for advanced, non-light-water power reactors and all non-power reactors.

There are two classes of licenses - Class 103 and Class 104, where the former is issued for commercial reactors and the latter is issued for research & development or medical therapy, basically non-commercial reactors. To that, the **Division of New and Renewed Licenses (DNRL)** is responsible for the licensing of all Class 103 LWRs. This includes both the re-licensing of existing commercial LWRs and the initial licensing of new LWR designs (e.g., the Westinghouse AP1000/AP300, Holtec SMR 300, GEH BWRX-300, and NuScale VOYGR). The **Division of Advanced Reactors and Non-Power Production and Utilization Facilities (DANU)** is responsible for the licensing of any Class 103 non-light water advanced reactors and all Class 104 reactors. This division handles reactors not licensed by DNRL, which can include commercial non-LWRs, medical, research, and test reactors. Examples of reactors licensed by DANU include the TerraPower Natrium, X-energy Xe-100, Kairos Power Hermes 1 & 2, and Abilene Christian University Molten Salt Research Reactor (MSRR).

In order to construct or operate a nuclear power plant, an applicant must submit a Safety Analysis Report. This document contains the design information and criteria for the proposed reactor, and comprehensive data on the proposed site. It also discusses various hypothetical accident situations and the safety features of the plant that would prevent accidents or lessen their effects. In addition, the application must contain a comprehensive assessment of the environmental impact of the proposed plant. A prospective licensee also must submit information for antitrust reviews of the proposed plant.

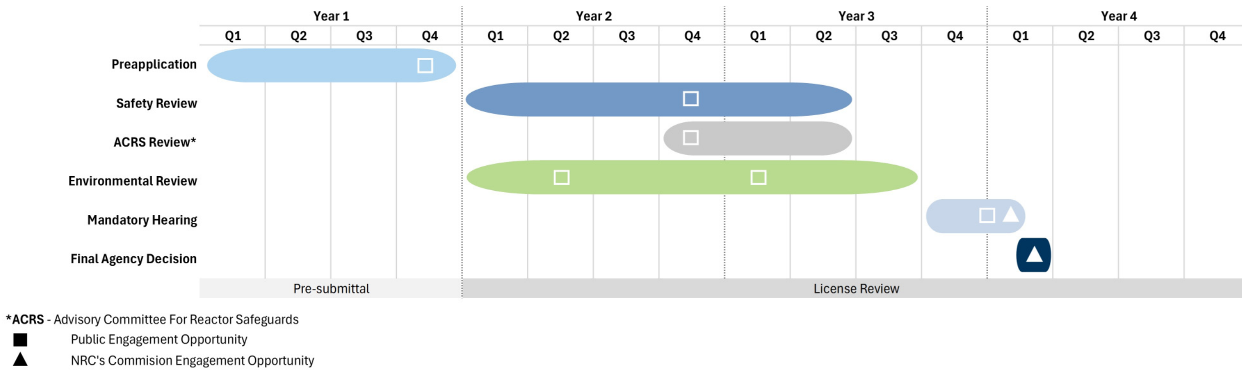
Processes

Currently operating nuclear power plants were licensed under a two-step process described in Title 10 of the Code of Federal Regulations (10 CFR) under Part 50. This process requires both a construction permit and an operating license. Eventually, the NRC worked to improve regulatory efficiency and add greater predictability to the process by establishing an alternative licensing process, 10 CFR Part 52, in 1989. Part 52 includes a combined license that provides a construction permit and an operating license with conditions for plant operation.

Part 50 - Two Stage Licensing Process

Part 50 is the traditional, two stage licensing process for nuclear reactors consisting of the Construction Permit (CP) and Operating License (OL) and can be used to license both Class 103 and 104 reactors. The process begins with obtaining a Construction Permit, which allows an applicant to start building the reactor. To receive this permit, the applicant must submit a detailed Safety Analysis Report (SAR) and an environmental impact assessment. After the CP is granted and construction is finished, the applicant must apply for an Operating License, which ensures the reactor has been built according to approved plans and is ready for safe operation. This stage requires updated safety reports and proof of operational readiness. Throughout the process, the NRC conducts thorough safety and environmental reviews to ensure the reactor does not pose a risk to the public or environment. Public involvement is also a key aspect of the process, allowing for hearings and comments on safety concerns, environmental impact, and the reactor's suitability for the proposed site. Once the reactor is operational, the NRC continues oversight through inspections and compliance checks.

Exhibit 62: The NRC's process to grant a license before a new reactor can start construction usually takes ~3-5 years under Part 50



Licensing schedules vary by application; however, the ADVANCE Act mandates the NRC licensing timelines for certain Combined Licenses (Part 52) to reach a final decision no longer than 25 months

Source: Nuclear Regulatory Commission (NRC), Third Way, Goldman Sachs Global Investment Research

Part 52 - One Stage Licensing Process

Title 10 CFR Part 52 is only a one stage process compared to Part 50's two stages and includes a combined license that provides a construction permit and an operating license with conditions for plant operation. Part 52 offers additional tools that are particularly useful for applicants seeking a more predictable and efficient path to reactor deployment. These tools allow applicants to address key regulatory requirements in phases, which can reduce the financial and schedule risks associated with reactor development.

Early Site Permit (ESP) - Allows applicants to obtain NRC approval of a site before applying for a CP or COL to resolve potential site-related issues early, securing a site for up to 20 years (with 20-year renewal possibility) without committing to a specific reactor project.

Standard Design Certificate (SDC) - The Design Certification (DC) process allows NRC approval for a reactor design independent of specific projects, reducing the need for site-specific reviews. Certified designs, valid for 15 years, enhance safety, reduce costs, and streamline the review process for future applicants.

Standard Design Approval (SDA) - The Design Approval (DA) provides NRC approval of a reactor design without formal rule-making, allowing it to be referenced in licensing applications. While not as certain as design certification, it reduces licensing time and can be renewed, though applicants must prove compliance with current regulations.

Manufacturing License - The Manufacturing License allows NRC approval to manufacture major reactor components before receiving a construction permit, speeding up deployment. Valid for up to 10 years and renewable, it benefits reactors with modular components by enabling standardized manufacturing and quality control.

Limited Work Authorization (LWA) - An LWA allows certain construction activities, like site preparation, before a full construction permit or COL is issued, helping reduce delays. It accelerates the project timeline but requires sufficient environmental and safety information, with the scope carefully controlled to avoid preempting the full licensing process.

Exhibit 63: Both processes offer different pros and cons

Part 50		Part 52		
# of Stages/Licensing Timeline		# of Stages/Licensing Timeline		
Stage 1	Construction Permit (CP) Application	1 Stage Only	Combined License (COL) Application	
Stage 2	Operating License (OL) Application			
Construction Permit	36 months	Design Certificate (Optional)	36 months for non-LWR, 42 months for LWR	
Operating License	36 months	Early Site Permit (Optional)	24 months	
		Combined License	LWR/non-LWR with a certified design	30 months
			LWR without a certified design	42 months
			Non-LWR without a cerified design	36 months
Pros	**Cons**	**Pros**	**Cons**	
Design Flexibility	Longer Timelines	Streamlined Process	Less Flexibility	
Start construction with a preliminary design	Risk of Delays	More Certainity	Upfront Commitment	
		Faster Time to Operation		
SMRs		**SMRs**		
Kairos Power - Hermes Reactor				
TerraPower & GE Hitachi - Natrium		NuScale Power - US 600		
X-Energy - Xe-100		Westinghouse Electric Company - eVinci		

Source: Nuclear Regulatory Commission, Goldman Sachs Global Investment Research

Part 53 - New licensing pathway under review

Congress recognized the need for a non-prescriptive regulatory framework with the passage of Nuclear Energy Innovation and Modernization Act (NEIMA). Instead of utilizing pre-defined outcomes for first-of-a-kind designs, a performance- based approach establishes performance goals in the form of numerical risk targets. The Nuclear Energy Innovation and Modernization Act (NEIMA) passed in 2019 mandated that the NRC develop a Risk-Informed, Technology Inclusive Regulatory Framework for Advanced Reactors, known as Part 53, which will accommodate new design developments through an efficient licensing framework tailored to the new way in which nuclear power will be deployed without compromising the level of safety ensured under Parts 50 and 52 today. This licensing pathway is still in the rule-making process, and NRC staff expects to provide the draft final rule to the Commission in 2025 and issue the final rule no later than the end of 2027.

The permitting and licensing process for nuclear power plants in the United States has long been under scrutiny for hampering the deployment of nuclear energy technologies. When Vogtle 3 came online in July 2023, it was the first time in the nearly 50-year history of the U.S. Nuclear Regulatory Commission (NRC) that a new commercial reactor design had been licensed and subsequently entered into operation. Numerous stakeholders from across the political spectrum have made recommendations for accelerating the NRC's regulatory process, but reforms so far have not been adopted or have not proved impactful.

Developers of advanced nuclear technologies are working to push the envelope on speeding reactor deployment, with some companies promising to reduce licensing and permitting hurdles by implementing conveyor-belt-like manufacturing and siting microreactors at existing industrial facilities. These efforts are finding support on Capitol Hill: in July 2023, the bipartisan ADVANCE Act, which aims to restore U.S. leadership in nuclear technology, passed the Senate as part of the National Defense Authorization Act (NDAA) by a vote of 86-11; more recently, the House Committee on Energy and Commerce passed H.R. 6544, The Atomic Energy Advancement Act, which contains similar provisions.