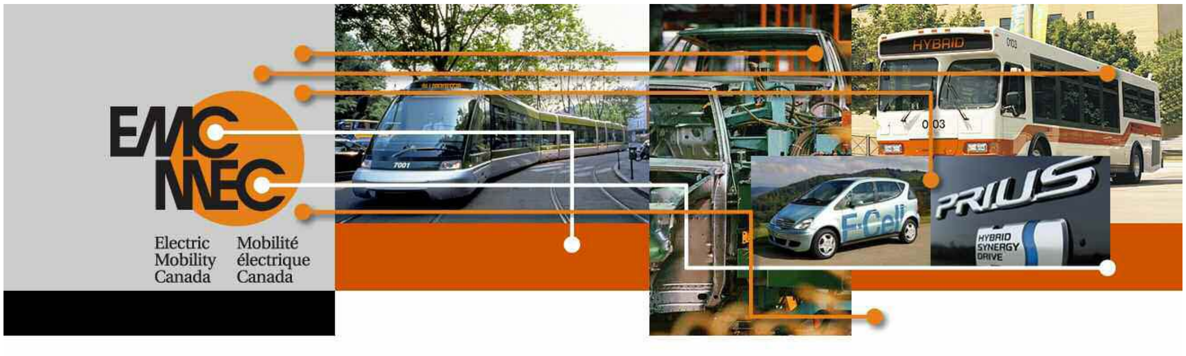

ACTION PLAN FOR

ELECTRIC MOBILITY IN CANADA

A document for debate at a workshop in Vancouver
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TABLE OF CONTENTS

1. OVERVIEW AND INTRODUCTION

We're on the brink of a major revolution in how we move people and freight. The internal combustion engine (ICE) has served us well for 100 years, but may not last for another fifty because of its emissions and dependence on non-renewable fossil fuel. Oil is becoming scarcer and more costly and ICE emissions—particularly of greenhouse gases—are more threatening than ever before. Many measures are required to curb the impacts of ICEs and to meet mobility requirements for people and goods. The measures include further improvements to ICEs, shifts to public transport, better freight logistics, and many others. A key part of the solution could be more electric mobility. Electric vehicles—powered by batteries or fuel cells or through direct connections to an electric grid—are a serious but so far underused alternative that can keep us moving without a major disruption. It may be time to start serious planning for a future in which electric transport becomes the norm.

Already autos, buses and trucks are sporting electric drives in addition to their ICEs. These hybrid vehicles use much less fuel than comparable ICE-only vehicles during stop and start driving because electric motors are much more efficient when speeds are low, and because electric drives can convert some of the momentum lost during braking into useful energy.

The battery powering a hybrid's electric drive in a hybrid is charged by its ICE. Many hybrid owners want more use of their electric drives than this arrangement allows. They convert their cars to 'plug-in' hybrids, which have larger batteries charged overnight from the domestic supply. In typical urban driving, plug-in hybrids can use less than one litre of gasoline for every 100 kilometres of travel, compared to the present ICE-vehicle average of 10 litres or more.

It's a short step from the plug-in hybrid to the all-battery vehicle, but a difficult step because of the trade-off between battery weight and range. Nevertheless, all-battery vehicles are making a come-back. A hundred years ago they were as popular as ICE vehicles. Now, electric drives are gaining popularity again in vehicles for short journeys, but need strong industry commitments and supportive policies at all levels of government to accelerate this needed comeback. Hybrid and electric vehicles are making important contributions to energy savings in many parts of the world. Canadians can catch up and perhaps pass other nations in the use of electric drive vehicles.

Many auto manufacturers and governments are looking to another kind of electric vehicle, powered by hydrogen fuel cells, to provide the range that battery vehicles still lack, and thus sustain the kind of transport arrangements we have now. There are major challenges with both parts of this concept. Fuel cells are currently expensive and unreliable. Hydrogen can be made inexpensively only from natural gas, another increasingly scarce fuel, and it is difficult to distribute and store. Nevertheless, the hydrogen-fuel-cell concept is attracting large amounts of investment that may well help overcome the challenges, although likely not for many years.

The most efficient way to deliver electricity to a vehicle is to connect the vehicle directly to an electric grid. Electric trains, streetcars, and trolley buses are familiar examples that provide almost half the transit trips in Canada's major cities. Connecting more transport directly to grids is possible, and batteries can provide these vehicles with limited off-grid movement when overhead wires are not available.

Canada is uniquely positioned to lead the transport revolution to electric vehicles. We are unusually dependent on good transport, and have among the world's most sophisticated transport industries, both manufacturing and services. We generate more of our electricity from renewable resources than almost any other country. Regional mismatches in supply and demand could be overcome through a national grid that would bind Canadians as rail did in the 19th century (and may be beginning to take shape with the recent decision to link the Manitoba and Ontario grids more tightly). The 30 per cent of our supply that is not from renewable sources could be replaced and expanded through massive investment in wind, solar, tidal, hydro, geothermal, and other renewable production. As the cost of conventional generation of electricity increases, these renewable sources become more attractive.

Much of the technology needed for a significant migration to electric transport is in place. Innovations continue to be introduced, and more will flow from continuing research and development. What is required is leadership in the form of partnerships between private and public sectors that identify and implement the ways in which Canadians can take the best possible advantage of available and emerging technologies, supported by an electricity supply strategy that provides for a truly sustainable future.

In the short term, wider use of electric vehicles will mean big steps towards meeting present and future obligations to curb climate change. In the long term, electric vehicles may provide the only way in which Canadians can continue to benefit from the comfort, convenience, and productivity that effective transport provides.

This paper elaborates the foregoing and makes the case for formation of Electric Mobility Canada/Mobilité Electrique Canada (EMC-MEC), a network of private companies and public sector agencies to bring together all with an interest in promoting electric mobility in Canada. It is to include government representatives, academics, vehicle and equipment manufacturers, component and technology suppliers, energy providers, and end users. There is an important emerging industry in electric mobility in Canada with expertise in electric and hybrid vehicles, batteries, hybrid technologies, grid-connected technologies, and fuel-cell vehicles. An effective network could stimulate this industry and provide valuable support to government agencies with a part to play in meeting Canada's obligations under the Kyoto Protocol or in supporting new industry sectors.

EMC-MEC will define a path towards promoting electric mobility in Canada (necessary legislation, research, funding, demonstrations, incentives, etc) and communicating proposed strategies to governments, industry sectors, and the general public.

2. Definition of Electric Mobility

Mobility of people and goods is electric when traction is provided by an electric motor. The motor can drive one or more wheels of a vehicle for movement on land, usually on a road or rails, and, more rarely, one or more propellers for movement through water or even air.[1]†

Electric mobility systems differ according to how electricity reaches the motor. There are basically three types of mobility system, each of which has numerous subtypes:

The electricity is generated on board the vehicle. Such generation is mostly by internal combustion engines (ICEs). Examples are hybrid ICE-electric automobiles and locomotives, in which ICE generators charge batteries that power electric motors that drive wheels.[2] The electric motors also charge batteries during deceleration, converting kinetic energy into electricity. In simpler configurations, ICE generators power electric motors directly, as in diesel-electric train engines and gas turbine-electric ships. The electricity can also be generated on board by a fuel cell or a photovoltaic array.

The electricity is generated elsewhere and stored on board the vehicle. Battery electric vehicles, which first provided electric mobility, fall into this class. Storage can also be achieved using capacitors and electromechanical systems (flywheels). Road-based battery-electric vehicles are rare, but many are used as golf carts, fork-lift trucks employed in warehouses, and other specialized applications.

The electricity is generated elsewhere and delivered to the motor during motion. Such 'grid-connected' or 'tethered' vehicles receive electricity continuously from one or more wires or rails. Today, most electric mobility is of this type, including electric trains, streetcars, trolley buses, and trolley trucks.

† Superscript numbers refer to 99 reference and other notes that begin on Page 39.

Actual vehicles can have features of more than one type. Some hybrid ICE-electric vehicles can also be charged from the grid—'plug-in hybrids'—although only when stationary. Some grid-connected vehicles can use battery power for limited off-grid movement.

A further point of differentiation among electric vehicles is their ultimate fuel use. In any of the three types listed above, this can be a fossil fuel or a renewable fuel. For example, an on-board generation vehicle with an ICE could use diesel fuel or gasoline, or sustainably produced biodiesel or ethanol. The hydrogen or methanol used as fuel in fuel cells can be derived from fossil fuels or be sustainably produced. Battery-electric and grid-connected vehicles can use electricity from a coal-fired generating station or from a renewable source such as a wind farm. (All three types of vehicle could make use of nuclear energy, which is sustainable or not according to perspective.)

3. ELECTRIC MOBILITY IS INCREASING

This section is organized according to the three principal means of delivering electricity to electric traction motors, as identified in definition of electric mobility in the previous section.

3.1. On-board generation vehicles, including hybrid electric-ICE vehicles (HEVs)

Most current discussion about electric vehicles in Canada with on-board generation of electric power concerns the **rapid growth in sales of hybrid electric-ICE automobiles**. According to one source, these increased more than six fold between 2003 and 2004. The 2004 total was about 2,300 units, between 0.1 and 0.2 per cent of the approximately 1.5 million personal vehicles sold in Canada in each of 2003 and 2004. (Personal vehicles, also known as 'light vehicles', are automobiles, SUVs, and minivans, and pick-up trucks used for non-business purposes.) A further doubling or tripling of hybrid sales has been anticipated for 2005. Of the total hybrid sales in Canada in 2004, almost 90 per cent were of one model, the Toyota Prius.[3]

There have been relatively more sales of hybrid electric vehicles in the U.S. where some 83,000 were sold in 2004, approximately 0.5 per cent of all personal vehicle sales,[4] a three-fold higher share than in Canada. Sales of hybrid cars in the U.S. are expected to rise to 200,000 in 2005,[5] and to about a third of all personal vehicles—i.e., to about five million annually—by 2015.[6] Sales will be helped by the planned introduction of at least 14 new hybrid models (seven SUVs, three pick-up trucks, and four sedans), in addition to the 10 available in early 2005 (three SUVs, two pick-up trucks, and five sedans).[7]

In Canada, only five hybrid models were available by the end of 2004 (one SUV, one pick-up truck, and three sedans).[8]

The price difference between hybrids and their (less expensive) ICE-alone counterparts seems to be about the same in Canada and the U.S.: about $3,500.

In Canada, the Prince Edward Island, British Columbia, and Ontario governments provide sales tax rebates on the purchase of a hybrid vehicle of $3,000, $2,000, and $1,000, respectively (see Section 5.1).[9] In the U.S., there is a $2,000 federal income tax deduction for hybrid vehicle purchases, and nine states provide a further income tax deduction or another financial incentive such as a partial exemption from sales tax.[10] For vehicles purchased after 2005, the U.S. federal support for hybrids will become much stronger.[11]

There are few **larger hybrid vehicles** in use in Canada, but this may be about to change. The Toronto Transit Commission has ordered 150 hybrid diesel-electric buses for delivery in 2006 from Orion Bus Industries of Mississauga, Ontario, a unit of DaimlerChrysler. According to the manufacturer, these will provide about a 30-per-cent improvement in fuel economy compared with regular diesel buses,[12] about the same improvement reported for comparable hybrid personal vehicles. Earlier, New Flyer Industries of Winnipeg, Manitoba, in partnership with General Motors, had sold six hybrid diesel-electric buses to B.C. Transit, claiming improvement in fuel economy of “up to 50 per cent”.[13] At the end of 2004, New Flyer had 309 hybrid buses in operation and was the major manufacturer of hybrid buses in North America.

New Flyer’s leadership is being challenged by DaimlerChrysler, which recently announced orders of 216 Orion hybrid buses by New York City Transit and of 284 of these buses by New York’s Metropolitan Transit Authority, for delivery beginning in late 2006. This followed an order of 56 buses by San Francisco’s transit system.[14]

New York City may well see many more hybrid vehicles on its roads as its Taxi and Limousine Commission has authorized the use of several hybrid automobiles as taxicabs.[15] Hybrid vehicles compare particularly favourably with regular ICE vehicles in stop-start traffic because electric motors have constant torque at all speeds whereas ICEs have poor torque at low speeds, and also because hybrids capture kinetic energy during braking. New York cabs drive on average over 70,000 kilometres a year, mostly in stop-start traffic. The Commission has estimated that use of the most fuel-efficient of the approved hybrid vehicles could reduce annual fuel costs for a cab by 70 per cent (i.e., by just over US$5,000) compared with fuels costs for the standard ICE cab.[16]

According to a recent report, there are approximately 700 hybrid buses in service in North America, with another 400 due for delivery in late 2005 and 2006.[17]

Canadian Pacific has ordered 35 Green Goat series hybrid diesel-electric locomotives from Railpower Technologies of North Vancouver, British Columbia, for delivery over the next four years. These are reported to be as much as 65-per-cent more efficient than comparable yard locomotives.[18]

Penetration of hybrid technology into the heavy truck market is less likely as these vehicles are used mainly for inter-city trips. However, this technology is ideal for local delivery trucks of all types, including heavy trucks where they used more for this purpose. As in the cases of automobiles and buses, a hybrid truck's greater fuel efficiency is achieved during low-speed travel, because a hybrid vehicle's electric motor is used more than and is much more efficient than an ICE at low speeds, and during stop-start traffic, when hybrid vehicles' regenerative braking provides energy savings. A current example of this kind of use of hybrid trucks is Purolator's deployment of 30 delivery vehicles across Canada that have hybrid drivetrains developed by Vancouver-based Azure Dynamics.[19]

A significant variant of the regular hybrid ICE-electric automobile is the **plug-in hybrid**, a regular hybrid that has been converted by the owner or a third party by replacing the manufacturer's 1.3-kilowatt-hour battery with a much larger battery—typically 9 kwh—that can be charged from a household socket. Gasoline use is reduced by as much as 100 per cent—typically 50 per cent—according to distance travelled between charges and kind of traffic. It is replaced by household electricity, costing in the U.S. about $1.50 rather than the gasoline cost of $6.25 per 100 kilometres.[20] (The difference would be roughly the same in Canada.) According to one installer of plug-in modifications, the conversion cost is "under US$12,000 per vehicle".[21] According to another source, the conversion cost is about 15 per cent of the cost of the hybrid, i.e., about $4,500 for a vehicle costing $30,000. If a $5,000 cost is amortized over eight years, and the electric motor rather than the ICE is used for 10,000 kilometres a year, this conversion cost would be in the order of $6.50 per 100 kilometres. A large part of the conversion cost is for the larger battery. Prices of these batteries could decline steeply with increased production, and the fuel price differential could well increase as world oil production fails to keep up with potential consumption. Thus plug-in hybrids could soon be less costly to operate than comparable vehicles as well as using very much less gasoline.

A possibly significant development towards widespread penetration of hybrid vehicles may be the recent formation of the Plug-In Hybrid Electric Vehicle Consortium, more formally known as the Advance Hybrid Vehicle Development Consortium. This is a group of four companies intent on making plug-hybrid technology sufficiently appealing that one or major automobile manufacturers will adopt it. The operational goal is to develop a hybrid system that gives a vehicle an 80-kilometre battery range, thereby providing for 80 per cent of all daily driving needs in the U.S. (and likely a higher share in Canada). The group includes Raser Technologies, a U.S. electric motor manufacturer, Pacific Gas & Electric, a major electrical utility, Maxwell Technologies, which makes ultracapacitors, and Electrovaya, a Mississauga-based lithium battery manufacturer.[22]

Five **fuel-cell vehicles** are in regular operation in Canada. They are part of the $9-million Vancouver Fuel Cell Vehicle Program.[23] The converted regular sedans will be used to provide “critical data for the continued development of fuel-cell technology”. Similar demonstration projects exist in other countries, some involving buses as well as automobiles.

Solar-powered vehicles are very much in their early developmental stage, and are noted here only for completeness and their possible longer-term promise. There were four Canadian participants, out of 21, in the July 2005 North American Solar Challenge, sponsored in part by Natural Resources Canada. It involved a 4,000-kilometre race from Austin, Texas, to Calgary, Alberta.[24]

3.2. Battery electric vehicles

Battery electric vehicles have been available for as long as ICE vehicles, but have been rarely seen on Canadian roads. How many are in regular use at present cannot be readily determined.

Two Canadian manufacturers produce what are known as ‘low-speed vehicles’,[25] which have been approved for road use in Canada by the federal government but only by the provincial governments in British Columbia and Quebec. (Neither province yet formally allows them on public roads, although they appear to be tolerated in B.C.) In the U.S., low-speed vehicles may be used in all but five states, but only on roads with a speed limit of about 55 km/h and only at a speed of less than about 40 km/h, and municipalities may apply further restrictions, including confining use to specific areas.

Battery electric vehicles can also be configured as regular automobiles, and have been produced as such by some major automobile manufacturers. A recent controversy concerned General Motors EV-1, produced in response to California’s ‘zero-emission vehicle’ requirement, which was strongly and successfully opposed by the industry.[26] Admirers of battery electric vehicles appear to have prevented GM from crushing its remaining EV-1s. Other electric vehicles produced in response to the zero-emission-vehicle requirement are also no longer in production.[27]

In the U.S. there are presently about one hundred battery-electric buses in transit operations. According to the authors of this estimate, “This deployment level is actually down somewhat from the mid-1990s, reflecting the drop-off in transit operator interest due to the failure of industry to achieve a major battery breakthrough. For those knowledgeable about the light-duty electric vehicle market, this is a familiar trend.”[28]

A recent analysis of why battery electric vehicles have not flourished argued that they have been held back by criticisms that battery electric vehicles have a limited range, sluggish performance, and high production costs, and produce more pollution overall (i.e., at the electricity generating plant) than ICE equivalents.[29] The analysis took issue with each criticism, showing that battery electric vehicles have extensive range, peppy performance, low costs, and little pollution.

This analysis in part contradicted an earlier assessment, which had put more emphasis both on users' satisfaction with ICE vehicles and on technical shortcomings of battery electric vehicles.[30] That assessment nevertheless argued that appropriate regulation could allow for the possibility of "the snowball effect that gives the electric car a chance to establish itself as a significant part of the automobile market".

A new type of battery electric vehicle is the Segway,[31] part of a class of vehicles known in U.S. legislation as Electric Personal Assistive Mobility Devices.[32] It is designed for use on sidewalks and other walkways. Use of these vehicles on sidewalks appears to be permitted in most U.S. states, but was recently forbidden in Toronto[33] and Montreal.[34] A demonstration of Segways is now under way in Quebec City.[35]

Electric watercraft have been preferred for years by users who seek quiet operation and minimal impact on waterways, and may be becoming more favoured as governments tighten regulations concerning marine emissions.[36] They are already common on small lakes where ICE-powered boats are not allowed. There are several Canadian manufacturers of electric watercraft.

Electric drives are also finding favour in larger vessels. The world's largest passenger liner, the *Queen Mary 2*, launched in 2004, has four diesel engines and two gas turbines, all producing electricity.[37] Propulsion depends on electric motors in four submersed 'pods', two fixed and two movable. This arrangement allows for much more precise steering and produces much less noise and vibration than convention drives in which propellers are connected directly to diesel engines. It also helps reduce emissions by allowing more operation of the ICEs at close to their optimal outputs.

3.3. Grid-connected vehicles

Most travel by electric vehicles in Canada involves the third type of system, with electricity delivered during motion by overhead wire, as in streetcars and light-rail vehicles, or by rail, as in subway and other heavy rail systems. Such grid-connected vehicles are found in five of Canada's six largest urban regions: Toronto, Montreal, Vancouver, Calgary, and Edmonton. (Ottawa-Gatineau, the fourth largest region, is presently the exception.)

The table in Box 1 on the next page provides details of current electric transit vehicle use in these regions.[38] Overall, just under half of the indicated trips (48 per cent) are by grid-connected vehicles, with available data suggesting that these vehicles may be responsible for a similar share of passenger-kilometres.

There used to be much more grid-connected transit. For differing periods during the 20th century, a total of 50 communities in Canada had streetcar service, 15 had trolley bus service, and 19 were served by interurban electric railways.[39] How grid-connected transit declined is matter of controversy.[40]

Box 1. Use of grid-connected transport systems in Canada

Jurisdiction	Transit vehicle	Annual trips (millions)	Annual PKM* (millions)
City of Toronto	All vehicles	418.1	
	Subway and SRT**	173.6	
	Streetcars	42.5	
	Electric share (%)	52%	
Greater Montreal	All	437.8	
	Electric train	7.5	
	Subway	217.5	
	Electric share (%)	51%	
Greater Vancouver Regional District	All	155.6	1,851.6
	Skytrain	36.6	435.6
	Trolley buses	39.2	466.0
	Electric share (%)	49%	49%
City of Calgary	All	80.6	1,024
	Light rail	34.7	440
	Electric share (%)	43%	43%
City of Edmonton	All	84.0	
	Light rail	11.7	
	Trolley buses	6.5	
	Electric share (%)	22%	

* PKM = passenger-kilometres ** SRT = Scarborough Rapid Transit

4. WHY ELECTRIC MOBILITY NEEDS TO BE PROMOTED, ACCELERATED, AND EXPLOITED IN CANADA

4.1. Overview

At least three factors point to the desirability of increased use of electric mobility for land transport in Canada. One is concern about climate change, which is induced in considerable measure by emissions of greenhouse gases (GHGs) from transport operations. Electric vehicles generally result in fewer GHGs per kilometre than ICE-powered vehicles. The second is concern about poor air quality in and near cities, most of which is the result of transport operations. Electric vehicles produce fewer emissions of all kinds per kilometre than ICE-powered vehicles, notably at the vehicle but also when electricity generation is taken into account. The third is concern about the future availability and price of oil, which presently fuels almost all transport.[41] Electric vehicles can readily use other fuels, including any form of renewable energy that can be converted into electricity. These and other matters are elaborated in later parts of this section.

Consideration of all three factors has raised the popularity of hybrid vehicles, and, to the extent these concerns continue and grow, should serve to increase the use of all types of electric vehicle.

Particularly desirable would be increases in the use of grid-connected vehicles as these have lower energy requirements per person- or tonne-kilometre performed than other electric vehicles (and other motorized vehicles of all kinds). Battery-electric vehicles also have relatively low energy requirements and are more flexible as to where they can be operated. Hybrid electric-ICE vehicles provide even more flexibility, and can have considerably lower fossil fuel use than regular ICE vehicles, particularly plug-in hybrids. Fuel cell vehicles may be of value if challenges concerning their cost, reliability, and fuelling are overcome. These matters are also elaborated in later parts of this section.

Grid-connected vehicles and battery electric vehicles are particularly suited to a transition to sustainable transport, in part because they can be fuelled by *any* means of production of electricity, and in part because changes in how the electricity is produced need have no impact at the vehicle system.

An additional factor particular to Canada and a few other countries is the relative abundance of renewably generated electric power. Canada produces more such electric power than any other country—chiefly hydropower—and, among OECD countries, only in Norway is renewable generation a higher share than in Canada (99 and 58 per cent, respectively).[42] Canada has the potential for renewable generation of all current and anticipated needs from hydropower and photoelectric generation alone,[43] not to mention opportunities for renewable generation of electricity from tides, wind, biomass, and geothermal sources.

These further sources will all become more viable as their technologies mature, as growing returns to scale are achieved, and as the cost of generation from fossil fuels increases.

What is required is an appropriate distribution system that provides sufficient interlinkage among Canadian producers and users and is ‘smart’ enough to accommodate a large number of small-scale electricity generators—often known as ‘distributed producers’—with widely varying outputs. Also required, to overcome regional mismatches in supply and demand, may be a national grid that would bind Canadians as rail did in the 19th century (and may be beginning to take shape with the recent decision to link the Manitoba and Ontario grids more tightly[44]).

Canada is well positioned to be a leader in the development of electric mobility. As well as the noted abundance of renewable electric energy, it has industry leaders in several areas relevant to such development. The world’s major supplier of grid-connected vehicles is headquartered in Canada (Bombardier[45]), as are major actors in fuel cell development (Ballard[46]), hydrogen for fuel cells (Hydrogenics[47]), low-speed electric cars (Dynasty[48]), batteries (Electrovaya[49]), electric motors (TM4[50]), hybrid drivetrains (Azure Dynamics[51] and electromechanical storage (Flywheel Energy Systems[52]). Other potentially relevant Canadian assets include a sophisticated automotive industry and major producers of transit buses.

Electric mobility options are already available with proven technology that can make an important contribution to sustainability in transport. While research and demonstration needs are always important to advance the industry’s capability, early implementation of electric mobility is feasible and needed and not dependent on further research.

What Canada lacks is identification of electric mobility as an industry sector and sufficient penetration of vehicle traction systems by electric motors. The main purposes in establishing the network proposed here (see Section 9) are to achieve and organize such and industry sector and work towards achieving the necessary penetration.

4.2. Environmental benefits of electric mobility, including helping meet Canada’s Kyoto Protocol obligations

Electric vehicles of all kinds represent a step towards sustainability, even if the electricity they use comes from fossil fuels or nuclear sources, but especially if it is generated from renewable sources. Compared with ICE vehicles, they use less energy, cause less pollution and noise at the vehicle, and cause fewer emissions overall.

Differences in energy use for some configurations of regular automobiles, hybrids, battery-electric, and fuel-cell vehicles are set out in the table in Box 2.[53] Except for the Mitsubishi MIEV, described further below, the fuel use data are from the U.S. Department of Energy for 2006 models except for the Nissan battery vehicle, which is a 2000 model. The indicated estimates of primary energy use and GHG emissions assume that the hydrogen is made by electrolysis and about 40 per cent of Canada's electricity is produced from coal, to decline to zero in the future. (Currently, hydrogen is produced from natural gas, which, compared with production by electrolysis, can result in less than half the greenhouse gas emissions per kilogram produced.)

A similar table could be developed for buses. It would show that trolley buses have similar advantages to battery-electric automobiles in terms of energy use and current and future GHG emissions.

The table in Box 2 could have been extended to show other transport-related emissions, notably particulates and nitrogen oxides. In general, these are correlated with GHG emissions, although for battery and fuel cell vehicles the emissions occur at the generating station rather than at the vehicle.

Models were selected for Box 2 to be as similar as possible to the one regular automobile with a fuel cell drive train that is in the 2006 listing. The last time a similar battery-electric vehicle was listed was in 2000. Mitsubishi has just announced a battery-electric concept automobile that is considerably larger and more powerful than the other vehicles in the table.[54] Its superior performance gives an indication of technological advances in this type of drivetrain (including batteries) that have been made in the last six years.

Even if initially the electricity is not sustainably produced, the generation can become sustainable—e.g., by use of wind power rather than coal power—without the need for changes in the transport system. Electric mobility is inherently *sustainability ready*.

Electric vehicles' lesser ability to serve scattered destinations would help curb sprawl, freeing land for agricultural and recreational purposes and thereby reducing transport activity and further reducing environmental impacts.

Box 2. Energy use by and GHG emissions from automobiles with different drive trains

		At-vehicle fuel use per 100 kilometres					Primary energy use/ 100km	Greenhouse gases	
		Gaso-line	Electri-city	Hydro-gen	Energy			Current	Future
Drive-train	Model	litres	kilowatt-hours	kilo-grams	mega-joules	Energy source to motor loss	mega-joules	kg/100km	
ICE	Honda Civic	6.9			229	0.00	229	16.9	16.9
Hybrid	Honda Civic	4.7			149	0.00	149	11.5	11.5
Battery	Nissan Altra		17.2		62	0.33	92	9.9	0.0
Battery	Mitsubishi MIEV		12.8		46	0.33	69	7.4	0.0
Fuel cell	Ford Focus			1.2	148	0.57	344	23.7	0.0

4.3. Health benefits of electric mobility

Health benefits flow from the environmental benefits, particularly reduced atmospheric pollution—a major cause of morbidity and mortality—reduced noise, reduced sprawl, and slower rates of climate change. Health benefits may accrue particularly to children and other vulnerable persons.

4.4. Further energy considerations for mobile uses

The ICE has served society well, but there are few who deny its days are numbered as the predominant type of drive in land vehicles. Even if petroleum fuels remain available, or suitable substitutes, in what is likely to be an energy-constrained world, ICE systems could well be considered too inefficient for widespread use. Further improvements to the efficiency of ICE vehicles will help sustain their use, but there are physical limits to ICE efficiency that will contribute to making them less acceptable.

Electric motors are for the most part acceptable alternatives to ICEs and, in time, may well replace ICEs as the main source of vehicle traction. They operate with almost 100 per cent efficiency, vs. about 25 per cent for an ICE. However, there can be much greater losses in getting the electricity to the motor than in getting the ICE fuel to the ICE. Of the means noted in Section 3, grid-connection has the lowest loss (about 10 per cent of original generation), followed by battery-based systems (about 20 per cent), followed by on-board generation (55-75 per cent).[55] The ultimate in low-energy, low-impact motorized transport could be a light-weight, grid-connected vehicle that is fuelled from renewable resources and is highly streamlined or limited to speeds below about 45 km/h.

Grid-connected systems have evident advantages in an energy-constrained world, but their use has been confined to public transport in high-density corridors, some rail freight, and to use of trolley trucks in limited off-road situations (e.g., in the Quebec-Cartier iron ore mine at Lac Jeannine in the 1970s). Many proposals have been made for what is known generically as Personal Rapid Transport (PRT), i.e., a transport system with some or all of the following characteristics:

- Fully automated vehicles capable of operation without human drivers.
- Vehicles captive to a reserved guideway.
- Small vehicles available for exclusive use by an individual or a small group, typically 1-6 passengers, traveling together by choice and available 24 hours a day.
- Small guideways that can be located above, at or below ground.
- Vehicles able to use all guideways and stations on a fully coupled PRT network.
- Direct origin-to-destination service, without a necessity to transfer or stop at intervening stations.

- Service available on demand rather than on fixed schedules.[56]

What gives current proposals for PRT more promise is not only an impetus from high fuel prices for ICE vehicles but also recent developments in information technology, discussed further below. In an energy-constrained world, PRT might well become favoured, offering huge advantages to economies where PRT development has been supported. Further research and development would be required for that to happen, and at least one large-scale demonstration project.

Battery-based drive systems can be almost as suitable to energy constraints, and offer considerably more flexibility in use. Hardly more than modest advances in battery technology and production, with commensurate reductions in price, would be required for battery electric vehicles to become favoured over alternatives.[57] Again, the advantages of being among early developers and adopters could be considerable.

So far, the research and development focus has been on on-board generation of electricity, particularly from fuel cells. This type of system offers the least radical shift in type of vehicle, but the most radical in fuelling aspects. Its fundamental challenge lies in the energy losses in fuel production, distribution, storage, and then conversion into the electric power for traction. Box 3 on the next page shows that the losses could be as high as 80 per cent, i.e., as much as *eight times* larger than the losses in providing electricity for a grid-connected vehicle.[58] There are also challenges in the cost and reliability of the fuel cells themselves.[59] Nevertheless, fuel cell systems remain potentially viable contenders for our transport future, not the least because of the huge ongoing research and development effort they have attracted, in Canada (see Section 5 below) and elsewhere (see Section 6 below), because the advantages of being an early developer and adopter have been recognized.

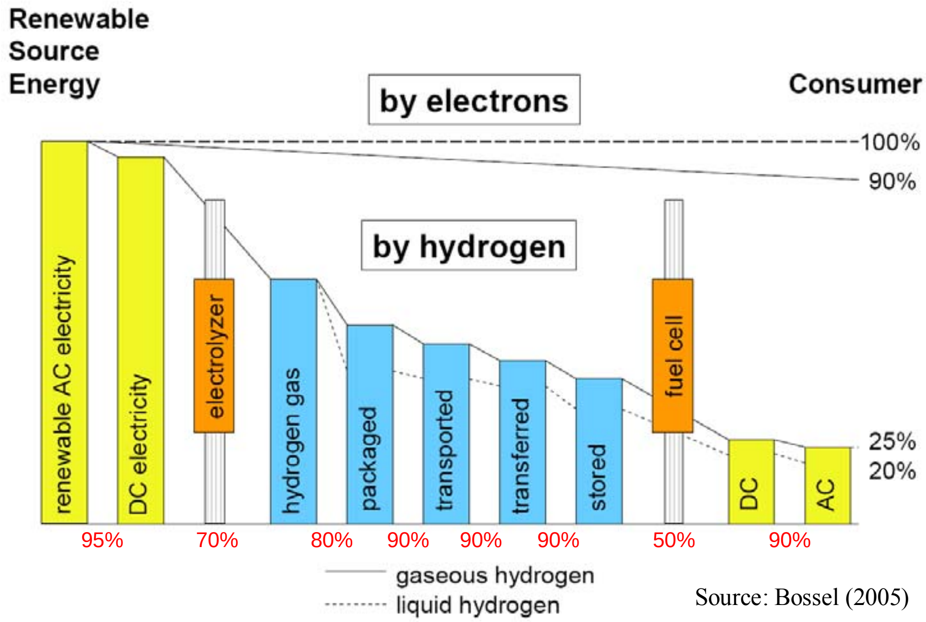
At the heart of all these systems is the electric drive, what may be the common element of future transport. It is the unifying feature that can define a new industry sector embracing systems involving grid-connection, batteries, and on-board generation, and combinations of these.

4.5. Economic and industrial benefits

There are at least three kinds of economic benefit to be derived from a focus on electric mobility. The first is from being an innovator in an expanding area. The second is from the expansion itself; accruing to the extent the expansion is embraced. The third is from being in a position to use an alternative to fossil fuels, particularly oil, in an era of growing scarcity.

There is another, particularly Canadian, benefit. It is the strong possibility developing an electric mobility industry that could be dispersed across Canada, perhaps with stronger

Box 3. Transport of renewable electricity by hydrogen and by electrons)



Source: Bossel (2005)

Percentages under bars indicate approximate conversion efficiencies of processes

focuses in provinces where electricity is presently abundant (British Columbia, Manitoba, Quebec).

4.6. Other benefits including IT links

Two other benefits of widespread use of electric vehicles could be: (i) much lower maintenance costs for users,[60] and (ii) opportunities to integrate with and thereby reinforce a national electric power grid that could be based in part on intermittently renewable energy. Concerning the second point, most vehicles are stationary for most of the day. With sufficient battery power—which electric vehicles would more likely have—stationary or even mobile vehicles could provide storage services to the grid. They could thereby buffer increasing potential variability in grid performance as intermittent generation, e.g., from wind and photovoltaic panels, comes more into use.[61]

An additional benefit is the greater compatibility of electric vehicles with the ongoing quite extraordinary advances in information technology. At the simplest level, this enhanced compatibility arises because electric vehicles are electric and because they have large batteries or are regularly connected to the grid, or both. More profoundly, electric vehicles can be more compatible with sophisticated guidance and scheduling systems, including those require for PRT, which must be fully automated.

5. CURRENT PROGRAMS FOR ELECTRIC MOBILITY

5.1. Existing Canadian incentives for electric mobility

Three Canadian provinces have adopted incentives which support the introduction of electric mobility. At this time, these incentives are financial in nature and do not include support of technical, legal or regulatory nature.

British Columbia

Since February 16, 2005, all alternative propulsion vehicles, including passenger vehicles using alternate fuels, are eligible for a tax reduction.

The amount of tax reduction depends on the vehicle purchased or leased as follows:[62]

- Electric hybrid vehicles, except passenger buses using alternate fuels: a reduction of 100 per cent of the provincial sales tax to a maximum of $2,000. This applies to all new vehicles acquired between February 16, 2005 and April 1, 2008. Then the maximum will be reduced to $1,000 until April 2009, when the reduction will be cancelled.
- Alternate fuel vehicles, other than electric hybrid vehicles and passenger buses using alternate fuels: a reduction of 50 per cent of the provincial sales tax to a maximum of $1,000.
- Passenger buses using alternate fuel: a 50-per-cent reduction in provincial sales tax to a maximum of $1,000.

Prince Edward Island

The provincial sales tax is refunded to a maximum of $3,000 for the purchase or lease of a hybrid vehicle. This is the largest incentive in Canada. Only vehicles purchased or leased after March 31, 2004, qualify.

Ontario

Ontario refunds provincial sales tax up to $1,000 in addition to other tax refunds for fuel conservation. Electric vehicles, hybrid electric vehicles, and vehicles using alternate fuels purchased after May 10, 2001, are eligible for a rebate of the provincial sales tax paid up to $1,000.[63]

5.2. Federal government programs that can support electric mobility

Apart from the Electric Vehicle Development Program, described below, there are no current federal programs that specifically deal with electric mobility. However, several programs of Environment Canada, Industry Canada, Natural Resources Canada, and Transport Canada have elements that support or could support work on electric mobility. The following describes some of these programs.

Transport Development Centre

Transport Canada says this about its Montreal-based Transport Development Centre:[64]

> As a centre of excellence for research and development, it manages a multimodal R&D program aimed at improving the safety, security, energy efficiency, and accessibility of the Canadian transportation system, while protecting the environment. Its mandate is to enhance the department's technological capability, to address the department's strategic objectives and federal government priorities, and to promote innovation in transportation.

Among the Centre's programs is the **Electric Vehicle Development Program**, which has executed or is executing the following projects, the last three of which were ongoing in October 2005:[65]

- Demonstration of commercial electric vehicle fleet – feasibility study
- Development of a low-floor electric bus
- Development of an advanced thermal management system for an electric vehicle – feasibility study
- Development of an advanced thermal management system for an electric vehicle – Phase 2
- Écolobus – comparative evaluation of ecologically friendly buses
- Electric bike 2000 project
- Evaluation of electric postal vehicle
- Hybrid refuse truck feasibility
- Improving winter performance of an electric vehicle
- Montreal 2000 – Electric vehicle demonstration
- Pilot demonstration of low speed vehicles (LSVs)
- Evaluation of the Segway™ HT Electric Personal Assistive Mobility Device (EPAMD)
- Lightweight urban delivery truck
- Pilot project for the safe introduction of low-speed vehicles into urban areas

Moving on Sustainable Transportation

According to Transport Canada,[66]

> The Moving On Sustainable Transportation (MOST) program is an innovative Transport Canada funding program that provides financial support to help organizations conduct projects that will produce the kinds of education, awareness and analytical tools necessary to make sustainable transportation a reality. Eligible organizations in-

> clude environmental groups, community associations, academic institutions, Aboriginal organizations and business and professional associations.
>
> The program seeks to stimulate the development of innovative methods for decreasing the impact of transportation on the environment, achieve quantifiable results and provide Canadians with practical information and tools to apply sustainable transportation thinking to their daily lives.
>
> The MOST program fulfils a commitment made in Transport Canada's first Sustainable Development Strategy, which was tabled in Parliament in 1997. The first phase of the program began in the fiscal year 1999-2000, with more than $1 million to be allocated over three years. In response to ongoing demand, the program was recently extended to 2007 with an additional $2.5 million to be allocated over five years. To date, about $3 million has been allocated towards a variety of initiatives aimed at encouraging sustainable transportation to diverse target audiences.

Only two of well over 100 MOST-supported projects have directly concerned electric mobility. The completed project helped lead to conversion of Calgary's light-rail system to use of wind energy.[67] The ongoing project concerns production of a workshop manual to guide Grades 11 and 12 and community college students in the conversion of a standard gasoline-powered vehicle to an electric vehicle (EV).[68]

Urban Transportation Showcase Program

According to Transport Canada,[69]

> The Urban Transportation Showcase Program (UTSP) is a Transport Canada initiative under the Government of Canada's Action Plan 2000 on Climate Change. The Program aims to reduce greenhouse gas emissions through the implementation of showcase demonstrations in communities across Canada and through the dissemination of information. …
>
> Urban transportation showcases are multi-year initiatives that demonstrate and evaluate integrated approaches to reducing GHG emissions. They are not stand-alone "pilot projects".
>
> Showcases must include several coordinated measures within a transportation and land use planning framework. The keys to a successful showcase will be innovation in planning and implementation, integration of measures, and the creation of valuable information.
>
> All showcases respond to local priorities, existing initiatives and plans. Participants have decided whether to emphasize operations or infrastructure, technology or education, motorized travel or active transportation, economic instruments or land use tactics.

Of the eight successful UTSP proposals, two specifically concern electric mobility. One concerns transit improvements in corridors in Gatineau and Montreal featuring hybrid buses, transit priority measures and terminal enhancements.[70] The other concerns enhanced modal choice in Montreal and Saint-Jérôme through self-serve access to electric cars and bicycles.[71]

Advanced Technology Vehicles Program

According to Transport Canada, this program "assesses vehicles with advanced power-trains, materials, chassis designs, emission controls, fuels, and other technologies to measure their impact on safety, energy efficiency and the environment".[72] By the end of 2003, this program had tested 11 hybrid vehicles, 10, battery vehicles, and no fuel cell vehicles.[73]

Technology Partnerships Canada

According to Industry Canada,[74]

> Technology Partnerships Canada (TPC) is a special operating agency of Industry Canada with a mandate to provide funding support for strategic research and development, and demonstration projects that will produce economic, social and environmental benefits to Canadians.
>
> Since 1996, TPC's activity has been rooted in helping Canadian companies perform R&D that takes new technologies closer to the marketplace. These R&D projects have the potential to improve the efficiency of production processes in traditional sectors as well as support innovation in emerging technologies, enabling Canadian companies to become world-class.
>
> Canadian industries take the lead in bringing innovation forward to the marketplace. TPC acts as a catalyst, investing strategically to accelerate the successful development of key technologies that will benefit Canadians in their everyday lives.

This program is being wound down and to a degree replaced by the recently announced Transformative Technologies Program (TTP), details of which are not yet available.

Canadian Foundation for Innovation

According to the corporate Web site,[75]

> The Canada Foundation for Innovation (CFI) is an independent corporation created by the Government of Canada to fund research infrastructure. The CFI's mandate is to strengthen the capacity of Canadian universities, colleges, research hospitals, and non-profit research institutions to carry out world-class research and technology development that benefits Canadians.

It's not evident that CFI funding has yet supported electric mobility initiatives, but it is clearly available for this purpose.

National Research Council

According to the National Research Council's Web site,[76]

> NRC is composed of over 20 institutes and national programs, spanning a wide variety of disciplines and offering a broad array of services. We are located in every province in Canada and play a major role in stimulating community-based innovation.

The Web site describes three instances of NRC involvement in work related to electric mobility. Two involve support for electric vehicle development in British Columbia through the Industrial Research Assistance Program.[77] One concerns research on batteries at NRC's Ottawa-based Institute for Chemical Process and Environmental Technology.[78]

Auto 21

According to Auto 21's Web site,[79]

> AUTO21 is a national research initiative supported by the Government of Canada through the Networks of Centres of Excellence Directorate and more than 110 industry, government and institutional partners.
>
> AUTO21 was formed to focus Canadian research expertise on the task of improving and enhancing the global competitiveness of the Canadian automotive industry. The Network currently supports over 230 top researchers working at more than 37 academic institutions, government research facilities and private sector research labs across Canada and around the world.

Work relevant to electric mobility presently supported by Auto 21 concerns fuel cells and hydrogen.

Program of Energy Research and Development

According to the Web site of Natural Resources Canada,

> The Program of Energy Research and Development (PERD) is a federal, interdepartmental program operated by Natural Resources Canada (NRCan). PERD funds research and development designed to ensure a sustainable energy future for Canada in the best interests of both our economy and our environment. It directly supports 40 per cent of all non-nuclear energy R&D conducted in Canada by the federal and provincial governments, and is concerned with all aspects of energy supply and use, with the exception of nuclear energy.

Part of PERD has or does focus on "development of fuel cells, their associated hydrogen technologies and infrastructures, and hybrid-electric vehicle components".[80]

Canadian Transportation Fuel Cell Alliance

According to the Web site of Natural Resources Canada,[81]

> The Canadian Transportation Fuel Cell Alliance is a $33 million federal government initiative that will demonstrate and evaluate fuelling options for fuel cell vehicles in Canada. Different combinations of fuels and fuelling systems will be demonstrated by 2008 - for light, medium and heavy duty vehicles. The initiative will also develop

standards and training and testing procedures as related to fuel cell and hydrogen technologies.

6. What is happening re: electric mobility in the U.S. and Europe

This section briefly describes some best practices favouring electric mobility in the United States and Europe. These include national and regional strategies, industrial policies, innovation, regulation, and training.

6.1. United States

On account of adoption of unusually stringent measures to control emissions from automobiles, California is often cited in discussions on electric mobility. To attack emissions from automobiles systematically, in 1967 the State created the California Air Resources Board (CARB), an agency attached to the California Environmental Protection Board, which reports directly to the Governor's office.

CARB's mission is to protect public health and natural resources by reducing emissions through the adoption of regulations and innovation approaches aimed at improving air quality. For the transport sector, CARB created the Zero-Emission Vehicle (ZEV) mandate as part of Low-Emission Vehicle (LEV) Regulations adopted in 1990.

The path towards electric mobility in California involves several dozen enterprises in four market sectors:

- Intelligent Transport System (ITS). This sector is among the most promising because the strong concentration of related companies in Silicon Valley.
- Fuelling infrastructure. This sector that benefited greatly from California's emissions-reduction regulations. The result has been an infrastructure for clean energy that is the most developed worldwide (electricity, biodiesel, methanol, natural gas and recently hydrogen, etc.).
- Electric buses. California has many innovative manufacturers and numerous transit demonstration projects.
- Individual electric vehicles and low-speed electric vehicles. This sector includes companies with several successes, among them EV Global Motors, Zap World, General Electric Motorcars, and LLC, a division of Daimler-Chrysler Company.

Highlights of U.S. strategies for Electric Mobility

In 1992, the *Intermodal Surface Transportation Efficiency Act* (ISTEA) established the Advanced Transportation Technology Consortia (ATTC).[82] Its purpose was to develop electric mobility technologies that would reduce emissions from automobiles, increase American competitiveness in this field, and reduce dependence on imported oil. (ISTEA was replaced in 1998 by the *Transportation Efficiency Act for the 21st Century*, also known as TEA-21).

The first of these consortia was created in California under the name WestStart-CALSTART in 1992.[83] This program is considered a model for partnerships that include private companies, research agencies, and the public sector, and have low research and development costs.

ATTC has received substantial research funding from the Departments of Defense, Energy, and Transportation. The Department of Defense, for example, funds the consortia for the purpose of developing a new generation of combat vehicles using hybrid traction technologies.

A national network of technology centres.

WestStart-CALSTART is part of a national network of technology centres/consortia concerned with electric mobility. Four of them are:

- Hawaii Electric Vehicle Demonstration Project (HEVDP), Honolulu, Hawaii[84]
- Electricore, Indianapolis, Indiana[85]
- Center for Transportation and the Environment (CTE), formerly the Southern Coalition for Advanced Transportation (SCAT), Atlanta, Georgia[86]
- Northeast Advanced Vehicle Consortium (NAVC), Boston, Massachusetts[87]

These centres have initiated more than 200 development projects for different technologies, involving more than 700 private companies. They are at times complimentary and at times competitive.

The centres have benefited from a range of funding:

- Federal funds conditional on the adoption of transportation plans designed to improve air quality.
- Funding for reforms in the public transport sector.
- Project support for new-generation commuter trains and for new transport modes (automated transport, electric shuttles, light rail transit, etc.).
- Support for use of clean fuels in urban buses.

The consortia have received funds from other federal programs, including ***FreedomCAR and Fuel Partnership***[88] aimed at reducing US dependence on imported oil:

- A total of $1.7 billion over five years of which $700 million is to be devoted to the development of technologies and infrastructure for the production, storage and distribution of hydrogen for use in electric drive vehicles.
- An additional amount of $273 million for research and development, in the 2004 budget.
- A provision for $4.4 billion in financial incentives until 2008 to support renewable energy initiatives and related technologies. The program consists mainly of purchase credits for hybrid and fuel cell vehicles.

Principal development activities of WestStart-CALSTART

- Heavy vehicles: Jointly with the US Army's National Automotive Center (NAC), WestStart-CALSTART is developing new technologies to improve the effective of heavy vehicle motors, mainly in the emission of greenhouse gases. WestStart-CALSTART and NAC manage the Hybrid Truck Users Forum, for the purpose of information exchange between the army and the private sector.[89]
- Clean technologies for buses: Public transport authorities are among key players in the introduction and trial of new electric mobility technologies. WestStart-CALSTART is seeking to develop technologies that are less polluting (fuel cells) and also less expensive, therefore affordable for the public transport authorities.
- Off-road utility vehicles: According to WestStart-CALSTART, this is one of the most interesting vehicle categories because it constitutes a market segment that contributes significantly to pollution but is less concerned with the vehicle autonomy questions—such as kilometres travelled—raised by technologies now available, including electric vehicles.
- Inter-modal transfer: WestStart-CALSTART acts as the secretariat for the activities of the Federal Transit Administration, a federal agency responsible for intermodal mobility in the U.S. Current projects concern the flexible urban mobility, principally links between public transit and rental vehicles (automobiles, bicycles, and scooters).

WestStart-CALSTART has recently focused on heavy vehicle research and development, mainly trucks. It is now working on projects subsidized by the U.S. Departments of Transportation and Energy that involve private-sector companies, including Mack Trucks, Caterpillar, and John Deer, and other centres including the National Renewable Energy Laboratory[90] and the Lawrence Livermore National Laboratory.[91]

6.2. Europe

Central to innovations in electric mobility are European Union regulations and directives relative to emissions from motorized vehicles. Most of the projects related to urban transport are carried out through the framework programs for research and technological development that support directly the implementation of a common transport policy in the EU.

Several projects are funded through related programs—energy, land use, the information society—and through other programs touching on local transport. The areas of interest are:

- Public transport
- Demand management and tolls
- Mobility management
- Urban goods movement
- Urban transport that respect the environment.

CUTE[92]

The *Clean Urban Transport for Europe* (CUTE) project is a demonstration project of 27 fuel cell buses fuelled by hydrogen and integrated in the public transport networks of nine cities (three buses per city) in seven countries. It is supported by €18.5 million provided by the European Union since the end of 2001, the largest project of this type.

The vehicle used for this project is the Citaro bus, manufactured by Evobus, based on a design by Daimler-Chrysler. These 27 buses have been tested across a two-year period, and conclusions from the project should be available early in 2006.

CIVITAS (CIty–VITAlity–Sustainability)[93]

This is another key EU project supporting sustainable urban transport. A budget of €50 million has been allocated for pilot studies in 19 cities. CIVITAS called for proposals along two principal themes: the development and perpetuation of public transport in the framework of sustainable mobility, and the use of alternative energies aimed at reducing greenhouse gases. CIVITAS sought "attractive solutions to replace individual automobiles in urban areas", aiming to "replace 20 per cent of gasoline used in transport with other fuels by the year 2020".

Electric Mobility Research and Development Funds

To complete the measures noted above, the European Union and its member countries allocate generous funds for research and development in actual transport systems.

The European Union defines the priorities for actions within the framework of development objectives. One objective is to support economic and social renewal in areas with structural difficulties. Across the period 2000-2006, €195 billion is being shared among member states. Funds are given as subsidies. For example, the Poitou-Charents region of France is receiving receives €305 million.[94]

Electric mobility—particularly electric and hybrid vehicles—is one of the key elements of this of this plan, which includes the following actions:

- Support for research programs linking laboratories to manufacturers.

- Support for the linking of projects with the incubation of companies with strong development potential.
- Support for structures aimed at the transfer of technologies, such as centres for technological resources, regional innovation, and technology transfer centres, and technology platforms.

At the moment, funding for initiatives related to fuel cells and hydrogen amount to about €58 million annually. Already, Germany has agreed to invest €99 million over the next three years in 44 research and development projects on fuel cells for stationary and mobile applications.

Fiscal and Regulatory Framework - France

The remainder of this section focuses on France,[95] which has perhaps gone the farthest in its support for electric mobility. To this end, France has a national policy and program that include fiscal, legal, and technical measures. Several relevant codes have also been adopted: in housing, construction, co-property ownership, environment, income taxation, and traffic regulation.

Fiscal measures favour the purchase or lease of electric drive vehicles. Local governments and manufacturers are targeted as first beneficiaries. These measures include assistance by Agence de l'environnement et de la maîtrise de l'énergie (ADEME) for acquisition or lease of electric vehicles of many types, ability to depreciate batteries and charging systems over 12 months, and an exemption from the tax on tourist vehicles. In addition, 60 of 100 departments (regions) have partially or exempted electric vehicles and their manufacturers from certain taxes. The national electricity company, Électricité de France (EDF), provides support for the installation of public charging stations.
Electric vehicles receive favoured treatment in traffic and parking regulations. Municipalities give priority to electric vehicles or low emission vehicles in traffic and parking. There are also measures to support the installation of charging stations in public and private places.

Operation 100 electric buses

This program was launched by ADEME, EDF, Groupement des autorités responsables des transports, and Union international des transports publics (UITP). Its aim is to encourage local governments to convert a part of their bus fleet to electricity, following the examples of several European cities including Rome, Florence, Bordeaux, Saint-Nazaire, and Liverpool. The purpose is to realize specific benefits principally in urban transport. In early January 2003, about thirty French cities operated electric buses.

To serve city centres and special districts, European cities are opting for clean transport modes that meet stringent environmental protection standards, notably streetcars and trolley buses. Bordeaux, France, in addition to its electric tramway, also has a fleet of six electric buses in operation since September 2001, which transport 300,000 passengers per year. In Saint-Nazaire, a line in operation since 2000 in the city centre and the docks area carries 100,000 passengers per year.

In France, for trolley buses with a capacity of 10-50 passengers and placed in service before July 2004, ADEME provided funds to cover 20 per cent of the extra cost over buses with internal combustion engines (i.e., €15,000-30,000). EDF added €15,000 per bus for the first four buses and €22,500-30,000 thereafter.

7. Goals for Electric Mobility

Considering the foregoing, and particularly the need to maximize the potential for energy savings, there are four overarching longer-term goals for electric mobility in Canada:

- Maximize the penetration of grid-connected vehicles and associated infrastructure.
- Maximize the penetration of battery-electric vehicles in places where grid-connected vehicles cannot be used.
- Maximize the penetration of hybrid or fuel-cell vehicles in places where grid-connected vehicles cannot be used and there are no charging facilities for battery-electric vehicles.
- In support of the foregoing, develop a national electricity grid that can accommodate sustainable, highly distributed electricity generation and widespread use of grid-connected vehicles.

Notwithstanding these goals, the Action Plan should aim at early implementation of electric mobility options across all modes. This will require identification of all opportunities for application of electric mobility and appropriate time frames for the introduction.

The above four goals should be considered in the context of the federal government's three overarching "strategic outcomes or ultimate results" for transport as set out by Transport Canada:[96]

- A safe and secure transportation system that contributes to Canada's social development and security objectives;
- An efficient transportation system that contributes to Canada's economic growth and trade objectives; and
- An environmentally responsible transportation system that contributes to Canada's sustainable development objectives.

Of these three goals, the last is the most relevant, but the goals for electric mobility must also be consistent with the first two. How electric mobility helps furtherance of the last goal is discussed above in Section 4.

8. Research and development needs to support the goals

Much of what is required for wider use of electric mobility in Canada involves well-established technology. Pure research and development, although always valuable, is not the key requirement so much as work on how best to implement what is already available.

8.1. What needs to be done

Several illustrative tasks are set out by topic in the partial list below.

Financial

- Determine the value of and how best to apply incentives for use of electric mobility until markets are sufficiently large to obviate the need for them. This will require careful analysis of the expected benefits and alternative approaches.

Regulatory

- Determine which likely applications of electric mobility can be facilitated by changes in laws, regulations, and standards. (For example, 'low-speed vehicles', discussed in Section 3.2, could be allowed on most roads. Another example concerns the quietness of electric vehicles, which could raise safety concerns in a population used to noisy vehicles. Should they be required to emit an audible warning in some situations? Yet another example might concern the value of requiring parking stalls also to serve as charging stations.)

Jurisdictional

- Identify issues that could arise for electric mobility through the multiplicity of jurisdictions for transport matters, and ways of resolving them.

Technical

- Some of the technical challenges require pure and applied research and development, for example, further battery improvement and all matters to do with production of hydrogen and fuel cells. Other technical challenges concern electric mobility applications. Examples are smart metering for electric vehicles (so that electricity consumed is automatically assigned to a vehicle), systems for rapid battery exchange at refuelling stations, and systems for grid connection in motion (so that a battery vehicle could be charged and powered while in use).

Power availability

Electricity generating and distribution systems are already stretched in parts of the country. Work needs to be done on how best to accommodate added loads for transport, and on how electric mobility can support electricity generation. On the latter point, a particular question concerns the amount of buffering of the grid against spikes in demand would be provided by regular attachment of a large electric vehicle fleet to the grid.[97]

8.2. Need for a research network

AUTO 21 provides an excellent model of how the above and other tasks may be facilitated. Development of a research network is discussed more fully in Section 9.

9. THE VALUE OF ESTABLISHING A NETWORK, AND WHAT IT COULD LOOK LIKE

9.1. Background

Experience has shown that advances in technologies and their applications are greatly facilitated when industry and governments work in partnerships to bring about desired changes. In furtherance of societal objects, governments may favour specific technologies, but the best results are often achieved when industry and government work together to address shared goals. In the case of electric mobility, there are likely many opportunities across Canada for collaboration among governments at all levels and private sector companies.

Governments have many tools that can help or hinder the implementation of electric mobility. Which tool will achieve which objective and for which benefit needs to be determined collaboratively. Government actions include:

- Permissive legislation (what mode and vehicle type is allowed to operate where).
- Operational regulations (safety standards, vehicle codes, maintenance standards, etc.)
- Financial (funding the operation completely or subsidizes carriers).
- Fiscal measures (tax penalties and incentives; depreciation schedules).
- Research and development support (funding and tax credits: through direct government programs or through assistance to universities, government funded research centres, and private-sector companies).
- Support for domestic business development and export activities.
- Monitoring (requiring activity reports from carriers and occasionally conducting studies).

- Policy development to influence all of the above.

The transport sector is large and includes many stakeholders, not only those involved in actual transport activities but also those who supply vehicles, fuels, repair and other services, and transport infrastructure. A well organized network of all stakeholders has the potential identify and emphasize desirable applications of electric mobility and to partner with appropriate government agencies to bring about appropriate changes. The uptake of the available technologies will be faster when they make economic sense.

Over the years, transport solutions have evolved with new technology, new regulations, and new emphases on specific sectors or modes. These evolutions are typically led by stakeholders who form necessary alliances. Some alliances are between private sector companies. Others involve the private sector and government agencies. The best known alliances are long-standing associations, including the Transportation Association of Canada and the Canadian Urban Transit Association. More recently established alliances tend to be formed along more specific interests. Examples are CEVEQ, Fuel Cells Canada, Canadian Transportation Fuel Cell Alliance (see Section 5.2), and Alternate Fuel Alliance.

As argued above, the pressures facing Canada's transport systems suggest the time is right to promote wider use of electric mobility. For electric mobility to reach its full potential in Canada, actions will be needed on several fronts, including:

- A careful analysis of which transport mode could benefit from electric mobility (including sub-activities within modes) and which electric mobility technologies are available in which time frame to fill that need.
- Permissive and supportive legislation and regulations at federal, provincial, and municipal levels for innovative electric mobility.
- Research and development projects within industry and within academia to address specific needs.
- Demonstration projects.
- Raising public awareness about the potential for electric mobility.

There are several ways the above points could be addressed:

- A government-sponsored and operated alliance such as the Canadian Transportation Fuel Cells Alliance (see Section 5.2), which represents more than 50 governments, associations, and businesses that play a key role in Canada's hydrogen and fuel-cell industries.
- A government-sponsored research centre that would work with private-sector companies and end users to seek innovative methods of introducing electric mobility in Canada's transport systems.

- A non-governmental research/experimentation centre such as CEVEQ.
- A national network embracing all stakeholders. This could lead to a national membership-based association with specific member-supported goals.
- All or combinations of the above noted.

Each option has its limitations in dealing with all the issues that need to be addressed if electric mobility is to take its proper place in Canada's transport arrangements. The ideal combination is the one that yields the required partnerships to move forward.

9.2. The former Electric Vehicle Association of Canada

The Electric Vehicle Association of Canada (EVAC) existed until the early 2000s. Its membership included major auto manufacturers, hydro companies, government agencies, component manufacturers, and others. Its stated mission was to be the premier advocate for Canada's electric transport industry. One of the reported reasons it folded was that its key industry members decided to focus their attention on longer-term fuel cell and hydrogen highway solutions.

EVAC intended to focus its activities on all forms of electric land vehicles including on-road, off-road, and low-speed vehicles, bicycles, specialty vehicles, and electric industrial vehicles.

9.3. Related organizations

There are many organizations operating at the national, regional or local level with programs that touch on electric mobility. Three of these are:

- CEVEQ (Centre for Experimentation in Electric Vehicles in Québec) offers business and governments at all levels broad expertise in the field of clean transport including management of demonstration projects and technology showcases, evaluation of electric vehicles (technology, operation, regulation), monitoring of technology and strategic trends, product development processes, networking and partnership development, coordination of economic, scientific and technical delegations, and organization of events.
- Fuel Cells Canada is focusing its activities on electric motors powered by fuel cells with on-board hydrogen manufacture. It is not looking at the broader applications of electric drive technologies.
- The Electric Vehicle Society of Canada is a Toronto-centred group of individuals who promote electric vehicles at every opportunity.[98] There are similar organizations in several Canadian cities. The Vancouver Electric Vehicle Association is particularly active.[99]

9.4. Conclusions regarding the formation of a network

Much has changed since EVAC folded a few years ago. Energy prices have risen sharply. Interest in all types of fuel-efficient vehicles has grown substantially. Canada has ratified the Kyoto Protocol for reduced greenhouse gas emissions and is hard pressed to meet its obligations under the Protocol. Auto manufacturers are beginning to embrace hybrid vehicles. Some Canadian jurisdictions provide financial incentives and regulatory support for electric mobility.

Planning has already started for actions necessary beyond Kyoto and early indications are that much more will be expected from all nations in reducing greenhouse gas emissions. This will place further pressures on Canada and other countries to explore all options reducing consumption of fossil fuels. Electric mobility can be a contributor of increasing importance to these goals.

The authors propose that:

- A new Canada-wide network to promote electric mobility in Canada is required to bring together all those who share an interest in the subject. No such national network currently exists. Much can be learned from the wide range of activities carried out by CEVEQ, the Washington-based Electric Drive Transportation Association, and from similar groups in Europe. Lessons can be learned too from the former EVAC.
- A Canadian network should be formed comprising those with an interest in electric mobility, including representatives of governments (who can facilitate the vehicles' introduction), academics (who can provide research support), vehicle and equipment manufacturers (who can make electric vehicles available), component and technology suppliers (who supply the vehicle manufacturers), energy providers, and end-users (public sector, private sector and individuals).
- The network could identify where short- and long-term options exist for the application of electric mobility in all surface transport modes.
- There is an important emerging industry in electric mobility in Canada with expertise in electric and hybrid vehicles, batteries, hybrid technologies, grid-connected technologies, etc. A network could stimulate this industry and provide valuable support to government agencies with a part to play in meeting the Kyoto Protocol or in supporting new industry sectors.

The new network could have the following organizational features:

- It should be membership based.
- Its suggested name is Electric Mobility Canada/ Mobilité Électrique Canada (EMC/MEC)

- Its membership should be open to manufacturers and distributors, end-users, government agencies, academics, and individuals.
- It should seek alliances with transport associations and related groups within and outside Canada.
- It could easily get started with CEVEQ providing secretariat services and being active across all of Canada. Eventually, it could have affiliated 'activity centres' in other places including B.C., Winnipeg (the new home of the Centre for Sustainable Transportation), southern Ontario, and Quebec.

9.5. Possible Vision for EMC/MEC

The proposed vision for EMC/MEC is this:

> *The Vision for EMC/MEC is* a *Canadian society that accepts electric mobility, in all its forms, as the first choice for the transport of persons and goods. This has been achieved though collaborative efforts between government at all levels and the private sector supported by an informed public faced with increasing energy costs and concerned about the impacts of burning fossil fuels on the environment and quality of life.*

This vision should be attainable by 2025.

9.6. Possible Mission Statement for EMC/MEC

> *To establish electric mobility, in all its forms, as the primary solution to Canada's growing transportation energy issues and to assist its members in the fulfillment of their mandates.*

9.7. Possible goals for EMC/MEC

To assist in providing greater direction towards achieving its mission, the goals need to reflect critical success factors and the vision of EMC/MEC. The goals proposed below have not been prioritized. Actions flowing from these goals would be the result of much analysis of costs and benefits.

- Raise public understanding of the larger issues affecting transport and create and maintain a positive image for the electric mobility industry.
- Define and establish the government/industry partnerships necessary to introduce electric mobility technologies as appropriate to achieve societal, economic, and transport objectives.
- Identify the actions required by industry and government agencies to accelerate the implementation of electric mobility. These actions could include research, funding, incentives, demonstrations, policies, regulations, etc.

- Secure funding and the necessary partnerships for an on-going research program to deal with technical and other issues related to the advancement of electric mobility.
- Provide members with current intelligence about the environment in which they do business, and develop strategies to assist them in successfully managing relevant issues.
- Maximize member access to information on technical and operational matters.
- Assist members to improve the efficiency, effectiveness, and overall competitiveness of their services and products.
- Maintain strong ties with other transportation industry stakeholders.

9.8. Possible organizational structure for EMC/MEC

CEVEQ is available to provide secretariat and other services for the launch of the proposed network. As the network grows in size and effectiveness, it will present CEVEQ with opportunities to reorganize itself and possibly become an activity centre for Electric Mobility Canada/Mobilité Ễlectrique Canada (EMC/MEC). It is important that early actions be taken to further identify market opportunities and strategies necessary to address these opportunities. As the network is organizing itself, CEVEQ could oversee the studies/research projects launched by the network.

The authors propose that EMC/MEC

- Should be registered as a national not-for-profit organization (NGO)
- Should be open to membership from the following areas:
    1. Manufacturers and suppliers
    2. Major end-users
    3. Labour
    4. Academia
    5. Government agencies
    6. Regional or local associations/societies promoting electric mobility
    7. Individuals
    8. Others as appropriate.
- Should be overseen by a board of directors that could have government representatives as non-voting members.

The authors believe that the proposed network will succeed for these reasons:

- It will be open to diversity, i.e., all that have an interest in the promotion of electric drives in surface transport.

- It will provide the needed connectivity between the stakeholders that does not exist presently, EVAC having disappeared and not having been replaced by another group.
- A broader membership base should allow for lower costs per member than a restricted membership base. It can also be structured to allow members to associate with the network's initiatives on a selective basis.
- It will provide the members with a voice representative of all aspects of electric mobility.
- It will allow the development of national initiatives to promote electric drive as a 'now' option for Canada and as an important solution to the pressing need to reduce greenhouse gases as required by the Kyoto commitment.

10. Recommendations

1. An Electric Mobility Network is to be established to promote, accelerate, and exploit the progress of electric mobility in Canada, with the goal of establishing a distinctive pan-Canadian electric mobility industry sector.

2. Development of the network is to be guided by an implementation committee comprised of private- and public-sector interests, to be named at the Vancouver workshop on December 6, 2005. Early network development activities, including projects, can be administered by CEVEQ until the network is operational.

3. An early task of the Network will be to identify *all* relevant private- and public-sector interests and initiatives in Canada.

4. The next tasks of the network will be to:
   - Identify the short- and long-term market opportunities for electric mobility technologies for all surface transport modes in Canada.
   - Determine research and development needs and appropriate funding and investment opportunities, in consultation with the businesses, institutions, organizations, and individuals identified in Recommendation 3.
   - Determine other actions necessary to allow the electric mobility industry to play a growing role in meeting Canada's transport needs for the movement of people and goods

5. A further task of the network will be to raise public awareness of the importance of electric mobility trends and the opportunities the trends provide.

6. The federal government has key roles to play in implementing the Kyoto Protocol, allowing the entry of new vehicles on streets and highways, and supporting promising industries. Accordingly, the federal government should be approached for *start-up*

funds for the network, to be supported more by provincial and business interests once the network is in place and functioning.

REFERENCE AND OTHER NOTES

1 In some applications—e.g., the funicular in Quebec City—the motor is stationary and the vehicle is moved via a cable. In electric motors, the torque providing rotary action is created by an electromagnetic effect. This effect can also be used in a linear configuration to provide a rare form of electric mobility known as magnetic levitation (maglev). Unless indicated, electric mobility in this paper refers to traction achieved with on-board electric motors.

2 There are two kinds of hybrid ICE-electric vehicle. In both, the ICE powers a generator that charges a battery that powers one or more electric motors that both drive wheels and convert kinetic energy into electricity during deceleration. In a *series* hybrid, all the traction is provided by the electric motor(s). In a *parallel* hybrid, both the ICE and the electric motor(s) drive the wheels through a common drive train. Confusingly, the most-used system, that in the Toyota Prius, is described by the manufacturer as a *series-parallel hybrid* because this manufacturer describes a parallel hybrid as one whose battery can be changed only when the motor is not providing traction. See http://www.toyota.co.jp/en/tech/environment/ths2/what.html (accessed October 11, 2005)

3 Most of the data in this paragraph are from an undated *Toronto Star* article reproduced at the *Mixed Power* Web site http://mixedpower.com/modules.php?name=News&file=article&sid=326 (accessed October 12, 2005). Data on the total of sales of new personal vehicles was derived from *New Motor Vehicle Sales*, July 2005. Statistics Canada, Catalogue no. 63-007-XIE.

4 Durbin D-A, Hybrid car sales soar in the U.S. in 2004, *Associated Press*, April 25, 2005, reproduced at http://www.commondreams.org/cgi-bin/print.cgi?file=/headlines05/0425-03.htm (accessed October 12, 2005).

5 Lazarony L, Is a hybrid car for you? *Bankrate.com*, April 27, 2005, at http://www.bankrate.com/brm/news/auto/20030507a1.asp (accessed October 12, 2005).

6 See the source detailed in Note 4.

7 See the source detailed in Note 5.

8 See the first source detailed in Note 3.

9 See *The Hybrid Experience Report* at http://www.hybridexperience.ca/Tax_Benefits.htm (accessed October 12, 2005).

10 See the U.S. Department of Energy's *Clean Cities Fact Sheet*, April 2005, at http://www.eere.energy.gov/cleancities/hev/pdfs/37651.pdf (accessed October 12, 2005).

11 As well as becoming richer, the U.S. federal support for hybrid purchases also becomes more complex. It becomes an intrinsically more valuable tax *credit* rather than a deduction, as high as US$3,400 per car (equivalent to a deduction of $13,600 where the marginal rate is 25%). However, the actual credit varies with the vehicle's rated performance and how many of the particular model have been sold. For an account of this feature of the 2005 *Energy Policy Act*, see Powers E, Hybrid Car Tax Credit - Energy Bill Goes Into Effect January 2006 at http://hybridcars.about.com/od/news/a/hybridtaxcredit.htm (accessed November 4, 2005).

[12] See http://www.orionbus.com/orion/0,,0-11-9892-1-486926-1-0-0-0-0-0-150-9892-0-0-0-0-0-0-0,00.html (accessed October 12, 2005). Note that 'fuel economy' is a term that has had a consistent meaning in the U.S. but that can now cause difficulties in application in Canada. Fuel economy refers to distance travelled per unit of fuel (e.g., miles per gallon). A 30% improvement in fuel economy means, for example, that a bus averages 6.5 miles per gallon rather than 5 miles per gallon. In Canada, the usual indicator of such performance is litres of fuel used per 100 kilometres, which corresponds to the scientific sense of efficiency (work done per unit of energy). A 30% improvement in efficiency could mean, for example that a bus uses 21 rather than 30 litres per 100 kilometres. Note that this is equivalent to a 43% increase in fuel economy (from 3.33 to 4.76 kilometres per litre). A given percentage improvement in economy is always less than the same percentage improvement in efficiency.

[13] See http://b2b.newflyer.com/index/PR_GM_Hybrid (accessed October 18, 2005).

[14] See the U.S. Department of Energy's *Energy Efficiency and Renewable Energy News* for October 26, 2005, at http://www.eere.energy.gov/news/enn.cfm (accessed October 29, 2005).

[15] See the source detailed in Note 14.

[16] See http://www.nyc.gov/html/tlc/downloads/pdf/hybrid_elec_veh.pdf (accessed October 29, 2005).

[17] The estimate is on Page 15 of Callaghan L, Lynch S, *analysis of electric drive technologies for transit operations: battery-electric, hybrid-electric, and fuel cells*. Boston, Massachusetts: North East Advanced Vehicle Consortium, August 2005.

[18] See http://www8.cpr.ca/cms/English/Media/News/Investors/2005/Hybrid+locomotives.htm (accessed October 12, 2005).

[19] See the Azure Dynamics' announcement at http://www.azuredynamics.com/may302005.htm (accessed November 6, 2005).

[20] Except for the estimate based on electricity prices ($0.10/kwh was assumed here), the foregoing information is from Moore B, The promise of plug-in hybrids. *Mother Earth News*, October-November 2005, available at http://www.evworld.com/modules/win_printdoc.cfm?section=article&docnum=897&doctitle=The%20Promise%20of%20Plug-In%20Hybrids (accessed October 13, 2005).

[21] See http://www.edrivesystems.com/Edrive-FAQ.html (accessed November 6, 2005).

[22] Two articles by Bill Moore on this consortium are in recent issues of *EVWorld.Com* and are available at http://www.rasertech.com/media/pdfs/PHEVconsortium_892.pdf and http://www.rasertech.com/media/pdfs/PHEVconsortium_895.pdf (accessed October 30, 2005).

[23] See http://www.nrcan.gc.ca/es/etb/ctfca/NewsReleases_e.html (accessed November 6, 2005).

[24] See http://www.americansolarchallenge.org/ (accessed November 6, 2005).

[25] The two manufacturers are Dynasty Electric Car Corp. of Delta, B.C., and Feel Good Cars Inc. of Toronto. Their Web sites are respectively at http://www.itiselectric.com (accessed October 13, 2005) and at http://www.feelgoodcars.com (accessed October 13, 2005).

[26] For the resolution of the challenge to the California ZEV legislation, see Automakers Drop Challenge of California Auto Plan, *Environment News Service*, August 13, 2003, at the URL below.
1. http://www.climateark.org/articles/reader.asp?linkid=24937. Accessed June 4, 2005.

[27] For the fate of TH!NK, Ford's electric vehicle, see the URL below.
1. http://biz.yahoo.com/ic/104/104119.html. Accessed May 26, 2005.

[28] The quotation is from Page 11 of the source detailed in Note 17.

[29] See http://visforvoltage.com/forums/index.php?s=5f2636046b50f60ddafe6021b819b468&act=Print&client=printer&f=6&t=1881 (accessed November 6, 2005)

[30] Cowan R, Hultén S, Escaping Lock-In: The Case of the Electric Vehicle. *Technological Forecasting and Social Change*, 53, 61-79, 1996.

[31] Manufacturer's information is at http://www.segway.com (accessed November 6, 2005).

[32] See http://www.segway.com/connect/newsletters/general_009.html (accessed November 6, 2005).

[33] See Spears, J, City says no way to Segways, *Toronto Star*, October 13, 2005.

[34] See http://lcn.canoe.com/infos/regional/archives/2003/07/20030724-231735.html (accessed November 6, 2005).

[35] See http://www.tc.gc.ca/cdt/projets/routier/i/5475.htm (accessed November 6, 2005).

[36] One source claimed that pleasure boats in the U.S. in the early 1990s caused almost as much atmospheric pollution as all automobiles, and spilled 15 times as much oil into waters as the *Exxon-Valdez*. (See Mele A, *Polluting for Pleasure*. (New York: Norton), 1993. The U.S. and Canadian governments have done much since then to tighten relevant regulations.

[37] Information about the *Queen Mary 2* is at http://www.cunard.com/images/Content/QM2Technical.pdf (accessed October 28, 2005).

[38] Box 1 is based on data for a recent year provided by the respective transit properties to Hamish Campbell of the Canadian Urban Transit Association. Note that data for Toronto are for the City of Toronto only (responsible for more than 80 per cent of the transit trips in the Toronto region), whereas other data are for the respective urban regions.

[39] These totals are from a Web site maintained by David Wyatt of the University of Manitoba at http://home.cc.umanitoba.ca/~wyatt/alltime/other-modes.html (accessed October 11, 2005).

[40] For an overview of one aspect of the controversy, see http://en.wikipedia.org/wiki/General_Motors_streetcar_conspiracy (accessed November 6, 2005).

[41] See Gilbert R, Perl A, *energy and transport futures*. Report prepared for the National Round Table on the Environment and the Economy, June 2005.

42 International Energy Agency, *Electricity Information 2005*. Paris, France: International Energy Agency, 2005.

43 Islam M, Fartaj A, Ting D S-K, Current utilization and future prospects of emerging renewable energy applications in Canada. *Renewable and Sustainable Energy Reviews*, 8, 493-519, 2004.

44 See http://www.energy.gov.on.ca/index.cfm?fuseaction=english.news&body=yes&news_id=113 (accessed November 6, 2005).

45 The company's Web site is at http://www.bombardier.com (accessed November 6, 2005).

46 The company's Web site is at http://www.ballard.com/ (accessed November 6, 2005).

47 The company's Web site is at http://www.hydrogenics.com/ (accessed November 6, 2005).

48 The company's Web site is at http://www.itiselectric.com (accessed November 6, 2005).

49 The company's Web site is at http://www.electrovaya.com (accessed November 6, 2005).

50 The company's Web site is at http://www.tech-m4.com/eng/about/ (accessed November 6, 2005).

51 For Azure Dynamics, see the source detailed in Note 19.

52 The company's Web site is at http://www.magma.ca/~fesi/ (accessed November 6, 2005).

53 The fuel use data in Box 2 are from the U.S. Department of Energy fuel economy ratings at http://www.fueleconomy.gov/ (accessed November 7, 2005). Assumptions about energy losses are similar to those in the second source in Note 58. Coal is assume to power 42% of Canada's electricity. Environment Canada's conversions factors for GHG emissions from the various fuels and coal were used.

54 For more information about the Mitsubishi vehicles, see http://www.japanesecarfans.com/news.cfm/newsid/2050824.001/page/1/mitsubishi/1.html (accessed November 7, 2005). The fuel use data come from Bossel U, *On the way to a sustainable energy future*. Paper presented to the Intelec '05 conference, Berline Germany, September 2005, at http://www.efcf.com/reports/E16.ppt (accessed November 7, 2005).

55 For these losses, see the sources in Note 58 below concerning Box 3.

56 A University of Washington Web site provides useful information about PRT, and links to numerous other sites. It is at http://faculty.washington.edu/jbs/itrans/ (accessed October 20, 2005).

57 See the second source (Mazza and Hammerschlag) detailed in Note 58.

58 Box 3 was adapted from Figure 9 of Bossel U, *Does a Hydrogen Economy make Sense?* Paper presented at the European Fuel Cell Forum, Lucerne, Switzerland, July 4-8, 2005, available at http://www.efcf.com/reports/E13.pdf (accessed October 30, 2005). Another estimate indicates losses of 57% for the fuel cell cycle vs. 10% for the electricity cycle, and 20% if there is to be battery storage. This is by Mazza P, Hammerschlag R, *Carrying the Energy future: Comparing Hydrogen and Electricity for Transmission, Storage and Transportation*. Settle, Washington: Institute for Lifecyle Environmental As-

sessment, June 2004, at http://www.ilea.org/downloads/MazzaHammerschlag.pdf (accessed October 30, 2005). This analysis differs from that of Bossel in five ways: (i) Bossel includes a 5% loss for 'conditioning' the electricity prior to electrolysis, (ii) Bossel assumes a 20% loss during compression rather than 8% (more, says Bossel, if hydrogen is liquefied); (iii) Bossel assumes a 10% rather than a 3% loss during transmission; (iv) Bossel adds a 20% loss for storage, etc. at the fuel cell site; (v) Bossel assumes fuel cells are 50% efficient rather than 60%; and (vi) Bossel adds a 5% loss for conversion of the fuel cell output.

59 See the second source (Mazza and Hammerschlag) detailed in Note 58.

60 Currently, maintenance costs for electric vehicles can be higher because of low fleet volumes. But, electric vehicles are intrinsically much simpler than ICE vehicles, with many fewer moving parts, and potentially much lower maintenance costs.

61 Authors of a forthcoming paper (Hammerschlag R, Mazza P, Questioning hydrogen. *Energy Policy*, 33, 2039-2043, 2005) have noted that if 1% of the battery capacity of the *current* U.S. vehicle fleet were available to the grid, the entire U.S. generating capacity of 800 gigawatts could be provided from the batteries for 8 minutes. It might be further estimated that if electric vehicles were commonplace, at least ten times as much storage capacity could be available, providing a buffer for 90 minutes a day or more, thereby substantially reducing the generating capacity required for meeting peak demand. Electric vehicle owner would buy electricity during off-peak periods and return it during peak periods, making considerable gains on account of the price difference that could partially or completely offset battery costs.

62 Government of British Columbia's Bulletin SST 085, *Alternative Fuel Vehicles and Alternative Motor Fuel Tax Concessions*, at http://www.rev.gov.bc.ca/ctb/publications/bulletins/sst_085.pdf (accessed October 14, 2005).

63 Retail Sales Tax (RST) refund available for vehicles powered by alternative fuels. See www.trd.fin.gov.on.ca (accessed October 14, 2005).

64 See Transport Canada's Web site at http://www.tc.gc.ca/tdc/about/introducing.htm (accessed November 6, 2005).

65 The list of programs is from http://www.tc.gc.ca/tdc/projects/road/i/menu.htm (accessed October 29, 2005), where there are links to descriptions of each program.

66 See Transport Canada's Web site at http://www.tc.gc.ca/mediaroom/releases/nat/2005/05-h202e.htm#bg (accessed November 6, 2005).

67 See Transport Canada's Web site at http://www.tc.gc.ca/programs/environment/most/pembina.htm (accessed November 6, 2005).

68 See Transport Canada's Web site at http://www.tc.gc.ca/programs/environment/most/electricvehiclesocietyofcanada.htm (accessed November 6, 2005).

69 The quotations are from http://www.tc.gc.ca/programs/environment/UTSP/menu.htm and http://www.tc.gc.ca/programs/environment/UTSP/whatisashowcase.htm (accessed October 29, 2005)

[70] For the Gatineau and Montreal UTSP proposal, see http://www.tc.gc.ca/programs/environment/UTSP/gatineau.htm (accessed October 29, 2005).

[71] See http://www.tc.gc.ca/programs/environment/UTSP/montreal.htm (accessed October 29, 2005).

[72] See Transport Canada's Web site at http://www.tc.gc.ca/programs/environment/atvpgm/menu.htm (accessed November 6, 2005).

[73] See Transport Canada's Web site at http://www.tc.gc.ca/programs/environment/atvpgm/reports/tests/adv_9903.pdf (accessed November 6, 2005).

[74] See Industry Canada's Web site at http://tpc-ptc.ic.gc.ca/epic/internet/intpc-ptc.nsf/en/h_hb00001e.html (accessed November 6, 2005).

[75] See the Web site of the Canadian Foundation for Innovation at http://www.innovation.ca/index.cfm (accessed November 6, 2005).

[76] See the National Research Council of Canada's Web site at http://www.nrc-cnrc.gc.ca/aboutUs/corporateoverview_e.html (accessed November 6, 2005).

[77] See http://irap-pari.nrc-cnrc.gc.ca/success/canadian_electric_e.html and http://irap-pari.nrc-cnrc.gc.ca/success/azure_e.html (accessed November 4, 2005). Information about NRC's Industrial Research Assistance Program is at http://irap-pari.nrc-cnrc.gc.ca/main_e.html (accessed November 4, 2005).

[78] See http://expert.nrc-cnrc.gc.ca/profiles/icpet-itpce/yoo_yeong_8588_e.html (accessed November 4, 2005).

[79] See Auto 21's Web site at http://www.auto21.ca/home_e.html (accessed November 4, 2005).

[80] See the part of Natural Resources Canada's Web site concerning PERD at http://www2.nrcan.gc.ca/es/oerd/english/view.asp?x=685&mid=7 (accessed November 6, 2005).

[81] See the information about the Canadian Transportation Fuel Cell Alliance at http://www.nrcan.gc.ca/es/etb/ctfca/index_e.html (accessed November 6, 2005).

[82] Overview information about ATTC is at http://scitech.dot.gov/research/energy/ (accessed November 6, 2005).

[83] Information about WESTART-Calstart is at http://www.calstart.org/ (accessed November 6, 2005).

[84] Information about HEVDP is at the Web site of the Hawaii Center for Advanced Transportation Technologies at http://www.htdc.org/hcatt/ (accessed November 6, 2005).

[85] Information about the Consortium for Advanced Technology Development (Electricore) is at http://www.electricore.org/ (accessed November 6, 2005).

[86] Information about CTE is at http://www.cte.tv/tech.htm (accessed November 6, 2005).

[87] Information about NAVC is at http://www.navc.org/ (accessed November 6, 2005).

[88] Information about the FreedomCAR and Vehicle Technologies Program is at http://www.eere.energy.gov/vehiclesandfuels/about/partnerships/freedomcar/index.shtml (accessed November 6, 2005).

[89] Information about the Hybrid Truck Users Forum is at http://www.calstart.org/programs/htuf/ (accessed November 6, 2005).

[90] Information about the National Renewable Energy Laboratory is at http://www.nrel.gov/ (accessed November 6, 2005).

[91] Information about the Lawrence Livermore National Laboratory is at http://www.llnl.gov/ (accessed November 6, 2005).

[92] This project is directed by the General Directorate for Energy and transport in the European Union

[93] A slide show describing the CIVITAS project is available at http://europa.eu.int/comm/dgs/energy_transport/rtd/6/call_2/doc/2003_09_24_info_day_civitas_alfayate_rommerts_en.pdf (accessed October 27, 2005).

[94] The transport sector in the region represents about 2,431 manufacturers who employ 20,000 persons and generate activities of €32.5 million annually (2001). In advanced ground transport, the region has two world class companies: Groupe Henri Heuliez and Groupe Saft. Heuliez has linked with Groupe Dussault for the development of the Cleannova electric deliveryvan, which being demonstrated with the Post Office. Saft, a world leader in battery manufacture, and Johnson Controls, which makes automobile batteries, have announced an accord for a joint-venture project to develop and market batteries for electric and hybrid vehicles.

[95] Information about the French programs was provided by CEVEC.

[96] See Transport Canada's Web site at http://www.tc.gc.ca/finance/rpp/05-06/en/Section_1.htm#1_2_1 (accessed November 6, 2005).

[97] See the discussion in Note 61.

[98] For Information about the Electric Vehicle Society of Canada see http://www.evsociety.ca/ (accessed November 6, 2005).

[99] For information about the Vancouver Electric Vehicle Association see http://www.veva.bc.ca/ (accessed November 6, 2005).