PROSPECTS FOR A HYDROGEN ECONOMY IN ATLANTIC CANADA

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Abstract

If a sustainable energy future is to be achieved, it is generally agreed that both energy sources and energy demands must be examined and possibly altered. In most western countries, this means moving away from fossil fuels and profligate energy usage to renewable sources and intelligent energy usage. This paper considers the prospects of implementing a sustainable hydrogen economy in Atlantic Canada through the use of renewable energy sources (notably hydro-electric, wind, and biomass) and a step-wise reduction in energy demand. The paper shows that this approach would be beneficial to Atlantic Canada's public health, its ecology, and its economy.

1. INTRODUCTION

It is generally agreed that anthropogenic activities are damaging the planet's fragile ecology [1]. One of the most conspicuous of these activities is fossil fuel consumption – resulting in the build-up of various gases including carbon dioxide (the major greenhouse gas), sulphur dioxide (the major component of acid rain), and nitrous oxides (low-level ozone) [2, 3, 4].

Canadians are among the most profligate users of energy in the world – they are the fourth largest producers of carbon from fossil fuel consumption in the world – over four tonnes of carbon per person each year [5]. Despite the Canadian government's pledge to achieve a 20 per cent reduction in 1988 carbon dioxide emission levels by the year 2005 [6], a previous report by the authors has shown that unless steps are taken immediately, Canadian carbon dioxide emissions will *increase* anywhere from 33 to 47 per cent [7]. Subsequent calls by the Canadian government to *stabilize* carbon dioxide emission levels at 1990 levels by the year 2000 [8] will require reductions in carbon dioxide emission levels by between 19 and 29 per cent.

One area of Canada that will probably exceed the national rate of carbon dioxide emissions is Atlantic Canada (see table I). Two reasons for this excess are:

- there is a growing reliance on coal for electrical production. As part of the federal government's plan to get 'off-oil', the fuel of choice is coal as shown by the projected growth in coal for electric generation in Atlantic Canada: from some 95 petajoules in 1984 to over 212 petajoules in 2005 [9].
- it has the highest regional industrial energy intensity (92 megajoules per dollar of industrial output) of any region in Canada [10]. This is due to the region's resource-based economy, which relies heavily upon fishing and forestry [11].

If a sustainable energy future is to be achieved, it will require a major shift in where and how energy is produced, as well as a reduction in per-capita energy demand and increased energy efficiency. In western countries such as Canada, this means moving away from fossil fuels and profligate energy usage to renewable sources and intelligent energy usage. One such energy system is hydrogen – based upon renewable and sustainable energy sources such as solar in all its forms (direct solar, hydro-electric, wind, and biomass).

The authors believe that a hydrogen-based economy is possible in Atlantic Canada for at least three reasons:

- First, the region is blessed with an abundance of renewable energy sources: direct solar, hydro-electric, wind, and biomass.
- Second, many sectors of the economy can become more energy-efficient, resulting in a decrease in energy demand.
- Third, projected population figures of negative or low growth [12] do not match the expected increase in energy demand.

2. CURRENT AND PROJECTED ENERGY SOURCES AND DEMANDS

Energy Sources

According to the National Energy Board (NEB) of Canada, primary energy demand in Atlantic Canada is satisfied through five major sources [9]:

- The fuel in greatest demand is oil, with the vast majority being imported from Venezuela and processed by several oil refineries located throughout the region. Oil is used primarily in three sectors: transportation (particularly the automobile and transport truck); home heating; and electrical generation.
- Coal is mined extensively in northern Nova Scotia and is used almost exclusively in electrical generation.
- Most available hydro-electric sites in New Brunswick and Nova Scotia have already been developed. However, considerable hydro-electric potential exists in Labrador.
- A single 630 MW Candu nuclear power station producing electricity primarily for export is located in southern New Brunswick near the Maine border.
- Wood and other renewables are found and used extensively throughout Atlantic Canada. Although these fuels are employed mainly for electricity and steam generation in paper mills, there is considerable demand for their utilization in home heating.

Energy Demands

Energy demand is divided into five sectors by the National Energy Board: residential, commercial, industrial, transportation (road, air, rail, and marine), and non-energy. NEB data projecting future energy demands is based upon high and low price scenarios (high demand implies high oil prices and low demand assumes low oil prices). Tables II and IV show the low and high price sectoral demand scenarios; in both cases, sharp rises in energy demand are predicted. Exactly which energy sources are expected to support this demand are shown in tables III and V: the low and high price scenarios show a 23 and 25 per cent increase respectively in oil demand between 1988 and 2005, while the demand for coal increases between 93 and 123 per cent for the same period.

Discussion

From the examination of energy demand in Atlantic Canada, it is apparent neither the projected energy demand nor the sources of energy are sustainable. First, energy efficiency is poor and there is little push for conservation. Second, the public health and environmental effects associated with this energy path are largely ignored.

For example, the reliance on coal shows a disturbing trend: the total carbon dioxide emissions *increase* between 1988 and the year 2005 anywhere from 40 per cent (low price case, see table VI), to over 52 per cent (high price case, see table VII) [13]. Not only does this exceed the overall Canadian average in carbon dioxide growth, it makes a mockery of both the Canadian government's call for a 20 per cent *decrease* in carbon dioxide emissions by the year 2005 and their call for a stabilization of carbon dioxide emissions at 1990 levels by the year 2000.

If a hydrogen economy is to be established, both energy demand and the reliance on fossil fuels must be reduced.

3. DEMAND REDUCTION

Energy demand reduction cannot occur overnight; it takes a long term commitment. The following section considers a three part scenario originally outlined by the authors in [7].

In the short term (immediately), it is expected that individuals will begin following more energy efficient practices, such as:

- lowering the energy demand for space heating and cooling (i.e. air conditioning) in both the residential and commercial sectors.
- limiting the volume of motorized transportation (particularly the private automobile) by the application of a carbon dioxide tax on automobile petroleum products [14].

In the medium term (5 to 10 years), there is the expectation that both individuals and government agencies will take the following actions:

- decrease electrical demand through increased energy efficiency [15].
- improving existing housing stock through insulation retrofitting as well as building new houses to meet greater energy efficiencies.
- develop efficient public and rapid transportation systems, thereby reducing the demand for private road transportation [16].

In the long term (15 years), it is assumed that a national energy policy will be adopted and will require that:

- residential and commercial heating and cooling systems (presently fuelled by natural gas and oil) be replaced by district heating and cooling systems [17].
- existing fossil fuel plants will either be closed or employ technological advances to capture the carbon dioxide [2].

4. SOURCES OF RENEWABLE ENERGY IN ATLANTIC CANADA

In order to achieve the proposed demand reduction and eventually to replace existing non-sustainable energy sources, sustainable energy alternatives must be found. This section examines some of Atlantic Canada's renewable energy sources.

Water

There are two major sources of water power in Atlantic Canada:

Hydro-electricity. As already mentioned, most hydro-electric sites in New Brunswick, Newfoundland, and Nova Scotia are already producing some 1269 MW [11]. However, Atlantic Canada's major source of hydro-electric power is found in Labrador at Churchill Falls (some 6,000 MW); the estimated potential of other sites exceeds 5,500 MW [13].

The major problem at present is *how* to get the power from Labrador to the southern parts of Atlantic Canada. Newfoundland and Labrador Hydro have proposed high-voltage transmission lines via under-sea cables. To date, this proposal has fallen on deaf ears, in part because of Nova Scotia's commitment to heavily-subsidized coal-fired electrical generation [18, 19].

Wave and Tidal Power. The proximity of Atlantic Canada to the Atlantic Ocean makes wave and tidal power potentially attractive options. For example, some of the world's highest tides occur in the Bay of Fundy, with the estimated output from a series of power stations (4,000 MW) being some 50 petajoules (PJ) [20]. Two issues of concern regarding the implementation of any tidal power scheme are the impact upon fish and shellfish stocks [20] as well as upon the tides themselves [21].

Wind

Atlantic Canada has some of the highest annual wind densities in Canada: from 250 Watts per metre^2 in Nova Scotia to almost 500 Watts per metre^2 on the Labrador coastline [22]. The application of wind farms in these areas could produce several hundred petajoules annually. For example, a series of one hundred wind farms on the Labrador coastline, each consisting of 200 one-megawatt wind turbines, could produce over 300 PJ annually.

In a recent paper, the authors have shown that electrical production costs from wind farms in the Atlantic region are competitive with existing (subsidized) costs of coal-fired electricity [23].

Wood

There is considerable scope in the use of renewable fuels for electrical generation in the Atlantic region. For example, the Small Power Producers Association of Nova Scotia is currently negotiating the sale of some 60 megawatts of electricity from the combustion of wood-waste in wood-fired power stations to the Nova Scotia Power Corporation [24].

A conservative calculation based upon the volume of wood cut in the Atlantic region serves to demonstrate that 240 megawatts of electricity could potentially be produced. The use of tree plantations could boost this annual output substantially.

5. THE APPLICATION OF HYDROGEN

Other than tidal power, the two main sources of renewable energy that Atlantic Canada can rely upon are hydro-electric and wind, primarily from Labrador. Labrador's geographic distance from the main centres of demand *and* the intermittent nature of wind-generated electricity suggest that converting the electricity into hydrogen and transporting it by pipeline for later use is a strategy that might usefully be examined [25, 26].

In an earlier paper, the authors proposed a scheme whereby hydrogen could be shipped, via pipeline, from the hydro-electric sites in Labrador to the southernmost provinces [27]. The scheme had hydrogen being produced in electrolysers at Churchill Falls, then being piped across Labrador to the Strait of Belle Isle. The pipeline would pass under the Strait in a tunnel (to avoid iceberg scouring) and down the western shore of Newfoundland. The pipeline would continue to the southernmost provinces through an undersea pipe joining Newfoundland and Nova Scotia. The hydrogen would be combusted in fuel cells, producing both electricity and heating water for district heating. The estimated cost of such a project is less than 2 cents per kilowatt-hour (electric).

The application of the hydrogen-from-hydro-electricity project alone would result in major carbon dioxide reductions. If the hydrogen was used to supply both electrical and thermal energy, the authors estimate that carbon dioxide emission levels would decrease – by between 24 per cent (low price case) and 21 per cent (high price case) of 1988 levels by the year 2005.

By extending the pipeline (or using existing grid connections) to wind farms around the region, hydrogen could be produced for storage in any of a number of salt domes found throughout Nova Scotia [28].

6. CONCLUDING REMARKS

This paper has shown that in Atlantic Canada, existing energy sources and demand are not sustainable. The paper has proposed a sustainable energy path that can be achieved by reducing existing energy demand and replacing fossil fuels by hydrogen using local, renewable energy sources for hydrogen production.

The proposed hydrogen economy is sustainable. First, energy efficiency and conservation are achieved through demand reduction. Second, the reduction in fossil fuel emissions could improve public health through the related decrease in greenhouse gases and low level ozone. Third, the use of renewable rather than fossil fuels offers an improvement in environmental protection.

There are other positive benefits, notably to Atlantic Canada's economy. Money is kept in the region: through employment, both in the construction of the power stations as well as in the manufacture of the necessary equipment; and by reducing the dependance on foreign oil. The reduction of fossil fuel usage also means that Canada could achieve the 20 per cent reduction in carbon dioxide emissions called for by the Toronto Conference on the Changing Atmosphere.

As with so many other areas of the sustainable society, these changes must be instituted now if the benefits are to be reaped in the future. Similar plans have been proposed elsewhere (for example, [29, 30, 31]): there is every reason to implement them in Atlantic Canada.

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Table I: Overview of region by population, land mass, and water area.

Province	Population (,000s)		Land Mass	Fresh Water
	1988	2011	(Sq. km.)	(Sq. km.)
New Brunswick	719	741	72,092	1,344
Newfoundland	570	566	106,614	5,685
Labrador			263,871	28,347
Nova Scotia	887	964	52,841	2,650
Prince Edward Island	130	139	5,657	0
Atlantic region (totals)	2,306	2,410	501,075	38,026
Canada (totals)	26,219	31,690	9,167,165	755,165

Table II: Sectoral Demand: Low Demand (Low Price) Case (Petajoules)

	1986	1988	2005	Increase (1988 - 2005)
Residential	111.5	115.5	131.7	14%
Commercial	53.9	56.3	66.1	17%
Industrial	167.2	179.4	212.4	18%
Road	116.7	121.5	147.1	21%
Air, Rail, Marine	39.2	46.9	52.4	12%
Transport (Total)	155.9	168.5	199.4	18%
Non-energy	15.3	15.1	19.7	30%

Table III: Primary Demand: Low Demand (Low Price) Case (Petajoules)

	1986	1988	2005	Increase (1988 - 2005)
Oil	370.5	406.0	498.8	23%
Natural Gas	0.0	0.0	0.0	0%
NGL	0.5	0.7	0.8	14%
Ethane	0.0	0.0	0.0	0%
Coal	83.8	95.2	183.4	93%

Table IV: Sectoral Demand: High Demand (High Price) Case (Petajoules)

	1986	1988	2005	Increase (1988 - 2005)
Residential	111.5	114.6	128.4	12%
Commercial	53.9	56.1	69.4	24%
Industrial	167.2	182.7	265.0	45%
Road	116.7	121.2	155.2	28%
Air, Rail, Marine	39.2	46.4	53.6	16%
Transport (Total)	155.9	167.6	208.8	25%
Non-energy	15.3	15.0	21.2	41%

Table V: Primary Demand: High Demand (High Price) Case (Petajoules)

	1986	1988	2005	Increase (1988 - 2005)
Oil	370.5	408.3	513.9	26%
Natural Gas	0.0	0.0	0.0	0%
NGL	0.5	0.7	0.9	28%
Ethane	0.0	0.0	0.0	0%
Coal	83.8	95.2	212.2	123%

Table VI: Carbon Dioxide Production: Low Demand (Low Price) Case (kilograms)

Year	Oil	NGL	Coal	CO_2Produced
1986	2.8×10^{10}	2.5×10^{7}	1.0×10^{10}	3.8×10^{10}
1988	3.0×10^{10}	3.5×10^{7}	1.1×10^{10}	4.2×10^{10}
2005	3.7×10^{10}	4.0×10^{7}	2.2×10^{10}	5.9×10^{10}

Table VII: Carbon Dioxide Production: High Demand (High Price) Case (kilograms)

Year	Oil	NGL	Coal	CO_2Produced
1986	2.8×10^{10}	2.5×10^{7}	1.0×10^{10}	3.8×10^{10}
1988	3.1×10^{10}	3.5×10^{7}	1.1×10^{10}	4.2×10^{10}
2005	3.9×10^{10}	4.5×10^{7}	2.5×10^{10}	6.4×10^{10}