Howard, Jeff (DEEP)

From: Joel Gordes <gordesj@comcast.net>
Sent: Friday, July 10, 2015 9:12 PM
To: DEEP ClimateChange
Subject: Official Comments for the Governor's Council on Climate Change
Attachments: Initial Comments to Gov Climate Change Council 7-10-15 JNG-.pdf

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To Whom it may concern:

While I unofficially entered some comments prior to this and oral comments at the July 10th meeting, please accept the attached as the official comments for your website and for distribution to your members.

Best,
Joel N. Gordes
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"...the problem at hand, which is that centrally generated electricity is a vulnerable genie. In order to be used it must travel on an ugly, complex and inefficient labyrinth of wires and substations...Even from a security view (national or otherwise) such a fragile system is suicide." Gordes-February 1978 in a published Hartford Courant Letter to the editor.

Comments to the Governors Council on Climate Change (GC3)

July 10, 2015,
Joel N. Gordes, dba Environmental Energy Solutions
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Governor's Council on Climate Change (GC3) Members, Commissioner Klee and DEEP Staff, my name is Joel Gordes. I am an independent energy consultant dba Environmental Energy Solutions (EES). I am purely representing myself in these remarks and have had the following pertinent experience:

- Exposed in 1967 in a Space Physics 370 course to the concept of global warming
- In 1990, as Vice-Chair of the Connecticut Legislature's Energy and Public Utilities Committee, was one of the original five co-authors of PA 90-219, AAC Global Warming.
- In 1996 authored *Climate Change and the Insurance Industry* for the BeCo Settlement Board
- From 1996 – 2001 worked with Dr. Jeremy Leggett (UK) on climate change issues. (Currently he is Board Chair of Carbon Tracker.)
- Served 10.5 years (2000-2011) as Technical Coordinator of the CT Energy Efficiency Board and later until 2014 for ~2 years as a Board Member.

EES appreciates the opportunity to comment on the reinvigoration of efforts by Connecticut to play an active role in climate change mitigation/abatement and adaptation. EES applauds this effort and hopes to add to the dialogue to promote truly meaningful outcomes. While the effects of climate change will cover a broad spectrum from land use to food production among others, EES will concentrate mostly on energy considerations but not to the total exclusion of other intersecting concerns. A summary of main points are in the first 5 pages followed and expanded upon in this document or as appendices include:

1) Diversity of thought is important in any critical decision-making process and the high number of State of Connecticut departmental officials involved, while important, seems to overwhelm those from the private, non-profit and educational sectors. As such, they are responsible to the Governor and unlikely to differ with him on certain already entrenched policies even if they might be found to run counter to best practices for climate change mitigation/abatement and adaptation practices or further exacerbate health, safety and security concerns some of which may be related to climate change. This may evidence itself as what is termed "confirmation bias" wherein all efforts are made to support a given outcome to the disregard or slighting of alternative options. Sometimes the word "groupthink" is used to characterize the process involved and it has been cited in such events as 1979 Three Mile Island event and the 1986 Space Shuttle Challenger disaster. Climate change carries even larger burdens.

2) Preliminary statements made in connection with this initiative and allied documents show Connecticut on track for obtaining some of its early goals for greenhouse gas (GHG) reductions but little mention is made that likely a significant portion of the attainments may be due to the Great Recession which appears to be lingering longer in Connecticut. To maintain intellectual honesty, this must be prominently stated and separated out as best possible in all documents issuing forth from this Council.

3) As in the *Two Storms Panel* of several years ago that investigated the prolonged power outages after Storm Irene and the Halloween Nor'easter, there must be a recognition that climate change goes far beyond immediate challenges (environmental in this case) but may have an immense effect on health, safety and the security of Connecticut citizens. While this may seem to be readily apparent to the most casual observer, other policies at play, endorsed by DEEP, may actually run counter to promoting this and under climate-change-driven threats, may exacerbate disaster conditions. As such, the Council

should mindful of Dr. Barry Commoner's First Law of Ecology that "Everything is connected to everything else". In accordance with that, there must be the recognition that in a climate-challenged world there may even be calls for compromises of what we think of as "freedom" such as where and how we build housing and other buildings but also undertaking energy projects that may ignore certain social justice/human rights issues and sacred rites of others who may even be far removed. Here, EES cautions that there are always alternative solutions but we must be intelligent enough to recognize them and never fearful of looking at the alternatives in new and different ways rather than staying with easier past and outdated ways that may conflict with human rights.

4) It is important to have some background in the history of energy-related technologies and policies to at least gain a general perspective of how and why they have evolved as they have. In some cases, lack of understanding by policy-makers have led to decisions that have strayed from their original intent in the name of expedience and adopting "cheap" solutions that we may come to deeply regret. This is particularly true of large, long term projects which lock capital up for many decades that cannot be used for more agile solutions later and may result in enormous stranded costs for all future ratepayers.

Examples of How Existing Energy Strategies May Negatively Impact Climate Change and Attendant Considerations

1) The Gas Pipeline Dilemma: Might it Actually Increase Greenhouse Gas Emissions?

A primary energy strategy for the State of Connecticut engendered in the most recent Comprehensive Energy Strategy as well as the Integrated Resource Plan is the expansion of natural gas via construction of pipelines to bring fracked gas from the Marcellus Shale in Pennsylvania and New York. The reported cost of doing so runs into the billions of dollars and maybe subject to point 4 above where we may lock in huge amounts of capital for decades to obtain what may only currently be the least expensive option. While EES has previously been enthusiastic about gas due to the high efficiency of the combined cycle gas turbine technology, the SOx-NOx cleanliness and its lower carbon footprint as ways to reduce climate change, new information indicates otherwise. Leakage rates have been called into question as being significantly more than originally thought as well as other multiplier effects and questions on the wisdom of hydraulic fracturing on several counts. So, this has personally become a conflict and question that, as economist John Maynard Keynes once put it, "When the facts change, I change my mind. What do you do, sir?"[1] And this is a major question this Council ought to ponder even in the face of this pipeline being looked upon as a done deal. In fact, let me be so audacious as to suggest a moratorium on pipeline construction ought to be implemented until such time as there are ironclad assurances that its entire cradle-to-grave life-cycle, including actual extraction in Pennsylvania and New York, are not net GHG drivers instead of being a part of the solution.

The recent book *Reason in a Dark Time* by Dale Jamieson is on climate change and it goes deeply into philosophical discussion of who become the drivers for errant climate behavior and to what extent any of us are or are not personally responsible (guilty) for our actions. In this case, our demand for more gas is more of a collective action but we cannot escape the end result if we are wrong in our assumptions or they are overly colored by political considerations or fixed in energy policy.

This also brings up another question concerning the actual supply of shale gas and asks how economically stable is the financial situation of the shale gas market? There are allegations from several quarters that the supplies may not be what were originally touted as providing decades of plentiful, cheap fuel and that some of the wells may be prematurely petering out. Others fear the irrational

[1] With thanks to former EEB Chairman Richard Steeves for bringing this to my attention.

jubilance may only foretell a "shale gas bubble" comparable to the dot-com and housing bubbles the latter of which gave us our carbon-reducing Great Recession. EES does not think that is the way we want to get there and urges this Council to thoroughly investigate these allegations as well. Any protest of it "not being in my department" would break Dr. Commoner's 1st Law of connectivity of all things (above) as well as being a breach of public trust.

Gas expansion raises many other question including ones of energy security of how much do we wish to increase our dependence on this one form of energy coming through only a very few, vulnerable pipelines? A casual review of the usage of natural gas for electric production reveals that on any given day we use it for meeting 40% to 62% of our electric load. So the question is how much more do we want to increase that figure to? 65% to 70%? More? Does it really make any economic or energy security sense to expand past that point--or even maintain it at that level? Putting on a "security lens" we must ask "How much do we really want to increase that figure when Osama bin Gordes, the renowned terrorist, is plotting to physically blow up a few strategic points in the gas line/compressors in the middle of the next major blizzard or ice storm or hack into their control systems (ICS) during similar events?" These are also questions this Council must ask if they undertake this study in a holistic, all-hazards approach.

<u>As an alternative, I also suggest this Council examine the question of whether by using funds that might otherwise go to pipeline construction into further actions with energy efficiency and local, clean distributed generation resources might we provide a surer supply of power under all circumstances while keeping money in local economies.</u>

2) Canadian Hydroelectric Power: Is This a Legitimate Climate Change Solution?

Connecticut's energy policy as espoused by the Governor and DEEP is "Cheaper, Cleaner and More Reliable." The Comprehensive Energy Strategy and Integrated Resource Plan have also rated the large hydro option as high on their totem pole of choices as meeting those requirements. But is it? This Council should thoroughly investigate the climate-related aspects of this option but also with attention to the other considerations already raised

In this section we will explore several issues associated with this option including the one referenced immediately above. To begin, below are some brief points which have some more detailed information in the appendices:

A) Social Justice/Human Rights: An earlier reference was made at the top of page 2 in this submission where EES said:

> "… there may be calls for compromises of what we think of as "freedom" such as where and how we build housing and other buildings but also undertaking energy projects that may ignore certain social justice/human rights issues and sacred rites of others who may even be far removed."

Actually, EES has brought this up before in other DEEP venues such as IRP and CES submissions but has never seen a response to it although they are aware of EES's concerns. In particular, The La Romaine Project by HydroQuebec from whom we may be receiving power has serious human rights allegations as concern the Innu (not Innuit), a First Nation people, who have issues over Hydro Quebec's expansionist plans on their sacred lands. We must insure that our clean energy is "clean" in every sense of the word; including morally. (See Appendix A on page 6 for some brief information on this and an explanation of how some native peoples look at land differently than most of us.)

B) Historical Role of the Renewable Portfolio Standard (RPS). The RPS was developed in the early 1990's by Dr. Donald Aitken of the Union of Concerned Scientists (UCS) and Ms. Nancy Rader of the American Wind Energy Association. It was meant to provide market support for emerging technologies such photovoltaics and wind by providing them what we call a "sustained orderly development" path toward cost-effective commercialization.[2] It has never been intended for the RPS to subsidize already mature technologies such as large hydro just because they might offer a cheaper path to meet goals that have been manipulated as a race to the bottom cost-wise. It is also interesting to note that Wikipedia uses large versus small hydro as a prime example of eligibility example:[3]

> States often start with an assessment whether the renewable technology is economically feasible in the absence of an RPS program. This is best personified by distinguishing between small and large hydroelectric facilities. Many states exclude existing renewable facilities from benefiting from an RPS program for the same reason.

Unfortunately, while Connecticut began in the intended manner, it has abandoned that intended approach in a quest to find "cheaper" ways to satisfy RPS requirements. Connecticut and several other states have bastardized the concept to in ways include large hydro as an option at the expense of the legitimate aims. A more detailed two page paper on this appears as Appendix B on pages 7-8.

C) Marginalization of In-State Renewable Distributed Resources: In numerous DEEP and utility studies there is mention of certain renewable energy sources being significantly higher in cost than large-scale fossil and nuclear power sources. If we look at it strictly on a dollar per kilowatt-hour basis, there may still currently be some support for this argument but thanks to global efforts of many nations and states and the effects of sustained orderly development and commercialization we have made tremendous strides in the past five years alone in reducing the cost of photovoltaic systems. The Swanson Effect is the photovoltaic equivalent of Moore's Law in the computer chip price reduction realm and says that for every doubling of the amount of PV in megawatts shipped there is a 10% reduction in price. A impressive chart showing the price reductions over time since 1976 appears in Appendix C on page 10.

What is also missing is valuation not merely of the cost of a kilowatt-hour but of the entire value stream provided by distributed energy sources. Photovoltaics (PV), in particular, are undervalued as at certain times they are a peaking resource that produces high output in summer that coincides when peak loads are most extreme. This translates into value gained from grid stability as well as not firing older, expensive and more polluting peaking generators --and many additional values. These were supposed to have been further investigated in detail under a section of SB 570 in the 2015 session of the legislature. Utility opposition to a robust community shared solar program may have been the driver for its absence in the Implementer Bill (SB 1502) that did contain other sections. Other values are also provided in a table in Appendix C on page 11.

D) Energy Resilience and Security: The addition of distant, foreign, large-scale hydroelectric power requiring large transmission further centralizes the grid. In contrast to DEEP claims, this reduces resilience, reliability and may endanger public health, safety and security compared to smaller scale Local options within the state located close to end users. NERC, tasked with grid security for the US, has warned of higher risks from purchasing power requiring transmission that spans several states. The ancient lesson of Napoleon invading Russia and suffering huge losses also has relevence. It was not the Russian winter that defeated him; it was the overextension of his supply lines.[4] Obtaining power from HydroQuebec

[2] Aitken, Dr. Donald W. *Sustained Orderly Development*. Solar Age. p. 21. May/June 1992.
[3] http://en.wikipedia.org/wiki/Renewable_portfolio_standard
[4] *Fighting the Russians in Winter: Three Case Studies*. Chew, Dr. Allen. Combat Studies Institute. US Army Command and General Staff College. Levenworth Papers No. 5. December 1981. p. vii.

via the Northern Pass power line does much the same. Appendix D on page 12 has an introduction to energy security aspects as well as a series of eight, 2-3 page papers, each on a threat to this proposed project.

E) Does Large Hydro Actually Provide as Much Greenhouse Gas Reduction as Other Options?

Much has been touted in the CES, RPS Study and IRP on how Connecticut should purchase upwards of 1200 MW of power from Hydroquebec to be transported by the Northern Pass transmission line to be built using Eversource resources at a cost of ~1.4 billion dollars. One claim made in addition to low cost and using it to meet our RPS standard is that it will provide greenhouse gas reductions that will also aid in attaining our goals under PA 08-98 AAC Connecticut Global Warming Solutions. That act aims to reduce our emissions 10% below the 1990 level by 2020 and by 85% below the 2001 level by 2050. Aside from questions surrounding this options "additonality", one of the requirements for eligibility for valid greenhouse gas reduction eligibility, there are also science-based questions on whether it lives up to its claims to reduce greenhouse gases at all during its formative years and for some time after its completion and operation.

According to an October 24, 2014, post on their website, Christophe Courchesne of the Conservation Law Foundation, a well-respected environmental group, stated:

> Given that hydropower projects do not have smoke stacks, when I say "carbon pollution" or "greenhouse gas emissions" from hydropower, what do I mean? … Drowned vegetation and biological material decompose over time and release carbon dioxide and methane into the water column and then into the atmosphere. In addition, the flooding destroys northern forested landscapes that can be potent carbon sinks (and are often called "lungs of the planet"), increasing the net greenhouse gas emissions of the reservoir by the amount of any lost capability to sequester carbon…
> In its press release, Hydro-Québec says that "CLF asserts that hydropower greenhouse gas (GHG) emissions are much higher than they actually are … by cherry-picking data contained in a scientific study on emissions from a recently created reservoir in Québec…. What that study really indicates is that hydropower is one of the lowest-emission generating options per kilowatthour produced."
>
> Here again, as with hydropower costs, Hydro-Québec misstates CLF's point. The number I cited does not pretend to describe all hydropower, or even all Hydro-Québec hydropower….*The 70% number clearly and expressly describes the emissions from a new large-scale hydropower facility during the first ten years of operation*. It is taken directly from peer-reviewed scientific analysis by Hydro-Québec and academic researchers of data collected at the Eastmain 1 reservoir, a new hydropower facility in northern Québec. My blog post includes the relevant graph, presented in a scientific paper that a Hydro-Québec scientist co-authored, showing a direct comparison of these emissions with natural gas and supporting CLF's statement that a new large-scale hydropower facility can emit 70% of the greenhouse gases of natural gas power plants in the decade following development.A 100-year life-cycle analysis shows lower *long-term* emissions, but in a world where climate change is accelerating and we desperately need to reduce emissions *now*, the early emissions of Hydro-Quebec's new facilities—several of which are under construction and slated for development in the coming few years—are vitally important. ..

So it would seem there is a situation of he-said/she-said and the need for an honest broker to make an impartial determination on this issue. This may be another role for the GC3 in the coming years and to determine if. because of the lowering cost of other alternatives that may have less baggage associate with them that this potentially risky source should be dropped from consideration

The history of our treatment of Native North Americans has been disgraceful and today would likely be called genocide, most of it over the taking of land and with it, destroying their culture. Before Connecticut chooses this option, it should be mandatory that we investigate the allegations being made by some Innu who, like many Native Americans, may hold beliefs different from the majority of Americans or Canadians. Former Yale Professor Dr. Albert E. Burke explained such beliefs this way:[5]

> As far as the American Indian was concerned, land was not an investment. It was not property. The idea that anybody could think so, simply made no sense. That idea was more than strange to the Indian. For good reason, he saw it as immoral, indecent, completely inhuman, and completely deadly. It was monstrous to think that anyone could claim this as personal, private property.

It is also noteworthy to recall that in the mid-1990's similar efforts to secure land from the Ouje Bougoumou Cree Native North Americans to enlarge Hydro Quebec's capacity was met with regional opposition but a later settlement occurred. The question of HydroQuebec conduct with First Nation peoples is not a new issue.

Activists From Québec's Innu First Nation To Protest This Weekend's New England Governors' Conference in Burlington

Posted by Ken Picard on July 26, 2012 at 12:43 PM. Click on this link for full article.

More than a dozen protesters from Quebec's Innu First Nation are due to arrive in Vermont this weekend to protest the Conference of New England Governors and Eastern Canadian Premiers, being held in Burlington. They are protesting against the construction of a new hydroelectric dam on the Romaine River by Hydro-Québec, which they say would destroy their entire way of life. Vermont purchases the vast majority of its power from the Canadian utility giant and Gov. Peter Shumlin currently chairs the New England Governors' Conference.

This new dam is but one aspect of a much larger development project in the region known as Plan Nord. According to the Québec government's official website, Plan Nord is "one of the biggest economic, social and environmental projects in our time." The 25-year, $80 billion project will create or consolidate an average of 20,000 jobs per year, the Québec government says.

The Innu people — not to be confused with Canada's Inuit people — come from the community of Mani-Utenam, near the city of Sept Iles. They are an indigenous population from northeastern Quebec and Labrador who claim they have never ceded their rights to the land to the Québec or Canadian governments…

Among the activists coming to Vermont is Elyse Vollant, an Innu grandmother who in June was arrested at the blockade, along with several others from the community. After the blockade was removed by dozens of riot police and Surete du Québec (Quebec state police), the Innu erected an encampment alongside 138.

Many Innu feel that the Charest government has ignored their concerns and traditional right to the land. While some tribal councils have signed on to the Romaine project, other Innu view these councils as colonial forms of government that were set up by the Québec government without much consent from Innu decades ago. According to Vermont activists working with the Innu, Mani-Utenam has not signed any agreements around the Romaine project. However, Hydro-Québec has started clear cutting swaths of forest near their community for the transmission lines that will carry power from the dams. For more on the Innu protests from earlier this year, check out this piece by Alexis Lathem in *Toward Freedom.*

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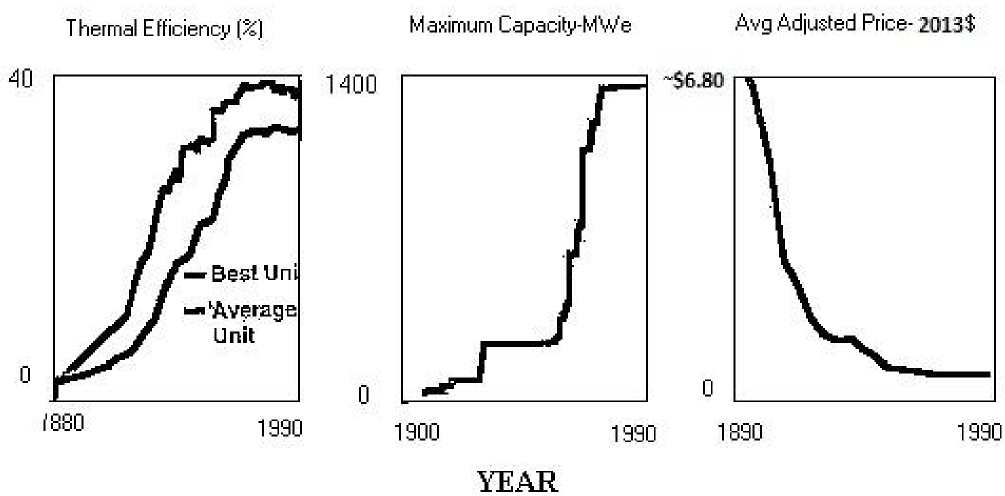
[5] Burke, Albert. *The Monster Slayer, Part II*. Probe TV Show Transcript. 1962

Putting the Renewable Portfolio Standard Into Historical Context

Actions are taking place in several states to repeal or significantly alter what is called a Renewable Portfolio Standard (RPS) as well as net metering. RPS mandates certain amounts of renewable energy be part of the electric mix. It was never the intent to provide incentives for mature technologies, like large hydroelectric projects in order to make the overall portfolio appear less expensive but it is being pursued as one reason for it.

To better understand the role of the RPS in advancing renewable energy, it is necessary to know how we have arrived where we are today with conventional power. In both cases it has all been about breaking down "market barriers" in similar yet distinct ways.

This is best explained by a brief historical look at how generation changed from the time Edison set up his first commercial generator in 1882 on Pearl Street in lower Manhattan. Back then, he had a dynamo generator that was DC power that could only travel about a half mile. Utility monopolies did not yet exist.



The graphs above show that from the late 1800's to1990 the initial efficiencies were very low in early power plants due to their very small generators (in MWe) which produced power at very high prices per kilowatt-hour. In today's dollars this would have been an astounding ~$6.80/kilowatt-hour.[6]

George Westinghouse, along with Nicola Tesla, Edison's competitors, knew that if they built larger AC generators with better economies of scale they would have much higher efficiencies allowing them to drastically lower the price of electricity. Samuel Insull, another innovator, who had worked for Edison, also recognized this need but the financial community was reluctant to bankroll the building of these new, larger steam turbine generators unless there was some guarantee that the power company would be able to repay the loans. To overcome this early "market barrier" to increased use of electricity, Insull began his effort in 1898 to make a grand bargain with the states. This was to allow the electric companies to become monopolies in return for being regulated and having certain obligations. While monopolies were seen by some as contrary to free market principles, the rail monopolies that preceded them set an example. By 1907 New York, Massachusetts and Wisconsin had set up commissions to regulate the companies later followed by others.[7]

As shown in the graphs above, it worked and, over time, the larger plants' economies of scale led to drastically increasing efficiency of the units which lowered the cost of power making it affordable for many more people. Providing a subsidy[8] by monopoly had proven successful and held valuable lessons for the future on when the free market works -- and when it does not.

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[6] Hirsch, Prof. Richard F., *Technology and Transformation In the American Electric Utility Industry* (Cambridge University Press, 1989). NOTE: Prof. Hirsh showed this as $3.20/kWh in 1986 dollars but this paper's author has updated this to 2013 dollars corrected for inflation.
[7] Op cit. Hirsh. p. 22
[8] Defined in this instance as "Financial assistance given by one person or government to another." See The Free Dictionary.

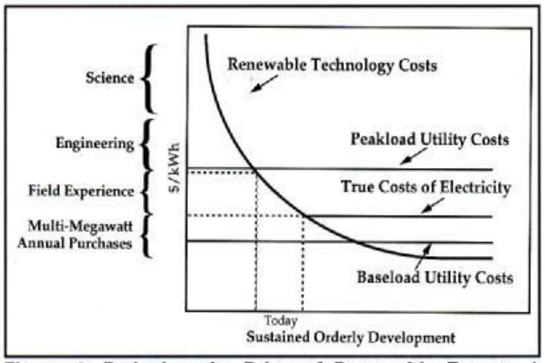

Figure 1: Reducing the Price of Renewable Energy. A schematic presentation of the various stages contributing to the "Sustained Orderly Development" of a renewable electric technology. Relative widths of brackets are hypothetical, for illustrative purposes only.

Fast forward nearly a hundred years later after Edison, a number of renewable energy technologies emerged but they suffered from similar "market barriers" as did their fossil fuel and nuclear predecessors. Sustained Orderly Development describes a strategy developed to move renewable energy sources toward cost-effectiveness by increased production and steady procurement of them to lower their prices and eventually match the cost of conventionally-generated power. [9] It is a method to overcome market barriers just as the early fossil-fueled electric industries had to overcome market barriers. Rather than anything as drastic as forming monopolies as an incentive mechanism, it employs increasing mass production to lower cost in a market-oriented way.

In 1995 Dr. Donald W. Aitken, with the Union of Concerned Scientists and Nancy Rader with the American Wind Energy Association (AWEA) developed the Renewable Portfolio Standard (RPS) policy and entered it for the first time in the California Electric Utility restructuring proceedings before the Public Utilities Commission. It was one of several tools developed to implement the Sustained Orderly Development path described above. It has since been widely adopted in a majority of U.S. States. The RPS has never been intended to support already mature technologies like large hydropower just because it might offer a less expensive path to meet overall goals set by the states. On the contrary, its goal has been to commercialize the immature renewables to eventually compete with those technologies that already enjoyed a number of subsidies over the past years.

The 1992 prediction in the chart above is very close to what has and is currently taking place. In the same article Aitken makes an important point relevant to this the large hydro controversy:[10]

> Thus the "push" from regulators and legislators is still warranted, along with a supportive understanding and participation by consumer and ratepayer advocacy groups, just to give the renewable technologies a fair chance against the major financial and institutional barriers they face. But unless actual market forces are harnessed in a way that can support the sustained orderly development of the solar electric technologies, no amount of governmental incentives will do the job. *Sustained orderly development does not imply that orders should be placed for unworthy technologies, nor that they should not also stand on their own correctly-defined economic merits.* [emphasis original]

This last sentence may be construed as saying certain technologies are unworthy of the aid provided by subsidies but even those that are worthy eventually need to economically stand on their own merits. Most renewable energy advocates look forward eagerly to the day when their technologies no longer need an RPS to provide "a fair chance against major financial and institutional barriers" and that day is relatively near compared to when this 1992 article was written. (Wind electric-energy generation is already today less expensive than new coal-powered electricity generation.) It also states that other technologies can be "unworthy" and large hydro seems to meet that criterion by all measures. Inclusion of mature technologies is a bastardization of what was intended as the primary purpose of the RPS. It is indicative of unfamiliarity with the history and justification for RPS to overcome market barriers and not to be in competition with those already deemed fully commercialized.[11]

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[9] Aitken, Dr. Donald W. *Sustained Orderly Development*. Solar Age. p. 21. May/June 1992.

[10] Op cit. Aitken, p. 22.

[11] Facts on the RPS development and intent verified by Donald W. Aitken, Ph.D. on 10/18/2013.

Marginalization of In-State Renewable Distributed Resources:

EES supports a strategy of decentralization that focuses on, over time, maximizing use of microgrids and renewable energy generated in-state. This keeps money in the state and provides a greater degree of local employment opportunities as well as security and resilience. As noted in the 2010 RPS study itself:[15]

> Connecticut benefits the most, in terms of employment and economic development, from development of in-state resources. In-state facilities result in growth of manufacturing and installation employment for renewable energy systems…help customers reduce their bills increasing ratepayers' expendable income and making local businesses more competitive. In-state project have an economic multiplier effect as a portion of these customer savings are then spent on local good and services.

The same cannot be said for large amounts of the money that will flow from Connecticut to Canada as well as losing much of that multiplier effect for jobs and revenues.

Most importantly, PV (and microgrids in general) cannot be solely judged by their current or even future price per kilowatt-hour alone as another important set of economic factors has been totally left out of the equation. That is, PV carries with it a stream of unarticulated values to the utility and its ratepayers. By way of one example, PV operates well during clear, sunny days and often in the summer that coincides with the peak demand on the system. Currently, expensive, highly polluting peaking units must be dispatched to meet those needs. Depending upon a number of factors specific to each utility and PV system, PV output coincides with these peaking needs as much as 60%. Any discussion of when PV-produced energy might reach grid parity is flawed unless the peak price of power is factored in for a certain amount of the PV's production. But that is just one unarticulated value both to utilities and ratepayers. A 2006 paper by Robertson and Cliburn[16] lays out tables showing values for PV systems for one representative utility[17] and the categories where they provide value. (See Page 11.) What is required is to look at these values streams for Connecticut's utility systems. How we value resilience for public health, safety and security as well as power for must-run businesses within microgrids is also yet to be determined but should be assigned some value. This topic of Value of Solar (VoS) and other distributed resources was originally part of SB 570 from the 2015 session but that bill did not pass. Portions of it did appear in the Implementer Bill (SB 1502) but not the VoS sections. Utility opposition to a robust community shared solar program may have been the driver for its defeat.

To re-enforce this, the RPS Study, itself, also goes on to state: "If the cost of solar and fuel cells decline as expected over the next few years, this option [in-state projects] may become more favorable as a way of meeting our RPS demand in the post 2020 timeframe." [18]

EES would, however, maintain that the rate of cost decline is accelerating such that a focused effort as epitomized by CEFIA's Solarize Connecticut programs can make real impacts on RPS goal realization in the near term and NOT merely in the study's post-2020 prediction seven or more years out. Look at the trends. While PV is still touted as one of the more expensive options for RPS, as can be seen in the chart on the next page, tremendous strides in PV deployment and price reductions have taken place just within the past four to five years. What stands out most is the tremendous rate of growth driven by advances such as PV gaining its own dedicated polysilicon feedstock for the first time whereas prior to that the PV industry used left over stock from semiconductor chip manufactures. Other factors were surplus supply of panels from Germany, Greece and Japan hitting the market.

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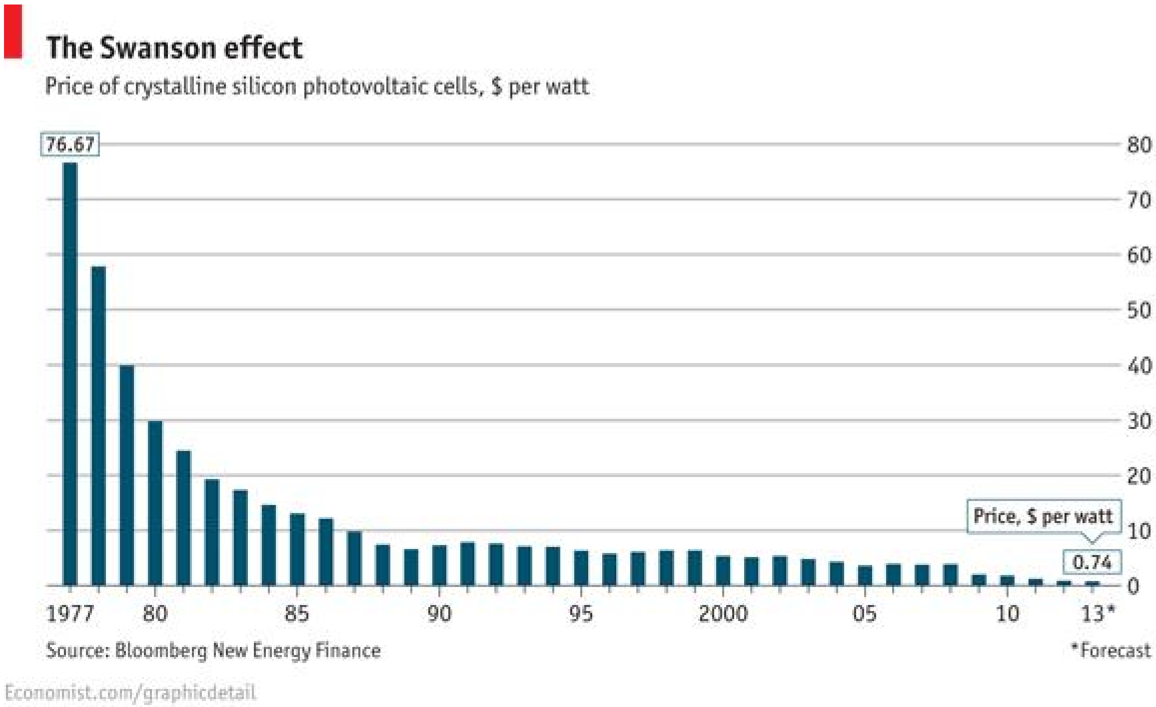
[15] Restructuring Connecticut Renewable Portfolio Standard [DRAFT]. March 19, 2013. P. 16.

[16] Robertson, Chris and Cliburn, Jill K. *Utility-Driven Solar Energy as a Les- Cost Strategy to Meet RPS Policy Goals and Open New Markets*. American Solar Energy Association Conference. Denver, CO. 2006.

[17] These figures are not for a CT utility but provided as an example of the value streams.

[18] Restructuring of Connecticut's Renewable Portfolio Standard. Draft of March 19, 2013. P. 15.

What has been most significant for expectations going forward is "The Swanson Effect". It is the photovoltaic equivalent of Moore's Law in the computer chip price reduction realm and says that for every doubling of the amount of PV in megawatts shipped there is a 10% reduction in price. See below.



Unarticulated Values Streams of Distributed Resources/Microgrids[12]

Table 1: Selected Sources of Value in Utility Budgets from Utility-Driven Distributed Photovoltaics

Source of Value	Example or Value if Publicly Available
Peak Load Value	
Distribution investment deferral[7]	< $0 to > $6000 per marginal kW for 5 year deferral
Transmission congestion relief[8]	$30 - $50/kW-yr
Transmission investment deferral[9]	$45/kW-yr
Generation capacity	$475/kW[10]; $1550 - $2000/kW if IGCC + Carbon sequestration[11]
Generation O&M[12]	~$10/kW-yr
Generation reserve capacity and O&M[13]	$.014/kWh for peak period
Natural gas[14]	$8.50/MMBTU; highly volatile future prices
Purchased power	PV supply curve offsets highest cost power in generation supply curve
Minimum load power plant dispatch[15]	$28/kW-yr
Environmental[16]	$0.014/kWh NO_X; also Mercury, SO_2, CO_2, PM10
Line losses	Up to 25% in some constrained systems
Reactive power[17]	$15/kW-yr
Voltage support	Varies; may be part of distribution investment deferral
Network O&M[18]	~ $16 to >$88/kW-yr
Intermediate Load Value	
Natural gas	$8.50/MMBTU; Peak + intermediate gas cost NPV $1800 - $3500/kW (increasing, with more volatility due to oil and gas depletion)
Environmental	$0.014/kWh NOx; others
Line losses	6% - 8%

Table 2: Policy and Business Model Economic Value from Utility-Driven Distributed Photovoltaics

Source of Value	Example or Value if Publicly Available
Policy-Driven Value	
Net metering payments	Normal utility rate; moving to Time-of-Use rate
Customer rebate payments	Varies by jurisdiction
Solar renewable energy credits	In NE US (PJM) region $200 - $600/MWh; others much less
Business Model Value	
Customer revenue retention	Normal revenue reduces non-participant cost issues
Peak-period DPV revenue	Sell DPV capacity into peak power market
Tax investor participation[19]	30% PV capital cost through '07; 10% after that
PV system portability[20]	~$2000/kW if redeployed 4x to dist. deferral projects
(Payment to PV host site)	Perhaps 10% of rate, plus insurance coverage

Source: ElectricSUN synthesis from published studies of distributed energy resource benefits and costs

Table 3: Risk Management Issues Affected by Utility-Driven Distributed Photovoltaics

Source of Value	Example or Value if Publicly Available
Grid reliability & outage prevention[21]	$Billions & lives lost -- societal
Natural gas availability	Threat of Fuel Use Act; oil and gas depletion; physical disruption from storm damage
Financial	Lower interest rates for PV due to lower risk
Regulatory	Avoid regulatory pre-emption
Carbon	New requirements likely
Insurance	Global warming liability coverage
Share price & fiduciary duty	Investor expectations for risk management leadership
Generation portfolio cost and risk	DPV net fixed cost reduces gen. portfolio cost & risk

[12] Robertson, Christopher, Cliburn, Jill. *Utility-Driven Solar Energy As A Least-Cost Strategy To Meet RPS Policy Goals And Open New Markets.* American Solar Energy Society Conference 2006.

Appendix D

Elaboration on Energy Security & Resilience

Very simply, large-scale, centralized hydro resources that use lengthy transmission to transport power over long distances into an already tightly-coupled, highly complex grid increases vulnerability. It is the antithesis of less complex, highly resilient decentralized microgrids using small, diverse sources close to the point of use. In addition, Amory Lovins, founder and Chief Scientist of Rocky Mountain Institute (RMI), in his seminal 1976 work *Energy Strategy: The Road Not Taken*[13] clarifies that these two philosophies are mutually exclusive; dollars invested into centralized systems are not only unavailable to fund decentralized systems but may also foreclose future choices. Lack of any discussion on these polar opposite paths in either the CES or RPS Study indicates DEEP may not fully appreciate how introducing large hydro into the RPS, and thus increasing centralization, has negative public health, safety and grid security implications. More recently NERC, tasked with grid security for the US, has warned of higher risks from electromagnetic events (EMP and CME) from purchasing power requiring transmission that spans several states.

Much of Lovins' strategy is reiterated in his newest book, *Reinventing Fire* wherein he lays out four scenarios any of which might become our energy future (*Maintain*, *Migrate*, *Renew* and *Transform*). In it he cautions:[14]

> All four cases depend upon the transmission grid (*Transform* less so) with its inherent physical vulnerabilities even after key nodes are hardened and cybersecurity ensured. Only *Transform*, with its option to work around grid failure, offers a far more resilient grid architecture. The more distributed the generators and the more granular and islandable the resources, the more the large-scale cascading grid failures that now are nearly inevitable could be made nearly impossible by design, and the more the grid that undergirds our nation's economic and military might could stop undercutting it.

So again, Lovins' RMI organization, consultants on both the Connecticut's IRP and CES, advises against additional large, expensive and more vulnerable transmission facilities but adds one additional admonishment:[15]

> Second, if resources can compete fairly at all scales, some, and perhaps much, of the transmission built for a centralized vision of the future grid could quickly become superfluous.

Put another way, policymakers/regulators should be acutely aware that large transmission projects could become the stranded cost of the future in addition to making the grid more complex and prone to failure.

The following pages provide detail on eight different security threats to the importation of power from Canada. Some are general in nature while others are specific to the HydroQuebec system.

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13 Lovins, Amory. *The Road Not Taken*. Foreign Policy. Vol. 55, No. 1. October 1976. pp. 65-96.

14 Lovins, Amory et al. *Reinventing Fire*, p. 214. 2011. Chelsea Green Publishing. One well-known reviewer notes:

"*Reinventing Fire* crackles with fresh perspectives and compelling insights about our energy past, present, and future. Drawing on the logic of economics, physics, geology, national security, and just plain common sense, Lovins and his colleagues blaze a trail toward an energy future that is cleaner, cheaper, and safer. A 'must read' book for business leaders, policymakers, environmentalists, academics, and anyone else who cares about our planet's future and our nation's prosperity."--Dan Esty, Director, Center for Business and the Environment at Yale University

15 Op. cit. Lovins p. 216

The 1998 Canadian/New England Ice Storm: Threat to Reliability

In 1998 portions of Eastern Canada, including Quebec, and the Northern New England states suffered an historic, record-breaking ice storm. A joint after-action report by the Institute for Catastrophic Loss Reduction (Canadian) and the Institute for Business and Home Safety (United States) stated:

> Starting late on January 4, 1998 and continuing for the next six days until January 10, 1998, freezing rain fell on eastern Ontario, southwestern Quebec, and southern New Brunswick and Nova Scotia. These areas were pelted with 80 millimetres [sic] or more of freezing rain. The event doubled the amount of precipitation experienced in any prior ice storm…[i]
>
> …According to Emergency Preparedness Canada, electric outages in the affected areas of Canada deprived 4.7 million people or 16 percent of the Canadian population of power. In the United States, there were 546,000 people without electricity. Thus, in both countries more than 5 million people were without power (heat, light and in many instances, water) in the cold of the mid-winter, which intensified the human suffering.
>
> Some 835,000 insurance claims were filed in Canada due to the outage, 20% higher than Hurricane Andrew's toll, and the leading to the highest losses for any catastrophe in Canadian history. The storm was responsible for more than US$1.2 billion in insured losses and total losses amounting to US$2.5 billion[ii]. [$1.72 billion and $3.58billion corrected for inflation.]

While the aforementioned portion of the report indicates "80 mm or more," in actuality, in certain locations, it was reported to be as much as 110 mm or the equivalent of ~ 4.3 inches. The report goes on to detail that the actual damage to the electric grid included:[iii]

> Several thousand kilometres of power lines and telephone cables were rendered useless; over 1,000 transmission towers, of which 130 were major structures worth $100,000 each, were toppled; more than 30,000 wooden utility poles, valued at $3,000 each, were brought down.

In terms of its effect on some utilities in New England who even then were importing power from HydroQuebec, it was reported that:

> … Hydro-Quebec, North America's largest electricity producer, was sued by 22 insurance companies for the unreliability of its grid. In their suit, the insurers claimed that not only bad weather was to blame for the damages, but also the power network configuration, inadequate maintenance, technical weaknesses as well as human errors led to high number and value of claims.[iv] The inclination of the insurers to sue a utility for poor grid design carries immense implications for distributed generation should the insurers come to believe that DE *[distributed energy]* offers a more resilient system to lower their risks.[v]

Reactions and Outstanding Issues[vi]

> The performance of Hydro-Québec TransÉnergie's power grid during 1998 Ice Storm raised questions about the fundamental concept, vulnerability, and reliability of the grid. Critics noted that the power generation facilities were located approximately 1,000 km (600 mi) away from population centres and that there was a lack of local power stations around Montreal, which is served by only six 735 kV feeder lines. In addition, the 735 kV transmission system received scorn from the public and the media. The power transmission grid was said to concentrate power transmission on only a few 735 kV lines, such as those that run from James Bay to Montreal. Out of the six 735 feeder lines in Montreal, five of them form a loop called the "ring of power" around the city. When the ring failed on January 7, 1998, roughly 60% of Greater Montreal's power supply was offline. Hydro-Québec's large above-ground transmission and distribution system was considered to be exposed to natural disasters, although the cost of undergrounding the grid was prohibitive.

> The technology utilized on Hydro-Québec TransÉnergie grid also came under fire from critics. It is claimed that this technology, used to improve performance, safety, and reliability, made people in Quebec over-dependent on the power grid for their energy needs, since electricity, especially hydroelectric power, makes up over 40% of Quebec's energy supply.

System Improvements

As might be expected, such staggering losses and near universal criticism prompted a number of system changes to attempt to make the system more robust. Among these have been:[vii]

- New construction standards that increase mechanical strength of the towers, poles and anchoring
- Making every tenth transmission tower anti-cascading to limit damage from single tower collapse
- Improved transmission configuration allowing redundant sources of energy supply
- Enhanced maintenance and vegetation control
- Major research and development efforts to better understand events and strengthen facilities
- Use of "interphase spacers" to curb galloping, high-amplitude line oscillations
- Investigation and limited deployment of de-icer technology[viii]

Final Cautions

One often-asked question is whether an event of this magnitude could reoccur and what the probabilities might be that it would impact the electric grid in a similar manner. A number of complex factors make this query difficult to answer with any certainty. Among them are: 1) the effectiveness of upgrades made to the system; 2) the impact of climate change may lead to more frequent icing; and 3) whether other hazards may surface that may not be related to icing but have a similar or even worse outcomes.

Professor Dennis Meleti, former director of the Natural Hazards Center[ix] has said that one of the most common mistakes in response to natural disasters is to take actions to mitigate the most recent disaster that actually make conditions worse for ensuing or maybe different hazards that follow. This is similar to what psychologists Amos Tversky and Daniel Kahneman, Nobel Prize winner in Economic Sciences, termed an "availability heuristic". It's akin to the old quote about the military "always preparing for the last war". The downside is it can lead to expending excess time and funds to prevent recurrence of the most immediate hazard although it might be a less significant one compared to others. For instance, "hardening" the transmission system as was done in Quebec may be like building a Maginot Line unless all basic grid components are made resilient and the grid is decentralized.

NYU Polytechnic Institute Professor of Risk Engineering, Nassim Taleb, cautions on the practice of: [x]

> …look[ing] in the past for information on the so called *worst-case scenario* and us[ing] it to estimate future risk—this method is called "stress testing…But they never notice the following inconsistency: this so-called worst-case event, when it happened, exceeded the worst case at the time…If humans fight the last war, nature fights the next one."

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[i] Lecomte, Eugene L., Pang Alan W. and Russell,Dr. James W. Ice Storm '98 December 1998. pp. 1-2.
[ii] Janet Abramovitz and Seth Dunn, "Record year for Weather-related Disasters," press release, Worldwatch Institute (November 27, 1998). Wikipedia has reported the losses at closer to $5-$7 billion dollars and may be based on updated figures not available at the time.
[iii] Op cit. Lecomte et al. p. 14.
[iv] Reuters. "Hydro-Quebec sued for C$300 million over 1998 ice storm," (February 24, 2001).
[v] Gordes, Joel N. and Lenssen, Nicholas. *Reducing Risks With Distributed Energy*. Primen. June 2004. pp. 12-13.
[vi]http://en.wikipedia.org/wiki/Hydro-Qu%C3%A9bec%27s_electricity_transmission_system . *See Criticism.*
[vii] Interview with Jean-Pierre Giroux at http://news.hydroquebec.com/en/news/116/ice-storm-1998-15-years-later/#.UjJfBz-AHXA
[viii] http://en.wikipedia.org/wiki/Levis_De-Icer
[ix] Keynote at Columbia University in December 1999. 50th Anniversary of the Lamont-Dougherty Observatory. *An Assessment of Natural Hazards in the United States*.
[x] Taleb, Prof. Nassim Nicholas. *Antifragile: Things that Gain From Disorder*. Random House. New York. 2012. pp. 45-46.

Terrorism as an Electric Grid Threat

The United States, by virtue of its geography, has large oceans to its east and west and generally friendly nations on its borders allowing it to have enjoyed protection from foreign invasions over most of its history. Unfortunately, this same geographically-provided security may have made us less diligent in preparation for terrorist activities. When the attacks of September 11, 2001, took place, the reaction of then-White House Press Secretary Ari Fleischer was, "Never did we imagine what would take place on September 11 where people use[d] those airplanes as missiles and weapons."[i] In reality, the late Tom Clancy in his 1994 book *Debt of Honor* did present a scenario wherein an airliner flew into the US Capitol building. This epitomizes what the Congressional 9/11 Commission Report (Kean-Hamilton) summarized:[ii]

> We believe the 9/11 attacks revealed four kinds of failures: in imagination, policy, capabilities, and management.

Increasing power dependence on HydroQuebec may represent further failures in these regards. Ensuing 9/11 initiatives formed the Department of Homeland Security (DHS) and reports by the National Academies and others looked at the security of the electric system. It is important to realize the grid was never designed with security as a primary concern. The 9/11 Commission went on to give grades for recommendations it made. Critical Infrastructure Assessment, which includes the electric grid, received a “D” grade.[iii] Securing the assets becomes even more difficult when the generation and transmission of power involves two nations and the lines span vast distances over somewhat remote areas.

Terrorism has many faces. The tools of terrorism can include both direct and indirect means to damage the critical infrastructure by physical and/or cyber means by both nation states and individuals. (See diagram at page 3.) The latter are often marginalized as threats but author Tom Friedman notes:[iv]

> When you combine the angry men that Americanization-globalization creates with the way in which globalization can super-empower people, you have what I believe is the real, immediate national security threat to the United States today: the Super-Empowered Angry Man.

Many of these adversaries, be they nation-states or individuals, are well-trained in technology and understand the workings and weak points of our heavily centralized, complex systems. Among their favored targets are: generators and generator components; transformers; circuit breakers; monitoring equipment including SCADA (controls); software; and natural gas lines. A Silicon Valley event in April 2013 against the Metcalf Substation illustrates the vulnerability:[v]

> In apparent acts of “sabotage” in the South Bay early Tuesday, someone cut fiber optic cables, knocking out some 911 service, and then fired a rifle at a PG&E substation, Santa Clara County’s sheriff said…PG&E officials told the sheriff’s office that the substation’s security fence had been breached, at least five transformers had been damaged and that hazardous materials had spilled…The California Independent System Operator issued a Flex Alert asking those in Santa Clara County and Silicon Valley to cut down on their electricity use until midnight…

While only moderate damage resulted from this episode, it demonstrates how open our system is in spite of wider deployment of more highly sophisticated monitoring equipment. The seriousness of this incident is underscored by the vast majority of large power transformer (>200 MVA) manufacturing capacity being overseas. While some improvement has taken place in recent years, most remain foreign-sourced[vi] and require 18 to 24 months for replacement if they are not available via utility sharing agreements. They are often subject to difficult transportation issues. This raises analogous questions on the vulnerability and availability of components of the HVDC transmission line components and converter facilities as targets for terrorism. Those critical components and facilities would surely be among the prime targets of any terrorist. Thus, we must seek answers to those questions regarding the vulnerability of Northern Pass converter facilities and other critical HVDC components before the project is allowed to proceed down the regulatory path.

An additional danger of these foreign-sourced products is not knowing what pre-installed viruses may be embedded that can show up months or years later to wreak havoc. Much has been made of one report about how the CIA was responsible for implanting faulty software into a valve used on a Russian gas pipeline which then exploded. While allegedly a false account, this method for terrorism has credibility and there is concern that many digital products that are produced overseas may carry malicious software (malware) capable of infecting any number of systems to which an electronic device may be attached. Making matters worse are recent reports that:[vii]

> At a time when millions of computer users face increasingly sophisticated cyberattacks, the antivirus software they rely on to keep their information safe frequently fails to do the job…Of 45 pieces of malware that lingered on the New York Times computer systems for a third of a year, just one was spotted by its antivirus software, the newspaper disclosed in January. ..Such examples are becoming alarmingly common. Recent studies have found much of the malware-fighting software on the market is virtually useless against the growing onslaught of attacks.

The effects of terrorist attacks such as the one on the Metcalf Substation can be enhanced by timing them to take place during periods when the grid is already under stress during peak electric use or after a hurricane when repairs are underway or an ice storm such as the 1998 one that incapacitated HydroQuebec. Such attacks on the US portion of the grid after the loss of Canadian power could prove difficult to manage particularly if the Northeast resources had also suffered similar losses to weather.

Low tech approaches can also cripple normal grid operations be it shooting out insulators on transmission lines[viii] or loosening transmission towers from their bases to topple them. Even using simple distributed denial of service cyberattacks against utilities during emergency situations can hamper their ability to communicate internally as well as with government officials thereby endangering the public.

The National Research Council requested release of an updated security assessment that while completed in the fall of 2007 was kept classified in its entirety until 2012. Their news release said.[ix]

> The U.S. electric power delivery system is vulnerable to terrorist attacks that could cause much more damage to the system than natural disasters such as Hurricane Sandy, blacking out large regions of the country for weeks or months and costing many billions of dollars, says a newly released report...The power grid is inherently vulnerable physically because it is spread across hundreds of miles, and many key facilities are unguarded…Considering that a systematically designed and executed terrorist attack could cause disruptions even more widespread and of longer duration, it is no stretch of the imagination to think that such attacks could produce damage costing hundreds of billions of dollars.

Further extending additional transmission to Canada without first addressing existing inadequacies would not only be irresponsible but potentially open the grid to increased terrorist threats.

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[i] Media looked past 9-11 Commission documentation of Bush administration fabrications

[ii] The 9/11 Commission Report. W.W. Norton & Co. New York. p. 339. Authorized edition.

[iii] Final Report on 9/11 Commission Recommendations. December 5, 2005. p. 1.

[iv] Friedman, Tom. 2000: *The Lexus and the Olive Tree* (updated). p. 398. Anchor Books, New York.

[v] Vandalism At San Jose PG&E Substation Called 'Sabotage' Channel 5. April 16, 2013.

[vi] Economic Benefits of Increasing Electric Grid Resilience to Weather Outages. Executive Office of the President. August 2013. p. 17.

[vii] Johnson, Steve. *Software Often Fails to Deter Hackers*. San Jose Mercury News. September 27, 2013.

[viii] *4 Charged in Vandalism*. Rutland Herald. November 10, 2012.

[ix] News release on the public release of Terrorism and the Electric Power Delivery System. National Academies. November 14, 2012.

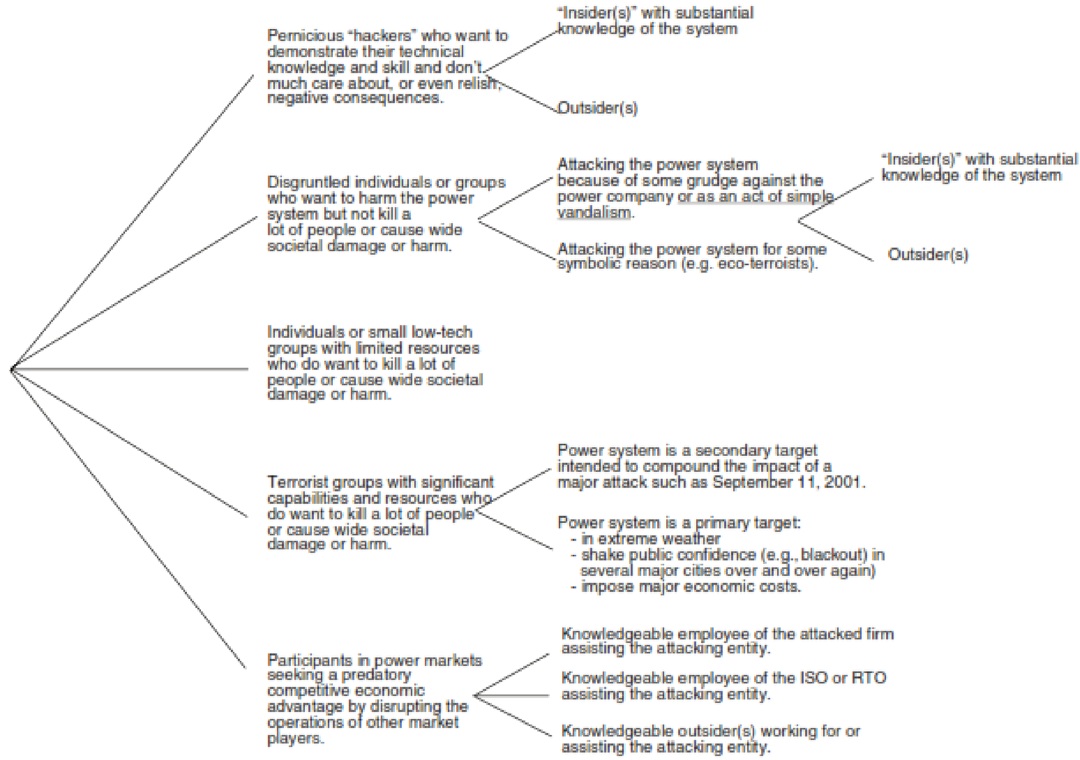
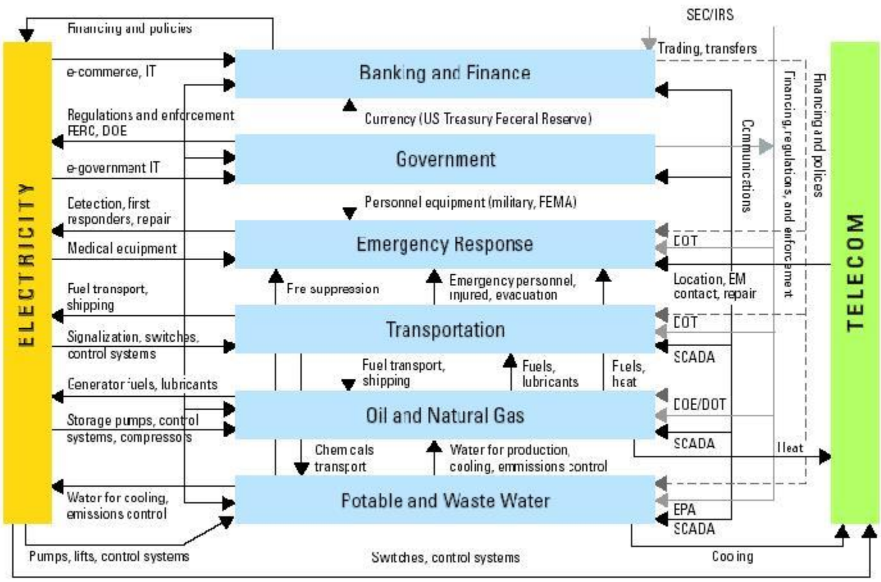


FIGURE 1.7 Simple classification of potential power system attackers.

From *Terrorism and the Electric Power Delivery System.* National Academies. 2007/2012. p. 15.

Cyber Threats to the Grid

One hazard that has the potential to inflict great harm is an intentional cyberattack that incapacitates the command, control and communications of the electric grid as well as most other aspects of our increasingly digital society. The diagram below shows the interactions of primary critical infrastructure and its heavy dependence on power and telecommunication:[i]



Increased dependence on HydroQuebec resources may enhance cyber threats via added digital complexity opening increased nodes for penetration that could compromise hydro resources at critical periods.

Cyberattacks, while not specifically detailed in most of the recent Northern Pass deliberations, should certainly be considered in the final EIS and in any decisions. In the most generic sense, "hacking" exploits weaknesses in a computer or network of computers. It may take a number of forms and the more common ones include[ii]:

Distributed denial of service attacks (DDoS): These are the least sophisticated and most common form of cyberattack and often use massive bombardment of information to overload and to slow or shut down information systems rendering them ineffective for business operations.

Viruses: Programs or lines of code that "infects" a computer without the owners knowledge. They are self-replicating and spreads from computer-to-computer causing problems of varying degrees from nuisance to total incapacitation.

Trojan Horses: Programs that are unknowingly inserted into a computer that pretend to be a non-threatening application but are malicious in nature. It is unable to replicate itself like the virus.

Worms: Programs that replicates over computer networks. They are usually employed to spread malicious actions. Stuxnet, that physically destroyed Iranian centrifuges setting back nuclear aspirations, was a worm.

Botnets: A botnet is a network of "computer robots" that have been transferred by malicious downloads (e.g. Trojan Horse) that infect multiple computers on the internet. The owner can direct the "bot" to join other bots on other infected computers to initiate DDoS attacks that can cause servers to go down. Computer owners are mostly unaware they are part of this malicious network.

It can only be speculated on the many reasons why cyberattacks have apparently not been pursued as a full-fledged and legitimate grid threats in regulatory processes such as the EIS. Among potential reasons they might not have been addressed are:

- The average person, including many regulators, knows little about cyber except what may appear in newspapers or web accounts. People often reject what they don't understand and "There is a tendency in our planning to confuse the unfamiliar for the improbable."[iii]
- Many policy-makers and regulators, by training or inclination, have little experience with technology and are often not comfortable in that realm.
- There is often a "not in my department" or siloed mentality and although the North American Electric Reliability Corporation (NERC) is the designated entity responsible for electric system cyber security the ball seems to be passed among several federal agencies.
- Although utility cyber intrusions have occurred[iv], no major regional outage has yet taken place.
- The utilities downplay cyber threats and claim compliance with all existing NERC standards.
- While NERC promulgates and enforces Cybersecurity Standards, (CIPs 002-009)) evidence indicates these standards, that also apply to Canada[v], have been called inadequate by some knowledgeable experts..

One of those most critical is Michael Assante, former Chief Security Officer of the NERC.[vi]

> Assante criticized past cybersecurity efforts focused on complying with lists of requirements, naming reliability standards released by the North American Electric Reliability Corp., or NERC. The group's standards are focused on perimeter protection and don't take into account new types of threats… …Instead, the U.S. government and businesses operating industrial control systems should focus on integrating forensic and security tools into the systems, pour more money into security research and spend more time training cybersecurity workers with attack simulations and other tools Assante said.

Mr. Assante has been joined in warning of cyber vulnerability by no less than former Secretary of Defense Robert M. Gates who articulated the dangers from cyberattacks in a 2011 speech [vii]. Former Secretary of Defense Leon Panetta, also sees cyberattack as a serious threat, predicted a cyber-Pearl Harbor[viii] as a strong possibility.

While the ultimate responsibility falls upon the private sector to protect their assets, unless government sets some basic framework, it will not happen. Perhaps tying regulated utility rates of return directly to their performance in this realm will help but setting the framework will fall to government either at the state or federal level. Let it begin here in this process.

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[i] Op. cit. *Making the Nation Safer*. National Academies Press. p. 301

[ii] Multiple sources were used to provide these definitions for laypersons.

[iii] Attributed to Nobel Prize winner in economics, Thomas Schelling in *The Signal and the Noise*. Silver, Nate. Penguin Press. 2012. p. 419.

[iv] See Update 1-Malicious Virus Shuttered U.S. Power Plant -DHS and Telvent Reports Hack

[v] Canada is a member of the Northeast Power Coordinating Council and subject to NERC standards.

[vi] Gross, Grant. *Experts, Stuxnet Has Changed the Cybersecurity Landscape*. IDG News. 11/17/2010.

[vii] Link leads to audio of former SecDef Robert M. Gates Answering Cyber question at CCSU on November 8, 2011.

[viii] Bumiller E. and Shanker T. The New York Times. *Panetta Warns of Dire Threat of Cyberattack on U.S.* October 11, 2012. Link leads to audio of Secretary of Defense Panetta delivering speech on Cyber Pearl Harbor.

Drought and Forest Fires

There are many expected hazards associated with generation and transmission facilities that include ice storms, lack of fuel supply and more recently the advent of potential cyberattacks. HydroQuébec (HQ) enjoys many advantages of not being directly dependent on any significant amount of fossil fuel sources that also makes it immune to severe price increases that might affect many power providers. But hydroelectric facilities carry their own specific risk profiles that include drought and, as a secondary effect of drought, the increased potential for forest fires particularly if climate change leads to a warmer temperature regime as a number of scientists suspect.

Drought has the potential to restrict water resources required to run the hydro facilities as well to serve the needs of other industries and agriculture which may be in competition for water resources during periods of constraint. Reports from 2012 note:

> This summer has seen record-setting temperatures in Ontario, Quebec and the Maritimes, along with far less rain than normal in many areas…"We've definitely beaten a few records in a few areas," Roberta Diaconesco of Environment Canada said Sunday. "Compared to other years, yes, we could say that it's pretty hot and humid." Montreal, for example, normally gets over 90 mm of rain in July, but has only had 21 mm so far this year, Diaconesco said…Some parts of southern Quebec haven't had rain since July 4, causing the St. Lawrence River to drop to levels that haven't been seen in years. [i]

> Most of Central and Eastern Canada is experiencing extreme heat and little rain causing drought conditions, a senior climatologist with Environment Canada says…"I'd call it a drought, no question about it," David Phillips told the CBC News Network in an interview Sunday afternoon…"Besides the lack of precipitation, there is just this hot weather and it's like a double whammy," Phillips said. "There's no rain and all that heat demands evaporation ... it's almost as if the atmosphere has forgotten how to rain."[ii]

One source reported in reference to a major fire that cut transmission to New England that:[iii]

> The fires are a result of the worst drought in the James Bay region in the last 40 years.

While 2012 HQ Annual Report does not mention drought per se as a risk factor, it does caution that:

> One of the principal uncertainties that Hydro-Québec faces relates to natural water inflows. Hydro-Québec Production must ensure that it is able to meet its commitments to supply the annual heritage pool of 165 TWh to Hydro-Québec Distribution and fulfill its contractual obligations. In concrete terms, this means being able to cover a natural inflow deficit of 64 TWh over two consecutive years, and 98 TWh over four consecutive years. To meet this requirement, the division applies a variety of mitigation measures and closely monitors them…[iv]

This admission of risk, while upfront, does throw some degree of doubt that whether under prolonged drought conditions HQ would be able to meet their contractual power obligations, particularly during the summer months when New England states have their peak needs. What protection would the Northeast have if a multiyear drought forced Canadian hydroelectric generators to curtail or cut off exports to enable them to serve other Canadian demands?

The exact wording of all contracts with HQ should, ideally, if not already made available and public, be made so before the construction of Northern Pass to insure that these conditions of availability will be met as a first order priority rather than experiencing an incredibly large buyers' remorse after the fact. Likewise, if there were to be shortages within the HQ system during winter when it has its peak usage, might they expect reciprocity from U.S. generators who are increasingly gas dependent and questions of available gas pipeline capacity having already been raised?

As noted above, climate change may lead to a warmer temperature regime that may exacerbate conditions leading to more frequent and more intense forest fires. A study originally conducted specifically for some specific California areas, provides some more generalized points that may apply to Quebec. These include:[v]

- Wildfire behavior is influenced by moisture content of vegetation and its density.
- Creating conditions that intensify wildfires by warming out and drying vegetation
- Climate change may also lead to increases in winds that spread wildfires.
- Rural areas with fewer resources for fire suppression are at greater risk.
- Wildfire behavior may also depend upon slope and other site-specific characteristic

While it may or may not be related to climate change, in July 2013 a record Canadian forest fire, induced by drought, led to the outage of major transmission lines from HydroQuebec and forced the New England Independent System Operator (ISO-NE) to scramble for make-up power. One report said "While ISO-New England was able to recover without any power loss, as did New York's ISO, it's arguable that had the timing been even slightly different, a catastrophic power failure could have occurred."[vi] Another source reported:[vii]

> The line tripping resulted in load and generation tripping within Quebec, and approximately 3,370 MW of exports to New England, New York, New Brunswick, and Ontario being tripped or reduced. When both Phase II and Highgate tripped, New England lost approximately 1,750 MW of imports from HQ over the span of a few minutes. New England recovered from the source loss in less than eleven minutes, which is within the NERC allowable timeframe of fifteen minutes. ISO-NE did not receive any notification from HQ of a possible problem before the lines tripped. NERC has initiated an investigation into the event.

This recent disaster points out that, in spite of partially addressing more predictable system failures (snow or ice storms), they were ill-prepared for one of a different type. What is particularly disturbing is the final sentence of the description of the forest fire event where it has been alleged that HQ had not alerted ISO-NE of any possible problem to allow them adequate time to bring online back-up resources. This lack of adherence to protocols, that could have led to a cascading grid failure episode, may make HQ a less than reliable partner in any future emergencies.

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[i] http://o.canada.com/news/eastern-ontario-drought-worst-in-a-decade-with-video/

[ii] Drought in Central, Eastern Canada baking crops. CBC New. July 15, 2012.

[iii] *Forest fires cause Montreal-area, QC power outages*. CTV News. July 5, 2013.

[iv] *Hydro-Quebec Annual Report. 2012* p. 68.

[v] *Will Climate Change Spark More Wildfire Damage*? Torn, Dr. Margaret S., Mills, Dr. Evan, Fried, Dr. Jeremy. Lawrence Berkeley National Laboratory. 1998.

[vi] *http://www.ctmirror.org/story/2013/08/08/canadian-fires-cause-close-call-new-england-power-supply*

[vii] *Incremental Hydropower Imports*. NESCOM Fall 2013. From: ISO-NE, Week of July 14-20, 2013 Operations; July 3, 2013 DCS Event, presented to the Reliability Committee, Aug. 15, 2013, available at http://www.iso-ne.com/committees/comm_wkgrps/relblty_comm/relblty/mtrls/2013/aug152013/index.html

HydroQuebec Capacity and Exports[i]

October 29, 2013

One of the largest advantages that HQ enjoys is its grid peaks in the winter because of building-related heating needs much of which is by inefficient electric resistance heating. This is countercyclical to exports to the U.S. where peak demands are primarily driven by air-conditioning needs in summer. In spite of this, there are multiple risks that have plagued and continue to plague this system.

When considering the importation of hydroelectric resources from HydroQuebec (HQ), it is important to examine a number of capacity-related risk factors before entering into any contracts. Among these are:

- What percentage of New England's total load would be it be prudent to provide by imports that may be subject to greater hazards than native supply due to distance and other factors?
- What is the all-in cost for construction of hydroelectric facilities and the entire infrastructure associated with delivery of power. This includes transmission lines, HVDC converter stations that may be necessary and maintenance required for the lifetime of the system.
- What has been the history and projections for the future precipitation and melt resources by which reservoirs will be replenished and can they meet peak needs by season and times of day?
- What contractual obligations are in place with other entities and where might a U.S. entity stand in relationship to them if hard decisions on capacity availability need to be made?
- While HQ does not have to be concerned with fuel price volatility issues, there are risks to the robustness of the hydro facilities associated with adverse weather, electrical or mechanical failures, terrorist attacks, cyberattacks and other known and unknown hazards that may affect the reliability and performance of not just the hydroelectric elements but the entire grid.

Two events offer historic examples, each highlighting the importance of one or more factors above pertaining to the adequacy and availability of HydroQuebec assets:

1) The ice storm of January 1998 lasted 7 days with freezing rain hitting eastern Ontario, southwestern Quebec, southern New Brunswick and Nova Scotia.

> These areas were pelted with 80 millimetres [sic] or more of freezing rain. The event doubled the amount of precipitation experienced in any prior ice storm…
>
> Several thousand kilometres of power lines and telephone cables were rendered useless; over 1,000 transmission towers, of which 130 were major structures worth $100,000 each, were toppled; more than 30,000 wooden utility poles, valued at $3,000 each, were brought down.[ii]
>
> .. Hydro-Quebec, North America's largest electricity producer, was sued by 22 insurance companies for the unreliability of its grid. In their suit, the insurers claimed that not only bad weather was to blame for the damages, but also the power network configuration, inadequate maintenance, technical weaknesses as well as human errors led to high number and value of claims.[iii]

2) In July 2013 a large Canadian forest fire, driven by a drought, led to the outage of major transmission lines from HydroQuebec and forced the New England Independent System Operator (ISO-NE) to scramble for make-up power. One report said "While ISO-New England was able to recover without any power loss, as did New York's ISO, it's arguable that had the timing been even slightly different, a catastrophic power failure could have occurred."[iv] Another source reported:[v]

> The line tripping resulted in load and generation tripping within Quebec, and approximately 3,370 MW of exports to New England, New York, New Brunswick, and Ontario being tripped or reduced.

> When both Phase II and Highgate tripped, New England lost approximately 1,750 MW of imports from HQ over the span of a few minutes. New England recovered from the source loss in less than eleven minutes, which is within the NERC allowable timeframe of fifteen minutes. ISO-NE did not receive any notification from HQ of a possible problem before the lines tripped. NERC has initiated an investigation into the event. [Emphasis added.]

In each of these two events, in spite of adequate generation capacity being available, the loss of power from remote sources led to catastrophic or almost catastrophic circumstances for not only HQ but to their client utilities as well. In the second event, this was even after the disastrous 1998 ice storm led to immense efforts to upgrade the system. This more recent second disaster, 15 years later, pointed out that in spite of addressing one set of system failures, they were ill-prepared for an ensuing failure of a different type. What is particularly disturbing is the final sentence of the description of the forest fire event where it has been alleged that HQ had not alerted ISO-NE of any possible problem to allow them adequate time to bring online back-up resources. This lack of adherence to protocols and common courtesy may make HQ a less than reliable partner in any future emergencies.

Keeping each of those very different events in mind, from the available information and projections from ISO-NE[vi], it is conceivable that a greater percentage of New England power may come from Canadian hydro sources. A combination of factors already in place could conceivably lead to raising the dependency from approximately 5% currently to ~10% over the next 10 years. These factors include:

- Retirement of existing nuclear and nonnuclear capacity in New England such as the 600 MW Vermont Yankee facility which came about in a fairly sudden manner. Additional closures should not be unexpected due to competitive pressures and other drivers.

- Bastardization of the Renewable Portfolio Standard (RPS) to relax requirements to allow greater percentages of large, foreign hydro to participate in New England states allowing them to attain their goals at cheaper prices. As all of HQ resources are already mature technologies, they may impede more resilient, local renewables from developing.

- Additional reductions in capacity needs served by ISO-NE due to enhanced energy efficiency and load management programs and advances in distributed energy (including combined heat and power) with greater numbers bypassing grid resources except as emergency backup.

This leads to another series of questions that ought to be asked before this project is approved on what protections would the Northeast have against any number of risks. For instance, if multiyear droughts with reduced runoff due to climate change[vii] or an unexpected earthquake[viii] forced Canadian hydroelectric generators to curtail or cut off exports, would this rank Canadian demand above New England's? How much notice would be provided? If sudden, could that lead to a cascading blackout over a large area?

The first duty of government is to the safety and security of its citizens. For that reason, answering these questions, and others, should be a priority of this process.

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[i] http://en.wikipedia.org/wiki/Hydro-Qu%C3%A9bec and other sources

[ii] Lecomte, Eugene L., Pang Alan W. and Russell,Dr. James W. *Ice Storm '98* December 1998. pp. 1-2.

[iii] Reuters. "Hydro-Quebec sued for C$300 million over 1998 ice storm," (February 24, 2001).

[iv] *http://www.ctmirror.org/story/2013/08/08/canadian-fires-cause-close-call-new-england-power-supply*

[v] *Incremental Hydropower Imports*. NESCOM Fall 2013. From: ISO-NE, Week of July 14-20, 2013 Operations; July 3, 2013 DCS Event, presented to the Reliability Committee, Aug. 15, 2013, available at http://www.iso-ne.com/committees/comm_wkgrps/relblty_comm/relblty/mtrls/2013/aug152013/index.html

[vi] Derived from ISO-New England 2013 CELT documents at http://www.iso-ne.com/trans/celt/report/2013/index.html

[vii] Blackshear, Crocker, Drucker et al. *Hydropower Vulnerability and Climate Change*. Middlebury College Environmental Studies Senior Seminar. Fall 2011. p. 29.

[viii] Natural Resources Canada

Grid Complexity as a Growing Security Issue

The National Academy of Engineering has called the electric grid **"**the greatest engineering achievement of the 20th century."[i] But the grid was never designed or built with security as a primary consideration. The grid is what is termed a tightly-coupled, complex system meaning:[ii]

> A system is said to be complex if the whole transcends its parts. Most complex systems consist of diverse entities that interact both in space and in time…often unpredictable, can produce large events
>
> The term tightly coupled refers to "any change in one part affect the other part quickly and repeatedly."

The effect of this has been some major cascading regional grid failures in November 1965 and August 2003. In September 2011, about the same time as when New England was involved with Storm Irene, a totally unexpected outage occurred in the San Diego area that cascaded into Arizona and finally into Mexico leaving 4.5 million customers in the dark. It resulted in 23 distinct events that occurred on 5 separate power grids in a span of 11 minutes. Further investigation pointed primarily to a procedural error in changing out a capacitor (normally, a routine maintenance item).[iii]

The topic of increasing grid complexity is not new. It was recognized by Italian computer expert and systems management engineer, Dr. Roberto Vacca. While somewhat dated, in 1973 the author noted:[iv]

> An increase in the number of interconnecting electric lines or a growth in their capacity is generally a positive good, for it allows the demands of vast areas to be distributed in a more balanced way among a larger number of generating station, but to increase the lines of interconnection is also to increase the complexity of the system, and this may make efficient automatic surveillance of it so difficult as to be actually impossible. Security margins ought not to be indiscriminately enlarged, therefore.

In looking at expanding the electric system to import more power from Canada, the US DOE and FERC should be more closely examining how does the addition of transmission capacity affect the rest of the system? Often it is added to relieve expensive congestion due to heavy load growth in an area or to bring in power from more remote locations such as envisioned by the Northern Pass project. But does added capacity and redundancy alone make the large, centralized system more resistant to failure? No less than the National Research Council (National Academies of Science/Engineering) has warned:[v]

> A direct way to address vulnerable transmission bottlenecks and make the grid more robust is to build additional transmission capacity, but there are indications that redundancy has a dark side (in addition to increased costs). The likelihood of hidden failures in any large-scale system increases as the number of components increases. Modeling techniques are only now emerging for the analysis of such hidden failures. *[Emphasis added.]*

In *Disasters by Design*, another National Academies-sponsored publication; a highly respected natural hazards expert, Professor Dennis S. Meleti, remarked on the complexity of energy systems:[vi]

> One of the first major projects San Francisco took on was lessening its reliance on complex and highly centralized utility grids. It learned a lesson from the 1994 Northridge earthquake when 3.1 million customers lost electricity and close to 100,000 homes and businesses were without power for over 24 hours…

More recently in a presentation on the grid Peter Fox-Penner, the respected principal of The Brattle Group concluded:[vii]

> ♦The electric power system is a vast and complex network with layers of physical, regulatory and market structure. It has a uniquely demanding operating environment that is highly vulnerable to many types of physical and cyber disruptions and the ability to cascade from local to large-scale failures.
> ♦ Current change drivers (climate change, smart grid, market complexity) will add to the vulnerabilities in the short term.
> ♦ The long term changes underway towards greater local generation, greater renewable generation, and smart grid will eventually make the grid much less vulnerable to widespread failures.

Nassim Nicholas Taleb, author of the well-known book *The Black Swan* that was on the New York Times bestseller list for 36 weeks, has observed:[viii]

> Man-made complex systems tend to develop cascades and runaway chains of reaction that decrease, even eliminate, predictability and cause outsized events. So the modern world may be increasing in technological knowledge, but, paradoxically, it is making things a lot more unpredictable.
>
> …the automation of airplanes is underchallenging pilots, making flying too comfortable for them, dangerously comfortable. ..But, thankfully, the same FAA finally figured out the problem; it has recently found that pilots often "abdicate too much responsibility to automated systems."

The Smart Grid, another heavily automated system, is often touted as a method to make the grid more resilient. Conversely, it also carries with it the risk of opening up innumerable new nodes for penetration by malicious software into grid operations. The nexus of complexity and grid security as it relates specifically to Smart Grid and cybersecurity was recently addressed by former IBM Security Lead, Andy Bochman when he was posed the question, "What are the dangers of keeping to business as usual on this front?"[ix]

> Business as usual is where there is a huge amount of complexity in utilities' systems, their systems are being increasingly interconnected, they're growing their attack surface in security terms -- more ways in, and easier ways in, for bad guys. Without an understanding of how security is a part of all business decisions -- I'm going to link with a new partner, I'm going to start buying cloud services, etc. -- they will continue to add complexity, and it will make the job of securing all of their assets that much harder.

An ongoing examination of this growing grid complexity should be subject to mandatory security reviews either integral to the *EIS* or by developing a separate energy security impact study. Either way, the grid security threat posed by the Northern Pass proposal must be studied and considered by DOE as part of its consideration of the Northern Pass Presidential Permit Application and its alternatives, including the no-build alternative.

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i http://www.nap.edu/catalog.php?record_id=11735

ii. Page, Prof. Scott. *Understanding Complexity*. The TeachingCompany. 2009. The definition for "tightly coupled" may be found at: http://in.answers.yahoo.com/question/index?qid=20091010060422AA2PSZJ

iii http://en.wikipedia.org/wiki/2011_Southwest_blackout

iv Vacca, Roberto. *The Coming Dark Ages*. Doubleday & Co. Garden City, New York. 1973. Pp. 67-68.

v *Making the Nation Safer: The Role of Science and Technology in Countering Terrorism.* National Academy Press. Committee on Science and Technology for Countering Terrorism, National Research Council. p.302 .2002.

vi Meleti, Prof. Dennis S. et al, *Disasters by Design*. Joseph Henry Press/National Academies Press. 1999. P. 59.

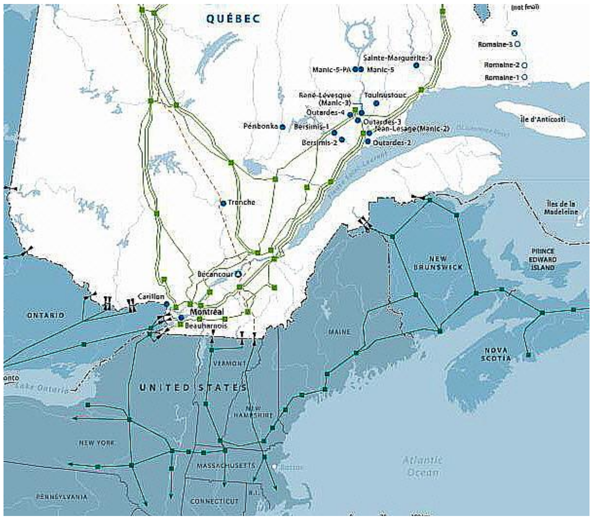
vii Fox-Penner, Peter. The Brattle Group. *An Introduction to Electricity Grid Infrastructure: System Complexity in a Rapidly Changing Industry*. Slide 18. August 31, 2010.

viii Taleb, Nissim Nicholas. *Antifragile:Things That Gain From Disorder*. Random House . New York. © 2012. pp. 7 and 43.

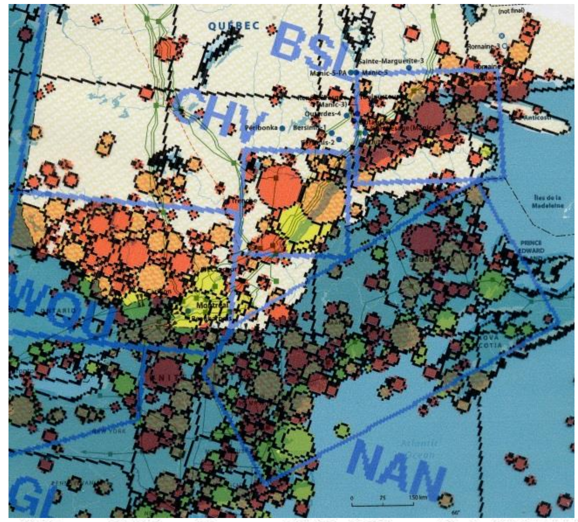
ix St. John, Jeff. GreenTechMedia. *Smart Grid Cybersecurity: Q&A With Andy Bochman*. September 6, 2013.

Earthquakes as Hydroelectric Generation and Transmission Risk Factors

October 29, 2013



Map showing all the major HydroQuebec Generation and Transmission Assets and Interconnections to the U.S.



Yellow: < 1900 Orange: 1900 - 1964 Red: 1965-2001

Uncertainty

+/- 50km +/- 25km +/- 10km

$2.5 \leq M < 3.0$ $M \geq 3.0$ $M \geq 4.0$ $M \geq 5.0$ $M \geq 6.0$

Unlike Japan, when one thinks of Canada, one does not conjure up thoughts of earthquakes as a major risk factor but the country is subject to some seismic activity and that is not confined to the western portions. The maps above demonstrate that there is a significant amount of activity in eastern Canada, including the area holding HQ's generation and transmission assets. Natural Resources Canada reports:[i]

> Eastern Canada is located in a stable continental region within the North American Plate and, as a consequence, has a relatively low rate of earthquake activity. Nevertheless, large and damaging earthquakes have occurred here in the past and will inevitably occur in the future...
>
> Each year, approximately 450 earthquakes occur in eastern Canada. Of this number, perhaps four will exceed magnitude 4, thirty will exceed magnitude 3, and about twenty-five events will be reported felt. A decade will, on average, include three events greater than magnitude 5. A magnitude 3 event is sufficiently strong to be felt in the immediate area, and a magnitude 5 event is generally the threshold of damage.

What this seems to indicate is that when dealing with an expansive network of generators and transmission facilities, even a quake at the lower end but above 6.1 on the Richter Scale has the potential to inflict damage that might interrupt the flow of energy within Canada as well as exports that could have an impact all out of proportion to what may be conceivable at this time. Some of the factors which may increase the percentage of power coming from Canada include:

- Retirement of existing nuclear and nonnuclear capacity in New England such as the 600 MW Vermont Yankee facility which came about in a fairly sudden manner. Additional closures, should not be unexpected due to competitive pressures and other drivers.

- Bastardization of the Renewable Portfolio Standard (RPS) to relax requirements to allow greater percentages of large, foreign hydro to participate in New England states allowing them to attain their goals at cheaper prices. As all of HQ resources are already mature technologies, they may impede more resilient, local renewables from developing.

- Additional reductions in capacity needs served by ISO-NE and ISO-NY due to enhanced energy efficiency and load management programs and advances in distributed energy (including combined heat and power) with more customers bypassing the grid except for emergency backup.

If, indeed, HQ does turn out to be the less expensive power option over the long term, the attitude of US Northeastern states may well be "if some is good, more is better" and remove any local source restrictions which may currently limit such imports.

Beyond this is the question of how "randomness" enters into the equation. Insurers have an old saying that "absence of certainty does not mean absence of risk" and some new insights into that time-tested wisdom seem to suggest that: 1) there is no credible way to accurately predict earthquakes; 2) just because a higher level intensity earthquake has not occurred in recent times does not mean it cannot occur in the future; and 3) earthquake standards for construction of critical facilities such as hydro dams may not be sufficient if based on those relatively mild past episodes. Robert Thorson, Professor of Geology at the University of Connecticut noted:[ii]

> It seems as if modern societies refuse to respect the well-known chaotic properties of nature. So, when faced with complexity, instead of holding back with reverence, people try to assert control and are surprised when failure occurs… However, more complex systems are often chaotic in an interesting way because slight initial variations become magnified through positive feedback. So, when it comes to safe design of important dynamic things like the global economy, ecosystems and nuclear reactors, I'm usually more nervous than the average citizen.

Internationally known statistician and analyst, Nate Silver, who firmly holds that earthquakes are not predictable but random, notes:[iii]

> Even if we had a thousand years of reliable seismological records, however, it might be that we would not get all that far. It may be that there are intrinsic limits on the predictability of earthquakes…Earthquakes may be an inherently *complex* process. The theory of complexity that the late physicist Per Bak and others developed is different from chaos theory, although the two are often lumped together. Instead, the theory suggests that very simple things can behave in strange and mysterious ways when they interact with each other.

For these reasons, it is important that the EIS recognize the limits of our current knowledge and inquiries be made on the ability of all components used in the production and transmission of energy from HydroQuebec facilities be subjected to rigorous investigation on their ability to withstand seismic activity at various levels. This should be done keeping in mind the words of NYU Polytechnic Institute Professor of Risk Engineering, Nassim Taleb, who cautions: [iv]

> But they never notice the following inconsistency: this so-called worst-case event, when it happened, exceeded the worst case at the time…If humans fight the last war, nature fights the next one."

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[i] See http://www.earthquakescanada.nrcan.gc.ca/zones/eastcan-eng.php
[ii] Thorson, Prof. Robert M. *Japan's Nuclear Disaster Stems From Unknowns*. The Hartford Courant. March 23, 2011.
[iii] Silver, Nate. The Signal and the Noice: Why So Many Predictions Fail—But Some Don't. The Penguin Press. New York. 2012.p. 172.
[iv] Taleb, Prof. Nassim Nicholas. *Antifragile: Things that Gain From Disorder.* Random House. New York. 2012. pp. 45-46.

Electromagnetic Pulse and Coronal Mass Ejections: Catastrophic Risks For Canadian Power

> It happened one July evening during an atomic test in1962. A rocket lifted off from Johnson Atoll, a speck in the Pacific 800 miles southwest of Hawaii. At a point in space 248 miles above the earth, the rocket turned into a ball of nuclear fire… A second or so after the flash, the Hawaiian islands were plagued by problems with things electrical. In widely separated parts of Oahu, 300 streetlights winked out, their fuses blown. Burglar alarms started ringing, and power lines went dead. Honolulu headlines the next day attributed the breakdowns to a nuclear "shock wave." It was not so easily explained[i].

> Because of the integration and interdependence of the electric system's components and the ever growing shift to electronics and particularly microelectronics for operation, protection and control, the Nation is particularly vulnerable to a major disruption of the electric supply.[ii]… The Commission's view is that the Federal Government does not today have sufficiently robust capabilities for reliably assessing and managing EMP threats.[iii]

Electromagnetic Pulse (EMP) and its naturally occurring cousin, Coronal Mass Ejection (CME), are closely related phenomenon that have the capability of inflicting widespread and lasting damage to the grid that could last for many months---or considerably longer. They bring a new meaning to the word "catastrophic".

As noted in the opening, it was the advent of transistors, integrated circuits and other microelectronics in our ever more digitally-dependent world that has increased our vulnerability to this form of hazard. All devices using semiconductors (cell phones, computers, tablets, automobiles) have the potential to suffer some degree of damage; often irreparable. That, along with the increasing interconnectedness of all critical infrastructures via the internet sets up a perfect storm for loss of not just power, but with it, most other essential services.

Nor is the EMP that accompanies a nuclear detonation the only method by which to induce such a pulse. What are called flux compression generators also have this ability and may not require the degree of knowledge and resources of a nation-state to develop and deliver albeit over much limited areas. Plans for such devices are already available on the internet but may lack critical details required for successful construction. Science, however, knows no national borders, and well-trained scientists and engineers in developing countries could have or may soon gain the capabilities to produce such weapons.[iv]

While EMP is termed a high impact, low-frequency event, the risks of ultra-high impacts prompted the North American Electric Reliability Corporation (NERC), tasked with the grid's security, to warn:

> For its part, NERC issued a 2010 report warning that geomagnetic storms, along with cyber attack and electromagnetic pulse attack with a nuclear weapon – were three high-impact but low-probability threats worth guarding against. Last May, NERC issued an advisory to regional power system operators identifying an array of steps available to them when NOAA issues warnings of a geomagnetic storm.

> <u>Practical actions that can be taken, for instance, include purchasing power from generators closer to where the power is being consumed rather than buying blocks of power that have to be sent on transmission lines that span several states</u>, a move that enhances the stability of the grid by helping maintain necessary voltages on the system. [Emphasis added.]

Coronal Mass Ejections: Mother Nature's EMP

A solar flare is a highly visible explosion of hot gases that propels light waves across a large spectrum including X-rays and gamma rays into space. They include frequencies we can't see and include radiation in the form of X-rays and gamma rays. These can be dangerous to humans and electrical devices in space but have lessor effects on earth due to the shielding effect of our atmosphere.

Coronal mass ejections (CME) differ from solar flares as they are caused by a rapid expansion of a large portion of the sun's surface and spew out an immense amount of particles. They may coincide with solar flares but not in all cases and they do not produce the same degree of light. The danger in a CME is the magnetic shockwave that it sends out into space that can impact the earth in several ways. This includes not only the formation of the Auroras Borealis but also inducing currents in electrical systems capable of destroying crucial elements of the grid as well as devices connected to it. It is another high impact, low-frequency event.

> The strongest geomagnetic storm on record is the Carrington Event of August-September 1859, named after the British astronomer Richard Carrington. During this event currents electrified telegraph lines, shocking technicians and setting their telegraph papers on fire; and Northern Lights (electrically charged particles from the sun that enter Earth's atmosphere) were visible as far south as Cuba and Hawaii. [v]

In 1989 HydroQuebec experienced grid collapse due to a (CME):

> On March 13, 1989, at 2:44 am, a transformer failure on one of the main power transmission lines in the HydroQuebec system precipitated a catastrophic collapse of the entire power grid. The string of events that produced the collapse took only 90 seconds from start to finish. There was no time for any meaningful intervention[vi]…. The March 13, 1989 Quebec blackout, the result of a major geomagnetic storm, caused a $6 billion loss to the Canadian economy.[vii] …Service to 96 electrical utilities in New England was interrupted while other reserves of electrical power were brought online. Luckily, the U.S. had the power to spare at the time…but just barely.[viii]
>
> …that [event] left six million people without electricity for nine hours. According to the North American Electric Reliability Corporation (NERC), the flare disrupted electric power transmission from the Hydro Québec generating station and even melted some power transformers in New Jersey. NASA stated, however, that this 1989 space weather event was nowhere near the same scale as the Carrington event.[ix] [Emphasis added]

We are currently in what is termed a "solar maximum" period (roughly 11 year cycles) where eruptions may become more common for several years. CMEs may also occur during off maximum periods. It is also known that during such events, transmission lines, particularly those at higher latitudes and with underlying igneous rock formations, act as large antennae to capture and transport the electromagnetic disturbances to points where critical equipment can be severely damaged. While HQ has taken steps, including installation of some blocking capacitors,[x] to correct weaknesses in its system, the ability of the overall grid to withstand CMEs is still suspect. These threats have massive consequences but are inadequately addressed at federal or state levels. Too often these threats do not appear to be real to those in positions of power who are uncomfortable with technology. We cannot afford to have decision-makers without some background in such matters or we will encounter the problem Nobel Laureate Thomas Schelling describes as follows:

> There is a tendency in our planning to confuse the unfamiliar with the improbable. The contingency we have not considered seriously looks strange; what looks strange is thought improbable; what is improbable need not be considered seriously.[xi]

The degree of risk from these threats suggests that construction of Northern Pass to import remote power may not be in the best interest of New England. While touted as being "cheap," HQ power, like most products promoted in this way, carry unforeseen liabilities. EMP and CME have the potential to bring associated impacts our society might not withstand. This needs to be seriously considered in the EIS process.

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[i] Broad, William J. *The Chaos Factor*. Science [not the AAAS Journal] January/February 1983.

[ii] *Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack*.. April 2008. P. 17.

[iii] Op cit. EMP Commission. P.viii.

[iv] Kopp, Dr. Carlo. *The Electromagnetic Bomb - a Weapon of Electrical Mass Destruction*. Air and Space Power Journal. 1996.

[v] Space Weather (FEMA Web Site)

[vi] http://www.windows2universe.org/spaceweather/blackout.htm

[vii] http://www.nasa.gov/mission_pages/sunearth/overview/Helio-facts.html#.UhzlFj9DvXA. There is a question as to the accuracy of this figure from a NASA site. Some other sources reinforce it while others provide figures as low as several hundred million dollars.

[viii] Odenwald, Dr. Sten. NASA Astronomer. http://www.nasa.gov/topics/earth/features/sun_darkness.html

[ix] Op cit. Space Weather

[x] *High-Impact, Low-Frequency Event Risk to the North American Bulk Power System*. U.S. Department of Energy. North American Electric Reliability Corp. June 2010. P. 63.

[xi] Thomas Schellingas quoted in *The Signal and the Noise*. Silver, Nate. Penguin Press. 2012. p. 419 and a portion also quoted on page A2 of the *EMP Commission Report*.