Commentary on NRTEE's "Advice on a Long-Term Strategy on Energy and Climate Change"

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Abstract

Globally, a decrease of at least 25% of 1990 emissions of Greenhouse Gases (GHGs) is needed to stabilize atmospheric GHG levels. In a World with today's population and with equitable distribution of energy usage per capita, countries such as Canada and the USA need to reduce CO_2 emissions by approaching 90%. Canada's National Round Table on the Environment and the Economy (NRTEE) has prepared a detailed review of how Canada's projected GHG Emissions could be reduced by 2050. The Study has ambitious targets for renewable energy sources, conservation, fuel efficiency and CO_2 sequestration but includes only a very small expansion of nuclear power. Although the stated aim is a 60% reduction in GHG emissions, the base year is 2003 and the Study identifies ways to achieve only a 50% reduction. Since 2003 emissions were 30.2% higher than those in the Kyoto base year (1990), the NRTEE target is substantially deficient if Canada is to achieve a fair contribution to GHG stabilization. The NRTEE Study serves to confirm the increasingly held view that "nuclear power is essential to attaining the goal of reducing emission of greenhouse gases while at the same time maintaining access to electricity"[1].

This paper reviews the NRTEE assessment and focuses on the impact of a much larger nuclear contribution than envisaged by the NRTEE Study. While the Study proposes only 9.2 GW of nuclear expansion, we show how an additional 55 GW of nuclear would result in Canada achieving a 75% reduction in GHG emissions. The rate of deployment to achieve this is within a factor of two of the actual deployment of nuclear reactors in the 1970s and 1980s.

Global Background to CO_2 Accumulation and Climate Change

Almost all climatologists and most governments now accept the link between accumulation of GHGs and rising temperatures on our planet. Modelling of details of the function by which the two are linked is exceedingly complex and so the details are very imprecise but a consensus of sorts has emerged that 550 ppm CO_2 should the upper bound beyond which there would be an unacceptably high risk of a runaway greenhouse effect – in which rising temperatures releases CO_2 from natural stores or impairs CO_2 removal mechanisms. This is partly a rationalization of suggesting a target that is technically attainable: 450 ppm would be safer but, at less than 70 ppm above the current level, is virtually unattainable. Thus, 550 ppm is the level proposed as a target by the "Stern Review[2]", a recent report prepared for the Government of the United Kingdom.

Stern further notes that attaining this stabilization will require a one-quarter reduction in CO_2 emissions by 2050 and a halving by 2100.

We stress that these are reductions in worldwide emissions and much deeper reductions by developed countries are essential to offset the rapidly rising energy demands of developing economies. Table 1 illustrates the situation as it existed in 2005[3] and as it would exist in a world where the CO_2 footprint of all nations was at 50% of the average of European countries[i] in 1990.

	Oil (Mt)	Natural Gas (Mtoe)	Coal (Mtoe)	Nuclear Power (Mtoe)	Hydroelectric (Mtoe)	Total (Mtoe)	Population (millions)	toe/person	Consumption at 50% European rates	Consumption at 75% 0f 1990 rates	Cut needed (or increase allowed)
USA	945	570	575	188	61	2337	300	7.8	533	370	84%
Canada	100	82	33	21	82	318	32	9.9	57	40	88%
Europe[i]	775	536	377	251	127	2063	570	3.6	1014	704	66%
Europe[i] (1990)	761	412	535	201	110	2020	568	3.6	1010	701	65%
Asia/Pacific	1117	366	1648	125	167	3424	2734	1.3	4862	3376	1%
China	327	42	1082	12	91	1554	1300	1.2	2312	1605	(3%)
India	116	33	213	4	22	387	1100	0.4	1956	1358	(251%)
Thailand	46	27	26	0	2	85	65	1.3	116	80	6%
World	3837	2475	2930	627	669	10537	6400	1.4	11380	7903	25%

Table 1: Energy consumption in Mtoe[ii] 2001 for selected regions and countries

The column third from the right of Table 1 shows what would happen if the CO_2 footprints of all countries were reduced to half the European level in 2001 – representative of either conversation measures on an almost imaginable scale or economic collapse. Even without allowance for future population increases, the emissions of an equitable world operating with this footprint results in a 19% increase in total emissions. With World populations expected to reach at least 9 billion by 2050, one can readily appreciate why projections of energy use virtually all expect total demand to at least double. For the world as a whole to achieve a 25% reduction in CO_2 emissions, a massive decarbonization of energy supplies is obviously an essential element.

The column second from the right shows the levels of equitable per capita emissions required to meet Stern's 25% reduction target. Note that the under-average contribution of the developing economies will not for long offset the above-average contribution of the developed economies: China's 1.2 billion population has already virtually reached the target recommended by Stern (having increased energy use by 55% in the four years to 2005); Thailand – a typical Asian emerging economy – already exceeds the target.

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[i] Excluding Russia and Belarus as well as central Asian states listed by BP under Europe.
[ii] Mtoe = million tonnes of oil equivalent

For developed countries such as Canada, a reduction of CO_2 emissions of 80 to 90% will be required. This will be hugely challenging and need for a cut of this magnitude does not yet seem to be widely appreciated in Canada. Canada's Clean Air Act has the stated aim of achieving by 2050 a 45 to 65% reduction of the 2003 levels. However, the 2003 level of energy use in Canada was 30.2% above that of 1990. So the Clean Air Act target is really aiming for a reduction of only 15 to 28% by 2050 when compared to the 1990 reference year.

The NRTEE has produced a draft review[4] with the stated aim of achieving a 60% reduction (based on 2003 levels) of Canadian CO_2 emissions by 2050 reduction. The review examines a very broad range of approaches to curbing CO_2 emissions but actually identifies means to accomplish only a 50% reduction. The Study's detailed analysis of what could be achieved by deployment of renewable energy sources, by conservation and efficiency increases, by reducing energy intensity, and by sequestration of CO_2 appear fairly optimistic. However, even if all of the contributing technologies deliver their assigned contributions, the Study's detailed assessment of these sources shows clearly that they are collectively incapable of delivering CO_2-emission reduction on anywhere close to the extent required for Canada to contribute an equitable footprint of GHG emissions.

<u>The Findings of the NRTEE Study[5]</u>

The NRTEE review is a valuable overview of possible routes to meeting Canada's energy demand in a way that is environmentally sustainable. Though the format of energy wedges, first suggested by Socolow[6], is rather simplistic, its adaptation to Canadian projections conveys important messages. As a basis for its economy, Canada is conspicuously dependent on supplying other countries with raw materials. The effect of this is particularly evident in the impact of oil sands development on Canada's CO_2 emissions and is clearly reflected in the Study's projection of an *increase* in energy demand *after allowance for the contribution of energy efficiency and conservation* of about one-third by 2050. We agree with the Study's inference that dealing with GHG emissions is far more likely to achieve political traction if living standards are not undermined. Consequently, the focus on ways to reduce CO_2 per unit of energy consumed is appropriate. To achieve this, the Study places emphasis on deployment of low-CO_2-emitting technologies for our energy supply.

Another important point made by the Study is the importance of a clear statement on long-term CO_2 emissions policy so that our economy can make the appropriate adjustments. Industry and individuals need to know now what CO_2 emissions will cost them in the future if they are to start making appropriate choices.

However, beyond the inadequate nature of its reduction target and its failure to place Canadian action in a global context, we note two other major weaknesses in the NRTEE Study. First, it does not compare the economics of the various routes to reduced CO_2 emissions. Second, it does not convey a sufficient sense of urgency: the emphasis on 2050 as the target date for reductions is far too leisurely. This distant focus and the linear nature of the projections do not encourage vigorous near-term action.

As they have generally been used, Socolow's wedges look forward around 50 years and are linear in time. We are concerned that Socolow's approach does not encourage action in the nearer future. With that caveat, Socolow wedges are well-suited to revision by expanding, contracting and even adding wedges and so we use them here. Figure 1 reproduces the projections of the NRTEE Study as Socolow wedges.

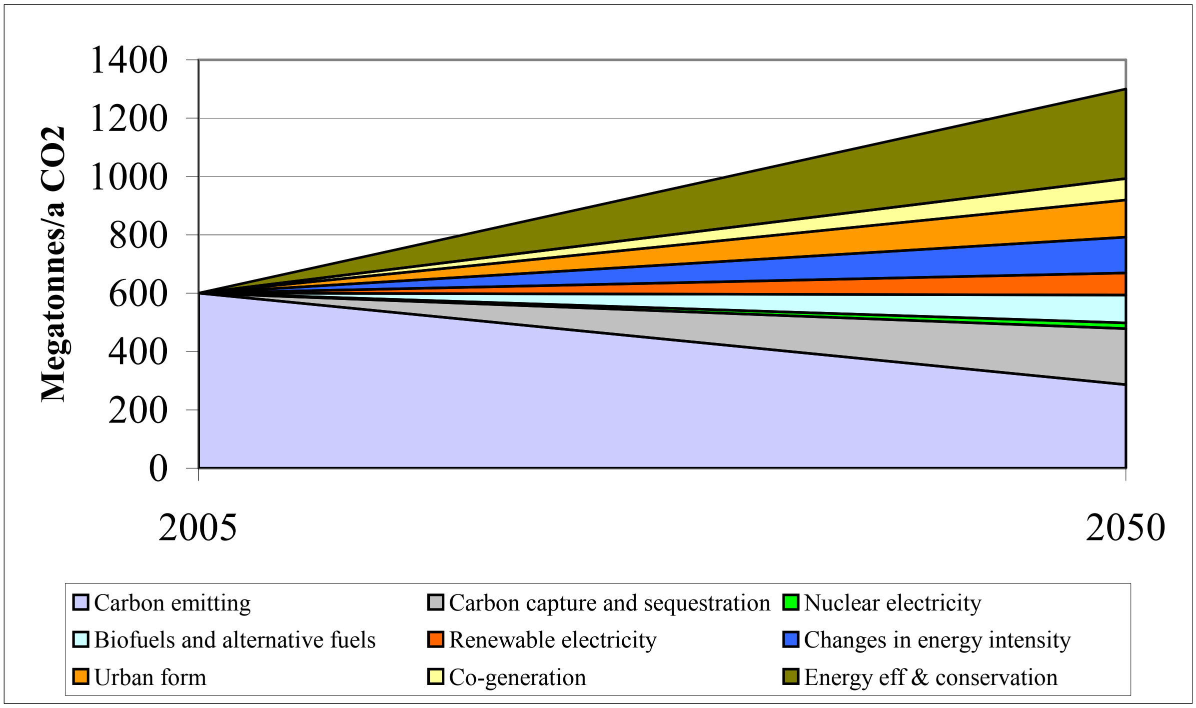

Figure 1: Projections for CO_2 Emissions by 2050 according to the NRTEE Study

<u>Comments on the NRTEE Study's Individual Technology Wedges</u>

- The Study places heavy reliance on "Clean Coal" technology with Carbon Capture and Storage (CCS).

While potentially important, CCS is not fully developed, has unknown economics, and its deployment and operation will produce substantial uncaptured collateral CO_2 emissions. The use of CCS to enhance oil and gas production is likely the best form of CCS but CCS's ability to retain CO_2 in geological formations for long periods is, while promising, still far from being sufficiently proven.

- After CCS, the Study places heavy reliance on renewables, particularly wind.

The serious limitations caused by wind's intermittency and seasonal variability are now widely appreciated. (See, for example, the studies by E.ON[7] and the Irish National Power Grid[8].) While a few percentage points of total electricity supply can be supplied by wind and other unreliable and intermittent energy sources, the experience in Germany[6] and Denmark[9] suggests the large-scale use of wind power for large industrialized economies like Canada's will be very difficult to manage. The E.ON study shows very clearly that there would be large collateral costs associated with introducing wind. These must be incurred to maintain back-up generating capacity and to strengthen transmission grids. The paper on the Danish experience highlights their total reliance on massive sources of hydro-electric power from Norway and Sweden to balance the variations in output of their wind turbines. Elsewhere, we have examined one possible way to circumvent the variability and intermittency of wind with our NuWind concept[10] in which nuclear and wind capacities are combined to supply a mixture of electricity and hydrogen by electrolysis with wind's variability absorbed by variation in the electrolysis rate.

- The Study's treatment of transport issues is questionable and has serious omissions.

Taking transport off petroleum is not considered: vehicles relying on both deeply pluggable hybrids and fuel cells look probable (e.g. Japan is forecasting two million hydrogen fuel cell vehicles by 2020). While this could be considered a part of improvements to vehicle efficiency, either deep hybrids or hydrogen-powered transport will entail expansions to electricity supply. For transportation, fuel cells are strangely underemphasised. They are mentioned only once in the Study as stationary power producers with the hydrogen produced from natural gas: this is not an effective way of abating CO_2 emissions. We see huge scope for transport switching either to electrolytically-produced hydrogen in fuel cells or to electricity from storage batteries. Both have particular strengths in niches within the sector: batteries for local transport; fuel cells for air, rail and sea transport

Aircraft emissions are ignored though this is the fastest growing transport segment. For this segment, liquid hydrogen offers substantial potential as a replacement of kerosene.

The Study's reliance on biofuels is dubious. Unless based on wastes, CO_2 avoidance by deployment of biofuels is often small or non-existent; the land areas required to produce significant amounts of biofuels are huge. And this at a time when climate change will likely be placing pressure on land for food production as well as for setting aside for carbon capture.

- The Study's expectations for improved energy efficiency seem ambitious but may collectively be attainable.

Thus, we are comfortable with the Study's assumptions for production of cement and for iron and steel and for improvements. Expectations for improvements in the efficiency of buildings are close to those of Socolow and seem somewhat unambitious even though constrained by the long life of housing stock. Much greater use of heat pumps seems possible and likely. For lighting, we expect LEDs will oust incandescents and fluorescents within a few years.

The Study's expectation about a two-thirds improvement in the fuel efficiency of light vehicles (to 3 L/100 km) and for light and medium trucks seems attainable – especially if pluggable hybrids are widely deployed. The Study's expectation of a 50% improvement for heavy trucks seems more dubious.

- The Study is dependent on a large increase in natural gas use.

This is a questionable assumption since no source of increased gas supplies is identified and no attention given to the effects of natural gas leakage in the course of production and transmission. Because methane is a much more potent greenhouse gas than CO_2 (a factor of 21, per unit of volume, is usually used), leakage of a few percent can offset the lower CO_2 emissions of methane per unit of energy produced.

- Improvements in energy efficiency do not necessarily result in reductions in greenhouse gas emissions.

The efficiency improvement data for Canada unfortunately show a positive correlation: a10% *increase* in energy use efficiency has been accompanied by a10 % *increase* in related GHG emissions, and by *no* reduction in total or specific energy use.

- The Study notes approvingly how Canada's industrial sector produced 24% more in 2003 than in 1990 while using only 11.7% more energy and emitting only 1.3% more CO_2. We wonder whether the projected improvements in energy efficiency in the industrial sector are fully allowing for the improvements already made.

While an energy intensity decline of 0.1%/a for the cement industry may not be too difficult to achieve and of a cumulative 20%/tonne for iron and steel by 2050, an expected reduction of 10%/tonne.a for pulp and paper and 2.5%/a for chemicals implies a surprising degree of existing inefficiency. We believe that the implied 2/3rd reduction of the chemical industry's energy use by 2050 is unlikely for an industry that is already efficient we question the real benefit of declines in manufacturing of energy-intensive goods since this amounts to export of an energy demand.

- The Study assumes real benefit from declines in manufacturing of energy-intensive goods.

This amounts to export of energy demand and has no value for the Global environment and may even increase emissions through added energy for transportation.

- The Study says that Canada must "deploy … *all* of the potential GHG-reduction technologies at unprecedented levels of implementation". It then almost ignores nuclear power though this is already a substantial contributor to CO_2 reduction in Canada, a proven technology with undisputed low CO_2 impact, and widely included in projections of future energy supplies (e.g. all of the main scenarios presented in the Third Assessment Report of the Intergovernmental Panel on Climate Change plus the International Energy Agency study, 2006).

The NRTEE Study expects all generating capacity in Canada to increase by 2 GW/a (about 1%/a) between 2005 and 2050 – a total of 90 GW. We view this as reasonable since electricity will be a major pathway to overall reduction of GHG emissions *provided it is produced with little or no CO_2 emission*s.

While we agree with the Study's emphasis on the need to transform the electricity generation and oil and gas industries, we do not agree that CCS is the only way to tackle this. Nor do we agree that development of Canada's fossil fuel resources should be transformed solely through CCS. Nuclear power can be a major source of energy for petroleum production and is already being actively assessed for this role in the Alberta oil sands. Because nuclear power's potential for emissions reduction is underestimated by this report, we conclude this paper with a new estimate of what nuclear could reasonably contribute and its effect on CO_2 emissions.

One very modest wedge included by NRTEE is for 9.2 GW of new nuclear capacity – envisaged as being deployed entirely in Ontario. Fortunately, a much larger role for nuclear power - which we see as a major omission from the Study – can provide large leverage to the Study's recommendations and could quite easily produce an outcome with a 75% reduction in CO_2 emissions by 2050 rather than the 50% reduction identified in the NRTEE Study. While even a 75% reduction is not going to win Canada high praise from the international community, it is a reasonable target for an economy supplying rapidly expanding quantities of primary resources to the global economy.

<u>Nuclear Power's Existing and Future Roles</u>

In 2005, Canada's nuclear power plants produced 86 TW.h of electricity avoiding about 73 million tonnes of CO_2 emissions, avoiding what would otherwise have been a 46% increase in coal-fired generation. Nuclear also avoided emissions of 284 thousand tonnes of NOx, 327 thousand tonnes of SO_2, and 103 thousand tonnes of particulates[11]. If nuclear electricity had been produced instead from coal-fired plants, an additional 23 million tonnes of coal would have had to be burned, raising Canada's coal consumption by 71%.

Canada's current coal-fired electricity generation is around 85 TW.h/a[12]. This is very close to current nuclear generation but the coal-fired fleet is larger since it is mostly operated to meet peak demand and is utilized on average for 54% of capacity. Simply to replace all existing coal-fired electricity-generating capacity in Canada would require 18 GW of new nuclear plants and, by operating with their expected 90% capacity factor, these would also produce 57 TW.h/a of additional, off-peak electricity. This would be sufficient to fuel 4 to 5 million light vehicles switched to using fuel cells or storage batteries or about one-quarter of the 18 million cars in the registered Canadian fleet. To raise the penetration of nuclear electricity to fuelling 80% of this fleet would require the full capacity of a further 24 GW.

Canada's oil sands are expected to add 2 million barrels per day of new capacity by 2015, most of it depending on Steam-Assisted Gravity Drainage (SAGD) technology. Assuming that 1 million barrels per day of SAGD can be supplied by nuclear heat using steam injection equal to two barrels of condensate per barrel of bitumen, another 3 GW of nuclear capacity would be required (with modest co-production of electricity since steam for SAGD is mostly not required at the full pressure available from a nuclear reactor). Extending the nuclear application to produce the hydrogen required to upgrade oil sands bitumen (assume 4 kg/bbl) by electrolysis would require a further 9 GW of nuclear capacity.

With the above scenario, these three major applications of energy could be supplied by about 50 reactors of the size of the ACR-1000. This corresponds to 55 GW of generation, a reasonable figure in the context of NRTEE's projected total increase of 90 GW, especially since we envisage deeper deployment of electrical energy in transportation. At that scale of nuclear deployment, the reduction in Canada's CO_2 emissions would go from the 50% detailed in the NRTEE Study to 75%. This would represent CO_2 emissions below one-third of the 1990 level and would allow Canada to reclaim some leadership in GHG abatement although it would remain desirable to do considerably more. . This outcome is summarized as Socolow wedges in Figure 2.

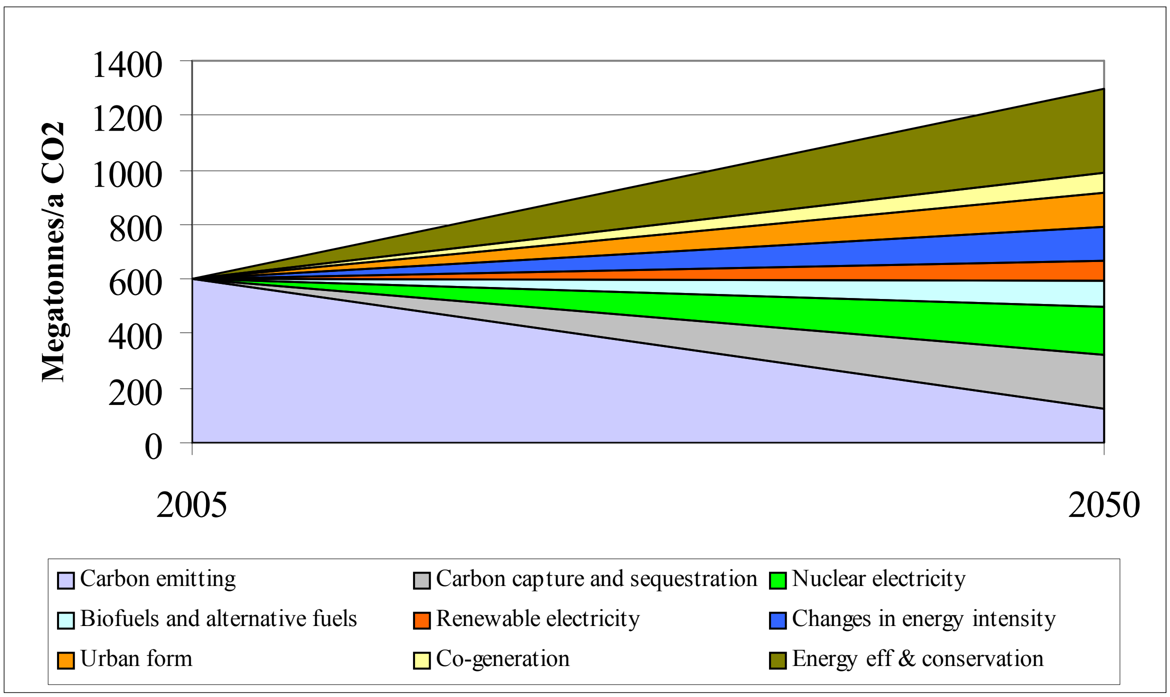

Figure 2: Projections for CO_2 emissions by 2050 according to the NRTEE Study with an enhanced nuclear role.

We stress that this modified NRTEE scenario is illustrative only and does not include electricity-based fuel for other forms of transportation although road freight, rail and marine transport could all be fuelled by hydrogen. Fuel consumption by transportation other than cars is approximately equal to that for cars. Some penetration of the non-car transport sector could easily offset situations where other substitutions are already factored in in the NRTEE Study and leave scope for even larger nuclear deployment.

The Practicality of Nuclear Deployment

In the 17 years between 1971 and 1987, Canada brought 18 nuclear reactors into service. A new nuclear program bringing reactors on-stream in between 2015 and 2050 would require under three reactors every two years. This would not be a difficult rate to achieve, especially since, unlike the 1970s and '80s, today's reactors utilize modular construction extensively.

As a "wedge", nuclear energy would avoid emission of about 130 Mt of CO_2 – compared to advanced coal-fired technology with an assumed 60% conversion efficiency. Detailed analysis of the nuclear opportunity can be found in a number of our papers[13,14,15]. Nuclear is the one established technology with the capacity to sharply curtail global CO_2 emissions Canada, with its indigenous reactor technology, is well placed to lead globally, and the NRTEE study is seriously remiss in its neglect of the nuclear option.

The biggest single attribute of nuclear power is its extreme density: uranium or thorium contains one million times the energy content of hydrocarbon fuels. So it is affordable and easy to make provision for the confinement of all waste products – as is currently practised. The world's uranium and thorium resources (of which Canada is a major repository) are enormous and capable of sustaining world energy demand for hundreds to thousands of years. In contrast, although renewable energies are permanent sources, their energy densities are a further million times less than hydrocarbon fuels and the impact on the environment of harvesting them is enormous compared to nuclear.

The economics of nuclear power are well established – Canada having sold reactors profitably to a number of foreign countries – and compare favourably with power from renewables and compete with energy from hydrocarbons when the cost of CO_2 is included.

We believe that the NRTEE study's seriously underestimates the scope for the nuclear wedge by at least factor of five (5), by only anticipating a 9.2 GW addition to the Ontario reactor fleet.

In Conclusion

As energy vectors, we are envisaging a strong move away from hydrocarbons and toward electricity. The electricity obviously must be produced with minimal release of CO_2. As envisaged by the NRTEE Study, some of this could come from fossil fuels adapted to use CCS but, as already noted, this technology is still under development and its effectiveness and economics are still quite uncertain. A fairly small proportion could come from renewable sources though the costs remain high and reliability and variability detract from most of them. Substantial additional deployment of nuclear energy is now widely envisaged in almost all major studies of future energy supply. For Canada, it provides a clean, safe, proven, indigenous option. Partly through existing technology and partly through evolution of new reactor types, nuclear energy's use can be extended to significant new roles where it is applied to provide heat to, for example, the oil sands as well as to unfamiliar new requirements for energy such as water desalination.

The recent Australian assessment states the nuclear case very unambiguously and we quote here two paragraphs from the report's Executive Summary[16]:

> "In the context of rapidly growing energy demand, particularly from developing nations, nuclear power represents the only means of limiting increased emissions while meeting the world's voracious appetite for energy. While the Committee recognises that there is a role for renewables, and certainly for greater use of efficiency measures, renewables are limited in their application by being intermittent, diffuse and pose significant energy storage problems. Renewables also require substantial backup generation, which needs to be provided by conventional baseload power sources. Promised baseload contributions from geothermal, which will be welcome, are yet to be developed on any scale.
>
> "The Committee believes that the 'nuclear versus renewables' dichotomy, which was explicit in some submissions, is a false debate and misses the point: while renewables have a contribution to make, other than hydro and (potentially) geothermal, they are simply not capable of providing baseload power on a large scale. The relevant comparison, if one needs to be made, is between baseload alternatives. On this issue the evidence is clear—nuclear power is the only proven technology for baseload power supply which does not release substantial amounts of CO_2."

We would take issue only with the Australian report's suggestion that nuclear deployment is essential mainly for developing nations. Our analysis indicates that it is also essential for developed nations such as Canada.

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