CANADIAN NUCLEAR SOCIETY

Bulletin

DE LA SOCIÉTÉ NUCLÉAIRE CANADIENNE

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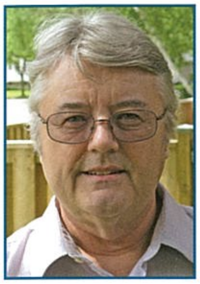
- The Case for New Nuclear
- Reducing Medical Radiation Dose
- Remedy for Radiation Fear
- Canadian Science Policy Conference

Editorial

Health, Safety, Cost and the Environment - Choosing the Best Source of Electricity



Nuclear, Hydro, Coal, Oil, Gas, Wind, Solar and Biomass - how do we choose the best options? There is a lot of discussion about the potential devastating impact of climate change due to GHG emissions, the variations in costs for technologies with low GHG emissions, the safety of workers and the public and the health effects associated with emissions. We can agree on one point - we want cheap reliable electricity that does not harm the planet or the society that occupies it.

There are those who advocate conservation and better efficiency, but let's face it - the world population is growing and developing countries want the better lifestyle enjoyed by the more developed countries. Population growth and improved lifestyle cannot be achieved without affordable and abundant energy, including electricity. Delivery of safe drinking water requires electricity, for pumping it, sanitizing it or desalinating it. Safe food products require electricity, such as for irrigation of crops and food production and refrigeration. Any economic growth is simply not attainable without new, affordable supplies of electricity.

Choosing the best generation option depends much on what we value. For those who value low cost and clean air, Bruce Power has provided a calculator on its web site at http://www.brucepower.com/energy-calculator/. Using a slider to increase or decrease a particular type of generation one can see at a glance how their monthly bill would be affected and how GHG emissions would change. For example, the cheapest option is Coal, but that has the worst impact on GHG emissions. The next cheapest is Hydro, with virtually zero GHG emissions. For Ontario, unfortunately Hydro is limited and can only supply about a third of its needs. With Hydro limited we need something else, and for zero GHG emissions, if we choose Solar to make up the balance it would bankrupt the Province and most people in it.

Aside from cost and the environment, how would our choice affect health and safety? There are some interesting mortality statistics on this topic published in Forbes magazine, which I have been unable to verify, but in my opinion the mortality numbers seem to be about right. The numbers represent deaths per trillion kWh of electricity, since we will need a given amount of kWh to meet our needs no matter what technology we choose. Except where noted, they are global averages. The % is for total energy, not just electricity.

Coal – global average	170,000	50%
Coal – China	280,000	75%
Coal – U.S	15,000	44%
Oil	36,000	8%
Natural Gas	4,000	20%
Biofuel/Biomass	24,000	21%
Solar (rooftop)	440	<1%
Wind	150	1%
Hydro	1,400	15%
Nuclear	90	17%

For Coal, the deaths are primarily due to lung diseases from air pollution and affects the general public, whereas for Wind and Solar the deaths are primarily due to workers falling from height during maintenance. Nuclear has the smallest number of fatalities, and is attributed to theoretical deaths due to use [misuse in my opinion] of the Linear-No-Threshold model. Deaths due to Hydro are attributed to rare but catastrophic dam failures.

It is easy to see that Nuclear is not only one of the cheapest options with very low GHG emissions, it is also the best option for good health and safety.

In This Issue

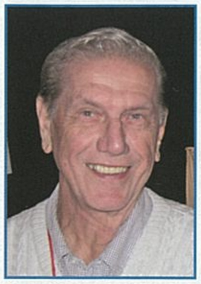
Dr. John C. Luxat, professor and former CNS President, delivered his talk entitled "The Case for New Nuclear" to the Economic Club of Canada in Toronto, on November 22, 2013. We are happy to include the text of his address in The Bulletin. The conference report in this edition is about Canadian Science Policy attended by some 600 people and covered several topics in research from genomics to oceans.

CNS member Nicholas Sion discusses means of reducing radiation doses in medical applications while Jerry Cuttler presents a well supported Remedy for Radiation Fear.

Retired engineer and historian James E. Arsenault reviews the history of electrical counting technology which is an important tool in nuclear physics. There is a short item on the OCI Suppliers Day hosted by Candu Energy, an opinion piece and a selection of general and CNS news. As usual, Jeremy Whitlock presents his "Snow Job" in Endpoint.

As the year comes to an end I wish you all a happy and safe festive season and all the best for the new year!

From The Publisher



The Society

Legalities

The legal transition of the CNS from an organization incorporated under the federal Canada Corporations Act to one under the recent Canada Not-for- Profit Corporations Act (CNCA) is finally approaching reality.

A Special General Meeting, noted in the last issue, was held November 3, 2013. That was the penultimate step in that transition. At the meeting members approved the modified By Laws to meet the new requirements of the CNCA. It took several months to reach that step. What had been predicted to be a short process, making the changes to the By Laws, elicited much more debate than anticipated.

In any event the modified By Laws are expected to be approved by Industry Canada relatively soon, along with the broad Articles of Continuance, which basically reiterate the objectives of the Society. That will clear the way for a formal vote on the transition at the next AGM to be held during the CANDU Maintenance Conference in May 2014.

Once the Society is incorporated under the CNCA, it will be possible for Council to amend the By Laws without reference to Industry Canada.

Finances

As noted in the last issue of the Bulletin, the Society has suffered two years of significant deficits. This was primarily caused by much smaller revenues from conferences together with some expansion of the Society's programs a few years ago when our income was strong.

With considerable agony Council has cut a number of programs with the aim of coming close to a break-even financial situation for 2014.

For anyone concerned about these moves it should be noted that the Society has a very small administration budget. Much of the program is conducted by volunteers. That includes much if not most of the organization of conferences and courses and the publication of the Bulletin. With such a structure, cutting expenses has been difficult.

PBNC

On the bright side, the organization of PBNC 2014 (19th Pacific Basin Nuclear Conference), to be held in Vancouver, August 24 -28, 2014, has gone very well under the leadership of Frank Doyle and Bill Kupferschmidt. As noted on the one page notice in this issue, they have already received over 300 abstracts for technical papers, along with commitments from many senior level plenary speakers from countries around the Pacific Rim (where the nuclear action is taking place). So, the message is, plan now to attend this major event.

The nuclear scene

Ontario plan

This is being written shortly after Ontario's Premier announced her government's questionable plan for the province's electricity system.

The limited good news is that the current provincial government is still supporting the refurbishment programs for Darlington and Bruce.

Beyond that, this (interim) government is continuing the folly of Premier McGuinty's *Green Energy Act* of 2009 which trampled on the rights of rural land owners, offered obscene bonuses for wind and solar generation and promised thousands of jobs based on superficial economic premises.

However, this is only the latest step in a two decade parade of political interference in the Ontario electricity system.

For 70 years. Ontario Hydro and its previous forms ran an integrated electrical system which included generation, transmission and system operation. Over most of that period Ontario had the lowest electricity rates in North America. The structure of the Hydro-Electric Power Commission enabled it, back in the 1950s, to grasp the promise of nuclear energy when viable hydro sources became scarce. Senior management was technically knowledgeable and financing was feasible through long-term bonds similar to the method used for large hydraulic dams.

Then came the politicians – of all stripes.

In the early 1990s, Bob Rae (NDP) appointed Maurice Strong, so-called international environmentalist, as chairman of Ontario Hydro. Under his direction needed renovations were denied, leading to decreased performance.

In 1998, Mike Harris (Conservative) broke up the integrated Ontario Hydro into five new companies: Ontario Power Generation; Hydro One, Independent Electric System Operator; Electrical Safety Authority and Ontario Electricity Financial Corporation. The Harris concept was to have a competitive system. That never materialized.

In 2004, McGuinty (Liberal) created the Ontario Power Authority. OPA was charged with producing plans for the future of Ontario's electricity production, which it did. But McGuinty ordered OPA to change its plan to meet his preconceived concept.

With so much muddling by politicians and their (often hidden) advisers, is it any wonder that the complex task of producing and distributing electricity in Ontario has become so confused.

The sad factor is that none of the political parties appear to support a rational, fact-based, electricity system.

Best wishes to all of our readers for a pleasant Christmas and a fulfilling New Year.

Fred Boyd

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~ Cover Photo ~

Nuclear Emergency Response Fire Truck, part of new emergency measures at Bruce Power post-Fukushima.

Photo courtesy of Bruce Power

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Le Bulletin SNC *est l'organe d'information de la Société Nucléaire Canadienne.*

CNS provides Canadians interested in nuclear energy with a forum for technical discussion. For membership information, contact the CNS office, a member of the Council, or local branch executive. Membership fee for new members is $82.40 per calendar year, $48.41 for retirees, free to qualified students.

La SNC procure aux Canadiens intéressés à l'énergie nucléaire un forum où ils peuvent participer à des discussions de nature technique. Pour tous renseignements concernant les inscriptions, veuillez bien entrer en contact avec le bureau de la SNC, les membres du Conseil ou les responsables locaux. Les frais d'adhésion par année de calendrier pour nouveaux membres sont 82.40$, et 48.41$ pour retraités.

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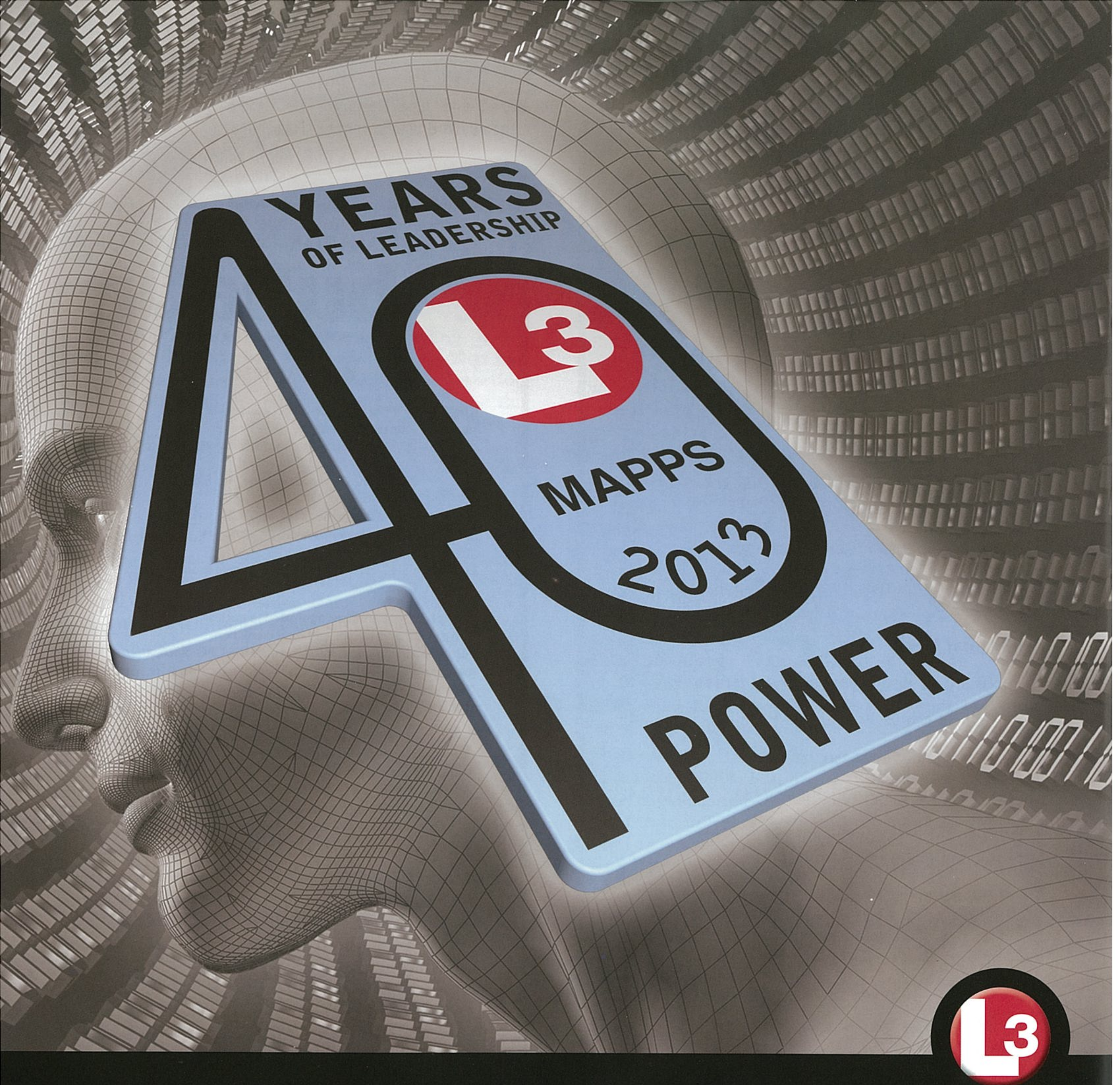
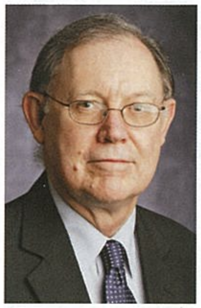

40 YEARS
OF LEADERSHIP
L3
MAPPS
2013
POWER
L3

The Case for New Nuclear

by DR. JOHN C. LUXAT[1]

[Ed. Note: Dr. Luxat addressed the Economic Club of Canada in Toronto, on November 22, 2013, with "The Case for New Nuclear: The Need for Energy and Economic Growth in Ontario".]



Over a 22 year period from 1971 to 1993 a total of 20 reactor units were brought into service - an average of approximately one unit per year. Ontario Hydro constructed the four-unit Pickering A station, four units at Bruce A, four units at Pickering B, four units at Bruce B and four units at Darlington during this period. This represents a capacity of nearly 14,000 MW, as shown in Figure 1. During this period there was a large increase in industrial capacity in Ontario, particularly in manufacturing, driven in large measure by the incentives offered by low electricity prices, skilled workers and a good health care system.

Subsequently in the mid-1990's the Pickering A and Bruce A units were laid up and maintenance efforts were focused on the Pickering B, Bruce B and Darlington stations. Two of the four units at Pickering A were returned to service in the early 2000's and the four units of Bruce A were returned to service with two units being refurbished. By 2010 nuclear capacity in the province had returned to 12,800 MW.

The Ontario Long Term Energy Plan[2] (LTEP) announced at the beginning of December does not include new build nuclear but does include refurbishment of the Darlington station as well as two units at Bruce A and four units at Bruce B. The six units at Pickering will be shut down by 2020. As shown in Figure 1, this will reduce the nuclear capacity from the current 12,800 MW to 8000 MW when the Pickering A and B units are removed from service in 2020 and the refurbishment of Darlington and Bruce units proceeds starting in 2016 and projected to complete by 2031. This will be the lowest nuclear generating capacity in the province since 1985.

Electrical Energy Generation in The Past Decade

In the 10 year period from 2003 to 2013 electrical energy generated from the available sources has been dominated by nuclear energy which experienced an increase from 65 TWh in 2003 to 89 TWh in 2013. This represents an increase in low-cost nuclear energy supply to Ontario from 43% in 2003 to 57% in 2013, as shown in figure 2. Since the introduction of the *Green Energy Act* renewable sources have increased due to encouragement from a feed in tariff (FIT) program and preferential access to the grid. This has distorted the market considerably and is currently resulting in rapidly escalating electricity costs to the point that Ontario is now the Canadian province with highest electricity costs - approximately twice those in Québec[3]. In fact, the electricity prices in Ontario are amongst the highest in North America. The approach Ontario has adopted in implementing the *Green Energy Act* is very similar to that which Germany adopted in their move to rapidly expand renewable energy in that country. The magnitude of renewable expansion in Germany has led to an explosion in electricity costs to the point that electricity prices in Germany are now the highest in Europe and German government has drastically reduced plans for offshore wind capacity increase in an effort to limit the cost explosion. The German example will be discussed in further detail later and will be compared to the more balanced approach United Kingdom has adopted.

Given Ontario's proposed long-term energy plan, an important question is how will the electricity needs of Ontario consumers be met in the next decade as nuclear capacity is reduced? Well, according to the long-term energy plan this will be achieved by a major increase in renewable capacity from nominally 3900 MW in 2013 to 10,700 MW by 2021 with an accompanying increase in natural gas capacity from 7500 MW to 10,000 MW, and the Bruce and Darlington nuclear units providing 9900 MW in 2026, as shown in Figure 3. Some of the issues and challenges associated with the three energy options that will undergo significant changes in the long-term energy plan, namely renewables, nuclear and natural gas, are summarized in Table 1. It is unclear whether fundamental issues associated with renewables and natural gas have been adequately considered in the development of this plan, nor is it clear that it is an environmentally responsible plan.

An unavoidable feature of renewables, such as wind and solar, is that they are intermittent generators of electricity and have low average capacity factors that limit their effective electrical energy generation. As shown in Figure 3, a nameplate capacity of 10,700 MW renewable generation with an average capacity factor of 25% is equivalent to only 2675 MW of "effective" capacity. This raises a sec-

1 Professor & NSERC/UNENE Industrial Research Chair in Nuclear Safety Analysis, McMaster University.

2 Achieving Balance – Ontario's Long-term Energy Plan, Government of Ontario, December 2013.

3 2013 Comparison of Electricity prices in Major North American Cities, Hydro Quebec, April 2013.

ondary question: what will be the impact on carbon emissions in the next decade, since the stated objective of the *Green Energy Act* is to reduce greenhouse gas emissions? The Ontario government has taken pride in the reduction of carbon emissions which indeed have fallen quite considerably since 2005 when CO_2 emissions where of the order of 33 Mt per year and have been reduced to 12 Mt per year in 2012[4]. This significant reduction in CO_2 emissions has come about by shutting down all but two of Ontario's coal-fired stations and bringing back the Pickering and Bruce nuclear stations. Therefore, it is fair to say that the carbon emission reduction has been achieved by the increase in nuclear capacity, that is, the return to service of Pickering units and refurbishment of Bruce units facilitated the retirement of coal-fired generation.

The proposed long-term energy plan is severely flawed since it will not be possible to sustain these low CO_2 emissions over the next decade. Indeed, as renewable capacity is increased there will be a need to substantially increase the burning of natural gas - the stated preferred backup option to compensate for the intermittency of renewables. The increased burning of natural gas will cause increased emission of carbon dioxide over the period of this plan. This is the consequence of what I refer to as the "intermittency paradox" which I shall describe in some detail in a subsequent section.

Implications of The LTEP

The proposed long-term energy plan will see a shift to wind and natural gas and a reduction in the role of nuclear which will have the following effects:

- Higher emissions: natural gas, while emitting less CO_2 than coal, is nevertheless a significant source of carbon emissions, producing between 56% to 58% of coal emissions per kilowatt hour of electricity generated. Carbon emissions are likely to increase above the 2005 level over the next decade as more natural gas is burned to backup the increased renewable sources.
- The plan is a poor investment choice: nuclear is the lowest cost option compared to renewables (including wind) particularly when one factors in the cost of backup power from natural gas. Interestingly, the 2013 LTEP shows nuclear being amongst the lowest cost options[5]. Nuclear also provides more jobs in Ontario which are high-quality sustainable jobs. There is no evidence that Ontario is becoming a "powerhouse" of wind turbine manufacturing as was claimed when the *Green Energy Act* was introduced. This is supported by a recent STRAPOLEC study[6] commissioned by OCI and the PWU which concluded that there are significant economic benefits from nuclear refurbishment and new build relative to expansion of wind in terms of direct Ontario spending, numbers of jobs and income generated, while also reducing greenhouse gas emissions and yielding lower residential electricity rates (Figure 4).
- There is a risk of supply shortage: a key assumption in the long-term energy plan is that there will be no significant growth in the demand for electricity, implying that the Ontario government is willing to accept no economic growth. Do the people of Ontario really want to have a stagnant economy over the next 10 to 15 years accompanied by ongoing hollowing out of manufacturing capacity in the province?
- There is a risk of increasing electricity costs: there is no assurance that natural gas prices in North America will remain low over the next 15 years, especially in the face of increased offshore demand from energy hungry countries such as China, India and Japan and the increased cost of shale gas extraction as production moves to less favorable sites. Increasing electricity costs are a negative incentive for industrial investment in Ontario, as compared to the southern states of the USA where nuclear energy is maintaining electricity costs lower.
- Public dissatisfaction: the recent public consultation regarding long-term energy planning recorded strong support for nuclear from the people of Ontario and significantly less for renewables. However this result appears to have had little influence on energy policy. This will likely compound the public dissatisfaction over the high cost of the gas plant cancellations prior to the last election.

The Intermittency Paradox

A common problem encountered in discussing renewable energy is that proponents talk solely about the installed capacity of renewables, in particular the nameplate capacity. However, the nameplate capacity is very misleading when there is a significant difference between the capacity factors of different generating sources. What actually matters is the energy generated, which is a product of **the capacity** times **the capacity factor**. Therefore when comparing nuclear capacity versus renewable capacity, which has a much lower capacity factor, one must account for the additional cost associated with generating the same amount of energy. For example a nuclear unit with capacity of 1000 MW and a capacity factor of 95% will generate energy equivalent to a renewable source of capacity 3200 MW at 30% capacity factor. In other words, one requires three times the capacity of that renewable in order to generate on average the same energy as the nuclear plant. Therefore, if one compares the cost to install capacity in terms of dollars per megawatt one has to increase the renewable cost by a factor of three or, alternatively, factor in the cost of the backup gen-

4 Status, Outlook and Options for Electricity Service – in support of the 2013 LTEP Consultation, Ontario Power Authority.

5 Achieving Balance – Ontario's Long-term Energy Plan, Government of Ontario, December 2013 (Figure 9).

6 Ontario Electricity Options Comparison, Strategic Policy Economics (STRAPOLEC) Report, June 2013.

eration source (natural gas). This leads to the intermittency paradox, a term I have coined to account for the inherent limitations associated with competing electrical energy sources. The intermittency paradox can be summarized by the following statements:

- The lower the capacity factor of an intermittent source, the larger is the required capacity of a backup energy source.
- In order to accommodate the range of intermittency of a renewable source, the capacity of the backup source must equal the installed capacity of the renewable source.
- If the backup energy source emits carbon, then the larger is the backup source is the larger the carbon emissions will be.

This paradox is a fundamental flaw in the long-term energy plan in which natural gas is to be used as a backup source for renewables, in particular wind and solar. The intermittency paradox is illustrated in Figure 5 which plots the effective capacity of an electrical generation source as a function of the installed capacity of that source for various capacity factors. For example, if an installed capacity of 10,000 MW is required in order to deliver a sustained hourly energy generation of 10,000 MWh, then the effective capacity of the renewable at 30% average capacity factor is only 3000 MW on average and an additional 7000 MW of backup capacity is required to supplement the renewable. Similarly if the capacity factor is lower, say only 20% capacity factor, then the effective capacity of that source is only 2,000 MW equivalent and an additional 8,000 MW of backup is required. In the extreme, to account for the periods when there may not be any generation from the renewable source, for example the wind is not blowing sufficiently strongly or the sun is not shining, then in order to deliver the 10,000 MWh of energy all the energy has to be generated from the backup source. Therefore, in order to assure that 10,000 MWh can be generated when required a full 10,000 MW capacity of backup supply is necessary.

A fundamental problem with intermittency is that the generation is not simply an average quantity but can vary between zero and the maximum installed capacity . In order to accommodate this variation, the capacity of the backup generation is required to be equal to the capacity of the intermittent source.

A corollary to the intermittency paradox is that :

- overbuilding of either the renewable source or the backup source is always required.
- If an energy storage capability can be developed on the scale required, then overbuilding of the renewable source will always be required.
- The amount of overbuilding of the renewable source is inversely proportional to the capacity factor of that source.

The corollary articulated above has important implications for the cost of renewable energy sources. For example, wind power capacity factors initially start out at higher values in the region of 30%, simply because the initial wind farms are located in the best areas for wind. As the number of wind farms increase so the overall average capacity factor of wind farms decreases since the incremental wind farms will end up being located in regions where the wind is not as high quality. This can be seen in numerous large-scale wind farms in Germany which currently has an installed capacity of 30 GW and the capacity factor for wind is down to a low value only 17%.

Energy storage is not the "silver bullet" solution to intermittency that it is often touted to be since, in order for energy to be stored when the renewable source is generating, there must be excess capacity available to generate the energy that is be stored. This, in turn, requires that the renewable generating source must be overbuilt in order to provide that stored energy This overbuilding of renewables will multiply the real cost of the renewables in order to provide reliable electrical energy on a continuing basis. The only way to avoid overbuilding capacity is to have available a reliable low-cost, low-carbon source, such as nuclear.

International Evidence

Clear evidence for the intermittency paradox is apparent in the contrast between the recent experiences of Germany and the United Kingdom.

1. Germany

In 2009 Germany reversed its own earlier policy decision of 2000 to phase out nuclear power. However, in 2011 following the events at Fukushima eight of the oldest nuclear units were shutdown, removing 8.4 GW of nuclear energy from the grid, and the German government announced that the remaining nine units, representing 4.1 GW, would be phased out by 2022. It also undertook rapid expansion of both wind and solar renewables to the extent that by the end of 2012 Germany had approximately 30 GW of install capacity of each of these two sources. The installed capacity of wind and solar in 2012 was approximately 84% of the German average electricity demand of 70 GW. Despite this apparent high installed capacity, wind and solar only generated approximately 12% of the total electrical energy in 2012. The capacity factor for wind is only 17% while the capacity factor for solar is even lower at 11%.

Since 2011 electricity prices have skyrocketed, leaving Germany with the highest priced electricity in Europe. Due to the very high price of natural gas in Europe and the abundant coal resources in Germany, coal-fired stations have become the backup sources to the renewables. Carbon emissions associated with burning coal have rapidly escalated to levels that exceed carbon emissions prior to 2011. It is projected that over the next five years carbon emissions will exceed 300 Mt which means that Germany alone will ensure that the European Union will not achieve its carbon reduction target of 315 Mt.

The skyrocketing cost of electricity[7] as well as the destabilization of the grid due to wind fluctuations is causing many major German industrial companies to threaten relocation of their plants to other countries – this includes the automobile companies, the pride of German manufacturing. In an attempt to control the price explosion the German Chancellor, together with her coalition partners, recently announced a significant scaling back of offshore wind expansion from 10 GW to 6.5 GW by 2020 and from 25 GW to 15 GW by 2030[8].

2. United Kingdom

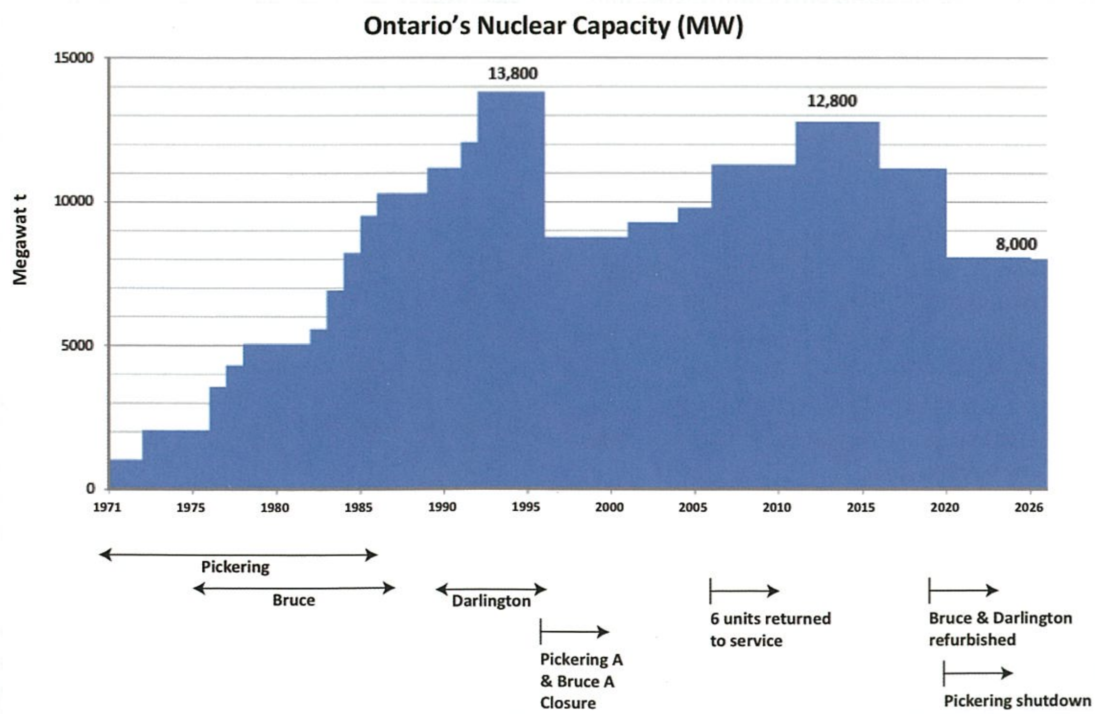
United Kingdom plans to shutdown all gas cooled reactor nuclear units (AGR) but is proceeding with plans for new nuclear build. Development of renewables is proceeding in a carefully planned and very controlled manner, despite the fact that the United Kingdom has some of the best wind potential in Europe, including offshore wind. As of 2011 the installed capacity of wind is 2.5 GW offshore and 5.3 GW onshore and total renewable energy accounts for 3.8% of energy consumption at an average capacity factor of approximately 30%. Solar installed capacity is 1.5 GW with a capacity factor of approximately 10%. Expansion of offshore wind, despite the good offshore wind potential, is not proceeding until such time as innovations in offshore wind technology can demonstrate a significant reduction in cost of at least a factor of two or more. Despite the cautious approach to renewables being followed by the United Kingdom there has been significant investments in wind technology development and manufacturing by a number of multinational companies such as Areva, Samsung, Mitsubishi and Gamenas. Electricity prices in the United Kingdom, while relatively high have remained stable and are substantially lower than in either Germany or Denmark. Overall, the United Kingdom displays evidence of the benefits of developing a rational energy policy coupled with careful and detailed planning[9].

Conclusions

Nuclear energy has in the past been the backbone of Ontario's low-cost electricity system and has provided significant competitive advantages to Ontario industry. More recently nuclear energy has facilitated the transition to lower carbon emissions as coal-fired generating stations have been taken out of service.

Building new nuclear now will keep significant high spend economic activity in the province, will support over 30,000 high quality jobs, and will provide the necessary support for increased economic growth in the province over the next decade. However, the provincial government must become significantly more proactive in driving economic growth, stopping the hollowing out of manufacturing capacity in the province, and attracting industries back to Ontario. To achieve this and sustain low carbon emissions, low-cost baseload nuclear energy is essential and we must undertake to replace the Pickering plant which is due to close in 2020. The alternative is to face a high risk, high cost and high carbon emission future.

Figure 1



7 Germany's Energy Poverty: How Electricity Became a Luxury Good, Spiegel Online International, September 4, 2013.

8 Merkel's Coalition to Slow Wind-Energy Expansion to Reduce Costs, Bloomberg Online, November 10, 2013.

9 UK Renewable Energy Roadmap Update 2012, UK Department of Energy and Climate Change, 27 December 2012.

Figure 2: Electrical Generation in Ontario

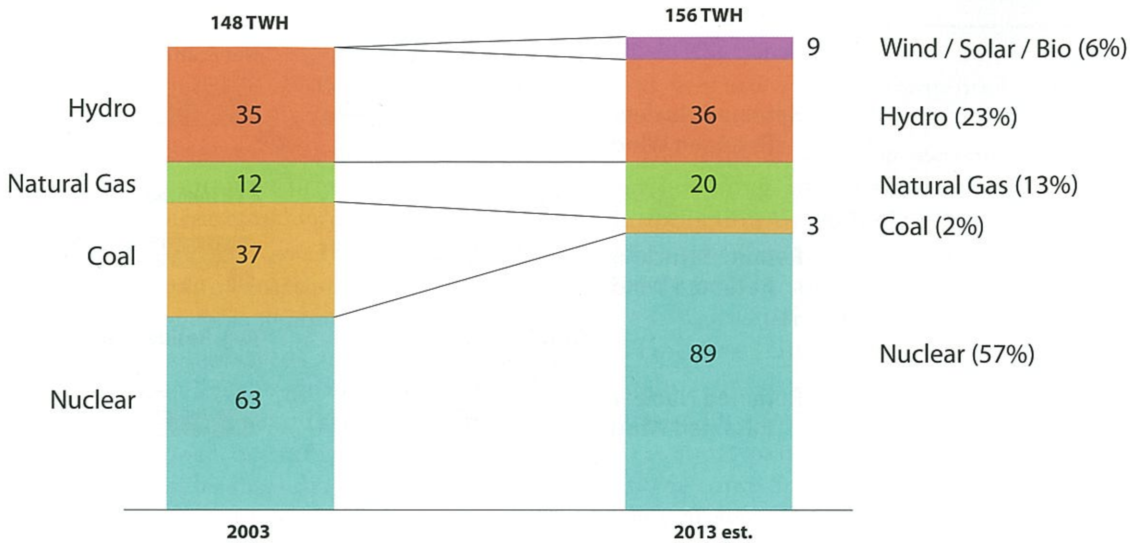


Figure 3: Working version of the Long-Term Energy Plan, Summer 2013

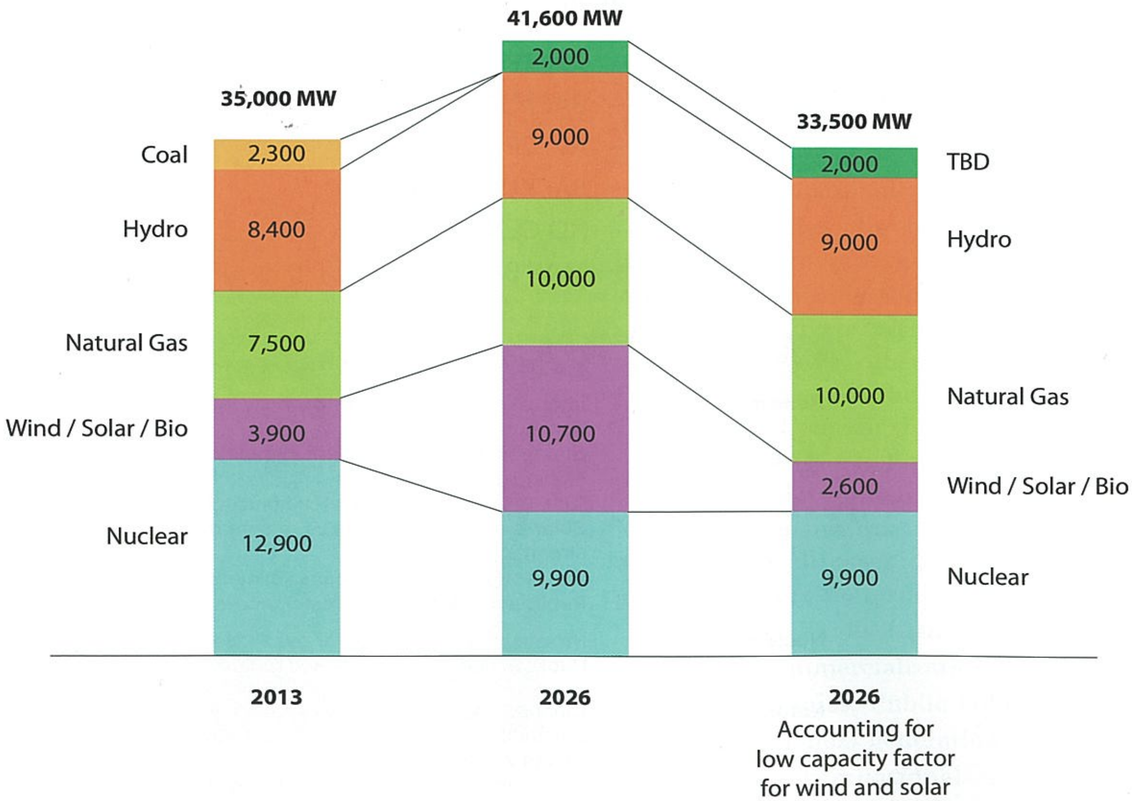


Figure 4

STRAPOLEC Analysis Findings
Total Impact 2014 to 2035

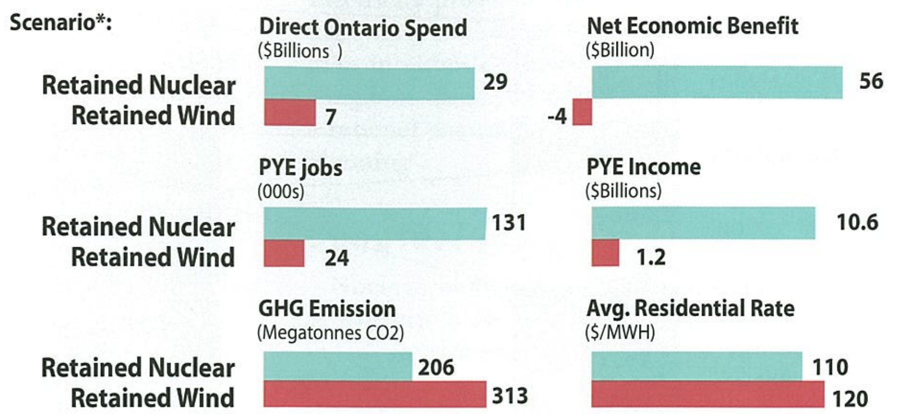


Figure 5:
The Intermittency Paradox

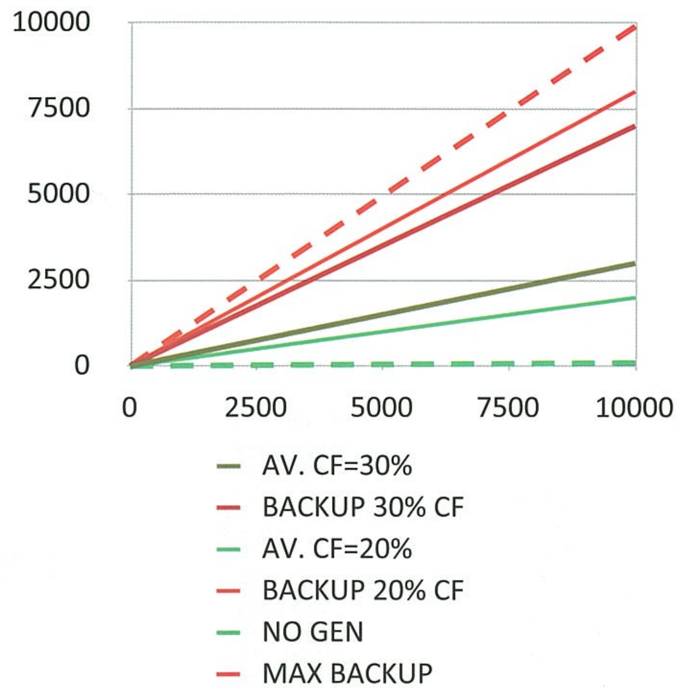


Table 1: Energy Options: Issues and Challenges

OPTION	ISSUES & CHALLENGES
Renewables	Intermittent producer; low capacity factors; require kW for kW backup Storage technology to offset intermittency does not exist & will be high cost "Smart grid" technology not a solution to intermittency Solar is reliant on expensive rare earth metals; toxic waste streams Susceptible to common cause climate events Public acceptance: local resistance in affected rural areas
Nuclear	Proven high capacity factor base load source Public acceptance: safety and radioactive waste management
Natural gas	Cleaner than coal and oil but not a low carbon emitter Electricity generation an inefficient way utilize an ultimately limited valuable resource Current low cost not sustainable – distortion of long term market Public acceptance: "fracking" issues

Conference Probes Canadian Science Policy by FRED BOYD

The fifth **Canadian Science Policy Conference,** held in Toronto, November 20 – 22, 2013, was the largest one of the series, with some 600 participants. The attendees included a large number of young people who had taken advantage of a greatly reduced registration fee.

Topics covered ranged from government policy to development of national and international cooperation to specific areas of research such as genomics and oceans.

There were a number of sessions related to linking computer centres to handle the growing amount of information arising from thousands of experiments. Although there was almost no reference to nuclear science, there was considerable discussion about a common problem – communication with the public and media. Scientists from almost all disciplines spoke of the difficulty of explaining their work.

While there were some workshops in the morning of the first day, the conference program began officially in mid-afternoon with four parallel panel sessions.

The one that most closely matched the public communication problem shared by the Canadian nuclear community was titled: *Journalists are from Mars; scientists are from Venus – Will they ever be on the same planet?*

The first panelist commented that journalists and the public lack an understanding of science and particularly of scientific research. Countering that he noted that scientists often spoke in what he termed esoteric language, difficult for a layperson to understand. He referred to the website of an organization called Bad Science Watch.

Another panelist noted the difference in schooling. While scientists typically have several years of study and research, she commented journalists normally stop at the bachelor level.

Mehrdad Hariri, chair of the CSPC, is shown (R) during one of the many interviews he held during the conference in front of the large poster set up for this purpose.

The official opening ceremony took place in the early evening after a short reception. It began with the introduction by **Mehrdad Hariri,** conference chair, of Michael Wilson, honorary Co-Chair of the conference. A former Minister of Finance in the federal government he is now Chairman, Barclays Capital Canada Inc., and Chancellor, University of Toronto.. He spoke briefly about mental health, having been at a meeting of the Centre for Addiction and mental health that morning.

A short panel session followed with three speakers, on the topic *Science in the C-Suite.* They were all executives of science-oriented businesses: Lorne Hepworth, president CropLife Canada; Robert Hardt, CEO Siemans Canada; and Mandy Shapansky, President and CEO, Xerox Canada Ltd.

Hepworth said his company has a $1 billion per year research and development program. Given the challenge of convincing farmers and the public about pesticides and GMOs (generic modified organisms), he stated there is a pressing need for science-based regulation.

Both Hardt and Shapansky noted that although their operations are part of large international corporations they do a significant amount of research in Canada.

The next two days each began with a plenary session. On the Thursday it was on: *Building the digital infrastructure – physical, regulatory and funding*

The panelists noted that research is becoming increasingly collaborative. Canadian researchers need digital scholarship supported by an infrastructure with a consistent regulatory framework and adequate funding to be internationally competitive.

On the Friday the opening plenary session was titled: *Global competiveness and innovation.*

The speakers focussed on the commercialization of public and private research and explored practices being followed in other countries. The participants emphasized the role the new Canadian Science Policy Council could play in this area.

The rest of the conference was structured primarily around a series of parallel panel presentations followed by extensive questions and comments from the audience. In all cases the discussion was active and generally had to be terminated by the time limit.

Some of the 22 discussion topics were:

- Canada's commercialization challenge
- Where Genomics, Public Policy and Society Meet
- Training the next generation of scientists
- Enriching international research collaboration opportunities for Canada

- Ocean research and policy
- Who are the innovators in Canada
- Big data: solutions for the big problems faced by modern societies

After lunch on the last day there was a spirited plea from a young researcher for more science bloggers. He referred to a meeting he had attended in the USA where it was noted that Canada had only 15 bloggers focussed on science.

This series of conferences on science policy had an unusual beginning.

Back in early 2009 Mehrdad Hariri, then a post-doctorate fellow, initiated some discussion among his associates about the state of research in Canada. They began to inquire about government and private industry research programs and found there was widespread concern about Canadian science research. From that, they boldly conceived the idea of a national meeting focussed on science policy in Canada.

The first Canadian Science Policy Conference was organized entirely by a loose organization of primarily post-doctorate fellows. Held in November 2009, it drew some 400 delegates including senior representatives of government and private enterprise.

With the profit from that first conference Hariri and a few associates decided to work on a second conference in 2010. That again was successful and has been repeated each year since.

Evolving from the conferences the group created a Canadian Science Policy Centre with a Board chaired by Janet Halliwell, formerly Executive Vice president of the federal Social Science and Humanities Research Council. The Canadian Science Policy Conference is now a subsidiary of the Centre.

The conference was organized by a committee of 15, supported by a group of 68 volunteers.

Honorary co-chairs were Michael Wilson and Mandy Shapansky.

Wilson is Chairman of Barclays Capital Canada Inc. He was federal Minister of Finance from 1984 to 1991 and subsequently Minister of Industry, Science and Technology. Mandy Shapansky is President and CEO of Xerox Canada Ltd, which is one of the largest private research organizations in Canada.

The conference was held in what is now called the Allsteam Centre, located within the grounds of the Canadian National Exhibition. For many years the building was known as the Automotive Building of the CNE. It was extensively renovated and now serves as one of Toronto's major conference centres.

Reducing Radiation in Medical Applications

by NICHOLAS SION

The advent of nuclear medicine is advancing rapidly with the increasing popularity of using CT and SPEC scans for improved imaging and hence achieve desired results. The radiation dose from these scanners is now causing concern among patients and medical operating staff. Furthermore, radiopharmaceuticals are also being used in radiotherapy causing additional dose to the patient. Protective measures in reducing radiation dose are being researched and some current applications are described below.

In order to quantify the radiation we are exposed to, i.e. the resulting dose, and to assess its health impacts in perspective, it is necessary to establish its units where the basic unit of radiation dose absorbed in tissue is the Gray (Gy), where one Gray represents the deposition of one joule of energy on one kilogram of tissue. However, since neutrons and alpha particles cause more damage per Gray than gamma or beta radiation, another unit, the Sievert (Sv) is used in setting radiological protection standards. This unit of measurement takes into account the biological effects of different types of radiation. One Gray of beta or gamma radiation has one Sievert of biological effect, one Gray of alpha particles has 20 Sv effect and one Gray of neutrons is equivalent to around 10 Sv (depending on their energy).

Note that radiation in Sv or in Gy measurements are accumulated over time, whereas damage (or effect) depends on the actual dose rate, e.g. mSv per hour, per day or per year, or Gy per day as measured for radiotherapy.

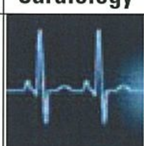
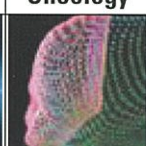
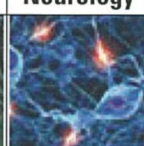
But why do we fear radiation? because of its latency for cancer initiation and with the probability of genetic aberrations. It is cumulative and is very much dependant on the total dose received; yet has benefits when used therapeutically in measured doses.

Table 1: Medical Exposures

Source	Global Average Dose mSv/year
Medical diagnosis	0.6 and growing
Occupational	0.005
Nuclear testing	0.005
Chernobyl Accident	0.002
Nuclear fuel Cycle	0.0002
Source: UNSCEAR 2008	

Table 1 shows the increase of dose in medical applications when compared to other non-medical exposures. The ICRP [1] has publications on radiation protection in medical applications based on Risk-Benefit to the patient and optimized on the ALARA principle with doses commensurate with the medical purpose

Table 2: Isotopes frequently Used in Nuclear Medicine

Isotope Used	Cardiology	Oncology	Neurology	Research	Diagnostic	Remarks
						
Mo-99	•	•	•		•	Used as the parent to generate Tc-99m
Tc-99m	•	•	•		•	Imaging the skeleton, heart muscle, also for brain, thyroid and lungs (perfusion and ventilation), liver, spleen and kidney, gall bladder, bone marrow.
I-131 solution or dry	•	•	•	•	•	For imaging and therapeutic applications for thyroid and carcinomas and abnormal liver and renal functions.
I-125		•		•	•	And for therapeutic purposes
Gallium-67		•			•	For tumor imaging and inflammatory lesions
Thallium-201	•				•	For myocardial perfusion imaging

The above is only a partial list of the commonly used isotopes from a long list comprising Cobalt-60; Copper-64, Yttrium-90; Selenium-75 etc — source : Nordion and other sources of the dose administered to the patient. For circulatory diseases (Cardiovascular and Cerebrovascular) the threshold is set at ~0.5 Gy. The time to develop cardiovascular and cerebrovascular fatality is >10 years.

Table 3: Effective Dose of Typical Radiologic Examinations	
Ab./Pelvic CT	8-11 mSv
Chest CT	5-7 mSv
Head CT	1-2 mSv
PA/Lateral CXR	0.04-0.06 mSv
Coronary Angiogram	3-5 mSv
MSCT Angiography	9.3-11.3 mSv
Average annual background radiation in USA ~ 3.6 mSv	

What isotopes are used in nuclear medicine? They are indicated in Table 2 and are either reactor produced or cyclotron produced. For studying brain physiology and pathology Carbon-11, Nitrogen-13, Oxygen-15, Fluorine-18 are used in PET scans. The F-18 in PET scans plays an important role in detecting cancers and for monitoring any progress in their treatment. From the above paragraphs and Tables it is clearly discerned that as more isotopes are used for diagnosis and for radiation therapy, such may reach a threshold where detrimental effects may arise to the patient and/or to the staff administering the therapy. Hence methods must be prescribed to reduce the received dose without compromising the treatment plan.

At the University of Sherbrooke [2], in vivo preclinical imaging is used on small animals with PET or SPECT scanners, supplemented by X-Ray CT scanners. Since these small animals host a large number of the human diseases, they can be studied under controlled conditions non-invasively then appropriate therapy can be extrapolated for size and weight, and then applied to humans in clinical therapy. As an example, the LD50/30** for a mouse is ~ 5-7.5 Gy. The recovery from residual radiation damage follows an exponential time course. If repeated, the sub lethal doses reduce the survival time (in a mouse by ~ -7%/Gy). Extrapolated and applied to humans, a dose of <1 Gy induces some blood cell destruction and releases free radicals. Doses of 5-200 cGy induces cell resistance to subsequent therapeutic radiation i.e. adaptive response. However, doses of 1-20 cGy have been reported to induce therapeutic effects in tumor cells. This procedure optimizes the dose to the individual patient.

Size Specific Dose Estimates (SSDE), where phantoms are used Fig. 1, is an alternative metric for better estimation of doses from CT scans in pediatric cases. Here, the dimensions of the children are considered and comparisons made between SSDE and **$CTDI_{vol}$. Compared to SSDE, $CTDI_{vol}$ has underestimated the dose received in 91% of chest examinations for all abdo-

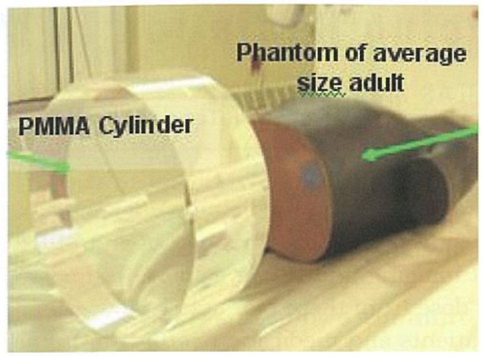


Fig. 1: Anthropomorphic Phantom has geometry and composition very different from the PMMA (Polyméthylméthacrylates, a plastic) cylinder. Differences between $CTDI_{vol}$ and actual patient dose can be more inaccurate when scanning children. Source: Sylvain Deschenes [3]

men-pelvis examinations. In summary, $CTDI_{vol}$ leads to false estimates and misinterpretation of the radiation dose from CT scans; whereas SSDE is easy to calculate offering a more accurate evaluation of dose. [3].

CT scan optimization is another method to reduce the patients' exposure to ionizing radiation, A study was carried out by the Centre for Clinical Expertise in Radiation Protection (CCER) to evaluate the functionality of CT scanners from 4 manufacturers [4], viz. from GE, Siemens, Toshiba, and Philips. The optimized protocols used by anatomy, were applied to viz. head exams, chest exams, and abdomen-pelvis exams. These procedures reduced the dose to the patient by 18-24% without degradation in image quality. The ensuing recommendations are to use Bismuth shielding as required, to use low dose protocols for follow-up exams and to be specific to children's size and age.

The 16 slice CT scanners came into use in 2002 and enabled non-invasive coronary angiography. However, the procedure delivered a higher dose to the patient than by the invasive procedure, the margins being 10-20 mSv by CT scan, and 3-6 mSv for the invasive technique [5]. Statistics show that between 1993 and 2006 the U.S. population grew by 1% annually, yet the use of CT scans increased by nearly 10%; and the effective dose increased by almost 600% from 0.5 mSv to 3 mSv (1980-2006). Table 3 shows the radiation dose a patient receives from CT scans. More dose reduction work needs to be achieved in either the equipment or in the procedure.

Following the ALARA principle, dose reduction methodologies were instituted, such as CT scanners gantry rotation speed, the number of installed detectors, iodine concentrations, software modifications i.e. by iterative reconstructions and pharmacological protocols, by using beta blockers and nitric oxide. High quality examinations can now be achieved with a radiation dose of 1-6 mSv, which is an improvement.

Current knowledge on cancer initiation and its pro-

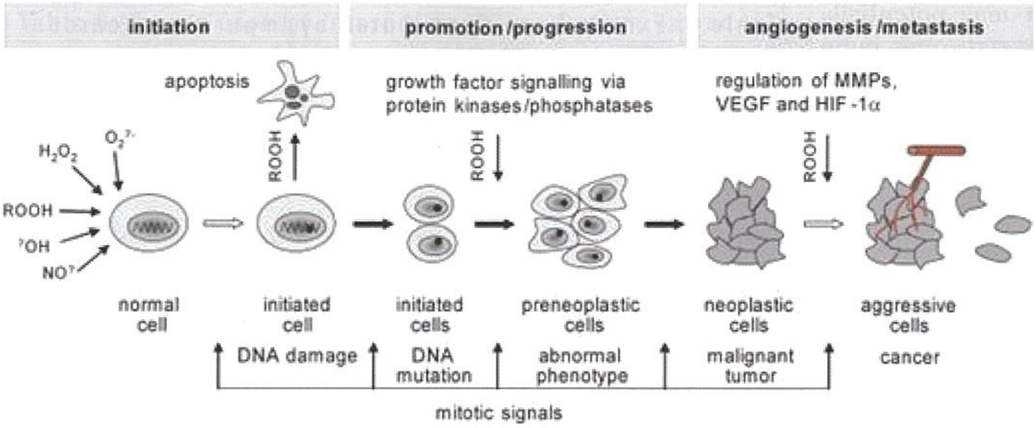


Fig. 2: Initiation and Progression Towards Cancerous Cells. Source: Benoit Paquette etal [6]

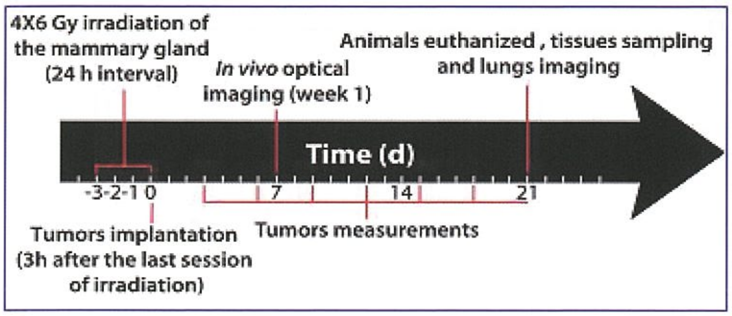


Fig. 3: Enhancement of Cancer Cell Invasion in vivo of Balb/c Mouse. Source: Benoit Paquette etal [6].

gression is that it initiates from chemical agents, radicals, and radiations that damage the DNA leading to mutations, excluding the hereditary factors. This is exacerbated by genomic instability to accelerate the accumulation of the mutations. The progression of cancer is also stimulated by radiation inflaming the surrounding normal tissue. This progression is shown in Fig.2. Hence, customized therapy is becoming increasingly prominent for breast cancer patients [6], knowing that:

1. Radiation favors the passage of cancer cells from the mammary gland and increases their number circulating in blood stream.
2. Irradiated mammary glands stimulate the migration of cancer cells.

However:

3. Proliferation of cancer cells is reduced in the irradiated mammary glands.
4. But, the irradiated mammary gland favors the development of lung metastases.

The above hypotheses was verfied by irradiatinig the mammary glands of Balb/c mice with 4 fractions of 6Gy at 24h intervals using a Gamma Knife. The glands were then implanted with breast cancer cells and tracked Fig. 3. The pre-irradiation increased the migration and quantity of cancer cells and the number of lung metastases as predicted. However, in conservative surgery and by using radiotherapy, the aim is at optimizing the long term results rather than eradicating all cancer cells.

The tendency now is to advocate the use of Intensity Modulated Radiation Therapy (IMRT) where radiation doses are delivered with precision without harming the surrounding cells by using 3-D CT scans, or with MRI imaging in conjunction with dose calculations.

Personalized medicine for cancer treatment can offer an alternative treatment plan to radio-sensitive individuals but would require genomic sequencing. It is known that exposure to ionizing radiation may cause double strand breaks in the DNA whose repair pathways are very complex. Regulating the repair pathways are the H2AX, ATM and the p53 proteins. However, there is a new candidate: the Foxo3A transcription factor. Tests on genetically matched mice showed that H2AX plays a role in the Foxo3A-regulated stress response whose deficiency would cause genomic instability and radio sensitiza-

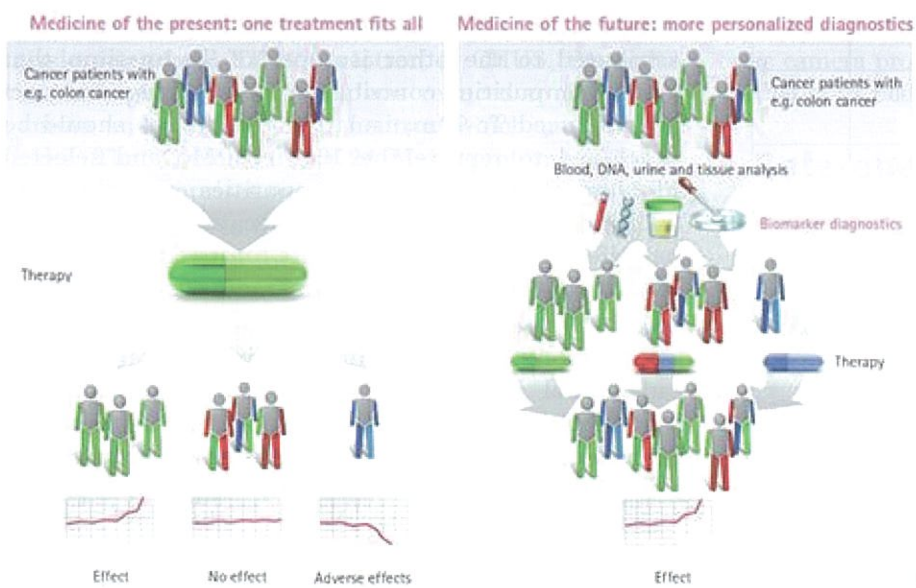


Fig. 4: The Case for Personalized Medicine in e.g. Colon Cancer Treatment. Source: Dmitry Klokov [7].

tion. Because of this linkage, it may potentially be used in nuclear medicine for screening radio sensitive individuals making a case for personalized medicine, where persons would have their genome sequenced and specialized treatment prescribed. Fig.4, [7]. There are already 30 genomic medical centres for personalized medicine in the USA. The FDA has also approved three drugs for personalized medicine for lung cancer, for cystic fibrosis, and for melanoma. However, genomic sequencing raises ethical issues when not relegated to a treatment plan and if used by insurance companies and/or by employers.

In the continuing effort to reduce dose to patients the question arises whether nuclear medicine examinations in pregnancy can be permitted, and what are the means to reduce exposure to the foetus. The answer is affirmative [8] if it is required to save the mother's life with strong considerations of the potential risks to the foetus and with the possibility of terminating the pregnancy (strong cultural and moral issues here). Efforts are usually made to explore alternatives using non-ionizing radiation, else by using smaller quantities of administered isotopes and extending the imaging time provided the patient can remain still during the procedure. Typical radiation doses to the foetus are shown Table 4.

Table 4: Whole Body Dose from Nuclear Medicine Therapy

Radio-pharmaceutical	Procedure	Activity Administered MBq	Early Pregnancy mGy	9 months (Term) mGy
^{99m}Tc	Bone scan (Phosphate)	750	4.6 – 4.7	1.8
^{99m}Tc	Lung Perfusion (MAA)	200	0.4-0.6	0.8
^{99m}Tc	Lung Ventilation Aerosol	40	0.1-0.3	0.1
^{99m}Tc	Thyroid scan (pertechnetate)	400	3.2-4.4	3.7
^{99m}Tc	Red Blood cells	930	3.6-6.0	2.5
^{99m}Tc	Liver Colloid	300	0.5-0.6	1.1
^{99m}Tc	Renal DPTA	750	5.9-9.0	3.5
^{67}Ga	Abscess/tumour	190	14-18	25
^{123}I	Thyroid Uptake	30	0.4-0.6	0.3
^{131}I	Thyroid Uptake	0.55	0.03-0.04	0.15
^{131}I	Metastases Imaging	40	2.0-2.9	11.0

Adapted from Russell, Stabin, Sparks et al., 1997, ICRP 53, and ICRP 80

Most female patients are advised not to become pregnant for at least 6 months after radioiodine therapy.

Table 5: Excess Dose Contributed by Impurities. Source: Svetlana Selinova etal [9].

70 kg adult (740 MBg)	Dose (mSv)							% Excess Dose
	Tc-93	Tc-94	Tc-95	Tc-95m	Tc-96	Tc-99m	Total	
Effective Dose Equivalent	1.72E-02	6.29E-02	3.47E-02	1.84E-01	9.25E-02	5.23E+00	5.62E+00	**6.96%**
Effective Dose	2.53E-02	9.18E-02	4.88E-02	2.56E-01	1.24E-01	7.99E+00	8.54E+00	**6.39%**
19 kg 5-yr old (185 MBg)	**Dose (mSv)**							**% Excess Dose**
	Tc-93	**Tc-94**	**Tc-95**	**Tc-95m**	**Tc-96**	**Tc-99m**	**Total**	
Effective Dose Equivalent	1.73E-02	5.86E-02	3.02E-02	1.77E-01	7.46E-02	6.55E+00	6.91E+00	**5.18%**
Effective dose	2.63E-02	8.81E-02	4.37E-02	2.57E-01	1.03E-01	1.02E+01	1.07E+01	**4.83%**

Metastable Technetium Tc-99m, is the isotope of choice in imaging with approximately 30000 therapeutic scans per week (Canada), 400000 (USA) and 600000 (Global). It becomes an issue to keep a supply chain open to maintain its availability. Since our governing authorities are demising the reactor based Tc-99m, the other source of supply is the cyclotron route where plans are to have one cyclotron per ½ million population to satisfy Canadian needs. Methods of generating Tc-99m can be found in Canadian Nuclear Society Bulletin March 2011, Vol 32 #1, p.15 *Update on Radioisotopes and Nuclear Reactors,* and on p.18 *Which Way Radioisotopes,* both authored by N. Sion.

Purity of Tc-99m is paramount because it adds to the patients' dose [9]. Table 5 shows the excess dose attributed to the other isotopes of Technetium that are the impurities contributing to the dose. In reactor produced Tc-99m, isolation procedures should be developed to remove the 100Mo/99Mo and selected niobium isotopes, These impurities contribute to additional radiation to patients because of their longer half-life. US Pharmacopoeia sets limits on these impurities to 0.015% of the Tc-99m radioactivity, and not to exceed 0.05% of the other radionuclide impurities.

But building cyclotrons and/or Linacs have their own radiological issues as highlighted in a recent CNSC workshop (Sherbrooke PQ, May 2013). They need to be housed in bunkers with licenses to construct, operate and finally to decommission. The previous photon energy exemptions of 10 MeV has now been reduced to 1 MeV. Regulatory requirements are increasingly stringent on the effects of neutrons, electron radiation; and the emanating secondary radiation via scatter and leakage. The aim is for a dose of 1 mSv/y for a NEW (Nuclear

Table 6: Comparison of Internal Exposure Pathways and Limits				
Isotope	Half Life $\tau^{1/2}$ h	Ingestion Effective Dose mSv/ MBq (Limit 1 mSv)	Inhalation Effective Dose mSv/ MBq (Limit 1 mSv)	Integrated Skin Dose Per 1 cm^2 mSv/MBq (Limit 500 mSv)
N-13	0.17	0.016	0.013	460
C-11	0.34	0.024	0.002	900
F-18	1.83	0.049	0.093	4600
Cu-64	12.7	0.120	0.150	18000
I-124	100.3	13	6.3	75000
What is a dangerous level of contamination? Source: CNSC Workshop (Adam Dodd)				

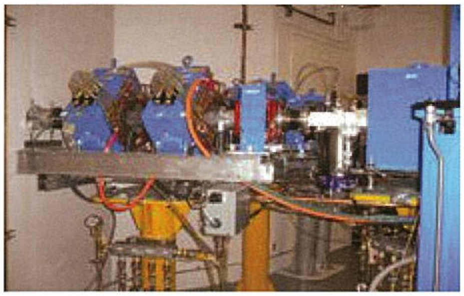


Fig. 7: Cyclotron Beam Line. Source: CHUS Facility

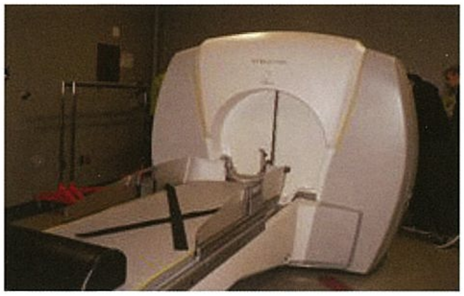


Fig. 8: Gamma Knife, the Leksell PERFEXION Elektra. Source: CHUS Facility.

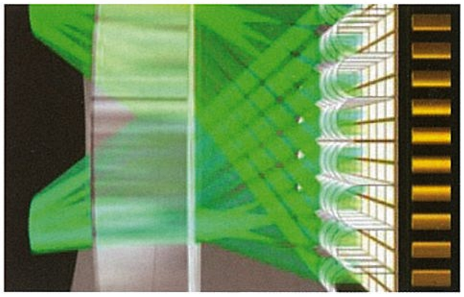


Fig. 9: Vision Sense's Multiple Scans on Array of Micron Sized Elements.

Energy Worker) and 50 µSv/y for the general public. At the primary and/or secondary walls, the Instantaneous Dose Rate < 25 µSv/h and the Time Averaged Dose Rate at < 20 µSv/h are being met as per NCRP-151 guides.

Cyclotrons are primarily for producing Tc-99m. Due to the nature of their operation, cautions must be taken should there be target failure, from emissions of $^{11}CO_2$ from the ventilation stacks, possible leakage from the vault airtight seals, and of air activation due to neutron capture by the Argon in the air. The exposure pathways are shown in Table 6 with their limits. During the commissioning of the TR24 Cyclotron at CHUS, the radiation leakage under the door was reduced to 1.5 µSv/h gamma and to 59.3 µSv/h neutron which met the set limits. That Cyclotron is a 24 MeV (protons), 500 µA device and comprises two beam lines for 2 targets, Fig.7.

When it comes to therapy and where delicate surgery is required such as for brain surgery, a robotic radiosurgery system is used, labeled the Cyberknife Fig. 8, where the tumor is targeted with extreme precision. An imaging guidance system relays instantaneous X-Ray images continuously to guide the surgeon to the tumor. Depth perception becomes crucial. There are only four such therapeutic instruments in Canada since 2004, one of which resides at CHUS, [10]. Some 400 treatments are performed there annually on certain tumors, vascular malformations and functional disorders. The Cyberknife has 192 collimated Co-60 sources that are used to deliver focused radiation to the tumor with an accuracy of 0.5 mm thus sparing the surrounding healthy tissue. The patient receives 8 Sv/h limited to the head area at the tumor. This is, of course, less invasive than traditional surgery. Each treatment is individualized and lasts about 30 min.

An addition to the Operating Rooms for conducting brain scans and aids surgery without the need for the X-Ray guidance system is a miniature stereoscopic (3D) sensor that optically maps the surgical field by a single sensor that divides the field into thousands of tiny "eyes" looking in different directions and impinging upon an array of micron-sized elements, Fig. 9. In essence, It is a stereoscopic camera providing endoscope mapping in a single device that gives better image quality at smaller dimensions.

References:

[1] ICRP Publication *Advances in Radiological Protection in Medicine.* Christopher Clement, Scientific Secretary of ICRP, and IRPA.

[2] Roger Lecomte, Professor of Radiobiology and Nuclear Medicine, University of Sherbrooke. *Dosimetry and Radioprotection In Preclinical Molecular Imaging*:

[3] Sylvain Deschenes PhD, CHU Ste-Justine, P.Q. *Use of SSDE to Report Dose and Evaluate Exposure in Pediatric CT Scans.*

[4] Renald Lemieux[1] Director General, Manon Rouleau, Moulay Ali Nassiri, Centre d'Expertise Clinique en Radioprotection, Centre Hospitalier Universitaire de Sherbrooke. *Optimization of CT Scan Protocols to Reduce Patient Exposure to Ionizing Radiation.*

[5] Gerald Gahide M.D. PhD, Sherbrooke University. *Cardiac CT and Radiation Safety: a Sherbrooke Experience.*

[6] Benoit Paquette[1] PhD, Gina Bouchard[1], Helene Therriault[1], Rachel Bujold[1], Caroline Saucier[2], University of Sherbrooke, *Pre-Irradiation Of Mouse Mammary Gland Stimulates The Migration Of Breast Cancer Cells.*

[7] Dmitry Klokov, Tanya Bhardwaj, Stephane Tarrade, AECL Chalk River Labs, *The Role Of H2AX In The Foxo3A-Regulated Molecular Pathways Elicited In The Response To Ionizing Radiation Exposure.*

[8] IAEA Doc. Radiation Protection of Patients (RPOP).

[9] Svetlana Selivanova PhD, Lidia Matei, Veronique Dumulon-Perrault, Jaques Rousseau, Eric Turcotte, Brigitte Guerin and Roger Lecomte, CHUS, Universite de Sherbrooke, *Tc-99m Pertechnetate Production Using a Cyclotron.*

[10] Patrick Delage M.D., Centre Hospitalier Universitaire de Sherbrooke. *Clinical Usage of Gamma Knife at the CHUS.*

Acronyms:

ALARA: As Low As Reasonably Achievable.

CHUS: Centre Hospitalier Universitaire de Sherbrooke.

CNSC: Canadian Nuclear Safety Commission.

CT: Computed Tomography.

$CTDI_{vol}$: The volume Computed Tomography Dose Index. CTDI is the measure of ionizing radiation exposure per slice of data acquisition. The $CTDI_{vol}$ is calculated as $[(NxT)/I] \times CTDI_W$ where N= number of axial scans per X-Ray source rotation; T= scan thickness in mm; I = table increment per axial scan in mm; CTDIw = average CTDI given across the field of view.

ICRP: International Commission on Radiological Protection.

IMRT: Intensity-Modulated Radiation Therapy.

LINAC: Linear Accelerator.

MRI: Magnetic Resonance Imaging.

MSCT: Multi-Slice Computed Tomography

PET: Positron Emission Tomography.

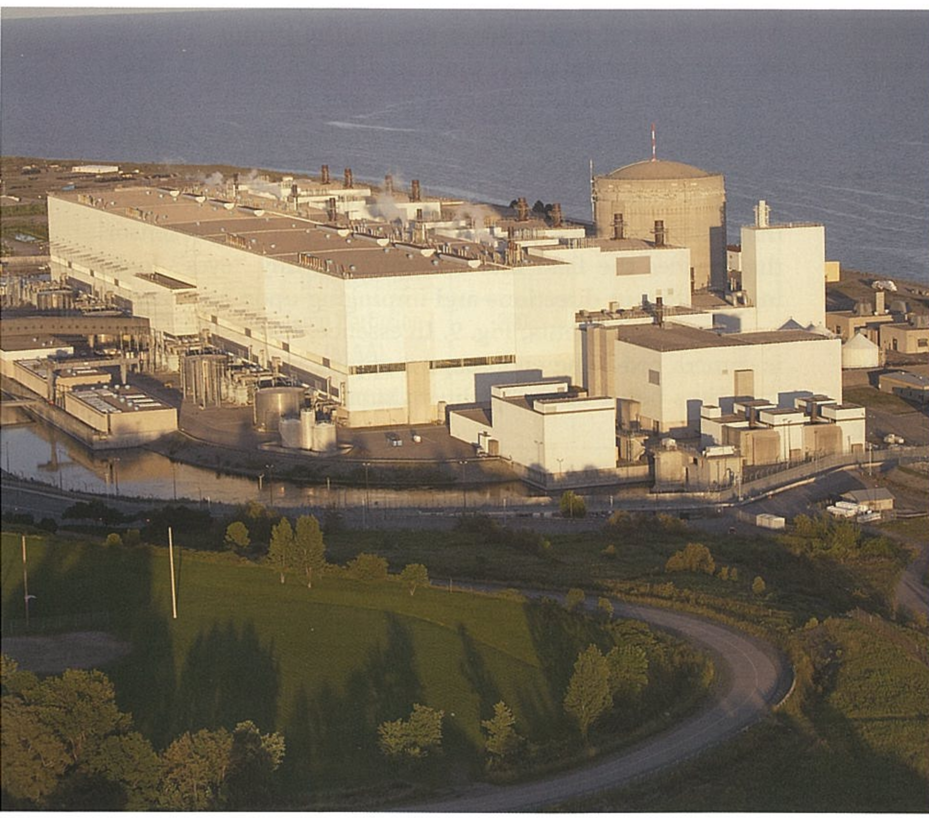
ROOH: Hydroperoxides (Reactive Oxygen, and hydroxyl radical OH*)

SPECT: Single Photon Emission Computed Tomography.

SSDE: Size Specific Dose Estimate.

**** Glossary:**

LD 50/30: is the radiation dose expected to cause death to 50 percent of an exposed population within 30 days. For humans the dose is in the range of 4-5 Sieverts received over a very short period.



Dear Editor,

In the September 2013 issue of the CNS Bulletin De Groeneveld indicated (p. 5) that the heat output of CANDU fuel bundles may not be limited by experimental experience of critical heat transfer but by regulation.

Something similar applies to the behaviour of the Zircaloy-sheathed uranium-dioxide fuel elements. In the early days designers, especially U.S. Westinghouse, considered central melting a physical limit and so set the operating limit lower. Our experiments with fuel elements in the NRX reactor demonstrated that those with central melting operated without rupture or physical damage.

Our interpretation was that the outer zone of the uranium-dioxide is cracked by thermal stress but held in place by the sheath. The next zone becomes increasingly plastic towards the centre and cracks become sintered so that this zone contains the central molten zone.

I invite designers to examine AECL Reports of the late 1950s and the 1960s by M.J.F. Notley, A.S. Bain, myself and others, also Geneva Conference papers of that period, all unclassified.

Yours sincerely,

J.A.L. Robertson

Dear Editor,

I must congratulate you on the excellent, informative editorial on the August 14, 2003 blackout. I hope it gets a lot more exposure in the public arena.

The CANDU nuclear industry should make better use of thoughtful articles like this one.

Congratulations again and thank you.

Hugh Irvine

CANADIAN NUCLEAR SOCIETY®
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What's Preventing Ontario's Darlington Nuclear Generating Station from Going Flexible?

by DON JONES

The frequent periods of Surplus Baseload Generation (SBG) on Ontario's electricity system arise when baseload supply exceeds demand. The Independent Electricity System Operator (IESO) takes steps to minimize the amount of SBG by increasing exports, reducing hydro and gas generation, and reducing output of the Bruce A/B nuclear stations by bypassing steam around the turbine-generators. Further reductions in SBG then come from curtailing output from wind generation and finally from nuclear unit shutdown.

Bruce Power now takes output changes in its stride, quickly responding to IESO dispatches day and night to reduce or increase output. Bruce Power should be congratulated for its initiative in providing the IESO with 2,400 MW of nuclear flexibility to help the IESO handle SBG (reference 1).

This 2,400 MW is equivalent to the full output of three Bruce B units. Without this flexibility nuclear units would have to come offline during periods of SBG and when shutdown they take two to three days to come back online. This means that frackgas-fired generation, producing greenhouse gases (GHGs), would be used in the interim as demand picks up. The flexibility provided by Bruce significantly reduces the number of times nuclear units need to be shutdown and reduces GHG emissions and wear and tear on the nuclear systems. The four nuclear units at Darlington do not provide flexibility but operate baseload. There would appear to be no technical reason why Darlington could not provide 1,200 MW of flexibility by using turbine steam bypass similar to Bruce A/B. This would reduce even more the need for a nuclear unit to shutdown and come offline during SBG periods. Like Bruce the steam bypass system was originally designed to keep the reactor from poisoning out (becoming unavailable for two or three days) after very infrequent loss of load events, e.g. a grid collapse - it was not designed for frequent use. Obviously Bruce Power took steps to examine the original as-built steam bypass system and made changes to enable it to be used more frequently. Bruce gets paid for the output lost from complying with the IESO SBG dispatches, deemed generation. The publicly owned Darlington generating station operates under a regulated generating price set by the Ministry of Energy (MOE) and would not get paid for any lost generation from curtailment of output to mitigate SBG. The IESO has to get on the case and convince the MOE that more nuclear flexibility is essential for the inflexible Ontario grid and the first step is to pay Darlington for deemed generation, then Ontario Power Generation can go ahead and make the turbine steam bypass systems more robust to handle more frequent use, just like Bruce.

Of course the IESO may have already asked the MOE about getting Darlington to contribute to SBG abatement and may have been rebuffed. The MOE may not want a lot of favourable publicity about nuclear flexibility since that would negate the premise in the 2010 Long-Term Energy Plan (LTEP) that nuclear generation must be limited to 50 percent (an installed capacity of around 12,000 MW) because it is an inflexible baseload supply. This is the foundation of the government's diversified energy mix policy of nuclear, hydro, wind/solar and frackgas, a view unfortunately supported by the province's pro nuclear organizations. Nuclear, especially the new Enhanced CANDU 6 (EC6), is far from inflexible (references 1 and 2).

The province's Professional Engineers Associations (Professional Engineers Ontario and the Ontario Society of Professional Engineers) support nuclear flexibility but only because it can be used to curtail nuclear output to accommodate wind during periods of SBG, something that makes no environmental, economic or technical sense. Instead, flexible nuclear must be used to accommodate more flexible nuclear on the grid. Wind is completely unnecessary on the Ontario grid. Nuclear flexibility capability can be used to make Ontario›s electricity grid completely free from the GHG emissions (reference 3) that contribute to climate change, using just nuclear and hydro.

Despite the need for more flexibility on the inflexible Ontario grid, and the need to reduce GHG emissions, nuclear flexibility must remain a government secret, hidden from public scrutiny, otherwise the public may start querying the premise of Ontario's soon to be released revised LTEP! Let's wait and see if the government mentions anything in its 2013 LTEP about the existing flexibility of Bruce A/B and any future Darlington flexibility proposal.

References

1. Ontario's already "flexible nuclear" CANDU even better by satisfying IESO requirements to replace flexible coal, see item 18*
2. Contenders for nuclear flexibility at Ontario's Darlington B, AP1000 and EC6, and the winner is...., see item 19*
3. An alternative Long-Term Energy Plan for Ontario - Greenhouse gas-free electricity by 2045, see item 2*

[Editor's Note: Full version of this article appears as item 33]*

* see http://thedonjonesarticles.wordpress.com/articles/

Remedy for Radiation Fear – Discard the Politicized Science

by JERRY M. CUTTLER[1]

[Ed. Note: The following reviewed paper was submitted to the Bulletin.]

Abstract

While seeking a remedy for the ongoing crisis of radiation fear in Japan and everywhere else, the author reread a recent article on radiation hormesis. It describes the political motivation for creating this fear and mentions the evidence, in the first UNSCEAR report, of a factor of 3 reduction in leukemia incidence of the Hiroshima a-bomb survivors in the low dose zone. Producing a graph of the tabulated data reveals that they fit a hormetic J-curve, not a straight line as reported. UNSCEAR data on the lifespan reduction of mice and Guinea pigs exposed continuously to radium gamma rays indicate a threshold at about 2 gray per year. This information contradicts the conceptual basis for radiation protection and risk determination that was established in 1956-58. In this paper, beneficial effects and thresholds for harmful effects are discussed, and the biological mechanism is explained. The key point is the discovery that the rate of spontaneous DNA damage (double-strand breaks) is more than 1000 times the rate caused by average background radiation. It is the effect of radiation on an organism's very powerful adaptive protection systems that determines the dose-response characteristic. Low radiation up-regulates adaptive protection systems, while high radiation impairs these systems. The remedy for radiation fear is to expose and discard the politicized science.

Introduction

Almost three years have passed since a major earthquake and devastating tsunami damaged the Fukushima-Daiichi nuclear power plant. An evacuation order forced 70,000 people to leave the area, while an additional 90,000 left voluntarily and subsequently returned. Many of those who left under the forced order have not gone back to their homes as removal of radioactivity continues. Approximately 1,600 people died, mainly due to psychological stress, in the evacuation process (Mainichi 2013)–about the same number of deaths in the Fukushima Prefecture from the earthquake and tsunami combined (Japan National Police Agency 2013). The precautions taken to avoid hypothetical health risks have proved to be much more harmful than the asserted risks.

The tragedy is that the radiation dose-response characteristic for leukemia in humans had been determined in 1958, but it was disregarded because of the policy decision to adopt the linear no-threshold (LNT) dose-response model. The threshold model had been the "gold" standard for medicine and physiology since the 1930s; however, in 1956, the US National Academy of Sciences adopted the LNT model for evaluating genomic risks due to ionizing radiation. The Genetics Panel members believed there was no safe exposure for reproductive cells. They thought that the mutation risk increased with even a single ionization. In 1958, the National Committee for Radiation Protection and Measurement generalized the LNT concept to somatic cells and cancer risk assessment. Soon after, the other national and international organizations adopted this model for radiation-induced genetic and cancer risks (Calabrese 2013a, 2013b).

Radiation Hormesis - A remedy for Fear

The enormous social fear and media frenzy surrounding the release of radioactivity from the damaged Fukushima NPP led the author to study again the facts in a remarkable paper by Jaworowski (2010) on radiation hormesis. He described the exaggerated fear of irradiating healthy tissues that arose during the Cold War period with its massive production and incessant testing of nuclear weapons. Radioactive materials from the atmospheric tests spread over the whole planet. People were quite rightly scared of the terrifying prospect of a global nuclear war and large doses of radiation from fallout. However, it was the leading physicists responsible for inventing nuclear weapons who instilled a fear of small doses in the general population. In their highly ethical endeavour to stop preparations for atomic war, they were soon joined by many scientists from other fields. Eventually, this developed politically into opposition against atomic power stations and all things nuclear.

Although the arguments of physicists and their followers were false, they were effective; atmospheric tests were stopped in 1963. However, this was achieved at a price–a terrifying specter had emerged of small, near zero radiation doses endangering all future generations. This became a long-lived and worldwide

1. Cuttler & Associates Inc, Mississauga, Ontario, Canada

UNSCEAR 1958. Table VII. Leukemia incidence for 1950–57 after exposure at Hiroshima[a]

Zone	Distance from hypocentre (metres)	Dose (rem)	Persons exposed	L (Cases of leukemia)	$\sqrt{L}$	N[b] (total cases per 10^6)
A	under 1,000	1,300	1,241	15	3.9	12,087 ± 3,143
B	1,000–1,499	500	8,810	33	5.7	3,746 ± 647
C	1,500–1,999	50[c]	20,113	8	2.8	398 ± 139
D	2,000–2,999	2	32,692	3	1.7	92 ± 52
E	over 3,000	0	32,963	9	3.0	273 ± 91

[a] Based on data in reference 13 (Wald N. Science 127:699-700. 1958). Prior to 1950 the number of cases may be understated rather seriously.

[b] The standard error is taken as: N times ($\sqrt{L}/L$).

[c] It has been noted (reference 15, 16) that almost all cases of leukemia in this zone occurred in patients who had severe radiation complaints, indicating that their doses were greater than 50 rem.

societal affliction nourished by the LNT assumption, according to which any dose, even that close to zero, would contribute to the disastrous effect. Radiation hormesis (Luckey 1991) is an excellent remedy for this affliction, and it is perhaps for this reason that it has been ignored and discredited over the past half century. What happened more than 50 years ago still influences the current thinking of both the decision makers and those who elect them.

The linearity assumption was not confirmed by early or later epidemiological studies of Hiroshima and Nagasaki survivors. No hereditary disorders were found in the children of highly irradiated parents. The United Nations Committee on the Effects of Atomic Radiation (UNSCEAR) was concerned mainly with the effects of nuclear tests, fulfilling a political task to stop weapons testing. The committee had mixed opinions regarding the LNT model, and its first report, UNSCEAR 1958, contains conflicting statements. Jaworowski states: "hormesis is clearly evident . . . in a table showing leukemia incidence in the Hiroshima population, which was lower by 66.3% in survivors exposed to 20 mSv, compared to the unexposed group (p.165). This evidence of radiation hormesis was not commented upon. Since then, the standard policy line of UNSCEAR and of international and national regulatory bodies over many decades has been to ignore any evidence of radiation hormesis and to promote LNT philosophy."

The very important data in UNSCEAR 1958, Table VII were not presented in graphical form. Figure 1, given here, shows these data together with the LNT model from 1300 to 0 rem[2]. A line through 100 rem was added to take into account Footnote c, which states that the doses in Zone C "were greater than 50 rem."

These Hiroshima leukemia data strongly contradict the LNT model, which predicts an increased degree of risk as the radiation dose increases. The data clearly indicate a reduction in incidence, by a factor of 3, in the dose range from about 0.1 to 10 rem (1 to 100 mSv). The threshold for increased risk is about 40 rem (0.4 Sv). The leukemia data fit a hormetic J-curve; they do not fit a straight line.

UNSCEAR 1958, page 165 in paragraph 31, states: "In zones A (1300 rem), B (500 rem), and C (50 rem), the values of P_L were calculated[3] to be . . . This finding was taken to support the suggestion that the extra leukemia incidence is directly proportional to radiation dose, and conversely to argue against the existence of a threshold for leukemia induction."

The discussion in paragraph 33 states "that a threshold for leukemia induction might occur. In fact, according to table VII a dose of 2 rem is associated with a decreased leukemia rate." But this observation was rejected because "the estimates of dose ... are much too uncertain ..." UNSCEAR should not have marginalized, because of dose uncertainty, the observation of this strong reduction in leukemia incidence for the 32,692 survivors in Zone D, which was far below the leukemia incidence of the 32,963 survivors in Zone E (the controls). This data disproved the LNT dose-response model, and UNSCEAR should have rejected the LNT model in its report.

Fliedner et al (2012) pointed out that bone marrow stem cells, which produce the blood cell components, are very sensitive to radiation, yet they are remarkably resistant to chronic low-dose exposure regarding function and maintenance of blood supply. Moreover, no increased cancer deaths occurred at doses below 700 mGy per year despite the fact that the latency time for leukemia is much shorter than for other radiation-induced cancers. This clear evidence of radiation hormesis - an absence of cancer risk at low dose radiation - adds to many other data of this kind and should cause UNSCEAR, the NAS and all radiation protec-

2 The different radiation units are discussed in Appendix 1.

3 P_L is the extra probability of leukemia occurring in an exposed person per rem and per year elapsed after exposure.

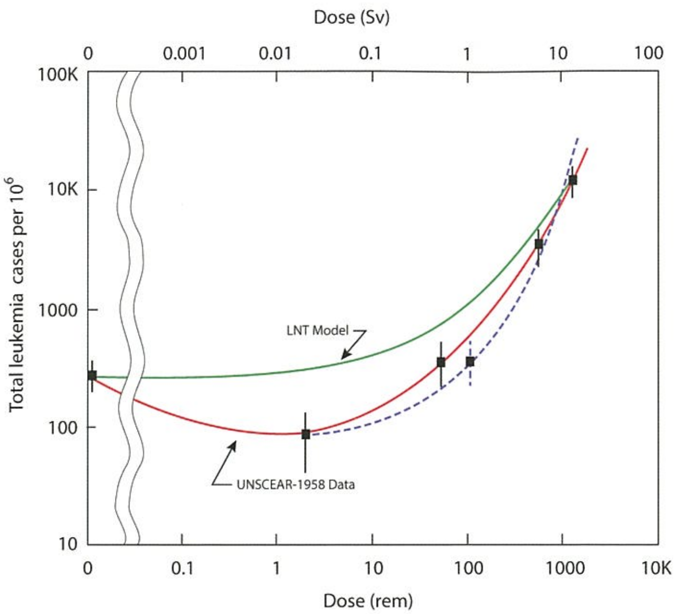


Figure 1. Leukemia incidence in the Hiroshima survivors for 1950-57.

tion organizations to revoke the generalized link they created in 1958 between low radiation and a risk of cancer; this link is the basis for the fear we see today.

Regarding the present concern about radiation-induced "health effects" on the residents around the Fukushima NPP, UNSCEAR states that that none were observed (UNSCEAR 2012, Chapter IIB, Section 9(a)) and discusses in Chapter III, Section 1 the difficulties in attributing health effects to radiation exposure and inferring risks. Section 2 points out that failure to properly address uncertainties can cause anxiety and undermine confidence among the public, decision-makers and professionals. If it wished, UNSCEAR could have attributed beneficial health effects to the low radiation, based on the extensive evidence in Annex B of its UNSCEAR 1994 report. This report contains summaries of 192 studies on *adaptive responses.* There have also been hundreds of additional scientific studies published during the subsequent 20 years. The World Health Organization's health risk assessment report (WHO 2013) contains estimates of lifetime risks of cancer; however, it uses the invalid LNT methodology.

Beneficial Effects

Positive health effects were identified by medical scientists and practitioners soon after x-rays and radioactivity were discovered in 1895-96. High, short-term exposures were harmful, but low acute doses or low dose-rate long-term exposures were beneficial. Often this was found inadvertently, while diagnosing bone fractures or other medical conditions. Recent review papers describe accepted medical applications, such as, accelerated healing of wounds and infections, cancer cures, and treatments of inflammations and arthritis that occurred before the introduction of the cancer scare in the late 1950s (Cuttler 2013). A new review discusses the historical use of low radiation to cure pneumonia (Calabrese 2013c), a very common occurrence in hospitals.

Beneficial effects have been known and studied for well over a century. The mechanism is explained in a medical textbook, in a chapter by Feinendegen et al. (2012). The key point is the discovery more than 25 years ago that spontaneous (endogenous) DNA damage, by the attack of reactive oxygen species (ROS), occurs at a relatively very high rate compared to the damage rate caused by natural background radiation. The natural rate of single-strand breaks from ROS attacks per average cell is many millions of times greater than the rate induced by ~ 1 mGy per year. Single-strand breaks are readily repaired, but double-strand breaks (DSBs) are relevant to induction of cancer and other genetic changes. Non-irradiated cells contain from about 0.1 to numerous DSBs at steady state. This agrees with the calculated probability of 0.1 for a DSB to occur per average cell in the human body per day from endogenous, mainly ROS sources (Pollycove and Feinendegen 2003). The probability of a radiogenic DSB to occur per day in background radiation is on average only about 1 in 10,000 cells. So the ratio of spontaneous to radiogenetic DSBs produced per day is about 1,000; i.e., the natural damage rate is a thousand times greater than the damage rate due to background radiation.

The critical factor is the effect of radiation on an organism's very powerful biological defences and protection systems, which involve the actions of more than 150 genes. They act on all the damage that is occurring (and its consequences) due to both internal causes and the effects of external agents. A low radiation dose or low level radiation causes cell damage, but it up-regulates adaptive protection systems in cells, tissues, animals and humans that produce beneficial effects far exceeding the harm caused by the radiation (Feinendegen et al. 2012). The net beneficial effects are very significant in restoring or improving health. The detailed behaviours of the defences are very complex, but the evidence is extremely clear. They range from prevention/cure of cancers to the very important medical applications of enhanced adaptive protections in the responses to stresses and enhanced healing of wounds, curing of infections, and reduction of inflammation, as mentioned earlier. In contrast, high level irradiation impairs these systems.

Thresholds for Harmful Effects

The evidence of net beneficial effects requires the determination of the threshold for harmful effects. This was known through more than thirty years of

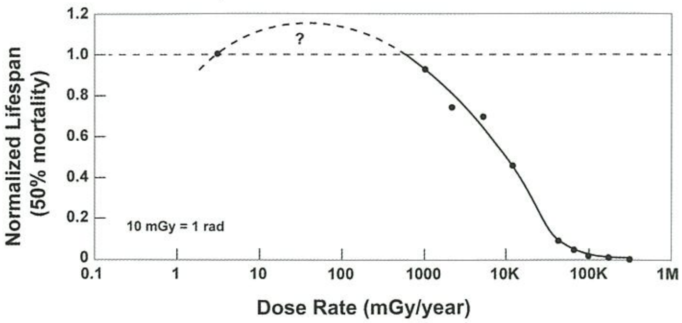


Figure 2. Lifespan versus radiation level (Cuttler 2013)

human experience when the first radiation protection *tolerance dose*, 0.2 roentgen per day or ~ 700 mGy per year, was established for radiologists in the early 1930s. Figure 2 is the result of a recent assessment of lifespan data for dogs exposed to cobalt-60 gamma radiation (Cuttler 2013). The threshold for net harm is also ~ 700 mGy per year. Similar data are found in UNSCEAR 1958, Annex G, page 162. The threshold for lifespan reduction of mice and Guinea pigs exposed to radium gamma rays is 4 roentgen per week or ~ 2000 mGy per year. Their mean survival time is 7% longer than the controls at a dose rate of 0.5 roentgen per week, which is about 240 mGy per year.

The "accepted" threshold for recognizing harmful late effects after a short-term exposure, according to a large set of experimental and epidemiological data, is an absorbed dose of about 100 mGy. However, the UNSCEAR data for leukemia incidence among the Hiroshima survivors, shown in Figure 1, suggests a threshold of about 400 mGy for leukemia.

Invalid basis for the LNT model

Calabrese reviewed the evolution of radiation protection from the tolerance dose (threshold) concept to the LNT concept. It began when early geneticists discovered that large numbers of mutations could be induced in germ cells of fruit flies by ionizing radiation. This would enable eugenicists to modify organisms for utilitarian purposes (Muller 1927). A high dose, at a high rate, produced a mutation rate that was 150 times greater than the spontaneous rate. This and other high-dose studies indicated that the mutation rate was proportional to the dose. A radiation target theory was developed by physicists to model the process of radiation-induced mutation, with mathematical calculations related to quantum mechanics (Calabrese 2013a). They established a conceptual framework for gene structure, target theory for the induction of mutations by ionizing radiation, the single-hit mechanism hypothesis to account for the shape of the LNT dose response and the application of this dose-response

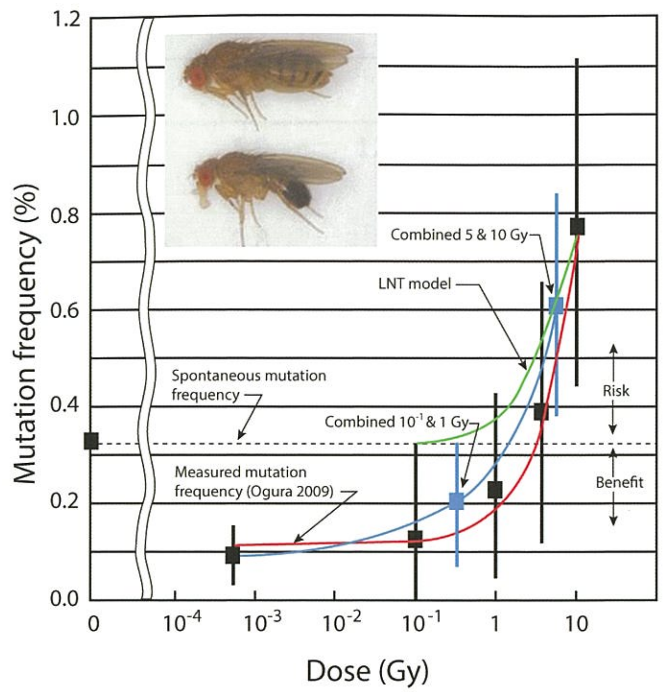


Figure 3. Fruit fly mutation frequency versus radiation dose (Cuttler 2013). A binomial distribution is assumed for the occurrence of the mutations. Each error bar is two standard deviations from the mean frequency. The data points at 0.3 Gy (0.19%) and at 7 Gy (0.61%) are obtained by "pooling" the Ogura et al (2009) data at 10^{-1} and 1 Gy, and at 5 and 10 Gy, respectively. Note that the mean mutation frequency is below the spontaneous level (0.32%) when the dose is below 1 Gy.

model for what was to become modern cancer risk assessment. However, bio-organisms do not behave according to this model. The Caspari and Stern (1948) study that irradiated 50,000 fruit flies to a dose of ~ 50 roentgen at a low rate, revealed a mutation rate that was the same as the 50,000 controls. This study was ignored. Recent studies on fruit flies at very low dose rate indicate a mutation frequency far below the spontaneous rate – genetic benefit instead of risk – below an absorbed dose of about 1 Gray, Figure 3 (Cuttler 2013). This evidence clearly falsifies the LNT model.

Discussion

Many researchers use the LNT model to predict the lifetime risk of cancer from a small dose of radiation. They calculate the expected cancer incidence from a very low dose by connecting a straight line between the zero-dose, zero-incidence point and the high-dose cancer incidence data of the A-bomb survivors. This procedure can only yield a risk of cancer. Most epidemiological studies are designed to measure radiation-induced cancer incidence, so they do not report any observations of beneficial effects. The data are fitted to the LNT model, presuming it is valid. Scott et al. (2008) list seven approaches that make it difficult to recognize bio-positive effects and thresholds, concluding that there is no credible evidence to support the contention that CT scans will cause future cancers. Scott (2008) points out three epidemiological "tricks" that are commonly employed to obtain a LNT dose-response curve. Relative risk and odds ratio values are often shown instead of cancer incidence data. In view of the extensive evidence of beneficial health effects and reduced health risks from low doses, misrepresentations of data and deceptions are exploited to fit the LNT model.

Conclusions and Recommendations

Social concern about the safety of all nuclear technologies is caused by the ideological linkage of any (human-made) radiation exposure to a risk of health effects, namely cancer and genetic harm, using the LNT model to calculate health risks. This link, created in the 1950s to stop the development and production of nuclear weapons, is maintained in spite of the extensive biological evidence of beneficial effects from low dose or low dose rate exposures. Ignoring biological facts and refusing to revert to the threshold model concept for radiation protection has created an enormous barrier against social acceptance of nuclear energy and the use of radiation-based medical diagnostics. The remedy is to discard this politicized science.

This enormous radiation scare surrounding the Fukushima-Daiichi is a very serious crisis. It should be looked upon as an opportunity to make changes in attitudes and concepts that would not otherwise be possible.

The following three fundamental messages should be communicated to everyone in order to explain the real effect of radiation on health and to eliminate the irrational fear.

1 Spontaneous DNA damage, mainly from reactive oxygen species, occurs at very high rate; the rate of double strand breaks (DSBs) is more than 1000 times the rate of DSBs induced by a background radiation level of 1 mGy per year.

2 Biological organisms have very powerful adaptive protection systems against harm to their cells, tissues and the entire organism, regardless of whether the harm is caused by natural internal processes or by external agents.

3 Low radiation generally up-regulates adaptive protection systems resulting in a net health benefit to the organism in terms of response to stress. High radiation generally impairs protection systems and results in more net harm than benefit. The effect of radiation on the protective systems is what determines the health benefit or risk.

Other recommendations are:

- Scientific societies should organize meetings to discuss the health benefits and risks of radiation.
- Regulatory bodies and health organizations should examine the scientific evidence.
- Radiation protection regulations should be changed. They should be based on science instead of politicized science.
- The basis for radiation protection should be restored to the *tolerance dose* (threshold) concept, in light of more than a century of medical evidence.
- Calculation of cancer risk using unscientific concepts, such as the LNT model, should be stopped.
- Regulation of harmless radiation sources, such as radon in homes, should be stopped.
- Based on biological evidence, the threshold for evacuations from low dose rate radiation should be raised from 20 to no more than 700 mGy per year, i.e., from 2 to ≤ 70 rad per year.

Appendix 1

Radiation dose is the amount of energy deposited in an irradiated object. Many different units have been used during more than 115 years of work with ionizing radiation (Henriksen et al. 2013, Chapter 5).

- Radiation dose is measured in units of gray (Gy), the System International (SI) unit. When one kilogram absorbs a joule of radiation energy, its radiation dose is one gray. So 1 Gy = 1 joule/kg, and 1 milligray (mGy) is a thousandth of a gray
- The roentgen unit R is a measure of radiation exposure, i.e., the ionization of air molecules. If soft tissue is exposed to gamma radiation of 1 R, the radiation dose will be approximately 9.3 mGy.
- The radiation absorbed dose (rad) was developed in 1953. One rad is 100 erg per gram or 10^{-2} joule/kg. Therefore, 1 gray = 100 rad.
- When biological organisms are irradiated with different types of radiation (x-rays, gamma rays, sub-atomic particles) the biological end result for the same dose given in Gy may vary. A relative biological effectiveness (RBE) factor is calculated for humans, and the dose is multiplied by the RBE weight factor to obtain "the effective dose." The unit is called rem in the old system and sievert (Sv) in the SI system. For x-rays and gamma rays, the RBE = 1. For these types of radiation, rem = rad and sievert = gray. One Sv = 100 rem.

References

Calabrese EJ. 2013a. *Origin of the linear no threshold (LNT) dose-response concept.* Arch Toxicol DOI 10.1007/s00204-013-1104-7. Available at: http://link.springer.com/article/10.1007%2Fs00204-013-1104-7

Calabrese EJ. 2013b. *How the US National Academy of Sciences misled the world community on cancer risk assessment: new findings challenge historical foundations of the linear dose response.* Arch Toxicol DOI 10.1007/s00204-013-1105-6. Available at: http://link.springer.com/article/10.1007/s00204-013-1105-6

Calabrese EJ. 2013c. *How radiotherapy was historically used to treat pneumonia: Could it be useful today?* Yale Journal of Biology and Medicine 86 (in press)

Caspari E and Stern C. 1948. *The influence of chronic irradiation with gamma rays at low doses on the mutation rate in Drosophila Melanogaster.* Genetics 33: 75-95. Available at: http://www.genetics.org/content/33/1/75.full.pdf+html?sid=cb861a39-fb63-48c4-bcbe-2433bb5c8d6a

Cuttler JM. 2013. *Commentary on Fukushima and Beneficial Effects of Low Radiation.* Dose-Response 11: 432-443. Available at: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3834738/

Feinendegen LE, Pollycove M and Neumann RD. 2012. *Hormesis by low dose radiation effects: low-dose cancer risk modeling must recognize up-regulation of protection.* In Baum RP (ed.). Therapeutic Nuclear Medicine. Springer. ISBN 973-3-540-36718-5. Available at: http://db.tt/UyrhlBpW

Fliedner TM, Graessle DH, Meineke V and Feinendegen LE. 2012. *Hemopoietic response to low dose-rates of ionizing radiation shows stem cell tolerance and adaptation.* Dose-Response 10: 644-663. Available at: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3526333/

Henriksen T and Biophysics and Medical Physics Group at UiO. 2013. Radiation and Health. Taylor & Francis. ISBN 0-415-27162-2 (2003 updated to 2013). University of Oslo. Available at: http://www.mn.uio.no/fysikk/tjenester/kunnskap/straling/radiation-and-health-2013.pdf

Japan National Police Agency. 2013. *Damage situation and police countermeasures associated with 2011 Tohoku district - off the Pacific Ocean earthquake, November 8, 2013.* Available at: http://www.npa.go.jp/archive/keibi/biki/higaijokyo_e.pdf

Jaworowski Z. 2010. *Radiation hormesis - A remedy for fear.* Human Exper Toxicol 29(4) 263-270. Available at: http://www.belleonline.com/newsletters/volume15/vol15-2.pdf

Luckey TD. 1991. Radiation Hormesis. CRC Press

Mainichi. 2013. *Stress-induced deaths in Fukushima top those from 2011 natural disasters.* The Mainichi. September 9, 2013. Available at: http://worldnews.nbcnews.com/_news/2013/09/10/20420833-fukushima-evacuation-has-killed-more-than-earthquake-and-tsunami-survey-says?lite

Muller HJ. 1927. *Artificial transmutation of the gene.* Science 66(1699): 84-87

Pollycove M and Feinendegen LE. 2003. *Radiation-induced versus endogenous DNA damage: possible effect of inducible protective responses in mitigating endogenous damage.* Human Exper Toxicol 22: 290-306. Available at: http://www.belleonline.com/newsletters/volume11/vol11-2.pdf

Scott BR. 2008. *It's time for a new low-dose-radiation risk assessment paradigm—one that acknowledges hormesis.* Dose-Response 6: 333-351. Available at: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2592992/

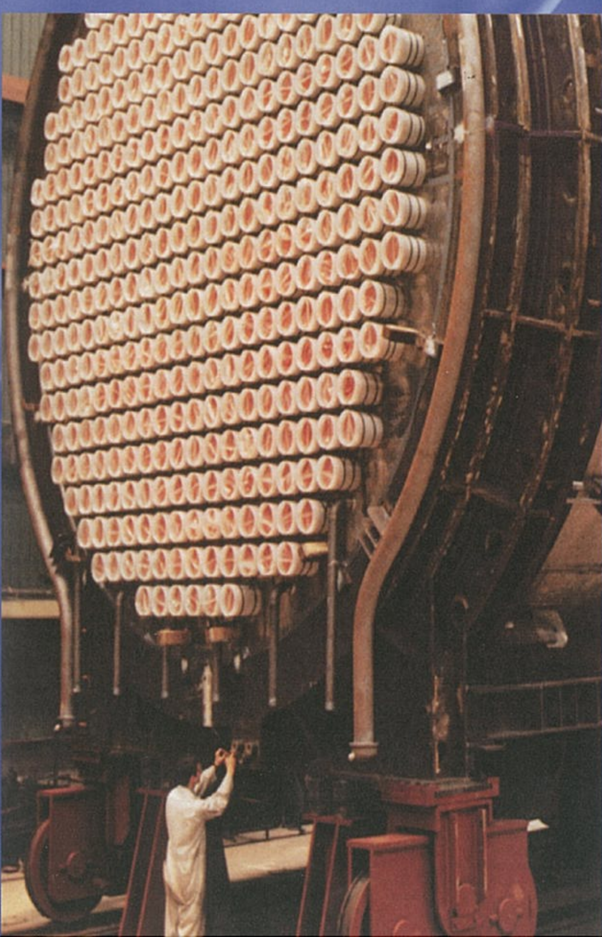
Scott BR. Sanders CL. Mitchel EJ and Boreham DR. 2008. *CT Scans May Reduce Rather than Increase the Risk of Cancer.* J Am Phys Surg 13(1): 8-11. Available at: http://www.jpands.org/vol13no1/scott.pdf

UNSCEAR. 1958. *Report of the United Nations Scientific Committee on the Effects of Atomic Radiation.* United Nations. General Assembly. Official Records. Thirteenth Session. Supplement No. 17 (A/3838). New York. Available at: http://www.unscear.org/unscear/en/publications/1958.html

UNSCEAR. 1994. *Adaptive Responses to Radiation in Cells and Organisms. Sources and Effects of Ionizing Radiation.* Report to the United Nations General Assembly, with Scientific Annexes. Annex B. Available at: http://www.unscear.org/unscear/publications/1994.html

UNSCEAR. 2012. *Report of the United Nations Scientific Committee on the Effects of Atomic Radiation. Fifty-ninth session (21-25 May 2012).* Available at: http://www.unscear.org/

WHO. 2013. *Health risk assessment from the nuclear accident after the 2011 Great East Japan Earthquake and Tsunami, based on a preliminary dose estimation.* World Health Organization. Available at: http://apps.who.int/iris/bitstream/10665/78218/1/9789241505130_eng.pdf



Electrical Counting Redux

by JAMES E. ARSENAULT, P.Eng.

"The technique of electrical counting has grown as an essential aid in research in nuclear physics... The electrical method...is unsurpassed for the rapid accumulation of data and for exact energy measurements."

W.B. Lewis, Electrical Counting, 1942.

1. Introduction

Measuring the energy of particle emission from radioactive substances accurately has been a crucial endeavour in nuclear science. Quantitative measurement began with the electroscope, galvanometer and zinc sulphide screen. Because the detector signals were very small, progress in measurement accelerated with their amplification by means of the vacuum tube. In turn this enabled the use of digital techniques and then computers. Today the measurement process is completely automated with digital signal processing and software run on personal computers.

Although the measurement processes now appear to be straightforward, they have had a long and interesting history of development which can be divided into three eras for discussion: early, middle and modern.

2. Early Era – Detectors

After radioactivity was discovered accidentally in 1896 by Henri Becquerel in France, researchers began efforts to define the mysterious 'rays' given off by certain naturally occurring minerals, such as pitchblende. In the same year Ernest Rutherford was working with J.J. Thompson, at the Cavendish Laboratory of Cambridge University in the UK, on the effects of newly discovered X-radiation on the discharge of electricity in gases, which led directly to the theory of ionization of gas molecules, i.e., the idea of the generation and liberation of positive and negative charges. In 1898 Rutherford arrived at McGill University, which marked the beginning of specific experiments designed to gain a detailed scientific understanding of the rays [----, 1995].

2.1 Ray detectors

The detectors used in early nuclear research were developed as a result of related investigations in other fields, and included photography, electroscope, and galvanometer.

Photography had been used by Becquerel in his discovery of the phenomenon of radioactivity. The electroscope was used to observe the rate of charge leakage of radioactive minerals in air. In their early researches, Pierre and Marie Curie also in France used the simplest of ion chambers, consisting only of two plates in air with a battery to create an electric field and they measured the resulting current produced by radioactive samples with an electrometer (much like a galvanometer). In some of his early work, Rutherford used a similar experimental setup, as shown in Figure 1 [Campbell, 1999].

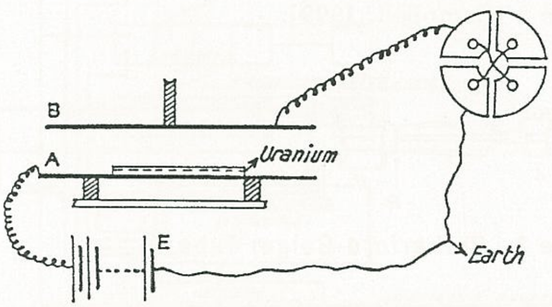


Figure 1: Ion Chamber

The ion chamber has evolved into its many contemporary forms, including those used in household smoke detectors. In 1899 Rutherford published that radiation consisted of two types of rays: alpha and beta, and employed an ion chamber to establish this fact. Then in 1903 William Crookes discovered that when the alpha rays struck a screen coated with zinc sulphide, a flash of light could be observed This method ultimately became Rutherford's preferred detector, until it was left behind by advancing technology.

In 1904 Rutherford was able to characterize the alpha and beta rays and added a third type: the gamma. The alpha he described as being readily absorbed by thin metal foil, positively charged, velocity about 1/10 the speed of light, and deflected little by electric and magnetic fields. The beta was described as more penetrating that the alpha, negatively charged, velocity near the speed of light, more readily deflected than the alpha and identical to cathode rays. The gamma ray was described as extremely penetrating, unaffected by magnetic fields and in some respects similar to X-rays [Rutherford, 1904].

So the net result of these early investigations was that the rays took on the characteristics of particles and the business of counting them began seriously. Today these rays are known to be particles: respectively the relatively heavy helium nucleus (two neutrons, two protons), the relatively light electron, and the energetic, massless photon.

2.2 Particle detectors

With the idea firmly established that the rays consisted of streams of particles, nuclear researchers invented a whole stable of new detectors capable of registering individual particles, including the Rutherford-Geiger tube, Geiger-Mueller tube and the ever-improving ion chamber.

In 1907 Rutherford moved to Manchester University and continued research with his favourite particle, the alpha, in association with Hans Geiger. In 1908 they fired alphas into an evacuated tube containing a central charged wire and were able to observe a magnification, or 'kick', of single ionization events using a galvanometer. The experimental tube is shown in Figure 2 [Campbell, 1999].

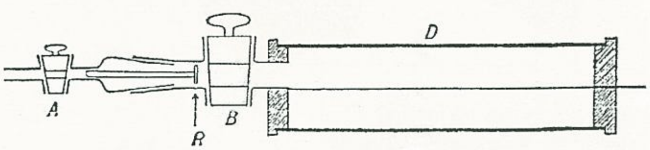


Figure 2: Rutherford-Geiger Tube

This breakthrough marked the first time it became possible to accurately and directly count the number of alpha particles per second emitted from a radium source. In addition, they were able to confirm coincidence between results obtained by a galvanometer and a zinc sulphide screen, which established the much easier scintillation counting method and later became a rite of passage for Rutherford's students, even though he regarded it as a drudge [Dahl, 1999].

In 1928, now in Germany, Hans Geiger and his student Walter Mueller invented the Geiger-Mueller (GM) tube, which was a variation on the Rutherford-Geiger Tube used in 1908. However, it depended on the avalanche mechanism provided by a gas to produce an output as high as in the 20-V range, so as to require little, if any, amplification for some events [Halliday, 1950].

The invention of the GM tube placed the art of electrical particle detection at the forefront of techniques but the zinc sulphide screen remained popular at the Cavendish Laboratory for many more years beyond 1928, when the Canadian B. W. Sargent, as a new student, entered the laboratory practice training course known as the Nursery, which included scintillation counting and glass blowing [Brown, 1997].

3. Middle Era – Electronics

Further progress in particle counting methods had to wait for the electronic vacuum tube amplifier to be developed, which was capable of amplifying the "kicks" to useful levels. Tube technology began with the simple diode and developed rapidly, eventually leading to the sophisticated pentode, which solved the remaining amplification shortcomings.

3.1 Vacuum tubes

It was found that by inserting a control element, that is a grid, within a diode tube, a small change in grid voltage would result in a large change in voltage output. The first practical tube was the triode invented by Lee de Forest in 1907, which was improved by Irving Langmuir in 1915. Then followed steady progress by Walter Schottky, who developed the tetrode in 1919, and Bernard Tellenger, who produced the pentode in 1928 [Antebi, 1982].

In the meantime, in 1919 Rutherford moved to Cambridge University, which under his direction became the pre-eminent nuclear science research institution in the world, with many breakthrough discoveries to its credit, including the neutron, artificial radioactivity, and splitting the atom. With the constant improvements in vacuum tubes, radio science had spread quickly and attracted many enthusiasts, including Wilfred B. Lewis, who remained at Cambridge after having graduated in 1930. He later earned a doctorate and stayed on to do research work in the Cavendish Laboratory. Lewis was, in reality, an electrical engineer, who with C.E. Winn-Williams applied vacuum tube technology to nuclear research and was able to push particle counting to a new level [Fawcett, 1994].

The state of the art of particle counting at the time can be gauged from the book Electrical Counting [Lewis, 1943]. It is possible to see the beginnings of the application of digital technology in it, through the frequent use of the Eccles-Jordan flip-flop (invented in 1920) for information storage and for dividing down the detected pulses prior to display by rather speed-limited electromechanical counters.

In 1939 came the discovery of nuclear fission, by Otto Hahn, Lise Meitner and Fritz Strassmann at the Kaiser-Wilhelm Institute for Chemistry in Berlin. Ideas for practical access to nuclear energy began to take shape soon after.

When the Second World War started, serious effort began in the UK and the US on research into the possibility of using nuclear weapons in the conflict. A collaboration in the area began but it did not progress well and the UK decided to move most of its nuclear war work to Canada, which appeared to provide a safe haven and more resources. Eventually, there was a collaboration between the UK, the US and Canada, which resulted in the formation of the National Research Council's Montreal Laboratory (ML), which existed from 1942 until 1952, when it was transitioned into the Atomic Energy of Canada Limited (AECL), a Crown corporation.

3.2 The "kicksorter"

"One of the most remarkable instruments used in conjunction with an ionization chamber and linear amplifier for alpha-particle counting is the pulse analyzer, sometimes familiarly known as a kicksorter. It consists of a number of electronic circuits permitting only the passage of pulses exceeding a certain minimum, ..., and then sorting them and counting them according to size. In this way the alpha particles originating from several radioelements in a mixture can be counted independently and simultaneously." [Glasstone, 1950].

The electronic kicksorter is an extension of the mechanical version invented by Otto Frisch when he was working at the the Cavendish Laboratory. It worked by rolling ball-bearings into different channels cut into a polystyrene block. Each ball-bearing would be held above the channels until it was 'kicked' by the signal in proportion to signal strength. This mechanical device built up an automatic histogram showing the number of pulses of different energies. A working model can be found at www-outreach.phy.cam.ac.uk/camphy/sweepnik.

The early electronic kicksorters were developed in the UK at Liverpool (Manchester University) and Cambridge, and in Canada at the ML [Laurence, 1980]. The ML developed several electronic kicksorter versions [Freundlich et al., 1947; Westcott, 1945]. The former reference is a complete description of a kicksorter, which is summarized in the paper as follows.

"One method of determining particle energies in nuclear research depends upon the measurement of pulses produced by the particles in an ionization chamber. The Pulse Analyzer is an instrument which analyzes the electrical pulses from the chamber into a number of classes according to their amplitude and hence produces an energy spectrum of the particles. It has the following features: (1) every pulse is counted ensuring the highest accuracy for a given time; (2) some indication of the final result appears while the experiment is in progress; (3) the number of pulses within a certain range is recorded by a mechanical counter, eliminating most of the labor required for obtaining results. ... This analyzer is designed for slowly rising pulses (up to 1 millisecond in duration) and for low counting rates (up to a few hundred per minute). It has 20 identical channels, each channel recording the pulses within an amplitude range that can be varied from 0.1 to 10 volts. ..." [Freundlich et al., 1947].

A block diagram of the kicksorter is given in Figure 3; in detail the design shows very clever use of electronic circuits bordering on digital techniques, exemplified by the then well-established flip-flop circuit for data storage and scaling. Each channel comprised a discriminator, trigger, and extinguishing circuit section followed by a scaling circuit and a mechanical counter. One of the novel features is that the channels are linked in such a way that as the pulse being analyzed rises, the current channel cancels the previous one so that in the end only the peak detecting channel is actually counted and registered by the electromechanical counters. Another novel feature was the use of a type of vacuum tube, known as the "magic eye", to indicate channel activity. This tube was essentially an inexpensive mini-cathode ray tube, used in lieu of an expensive meter movement.

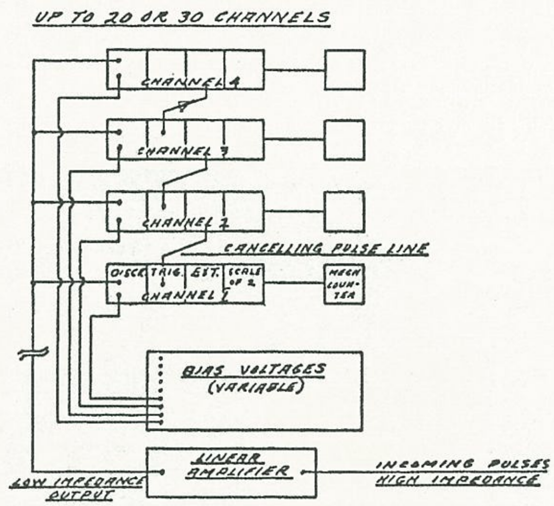


Figure 3: ML 20-channel Kicksorter Block Diagram.

The design was implemented with tubes but although they provided a great advance in speed, they suffered from the disadvantages of high power consumption, unreliability, poor stability, large size and weight, and cooling issues [Eggleston, 1966]. Each channel unit used eight tubes, making a total of 160 tubes for 20 channels, plus four in the discriminator power supply and another four in the input amplifier, for a final total of 168. Thus the power consumption would be in the kilowatt-plus region. The channel hardware was organized into five racks about four-feet high, with the discriminator power supply and input amplifier housed in a separate package. The instrument was usually used with ion chambers developed at the ML and details about their construction and amplification requirements are given in the series of 43 lectures presented by the laboratory staff [Hurst, 1945; Ozeroff, 1945].

The kicksorter was calibrated using a radioactive

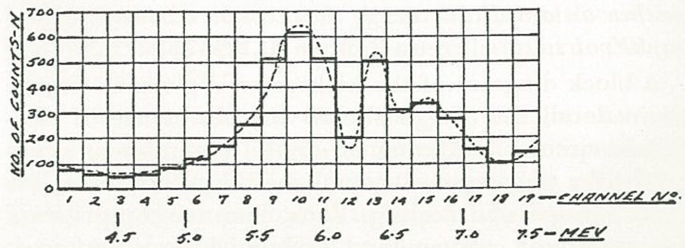


Figure 4: Alpha Spectrum of Ra-225 Products.

source with a known spectrum. When the data from the instrument was compiled from the mechanical counters it was plotted to form spectra, such as the example in Figure 4.

Inspired by the 20-channel kicksorter approach just described, the author and a colleague replicated a working four-channel kicksorter, shown in Figure 5, using the same design principles and about $10-worth of readily available integrated circuits. Complete design details [Arsenault and Hicks, 2013] have been posted to the CNS website at www.cns-snc.ca/cns/history.

One cannot fail to be impressed by the problems overcome by these early instrument designers, compared to the ease of design possible today.

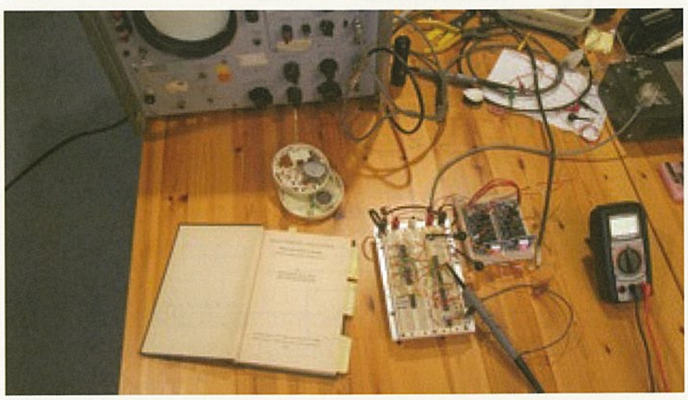


Figure 5: Author's Four-channel Kicksorter In Operation.

Because the kicksorter was such a valuable research instrument, its use spread to universities. A 10-channel model was available in 1952 at the Foster Radiation Laboratory, McGill. In 1954 the Laboratory, under the leadership of R.E. Bell, had developed a 28-channel instrument in a wheeled, six-foot relay rack at a cost of $1500. Each channel used seven tubes and the spectrum could be displayed on an oscilloscope and recorded on a paper chart. This machine provided the data for many theses and papers [Bell, 1981].

3.3 Wilkinson analogue-to-digital converter

The original analogue-to-digital converters (ADCs) in kicksorters were of the direct-conversion type, also known as flash ADCs, which have a bank of comparators and associated components sampling the input signal in parallel, each firing for their decoded range. However, flash converters exhibit drifts and uncertainties associated with their analogue components. In 1950, an ADC was developed by Denys Haigh Wilkinson, a nuclear physicist, which overcame the linearity problems associated with flash ADCs, by essentially eliminating the comparators and associated components. An input signal charges a capacitor for a fixed time, which is then discharged by a constant current while a fast counter, which requires only short-term stability, counts up the address. This type of ADC is more commonly known as a dual-slope ADC and, although not as fast as flash types, superior stability and reasonable speed makes it popular in contemporary instruments [Horowitz and Hill, 1980].

3.4 Transistors

Meanwhile the invention of the transistor, by W. B. Shockley, W.H. Brattain and J. Bardeen at the Bell Telephone Laboratories in 1948, allowed the design of much smaller instruments with many more channels.

In 1955, the Chalk River Nuclear Laboratory (CRNL) began development of a 100-channel, transistorized instrument, as the 20-channel unit then in use (having performed yeoman service) was proving inadequate for some investigations. The unit began working in 1957 and was built from 31 tubes, 170 transistors, magnetic core memory (that had been invented in 1949) used an oscilloscope for a display, and employed a Wilkinson ADC. Physically it was in a 42-inch high rack, weighed 45 lbs and consumed 100 W [Goulding, 1957].

It is interesting to note that CRNL awarded a series of contracts to Computing Devices of Canada (Bell's Corners, Ontario, now General Dynamics Canada Limited), for the production of a large number of instruments between 1957 and 1963. These contracts were vital in allowing the company to expand and diversify to become one of Canada's largest defence/aerospace equipment suppliers [Smillie, 2013].

Commercial instruments began to enter the market and in 1960 the Foster Laboratory purchased a fully transistorized, 256-channel kicksorter known as the TMC-256, from the Technical Measurement Corporation (New Haven, Connecticut), for $17,000. The successor to the TMC-256 at the Laboratory was a 400-channel analyzer from The Victoreen Instrument Corporation (Cleveland, Ohio), known as the Victoreen 400, which employed magnetic core memory. This instrument was advertised for sale in 1963 for $8450 [Bell, 1981].

4. Modern Era – Computers

When the integrated circuit was invented by Jack Kilby in 1958 at Texas Instruments (Dallas, Texas), the revolution began that enabled the introduction of

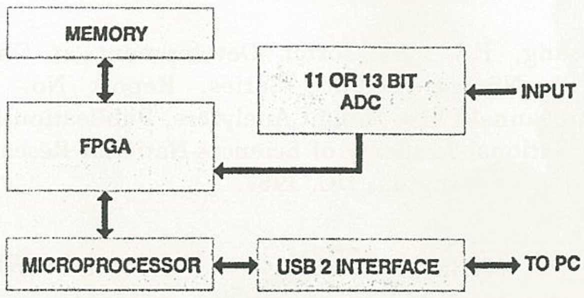


Figure 6: Simplified EASY-MCA Block Diagram.

the many discrete logic families for use in computer design. In 1965 Gordon Moore at Intel (Mountain View, California) formulated Moore's Law, which predicted the doubling of transistor density every year and has proven to be fairly accurate even up to the present. This continuous progression allowed the development of the first microprocessor in 1971 (Intel 4004) and the evolution of computers into their current myriad types, including the personal computer [Jackson, 1997].

4.1 Computer development

When it was realized that kicksorters were, with a few changes, essentially hard-wired computers, the next stage of development was to replace them with programmable computer types. One of the first instances of this took place at CRNL, when AECL purchased a programmable data processor computer, the PDP-1, made by Digital Equipment Corporation (Maynard, Massachusetts), and introduced in 1959. This computer was priced at $120,000 and was comprised of 2700 transistors, 3000 diodes and had 9216 bytes of magnetic core memory that could be upgraded. This particular computer was donated by AECL to Science North at Sudbury, Ontario, but later was scrapped [----, Oct. 2013]. At some point the term 'kicksorter' was replaced with the more sophisticated term, multi-channel analyzer (MCA), which is in common use today.

4.2 Current state

Current state-of-the-art MCAs are available from commercial sources and are implemented using personal computers (PCs). The detector signals to be analyzed are interfaced to the computer using a dedicated plug-in board or by an external unit connected via a USB cable. The installed software interacts with the operating system to display a spectrum in real time.

An example of an advanced PC-based 2000/8000-channel MCA is the ORTEC (Oak Ridge, Tennessee), EASY-MCA-2k/8k unit with MAESTRO software, designed to operate in the Windows 7 and XP environments. This unit is connected to the computer with a USB2 cable and can process conditioned inputs from various detector/amplifier arrangements. Processing control is exercised through screens using a keyboard or a mouse, and measurement results from selected modes are displayed. The units are about the size of a cigar box, weigh 0.6 kg, consume about 5 W and cost $5000/$6500, complete with software. Figure 6 is a simplified block diagram for the ORTEC unit [-----, Feb. 2013].

5. Conclusion

The discovery and measurement of radioactivity has progressed from photographic paper to the personal computer, with many technological breakthrough stages in between. Through the ever-evolving progress of electronic technology, spectrographic measurement of radioactive substances is automatic, fast, accurate, comprehensive and inexpensive.

This article explored one thread of electrical counting and many others have not been taken up. This deficiency is especially true for the detector family, which also includes cloud, bubble, scintillation, photoelectric, and semiconductor types. The most sophisticated detectors today may be found at the European Council for Nuclear Research (CERN), near Geneva, Switzerland, used with very high energy accelerators to confirm the existence of theoretical particles. Complementing these detectors are advanced computers and algorithms capable of processing the enormous amounts of data produced, including data generated in three dimensions.

Regrettably, it appears that no early electrical counting machines have been preserved in Canada. Perhaps this article will alter that.

6. Acknowledgements

The author would like to acknowledge the assistance of Terry Hicks in the design, fabrication and debugging of the 4-channel kicksorter project. Thanks to John Campbell (University of Canterbury, New Zealand) for permission to reproduce the illustration from his lavish book on Rutherford. Thanks to Morgan Brown (AECL), Heather Marshall, John Crawford (McGill), and Mike Attas (AECL) for providing the article by Robert Bell on the history of early kicksorters at McGill; to Andrew Munro (Gamble Technologies Limited) who supplied much up-to-date information on commercial MCAs; and to Ted Clifford (Bubble Technology Industries) for the reference to the 100-channel kicksorter, developed by CRNL. Thanks to the several reviewers of this article: Mike Attas, Fred Boyd, Terry Hicks, Andrew Munro, and Don Wiles. Lyn Arsenault did her usual high-quality editorial work and made this article much better than it was originally. The responsibility for any errors herein is mine alone.

7. References

----, Notes from the Editors: Radio-activity, Ernest Rutherford. Prepared for the 1995 reprint by The Classics of Science Library, Division of Grypons Editions, Delran, New Jersey. 1995.

----, ORTEC EASY-MCA-2k/8k Product Brochure. ORTEC, Oak Ridge, Tenn. 20 February 2013.

----, PDP-1 (Programmed Data Processor-1). en.wikipedia.org/wiki/PDP-1. Accessed 31 October 2013.

Antebi, E. The Electronic Epoch. Van Nostrand-Reinhold, Toronto, Ont. 1982.

Arsenault, J.E. and T.A. Hicks. A Four-channel Digital Kicksorter. Canadian Nuclear Society: cns-snc.ca/cns/history. 15 October 2013.

Bell, R.E. "Elegy for an Electronic Suicide". McGill News, Summer 1981, McGill University, Montreal, Que. 1981.

Brown, A. The Neutron and the Bomb: a biography of Sir James Chadwick. Oxford University Press, Oxford, UK. 1997.

Campbell, J. Rutherford: scientist supreme. AAS Publications, Christchurch, New Zealand. 1999.

Dahl, P.F. Heavy Water and the Wartime Race for Nuclear Energy. Institute of Physics Publishing, Bristol, UK and Philadelphia, Penn. 1999.

Eggleston, W. Canada's Nuclear Story. Harrap Research Publications, London, UK. 1966.

Fawcett, R. Nuclear Pursuits: The scientific biography of Wilfred Bennett Lewis. McGill-Queen's University Press, Montreal, Que. and Kingston, Ont. 1994.

Freundlich, H.F., E.P. Hincks, and W.J. Ozeroff. "A Pulse Analyzer for Nuclear Research". The Review of Scientific Instruments, Vol. 18, No. 2, p. 90-100. February 1947.

Glasstone, S. Sourcebook on Atomic Energy. Macmillan and Co. Limited, London, UK. 1950.

Goulding, F.S. "Kicksorter Development at Chalk River". Nuclear Science Series, Report No. 20, Multichannel Pulse Height Analyzers, Publication No. 447, National Academy of Sciences-National Research Council, Washington, DC. 1957.

Halliday, D. Introductory Nuclear Physics. John Wiley & Sons, Inc., New York, NY. 1950.

Horowitz, P. and W. Hill. The Art of Electronics. Cambridge University Press, Cambridge, UK. 1980.

Hurst, D.G. "Detection of Fundamental Particles by Counting Methods". Lecture No. 16 from Notes on Lectures Given in Montreal Training Course. Public Records Office, Kew, UK. 1945.

Jackson, T. Inside Intel: Andy Grove and the world's most powerful chip company. Dutton, The Penguin Group, New York, NY. 1997.

Laurence, G.C. Early Years of Nuclear Energy Research in Canada. Chalk River Laboratory, Atomic Energy of Canada Limited, Chalk River, Ont. 1980.

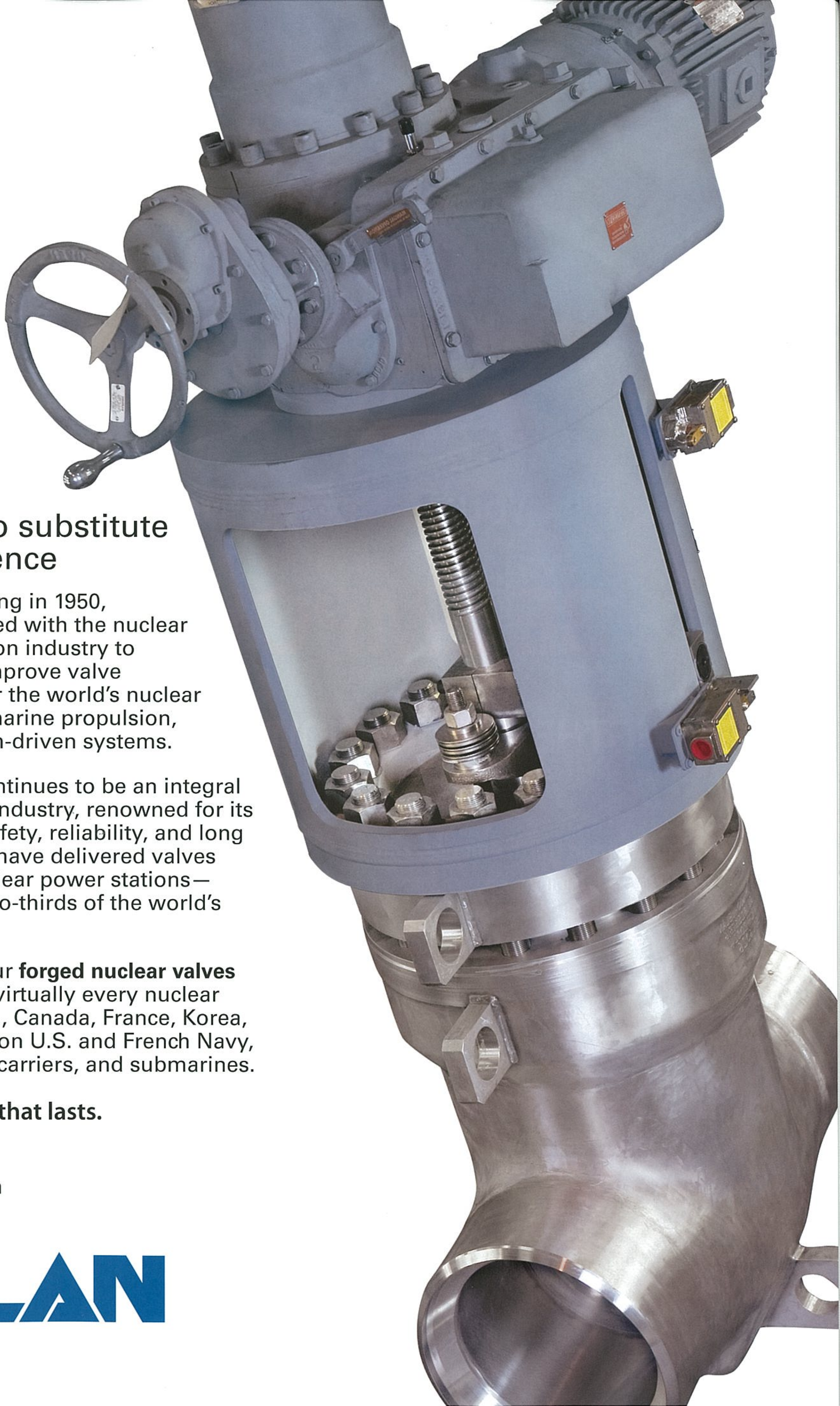
Lewis, W.B. Electrical Counting: with special reference to counting alpha and beta particles. At the University Press, Cambridge, UK and The Macmillan Company, New York, NY. 1943.

Ozeroff, W.J. "Shutoff Amplifiers: purpose and characterizations; pulse amplifiers and counters." Lecture No. 29 from Notes on Lectures Given in Montreal Training Course. Public Records Office, Kew, UK. 1945.

Rutherford, E. Radio-activity. Cambridge University Press, Cambridge, UK. 1904.

Smillie, K. "Computing Devices I." webdocs.cs.ualberta.ca/~smillie/ComputerAndMe/part11.html. Accessed 21 October 2013.

Wescott, C.H. "The 1945 Kicksorter – Preliminary Information". Montreal Laboratory, National Research Council, Montreal, Que. June 22 1945.



Candu Energy Inc. Hosts OCI Suppliers

by KATHERINE WARD

Candu Energy Senior Vice President, Marketing & Business Development, Ala Alizadeh, welcomes the nuclear supply chain to OCI Suppliers Day at Candu.

The weather co-operated in late September when more than 60 members of Ontario's nuclear supply chain set up shop at Candu Energy in Mississauga, Ontario, to network and show off their latest technology and services.

On Thursday, Sept. 26, Candu Energy opened their doors for the exposition, an annual event organized by the Organization of Canadian Nuclear Industries (OCI).

"We look forward to OCI Suppliers Day every year," said Ala Alizadeh, Candu Energy's Senior Vice President, Marketing and Business Development. "It provides us with a way to update our key suppliers and learn about their advances as well."

L-R Ron Moleschi, VP Corporate Development & Major Projects, SNC-Lavalin Nuclear Inc. and Chair of the OCI Board of Directors; Ron Oberth, President, OCI; Ben Lobb, MPP, Huron-Bruce; Rob Burton, Mayor of Oakville; Ala Alizadeh, Senior Vice President, Marketing & Business Development, Candu Energy.

OCI Supplier Day provides an opportunity for suppliers to speak with Candu Energy's engineers, procurement professionals and senior staff. Discussions through the day focused on the latest nuclear technology and services available to Candu Energy. OCI President Ron Oberth noted "OCI companies are proud of their long and successful partnership with the CANDU reactor program and appreciate this opportunity to strengthen and expand this partnership."

Oberth and Alizadeh opened the event with official greetings from Oakville Mayor Rob Burton and Huron-Bruce MP Ben Lobb.

"Candu Energy's value proposition benefits from close partnering with members of the Canadian nuclear supply chain ", said Oberth. " We bring a wide variety of engineering and manufacturing capability to the Candu Energy team along with a willingness to partner with suppliers in offshore CANDU reactor markets."

CANDU reactor new build projects abroad have historically brought a great deal of manufacturing business back to Canada. A 2012 study by the Canadian Manufacturers and Exporters showed the economic impact in Canada of building a 2-unit Enhanced CANDU 6 (EC6) project in the order of $2.57 billion. The study, commissioned by the Canadian Nuclear Association, is available on their website [http://www.cna.ca/wp-content/uploads/CNA-CME-2012-Study-Highlights.pdf]

Justin Hannah, Senior Manager, Marketing & External Relations provided OCI representatives with an overview of Candu Energy's current international marketing efforts, including opportunities for advanced fuels in China and the UK.

This year, OCI also held Supplier Days at Atomic Energy of Canada Ltd., and Ontario Power Generation.

Exhibitors and guests at OCI Supplier Day listen intently to the opening ceremonies.

[Ed. Note: Katherine Ward is Director, Communications at Candu Energy Inc.]

GENERAL news

(Compiled by Fred Boyd from open sources)

Deep Geologic Repository at Bruce

Panel Orders OPG to Answer Key Concerns

On November 8, 2013 the federal panel considering Ontario Power Generation's plan to bury nuclear waste underground near Lake Huron ordered the utility to address key concerns raised during the public hearings held in October. In a letter from the panel chair, Stella Swanson, to Laurie Swami, OPG Vice-President, Nuclear Services, she requested responses to several topics by November 29.

Following is a very short summary of the requests.

Significance of Residual Adverse Effects

The panel ordered OPG to explain how it determined the significance of the DGR's potential effects on the environment.

The panel commissioned a report from Dr. Peter Duinker, an environmental impact assessment expert. His report questioned the "credibility" and "reliability" of the project's environmental impact statement (EIS). Duinker criticized OPG's classifications of 'high,' 'medium' and 'low' environmental impacts, calling them "arbitrary and largely unjustified."

The panel cited Duinker's submission in its written order and asked OPG for a "clear explanation" of what the DGR's environmental impacts would be and the logic used to determine the significance of those impacts.

Geoscientific Verification Plan (GVP)

OPG provided a GVP for conducting additional geologic studies during construction and early operations. The panel wrote the characterization of the site's geology is "extremely limited and will require more extensive evaluation."

OPG is ordered to update plans to verify the site's geology throughout the DGR's construction and operation.

DGR Expansion

The panel ordered OPG provide any existing technical documents and timelines related to the expansion of the DGR to include decommissioned waste from Ontario's nuclear reactors.

The license application to build the DGR only mentions 200,000 cubic metres of waste. But OPG plans to store at least an additional 135,000 cubic metres of decommissioned waste from the Pickering nuclear station after it is mothballed in 2020.

Alternative Means Risk Analysis

The panel ordered OPG provide a renewed analysis of the relative risks of alternatives to the proposed DGR following EIS Guidelines issued by CEAA.

OPG must use "independent risk assessment experts" to study three alternatives: (1) continued storage at the Western Waste Management Facility, already at the Bruce site; (2) constructing "hardened" surface storage; and (3) a conceptual DGR constructed in the granite bedrock of the Canadian Shield.

In the DGR's EIS, the analysis of alternative sites "was limited to locations within the Bruce Nuclear site and a very generic 'off the Bruce nuclear site' location," the panel wrote.

OPG had told the panel it "did not actively solicit other potential host communities or undertake geoscientific studies at other sites" because it required a "willing host community" and the Municipality of Kincardine was the only one to come forward.

The request stated that the panel would determine by Nov. 29 if it requires further submissions from OPG before officially closing the review record.

The panel will then have 90 days to make recommendations to the federal minister of the environment who can then authorize the licence to prepare the site and build the DGR.

For the panel's complete request, visit: http://www.ceaa-acee.gc.ca/050/documents/p17520/96032E.pdf

World Mo 99 production problems

Separate incidents at research reactors around the world (including NRU) interrupted the supply of molybdenum-99 (Mo-99) in November 2013.

In South Africa, production was suspended at the Safari 1 reactor after a release of iodine and noble gas during cleaning processes on November 2. The release, caused in a "very rare combination of circumstances" by a chemical reaction between cleaning materials used in preparation


View of top deck of NRU (Image: AECL Chalk River Laboratories).

for a new production run was "momentary and minimal," according to an update issued on 11 November by South African Nuclear Energy Corporation (Necsa) subsidiary NTP Radioisotopes. Production at the site was halted pending the completion of investigations.

The molybdenum production lines at NRG's Dutch facility were closed November 8 because of concerns over levels of uranium in a liquid waste tank. NRG's High Flux Reactor (HFR) is currently out of service while investigations are ongoing into control rod issues identified in early October. The company subsequently announced that it has launched a "return to service" program that it says will help it to avoid unplanned outages in the future. As part of that process, it is bringing all nuclear facilities and connected processes at its Petten site into a safe shutdown mode which could last up to three months.

At NRU repairs to the flask used to transport fuel rods and other components including Mo-99 rods in and out of the NRU reactor resulted in AECL announcing on November 19 that it would be unable to meet its planned isotope deliveries for the week ending 23 November. Repair activities were started immediately and the company anticipated a return to service within the week.

The fragility of the Mo 99 supply from these aging facilities has prompted efforts to investigate production of Mo-99 via other routes, such as in cyclotrons, as well as efforts to increase capacity at existing suppliers. Australia's OPAL reactor, which started up in 2007, could potentially supply half of the world's demand. Work is currently under way on an expanded molybdenum production facility, with the new capacity due to come online in 2016.

Canada and Kazakhstan Sign Administrative Arrangement

On November 13, 2013, the Canadian Nuclear Safety Commission and the Committee of Atomic Energy of the Ministry of Industry and New Technologies of the Republic of Kazakhstan signed an Administrative Arrangement pursuant to the *Agreement Between the Government Of Canada and the Government Of the Republic of Kazakhstan for Cooperation in the Peaceful Uses of Nuclear Energy.*

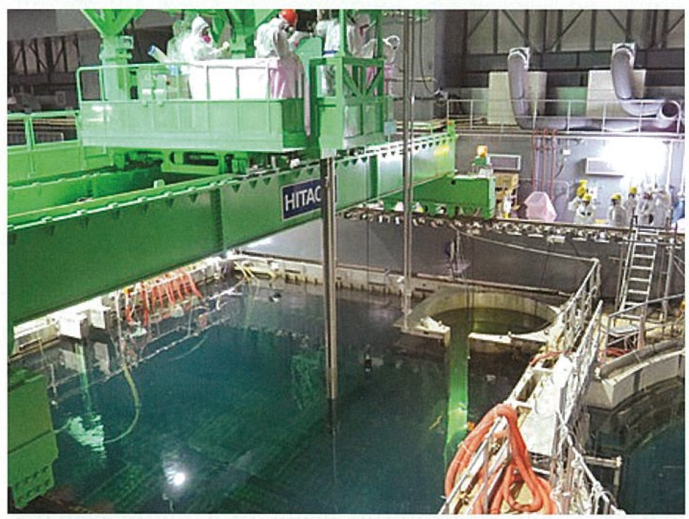
The Agreement and the Administrative Arrangement will allow Canadian companies to export nuclear items for peaceful uses, in accordance with Canada's nuclear non-proliferation policy.

The Administrative Arrangement implements the provisions of the Agreement to ensure the peaceful use of Canadian nuclear items authorized for export to Kazakhstan by the Canadian Nuclear Safety Commission.

The signing of the Arrangement between the Canadian Nuclear Safety Commission and the Committee of Atomic Energy of the Ministry of Industry and New Technologies of the Republic of Kazakhstan reflects the shared commitment by both organizations to work collaboratively to facilitate nuclear cooperation, while maintaining strong and effective non-proliferation standards.

Fuel removal at Fukushima 4

The first four fuel assemblies have been removed from Fukushima Daiichi unit 4's storage pond, marking the start of an operation expected to be completed at the end of next year.



The work employs the same equipment and procedures as seen routinely at normal nuclear power plants (Image: Tepco)

After completing trials using dummy fuel, Tepco reported that preparations for the removal of the first actual assembly began Nov. 18. A fuel transport container was moved from a temporary storage location on the fifth floor of unit 4's reactor building to the fuel storage pool using the main crane.

The smaller refuelling crane was started up, marking the start of the fuel removal process. Tepco completed the removal of the first 22 unused fuel assemblies within the next two days.

When the container is full it will be sealed, lifted from the water by the main crane, placed on the service floor for decontamination and then taken through a special route to a vehicle that will move it across the site to be unloaded at the site's shared storage facility. This process will be repeated until the pool is empty. Two containers will be used in relay.

With a total of 1533 fuel assemblies in the pool (1331 used, 202 unused) the whole fuel removal operation is expected to take until the end of 2014.

Tepco will move the fuel during the day and clean dust and debris from the pool water during the night.

Unit 4 was off line for maintenance at the time of the 2011 accident with its full core load of fuel, as well as used fuel from previous operation, stored in a fuel pool at the top of the reactor building. Although this meant there was no possibility of a reactor accident at unit 4, there was a risk of the pool overheating. The stability of the pool was then reduced by major structural damage to the building caused by the ignition of hydrogen that leaked through ventilation systems shared with unit 3.

The building has since been reinforced, and thousands of tonnes of debris and rubble have been removed from its roof. A new cover has been constructed with all the fuel handling equipment of a normal nuclear power plant and inspections of the pool have shown the fuel to be undamaged and not suffering from corrosion.

Engineering Contract For Accelerator-Driven Reactor in Belgium

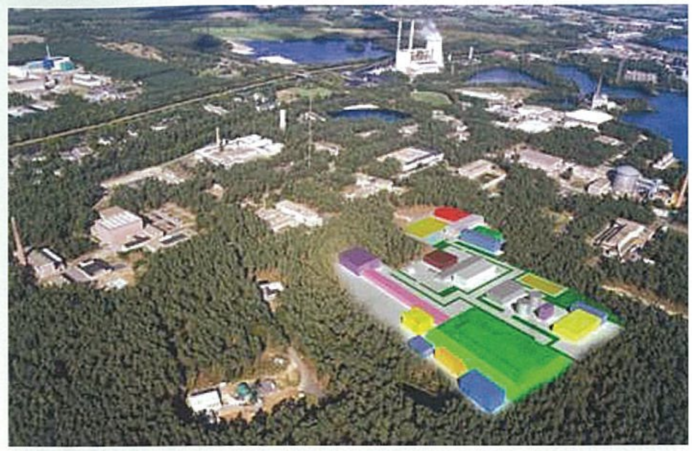
Belgium's SCK-CEN has awarded a Ð24 million ($32 million) contract for front-end engineering design for the **Myrrha** accelerator-driven research reactor to a multinational consortium led by Areva.

The consortium of France's Areva TA, Italy's Ansaldo Nucleare and Spain's Empresarios Agrupados was chosen after a two-year selection procedure.

Myrrha - Multipurpose Hybrid Research Reactor for High-tech Applications - will be a 57 MWt accelerator-driven system (ADS) in which a proton accelerator will deliver a 600 MeV proton beam to a liquid lead-bismuth (Pb-Bi) spallation target that is in turn coupled to a Pb-Bi cooled subcritical fast nuclear core.

It is intended to replace Belgium's ageing BR2 research reactor, and will be used in a range of research functions including the demonstration of the concept of transmutation of long-lived radionuclides in nuclear waste, as well as producing radioisotopes for medicine. The project forms part of the European Strategy Forum on Research Infrastructures (ESFRI), and is one of three new research reactors forming the cornerstones of the European Research Area of Experimental Reactors (ERAER), alongside the Jules Horowitz Reactor at Cadarache in France and the Pallas reactor at Petten in the Netherlands.

The reactor and accelerator have been designed by



How Myrrha is envisaged at SCK-CEN's Mol site (Image: SCK-CEN)

SCK-CEN, but the contract awarded to the consortium covers everything that is not part of the SCK-CEN specialisations. It covers the technical design of all elements of the infrastructure of the first-of-a-kind plant, including buildings, cooling systems and instrumentation and control for the reactor and the particle accelerator. Its scope includes estimating the investment and operation costs for the reactor, validation of performance objectives, preparation for obtaining an operating licence and the definition of a detailed project schedule.

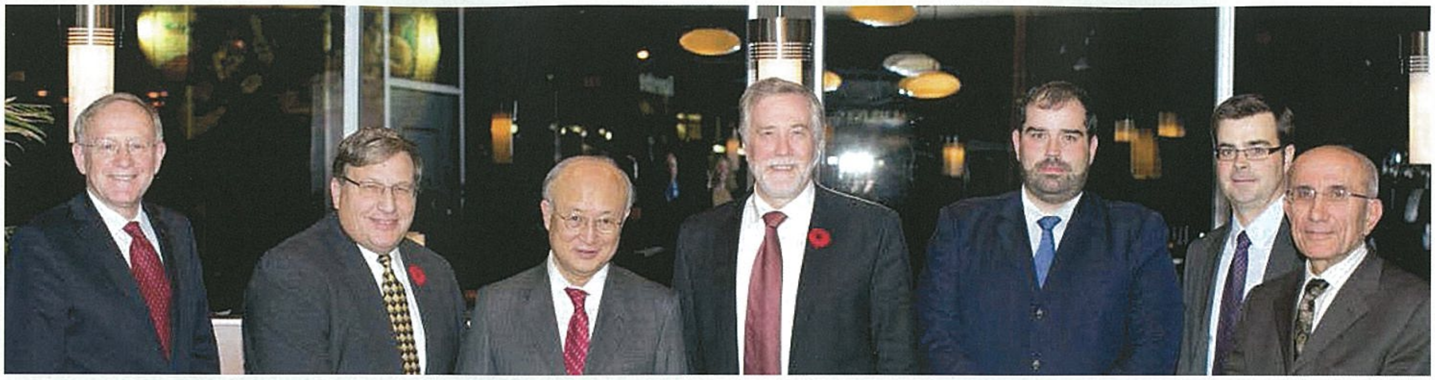
Once the contract has been completed the project will be ready to begin construction, SCK-CEN says. Myrrha is expected to enter service in 2024-25.

[Ed. Note: A somewhat similar concept was proposed by Dr.W. B. Lewis, Vice-President of AECL in the 1960s, as a means of achieving a higher flux than obtainable in NRX or NRU. Considerable engineering was carried out at CRNL. However when the plan was presented at a special symposium in 1965 university researchers were quite negative. It was conditionally approved by the newly created Science Ccouncil in 1967 but cancelled by the Trudeau government in 1968.]

IAEA DG Amano Visits Canada

CNA President John Barrett hosted a dinner on November 3 for International Atomic Energy Agency Director-General Yukiya Amano and executives from CNA member companies plus CNA staff. DG Amano, who was en route to New York to address the UN General Assembly, was in Canada for the first time in his 4-½ years as IAEA DG.

The discussion covered a range of nuclear technologies and the full nuclear fuel cycle from mining to repositories. DG Amano showed particular interest in Canadian technology for removal of tritium from water. Dealing with contaminated water is currently a key issue in managing Fukushima Daiichi, especially for its impact on political and international perceptions. DG Amano also revealed wide-ranging interests in other nuclear technologies, such as the under-applied potential for nuclear medicine to save lives in



John Barrett (CNA), Tom Mitchell (OPG), Yukiya Amano (IAEA), Bob Walker (AECL), J.F. Beland (Areva), Mark Ward (GE), Ala Alizadeh (Candu).

the developing world.

Among the leaders of CNA companies at the dinner were: Ala Alizadeh of Candu Energy; Tom Mitchell from Ontario Power generation; Bob Walker of Atomic Energy of Canada Limited; J.F. Beland of Areva Canada and Mark Ward of GE Hitachi.

CNSC Invites Comments on Amendments to Regulations

The Canadian Nuclear Safety Commission (CNSC) is asking the public to provide their comments on draft discussion paper DIS-13-02, *Proposed Amendments to Regulations Made under the Canadian Nuclear Safety and Control Act.*

DIS-13-02, seeks feedback from licensees, the Canadian public and other interested stakeholders on the CNSC's proposal to amend several regulations, including:

- the *Class I Nuclear Facilities Regulations*,
- the *Class II Nuclear Facilities and Prescribed Equipment Regulations*,
- the *General Nuclear Safety and Control Regulations*,
- the *Nuclear Substances and Radiation Devices Regulations*, and
- the *Uranium Mines and Mills Regulations*

These amendments are proposed in part to respond to recommendations made by the CNSC Fukushima Task Force; while other suggested changes would help to further strengthen and clarify the CNSC's regulatory framework.

To review and comment on the document, visit the DIS-13-02 Web page.

Feedback deadline is January 20, 2014. Comments submitted, including names and affiliations, are intended to be made public.

CSA Nuclear Standards Available Online

The Canadian Nuclear Safety Commission (CNSC) is pleased to announce that the CSA Group is now offering complimentary access of their nuclear standards. This new access platform allows interested stakeholders to view these standards online through any device that can access the internet. Please note that the access platform is limited to read only.

Domestic and international standards, in particular consensus standards produced by the CSA Group, are an important component of the CNSC regulatory framework. Standards support the regulatory requirements established through the NSCA, its regulations and licences by setting out the necessary elements for acceptable design and performance at a regulated facility or activity. Standards are one of the tools used by the CNSC to evaluate whether licensees are qualified to carry out licensed activities.

To view access platform please visit: https://community.csagroup.org/community/nuclear

For additional information, visit the CNSC Web site at nuclearsafety.gc.ca

CSA Approves Two New Nuclear Standards

In early November 2013, the Canadian Standards Association (CSA) formally approved two new nuclear standards:

N290.1	Requirements for the shutdown systems of nuclear power plants
N290.11	Requirements for reactor heat removal capability during outage of nuclear power plants

The one on shutdown systems replaces one that was issued in 1980. While the earlier one was based on the CANDU design, the new one has been prepared to be technically neutral.

Both standards will be available in print or electronic format in December, 2013.

Jerry Cuttler, a past-president of the CNS was the chairman of the committee that prepared the new N290.1.

The CSA is now inviting comments on a revision to N294.09 Decommissioning of facilities containing nuclear substances. If interested go to the CSA website.

Four Communities Advance in NWMO Site Selection

The Nuclear Waste Management Organization has announced the results of its first phase of preliminary assessments in its program to selection a site for the proposed Deep Geologic Repository for spent nuclear fuel.

Eight applicant communities were reviewed with four being chosen for the next phase of the selection process.

The four chosen are: Creighton in Saskatchewan and three communities in northern Ontario: Ignace; Hornepayne and Schreiber.

Eliminated were: English First River and Pinehouse in Saskatchewan; and Ear Falls and Wawa in Ontario.

NWMO notes that findings to date have not confirmed the suitability of any site. Further, no community has expressed willingness to host the project at this early point in the site evaluation process.

Work is proceeding with 13 other communities that are involved in earlier stages of the process.

NWMO emphasized that with 21 communities exploring potential interest and suitability for hosting the project, the siting process must provide a basis to progressively narrow the focus to communities with strong potential to meet requirements until a single preferred site and area is identified.

Those identified to continue for more detailed study appear to have a strong potential for meeting strict safety and geotechnical requirements, and for the project to align with their long-term community vision.

USNRC Resumes Review of Yucca Mountain

On November 19, 2013 the United States Nuclear Regulatory Commission (USNRC) directed its staff to complete work on the safety evaluation report (SER) for the Yucca Mountain geologic repository.

As well as instructing its own staff to complete work on the SER, the NRC requested the Department of Energy (DoE) to prepare a supplemental environmental impact statement (SEIS) to enable the completion of the environmental review of the application to build the Nevada facility.

The DoE's application to build and operate the USA's first permanent repository for the disposal of used nuclear fuel and military high-level wastes was lodged in 2008, but the regulator suspended work on reviewing the application following a 2009 decision by the US administration to abandon the project. The NRC is resuming the review following an August 2013 ruling by the US Court of Appeals that it had acted illegally in abandoning the project, for which it had in hand some $11 million of appropriated funds.

The NRC review initiated in 2008 comprised two concurrent processes: a technical review by NRC staff and an adjudicatory hearing before an NRC Atomic Safety and Licensing Board (ASLB) panel to consider third-party technical and legal challenges against the project. The adjudication process is still held in abeyance, but the NRC has ordered staff to load documents gathered by the adjudicatory hearing's licensing support network (LSN) into the ADAMS online database. Documents referenced in the SER and SEIS will be publicly released, although the release of all the LSN documents "will depend on whether adequate funds are available," the NRC said.

Damages for Yankee trio

Meanwhile, a court has awarded over $235 million of damages to three utilities affected by federal failure to fulfil used fuel disposal commitments.

The NRC announcement comes as a US court awarded three utilities known as the Yankee Companies over $235 million in combined damages for the US government's failure to meet its used fuel obligations. All three of the utilities' nuclear power plants have now been decommissioned, but the failure of the federal government to remove used fuel and other high level wastes has seen the utilities forced to continue to store the materials on site. The court award was slightly less than the $247 million sought by the utilities.

NRCan to Expand Study

Natural Resources Canada (NRCan) has contracted consulting firm KPMG to expand on a study initiated by CNA in 2011. KPMG will study the contribution of Canada's nuclear science and technology (S&T) capabilities to Canada's economy, job market and broader innovation system. The objectives are to (1) characterize how these capabilities generate cross-sectoral economic growth and innovation, and (2) to describe how nuclear S&T contributes to broader innovation outcomes. This will build on work done for CNA by SECOR (since acquired by KPMG) which mapped the spending and stakeholder relationships in Canada's nuclear S&T ecosystem. NRCan now wants to look more closely at non-energy aspects of nuclear technology (such as medicine, food safety, and materials science).

Canada joins International Convention on Nuclear Liability

On December 3, 2013, Lynne Yelich, Minister of State (Foreign Affairs and Consular) announced that Canada has signed the *Convention on Supplementary Compensation for Nuclear Damage*, bringing the treaty another step closer toward full ratification. She made the announcement during a signing ceremony in Vienna alongside Alexander Bychkov, the International Atomic Energy Agency (IAEA)'s Deputy Director General and Head, Department of Nuclear Energy.

Joining the IAEA convention complements new measures that the Government of Canada will introduce in Parliament in the coming months to strengthen Canada's nuclear liability legislation. The replacement of the *Nuclear Liability Act* with stronger, up-to-date legislation is the final element in creating a modern nuclear legislative framework for Canada, following enactment of the *Nuclear Safety and Control Act* and the *Nuclear Fuel Waste Act*.

In Ottawa, Joe Oliver, Minister of Natural Resources, commented that the government will soon introduce legislation to increase absolute nuclear civil liability to $1 billion.

Chernobyl Fuel Transferred

The transfer of undamaged used fuel to an on-site interim storage facility from units 1 to 3 of the Chernobyl nuclear power plant in Ukraine has now been completed.

Used nuclear fuel from Chernobyl 1, 2 and 3 has been progressively removed from plant cooling ponds and the reactor cores as part of an overall decommissioning program, separate from dealing with the destroyed unit 4. During the entire operation of the Chernobyl plant, more than 21,000 used fuel assemblies accumulated at the site.

The Chernobyl plant

On 28 September, the final undamaged used fuel assembly from unit 1 was transferred to one of the five compartments in the cooling pool of the existing wet-type interim storage facility 1 (ISF-1). Since December 2011, a total of 1333 used fuel assemblies were transferred from the unit. The transfer of all undamaged fuel from unit 3 to ISF-1 was completed in September 2010, while the last from unit 2 was moved in November 2012.

Workers continue to address the issue of removing some damaged fuel assemblies which remain in units 1 and 2, the plant said, without specifying the nature of the damage or the number of assemblies remaining.

ISF-1 was commissioned in 1986, but its existing design does not allow for the storage of all the used fuel assemblies. A dry-type interim fuel storage facility (ISF-2) is under construction by US-based Holtec International under a contract signed with Ukraine in September 2007. Once completed in 2015, it will be used to store all the used fuel on the site for at least 100 years.

On 26 April 1986, a power runaway event in Chernobyl unit 4 wrecked the reactor, leading to a hydrogen explosion that destroyed the reactor building and exposed the radioactive remains of the reactor core. The three remaining reactor units, however, were vital to Ukraine's electricity needs and continued to operate for some years. Unit 2 shut down in 1991, unit 1 in 1996 and unit 3 in 2000.

Canadian Nuclear Partners new website

Canadian Nuclear Partners (CNP), a wholly owned subsidiary of Ontario Power Generation, launched a new website in November 2013.

CNP is a committed, full service provider who will safely deliver improved performance in many areas of nuclear, hydroelectric and thermal electricity generation.

The company offers expertise in the following areas:

- Project management to provide turn-key services;
- Leadership in nuclear, hydro and thermal plant operations;
- Strategic leadership in operations and decision-making;
- Nuclear regulatory and licensing;
- Work management and outage management.

Its aim is to establish long-term relationships with customers by providing good value and by working to meet agreed goals and targets. CNP experts are experienced in operating nuclear, hydro and thermal plants.

The web address is: canadiannuclearpartners.com

First Meeting of Canada-India Joint Committee

On November 30, the CNSC participated in the first meeting of the Joint Committee established under the India-Canada Nuclear Cooperation Agreement. On this occasion, Joint Committee members were able to share information and ideas to further improve technical and regulatory nuclear cooperation. This includes an agreement to establish a Memorandum of Understanding between the CNSC and Indian authorities in order to facilitate the exchange of regulatory experience.

The meeting was held on the margins of the India Nuclear Energy Summit 2013, which was attended by a delegation of Canadian business and government representatives, including the Honourable Lynne Yelich, Minister of State (Foreign Affairs and Consular).

"The Canada-India Nuclear Cooperation Agreement and Appropriate Arrangement, which entered into force in 2013, mark the two countries' shared commitment to expanding cooperation in the nuclear sector in a safe and secure manner, under International Atomic Energy Agency safeguards," said CNSC President Dr. Michael Binder.

The CNSC regulates the use of nuclear energy and materials to protect the health, safety and security of Canadians and the environment, and to implement Canada's international commitments on the peaceful use of nuclear energy.

CNS news

Special General Meeting

On Sunday, November 3,2013, the Canadian Nuclear Society held a Special General Meeting of the Membership. The meeting, held at the Toronto Downtown Renaissance Hotel, had two purposes.

The first was to accept the report of the Auditors for 2012, which was not ready for the Annual Meeting held in June. The second purpose of the Special Meeting was to approve new By-Laws for the Society.

In 2010, the Government of Canada passed a new Not-For-Profit Corporations Act, replacing the previous statute found within the Canada Corporations Act. All not-for-profit corporations such as the CNS were given until the end of 2014 to be in full compliance with the new statute.

Changes were required to the existing CNS by-laws, because some past practices such as ex-officio appointments to Council or multiple classes of members with different membership rights were no longer allowed.

In consultation with legal advisors, the CNS drafted a new set of by-laws for consideration by the Membership. Also for approval by the Membership were documents called Application for Continuance, which in essence allow the CNS to move from governance under the old statute to the new.one

Both the Application for Continuance and the new draft by-laws were approved by the membership at the Special Meeting.

Jerry Cuttler Named to INEA

At a special meeting of the International Nuclear Energy Academy (INEA), held November 12, 2013, during the Winter meeting of the American Nuclear Society in Washington, D.C. **Jerry Cuttler**, a former president of the Canadian Nuclear Society (and still active member) was inducted as a member of the prestigious society.

INEA is an honour society of the international nuclear scientific and engineering community. The objective of the INEA is to foster the development and utilization of the peaceful application of nuclear energy in a safe and economic manner through-out the world. INEA, being a learned association, can keep a scholarship character in all its activities.

It was founded on 22 June 1993 by the International Advisory Committee - IAC, a group of international nuclear experts associated with the International Atomic Energy Agency. It has more than 100 experts as its international members in the nuclear energy fields and holds the Non-Governmental Organization Status of IAEA.

INEA conducts studies, discussions, and develops recommendations for the international nuclear community on generic issues relevant to nuclear energy matters.

Dan Meneley, also a past-president of the CNS is a member of the INEA executive committee and a former chair of that group.

Meeting with Delegation from Finland

A delegation of fifteen members from Finland's nuclear industry and government visited nuclear sites in Canada in September-October. Among the sites visited were Darlington and McMaster research reactor. The Canadian Nuclear Society hosted a dinner for the Finnish delegation at Mandarin restaurant in Mississauga on their last night in Canada. On conclusion of the dinner, CNS President Adriaan Buijs gave the Finnish delegation leader Mr Juhani Palmu a small memento for their Canadian visit.

Adriaan Buijs, CNS President presents a small gift to Juhani Palmu, representing a delegation from Finland, at a farewell dinner in early October 2013.

News from Branches

Ed. Note: This article is based on reports from Branches in late October and consequently does not include events held after that time.

BRUCE – John Krane

The CNS Bruce Branch hosted, in partnership with Bruce Power, a delegation from the Finnish Nuclear Society. The delegation was given an in-plant tour of Bruce A followed by a lunch reception at the Bruce Power visitor Centre. CNS past president, John Roberts, also attended.

CHALK RIVER – Ruxandra Dranga & Bruce Wilkin

Speakers:

- **October 15th** - The Chalk River Branch held its Annual General Meeting, followed by a talk by Dr. John Root, titled *"How NRU Delivers Value to Canada Through Materials R&D with Neutron Beams"*.
- Scott Read was elected as the new Chair of the Branch.

The new branch executive committee includes:

Chair	Scott Read
Past Chairs	Ruxandra Dranga and Bruce Wilkin
Treasurer	Tracy Pearce
Secretary	Ken McDonald
Program Coordinator	Geoff Edwards
Membership Committee	Kannan Krishnaswamy
Communications	Jeremy Pencer
RP Program @ Algonquin College	Bruce Wilkin
High School Liaison	Karthik Kannan (to renew membership)
Members at Large	Laura Blomeley, Dan Campbell, Ruxandra Dranga, Bruce Wilkin
NRU Utility Rep	Masih Balouch

- **November 6** – A joint CNS and WiN meeting is scheduled with Rose-Marie Dolinar speaking on- *"Increasing awareness and decreasing fear: response to radiation exposure incidents by emergency personnel"*.

Education and Outreach:

- On **October 18th**, Ruxandra Dranga participated, as a judge and witness, for the Largest Practical Science Lesson, a Canada-wide science activity which is part of National Science and Technology Week.

DARLINGTON Branch – Jacques Plourde

The merger of Darlington & Pickering Branches to form Durham Branch is pending, Leon Simeon to provide a report for Durham Branch, and update the status of the merger.

OTTAWA – Mike Taylor

The Ottawa Branch has not yet started its program for this season and is in the process of changing Chairs. The new executive will be announced in the next report.

WESTERN Branch – Jason Donev

1) **A** partial executive meeting was held August 20th in Saskatoon to discuss our goals and directions.
2) Hosted Dr. John Roberts from the University of Manchester at the **August 21st** in Saskatoon SK.
3) We are now established as a joint branch covering AB, BC, SK and the territories. We are currently in the process of:
   a. Exploring opportunities for outreach and education opportunities, first to engage the branch's membership and then look at broader public engagement:
   b. Speakers Series delivered by webinar, with Jerry Cuttler as our first speaker on radiation hormesis.
   c. Exploring opportunities for First Nation and Northern engagement
   d. Creating and delivering a nuclear and radiation awareness professional development session for science teachers
   e. Have started reaching out to pools of potential members such as uranium mining companies, as well as CNS members who have claimed a past affiliation with one of the branches that are now encompassed by the Western Branch
4) We are creating a nuclear and radiation awareness professional development session for science teachers, to be offered for delivery at professional development institutes and subject conferences (i.e. Sciematics in SK)
5) Shaun Ward, Aaron Hinman and Rob Varty are all preparing to go to the Alberta Teacher's association conference in Edmonton.
6) Gary Lewis attended the screening of Pandora's Promise in Saskatoon and presented nuclear information.

"Badge-Draw" Winners at the 2013 Oct. 28-30 CNS CANDU Technology & Safety Course

At the end of the CNS CANDU Technology & Safety Course, on Oct 30, 2013, 8 prizes were awarded by random draw from among badges returned by Course attendees.

The winners:

- Bartek Rzentkowski, of Candesco, and Changqing Zhang, of AECL, each won a CNS membership valid to end of December 2014.
- Kevin Cabral and Shahab Dabiran, both of Candu Energy Inc., James Gandhi, of Aecon Industrial, Bryan Hudson, of Ryerson University, Derek Leung, of Ontario Power Authority and Neal Tanaka, of Lakeside Process Control, each won a CNS sweatshirt.

Congratulations to all the winners!

Gagnants de prix au tirage des porte-insignes au cours de la SNC sur la technologie et la sûreté des réacteurs (du 28 au 30 octobre 2013)

À la fin du cours sur la technologie et la sûreté des réacteurs, le 30 octobre 2013, 8 prix ont été tirés au sort parmi les porte-insignes retournés par les participants du cours.

Voici les gagnants :

- Bartek Rzentkowski, de Candesco, et Changqing Zhang, de l'EACL, ont chacun gagné une adhésion gratuite à la SNC, valide jusqu'à la fin de décembre 2014.
- Kevin Cabral et Shahab Dabiran, tous deux de Candu Energy Inc., James Gandhi, de Aecon Industrial, Bryan Hudson, de Ryerson University, Derek Leung, de Ontario Power Authority et Neal Tanaka, de Lakeside Process Control, ont chacun gagné un chandail sport de la SNC.

Félicitations à tous les gagnants!

CNS at International Meetings

Representatives of the Canadian Nuclear Society participated in meetings of two international organizations in early November.

Meetings of both the Pacific Nuclear Council (PNC) and the Interntional Nuclear Societies Council (INSC) held their bi-annual meetings during the Winter Meetng of the American Nuclear Society held in Washington D.C. November 10-14, 2013.

Fred Boyd and Ben Rouben are the CNS official representatives to these two international organizations. Frank Doyle, as chair of the PBNC 2014 also attended to invite members of all of the organizations represented to attend that conference in Vancouver next August. In addition he held a special meeting of representatives of country organizations who have indicated their participation in PBNC2014.

A number of other active CNS members attended the ANS meeting, including past presidents Jerry Cuttler and Dan Meneley and chair of the CNS Fusion Division, Blair Bromley.

During the summer the Chalk River Branch joined with the Deep River Science Academy to present a series of lectures. This photo is from the one given on July 18 by Peter Lang.

From left to right: Bruce Wilkin, Ruxandra Dranga, Peter Lang (speaker), Geoff Edwards, and Bryan White.

10th International Conference on CANDU® Maintenance

Metro Toronto Convention Centre, Toronto, Ontario, Canada
May 25-27, 2014

CMC 2014 will bring together subject matter experts from Operating Utilities and Service Providers under the banner of CANDU® Maintenance, with the objective of ***Revamping the Technical Strength of Our Industry.***

Four key drivers to achieve and sustain high performance will be the primary focus of the Plenary and Technical streams: Policy and Vision, Equipment and Reliability, Processes and Tools, and People and Skills.

Bruce Power

Policy and Vision

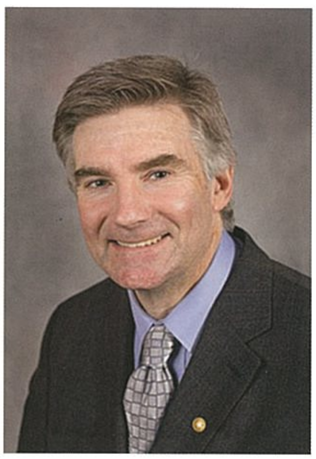
Led by Bruce Power

Gary Newman
Chief Engineer and Vice-President of Engineering, Bruce Power

Ontario Power Generation

Plant Equipment and Reliability

Led by Ontario Power Generation



Mark Elliott
Senior Vice President and Chief Nuclear Engineer, Ontario Power Generation

Énergie NB Power

Processes and Tools

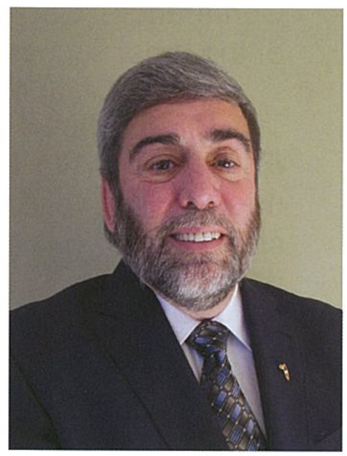
Led by NB Power

Alnoor Bhaloo
Chief Nuclear Engineer and Engineering Director, NB Power

Canadian Nuclear Society® Société Nucléaire Canadienne

People and Skills

Led by Canadian Nuclear Society, NOM Division



Jacques Plourde
Chair, CNS Nuclear Operations and Maintenance Division

Register to Participate – to network with participants and renew or establish new industry contacts

Provide Sponsorship – to become recognized as a "Leader of the Industry"

Book a Trade Show Booth – to showcase your company's products and services

For all details go to

www.cmc2014.org

Revamping the Technical Strength of Our Industry

Canadian Nuclear Society® Société Nucléaire Canadienne

Hosted by the Nuclear Operations & Maintenance Division (NOM) of the Canadian Nuclear Society

PBNC-2014 Updated Conference Announcement

PBNC-2014

Vancouver, British Columbia, Canada

2014 August 24-28

The Canadian Nuclear Society, the Canadian Nuclear Association, and Natural Resources Canada, in collaboration with the International Atomic Energy Agency, are proud to host the 19th Pacific Basin Nuclear Conference (PBNC-2014) August 24-28, 2014, in Vancouver, Canada, under the aegis of the Pacific Nuclear Council.

The Pacific Basin Nuclear Conference (PBNC) held biannually, is the premier global nuclear conference and exhibition bringing together senior industry executives, senior government officials, international energy organization leaders, and technical experts from the Pacific Rim and Europe. 500-600 Delegates are anticipated for the Conference. Canada previously hosted this conference at Banff, Alberta in 1998 – one of the most successful PBNCs. The most recent PBNC 2012 was held in South Korea.

The Conference Theme is "***Fulfilling the Promise of Nuclear Technology around the Pacific Basin in the 21st Century".*** PBNC-2014 will: (i) showcase the advancement of nuclear technology in power generation, health science, and environmental stewardship; (ii) discuss challenges facing nuclear technology; and, (iii) highlight future developments.

The conference includes Keynote Speakers, Plenary Sessions, Technical Paper Presentations, and Conference Exhibits. Also embedded in the Conference is the CNS/CNA Student Conference.

Plans have progressed well for PBNC-2014.

Many international and Canadian speakers have agreed to participate in the Plenary and Key Note Speaker Program. More than 300 abstracts from a number of countries have been received for the technical program. A number of sponsors and exhibitors have already registered..

Visit the web site http://pbnc2014.org to participate in the Program.

Calendar

2014

Feb. 26-28 — **CNA Nuclear Industry Conference and Tradeshow**
Westin Hotel, Ottawa, ON
website: www.cna.ca

Apr. 27-30 — **Canada - China Conference on Advanced Reactor Development**
Niagara Falls, ON
website: www.cns-snc.ca

May 4-6 — **NEO 2014 Nuclear Education and Outreach**
Hamilton, ON
website: www.cns-snc.ca

May 25-27 — **10th International CNS Conference on CANDU Maintenance**
Metro Convention Centre
Toronto, Ontario
website: cns-snc.ca

June 15-19 — **American Nuclear Society - Annual Conference**
Reno, NV, USA
website: www.ans.org

Aug. 24-28 — **19th Pacific Basin Nuclear Conference**
Hyatt Regency Hotel,
Vancouver, BC
website: www.cns-snc.ca

Sept. 28-Oct. 3 — **Physor 2014**
Kyoto, Japan
For information: CNS office
cns-snc@on.aibn.com

Oct. 26-31 — **Nuclear Plant Chemistry Conference 2014 (NPC-2014)**
Sapporo, Japan
website: www.npc2014.net

Nov. 9-13 — **American Nuclear Society - Winter Meeting**
Anaheim, California
website: www.ans.org

The Ontario government announcement of plans for Ontario's electricity system on December 3, 2013 confirmed that the refurbishment of the Darlington NGS, shown in this aerial view, will proceed.

Snow Country for Old Men

by JEREMY WHITLOCK

This Christmas marks the 75th anniversary of one of the most famous "walks in the snow" in history.

The universe, and the laws of physics that govern it, lay before Lise Meitner as enigmatic and beckoning as the snowy Swedish landscape. An Austrian-born Jew, Meitner was not enjoying her refugee life in Stockholm. She had never stopped thinking about the mysterious uranium-neutron reaction that she and Otto Hahn had struggled with before her flight from Hitler's Germany earlier that 1938.

Hahn himself continued to look to Meitner for a brilliant explanation that had evaded science's best and brightest for four years now – even the great Enrico Fermi himself, who performed the initial experiment in 1934. Fermi knew then, as everyone knew, that adding a neutron to nature's heaviest element would lead to an uncharted world of transuranic wonder: creating super-heavy elements that hitherto only nature herself had played with briefly.

Even some timely out-of-the-box thinking by another woman scientist at the time couldn't dissuade the scientific elite from its march to glory: Ida Noddack, a chemist of no small repute herself (co-discoverer of the element rhenium in 1925) had criticized Fermi's results in 1934, pointing out the possibility that the neutron-bombarded uranium could instead have broken into "several large fragments". Being a woman, and a chemist, and failing to provide theoretical backup to her lateral thinking, she was ignored (and how differently World War II might have progressed otherwise...).

On Christmas Day 1938, Lise Meitner clutched in her hands evidence that she could expect to be treated a little better: a desperate letter from Otto Hahn, begging her to come up with something brilliant to explain had now proven – of the products of Fermi's famous neutron bombardment of uranium was, in fact, barium. But how could something half the mass of uranium result from adding something as inconsequential as a neutron? Unlike 1934, it was now chemistry asking physics for an answer.

With Meitner was her nephew, Otto Frisch, another refugee Jewish physicist. The two had met up at a friend's home in Kungälv for the Christmas holidays, and now struck out on a bracing walk in the snow – and into the history books.

Frisch on skis, with Aunt Meitner trudging alongside, talked about Hahn's conundrum – more than a conundrum: a constipation of science four years old. Perhaps it was the clarifying embrace of the wintry air, or perhaps the mental unschackling of refugee life, or perhaps the non-linear insight of the gentler gender that had been advancing nuclear science since Marie Curie – somewhere in the Swedish snow the light went on.

Surrounded by frozen liquid drops, Meitner speculated whether the Liquid Drop Model of the nucleus might explain a single neutron inducing oscillations in a uranium nucleus, causing it to break up. Energy would be liberated in the process, and thanks to Einstein they were able to estimate how much: the answer quite literally stopped them in their tracks.

The rest, as they say, is history. Frisch went on to experimentally prove the process, which he coined "fission". Otto Hahn went on to receive a Nobel Prize with his chemist protégé Fritz Strassmann, downplaying for the rest of his life the role of Lise Meitner – now seen as one of the biggest oversights in Nobel Prize history.

There have been other famous "walks in snow" in history. Pierre Trudeau's legendary midnight stroll in an Ottawa snowstorm in 1984 led to his decision to retire after 15 years as Prime Minister. Hitler without a doubt took a snowy stroll or two around his Führerbunker that final winter of 1945 before deciding to end it all.

Lesser known is the frigid stay of a small group of chemists for the National Research Council, who camped that first winter in 1944 at what would soon become Chalk River Nuclear Laboratories, with orders to design the water treatment plant for the reactors to come. Socked in with few supplies, alone, and freezing, they likely took more than a few strolls in the snow to question their respective decisions to become government scientists.

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