Saving the planet step 2 – let’s build as many Generation III nuclear plants as we can

It has been more than a decade since the nuclear industry focused its attention on the next generation of nuclear plants, the Generation III designs. Most of the world’s current operating fleet (440 nuclear reactors in 30 countries) are classified as Generation II plants, the first generation of truly commercial nuclear generating stations (Generation I were the early demonstration units). The idea behind Generation III was to take the lessons learned from the many years of operation of these plants and design the next evolution of nuclear; new plants that would be more cost effective to build, easier to operate and safer than their predecessors.

But these new designs did not progress as easily as their designers envisaged. In many cases there were delays in getting approvals, delays in construction and cost overruns. A decade passed and there were still no Gen III plants in operation – until now. In the past year or so, not only did one of these designs come into service, most of them did.

Haiyang AP1000 nuclear plant China

Here is the list of newly operating Gen III nuclear plants:

- 4 AP1000 units operating at Haiyang and Sanmen China
- 2 VVER 1200 units operating in Russia
- 2 EPR units operating in China
- 2 APR1400 units operating in Korea
- 2 ACPR1000 unit operating in China

And there are many more on the way. EPRs in Finland and France. APR1400s in Korea and UAE, VVER 1200s in Russia, Turkey and Bangladesh, AP1000s in the United States, and the new Hualong One design in China which is nearing its first unit completion to name a few.

Why is this important?

We have often talked about building fleets of standardized nuclear plants to control both cost and risk and now these designs all have their First of a Kind (FOAK) challenges behind them.

This means the industry has never been in a better position to move forward with large standardized fleets to take advantage of all the lessons learned and the ready supply chains. And with a number of designs to choose from, there are options for everyone while maintaining a healthy competition amongst the vendors.

Governments are getting ready too. For example, recently the French government instructed EDF to prepare a plan for another 6 EPR units in France and India is preparing a site for 6 AP1000s.

And the need couldn't be greater, as the just released 2019 edition of the World Energy Outlook (WEO) shows how the world is struggling to find a way to meet carbon emission targets. There are no easy answers. It states, "*More than ever, energy decision makers need to take a hard, evidence-based look at where they stand and the implications of the choices they make*." Even assuming a massive new build renewables program with solar growing its capacity by an order of magnitude, from about 500 GW today to almost 5,000 GW by 2040 the challenge is that "*the momentum behind clean energy technologies is not enough to offset the effects of an expanding global economy and growing population.*" So, as it did last year, in order to meet the emission targets in its sustainable development scenario, it assumes very aggressive energy efficiency to eliminate the projected 24% increase in energy demand growth to 2040 from its stated policy scenario. Now, does anyone really believe in 20 years time we will be using less energy than we do today? The conclusion is clear. Renewables cannot meet the challenge alone.

Our Generation III plants are here and ready to make their contribution to meeting the low carbon energy challenge. So, as we wrote before, if step 1 to saving the planet was to keep

the current nuclear fleet operating as long as possible to avoid going backwards by having to replace one low carbon source with another, then step 2 becomes obvious – in addition to a rapid build of renewables, build as much more nuclear as we can. Keep in mind that the difference in efficiency means that every new GW of nuclear (typical size of Gen III reactor) is equivalent to about 5 GW of solar, not to mention the battery storage required to ensure the solar energy can be used when needed, not just when the sun shines.

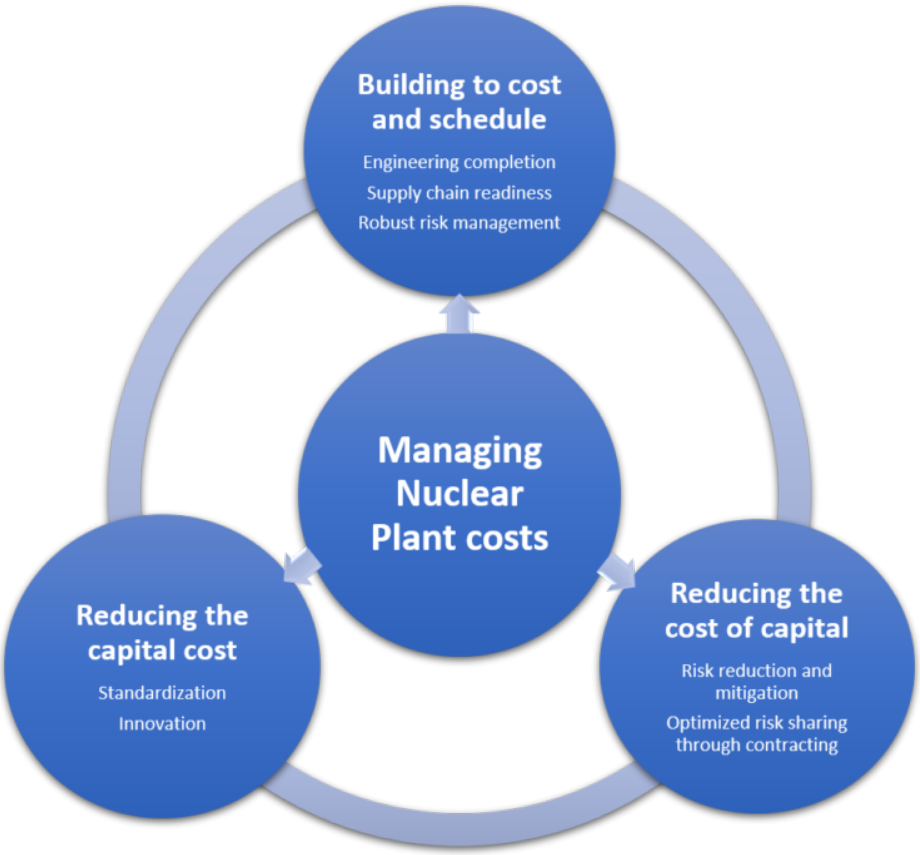
Having been the largest source of low carbon electricity generation over the last 50 years in advanced economies, nuclear is already an indispensable part of the world's low carbon energy system. As an industry, it's time to show what we can really do to play an increasing role in meeting the challenges of the future. We are making progress. In 2018 10.4 GW of new nuclear were added to the global grid. Let's keep going and scale up our efforts to meet the industry Harmony goal of nuclear providing 25% of the electricity supply by 2050. With a full suite of Generation III designs up and running and an industry ready to go, all that is left to do is build, build and build some more.

[Note: for those of you wondering how small modular reactors (SMRs) fit into this picture, you will have to wait until we discuss Step 3 to
saving the planet in a future post]

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.

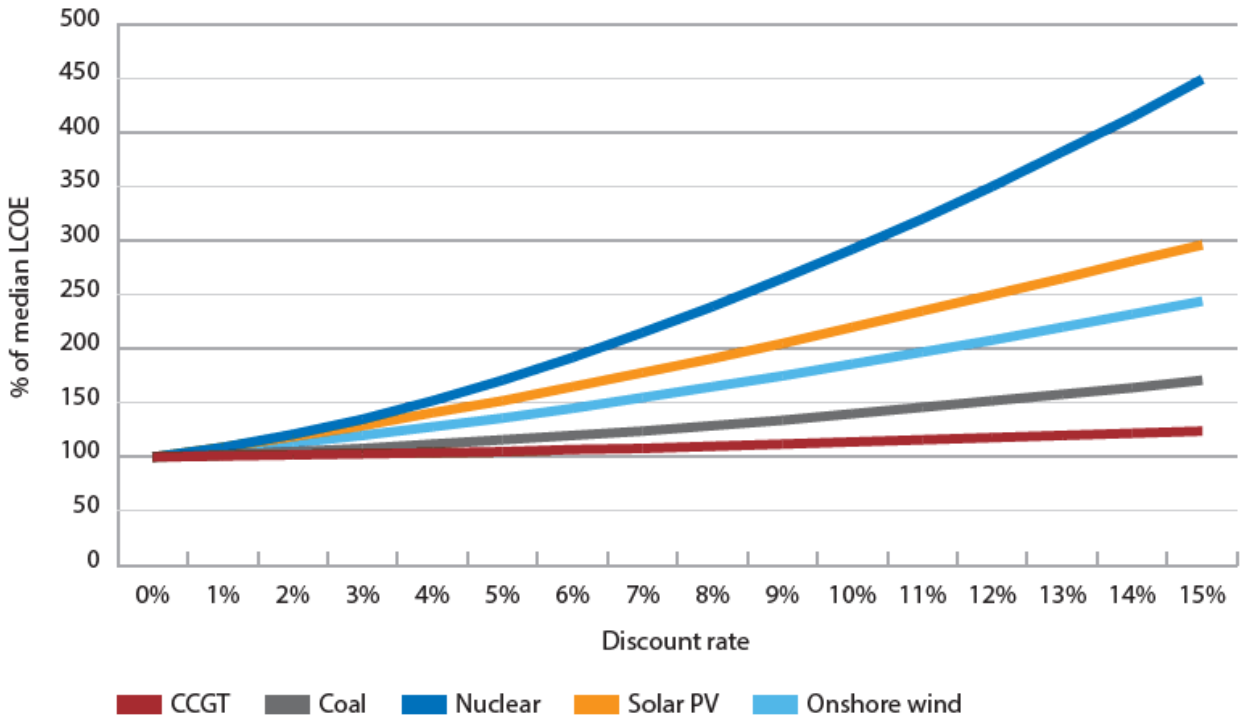
Nuclear economics – reducing costs by managing the cost of capital

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

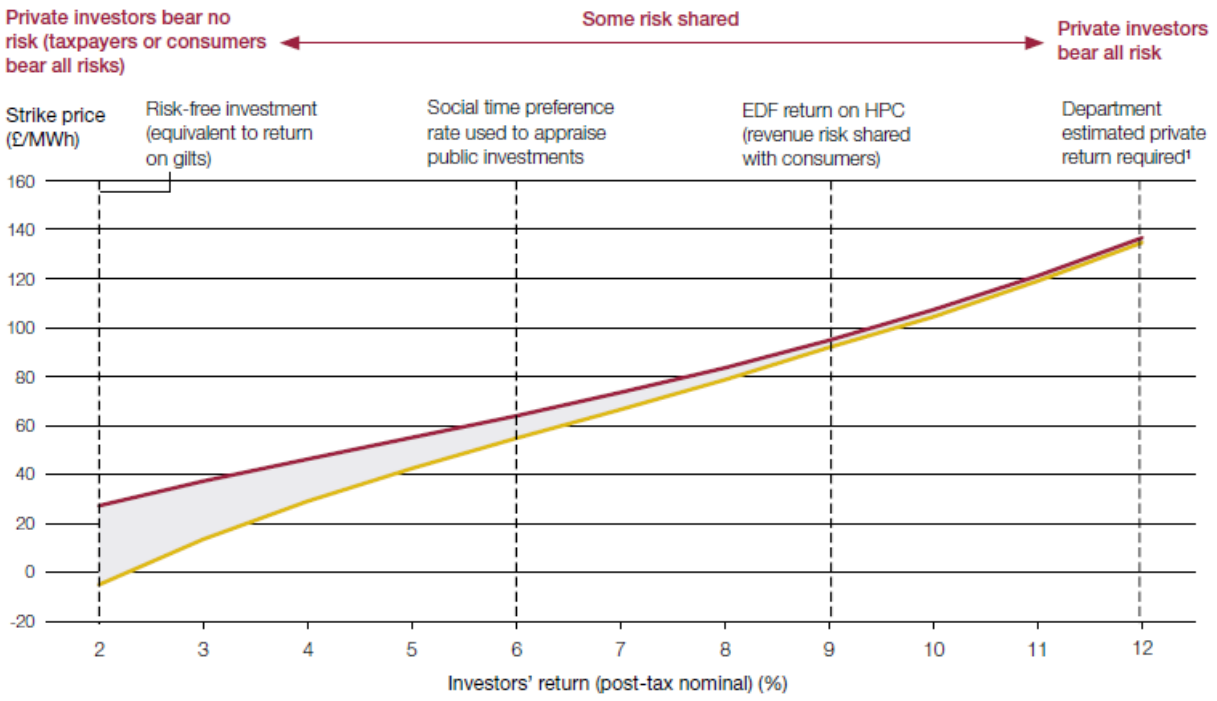
in discount rate have relatively large impacts on the cost of energy.

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



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.

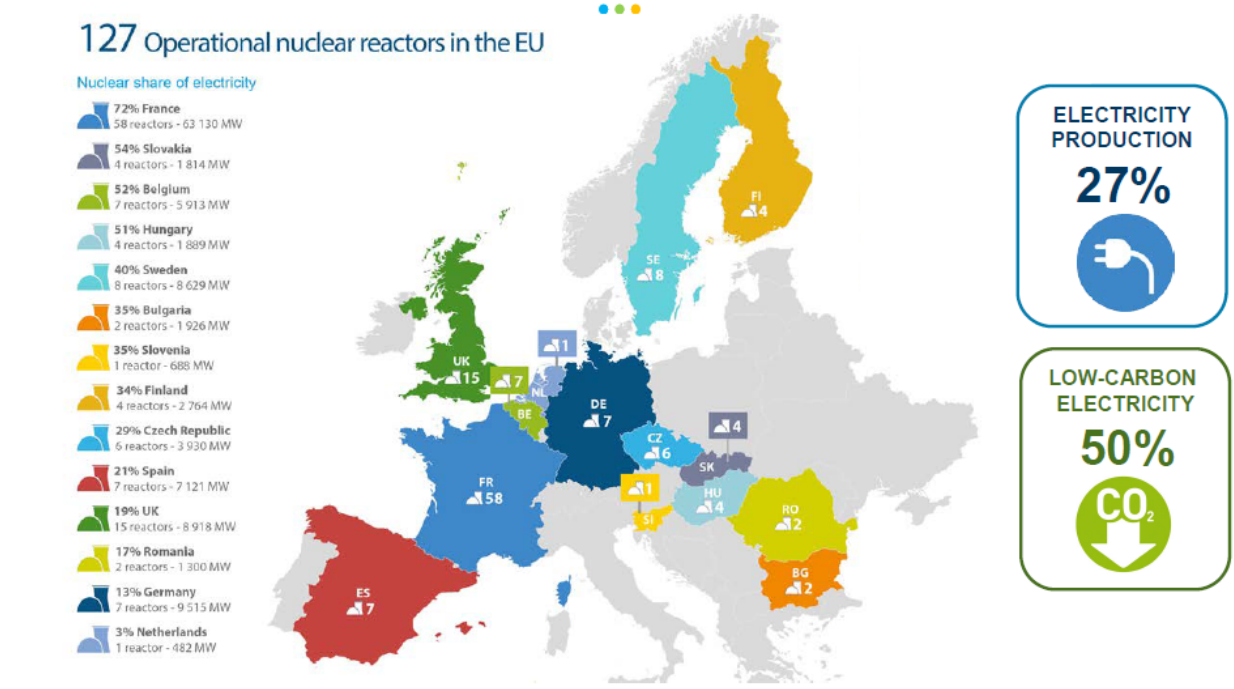
For many years Government has been making investments in renewables to support their development as viable options for future generation primarily through direct subsidy. Following

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.

The road to a low carbon Europe is nuclear power

There are more nuclear plants in the European (EU) than anywhere else. Yet a broad range of nuclear policies across the European nations is having a large impact on its future. Currently there are 127 nuclear plants in operation in the EU (plus another 5 in Switzerland). Of the 14 EU countries with nuclear power, a quarter generate more than 50% of their electricity with nuclear power and more than half generate more than 30%. In total, nuclear in the EU, generates 27% of its electricity and accounts for fully half of the EU's low-carbon electricity.



Source: Foratom presentation "Keeping Europe lights on – a role for nuclear", WNFC, Madrid April 2018

Nuclear power has provided decades of low carbon, reliable and very economic energy to the people of Europe playing an important role in fueling the European economy. It provides over 800,000 jobs at over 3,000 companies and provides security of supply needed by a region that mostly imports its fossil fuels (although some countries are coal rich). Most gas and oil come from Russia and Norway. It is not by accident that the lowest carbon emitters are the largest users of nuclear power.

You would think that there is nowhere on earth where nuclear has a brighter future. But you would be wrong. There has always been a strong anti-nuclear presence in Europe, more in some countries than others. Countries like Austria and Italy are anti-nuclear to their core, while other nuclear power houses such as Sweden, Belgium, Spain and of course, Germany, have continuously had to address strong anti-nuclear sentiment. These anti-nuclear forces are primarily based on ideology. They are the greens that have since the 1970s

simply believed that nuclear energy is dangerous and needs to be stopped. But there are also countries like the UK, Finland and Hungary that have relatively high support for nuclear and are either building new plants or are planning to.

Greens have been successful in convincing the public that if you support the environment, then you must be against nuclear power. This belief was re-enforced by the Chernobyl accident in the Ukraine 30 years ago, and then again following the Fukushima nuclear accident in Japan in 2011. Couple this with a strong belief that renewables, primarily in the form of solar and wind energy can simply replace nuclear, then the solution seems simple – who would say they don't like sun and wind?

Some European nuclear countries, where greens have had influence in government, have been fighting to sustain their programs for decades. Anti-nuclear supporters have succeeded in getting government to impose special taxes on nuclear to make it costlier while at the same time subsidizing renewables. Under pressure from the Greens, some governments have agreed to long term nuclear phase outs. These deals were made (Sweden, Germany, Belgium) at the time as a compromise to enable continued operations in the short term, with nuclear supporters maintaining hope that in the long term it would become obvious that the phase out would not be practical. Unfortunately, as the time for these phase outs is now approaching, the opposite rings true. These policies have been in place for a long time and the public have simply accepted that new renewable technology will be there to replace the aging nuclear fleet when its time comes.

With nuclear closures on the horizon, governments have had to take action with mixed results. Sweden has made progress to maintain their fleet having allowed plants to run longer and eliminating its nuclear tax, while Belgium has confirmed its phase out for 2025, and Spain is still working on its plan going forward.

Even France, Europe's largest nuclear country, has not been immune to anti-nuclear thinking. Its previous government mandated a maximum nuclear capacity to ensure the share of nuclear doe not increase and then a planned reduction of the nuclear share from about 75% down to 50% within 15 years. In the short term this means that for the soon to be completed new plant at Flamanville to come into service, an existing plant has to be shutdown; the country's oldest at Fessenheim. The new government has taken a more pragmatic stance and has deferred the target date while undertaking a review of its nuclear reduction plan. Let's face it, it is literally crazy to shut down an excellent operating asset at Fessenhiem for no reason other than it is politically mandated. The French regulator has said that these plants are safe to operate for another decade. This is an expensive political give –and needs to be seen for what it is, a plan by those opposed to nuclear to exert pressure to close plants, demonstrate there are viable alternatives, and over time push for a complete phase out.

Of course, the biggest change has been in Germany, Europe's technology powerhouse. After finally starting to reconsider the timing of its planned nuclear phase out, the Fukushima accident happened, and the Greens pushed for immediate closure, even sooner than was originally planned. And they succeeded. As part of its Energiewende, nuclear plants have started to close, and the share of nuclear energy has dropped significantly with a total shutdown only a few years away. In December of last year, one of Germany's top economists, Prof. Dr. Hans-Werner Sinn, made news when he published a paper stating it is unrealistic to believe that Germany can power itself with only wind and sun due to their immense supply volatility. He concludes that 30% renewable is a viable target although this can increase through cooperation with neighbouring countries.

To those of us outside of Germany, their strong commitment to

quickly removing nuclear from the mix is a complete mystery. Fear of nuclear in Germany has put the shutdown of nuclear ahead of reducing carbon emissions. No German has ever been hurt by a nuclear plant and German industry has benefited from abundant economic nuclear energy for a generation. With the highest energy carbon intensity in Europe, Germany recently accepted that it cannot meet its 2020 commitments as carbon emissions reductions have ground to a halt in the few years since nuclear started shutting down. Shutting coal plants instead of nuclear would have shown Germany as a carbon reduction leader, but for some reason they chose to continue to damage the environment by opening new coal mines and building new coal plants, as they prioritize nuclear shutdowns over carbon reductions. The German Energiewende is a good albeit expensive experiment, and the results to date should make others think twice about going down this path.

The fight for nuclear power in Europe has been long and hard. In some countries nuclear supporters have been worn down and sometimes wonder if they are fighting a losing battle. But they must always remember that European anti-nuclear sentiment is rooted in an ideology that is out of step with the current need to combat climate change. In reality, nuclear power has made Europe better in every way by delivering economic reliable electricity, while providing energy security of supply and preserving the environment by reducing the use of fossil fuels.

Even with the new build plans currently in place, Europe will need another 80 GW of nuclear by 2050 just to maintain the status quo. And that is not good enough. Rather than accept the political views of those that oppose; bold new plans should be made to increase the nuclear footprint in Europe including the very challenging task of changing views in anti-nuclear countries. If decarbonization is a goal, then there must be a realization that nuclear has been a great success in Europe and represents the best path forward to secure a low

carbon economic energy future for all Europeans. A strong Europe needs nuclear power.

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

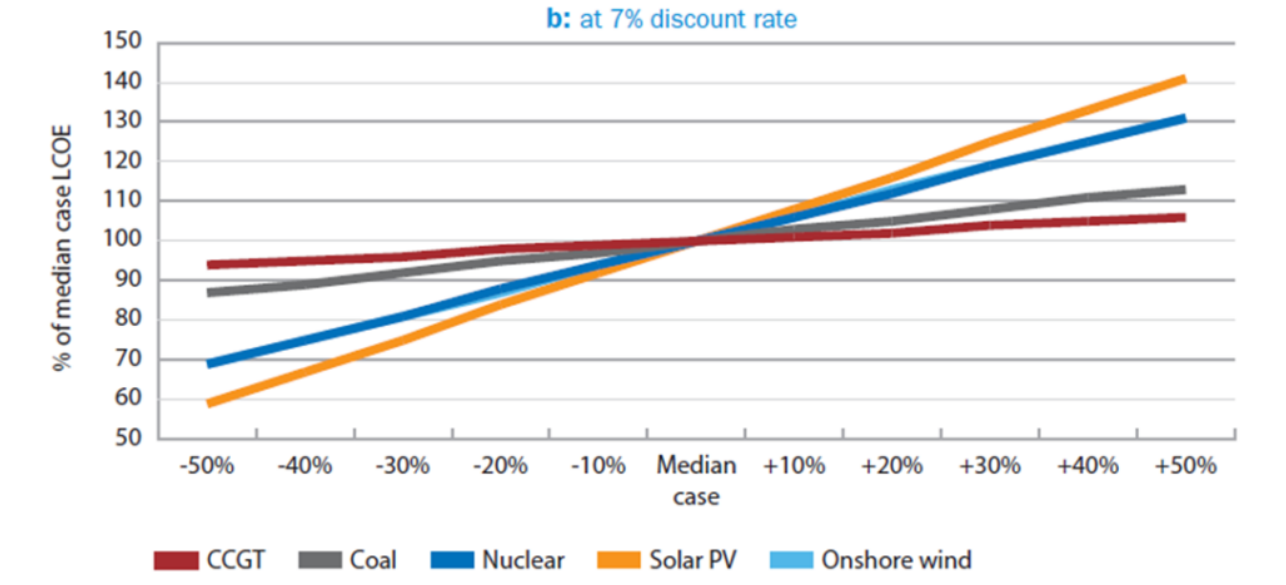
Large capital projects are hard. They require a huge amount of planning, the logistics are often staggering and depend upon many contractors and suppliers, all who must perform completely in step for everything to come together as planned. The project manager is like the conductor of a large orchestra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

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.

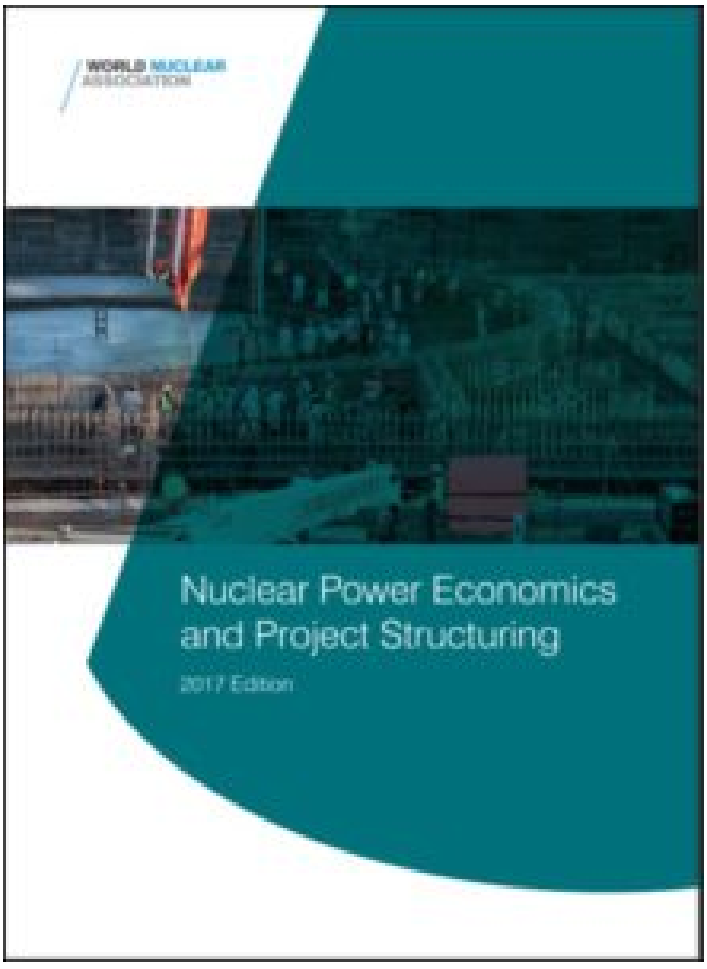
Nuclear plants are extremely reliable, efficient, low carbon and cost-effective producers of electricity. As they are capital intensive, their economics depend upon successful project implementation. Therefore, once you take a decision to implement such a project always remember that success is your 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.

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.

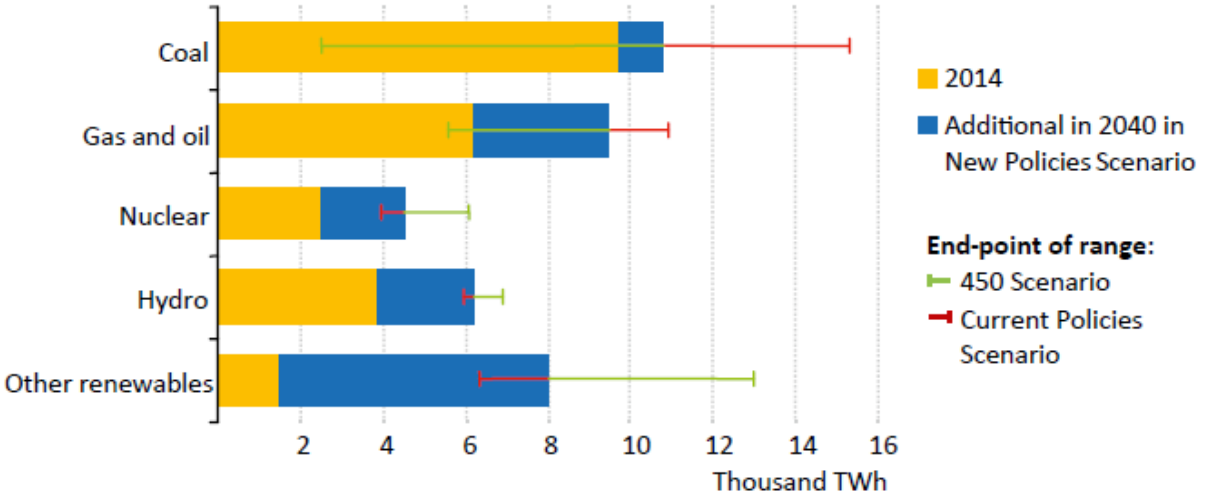
In other countries, Japan continues to struggle with bringing back its nuclear fleet in a timely manner; South Africa seems to have postponed the bulk of its nuclear plan; and Vietnam cancelled their nuclear projects outright.

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.

It is broken markets, not uneconomic plants that are putting nuclear plants at risk

A huge milestone has been achieved in the United States as Watts Bar Unit 2 produced its first electricity; becoming the first new nuclear plant in the US to start up in 20 years

since Watts Bar Unit 1 came into service in 1996. Unfortunately, this good news was overshadowed by the announcement by Exelon that its Quad Cities and Clinton power stations in Illinois would close. This decision was the most recent but not the first, with headlines such as “Nuclear plants need boost to stay open, industry warns” or” Nuclear power plants warn of closure crisis” pointing to more nuclear plants that are at risk of premature closure because they are no longer economic in the competitive markets in which they operate.

Watts Bar – America’s newest nuclear plant

There are many explanations as to the cause of this “crisis”. Gas prices are currently very low, renewables are subsidized and the costs of some of the smaller oldest single unit nuclear plants in the country have been rising as they age. While all of these points are true, they are not in and of themselves, the direct cause of the problem. They are symptoms of deep structural issues in those parts of the

country where electricity is bought and sold in so called open or deregulated markets.(Note: Watts Bar, owned by the Tennessee Valley Authority, is in a regulated market.)

This was the topic of a recent DOE summit on how to "save" the nuclear fleet ("*Summit on Improving the Economics of America's Nuclear Power Plants*") to address the crisis and take steps to avoid the unnecessary closing of a significant number of plants. So here we are and once again, we fall into the trap of incorrectly defining the problem as costly inefficient nuclear plants. After all the US summit is on how to **improve the economics of nuclear plants**, not how to fix poorly structured markets – the real problem. (Note: In Europe there are similar issues driven by a high level of subsidized renewables rather than low gas prices. But the need to find a solution is the same. A European Commission official assured delegates at a recent nuclear financing conference held in Paris that the design of European wholesale electricity markets and the emissions trading system (EU ETS) will be improved to help – and no longer hinder – nuclear energy as a low-carbon source of electricity.)

In the guise of providing the lowest cost to ratepayers, most markets are completely focused on the short term. There is little consideration of risk built into the pricing mechanisms, only what is the lowest cost to generate electricity right now. This means that there is no value attributed to any of the other important operating attributes required for a reliable and secure electricity supply system such as fuel availability, maneuverability, flexibility and price volatility. On top of this, things like government environmental policies and subsidies further distort the markets to ensure that mandated renewables have a role in the system. (Of course nuclear has not benefited from such support even though it is a low carbon option.)

This may have all worked fine 25 years ago when markets were opened with the objective of creating efficiencies in the

existing operating fleet –a time when many jurisdictions were in oversupply. But when it comes to adding capacity or making other substantive changes to the system, electricity markets are not nimble. While there may be a desire to respond to price signals in the short term, building new plant takes time. And one thing is for sure, no one will build new plant of any kind without some confidence that they will generate sufficient revenue to operate for their projected lives and earn a return on their investment. Or as stated in the OECD report Project Costs of Electricity, "*The structure of the electricity generation mix, as well as the electricity demand pattern, is quite inelastic in the short term: existing power plants have long lifetimes and building new capacity and transmission infrastructure may require a considerable lead time as well as significant upfront investments. In other terms, electricity systems are locked in with their existing generation mix and infrastructure, and cannot quickly adapt them to changing market conditions*."

It is also important to understand that not all market participants are equal. In most markets gas is the price maker, not a price taker. So when gas prices are high, everybody else in the market makes money and when gas prices are low, everybody struggles. And yes, today gas prices are very very low. Yet gas operators are relatively indifferent as they are the risk free players in the market. Even in this enviable position, gas generators did not have sufficient incentive to build new plant, so many markets have responded with the development of capacity markets. These capacity payments then compensate gas plants for sitting idle – effectively removing the risk to gas generators of building new plants.

So you may ask, what's the problem with that as long as we have low energy prices?

If open markets are so efficient then we should expect that prices in these areas should be lower than in areas where

regulated markets have remained. Not so, says an April 2015 study by the American Public Power Association. In fact, in 2014 prices in de-regulated markets were as much as 35% more than those in regulated states. (Note: this study has been done by an organization with an interest in the result and as such may contain bias.)

So let's go back to electricity system structuring. When it comes to managing risk, we know risk is generally reduced through a diverse portfolio of alternatives. The more diverse, the more risk can be reduced. The current path will result in systems that are not diverse, but rather all gas, currently the most economic alternative. If markets do not adapt to better accommodate risk management into their pricing strategies, we face a future of volatile energy prices, possible energy shortages as new plant construction lags market needs and increases rather than decreases in carbon emissions; all in the guise of more efficient markets. Back to the decision in Illinois. As stated in the referenced article, not only are these two plants Exelon's best performers, they "*support approximately 4,200 direct and indirect jobs and produce more than $1.2 billion in economic activity annually. A state report found that closing the plants would increase wholesale energy costs for the region by $439 million to $645 million annually. The report also found that keeping the plants open would avoid $10 billion in economic damages associated with higher carbon emissions over 10 years*."

We only need one major market disruption to remind us all of the importance of truly reliable baseload power at a stable and economic price and how that protects us from the risk of higher prices and lower security of supply. And today, there is only one low carbon highly reliable baseload option, nuclear power.

So while a short term fix to keep operating nuclear plants open is required and more urgent than ever, let's stop talking

about how plants are uneconomic and work to properly improve market structures to build and maintain the strong, reliable, economic and low carbon systems needed to power our modern economies.