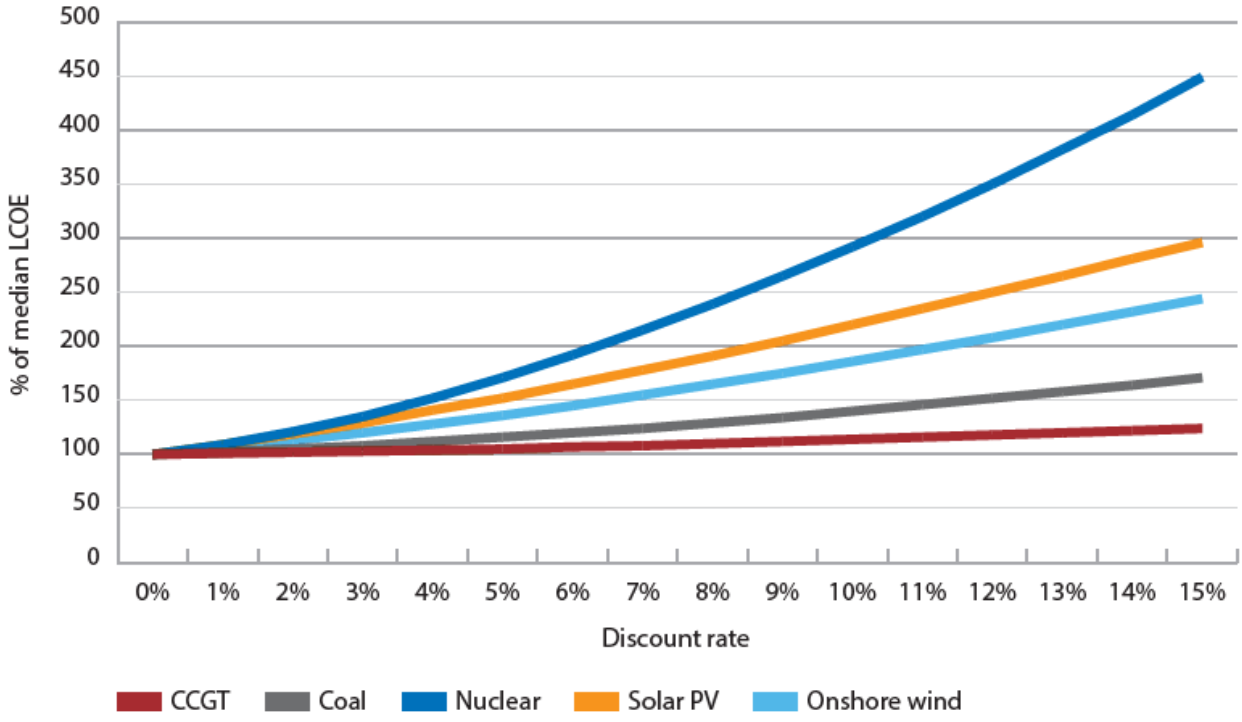
Nuclear economics – reducing costs by managing the cost of capital

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.

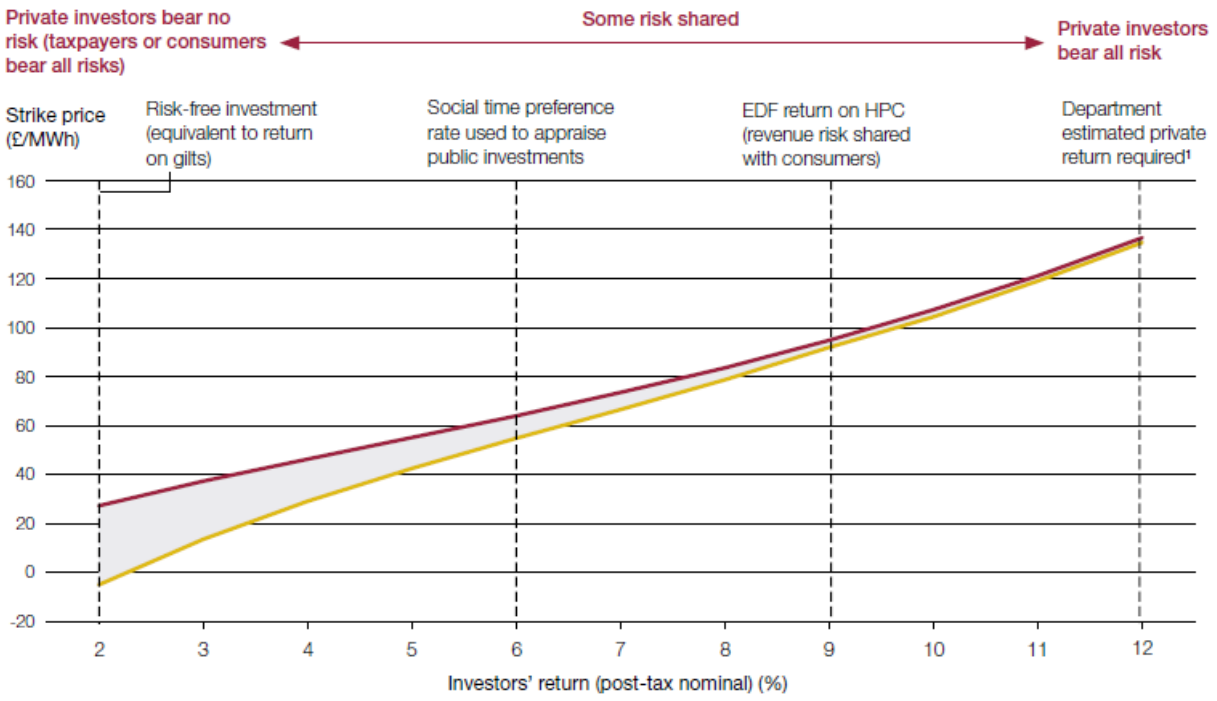
With project risk under control, the next step is to find ways to improve the overall economics of new nuclear plants. Studies have shown that the two largest drivers of the Levelized Cost of Electricity (LCOE) from a nuclear plant are the cost of capital and the capital cost. So today we will talk about 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



Strike price at BEIS electricity wholesale price projections (March 2016)

Strike price at HPC financial model electricity wholesale price projections

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

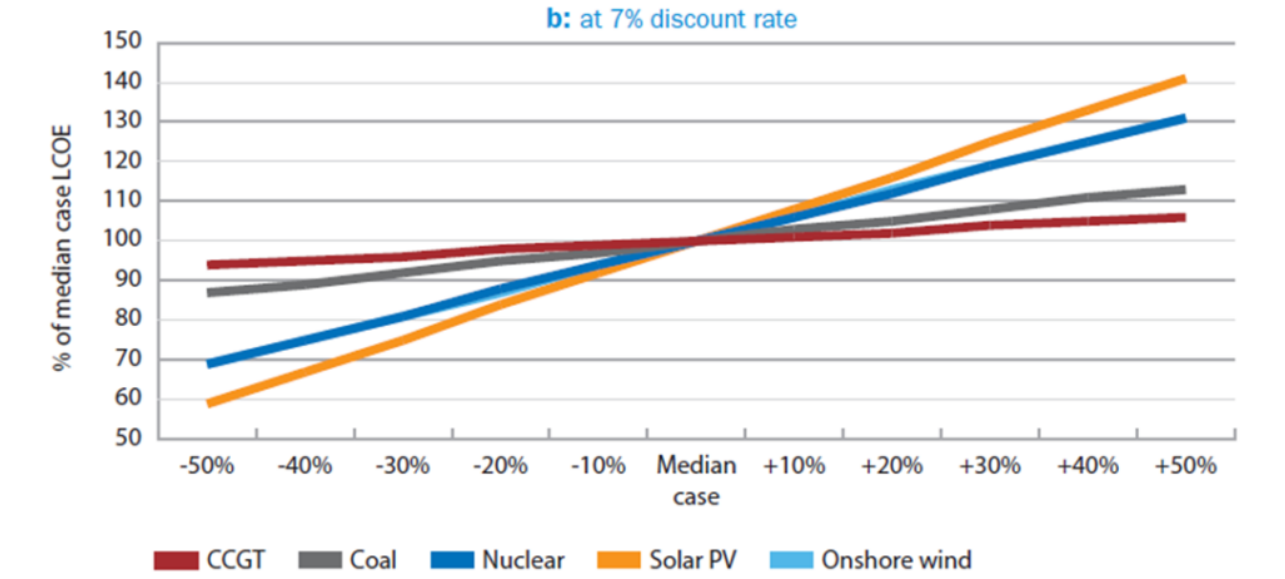
Large capital projects are hard. They require a huge amount of planning, the logistics are often staggering and depend upon many contractors and suppliers, all who must perform completely in step for everything to come together as planned. The project manager is like the conductor of a large orchestra 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.

Planning for nuclear project success – the false security of a fixed price contract

Nuclear plants can be the workhorse for many utilities, offering reliable and economic electricity into their grids. Operations across the globe have been excellent with the entire US fleet, representing a quarter of the world's operating plants, consistently operating at 90% capacity factors or better. However, building new nuclear plants is more challenging especially in Europe and the US where there has been a long pause in new plant construction. This has meant the infrastructure and supply chain has had to be re-established for new plants to be built.

As a result, when it came time to restart nuclear construction, utilities who had not built plants for decades saw a path forward by passing on as much of the construction risk as possible to the plant vendors. The strategy is straight forward; get a fixed price EPC contract so that the

vendor takes on all the project risk and responsibility. The belief is that these companies have developed the technology so they are obviously best suited to take this on. The only problem with this logic, is that it is wrong.

Just talk to Southern Company or SCANA in the US, or TVO in Finland. They negotiated hard and got their technology vendors to take on large fixed price contracts. The result, Olkiluoto 3 is 9 years late and counting; and Areva has been forced to restructure. And with Westinghouse in Chapter 11 bankruptcy, Southern has had to take over the main contractor role at Vogtle and the Summer project has been cancelled. Not quite the outcomes these owners were planning on. While there are a number of reasons these projects have struggled, it is not because of the technologies themselves. We have little doubt that once operating, these advanced designs will generate reliably for many years to come. And while some believe nuclear plants just can't be built to cost and schedule, we know this is not the case as can be seen in countries like China and Korea where they have been successfully implementing large ongoing new build programs consisting of standardized designs for many years. Therefore, in this post we want to focus on some principles that owners should consider when structuring a project to effectively manage nuclear project risk and achieve project success.

Let’s start with some basic facts about nuclear projects. They are large, capital-intensive projects with relatively long project schedules. Once they are operating they have low and stable operating costs primarily due to the low cost of nuclear fuel. Therefore, to maintain the economics of a nuclear project – plants must be built to cost and schedule. And we all know, this often does not happen. Large projects (of all kinds) are renown for going over budget and over time.

Nuclear projects take an incredible amount of planning and effort to complete successfully. **Success;** this is the most important word not used nearly often enough in planning and executing a large nuclear project. It is easy to get so consumed when talking about risk with figuring out which party will pay when things go wrong, we forget the most important objective is to absolutely ensure that things go right.

One of the most important lessons learned from these recent difficult projects is that the project owners took too much comfort from placing a huge amount of risk on the contractor – and the contractors’ willingness to take on this risk was accepted as a proxy for both capability and confidence that

the overall level of risk was manageable. The reality is that if you are an owner building a plant, there is one absolute truth – if it is your plant, then it is your risk. There is no way out of it. I can assure you that if the contractor fails, the owner fails. Always.

It is essential to recognize that managing this risk is the owner's responsibility. And while this can be accomplished by transferring some risks to contractors and others to insurance – most of all, the owner needs to manage and mitigate this risk through its own strong project management.

How do you, the owner do this? First of all, build a strong internal project management team to control the project. If you don't have enough experience, get it. Once you have a team in place here are a few key tips.

- Choose a design that has been built before. A standard deign will be lower in risk. First of a Kind (FOAK) risk is real. If it is not possible to avoid a new design, then plan to get the engineering completed before a final decision is made to proceed with the rest of the project and have a cost and schedule that take this higher level of uncertainty into account;
- Invest in your supply chain. Don't select your major contractors based on reputation alone. Projects are built by people, not reputations. Make sure the best people are assigned to your project. Assume the contractors are not as good as you think they are and be prepared;
- Choose contract structures that transfer risk to your contractors sufficient to incentivize them to perform. Pushing too much risk and then driving your main contractors into bankruptcy serves no one; and
- Most of all, no matter the contract structure, there must be transparency through the contract because it is always your job as the owner to manage your project. It is in no one's interest to allow the contractor to

manage on his own and then watch him fail. It is only with a strong set of project metrics and efficient reporting that problems can be identified early and acted upon – by all parties – with an unwavering focus on project success.

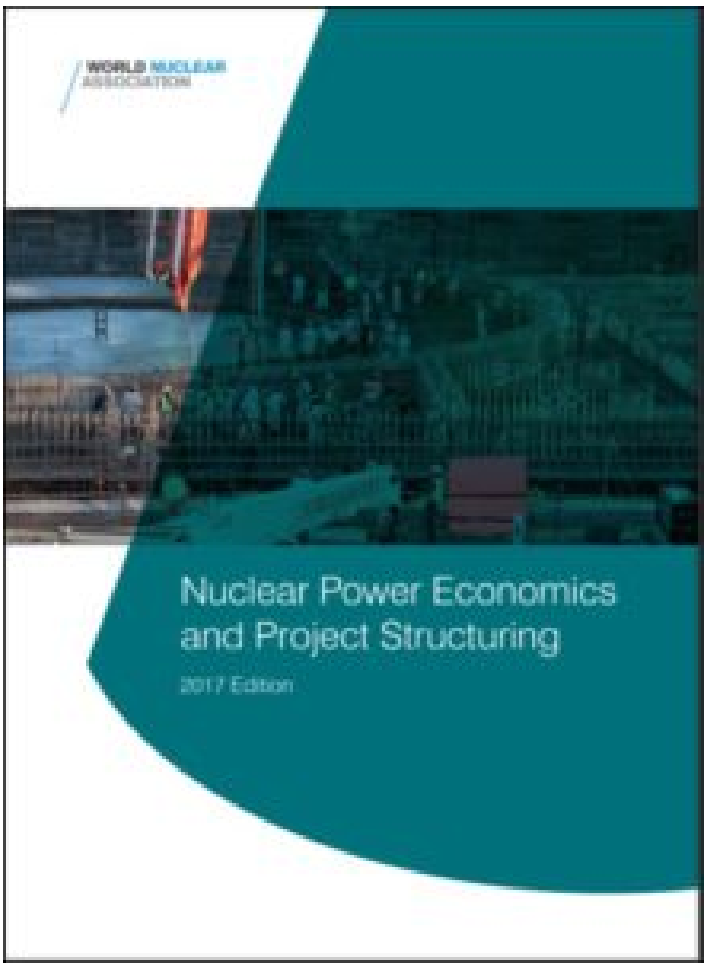
Nuclear plants are extremely reliable, efficient, low carbon and cost-effective producers of electricity. As they are capital intensive, their economics depend upon successful project implementation. Therefore, once you take a decision to implement such a project always remember that success is your responsibility and this responsibility cannot be passed on to others. Keep that in mind when structuring your project and in all decisions you make – and you will be well on the road to achieving your goal – a successful nuclear project built to cost and schedule.

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

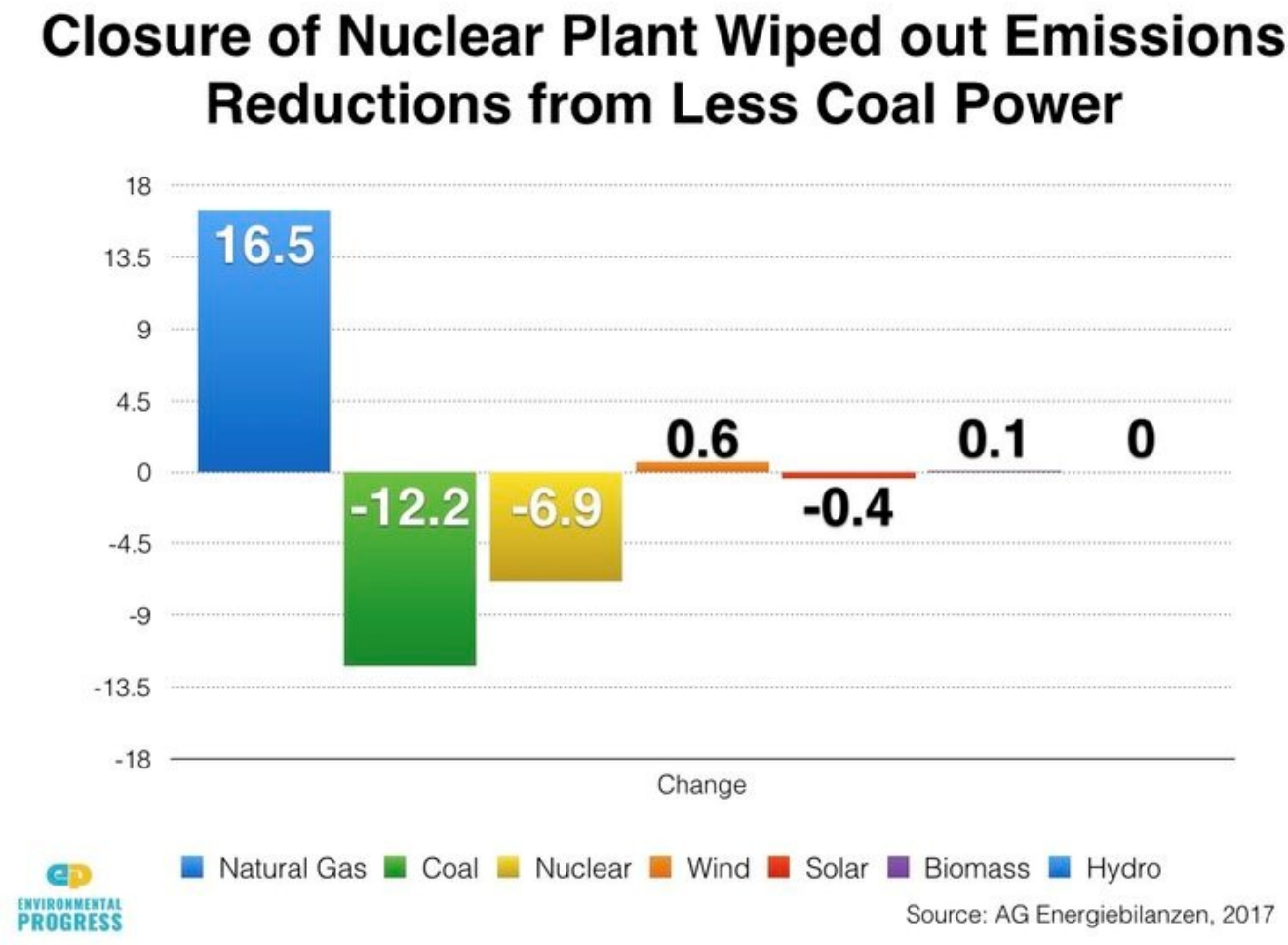
paradigm of fear of radiation is more emotional than fact based and I agree that we need to appeal to emotions to create the change we need – but let's leave that to a future discussion. In any case it certainly doesn't hurt to have the facts on your side.)

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.



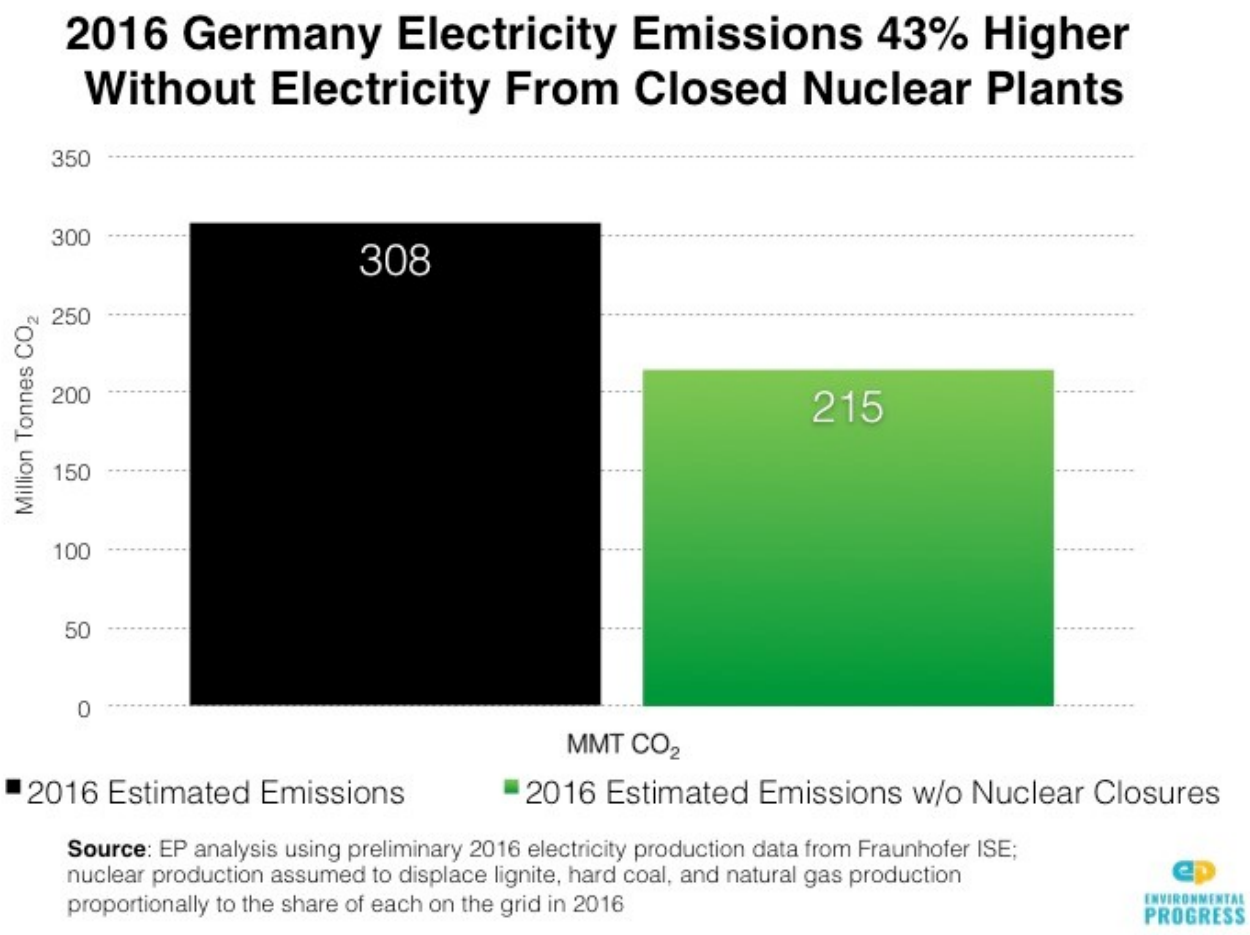
As shown above, closure of another nuclear plant in 2015 resulted in increased emissions in 2016 (the first full year it was out of service) even though there was a substantial substitution of gas to replace coal.

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?"?

2016 was a challenging year for nuclear power – or was It?

There is no shortage of people happy to see 2016 come to an end. It has been an extraordinary year characterized by strong popular revolt to the status quo resulting in unexpected government changes in places like Britain and Italy and a surprising result in the US election.

For those of us in the energy industry it has also been a challenging year. Oil prices have remained low depressing economies supported by oil. North American gas prices seem to have no bottom and these historic lows have led to dysfunction in electricity markets. This coupled with highly subsidized prices for renewables has resulted in tremendous economic pressure on American nuclear plants with a number of them closed and more slated for early closure. The most recent was just this month as Entergy announced that Pilgrim would be closed early in 2018.

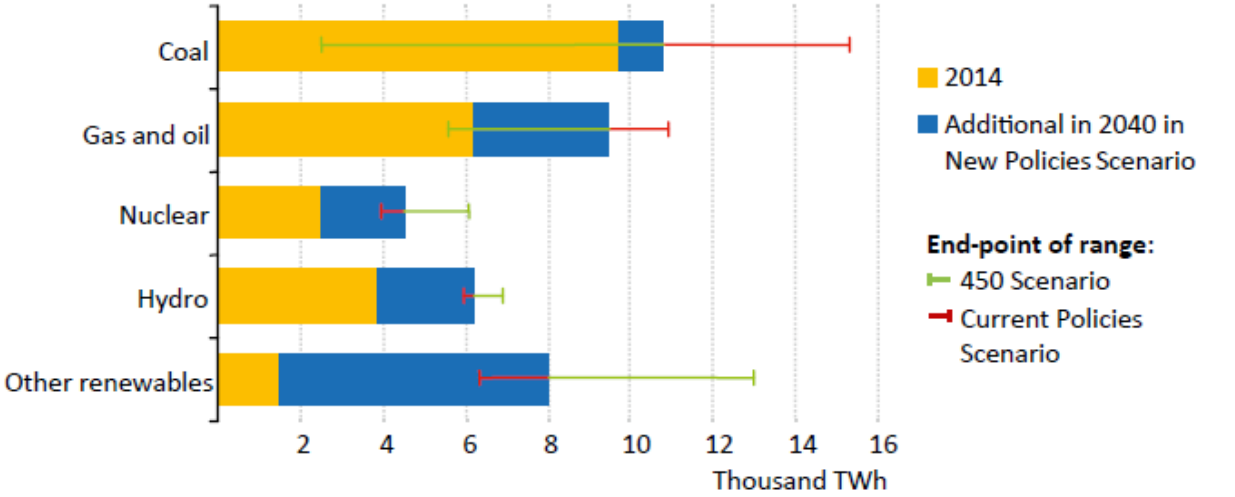
In other countries, Japan continues to struggle with bringing back its nuclear fleet in a timely manner; South Africa seems to have postponed the bulk of its nuclear plan; and Vietnam

cancelled their nuclear projects outright.

What makes these changes of more concern is that on the surface they are said to be a result of challenging nuclear economics rather than any specific anti-nuclear attitude.

But all this negative pressure also helped to put the need for nuclear in perspective. More and more countries have accepted that meeting climate goals will require continued use of nuclear power. Its 24/7 reliable low carbon generation can be the back bone for a healthy economic low carbon world. As shown by the IEA in their World Energy Outlook 2016 (WEO) in the figure below, there is strong growth expected for nuclear in the New Policy Scenario (base case) and that the number of nuclear plants will have to more than double for their 450 (low carbon) scenario.

Figure 6.3 ▷ Global electricity generation by fuel and scenario



Source: World Energy Outlook 2016

While the press has been consumed with the challenges, there has been a string of good news for the sector this year. In Britain, there was a final commitment to the Hinkley Point C project and in Switzerland the early closure for their nuclear plants was strongly rejected in a referendum. In the United States, while the focus was on the plants that have closed and

that may be closing both Illinois and New York states have taken government action to keep their plants open recognizing their essential contribution to both the local economies and to their carbon emissions targets. Also in the US, Watts Bar 2 came into service as the country's first new nuclear plant in more than two decades. And so far, it looks like the incoming administration, while not necessarily on the side of combating climate change, will be supportive of nuclear energy going forward.

Here we are; another year has come to an end and once again it has been a tumultuous year for nuclear. But overall, I believe it has been positive and we are well placed for 2017. There is a broad recognition of the importance of nuclear to meet climate change targets and there is a better understanding of the problems with market structures in supporting low carbon economic generation that is needed. All of this without even mentioning China which continues with its strong nuclear expansion.

One thing is clear. The world needs more nuclear if we are to have a reliable secure low carbon generating system. With the IEA forecasting a doubling of plants in the next 25 years, we had better get on with it…….

Thank you for continuing to read this blog – wishing you all a very happy, healthy and prosperous 2017.

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 5th and 6th 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.

Abundant and economic – Nuclear power delivers

The past few weeks have seen lots of excitement as the world reached agreement to tackle climate change in Paris. What is key to the Paris deal is a requirement that every nation (all 195 of them) take part. Ahead of the talks, governments of 186 nations put forth public plans detailing how they would cut carbon emissions over the next 10 to 15 years. However, these plans alone, should they come to fruition, will cut emissions by only half the levels required to meet the targets set out in the agreement. The plans vary significantly from country to country with some like China depending upon nuclear power as part of their plan – and others not. With no concrete plan to achieve the goals in the agreement, one thing is clear; that if there is any chance of meeting these ambitious goals, there will have to be a larger role for nuclear power.

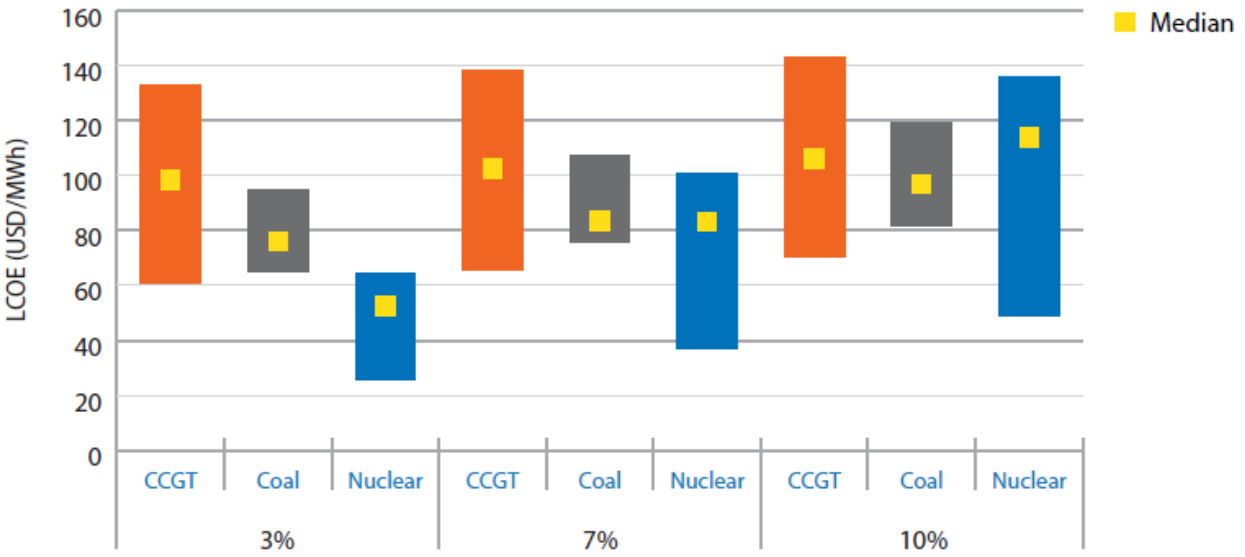
Critics of nuclear power generally focus on two main issues: safety, mostly concern that the consequences of a possible nuclear accident are not worth the risk; and cost, with many noting that nuclear is a high cost option that just diverts funds from the real environmental options for future generation, wind and solar. This month we will talk about cost and how to ensure that nuclear is seen for what it is, a capital intensive yet highly economic option for reliable 24/7 generation. If nuclear is to play the role that it can, and must play in the future generation mix, it can only get there by being the economic option of choice.

In our last post we noted the updated version of "Project Costs of Electricity" has recently been published. This is an important report that is now in its 8th edition from the IEA

and NEA looking at the costs of various forms of electricity generation.

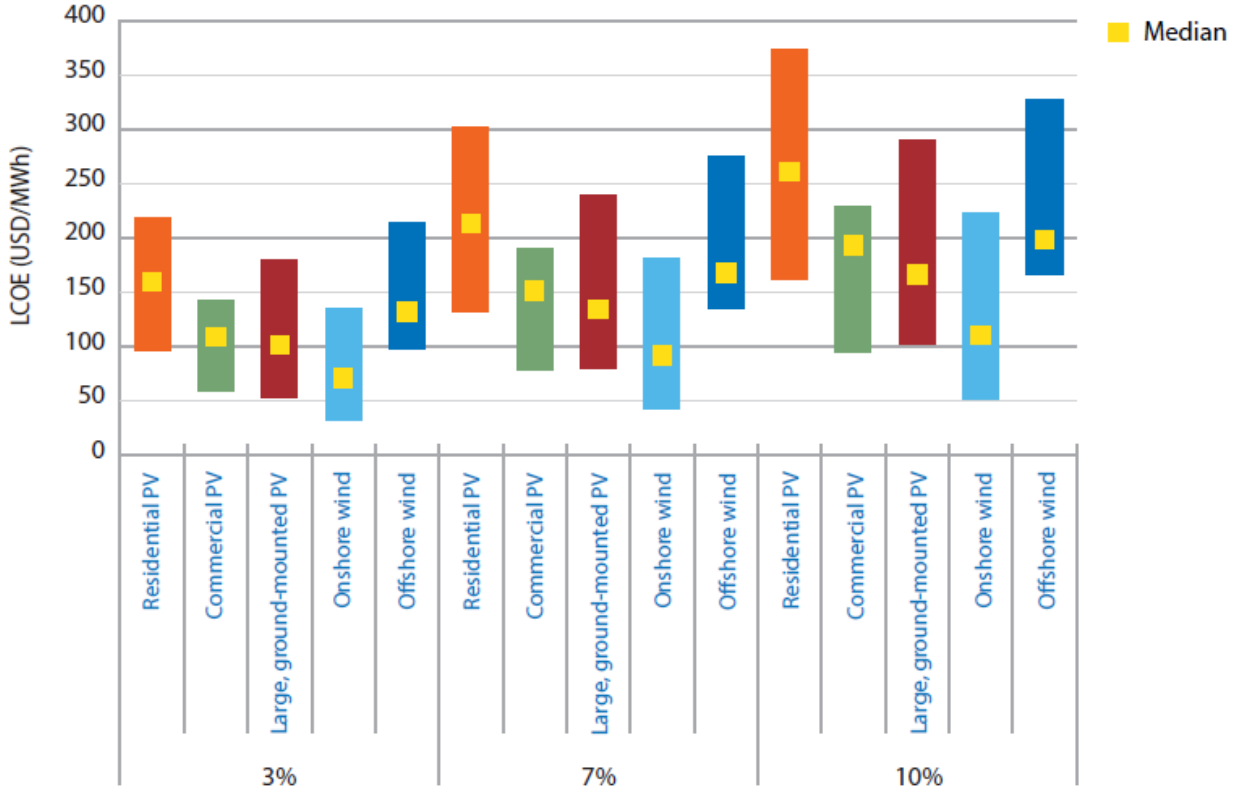
The results of this study are very clear. It shows that nuclear is a very competitive option on a Levelized Cost of Electricity (LCOE) basis.

Figure ES.1: LCOE ranges for baseload technologies (at each discount rate)



The ranges presented include results from all countries analysed in this study, and therefore obscure regional variations.

Figure ES.2: LCOE ranges for solar PV and wind technologies (at each discount rate)



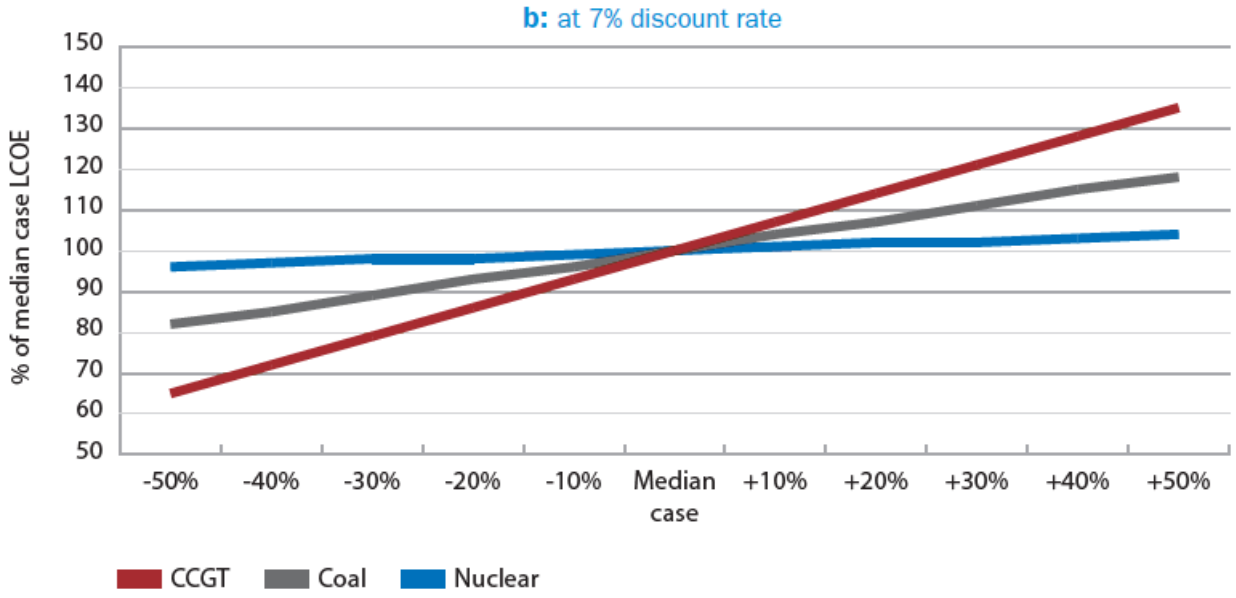
The ranges presented include results from all countries analysed in this study, and therefore obscure regional variations.

In fact, at low discount rates (3%), it is the clear winner among both traditional fossil technologies and the cost of renewables. While the report acknowledges the huge gains made by renewables in reducing their costs, it also notes the belief that nuclear costs continue to rise is false.

What is of interest is how the results are presented. The main comparisons in the executive summary are provided varying only one parameter, discount rates, that range from 3% to 10%. This represents a three-fold increase in the discount rate over the range. It is therefore not surprising that the technologies that are capital intensive, i.e. nuclear and renewables show the greatest sensitivity to this one parameter. This is one way to look at the comparative economics. On the other hand, generating stations powered by fuels like coal and gas are much more sensitive to fuel price. This sensitivity is only shown later on in the report in a sensitivity section.

Figure 7.12: LCOE as a

function of fuel cost



So for example, while gas plants (CCGT) vary little with discount rates due to their relatively low capital costs and higher fuel costs, their LCOE is very sensitive to fuel prices. In the chart above, the sensitivity only varies fuel prices by up to 50%; rather small in comparison to the three-fold change in discount rates in the earlier chart. Yet we all know that today's very low gas prices in North America are easily less than half as much as they were only a few years ago. Doubling gas prices or more would have a huge impact on electricity costs.

As would be expected, the economics also vary by region. It is no accident that China is building the most nuclear plants in the world. Even though they are also building many more coal plants to meet their ever increasing hunger for energy, nuclear plants provide clean reliable energy at about half the cost of coal in China making it an easy decision to move forward with new nuclear plants as quickly as they can. On the other hand, this past month we have once again heard about nuclear plants in the United States that are likely going to close prematurely due to poor economics. This results mostly from very low gas prices that impact the economics in those

parts of the country that have open competitive markets. The units that are most impacted are the older smaller single unit stations that are requiring capital investment at this stage of their life cycle. Without any acknowledgement of the low carbon characteristics of nuclear, or the reliability of fuel supply (gas plants generally are fed by pipelines that are at risk in cold winter months), these units are struggling. Yet the industry in the USA is not standing still. As reported in the December 10 Nucleonics Week, the US industry is targeting to reduce its costs for the existing fleet by 30%. Once achieved, this will ensure that once again nuclear will be the lowest cost generation on the system.

However, this is only the first step. Being a low carbon generator is only sufficient to ensure that nuclear remains an option. The key to long term success is the ability to reduce the capital costs of constructing the plant; producing low cost energy is what will really drive a strong new build program. This can be seen in countries such as China and Korea, where capital costs are relatively low, making nuclear by far the most economic option available. Lessons learned in these markets must be shared and implemented globally to bring down capital costs in other markets as well. China and Korea are showing the way. If the rest of the world follows, abundant nuclear power will play a large role in tackling climate change as the electrical grid workhorse of reliable low-carbon and mostly, economic generation, for decades to come.

Dreaming of a future with

abundant clean reliable energy – then dream about nuclear

When we look to the future, people the world over are hopeful for an era of abundant reliable electricity supplying all of our energy needs; all at a reasonable cost and with little to no impact to the environment. Unfortunately, in many western countries the politics of electricity planning has become largely a case of exploring the depths of our imagination with no real path to achieving this essential goal.

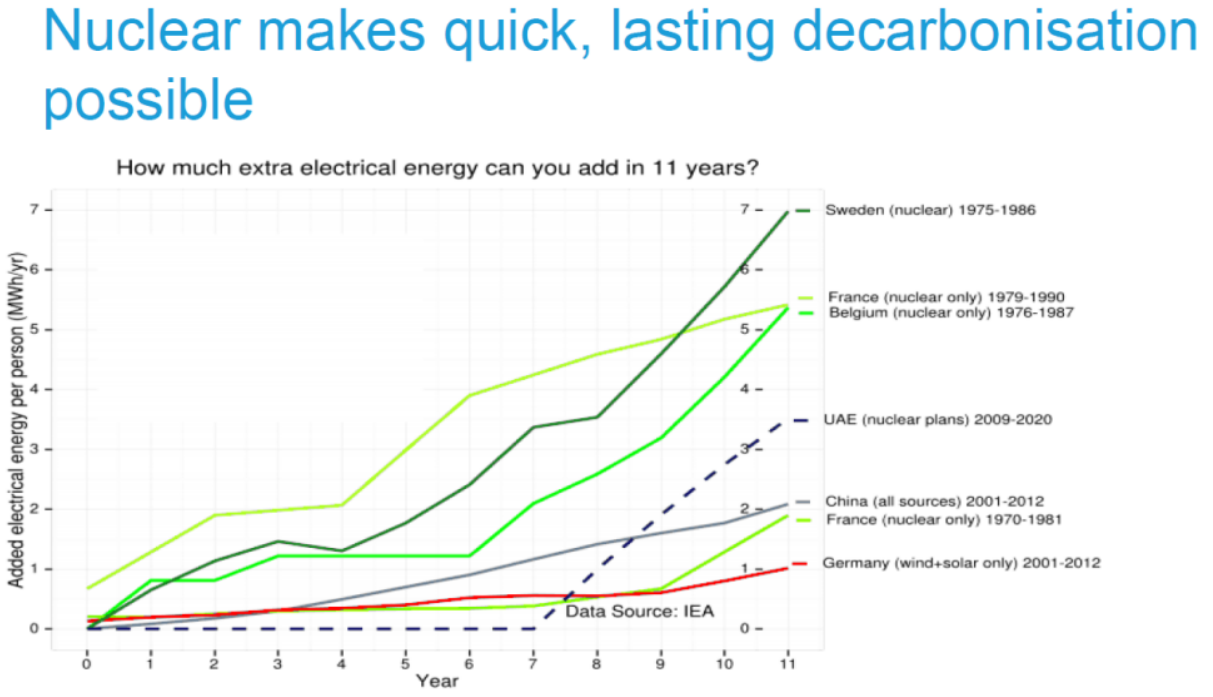
As stated by Malcolm Grimston at the World Nuclear Association (WNA) Annual Symposium last month in his brilliant talk "***Sclerosis at the heart of energy policy***" (in advance of a book he has coming out), we have become so accustomed to reliable and cost effective electricity supply that we can no longer ever consider a scenario where this can be at risk. He noted we even use the less than frightening phrase "keeping the lights on" when talking about reliability which greatly understates the importance of reliable electricity supply to our modern society. (As he said, he turns out his lights every night without concern – certainly a large scale disruption to our energy supplies would be much worse than having the lights go off.)

Given we can't imagine electricity reliability to be at risk; and given we have relatively slow growth in most western advanced economies there is a major reluctance to take decisions to protect and invest in our infrastructure for the future even while we want to work towards decarbonizing the system. Yes electricity demand growth is modest, but our lives depend more on reliable electricity supplies than ever before. Without electricity society quickly becomes paralyzed with no ability to communicate, travel, maintain our food supply,

sanitation, deliver health care and so on…in fact it is very difficult for us in all of our modern comfort to imagine how severe the consequences would be. Therefore in our great complacency we continue to do nothing because we all expect that the next great technological breakthrough is just around the corner. All we need to do is wait and advanced renewables will be available so we can have clean limitless energy forever. And so goes the narrative.

Ben Heard in his excellent WNA presentation "***World without Nuclear***" quotes Naomi Klein as she spoke to the media against the nuclear option in South Australia – "*What's exciting about this renewables revolution spreading around the world, is that it shows us that we can power our economies without the enormous risk that we have come to accept*". She said the latest research showed renewables could power 100 per cent of the world's economies. "*We can do it without those huge risks and costs associated with nuclear so why wouldn't we*?" she said.

But of course if it sounds too good to be true, it probably is. Ben's presentation goes on to review 20 studies that suggest that a world powered by 100% renewables can be a reality. However, in his review he rates most of these studies as poor. Overall he concludes that there is actually scant evidence for 100 % renewable feasibility while the literature affirms large dispatchable, i.e. guaranteed 24/7 supply is indispensable. His final conclusion is that global decarbonization requires a much faster-growing nuclear sector.



Source: Geoff Russell – nuclear has scaled far more rapidly than renewables

Reproduced from Agneta Rising Presentation at the WNA Annual Symposium 2015

But how can we have more nuclear when it has this perception of huge risks? We have written extensively on the issues associated with the perception of nuclear as a dangerous technology when in reality it has the best safety record of all technologies out there so we won't talk about that again now. In his presentation Malcolm Grimston places much of the responsibility for this public perception squarely on the nuclear industry noting that the industry "*spends half of its time implying that it is the new priesthood, with superhuman powers to guarantee safety; and the other half of its time behaving as if radiation is much much more dangerous than it actually is*." While it is hard to know what comes first, the fear or the industry reaction to it, we certainly agree that Malcolm makes a good point.

Then there are those that say nuclear power is way too expensive to be part of our future electricity system even though there is no doubt that wind and solar power are clearly the more expensive options. The most recent edition of

“Project Costs of Electricity”; an important report that is now in its 8th edition from the IEA and NEA looking at the costs of various forms of electricity generation has just been published. (This report is a must for anyone seriously looking at trends and costs of electricity generation around the globe.) While the report acknowledges the huge gains made by renewables in reducing their costs, it also demonstrates that nuclear power is one of the lowest cost options available depending upon the scenario. Of more importance, the report notes that the belief that nuclear costs continue to rise is false stating that, in general, baseload technologies are not increasing in costs and specifically “t*his is particularly notable in the case of nuclear technologies, which have costs that are roughly on a par with those reported in the prior study, thus undermining the growing narrative that nuclear costs continue to increase globally*”.

We will have more to say about this report in upcoming posts. But for now, let’s all do more than dream about a future of abundant, reliable, clean and yes, economic electricity; let’s make this dream a reality by making sure that the electricity system of the future includes highly reliable 24/7 nuclear power.