Death of Uranium and Renaissance of Vanadium Batteries

March 17, 2017 by John Lee, CFA (https://twitter.com/johnlee25893955?lang=en)

I have owned shares of uranium mining companies in the past, anticipating the inevitable rebound of nuclear energy following the Fukushima nuclear plant accident.

However, through my recent research into the renewable energy sector and vanadium batteries, I became bearish on nuclear energy and sold my shares in Energy Fuel Inc. (TSX: EFR) and Fission Uranium Corp. (TSX: FCU) in February 2017.

Why? In this article, I will discuss:

1. The state of the big four nuclear power houses (Westinghouse, Toshiba, Areva and EDF), and the rising costs and long delays associated with nuclear power plant construction;

2. The case for uranium bulls;

3. The Nuclear Power Generating Capacity Growth Forecasts by 2030 issued by the International Atomic Energy Agency (IAEA) which, over the years, turned me into a uranium bear;

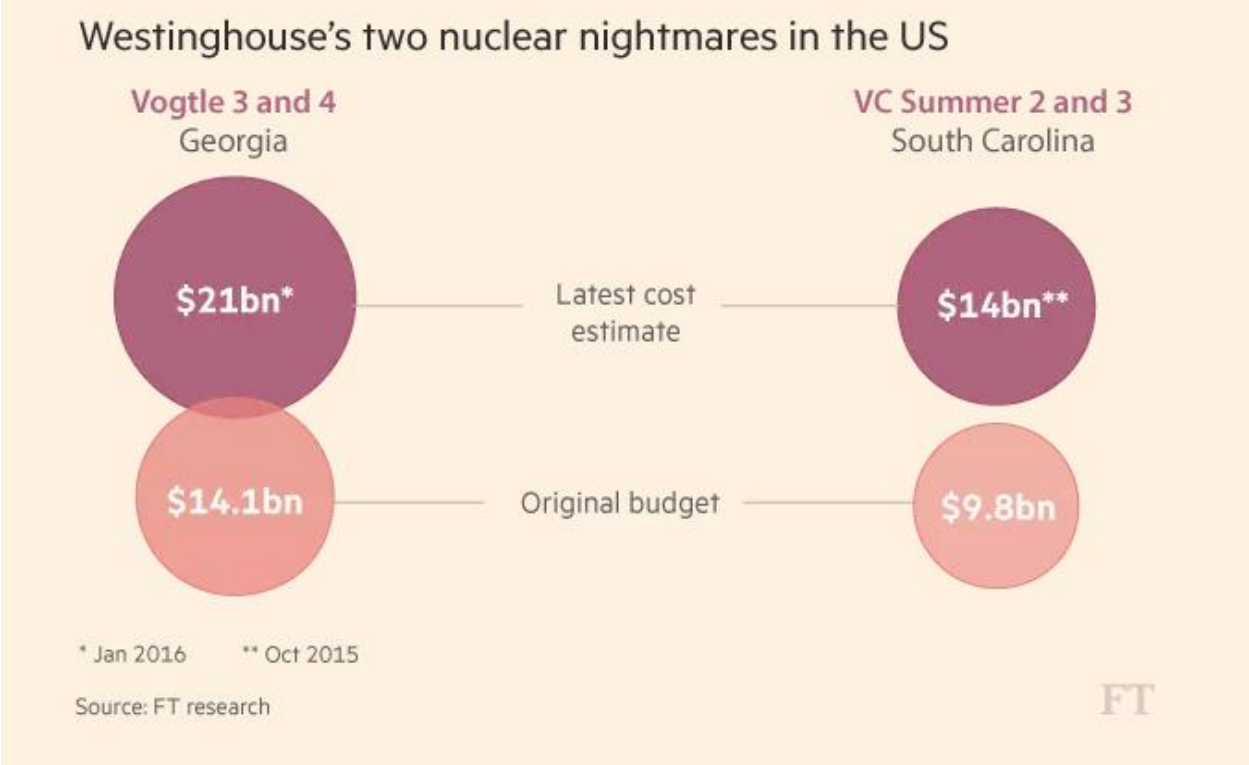
4. The rapidly decreasing cost of renewable energy and its deployment on a worldwide scale as the green energy of choice; and

5. The emergence of utility-scale batteries that improve the availability factor of wind and solar power to serve as base load energy.

1. The rising costs and long delays associated with nuclear power plant construction

I shall start by quoting a *Financial Times* article dated February 16, 2017 by Ed Crooks and Kana Inagaki, titled "Toshiba brought to its knees by two US nuclear plants":

"Westinghouse, Toshiba's US-based nuclear engineering subsidiary, is building at Vogtle two of its new AP1000 reactors, a "generation III plus" design that was intended to be the flagship of its expansion into markets around the world. Two more are being built about a hundred miles away in South Carolina at a plant called VC Summer….The projects are already more than three years behind schedule and, on a combined basis, more than $10bn over their original budgets. This week the timetable for the Summer project was pushed back again, and there were warnings that construction at Vogtle could also slip further.



… The contracts for the new reactors were signed in 2008 by the plants' owners, led by Southern Company for Vogtle, and Scana for Summer….

Scana said on Tuesday that it now expected the first new reactor at Summer to be in service in 2020, not 2019 as it had previously planned.

At Vogtle, the plan to start the first new reactor in 2019 looks 'extremely challenging', Mr Jacobs and Mr Roetger (Georgia Public Service Commission) warned on Monday, as a result of a 'lack of construction progress' since their previous report last August.

If construction continues to fall behind schedule, Westinghouse's losses on the two contracts could grow even larger.

[Gregory Jaczko, who was chairman in 2009-12 of the Nuclear Regulatory Commission] says the problems of Vogtle and Summer have probably stopped any new nuclear development in the US for a generation.

'These projects are killing construction, because nobody can finance new reactors,' he says. 'It may be 20 or 30 years before investors will be interested again.'"[1]

[1] E. Crooks & K. Inagaki, "Toshiba brought to its knees by two US nuclear plants" (February 16, 2017) *Financial Times*.
https://www.ft.com/content/b7053ab4-f45e-11e6-95ee-f14e55513608

A month later, according to the *Asia Nikkei* article dated March 11, 2017, titled "Toshiba scrambles to stem further bleeding from Westinghouse":

"Toshiba is considering having subsidiary Westinghouse Electric file for Chapter 11 bankruptcy protection to limit liability for future cost overruns on long-delayed U.S. nuclear projects. Yet loan guarantees and potential compensation claims could still prove costly if progress remains slow.

Cutting losses

Westinghouse signed fixed-price agreements in the fall of 2015 for two ongoing nuclear power projects in the U.S. The power companies operating the plants agreed to pay more for construction work in exchange for the Toshiba unit covering any additional costs.

Less than a year and a half later, Toshiba announced an estimated 712.5 billion yen ($6.18 billion) impairment loss on its American nuclear operations for the nine months through December, stemming from sluggish demand and soaring costs to comply with higher safety standards. Liabilities will likely exceed assets by 150 billion yen when the company closes its books for the fiscal year this month.

…U.S. government guarantees on $8.3 billion in loans for one project in Georgia. If Westinghouse cannot finish the job, repayment of these loans will likely be delayed, in which case the government would take on the debt.

It remains unclear how Washington and Toshiba would split the costs in this case. But the possibility that American taxpayers could bear some of the burden has spurred negotiations involving the U.S. and Japanese governments to settle the matter."

Toshiba is reported to exit the nuclear power business in an article dated January 29 2017, at neutronbytes.com titled

"Toshiba to withdraw from nuclear plant construction":

"The company's decision to cease taking orders effectively marks its withdrawal from the nuclear energy business. It also apparently ends the so-called nuclear renaissance in the U.S. for full size reactors.

During 2007-2010 there were more than two dozen applications expected for new reactors, but now only a few licenses that have been completed and they do not have any links to near term plans to build the units."[2]

Almost half of the reactors in the United States have been operating for 40 years or more and are nearing retirement. Yet the four AP1000 reactors are the only ones under construction.[3]

[2] D. Yurman, "Toshiba to withdraw from nuclear plant construction" (January 29, 2017) *Neutron Bytes*. https://neutronbytes.com/2017/01/29/toshiba-to-withdraw-from-nuclear-plant-construction/

I believe that nuclear power is certain to continue its downward slide in the US for the reasons I will explain.

How about EDF and Areva, two of the remaining global nuclear industry giants?

According to an article by Mycle Schneider posted at worldnuclearreport.org dated April 14, 2016, titled "Asahi WebRonza (Japan): After the Paris-Agreement: Corporate Meltdown in the Nuclear Industry":

"Launched as a response to the Chernobyl accident, at the brink of the 30th anniversary of the disaster in Ukraine, not a single so-called Generation-III+ EPR reactor is generating power anywhere in the world.

In the meantime, the self-proclaimed 'global leader in nuclear energy,' the French state-controlled AREVA, went bankrupt. After a cumulate loss of €10 billion ($11.4 billion) over the past five years, significantly exceeding its peak annual turnover, and a debt load of €6 billion ($6.8 billion), the company will be taken apart. Its share value has eroded by 95 percent over the past eight years—a plunge exceeding TEPCO's fall after the Fukushima crisis hit the company and prior to its de-facto nationalization—hitting a new historic low on February 19, 2016. The government's rescue strategy—injecting €5 billion and forcing EDF to absorb AREVA's reactor business—is in-turn increasing the risk for EDF. Another significant barrier for the conclusion of the rescue deal remains the multibillion-euro liability of the Hinkley Point predecessor projects in Olkiluoto, Finland, and Flamanville, France. The EPR construction in Finland started over ten years ago. The plant was to begin generating carbon-free electricity by 2009 and was part of the country's greenhouse gas abatement strategy under the Kyoto Protocol. Now, the plant is scheduled to produce power in 'late 2018.'

The sister plant in France is not doing any better—on the contrary. Construction started in 2007 with completion planned for 2012. Officially, the target date currently is the same as for the Finnish project. The investment-cost estimate since construction start, exploded by more than a factor of three to €10.5 billion ($12 billion).... In addition, EDF struggles with a €37.4 billion ($42.6 billion) debt burden, rapidly increasing production costs in its aging nuclear fleet, significant post-Fukushima and other investment needs, and a shrinking client base with stagnating or declining consumption levels over the past five years in a row.

The international outlook is not any rosier. There have been 40 reactors connected to the world's power grids in ten years after an average construction time of close to 10 years. Compare this

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[3] "United States of America." *iaea.org.* Power Reactor Information System (PRIS), International Atomic Energy Agency (IAEA), 14 March 2017.
https://www.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=US

with the four climate heros' 'illustrative scenario' of 115 startups per year to 2050. Too little renewal to avoid the continuous aging of the world nuclear fleet whose average age is now standing at around 30 years. Some 60 units under construction have been in the building stage for an average of around eight years; at least three-quarters are delayed, four have been listed as 'under construction' for over 30 years. The Organisation for Economic Co-operation and Development's International Energy Agency projects in its 'New Policy Scenario' a net addition of 222 nuclear gigawatts (GW) over the coming 25 years. This compares with the net nuclear addition of 22 GW over the past 25 years—another illustration of the level of wishful thinking in current international projections.

On the other side, the renewable energy sector is booming and the worldwide investment levels increased by 4% to reach a new record level in 2015 with an estimated $329 billion. The numbers are all the more remarkable as fossil fuel prices were low and renewable energy system costs continued to fall, leading to a 30% increase of installed capacity in wind (+64 GW) and solar (+57 GW), sixteen times the quite exceptional net nuclear addition (+6.7 GW). Even with three to eight times lower power generation per installed GW, renewable electricity production is growing much faster than nuclear. At least eight countries, one quarter of the nuclear nations, including three of the four largest economies in the world (China, Germany, Japan) are already generating more power from renewables than from nuclear.

…renewables—are not only considerably cheaper, they are also much faster to implement….

…the reactor-building industry might want to turn to a safe haven: decommissioning….

"Indeed, Masayoshi Hirata, Toshiba's senior Vice-President, told analysts in November 2015: 'We believe there will be a more global demand for the nuclear decommissioning'. JP Morgan Securities Japan responded by issuing a research note entitled 'First Step Toward Change'"[4].

Continuing the debate over nuclear energy versus renewable energy, EDF Vice President, Mark Boillot opined on February 15, 2017, in his article published on lesechos.fr titled "Le solaire peut-il tout emporter dans l'énergie?"[5] (the following is a Google translation):

[4] M. Schneider, "Asahi WebRonza (Japan): After the Paris-Agreement: Corporate Meltdown in the Nuclear Industry" (April 14, 2016) *worldnuclearreport.org*. https://www.worldnuclearreport.org/Asahi-WebRonza-After-the-Paris-Agreement-Corporate-Meltdown-in-the-Nuclear.html

[5] "Can solar energy carry everything?"

"Over the last twelve months in France, more than 2 GW of solar and wind power have been put into service, ie more than one EPR reactor (1.7 GW)….

And yet, solar electricity production and wind power are becoming less and less expensive. Microgrids, electrical islets at the scale of a neighborhood or a village, are multiplying. Battery storage is expanding massively in the United States. Large nuclear or thermal power plants designed to function as a base are chal- lenged by the more flexible decentralized model….

Citizens are seduced by this decentralized model. They are willing to pay more for solar electricity. They want to be able to become actors of the electrical system by acting at the right time on their electrical appliances by delaying or reducing their consumption, by charging their electric car when the wind blows or the summer when the sun is shining."[6]

At Hinkley Point in the UK, where EDF has a contract to build two EPR reactors at an estimated construction cost of £18 billion, or £24.5 billion including financing costs. The National Audit Office estimates the additional cost to consumers under the "strike price" will be £29.7 billion.[7] Any hiccup at Hinkley Point could spell the end of nuclear power in the UK.

What is the future of nuclear power and who are the players? According to a *Financial Times* article dated February 14, 2017, by Kana Inagaki, Leo Lewis, and Ed Crooks titled "Downfall of Toshiba, a nuclear industry titan":

"'From now on, there are only three major players in the global nuclear power plant market: Korea, China and Russia,'" says Michael Shellenberger of Environmental Progress, a pro-nuclear campaign group. 'The US, the EU and Japan are just out of the game. France could get back in, but they are not competitive today.'

Toshiba bought the US-based Westinghouse nuclear business from the British government's BNFL for $5.4bn in 2006, in the hope of profiting from an upturn in reactor construction that was optimistically dubbed the 'nuclear renaissance'.

Instead, the Westinghouse deal has brought Toshiba to its knees."[8]

But they might end up squabbling over scraps – there were just three reactor construction starts last year around the world.

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[6] M. Boillot, "Le solaire peut-il tout emporter dans l'énergie?" (February 15, 2017) *LesEchos.fr*. https://www.lesechos.fr/idees-debats/cercle/0211803366658-le-solaire-peut-il-tout-emporter-dans-lenergie-2065262.php

[7] Wikipedia contributors. "Hinkley Point C nuclear power station." *Wikipedia, The Free Encyclopedia*. Wikipedia, The Free Encyclopedia, 11 Mar. 2017. Web. 15 Mar. 2017. https://en.wikipedia.org/wiki/Hinkley_Point_C_nuclear_power_station

[8] K. Inagaki, L. Lewis & E. Crooks, "Downfall of Toshiba, a nuclear industry titan" (February 14, 2017) *Financial Times*. https://www.ft.com/content/416a2c9c-f2d3-11e6-8758-6876151821a6

A wave of retirement of aging nuclear reactors is approaching: almost 200 of the 434 reactors operating at the end of 2013 are set to be retired in the period to 2040 according to The International Energy Agency.[9]

While nuclear accidents are few and far between, the recent *The New York Times* article dated March 11, 2017 by Motoko Rich, titled "Struggling With Japan's Nuclear Waste, Six Years After Disaster", remind us of the devastating economic and environmental impacts of a nuclear accident: "FUKUSHIMA DAIICHI NUCLEAR POWER STATION — Six years after the largest nuclear disaster in a quarter-century, Japanese officials have still not solved a basic problem: what to do with an ever-growing pile of radioactive waste. Each form of waste at the Fukushima Daiichi Nuclear Power Station, where three reactors melted down after an earthquake and a tsunami on March 11, 2011, presents its own challenges.

400 Tons of Contaminated Water Per Day…

3,519 Containers of Radioactive Sludge…

64,700 Cubic Meters of Discarded Protective Clothing…

Branches and Logs From 220 Acres of Deforested Land…

200,400 Cubic Meters of Radioactive Rubble…

3.5 Billion Gallons of Soil…

1,573 Nuclear Fuel Rods…

But the Japanese government and Tokyo Electric say they are committed to removing all the waste and cleaning the site, estimated at a cost of $188.6 billion."[10]

The New York Times quotes Mark Cooper in its article dated February 18, 2017 titled "The Murky Future of Nuclear Power in the United States":

"'You can make it go fast, and you can make it be cheap — but not if you adhere to the standard of care that we do,' said Mark Cooper of the Institute for Energy and the Environment at Vermont Law School, referring to the United States regulatory body, which is considered one of the most meticulous in the world. 'Nuclear safety always undermines nuclear economics. Inherently, it's a technology whose time never comes.'"[11]

2. The case for uranium bulls

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[9] "WORLD ENERGY OUTLOOK 2014 FACTSHEET Nuclear power: retreat, revival or renaissance?" *International Energy Agency*
http://www.iea.org/media/news/2014/press/141112_WEO_FactSheet_Nuclear.pdf

[10] M. Rich, "Struggling With Japan's Nuclear Waste, Six Years After Disaster" (March 11, 2017) *The New York Times.* https://www.nytimes.com/2017/03/11/world/asia/struggling-with-japans-nuclear-waste-six-years-after-disaster.html

[11] D. Cardwell, "The Murky Future of Nuclear Power in the United States" (February 18, 2017) *The New York Times.* https://www.nytimes.com/2017/02/18/business/energy-environment/nuclear-power-westinghouse-toshiba.html?_r=1

Any discussion on uranium is not complete without commentary from Marin Katusa, the uranium "perma-bull" of Katusa Research, who wrote in his article dated January 6, 2017 and titled "Prepare to Profit Series: Why I'm About to Make One of the Biggest Bets of My Career":

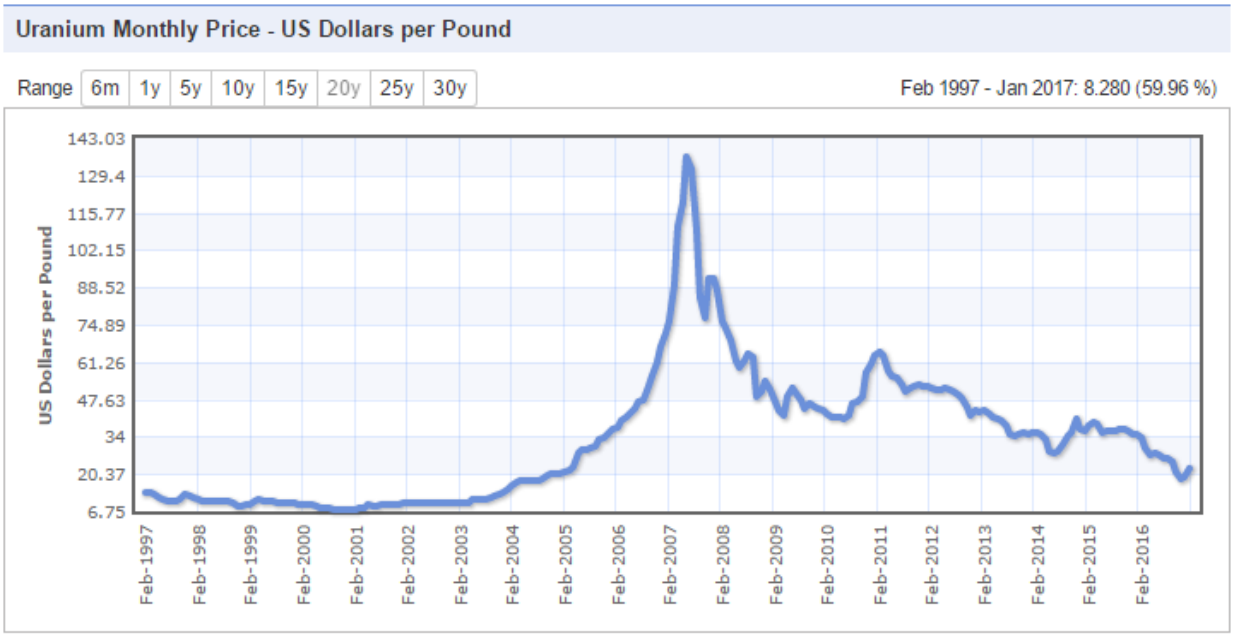
"The $20 per pound range– is a crisis price for the uranium industry. Anything under $30 per pound will prevent any new mines from being built….

Uranium spot pricing is below levels set during the 2008 financial crisis. '*There has never been a worse time'* than now an industry CEO recently told Reuters.

Statements like this scare most investors away from a market. But bargain hunting contrarian investors know these statements often mark the point of maximum pessimism… and signal major investment opportunities. Investment legends like Warren Buffett and Sir John Templeton built their fortunes and reputations on buying assets when it seems like '*things can't get any worse*.' After all, when things can't get any worse, they can only get better….

That's why I'm making this sector one of the biggest bets of my career."[12]

The price of uranium did spend 20 years under $20 per pound, and the chart below does not seem to indicate any imminent rebound (if at all).



Description: Uranium, u3o8 restricted price, Nuexco exchange spot, US Dollars per Pound

www.IndexMundi.com

[12] M. Katusa, "Prepare to Profit Series: Why I'm About to Make One of the Biggest Bets of My Career" (January 6, 2017) *Katusa Research*.
https://katusaresearch.com/prepare-profit-series-im-make-one-biggest-bets-career/

"The Onagawa plant's 46-foot tall seawall was large enough and strong enough to prevent extensive flooding. The construction of the Onagawa plant was solid enough to endure high levels of ground shaking. The facility's staff was trained to handle problems.

Instead of evacuating the area like people did at Fukushima I*, Onagawa locals sought refuge at the nuclear power station*. It was the safest place around.

You probably didn't hear this story on the news. It wasn't sensational. But the fact remains that in 2011, a well-built nuclear power plant took a direct hit from one of the largest earthquakes in recorded history, without incident.

The story of Onagawa is an important chapter in the story of nuclear power. It shows how the right people can make nuclear power very safe… and it shows that used the right way, nuclear power is the ultimate form of clean energy."[13]

What would you rather have next to your home? – A thermal power plant, wind farm, or nuclear plant?

Katusa writes in his next article dated January 13, 2017 and titled "Prepare to Profit Series Part 2: A Clear Path to Much Greater Uranium Demand":

"On the mine supply side, the central Asian country of Kazakhstan (yes, where Borat is from) is currently responsible for 41% of global mining production. Canada is a distant second (16%) and Australia is a distant third (8.9%)….

On the demand side, the Big 5 consume 130 million pounds of the global uranium consumption of 182 million pounds per year. The Big 5 are: United States (30%), France (15%), China (11%), South Korea (8%), and Russia (7%). Together, these five make up around 71% of global demand….

Growing Asian demand and steady demand from massive current consumers (United States and France) means that uranium demand will grow to 190 million pounds per year by 2020 and to 220 million pounds per year by 2030, a growth of 20% in 15 years."[14]

Even accepting those highly questionable growth assumptions, 20% growth in 15 years hardly warrants a big bet on uranium.

Katusa says in his latest article dated January 25, 2017 and titled "Prepare to Profit Series Part 3 – A Huge Part of the Russia/Trump Story Nobody is Talking About":

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[13] *Ibid.*

[14] M. Katusa, "Prepare to Profit Series Part 2: A Clear Path to Much Greater Uranium Demand" (January 13, 2017) *Katusa Research*.
https://katusaresearch.com/prepare-profit-series-part-2-clear-path-much-greater-uranium-demand/

"…the U.S. generates 20% of its electricity from nuclear power. It consumes just over 45 million pounds of uranium each year. Yet, it gets just 7% of its supply from domestic U.S. uranium mines….

As for the long-term, the U.S. must encourage a massive expansion in domestic mine supply and enrichment capacity. This includes "fast tracking" the permitting process for new mines and enrichment facilities."[15]

I say, not if the US follows in the footprints of Germany and goes nuclear free.

"In summary…

Climate change is the number one worry for many people around the world. However, those people also want reliable, reasonably priced electricity to power their modern way of life. Nuclear energy provides stupendous amounts of secure, always on, always there, base load power."[16]

I disagree – nuclear power is not reasonably priced. Each new plant takes on average 10 years to build and costs $10-$20 billion or more.

"These [uranium mining] stocks have been obliterated over the past five years. The industry is in crisis. But the worse a situation is, the greater the upside when things turn around. That's why I'm making uranium one of my biggest bets of 2017."[17]

I note however, that the bottom of a market can only be known in hindsight, and the examples of Uranium Participation Corp. and Fission Uranium Corp. below, illustrate why I think the uranium bear still has some ways to go.

The following is from Uranium Participation Corp.'s latest corporate news release dated March 10, 2017:

"URANIUM PARTICIPATION CORPORATION REPORTS NET ASSET VALUE AT FEBRUARY 28, 2017

Uranium Participation Corp. had an estimated net asset value at Feb. 28, 2017, of $462.3-million or $3.83 per share. As at Feb. 28, 2017, UPC's investment portfolio is as shown in the attached table.

UPC INVESTMENT PORTFOLIO
(in thousands of dollars, except quantity amounts)

Investments in uranium	Quantity	Fair value
Uranium oxide in concentrates (U_3O_8)	10,080,024 lb	$ 297,127

[15] M. Katusa, "Prepare to Profit Series Part 3 – A Huge Part of the Russia/Trump Story Nobody is Talking About" (January 25, 2017) *Katusa Research*. https://katusaresearch.com/prepare-profit-series-part-3-huge-part-russiatrump-story-nobody-talking/
[16] *Ibid.*
[17] *Ibid*.

Uranium hexafluoride (UF6)	1,903,471 kg U	$ 161,390
U3O8 fair value per pound		
In Canadian dollars (1)		$ 29.48
In U.S. dollars		$ 22.25
UF6 fair value (1) per KgU		
In Canadian dollars (1)		$ 84.79
In U.S. dollars		$ 64.0

(1) Fair values are month-end spot prices published by Ux Consulting Company LLC, translated at the month-end noon exchange rate of $1.3248.

On Feb. 28, 2017, the common shares of UPC closed on the Toronto Stock Exchange at a value of $4.37, which represents a 14.1-per-cent premium to the net asset value per share of $3.83.

About Uranium Participation Corp.

Uranium Participation is a company that invests substantially all of its assets in uranium oxide in concentrates (U3O8) and uranium hexafluoride (UF6), with the primary investment objective of achieving appreciation in the value of its uranium holdings through increases in the uranium price. UPC provides investors with a unique opportunity to gain exposure to the price of uranium without the resource or project risk associated with investing in a traditional mining company."[18]

Closed-end commodity funds such as Central Fund of Canada (NYSE MKT: CEF) that stores precious metals, typically sells at a discount (not premium) to the net asset value, at the bottom of the commodity cycle.

The next example is a uranium exploration company – Fission Uranium Corp.:

"Fission Uranium Corp (TSX: FCU) owns the award-winning PLS uranium project, host to the near-surface, high-grade Triple R deposit - part of the largest mineralized trend in the Athabasca Basin region. Major new high-grade zones have been discovered each year since discovery in 2012 and, recently, exploration drilling encountered mineralization 600m west of the trend. Headed up by CEO, Dev Randhawa, and President & Chief Geologist, Ross McElroy, Fission is one of the most successful exploration companies in the uranium sector."[19]

According to an independent report:

[18] Uranium Participation Corp., "URANIUM PARTICIPATION CORPORATION REPORTS NET ASSET VALUE AT FEBRUARY 28, 2017" (March 10, 2017).
http://www.stockwatch.com/News/Item.aspx?bid=Z-C%3aU-2451362&symbol=U&region=C

[19] "Corporate Overview" Fission Uranium Corp.
http://www.fissionuranium.com/about/overview/

TABLE 1-7 URANIUM PRICE SENSITIVITY ANALYSIS
Fission Uranium Corp. – Patterson Lake South Property

Uranium Price (US$ / lb U_3O_8)	Uranium Price (C$ / lb U_3O_8)	Post-Tax NPV @ 10% (C$ Millions)
30	35	(186)
40	47	174
50	59	524
60	71	855
65 (Base Case)	76	1,020
70	82	1,185
80	94	1,514
90	106	1,847
100	118	2,175

[20]

Company Stock Issues - FISSION URANIUM CORP. J

Symbol	Name
FCU	FISSION URANIUM CORP. J

Fundamental Data - FCU

Security Type	Equity
Shares Issued	484,187,994
Market Cap	397,034,000
Year High	0.92
Year Low	0.49
Annual Earnings/Share	-0.02 CAD
P/E Ratio	-41.00
Annual Dividend/Share	0.00 CAD
Annual Dividend Yield	0.00 %
Ex-Dividend Date	
Sector	15104020 - Diversified Metals & Mining

source: stockwatch

Fission's Patterson Lake South Property carries pre-production capital costs of C$1,095 million, spread over three years, and has a negative project NPV of $186 million at $30/lb. of uranium. The project

[20] J. Cox, D. Ross, D. Robson, V. Liskovych & M. Wittrup, "TECHNICAL REPORT ON THE PRELIMINARY ECONOMIC ASSESSMENT OF THE PATTERSON LAKE SOUTH PROPERTY, NORTHERN SASKATCHEWAN, CANADA" (September 14, 2015) *FISSION URANIUM CORP.*
http://www.fissionuranium.com/_resources/reports/RPA_Fission_U_Patterson_Lake_South_PEA_NI_43-101_Report_FINAL_Sept_14_20.pdf

requires uranium price needs to double from the current $25/lb. to achieve a project NPV of C$524million to justify Fission's current market capitalization of nearly C$400million.[21]

3. The Nuclear Power Generating Capacity Growth Forecasts by 2030 issued by the International Atomic Energy Agency (IAEA) which, over the years, turned me into a uranium bear;

Here are official forecasts from the IAEA:

I tabulated the Nuclear Power Generating Capacity Growth Forecasts by 2030 made in the last 5 years. For example, in 2012, the IAEA forecasted 200% growth by 2030 from the 2012 level at the high end, and 23.2% at the low end.

table 1

Base Year	2016	2015	2014	2013	2012
High End	56%	68%	77%	94%	200%
Low End	1.9%	2.4%	8.8%	17%	23.2%

Notice that both the High End and Low End growth estimates have been revised sharply downwards every year for the last 5 years since the Fukushima nuclear accident. Following this trend, in 2020 the IAEA could very well forecast nuclear power generating capacity in 2030 to be less than the capacity in 2020 (under the Low End estimate).

How is that possible? Simply put, nuclear plant decommission rates are higher than commission rates.

Currently, 60 are under construction with construction for three started last year.[22] Assume it takes five years to commission a new plant (from start to finish) and at three new plant construction starts per year, there will be 25 new plants with construction starting between 2017 to 2025 that will come on line before 2030. At the same time, let's assume that 50 of the 60 plant constructions that started before 2016 come on line before 2030. The total new projects that will come on line will then be 75. This number underwhelms the 132 reactor shut-downs that are projected by 2035 as estimated by The World Nuclear Association[23].

Indeed straight from the IAEA:

"Uncertainty related to energy policy, licence renewals, shutdowns and future constructions accounts for the wide range. The projections from 2030 to 2050 involve greater degrees of uncertainty….

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[21] *Ibid.*

[22] "The Database on Nuclear Power Reactors - Overview" *iaea.org.* Power Reactor Information System (PRIS), International Atomic Energy Agency (IAEA), 15 March 2017.
https://www.iaea.org/PRIS/home.aspx

[23] "The Nuclear Fuel Report - Global Scenarios for Demand and Supply Availability 2015-2035" *world-nuclear.org.* World Nuclear Association, 15 March 2017.
http://www.world-nuclear.org/our-association/publications/publications-for-sale/nuclear-fuel-report.aspx

The world's nuclear reactor fleet is also ageing, with more than half of the 450 reactors currently in operation over 30 years old. While the low projections show only modest capacity growth, the need to replace scores of old reactors means that 'total new capacity constructed will be much greater than the apparent net increase,'…

Western Europe risks the biggest decline. With Germany phasing out nuclear power in response to the Fukushima accident...

North American capacity is also seen falling..."[24]

Going one step further, I compiled the IAEA forecasts by region in table 2 to 4 below:

Table 2: Far East (in GWe)

	Current Year	High End 2030	Low End 2030
2016	93.8	215.5	132.2
2015	87.1	219	131.8
2014	83	268	147
2013			
2012	80	274	153

Table 3: Western Europe

	Current Year	High End 2030	Low End 2030
2016	112.1	111.8	77
2015	113.7	112	62.7
2014	125	144.3	81.5
2013	114	124	68
2012	115	126	70

Table 4: North America

	Current Year	High End 2030	Low End 2030
2016	112.7	126	92.5
2015	112.1	139.7	92
2014	112.6	138.9	92.4
2013	116	143	101
2012	114	148	111

Table 1, 2, 3, 4 Source:

https://www.iaea.org/newscenter/pressreleases/iaea-sees-global-nuclear-power-capacity-growing-through-2030

[24] "IAEA Sees Global Nuclear Power Capacity Growing Through 2030" (September 23, 2016) *International Atomic Energy Agency*.
https://www.iaea.org/newscenter/pressreleases/iaea-sees-global-nuclear-power-capacity-growing-through-2030

https://www.iaea.org/newscenter/news/iaea-sees-global-nuclear-power-capacity-expanding-in-decades-to-comehttps://www.iaea.org/About/Policy/GC/GC58/GC58InfDocuments/English/gc58inf-6_en.pdf

https://www.iaea.org/newscenter/news/iaea-issues-projections-nuclear-power-2020-2050

https://www.iaea.org/newscenter/news/iaea-updates-its-projections-nuclear-power-2030

In my opinion, the High End and Low End forecasts in Europe, America and the Far East are still far too optimistic given the new plant construction start up rates and the old plant decommissioning rates.

I am no longer a fan of uranium, which eliminates the need for me to look for an entry point.

4. The rapidly decreasing cost of renewable energy and its deployment on a worldwide scale as the green energy of choice

First, let's review the cost of energy by source. According to Wikipedia:

Historical summary of EIA's LCOE projections (2010–2016)

Estimate in $/MWh			Coal	NG combined cycle		Nuclear	Wind		Solar	
of year	ref	for year	convent'l	convent'l	advanced	advanced	onshore	offshore	PV	CSP
2010	[53]	2016	100.4	83.1	79.3	119.0	149.3	191.1	396.1	256.6
2011	[54]	2016	95.1	65.1	62.2	114.0	96.1	243.7	211.0	312.2
2012	[55]	2017	97.7	66.1	63.1	111.4	96.0	N/A	152.4	242.0
2013	[56]	2018	100.1	67.1	65.6	108.4	86.6	221.5	144.3	261.5
2014	[57]	2019	95.6	66.3	64.4	96.1	80.3	204.1	130.0	243.1
2015	[52]	2020	95.1	75.2	72.6	95.2	73.6	196.9	125.3	239.7
2016	[58]	2022	NA	58.1	57.2	102.8	64.5	158.1	84.7	235.9
Nominal change 2010-2016			**NA**	**-30%**	**-28%**	**-14%**	**-57%**	**-17%**	**-79%**	**-8%**

Note: Projected LCOE are adjusted for inflation and calculated on constant dollars based on two years prior to the release year of the estimate. Estimates given without any subsidies. Transmission cost for non-dispatchable sources are on average much higher.

The **levelised cost of electricity** (**LCOE**) is a measure of a power source which attempts to compare different methods of electricity generation on a consistent basis. It is an economic assessment of the average total cost to build and operate a power-generating asset over its lifetime divided by the total energy output of the asset over that lifetime. The LCOE can also be regarded as the minimum cost at which electricity must be sold in order to break-even over the lifetime of the project."[25]

Nuclear power at $102/Mwh in 2016, is already more costly than coal, natural gas, on shore wind, and PV solar power.

The LCOE for new nuclear plants under construction in the US, Finland and France will certainly be significantly higher as they experience multi-year delays and as much as doubling cost overruns.

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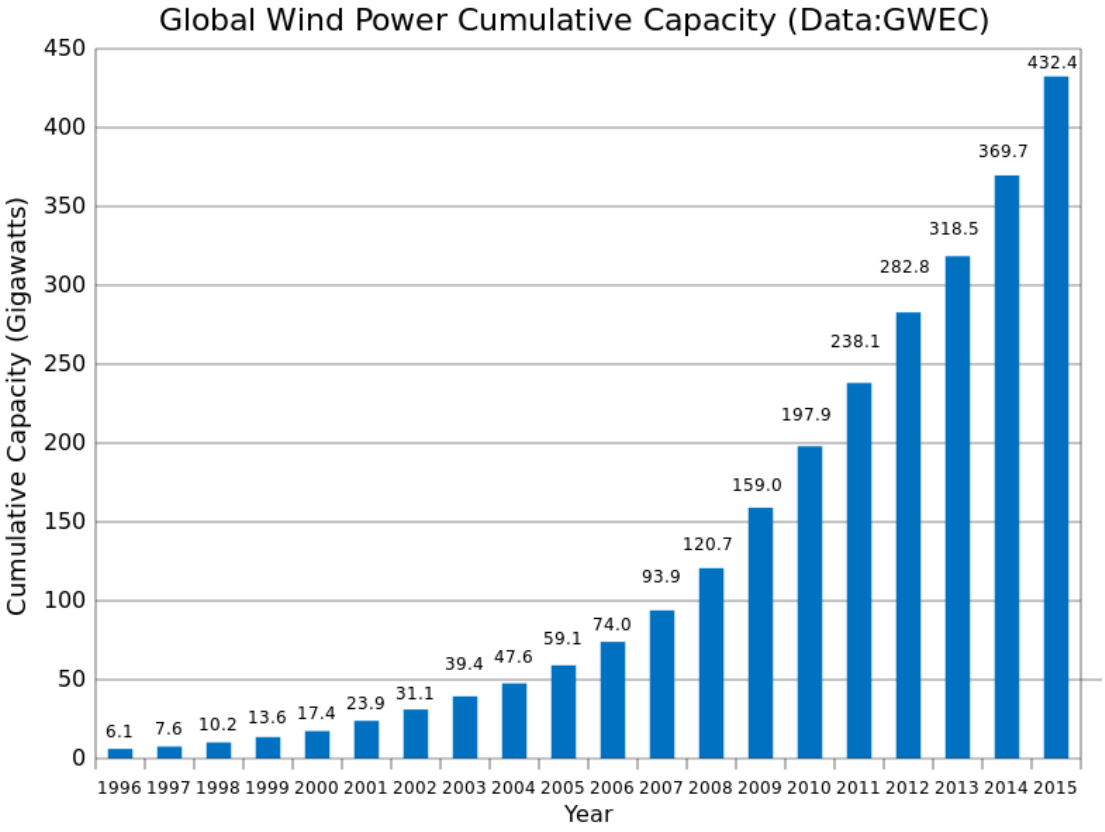
[25] Wikipedia contributors. "Cost of electricity by source." *Wikipedia, The Free Encyclopedia*. Wikipedia, The Free Encyclopedia, 6 Mar. 2017. Web. 15 Mar. 2017.
https://en.wikipedia.org/wiki/Cost_of_electricity_by_source

Coming back to renewables, energy sources have expanded significantly in recent years, especially wind and solar.

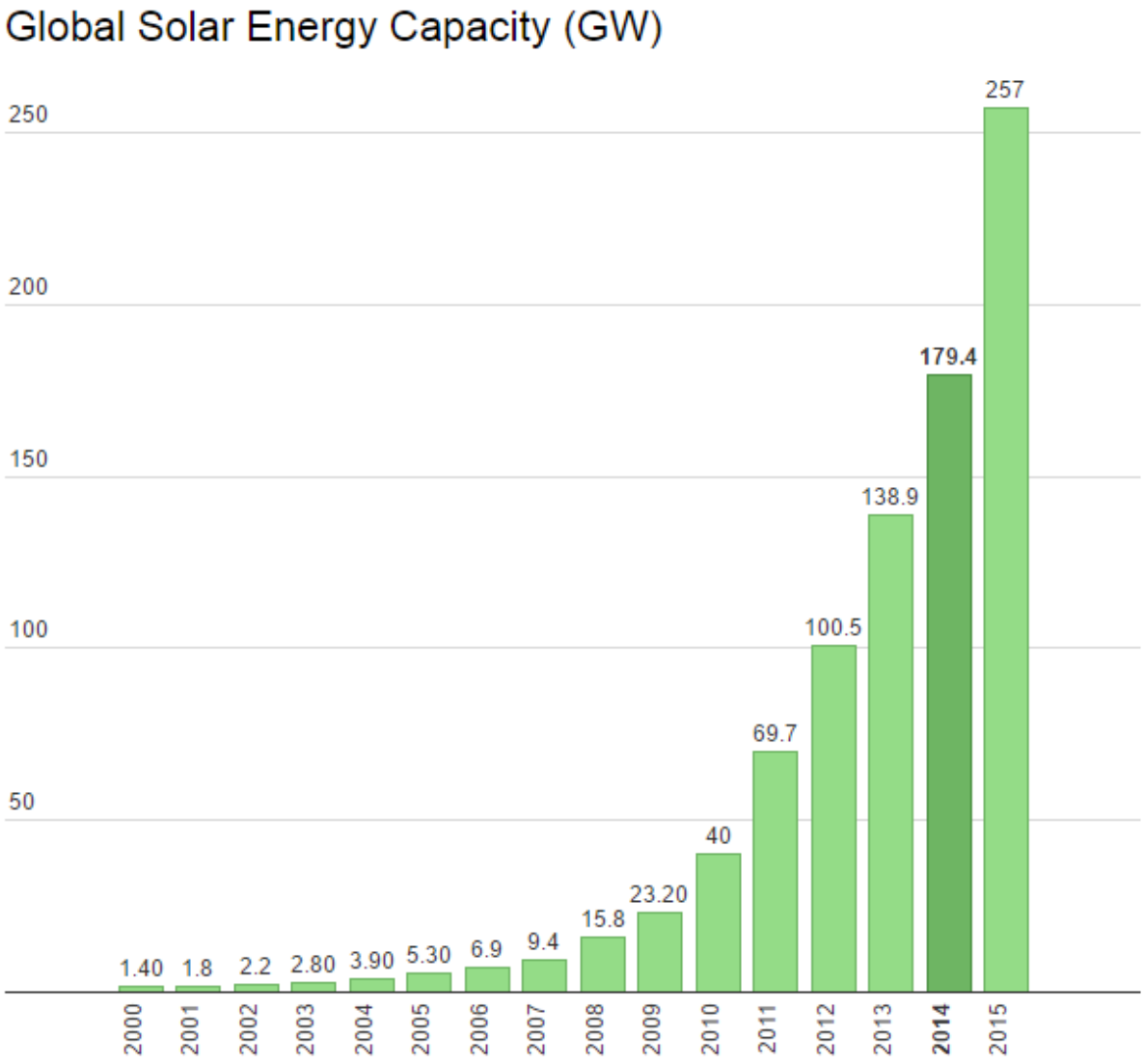
Global wind energy production has increased eightfold in the last 10 years. At 432 GW output in 2015, wind power alone has already surpassed the 392 GWe nuclear capacity from the 449 nuclear power reactors installed and in operation today.[26]



Source: Global Wind Energy Counsel

[26] *op. cit.*
https://www.iaea.org/PRIS/home.aspx

Solar energy capacity is also not far behind the curve, registering 500% capacity gains from 2011 to 2015:



Source: CleanTechnica Get the data

Renewable energy capacity growth is showing no signs of slowing down, while the cost continues to come down.

An *Asian Power* article dated February 15, 2017 and titled "India hits another record low bid for a solar project" reports:

"India has beaten its own record, according to the Institute for Energy Economics and Financial Analysis. The three winning bids for the 750MW auction, by Mahindra Renewables, Acme Solar, and Solenergi Power, came in at below Rs2.97-Rs2.979/kWh. Bidding opened at Rs3.59-3.64/kWh."[27]

According to those figures, Rs 2.979/kwh at USD$1 = Rs 66.5550 would be the equivalent of US$0.0448/kwh, or $44.8/MWh.

Another *Asian Power* article dated February 17, 2017 and titled "India's installed capacity for solar parks hiked to 40,000MW" reports:

"50 parks with at least 500MW capacity each will be constructed.

The Cabinet Committee on Economic Affairs has approved an increase in solar park installed capacity target from 20,000 MW to 40,000 MW for projects to be development in solar parks and ultra-mega solar power projects, according to Mercom Capital Group.

Fifty solar parks each with a capacity of 500 MW or above will be constructed in various parts of the country, stated the Government of India. Solar Energy Corporation of India (SECI) will be the implementing agency.

Here's more from Mercom Capital Group:

> *The new solar parks will be constructed by 2019-2020 with central government financial support of Rs.81 billion (~$1.207 billion) and are expected to produce 64 billion units of electricity every year.*
>
> *The target capacity increase from 20 GW to 40 GW had been confirmed in the new budget. The solar parks will be developed in collaboration with state governments and union territory administrations, who are required to select the solar power park developer to develop and maintain the parks.*
>
> *The park developers will be given a grant of up to Rs.2.5 million (~$37,271) to prepare a detailed project report on the park. Thereafter, Central Financial Assistance of up to Rs.2 million (~$29,816)/MW or 30 percent of the project cost, including grid-connectivity costs, whichever is lower, will be released under the program milestones.*
>
> *Mercom had previously reported that 34 solar parks across 21 states aggregating 20 GW are under various stages of construction and completion."*[28]

40,000 MW represents the capacity equivalent of 40 modern nuclear power plants.

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[27] Staff Reporter, India, "India hits another record low bid for a solar project" (February 15, 2017) *Asian Power.* http://asian-power.com/ipp/news/india-hits-another-record-low-bid-solar-project

[28] Staff Reporter, India, "India's installed capacity for solar parks hiked to 40,000MW" (February 17, 2017) *Asian Power.* http://asian-power.com/power-utility/news/indias-installed-capacity-solar-parks-hiked-40000mw

5. The emergence of utility-scale batteries to improve the availability factor of wind and solar power to serve as base load energy

One of the largest issues with wind and solar energy sources is the need to store and release the electrical energy produced. Specifically:

How to plug the hole in the grid supply when the wind stops and the sun does not shine?

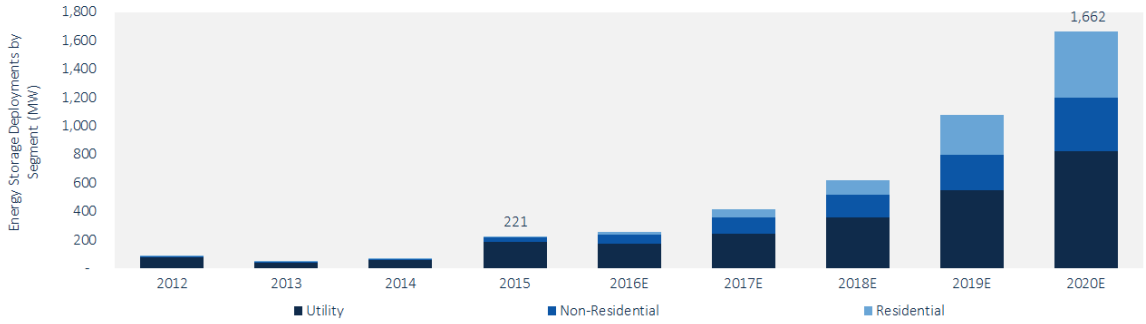
What to do with excess wind and solar power?

A promising storage technology is vanadium redox flow batteries (VRB). They are the most practical solution and will increase the demand for vanadium.

The emergence of utility-scale battery storage for energy is happening now, accelerating, and will get bigger in the next two to five years, according to Andrew Slaughter, the Deloitte Center for Energy Solutions' Executive Director and co-author of *Electricity Storage Technologies, Impacts, and Prospects*.[29]

Grid-level battery costs have also come down remarkably in recent years. At the LCOE of 20 to 30 cents per kwh, vanadium batteries are gaining traction on certain on-grid applications such as substituting peaker plants and tiered pricing arbitrage.

At the current rate of innovation and adoption, the LCOE for grid batteries may come down to 10 to 15 cents per kwh within 3 to 5 years to dominate the fast-growing energy storage market estimated to be $2.5 billion or 1,662 MW by 2020 – more than 8 times the 2016 level.



Source: GTM Research/*ESA* U.S. Energy Storage Monitor

Vanadium batteries combined with the ultra-low cost of wind and solar energy are starting to compete with traditional base-load energy sources such as coal, natural gas and nuclear. In Japan, Hokkaido Electric Power Co.'s 15-megawatt/60-megawatt-hour vanadium redox flow battery from Sumitomo Electric Industries, Ltd. started operation in December 2015.[30]

Lithium-ion batteries are not ideally suited for grid-level energy storage because they have a short-duration and discharge run time cycle, and begin to degrade after a few hundred discharge cycles (i.e. 1,000 cycles at most), whereas vanadium batteries can operate for 10,000 cycles. Vanadium batteries

[29] A. Slaughter, "Electricity Storage Technologies, Impacts, and Prospects" (September 2015) *Deloitte Center for Energy Solutions*.

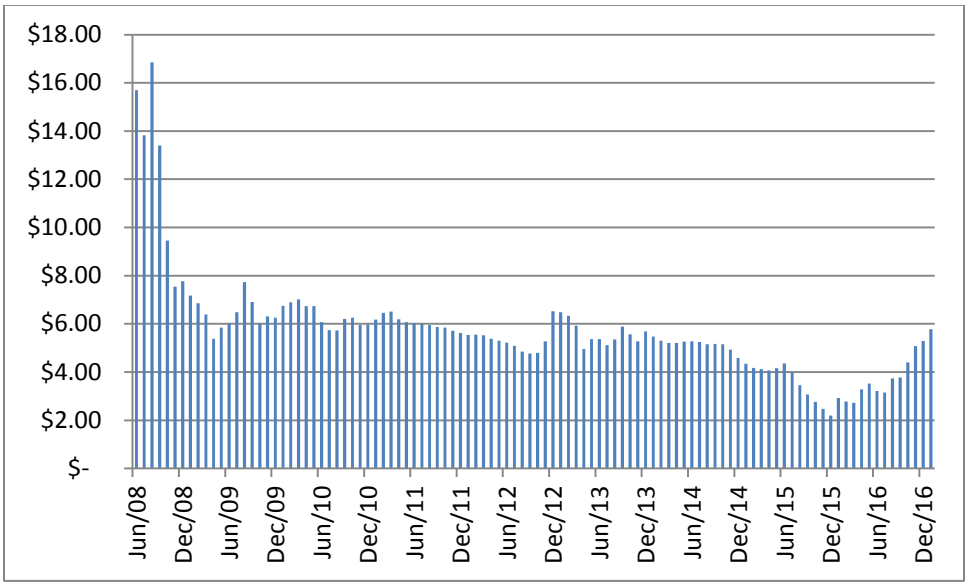
[30] M. Stone, "A Look at the Biggest Energy Storage Projects Built Around the World in the Last Year" (February 3, 2016) Greentech Media. https://www.greentechmedia.com/articles/read/a-look-at-the-biggest-energy-storage-projects-built-around-the-world-in-the

can scale up with decreasing unit storage costs, whereas the unit cost of lithium batteries increase when sizing up.

Lastly, vanadium accounts for 30% to 50% of the cost of VRBs, making it essential for VRB manufacturers to secure vanadium supply.

The price of vanadium has recently doubled in the last 12 months:

Vanadium Pentoxide Price $US/lb 2008-2016



source: https://www.metalbulletin.com

In the battle over uranium versus vanadium as an investment, I am picking vanadium – there is no contest.

Billions of dollars have poured into VRB research and development in the past decade with inevitable mass utility-scale VRB adoption. Thus, the long-term vanadium price trend looks promising, making for increased interest in miners that produce the metal vanadium.

In terms of vanadium mining, fewer than 10 companies are listed on American stock exchanges that offer exposure to vanadium.

There are currently no operating vanadium primary mines in North America and only a handful of vanadium deposits in North America. Prophecy Development Corp. (TSE: PCY, OTCPK: PRPCF) is looking to develop its 100% owned titanium-vanadium-iron deposit, "Titan" into production. Mine Development Associates prepared the Titan technical report dated February 26, 2010, which is compliant with National Instrument 43-101, that discloses a resource estimate prepared according to the CIM Definition Standards for Mineral Resources and Reserves, and was filed on SEDAR by Prophecy. The report is available at: http://www.prophecydev.com/pdf/titan_feb2010.pdf.

You can also find additional articles I wrote recently on vanadium batteries at the links below:

http://seekingalpha.com/article/4038919-vanadium-batteries-power-27-billion-grid-energy-market

http://seekingalpha.com/article/4031425-ride-vanadium-wave-lithium

I manage Prophecy Development Corp. (TSX: PCY, OTCPK: PRPCF) which engages in among other things, vanadium exploration.

John Lee, CFA.
jlee@prophecydev.com
follow me: twitter https://twitter.com/johnlee25893955?lang=en
linkedin https://ca.linkedin.com/in/john-lee-baa93422

John Lee, CFA is an accredited investor with over 2 decades of investing experience in metals and mining equities. Mr. Lee joined Prophecy Development Corp. (www.prophecydev.com) in 2009 as the Company's Chairman. Under John Lee's leadership, Prophecy raised over $100 million through the Toronto Stock Exchange and acquired a portfolio of silver assets in Bolivia, coal assets in Mongolia, and a Titanium project in Canada. John Lee is a Rice University graduate with degrees in economics and engineering.