In 2017, the myth of powering the world with 100% renewables has started to crack

When thinking about 2017, it is easy to see the bankruptcy of Westinghouse and the subsequent cancellation of its Summer project in South Carolina as this year's big issue. But as the year has drawn to a close, the continuation of its AP1000 project at Plant Vogtle in Georgia has been approved by the regulator and there is every expectation that Westinghouse will emerge from bankruptcy in 2018.

So while important, to us there is a much more important defining issue for 2017. It is the very real start of a movement that recognizes that powering the world with 100% renewables is a myth – and that chasing a myth will not get us to our global goal of meeting the world's increasing energy needs while reducing carbon emissions and successfully combating climate change.

There were a number of defining moments in 2017 that highlight this change in attitude.

First there was the paper published in the Proceedings of the National Academy of Sciences, "Evaluation of a proposal for reliable low-cost grid power with 100% wind, water, and solar", by 21 prominent scientists taking issue with Mark Jacobson's earlier study claiming that 100% renewables is feasible in the USA by 2050. In a nutshell, the paper found many poor assumptions in the Marc Jacobson paper and ultimately finds that its conclusion that 100% renewables in the United States by 2050 is false. And how does Marc Jacobson respond to this criticism? Does he review his work,

make changes and then show that his conclusion remains valid? No, he does what some would do when their beliefs are under attack, he sues. This is one of the most shameful episodes of the year. A scientist suing when others disagree with him is just not the way things are done. Science is about skepticism and continuous questioning. A peer reviewed paper that is critical of another one is to be applauded and responded to, to continue the discussion. Suing those who disagree is simply not one of the options.

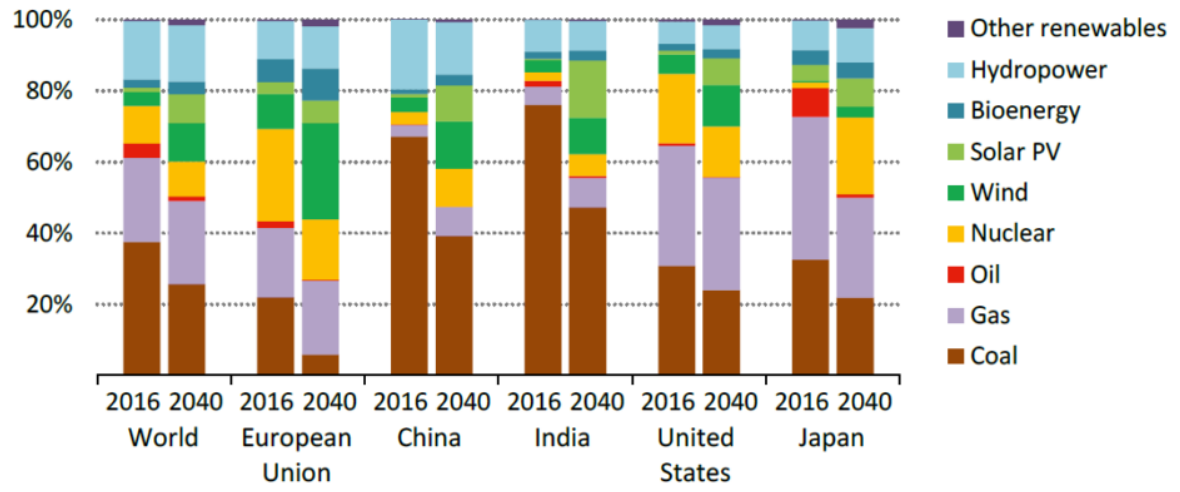
Second, we saw Germany called out for its lack of progress on decarbonization in recent years while holding COP23 in Bonn late this year. While massively investing in new renewables, these are unable to take the place of its closing nuclear plants, thereby making coal king in Europe's most polluting nation. This story shows how a 12-thousand-year-old forest that has been almost completely consumed by the country's ravenous addiction to coal power.

Other countries have seen the light as well. The UK is strongly committed to new build nuclear and Sweden and France have realized that removing nuclear from the mix will do nothing to achieve their climate goals. In Korea, the public decided to continue with a new build going against its new government's policy.

And finally, we saw something this past year, we have not seen before – the rise of the pro-nuclear environmental NGO – as those who care about the environment and climate change are starting to realize that renewables alone is a path to nowhere. This includes such organizations as Environmental Progress, Energy for Humanity and Mothers for Nuclear.

A look at the 2017 edition of the World Energy Outlook tells an interesting story.

Figure 6.14 ▷ Share of total generation by type worldwide and in selected regions in the New Policies Scenario



Current and proposed policies strongly reshape the power mix in the New Policies Scenario, nearly doubling the share of renewables and driving down coal's contribution

Source: World Energy Outlook 2017

Even with massive investment in renewable technology, fossil fuels remain king in electricity generation by 2040 still producing about half of all global electricity. Wind and solar increase to anywhere from 20% in the New Policy scenario to about a third of electricity generation in the Sustainable Development Scenario (the scenario that shows what can be done to meet Paris objectives). This is even though wind and solar make up about 45% of the total investment in new capacity and global subsidy for renewables grows from about $140 billion per year to $200 billion.

Looking deeper at the numbers, it can be seen that this investment results in a huge increase in wind and solar capacity of 5000 GW in the Sustainable Development Scenario. All other things being equal, this same amount of energy would only have required about 1500 GW of nuclear to be built since a nuclear plant produces about 3 times more energy than an equivalent size of solar plant and more than 4.5 times as much energy as wind capacity. And this is before any consideration of the intermittency of wind and solar and the needed

improvements to systems to accommodate that – and of course the predominantly fossil backup needed for when the wind doesn't blow, and the sun doesn't shine.

What this shows is that wind and solar are good ways to reduce fossil use, probably by about 30% or so. But they are not good ways to REPLACE fossil fuels in their entirety. This must be done by more robust alternatives such as hydro and nuclear. These are the only large-scale base load options that are both reliable and low carbon available today.

And what about storage? Often, we hear that once storage technology improves, this will be what is needed for renewables to break free of their intermittency. Of course, this sounds better than it actually is. In reality, storage would be ideal for base load plants like nuclear where it can help store energy generated during times of low demand reducing the need to build new peaking generating plant. On the other hand, storing enough energy from wind and solar would require massive overbuilding of capacity to collect extra energy during the 20% of the time the sun is shining and the 30%, the wind is blowing.

Changing beliefs is hard. We live in a time when all opinions are considered valid, whether from experts or lay people. And most of all, people are challenging expert views as never before. Yes, it is a romantic view of the future to believe that all of our energy will come from energy sources such as the wind and the sun. But beliefs don't change physics and if we really want to change the world, we need more nuclear power to replace a large portion of today's fossil generation. Only then will we be on our way to a truly low carbon economy. We are under no illusion that this change is coming quickly, but 2017 saw the start. There are now cracks in the 100% renewable myth. It will take hard work and ongoing support from the new generation of pro-nuclear NGOs to keep broadening the crack in 2018 – and who knows? Maybe the tide will shift, and we will be on our way to a truly

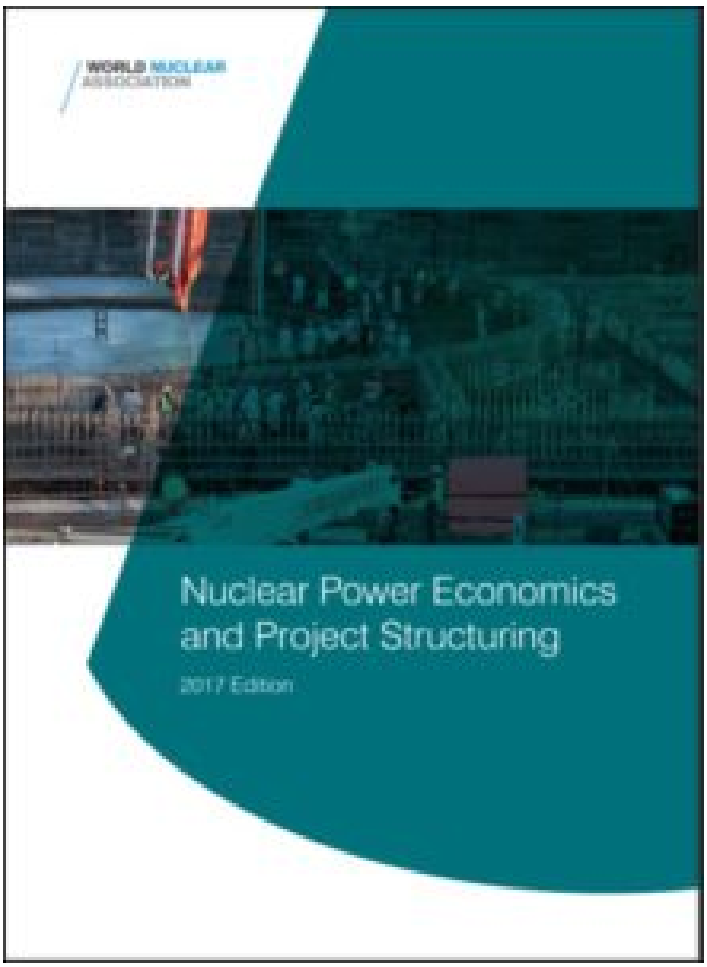
sustainable future.

Wishing you all a very happy and healthy new year!

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

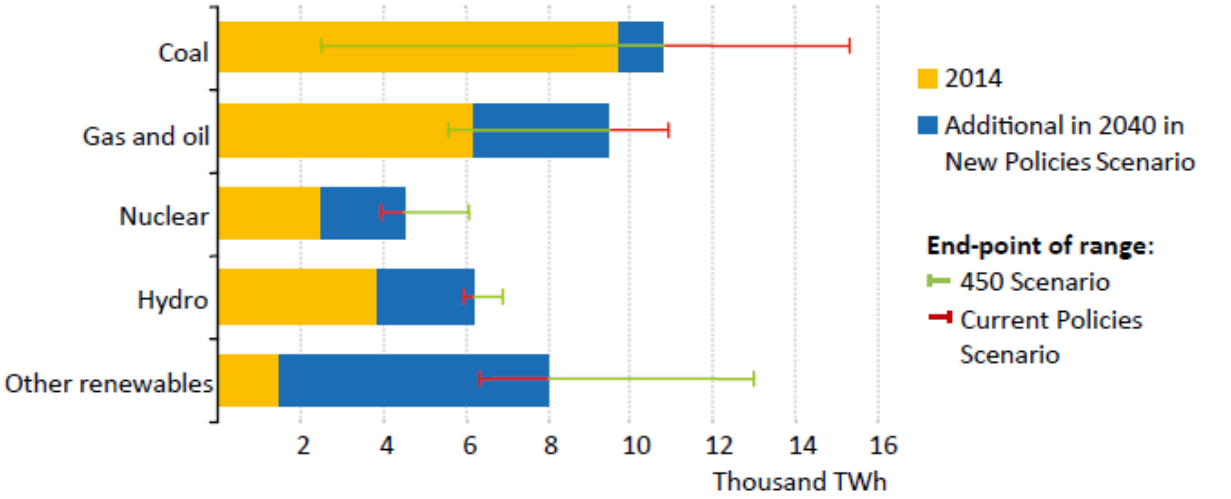
economies supported by oil. North American gas prices seem to have no bottom and these historic lows have led to dysfunction in electricity markets. This coupled with highly subsidized prices for renewables has resulted in tremendous economic pressure on American nuclear plants with a number of them 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.

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

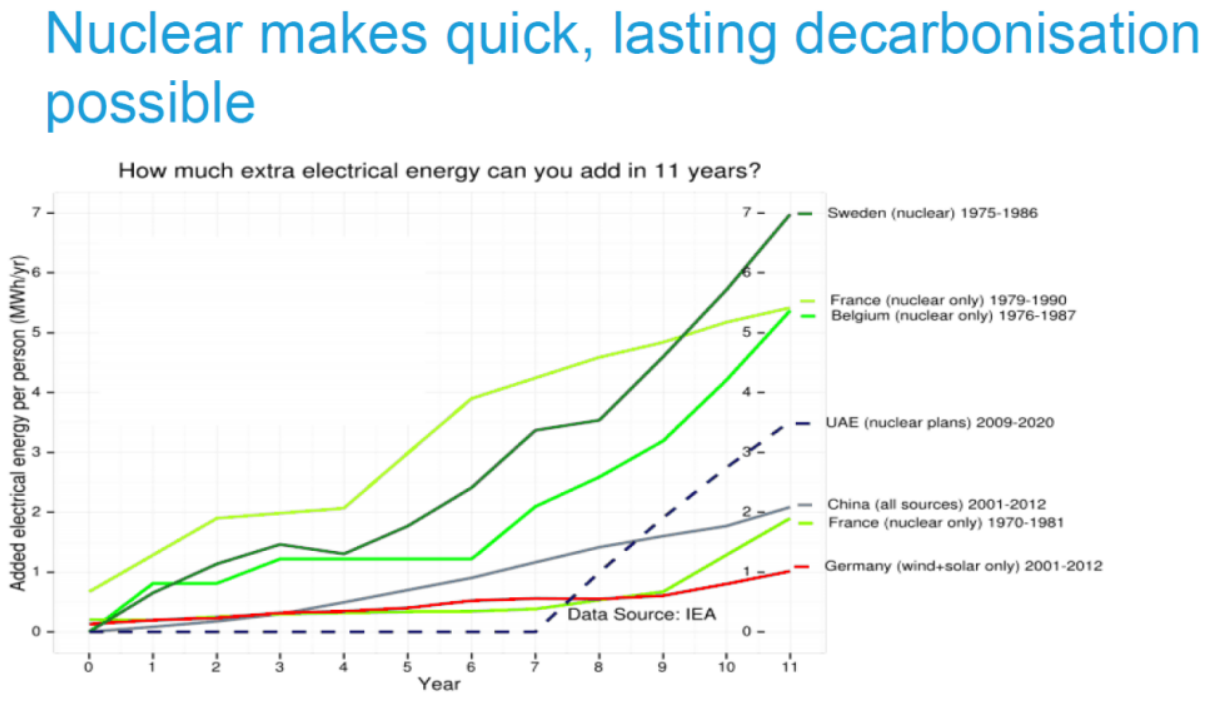
the lights on" when talking about reliability which greatly understates the importance of reliable electricity supply to our modern society. (As he said, he turns out his lights every night without concern – certainly a large scale disruption to our energy supplies would be much worse than having the 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.

It’s time to put nuclear on the offensive – and make it the low carbon energy generation option of choice

Have you ever seen something that just amazed you? We were wowed by a recent YouTube video showing what the Chinese have achieved in turning conventional high-rise construction on its head. A 57 story building was built in 19 days – yes – 19 days! Who would ever believe this could be possible? I live in Toronto, a city that has been undergoing a huge hi-rise building boom over the last few years and the time it takes to build these tall towers can be measured in months and years, not days. This just shows what can be achieved when the imagination is let loose and innovation results in outcomes never before thought possible.

We first wrote about the importance of innovation in the nuclear sector last year. In its history nuclear power has shown incredible innovation, leading the way in a range of technologies especially with respect to delivering a level of safety and security not seen in any other industry. More recently there have been dramatic improvements in operations as the global fleet has reached a level of performance never even dreamed of in the early days of the industry. Current new build projects are using the most up to date methodology in modularization and other advanced construction techniques.

And yet when the IEA issued the 2015 version of its Energy Technology Perspectives (ETP 2105) report focusing on the need for energy technology innovation if the world is to address climate change; it doesn’t mention this innovation, nor does it include discussion of potential future innovation with

respect to the nuclear option.

As stated, *"Energy technology innovation is central to meeting climate mitigation goals while also supporting economic and energy security objectives. Ultimately, deploying proven, cost-effective technologies is what will make the energy system transformation possible. Continued dependence on fossil fuels and recent trends such as unexpected energy market fluctuations reinforce the role of governments, individually and collectively, to stimulate targeted action to ensure that resources are optimally aligned to accelerate progress. Establishing policy and market frameworks that support innovation and build investor confidence over the long term is a first-order task to deliver."*

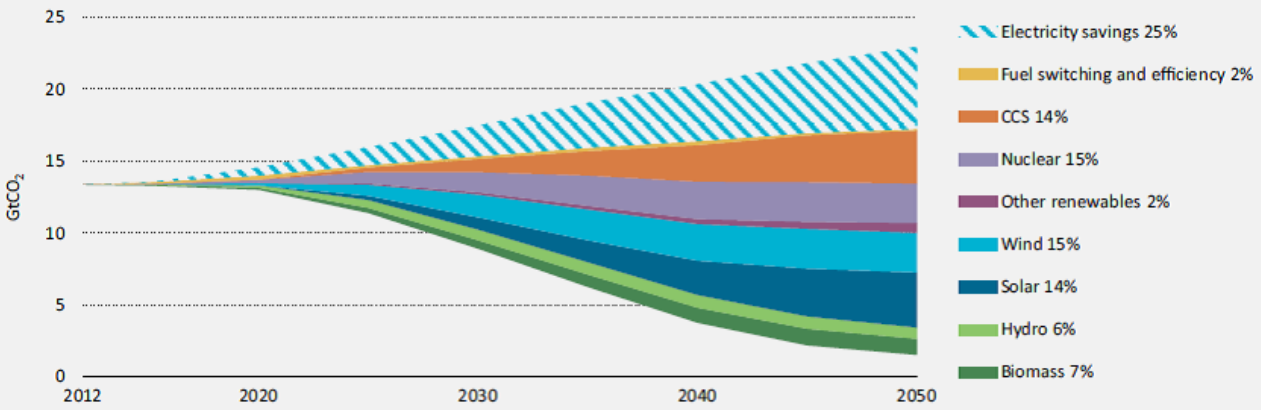
The report is clear when it says that "*Innovation support is crucial across the low-carbon technology spectrum".* The discussion focuses on renewable technologies in the short term due their relative readiness and lack of a need for long term investment in development; and carbon capture (CCS) in the medium to longer term even though it requires substantive investment in development as it remains essential to address the large number of fossil plants being built and still in operation by 2050 that will require decarbonizing.

As usual, the same issues that have plagued nuclear for the last 30 years; primarily public acceptance issues, mute a positive discussion for the nuclear option. While recognizing its importance in achieving increased energy security, diversity of fuel supply and lower emissions, the report goes on to state "t*his awareness has yet to be translated into policy support for long-term operation of the existing fleet and construction of new plants" … "to recognize the vital contribution that nuclear energy can make."*

Yet the actual IEA scenarios have changed little from last year. As shown below, when considering technologies individually (rather than grouping into "renewables"), nuclear

actually plays the largest role of any single technology in meeting carbon reduction targets showing that, even as it is stands today, the nuclear option is absolutely essential to moving to the IEA 2 Degree Scenario (2DS).

Figure 1.11 Key technologies to reduce power sector CO_2 emissions between 6DS and 2DS



Note: Percentage numbers refer to the contribution of the technology area to the cumulative CO_2 reduction between the 6DS and 2DS over the period 2012-50.

Key point *Electricity savings in the end-use sectors would stabilise power sector emissions at levels slightly above today's; a portfolio of low-carbon generation technologies is needed to sufficiently decarbonise electricity for 2DS targets.*

This can only be the case if nuclear is currently meeting its responsibility to be economic and reliable while being an essential large scale low carbon option. Given that we know the largest challenges in building new nuclear plants is related to their relatively high capital costs and long project schedules relative to other options; consider the role nuclear can play if improvements similar to those demonstrated in the Chinese YouTube video were implemented. Not marginal improvements, but mind blowing changes in approach that shake current thoughts about the costs and schedules of nuclear projects to their very core. This is the way forward. While discussion of next generation plants and SMRs is of interest, we need continued innovation that takes what we know now and improves it beyond what anyone can imagine.

The report shows that government investment in nuclear R&D has

been dropping and in renewables has been increasing. This investment must be refocused on project improvement and innovation rather than the traditional areas of research such as safety and waste management where it has been spent for decades. While important for the nuclear industry, too much of this spending is focused in these areas just to pander to the ongoing public beliefs that safety and waste issues remain unresolved. Rather, emphasis should be on continuing to improve new build project performance. Let’s think about new build nuclear in the same way we think about renewable technologies; that more investment and research will lead to shorter construction schedules and lower costs. It is time to let the innovation genie out of the bottle, stop being on the defensive and move forward with great things. With changes like this, the nuclear share will grow well beyond current expectations bringing a real solution to climate change while keeping electricity bills low and system reliability high.

So remember, nuclear power is essential in achieving increased energy security, diversity of fuel supply and lower emissions; and is already expected to have the largest impact on meeting climate goals of any other single technology. Today’s plants are economically competitive and provide safe and reliable electricity. Talking about investing in energy innovation without a discussion of investing in nuclear, when it’s currently the best option available, is absurd. Governments need to recognize the incredible innovation already achieved by the nuclear option, and unleash even greater potential by investing in this well proven technology.

A nuclear future means clean, reliable and economic electricity; yet fossil fuels reign supreme

This past month, following the fourth anniversary of the Fukushima accident, it is good to see there is less emphasis on the nuclear accident and more discussion of the significant natural disaster – the tsunami and earthquake that killed some 20,000 and destroyed so much, leaving 300,000 homeless. It is now clear that the nuclear accident will not be a cause for radiation-induced cancer, food is not contaminated, and most people can return to their homes should they so desire. While there continues to be a big mess to clean up and many important lessons in managing nuclear accidents to learn, there is no disaster in terms of either immediate or long-term health impacts. Yet we still see news such as was reported this week- that Fukushima radiation has reached the west coast of Canada – one then has to read the report to find out it is so minute as to be a non-event.

So now 4 years on, if we look at China one could conclude the nuclear industry is booming. CGN reported 3 new units were connected to the grid in March, with 2 more expected to be connected within this year. Overall China now has 24 units in operation and another 25 under construction targeting 58 GW in service by 2020 and then accelerating from there to bringing as many as 10 units per year into service in the 2020s targeting about 130 GW by 2030. Two new reactors have just been approved in the first approvals for new units post Fukushima. In addition to this, China is now developing its Hualong One reactor for export as it strives to become a major player in the global nuclear market.

China Hongyanhe 3 completed

China’s commitment to nuclear power is strong and unwavering. An important reason for this rapid expansion is the need for clean air. Pollution in China is a real and everyday problem for its large population. The Chinese see nuclear power as path to ultimately reducing their need to burn coal and hence help the environment.

On the other hand, in Germany a decision to shut down some nuclear units in 2011 immediately following the Fukushima accident and to close the rest by 2022 has led to a large new build construction program of lignite-fired units to meet short term energy needs. With several under construction and some now in operation, coal is producing about half of Germany’s electricity. Keep in mind that these new plants will likely be in service until about 2050. This is while Germany supposedly is focusing its energy future on ensuring a cleaner environment using renewables. I would expect their goal would be easier to reach without a number of new coal-fired units going into operation to replace clean carbon free nuclear energy.

The lignite coal fired power plant Frimmersdorf

It is with these two extremes in mind that I noted when attending the Nuclear Power Asia conference in Kuala Lumpur this past January that while almost all South East Asian countries are planning to start nuclear power programs, they have had little success in getting them off the ground. Currently Vietnam is in the lead and countries such as Indonesia and Malaysia are continuing with their plans, but with little progress. For example, Indonesia has been talking about nuclear power for more than 30 years. With a need for 35 GW of new capacity in the next five years and an annual expected growth of 10 GW per year after 2022, it is easy to ask why a decision for new nuclear seems perpetually stalled while there has been no problem building new fossil plants.

While in Malaysia I couldn’t help but think – why is it so difficult to make a decision to invest in new nuclear plants, especially for first-time countries? Is it a fear of nuclear itself and the issues associated with public acceptance – or is it the commercial aspects whereby nuclear plants have relatively large capital expenditures up front raising

financing and risk issues? Or, more likely, a combination of the two.

At the same time as decisions on new nuclear seem to be so difficult to take, literally hundreds of coal plants and thousands of gas fired plants are being built around the world. If the environment is actually important, why is it so easy to invest in fossil stations and so hard to invest in nuclear? One simple answer is the size of the global fossil industry. Countries like Indonesia and Malaysia have huge industries with fossil fuel development being an essential part of their economies. The public is comfortable with this industry and many either work in, or profit from the industry in some way. The same is even true in Germany, where coal and lignite mining is entrenched. While committed to reducing hard coal use over time, once again this is an important industry in the short term.

For a country looking at nuclear for the first time, like those in South East Asia, there has to be a strong base of support to get the industry off the ground. They need to be serious about their consideration of the nuclear option, not just dabbling with little real interest. While these countries have modest research and other programs, there is simply not enough going on nor a strong belief that there are no alternatives to garner the political support to move forward. Starting a nuclear program is a large undertaking and the fear of securing public support and concerns about safety and financial ability to support the program are paramount. This makes it difficult for decisions to be taken. A strong and committed view from within government is needed and this can only be achieved with a strong need for energy and an even stronger belief that the public is on side.

China has passed this milestone and now has a large and vibrant domestic industry. Government support is assured so long as the industry continues to thrive. To the Chinese, the issue is clear. Nuclear plants are economic and their

environmental benefits are essential to helping solve their huge environmental issues. The Chinese have CONFIDENCE in their ability to deliver safe, economic and reliable nuclear power stations.

On the other hand, the Germans have decided their fear of nuclear is stronger and more urgent than their need to reduce their carbon emissions in the short term even though they had a large and strong domestic nuclear industry. In this case, Germany is an outlier and to this end they justify building new coal units even when their overriding goal is environmental improvement.

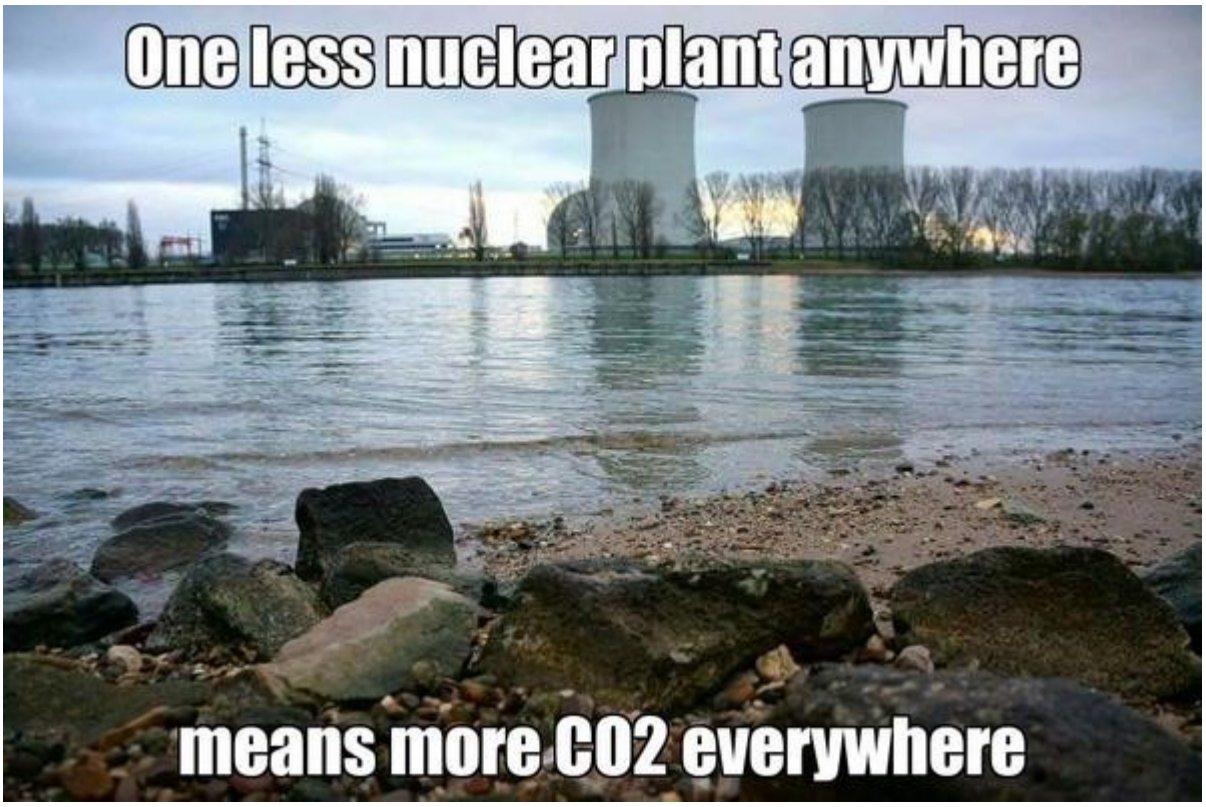
I am confident that nuclear plants will expand their already important role in the future electricity mix of the world and, as such, the industry needs to find new and innovative ways to make taking a nuclear decision easier. This includes ways to gain a higher level of public support, ensure that project risks are manageable and that costs can be kept under control. In some future posts, we will talk about some of these ideas and how we can unlock the global nuclear potential.

As 2014 comes to a close, nuclear power is at a crossroads – again!

The world needs nuclear power – so says the latest edition of the World Energy Outlook (WEO) issued in November. *"Nuclear power is one of the few options available at scale to reduce carbon-dioxide emissions while providing or displacing other forms of baseload generation. It has avoided the release of an estimated 56 gigatonnes of C02 since 1971, or almost two years*

of total global emissions at current rates."

Yet looking back at 2014, the industry has had its ups and downs. There were setbacks as France formalized its intention to reduce its reliance on nuclear going forward, Sweden pulled back after its most recent election, and in Finland the Olkiluoto 3 project was delayed once again. In the US, the most recent plant to be shutdown is the Vermont Yankee plant; shutdown after 42 years of operation as not being economic, yet its shutdown will definitely raise electricity costs for its consumers and impact the local economy as a result of its closure-related job losses.



Vermont Yankee shuts down

There was good news in Japan as the first units were approved for restart since the 2011 Fukushima accident, although the actual restarts are taking longer than expected. The re-election of the Abe government also bodes well for Japan's nuclear future. In the UK, there was a big win as Europe approved the project at Hinkley Point as not contravening state-aid rules; but once again progress is slower than most

would like.

And then there are places where nuclear power is booming. China brought new units into operations and approved numerous new units with a larger-than-life target for its nuclear share in 2020 and beyond. The Chinese also approved its first Hualong One reactor, the evolution and combining of designs from both CGNPC and CNNC, as they plan for future exports. Korea approved new units and its first new site in decades. Russia continues to grow both domestically and continues to be very aggressive in the export market.

Given the importance of nuclear power, it is the first time since 2006 the WEO includes a special chapter on nuclear – in fact this time 3 full chapters performing a detailed in-depth analysis of the nuclear option. It clearly demonstrates the benefits of nuclear power in addition to being one of the only generation options at scale available to reduce carbon emissions; it also plays an important role as a reliable source of baseload electricity that enhances energy security. Clearly the benefits and the need for more nuclear is becoming clearer than ever. So why is there this continuing imbalance as we look around the world at various counties' policies for nuclear power?

The WEO notes two significant issues holding back a large-scale nuclear renaissance. These are public concern and economics. Both are valid and need to be better addressed by the industry. We have written much over the past year or so on the importance of improving public attitudes and, in fact, in many countries we now see improvement. But we also acknowledge there is a long way to go to reduce public fear about nuclear power. For example, even though the main objective of Germany's Energiewende is to reduce carbon emissions; their even stronger emotional response against nuclear is causing a short term increase in carbon emissions .i.e. their fear of nuclear is stronger than their desire for a cleaner environment.

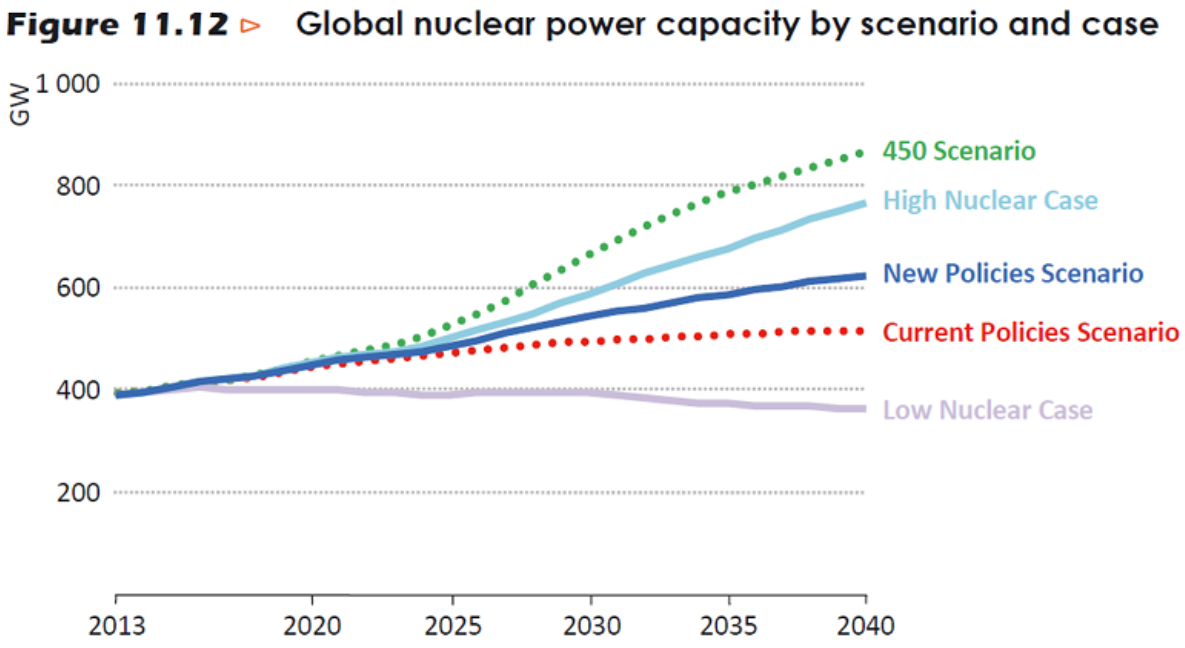
On the cost side, concerns about high capital costs and completing projects to cost and schedule are valid. The industry has more work to do on this issue as evidenced by some recent projects. At the same time we see that countries such as Korea and China, who are building series of plants in sequence and are achieving the benefits of replication and standardization resulting in lower costs and improved certainty, are completing projects to cost and schedule. Yes, it can be done. But even these countries are not immune to public concerns.

The real problem is that these concerns tend to overwhelm the discussion even amongst energy professionals. For example the summary in Chapter 12 of the WEO, "The Implications of Nuclear Power", starts "*Provided waste disposal and safety issues can be satisfactorily addressed, nuclear power's limited exposure to disruptions in international fuel markets and its role as a reliable source of baseload electricity can enhance energy security…..* ". Renewables are always addressed with hope and little concern for their very real issues while discussions about nuclear are most often focused on its challenges.

Yet even at Google, engineers have come to a conclusion that the challenges to achieving climate goals with renewables are very large. Two Google engineers assigned by the company to show how renewable energy can tackle climate change each came to a blunt conclusion: It can't be done. As stated, "*Trying to combat climate change exclusively with today's renewable energy technologies simply won't work; we need a fundamentally different approach*."

The following figure sums it up very clearly. In the case that doom and gloom overwhelms good policy and decision making, we may end up with the Low Nuclear Scenario. But this scenario has real implications – "*taken at the global level, a substantial shift away from nuclear power, as depicted in the Low Nuclear Case, has adverse implications for energy security, and economic and climate trends, with more severe*

consequences for import-dependent countries that had been planning to rely relatively heavily on nuclear power." Of more importance, at the other end of the spectrum is the 450 Scenario which the IEA believes we need to achieve to truly have an impact on climate change. And in this case, even more nuclear power than the so called "High Nuclear Case" Is needed.



So there it is, the best way to economically and efficiently address climate change is with a substantial contribution by nuclear power. This year's WEO lays out the challenge very clearly – once gain nuclear power is at a crossroads. The options range from a slow decline to a more than doubling of nuclear power in the next 25 years. Nuclear power must be an important part of any future low carbon energy system but there are beliefs that are very well entrenched in the minds of both the public and even many global energy professionals that must be addressed once and for all. It is our responsibility to take on these challenges for a brighter future. It's time to go big and work together to build a strong base of global support for nuclear power. Beliefs are hard to change, but change them we must if we are to have a sustainable, abundant and economic energy future for us all.

And as 2014 comes to a close, I want to thank all of you for continuing to read our blog and contribute to the discussion. Wishing you all a very happy, healthy and prosperous 2015!

The challenge of financing nuclear plants – financing energy requires huge investment

Quite often we hear about the problem of attracting financing to support new build nuclear projects. In fact financing will be a topic of major interest at a number of upcoming nuclear conferences. While it is easy to agree that financing nuclear projects is a big challenge, in my view difficulty securing financing is not the issue – rather it is a symptom of a number of other very important issues that are the root cause. Necessary conditions to secure financing for any project is first and foremost, an economically viable project. Next comes the project structure – or to state it more simply – ensuring the risks are managed in a way that can satisfy investors that they will receive an adequate return for their investment. These concepts will be discussed further in a future post.

For today, I will look at the $40 trillion energy industry and consider nuclear's share of the overall expenditure needed for energy over the next 20 years. I would like to put some context on the issues related to financing nuclear plants by looking at a recent IEA report called the "World Energy Investment Outlook" or WEIO. I found this report of interest

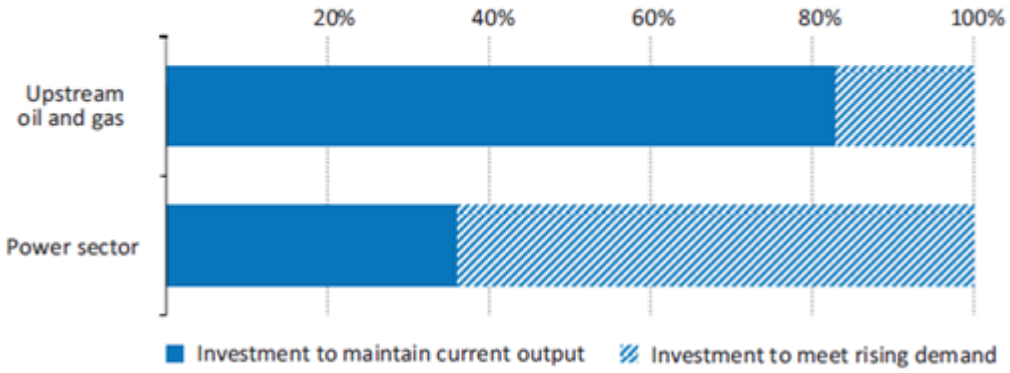
because it provides useful data on global funding required to support energy. Or as stated in the Forward to the report "…. *data on today's investment flows have not been readily available and projections and costs for tomorrow's investment needs are often absent from the debate about the future of the energy sector*."

We often talk about the large size of nuclear projects and how they require huge amounts of funds. Nuclear projects are very capital intensive and have relatively long project schedules; both important issues when trying to secure financing. When we talk about large, a good first step is to try and understand how much funding is required for nuclear projects relative to the rest of the energy industry. And for this we turn to the WEIO.

With annual spending in 2013 of $1.6 trillion rising to about $2.0 trillion by 2035, meeting global demand for energy requires an enormous amount of money. This excludes another $500 billion or so per year to be spent on energy efficiency to try and moderate this growing demand.

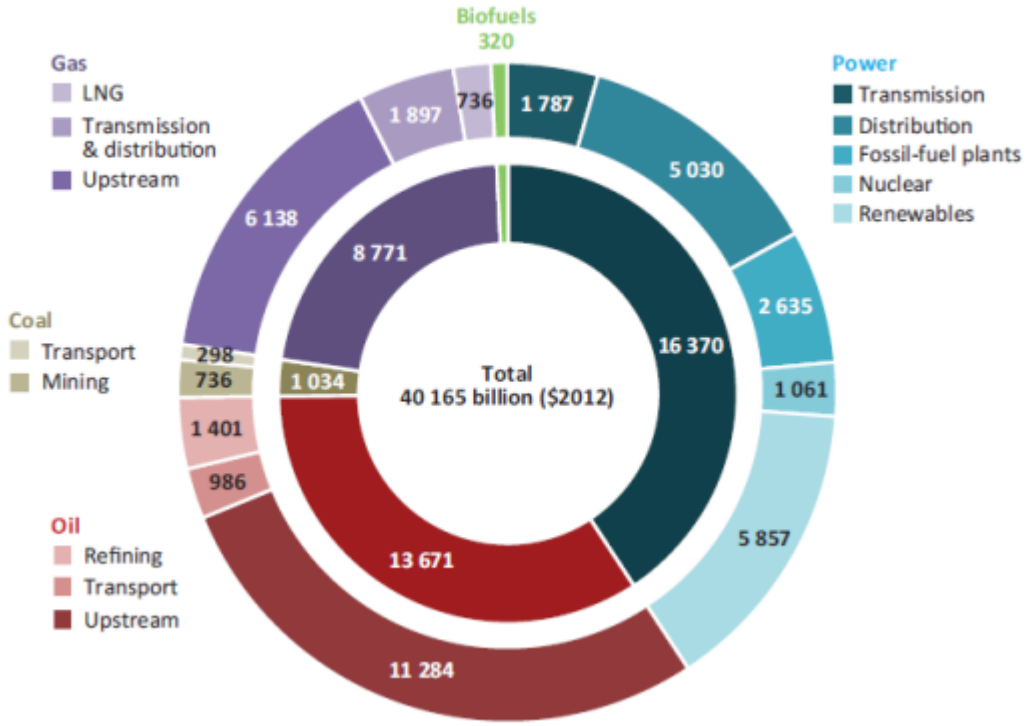
Of even more interest, the report specifies that less than half of the $40 trillion dollars required to meet energy demand between today and 2035 goes to meet demand growth; the larger share is required to offset declining production from existing oil and gas fields and to replace power plants and other assets that reach the end of their productive life.

Figure 1.5 ▷ Share of investment required to keep global output at current levels versus total investment required in the New Policies Scenario, 2014-2035



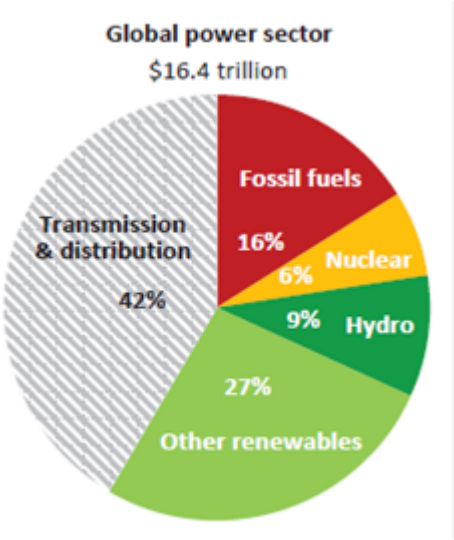
A staggering statistic – more than $20 trillion is required over the next 20 years just to stand still. And of course, most of this investment is in fossil fuels that continue to emit carbon as the world tries to find a way to turn the corner and find alternatives.

Figure 1.3 ▷ Cumulative global energy supply investment by type in the New Policies Scenario, 2014-2035



If we drill down and focus on the electricity sector, we can see that of the above $40 trillion about $16.4 trillion is investment in the electricity sector. The largest component of

this investment (about 40%) is in transmission and distribution. In the developed world this essential infrastructure is ageing and requires significant investment to meet growing needs. In the developing world, there is a huge need to build up the infrastructure for a population hungry to enjoy the benefits of using electricity.



Looking further we can see two important facts. First, nuclear power only needs about 6% of the funds for the electricity sector; this is assuming the very modest growth for nuclear in the WEO New Policy Scenario. The other is that renewables are demanding a very large share of the available funds as more and more markets turn to these forms of energy to meet their growing energy needs while trying to curb carbon emissions.

What can we learn from this high level look at the funding requirements for the energy industry? On the one hand, nuclear projects require only a very small portion of the total funds being invested today and for the next 20 years in energy. The main uses of funds are to replace existing depleted fossil fuel reserves – usually at a cost higher than the resources they replace; to invest in critical T&D infrastructure, in part due to the need to expand transmission to be able to accommodate renewable energy generation; and the investment in renewable energy generation itself, virtually all of this last

investment subsidized by governments to encourage growth.

On the one hand, there is tremendous competition for funds in the energy industry meaning nuclear projects need to be an attractive financial proposition to get its share of these funds. And on the other hand, much of the competing technologies are being supported by governments with subsidies based on policy decisions.

So what is it that makes nuclear plants so difficult to finance? As I said at the start of this post, there are a number of issues that need to be discussed. These include project economics, energy market structures, poor project construction performance in a number of markets; and of course, public perception that skews the risk profile of nuclear projects in a way not seen in other industries. But a discussion of these factors will have to wait until another time…….

Note: all figures above are from the IEA World Energy Investment Outlook.

The changing face of global energy – Is nuclear power being left behind?

I have just done my first pass of the Word Energy Outlook 2012 issued by the IEA this November. Many of you will have seen some of the headlines – one of the most intriguing is that the US is expected to become the world's largest oil producer by 2017 exceeding the output of Saudi Arabia. With headlines like that how can you not want to read this report?

The trouble with trying to read and write about this report is that, as was the case with the Energy Technology Perspectives (which I talked about earlier this year), there is just so much in it to make you think that, agree or disagree, the report is full of interesting information that is worth discussing.

I have been a bit stuck on what perspective to take in this post. Ultimately I decided to focus on some general points this month (of course with the outlook on nuclear as the key talking point) and then I will undoubtedly use the report for future discussions on more focused topics.

Reading the Executive Summary the report starts off with "***The global energy map is changing, with potentially far-reaching consequences for energy markets and trade. It is being redrawn by the resurgence in oil and gas production in the United States and could be further reshaped by a retreat from nuclear power in some countries, continued rapid growth in the use of wind and solar technologies and by the global spread of unconventional gas production***."

When it comes to global energy production, this short phrase pretty much sums it up. Strong North American oil production, more coal, less nuclear, more renewables and much more gas. And not surprisingly, this translates into more difficulty meeting climate change objectives. It continues, "***Taking all new developments and policies into account, the world is still failing to put the global energy system onto a more sustainable path***. ***Successive editions of this report have shown that the climate goal of limiting warming to 2 °C is becoming more difficult and more costly with each year that passes. Our 450 Scenario examines the actions necessary to achieve this goal and finds that almost four-fifths of the CO2 emissions allowable by 2035 are already locked-in by existing power plants, factories, buildings, etc. If action to reduce CO2 emissions is not taken before 2017, all the allowable CO2 emissions would be locked-in by energy infrastructure existing***

at that time." Another testament to the continuing lack of progress on meeting the world's climate change challenges.

And finally when it comes to the future of nuclear power it recognizes the changes in some countries to cut back while others continue to move forward.

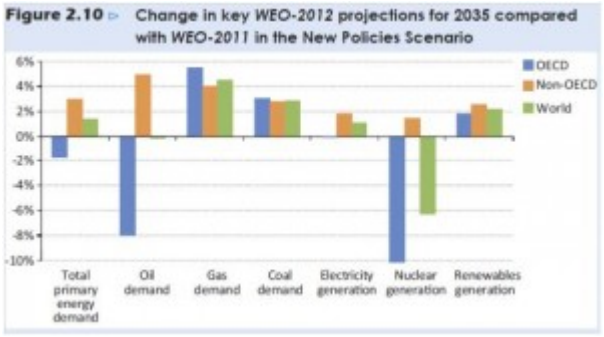
"The anticipated role of nuclear power has been scaled back as countries have reviewed policies in the wake of the 2011 accident at the Fukushima Daiichi nuclear power station. Japan and France have recently joined the countries with intentions to reduce their use of nuclear power, while its competitiveness in the United States and Canada is being challenged by relatively cheap natural gas. Our projections for growth in installed nuclear capacity are lower than in last year's Outlook and, while nuclear output still grows in absolute terms (driven by expanded generation in China, Korea, India and Russia), its share in the global electricity mix falls slightly over time."

I am showing all of the above quotes because in a few words from the Executive Summary, the report says so much. The figure below shows the key changes in projected energy use from the 2011 WEO. In summary, as I read this report we can conclude that:

- Fossil fuel use is thriving. Clearly North American policies to increase both oil and gas production are very effective. Coal use is up again globally from the last WEO even with a larger increase in (mostly unconventional) gas use. Fossil fuel subsidies continue to be the largest of any energy source estimated at $523 billion, more than 6 times that for renewables and a 30% increase from 2010.
- Renewables use continues to grow without any real demonstration that increasing renewables to that extent is feasible. Subsidies are at $88 billion and rise to $240 billion in 2035

- Nuclear is being left behind as the 6% reduction in nuclear compared to 2011 is the largest single change in the new WEO New Policies Scenario.

And this path is taking us down the road to being unable to meet the 2 degree climate change scenario. After trying everything else in past reports, this year they try to demonstrate that increased efficiency is a potential path to delaying the inevitable and make time for more policy change to support the environment. This has the potential to extend the 2017 date for lock-in to 2022. However we can also ask, without a real and substantive global commitment to reducing carbon emissions, what will these extra few years actually achieve? Most likely – nothing!



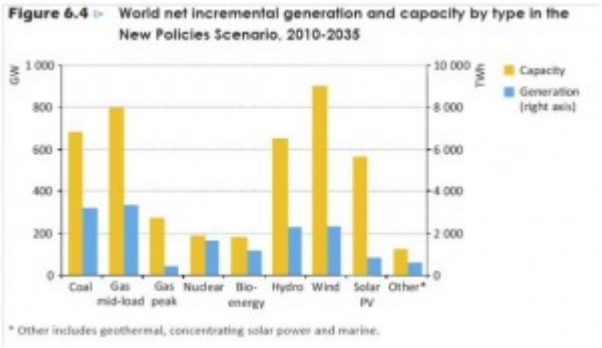
So let's look at the nuclear case in a bit more detail. Compared to the 2011 scenario, nuclear use is decreasing in those countries with the most to lose, Japan, Germany, Switzerland and even France, while being economically challenged in North America; and rising in the more rapidly growing economies of the east led by China. This leads to an important question. Is nuclear power becoming a transient technology that helps countries develop and then once there, can be phased out over time by a policy shift to renewables? This seems to be a possible theme going forward but in practice nothing can be further from the truth. It is interesting to note that this past week was the 70th anniversary of the first sustained criticality at CP-1 by Enrico Fermi. And here we are today with the countries named above all having substantial nuclear programs providing a

large and important part of their electricity generation (Japan 30%, Germany 30%, Switzerland 40% and France 75%). Clearly, with this much nuclear, replacing it is not trivial and will have significant impacts. Even the WEO acknowledges that ***"shifting away from nuclear power can have significant implications for a country's spending on imports of fossil fuels, for electricity prices and for the level of effort needed to meet climate targets."***

And that is what we are seeing today as Germany and Japan wrestle with these impacts as they try to reduce the use of nuclear very quickly. Based on hysteria following the Fukushima accident, the politicians in these countries (even France) seem to have forgotten what they have achieved since that famous date 70 years ago and why they built such large nuclear fleets in the first place. Building a successful nuclear program is a major undertaking requiring investment in regulation, infrastructure and industry. Germany, Japan and France have all benefited from this investment as they developed significant technology, know-how and industrial capability with the result being, in all cases, a very large portion of their electricity generation being economical, clean and reliable. Reducing its use as a result of a misguided view on nuclear safety will result in a large negative impact to industry and their economies. In Germany, utilities are suffering financially and in Japan, there is the risk of losing capability and business to the new nuclear powers of Korea and China while having staggering increases in imported fossil fuels and a devastating impact to the local economy.

In fact, looking at the following figure from the WEO shows the bigger story. Just compare the capacity bar with the energy bar in each case and one thing is clear. Nuclear power is a key workhorse of the global energy system. It is by far the most efficient investment as every GW of capacity produces more GWh of energy than every other type of electricity

generation. As I stated in my earlier post on the ETP, one of the reasons for the enormous investment in renewables is that you have to build about three times as much capacity as nuclear to get anywhere near the same energy output – and of course even then this energy is not dispatchable. But even looking at the use of more tradition fossil fuels, because nuclear fuel costs are very small, they are dispatched before more expensive coal and gas plants and, as the figure shows, 3 times as much coal capacity and almost 4 times as much gas is projected to each only generate twice the energy as nuclear.



It is important to remember that the WEO is not a forecast per se; rather it is a projection of how government policies would look once implemented. And what we see is a world investing heavily in fossil fuels to protect the status quo while also investing in renewables as a token path to the future. The fall in nuclear power use in developed countries is an important testament to the ongoing impact of the Fukushima accident on government policies in the west.

While the 2012 projection is less than 2011, nuclear power does continue to grow and in 2035 it is projected to supply 12% of world electricity (13% in 2011 projection). Yes, it is being left behind relatively but, as I see it, this report clearly demonstrates the importance of nuclear power as a clean, efficient and reliable source of non carbon electricity going forward. Implementing policies that reduce its use is folly as it definitely will result in expanded fossil use, higher costs, trade imbalances and higher carbon emissions; all leading us down an unsustainable path.

Therefore the policy answer is not to limit and reduce the use of nuclear energy, but to expand its use because even a small expansion in capacity results in a relatively large increase in energy generated. And that means that we need to work harder to address the issues resulting from the Fukushima accident in the developed world and remind those governments who are reacting to short term pressures why they went nuclear in the first place; and of the consequences of reducing its use to their societies so they can rethink potential policies that may move them away from this very important part of our global energy mix.

The obvious answer to a low carbon electricity system – More Nuclear Power

I started writing this while sitting on the very long plane ride on my way to China. The Rio+20 conference had just started, the largest ever UN conference and yet it was receiving relatively little press. I remember the first Rio conference 20 years ago when there was so much hope for the environment and the conference was seen as an important beginning in addressing climate change. Now 20 years later, expectations were low and interest even lower. I guess it's not surprising. With economic crisis ongoing in Europe, a weak recovery in the US and a slowdown in China, environmental issues have fallen way down on many people's list of priorities.

In advance of this conference, the IEA recently issued its Energy Technology Perspectives Study (ETP 2012), where they

make a passionate case in support of the environment and the need to develop a low carbon energy system. Love it or hate it, this study is a gold mine of interesting and useful information in its almost 700 pages. This study takes the 450 ppm scenario in the World Energy Outlook 2011 and extends it out to 2050, now calling it the 2 degree scenario (2DS). This is then compared to the status quo (6 degree scenario) with a 4 degree scenario in between. It then goes a step further to see if a zero emissions energy system is possible by 2075. It is just not possible to discuss the entire study in one short (actually not so short) blog post, so I will focus on a few key issues and will likely continue to use it as a valuable source of data in future postings.

The study makes the case that environment and energy development must go hand in hand. Here are some of the findings:

- **A sustainable energy system is still within reach and can bring broad benefits**
    - **Technologies can and must play an integral role in transforming the energy system.**
    - **Investing in clean energy makes economic sense – every additional dollar invested can generate three dollars in future fuel savings by 2050.**
    - **Energy security and climate change mitigation are allies.**
- **Despite technology's potential, progress in clean energy is too slow**
    - **Nine out of ten technologies that hold potential for energy and CO2 emissions savings are failing to meet the deployment objectives needed to achieve the necessary transition to a low-carbon future. Some of the technologies with the largest potential are showing the least progress.**
    - **The share of energy-related investment in public research, development and demonstration (RD&D) has**

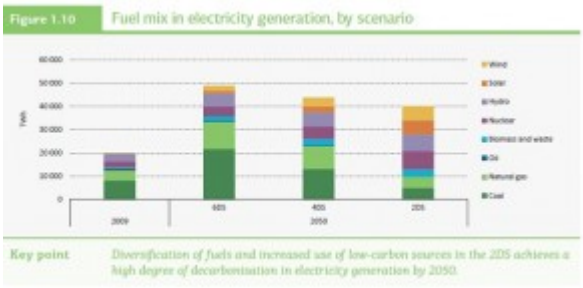
fallen by two-thirds since the 1980s.

- **Fossil fuels remain dominant and demand continues to grow, locking in high-carbon infrastructure.**

It then goes on to focus on how energy policy must address the key issues and the role of government in making it all happen, finally concluding with recommendations to energy ministers (assuming these recommendations were to be considered at Rio+20).

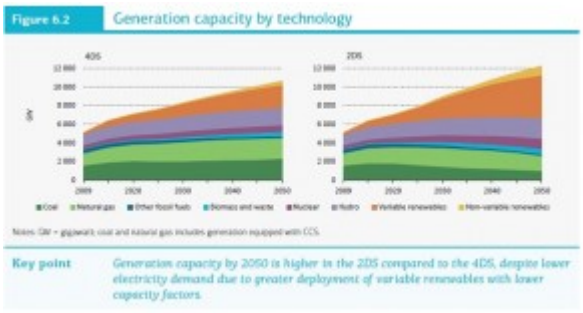
When considering "technologies" the focus is on renewable technologies such as wind and solar, energy efficiency technologies to reduce demand and carbon capture technologies to clean up the ever-expanding fossil infrastructure. Nuclear is also shown to be important although it role is somewhat less than the other technologies. It is these same technologies, primarily renewable and Carbon Capture and Sequestration (CCS) they are talking about when they say "progress in clean energy is too slow"

Focusing on a few key issues, consider the following two figures. The first illustrates the change in electricity generation mix for each of the three scenarios. Improved energy efficiencies is the most important source of clean generation. The figure shows that in the 6DS there is almost 50,000 TWh of generation required dropping to about 40,000 TWh in the 2 DS. It can be seen that there is huge growth in renewable generation (wind, solar, hydro and biomass) and an increase in nuclear capacity. Most of the remaining fossil generation is assumed to have CCS installed.

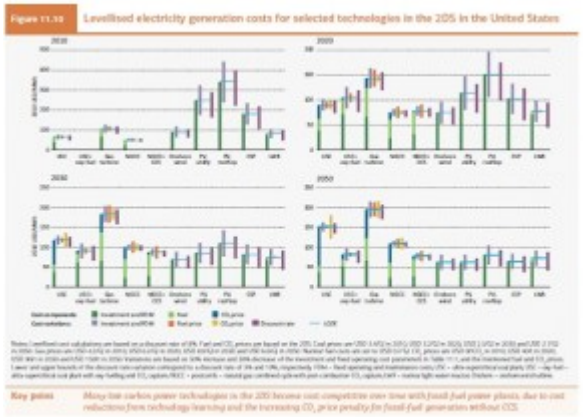


The next figure is somewhat more telling. It shows the needed capacity and illustrates that due to the variability

and low capacity factors of renewables such as wind and solar, capacity must still increase even though total generation decreases by 20% (50,000 to 40,000 TWh Fig 1.10). This demonstrates the importance of nuclear as it has high efficiency relative to other forms of generation. With less than 5% of the generating capacity (about 550 GW), it produces close to 20% of the electricity! i.e. nuclear is an essential technology in a low carbon electricity system.



The main tool in achieving CO2 reduction targets for the 2DS is CO2 price, increasing from USD 40/tCO2 in 2020 to USD 150/tCO2 in 2050. This greatly increases the electricity generation costs of CO2-emitting technologies and thereby improves the relative cost-competitiveness of low-carbon power technologies. The following figure is a bit busy but important as it clearly shows how CO2 pricing is implemented to achieve this result.



The cost increase to effect change is one of the key points made in Jeff Rubin's new book "The end of Growth". In an excerpt published in the Globe and Mail on May 5, Jeff talks about the electricity and transport systems in Denmark. The Danes have achieved a heroic drop in carbon emissions of 13%

over the past twenty years while those of us in North America have seen an increase in emissions of 30% in the same time period. Often praised for its commitment to renewable energy, now producing 20% of its electricity from wind power, what often goes unsaid is that the remaining 80% of its electricity is generated by coal.

So how is Denmark achieving this great carbon reduction? Simple – price. At $0.30/KWh, the price of electricity in Denmark is 2 to 3 times higher than in most jurisdictions in North America. And at this relatively high price has a significant impact on behaviour and usage drops dramatically.

This is absolutely consistent with the IEA report as it suggests the only way to achieve a low carbon world is to price carbon aggressively to force behavioural change; first by reducing demand and second through the implementation of higher cost low carbon technologies.

Now while this may work in Denmark and in other countries where there is no choice but to implement higher prices to manage the transition such as in Japan and Germany (due to their need to replace idled nuclear), any politician who takes the position of significant increases in energy costs in North America will not keep his or her job for very long. In North America the population believes that cheap and abundant energy is a right and anyone who tries to say we need to do otherwise won't make it very far at voting time.

So what are we to do? I do believe that the IEA's ETP report has this answer as well. And for us in the nuclear industry it has always been quite clear. More nuclear power.

I have talked about the IEA's nuclear roadmap before. In effect, they prepared a number of "roadmap" reports for various technologies and this ETP report is where they bring them all together in a cohesive model of a clean energy system for the future. When it comes to nuclear the IEA continues to

be positive and sees an increase in nuclear generation from about 14% of electricity supply to almost 20% in 2050. While the increase in nuclear capacity may appear to be modest, as stated earlier this modest capacity provides a significant portion of the needed electricity generation!

It should be noted that this target represents a decrease from their original target of 24% in their nuclear roadmap due to the impact of the Fukushima accident on public acceptance which has become the limiting issue. This is based on a 2011 post Fukushima survey in which support for nuclear power drops due to an increased concern about nuclear safety with more people now supporting nuclear shutdown due to its inherent dangers.

Of importance, the study continues to include a "high nuclear" sensitivity case for the 2DS scenario. In the 2DS-hiNuc case, nuclear generation is increased to 34% in 2050. Compared with the base 2DS, nuclear replaces fossil power plants with CCS and renewables, whose share in 2050 falls: in the case of CCS from 15% to 7%, and in the case of renewables from 57% to 49%. This scenario reflects a world with greater public acceptance of nuclear power. On the technical side, the average construction rate for nuclear power plants in the period 2011 to 2050 rises from 27 GW/yr in the base 2DS to 50 GW/yr. The cumulative investment costs of this case are only USD 0.2 trillion higher than in the base 2DS and are more than offset by costs savings for fossil fuels in the order of USD 2 trillion (10 to 1).

Going back to the cost figure above, this is not surprising because nuclear is competitive with other forms of generation and can be built now without the need for high carbon costs to incentivise it. (I know in North America current low gas prices are challenging new nuclear and this was my topic last time – but keep in mind this study is looking at the bigger picture over a longer timeframe).

A system with about one third of the generation provided by nuclear seems very sensible and achievable so long as the industry can overcome the major issue of public acceptance. Therefore the challenge is clear. The industry should focus on the high nuclear scenario as our base case and work hard to regain public trust – no small task that will certainly require a long term sustained effort.

In the end, our world will become more electrified and we need to move forward with a cleaner, sustainable electricity system for our future. So what is harder for the public to accept – very high carbon costs and a very large increase in variable renewable generation or a bigger role from a relatively modest increase in the number of nuclear power plants??