PHASING OUT NUCLEAR POWER IN CANADA

Toward Sustainable Electricity Futures

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Prepared for the Campaign for Nuclear Phaseout

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CAMPAIGN FOR NUCLEAR PHASEOUT LA CAMPAGNE SORTIR DU NUCLÉAIRE

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The executive summary of this report is available in English and French.

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The Campaign for Nuclear Phaseout/la Campagne sortir du nucléaire represents an alliance of Canadian public interest organizations concerned with the environmental consequences of nuclear power generation. CNP's mandate has been endorsed by over 300 public interest groups from across Canada.

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Torrie Smith and Associates is an Ottawa-based consulting firm specializing in sustainable energy policy. The lead author of this report, Ralph Torrie, has been studying sustainable energy futures for 27 years. He served on the Royal Society of Canada's blue ribbon panel on greenhouse gas emission reductions, and is the co-inventor of environmental planning softwarde used by over 300 municipalities and companies around the world.

Additional copies of *Phasing Out Nuclear Power in Canada – Toward Sustainable Electricity Futures* are available from the Campaign for Nuclear Phaseout.

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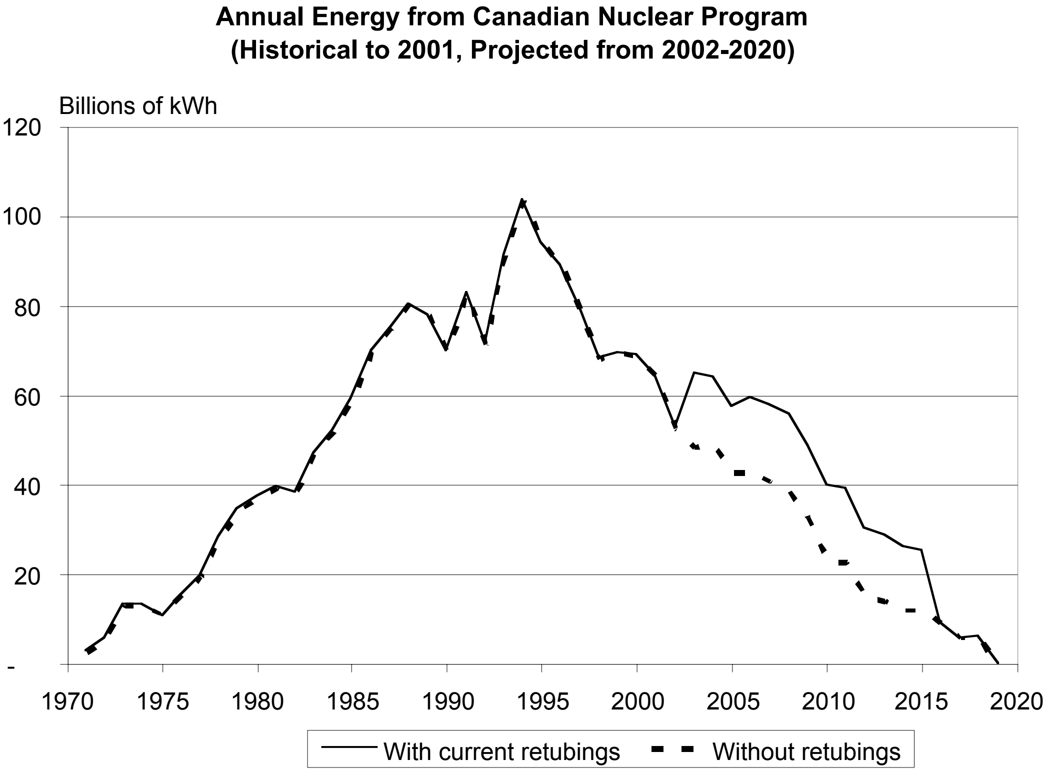
EXECUTIVE SUMMARY

The output of Ontario's nuclear power plants has dropped by a third since it peaked in 1994. It will soon begin a further steep decline. By 2010 it will have dropped to 50% of its peak levels. Sometime in the next 10-15 years, electricity production from nuclear power in Canada will drop to zero. This projection assumes that the reactors that are still operating will continue producing until they are 27 years old, more than five years longer than any CANDU has ever operated without having to be shut down. It also assumes that the current reconstruction of one unit at the Pickering A Station and two units at the Bruce A Station are successful and the rebuilt units operate like new for another 13 years or more.

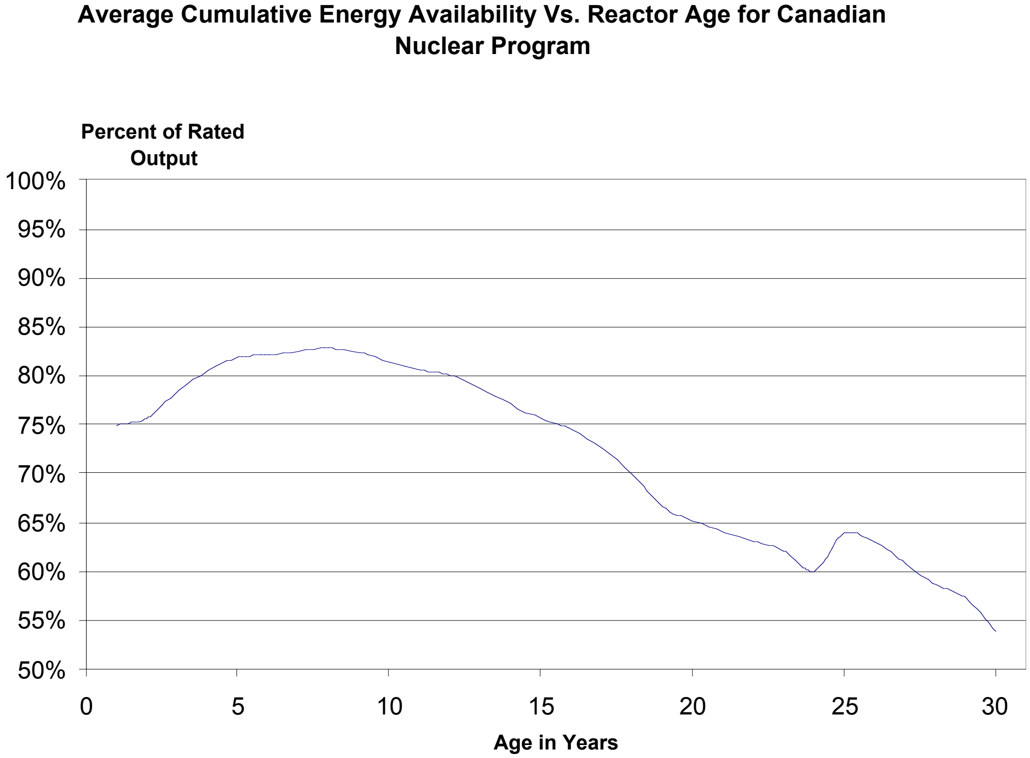
Figure ES-1



This steep decline in nuclear power capacity is the "flip side" of the rapid growth in nuclear power that occurred in the 1970's and 1980's, combined with the premature aging and poor performance that have characterized CANDU technology. The first commercial CANDU power plants were the four unit stations at Pickering A and Bruce A; the Pickering Station had some serious problems in the early years of its operation, but in general the early year performance of the Pickering A and Bruce A stations was satisfactory. It wasn't until they had been in operation for ten years that the deterioration in their performance began to materialize. In the largest nuclear shutdown in world history, these eight reactors were 'laid up' (taken out of service for a long period) between 1995 and 1998, after only 18 to 23 years of operation, because of accumulating safety and performance problems. Three of these old reactors are having their cores rebuilt– one at Pickering A and two at Bruce A. Ontario Power Generation has suggested that it would like to rebuild the cores of the remaining three reactors at Pickering A.

Before the extent of the CANDU performance problems became apparent, Ontario Hydro had already committed to building 12 more reactors, and Hydro Québec and New Brunswick Power had also committed to one single-unit CANDU station each. By the spring of 1993, these fourteen reactors were all in operation, but none have been built or ordered since.

Figure ES-2



These 14 operating reactors are now approaching the end of their expected lifespan, and in the absence of heroic efforts to rehabilitate these plants and perhaps even with such efforts, by 2019 the output of the Canadian nuclear program will decline to zero. While some argue that this decline can be reversed or at least arrested by rebuilding the cores of all the reactors (an operation called “retubing”), it would cost on the order of $15-$20 billion to do that. Moreover, it is not clear how many more years of operation that would buy before the plants would once again require multi-billion dollar reconstruction operations.

It is possible that the plants will not be able to operate for the unprecedented 26 years assumed here. It is also possible that the newer reactors will not perform even as well as the older plants ˜ the Darlington Nuclear Station is the most recent CANDU power plant built and it has the worst early year performance record in the history of the Canadian nuclear program. We also do not know whether the reconstruction projects are going to work. Even if the rebuilt reactors perform like new when restarted (as assumed here), we do not know how quickly their performance will deteriorate with increasing age. As we have seen with the original Pickering A and Bruce A start-ups, even if the rebuilt units work satisfactorily for the first few years after restart, that is no assurance that they will continue to perform as they continue to age. The essential fact remains that by the year 2020 or sooner the output of Canada's nuclear program will have declined to zero in the absence of the risky, multi-billion dollar investments it would take to rebuild the cores of all the reactors when they reach the end of their current life spans.

At the same time that the aging nuclear plants are reaching the end of their useful lifetimes, the emissions of air pollutants and greenhouse gases from coal and oil-fired power plants are of increasing concern. But our choice need not be between nuclear power and coal; it can be instead a choice between the unsustainable energy options based on nuclear and coal, and more sustainable options based on energy conservation, efficiency improvements, cogeneration, renewables and other alternatives. Seen in this light the decline of the Canadian nuclear program presents an opportunity for an orderly transition to a more sustainable electricity future.

The technologies that could facilitate a transition away from coal and nuclear power have already been developed, In the scenario explored in this analysis we present one example of how they can be combined to meet growing demands for energy services while at the same time reducing and eventually eliminating reliance on centralized nuclear and fossil fuel power plants. The institutional, policy and business innovations that will be required to mobilize these technologies on the necessary time scale will vary from province to province, and are not at present well developed. However, change in these areas can take place quickly provided that the possibilities, opportunities and benefits are appreciated and incorporated into policy decisions.

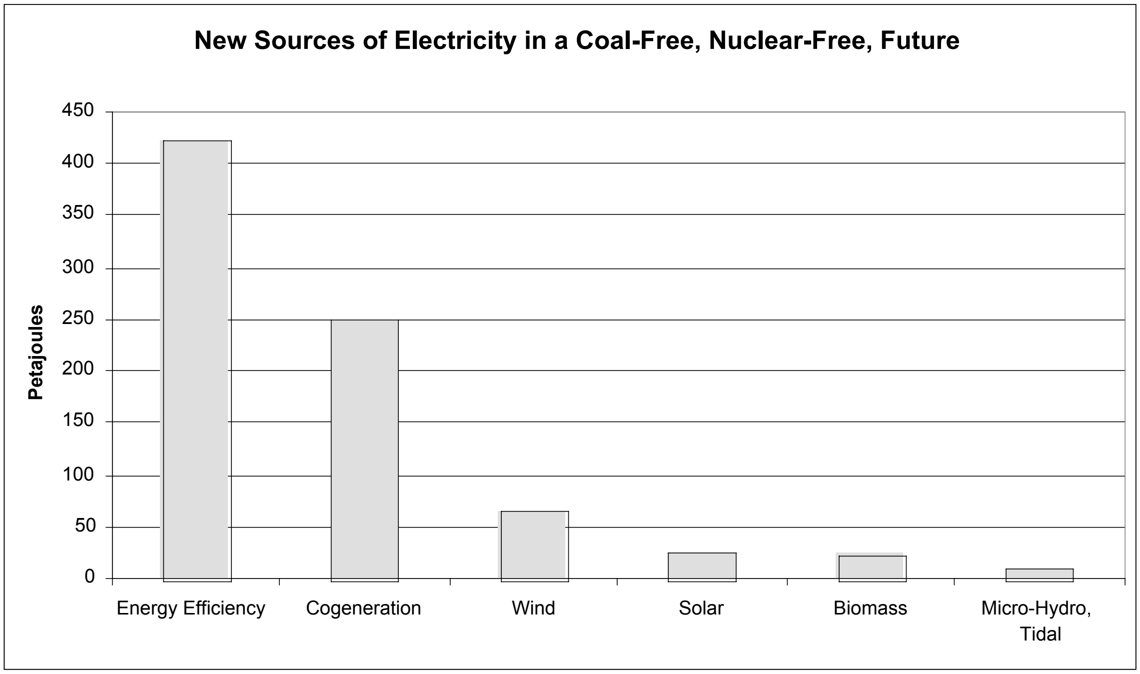
There are five key building blocks to a sustainable transition away from central coal and nuclear power plants and toward a more sustainable energy future:

- **Improved efficiency of electricity use.** This is by far the most important element of any strategy for a nuclear phase-out and a sustainable, low-emission energy future.
- **A reduction over time in the use of electricity for heat.** Electricity is really only essential for about 12-14% of total end use energy, but in all three of Canada's nuclear provinces it provides a much greater share of energy use because it is used for space heating, water heating and even for industrial boilers. Electricity's share of the heating market has peaked in all three of these provinces and continues to decline in the scenario presented here.
- **Industrial Cogeneration**. All three of Canada's nuclear provinces have significant numbers of energy intensive industrial establishments that are prime candidates for electricity cogeneration. In Ontario and New Brunswick, cogeneration is second only to improved efficiency in the size of the contribution it can make to a more sustainable and efficient electricity supply and demand system.
- **Strengthen East-West Electricity Trade**. Both Ontario and New Brunswick are adjacent to provinces with large, already installed, hydroelectric capacity. There is a case to be made for greater east-west electricity trade that would allow the Maritimes and Ontario to access this hydroelectricity.
- **New and Renewable Electricity**. Over the scenario period (to the year 2020) there will be increasing contributions from wind, solar and biomass electricity. Indications are that growth in wind power will be particularly strong over this period.

These five elements were combined in different ways to produce a scenario for the electricity systems in Ontario, Québec, and New Brunswick in which all central coal, oil, and nuclear power plants would be phased out by 2020. In general, as shown in Figure ES-3, efficiency improvements can contribute more than cogeneration and renewables combined On the other hand, the potential for cogeneration is at least twice as large as the potential from wind and solar and other renewables. Indeed, the possibility of an eventual transition to a sustainable electricity system depends utterly on the efficiency gains being put in place first.

The technologies employed in this scenario is feasible from both a technological and economic perspective, but much more organizational and financial innovation is required to realize the potential. When a consumer flicks a light switch, a vast technological, organizational and financial infrastructure is instantaneously available. Multi-billion dollar capital investments and highly evolved business organizations with thousands of employees are dedicated to making it easy and economically efficient to buy and have instantaneously delivered a kilowatt.hour of central grid electricity. On the demand side of the equation however, business and financial organization for the easy, cheap delivery of energy efficiency is not so well organized.

Figure ES-3



The summary results for the scenario for Ontario, Québec and New Brunswick are illustrated in Figure ES-4, Figure ES-5 and Figure ES-6, respectively.

- Ontario has the largest dependence on nuclear power. It also has the greatest problems with regard to air pollution from its coal-fired power plants. On the other hand, it has the greatest potential for cogeneration and a deep capacity for mobilizing the technological, financial and organizational resources necessary to put the province on the forefront of the sustainable electricity market. In addition to efficiency gains, cogeneration, and renewable electricity deployment, we have included increased imports of hydroelectricity from Manitoba and Québec by 2020.

- Hydro-electricity dominates Québec's electricity supply, with very minor contributions from nuclear energy and fossil fuels. Thus the phasing out of both nuclear and fossil fuel electricity is a relatively simple matter for Québec. The reduction in demand and increased supply from renewable sources will allow Quebec to phase out its nuclear and fossil electricity generation, while maintaining a significant surplus. This surplus will be available even without Churchill Falls power, and Québec will be able to continue exporting power to the United States, begin exporting significant amounts of power to Ontario and/or New Brunswick, and still have surplus power.

- The challenge of phasing out nuclear and fossil electricity in New Brunswick will require a concerted effort to increase energy efficiency, switch to other fuels for space and water heating, bring in new, cleaner sources of electricity supply, and import clean electricity from other provinces. As with Ontario, efficiency improvements and cogeneration are the most important elements, supplemented by increased use of natural gas combined cycle technology and the development of wind, biomass and solar potential. In addition, the large surpluses of hydro-electricity in Québec and Labrador that exist now and will continue to be available in the future can be used to make up for any shortfall in electricity supply that may remain in 2020.

Conclusion

Over the next 15 years, the aging nuclear power plants in Ontario, Québec and New Brunswick will either have to be shut down or will require reinvestment on the order of $15-$20 billion to keep operating, with no guarantee or past record of success. Even if such refurbishments are successful subsequent aging would require another cycle of reinvestment 10-14 years later.

There is another possible path, and the scenario described here illustrates a safer, cleaner alternative that is technically feasible and economically sustainable. It is a future that builds on trends that have already started to develop. In this scenario, efficiency, cogeneration and renewable energy are deliberately phased in at a pace that will ensure an orderly transition to a sustainable electricity future as the nuclear and fossil power plants are phased out.

Figure ES-4

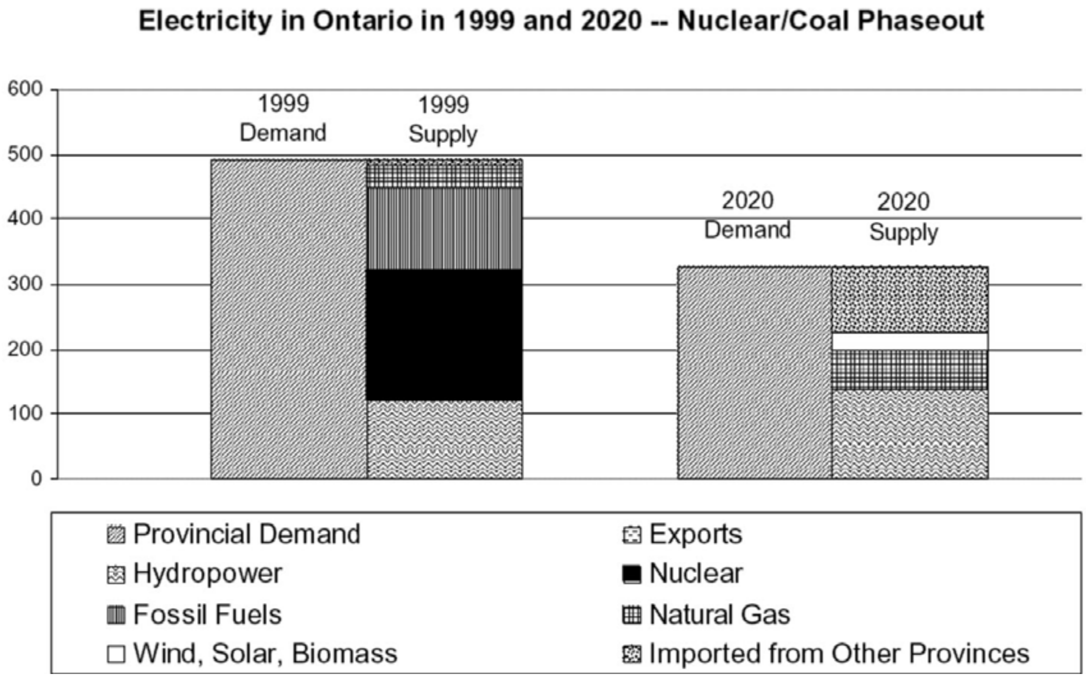


Figure ES-5

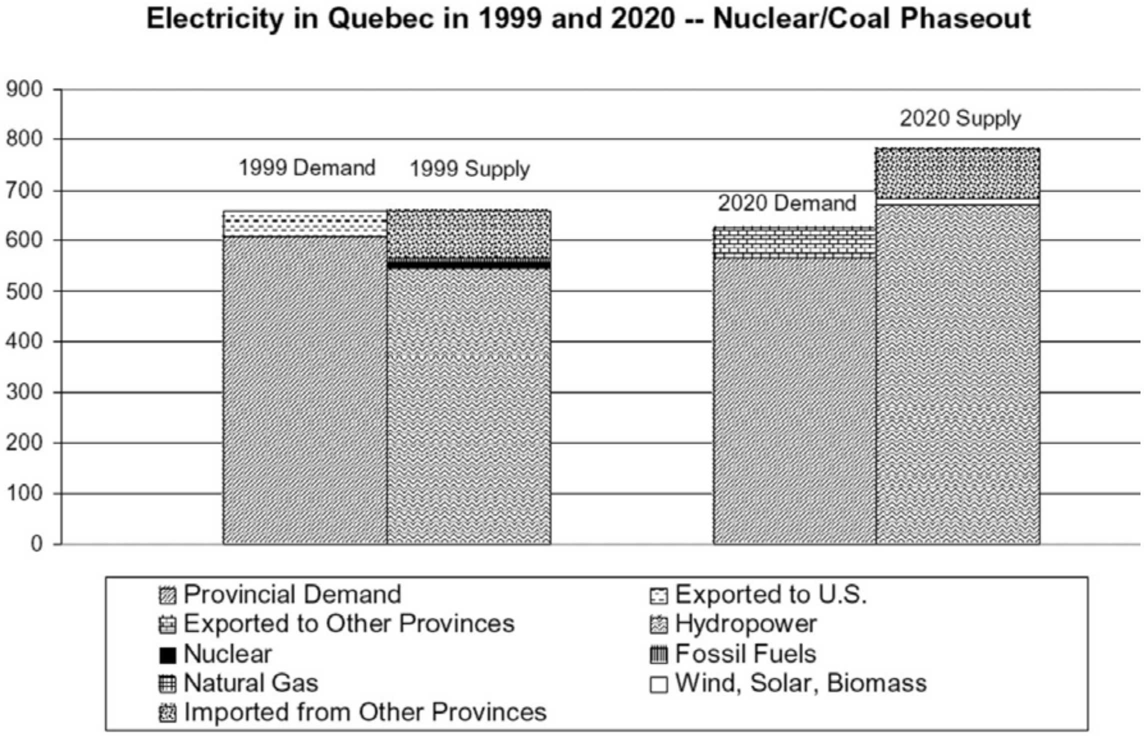


Figure ES-6

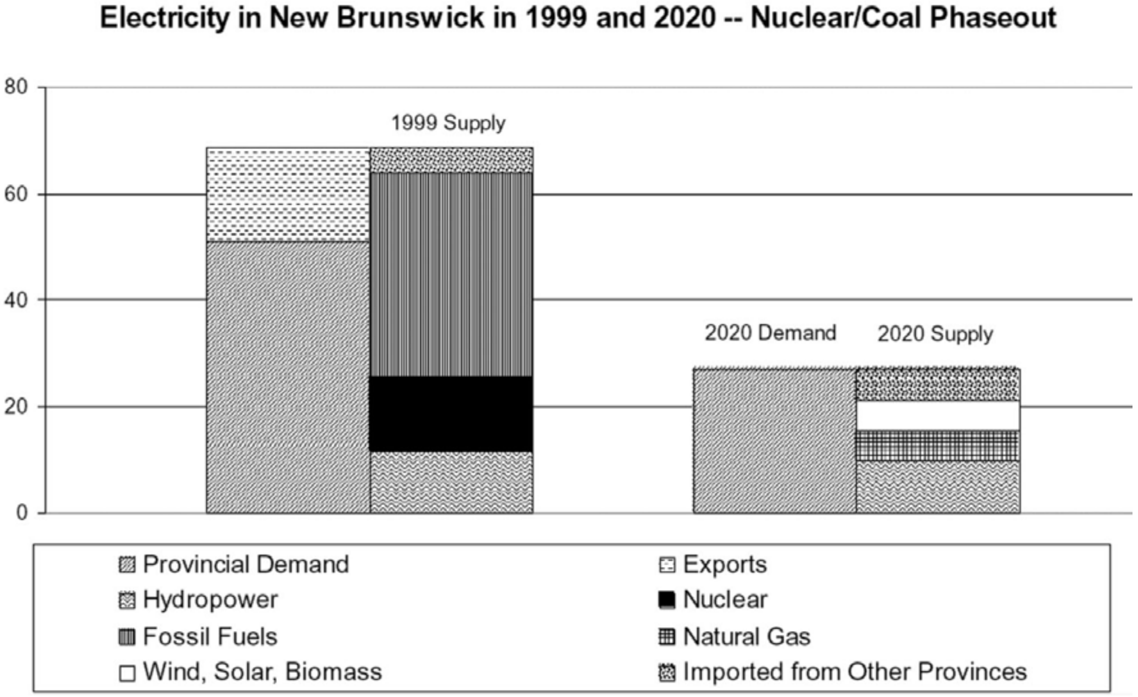
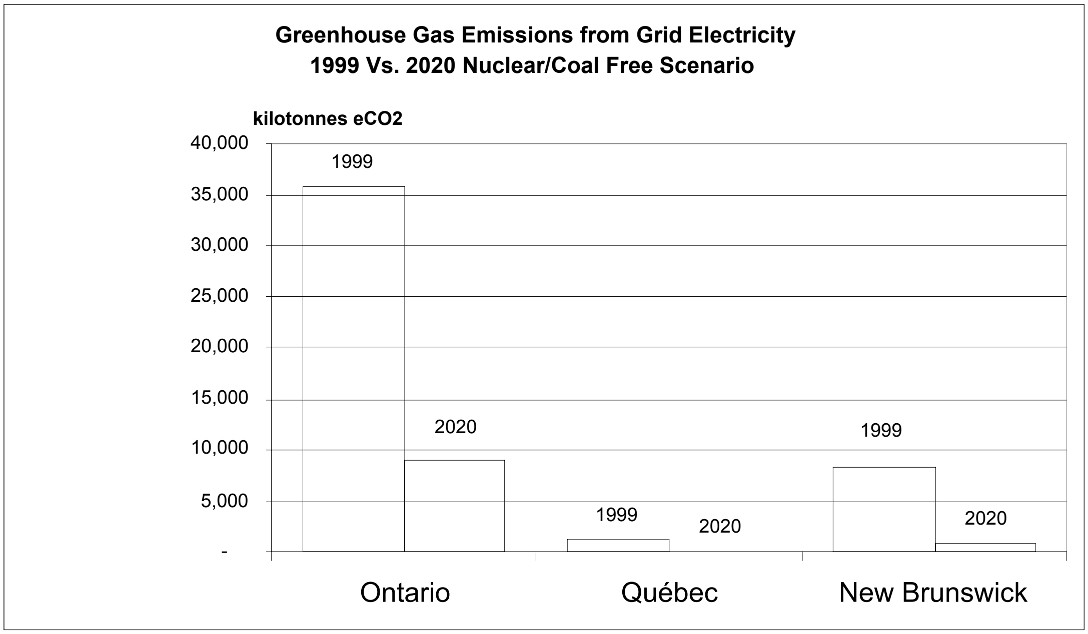


Figure ES-7



Phasing Out Nuclear Power in Canada
Toward Sustainable Electricity Futures

Introduction

This report describes a scenario in which nuclear power would be phased out of use in Canada, and done so in the context of a move toward a sustainable energy future in which greenhouse gas emissions are brought down well below current levels. The results presented here are based on a recently completed scenario analysis of how Canada could reduce its greenhouse gas emissions by 50% over the next 25 years – "Kyoto and Beyond: The Low Emission Path to Innovation and Efficiency".[1] The scenario developed in the "Kyoto and Beyond" report is focused primarily on reducing Canadian greenhouse gas emissions, but doing so in a way that would move the economy toward a sustainable energy future. A number of "design principles for sustainable energy" (see box) were applied to evaluating future energy options, and the resulting scenario excluded nuclear power, coal power and any additional hydroelectric megaproject development.

With the very limited resources available for this work, we set out to simply elaborate on the results of the "Kyoto and Beyond" analysis, with the focus on the electricity supply/demand balances in Ontario Quebec and New Brunswick, the three Canadian provinces with nuclear power reactors. However, the "Kyoto and Beyond" analysis was a national scenario; while the electricity supply/demand balance was done separately for each province, we found that we had to revisit the electricity analysis for the each of the provinces included here so that we could take into account important provincial variations in electricity consumption patterns. Notwithstanding this additional analysis, the scenario presented here is still only a rough sketch of one possible path to a sustainable energy future.

As already indicated, there were two key objectives in the development of this scenario analysis. First, we wanted to analyze what a nuclear "phase-out" might look like in Canada, and hence the focus on Ontario, Québec, and New Brunswick. In addition to having nuclear in common, all three of these provinces come from a fairly typical, Canadian tradition of public power. Beyond that, however, these three provinces have very different historical mixes of resources and technologies, different utility cultures, and are pursuing different response strategies to the "electricity revolution".

The second feature of the scenario that we wished to explore is a dramatic reduction in greenhouse gas emissions and air pollution from electric power production. Combined with the nuclear-phase-out component of the scenario, this means that we were interested in a scenario in which the use of coal-fired power plants could also be phased out. Finally, the scenario was developed without any new expansion of hydro megaprojects.

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[1] Ralph D. Torrie, Richard Parfett and Paul Steenhof, "Kyoto and Beyond: The Low Emission Path to Innovation and Efficiency", published by CANET and the David Suzuki Foundation, October 2002. Available from www.torriesmith.com.

TECHNOLOGY DESIGN PRINCIPLES FOR SUSTAINABLE ENERGY FUTURES

ENERGY SERVICES FOCUS

Fuels and electricity are not demanded or needed for their own sake, but for the ***services*** *they provide. In this framework, the "demand side" measures -- conservation, efficiency improvements, and renewables – are seen as alternative means for supplying services, and emerge as the key to energy and environmental security in both the short and long terms.*

EFFICIENCY

In sustainable energy futures, there is a premium on efficiency, on matching both the scale and the quality of the energy source with the end use demand.

RENEWABLE ENERGY SOURCES

In sustainable energy systems, energy services are provided by ***renewable*** *supply sources.*

ENVIRONMENTALLY BENIGN

Energy services are provided by technologies which are ***environmentally benign*** *and which maintain rather than diminish the health of the ecosystems in which they operate. Technologies with the potential to cause irreversible ecological damage are rejected in favour of* ***"safe-fail"*** *technologies.*

LEAST COST

Energy services are provided at the ***least cost****, consistent with social, environmental and other objectives. An energy economy rife with unjustifiable subsidies and market distortions is ultimately a vulnerable energy economy, sluggish in its response to changing circumstances and prone to sudden disruptions.*

DIVERSITY

The demands for energy services are matched in both scale and thermodynamic quality by a ***diversity*** *of* ***dispersed*** *sources so that both risks and benefits are widely spread, while vulnerability to any single failure is minimised. All else being equal, a system composed of* ***smaller rather than larger units*** *exhibits greater reliability and is less vulnerable to massive failure, provided the units are optimally interconnected.*

FLEXIBILITY, RESILIENCE

Energy services are provided by technologies with ***short lead times****, thus allowing a quick response to changes and* ***flexibility*** *in planning. Energy services are provided by* ***indigenous*** *sources, thus providing* ***self-reliance*** *and insulating society from the adverse impacts of geopolitical events beyond its control. Energy services are provided by technologies that allow* ***early failure detection*** *and quick repair.*

EQUITABLE

The equitable distribution of costs and benefits is a defining feature of sustainable energy futures. Decentralised technologies are preferred over centralised technologies that tend to allocate benefits to one end of the transmission line and costs to the other. Technologies and energy options are rejected unless they can be deployed in a way that eliminates the passing on to future generations of wastes, risks and costs.

SOCIALLY BENIGN

Technologies, even apparently simple technologies, contain embedded social values. In considering technologies for our future energy systems, we must ask ourselves the question: is this a technology that is compatible with the principles of sustainable development, of human welfare, social justice and self-determination, or is this a technology that may constrain society from developing in a sustainable way.

The time horizon for the scenario is the year 2020. This is far enough in the future to allow for widespread "phasing in" of efficiency and other distributed resources, and is also past the date when all of the currently operating nuclear reactors in Canada will have been retired, including the three reactors in Ontario that have been undergoing reconstruction and are scheduled to start up again in 2003 after being shut down for over five years.

Historical Context

There are two important historical realities that form the context for considering a transition away from nuclear power in Canada. First, the existing reactors are fast approaching the end of their expected lifespans, and in the absence of heroic efforts to rehabilitate and rebuild these plants (and perhaps even with such efforts), by 2019 the output of the Canadian nuclear program will decline to zero. Second, there are some remarkable and accelerating trends in the energy economy in general, and in the electricity sector in particular, that hold out promise for a future electricity system in which reliance on central power plants (whether coal or nuclear) would be replaced by a combination of energy productivity improvements and widespread deployment of distributed resources. These two themes are elaborated upon below.

The Decline of the Canadian Nuclear Program

There are 22 CANDU power reactors in Canada,[2] of which 20 are in Ontario, one in Québec and one in New Brunswick. In 2001, these reactors produced 41%, 2.5% and 23% of total electricity in Ontario, Québec and New Brunswick, respectively. As of early 2003, eight of Ontario's reactors had been shut down for five years or more (Pickering A Units 1-4 and Bruce A Units 1-4), although three of those (Units 3 and 4 at Bruce A and Unit 4 at Pickering A) have been undergoing "retubing"[3] and are scheduled to be restarted some time in 2003 or 2004. All of the operational reactors, including the three that are about to be restarted, will reach the end of their expected operational lifetimes during the next fifteen years.

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[2] In addition to the 22 power reactors listed in Table 1, there were three others not counted here. In Ontario, the Pickering A Station was the first full scale commitment by Ontario Hydro to nuclear power, but it was predated by two prototypes – the 20 MW Nuclear Power Demonstration (permanently shut down in 1987) and the 200 MW Douglas Point plant (permanently shut down in 1984). In Québec, the Gentilly 1 power plant was a failed attempt to build a CANDU that used light water as a coolant instead of heavy water. Its control systems were not stable, it produced very little electricity (10% lifetime availability factor), and was shut down in 1977 only five years after the first attempt to start it up.

[3] The CANDU reactor consists of a cylindrical reactor vessel full of heavy water with hundreds of horizontal fuel channels, consisting of an outer calandria tube and an inner pressure tube that contains the uranium fuel bundles. When large CANDU reactors were first built, it was hoped that they would operate for 30 to 40 years before the extreme conditions of the reactor core affected the calandria tubes and forced the plant to be either shut down or rebuilt. All four reactors at the Pickering A nuclear station had to be shut down and retubed after a major Loss of Coolant Accident (LOCA) in August 1983 in reactor 2. Reactors 1 and 2 at Pickering A operated for only 13 years before being shut down for about four years of retubing. They operated for only about ten more years before being shut down at the end of 1997 for major refurbishment. Reactors 3 and 4 at Pickering A were operated for about 17 years before being shut down for retubing. After being restarted, reactor 3 was shut down in 1997 after six years, and reactor four in 1996 after only three years. Ontario Power Generation hopes to restart Pickering reactor 4 in August 2003 (more than three years behind schedule), and currently has no timetable for restart of the other three reactors. Restart of the reactors is controversial because of the absence of a second fast shutdown system, required in all other nuclear stations. In the case of the Bruce A nuclear station, reactor 2 was shut down in 1995, and reactors 1, 3, and 4 in 1998. The station operator, Bruce Power, hopes to restart reactors 3 and 4 in the summer of 2003. This restart operation is controversial because the company is cutting costs by avoiding a wholesale retubing of the reactors.

In selecting a time horizon for the scenario analysis here, we did not impose an accelerated schedule of plant shutdowns beyond what can be expected as the plants reach their mandatory retirement age. Indeed, we assumed that the each of the existing plants would not retire until it had operated for 26 years, longer than any CANDU has lasted to date. With regard to the three reactors in Ontario that are currently being rebuilt we have assumed they will operate successfully for 13 years after they are restarted, nearly the twice the historical success rate for rebuilt reactors and at the upper range of the expectations of the plant operators.

Based on these "optimistic" assumptions about the future performance of the reactors, summarizes the reactor retirements dates. The last units to be retired are at the Darlington station in Ontario where the year 2018 will be the final year of operation for Units 3 and 4.

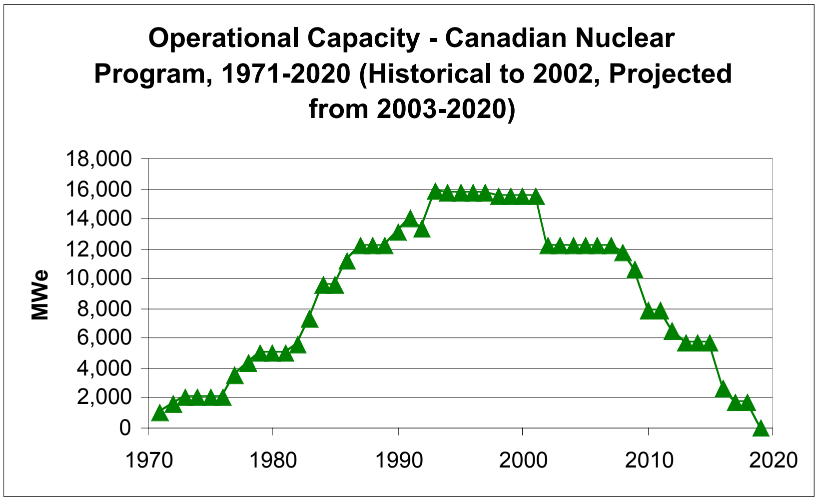
Figure 1 illustrates the historical and projected generating capacity of the Canadian nuclear program with the plant retirement dates listed in Table 1 . While the installed capacity has remained fairly level in recent years, much of it is not producing any electricity. With the assumed retirement age of 27 years used here, the installed capacity will begin to decline again in 2009 and by 2019 all the plants will have reached their retirement age, including the rebuilt units. While some argue that this decline could be avoided by

Table 1.
Canadian Nuclear Power Reactors – Capacity and Final Year of Operation

Province	Unit	Last Year of Operation	Net Capacity (MW)
Ontario	Bruce 2	1995	848
Ontario	Bruce 1	1997	848
Ontario	Pickering 1	1997	515
Ontario	Pickering 2	1997	515
Ontario	Pickering 3	1997	515
Ontario	Pickering 5	2008	516
Ontario	Pickering 6	2008	516
New Brunswick	Pt. Lepreau	2008	635
Ontario	Bruce 5	2009	785
Ontario	Bruce 6	2009	785
Quebec	Gentilly 2	2009	635
Ontario	Pickering 7	2009	516
Ontario	Bruce 7	2011	785
Ontario	Pickering 8	2011	516
Ontario	Bruce 8	2012	785
Ontario	Darlington 2	2015	881
Ontario	Darlington 1	2016	881
Ontario	Darlington 3	2018	881
Ontario	Darlington 4	2018	881
Ontario	Pickering 4 (Rebuilt)*	2016	515
Ontario	Bruce 3 (Rebuilt)*	2016	848
Ontario	Bruce 4 (Rebuilt)*	2016	848

* Pickering Unit 4 and Bruce Units 3 and 4 were shut down in the 1990's but are in the process of being rebuilt and are scheduled to resume operation in 2003.

Figure 1



rebuilding all the reactors, it would cost on the order of $15-$20 billion to do that, and it is not clear how many more years of operation that would buy before the plants would once again require multi-billion dollar reconstruction.

In addition to specifying the years in which these plants will shut down, we also need to make some assumption about how much power they will deliver between now and then in **Figure 2** we show the performance of Canada's nuclear power plants and how it deteriorates as the plants get older.

Figure 3 shows the average performance vs. plant age for the entire Canadian nuclear program. The figures show the cumulative "energy availability" of the plants – the standard industry indicator of reactor performance. The Energy Availability factor measures the amount of energy that a particular plant produced as a percentage of its rated power output. CANDU Energy Availability factors are below the world average and decline fairly steeply as the plants age.[4] In estimating the output of Canada's power reactors in future years, we have assumed they will perform as well as the historical average for CANDU reactors of their age. One might think this would underestimate the power that can be expected from these plants, but it is not obvious that the newer CANDU's are performing any better than the older ones when they were the same age. In fact, the newest multi-unit station – Darlington – has the worst "early year" performance record in the Canadian nuclear program. As for the rebuilt reactors, we have assumed they will perform with Energy Availability rates equivalent to brand new reactors, clearly an "optimistic" assumption.

Combining these assumptions about plant shutdown dates and performance yields the historical and projected pattern of electricity production shown in **Figure 4**, and the pattern is very similar to that for installed capacity. The installed capacity and energy output of the program peaked in 1993-94 and then began declining as the Pickering A and Bruce A plants were shut down for indefinite periods. Currently, output is on a plateau, but the decline will begin again by 2009 when the reactors that came on line in the 1980's begin to reach the end of their operational lifespans.

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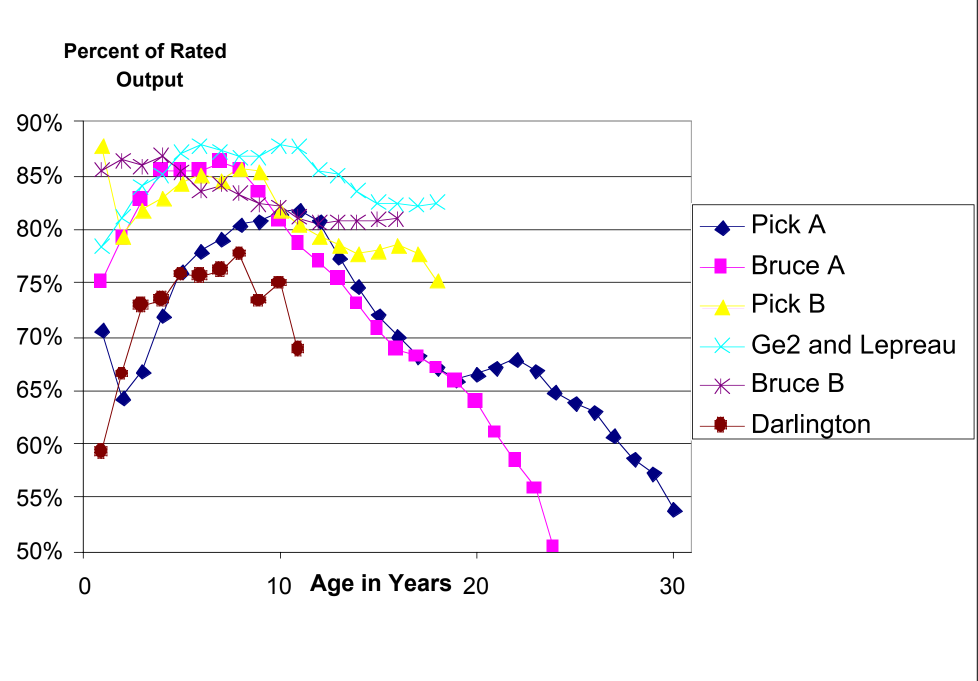
[4] The data on energy availability ratings for CANDU's used here is taken from the PRIS database of the International Atomic Energy Agency, online at http://www.iaea.org/programmes/a2/. Detailed technical definitions and data can be reviewed on IAEA web site.

Figure 2 – Lifetime Performance Vs. Age for Canadian Nuclear Power Plants



To keep the figure from being too "noisy" it shows averages for each of the four-unit stations, and Pt. Lepreau and Gentilly-2 are combined. Individual reactors details are available on the web site for the IAEA PRIS database at http://www.iaea.org/programmes/a2/.

Figure 3

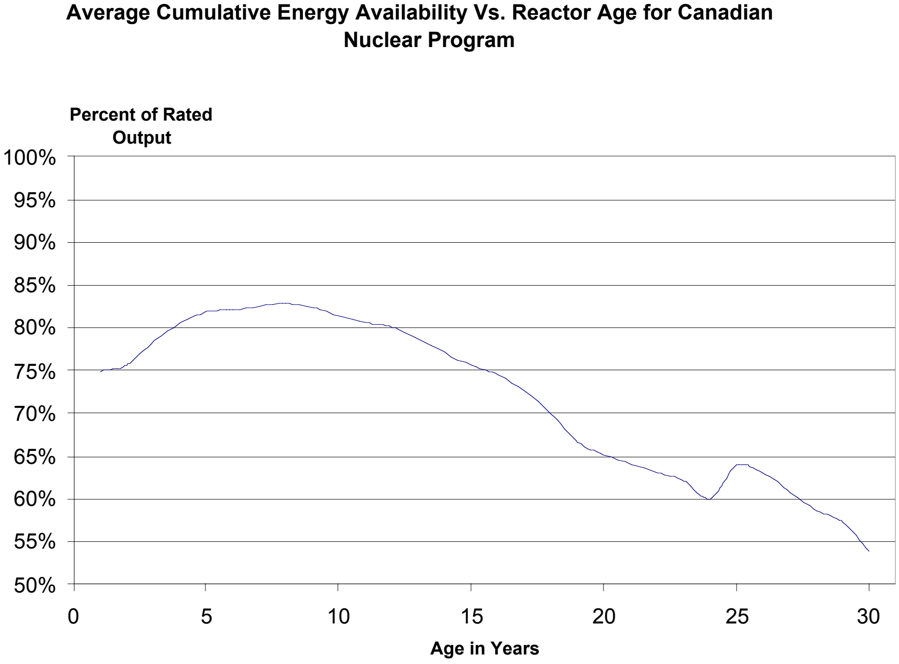
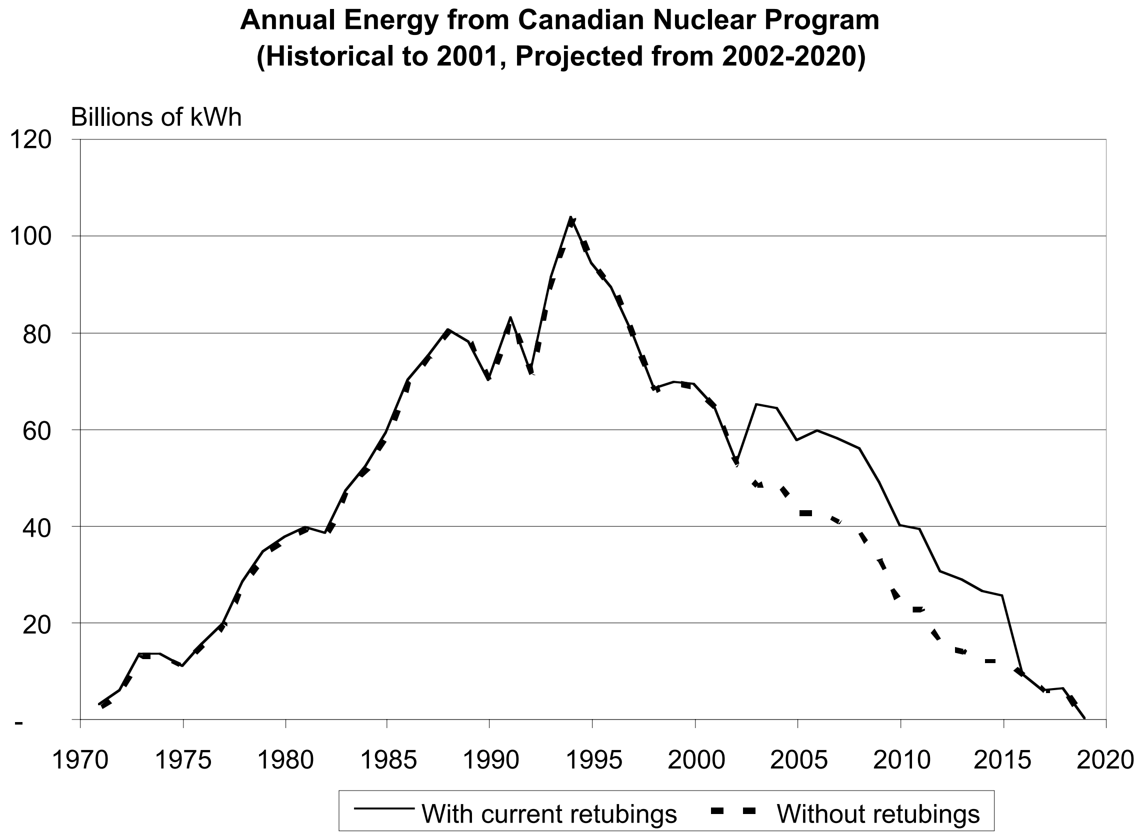


Figure 4



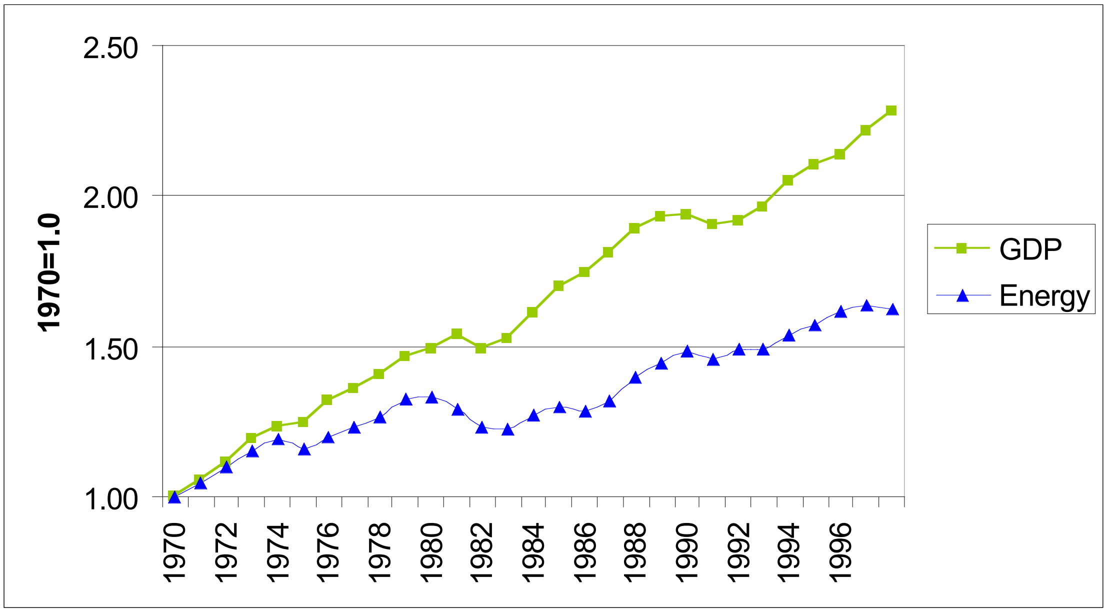
This timetable for nuclear plant retirements largely defines the time horizon and scope of the scenario analysis done here. It is possible that the plants will not be able to operate for the unprecedented 26 years assumed here. We also do not know whether the reconstruction projects are going to work. Even if the rebuilt reactors perform like new when restarted (as assumed here), we do not know how quickly their performance will deteriorate with age. As we have seen with the original Pickering A and Bruce A start-ups, even if the rebuilt units work satisfactorily for the first few years after restart, that is no assurance that they will continue to perform as they age. The essential fact remains that by the year 2020 or sooner the output of Canada's nuclear program will have declined to zero in the absence of the risky, multi-billion dollar investments it would take to rebuild the reactors when they reach the end of their current life spans.

To make a smooth transition from nuclear power will require that efficiency, cogeneration, renewables and other alternatives are phased in at a rate no slower than the rate at which the nuclear plants will be shutting down.

Energy Productivity

During the period when electric utilities in Ontario, Québec and New Brunswick were making commitments to nuclear power, conventional wisdom held that economic growth required growth in energy consumption in general, and electricity consumption in particular. For most of the period from World War II until the early 1970's, it was true that there was a strong correlation between growth in economic output and growth in consumption of fuels and electricity, but that began to change in the early 1970's and the "decoupling" of growth in the consumption of fuels and electricity from growth in the economy has been and continues to be the central story of energy economies throughout the industrial world, including Canada's, as shown in **Figure 5.** Between 1970 and 1998, while primary energy consumption increased 63%, the real Gross Domestic Product grew twice as fast, by 128%.

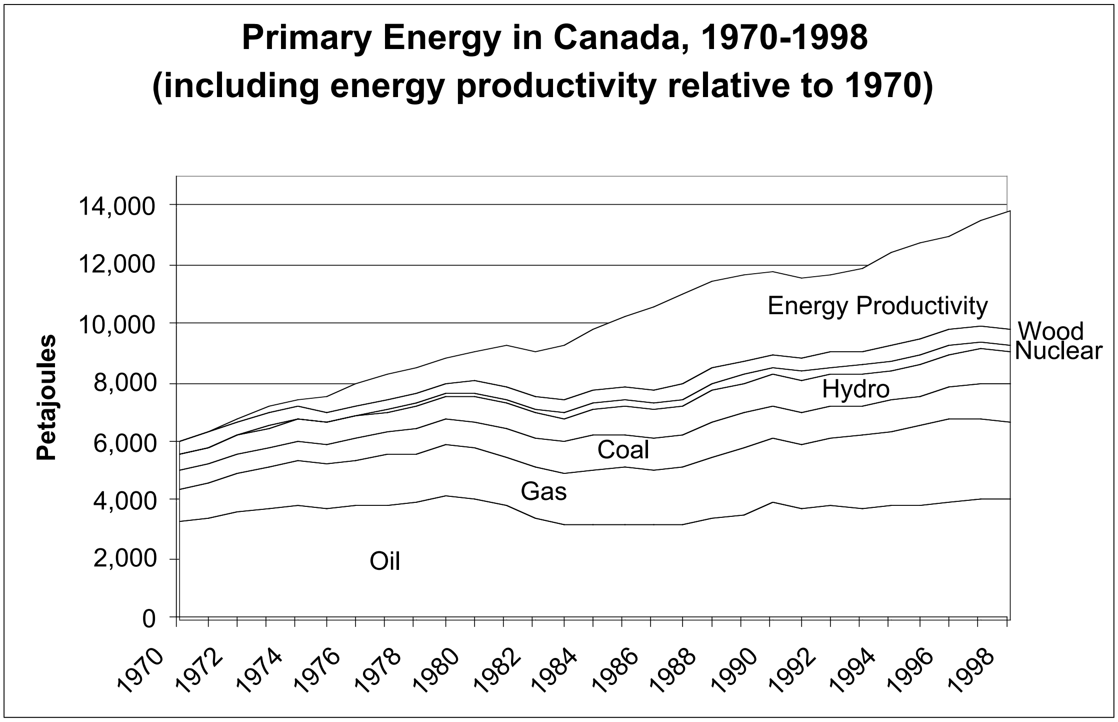
Figure 5 – GDP Vs. Energy, 1970-1998



If it were not for improvements in energy productivity, there would be no gap between the "GDP line" and the "energy line" in Figure 5; additional growth in all the primary energy sources would have been needed to "fill the gap".

Figure 6 shows the growth in the domestic demand for primary energy between 1970 and 1998, with the contribution from "energy productivity" improvement shown alongside the conventional fuel and electricity commodities. Energy productivity is shown as the new "source" of energy that filled the gap between the actual supply of fuels, including primary electricity, and what total primary energy demand would have been in the absence of the productivity improvement.

Figure 6

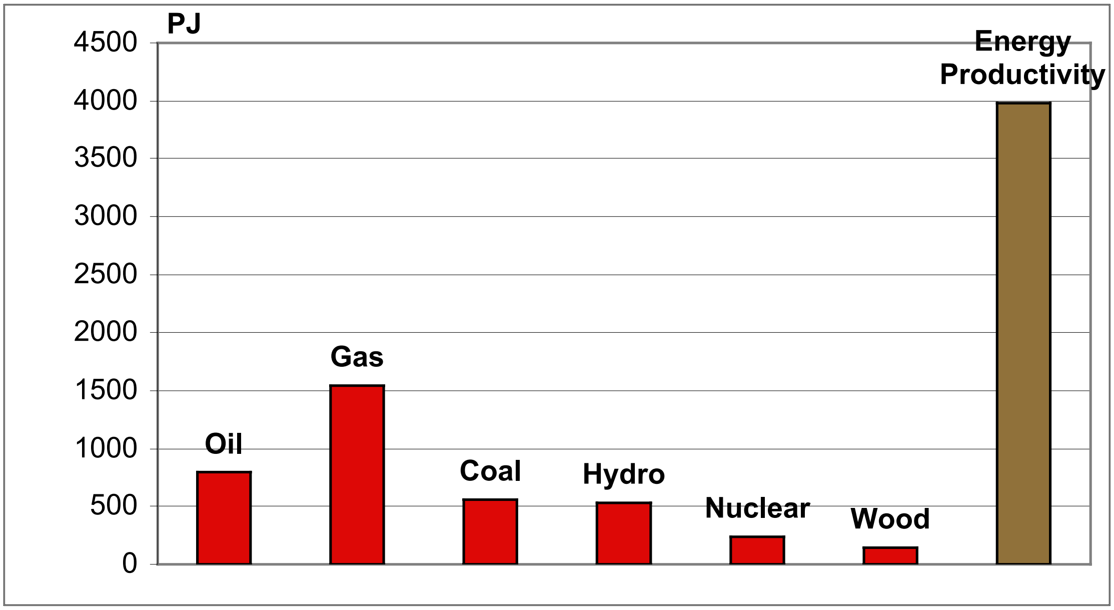


In 1970, the total demand for primary energy of all forms in Canada was about 6,000 PJ; by 1998 there was an additional 3,800 PJ of fuels and primary electricity, plus an additional 3,900 PJ of energy productivity improvement. In other words, as shown in **Figure 7**, by 1998 energy productivity was contributing more new energy (relative to 1970) than all the new sources of oil, gas, coal, hydro, nuclear and biomass *combined*.

This energy productivity improvement has brought Canadians enormous economic, environmental, public health and employment benefits. The energy productivity resource is purely renewable, and its size is limited only by human ingenuity. It grows whenever fuel or electricity is conserved or used more efficiently, and it also grows every time there is shift toward higher value-added goods and services, either within or between sectors of the economy. In the oil industry, a "supergiant" field is one containing over five billion barrels; between 1970 and 1998, the energy productivity "resource" delivered the equivalent of 7.5 billion barrels of oil. Not only has its growth outstripped all the supply side resources combined, but it now makes a larger contribution than any other single supply source, including oil, and is *sixteen times* bigger than Canada's entire nuclear program, which got started about the same time. With almost no government assistance, in the absence of well organized institutional and financial infrastructure for its delivery, and against heavily subsidized and highly organized competition from oil, gas and nuclear power, the demand side has still managed to outperform the supply side of the energy economy since 1970.

Figure 7

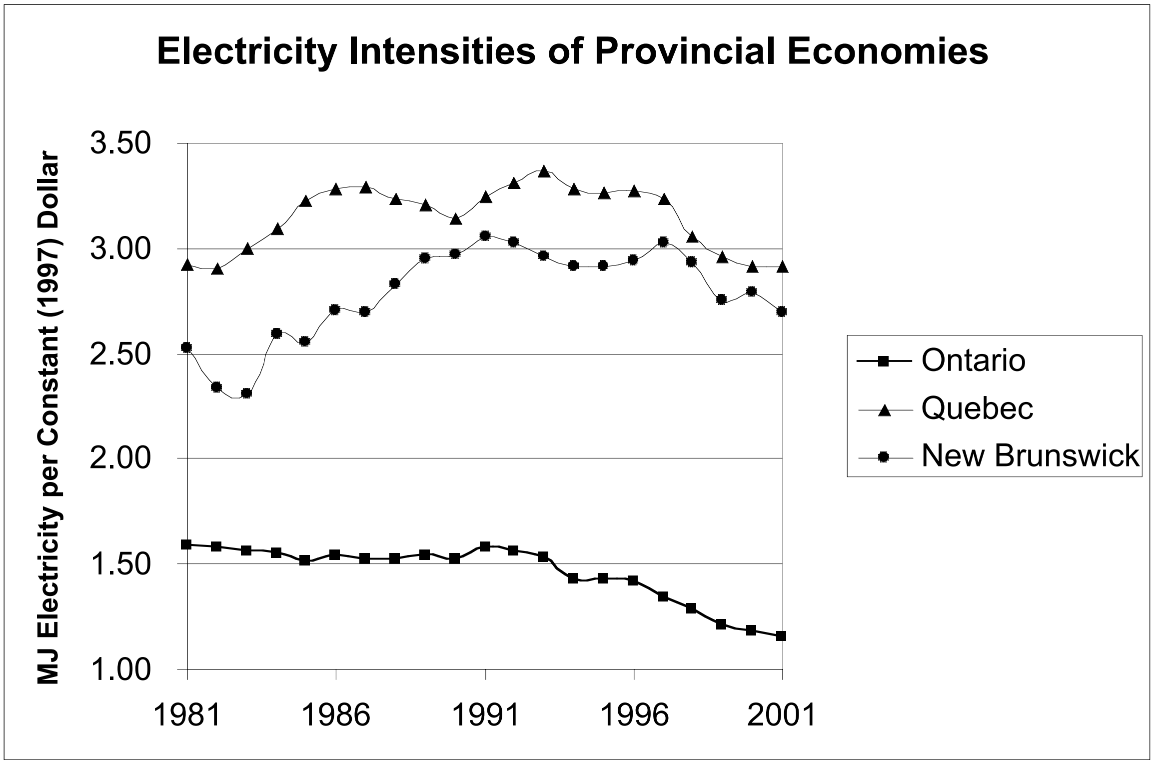
New Primary Energy in Canada, 1998 vs. 1970



In Ontario, New Brunswick and Québec, the decoupling of economic growth took place much sooner for fuels than for electricity. Throughout the 1980's the electricity intensity of these provincial economies (as measured in electricity use per dollar of output) held steady in Ontario and increased somewhat in Québec and New Brunswick, largely due to deliberate policies in these provinces to encourage the substitution of electricity for fossil fuels as a source of space heating, water heating and even industrial process heat (in Québec). During this period, utility planners often argued that electricity was immune to the "energy/economy" decoupling that was taking place for fossil fuels, and continued to commit to additional hydro and nuclear megaprojects.

But, as shown in **Figure 8**, technological change and innovation in the economy eventually caught up with the growth in electricity consumption. In Ontario, the electricity/economic output ratio has been falling since 1991. In New Brunswick, it levelled off in 1991 and began declining fairly steeply in 1997. Even in Québec, where electricity consumption has been promoted more vigorously than anywhere else in Canada, the electricity/economic output ratio has been falling since it peaked in 1993 and is now lower than it has been for over twenty years. In light of some persistent claims that growth in electricity consumption is necessary for economic prosperity, it is also interesting to note that the richest and fastest growing of these three provincial economies (Ontario) exhibits both the lowest electricity/GDP ratio and largest drop in this ratio over the 1981-2001 period.

Figure 8



Throughout the 1970's and well into the 1980's, the electric power industry misjudged what was happening in their market place on a monumental scale. Utilities in Canada and elsewhere, both publicly and privately owned, invested heavily in nuclear power in the mistaken belief that growth in the demand for central power plant electricity was somehow necessary for growth in the economy. Utilities that made their plans and their investments in the 1970's did not see the change that was coming, or saw it coming but thought that electricity was a special case or that the decoupling would be a passing trend and then growth would return to its historical relationship to economic growth. It didn't happen, and the shock waves from that misjudgement are still oscillating wildly through the electric utility sector in the form of any number of restructuring and deregulation or re-regulation policy responses. Whether publicly or privately owned, the very structure of "Big Electricity" is being shaken to its foundations by a wave of technological and organizational innovations in the provision of energy services to final consumers.

At the centre of transformation taking place in the electricity sector is the fact that electricity and fuels are not demanded for their own sake, but for the services they can help provide -- heat, light, motive power, information processing, etc. The "overshoot" in power plant investment in the 1970's and 1980's could have been avoided if this simple fact had been more widely appreciated when utilities mistakenly forecast the need for dozens of new power While some visionary thinkers at the time (most notably Amory Lovins), were sounding warning bells, those alarms fell on deaf ears. Lovins and others argued in the 1970's that it would be a mistake to think that the demand for fuels and electricity necessarily must go up before economic growth can take place.[5] Canadian utilities were among those with dramatic overshoot in their investment strategies, and commitments were made to megaprojects that, as it turned out, were not needed. By the time the utilities realized that the ground was shifting under their feet, there was a scramble to scale back investment plans, cancel plants that were not "beyond the point of no return" in their development cycles, and refinance the ones where they were in too deep to get out.[6] Even today, the business reorganization of the electricity services market is playing "catch-up" with the global changes that technology and the changing times are bringing, unavoidably, to this area of economic activity.

Distributed Resources

The decoupling of economic growth from growth in the demand for central power plant electricity is a high level trend that captures a number of technological, structural and organizational changes that are going on with regard to electricity. Compared to the traditional "central power plant" model of electricity supply, there is a rapidly emerging alternative structure to the supply and use of electricity that offers the possibility of a sustainable system based on "distributed resources", including end use efficiency, cogeneration and renewable energy. As described by Lovins[7]

> *Through the twentieth century, thermal (steam-raising) power stations evolved from local combined-heat-and-power plants serving neighbourhoods to huge, remote, electricity-only generators serving whole regions. Elaborate technical and social systems commanded the flow of electrons from central stations to dispersed users and the reverse flow of money to pay for power stations, fuel, and grid. This architecture made sense in the early twentieth century when power stations were more expensive and less reliable than the grid, so they had to be combined via the grid to ensure reliable and economical supply. The grid also melded the diverse loads of many customers, shared the costly generating capacity, and made big and urban customers subsidize extension of electric service to rural customers.*

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[5] Amory Lovins, Soft Energy Paths, Ballinger, Cambridge Mass., 1977.

[6] If nothing else, the magnitude of the utilities' mistaken understanding of the future demand for their product should serve as reminder of just how wrong conventional thinking can be. For example, in 1977, when Ontario Hydro had eight reactors in operation (Pickering A and Bruce A), eight more under construction (Pickering B and Bruce B) and four more (Darlington) about to be approved for construction, they were projecting that by 2003 Ontario would need *40 additional* nuclear reactors to be in operation, with *size increasing to 1200 MW and eventually to 2000 MW*. The same expansion plan called for *34 new 750 MW coal-fired units*. By 1989, they had lowered their projections and filed a plan with the Environmental Assessment Board that included no more than six new nuclear reactors to be in operation by 2003 (with many more under construction by then). That plan was based on a forecast of electricity demand in Ontario in 2001 of between 159 and 221 TW.hours. As it turned out, by 2001, eight of the old reactors were "laid up", no new reactors were under construction, and the total consumption of electricity in Ontario was just over 135 TW.hours.

[7] Amory Lovins *et. al*. Small is Profitable: The Hidden Economic Benefits of Making Electrical Resources the Right Size, Rocky Mountain Institute, Snowmass Colorado, 2002. www.rmi.org. This book is highly recommended for those interested in the future of electricity; *The Economist Magazine* named it a 2002 Book of the Year in the "business and economics" category. Small is Profitable challenges the long-standing notion that large, centralized electricity generation facilities are economically sound, and shows through example how small, distributed generation facilities placed close to end users provide cheaper and more reliable electricity. The book proves that properly valuing the benefits of distributed generation brings great economic advantages. The increases in value that result can be large enough to make seemingly expensive technologies economically viable—a revolutionary concept for the electricity industry.

> *By the start of the twenty-first century, however, virtually everyone in industrialized countries had electric service, and the basic assumptions underpinning the big-station logic had reversed. Central thermal power plants could no longer deliver competitively cheap and reliable electricity through the grid, because the plants had come to cost less than the grid and had become so reliable that nearly all power failures originated in the grid. Thus the grid linking central stations to remote customers had become the main driver of those customers' power costs and power-quality problems—which became more acute as digital equipment required extremely reliable electricity. The cheapest, most reliable power, therefore, was that which was produced at or near the customers.*

There are many technological, organizational and historical aspects of electricity production and use that contribute to the possibility of sustainable electricity futures,[8] but there are two related concepts that are central to understanding the new thinking – *energy services* and *scale*.

Energy services. In the energy services framework, more efficient end use technologies (e.g. compact fluorescent light bulbs, variable speed drives, better insulated buildings, better energy management control systems, more efficient office equipment and home appliances, etc.) are at least as effective as increased electricity supply in satisfying the underlying demand for service. In fact, efficiency improvements have numerous economic and environmental advantages over increased electricity production from central power plants, advantages that are almost always underestimated and undervalued by utilities. They can be deployed in small units, and very quickly relative to the time it takes to plan and build a centralized power plant, thus reducing and diversifying risk. They can also deliver significant power quality and system benefits and by delivering a particular service with less electricity and they reduce ecological risk and stress not only at the point of end use, but all the way "upstream" to the power plants, uranium and coal mines.

Scale. The Canadian electricity industry has followed the North American trend toward larger and larger power plants, to the point where the scale individual generators dwarfs the scale of most end uses. A single coal or nuclear power plant produces electricity at a rate that is hundreds of thousands times higher than the power demand of typical households, businesses and industrial establishments. The "economy of scale" arguments for the system developing this way are well known, and went largely unquestioned so long as power consumption was doubling every ten years, the production of electricity was controlled by large monopolistic organizations, and communities could be persuaded to host behemoth power plants. But given the scale of end use demand and the fact that the grid is now essentially completely built out, there is no fundamental reason why electricity needs to be made in GW blocks. Technological advances and the emergence of mass production of electricity generators have reversed the traditional scale economies, especially after consideration of the numerous but often overlooked or undervalued economic and financial benefits of the smaller, distributed generators.[9] Combined with end use efficiency improvements (the ultimate distributed resource, deployed at the scale of the end use itself) that are developed first in the highest cost electricity regions but then marketed globally, the stage is set for a radical transformation of the electricity system.

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[8] In addition to Small is Profitable, cited above, see also Walt Patterson, Transforming Electricity: The Coming Generation of Change, Royal Institute of International Affairs and Earthscan, London, 1998, and Patterson's more recent working paper "Overview: The Electric Challenge", Working Paper No. 1, available at www.riia.org.

[9] Amory Lovins, Small is Profitable, *op. cit.*

Building Blocks for a Safe Electricity Future

The technologies that could make a transition away from coal and nuclear power have already been developed, and in the scenario developed in this analysis we present one example of how they can be combined to meet growing demands for energy services while at the same time reducing and eventually eliminating reliance on centralized nuclear and fossil fuel power plants. The institutional, policy and business innovations that will be required to mobilize these technologies on the necessary time scale is not so well developed, but change in these areas can accelerate quickly once the possibilities, opportunities and benefits are appreciated.

The manner in which the new electricity regime will take shape will vary with historical circumstance, public policy, and business culture. The three provinces included in the scenario presented here – Ontario, Québec, and New Brunswick – differ with respect to these factors, but we have identified five common elements that will play an important role in the electricity transition that lies ahead.

- **Improved efficiency of electricity use.** This is by far the most important element of any strategy for a nuclear phase-out or more generally for a sustainable and low emission energy future. It is simply not possible to achieve a sustainable electricity future in the face of inefficient uses of electricity. Fortunately, there are have been and continue to be remarkable advances in the efficiency of electricity use for lighting, motors, appliances and all manner of electronic devices, so there is a great deal of unrealized potential here. Given the clear social and environmental benefits of the demand side investments (benefits which are not included in the economic valuing of these measures), a strong case exists that the demand side investments should be receiving preferential consideration over supply side investments. Unfortunately, just the opposite is the case, and the reversal of this wrong-headed approach to energy investment remains the top priority for achieving a low emissions and nuclear-free electricity system.

- **A reduction over time in the use of electricity for heat.** Electricity is really only necessary for about 12-14% of total end use energy, but in all three of Canada's nuclear provinces it provides a much greater share of energy use. This is because it has been promoted in those provinces as a heating energy source, for building space and water heating and in Québec even for industrial boiler applications. Electricity's share of the heating market has peaked in all three of these provinces and has been in decline for some time now. A continuation of the reduction in electricity's share of the heating market is an important element of the sustainable electricity strategy, particularly in Ontario and in New Brunswick. This does not mean a complete phasing out of electricity for heat; there are and will continue to be specific circumstances where it will not be possible or feasible to eliminate the use of electricity for heat, in spite of the fact that its "like cutting butter with a chainsaw". Where electricity continues to be used to supply space and water heating, conservation and efficiency improvements in the buildings and water heating systems can reduce consumption.

- **Cogeneration**. All three of Canada's nuclear provinces have significant numbers of energy intensive industrial establishments that are prime candidates for electricity cogeneration (e.g. pulp and paper mills, primary metal smelters and refineries, industrial chemical and petrochemical establishments, etc.) A review of the international literature on low emission futures reveals cogeneration to be second only to improved efficiency in the size of the contribution it can make to a more sustainable and efficiency electricity supply and demand system. The electricity industry is in the early stages of a transition that will see a multitude of distributed sources of generation displace the need for large, centralized coal and nuclear stations, and the growth of industrial cogeneration is part of the leading edge of this wave of change. In the longer term, it will extend to microcogeneration at commercial and even residential buildings, but in the short to medium term it is the potential for increased industrial cogeneration that looms largest. Clearing the obstacles to increased investment in industrial cogeneration is an important element of the nuclear phase-out strategy, especially in New Brunswick and Ontario.

- **Strengthen East-West Electricity Trade**. Both Ontario and New Brunswick are adjacent to provinces with large, already built, hydroelectric capacity. According to our analysis, the changes in the technology of electricity use, combined with the continued decline of electricity as a source of heat, will lead to surpluses of electricity in Manitoba, Québec and Labrador. There is a strong case for greater east-west electricity trade that would allow the Maritimes and Ontario to access this hydroelectricity, and we have included increased interprovincial electricity trade in our scenario.

- **New and Renewable Electricity**. Over the scenario period (to the year 2020) there will be increasing contributions from wind, solar and biomass electricity. Indications are that growth in wind power will be particularly strong over this period. We have included aggressive growth for wind and solar power in our scenario, and also some biomass electricity growth in New Brunswick. Even with these strong growth rates, electricity supply in a nuclear-free, coal-free electricity system in 2020 will be dominated by the output of the existing hydroelectricity resources, although the contribution from the new and renewable sources could be on a par with natural gas cogeneration by the end of the scenario period.

The Scenario Analysis

Method

Our basic approach was to adopt a "business-as-usual" outlook for population and economic activity in the three provinces, and then to analyze the changes in the electricity demand and supply system that would be necessary to achieve a phasing out of nuclear and coal-fired power plants by 2020. The analysis was conducting using a "bottom-up", end use-oriented and technology-based simulation of the Canadian energy economy. A computer model of the Canadian economy was employed that simulates energy use by end use, fuel and activity subsector.[10] Energy use by fuel is computed by multiplying activity drivers by their respective energy intensities for each end use and subsector (e.g. energy use per household for space heating in new single family detached housing in the residential sector). An additional variable distributes the energy use by fuel, and the results are then added up to obtain total energy use by fuel and sector of the economy.

We began by calibrating the energy model to historical data for energy use by end use and fuel. Once we had a fully calibrated model of Canadian energy, we then projected all the activity variables (number of households, square metres of commercial and institutional buildings, passenger-km and tonne-km of travel, physical and dollar values of industrial production) to the year 2020. In general, this was done by accepting without question conventional forecasts for Canadian demographic and economic growth.

We then conducted a sector-by-sector analysis of opportunities for efficiency improvement, cogeneration, and reduced use of electricity. The resulting (much reduced) demand for grid electricity in 2020 was then compared with the existing supply of hydroelectricity. In the

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[10] A somewhat more detailed description of the method is contained in "Kyoto and Beyond", op. cit.

national analysis, the result was a surplus of hydroelectricity in British Columbia, Manitoba, Quebec and both Labrador and the Island of Newfoundland. For the other provinces, including Ontario and New Brunswick, the deficit was made up through a combination of hydroelectricity from neighbouring provinces, high efficiency combined cycle natural gas plants, new wind and solar generation, and other new "green" sources of electricity. Centralized coal, nuclear and thermal power plants are phased out over the course of the study period, and no new hydroelectric generation was assumed.

Improved Energy Efficiency of Electricity Use

Residential Sector

Our scenario for 2020 envisages two principal changes for Canadian housing:

1. Every existing single detached or single attached home where it is reasonable to do so[11] is retrofitted with higher levels of insulation, high efficiency doors and windows and is air sealed to higher levels. In practical terms, the application of these measures reduces the space heating energy consumption of existing homes to about two-thirds of their current levels. It is worth noting that one of the biggest energy saving measures on the list is simple caulking and weather-stripping, a measure that also has one of the lowest costs. Reducing air leakage from a home results in large energy savings and almost every home in Canada can benefit from caulking and weather-stripping improvements.

2. All new construction as of 2004 is built to the highest possible levels of insulation, and with the most efficient doors and windows currently on the market. Using only technologies that are currently on the market, new houses are built to the highest possible insulation standards. In practical terms, this means that new homes require only about one-third the space heating energy of today's existing homes[12]. Measures include super-insulating the walls, attic, and basement floor, using triple-glazed low-e argon filled windows, construction techniques designed specifically to reduce air leakage and making maximum use of passive and active solar heating. Heat recovery ventilators are used to ensure sufficient and controlled ventilation while minimizing heat loss. Some modifications to wall construction are required, which must be built with double 2x4s rather than the standard 2x6 studs, but incremental costs are under $15,000 per single detached house, and will certainly drop once these practices become the norm.

Existing apartments and condominiums[13] can also be significantly improved in terms of their overall energy efficiency, although not as much as single attached and single detached housing. The reason for this is that apartments and condominiums are already fairly energy-efficient forms of housing because they have much less surface exposure to the outdoors per square foot of floor area (a typical apartment has only one exterior wall, whereas detached homes have four exterior walls and a roof). However, the application of low-e argon filled, triple glazed windows, higher levels of exterior wall insulation and better air sealing can still improve space heating energy efficiency by about 20%. We have assumed that by 2020 all existing apartment buildings have been retrofitted.

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[11] "Reasonable" means when it could be considered cost-effective to carry out the retrofit.

[12] Calculated using Natural Resources Canada's HOT2XP residential computer simulation model.

[13] An apartment or condominium is defined here as a single unit (a household), not the entire building unless otherwise noted in the text

Water conserving showerheads, faucet aerators, dishwashers and washing machines, combined with a increased conservation awareness among consumers, have the effect of reducing household hot water energy requirements by 50% in our scenario. By 2020 all electric hot water heaters in use can be replaced by tankless water heaters. Virtually all hot water heaters currently in use will have been replaced by 2020. Assuming that policies were put in place today, all these electric hot water heating tanks could be replaced by the tankless water heaters, which produce hot water on demand and thereby eliminate standby heat and energy losses (responsible for as much as 50% of total water heating energy consumption).

By 2020, we have assumed that all air conditioners in use are as efficient as the most efficient air conditioners for sale today (e.g. central air conditioners with a Seasonal Energy Efficiency Ratio or SEER of 15).

Lighting energy consumption per household is cut by two-thirds through a combination of energy-efficient lighting products (bulbs, fixtures, timers and occupancy sensors), improved lighting design in homes, and householder conservation practices brought on by a combination of education and auditing services to help people identify the best opportunities for saving lighting energy in their homes.

For the purposes of our analysis, we assumed that by 2020 most household consumer products have similar energy efficiency characteristics to Energy Star labelled products today, resulting in miscellaneous plug load energy consumption dropping to 600 kilowatt-hours per household per year from its base year level of 1,300 kilowatt-hours per year.

Commercial Sector

For existing commercial buildings of all kinds, there are large opportunities for reducing energy consumption through the application of advanced technologies for lighting, heating, ventilating equipment and “plug load” equipment (computers, monitors, printers, photocopiers, etc.). For new buildings, there are even larger opportunities to save energy (and capital costs) when the architects and builders are able to integrate energy efficiency into the building concept, the site plan, the building skin and fenestration design, and the interior design. We have assumed that beginning in 2004, all new commercial construction meets the existing C-2000 construction energy efficiency standards. In addition, we have assumed that the existing buildings are renovated at the rate of four percent per year, at which time energy efficiency is improved to C-2000 levels. By 2020, the base stock of buildings in our scenario has reduced its energy intensity to 40% of current levels, and new buildings achieve on average what the best buildings were already achieving in the late 1990’s.

Overall, we have assumed that fans, blowers and pumps will consume about half the energy they consume in 2004. This can be accomplished by using high efficiency motors, variable speed drives, more efficient impeller design and low friction surfaces, all technologies that are being successfully employed today. By 2020, we have assumed that existing commercial buildings can reduce their lighting energy consumption by 30% overall, and that new commercial buildings will use only half the energy of today’s buildings for lighting. These very modest targets can be met simply by ensuring the use of currently available and highly cost effective lighting technologies such as T8 lamps, electronic ballasts, and controls. Natural replacement of lighting fixtures (which occurs in office buildings about once every five to eight years during renovations, but may only occur once in twenty years in other buildings)[14] would ensure complete replacement of T12 with T8 or metal halide fixtures in warehousing and other high ceiling areas (or other systems at least as energy-efficient) by 2020. Education, incentives and professional training to promote the application of advanced systems by architects and building engineers could produce

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[14] Ibid

savings well in excess of the levels we have assumed in our scenario. Setting C-2000 as a standard for new buildings would by itself ensure much higher energy efficiency in building lighting systems. Requiring the use of natural lighting where feasible would further increase savings. Architectural systems such as skylights, light pipes and light shelves have been successfully employed to bring daylight deep into a building interior.

New office and other commercial equipment is typically much more energy efficient than older equipment. Natural Resources Canada's Energy Star program rates the energy efficiency of computer equipment, fax machines, photocopiers, scanners, multi-function devices, water coolers, and commercial refrigerators and freezers and provides an "Energy Star" rating to the most efficient among them. Other equipment used in offices and rated by the Energy Star program includes phones, answering machines and lighting products. There are a wide range of brands and models in each of these equipment categories that are rated by Energy Star. For all these products, if all offices replaced their existing equipment with Energy Star equipment, it would cut the amount of energy used by these devices by 40-50%[15]. These devices are more energy efficient largely because they are designed to reduce energy consumption when in standby mode or when turned off. By 2020, in our low emission scenario all office and commercial equipment is 50% more energy efficient than today. Again, simply ensuring that the Energy Star standard prevails in new equipment purchasing would be sufficient to achieve most of the savings included in the scenario.

Hot water use is reduced by 50% through leak repairs, the use of faucet aerators, low flow showerheads, clothes washers that are at least as energy-efficient as front-loading washing machines today and dishwashers in 2020 that are on average as efficient as the most energy efficient on the market today.

The effect of the technologies and measures described above is a sharp drop in energy consumption, in spite of the increased floor area that will be in service by 2020. The buildings and the lights and equipment in them are several times more efficient than current practice, and by 2020 commercial and institutional buildings will be getting more of their electricity from self-generation (micro co-generation, fuel cells, CHP) (described below), which will reduce their need for grid electricity.

Industrial Sector

It is a particularly complex task to analyze the potential for energy efficiency improvements in the industrial sector because of the complex and varied nature of energy use in this sector. Our approach was to use historical analysis of energy/output trends by industry. The overall energy intensity of Canadian industrial production improved about 14% between 1990 and 1999, due to a combination of more energy-efficient technology and "structural change" both between and within industrial subsectors.

Utilizing Natural Resources Canada's (NRCan's) Energy Efficiency Indicators Database, a time series was constructed consisting of output, energy use by fuel, and energy intensity for 54 separate industries, including agriculture. Production was allocated by province so that the marginal grid electrical source that would be displaced by any increase in industrial co-generation could be identified. Activity was expressed in dollar value for some industries and in physical units for others, and activity was projected forward to 2020 on the basis of growth rates used by NRCan for projecting industrial energy use.[16]

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[15] http://www.energystar.gov/products/. See the pages specifically related to office equipment, water coolers and commercial refrigerators/freezers.

[16] http://www.nrcan.gc.ca/es/ceo/cansd.pdf

In our analysis, with a few exceptions, the market shares of fuels used in industry were held constant at their current levels. Based on recent experience, an annual rate of improvement in energy/output of just one percent per year was assumed for the 2004-2012 period for most industries, increasing to 1.25% per year for the 2013-2020 period. A somewhat higher rate of 1.5% per year to 2012 and 2% per year thereafter was assumed for the pulp and paper and industrial chemical industries, and for the steel industry an average annual improvement rate of 2.5% was assumed for the entire 2004-2020 period. The NRCan growth rates for these energy-intensive industries are quite robust, and are unlikely to be realized except in the context of a move to higher value added products and lower energy intensity of production. In summary, the energy intensity for industry is expected to decline over time, reflecting the combined effect of intra-industry structural change and energy efficiency improvements.

Reflecting the conservative nature of the analysis, industrial electricity consumption is only modestly reduced in each province in this scenario (see individual province descriptions below). Policy measures that would help to achieve this result include the establishment of robust targets for each industrial sub-sector, based on actions identified in the various industry tables in the National Climate Change Process, together with mechanisms that will allow for the adjustment of these targets.

Fuel Switching

In Ontario and New Brunswick, we are anticipating that there will be a significant move away from electricity as a source of space and water heating. In both provinces, it is assumed that trends continue toward the use of natural gas as a source of space and water heating, appliances (ranges and clothes dryers) and commercial space cooling applications. In the case of Québec, we have held electricity's space heating market share at its current levels.

While renewable energy grows at only modest rates as compared with efficiency improvements and passive solar techniques in building design, we have assumed a fairly significant development for solar water heating. Solar hot water heaters are widely available today, are designed to work in tandem with existing gas and electric water heating systems, and can provide 35-50% of hot water requirements for a typical home or commercial building[17]. With the reduction in demand for hot water in a typical home or commercial building resulting from the energy conservation measures discussed above, solar hot water heaters could provide an even larger share of their hot water needs. For the purposes of our scenario analysis, solar water heaters provide 30-40% of the residential sector's hot water needs and 20-45% of the commercial sector's hot water needs by 2020.

Distributed CHP Production

Between 60% and 75% of the energy generated in large coal and nuclear power plants is wasted, discarded in the form of low temperature heat to the adjacent lake or river water. With so much heat being produced in one location, it is virtually impossible to make use of a significant portion of it. In contrast, when thermal electricity is made on a smaller scale, it is more feasible to make use of the waste heat in nearby buildings or factories. This type of "combined and heat power" plant (or CHP plant) is very common in many parts of Europe; in Denmark, for example, most of the electricity in small power plants that are also supplying neighbourhood-scale district heating systems. These systems can achieve overall energy efficiencies of 80%.

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[17] Canadian Solar Industries Association, *Solar Energy in Canada*, Ottawa (http://www.cansia.ca/pdf/17.pdf)

Combined heat and power systems will be important in the commercial building sector. Such systems, which are very common in Europe, have traditionally been based on conventional technologies for the steam generation or turbine generation of electricity. In addition to electricity, the system also provides heat to a distribution system that includes buildings or households in the vicinity of the plant. The technologies for CHP plants have been getting smaller and cheaper in recent years, opening up the possibility for application at the level of the individual building or building complex. In these systems, natural gas fuelled reciprocating engines or hydrogen fuel cells (with the hydrogen produced by on-site natural gas reformers) can provide a mix of electricity and useful heat. CHP plants, fuel cells and reciprocating engines can also provide space cooling, generally more efficiently than individual rooftop air conditioning systems.

In our scenario, distributed energy systems provide about 20% of space heating, water heating and electrical needs in houses and about 35% of space heating, water heating and electrical needs in apartments by 2020. Distributed energy systems are better suited to apartments/condominiums than to houses, because of the higher proportion of total energy requirements that must be met by electricity in these larger buildings. New commercial buildings will be designed so that their space heating needs will be met with waste heat and passive solar gain. Existing commercial buildings will use waste heat from on-site fuel cells and micro co-generation systems, with some development of active solar heating and, where feasible some buildings will be connected to CHP plants when they are in areas with high floor space densities.

The efficiency of water heating systems improves with the move to natural gas condensing systems where domestic hot water systems are required and combined heat and power systems, fuel cells and solar systems take some share of the commercial sector water heating market by 2020. Solar water heating systems are most effective for pre-heating when combined with conventional systems, and with the hot water conservation measures assumed in the low emissions scenario, solar systems could eventually provide 20-45% of the commercial sector's hot water needs.

Space cooling in the commercial sector is provided primarily by electricity-driven air conditioners, but there has been a significant shift recently in the commercial sector towards the use of natural gas driven air conditioners. Instead of using an electric motor to drive the compressor (the principal component of an air conditioner), it is possible to use a natural gas powered internal combustion engine. The use of natural gas powered air conditioners is often both cheaper and more efficient than electricity-driven air conditioners. As a result, natural gas has captured about 20% of the commercial space cooling market. Its share of the market will likely continue to grow over time, and in our scenario, 45% of commercial space cooling will eventually be powered by natural gas. Micro co-generation and fuel cells provide 10% and 25%, respectively, of space cooling in the 2020 scenario, with grid electricity providing only 20% of space cooling demand.

Industrial Co-generation

We also assessed the potential for new industrial co-generation over the 2004-2020 period. The analysis was restricted to the pulp and paper, metals and steel, and industrial chemicals industries in Ontario and New Brunswick. Provincial shares of production in these industries were used to determine the potential for co-generation in the relevant provinces. The supplementary natural gas required by these industries for the co-generation units was added to their total gas consumption for each year, and the electricity output was subtracted from their demand for grid electricity. The total new capacity by 2020 is over 4,000 MW.

New and Renewable Electricity Generation

The above measures – energy efficiency improvements, fuel switching, increased CHP and cogeneration – all have the effect of reducing the demand for what we call "grid electricity" from central power plants, and the deployment of these options is the key to achieving a more sustainable electricity future in which the large coal and nuclear plants can be permanently retired without causing supply shortages. We have also assumed that there will be growth in the use of a number of renewable generation technologies, specifically wind power, solar photovoltaics, biomass power plants, and some small hydro development. In the "Kyoto and Beyond" scenario, the supply of these new and renewable sources of electricity increases from 10 PJ in 2004 to 61 PJ in 2012 to 127 PJ in 2020.

- Most of this growth is in the form of wind energy, which by 2020 supplies about half the new renewable electricity in our scenario. This corresponds to 7,000 MW of installed capacity, or about 3,800 wind machines of 1.8 MW capacity each. Wind machines have relatively low load factors, so this 7,000 MW represents the equivalent of about 2,500 MW of baseload capacity.

- The solar energy component of the renewable electricity supply represents the installation of 3,600 Megawatts of solar panels by the year 2020. A national residential solar roof project could achieve this by installing 5-kilowatt systems on 722,000 roofs across the country, or on less than 10% of single family housing stock in 2020. Again, the peak capacity of solar systems is several times higher than their average output; this 3,600 MW delivers the equivalent of about 600 MW of baseload capacity.

- Micro-hydro is small scale, run-of-the-river hydro systems that make very little disruption to the natural flow of a river. Estimates of the potential in Canada vary, but in our scenario about 320 Megawatts of potential will be installed by 2020. This is a conservative number, but many potential sites would likely not be developed for a number of reasons, including poor economic feasibility, and conflicts with existing land uses and other ecological and social values. We have assumed a 65% load factor, making the 320 MW equivalent to about 200 MW of baseload capacity.

- The burning of biomass, which includes landfill and sewage gas combustion, and agricultural waste, will also increase significantly. There is currently about 85 MW of installed capacity at landfills across the country, and some additional sewage gas electricity generation. The total potential for landfill gas electricity in Canada is currently estimated at 200 Megawatts and all this potential is expected to be developed by 2020. Biomass burning here does not include the burning of wood waste in the forest and forest products industries. Forest and forest product industry use of wood waste for energy is included in our analysis as an overall reduction in that industry's energy requirements.

These are national totals, and the specific amounts for Ontario, New Brunswick and Québec are described below in the summaries of the provincial analysis. The growth in solar and wind this energy development that would be necessary to achieve these levels of implementation by 2020 is aggressive but achievable and would ensure that Canada remains "in the game" with regard to the emerging technologies for renewable, distributed generation. It is important to realize, however, that even with these aggressive growth rates, the total contribution of renewables by 2020 would be the equivalent of about 3,500 MW of baseload capacity, on a national scale. In terms of reducing dependence on central coal and nuclear power stations, this is a significant contribution, but the contribution from cogeneration is twice as big and energy efficiency improvements will be four times bigger than renewables in facilitating the phasing out of coal and nuclear stations.

Interprovincial Electricity Flows

There could be an important role for increased interprovincial trade in electricity in achieving a sustainable energy future in Canada. Under the efficiency improvement scenario developed for the "Kyoto and Beyond" analysis, the demand for grid electricity drops below the level that can be provided with existing hydroelectric capacity in Manitoba, Québec, Newfoundland and Labrador. For these hydro-rich provinces, electricity export markets and emerging high-value applications for electricity (e.g. hydrogen production) will be important strategic directions. Given that Ontario and New Brunswick (and the Maritimes in general) will not likely be able to achieve self-sufficiency in renewable electricity in the medium term, they could benefit from greater access to power from the hydro-rich provinces. In the Kyoto and Beyond scenario, we assumed an increased flow of electricity into New Brunswick from Québec (although the ultimate source could be Labrador) and an increased flow of power into Ontario from Manitoba and/or Québec. The volumes are modest in our scenario, and would still leave substantial surpluses in the exporting provinces that could be used for hydrogen production or sold to other export markets. In the case of the New Brunswick inflow, it is kept below the level that can be provided with existing interconnection capability.

For Ontario to be able to access significant amounts of power from Manitoba would require new transmission line capacity through Northern Ontario, and to increase capacity to import from Québec would require new power conversion facilities connecting the two grids. These are relatively capital intensive facilities, and initial feasibility studies have been done in the past for both these options, but were shelved as part of the scaling back of expansion plans that took place when the electricity demand forecasts of the 19870's and 1980's did not materialize. These proposals should be reconsidered now, including an assessment of their environmental impacts, as a possible component of a long term trend toward a renewable-based electricity future in Canada, in which greater east-west flow of hydroelectricity could play an important role.

Scenario by Province

The three provinces considered in this analysis – Ontario, Québec and New Brunswick – have very different levels and patterns of fuel and electricity consumption, and the role of central coal and nuclear plants is also very different in each of these provinces. A scenario for the supply and demand of electricity in 2020 for each province was prepared by combining the elements described above in combinations appropriate to the unique circumstances of each province.

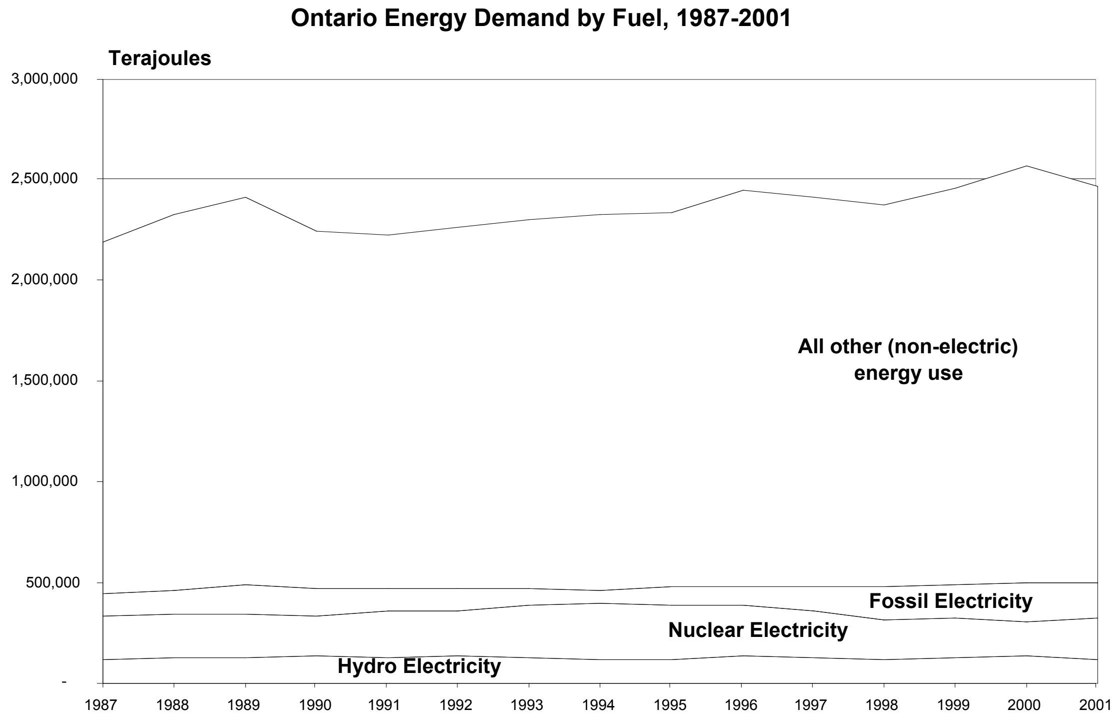
Ontario

Total consumption of fuels and electricity in Ontario for the 1987-2001 period is illustrated in **Figure 9**. During this period, the Ontario economy grew four times faster than fuel and electricity consumption.

The total electricity demand of about 500 PJ (139,000 GW.hours) in Ontario is split fairly evenly between the residential, commercial and industrial sectors (29%, 34% and 37% respectively). Almost half (46%) of residential demand for electricity was used to power appliances, with 18% used for space heating, 15% for water heating, and 15% for lighting. Air conditioning consumed 5% of provincial residential electricity use.

For the commercial sector, lighting comprises fully 37% of electricity use, and an additional 27% goes to fans, pumps and blowers associated with heating, ventilation and air conditioning systems, 20% goes to air conditioning, and 15% goes to "plug load" equipment (computers, monitors, fax and photocopy machines, printers, refrigerators and freezers, other electrical appliances and devices). Space and water heating account for a very small portion of electricity use in Ontario.

Figure 9

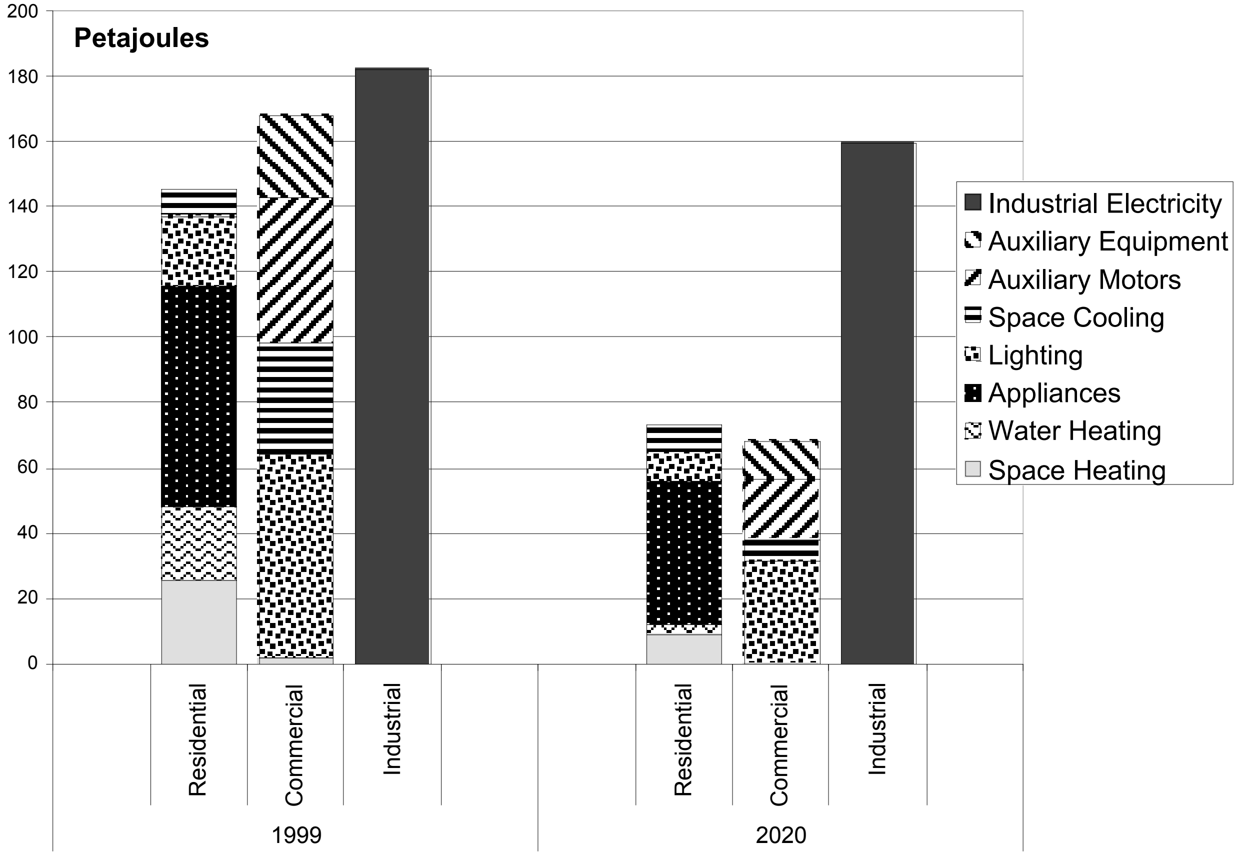


By 2020, the total demand for grid electricity will have fallen to 302 PJ, a 40% drop from 1999 levels. This dramatic drop in grid electricity consumption results primarily from energy efficiency improvements and cogeneration in the industrial, commercial and residential sectors. The largest reductions are in residential and commercial space heating and water heating, and in commercial space cooling. Electricity's share of the residential space heating market was already low in 1999, but drops further by 2020, from 9% to 5% in existing housing and 2% in new housing. A more significant shift away from electric space heat occurs in apartments, where electric space heat's share of the market drops by half, from 31% to 15% in existing apartments and to 5% in new apartments by 2020. Electricity's share of the commercial space and water heating markets is already extremely low in 1999 (around 1%) and remains at those levels or below in 2020. Electricity is also gradually phased out as a water heating fuel in the residential sector.

As noted in the section above, grid electricity's share of commercial space cooling drops off dramatically, to 20% of total demand by 2020. Gas-fired reciprocating engine driven air conditioners, combined heat and power plants, microturbines and fuel cells all pick up grid electricity's market share, as they are ideal and cost-effective technologies for this end-use by 2020.

More modest reductions have been assumed for the industrial sector, but there is a large potential for cogeneration in Ontario industry. After improvements in energy efficiency, cogeneration will be by far the largest source of new energy supply for Ontario. Already in 2003, significant new potential has been brought on line in the province, and this trend will very likely continue in the deregulated and supply-constrained environment Ontario now finds itself in.

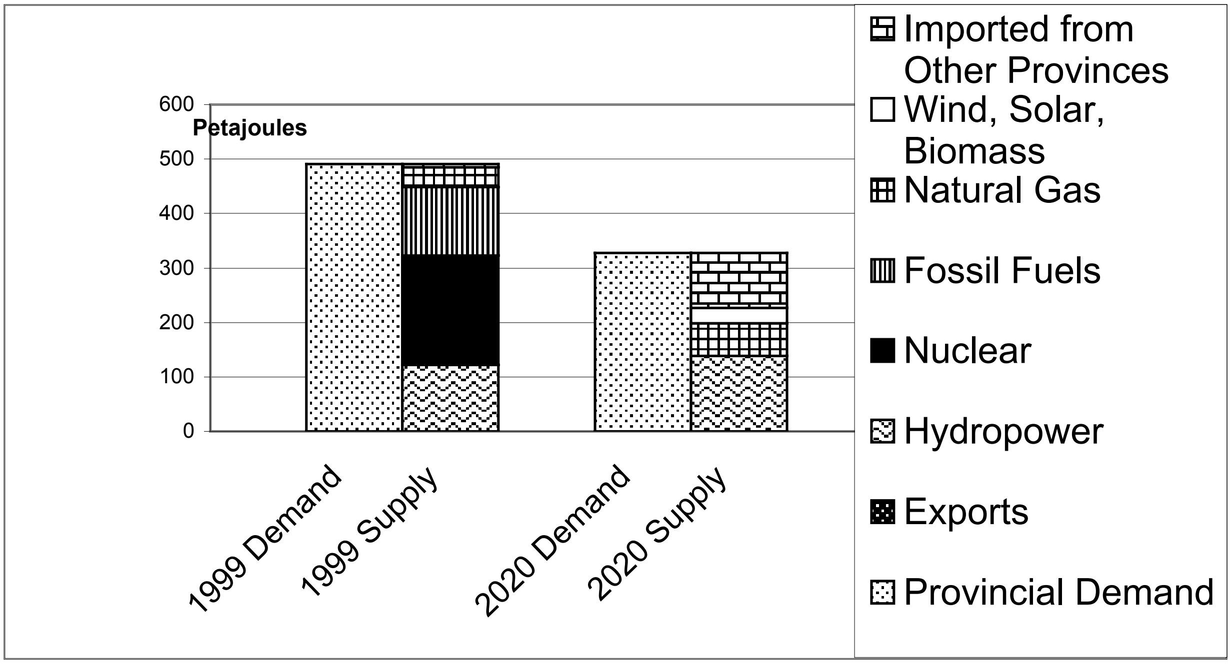
Figure 10 – Demand for Grid Electricity in Ontario by Sector and End Use in 1999 and in the Nuclear/Coal Phaseout Scenario for 2020



These reductions in the demand for grid electricity will be complemented by increases in the supply of renewable sources of electricity, including wind, solar, biomass and new traditional hydro-electric supply. We have also included increased power imports of 2000 MW from Québec and 1000 MW from Manitoba. Proposals have been developed for some time to bring these quantities of energy into Ontario from Manitoba and Québec, and we have included these plans in our scenario. The final balance of grid electricity demand and supply for Ontario in 2020 is shown in **Figure 11**. The combination of demand reductions and the new sources of supply will allow the province to phase out both its nuclear generating stations and its coal-fired generating stations.

Figure 11

Electricity in Ontario in 1999 and 2020 – Nuclear/Coal Phaseout

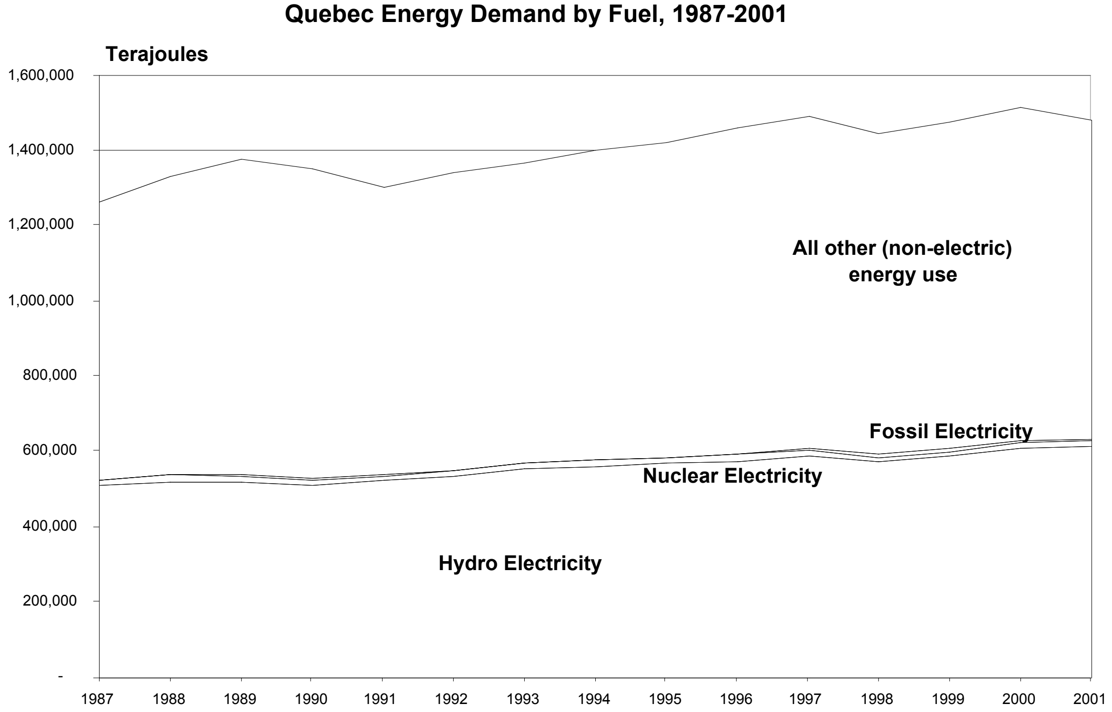


Québec

Québec has seen fairly significant increases in its demand for all forms of energy, including electricity. Electricity provides a much greater share of total energy in Québec than elsewhere in Canada, as shown in **Figure 12**. Whereas Ontario's consumption of electricity is around 20% of total demand, Quebec's electricity consumption is about 43% of total energy demand. This is due to the significant penetration of electricity as a source of space and water heat in all sectors of the economy. In addition, Québec's relatively cheap electricity rates have attracted electricity intensive industries such as aluminum manufacturing. Nevertheless, the intensity of energy use in Québec has declined over time, although these declines have been more modest than in Ontario.

Hydro-electricity dominates Quebec's electricity supply, with very minor contributions from nuclear energy and fossil fuels, and the phasing out of both nuclear and fossil fuel electricity is a relatively simple matter for Québec. Because electricity is such a clean source of energy in Québec, we have assumed that the degree of fuel switching that would have to occur in Ontario and New Brunswick in order to phase out nuclear power and fossil electricity need not occur in Québec. As a result, we have frozen electricity's share of the commercial and residential space and water heating markets at 1999 levels. Instead of fuel switching, we have relied primarily upon energy efficiency improvements to reduce demand in Québec. However, fuel cells achieve a 20% overall penetration rate in residential and commercial electricity supply (with the exception of the health sector, where fuel cells and combined heat and power achieve a 40% penetration rate due to the large economic benefits of combined heat and power production in these facilities).

Figure 12



The assumption is that fuel cells are brought into the Québec market as a source of distributed energy, largely to create a more robust electricity distribution system and not really to displace hydro-electricity. The heat generated by the fuel cells is used to displace other forms of heating, such as fuel oil. The reduced demand for grid electricity allows the province to phase out its nuclear and fossil electric supply, while maintaining large electricity surpluses that can be used for export and/or hydrogen production in the future. Québec has the advantage in our analysis of having a wide variety of energy options open to it.

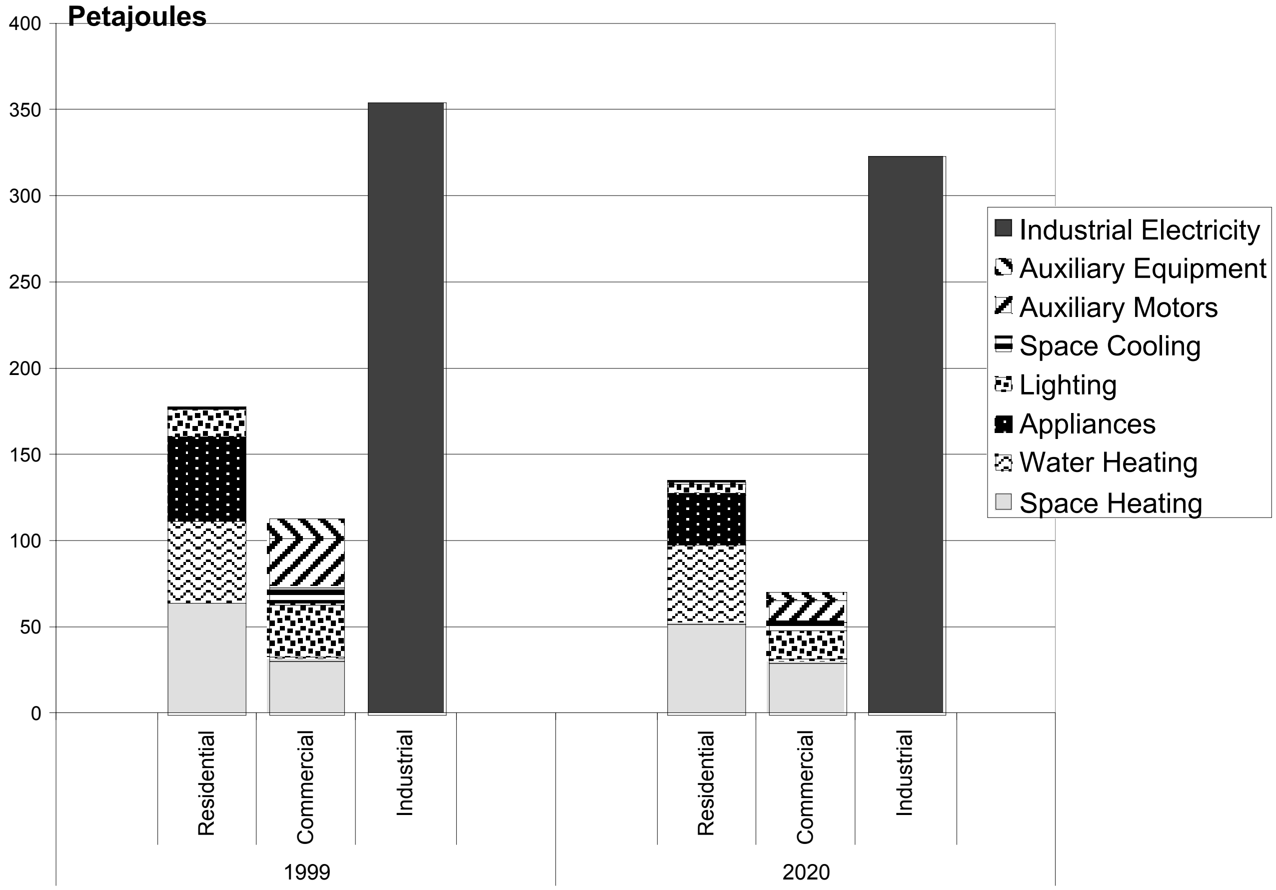
In 1999, total demand for electricity equalled almost 645 Petajoules. More than half (55%) of this demand for electricity occurs in the industrial sector, while 28% occurs in the residential sector and 17% in the commercial sector. In the residential sector, 36% of electricity is used for space heating, while another 26% is used for water heating. Appliances use 27% of residential electricity, while lighting uses 9% and air conditioning uses 1%.

In the commercial sector, space heating and lighting each consumed about 27% of commercial electricity, while fans, pumps and blowers consumed 25%, office equipment 10%, space cooling 9% and water heating, 2%.

By 2020, total demand for electricity in Quebec will have fallen to 529 Petajoules. The biggest decreases will occur in residential and commercial lighting, commercial space cooling, fans, pumps and blowers and office equipment. Only modest decreases in electricity consumed for space and water heating will occur, and industrial demand for electricity will also only see modest drops.

Figure 13

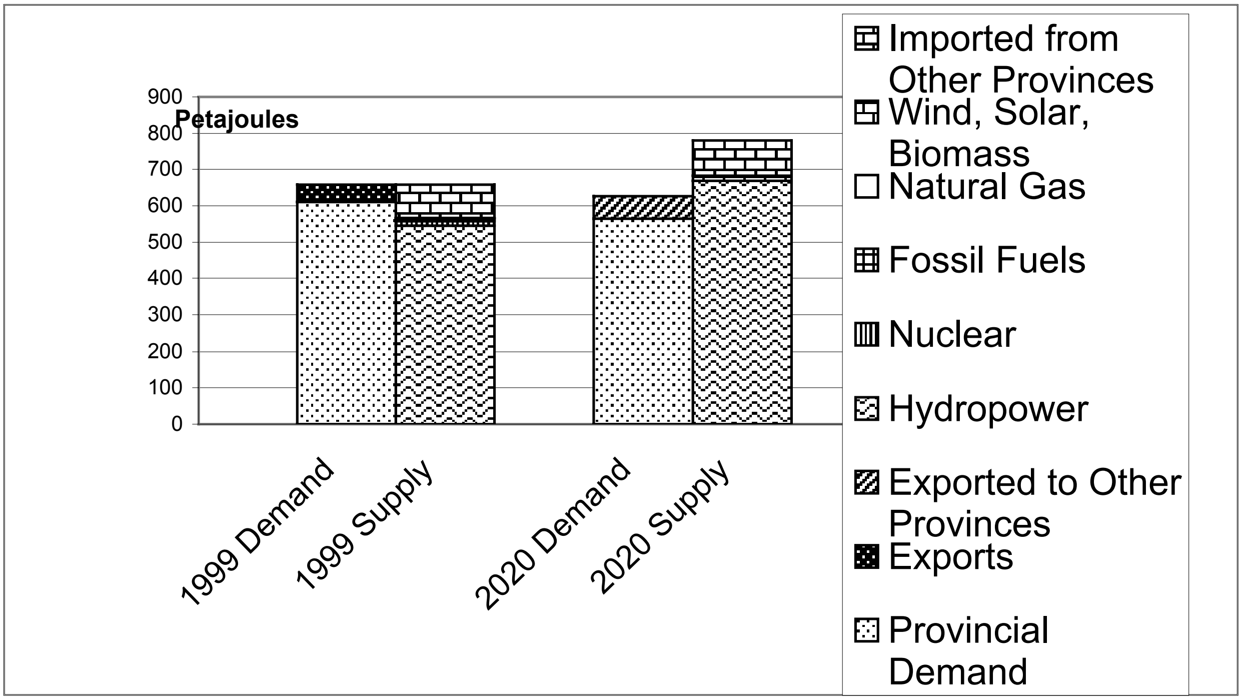
Demand for Grid Electricity in Québec by Sector and End Use in 1999 and in the Nuclear/Coal Phaseout Scenario for 2020



These reductions in the demand for grid electricity will be complemented by increases in the supply of renewable sources of electricity, including wind, solar, biomass and new traditional hydro-electric supply. The result of the reduction in demand and increased supply from renewable sources will allow Quebec to phase out its nuclear and fossil electricity generation, while maintaining a significant surplus. This surplus will be available even without Churchill Falls power, and Québec will be able to continue exporting power to the United States, begin exporting significant amounts of power to Ontario and/or New Brunswick, and still have surplus power to generate hydrogen fuel.

Figure 14

Electricity in Québec in 1999 and 2020 –Nuclear/Coal Phaseout

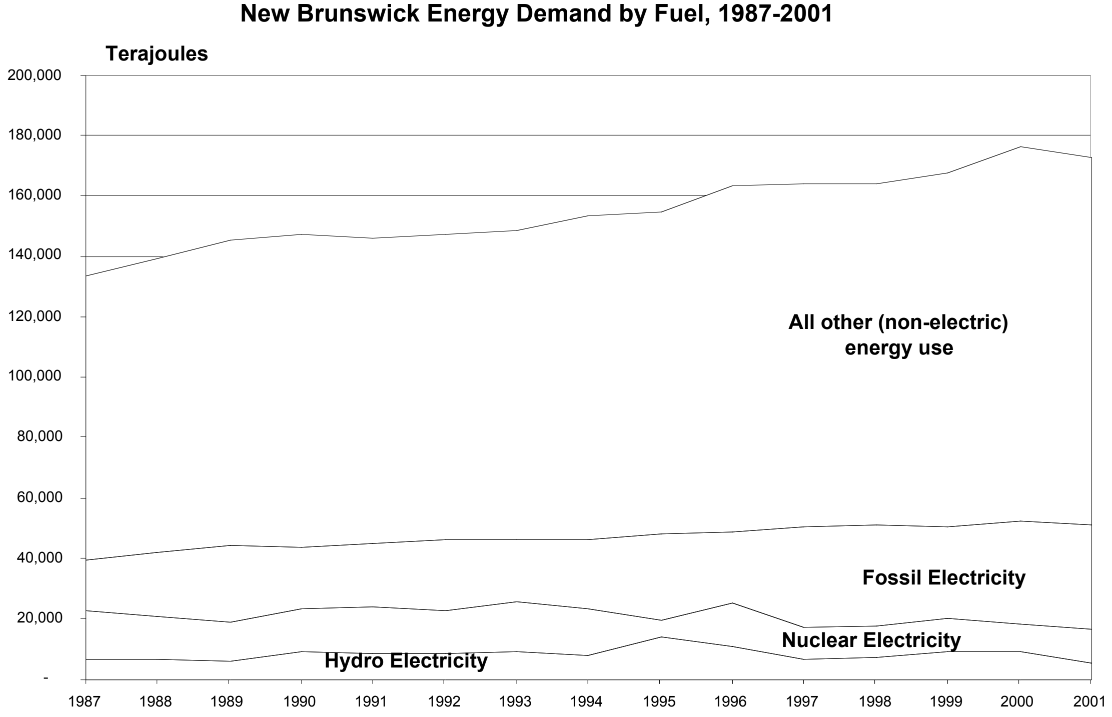


New Brunswick

As shown in **Figure 15**, total consumption of fuels and electricity has continued to grow in New Brunswick, although electricity growth has been modest, reflecting the trend toward improved electricity productivity that began in the early 1990's. New Brunswick relies heavily on coal (and increasingly on orimulsion) for its electricity. It has only modest hydro-electric capacity and a single 600 MW nuclear plant at Pt. Lepreau. Fossil fuels supply two-thirds of the province's electricity needs. Electricity has a large share of the space heating market in New Brunswick (fuel oil is the other principal heating fuel) and virtually all of the residential water heating market. As a result, electricity supplies about 30% of the province's entire energy needs.

The challenge of phasing out nuclear and fossil electricity in New Brunswick is somewhat more difficult in New Brunswick than in Ontario, especially considering that limited operating life left in the Point Lepreau station. It will require a concerted effort to increase overall energy efficiency, switch to other fuels for space and water heating, bring in new, cleaner sources of electricity supply and import clean electricity from other provinces.

Figure 15

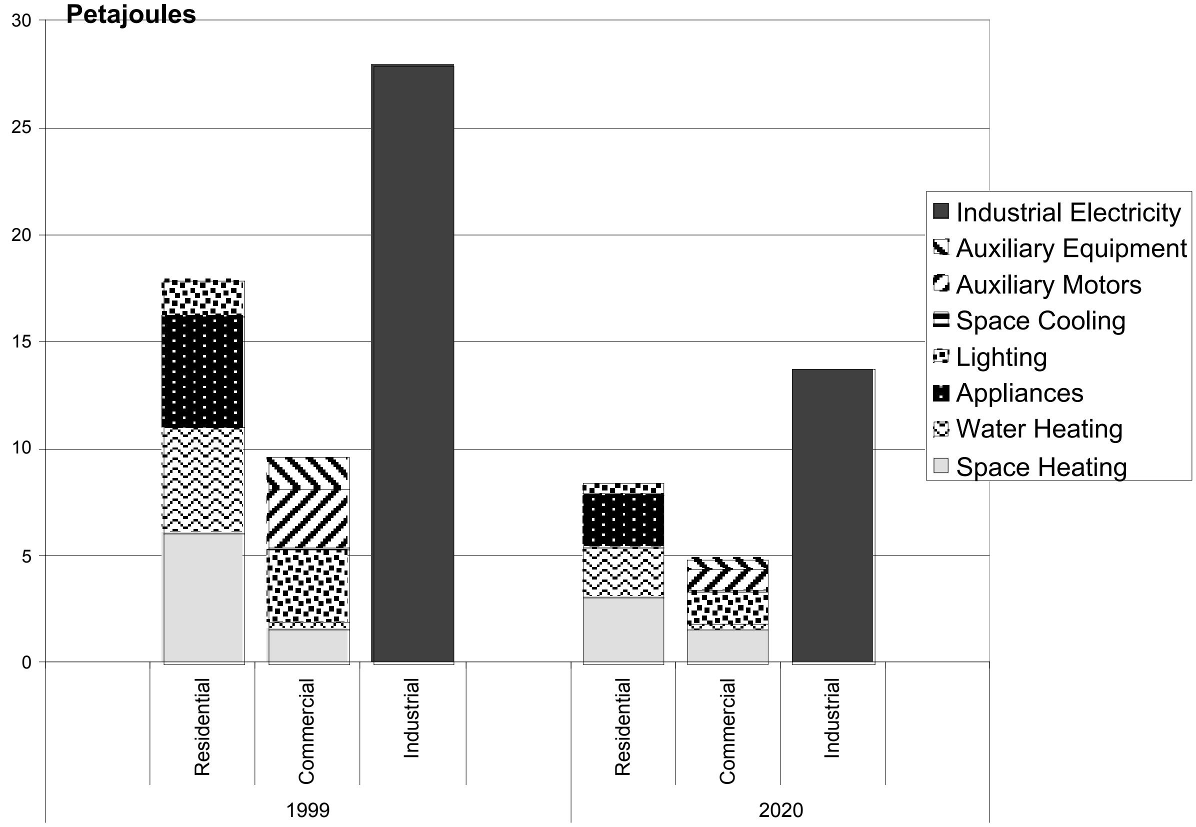


In 1999, total demand for electricity equalled a little more than 55 Petajoules. About half of this demand occurs in the industrial sector, with another one-third in the residential sector and 17% in the commercial sector. In the residential sector, 34% of electricity use is for space heating, and 27% is for water heating. Appliances consume 29% of residential electricity, while lighting consumes about 9%. There is no significant use of air conditioning in New Brunswick.

In the commercial sector, lighting consumes about 35% of commercial electricity, while fans, pumps and blowers consume 29%. Space heating consumes 16%, office equipment 15%, water heating 3% and air conditioning 1%. Industrial demand for electricity is highly concentrated in the forest products and mining industries.

By 2020, total demand for grid electricity in New Brunswick will have fallen to 27 Petajoules from 55 Petajoules in 1999. The biggest declines in demand will occur in lighting, commercial space cooling, office equipment and fans, pumps and blowers. Significant declines will also occur in residential space heating, water heating and appliance use, all of which will see their demand for grid electricity cut in half or more. New Brunswick Power has conducted a load forecast analysis for the period 2002-2011 in which it made predictions with respect to grid electricity's share of the market for various end-uses. Its most important conclusion was that electricity would lose residential and commercial space and water heating market share to natural gas. These results have been incorporated into our analysis, but modified somewhat to reflect more aggressive penetration of alternatives to electric space and water heating in new residential and commercial construction. These alternatives include fuel cells and solar heating, neither of which was included in the NB Power analysis. In existing residential buildings, electricity is expected to maintain a one-third share of the space heating market and a two-thirds share of the water heating market. In new residential construction, those shares fall to 10% and 25%, respectively. In the commercial sector, electricity's share of the space and water heating markets remain unchanged from 1999 levels (penetration of alternative sources of energy are assumed to displace other fuels, such as heating oil). As noted in the section above, grid electricity's share of lighting, office equipment, and fans, pumps and blowers energy consumption falls to 65% of total. Grid electricity's share of the space cooling market falls to just 20% of total, due to the penetration of gas-fired air conditioners, microturbines, district heating and cooling and fuel cells. Industrial demand for grid electricity will also fall to about half 1999 levels.

Figure 16 – Demand and Supply of Grid Electricity in New Brunswick in 1999 and 2020 – the Nuclear/Coal Phaseout Scenario

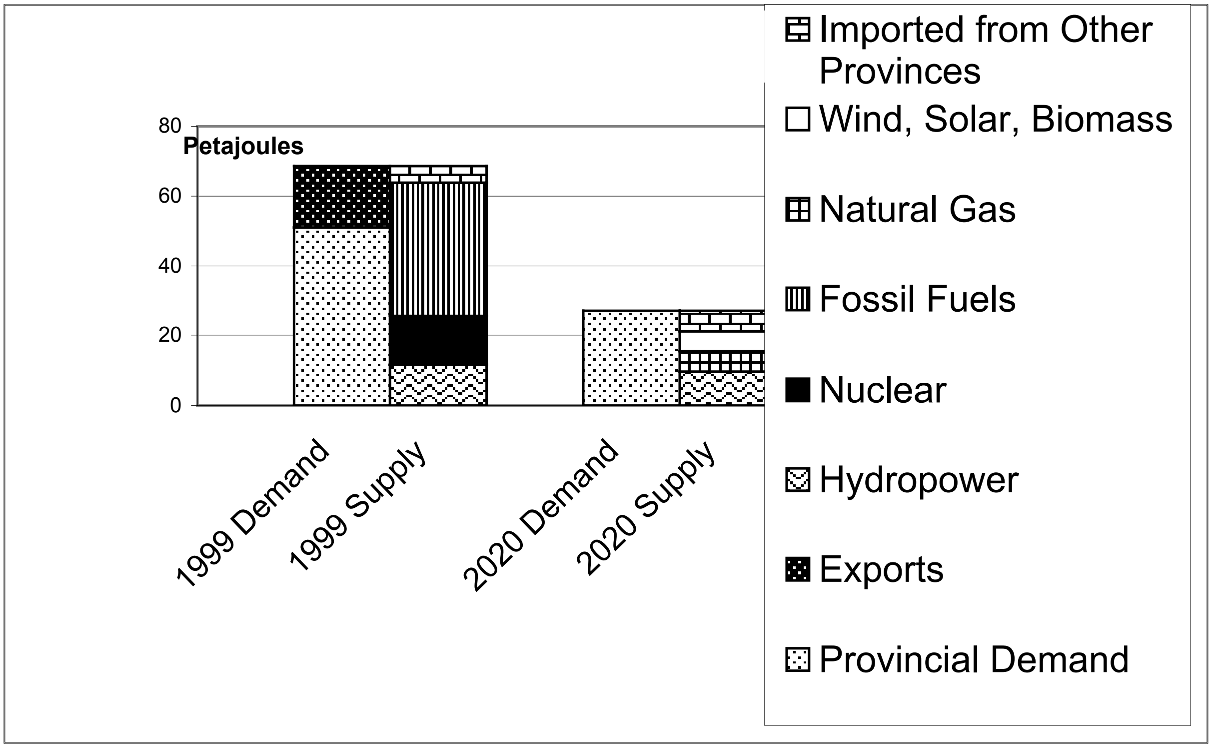


This scenario can occur only if a concerted effort takes place to reduce demand for grid electricity. The energy efficiency improvements described in the preceding section, coupled with a significant penetration of cogeneration in the industrial and commercial sectors, with more modest penetration of fuel cells in the residential sector, and fuel switching, principally to natural gas, must all occur for this scenario to become reality.

In order to make up for the phasing out of both nuclear and fossil generation, the electricity supply system in New Brunswick will need to bring new natural gas combined cycle turbine technology on line to provide electricity. It will also need to tap the considerable wave, wind, biomass and solar potentials that exist in the province to provide new sources of electricity. In addition, the large surpluses of hydro-electricity in Quebec and Labrador that exist now and will continue to be available in the future can be used to make up for any shortfall in electricity supply that may still exist in 2020. We have assumed that modest imports of hydro electricity would be needed (on the order of 200 MW).

Figure 17

Electricity in New Brunswick in 1999 and 2020 – Nuclear/Coal Phaseout



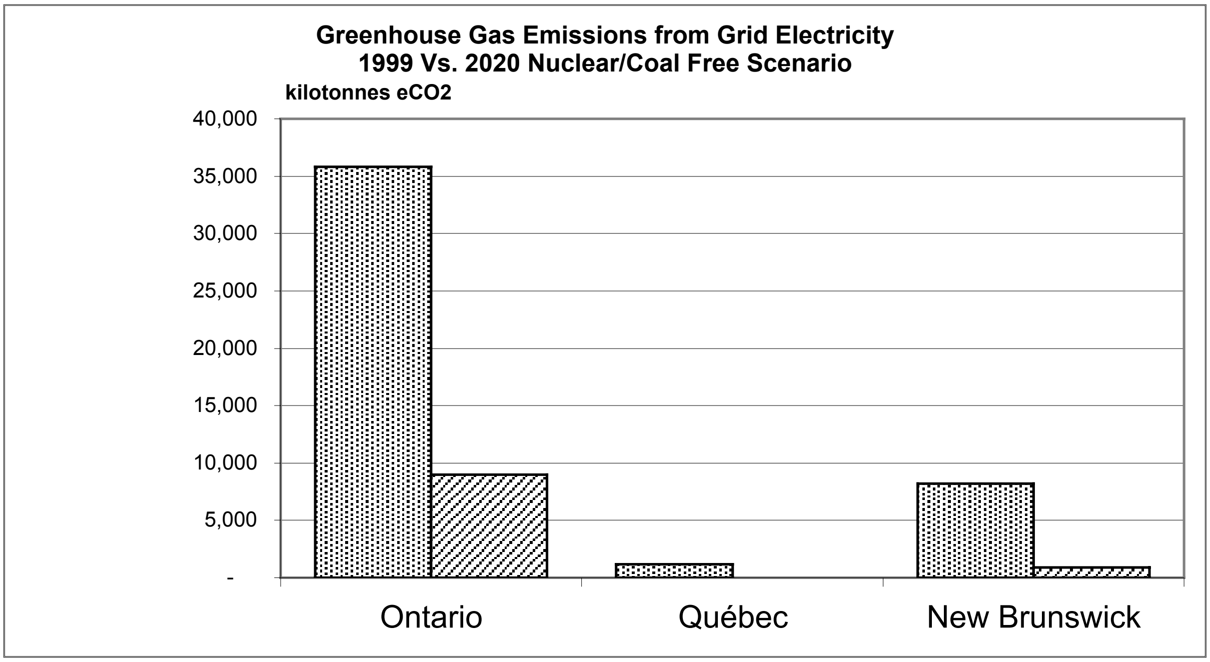
Conclusions

The scenario outlined here is only a very broad brush picture of one future in which the central coal and nuclear plants in Ontario, Québec and New Brunswick could be phased out as they reach the end of their operational lifespan, replaced with a combination of greatly increased efficiency of fuel and electricity use, expansion of combined heat and power technology, and deployment of renewable and distributed sources of power generation. There is an urgent need for more detailed research and analysis of this and other alternative scenarios that offer the possibility of a transition to a safe and sustainable energy future. Having said that, the work described here has led us to some robust conclusions about the technological, economic and organizational feasibility of such futures.

This type of work proceeds backward from conventional economic forecasting. We ask first, “Could we do it?” and if yes, “would it be economically feasible?” The answer to the question “could we do it” requires looking for ways that consumers and industries can get the energy services they demand while at the same time reducing the need for central grid electricity. On the question of technological feasibility, the requisite technologies are here now. Three general categories of technological deployment all play a critical role in the transition: (1) the phenomenal advances in the efficiency of buildings and all manner of fuel and electricity using devices, (2) the widespread deployment of combined heat and power plants on a much smaller scale than the historical norm, and (3) the burgeoning wind, solar and other renewable energy technologies that are now outpacing the growth rates of all other types of power generation.

The scenario presented here has clear environmental advantages over a continued commitment to the central power plant model of electricity. As shown in **Figure 18**, emissions from grid electricity in this scenario would be reduced by 75% in Ontario, by 90% in New Brunswick and would be eliminated altogether in Québec. In the long term, central nuclear and fossil-fuelled power plants are not alternatives to each other but part of an environmentally unsustainable approach to the electricity system.

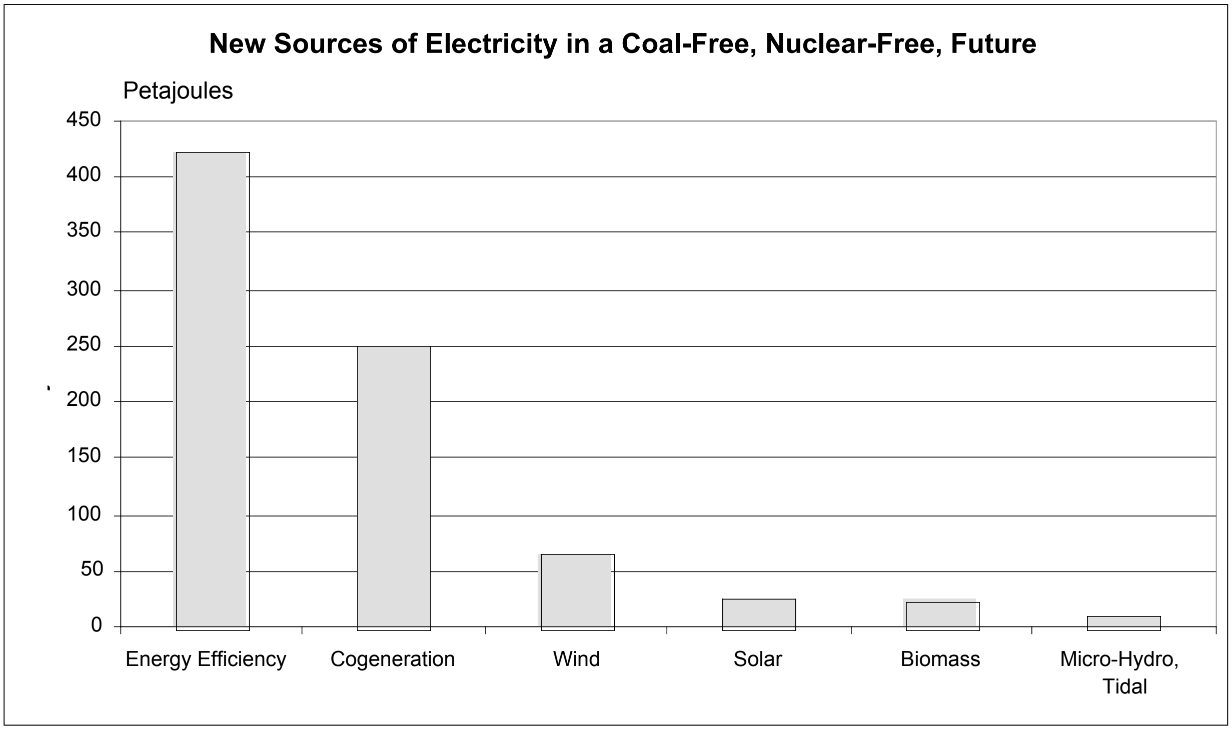
Figure 18



There is also a clearly defined hierarchy with regard to the importance of the technologies that can contribute to a sustainable electricity future. As illustrated in **Figure 19**, efficiency improvements contribute more than cogeneration and renewables combined, and the potential for cogeneration is at least twice as large as the potential from wind and solar and other renewables. Indeed, the ability of an eventual transition to a sustainable electricity system depends utterly on the efficiency gains being put in place first.

The costs of these technologies do not represent a fundamental barrier to their deployment. Indeed, electricity productivity is growing, and growing fastest in the richest and most industrialized economies, precisely because efficiency improvements in the use of electricity have proven quicker and cheaper to implement than increased central power plant supply. Most of the technologies included in the scenario analysis presented here have little or no incremental cost above conventional technology. The example of the dramatic improvement in the efficiency of residential refrigerators comes to mind – the straightforward, inexpensive and effective implementation of technology improvements in refrigerators has resulted in the fact that the typical residential refrigerator sold today uses 50% less electricity than was the case 10-15 years ago. Similar advances have been made in lighting, motive drive, electronics, and even building and industrial production design, and many of these advances are just beginning to work their way into the capital stock.

Figure 19



In addition, it is becoming increasingly apparent that there are numerous financial benefits to the distributed resources (efficiency, small scale renewables, cogeneration, transmission and distribution upgrades) that have not been properly accounted for in previous consideration of these technologies. At the same time these risk reduction and system benefits were being discounted, the significant environmental and public health risks and costs of central coal and nuclear plants were also being left out of the equation. The result is a huge pent-up supply of distributed resources that can be deployed in less time than it takes to site, design, approve and build a Gigawatt-scale power plant.

If the technological and fundamental economic feasibility is present, then why are these technologies not being deployed at a much greater rate? First, the rate at which these technologies are being deployed is already quite significant; again, that is a major reason why the growth in demand for central grid electricity has slowed as much as it already has. But it is also true that much more organizational and financial innovation is required to realize the potential for efficiency and renewables. When a consumer flicks a light switch, or squeezes the pump handle at the local filling station, a vast technological, organizational and financial infrastructure is at their service. Multi-billion dollar capital investments and highly evolved business organizations with thousands of employees are dedicated to making it easy and economically efficient to buy and have instantaneously delivered a litre of gasoline or a kilowatt.hour of central grid electricity. On the demand side of the equation, business and financial organization for the easy, cheap delivery of energy services is not so well organized.

Underlying this problem are attitudes toward electricity supply that do not fully recognize the legitimacy of demand side investments as a means for providing customer service.

In considering the potential for electricity efficiency improvement, for example, N.B. Power starts with the technological and economically feasible potential, and then discounts it further to reflect the extent they believe their customers would be willing to contribute to the capital cost of the demand side measures. This is a common utility practice, but the equivalent test on the supply side would be to only proceed with a new coal or nuclear power plant if the utility customers were willing to contribute to the capital cost, up-front and directly from their own pockets.

Until these attitudes change, and the corresponding adjustments are made in the way that we finance and organize to deliver energy services, there will be an important role for public policy in "levelling the playing field" for efficiency, cogeneration and renewables. How this is done will vary from one province to the next according to their historical circumstances, and an individual analysis of those factors was well beyond the scope of this study. But we can be sure from our research that the risks of failing to ensure that energy services are being provided for the least total cost are very large, not only in economic terms but also in terms of environmental and public health costs.

While the electricity future suggested here may seem like a radical departure from the past, it builds on trends that have already started to develop. The electricity productivity of all three provinces included in this analysis has been improving in recent years; the scenario presented here would build on and amplify that trend by ensuring at the very least that efficiency, cogeneration and renewables are not at a disadvantage to coal and nuclear power when it comes to attracting organizational and financial capital.

Over the next 15 years, the aging coal and nuclear power plants in Ontario, Québec and New Brunswick will either have to be shut down or will require reinvestment on the order of $15-$20 billion to keep operating, with no guarantee or past record of success, and even if successful would require another cycle of reinvestment 10-14 years later. There is another possible path, and the scenario described here illustrates a safer, cleaner alternative that is technically feasible and economically sustainable. It is a future that builds on trends that have already started to develop, but in which efficiency, cogeneration and renewable energy are phased in at a pace that will ensure an orderly transition to a sustainable electricity future as the nuclear and fossil power plants are phased out.