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In this Issue

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Uranium: An Energy Source We Cannot Exclude

Prologue

As one of the cleanest and most powerful sources of energy, nuclear power could play a key role in helping countries achieve decarbonization goals in the fight against climate change. The world's energy needs are growing with its population. As such, achieving a net-zero carbon economy while meeting growing energy needs will require clean, sustainable, and reliable energy sources to play a larger role in our energy mix. Nuclear is one such source.

All energy sources have trade-offs, but some are better for the environment than others. In that regard, an interesting metric to look at is CO2 equivalent emissions per gigawatt-hour ("GWh") over the lifecycle of power plants for different energy sources. The measure includes the carbon footprint of raw materials, transport, and construction of power plants.

Unsurprisingly, coal, oil, and natural gas plants emit substantially more greenhouse gases than their renewable (e.g., solar, wind, hydro) and non-renewable (e.g., nuclear) counterparts. Coal power plant emissions are 273x higher than nuclear power plants ("NPPs") per GWh.

Hydropower is a cleaner and renewable alternative to fossil fuels, but concrete and materials used in dam constructions contribute to high emissions. Then, the underwater vegetation's decomposition in reservoirs releases methane and carbon dioxide. Although hydropower plants emit around 24x less than coal plants, they still emit 11x more than nuclear plants.

Solar and wind are undoubtedly the most mentioned energy sources in the energy transition. However, their energy densities are lower than fossil fuels meaning they require more units to generate the same amount of power. To put it in perspective, generating 1GWh of electricity can take over 3.1m PV panels or 431 utility-scale wind turbines. The land footprint per GWh of electricity per year is 3.4km2 for nuclear, 75x more for solar, and 360x more for wind.

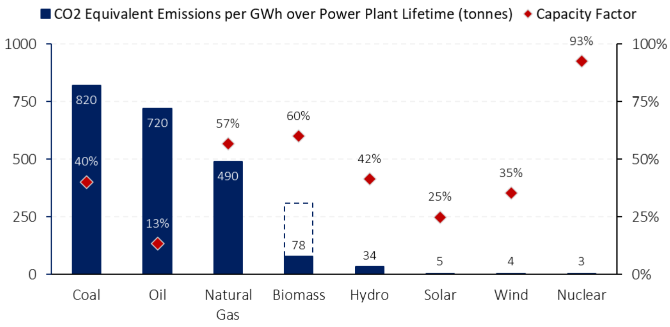
How does nuclear come out on top as the cleanest source of energy?

The high energy density of uranium makes it a strong contender among clean power sources. An eraser-sized uranium pellet has the same amount of energy as 120 gallons of oil or 17,000 cubic feet of natural gas. Then, NPPs have the lowest structural material requirements of all low-carbon energy sources as reactors are built with long useful lives in mind, 30-80 years. This compares to 20-25 years for solar and 2 years for wind. The near-carbon-free, low land footprint, reliability (capacity factor of 92.5%), resource efficiency, long-term affordability, safety, and low waste amount make nuclear power a compelling energy source **(Chart 1)**.

Why does nuclear not hold a more central role in our energy production mix?

Accidents and public perception. Fukushima and Chernobyl are still rooted in memories, myths have taken the ascend over facts, and the topic divides. Long development cycles, politics, and red tapes also contributed to limited adoptions. Then, there is waste. Albeit in small amounts, NPPs produce highly radioactive waste. While most is processed (e.g., 97% recycled), small amounts (e.g., 3%, or 700kg per GWh) are hazardous and need to be isolated for a long time (although it becomes substantially less hazardous even in a few decades). The small hazardous waste quantities do make it readily manageable though.

Chart 1. Nuclear, Cleanest and Most Efficient Energy Source



Source. MAM Research, Sprott, US Department of Energy

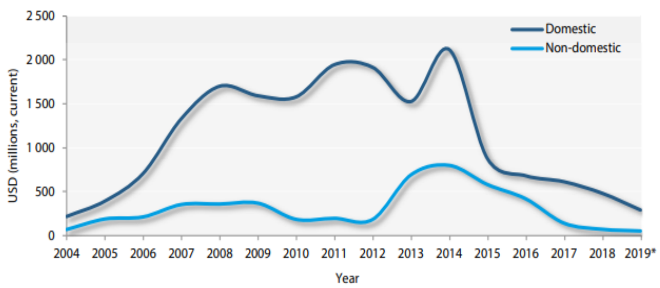
After a decade of low capital expenditures and governments coming to the realization that we cannot exclusively rely on renewable energies to power the grid, nuclear comes back into the picture. We saw major sentiment shifts from hate to love for nuclear in recent quarters. The US senate committee officially stated nuclear power is key to getting to zero carbon emissions in December 2020. Democrats voted in favor. CNN broadcasted a positive show on nuclear power. Four years after Fukushima, Japan restarted some of its nuclear plants.

In our view, we are at the forefront of a secular bull market in uranium. In the past couple months, we have been tracking and looking to understand the market dynamics at play and come down to the conclusions this could very well be the opportunity of the next 3-5 years, maybe even the decade. Let us dive into more details.

Uranium Resources

Sufficient uranium resources have been identified to support even the most aggressive growth scenarios in nuclear power capacity. However, most of the in-ground uranium cannot be brought to market without improved pricing conditions. Unattractive dynamics slowed exploration investments in the last decade **(Chart 2)**. From 2014 to 2015, total expenditures dropped from over 2bn to 875m, and continued to decline. 681.9m in 2016, 614.2m in 2017, 482.9m in 2018, and so far 292.4m in 2019 (est.). Exploration and mine development expenditures dropped 85% between 2012 and 2019.

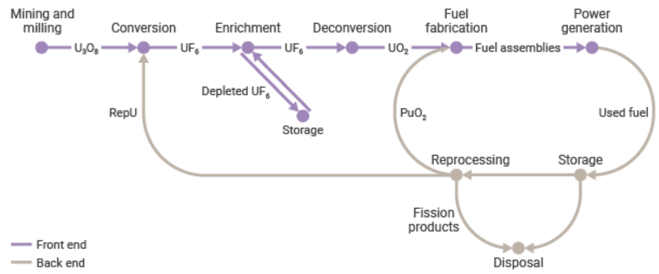
Chart 2. Trends in exploration and development expenditures



Source. OECD

Mining and milling, conversion, enrichment and deconversion are fairly standardized - *commoditized* - processes. However, fabrication is a specialized manufacturing process unique to each reactor and the specifications of each operator. As such, it is not a commodity-like product. The nuclear fuel cycle is a long process **(Chart 3)**. Not only does it take years for mining to begin once a uranium deposit is considered economically viable, but the yellowcake by-product produced by mines cannot be directly used as a nuclear fuel. Fuel processing also takes a substantial amount of time.

Chart 3. Nuclear fuel cycle overview

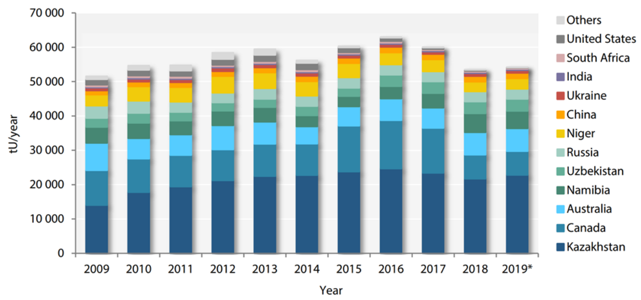


Source. World Nuclear Association

Uranium Supply

19 countries were producing uranium, or 54.2 ktU, in 2019. Kazakhstan remained the largest producer **(Chart 4)**, by far, despite having instituted production cuts in response to an oversupplied market and consistently falling spot prices over the last decade **(Chart 5)**. The country itself produces more than the next four largest producers (e.g., Canada, Australia, Namibia, and Uzbekistan). Global annual production dropped from 63.0 ktU (at the peak) in 2016, a 14% decline.

Chart 4. Recent world uranium production (tU p.a.)



Source. OECD

Chart 5. Uranium (U3O8) Swap Futures Continuous (Weekly)

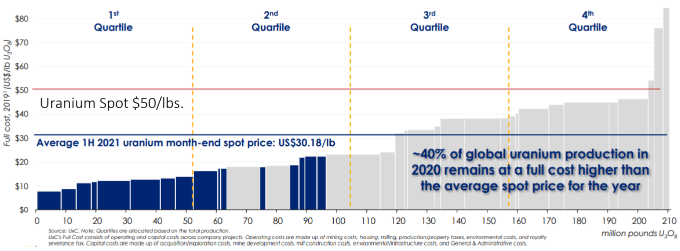
Source. Bloomberg, MAM Research

Amid persistently poor market conditions, miners have been constrained to cut back or shut down production altogether at some facilities to reduce the oversupply and, in turn, exert upward pressures on prices. Total idled uranium production capacity currently stands at 27.7 ktU p.a. Although each mine operation is unique in terms of operation costs and regulatory requirements, idled mines could resume production within roughly one year, given all permits and licenses remain valid. These facilities could be expected to be brought back online before new mines are established.

Significant portions of identified resources have nonetheless never been extracted. On average, timelines for extractions of identified resources are in the order of a decade or more. The timeframe expands to several decades for delineation of undiscovered resources (IAEA, 2020).

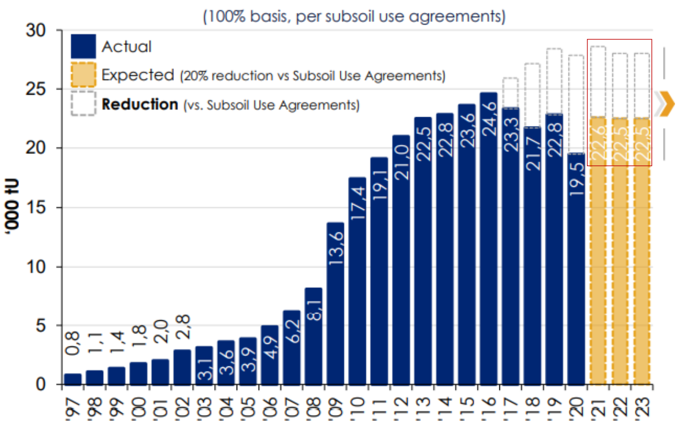
Spot uranium price from a few weeks ago ($30/lb.) implies a little under half of today's mines would not be economically viable **(Chart 6)**. Current prices ($50/lb.) imply that 75% could be economically viable. However, for mines to come online, producers need prices to sustainably remain elevated. Miners are inclined to stay disciplined to achieve persistently higher prices, as expressed in some investor presentations **(Chart 7)**. Strategies are moving away from volume and into value, thus implying prices could remain elevated in the coming decade.

Chart 6. Global Uranium Cost Curve



Source. Kazatomprom H1 2021 Investor Presentation

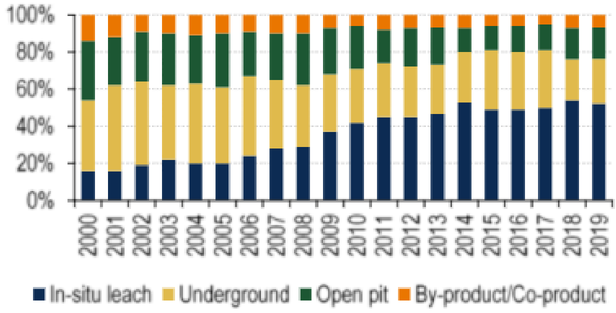
Chart 7. Kazakhstan production volume



Source. Kazatomprom H1 2021 Investor Presentation

In 2019, over 50% of uranium production was done through in-situ leaching **(Chart 8)** with costs typically at the bottom of the curve. It falls in contrast with other mined commodities where low cost producers typically are the more conventional miners. Underground mining (e.g., Cigar Lake, Canada) tends to have slightly higher costs. Open pit (e.g., Rössing, Namibia) operates on the higher end of the curve. Sometimes, uranium extracted is more of a by-product of other mining operations (e.g., Olympic Dam, Australia: copper, uranium, and gold).

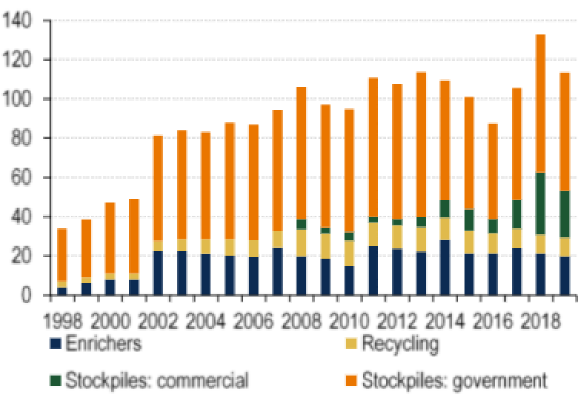
Chart 8. World Uranium production by method (% of total)



Source. UxC

A big question mark around readily available supply, outside production, is inventory. Uranium inventories are difficult to estimate. There are two primary, yet different, approaches. Our preferred method is the one taken by UxC. According to them, a large portion of commercial inventories are "pipeline materials" necessary to the normal operation of the nuclear supply chain and is not "excess". Excess commercial inventory was estimated around 166 ktU (U3O8) at year-end 2017, of which 5-10% could be considered mobile at any given time (e.g., available to the spot market) **(Chart 9)**.

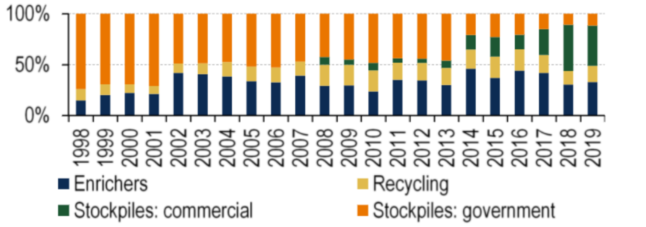
Chart 9. World secondary uranium supplies by source (Mlbs.)



Source. UxC

The contribution of commercial stockpiles to the secondary supply market surged post-Fukushima **(Chart 10)**. Japan, then the world's fourth largest producer of nuclear power, began shutting down its nuclear power plants rapidly thus creating a change in the supply-demand balance. Inventories expanded rapidly. However, the trend is inverting. Inventories are being drawn. We see two factors likely at play here. (1) Mines were forced into shutdown or idling from persistently low uranium prices. (2) The pandemic and subsequent restrictions forced additional capacity offline, thus leading to an even tighter and imbalanced market per 2020 estimates.

Chart 10. World secondary uranium supply by source (% Total)

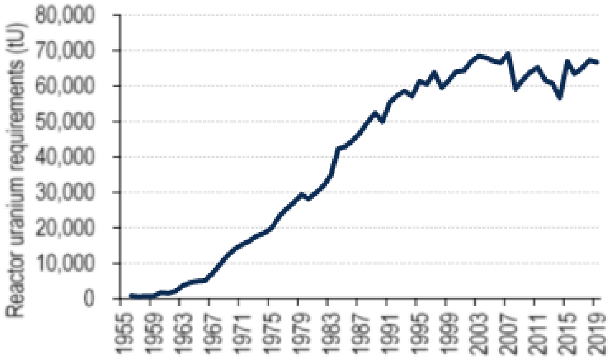


Source. UxC

Uranium Demand

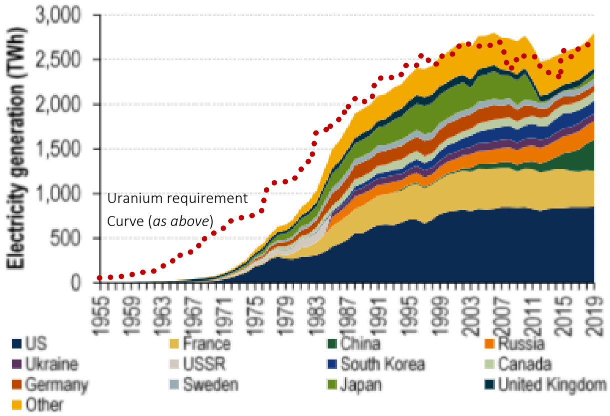
99% of mined uranium is used for nuclear power generation, contributing to approximately c.10% to the global electricity generation in 2019. As such, demand for electricity generated from NPPs drives demand for uranium. Uranium demand has two key components: requirements (current year fuel needs) and inventory build. Global uranium requirement **(Chart 11)** and electricity generation from nuclear power **(Chart 12)** have very similar curve shapes.

Chart 11. World uranium requirements (tU)



Source. OECD

Chart 12. World electricity generation from nuclear (TWh)



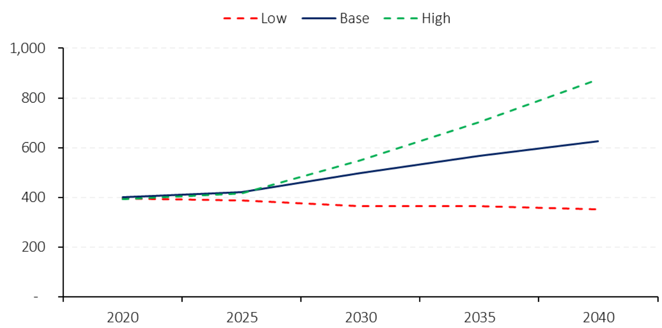
Source. BP Statistical Review of World Energy 2020

The United states are the largest producer of electricity from nuclear power in the world. France is the most nuclear energy dependent country with 70.6% of its electricity generation sourced from NPPs. The 443 operational commercial nuclear reactors in the world currently generate 393.2GWe per year.

Over the next three decades, the global population is bound to grow further. Urbanization trends are unlikely to abate any time soon. Global electricity demand is expected to grow at 2.1% p.a. to 2040 (83% increase), twice the rate of primary energy demand, and between 123% and 150% by 2050 (IEA). As the shift towards clean and sustainable energy continues, the importance of nuclear power in the energy mix to serve as a base load is bound to increase. Although not as impactful on demand, other factors need to be considered: capacity factor, U-SWU substitution, burn up, and operating license renewals and extensions. To better assess the future end demand, we assume each gigawatt electric ("GWe") of added electricity production capacity requires approximately 150 tU of incremental mine production per year and 300-400 tU for the initial fuel load. We projected minimum production needs at around 98 ktU by 2040, a 52% increase from 2020 levels.

The installed capacity and uranium requirement forecasts, although uncertain because of the aforementioned factors, point to long-term demand growth. Installed nuclear capacity is projected to increase from about 400GWe in the beginning of 2019 to about 626GWe by 2040 **(Chart 13)**, a 57% jump.

Chart 13. Projected installed nuclear capacity (GWe)



Source. BNEF, OECD

However, we believe current assumptions of future installed nuclear capacity are grossly underestimated. From the get go, current estimates do not include electricity requirements for green hydrogen production. Then, when doing the math, you realize current estimates expect the share of nuclear power in the global energy mix to decline from around 10-11% today to somewhere around 7-8% by 2040. We do not believe in a phase out of NPPs globally. In our view, nuclear energy has the potential to gain "market share" in the global energy mix. In a move to net-zero, the above figures likely underrepresent the future installed nuclear capacity, a strong upside risk.

Race to Net Zero

Relying almost exclusively on renewable energy for our grid is wishful thinking. The energy grid of tomorrow will likely blend renewables, hydrogen, and nuclear. If the Covid-19 pandemic and other events of the past year can teach us anything is we cannot rely exclusively on renewables. Numerous are the grid stability issues arising with high inputs from the intermittent power provided by renewable energy sources like wind and solar without battery storage.

Balancing a power grid with subsidized renewables that have preferential feed-in access is proving to be quite a technical and economical challenge in Europe, England, and the US. Had Texas relied even partially on nuclear, $1,000 electric bills would not have been in the mail. This argues strongly in favor of nuclear as a complementary carbon-free source of electricity to solar and wind. Research already demonstrate how nuclear power can provide a baseline **(Chart 14)**.

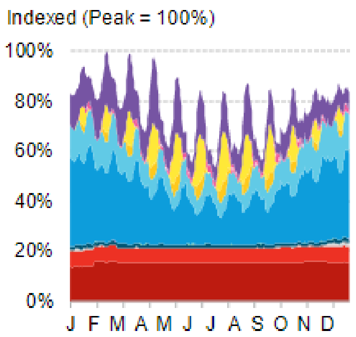


Chart 14. Annual electricity generation to supply end-use in Europe by 2050

Dark and light red: Nuclear
Dark and light blue: Wind
Yellow: Solar
Purple: Geothermal

Source. BloombergNEF

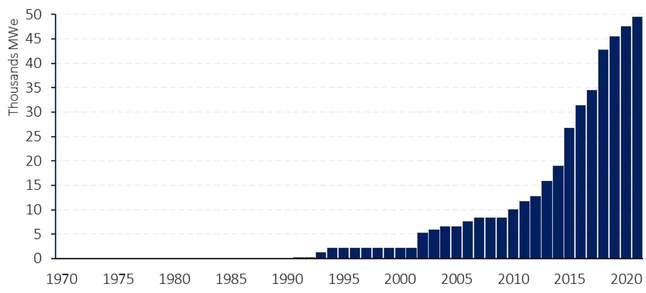
Already the world's fourth largest nuclear energy producer, Japan will need to more than quadruple the pace at which it shuts down coal power plants and ramp up the renewable energy capacity over the next decade to meet its climate pledge to zero out on carbon emissions. As of March 2020, there was a total of 54 nuclear reactor, out of which 42 were operable in the country, but only 9 reactors in 5 NPPs were operating. These offline reactors are now restarting.

In Europe, experts have bene tasked with assessing whether the European Union should be labeling nuclear power as a green investment and define/qualify the fuel as sustainable. Preliminary findings are in favor. "We cannot afford to ignore any energy sources that have prerequisites to make a positive contribution on the path towards climate neutrality", wrote the members of the European Parliament in a letter to the European Commission. These are crucial developments since they have the potential to unlock billions of euros in funding. It could also open up the door for ESG investors to invest in the future of nuclear (fission) and potentially uranium. Unlike others however, we do not place a big emphasis on Germany shutting down coal plants in favor of a nuclear program yet.

China's Big Bid

In order to reach its zero carbon emission goals, China needs to materially invest in nuclear power and it knows it. Moves to build out nuclear power plants can be traced to the 1970s. In 2005, the country moved into a rapid development phase **(Chart 15)**, laid out in its 11th Five-Year Plan. Recently, the draft of its 14th Five-Year Plan (2021-2025) showed how it is planning to reach 70GWe in nuclear capacity by 2025.

Chart 15. Operable NPPs Capacity in China (MWe)



Source. MAM Research, World Nuclear Association

China is also heavily investing in the future of nuclear energy as it breaks ground on a next generation of smaller reactors that could be paced closer to urban centers, or end demand.

In October 2018, the NDRC's Energy Research Institute noted China's nuclear power generating capacity needs to increase to 554GWe by 2050 if the country is to play its part in limiting global temperature from rising by more than 1.5°C. Implicitly, the share of nuclear power in its energy mix would increase from 4% to 28% over this period.

The most recent projections see China generating 70-80GWe by 2025, 200GWe by 2030, and 400-500GWe by 2050. This is a huge increase from current levels. Arguably, one of the key components in our bull case is how widely underestimated the demand for uranium out of China is in the long-term. Consensus figures call for 559GWe by 2050!

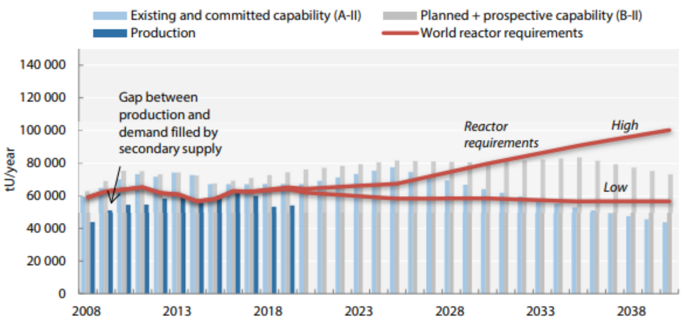
In the base case we established using trusted sources, global electricity generation capacity from nuclear power is bound to growth to 626GWe by 2040, implying China will represent about 56% of global production. The country's move towards nuclear makes sense if it wants to achieve its zero carbon emissions target by 2050.

A key angle to nuclear is its resilience in times of trouble, this becomes particularly interesting for China who is a resource poor country. It makes a lot of sense for the country to shift hard to nuclear and continually store over 10 years of fuel on the mainland. The more the CCP finds itself in conflict with the West in the future, the more such move has meaning. In light of their plan, it is set to exert pressure on spot markets.

Welcome to ETF Country

The interesting thing about the uranium market is how tight it is today, even without projecting for a rapid electrification or transition to net-zero by 2050. After 2020, secondary sources of uranium are expected to decline in availability and reactor requirements will gradually have to be met through primary production. After 2028, as secondary sources of uranium run out, demand needs will need to be met exclusively through primary production: market enters a supply deficit **(Chart 16)**.

Chart 16. Projected world uranium production capability

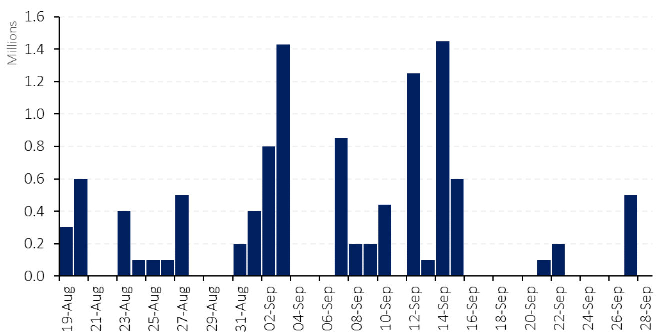


Source. OECD

However, this is where things become even more interesting. In April, Sprott announced its intent to acquire UPC (Uranium Participation Corp.) to convert it in a trust managed by Sprott. UPC had just over 16Mlbs. of physical uranium in its holdings. Sprott is a very serious player in the commodity space and its entry into the uranium market is a true game changer.

The uranium market is different. Almost everyone who owns uranium today owns it because they intend to consume it in their reactors. The utilities are only hedging on average about 35% of their future uranium needs. In a market with a deficit, they are all implicitly short uranium. With an entity like Sprott buying up the free float **(Chart 17)**, utilities are going to get squeezed. We all know how squeezes work. Utility companies are blissfully unaware, eventually they will panic and pay any price for uranium to fuel their reactors. A reactor running out of uranium is nothing but an expensive paperweight.

Chart 17. Sprott Physical Uranium Trust Purchases (Daily)



Source. MAM Research

Risks to Our Thesis

As per all investment theses, we acknowledge downside risks.

- A lack of discipline from miners and producers would lead to excess supply in the market. In turn, it has the power to invert the inventory draws observed in the past couple of years, ultimately exerting downward pressures on prices.
- Current fiscal plans in the work include life extensions of aging nuclear power plants as well as the build out of new capacity over the next decade. Changes in government policies and a shift away from nuclear would imply a lower than expected future demand for nuclear. As a result, the market could rely on theoretically longer lasting secondary supplies over primary production, thus maintaining prices lower for longer.
- China is primary to a long-term uranium bull cycle. Slower than anticipated nuclear power plants constructions and developments would impact long-term forecasts. In turn, it reduces long-term demand outlooks for the commodity and affects the supply-demand dynamics core to uranium bull cases.
- China, or any other country, successfully develops more efficient reactors. The technological improvements could require less burn up fuel or simply less uranium for a given electrical output.
- Japan reverses course on its plan to turn back online its nuclear reactors, meaning anticipated short-to-medium term demand needs fade.
- The global electrical energy needs do not grow as much as expected in the long-term.
- The regulatory changes currently in the works in Europe to classify nuclear power as a sustainable source of energy fail. As a result, less investments will be attributed to the energy source, not as many nuclear plants power see the light of day, ultimately impairing end demand outlooks.
- Non-commercial buyers of uranium begin to lose interest in the commodity. As such, we could see outflows from the physical uranium trust. In turn, the spot market would be “flooded” with secondary supply, exerting downward pressure on prices.
- As tragic as can be, a nuclear incident occurs. While there have been tremendous improvements on nuclear reactor safety, the world is never safe from a failure. This would spark back a wave of “hate” for the energy source and significantly dent the outlook for uranium.

Investment Implications

No matter what happens to uranium prices from here on out, two things are certain. First, nothing goes up in a straight line. As such, the recent price increase seen as we were working on this thesis is likely to retrace, thus offering more attractive entry points. We currently expect significant market volatility in the days to weeks ahead for uranium. Second, this has now become one of the most interesting stories in finance. The situation is truly unprecedented. Given the critical nature of the commodity being cornered, governments could be forced to intervene. However, though we are not sure how it could happen yet, we certainly doubt any intervention would occur this far below the previous all-time highs.

The recent price retracement and heightened volatility now make an attractive entry point. Though we like the long-term prospects, we look to tactically take advantage of heightened volatility on uranium miners. We were looking for uranium prices to fall lower than $35 to "dip our toes" with outright long positions. However, today, we favor selling at-the-money put options on the Northshore Global Uranium Mining ETF.

1. Northshore Global Uranium Mining ETF (**Chart 18)** gives exposure to companies that devote at least 50% of their to mining, exploration, development, and production of uranium and/or hold physical uranium, owning uranium royalties, or engaging in non-mining activities. It is one of, if not, the most pure-play equity ETF on uranium.

We continue to monitor the Sprott Physical Uranium Trust **(Chart 19)**, a commodity backed fund holding uranium, but in our view it is not the true opportunity right now.

We will keep you informed as we look to add or adjust exposure to the commodity in the portfolios.

As always, please feel free to reach out to us if you have any questions regarding this research.

Kind regards,

MAM Investment Team

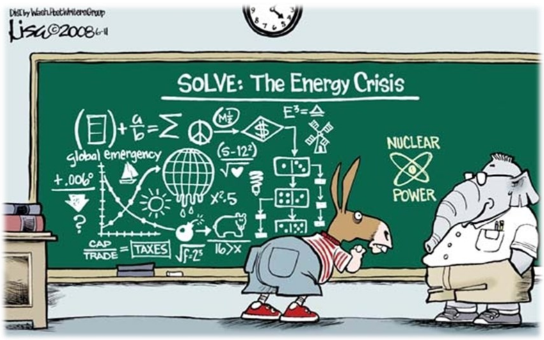


Chart 18. Northshore Global Uranium Mining ETF (Daily)

Source. MAM Research, Bloomberg

Chart 19. Sprott Physical Uranium Trust (Daily)

Source. MAM Research, Bloomberg

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