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.

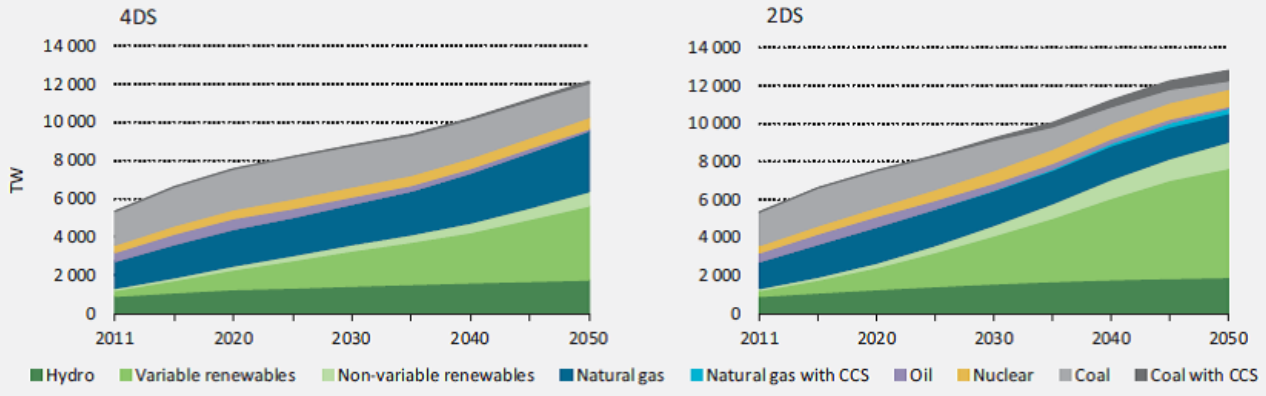
On the positive side, the IEA sees the opportunity by which "*policy and technology together become driving forces – rather than reactionary tools – in transforming the energy sector over the next 40 years.*" The report looks to balance energy security, costs and energy-related environmental impacts. 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.

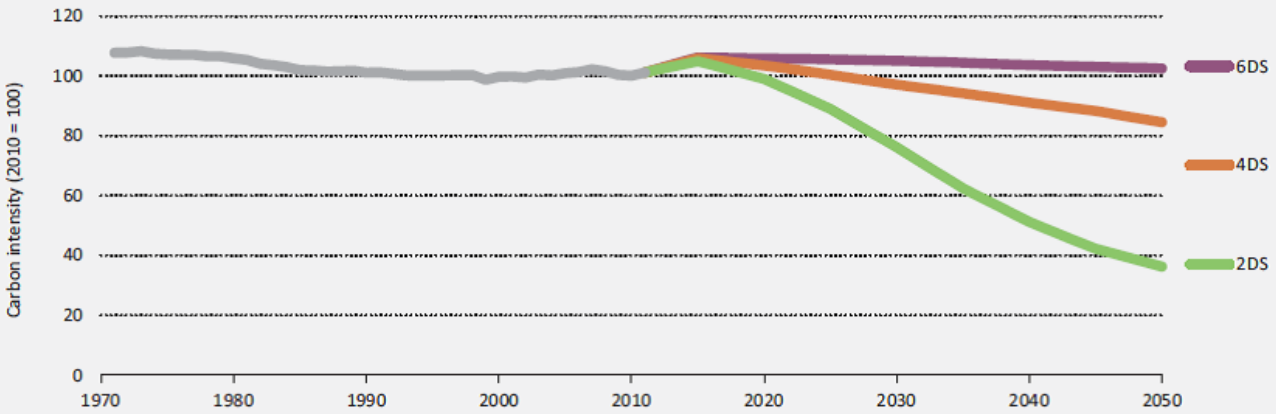
Figure 3.4 Global electricity generation capacity by technology



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.*

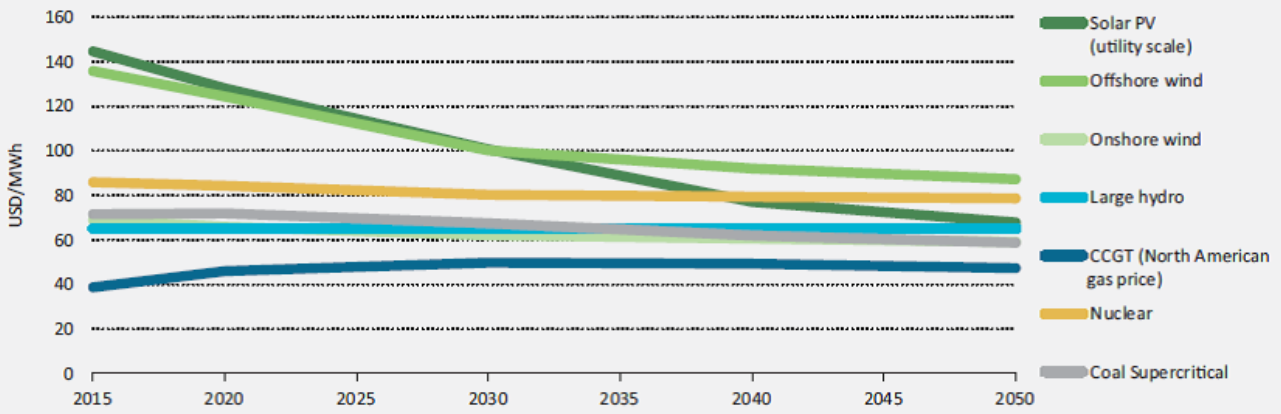
The reason is simple. Fossil fuels still represent 80% of global electricity generation and most of the energy used for transport. To disrupt the curve requires going off fossil fuels to cleaner alternatives. To achieve the 2D scenario, electrification is paramount given the option of generating electricity 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.

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.**

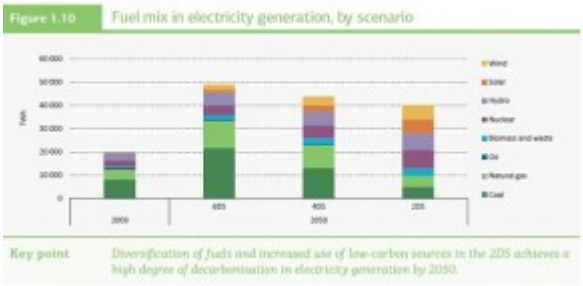
        - **Energy security and climate change mitigation are allies.**
    - **Despite technology's potential, progress in clean energy is too slow**
        - **Nine out of ten technologies that hold potential for energy and CO2 emissions savings are failing to meet the deployment objectives needed to achieve 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).

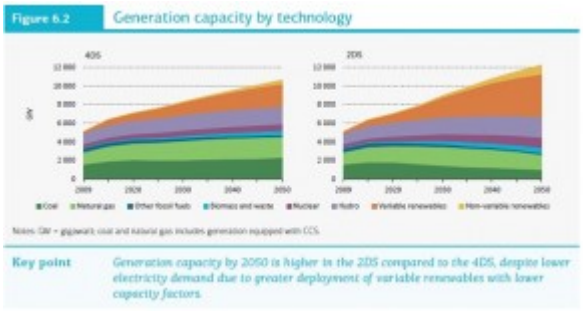
When considering "technologies" the focus is on renewable technologies such as wind and solar, energy efficiency technologies to reduce demand and carbon capture technologies to clean up the ever-expanding fossil infrastructure. Nuclear is also shown to be important although it role is somewhat less 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

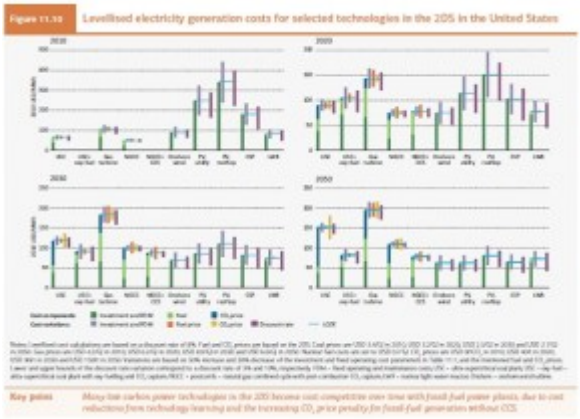
in the 2 DS. It can be seen that there is huge growth in renewable generation (wind, solar, hydro and biomass) and an increase in nuclear capacity. Most of the remaining fossil generation is assumed to have CCS installed.



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.

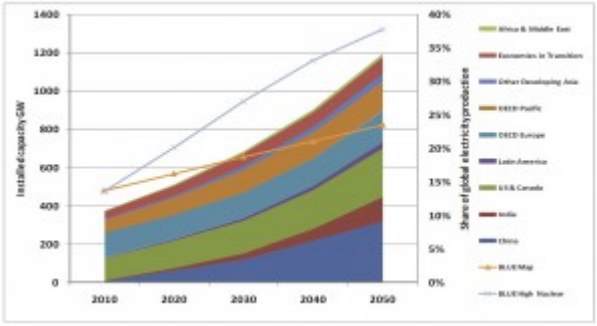
In the end, our world will become more electrified and we need to move forward with a cleaner, sustainable electricity system for our future. So what is harder for the public to accept – very high carbon costs and a very large increase in variable renewable generation or a bigger role from a relatively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

What a difference a year

makes! With New Build taking hold in the west in 2012 now is the time to sell the benefits of nuclear power to overcome the Fukushima effect.

The good news is that as 2011 comes to a close, Fukushima has achieved cold shutdown and the recovery is moving to the next stage. The emphasis is now on decontamination and getting the dislocated people back into their homes as soon as possible. Does this mean that nuclear will overcome the effects of Fukushima starting in 2012?

It was only a year ago that the International Energy Agency ("IEA") issued its Nuclear Roadmap 2010. This report clearly demonstrates the important role that nuclear power can play in meeting climate change targets. With a 50% CO_2 reduction targeted by 2050 in the so-called IEA Blue Map scenario, nuclear capacity triples and its share of electricity generation rises from 14% today to 24%, the largest of any generation technology. Under a postulated High Nuclear scenario, the nuclear share would reach as much as 38%!



IEA Nuclear Roadmap 2010 share of nuclear

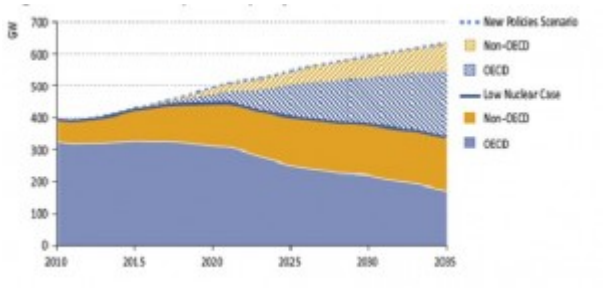
But that was then and this is now. On March 11, as we all know, a devastating earthquake and tsunami struck Japan with horrific consequences – killing more than 20,000 and causing a nuclear accident at the Fukushima Daiichi Nuclear Plant.

There was significant fuel melting in three units resulting in radioactive releases to the environment. Even though there have been no fatalities due to radiation and there is little risk of any future radiation health impacts, the global impact of this event to the nuclear industry was overwhelming. While many countries re-confirmed their commitment to nuclear power after reviewing plant safety and implementing lessons learned, some countries in Europe led by Germany have taken the decision to scale back or even move away from nuclear power.

In the IEA's World Energy Outlook 2011 released in early November they added a new scenario – Low Nuclear – to account for a possible post-Fukushima shift away from nuclear power in addition to the New Policies (reference) and Current Policies scenarios. In the reference case, global nuclear power is expected to rise 70% by 2035 with China, Korea and India leading the growth. This case is only slightly less than the projection last year. In the new Low Nuclear Case, the total amount of nuclear capacity actually falls from 393 GW at the end of 2010 to 335 GW in 2035. According to the IEA, this scenario has severe implications for energy security, diversity of the fuel mix, spending on energy imports and energy-related CO2 emissions.

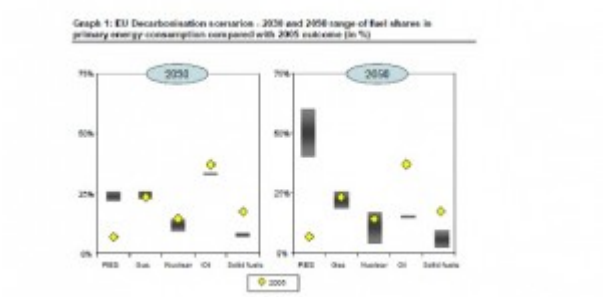
In this low nuclear scenario, by 2035, coal demand increases to over twice the level of Australia's current steam coal exports. The increase in gas demand is equal to two-thirds of Russia's natural gas exports in 2010. The increase in renewables-based generation is equal to almost five-times the current generation from renewables in Germany. Energy-related CO2 emissions also rise with increased use of fossil fuels in the power sector. This clearly has significant implications for global energy supply making it extraordinarily difficult

to meet carbon targets. As stated in the IEA's WEO report "*Following this trajectory would depend on heroic achievements in the deployment of emerging low-carbon technologies, which have yet to be proven. Countries that rely heavily on nuclear power would find it particularly challenging and significantly more costly to meet their targeted levels of emissions*."



WEO New Policies (Reference) and Low Nuclear Scenarios nuclear capacities

And now, Europe has issued its Energy Roadmap 2050 with the overall emphasis on renewables and energy efficiency; a policy document that has been clearly impacted by the post Fukushima shift in thinking in Europe. As illustrated in the chart below, even with five different scenarios, the one thing they all have in common is a large increase in renewable energy generation. No other form of generation increases anywhere near to that of renewables; and in fact most other forms decline over the plan period with only the size of the decline depending upon the specific scenario. But even with this emphasis on renewables, the report does make important positive points on the role of nuclear power noting that nuclear energy is an important contributor to meeting the roadmap objectives.



In fact the report notes that today nuclear energy is the decarbonisation option providing most of the low-carbon electricity consumed in the EU. It then goes on to note the post Fukushima reality. "*Some Member States consider the risks related to nuclear energy as unacceptable. Since the accident in Fukushima, public policy on nuclear energy has changed in some Member States while others continue to see nuclear energy as a secure, reliable and affordable source of low-carbon electricity generation*."

When it comes to cost, the impact is clear. Consistent with the IEA Nuclear Roadmap, this report states "*the scenario analysis shows that nuclear energy contributes to lower system costs and electricity prices. As a large scale low-carbon option, nuclear energy will remain in the EU power generation mix.*"

This is critical since the average capital costs of the energy system will increase significantly due to investments in power plants and grids, industrial energy equipment, heating and cooling systems, smart meters, insulation material, more efficient and low carbon vehicles, devices for exploiting local renewable energy sources (solar heat and photovoltaic), durable energy consuming goods etc. And the reality is that renewables are expensive with the highest electricity costs in the "near 100% RES power" scenario which the RES power generation capacity in 2050 would be more than twice as high as today's total power generation capacity from all sources (I am assuming primarily due to the low capacity factors of renewable generation). Other scenarios such as the High Energy Efficiency scenario and the Diversified Supply Technology scenario have the lowest electricity prices due to somewhat lower renewable penetration (60 to 65%) taking advantage of the lower costs of efficiency, gas and nuclear. The report notes that many renewable technologies need further development to bring down costs.

So as we enter 2012, where does this leave us? One lesson

from Fukushima is that many in the world are still very afraid of nuclear power because of the huge fear of radiation. There was an interesting piece on this in a CNN Health article this past week which argues that public trust in nuclear energy should be built on the existing acceptance of medical radiation dose levels. The public welcome moderate medical radiation levels from both internal and external sources, for medical imaging (CT, PET, SPECT scans) yet fear the much smaller levels from nuclear plants. And as I stated in my last blog entry, as an industry our work is cut out for us in changing this thinking. Reducing the public fear of radiation is no small task and will take time and a carefully coordinated approach from us all. Professor Wade Allison argues that the ALARA principle has hurt us and increases this fear of radiation and suggests that this policy should be replaced with "As High As Relatively Safe (AHARS)", mindful of other dangers, local and global. An interesting approach indeed.

One thing is clear from the above IEA studies and the European Roadmap 2050. Reading between the lines nuclear power is essential to meeting long term carbon reduction goals. Relying too much on renewables is far too risky an approach and is more of a wishful thinking scenario than a realistic one. To achieve global carbon reduction objectives, it makes no sense to not take advantage of the one true large scale low carbon technology – nuclear power. It is here today – it is safe and in most jurisdictions it is economic.

So what about 2012? So far it looks like it can be a good year for nuclear power. Important progress in new build is being made in the UK; the US will see its first COLs enabling the first new builds to start construction in a generation; Canada may make a decision on its new build; and, of course China and others in Asia will continue to expand their programs.

Work in Japan will continue and will not be easy as the

government works to decontaminate the area around Fukushima and hopefully many will get to return to their homes. Of importance we can expect to see many of the idled plants in Japan get approvals to restart easing the electricity shortage caused by these units not running. Again a recent Japanese study shows that nuclear remains the low cost option to 2030.

But of most importance, this is not time for industry complacency. This has to be the year where the industry marshals its forces to get the message out – in a thoughtful, clear, unambiguous way. The future is up to us so let's get on with it and tell our story. Even though truth may be on our side, the path is going to be long and the work hard……..but in the end it is worth it for us all……

We offer a proven large scale clean, economic and, of utmost importance, safe option for electricity generation. As the only proven large scale low carbon option that can meet the world's energy needs, nuclear power must continue to be an important part of the electricity generation mix now and into the future.