Everybody knows how energy will be generated in the future, or do they?

At an event a few weeks ago, a number of speakers prefaced their comments with statements like "**everybody knows** the future will be based on distributed generation – primarily with small scale renewables and storage to provide reliability". While there is currently a trend towards increased use of wind and solar and batteries are increasing their footprint as viable short-term storage (current batteries mostly provide 4 hours of energy and some provide 8 hours), pronouncing this as the definitive path for the future is premature.

It is hard to understand why so many people seem to believe that securing energy from a traditional large electricity grid is the way of the past and that generating your own electricity, perhaps together with your neighbours in a microgrid, is by far the better way.

After all, in most aspects of our modern lives, we are becoming more and more networked and interdependent with others. We have no problem securing our internet from large telecoms and we love using large social media sites such as Facebook and Instagram to share our most private thoughts with our global network. We are comfortable being totally dependent upon large companies for so many aspects of our

daily lives. We read books and listen to music on our various devices where we depend upon the company being in business as we no longer take physical delivery of content. I spent thousands of dollars on Sonos speakers that provide fantastic sound, but if Sonos disappears tomorrow they will no longer function since they need the Sonos app and its business associations with a range of music providers to keep working. Our NEST thermostats require the app to function at their best and as we move to the "smart" home, all of these devices are operated with apps that require the company supporting them to be in existence for the long-term while we naively assume that because they are so large that Amazon, Facebook and Google will always be there and can never go bankrupt.

Yet somehow, when we have accepted being so dependent upon companies that are larger than some nations for most of what we consider important in our lives, for a basic commodity like electricity, which is essential to enable all of these other services we both need and desire, we conclude that generating it ourselves on our roofs is the best way forward. We have this romantic fantasy that we can live off-grid with a combination of solar power and battery backup. Of course, with a bit of thought we realize that it would be a crisis if it rains for a week and we can't charge our iPhones, so we accept that we cannot go it completely alone. The conclusion being that maybe we need to collaborate with our neighbours and build a small system (or microgrid) to achieve the reliability that we need to power our lives. The question then becomes how big a system do we need?

Electricity generation and distribution is a complex system. It is already distributed in a sense because a traditional grid requires a number of generating stations in different locations connected by a system of wires to provide customers with cost effective and reliable electricity. How big a system do we need to maintain reliability? Well, after the big black out in North America in 2003, it was decided by US

regulators that increased inter-connectivity would be required and all utilities would have to adhere to stringent reliability standards to maintain this interconnection so that one bad actor cannot bring everybody down. So, in a sense we are all connected. The same in Europe where most countries' grids are interconnected to provide a robust reliable system.

Since it is likely that distributed generators will have to be connected to a microgrid and that microgrids will have to be interconnected to maintain robustness and reliability, then aren't we just building a new type of large system similar to what we have now? I guess it is the larger centralized generating stations that people dislike as they believe that smaller renewable generation with each of us being generators is the way forward.

But is it? It may be nice for middle class and wealthy environmentalists to dream about a simple life in which they generate their own electricity on their roof, grow much of what they eat in their own garden and buy organic and GMO-free products to meet the rest of their dietary needs; but does this really reflect the reality of society as it is developing today? The world is urbanizing quickly with most people not living in single family homes in the suburbs, but in high density buildings in cities. Is it realistic to generate our own electricity on the roof of a 200 unit apartment building where our own unit may be only 600 square feet? Should we grow our own food on our concrete balconies? Should we drive our electric car to work and clog the roads because we can charge it overnight when demand is low and avoid the subway because it uses on peak electricity when demand is high?

As the world moves to higher density living, it seems unlikely that we can meet our energy needs with lower density sources of supply. As stated by Michael Shellenberger, "Humankind has *never* transitioned to energy sources that are *more* costly, *less* reliable, and have a *larger* environmental footprint than the incumbent – and yet that's precisely what adding large

amounts of solar and wind to the grid requires. " …. "In other words, going from energy-dense fuels to solar and wind requires the *rematerialization of energy* in the form of more land, materials, mining, storage, and waste."

While idealistic environmentalists can live in their big homes in the suburbs and pretend they are living in an isolated cabin in the woods, the rest of us need to power our lives with reliable economic and low carbon electricity. This means high density generation for high density living, and there is no better high-density fuel source than uranium.

One thing we know for sure is that predicting the future is perilous at best. We can be certain that we are more likely wrong than right when gazing into our crystal balls. The next time someone tells you that "**everybody knows…**" remember that this a way to avoid actually providing supporting evidence for their view of the future. What we do know is that the future is ours to shape; that reliable and abundant low carbon energy is required to power it, and that nuclear power has the density to meet these needs economically.

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

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

to spring back into shape”

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

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

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

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

Last year, the US Department of Energy completed a study that emphasized the importance of **resilience** to our energy infrastructure. The cover letter from the Secretary of Energy

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

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

Then as we entered the new year, it was once again extreme cold that impacted the supply of electricity in the North East. Wind and solar don't do well in these extreme conditions and gas is directed to homes first for home heating. The result – New England was saved by oil, yes it was oil that provided a third or more of New England's electricity needs. And even that was at risk if the cold spell would have lasted much longer as reserves started to dwindle. Yet there is still a discussion of closing nuclear plants that just keep on generating during these events. So

let's remember what Secretary Perry said, "*Customers should know that a **resilient** electric grid does come with a price.*" What should really be said is that not having the **resilience** needed comes at a significant cost for us all should the electricity we need not be there when we need it.

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

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,

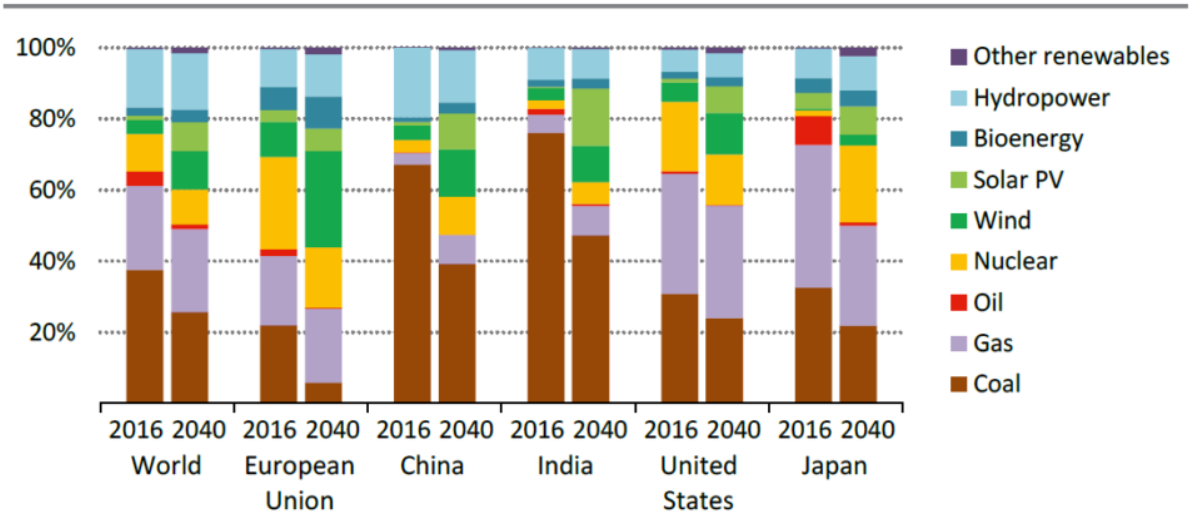
these are unable to take the place of its closing nuclear plants, thereby making coal king in Europe's most polluting nation. This story shows how a 12-thousand-year-old forest that has been almost completely consumed by the country's ravenous addiction to coal power.

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!

An Inconvenient Reality – Nuclear Power is needed to achieve climate goals

On a quiet Wednesday afternoon, I decided to go and see Al Gore's update on climate change, "**An Inconvenient Sequel:**

Truth to Power”. While certainly a powerful update on the importance of climate change and on the need to do something about it, I was disappointed. Why? Because, once again, after repeating the phrase “climate crisis” many many many times over its 140 minutes (would really like to know how many times this phrase is repeated), the solutions presented exclude the one with the largest potential, nuclear power.

While showing us melting glaciers and extreme weather, a case is then made that renewables are finally taking hold and the future is now within reach. The film claims there are jurisdictions that are indeed close to 100% renewables and talks about some already achieving 100% for limited periods of time.

We have talked about this before in our discussion of the recently published study that criticized the popular Marc Jacobson paper claiming a 100% renewable United States is achievable by 2050. It simply cannot be achieved; and it’s time to focus on a larger basket of solutions that can actually solve the climate crisis.

The large Banning Pass 615 MW wind farm in California provides as much energy as one fifth of a standard 1,000 MW nuclear plant – is this what we consider environmental progress?

After watching the movie, I went to the web site and signed up for emails from the Climate Reality Project. On the first email, there was a box asking for donations labelled “Science Matters”. And yes, it does. Science tells us that nuclear power provides large amounts of low carbon electricity economically and reliably. In fact, during the recent Hurricane Harvey that flooded Houston Texas, it was the South Texas Project nuclear plants that kept running ensuring ongoing electricity supply. If you want to advocate to resolve the climate crisis, then all science matters, not just the science that supports a certain point of view.

However, there are also important lessons to be learned for the nuclear industry from this movie. First of all, the environmental movement has succeeded in making the word “renewable” completely synonymous with both “low carbon” and

“clean”. There is little argument from the public when stating renewables are the solution to climate change. Whereas in reality it is “low carbon” energy that is needed. Look at any country’s projections for the future and they will talk about their target for renewables, not for low carbon energy. If we really have a “climate crisis”, then limiting the solution to a subset of what is available when it comes to low carbon options will not lead to the outome that we all need.

There is no doubt that Al Gore is a very credible champion in the fight against climate change. The nuclear industry does not have the same although change is in the air. As we discussed last month, there are now pro-nuclear NGOs with credible leadership. In the movie, Al Gore offers training to support those who want to become climate advocates. This includes lectures and the provision of useful presentation materials. I suggest that this is what is required for the nuclear industry. Provide training in nuclear advocacy and offer up materials to be used. While there is excellent information available on industry websites such as the Canadian Nuclear Association, the Nuclear Energy Institute and of course the vast resources on the World Nuclear Association site, I would suggest there is still more work to be done. We now live in a visual world so let’s make sure we offer a large photo gallery and useful charts and diagrams that can readily be dropped into any presentation. This includes factual information on other forms of energy as well such as wind and solar – and information on countries such as Germany who have taken decisions on their energy future that clearly show their progress, or lack thereof.

So, if the movie is right and the world is in crisis, it makes absolutely no sense to not use all the options available to humanity to solve this crisis. Limiting the fight to options that are clearly insufficient is akin to madness. At the end of “An Inconvenient Sequel: Truth To Power,” the audience is

asked to take the pledge to be inconvenient – to keep demanding schools, businesses and towns invest in clean, renewable energy. We agree, be inconvenient and also demand that nuclear power play the significant role that it can to really make a difference because the inconvenient reality is that renewables are just not going to get us there.

Sometimes we need to ask if, for many in the environmental movement, decarbonization is really the goal? Imagine a world where all the electricity was suddenly generated by nuclear power eliminating carbon emissions completely so that the climate crisis was solved. Would Al Gore consider this a win? I just don't know.

Energy policy cannot be based on fantasy – the truth may yet prevail

Over the last week or so, the internet has been abuzz with articles on the recent 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. Given the strong desire to believe in this utopian future; and how many prominent people have referenced this Jacobson paper to support their energy views, it is somewhat surprising how much press the opposing view elicited. That being said, most of the articles had titles like, "*A bitter scientific debate just erupted over the future of America's power grid*" or "*Fisticuffs Over the Route*

to a Clean-Energy Future" making it seem like this is about scientific debate, when it is actually about a paper that has been proven to be false.

As stated by this paper's authors, *"In this paper, we evaluate that study [the Jacobson study] and find significant shortcomings in the analysis. In particular, we point out that this work used invalid modeling tools, contained modeling errors, and made implausible and inadequately supported assumptions. Policy makers should treat with caution any visions of a rapid, reliable, and low-cost transition to entire energy systems that relies almost exclusively on wind, solar, and hydroelectric power."* These are pretty strong statements for an academic paper.

Of course, for most of us in the industry this study is telling us what we already knew, that 100% reliance on intermittent low-density energy sources is not going to meet the needs of an energy hungry world. We suggest you read a few of the articles and of most importance, the actual paper. We would also recommend you read the article by James Conca "*Debunking The Unscientific Fantasy Of 100% Renewables*" which takes aim at the issue of bad science.

But the world is passionately in love with renewables. What can be better or more natural than wind and solar? It makes you feel good – there are no problems that can't be overcome with these wondrous technologies. They definitely don't cost too much [but they need subsidies], or have environmental or waste issues [solar waste is increasing] and of course their intermittency is a modest problem to be resolved by smart people [by building more gas to back them up]. On the other hand, fossil fuels emit carbon and while nuclear plants are low carbon, they are dangerous – everybody knows that. And in this era of fake news and alternate facts, why would anyone want to change this glorious view of the future?

Of course, the option that does tick all the boxes for a low carbon energy revolution is nuclear power. And we are starting to see this position being more widely accepted. As the dream of a renewables only future fades, the merits of nuclear are once again coming to the forefront. That is why the US government is taking action to save its operating nuclear plants that are struggling in de-regulated markets, the UK is strongly supporting new build, Canada is refurbishing its aging nuclear fleet and China is rapidly expanding its share of nuclear production.

Countries like Germany that are committed to phasing out nuclear for a 100% renewable future are further proof that this approach to decarbonization is flawed as they add coal production to make up for their nuclear shortfall. Now Korea seems to be following this approach as their new president is committed to getting rid of both coal and nuclear (70% of their current system) for a renewable future. We only hope this analysis of Jacobson's paper is a wake-up call that is heeded in these markets that now seem to be following an unrealistic romantic world view rather than a realistic one.

Once again, I have to quote Michael Shellenberger. In his proposal for Atomic Humanism his first principle is – "*nuclear is special. Only nuclear can lift all humans out of poverty*

while saving the natural environment. Nothing else – not coal, not solar, not geo-engineering – can do that. How does the special child, who is bullied for her specialness, survive? By pretending she's ordinary. As good as – but no better than! – coal, natural gas or renewables."

And it is this pretending that needs to stop. There is no longer a need to be defensive when supporting the nuclear option. Or as stated by the Department of Energy in the USA. *"… we're particularly proud of the contributions being made by the nation's nuclear power plants. Nuclear is, in short, a clean, constant, and downright cool energy resource. Unfortunately, many people may not understand how remarkable this unique energy source truly is, or the role that it plays in our energy portfolio and Americans' daily lives."*

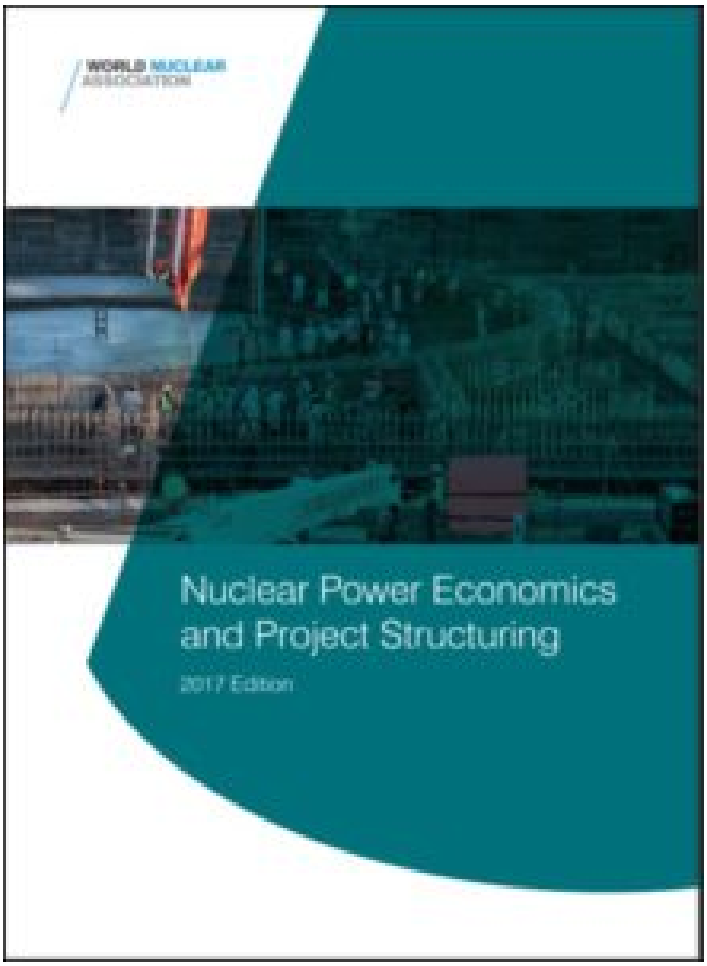
We are at a crossroad. The time has come to strongly support the best technology that can reliably meet the energy hunger of the world and we need to make it known to policy makers everywhere. Making energy policy on a hope and a dream is no way to plan our energy future. Nuclear power is the only true path to a low carbon future with the vast amount of energy needed to fuel the world that is both economic and reliable – and yes safe. If we work hard to support the facts, the truth may yet prevail. Or as stated by Michael Shellenberger – Nuclear is special – let's say it loud and let's say it proud!

Nuclear Power Economics

At the World Nuclear Fuel Conference (WNFC) conference in Toronto this month, I will be presenting a paper "**Nuclear Power Economics and Project Structuring – 2017 Edition**" to introduce the most recent version of this World Nuclear

Association (WNA) report. For full disclosure, I am the chair of the WNA Economics Working Group and this is the group responsible for the report's preparation.

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



When it comes to the conclusion, little has changed since the first report was issued back in 2005. At that time, it concluded "*In most industrialized countries today new nuclear power plants offer the most economical way to generate base-load electricity – even without consideration of the geopolitical and environmental advantages that nuclear energy confers*." The 2017 version comes to the same conclusion

stating, *"Nuclear power is an economic source of electricity generation, combining the advantages of security, reliability, virtually zero greenhouse gas emissions and cost competitiveness."*

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

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

And what about the competition? There has been huge global growth in renewables strongly supported with government subsidies and a dramatic drop in the price of gas in North

America. The impacts of these subsidised intermittent renewables and 'un-carbon costed' gas have depressed wholesale prices in deregulated electricity markets creating a number of issues in maintaining existing large scale nuclear baseload generation (as well as other baseload options). Policymakers are finally seeing the negative impact of these issues and are just starting to address these fundamental market design problems.

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

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

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

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

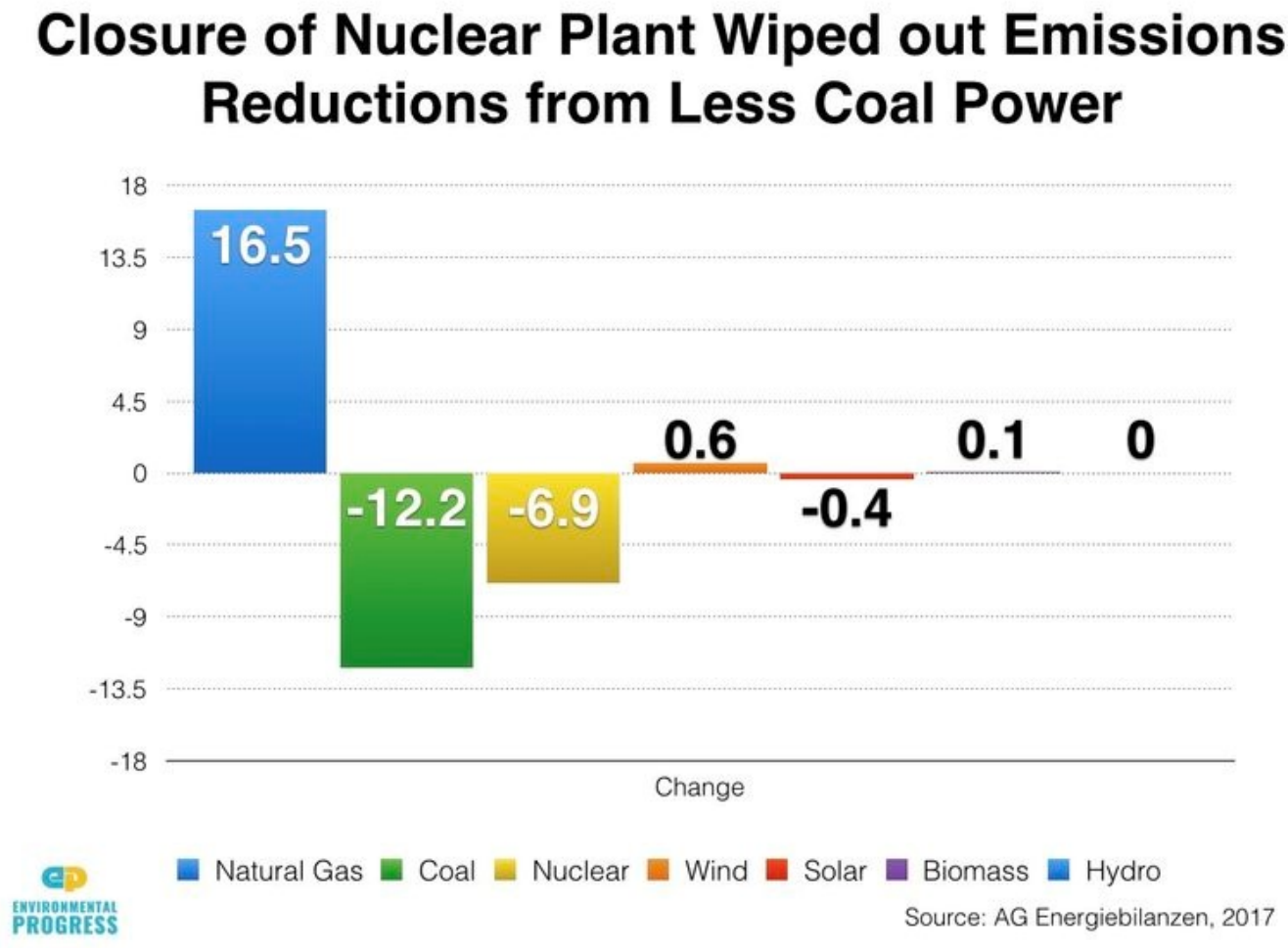
Over the last few years, we have written extensively about the strength of peoples' beliefs and how difficult it is to change them. In spite of this, I thought we were making progress with a push to more evidence-based decision making. For something as polarizing as nuclear power, facts-based decision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

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

So, let's look at what happens when countries believe they can eliminate nuclear power from the mix and replace it with more wind and solar power. Of course, I am talking about Germany. Reducing carbon emissions is a reasonable goal as evidence (alternative facts notwithstanding) shows that climate change is impacting our environment and has long-term implications for our entire society. On the other hand, removing a low-cost low-carbon source of energy like nuclear power because of safety concerns is based on a strong element of fear rather

than evidence. In fact, Germany's nuclear plants are likely some of the safest in the world and there is no reason to suspect they will result in a catastrophic accident that means the end of Germany as we know it – yet that is what people fear.

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



As shown above, closure of another nuclear plant in 2015 resulted in increased emissions in 2016 (the first full year

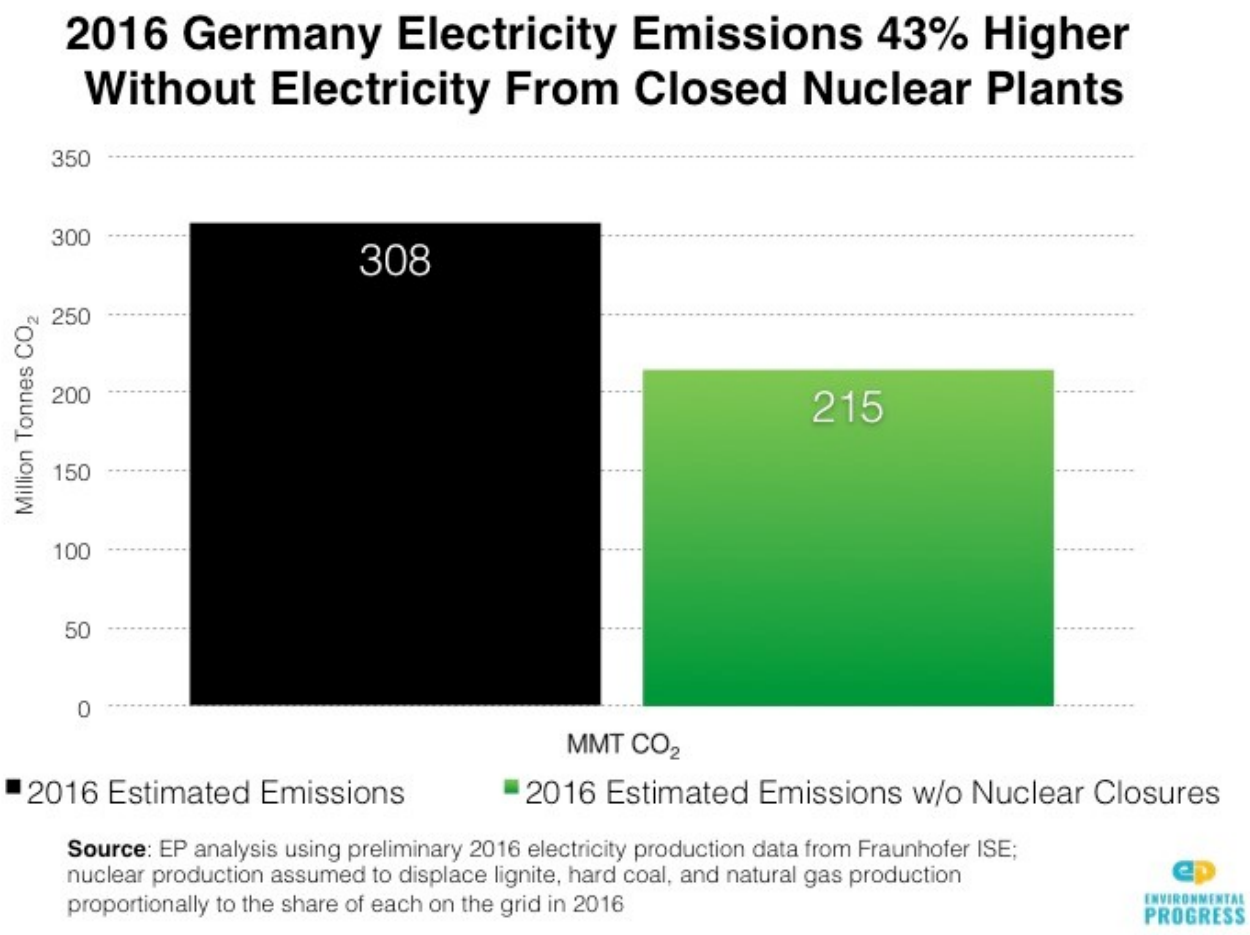
it was out of service) even though there was a substantial substitution of gas to replace coal.

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

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

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

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



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

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

So, we can all continue to hold our beliefs very dearly and only listen to those that support them, while vilifying those that do not. However, please keep in mind that in a world where the farcical becomes reality, results still matter. And

for now, the results are clear, taking nuclear power out of the mix in Germany is not achieving its political-planners' goals. Yet these results are also not likely to change any German minds when it comes to nuclear power. But hey, why worry about the outcome when you know you are right or as said by comedian Chico Marx in the famous Marx brothers movie Duck Soup "Who you gonna believe – me or your own eyes?"?

Want to minimize radiation from power generation – build more nuclear

Yes, you read that right. For years, there have been efforts to demonstrate that people who live near nuclear plants or work at nuclear plants are getting sick from all that darn radiation they are receiving. Over the years these stories have been debunked as study after study has shown that there is no impact from radiation from living near or working at a nuclear plant.

But now a study has been done that shows that of most of the options to generate electricity, nuclear actually releases the least amount of radiation. This is documented in UNSCEAR's, the United Nations Scientific Committee on the Effects of Atomic Radiation, most recent report to the United Nations General Assembly, on its study to consider the amount of radiation released from the life cycle of different types of electricity generation.

The Committee conducted the comparative study by investigating sources of exposure related to radiation discharges from electricity-generating technologies based on nuclear power;

the combustion of coal, natural gas, oil and biofuels; and geothermal, wind and solar power. The results may surprise some, especially those that strongly believe that nuclear pollutes the earth with radiation, coal with a range of air pollutants and carbon, and that solar and wind are environmentally wonderful.

Coal generation resulted in the highest collective doses to the public, both in total and per unit energy. Coal radiation emissions result from coal mining, combustion of coal at power plants and coal ash deposits. The study also considered occupational doses to workers. Here is the biggest surprise. As stated "*With regard to the construction phase of the electricity-generating technologies, by far the largest collective dose to workers per unit of electricity generated was found in the solar power cycle, followed by the wind power cycle. The reason for this is that these technologies require large amounts of rare earth metals, and the mining of low-grade ore exposes workers to natural radionuclides during mining*." It is important to note that in all cases these levels of exposure are relatively low and have little impact to public health.

This study only addresses normal discharges during the lifecycle of the station. Possible larger releases as a result of nuclear accidents are not considered and we recognize that many will argue it is accidents and their consequences that create the largest fear of nuclear power.

So why talk about this? The reality is that this information is not likely to change even one single mind on whether someone supports nuclear power or fears it. We live in a world where facts no longer matter – the only truth is the one that any one person believes. Well, we believe that scientific study remains the best way forward to establish truth and that studies such as these are part of the path forward. No one electricity generation technology is perfect. Coal is cost effective and technically strong, but is also a strong emitter of a range of pollutants (including radiation); renewables such as solar and wind are clean but their resource is intermittent and they have issues with both their front end (mining of rare earths) and disposal at the end of their life cycle.

Nuclear power continues to have a good story to tell, with respect to its economics, reliability, environmental attributes and the many good jobs it creates for local economies. Concerns about nuclear relate mostly to one major issue – fear of radiation. And fear is a strong emotion that is not easily changed. But at least what we have here is another study to show that radiation emissions from normal operations of the nuclear fuel cycle is not something to fear – and in fact if you really want to minimize the collective dose to the public, nuclear power remains the option of choice.

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.

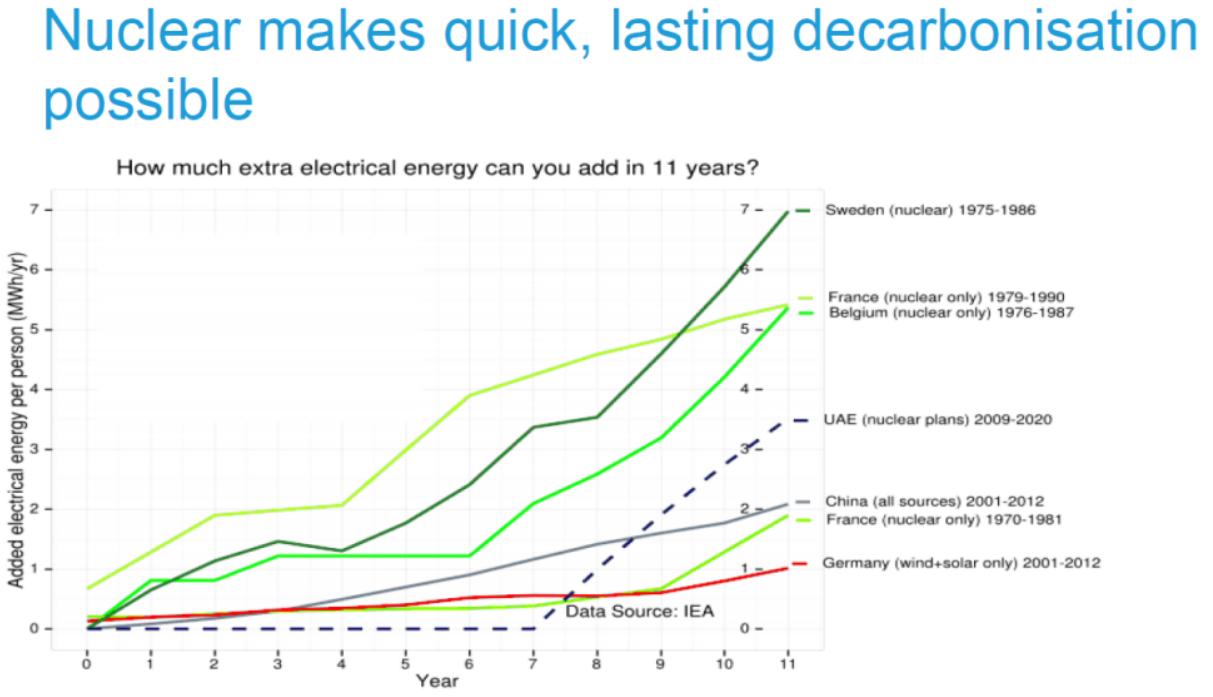
As stated by Malcolm Grimston at the World Nuclear Association (WNA) Annual Symposium last month in his brilliant talk "***Sclerosis at the heart of energy policy***" (in advance of a book he has coming out), we have become so accustomed to reliable and cost effective electricity supply that we can no 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.

As a solution for climate change – nuclear power is falling behind

Recently, the 2014 edition of the International Energy Agency’s (IEA) Energy Technology Perspectives (ETP) was issued. The ETP is issued on a two year cycle; the current

edition takes the World Energy Outlook 2013 forecasts and looks to the longer term out to 2050. With climate change now becoming even more pressing I thought it would be interesting to see the progress over the last two years (I wrote about the 2012 edition back in June of that year). According to the report, as an important contributor to meeting climate requirements going forward, nuclear power is falling behind.

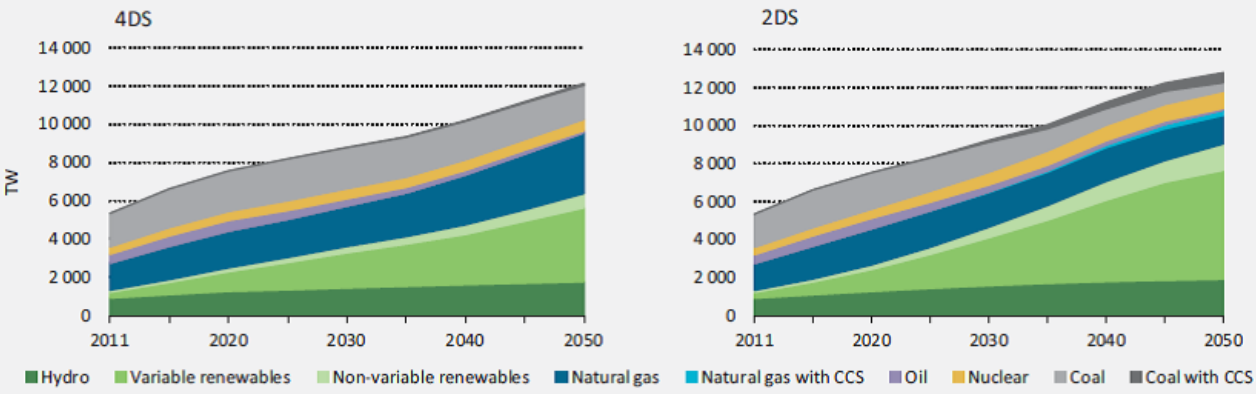
On the positive side, the IEA sees the opportunity by which "*policy and technology together become driving forces – rather than reactionary tools – in transforming the energy sector over the next 40 years.*" The report looks to balance energy security, costs and energy-related environmental impacts. But in the end it concludes that "*Radical action is needed to actively transform energy supply and end use*. "

Why is radical action required? Of all the technologies required to meet the 2D target (this scenario sets a target of only 2 degrees C change as compared to 6 degrees in the status quo scenario), the IEA suggests that only renewables are on track while pretty much every other clean technology is not moving fast enough. Two important technologies not meeting targets are Carbon Capture and Storage (CCS) and Nuclear Power. To no one's surprise, CCS has yet to be proven and become a viable commercial option to de-carbonize fossil fuel emissions. As for nuclear power; after the Fukushima accident, growth has been slower than previously predicted and is expected to be 5 to 25% below the level required by the 2D scenario in 2025.

This leaves much of the burden on renewables to meet the need for lower carbon emissions. Surprisingly, in the hi-renewables scenario, solar becomes the dominant source of electricity reaching 40% penetration by 2050. Realistic or pipe dream? I don't know. One thing is certain, (see chart below), with almost half of future electricity generation coming from variable renewables, compared to almost nothing today, the IEA is demonstrating the need for a huge technology transformation

in how the world generates electricity.

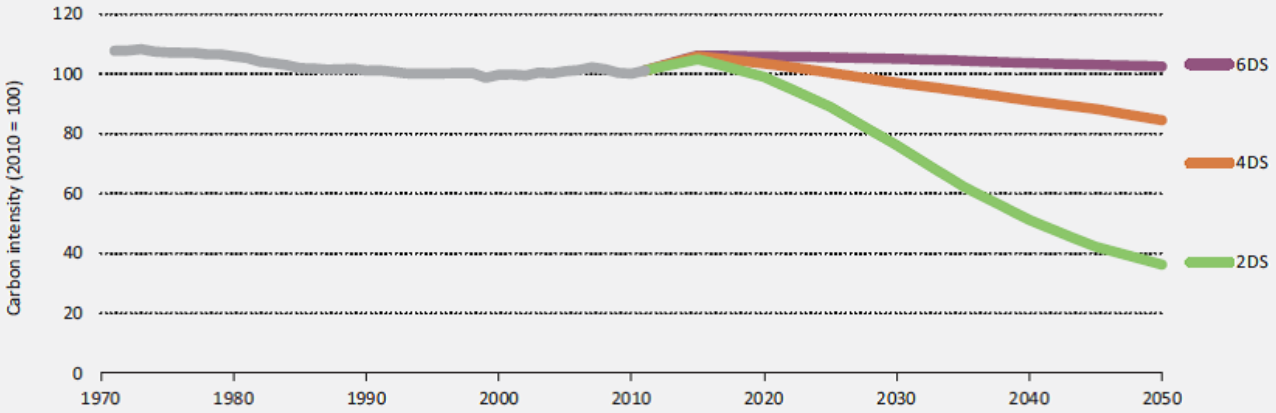
Figure 3.4 Global electricity generation capacity by technology



Note: TW = terawatts.

The following chart is the most telling of all. Over the past 40 years carbon intensity (the amount of carbon emitted per unit of energy supplied) has barely budged. Almost no change at all. Yet now we require the carbon intensity to be cut in half in the next 35 years (meaning less than half as much carbon produced per unit of energy supplied). This requires a complete change in how energy is delivered.

Figure 1.1 The Energy Sector Carbon Intensity Index (ESCII)



Notes: the ESCII illustrates the aggregate impact of technology shifts on carbon emissions in the energy sector. It measures how many tonnes of CO_2 are emitted for each unit of energy supplied. Under the ESCII, 100 represents CO_2 intensity in 2010, providing a base to measure progress. Unless otherwise indicated, all tables and figures in this chapter derive from International Energy Agency (IEA) data and analysis.

Key point *The carbon intensity of the global energy supply improved only slightly over the last 40 years, but with growing energy demand, annual emissions have increased by more than 17 gigatonnes (Gt) of CO_2 per year.*

The reason is simple. Fossil fuels still represent 80% of global electricity generation and most of the energy used for transport. To disrupt the curve requires going off fossil fuels to cleaner alternatives. To achieve the 2D scenario, electrification is paramount given the option of generating electricity with clean alternatives. Fossil fuel use must then be cut in half to about 40% of electricity generation and much of the remainder makes use of CCS to reduce its carbon footprint. The report notes that gas must only be a bridging technology to support renewables in the short to medium term as gas still represents a major carbon source. So what's left? Solar and wind to replace fossil fuels and CCS to make them cleaner.

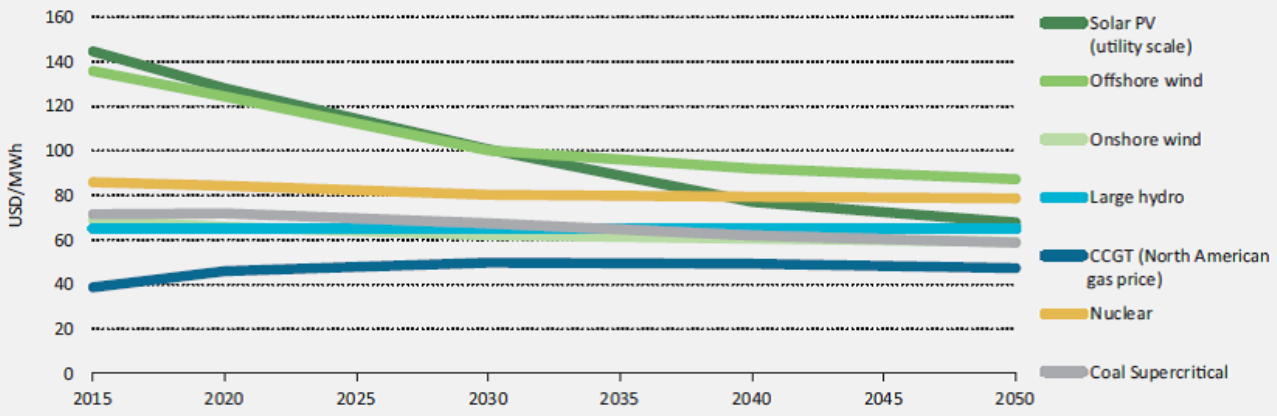
Of course nuclear power is an obvious candidate to make a larger contribution. It is a mature technology and already is an important source of low carbon energy. Given its energy intensity it is certainly feasible to implement more nuclear power on a very large scale. And even with recent set-backs, there are now clear signs of renewal as the industry puts the Fukushima accident behind it.

For example, China continues to expand nuclear power at an ever increasing pace. Japan has reconfirmed its commitment to nuclear although restarts are slower than anticipated and the ultimate level of nuclear in post-Fukushima Japan remains unknown. Russia is increasing its commitment to nuclear and, of most interest, is becoming a major exporter offering innovative risk and financing structures that have not been seen in the market to date. Other markets are also starting to move; the latest being Hungary which has just approved a new plant for the PAKS site. However some other important nuclear markets are having challenges. Korea has cut back its long term plans and France is looking to limit the contribution of nuclear power in the future.

While nuclear power has challenges with public acceptance, this report notes the commercial issues – economics and

implementation risk. As can be seen in the following chart, the IEA estimates nuclear to be the most expensive option after off-shore wind. I have not had time to delve into the details and review the numbers. However, taking this at face value, we know that some projects in the west are not doing as well as they should be. On the other hand, standardized series-build in countries like China and Russia are demonstrating a strong path to lower project costs and risks.

Figure 8.1 *ETP's LCOE excluding a carbon price*



Notes: unless otherwise noted, material in all figures and graphs in this chapter derive from IEA data and analysis. PV = photovoltaic. CCGT = combined-cycle gas turbine. MWh = megawatt hour. Figures and data that appear in this report can be downloaded from www.iea.org/etp2014.

Key point *Based on LCOE, low-carbon technologies remain more expensive than generation from fossil fuels over the transition period to the 2DS.*

There is no hi-nuclear scenario in this edition of the report. That is quite unfortunate as a strong renewed commitment to nuclear power is a very good way to help move this plan to achieve a 2D future become a reality. By stating that nuclear power is not meeting expectations, the report lays out a clear challenge. Now it's time to show the nuclear industry is up to it. If we really want to bend the carbon intensity curve, then more than ever, the world needs more nuclear power as an important part of a low carbon future.