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.

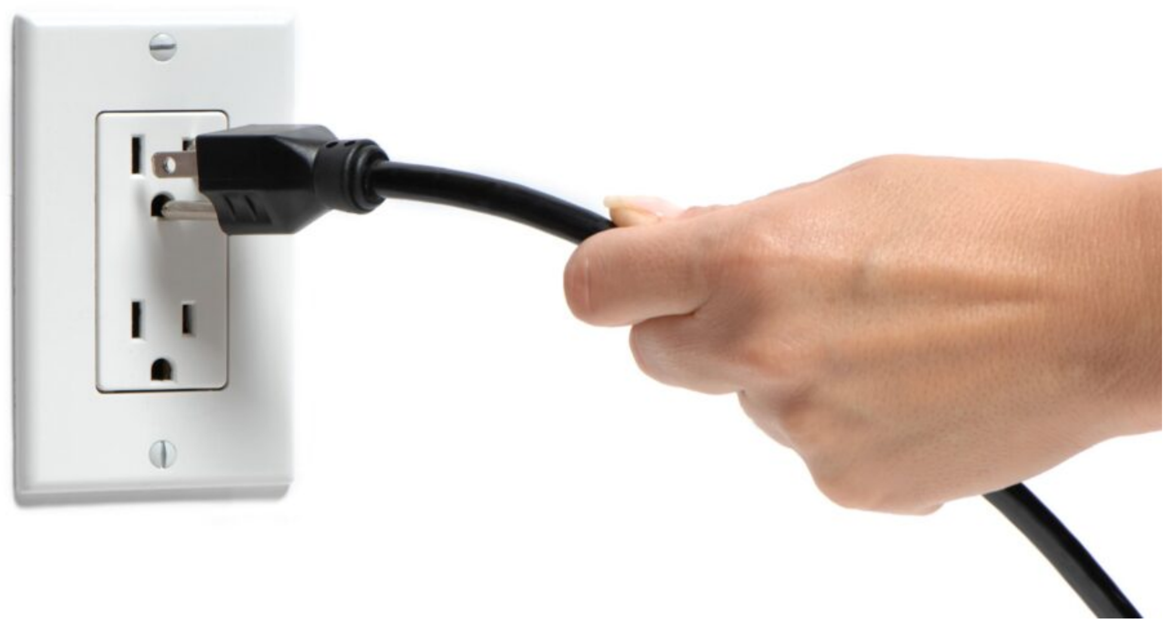
The lesson is that when developing project structures, the objective is to manage risk while incentivising the behaviours from the project stakeholders necessary for project success; not to decide who suffers the most in the case of failure. Because for **long term commercial success**, there is one 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.



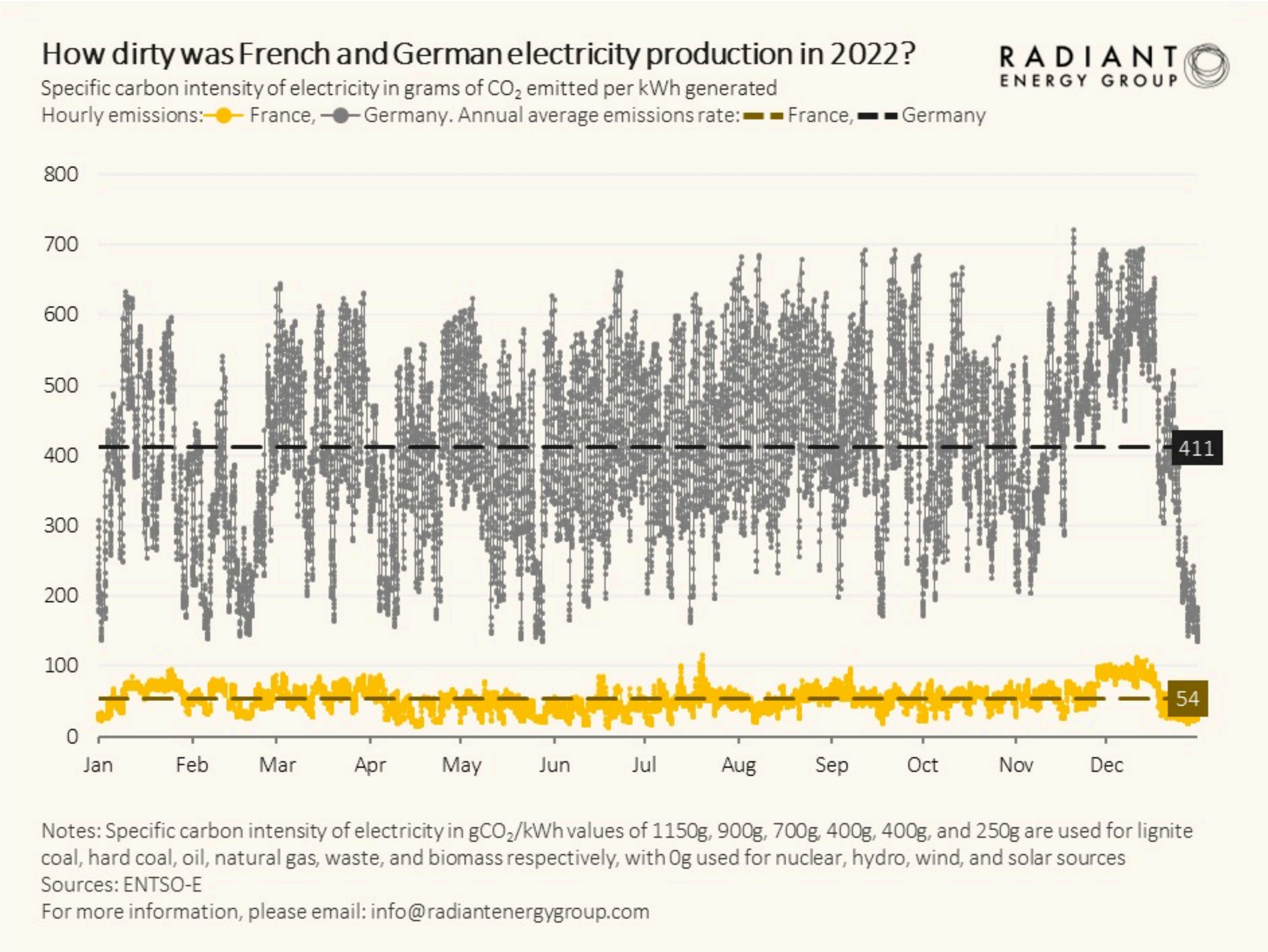
Source: istockphoto.com

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!

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Energy economics – why system costs matter

In our last post, we quoted from recent reports that clearly lay out the environmental benefits of nuclear power. This month we want to start off the year by launching a short series addressing some of the issues that impact energy economics. Today we will talk about the importance of **system costs** in understanding the relative costs of different generation technologies.

Last year at this time we wrote about the IEA/NEA report, Projected Cost of Electricity 2020, that shows nuclear is competitive with alternatives in most jurisdictions using the traditional Levelized Cost of Electricity (LCOE) approach. LCOE is a great way to compare costs of electricity as it is generated from two or more different options to be implemented at a single spot on the grid with similar system characteristics. With intermittent variable renewables on the system, LCOE alone no longer provides a sufficient basis for direct comparison. By their very nature, deploying these renewables add costs to the system to be able to deliver reliable electricity in the same way as more traditional dispatchable resources like nuclear, hydro and fossil generation.

Source: pexels.com

What are system costs? In a report issued by the OECD Nuclear Energy Agency (NEA), system costs (see the report for a full definition) are basically the additional costs to maintain a reliable system as a result of intermittent variable renewables only producing electricity for a limited number of hours when the resource is available (e.g. daytime for solar), their uncertainty due to the potential for days with little resource (e.g. rainy or cloudy days), and the costs to the grid to be able to access them given their more distributed nature (e.g. good source of wind but far from demand).

A 2018 study undertaken by MIT “The Future of Nuclear Energy in a Carbon Constrained World” considers the impact of nuclear power on the cost of electricity systems when deep decarbonization is desired. It looks at various jurisdictions around the world and the conclusion is always the same; the cost of electricity is lower with a larger nuclear share than trying to decarbonize with intermittent variable renewables (and storage) alone.

The reason for this impact is fundamentally due to the relatively little time these resources produce electricity. Solar and wind only generate when the sun shines and the wind blows, meaning they produce only some of the time and not always when needed. The average capacity factors of these technologies vary by location with world average capacity factor of just below 20% for solar and about 30 – 35% for wind (capacity factor is the amount of time a resource produces compared to if it would produce 100% of the time). Contrast this with the 24/7 availability of nuclear power, which can operate at capacity factors of more than 90%.

The impact on electricity systems is clear. Given the limited duration of operation of intermittent variable renewables, there is a need to dramatically overbuild to capture all the electricity needed when the resource is available to cover periods when the sun is not shining, and the wind is not blowing (all assuming there is reasonable efficient storage available which is not yet the case). The result is a system with much larger capacity than a system that includes nuclear (or any other dispatchable resource). In the MIT study for example, the system in Texas would be 148 GW including nuclear but would require 556 GW of capacity with renewables alone. In New England a system with nuclear would have a capacity of 47 GW but would require a capacity of 286 GW with renewables alone. In the UK this would mean 77 GW with nuclear compared to 478 without. And so on. The costs of adjusting the system to accommodate these much larger capacities is significant.

Since that time study after study finds the same result. This includes a study in Sweden in which 20 different scenarios for full decarbonization always come out the same; in every scenario the most cost-effective system has continued long-term operation of existing nuclear. And more recently a study in France has shown that decarbonizing without nuclear means a system more than twice as large as one with nuclear and the more nuclear in the system, the lower the overall average cost of production.

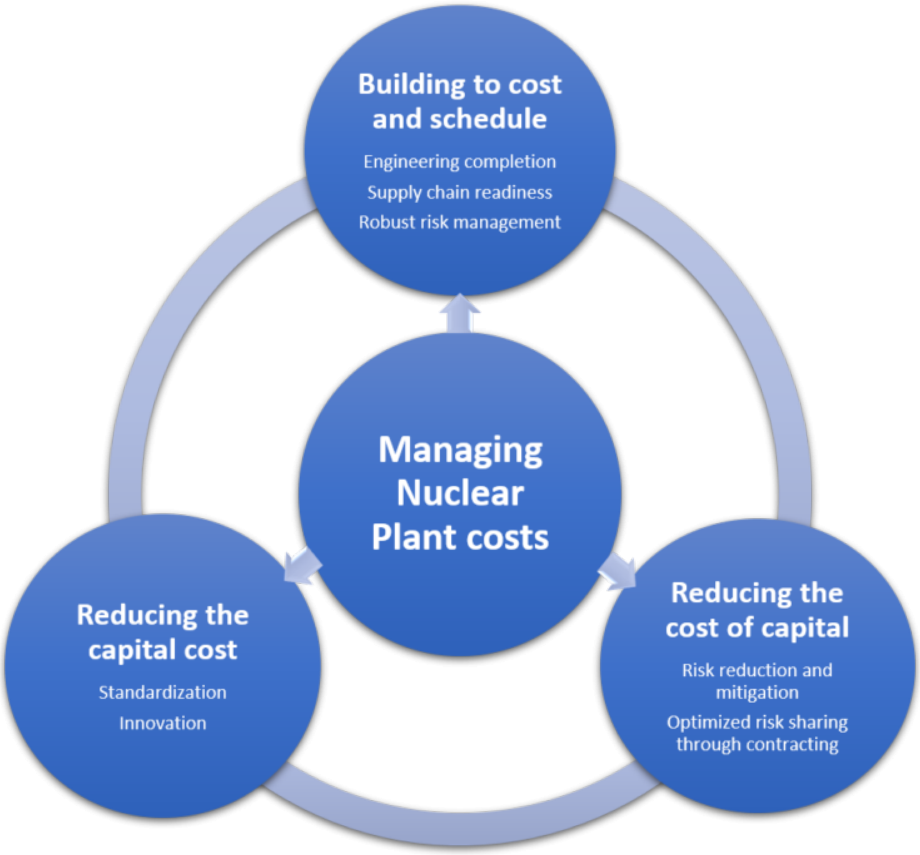
So, what does this mean for planning? The approach to implementing a reliable economic low carbon electricity grid must start with looking at the entire system. A study should assess the total costs of deploying the system under a range of scenarios using different shares of available resources. Different forms of generation have different capabilities and these need to be modelled. Once an efficient mix is determined, a plan should be put in place to implement it (i.e., X% nuclear, Y% solar, Z% wind, A% storage, etc.). When looking to deploy each technology, LCOE can be used to compare various options. For example, when comparing one solar project to another or one nuclear project to another. And of course, should the costs of any given technology vary too significantly from the assumptions in the system study that determined the efficient mix, then the system study should be updated.

Today’s energy markets are most often based on the assumption that all electricity generated is the same (to be discussed in a future post). This is true at the moment of generation when yes, an electron is an electron. Unfortunately, the ability of any given technology to actually be there to produce at the moment it is needed varies substantially. Therefore, a direct comparison of the LCOE of one option vs another is only part of the story.

To fully understand the costs of electricity generated, the costs of integrating any given technology into a reliable system must also be considered. After all, what really matters is how much we pay as customers for our electricity and the studies are clear, nuclear as part of a fully decarbonized system is always lower cost than a system based on renewables alone.

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.

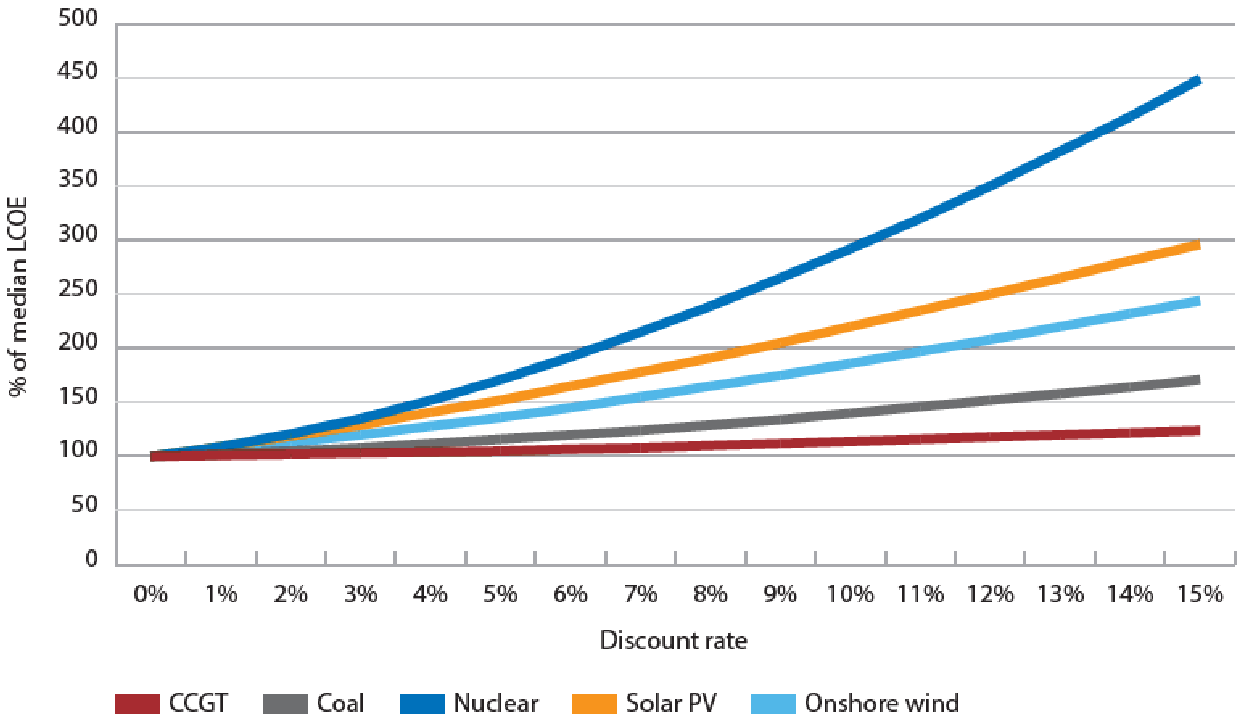
As nuclear power becomes recognized as the only large-scale generation option that meets both environmental and reliability requirements for an energy hungry world, there is no better way to get the world to accept nuclear than bringing down the cost of energy.

Nuclear economics – reducing costs by managing the cost of capital

Of the many challenges to expanding the use of nuclear power, economic competitiveness is essential for future success. Nuclear projects are large complex projects that have frequently experienced delays and overruns. Earlier this year, we wrote about the need to build nuclear plants on time and on budget as the first step in making sure the economics of new build nuclear are robust. Improving the predictability of cost and schedule, i.e. making sure that when a project is approved, the costs and schedule are well understood and then they are reliably delivered, is a path to reducing the risk of these projects and securing public, government and investor confidence.

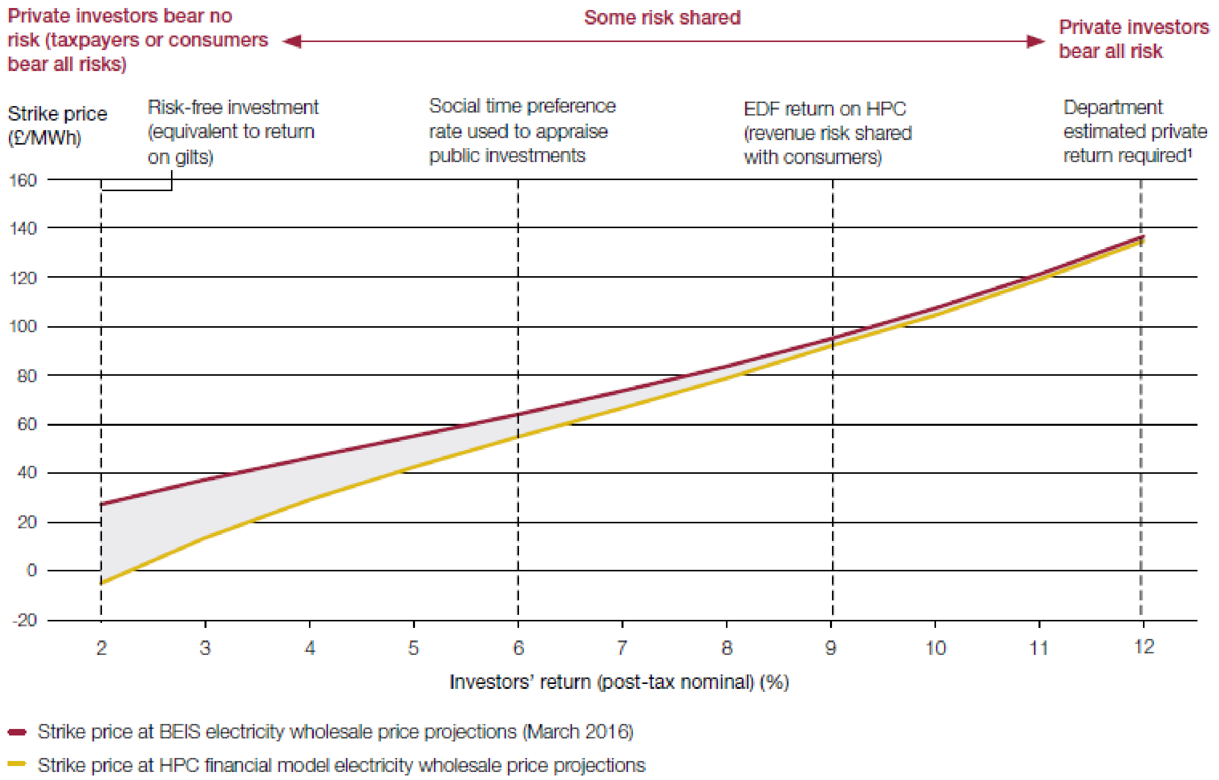
With project risk under control, the next step is to find ways to improve the overall economics of new nuclear plants. Studies have shown that the two largest drivers of the Levelized Cost of Electricity (LCOE) from a nuclear plant are the cost of capital and the capital cost. So today we will talk about lowering the cost of capital as a viable approach to improved economics and we will discuss ways to improve the capital cost in a future post. The diagram below shows the sensitivity of the cost of energy to the cost of capital from the OECD/NEA report Projected Costs of Electricity, 2015 Edition. As can be seen by the dark blue line, small changes in discount rate have relatively large impacts on the cost of energy.

Figure 7.6: LCOE as a function of the discount rate



For this discussion we go to the UK, where its own National Accountability Office (NAO) did a review of the contract for difference model agreed to for the Hinkley Point C project. While it concluded the HPC deal is competitive in price and comparable in IRR to the 40 other similar contracts with low carbon generators, it noted that the economics have deteriorated since 2013 when negotiations occurred as the costs of some alternatives have improved. A construction risk analysis presented in an appendix to this report considered alternative models in which the UK government and consumers might choose to provide more support to arrive at lower energy costs. Consistent with the graph above, the NAO came to the same conclusion; that if a model can be developed with a different risk profile that reduces the cost of capital, the customer can benefit greatly through reduced energy costs.

Sensitivity of strike price to investors' return



The chart presents the strike price necessary for investors to achieve different levels of return based on two sets of electricity wholesale price projections. The higher the level of risk private investors bear, the higher the strike price. In the summary table (Figure 19), we show three different scenarios:

- '100% private risk' assumes private investors carry all risks. The Department has estimated that the hurdle rate for nuclear projects is about 12% (post-tax nominal).[1] To achieve this return, the price they receive would need to be between £135 and £137 per MWh during the first 35 years of generation;
- 'HPC' scenario replicates the current deal. By removing the electricity price risk for 35 years as well as other risks, it reduces the investors' required return to 9% which results in a strike price between £91 and £95 depending on the forecasts for market prices after the CfD period; and
- '100% public risk' assumes all risks are transferred to the public sector and the taxpayer would have to pay the full project cost (£19 billion). In this case the strike price for 35 years would range from -£6 to £28 depending on the electricity price forecasts. The combination of low discount rate and high future electricity prices makes the present value of the cash flows post CfD so high that it compensates for the negative strike price during the CfD period to achieve an overall investor return of 2%. Such a strike price is a theoretical price based on a comparison with the 35-year CfD structure used in HPC.

This led to the UK government recently agreeing to a revised model for the upcoming Wylfa project to be implemented by Horizon Nuclear in Wales relative to that agreed for Hinkley C. By agreeing to some level of direct government investment, it reduced the cost of capital and is expecting the result to be a lower cost of energy. While Hinkley Point C has an agreed cost of £92.50 / MWh, it is anticipated that the Wylfa project may have a price in the range of £75 – 77 / MWh, a possible reduction of 15% or more in cost to the ratepayer. This is a game changer. By taking on a larger share of the risk, government can drive down energy costs. Of course, this also means that it must be comfortable that this risk can be effectively managed. This is likely as the private players, in this case Horizon nuclear, are still heavily incentivised to perform. It would also be recommended that government install some form of oversight on the project to stay informed of progress and to ensure that there is transparent reporting of its risks. It should be noted that this negotiation is not complete, and the final outcome is still unknown.

In fact, there is now thought that government should consider a regulated asset base (RAB) model further reducing the cost of capital and hence the cost of energy. A paper by Dieter Helm suggests the cost of energy can be greatly reduced if this model were to be considered. It is in common use in other utilities in the UK such as water and rail where long term assets are the norm.

The outcome would be nuclear projects with significantly lower energy costs. With appropriate risk management, it can easily be shown that the magnitude of the potential savings in energy cost is well worth the increased risk sharing. In other words, the private sector is charging too steep a risk premium to take on risks that are too long term in nature and difficult to price effectively. A more balanced approach to risk sharing could bring benefits to all stakeholders. Not everyone agrees. Government advisors of the National Infrastructure Commission have recently suggested slowing down nuclear approvals since renewables costs are improving faster than was previously anticipated. Of course, if renewables can improve, so can nuclear and this is exactly what the UK government is trying to support. If the nuclear cost can indeed come down so dramatically, then there is no reason to slow down as all good options for future generation are improving with time and the result will be a robust set of diverse generating options going forward.

For many years Government has been making investments in renewables to support their development as viable options for future generation primarily through direct subsidy. Following the commitment to Hinkley Point C, efforts are underway to develop policies that specifically target the unique challenges of nuclear power. These policies are creative ways to understand the investment and risk profile of nuclear and then address them in ways that are productive and continue to incentivize the private sector to perform.

Nuclear power is an essential tool in meeting the low carbon generation needs of the future. The UK government should be applauded for not only accepting this but now moving on to finding ways to improve this much needed option. The UK has got it right – focus on policies that reduce nuclear costs to customers and we all win.

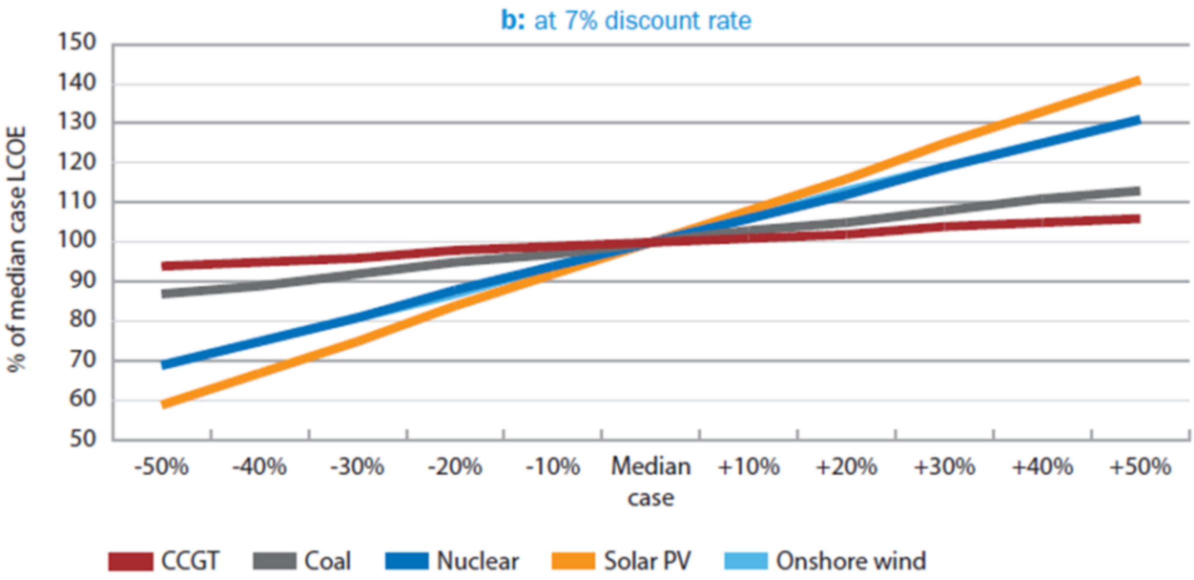
Building nuclear on time and on budget – yes, it is possible…and essential

Large capital projects are hard. 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.

Nuclear projects are often criticized for being delivered well over cost and schedule. Examples abound. Currently we have the Olkiluoto plant in Finland, the Vogtle plant in Georgia and the Flamanville plant in France all running late and over budget while Watts Bar 2, the first unit to enter service in the USA in 20 years was also recently completed well over its original budget. On the other hand, many plants being built in China and Korea are on time and on budget and even the first new plant in a new nuclear country in a long time, Barakah in the UAE, was built on time and on budget, although there are now some delays in the first unit entering into operations. Of course, nuclear projects are not the only large projects to suffer from overruns. A 2017 report on North American projects by EY Canada has determined that "*Canadian infrastructure megaprojects run 39% (US$2.2b) over budget and behind schedule by 12 months on average. However, Canadian megaprojects perform better than those in the US, where the average project delay is a little more than three years*."

Now, we have talked in the past about the economics of nuclear plants and one thing is clear, the largest component of the cost of energy from a nuclear plant is the capital cost representing about two thirds of the total cost of energy. Therefore, building to budgeted cost and schedule is essential to maintain the estimated economic competitiveness of the plant that was the basis for securing project approval. And because the capital cost is such a large component of the cost of nuclear (and solar) energy, the cost of energy is very sensitive to cost overruns. This can be seen in the chart below from the IEA/NEA report "Projected Costs of Generating Electricity – 2015 edition".

Figure 7.8: LCOE as a function of overnight cost



There are many reasons why large projects go over budget and are late. What is in vogue these days is to put the blame primarily on the fact that these poorly performing projects are First of a Kind (FOAK) projects, meaning they are building a new design for the first time. Other factors include the significant regulatory burden placed on the nuclear industry and the challenges being experienced by a supply chain that has not delivered to a nuclear project in these jurisdictions in a long time and needs to re-establish its capability.

Clearly the strength in the Chinese and Korean programs are from both standardization and the relatively large number of units being built, which provides for more certainty and a well-developed supply chain. And while it is true that doing things for the first time makes a project more difficult, the fact that a project is FOAK may be an explanation but is not a good excuse for the magnitude of overruns we are seeing. If we want to be credible, we must deliver on our commitments. After all, these are large multi-billion dollar projects. While there are many excellent reasons to support nuclear power, who will approve future projects if the outcome is not predictable?

We recently wrote about using fixed price contracts to mitigate some of these risks and why this has resulted in a false sense of security. Today, lets look at some of the things we can do to assess and mitigate the risk of overruns on nuclear projects, primarily those with larger FOAK elements.

Why do we say FOAK elements? Those that know us well, know our complete preoccupation with standardization as a means to controlling project risk. But as much as we would like to say that after the first project the next units will be standard, it is always a matter of degree. For example, the highest level of standardization is when there are multiple units being built at the same site. This allows for everything learned on the first unit to be immediately implemented on the subsequent units by the very same people that have just completed the previous project. Then there is the case where the same design is being implemented on a different site in the same jurisdiction so that most (but not all) of the supply chain and management can also be the same. But for other projects, we know that even when repeating a design, there are many things that can be new or different. Often there are different suppliers and contractors as projects are built in different jurisdictions; and there can also be changes in the financial and contractual structure of the project, that can impact project implementation. And of course, there are always design changes as designs are updated to meet new codes, address site specific issues and meet local regulatory requirements.

As we stated above, large nuclear projects are hard. But hard does not mean impossible. Hard takes the right approach to deliver success. So, what are we to do to deliver projects to time and budget?

We need to all learn from each other. We do not implement enough projects in most jurisdictions to benefit from the series effect on our own. Here are some of the lessons learned gathered from those that have succeeded:

- Plan, plan and plan some more. Nothing is more important than understanding what has to be done before you do it. Large overruns and delays usually come from surprises, i.e. issues that come up that nobody thought about and now take time to resolve when the project clock is ticking.
- Ensure adequate design completion before construction. Understanding scope can only be done when the plant is designed. This is where FOAK plants need a larger investment before the first shovel hits the ground. You cannot plan your project if it is not designed.
- Ready your supply chain. If there are many new suppliers in the mix, or a number have not supplied in a long time, invest in their development and allow time in the program for them to come up to speed.
- Develop and implement a robust risk management program. Identifying and understanding the project risks, and then developing risk mitigation plans are essential to being ready for whatever comes up during project execution. This risk plan should be the basis for project contingencies for both cost and schedule. And even if the risk that comes up was not in the original risk register, having a robust process will ensure that action can be taken quickly and effectively to mitigate and keep the project on track.
- Develop a project financial structure that enables the investment necessary to prepare for the project so that the project plan, estimate and risk program are at a level that can support project success when the project cost and schedule are committed; and finally,
- Get the best possible people you can. We think of large projects as a combination of technology and commodities. But in reality, it is people who build projects and strong leadership is the special sauce that leads to project success.

As we have said many times before, nuclear plants are extremely reliable, efficient, low carbon and cost-effective producers of electricity. As they are capital intensive, their economics depend upon successful project implementation. Project delays and overruns have large impacts on the project economics and negatively impact the credibility of the industry. After all, just like a great symphony, there is something beautiful when a large complex project comes together as planned – and there is nothing more important for the long-term health of the nuclear industry than building projects to cost and schedule.

Going for gold, nuclear plants contribute to a resilient electricity system

Over the years, when talking about the pros and cons of various generating assets, we have talked about economics, environment and reliability – but more recently a new word has entered the energy lexicon – **Resilience**. As defined by Oxford, “***resilience** is the capacity to recover quickly from difficulties; toughness, the ability of a substance or object to spring back into shape*”

Well, if you are anything like us, you have been glued to your TVs watching the winter Olympics in PyeongChang Korea over the last two weeks. Watching these athletes whose hard work knows no bounds do their best to represent their countries and try to secure a medal is truly inspirational and their **resilience** is what keeps them going above all odds. With close to 3,000 athletes competing and only 307 medals earned, most were disappointed in their quest for gold, yet they are all proud to have represented their countries and performed at their best. They never quit. They work for years to make it to a global competition where most do not win medals and then go back home, work even harder, and then hope to have the chance to do it all over again in another four years. I find that every time the Olympics are on, I feel inspired to work harder and do more to achieve my own goals.

The following Olympic ad by Toyota shows how shear determination and hard work can overcome the one billion to one odds of winning Olympic gold. It still brings tears to my eyes every time I watch it.

https://www.youtube.com/watch?v=sefscV3GvWM

Now that we have all been inspired, what do we mean when we talk about **resilience** of generating assets like nuclear plants? We mean being able to continue to operate through difficult and extreme external events, usually weather related. We first took notice a few years ago in 2014 when North America experienced the polar vortex and it was clear that gas couldn't meet generating requirements in the extreme cold, but that America's nuclear plants continued to run and keep Americans' lights on.

Last year, the US Department of Energy completed a study that emphasized the importance of **resilience** to our energy infrastructure. The cover letter from the Secretary of Energy started "*A reliable and **resilient** electric grid is critical not only to our national and economic security, but also to the everyday lives of American families.*" It also introduced the idea that **resilience** has value to energy customers stating, "*We also need to recognize the relationship between **resiliency** and the price of energy. Customers should know that a **resilient** electric grid does come with a price.*" Ultimately the Energy Secretary recommended to FERC that they compensate nuclear and coal generators for their **resilience** based on fuel availability on site. Unfortunately, this approach failed but did start an important conversation.

This past fall during hurricane season, we used this word again when there were extreme storms in Houston, Florida and Puerto Rico. At the time it was noted that even though communities suffered greatly, the South Texas Project nuclear plant continued to run during the hurricane in Houston and that most nuclear plants were able to ride out the storm in Florida. On the other hand, even today, about 5 months after hurricane Maria devastated Puerto Rico, approximately one third of the island's residents are still waiting for power to return. Much of the reason for lack of power is the collapse of the transmission and distribution system, but this clearly demonstrates the importance of the electricity system as critical infrastructure in being able to successfully recover from natural disasters.

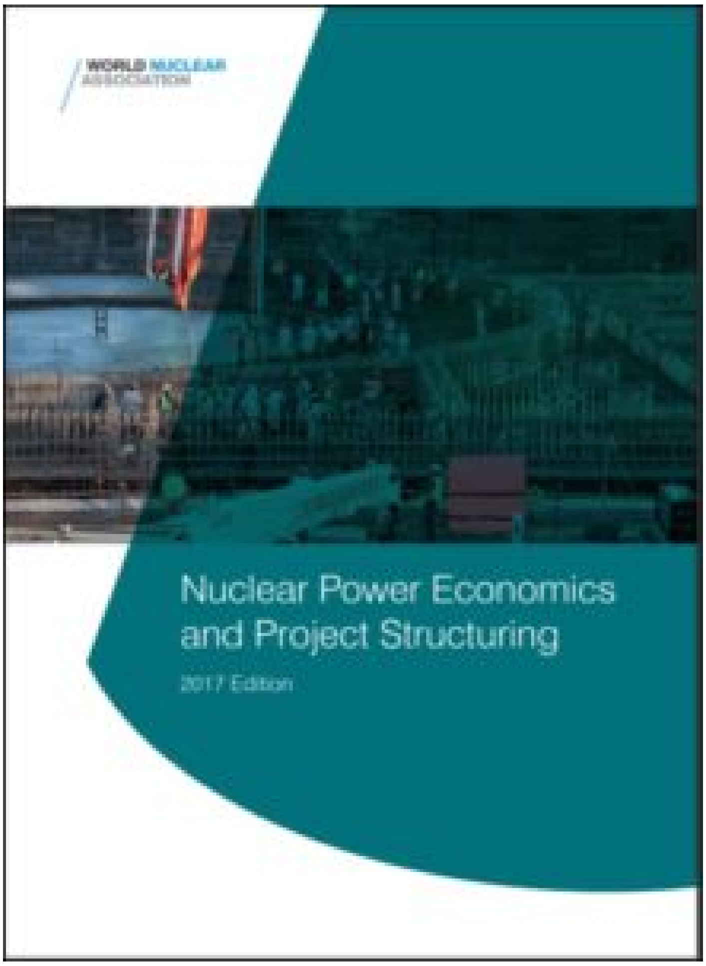
Then as we entered the new year, it was once again extreme cold that impacted the supply of electricity in the North East. Wind and solar don't do well in these extreme conditions and gas is directed to homes first for home heating. The result – New England was saved by oil, yes it was oil that provided a third or more of New England's electricity needs. And even that was at risk if the cold spell would have lasted much longer as reserves started to dwindle. Yet there is still a discussion of closing nuclear plants that just keep on generating during these events. So let's remember what Secretary Perry said, "*Customers should know that a **resilient** electric grid does come with a price.*" What should really be said is that not having the **resilience** needed comes at a significant cost for us all should the electricity we need not be there when we need it.

So why talk about this now? We were thinking of writing about the importance of **resilience** to the electric grid for some time since the DOE study came out last year. We know that nothing continues to operate in extreme conditions better than our nuclear plants. But having been inspired by our Olympians, we realize it is not only the **resilience** of the nuclear plants we build that are so important to all our lives; rather, it is the **resilience** of those that work in the nuclear industry that will ensure our success. Just like those Olympic athletes, the people that work in the nuclear industry have unlimited passion for what they do – because they know they are working to make the world a better place, providing abundant economic, reliable, low carbon – and yes – **resilient** – energy to power our dreams for a better future.

Nuclear Power Economics

At the World Nuclear Fuel Conference (WNFC) conference in Toronto this month, I will be presenting a paper “**Nuclear Power Economics and Project Structuring – 2017 Edition**” to introduce the most recent version of this World Nuclear Association (WNA) report. For full disclosure, I am the chair of the WNA Economics Working Group and this is the group responsible for the report’s preparation.

The report sets out to highlight that new nuclear build is justified in many countries on the strength of today’s economic criteria, to identify the key risks associated with a nuclear power project and how these may be managed to support a business case for nuclear investment and, of major importance, to promote a better understanding of these complex topics and encourage subsequent wider discussion.



When it comes to the conclusion, little has changed since the first report was issued back in 2005. At that time, it concluded *“In most industrialized countries today new nuclear power plants offer the most economical way to generate base-load electricity – even without consideration of the geopolitical and environmental advantages that nuclear energy confers*.” The 2017 version comes to the same conclusion stating, *“Nuclear power is an economic source of electricity generation, combining the advantages of security, reliability, virtually zero greenhouse gas emissions and cost competitiveness.”*

Of course, while some will say this is no surprise given the report is prepared by the nuclear industry; it must also be noted that it is not based on any industry funded research – but rather it is based on high-quality mostly-government reports on the economics of various energy options such as the “Projected Costs of Electricity” issued by the IEA and the

NEA.

While the conclusions may not have changed in the last decade, the nuclear world certainly has. Who would have guessed back in 2005 that the Koreans would have won a bid to build the first nuclear power plants in the UAE and that the first of these units would now be nearing completion while the first EPR in Finland continues to be delayed? There was the accident at Fukushima in Japan in 2011, major financial issues at the traditional large nuclear power companies such as Areva of France and Westinghouse of the USA; all while the companies from Russia, China and Korea have grown both domestically and with exports. Projects in the East are being built to cost and schedule with their outcomes being predictable due to the large programs underway in places like China and Korea using largely standardized designs. On the other hand, first of a kind projects in Europe and the USA are experiencing significant challenges. With new build being a function of capital cost and schedule, clearly poor construction performance will have an impact on the economics. The global industry is now also contemplating a new generation of Small Modular Reactors (SMRs) intended to reduce both project cost and risk.

And what about the competition? There has been huge global growth in renewables strongly supported with government subsidies and a dramatic drop in the price of gas in North America. The impacts of these subsidised intermittent renewables and 'un-carbon costed' gas have depressed wholesale prices in deregulated electricity markets creating a number of issues in maintaining existing large scale nuclear baseload generation (as well as other baseload options). Policymakers are finally seeing the negative impact of these issues and are just starting to address these fundamental market design problems.

Yet in spite of all of these massive changes in the market, the reality remains that:

- Existing nuclear plants are operating very efficiently and unit operating costs are low relative to alternative generating technologies in most markets
- The global growth in demand for electricity creates opportunity for continued nuclear growth even when ignoring environmental considerations
- Nuclear energy competitiveness depends mainly on the capital required to build the plant. At discount rates of 5-8% nuclear is generally competitive with other generating technologies

While there are a host of issues affecting the future of nuclear power that are far from easy to address, the fundamentals remain. Overall, new nuclear plants can generate electricity at predictable, low and stable costs for 60 years of operating life and in all likelihood even longer in the future. Investment in nuclear should therefore be an attractive option for countries which require significant baseload amounts of low cost power over the long term.

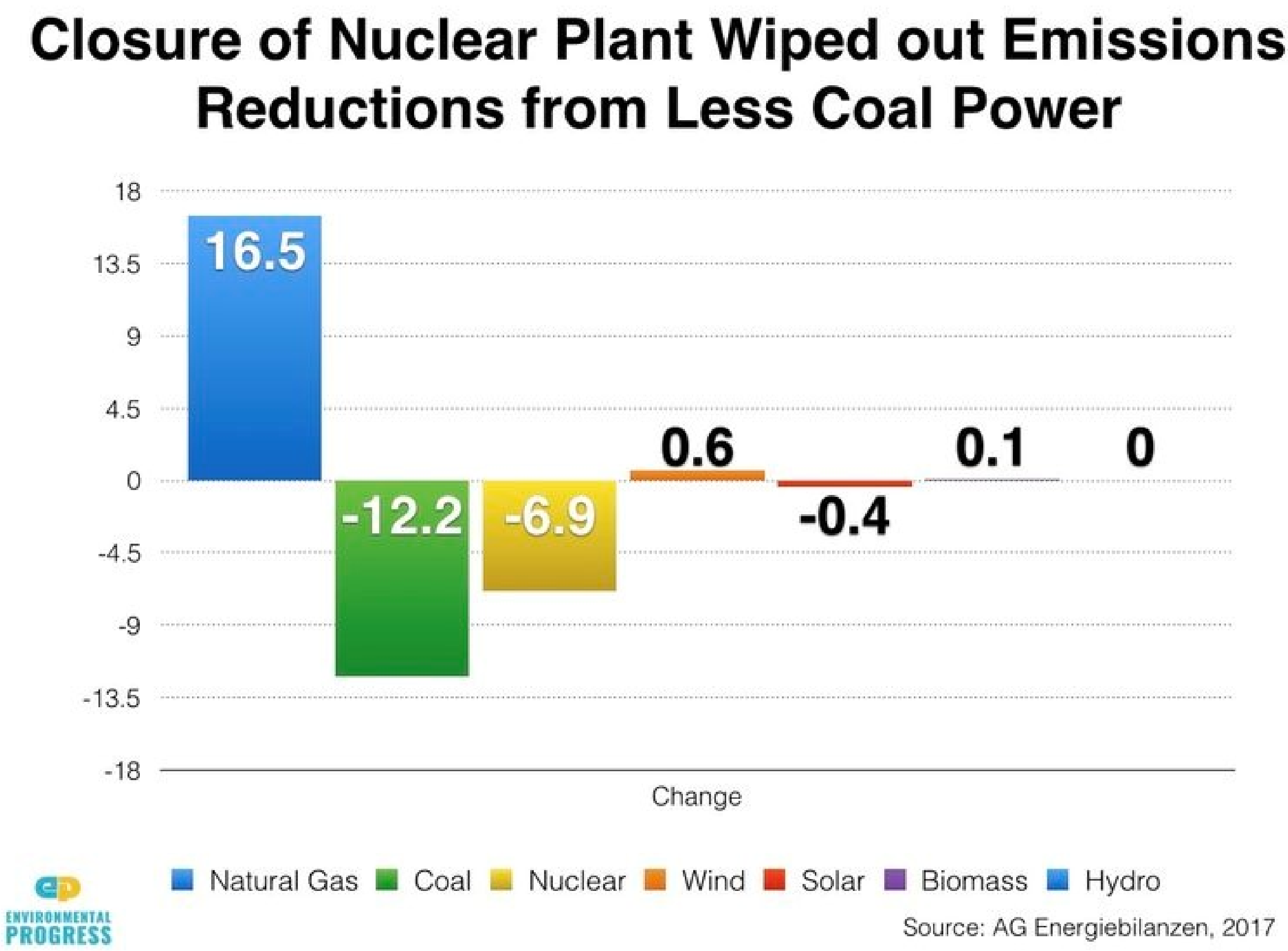
In an era where facts no longer matter, consequences still do

Over the last few years, we have written extensively about the strength of peoples' beliefs and how difficult it is to change them. In spite of this, I thought we were making progress with a push to more evidence-based decision making. For something as polarizing as nuclear power, facts-based decision making is critical to increasing support. (I understand the paradigm of fear of radiation is more emotional than fact based and I agree that we need to appeal to emotions to create the change we need – but let's leave that to a future discussion. In any case it certainly doesn't hurt to have the facts on your side.)

With the populist surge in 2016 we have seen an accompanying rise in complete disregard for facts; all the way to the propagation of absolute lies (or "alternative facts") to support peoples' beliefs. I don't want to get into a political discussion nor take sides on right versus left. What I do want to do in today's post is to discuss something more fundamental – i.e. that although we are free to believe what we want – that beliefs have consequences – and that consequences matter.

So, let's look at what happens when countries believe they can eliminate nuclear power from the mix and replace it with more wind and solar power. Of course, I am talking about Germany. Reducing carbon emissions is a reasonable goal as evidence (alternative facts notwithstanding) shows that climate change is impacting our environment and has long-term implications for our entire society. On the other hand, removing a low-cost low-carbon source of energy like nuclear power because of safety concerns is based on a strong element of fear rather than evidence. In fact, Germany's nuclear plants are likely some of the safest in the world and there is no reason to suspect they will result in a catastrophic accident that means the end of Germany as we know it – yet that is what people fear.

So, what happens in a case like this? The results are in. Fossil fuel use is increasing in Germany, carbon emissions are going up and so is the cost of energy. The German people are paying more money for an outcome that does more damage to the environment and hence, their health. Frankly, it's a high price to pay for the piece of mind that comes from eliminating the perceived risk of nuclear. Or in other words, the extreme fear of nuclear is driving policy more than concern for either energy cost or the environment.



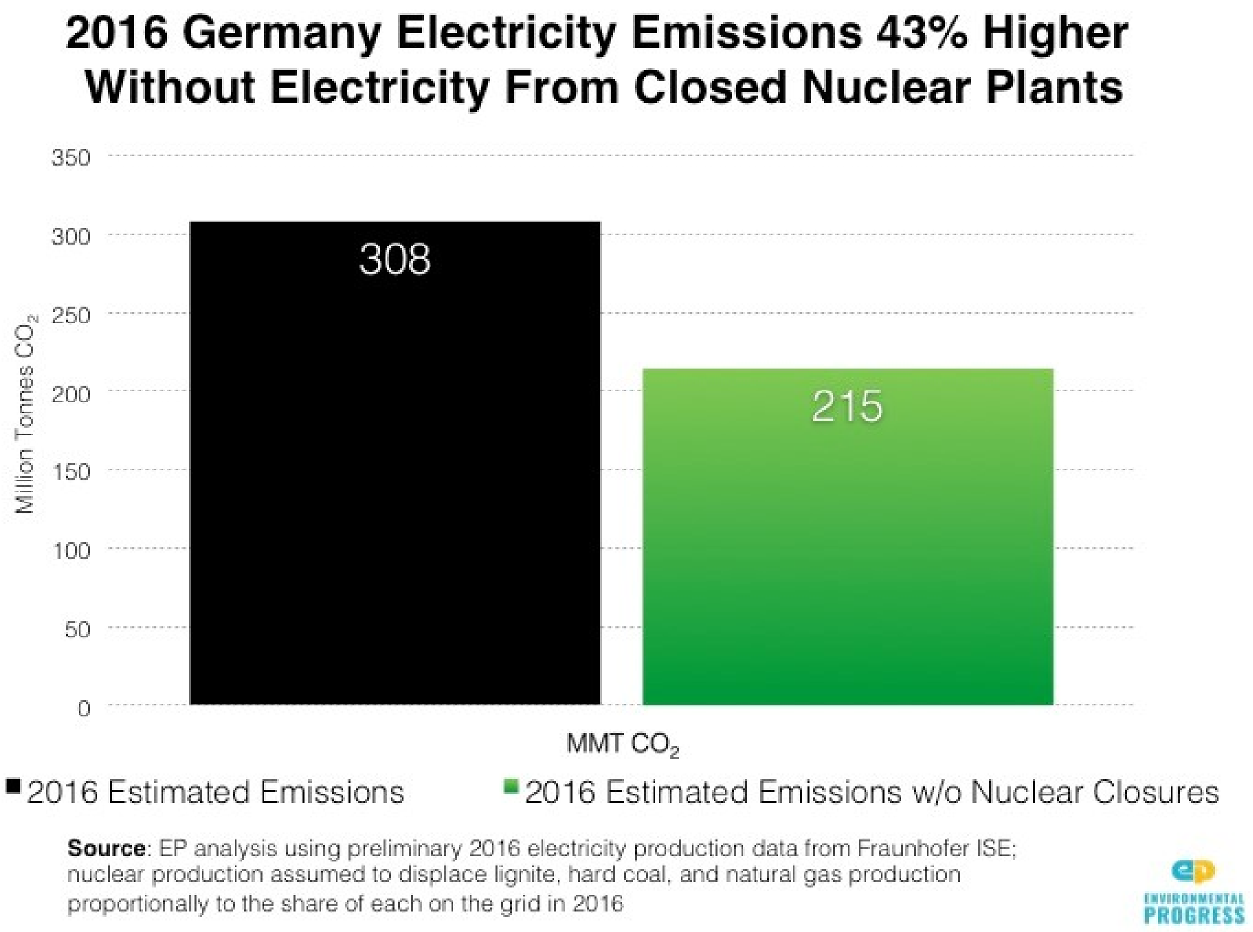
As shown above, closure of another nuclear plant in 2015 resulted in increased emissions in 2016 (the first full year it was out of service) even though there was a substantial substitution of gas to replace coal.

And after adding 10 percent more wind turbine capacity and 2.5 percent more solar panel capacity between 2015 and 2016, less than one percent more electricity from wind and one percent less electricity from solar was generated in 2016. So, not only did new solar and wind not make up for the lost nuclear, the percentage of time during 2016 that solar and wind produced electricity declined dramatically. And why was this the case? Very simply because Germany had significantly less sunshine and wind in 2016 than 2015.

This analysis was done by Environmental Progress and shows that the intermittency of these renewable sources of electricity both throughout the day and from year to year mean that even huge increases in capacity of these forms of generation will continue to require fossil backup in the absence of nuclear power making 100% renewables an unachievable goal. Another study shows that to achieve a 100% renewable system in Germany would require a back-up system capable of providing power at a level of 89% of peak load to address the intermittency.

Comparing Germany to France, France has more than double the share of low carbon energy sources and Germany has more than twice the cost of energy as France.

So, trying to decarbonize by also removing nuclear from the mix at the same time is simply too high a mountain to climb. The following shows that German emissions were 43% higher in 2016 without the nuclear plants that have been already shut down. Keep in mind that they still do have operating nuclear and with more plants to shut down, the future trend is not likely to change.



It's not just about Germany. As Japan struggles to get its nuclear plants back on line after the 2011 Fukushima accident, its use of coal has skyrocketed. In 2015 its use of fossil fuels for electricity generation was 82% compared to 62% in 2010 when the nuclear plants were in operation. And now Japan plans to build 45 new coal plants (20 GW) over the next decade to meet its energy needs.

Finally, we can also look at South Australia, a nuclear free zone. Recent blackouts due in part to lower wind availability and the inability of thermal plants to make up the shortfall are also leading to questions on 'how much renewables is too much'.

So, we can all continue to hold our beliefs very dearly and only listen to those that support them, while vilifying those that do not. However, please keep in mind that in a world where the farcical becomes reality, results still matter. And for now, the results are clear, taking nuclear power out of the mix in Germany is not achieving its political-planners' goals. Yet these results are also not likely to change any German minds when it comes to nuclear power. But hey, why worry about the outcome when you know you are right or as said by comedian Chico Marx in the famous Marx brothers movie Duck Soup "Who you gonna believe – me or your own eyes?"?

UK commits to nuclear new build – a critical decision for the future of nuclear

More than a decade since then Prime Minister Tony Blair launched a review into UK energy policy, a positive decision has been taken to approve the construction of the first new nuclear station in the UK in a generation, Hinkley Point C.

Finally, after more twists and turns than a good British mystery novel, including: EDF's purchase of British Energy, the nuclear accident at Fukushima in Japan, agreement to an innovative Contract for Difference (CFD) type of contract to support the project, the introduction of a significant role for the Chinese, and most recently the Brexit vote; the UK decision shows that Europe remains a nuclear continent.

The project is not without its opponents; some of whom are supportive of nuclear new build in the UK, but do not support this particular project. Concerns range from the cost of energy to the inclusion of the Chinese. But following extensive review and assessment, the decision has been taken, and its importance goes well beyond just approving a single new nuclear project in Britain.

Following the Fukushima accident in Japan, a number of European countries reconsidered their commitment to nuclear power, the most significant being Germany, who immediately shut down a number of their nuclear units and made a clear plan to retire the remainder. Many said nuclear in Europe, where there are the most nuclear units in the world, is a technology of the past. Renewables are the future. Even the French government, with the world's largest nuclear fleet in terms of share of electricity generated, said it would cut back on its use.

Through it all, the UK maintained its strong commitment to new nuclear. Its existing fleet is aging and with domestic gas waning and energy imports on the rise, it recognized that new nuclear is the best, and likely only way, to both achieve energy security and meet its carbon reduction goals.

While all the talk has been about delays in securing approvals for its new nuclear ambitions, EDF Energy, the operator of the current UK fleet, has been quietly going about its business and making game-changing improvements in its operations. On September 16, Heysham II was taken off line after 940 days of continuous operations, a new world record beating the record held by Pickering Unit 7 in Canada (894 days) for more than 20 years. **[***As we all think about light water reactors (PWRs and BWRs) as the global standard, we often forget that these other reactor types, AGR in the case of Heysham and CANDU in the case of Pickering, have their own specific advantages.***]** In addition, EDF has been able to extend the lives of the AGR fleet by an average of 8 years. This shows the strong capability of EDF Energy as an operating entity and bodes well for the next step; new build.

So why is the approval of Hinkley Point C so important to the nuclear industry? First of all, it is the first new build nuclear project in the UK since Sizewell B came into service in 1995 and, even more importantly, is expected to be the start of a major ongoing new nuclear program. It is the base to rebuild the UK nuclear supply chain, once a world leader, and support the broader European nuclear supply chain. It is the first new unit to be built supported by a CFD type agreement and as stated by Duncan Hawthorne, CEO of Horizon Nuclear, likely the next to build in the UK, it “blazes the trail” for those that follow. The UK is taking an interesting approach to new nuclear going forward as there are multiple companies who are planning to build a multitude of designs (EDF Energy with the EPR, Horizon with the ABWR, NuGen with the AP1000 and CGN with its HPR1000). And finally, after years of cooperation in China, it entrenches EDFs global partnership with CGN and establishes China as a reputable exporter of nuclear power.

But most of all, it is further evidence that Europe remains a nuclear continent. While most articles on nuclear tend to say nuclear is languishing everywhere except for its saving grace – China – Europe is moving forward. Sweden is taking real steps to keep its fleet operating, France and Finland have new build underway albeit while experiencing First of a Kind (FOAK) issues, Finland now has a second new unit going ahead, Hungary is waiting for an imminent decision from Europe on state aid and is ready to start its a new station at Paks, with other countries continuing to plan for new nuclear plants. And now the UK starts a new program – one that will ultimately include a number of vendors and countries.

Of course the real challenge is just beginning – that is for EDF Energy to demonstrate that it can build Hinkley Point C on time and on budget – and as the 5^{th} and 6^{th} EPR units to be built, there is certainly a very good chance that they will.

Nuclear, a technology of the past in Europe – I don’t think so – in Europe nuclear power is a technology of the future.