Nuclear project structures – it’s about managing risk

In our recent post on nuclear project financing, we noted the importance of reducing risk to investors to ensure projects can raise sufficient competitively priced capital needed to build them. Today we will discuss project structures. What are they and why are they important?

The project structure is how the project is organized contractually to build the plant and then sell the electricity to the market. Good structures help the project to succeed while poor ones end up with lawyers arguing where to lay blame rather than people delivering on their commitments.

Source: pexels.com

There are four major categories of participants in a large energy project.

- The customer – who needs the energy and pays for it to be reliably delivered to their home or business;
- The owner/operator (yes these can be separated, but we will keep them together for simplicity), who is responsible for building and operating a generating station to provide the energy to the customer;
- The contractor(s), who have technology, design, and construction capabilities to build the plant; and
- The investors, who provide the funding to support this construction and who will be repaid during plant operations when there are revenues from selling electricity.

When talking about contractual structures, the primary relationships are between the owner/operator and the customer (market structure); and between the owner/operator and the contractor (project structure).

There are a whole range of contractual structures for both relationships. Some are simple and some are complex. None are perfect. Historically, electric utilities tended to be vertically integrated monopolistic companies, often owned by governments, who were charged with delivering electricity to customers at low cost. Utilities carried most project risks and passed them on to the customers. A government regulator was charged with setting rates for customers (while looking out for their best interests) based on the utility costs and performance.

Poor project performance and a belief that competition would incent better results led to a shift to deregulated markets in many jurisdictions in the early 1990s whereby the utilities would be broken up and generators would have to compete to sell their electricity to the market. (We wrote a previous post on why these deregulated markets do not work well for building new low carbon generation.)

Being forced to take on more risk by their customers, owners wanted more certainty of outcomes and believed contractors, as the experts in performing the work, were in the best position to take on these risks. Wanting this work, contractors agreed to take on more project risk, for a price. This provided a sense of security to the owners that their risk was limited, and that they could rest easy, knowing it would be up to others to ensure successful project delivery.

Unfortunately, this has been proven to be nothing more than an illusion. In reality, the contractor's ability to take on additional risk is limited and when project costs increase, they will generally make a claim for a change in scope requiring additional funds. This often results in contractual disputes that slow down project progress and negatively impact company relationships. In the end, there is no escaping the project risks for the owner, as it is their project and their money. After all, there is no scenario where the contractor fails, and the project succeeds.

The lesson is that when developing project structures, the objective is to manage risk while incentivising the behaviours from the project stakeholders necessary for project success; not to decide who suffers the most in the case of failure. Because for **long term commercial success**, there is one truth. All costs must be borne by the customer. There is no one else (unless government provides a subsidy in which case taxpayers are involved which is a different discussion – we will talk about the potential role of government in mitigating risk in a future post). When the investors state that they do not want to be exposed to excessive risk, what they mean is that they want a credit worthy borrower who can reliably replay loans and deliver a return on equity. And while ensuring they are contractually protected from risk is important, the best way forward is to confidently deliver projects to cost and schedule.

This is changing the way that projects are structured to more

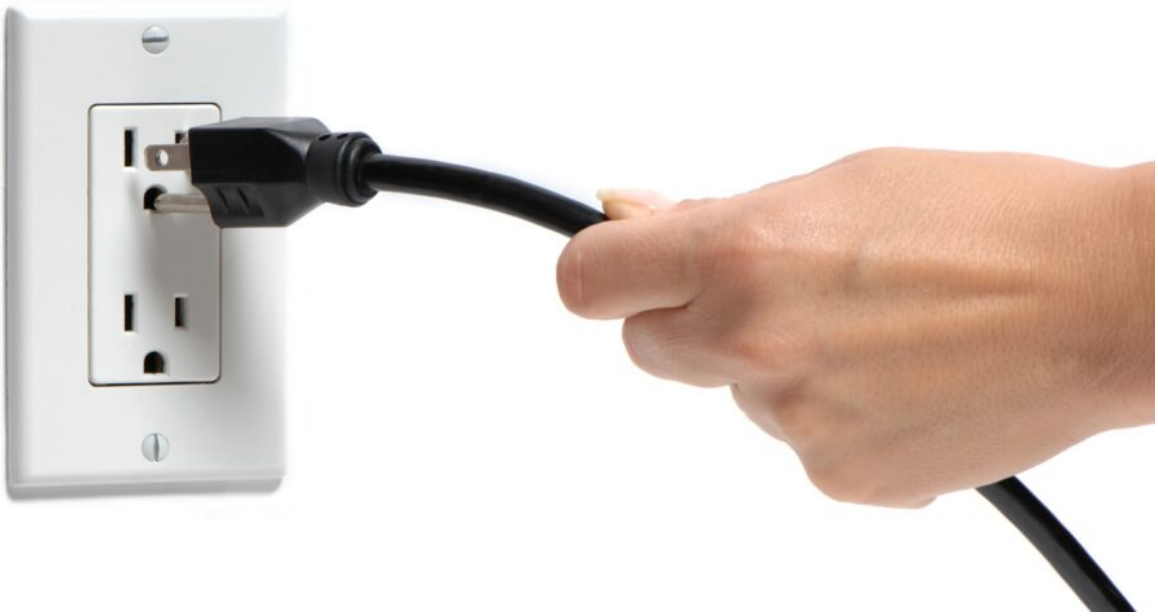
collaborative models whereby all parties' objectives are aligned, and everyone sinks or swims together. Good project contracting is important in defining the project, but on its own is insufficient to ensure good project outcomes. Successful project delivery results from good project planning, doing enough work upfront to set a realistic cost and schedule; and excellent project management, supported by a high level of transparency together with a strong set of project metrics to enable informed rapid decision making to keep the cost and schedule under control. Continuously improving the ability to deliver successful projects to cost and schedule will ensure that nuclear power can meet its full potential on the road to a Net Zero future.

Closing perfectly good nuclear plants before their end of life – it's a sin!

In March, Kuosheng Unit 2 became the latest nuclear unit to be retired following the expiry of its 40-year operating licence in accordance with Taiwan's nuclear phase-out policy. This is the fourth unit to be shut down in Taiwan leaving just two more operating units at Maanshan. When their licences expire in 2024 and 2025, the island's phase out will be complete, taking its once 20% nuclear share down to zero. And as has been the case with most other nuclear plant closures around the world, its output will be replaced with fossil fuels, adding carbon emissions at a time when we are all trying to reduce them. Taipower has reassured its customers there are numerous new gas-fired power generation projects and even new coal-powered units being brought online this year to make up

for the energy lost as a result of its unnecessary nuclear phase out.

Of course, Taiwan is not the first to go down this path. Over the last few years, there have been a number of plants that were closed before their time. In the US, it was primarily due to competition from low-cost gas in deregulated markets. In Europe and Asia, it was simply a result of government anti nuclear policies. Today as we pass the 12th anniversary of the Great Tohoku earthquake and tsunami in Japan, that also triggered the Fukushima nuclear plant accident, things are changing rapidly.



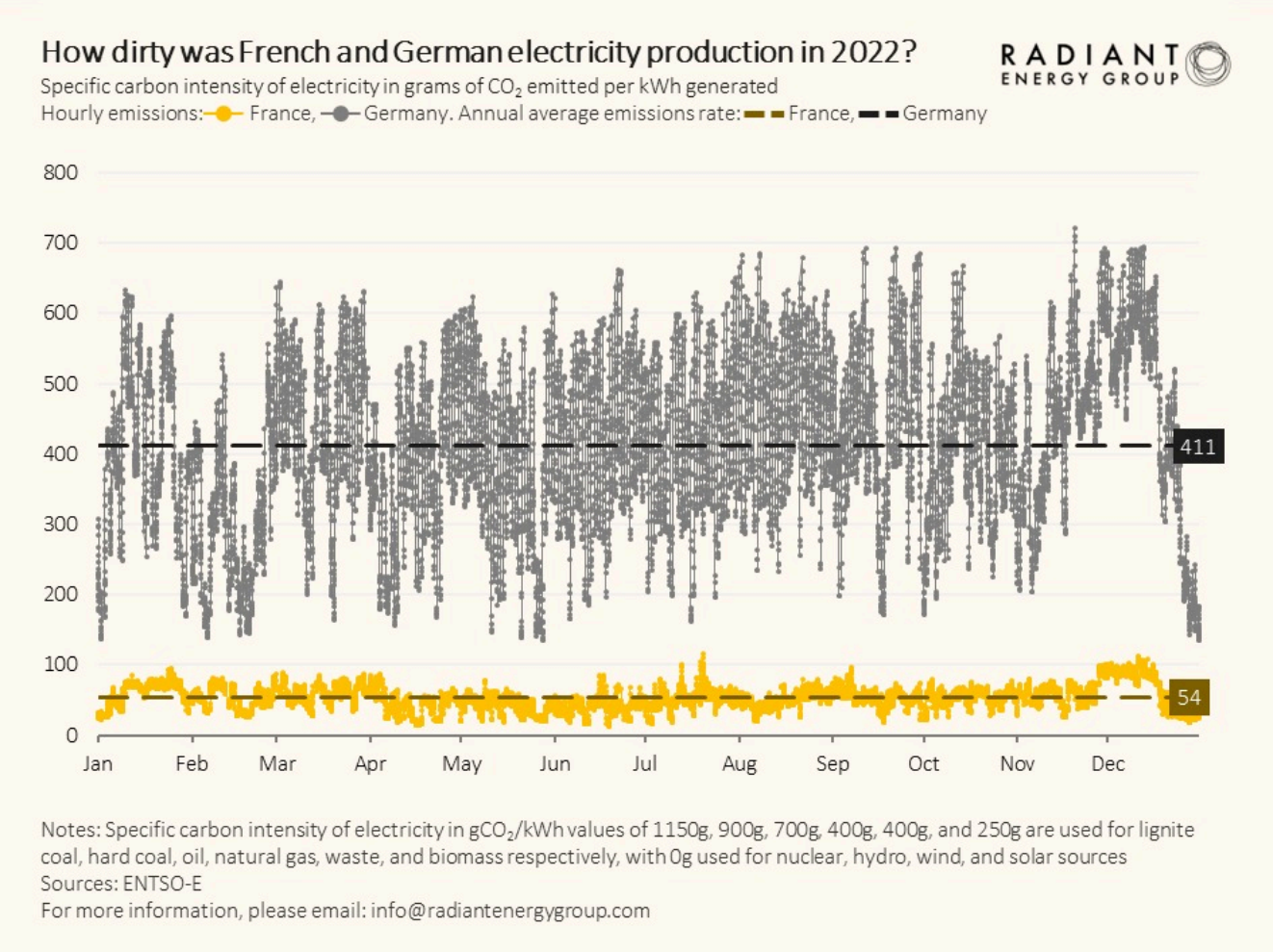
Source: istockphoto.com

Why? There are two urgent drivers to the revisiting of nuclear power. First and foremost, is the energy crisis in place in Europe due to the war in Ukraine. When energy security is at risk, people respond, and respond quickly. And then there is climate change. With more and more countries setting net zero goals, it has become crystal clear that nuclear must be part of the mix. We have never been more optimistic about the future of nuclear power playing an essential role in a decarbonizing world.

As we have said many times before, deciding not to continue to use nuclear power is the right of every sovereign nation. However, if you believe you have better options, build them, then shut down the old plants. What we have seen is the opposite. Closing nuclear plants in Germany, emissions go up, close Indian Point in New York, emissions go up, close San Onofre in California, emissions go up. Belgium plans to close its nuclear fleet and replace it with gas, emissions will go up. And so on and so on and so on.

It took an energy crisis in Europe for the penny to drop. Closing perfectly good plants that emit zero carbon without having something better to replace them is folly.

Progress has been made. After seeing about 10% of its operating units close, the US started saving units through state legislated support, and now is ensuring nuclear remains an essential part of its carbon reduction strategy with provisions in the recent federal Inflation Reduction Act (IRA). Even when it was generally thought to be too late to save Diablo Canyon in California, common sense prevailed. Belgium has agreed to run its two newest plants another decade and is considering minor extensions for its older units. Korea has recovered from its period of anti nuclear policies and is once again moving full steam ahead. Japan, a decade after the Fukushima accident is recommitting to nuclear power. Even Germany is contemplating extending its final units' lifetimes, even if only by a very little bit.



We now have enough experience with the early movers who have hoped to decarbonize with renewables alone. Germany has spent two decades and over $500 Billion dollars and made little progress on its emissions reduction goals. Its huge investment in renewables has not been sufficient to overcome the impact of shutting down most of its nuclear fleet. The chart above shows that in 2022, France, with its mostly nuclear fleet emitted about 8 times less carbon than Germany. The evidence is in. Trying to decarbonize with renewables alone is simply not feasible.

But the worst offences remain shutting down perfectly good operating plants before their time. There are 437 nuclear units in operation around the world producing about 10% of the world's electricity. Yet they also represent the second largest source of global low carbon generation after hydro. Add to that, as stated in the IEA/NEA Projected Cost of Electricity 2020, life extending nuclear plants is the single

lowest cost option of any type of electricity generation. No surprise. If something is capital intensive, as nuclear power is, then it makes sense to maximize use of the asset once you have the capital behind you.

So, for all those countries thinking about closing well operating zero emissions nuclear plants before their time, remember what the Pet Shop Boys have said many years ago – It's a Sin!

Press Play to enjoy!!

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Deregulated electricity markets don't support a viable energy transition

In the early 1990s, deregulating electricity generation seemed like a good idea. Led by the UK, many markets rushed to dismantle their vertically integrated electric utilities with the goal of creating competition to benefit their customers, the electricity using public. The view was that utilities had become fat and lazy and since they were mostly able to pass on their costs through a regulated pricing system, they didn't do their best to keep prices low. Competition would remove the fat.

Fast forward 30 years or so and much of the world has followed this path. There is a large relatively integrated European

electricity market, the UK continues to operate its market and there are multiple states in the United States that operate this way. But is it working – and of more importance – is this the right path to support the transition to a low carbon energy system?

Source: iStockPhoto.com

To fully answer this question is a subject that requires a much longer discussion than is possible in a blog post. We will address some of the issues and explain why we believe large scale market redesign is required. For another excellent perspective we strongly recommend the book "*Shorting the Grid*" by Meredith Angwin that clearly explains how the current US deregulated model is failing the customer while reducing the reliability of the electric grid. Read it – please.

The original concept was sensible. Create competition in the electricity market to force electricity generation companies to become more efficient (In most cases transmission and distribution were not deregulated). It seemed to work in

telecom. Why wouldn't it work in electricity generation? And at the beginning it did work. Government owned electricity companies were sold off and broken up. New generating companies competed with existing companies and yes, the result was improved operations of the existing generation fleet.

The markets were mostly created as **energy** markets, where generators competed on marginal cost of production (variable operating and fuel costs) in basically real time markets to sell electricity. All that mattered was the price of electricity at any given moment. This was happening at about the same time as gas was ascending to be a major player in electricity generation both in the US and in the UK. Each generator would bid into the market at its marginal cost. The market would accept bids at the lowest cost available and continue to accept higher prices until the demand was met. The market price was the energy cost of the last generator who bid, and all participants received this price (the clearing price). When demand was high, the last bid accepted was usually gas generation which has the highest marginal cost of production and this price seemed to be enough to keep the other players with lower marginal costs but higher fixed costs content.

Then three things happened that started to change the equation.

First, at least in North America, the price of gas fell dramatically so that the only technology actually making money were gas generators. Their marginal cost had become very low given the low cost of gas and other forms of generation could no longer survive at that price. Hence the current situation where nuclear plants are closing before their end of life as they struggle to compete at very low gas prices. The US government has just launched a $6 Billion program to help save these plants. Market supporters may say – who cares? The market is the market. If gas plants are the lowest cost, then just run gas plants. And yes, that is certainly an option if

a single source electricity system based on 100% gas is deemed acceptable. But if the objectives of the system are broadened to include diversity of generation for security purposes or to mitigate the risk of volatile fuel prices (yes, gas prices can and do go up), or to lower carbon emissions, then change is required.

Second, having an **energy** market only made it impossible to build new **capacity**. Since everyone was operating on marginal cost, there was no possibility to recover full costs – which is needed to support new plant investment. The solution was to create **capacity** markets. Payments would be made for capacity based on a bidding process so that low-cost capacity would be added to the system. Once again, in most jurisdictions, gas came to the rescue. The cost structure of a gas plant is just right for this type of market. The capital to build a plant is relatively low. Once the capacity is paid for, you only operate the plant when the energy is needed, at an energy cost that covers the marginal costs (which is primarily based on the cost of fuel).

The issue with this market structure is that gas generators were always price makers, and all other technologies were price takers. In other words, the business of electricity generation for all other technologies became a competition with gas. While these technologies made or lost money based on this competition, gas generators were always whole, no matter the price of gas. In effect, gas generation is pretty much a risk-free business in this market structure. Consumers are happy as long as gas prices are low – but will be very unhappy when prices rise.

Next, countries committed to decarbonization goals and started to support adding low carbon electricity, primarily intermittent variable solar and wind power on the system. To get these to work, subsidy was required both for price and to ensure the market takes the output of these resources when they produce, when the sun is shining and the wind blows.

To keep this story short, this structure made it near impossible for any other technology than gas or subsidized renewables to be built. Other projects were just too risky, especially those technologies like nuclear power where the bulk of the cost of energy is based on their capital investment. Even though a nuclear project is projected to be economic, once built, the price of the alternatives may change in the future so that the plant becomes unprofitable. Or in other words, no matter how successful and low cost the project, the risk of having to compete with daily changes in gas prices would be unmanageable. The solution was once again to contract outside of the market. Power purchase agreements, contracts for difference (Hinkley Point C) and other approaches were developed to support these types of projects. The result, more complexity, and complexity tends to increase costs. That is why we see the Sizewell C project in the UK moving to a Regulated Asset Base (RAB) model, to simplify the project structure and keep costs lower. (We will talk about this model in a future post.)

The reality is that data from the US DOE Energy Information Administration (EIA) show that customers do not benefit from these market structures. 2020 data shows that customers in deregulated states pay on average about 23% more for electricity than those in regulated ones. And while most states remain regulated (about 32 to 19), when you consider the actual amount of generation under both regimes, it is much closer to half of US generation is deregulated and half regulated.

Back to the point of this post. If you want to ensure grid stability, the markets need to change. If you want to encourage diversity of generation, the markets need to change. But most of all, a completely new structure has to be developed because the low carbon options (wind, solar, nuclear, hydro) have relatively high fixed costs and near zero marginal costs making an energy cost based market unworkable.

For these forms of generation, a market structure based on recovering fixed costs is required.

If we really want to work towards net zero carbon emissions, now is the time to re-imagine how we are going to generate electricity and pay for it. One thing is certain. The existing deregulated model in place in many jurisdictions will not take us where we need to go and the longer we take to accept that, the longer it will be to reach our carbon goals.

The Energy transition requires a huge increase in mining of critical minerals

When considering the sustainability of future low carbon energy sources, the focus tends to be on where the energy comes from. Renewable energy is seen as environmentally sustainable in that it is both low carbon and the resource unlimited; energy from the sun, wind and water will never run out. But, as with everything in life, nothing is perfect. All these energy sources require a variety of critical minerals for their manufacture. This means mining – a lot of mining. The issue is so important to the energy transition, the International Energy Agency (IEA) recently (May 2021) released a World Energy Outlook Special Report, "*The Role of Critical Minerals in Clean Energy Transitions.*"

Source: istockphoto.com

As stated by IEA Executive Director Fatih Birol, *"Today, the data shows a looming mismatch between the world's strengthened climate ambitions and the availability of critical minerals that are essential to realising those ambitions."*

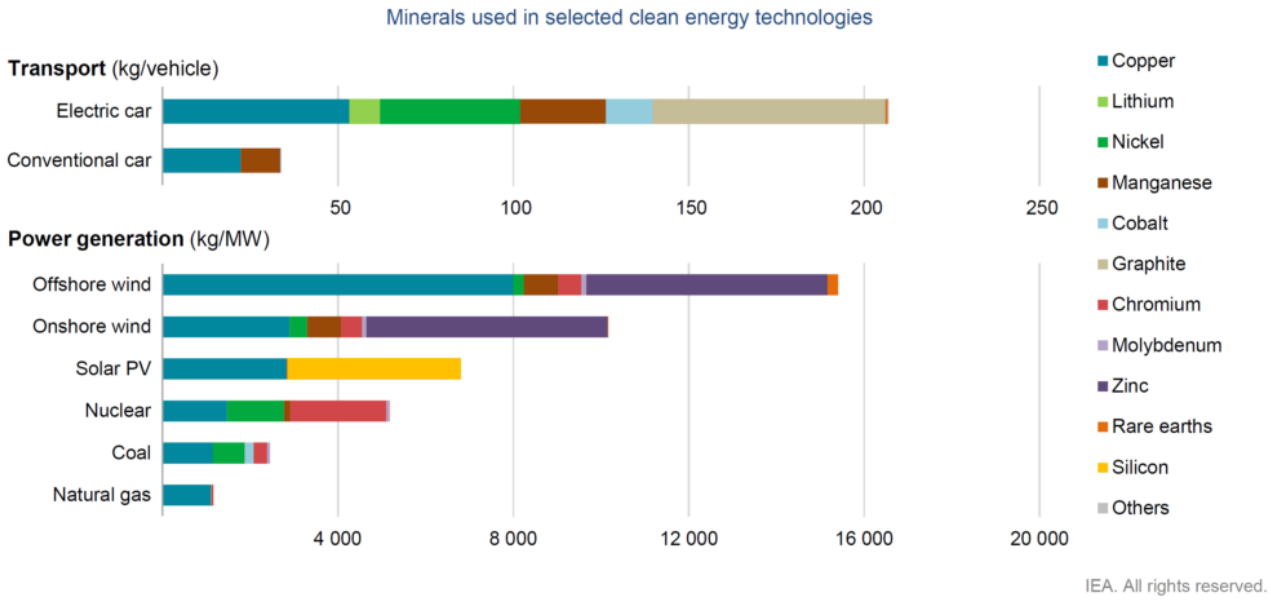
Reading this report, one thing is for certain – **demand for minerals goes up, way up.** [all numbers in the next paragraphs come directly from the IEA report.]

An energy system powered by solar, wind and electric vehicles (EVs) requires more critical minerals than today's fossil fuel-based generation and transport. An electric car requires six times the critical mineral inputs of a gas fuelled car, and an onshore wind plant requires nine times more mineral resources than a gas-fired power plant. Since 2010, the average amount of critical minerals needed for a new unit of power generation capacity has increased by 50% as the share of renewables has risen.

And this is going to increase even faster going forward. To hit net-zero *globally* by 2050, would require six times more critical minerals in 2040 than today. Examples of the magnitude of this growth would see critical mineral demand for

use in EVs and battery storage grow at least **thirty times** to 2040.

This represents dramatic change. Prior to the mid-2010s, the energy sector represented only a small part of total demand for most minerals. Now, clean energy technologies are becoming the fastest-growing segment of demand. In order to meet the Paris Agreement goals, clean energy technologies' share of total demand rises significantly by 2040 to over 40% for copper and rare earth elements, 60- 70% for nickel and cobalt, and almost 90% for lithium. EVs and battery storage have already displaced consumer electronics to become the largest consumer of lithium and are set to take over from stainless steel as the largest end user of nickel by 2040.



This rapid increase in demand and the world's hunger for these critical minerals will also change the geopolitical landscape. In the past, much of the world was concerned about security of supply of fossil fuels, primarily oil. Policy makers will now have to consider the challenges with security of supply and prices from a different set of resources which are mostly concentrated in a small number of countries.

And of course, with expanded supply, comes the issues of expanding waste volumes as these new sources of energy reach their end of life. In 2016, IRENA (International Renewable

Energy Association) estimated there would be up to 78 million tons of used solar infrastructure to look after by 2050. However, this assumed solar panels would all stay in service to end of life. But newer better solar panels have people replacing their panels early so that this number can increase by 2.5 times if the current trend continues. To date there is no clear path as to who will pay for this disposal and/or recycling.

With massive projected growth in renewables as they become the main source of energy replacing fossil fuel in the IEA scenarios, we can see the impact of their low energy density and relatively low resource availability. In other words, while these technologies produce very low carbon renewable energy, they do not use minerals very efficiently.

This is where nuclear power shines. It is extremely energy dense and operates at very high-capacity factors. The IEA report notes that nuclear has comparatively low mineral requirements. But the figure above is deceptive. Comparing on a MW capacity basis does not reflect the true nature of the mineral use as 1 MW of solar does not produce the same amount of energy as 1 MW of wind which does not generate the same amount of energy as 1 MW of nuclear. So, while it may look like solar uses 40% more and wind double the materials used in nuclear from the figure, this is not the whole story. Solar generates energy less than 20% of the time (when the sun shines) and wind about 35% of the time (when the wind blows), much less than nuclear that operates more than 90% of the time. And the average life of a solar or wind farm is 30 years or less while a nuclear plant lasts 60 years or more. In other words, a nuclear plant will produce between 10 and 15 times more energy per kg of critical materials used over its life than a solar panel or a windmill making nuclear plants much more mineral efficient. And, given the long life of a nuclear plant, this also greatly reduces the future mineral waste burden.

We often write about nuclear being a low carbon, reliable and economic source of electricity. Now we can add another important environmental attribute, it uses much less critical minerals than renewables per unit of energy produced. Therefore, increasing the share of nuclear power in the future energy mix will greatly reduce the burden on the mining industry (and the planet) as it tries to keep up with a rapidly growing critical mineral demand.

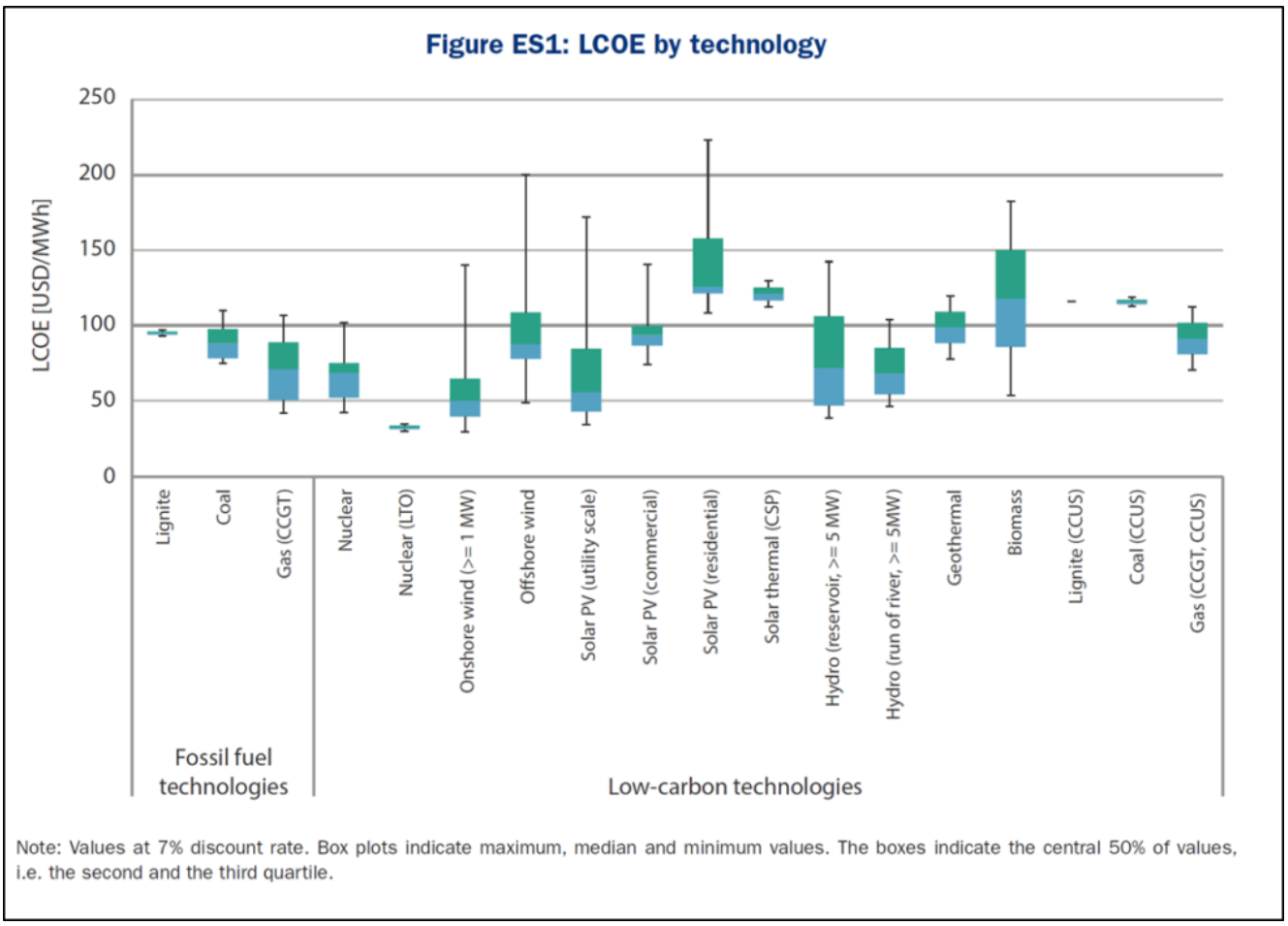
Yes – Nuclear power is an economically competitive low carbon energy source

When it comes to the economics of electricity, there is no report more important than **Projected Cost of Electricity**, issued every 5 years by the International Energy Agency (IEA) and the OECD Nuclear Energy Agency (NEA). This report (now in its 9th edition) collects electricity costs of various technologies from a range of countries and reports on the competitiveness of each. The 2020 version of this report was issued in December and its conclusion is clear – nuclear power is the dispatchable (meaning always available) low-carbon technology with the lowest expected costs.

Source: pexels.com

This is in stark contrast to what we often hear – that even though nuclear power may well be a low carbon solution, its costs are much too high to consider. Recent projects that have not gone well, primarily in the west due to a long absence from nuclear construction coupled with the challenges of building first of a kind (FOAK) designs are the evidence to support this argument. The successful economic deployment of nuclear in countries like China, Korea and Russia are ignored. We even have a good example that new countries can successfully build nuclear plants with the start up of the Barrakah nuclear power plant in the UAE.

This report sees through this bias. This is not a nuclear report. It is about electricity and its costs. The conclusions are based on the results of the analysis, not on any preconceived biases. It concludes that all low carbon options have improved their costs since the 2015 version.



Projected Cost of Electricity 2020 (IEA/NEA)

One change since the 2015 version of this report is the inclusion of nuclear life extension or Long-Term Operation (LTO) in addition to the traditional consideration of the economics of nuclear new build. The results show that LTO provides the lowest cost electricity of all technologies considered. This makes for a very simple message – for the best low carbon, low-cost option – invest in keeping the current nuclear fleet operating.

Given the changing generating mix from traditional fossil fuelled plants to more and more variable renewables; there is an acknowledgement that to truly understand their economics the costs to the system of incorporating these variable resources must be considered. A model, called the Value Adjusted Levelized Cost of Electricity (VALCOE) has been developed but adds considerable complexity given, as would be expected, results are very sensitive to the actual system being analysed. This approach continues to be a work in

progress. We should expect a more fulsome analysis in the next edition.

When it comes to nuclear, this report notes that countries willing to pursue the nuclear option have three main technology solutions to reduce cost at the system and plant level (interestingly consistent with our previous series on Saving the Planet):

1. LTO or investing to keep the current fleet operating into the future.
2. Building existing Generation III reactors. These designs have now passed their FOAK demonstrations and are ready to demonstrate improved economics going forward; and
3. New designs being developed such as Small Modular Reactors (SMRs). These designs are poised to extend the value proposition of nuclear power.

The IEA/NEA, in its updated Projected Cost of Electricity report, has assessed the costs of the many low carbon options to meet electricity needs going forward. Based on this analysis, nuclear power is well positioned to continue and expand its role in providing reliable, economic, low carbon electricity to the world.

Saving the planet step 3 – Move forward with Small Modular Reactors (SMRs)

Last year we started a 3-part series on Saving the planet with nuclear power. First, we talked about keeping the existing nuclear fleet operating as long as possible (Saving the planet

step 1). Then, in step 2, we talked about building a new global fleet of large Generation III nuclear plants. Today, we are concluding this series with a discussion on the role of Small Modular Reactors (SMRs).

SMRs represent the next generation of nuclear energy innovation. They are defined as nuclear plants that produce 300 MW of electricity (or combined heat and power) or less replacing the traditional economies of scale of large reactors with economies of numbers. Their objective is to reduce the risks of delay and cost overruns associated with more traditional large nuclear units by deploying them more quickly and at lower cost.

Some of the many SMR designs available in the market

While the fundamental objective of SMRs is to enable the expansion of the nuclear market to include a broader customer base who can benefit from these lower cost solutions, SMRs

actually represent two different sizes of reactors, each with its own well defined use case.

On-grid applications are an evolution of more traditional electricity generation and are rooted in the familiar. They will be connected to electricity grids as an alternative to fossil and other forms of generation. The owners/operators will likely be utilities who are in the business of generating electricity, both government owned and private corporations. With their lower costs and shorter deployment schedules, they will appeal to a much larger market of new potential owners for whom large units are simply not an option to fit their systems or, who prefer to manage their risk by making their generation investments in smaller increments.

Off-grid applications are more revolutionary. Very small SMRs (vSMRs or micro SMRs – about an order of magnitude smaller than grid-scale SMRs) could meet the needs of remote communities or commercial enterprises that are not grid-connected including remote mining and other industrial applications demanding both heat and power. The customers are non-traditional users who are often in another business, such as mining, but who need low carbon economic energy as an input to their operations. While economies of scale do have an impact on costs at this very small size, these vSMRs often compete with diesel generation that can be very expensive, polluting, and in some remote applications, difficult to ensure fuel availability due to restricted transport options.

SMRs can be a game changer.

We know from previous studies (MIT and NEA) that renewables cannot decarbonize the world alone. In fact, these studies point to the same conclusion, that fully decarbonized systems are always lower cost with nuclear than without. A new recently released US study (Cost and Performance Requirements for Flexible Advanced Nuclear Plants in Future U.S. Power Markets – Report for the ARPA-E MEITNER Program, July 2020)

considered the cost required for SMR market success. They found there will be large markets for advanced reactors that cost less than $3,000/kW which will also be attractive investments for owners; and that together, renewables plus advanced nuclear (with thermal energy storage) lower overall system costs, reduce emissions, and improve performance in future U.S. electricity grids.

And much progress is being made.

In the US, the DOE has an aggressive strategy through its ARDP (Advanced Reactor Development Program) now underway to demonstrate two advanced reactor designs within five to seven years, and is also planning two to five smaller awards to address technical risks in other advanced designs. In addition, the US Department of Defence is investigating very small, transportable micro SMRs to support tactical deployments.

Here in Canada, in addition to the Canadian SMR Roadmap setting out a plan, the provinces of Ontario, Saskatchewan and New Brunswick have signed an MOU (Memorandum of Understanding) to move forward with the development and deployment of SMRs across Canada. Work is underway to develop projects in all three provinces, both for on grid use and for remote locations. Just recently the province of Alberta announced it will soon join this MOU.

In the UK, in November 2019, the government confirmed that it is investing in the UK SMR consortium led by Rolls-Royce. Just recently, in June 2020, the consortium has submitted proposals to Ministers to accelerate the building of a new fleet of up to 16 SMRs in the North of England by 2050. Most recently, on July 10, The UK government awarded funds to three advanced reactor developers to kick start next-gen nuclear technology.

From the basic needs of ensuring we are warm and fed, to

keeping us connected to our co-workers, friends, and family; having access to affordable energy is critical to our quality of life. To meet these needs while aggressively lowering carbon emissions requires investment in technologies to deliver a future where we no longer rely on fossil fuels. Most studies agree, a combination of nuclear power and renewables makes an excellent path forward while delivering the lowest cost energy solutions.

How do we ensure that nuclear power plays its role and meets its potential? Three steps.

- Step 1 – Keep the existing nuclear fleet operating as long as possible – as a major source of existing low carbon electricity, losing these plants sends us backwards in meeting our goals
- Step 2 – Let's build as many Generation III nuclear plants as we can – these large units all have completed and operating demonstration units with their standard designs ready to add large amounts of new low carbon electricity to our grids; and
- Step 3 – Move forward with Small Modular Reactors (SMRs) – to disrupt the electricity market and bring the potential of nuclear power to a whole new set of customers who would not have considered the nuclear option before.

Nuclear power currently provides the second largest amount of low carbon electricity in the world (slightly behind hydro) and stands ready to do so much more. While much work is already under way, there remains much more to be done. But one thing is certain, the world needs energy, and lots of it. With nuclear power making the contribution we know it can, our future is bright.

Nuclear cost reduction: Learning lessons requires investing in people

Nuclear power is a people business. Through the hard work of many, most plants operate at very high operating factors and produce clean economic electricity 24 hours a day 7 days a week. They produce in good weather and bad, when it is sunny and when it is dark, when it is windy and when the air is still. This was not always the case. It is decades of effort by an industry dedicated to continuous improvement and learning that led to this outcome. Utilities collaborate and participate in groups such as the Institute of Nuclear Operators (INPO) and the World Association of Nuclear Operators (WANO) to ensure that operators have access to industry best practices and then they work hard to implement them at their own plants.

This process of continuous learning has not yet been fully achieved when it comes to building new plants. Here the experience is more regional with some countries like Korea and China having great success, and others struggling with new build projects that have been both behind schedule and over budget. A new report by the OECD Nuclear Energy Agency (NEA) addresses this issue head on. "**Unlocking Reductions in the Construction Costs of Nuclear: A Practical Guide for Stakeholders**" focuses on both the reduction of construction costs through a selected number of well-defined cost drivers and on the reduction of the cost of capital through the improved allocation of construction and market-related risks faced by new nuclear projects.

Back in 2018 we posted with our own three-part series on managing nuclear costs. As we noted then, large capital projects are difficult. They require a huge amount of planning, the logistics are often staggering and depend upon many contractors and suppliers, all who must perform completely in step for everything to come together as planned. The project manager is like the conductor of a large orchestra and as good as all the musicians may be – it only takes one misstep to ruin a beautiful piece of music. Strong leadership and good people are the key.

The NEA report focuses heavily on implementing the many **lessons learned** from existing projects to make the next projects better. As they state, *"to reduce nuclear construction costs, eight drivers have been identified to unlock positive **learning**".*

We have all heard about the importance of having a strong "***lessons learned***" program. To be truly successful, the meaning of each of these words needs to be fully embraced.

First, we have **lessons**. These come from the difficulties identified in a project that should not be repeated, or new better ways to do things based on experience in the field. At the end of a project, you may hear there have been many lessons learned that have been collected ready for the next project. In reality, these are just lessons as we don't yet have any evidence they have actually been "learned" by those who need them most, the people who are going to build the next plant.

"**Learned**" is defined In the dictionary as *acquired by learning, acquired by experience, study.* The operative word here is "acquired". What we so often forget when we talk about lessons learned is that identifying a lesson is only the beginning. What is really important is to ensure the lesson is actually "learned" by the people who need to learn it and then successfully put into practice. We can only know this when the next project comes, the lesson has been applied and the results measured to demonstrate the lesson has indeed been learned with the project seeing the expected benefit.

Yes, new methods can be recorded based on previous projects that will avoid errors and improve project performance. But to really make improvements in project delivery requires the kind of learning that comes from experience and improving individual efficiencies. These lessons are carried by people, not databases. This means that to get the best project results, the same people must do the same tasks over and over again going from one project to the next.

Or as said in the NEA report – "*the most effective way to reduce construction costs in the near term (early 2020s) is to develop a nuclear programme that takes advantage of serial construction with multi-unit projects on the same site and/or the same reactor design on several sites.*" While it is true there are technical savings building on the same site, the largest savings occur because the use of the same workforce is maximized. As a task is completed on one unit, the same

people can use what they have learned and immediately move on to the next unit and repeat the effort. This ensures the largest possible cost reductions.

We can use a simple example from our own lives familiar to us all. Who hasn't had to do a project around the house and found a video on YouTube to show you how to do the task at hand? What an amazing tool! Yet even with the best step by step instructions from an expert on YouTube, we will still do the job much faster the second time. There is simply an experience factor in everything we do that cannot be easily transferred from person to another.

The path to success is through empowering people, providing them the opportunity to maximize their learning and then make use of this learning to continue to improve project performance. While it may sound counter intuitive, this will also fuel innovation as those with the most knowledge and experience continue to find ways to get even better. This means:

- Standardizing is much more than just repeating a design. It is using the same people who have done the same work (engineers, project managers, suppliers and trades) on the previous project. They know exactly what to do and how to do it.
- Recognizing there are limits to using all the same people for multiple projects – train, train and train some more to develop those that are new to the project. Avoid the mistake of training for competency and train for proficiency. Training must be managed by people who have actual experience. They must transfer not only their expertise but their experience as well.
- When preparing for a new nuclear project, build the experience of as much of your workforce as is practical by sending them to participate in on an ongoing project before they start work on your project. The more people you have who are not touching something for the first

time on your project, the better.

Of course, this can only be accomplished with an active new build program. The example of China and Korea and their success in lowering nuclear costs and building to schedule are cited regularly. Their strength is in the size of their programs. We have personally had much experience in working with Korea and we can honestly say, that having been in the industry a very long time, we actually know Koreans who have worked their full careers and have recently retired. Each one of them has worked on a real new build project every day of their 30 plus year careers. This kind of experience is invaluable and is why their projects have continued to improve. In the western world where new build has been paused, who can say the same?

Remember, when we talk about lessons learned, the operative word is “learned”. All the lessons in the world are of no value unless this knowledge is acquired by people and put into practice. This means collaborating to develop capabilities and install a system of continuous learning throughout all aspects of the industry, just as we have done to improve nuclear operations. After all, we only need to look at global nuclear plant performance to know this works.

This is an industry that attracts the best and brightest. Let’s give them the tools to acquire the knowledge they need, and more importantly, lets offer them exciting careers to develop the experience required to build the nuclear future we all aspire to. We have so many great lessons available to us; now let’s put the emphasis on learning them.

10 years of blogging…. Nuclear power is making progress, but it hasn't been easy

It's hard to believe, but this month it is 10 years since our first blog post in May of 2009. 10 years! And what a decade it has been for the nuclear power industry. There were highs and lows, and most of all change…..

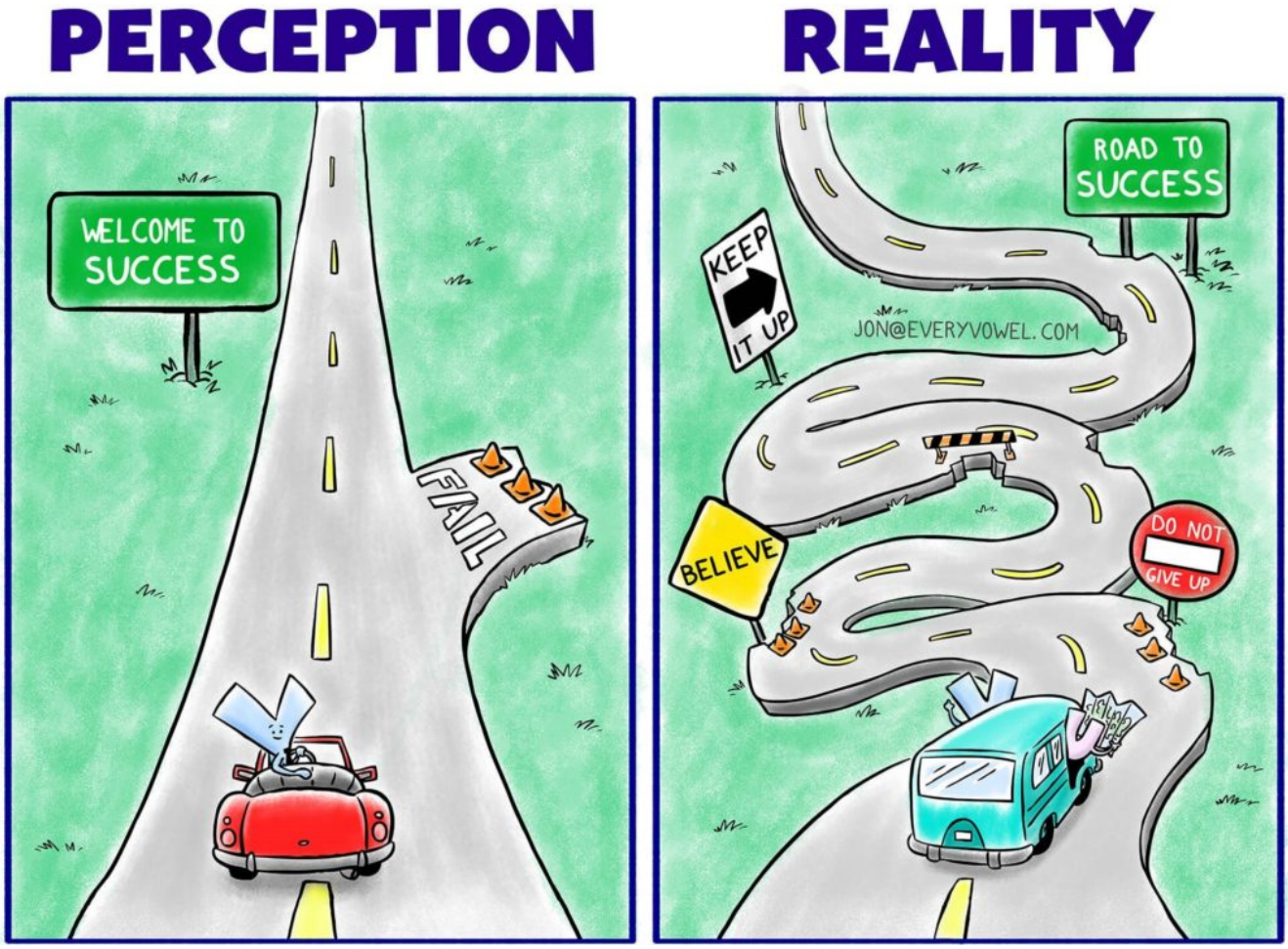
In 2009, there was still optimism about the nuclear renaissance, until the effects of a world financial crisis and the first downturn in global energy demand since World War 2 made it a difficult time to support large energy projects. Nevertheless, the first next generation EPR design in Finland was under construction, and the UAE would soon select the Koreans to build their new nuclear plant (based on their next generation APR1400), to become the first nuclear newcomer-country in many years.

This was also the time the environmental movement started to consider the merits of nuclear power. It was 2009 when Stuart Brand published his book "Whole Earth Discipline: An Ecopragmatist Manifesto" in which he took on the environmental establishment with this statement that "***Cities are green. Nuclear energy is green. Genetic engineering is green.***" This was a turning point for some environmentalists as they started to question their life-long opposition to nuclear power.

It was looking like the industry would weather the financial storm, but then in 2011, the great Tohuku earthquake and the tsunami that followed devastated the coast of Japan resulting in a serious accident at the Fukushima Daichi nuclear power plant. While no one was killed, an event of this magnitude in an advanced country such as Japan heavily reliant on nuclear power caused a huge amount of global fear. To this day Japan only has 5 of its units in operation with some others permanently out of service as many more are working to meet new higher safety standards to enable them to restart. Some countries took a common-sense approach such as China, who stopped approving new builds until they could satisfy themselves that all was in order. Others such as Germany decided to abandon the technology altogether.

There were some positives in this immediate post Fukushima accident period. In the US, two AP1000 projects were approved in 2012 at Vogtle and VC Summer. The UK continued to march forward with its commitment to new build although it took another year for the UK government to agree to a price of energy for the Hinkley Pt C project which is now under construction.

In 2015 Canada made a big re-commitment to nuclear power approving the refurbishment and life extension of 10 units at Bruce and Darlington, a commitment of $25 Billion over 15 years. This clearly showed a strong commitment to nuclear as these plants will continue to be the backbone of the Ontario electricity system into the 2060s.



And there were many challenges. The world's two largest nuclear vendors,
Westinghouse and Areva, struggled financially as a result of difficult projects
that impacted their financial viability.
After taking a huge financial hit, the VC Summer project was cancelled,
and Toshiba sold the bankrupt Westinghouse to Brookfield.
Meanwhile In the US, hydraulic fracking
produced very cheap natural gas causing financial mayhem in those states with
de-regulated electricity markets resulting in some early nuclear plant closures
and more being considered for economic reasons.

In France, Areva was restructured into Framatome and Orano as the Olkiluoto project in Finland and the Flamanville project in France continued to be delayed. French government support

for nuclear weakened as it set out a policy to reduce its reliance on nuclear from 75% to 50% by 2025.

However, in the US today many states are pushing back and providing support to keep their plants operating as they acknowledge the benefits of nuclear power to grid reliability and their near zero carbon emissions. And in France, the current government has accepted the importance of nuclear power delaying the roll back to 50% to at least 2035 as they consider their future strategy.

While many countries in the west continued to experience challenges, the east is charging ahead. China has the world's most ambitious nuclear program having reached 45 units in operation and targeting to triple this by 2030. They are also starting to work their way into the export market with success in Pakistan and discussions ongoing with many countries. And Russia is having a big impact on the global industry as Rosatom has become a leading exporter of nuclear plants.

Concern about climate change has increased with the most recent agreement to reduce green house gases made in Paris in 2015. Following in the steps of Stuart Brand, more environmentalists now believe that nuclear power must be a part of the solution. The evidence from Germany and California demonstrate that a 100% renewable future is not in the cards as the challenges of managing a system based on an energy-diffuse, intermittent energy source becomes clear. To really decarbonize the world must use all the tools available to reduce emissions. This includes nuclear power. Many governments agree and at the Clean Energy Ministerial (CEM) meeting in Vancouver (just getting underway as we write this post), discussion will continue about the NICE initiative (Nuclear

Innovation – Clean Energy future (NICE)) advocating for all clean energy options to be on the table – and this includes nuclear power. During this meeting, the IEA is expected to release a report that supports the need for nuclear energy to meet climate goals.

There is also an active movement to develop the next generation of nuclear plants, so called SMRs (small modular reactors), that are to be smaller, more versatile and easier to build. The thought is to replace the economics of scale with the economics of numbers. The UK, Canada and the US are all promoting these options with a plethora of companies working on these novel designs.

While there have been challenges over the years, we have seen much progress. Every time negative emotions knock us down, facts and logic raise us up. Today we have the first AP1000s, EPRs, VVER1200s and APR1400s in operation, governments are talking about the role of nuclear power to decarbonize the world to combat climate change, a new generation of SMRs is under development, and environmentalists are seeing the possibility of using these plants going forward. This provides us with hope, but we always recognize that while hope is nice, it is not a strategy. There is much work to do in the next decade and the outcome is far from certain. But there is one thing we are certain of – the world needs lots of energy, clean, reliable and economic to power mankind – and nuclear power has what it takes to deliver.

As for our blog, over the last decade we have written about nuclear power's ups and downs, focused on various countries from China to Korea to Canada and the UK, talked about economics and how to make projects successful and the impact of the Fukushima accident on the psychology of the world.

What about the future?
While our audience has increased dramatically over the last 10 years, we are still talking mostly to ourselves – the nuclear industry – and while that may make us all feel good, it does not change minds. We plan to work hard to expand our reach and start a dialogue with those who are more skeptical of nuclear power and see where that takes us. And of course, we want to continue to talk about those things that are happening and what they mean for both the industry and the world at large.
Your thoughts and recommendations on future direction are welcome.

We thank you for reading our blog and hope you will continue.

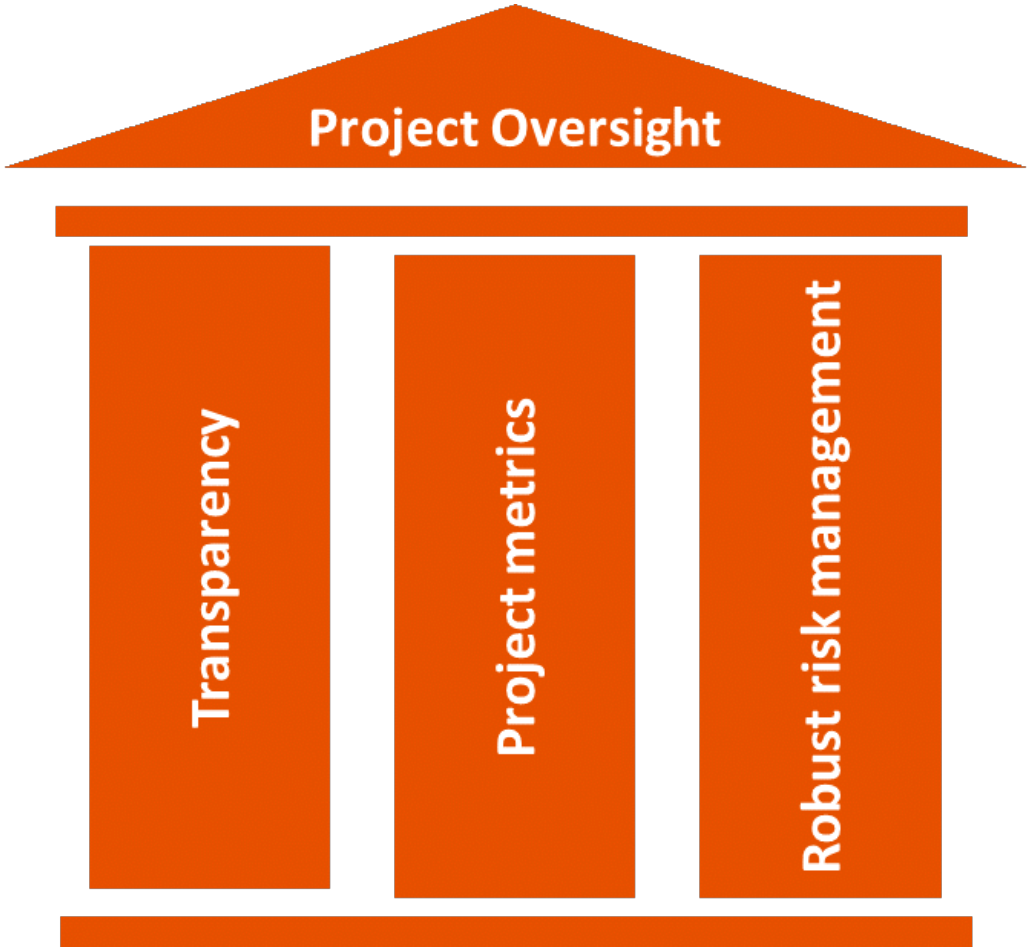
The importance of strong and effective project oversight

to project success

Nuclear projects are large and large projects are hard. They are hard to organize, and they are hard to execute. We have seen what happens when we try and convince people they are easy – or that we can make them easy by shifting the risk onto the vendor/contractor – and then expect everything to turn out all right. The outcome is either a project that is cancelled before it starts, or that runs over budget and over schedule.

Last year we did a three-part series on how to manage nuclear costs. We focused the discussion on how to build to cost and schedule, how to control the cost of capital and finally, how to control the capital cost. Today we are going to focus on an essential element of managing large projects to cost and schedule – project oversight. Project oversight can mean both the direct project management of a project, as well as the indirect and independent oversight that may be put in place by project investors or customers. In all cases, the need is the same. We must make sure projects are well managed and proper oversight plays an essential role in meeting this objective.

The purpose of project oversight is to ensure the project is proceeding on time and on budget – and of more importance, that problems are identified early so that corrective action may be taken while the cost to correct the issues are manageable. In our work on various nuclear projects we have identified a set of three pillars for successful project oversight:



Transparency – Transparency incentivizes good behaviour. The owner and other stakeholders must all have complete transparency through to every project detail. Once there is project transparency, it becomes clear that all project participants must line up with the same objective, completing the project successfully. Don't listen to contractors that say they are taking a firm price so you can't see the project details – no matter what the contractual model, there can be no secrets when it comes to project progress. This is the only way to see issues early and then take decisive action to resolve them quickly and efficiently. Otherwise, there will be delays as the contractor will only approach the owner for assistance after all other efforts have failed, greatly increasing the cost of correcting the

issue and adding
time that cannot be recovered.

**A strong set of
project metrics** – numbers don't lie, people do. The next step adding to transparency is to
base project reporting on a clear unambiguous set of project metrics. These metrics must be kept current and be
used to assess real project progress. If
there has been poor progress in the past period, the metrics will show it, but
more importantly, force a realistic recovery plan. We have all seen reports that say things were
slow last week but will be made up next week – but the numbers show that this
is not possible without adding resources i.e. to make up time, you need enough
people to do the planned work for the next period AND the additional work that
is behind. Metrics keep the project on
track and demonstrate where there are issues that need attention, and then whether
the attention is having the desired impact.

**A robust risk
management plan** – we don't create confidence by being told not to worry and
that everything is under control; rather we want to know the risks are well
understood and that a mitigation plan is in place should they be realized. Large projects will have things go
wrong. It is inevitable. It is what we do about it and how well
prepared we are that will make the difference on the project outcome.

All big projects are hard; nuclear projects are not unique. Clear precise reporting is an important

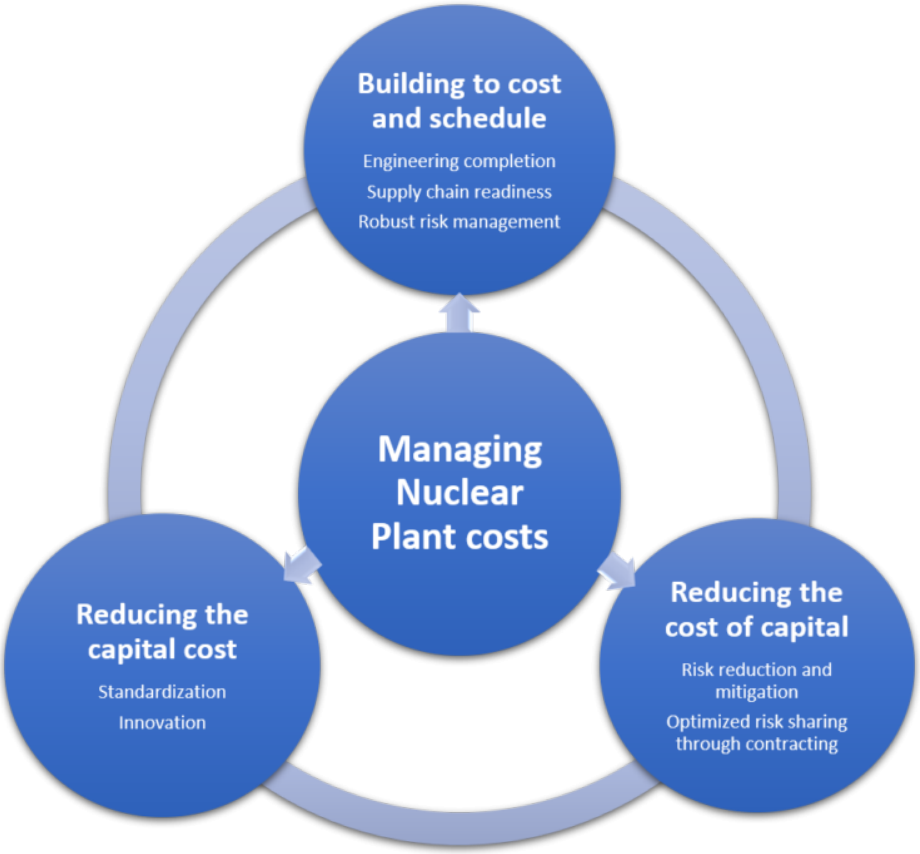
element to understand project status and take action for project improvement. We have all been on projects that have "what
I did on my summer vacation" type reporting telling us what has been achieved
in the last period without providing context.
This will not get the job done.
However, if a project has adequate oversight based on these three pillars,
it has the tools in place necessary for project success.
Remember, success means finding ways to manage
and mitigate risk, not pretending it doesn't exist because it has been passed
on to specific project participant making it their problem. As we have said many times, there are no
scenarios where your contractor fails, and you succeed.

Nuclear plants have an important role to play in our current and future energy mix. To properly play
its part requires projects to be economic with predictable outcomes. If we do our part to demonstrate we can
deliver on our commitments, we can then work to secure more support from our stakeholders,
and of most importance, the public.

Making nuclear plants cost less – build and repeat, the benefit of standardization

When it comes to nuclear project implementation there is no greater challenge than getting the costs right. The industry

can focus on improving public acceptance and demonstrating a need for low carbon generation, but only a cost competitive nuclear industry will really meet its full potential. This is the third part of our 3-part series on managing nuclear costs. The first part focused on the need to build to cost and schedule (March 2018) avoiding the severe overruns that have been experienced in the past. The second part considered how to bring down the cost of capital (July 2018), which can be shown to be the most sensitive parameter when considering the cost of energy from a nuclear plant. In this final part, we will focus on the very root of the nuclear cost structure, the capital cost of building a new plant and how to reduce it, primarily through standardization.



We need to look no further than nuclear construction in China and Korea to see how nuclear can be done right. Building a fleet of plants of the same design is paramount to reducing risk and managing cost. There is little doubt that standardizing plant designs and building the same plant over and over reduces both risk and cost. Risks are reduced by

doing what has been done before and is well understood, and costs are reduced by learning by doing – or simply getting better at doing the same thing over and over again.

Often, we limit the definition of a standard plant to repeating the same design for a series of projects. However, to get the maximum benefit, it must be thought of in much broader terms. Any change, no matter how small introduces risk that can negatively impact the outcome. The ultimate in standard plant construction is when an exact replica is built on the same site as the previous project. This means using the same design and drawings, the same suppliers of both equipment and construction, the same commercial structure, the same project management approach, and most of all using the very same people who did the work the last time, all in a time frame that maximizes the continuity of what was done before. This is no surprise. Keep in mind that success is all about people. We all know that when we want to do something at home, we have the world's best teacher in YouTube to show us how to do whatever we are doing. But we also know, that no matter how well we are instructed, we still do better when we do the job for the second time.

Barakah Nuclear Power Plant – United Arab Emirates

Evidence shows that huge gains can be made replicating at the same site. The ETI (Energy Technology Institute) report on nuclear cost drivers notes that early units have higher costs

for the Barakah project and later units have significantly lower costs through both multi-unit efficiencies and learning effects (The final unit is about 40% less cost than the overall site average cost). However, once we leave a given site, replication benefits start to be reduced. In the same jurisdiction we are likely to closely replicate what has been done at one site to another although different site conditions will have to be considered. In a second jurisdiction, where there may be new project managers, new suppliers and new site conditions, more challenges arise. It is essential to maximize what is replicated and minimize what is not. Of course, moving around the world, we know the challenges. Re-localizing the same components and services for each new market is a recipe for added risk. A model where we globalize supply would be much better so that the same suppliers can have the same scope in many different jurisdictions. However, political reality makes this difficult. The next best thing is to use the same design and then do our best as an industry to institutionalize the processes so that new suppliers and contractors can replicate what has been done by others with appropriate learning methods to ensure the benefits of replicating can be maximized.

Once we are focused on replicating standard plants, we can then further improve costs by innovating. It seems counter intuitive since innovation means change, and change means moving away from the standard. While true, the key to success is modest and managed change within the construct of a standard plant. As we learn, and new technologies become available, we can innovate through improved methods and smarter design.

A 2016 study by McKinsey found that productivity in the construction industry is poor compared to other industries for a range of reasons. One is the slow adoption of digital technologies into the field. Using technologies found in other industries to improve construction in general and

nuclear project implementation specifically can make a huge difference. Anything that improves the cost and reduces time and risk is worth considering. This does not mean huge design changes but rather project management and construction improvements. Construction of large projects means managing large amounts of information and ensuring modern information management techniques are used by this industry will bring obvious benefits.

Design changes need to come as well but based on learnings from a series of plants. The big issue is whether or not we can achieve the volume of projects required to build a series, make changes and then implement an updated model for a new series of projects. This is what the French did in the past and the Chinese are going down this path with their large domestic program. As seen above at Barakah, the Koreans have been masters at developing and implementing standard plants.

The bottom line is that lower costs are a key driver for future industry success with improvement not only being possible, but well within reach of the industry. If we pay attention to all three paths to cost reduction, i.e. ensure projects are built to cost and schedule, reduce the cost of capital through more realistic risk management, and reduce the cost of building plants through standardization with innovation in construction methods, the result will be significantly lower costs of energy (likely anywhere from 25 to 50%) than are being realized in western countries today. This would be a game changer.

As nuclear power becomes recognized as the only large-scale generation option that meets both environmental and reliability requirements for an energy hungry world, there is no better way to get the world to accept nuclear than bringing down the cost of energy.