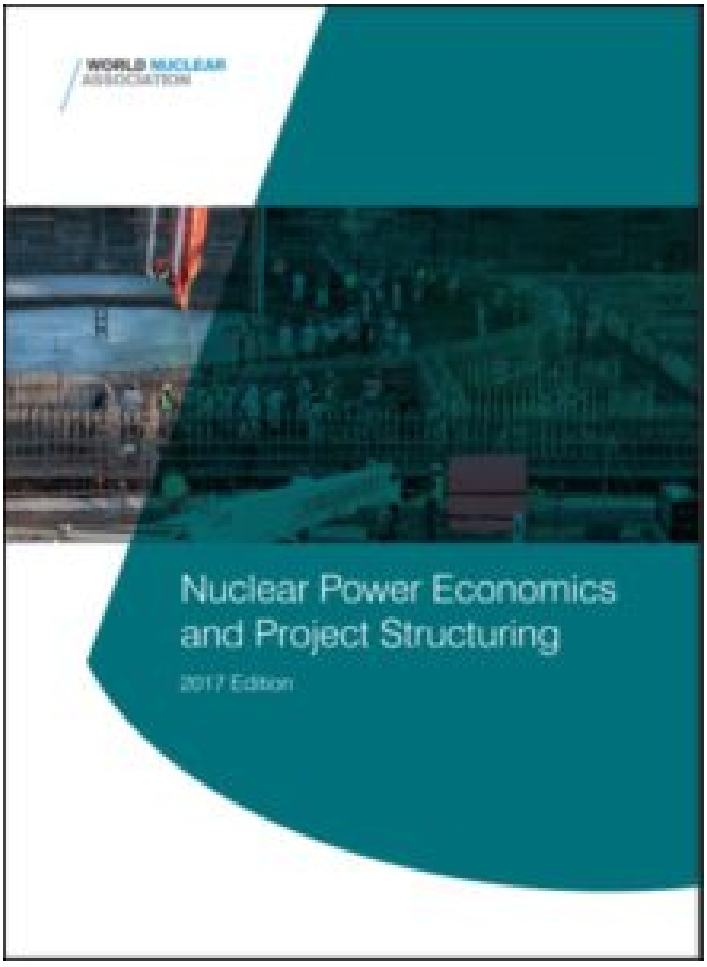
Nuclear Power Economics

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.

Reliability means being connected – we need a strong integrated electricity system with nuclear generation as its workhorse

It was with great fanfare that Tesla launched its home battery recently. Headlines like "*Tesla launches Powerwall home battery with aim to revolutionize energy consumption*" were the norm as the public read about this revolutionary jump forward in energy storage. A recent article on where famed author Margaret Atwood is investing says it all …. "*if [Tesla CEO] Elon Musk was putting his Powerwall on the market, I would certainly buy a piece of that. My feeling is that, once that becomes affordable, everyone is going to do that. I think that's definitely the wave of the future*."

After all, this is the dream isn't it? We can all generate our own electricity with clean energy efficient solar panels and store enough on our home batteries to keep us going when the sun goes down. What can be better for our common future?

Well, in fact, just about everything.

It must be my age and my years in the energy industry that remind me of what are the real essential attributes of electricity supply. **Reliability and Economics**. Yes, that's right. For anyone who works in a modern electricity utility,

that is what they focus on; delivering cost effective reliable electricity to users. And in today's energy intensive world where we need electricity for every aspect of our hyper active and energy intensive lives, this is even more critical. We have all experienced temporary blackouts and know well the negative impact it has. The problem then with renewable energy generated at home is that, at least for now, it is neither reliable nor economic. Since the announcement from Tesla there have been a number of articles that explain this in detail, but of course supporters will just say that in time all problems will be solved. And frankly they may be right.

" Will I be able to have a night light if we switch to *solar power ?*

So let's step back and ask ourselves a more important question – are we trying to solve the right problem? Most people have no idea what it takes to generate and deliver the electricity (the so-called "grid") we take for granted in the modern world. In fact, many just think electricity is something that comes out of the wall outlet. What we all want is that when we turn on the switch, or plug in our phones, it just works. We are not in any way prepared for a world in which we say – oh,

it’s cloudy so we better not charge our iPhone today! I love the recent TV ads where BMW is explaining how they build their new I3 electric car in wind powered factories. Yet, do any of us really think that on days when it is not windy, these factories sit idle? No, of course not.

In most advanced economies around the globe we have achieved a high level of reliability in electricity supply. In fact this is one of the measures that makes an economy ‘advanced’. **The problem is that much of our electricity is generated with fossil fuels; primarily coal.** (Coal continues to be the largest source of Germany’s electricity where BMW has its factories, at nearly 50% of total supply). And along with this comes both pollution and a high level of carbon emissions. Therefore, the only way to address these environmental issues is to reduce the use of fossil fuels, not to eliminate an integrated grid.

Just like being connected to the internet improves our lives, so does being connected to a reliable electricity grid. Do we really want to live a life where if it is cloudy for a few days and our batteries run dry we do without? Of course not. Just imagine how much excess battery capacity we would each need to avoid this possibility. Even Elon Musk notes that his battery is currently for emergency backup – not for daily use – and yes it would be great to have some amount of reasonably economic backup for when we experience an outage. But as is starting to be seen in California where there are numerous discussions of the “duck curve”, people want it all – they want to generate their own electricity when they can believing this is the best approach, but they also want the system to be there just in case they need it; and at a moment’s notice. The result – higher costs all around. The less the grid system is used, the more it costs to keep the infrastructure in place to make up the shortfall when needed.

The answer is simple, let’s take what works and make it even better. That is a large interconnected grid that includes

large scale reliable economic generation based on nuclear power, and hydro where available, supplemented by wind and solar depending upon the local availability of these resources. To be reliable and cost effective, a system needs generation that can run all the time, not just when the wind is blowing or the sun is shining. As storage technology improves, it can then contribute to both help manage the intermittency of renewable generation as well as flattening the demand curve to enable an even larger share of nuclear generation.

Remember, our economy, and in fact our very way of life, is completely dependent upon the availability of reliable, clean and economic electricity. So while we may dream of not needing the grid as we each generate our own electricity, what we really need is a strong well interconnected grid made up of reliable economic nuclear power as its work horse, with wind, solar and other forms of generation contributing when they can; all coupled with new forms of large scale storage to both even out demand and supply. Now this is more likely to be the system of the future.

When it comes to our need for electricity, reliability is essential.

As we come to the end of another year, it is not a nuclear issue that I want to discuss but rather the broader issue of our need for reliable electricity. Last month I started with a quote from the IEA's World Energy Outlook 2013 highlighting how important energy has become to our society – affecting the

economics of nations and our environment as well as our daily way of life.

Over this holiday season in North America the importance of electricity to our very survival has become more evident. On the Friday before Christmas the northeast United States and Canada were hit with a massive ice storm. Hundreds of thousands of people lost power. The cause was primarily due to power lines being affected both directly by intense icing as well as by debris from trees and other items that fell onto the lines as they became heavy with ice causing the lines to fall.

And here we are days after Christmas and while most households have had their power restored (many after more than 5 days without), thousands continue to wait. This is different from other extreme weather events such as hurricanes that have been responsible for mass destruction of homes and infrastructure. This ice storm, while also an extreme weather event, has only caused power loss as its lasting effect. The result is we are

able to specifically see the importance of electricity to our modern societies.

So what is the impact of a prolonged loss of electricity? Frankly it is very difficult for those without – especially for those most vulnerable – the elderly, the sick and those without friends or family nearby to take them in.

Living a large city in a cold climate, just imagine your home without heat in subfreezing weather, no power for the refrigerator or freezer (although outdoors can work), no water to flush the toilet or bathe or even more importantly drink; and you have the makings of a catastrophe – people freezing and hungry without the basics required for survival. And to make matters worse it is over the holiday season when most had plans to be with family. In some cases large family holiday meals were no longer possible as the emphasis was on finding ways to stay warm. The added downside of the season is that on Christmas almost everything is closed, no supermarkets, very few restaurants; no services of any type.

On the positive side, the number of people without power is now in the minority so there are many options for them to seek help and get warm. But others continue to struggle. The news has recently reported on police and fire departments having to visit large apartment buildings and take elderly sick residents down numerous flights of stairs to safety. These people have been stuck in their cold apartments for days without food or water. With no one to check on them, their lives were at risk.

As stated earlier, the cause of this mayhem is related to the transmission and distribution system failing in the weather, not generation. But the point to be made is that without electricity in our cities; it would only take days until the population would need to find ways to feed and warm themselves on mass.

So it is pretty obvious that we need to have reliable electricity supply to keep society working. And reliable supply means robust generation and distribution. Our aging infrastructure can no longer be left to decay further so that with every extreme weather event, we take days or weeks to recover. After the major blackout in the North American northeast a decade ago, the focus was on ensuring system reliability. The rules changed and all North American utilities now adhere to these rules, making our system better. But here we are a decade later and the issue has changed. It is no longer about reliability in general, but the ability to withstand extreme weather events. And most of all our ability to recover when the system is damaged during such events.

And of course we have the issues associated with individuals that oppose what is necessary to keep our system running. For example, power lines have fallen when tree branches have damaged them. While simple measures like pruning may be the cost-effective way to protect power lines, it can carry a public-relations price. As stated by the CEO of Toronto Hydro "You can imagine … our arborists show up on the curb and knock on the door and say 'We're here to cut your branches down.' They're not necessarily a welcome news," he said. "So it's really finding that right balance." This shows that no matter what the issue, there are always those opposed (as with those opposed to nuclear power); but these are also usually the first to complain when they lose power and need their lines restored.

So while this is not directly about generation or nuclear power, it is important to remind ourselves of the importance of reliable supply as we continue the debate on how we want to generate our electricity going forward. Robust, reliable baseload electricity is important. And this is where nuclear power plays a very important role. We also talk about economics and environment. Both essential – so how can we

meet the challenge of having reliable, economic and environmentally benign electricity?

As we prepare to enter a new year, let's remember that fossil fuels like coal and gas are reliable, can be economic, but impact our environment. Renewable sources like wind and solar are good for the environment but can be costly and unreliable. Nuclear Power is an important source of electricity that can provide large amounts of clean, reliable and economic electricity to keep our society moving.

I hope that all power is restored to those without as soon as possible so they can enjoy what is left of the holiday season.

Wishing you all a very happy and healthy 2014

Meeting the energy needs of the 21st century – is it time for a real nuclear renaissance?

As I started to read this year's World Energy Outlook (WEO 2013) from the International Energy Agency (IEA), it was the very first line in the executive summary that caught my interest. The report starts out with "**Many of the long-held tenets of the energy sector are being rewritten.**"

It then goes on to explain: "*Major importers are becoming exporters, while countries long-defined as major energy exporters are also becoming leading centres of global demand growth. The right combination of policies and technologies is*

proving that the links between economic growth, energy demand and energy-related CO2 emissions can be weakened. The rise of unconventional oil and gas and of renewables is transforming our understanding of the distribution of the world's energy resources. Awareness of the dynamics underpinning energy markets is essential for decision makers attempting to reconcile economic, energy and environmental objectives. Those that anticipate global energy developments successfully can derive an advantage, while those that fail to do so risk making poor policy and investment decisions."

What is clear is that energy is important! Most of all there is change in the air – ignore it at your peril. And with change comes opportunity. This is where I want to focus my discussion this month. But before I go on, I think it is useful to summarize the key points from the report to further clarify the paragraph above. The WEO 2013 is concluding the following:

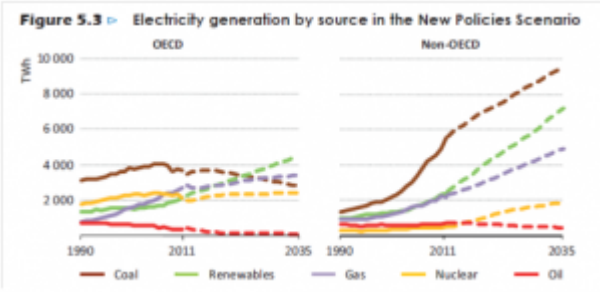
- The centre of gravity of energy demand is switching decisively to the emerging economies, particularly China, India and the Middle East, which drive global energy use one-third higher.
- As the source of two-thirds of global greenhouse-gas emissions, the energy sector will be pivotal in determining whether or not climate change goals are achieved.
- Large differences in regional energy prices have started a debate about the role of energy in unleashing or frustrating economic growth.
- Energy price variations are set to affect industrial competitiveness, influencing investment decisions and company strategies.
- Countries can reduce the impact of high prices by promoting more efficient, competitive and interconnected energy markets.
- A renewed focus on energy efficiency is taking hold and

is set to deliver benefits that extend well beyond improvements in competitiveness.

- Enhancing energy competitiveness does not mean diminishing efforts to tackle climate change. Renewables account for nearly half of the increase in global power generation to 2035, with variable sources – wind and solar photovoltaics – making up 45% of the expansion in renewables.
- Coal remains a cheaper option than gas for generating electricity in many regions, but policy interventions to improve efficiency, curtail local air pollution and mitigate climate change will be critical in determining its longer-term prospects.
- Market conditions vary strikingly in different regions of the world, but the flexibility and environmental benefits of natural gas compared with other fossil fuels put it in a position to prosper over the longer term.

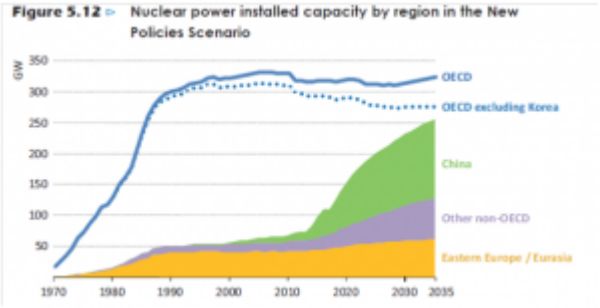
So there you have it. The fastest growing economies have the fastest growing demand, high energy prices are slowing growth in some markets and giving an economic advantage to others with lower prices; and climate change is having an impact on energy decisions.

The above makes it sound as if the path to a low carbon future is built on more renewables and gas. But is it really? Looking at the following chart we can see that in the OECD countries where demand growth is modest and electricity supply is already robust, gas is the go-to fuel both due to cost and as a cleaner alternative to coal; and renewables are the supposed clean generation of the future. Not surprisingly in the non-OECD countries where demand is growing much more quickly (read mostly China!), they are doing everything they can to develop all kinds of supply – including more coal, more gas, more renewables and yes, more nuclear.



So what does this mean for nuclear power? According to the IEA, "*Nuclear power generation increases by two-thirds in the New Policies Scenario, reaching 4,300 terawatt-hours (TWh) in 2035. Demand is driven heavily by expansion in just a few countries: China accounts for around half of the global increase; Korea experiences the next largest increase over the projection period (the only OECD country to see appreciable growth), followed by India and Russia. Overall, non-OECD economies see their share of global demand for nuclear power jump from less than 20% to nearly 45% in 2035. While prospects for nuclear power at the global level are now less uncertain than they were two years ago, there are still key issues that remain unclear. These include the possibility of further changes in government policy, implications of the ongoing safety upgrades for plant economics and public confidence, and the impact of increased competition from shale gas*."

It should not be a surprise that those countries with the largest demand growth see a large benefit from increasing the use of nuclear power. They need clean reliable baseload and nuclear meets this need. In the more advanced OECD countries, many of these already have significant nuclear fleets (80% of current nuclear capacity is in OECD countries), have lower baseload growth and can (or at least they think they can) look at other alternatives. Gas is replacing coal as a cleaner fossil option so long as it remains competitive and the challenges of new nuclear coupled with low demand growth put it more on the back burner.



But is this the right path? As I said last year when I reported on the WEO 2012, it is important to remember the WEO is not a forecast per se; rather it is a projection of how existing and potential government policies would look once implemented. And what we still see one year later 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. Of more importance, the WEO shows a path to meet climate change goals that is based on efficiency to lower demand, movement from coal to gas and CCS technology to clean up some of the coal and then more renewables.

What goes unsaid is how this is fantasy. Not that the world will continue down the path of burning fossil fuels for our electricity, but rather that we can do so and meet climate goals. The 2013 WEO New Policy scenario "*leaves the world on a trajectory consistent with a long term average temperature increase of 3.6C, far above the internationally agreed 2C target*". In their 450 scenario where the target is 2 degrees, there is more renewables, more conservation, more technology to clean fossil fuels and yes, a little more nuclear.

Given the need to decarbonize the electricity sector and the limits to using wind and solar (about half the renewable additions), it should be obvious that nuclear be a stronger option. Yes, currently in North America low gas prices are challenging its competitiveness while in Europe, green ideology has a larger impact. There is a onetime carbon improvement as coal is replaced by gas; but then gas becomes the largest carbon producer on the system – so where do we go

from there? And renewables will remain intermittent and likely costly for some time to come. Nuclear power is clean, reliable and in most cases, economic; but of most importance – abundant. Yes, in a resource constrained world, the amount of electricity we can potentially generate with nuclear power is almost limitless. So why don't we see more of it in the developed world?

The answer is that we still don't have the political will. And that comes from lack of public support. Just this week the World Bank reiterated its policy that they don't support nuclear power – even though they support all other forms of electricity generation. Continued negative press about the status of Fukushima keep the public on edge. For example this past month TEPCO started to remove the used fuel from the Unit 4 spent fuel bay. This should have been a good news story yet most stories made it seem like a horrifically dangerous undertaking (and of course it is not).

The WEO makes the case that government support is what drives nuclear. "*The rate of expansion of nuclear power continues to be mainly policy driven. It expands in markets where there is a supportive policy framework, which in some cases actively targets a larger role for nuclear in the mix in order to achieve energy security aims. But policy frameworks can also hinder or eliminate nuclear power, often as a result of public opposition: even where there is no explicit ban, long permitting processes, such as in the United States, can significantly hinder development by increasing uncertainty about project completion and increasing costs*."

I was listening to a radio interview this past week with climate change scientist Richard Peltier. [Interview starts at about 31:40 in the link]. He makes a strong case for getting the message out about scientific consensus. While he notes that between 95 and 98% of scientists agree on the science of climate change, the press reports make it seem there is much more disagreement than there really is with the

result that the public is confused. The answer is to get out and speak at the grass roots level. Governments will not strongly support policies that battle climate change until the public believes it is necessary. The same is true for nuclear power. Governments will not strongly support increasing its use until the public are in agreement that it is safe and necessary.

We are seeing some progress. In Pandora's Promise, five environmentalists are now convinced of the advantages of nuclear power and they are actively advocating its use. This past month four other environmentalists have released an open letter calling on world leaders to support development of safer nuclear power systems. In their letter they state, "*As climate and energy scientists concerned with global climate change, we are writing to urge you to advocate the development and deployment of safer nuclear energy systems. We appreciate your organization's concern about global warming, and your advocacy of renewable energy. But continued opposition to nuclear power threatens humanity's ability to avoid dangerous climate change*."

Some governments are also taking on the challenge. In the UK there is pretty much political unanimity that new nuclear is required to meet their climate goals. The result is strong political support for nuclear new build. A recent quote by Hergen Haye, Head of New Nuclear & Strategy, Department of Energy and Climate Change (DECC), UK government *"To replace Hinkley alone, we have to build 6000 wind turbines. Nuclear will help us to cut costs and to face the other environmental challenges. We cannot do without nuclear because renewables will not do things alone without making electricity bills rise." (*21 November 2013 in Brussels).

In France, after pandering to the greens and committing to close Fessenheim, the French government is finally saying that there will not be more closures. We see strong political support where nuclear is needed most in China, Russia and

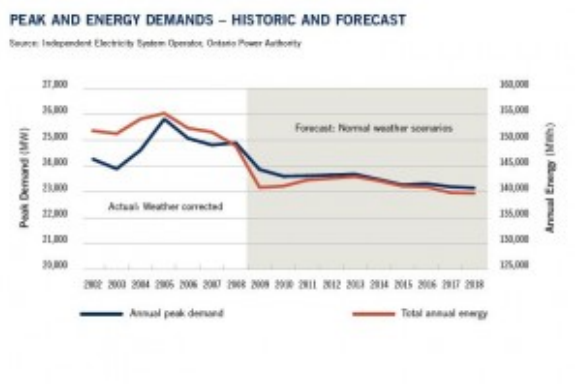
India although Korea is wrestling with their future plan due to recent scandals.

I come back to the first line of the WEO 2013, "**Many of the long-held tenets of the energy sector are being rewritten.**" This is a time of great opportunity. So let's make sure nuclear power is playing its increasingly important role by providing clean reliable generation to support economic growth and a brighter more secure future for us all.

Lower demand and more renewables – is Surplus Base Load Generation here to stay?

Late in November I blogged about a recent phenomenon being experienced in some systems – Surplus Baseload Generation (SBG). This is being experienced in Ontario, Canada due to falling electricity demand and the increased use of variable renewable energy sources such as wind and solar.

At that time, I started a poll asking about the future of baseload power. Since then, the IESO in Ontario has published its latest Reliability Outlook. The numbers are striking. Demand was down 6.4% in 2009. The following graph shows that demand is not expected to reach pre-economic crisis peaks even by 2018.



Ontario Demand Forecast

As of result the province continues to experience Surplus Baseload Generation (SBG). Forecasts of SBG are now made daily. With the growth of renewable generation SBG is expected to continue into the future. This will certainly impact any decision for building new nuclear, as nuclear plants are most suited to providing long term stable baseload power and energy.

The commitment to renewable energy continues to grow. Wind generation in Ontario rose by more than 60 per cent in 2009 over the previous year, to 2.3 TWh. Ontario has implemented the Green Energy Act, arguably making it one of the "greenest" jurisdictions in North America. Just this past week, government announced a $7 Billion deal for 2,500 MW of new renewable generation from a Korean consortium led by Samsung C&T. The deal includes the implementation of new manufacturing in the province for both wind and solar components.

While the above chart does not show baseload, with 1,000 MW of wind on the system and 11,500 MW of nuclear, this spring, Ontario started to experience SBG on a weekly basis. This resulted in nuclear unit reductions on 54 days, nuclear shutdowns on five days and water spillage at hydro facilities on 33 days. In the Reliability Outlook the projection is for 1600 MW of wind by 2013. With the Samsung deal and other FIT program renewables, we could be approaching 4,000 MW of wind and solar in the coming years while the overall demand is not

expected to increase dramatically. Therefore, the baseload requirements will be further squeezed from the bottom as renewable generation has priority to the system when available. In other words, both renewables and nuclear are “non flexible” load i.e. not readily dispatchable. Clearly SBG will be an ongoing issue.

And now, for the results of my earlier poll. Although the number of votes was somewhat modest, the trend was clear.

While the comments suggested that baseload is important, only 10% of respondents thought that renewables will have a small impact on the use of baseload. The most votes were for “Medium Impact” as it seems to be recognized that renewables are here to stay and that the nature of electric grids are going to be changed forever.

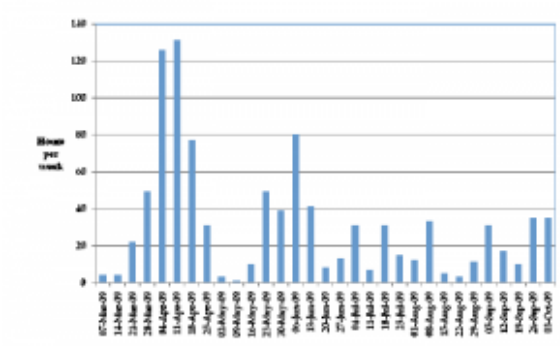
Is there a future for base load generation? Please respond to the poll?

System operators have recently seen something rather new – SBG – or “Surplus Baseload Generation”. This is due to falling demand related to the current economic situation and a newer phenomenon; the displacement of base load by variable load renewable generation.

With governments everywhere and the public strongly supporting new renewable generation, primarily wind and solar; these forms of variable generation are displacing base load by being must run when the resource is available. So the question is "Is there a future for base load generation?". Please respond to the poll at the bottom of this blog entry

This issue was addressed at last week's Association of Power Producers of Ontario (APPrO) annual conference where a session was dedicated to this new phenomenon. The following shows the amount of time Ontario experienced SBG over the past 18 months. Excess generation of well over 1,000 MW was experienced! This resulted in shutting down low marginal cost nuclear plant as well as spilling water at hydro plants. The 18-month forecast by the IESO in Ontario expects SBG to continue to be an issue going forward.

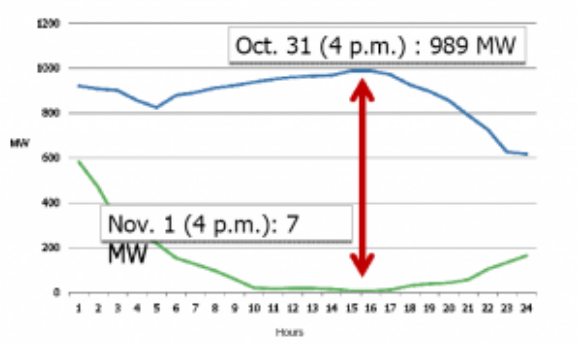
Surplus Base load Generation



IESO Presentation to APPrO
2009

The variability of the wind is shown in the following chart illustrating how two days in a row the wind at the same time varied from 989 MW to 7 MW on the following day.

Wind Capacity on Consecutive Days



IESO Presentation to APPrO 2009

So what does this all mean? In the smart systems of the future is the concept of large scale base load generation doomed? Do you have to be able to manoeuvre to survive? Or will policies change to ensure that low cost base load generation is not displaced for higher cost alternatives?

This is just the beginning of the discussion for this subject. Please answer the following simple poll. I would like to get your views. More work is needed on this issue as we plan the systems of the future.

[polldaddy poll=2259325]