The Centre for
Sustainable Transportation

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Centre for Sustainable Transportation
15 Borden Street
Toronto, Ontario
Canada M5S 2M8

Phone (416) 923-9970
Fax (416) 923-6531
E-mail cstctd@web.net
Web site www.web.net/~cstctd

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THE FUTURE OF AVIATION

Aviation news in Canada in 1999 focused on the economic sustainability of the industry, particularly that of the second largest carrier, Canadian Airlines International, purchased in December by the largest carrier, Air Canada. Absent from the hundreds of metres of newsprint on the topic was any discussion of the *environmental* sustainability of aviation.

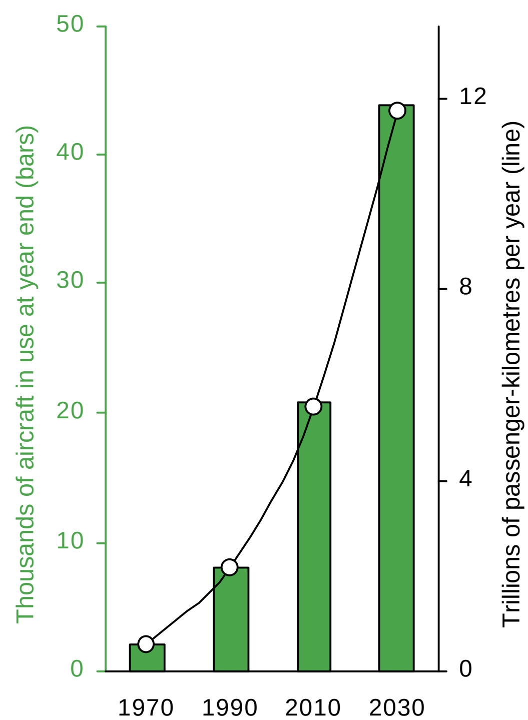
As will be suggested in this issue of the *Monitor*, **of all transport modes, aviation is the least environmentally sustainable at present, and shows the least promise of becoming sustainable.** Indeed, if industry projections of world aviation activity come to pass, aviation will become a more important contributor to potential climate change during the next few decades than either personal vehicles or trucks, which are presently the two main transport contributors. Climate change is the major—but certainly not the only—factor in environmental unsustainability.

Box 1 shows recent and projected growth in commercial aviation fleets and in passenger movement by air.[1*] Box 2 on the next page shows recent and projected growth in energy use by aircraft, and also by personal vehicles and heavy trucks, the two modes that presently use the most energy.[2] Box 3 shows recent and projected contributions to global warming by these three modes; and indicates that by 2030 aviation's contribution could exceed that of trucking or of travel by personal vehicles.[3] Box 4 sets out recent Canadian and U.S. patterns of air travel.

Two factors are likely to curtail the kind of growth illustrated in Box 1. One is the need to sharply reduce emissions of greenhouse gases and thereby avoid further climate change. The other will be the lack of availability of low-cost aviation fuel.

Box 1 CST

Actual and projected aircraft in use and passenger activity, worldwide, 1970-2030

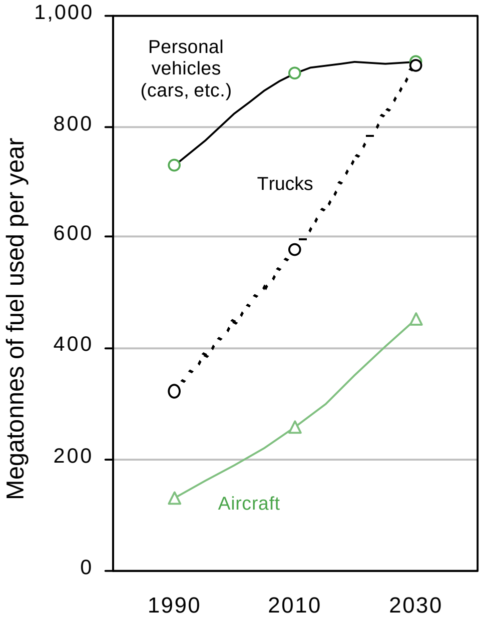


Sources: Boeing Corporation; Intergovernmental Panel on Climate Change

The *Sustainable Transportation Monitor* is the collective expression of the Board of Directors of the Centre for Sustainable Transportation. Members of the Board are listed on Page 14. The views and analyses presented here are not necessarily those of the organizations with which members of the Board are affiliated. * The superscript numbers in the text refer to reference notes that begin on Page 15.

Box 2 CST

Energy use by personal vehicles, trucks, and aircraft, worldwide, 1990-2030



Sources: Intergovernmental Panel on Climate Change; Organization for Economic Cooperation and Development

As a consequence, the kind of growth predicted by the industry is unlikely to happen. A more likely scenario is that aviation activity will actually decline over the next 30 years. The current rate of investment in airport infrastructure will be found to be unjustified.

AVIATION AND CLIMATE CHANGE

Largely because commercial aircraft are usually well occupied and automobiles are not, fuel use per passenger-kilometre (one person travelling for one kilometre) is only slightly higher on average for aircraft than for cars. **However, because exhaust gases appear to have a much more potent greenhouse effect 10-11 kilometres above ground—where modern jets fly—than at sea level, burning a given amount of fuel in a plane appears to be equivalent to burning about three times as much fuel in a car.**[4]

What this would mean in practice is that a person flying from Toronto to Paris and back—some 12,000 kilometres—would make a global warming contribution similar to that from travelling about 36,000 kilometres by car, assuming average occupancies of typical automobiles and aircraft. The average Canadian travels about 16,000 kilometres by car each year; **so one return trans-Atlantic trip could be equivalent in global warming impact to more than two years of automobile travel.**

This and a wealth of other information can be gained from the most significant publication during 1999 relevant to sustainable transportation. It is a 383-page report by the Intergovernmental Panel on Climate Change (IPCC) entitled *Aviation and the Global Atmosphere*.[5] The IPCC comprises several thousand scientists assembled by the World Meteorological Organization and the United Nations Environment Program. Its mission is to gather information and provide advice about climate change. Some 350 scientists were involved in the preparation of the *Aviation* report,[6] which is the IPCC's first assessment of the global environmental impact of an individual industry.[7]

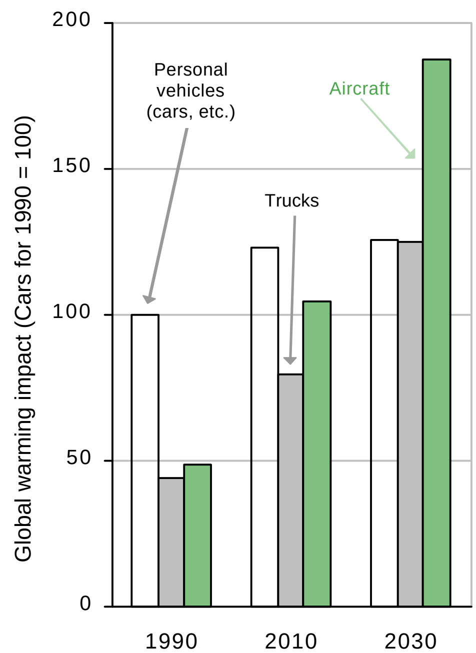
Aviation now accounts for about 10 per cent of all motorized person-kilometres worldwide (compared with roughly 60 per cent for automobiles and two-wheeled vehicles, 20 per cent for buses, and 10 per cent for rail).[8] There is more than *twenty times* as much air travel today as there was in 1960, although the rate of growth has slowed recently, from about ten per cent to about five per cent per year,[9] a rate that the industry expects will continue beyond 2015.[10] Movement of people by automobile, the next fastest growing mode, has been increasing worldwide at an annual rate of about 4.5 per cent.[11]

Air freight comprises less than one per cent of all tonne-kilometres moved by motorized transport worldwide, although in terms of the *value* of the freight the proportion of all freight carried by air is perhaps as much as 40 per cent.[12] There has been even more growth in air freight than in air travel; although it has also slowed recently from about 15 per cent to about 8 per cent,[13] still higher than the 7-per-cent annual increase in movement of freight by truck, the next fastest growing mode.[14]

Transport makes use of about 22 per cent of all fossil fuels used worldwide. Aviation is responsible for about an eighth part of this 22 per cent, and for similar proportions of carbon dioxide emissions.[15] The fuel intensity (litres per 100 kilometres) of aircraft in use has declined by about 40 per cent over

Box 3 CST

Global warming impact of transport modes, worldwide, 1990-2030

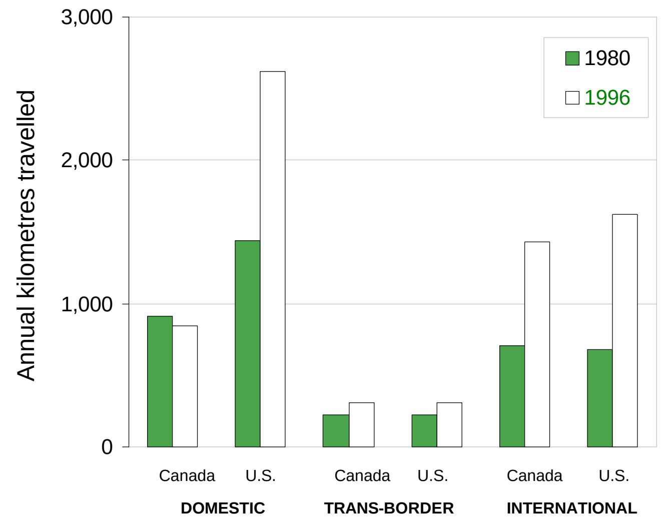


Sources: Intergovernmental Panel on Climate Change; Organization for Economic Cooperation and Development

Box 4

CST

Per-capita travel by air originating in Canada and the United States, 1980 and 1996



Sources: Transport Canada; U.S. Bureau of Transportation Statistics

the last few decades (although more slowly recently),[16] and occupancy levels have risen.[17] As a result of these two factors, *the fuel use per passenger-kilometre of air travel is now on average only a little higher than that for cars, varying in both cases greatly with actual occupancy and with age and type of vehicle*.[18]

Because about 80 per cent of air freight is carried in passenger aircraft,[19] it is difficult to determine an overall figure for energy use for air freight. When freight-only aircraft are used, the energy consumption per tonne-kilometre of freight moved is 5-10 times higher on average than when goods are carried by truck, the next most intensive mode.[20]

Even though the energy use and carbon dioxide emissions associated with air travel are now similar to those for travel by car, *the actual contribution of aviation to potential climate change is much higher*. Engines operating at high altitudes produce additional greenhouse effects.

The main such effect is production of ozone—a greenhouse gas—resulting from the injection of nitrogen oxides (NO_x) into the upper troposphere and lower stratosphere. NO_x are produced by all engines burning fuel in air, and NO_x production facilitates ozone formation at all altitudes. However, the effect appears to be much greater at the height that most modern aircraft cruise—about 10-11 kilometres—than at or near sea level. Moreover, ozone at these higher altitudes is more effective as a greenhouse gas. High-flying aircraft also produce water vapour and line-shaped contrails, both of which have global warming effects. Offsetting these contributions to climate change to some degree is a second effect of NO_x emissions at high altitudes, which is to reduce concentrations of methane, another greenhouse gas.[21]

The atmospheric chemistry is complex, but the result is simple: **burning a litre of jet fuel at a height of 10 kilometres appears to have two to four times the global warming effect of burning the same amount of fuel at sea level**—whether for a plane, car, train, bus or boat.

Thus, given the slightly greater fuel use per passenger-kilometre and the much greater impact of burning that fuel, this means that each kilometre a person travels in the air has the global warming impact of some three or more kilometres travelled by car—hence the above conclusion about a trans-Atlantic trip having as much effect as more than two years of automobile travel.

That's the bad new about the global effects of aviation. The good news in the *Aviation* report is that the increased ozone in the stratosphere due to NO_x emissions from aircraft slightly offsets the depletion of the ozone layer caused by release of CFCs and other coolants. The result is a slight reduction in damaging ultraviolet radiation reaching the Earth's surface.

There's some good news too about the local effects of aviation, a matter hardly discussed in the IPCC report. The main impacts are aircraft noise and the pollution of air, land, and water from airport activity, including transport to and from airports, aircraft taxiing, and the use of auxiliary power units. Noise is historically the main local issue associated with airports, and regulations have been tightened greatly over the last few decades. Aircraft design has changed accordingly. However, there is a considerable trade-off with energy efficiency—quieter aircraft use more fuel, other things being equal[22]—which may account in part for the recent slowdown in efficiency improvements.

PATTERNS OF AIR TRAVEL IN CANADA

Canada appears to be one of the few countries in the world in which domestic aviation did not grow relative to population during the period 1980-1996. Box 4 shows the difference from the United States in this respect.[23] Domestic per-capita passenger-kilometres flown in the U.S. increased during this period by 82 per cent, while in Canada there was a 7-per-cent *decline*.[24]

The difference in domestic air travel between Canada and the U.S. is made starker by the similarities in international air travel (i.e., travel outside the U.S. and Canada). Box 4 shows that between 1980 and 1996 per-capita international air travel from Canada increased by 102 per cent. Such travel from the United States increased by 139 per cent. And whereas the average U.S. resident flies three times as much domestically as the average Canadian resident, he or she flies only 13 per cent more internationally.

Domestic aviation in Canada could have declined because of the ongoing reorientation of business and trade from east-west to north-south. The data for trans-border air travel (i.e., between Canada and the U.S.) in Box 4 suggest this may not have been so. Other explanations point to the growing fragmentation of Canada, to her historically poor transport data, to the structure of the domestic airline business, and to the higher domestic airfares in Canada. To the extent that the last two factors played a role, **the recent reorganization of the industry to provide less competition for journeys within Canada could reduce domestic air travel more. In this respect, the reorganization would be contributing to sustainable transportation**.

IS THERE HOPE FOR AIR TRAVEL?

Air travel as we presently know it is not sustainable. Industry projections of aviation activity fly in the face of rapidly emerging concern to reduce human impacts on the global environment. Unlike for other transport modes—where for the most part there are potentially satisfactory alternatives to present vehicles and infrastructure—there is no alternative to fossil-fuel-using aircraft engines in sight.

Aviation activity will be curbed initially by increasing fuel prices, a consequence of the imminent end of cheap oil (see Page 5 below). Fuel prices are already a more significant factor for air travel than for other modes, even though aviation fuel usually incurs much lower taxes.[25] Moreover, air travel seems unusually sensitive to price increases. Studies suggest that a 10-per-cent increase in airfares can reduce travel by as much as 27 per cent, whereas a 10-per-cent increase in gasoline prices reduces automobile use by only two to three per cent.[26]

But to be sustainable, fossil fuel use is going to have to be reduced to well under half of 1990 totals,[27] and thus to a very small fraction of projected 2030 totals (see Boxes 2 and 3). Such changes are unlikely to occur only through fuel price increases. Already, the Swiss and other governments are raising the specter of rationing air travel.

There seems to be little possibility of a technological fix that will make industry projections feasible. Improvements in fuel efficiency will continue, but the laws of physics will continue to mean that getting aircraft into the air and keeping them there will require much energy, and there is nothing on the horizon that can replace fossil fuels.

Air travel over land can be replaced by train travel, which can be fueled by renewable sources and for distances of up to 1,000 kilometres can be as convenient as air travel. Intercontinental travel will require a radical change. One option is to revert to travel by sea, which can also depend on renewable sources. Another is travel by airships, which are already showing a renaissance. Both modes require much longer travel times than travel by airplane, but better communications will allow the time to be used productively. A business trip to Europe may require up to ten days of travel rather than two, but the extra travelling time could be an opportunity for productive work and leisure.

There is a profusion of airport expansion worldwide, including in Canada.[28] Major new airports have been completed recently in Japan, Hong Kong, and the U.S.; Asia's largest airport is under construction near Seoul, South Korea. Billions of dollars are being invested in Canadian facilities, notably Toronto's Pearson airport. These investments have all been predicated on the kind of expansion in aviation activity indicated in Box 1. **They would appear to be unwise investments.** They may also be counterproductive in that they pre-empt investments in infrastructure for transportation that is more sustainable.

REDEFINING PROGRESS

The late, much-missed John Hartman, Vice-Chair of the Centre for Sustainable Transportation's Board of Directors, believed strongly that unsustainable transport activity is driven in part by perverse thinking about economic progress. He inspired what follows.

When trying to get a better handle on what might be real economic progress, a good place to start is the 50-page paper *Why Bigger isn't Better: The Genuine Progress Indicator—1999 Update*,[29] produced by Redefining Progress (RP), a San Francisco-based organization. RP seeks "to ensure a more sustainable and socially equitable world for our children and our children's children". The organization's title comes from its core belief that conventional notions of economic progress are an impediment to human welfare.

RP's main peeve concerns the Gross Domestic Product (GDP), "a gross tally of money spent—goods and services purchased by households or government and business investments, regardless of whether they enhance our well-being or not. Designed as a planning tool to guide the massive production effort for World War II, the GDP was never designed to be a yardstick of economic progress; yet, gradually it has assumed totemic status as the ultimate measure of economic success. When it rises, the media applaud and politicians rush to take credit. When it falls, there is hand-wringing and general alarm."

GDP rises with many factors that are not normally associated with well-being: " … crime, divorce, legal fees, and other signs of social breakdown … car wrecks, medical costs, locks and security systems, and insurance." RP notes that pollution is a double gain to the economy: oil production adds to the GDP; cleaning up oil spills and other pollution add even more. Moreover, "in treating the depletion of our natural resources as income rather than depreciation of an asset, the GDP violates both basic accounting principles and common sense". GDP does not acknowledge the contributions to well-being of unpaid work, relaxation, fresh air or indeed anything that does not have a price and is not bought and sold.

RP has developed the Genuine Progress Indicator (GPI), which corrects for the above anomalies and more, notably income inequality. While the GDP of the United States rose almost every year for a total increase of 164 per cent per capita between 1950 and 1998, the per-capita GPI rose only by 23 per cent over the same period (up 64 points to 1980, down 41 points thereafter). The GPI corresponds more to people's perception of progress or the lack of it, says RP. As well, a focus on GDP encourages short-term prosperity and long-term debts.[30]

Much of what constitutes movement towards sustainable transportation would lower the GDP. Less fossil fuel use and fewer vehicles would mean reduced GDP and thus, according to conventional thinking, reduced well-being. But, because they imply less use of non-renewable resources, they could mean an increased GPI and thus, according to RP, increased well-being. **Thus, as John Hartman believed, if an indicator such as the GPI were to replace the GDP in economists' and journalists' accounts of how well we are doing, we might be more likely to make progress towards sustainable transport.**

Adoption of the GPI rather than the GDP as the basic indicator of our economic well-being could help dispose of one of the two main objections to sustainable transportation, which is that it would be bad for the economy. Use of the GPI may even help address the second main objection, which is that unsustainable transportation is so desirable it could never be replaced. If today's transportation systems were shown in the course of application of the GPI to foster poverty, inequity, crime, and so on, there may be more reason to move on to something else.

> Box 5 — CST
>
> **The Centre's definition of Sustainable Transportation**
>
> A sustainable transportation system is one that:
>
> - allows the basic access needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem health, and with equity within and between generations.
> - is affordable, operates efficiently, offers choice of transport mode, and supports a vibrant economy.
> - limits emissions and waste within the planet's ability to absorb them, minimizes consumption of non-renewable resources, reuses and recycles its components, and minimizes the use of land and the production of noise.

SUSTAINABLE TRANSPORTATION PERFORMANCE INDICATORS

John Hartman was the inspiration for the Centre's project with the above title, which got under way in January 2000, funded by Transport Canada and Environment Canada.

Indicators are statistics designed to allow significant trends to be monitored. They are selected, targeted, and compressed variables that reflect public concerns and are of use to decision-makers.[31]

Sustainable Transportation Performance Indicators (STPIs), when developed, will allow monitoring of progress towards sustainable transportation. **John Hartman had a simple and surprisingly novel idea: define what you mean by sustainable transportation and develop indicators for the components of the definition.**

An early task of the Centre was to develop a definition of sustainable transportation, reproduced in Box 5. John Hartman deconstructed the definition into 17 elements amenable to quantification. For example, the element 'minimizes the use of land' could be quantified as the amount of land used for transport infrastructure; the element 'affordable' could be quantified as the cost of transportation, perhaps stated in relation to average income.

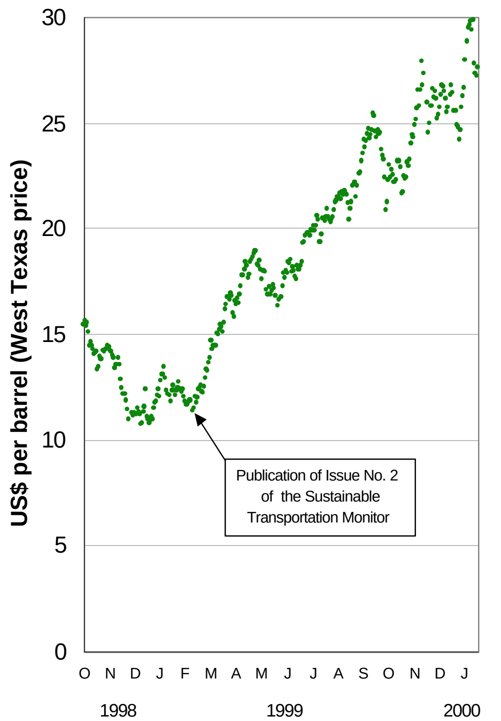
It may be that 50-100 such indicators will be needed in the first attempt to flesh out the definition in this way. Developing such a long list of indicators is the goal of the first phase of the Centre's STPI work. As well, we will review the world literature on transport indicators. The review will be useful in developing the long list of indicators and in other ways. This work is due for completion in June 2000.

A later phase of the STPI project will refine the long list into a short list of about 10 indicators and a very short list of about four indicators. The short list will be directed at transport professionals and the very short list at the general public. The idea of the very short list is to be able to use it to say at the end of a year, for example, 'that transport became more environmentally sustainable during the year and more economically sustainable, but it became less socially sustainable.'[32]

Development of such indicators will help identify the critical variables in attainment of sustainable transportation and the most important barriers and gaps in knowledge. It will help refine what we mean by sustainable transportation. Above all, it will allow useful monitoring of progress towards—or away from—sustainable transportation.

Box 6 CST

Crude Oil Prices: October 1998-January 2000



Source: Alaska Department of Revenue

UNIVERSITY CURRICULUM PROJECT

This is the major project the Centre has under way at the moment. Its goal is to bring consideration of sustainability into university-level courses on transportation across Canada, in a consistent and comprehensive way.

An initial survey of 52 universities identified over 1,000 courses in several disciplines—from economics to engineering—in which at least half the content concerned transportation. A more detailed evaluation was made at three universities. Results showed that about three quarters of transportation courses at the three selected universities had no environmental content, thus confirming the need to continue this project. A subsequent phase, funded by Transport Canada and Environment Canada, enabled development of three valuable analytical resources: an instructor survey instrument, a database of transportation course syllabi, and an international survey of educational efforts in sustainable transportation.

The current phase, funded by the federal government's Climate Change Action Fund, will result in production of three reports to be produced before the end of 2000. They will have the following titles:

- *Course Content for the Environmental Training of Transportation Professionals in Canadian Universities*
- *Canadian University Faculty Approaches and Attitudes to Training Transportation Professionals*
- *Enabling Tomorrow's Transportation Professionals to Address Climate Change*

The third report, which will summarize the other two, will form the basis of a series of private-sector supported Canada-wide workshops to be held early in 2001. The workshops will further the development of university-level curricula that emphasize the attainment of sustainable transportation.

OIL UPDATE

The lead article in the last issue of the *Monitor* was entitled, "Sustainable Transportation and the End of Cheap Oil". It reviewed recent work and concluded that oil prices will rise steeply during the present decade because production of cheap, conventional oil will begin to fall (i.e., oil that can be pumped from the ground, usually under it own pressure) even though transport and the other uses of oil appear set to increase. We noted Canada's special position as the world's major producer of non-conventional oil from oil sands and other sources. The high environmental costs of this production mean that transportation using such oil is less sustainable than transportation that uses conventional oil.

Almost as soon as the last issue of the *Monitor* was published, the price of oil began to rise, as shown in Box 6.[33] Now, a year later, the price is three times higher than it was in early 1999.

The immediate reason for the price increase is an eight-per-cent cut in oil production by members of the Organization of Petroleum Exporting Countries (OPEC), instituted in March 1999.[34] The reason for OPEC's cut in production is unclear. A likely reason is awareness of the factors outlined in the last issue of the *Monitor*, notably the poor prospects for new discoveries of oil and the continued growth in demand. What the OPEC countries may be doing is flattening the production peak a little and thus bringing forward the inevitable price increases by a few years at the cost of small amounts of later income.

The result in Canada has been the predicted massive investment in production of non-conventional oil. Production in 2010 is now projected to be 65 per higher than the official projection for that year that was reported in last year's *Monitor*. Non-conventional oil is now set to comprise 50 per cent of Canadian oil production in 2010, compared with last year's estimate of 38 per cent and the present 34 per cent.[35]

The environmental costs of non-conventional oil are already several times higher than those of conventional oil.[36] As the easier-to-recover materials are extracted, the environmental costs of production of vehicle fuel from oil sands will likely increase, and thus the environmental costs of transport using such fuel. The greater environmental impact will be offset to a degree by increases in energy prices and a resulting moderation of energy use. In the short and medium term at least, the overall result could well be a worsening of the environmental impacts of transportation.[37]

THE TRANSPORTATION TABLE'S OPTIONS PAPER

The Kyoto Protocol to the United Nations Framework Convention on Climate Change was negotiated in December 1997 and signed by Canada in April 1998. It would—if ratified by enough countries[38]—commit Canada to reducing its emissions of several greenhouse gases (GHGs) to six per cent below 1990 levels, by 2008-2012.[39] By December 1999, there were 88 signatories to the Protocol, and it had been ratified by 19 national governments (not yet including Canada, or any of the other 37 countries required by the Protocol to reduce or moderate their GHG emissions).[40] The current target year for ratification appears to be 2002.[41]

Canada is behaving as though the Kyoto Protocol will be ratified. The National Climate Change Process was set in motion early in 1998. The NCCP established 16 tables (forums of interested parties), including the Transportation Table. This Table issued its *Foundation Paper* at the end of 1998 and a paper entitled *Transportation and Climate Change: Options for Action* (the *Options Paper*) at the end of 1999.[42]

The 244-page *Options Paper* is a profoundly important document, not the least because of who was behind it. It involved most of the major transportation interests in Canada, and represents a high degree of agreement among them, except on increases in fuel taxes. As well as the 25 members of the Table itself, there were several hundred other participants in the Table's work, including members of numerous Groups, Subgroups, and Committees associated with the Table, the consultants who conducted the 24 research studies commissioned by the Table, and the several dozen federal government employees who assisted the Table.[43] Moreover, the Transportation Table was the only one of the 16 NCCP tables to undertake nationwide consultations.

The Table's mandate was "to analyze options that achieve progressively greater reductions [in emissions of GHGs] within transportation until reaching or, if possible, going beyond a six-per-cent reduction from 1990 levels". **The mandate thus implied that transport's share of the reductions in GHGs required to meet the Kyoto commitment would be at least equal to transport's share of all GHG emissions.**

The GHGs were stated in terms of megatonnes (Mt) of carbon dioxide equivalent. For example, emissions of nitrous oxide, another of the six GHGs covered by the Kyoto Protocol, are multiplied by 200 because N_2O is about 200 times as potent a GHG as CO_2.[44] GHG emissions from all Canadian sources are to increase from 601 Mt in 1990 to 764 Mt in 2010 (a 27-per-cent increase) if no special action is taken to reduce them.[45] According to the Transportation Table, GHG emissions from transport are to increase from 148 to 193 Mt (a 31-per-cent increase); the required *reduction* in transport GHGs is from 193 Mt to six per cent below 148 Mt, i.e., 54 Mt.[46]

The strategy of the Table was comprehensive. It examined 113 options (measures to reduce GHGs) in five categories, assessing the GHG reduction potential of each measure and the cost and feasibility of implementing it. Measures were evaluated according to ten criteria,[47] and given one of four ratings, from 'most promising' to 'unlikely'.[48] The Table's results for the 113 measures are summarized in Box 7.[49]

The Table also considered six scenarios involving increases in fuel taxes. One of these involved raising taxes

Box 7

CST

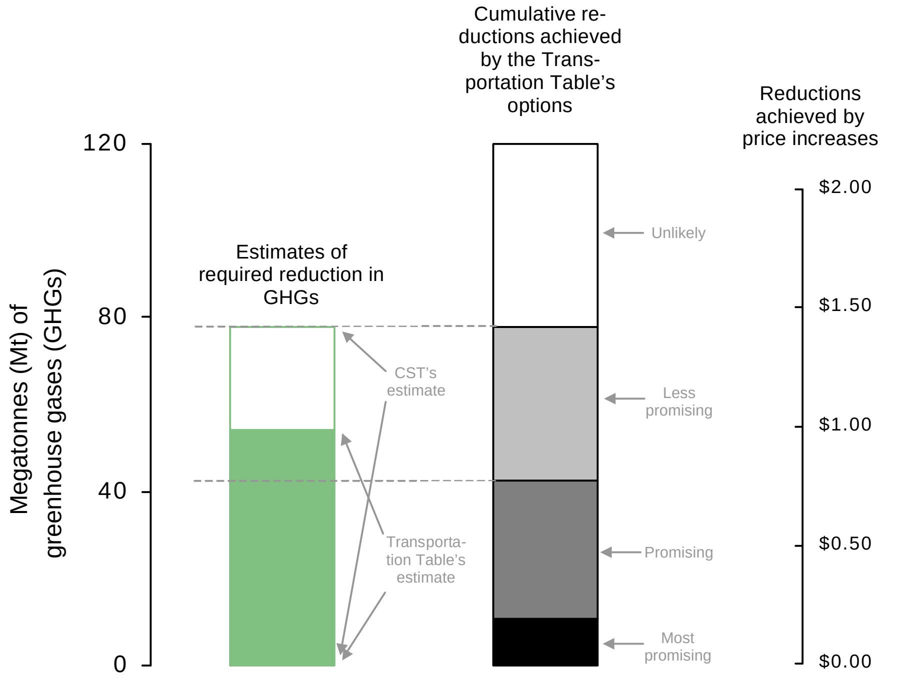
NCCP Transportation Table: Measures (options) by category with estimated GHG reduction in megatonnes of CO_2 equivalent

	Passenger		Road Infra-structure		Freight		Road vehicles and fuels		Off-road		Totals		Cumu-lative reduc-tion
	No. of meas-ures	GHG reduc-tion	No. of meas-ures	GHG reduc-tion	No. of meas-ures	GHG reduc-tion	No. of meas-ures	GHG reduc-tion	No. of meas-ures	GHG reduc-tion	No. of meas-ures	GHG reduction	
Most promising	7	3.7	5	5.0	2	2.0	0	-	0	-	14	10.7	10.7
Promising	7	10.1	4	1.5	8	7.0	8	8.9	3	4.3	30	31.8	42.5
Less promising	6	12.9	4	11.7	9	2.4	4	8.5	0	-	23	35.5	78.0
Unlikely	9	6.6	0	-	26	11.7	11	23.7	0	-	46	42.0	120.0
Totals	29	33.3	13	18.2	45	23.1	23	41.1	3	4.3	113	120.0	

Source: Transportation Table, National Climate Change Process (Canada)

Box 8 CST

Transportation Table's and revised GHG reduction targets, effects of Table's options, and approximate effects of fuel-price increases



Source: Transportation Table, National Climate Change Process (Canada)

enough to secure the whole of the required 54-Mt reduction in GHGs. The required increase, according to the Table would be to about $1.40 per litre in today's dollars.[50] The Table also looked at the effects of raising gasoline taxes in urban areas by 1, 2, and 4 cents per litre and at raising road gasoline and diesel taxes across Canada by 10 and 20 cents per litre. The increase for urban areas would reduce GHG emissions by about 0.4, 0.8, and 1.5 Mt, respectively; the Canada-wide increases—which would be for diesel fuel as well as gasoline—would reduce GHGs by about 7.5 and 12.6 Mt, respectively. **The Table did not reach agreement as to whether to include fuel tax increases among the options put forward**, and they were not further assessed.

The Table noted that implementation of the 'most promising' and 'promising' measures would reduce GHG emissions by 42.5 Mt (see Box 7)—just under 80 per cent of the Table's target of 54 Mt. The 'most promising' measures for the most part involve voluntary actions that would readily meet with public support. The 'promising' measures would involve "financial incentives, infrastructure improvements and targets to encourage new technologies, improve energy and transportation efficiency, and change practices and behaviour". The average cost of implementing the 'most promising' and 'promising' measures would be -$4.3 per tonne of GHG emissions reduced (i.e., they would save money). The Table noted too that further reductions—i.e., up to and beyond the stated Kyoto target of 54 Mt—would involve the use of some of the 'less promising' measures "that are more difficult and expensive, and generally involve restricting activity or introducing pricing mechanisms".[51]

Heading the Table's list of 'most promising' measures is the introduction of tax exemptions for employer-provided transit benefits—e.g., provision of monthly passes—estimated to have a cost of -$941 per tonne of GHG emissions reduced (i.e., it would provide an enormous financial benefit). This measure was proposed in the last issue of the *Sustainable Transportation Monitor* as a "good first step" towards sustainable transportation. Recommending inclusion of this measure in the 2000 federal budget to all MPs has been the only 'political' action undertaken by the Centre. (The requested tax exemption was not included in the budget.)

The Transportation Table has done its job of pointing the way towards how emissions from the transport sector can be reduced enough to meet transport's share of the Kyoto commitment. It provided additional value by extending its analysis to 2020, and by projecting emissions of several local and regional pollutants not covered by the Kyoto Protocol (e.g., particulates and sulphur dioxide).

An important question about the Transportation Table's work concerns the adequacy of the projections on which it was based, which were the responsibility of another part of the National Climate Change Process, the Analysis and Modelling Group. The basic projection is that GHG emissions will increase at an average annual rate of 1.5 percent over the period 1990-2010.[52] But **the actual annual rate of increase in transport energy use—and thus GHG emissions—during the 1990s has been 2.2 per cent**, even higher since 1996.[53]

If the average rate for the 1990s is sustained until 2010—which in light of recent increases may be a conservative estimate—there will be a 53-per-cent increase in emissions from transport, not the 31-per-cent increase used by the Transportation Table. The corresponding required reduction in GHG emissions from transport will be 78 Mt rather than 54 Mt.

Thus, whereas Transportation Table may have believed it was providing

for about 80 per cent of the required emissions reduction with its 'most promising' and 'promising' measures, it was—if the above projection is valid—accounting for only 46 per cent of the required reduction (42.5 Mt out of 78 Mt). Instead of GHG reductions of 12 Mt beyond those to be achieved with the Table's 'most promising' and 'promising' measures, the requirement is now for further reductions of 36 Mt.[54]

There are two general options for doing this. One would be to implement all of the measures that the Transportation Table identified as 'less promising'. These would almost exactly provide for the required reduction. The other would be to raise road fuel taxes by about 50 cents per litre.[55] (Or there could be some combination of tax increases and 'less promising' measures.) Box 8 shows the required reductions in relation to the Table's targets, the estimated effects of the different categories of measures, and the Centre's estimates of the *approximate* effects of different fuel-price increases.[56]

The 'less promising' category includes some controversial measures: for example, urban road pricing, reducing expressway speed limits to 90 km/h, applying incentives and penalties (feebates) at the time of purchase for low- and high-fuel-using vehicles, and requiring improvements to truck tires.

Some of the other questions about the Transportation Table's work are to do with the treatment of aviation. Part of the concern is with the Table's estimates of emissions of GHGs from aviation activity. The Table severely underestimated the 1990 contributions of Canadian domestic and international aviation (the total should be 15.9 Mt not 10.6 Mt) and provided an unrealistically low projection for 2010 (the Centre proposes a total of 28.2 Mt rather than the Table's 17.6 Mt).[57]

However, the Table's responsibility was for domestic aviation only. According to the Kyoto Protocol, responsibility for securing reductions in GHGs from international aviation lies with the Montreal-based International Civil Aviation Organization rather than with national governments acting directly. Thus, it may have been more appropriate for the purposes of the Kyoto Protocol to exclude international aviation from Canada's GHG emissions total. In this case, the Transportation Table *overestimated* aviation's 1990 GHG contribution (it should be 8.0 Mt not 10.6 Mt) and provided an unrealistically *high* projection for 2010 (the Centre proposes 9.4 Mt rather than the Table's 17.6 Mt—i.e., a relatively low increase in emissions from domestic aviation corresponding to the activity pattern seen during the 1980s and 1990s described here in Box 4).[58]

Even though the Table may have given a high estimate of the increase in emissions from domestic aviation, only one aviation measure was included among its 'most promising' and 'promising' categories. The measure concerned improving flight routing and ground operations, estimated to reduce GHG emissions from aviation by 1.6 Mt by 2010. Even if the Centre's estimates and projections were accepted rather than the Table's, this measure would nevertheless be enough to reduce GHG emissions from domestic aviation to about three per cent below the 1990 level.

The real aviation greenhouse issue for Canadians is international aviation, which grows at a much faster rate than most of the rest of the transport sector.[59] If the altitude multiplier effect noted on Page 3 is factored in, international aviation is by far the most rapidly growing contributor to potential climate change. Indeed, largely because of the high growth rates of transborder and other international aviation, Canadian aviation's contribution to global warming by 2010 is set to be equivalent to annual emissions of close to 85 Mt of GHGs, well over a third of transport's total contribution.

Even though it was not the Table's immediate responsibility to address most of the aviation issues, it can be argued that because of the huge potential impact of this transport mode on climate change **the Table should have given aviation much more attention than it did**.

There are several other concerns that can be raised about the *Options Paper*, all significant but of lesser importance than the two raised above. One is the Table's rather thin consideration of the potential roles of telecommunications as both replacing and enhancing transport activity.[60] Another is its treatment of the potential impact of the world oil supply situation, covered in detail in the last issue of the *Monitor* and discussed briefly here on Page 5.

World oil prices are set to rise at a much higher rate than assumed by the NCCP's Analysis and Modelling Group; the current price is already close to 50 per cent above the Group's 2010 projection of US$20.60 per barrel.[61] There will be some effect on consumption of oil, but the larger short-term effect of the price rise could be to encourage the use of unconventional oil—chiefly from Alberta oil sands—whose production results in much higher emissions of GHGs per barrel than conventional oil.[62] These higher emissions rates are taken into account to some extent by another part of the NCCP, but because the unconventional oil is used mainly for transport—and therefore effectively increases transport's share of GHG emissions—**there should have been more acknowledgement of world oil supply factors in the Transportation Table's analysis**. The Table took an opposite position, specifically excluding certain increases from oil and gas production that both the Analysis and Modelling Group and Environment Canada, following international practice, consider as part of transport's share of emissions.[63]

Notwithstanding the above concerns, the Transportation Table has produced

Box 9 CST

Comparison of the Canadian and The Netherlands' strategies for the transport sector with respect to the Kyoto Protocol

Item	Canada	Nether-lands
1. Projected population increase 1990-2010 (%)	16.4%	6.3%
2. Road transport GHGs in 1990 as a % of GHGs from all sectors	20.6%	13.5%
3. Road transport GHGs in 1990 per capita (tonnes)	4.4	1.9
4. Increase in road transport GHGs per capita, 1990-1997 (%)	6.5%	11.7%
5. Projected 'business-as-usual' (BAU) increase in road transport GHGs per capita, 1997-2010 (%)	5.3%	8.6%
6. Required* GHG reduction per capita from 2010 BAU (tonnes, road transport only)	1.4	0.6
7. Number of measures set out in an *Options Report*	115	14
8. Number of measures finally selected for implementation	Not yet known	9
9. Percentage of reduction requirement* that could be met by identified (Canada) or selected (Netherlands) measures	80%	29%

* Assumes transport sector's GHG reduction target in each country is the same as the target for all sectors (6% in each case)

Sources: Transportation Table, National Climate Change Process (Canada); The Netherlands Ministry of Housing, Spatial Planning and the Environment; World Bank

a productive analysis that could serve Canadians well in addressing the difficult issues concerning how to move towards sustainable transportation. It may be a good thing that the Table did not take on the concerns about aviation and about the adequacy of the projections on which its work was based. **Accommodation of these concerns could well have prevented the Table's greatest accomplishment, which was achieving agreement that action must be taken.** However, these concerns should be addressed in subsequent stages of the work of the National Climate Change Process in order to provide for full compliance with the spirit of the Kyoto Protocol.

The primary message the Centre wants to convey is this: **GHG emissions from transportation are being substantially underestimated by the National Climate Change Process**, mostly for reasons beyond the immediate purview of the Transportation Table. As a consequence, the 'most promising' and 'promising' measures identified by the Table fall far short of what will be required to ensure that by 2010 total GHG emissions from the transport sector will be below 94 per cent of the 1990 level. **Many other transport-related measures will have to be implemented before 2010 if this target is to be met. These measures will likely have to include price increases for transport fuels as well as many of the Table's 'less promising' measures.**

The second message is that **there is a serious aviation problem that does not appear to be being addressed**. The International Civil Aviation Organization (ICAO), which has responsibility for most aviation emissions, may not be acting in a way that will lead to reductions commensurate with requirements of the Kyoto Protocol.[64] The Government of Canada, a member of ICAO, should be prompted by the National Climate Change Process to ensure that ICAO acts in an appropriate manner.

There is substantial agreement among climatologists and atmospheric scientists that reductions in GHG emissions of more than 50 per cent below 1990 levels will be required to avoid potentially catastrophic instability in the global climate during the 21st century.[65] In this light, Canada's six-per-cent Kyoto commitment is no more than a good beginning. **Meeting this relatively modest commitment is essential if we are to come to terms with the larger reductions required after 2010, and thus provide our grandchildren and their grandchildren with the well-being and security that present generations in Canada have enjoyed.**

COMPARISON WITH THE NETHERLANDS

As noted, Canada is only one of many countries going through the throes of deciding how to meet a Kyoto commitment. It may be instructive to compare in some detail Canada's effort to date with that of a country that is in some ways comparable.[66] The Netherlands has reached the point of cabinet-level decisions regarding some of its Kyoto Protocol commitments. Like Canada, she has an overall GHG emissions reduction target of six per cent below 1990 levels.

Box 9 provides comparisons between the two processes.[67] Item 1 shows the key difference between the two countries. **Canada's high rate of population growth is the main reason Canada will have a harder job meeting its Kyoto commitment than several other countries.**[68]

Items 2 and 3 indicate that road transport is relatively more important in Canada than in the Netherlands. Items 4-5 show that *per capita* emissions grow at a higher rate in the Netherlands, but not enough to offset Canada's higher 1990 level; consequently, assuming the transport targets for both countries are the same as their overall targets, the reductions in emissions required per person are much higher in Canada (Item 6).[69]

Items 7 and 8 illustrate a key difference in approach between the two countries: the number of instruments considered.[70]

Item 9 reflects what may turn out to be a key difference in strategy between the two countries. The Netherlands has departed from the requirements of the Kyoto Protocol in that its government expects that half of its obligation will be met abroad using processes of "joint implementation", "clean development mechanism", and "emission trading". The Kyoto Protocol requires that a "principal part" of the obligation be met by reductions in GHG emissions within the country in question.[71] Canada's position in this respect is not yet clear.

Because the measures selected by the Netherlands will reduce GHG emissions from transport by only 29 per cent of what could be transport's share of the overall reduction target, it seems that the balance will be met from a combination of activities abroad and larger reductions in other sectors. Again, Canada's position in this respect is not yet clear.

A major problem inherent in the kind of strategy adopted by the Netherlands, which makes a relatively modest demand on the transport sector, is that larger reductions may remain to be achieved after the Kyoto process, and that these may be even more difficult to achieve. A basic rule for all interventions—whether with respect to medical conditions or unacceptable behaviour—is that early intervention is more effective and less painful than later intervention.

RESEARCH AND ACTIONS ON ROAD FREIGHT TRANSPORT

The challenges posed by high rates of growth in road freight transport have been highlighted in the two previous issues of the *Sustainable Transportation Monitor*. Worldwide, road freight activity has been growing by about seven per cent a year. Its global warming impact, now only a little more than half that of personal automobiles, is set to exceed that of personal automobiles during the next few decades (see Box 3 in this issue of the *Monitor*). Road freight activity in Canada during the 1990s increased at a lower rate than the world average, but much more rapidly than activity involving other road vehicles.[72]

Of particular concern are emissions of small, breathable particles from diesel engines. These engines power most road freight activity worldwide and—in several countries although not Canada—a substantial proportion of personal automobiles. **The California Air Resources Board has concluded that diesel exhaust is a likely or probable human carcinogen.** The German Environmental Protection Agency has concluded that currently produced diesel-fueled cars carry a more than ten-fold cancer risk compared with currently produced gasoline-fueled cars. The risk from current diesel-fueled heavy-duty trucks and buses is 38 times higher than from comparable vehicles fuelled by natural gas.[73]

As a result, there has been much recent research activity—and, to a lesser extent, policy activity—directed towards reducing road freight transport and its impacts. Standards and the technology required to reduce several of the local impacts of diesel engines are in sight, particularly in respect of particulates and the precursors of ground-level ozone (smog).[74] **Much less progress is being made in reducing the fuel intensity of heavy-duty vehicles and the amount of road freight activity, which together determine most of the global impacts**.

One focus of current research that could lead to reductions in global impacts, particularly in Europe and Japan, concerns the *logistics* of road freight transport and associated aspects of fleet management. Here are some of the significant findings:

- About two thirds of the increase in road freight activity has been related to increases in average haulage distance; one third has resulted from increases in amounts carried. A key factor in rising haulage distances is concentration of production in efficient, centralized facilities. Another factor is the broadening of both markets and sources of materials. Very large increases in transport costs would be required to offset the cost-savings achieved through centralization and to induce local sourcing and marketing.[75]
- There is large variability in the fuel efficiencies of comparable fleets. A UK study indicated that if the performance of the worst-performing two thirds were to be raised to the average of the best-performing one third, a 30-per-cent savings in overall fuel use for road freight could be realized.[76]
- The most promising measures for improving fuel efficiency are those targetted at making better use of existing vehicle capacity. This has three main aspects: (i) avoidance of empty running; (ii) more complete loading of vehicles (more with respect to space than to weight); and (iii) scheduling to avoid congestion and idling. Concerning the third point, there is a particular interest in refrigerated trucks, which use about 20 per cent more fuel on average than comparable vehicles without refrigeration. Refrigerated trucks have been found to spend on average only about a quarter of their time in motion, and most of this is during periods of heavy traffic flow.[77]
- Small road freight vehicles are of special concern, particularly in Japan, and particularly vehicles operated by the goods producing and distributing companies rather than those operated by specialist common carriers. Comparisons of actual operations in Japan indicate that such vehicles use over 12 times as much fuel per tonne-kilometre as heavy-duty trucks, and more than three times as much as is used by light-duty trucks operated by specialist carriers.[78]

Some of these findings would appear to apply to North America; others may not. **What is clear is that taking effective action to reduce the global impacts of road freight transport depends on sophisticated understanding of its logistical and related factors**. One of the consultants for Canada's National Climate Change Process's Transportation Table noted that such understanding does not seem to be available in North America, in large part due to inadequate data collection.[79]

Sweden is perhaps the country in which the most action has been taken to date towards reducing emissions from freight transport, including road freight. At the initiative of the late

John Hartman, Swedish practice was highlighted at the September 1999 annual conference of the Transportation Association of Canada.

What characterizes the Swedish approach above all are complementary focuses on 'green procurement' and on 'transport chain environmental management'. Green procurement means that companies include environmental performance among their criteria for choosing suppliers of transport services. Transport chain environmental management involves life-cycle analysis of the impacts of manufacture, distribution, use, and retirement of products, all from the perspective that manufacturers are responsible for the whole life cycle of their products. For many products, life-cycle analysis shows that freight transport is the largest source of associated emissions.[80]

Transport chain environmental management follows standard environmental management practice:

- identify significant environmental aspects of freight transport and their impacts
- set policies to reduce such impacts, at the highest level in the company
- establish performance objectives
- provide adequate responsibility and resources
- monitor performance and take corrective action.

All of this is backed by the Swedish government, including the introduction in 1998 of an eco-label for freight transport. Preliminary results indicate that several companies have or will shortly have reduced carbon dioxide emissions from their transport operations by some 50 per cent.

HISTORY OF MOTORIZED TRANSPORT ACTIVITY

The Centre was pleased to play a role during 1999 in the preparations for the forthcoming five-volume *Encyclopedia of Global Environmental Change*, which will include a version of what appears here as Box 10.[81]

It should be stressed that Box 10 shows *per capita*, *worldwide* data. Recent total transport activity rose much more steeply because of the growth in the world's population, which doubled from 3.0 to 6.0 billion between 1959 and 1999.

The left-hand panel of Box 10 shows the dominance of the automobile in the movement of people, roughly equivalent now to all other modes combined, including walking and bicycling. The right-hand panel shows the surprising dominance of ocean freight, which involves many more tonne-kilometres of transport activity than all other modes combined (probably also including carriage by humans and animals, which could not be estimated).

Ocean freight is a near invisible form of transport. Ocean freighters use less fuel per tonne-kilometre than other freight modes (on average very roughly half of that of rail, one tenth that of trucks, and one seventieth that of air freight[82]). Nevertheless, because of its large share of actual transport activity, ocean freight comprises about eight per cent of all transport fuel use[83] (and thus global environmental impacts), and about a quarter of all fuel used for freight transport—substantially more than any other freight mode except trucking.

The responsibility for securing compliance of ocean transport with the Kyoto Protocol lies—like aviation—with an international organization rather than with national governments, in this case the International Maritime Organization, headquartered in London, UK. Review of the IMO's Web site revealed no activity related to compliance with the requirements of the Kyoto Protocol.[84]

Ocean freight requires further scrutiny in relation to its global environmental impacts and the processes for reducing them. These matters may be addressed in a future issue of the *Sustainable Transportation Monitor.*

PROMISING SIGNS

Current progress towards sustainable transportation almost entirely comprises improvements in technology. The progress is considerable. Some of the highlights of the last year or so are detailed in the promising signs set out below.[85] An important caution is that the best available analysis suggests that such improvements will be able to amount to less than half of the effort required to secure sustainable transportation; the larger share will have to come from changes in transport activity (e.g., mode shifts and overall reductions in activity).[86] Thus the promising signs, while valuable in the short term, are only part of answering the sustainable transportation challenge, and should serve to highlight the lack of progress in the main part of the challenge. Here are the promising signs:

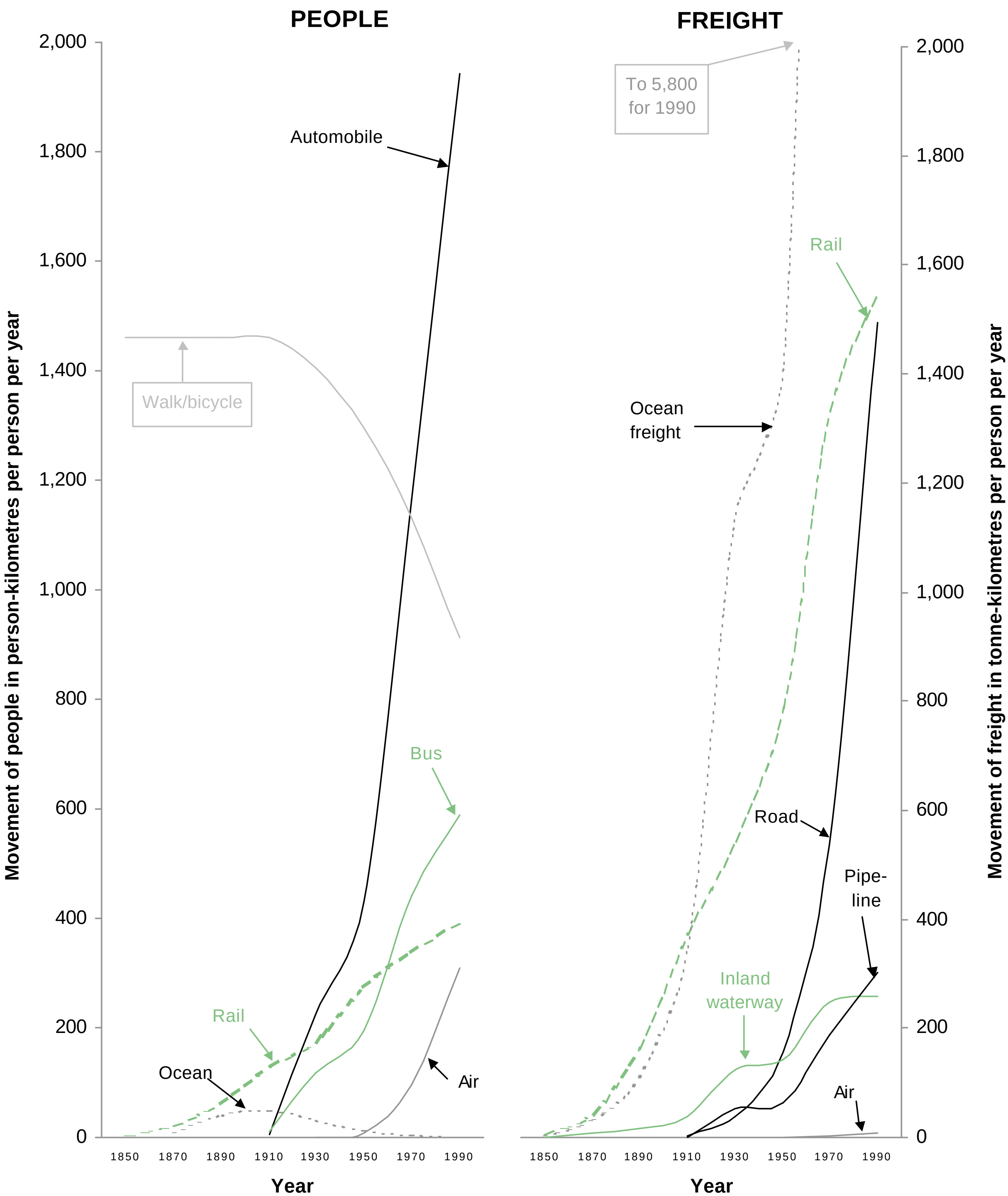
- The European Union has adopted directives regarding both light-duty and heavy-duty vehicle emissions that tighten standards considerably. The EU and auto manufacturers agreed to reduce carbon dioxide emissions per kilometre driven by 25 per cent by 2008.
- The U.S. Environmental Protection Agency (EPA) and the automobile industry have agreed to the voluntary introduction across the country of California's trail-blazing and stringent low-emissions vehicle standards (with likely Canadian compliance). The EPA announced a further tightening of heavy-duty vehicle standards. Meanwhile, California further tightened its standards, notably requiring that diesel-fueled vehicles meet the standards of gasoline-fueled vehicles, and that all personal passenger vehicles (including sport utility vehicles,

(Continued on page 14)

Box 10

CST

Worldwide trends in the movement of people and freight, 1850-1990



Sources, *International Historical Statistics* (Macmillan); United Nations Environment Program; European Commission

(Continued from page 12)

vans, and light trucks) meet the same standards as regular cars.

- Japan tightened its standards for gasoline-fueled vehicles for the first time for 20 years, tightened diesel-fueled vehicle requirements further, and announced an agreement with its auto industry to reduce carbon dioxide emissions from vehicles.
- China and India have adopted early-1990s' auto emissions standards (Euro 1), are quickly phasing out unleaded gasoline, and are moving towards imposing mid-1990s' standards (Euro 2).

THE CENTRE FOR SUSTAINABLE TRANSPORTATION

The Centre is a federally chartered, non-profit organization.

It began work in 1996 with start-up funds from Environment Canada and Transport Canada. These departments of the Government of Canada continue to contribute support.

The Centre's mission is to provide leadership in achieving sustainable transportation in Canada by facilitating cooperative actions, and thus contributing to Canadian and global sustainability.

To achieve its mission the Centre provides reliable information, fills knowledge gaps through research, educates stakeholders and raises awareness among them, and offers strategic policy advice in selected areas.

The Centre's first publication was its *Definition and Vision of Sustainable Transportation*, published in mid 1997. You are reading the third issue of the *Sustainable Transportation Monitor*, published annually or more frequently. The first and second issues appeared in March 1998 and February 1999. All three issues are available at the Centre's Web site, as are the Centre's other publications (visit www.web.net/~cstctd). The *Monitor* provides evaluation of progress towards or away from sustainable transportation and discussion of related matters.

Comments on this issue of the *Monitor* and proposals as to what should be covered in coming issues are much appreciated. E-mail is the preferred mode of communication but feedback by any mode is welcome. **Please see Page 1 for our e-mail address, fax and phone number, and mailing address**. Contact the Centre as well if you would like to find out how to become a corporate or individual member of the Centre.

JOHN HARTMAN

The Board of Directors of the Centre for Sustainable Transportation wishes to express its great and continuing sadness at the unexpected passing of John Hartman, Vice-Chair of the Board of Directors, on August 31, 1999. John was among the people who helped create the Centre. As a Board member since the beginning he was a powerhouse of activity, a wonderful inspiration, and a firm guide as to what the Centre should do and how it should be done. Production of the *Sustainable Transportation Monitor* was his idea. Some of his other contributions are acknowledged elsewhere in this issue. His loss is being felt throughout Canada's transportation community, especially among those concerned to move Canada towards sustainable transportation.

REFERENCE NOTES

1. The data for world fleets in Box 1 are extrapolated from information in the Boeing Corporation's Web site, chiefly www.boeing.com/commercial/cmo/5apb2.html, visited on January 7, 2000. The data for passenger activity for 2010-2030 in Box 1 are from Table 9-10 of the IPCC's *Aviation* report, Scenario Fe. (See the source in Note 5, p. 312.) This scenario was developed by the Forecasting and Economic Support Group (FESG) of the International Civil Aviation Organization. Scenario Fe is used rather than FESG's baseline scenario (Fa) because it is more consistent in terms of passenger activity with industry projections, and with the projections of the UK Department of Trade and Industry, the lower projections of the Environmental Defence Fund (see Figure 9-7 and Table 9-29 in the first source in Note 5, pp. 301 and 329). Scenario Fe appears more consistent in its energy use aspects with the projections of NASA and other agencies (see Note 2). The data for 1990 passenger traffic in Box 1 were taken from the Boeing Web site (Appendix A: Revenue Passenger Kilometres). The data for 1970 were taken from Table 9-1 of the first source detailed in Note 5, p. 297.
2. The data for aviation energy use in Box 2 are interpolated and extrapolated from information in Table 9-4 of the first source detailed in Note 5 (NASA inventory), and from Table 9-29 of the same source (Fe scenario). The energy use data for road vehicles in Box 2 are from OECD *Motor Vehicle Pollution: Reduction Strategies beyond 2010*. Organization for Economic Cooperation and Development: Paris, 1995.
3. The global warming effect presentation in Box 3 assumes that for road vehicles radiative forcing is directly equivalent to that from carbon dioxide from fuel burning, using the data and projections used to create Box 2. For aviation, the forcing is that shown in Table 6-1 on p. 194 of the first source detailed in Note 5, for NASA and the FESGe (tech1) scenario. The aviation values shown in Box 3 are extrapolated and interpolated from these values, setting the value for personal vehicles for 1990 equal to 100.
4. The first source detailed in Note 5 is the source for this (pp. 8-9) and many other statements in these sections on aviation.
5. Penner JE et al. (eds.) *Aviation and the Global Atmosphere.* Cambridge University Press, Cambridge UK, 1999. A useful assessment of the IPCC report was produced in February 2000 by the U.S. government's General Accounting Office. Entitled *Aviation and the environment: Aviation's effects on the global atmosphere are potentially significant and expected to grow* (Report #GAO/RCED-00-57). It can be downloaded from www.gao.gov/new.items/rc000057.pdf.
6. See the first source in Note 5, p. ix and Annex A.
7. See the first source in Note 5, p. 19.
8. Based on information developed for Box 10 found here on Page 13. See Note 81 below for sources.
9. See the first source in Note 5, p. 297 (Figure 9-2),
10. See the first source in Note 5, pp. 4, 300.
11. See the source in Note 81.
12. See the source in Note 81 for "less than one per cent". See www.geocities.com/MadisonAvenue/Boardroom/3533/page4.3.html for an estimate that 35-40 per cent of world trade by value travels by air. Much is made of this estimate by economists, and of the more general indicator of emissions per unit of Gross Domestic Product (GDP). The perversity of the latter is addressed in Note 32.
13. See the first source in Note 5, p. 296 (Figure 9-1).
14. See the source in Note 81.
15. See the first source in Note 5, pp. 6, 284.
16. Estimate based on Figure 9-4 on p. 298 of the first source in Note 5. Roughly 60% of the improvement has come from engine design and 30% from airframe design (see the first source in Note 5, p. 297). Data from Transport Canada's *T-Facts 1999* show that the energy intensity per passenger- kilometre of Canadian aviation fell 38% between 1976 and 1996; 26% from 1976-68 and 16% from 1986-96. In the U.S., the slowdown in energy efficiency improvement is even more marked. The energy intensity of aviation there fell by 34% from 1975-85, but only by 13% from 1985-95.
17. See the first source in Note 5, p. 281.
18. See the first source in Note 5, p. 285 (Figure 8-4).
19. See the first source in Note 5, p. 296. On average, about 80 per cent of the fuel can be allocated to passengers and their baggage (0.1 tonne/person) and about 20 per cent to the freight carried in passenger planes, according to the EGEC article.
20. See the first source in Note 5, p. 287 (Figure 8-7). This comparison applies to the kind of heavy-duty trucks used for intercity transport, and to typical loadings of these vehicles. If light-duty trucks (vans) are used to carry the freight, aviation is *less* fuel-intensive. (Based on data provided by INFRAS reported in Crist P and McGlynn G, *Freight Transport Trends and GHG emissions: Issues Paper*, prepared for the Annex 1 Expert Group on the United Nations Framework Convention on Climate Change, February 2000.)
21. For the points in this and the next paragraph see the first source in Note 5, pp. 6-9. According to the second source in Note 5, "current aircraft technologies generally require a trade-off between NO_x and CO_2 emissions—when engines are designed to minimize NO_x emissions, they generally emit more CO_2, and vice versa" (p. 20).
22. See the first source in Note 5, p. 283. The general trade-off seems to be a 5% increase in fuel use, and emissions, for each 3-decibel reduction, more for retrofitted aircraft and when reductions for other than flyover impacts are required.
23. Box 4 is based on information in Transport Canada's *T-Facts 1999*, and on the 1999 edition of *National Transportation Statistics* produced by the U.S. Bureau of Transportation Statistics.
24. This reported decline seems at first sight to be at variance with the recent projection by the Analysis and Modelling Group of Canada's National Climate Change Process that there will be an increase of 99 per cent in emissions of greenhouse gases from aviation between 1990 and 2010. The Group appears to have included some international aviation in this increase. Also see Note 57.
25. See the first source in Note 5, p. 342.

26. See the first source in Note 5, p. 340 for information about fare elasticities of air travel. See Box 37, 50, and 55 below for information about fuel elasticities of automobile use.

27. See Houghton JT et al, *Climate Change 1995: The Science of Climate Change*, Cambridge University Press, Cambridge UK, and New York, 1996, Fig. 2.6. The Centre for Sustainable Transportation's position is that sustainability for industrialized countries requires reductions in GHG emissions in the order of 80% to allow some 'room' for development in other countries (*Definition and Vision of Sustainable Transportation*, 1997).

28. A 1991 study by the International Civil Aviation Organization indicated that the cost of worldwide infrastructure projects required by 2010 to meet the projected growth in aviation would be US$250-350 billion. (See www.atag.org/ECO/eco5.htm.) It was not possible to determine how much of this was spent during the 1990s.

29. Clifford Cobb, Gary Sue Goodman, and Mathis Wackernagel, *Why Bigger Isn't Better: The Genuine Progress Indicator—1999 Update*. Redefining Progress, San Francisco, November 1999 (from www.rprogress.org, visited on Jan. 11, 2000)

30. A particularly perverse use of GDP relevant to attainment of sustainability is discussed below in Note 32.

31. This definition of indicators is based on the work of Henrik Gudmundsson of the Danish Environment Agency (from a paper presented at a conference entitled *Social Change and a Sustainable Transport*, organized by the European Science Foundation and the U.S. National Research Foundation and held at the University of California, Berkeley, March 1999).

32. An indicator that is unlikely to find its way on to the longer or the shorter lists is carbon dioxide emissions per unit of GDP. This indicator—or its surrogates energy use per unit of GDP and GDP per unit of energy—is sometimes used by economists to demonstrate that things are getting better with respect to greenhouse gas emissions. If CO_2/unit of GDP falls at 1%/year and GDP rises at 3%/year, the discussion should focus not on the improvement in energy 'efficiency' but on the continuing increase—by about 2%/year—in CO_2 emissions. ('Efficiency' is in quotes in the foregoing because a reduction in CO_2 emissions per unit of GDP represents an efficiency improvement only in the discourse of economists. The usual use of the term is based on the concepts of physics. Thus a car is considered to be more fuel efficient when its fuel use per 100 kilometres declines, not when its fuel use per value of transactions involving the car or its owner declines.)

33. The data in Box 6 are from a Web site maintained by the Alaska Department of Revenue (www.revenue.state.ak.us/oil, visited on February 10, 2000).

34. From "Oil prices are a worrisome peak in a landscape of low inflation." *New York Times*, January 30, 2000.

35. The comparisons of Canadian oil production are based on projections in what were the official projections in early 1999 (in *Canada's Energy Outlook: 1996-2020*, Natural Resources Canada, April 1997, available at nrn1.nrcan.gc.ca/es/ceo/toc-96E.html) and the current official projections (in *Canada's Emissions Outlook: An Update*, Analysis and Modelling Group, National Climate Change Process, December 1999, available at www.nccp.ca/html/index.htm).

36. See Chart 3.10 on Page 27 of *Canada's Emissions Outlook Update* (detailed in Note 35). The work summarized in the chart indicates that production of oil from oil sands produces about 2.5 times the amount of greenhouse gases (in CO_2 equivalents) as conventional oil, rising to about 6 times as much if the methane is flared. See also Youngquist W, *GeoDestinies*, National Book Co, 1997. Youngquist wrote that "With the strip mining and refining now in use, it takes the energy equivalent of two barrels of oil to produce one barrel."

37. This statement is based on indications that short- and medium-term elasticities of price demand for vehicle fuel are quite low (in the order of -0.25). See Goodwin PB, A review of new demand elasticities with special reference to short and long run effects of price changes. *Journal of Transport Economics and Policy*, 26(2), 155-169, 1992., Table 1. Thus, a perhaps unthinkable doubling in fuel price would be required to compensate for a 25% difference in total CO_2 emissions between conventional and non-conventional fuels

38. "Enough countries" means essentially 55 countries responsible for 55% of GHG emissions in 1990. See the sources in Note 40 for a fuller account.

39. The six greenhouse gases in approximate order of their potential significance for climate change are carbon dioxide, methane, nitrous oxide, and hydrofluorocarbons—all emissions related to motorized transport—as well as perfluorocarbons, produced during the production of aluminum, and sulphur hexafluoride, used as an insulator in power grids.

40. See www.unfccc.de/resource/kpstats.pdf (report of the United Nations Framework Convention on Climate Change). See also Bernstein S, *From leader to laggard to follower: Canada's curious climate change journey*. Paper presented at a conference on Canadian Environmental Policy, Sookmyung University, Seoul, Korea, February 2000.

41. German Chancellor Gerhard Schroeder opened the Fifth Conference of the Parties to the United Nations Framework Convention on Climate Change, held in Bonn in November 1999, calling for ratification of the Kyoto Protocol by 2002. He told the delegates that the industrialized nations must set an example for developing countries. Michael Zammit Cutajar, executive secretary of the Convention, applauded Schroeder's speech and that the proposal is "an encouraging goal". (www.globalwarming.org/polup/pol11-1-99.html, visited on January 14, 2000).

42. Both papers are available at the Transportation Table's section of the Web site of the National Climate Change Process (www.nccp.ca/html/index.htm).

43. *Options Paper*, Appendix 1 (detailed in Note 42).

44. This is the factor value for N_2O given in the 1996 report of the Intergovernmental Panel on Climate Change (Schimel D, et al, Radiative Forcing of Climate Change. In Houghton JD, et al. eds., *Climate Change 1995: The Science of Climate Change*. Cambridge University Press, Cambridge UK, 1996, pp. 65-131). The NCCP may have used a different value.

45. *Canada's Emissions Outlook*, Chart 3.20, p. 38 (detailed in Note 35).

46. There are some anomalies in these numbers. Using the Transportation Table's figures, the required reduction is 55 Mt not 54 Mt, from 193.3 Mt to 6% below 147.5 Mt, i.e., a required reduction of 54.7 Mt (see *Options Paper*, Table 2.4, p. 10—

further detailed here in Note 42). The source on which the Transportation Table's figures are based indicates that 'business-as-usual' GHG emissions from transport will be 197.3 Mt in 2010 not 193.3 Mt, which would mean a required reduction of 58.7 Mt. (See *Canada's Emissions Outlook*, detailed in Note 35. See particularly Chart 4.1 on p. 42 for the overall GHG emissions and Chart 4.7 on p. 47 for the transport emissions.) Thus, it could be argued even at this point that the required reduction for transportation is 59 Mt (29.8%) and not the 54 Mt (27.9%) target used by the Transportation Table. See also later text and Note 57 below for comments on how the totals might be adjusted with respect to emissions from aviation.

47. The 10 criteria used to evaluate each measure were: *cost*–the total economic cost per tonne to achieve the GHG reduction for a given measure; *GHG impact*–the amount of GHGs reduced by the application of the measure; *ancillary impacts*–the influence of the measure on aspects of quality of life, notably safety, health, and air quality; *economic impacts*–the effect on Canadian business mainly in respect of affordability, employment, the generation of new technologies; *complementarity*–the extent to which the measure reinforces or enhances the effectiveness of other measures or is essential for other measures to be effective; *implementation/administration*–ease of implementation of the measure; *certainty*–the degree of confidence that the measure will work; *equity*–the degree to which the costs of the measure are equally shared by business sectors and by regions of the country; *public support*–the extent to which the public accepts or could accept the measure; *other costs*–financial costs of implementation not included in the other criteria.

48. It is not clear from the *Options Report* (detailed in Note 42) exactly how the evaluations in terms of the ten criteria were carried out. The report says, "Table members discussed the measures in the context of these criteria and identified the measures as falling into one of … four categories." (p. 86).

49. Box 7 is based on the corresponding tables in Appendix 4 of the *Options Paper* (detailed in Note 42).

50. Our own analysis suggests that $1.40 is an underestimate, and that the road fuel price required to meet the Table's target would be in the order of $1.70 in today's dollars. The difference is mainly due to the use of a different baseline price (our analysis uses the current average price of close to 70¢/litre rather than the Table's 54¢/litre), offset a little by our use of a slightly lower price elasticity of demand for fuel. $1.70/litre is almost exactly the present road fuel price in the U.K., which now has the highest road fuel prices among major countries.

51. Quotes are from the *Options Paper*, p. xii (detailed in Note 42).

52. From Appendix C to *Canada's Emissions Outlook* (detailed in Note 35), Table C-8 for the energy use increase (33.8%, from 2098.9 to 2792.3 petajoules) and Table C-26 for the GHG emissions increase (33.6%, see also Note 46 above).

53. This estimate that 2.2% has been the actual the rate of increase in transport energy use in the 1990s is based on two sources. The rate until 1996 is based on information in Transport Canada's *T-Facts 1998*. The rate since 1996 (until November 1999) is based on information provided regularly in Statistics Canada's *The Daily* concerning domestic sales of refined petroleum products. The respective annual rates are 1.6 and 3.9 per cent. In *Energy Efficiency Trends in Canada: An Update*, Natural Resources Canada, January 2000, Table 2-1, an annual rate of increase of 1.8 per cent for the period 1990-1997 is indicated.

54. Some adjustments should likely be made to the totals and required reductions on account of the aviation data and revised projections set out in later text and in Note 57. However, the complexity of the aviation issue precludes simple modifications at this point.

55. The new total GHG emissions from transport in 2010 is estimated to be 226 Mt. The required reduction from this amount is 36 Mt, or 16%. Assuming an elasticity of -0.23 for this degree of reduction and more-or-less exact correspondence between fuel use and GHG emissions, the required price increase is 70%, or about 50¢.

56. Box 8 is based on the information in Box 7, except for the right-hand scale. This scale, when referenced against the left-hand scale, shows the Centre's estimates of the approximate reductions in GHG emissions that would be achieved by particular *increases* in the prices of vehicle fuels.

57. Use was made by the Table of projections provided by the Analysis and Modelling Group, notwithstanding a caution by the Table's Air Sub-Group on Page 15 of its report that they "need some review", and the provision by the Sub-Group of alternative projections on Pages 19 and 30. The Centre agrees with the Air Sub-Group's criticism of the work of the Analysis and Modelling Group, but believes the Sub-Group's remedy is also flawed. The Sub-Group estimated the domestic proportion of all airline activity in 1990 to be 32%; data in Transport Canada's *T-Facts 1999* suggest that 39% is a better estimate. The Sub-Group appears to have overestimated recent domestic aviation activity and underestimated international (including trans-border) activity. The Centre assumes that fuel use for domestic aviation will increase by 0.8%/year between 1990 and 2010 (2.3%/year increase in activity less an overall 25% reduction in fuel intensity—see Note 16) and for international aviation, including transborder, will increase by 4.4% a year from 1990 to 2010 (6.0%/year increase in activity less an overall 25% reduction in fuel intensity—see Note 16).

58. See Note 57. Box 4 represents *per capita* changes in aviation. The statements in the present paragraph concern *absolute* changes in GHG emissions.

59. Canadian trans-border aviation grows at a about the same rate as international aviation worldwide (4.8%/year vs. 4.7%/year). However, Canadian international aviation other than to the U. S. grows at a much higher rate (6.2%/year). See the sources for Boxes 1 and 4 (detailed in Notes 1 and 23).

60. For a useful discussion of the Internet and Global Warming, including transport matters, see a December 1999 paper with this title by Joseph Romm at www.cool-companies.org.

61. See Page 6 of the source cited in Note 45.

62. See Note 36.

63. See Pages 22-23 of the source cited in Note 45.

64. Review of ICAO's Web site (http://www.icao.org/index.html, on February 29, 2000) indicates that policy options for limiting or reducing GHG emissions will be considered by ICAO's Assembly late in 2001. Examination of ICAO's "Draft Action Plan on Aircraft Engine Emissions" does not reveal concern

about the altitude multiplier effect discussed in the first article of this issue of the *Monitor*. Transport Canada has advised that ICAO's Committee on Environmental Protection has established Working Group 5 to evaluate the role of market-based options to reduce GHG emissions. The options include "emissions trading". If this option is taken to mean a form of *rationing* of aviation activity—as proposed by the U.S. General Accounting Office (see the second source in Note 5)—then progress could be made towards reducing GHG emissions. However, if it is taken to mean trading of entitlements to emit GHGs with other sectors, reduced aviation activity is a less likely result.

65. See the source detailed in Note 27.
66. The Transportation Table—in Appendix A6 to its *Options Report*—provided useful accounts of what is happening relevant to the Kyoto Protocol in the U.S., the European Union (EU), and Japan. The Netherlands is one of the 15 EU countries acting in consort for the purposes of the Kyoto Protocol.
67. Information about Canada in Box 9 comes directly from the Transportation Table's *Options Report* (detailed in Note 42). Information about the Netherlands is based on a document produced by The Netherlands' Ministry of Housing, Spatial Planning and the Environment entitled *The Netherlands' Climate Policy Implementation Plan: Measures in the Traffic Sector*, The Hague, July 1999. (Available at www.minvrom.nl.)
68. The population data on which Box 9 is based come from World Bank, *World Development Indicators*, Washington D. C., 1999, Table 2.1, Page 43. Canada's population in 1990 was 27.8 million; that of The Netherlands was 15.0 million. The same source (Table 1) indicates Canada's GDP per capita in 1998 was US$20,100; that of The Netherlands was US $24,900.
69. If the revised projections set out here on Pages 8 and 9 are used rather than those of the Transportation Table, the per capita reduction in GHG emissions required in Canada will be 2.1 tonnes of CO_2 equivalent rather than 1.4 tonnes.
70. The Netherlands' nine chosen measures are (1) promotion of more fuel-efficient cars through international agreements; (2) tax incentives for fuel-efficient cars; (3) road pricing; (4) measures to reduce passenger traffic (removal of deduction for car use, reduction in deduction for transit use); (5) improved enforcement of speed limits; (6) tax incentives for instruments that monitor fuel-efficient behaviour; (7) raising tire pressures; (8) miscellaneous programs, including driver education and improved freight logistics; (9) research and development to reduce nitrous oxide production from catalytic converters.
71. Dodgson J, *Issues in quantifying transport-related CO_2 abatement policies.* Paper prepared for Annex 1 Expert Group on the United Nations Framework Convention on Climate Change, February 2000.
72. See Box 3 in the 1999 issue of the *Monitor*, available at www.web.net/~cstctd.
73. The information in this paragraph comes from Walsh M, *Global motor vehicle emissions: The remaining challenges*. Keynote address at the Second International Conference on the "Health Effects of Vehicle Emissions", Commonwealth Institute, London, UK, February 24-25, 2000.
74. See the source in detailed in Note 73.
75. McKinnon A, "A Logistical Perspective on the Fuel Efficiency of Road Freight Transport", presented at a workshop on *Improving fuel efficiency in road freight: The role of information technologies*, OECD, Paris, February 1999.
76. Study conducted by Alan McKinnon of Herriot-Watt University, Edinburgh, UK, cited in the second source detailed in Note 20 (Crist & McGlynn).
77. See the source cited in Note 75.
78. See Nakagawa S, *CO_2 reduction measures in the freight sector in Japan*, Paper prepared for Annex 1 Expert Group on the United Nations Framework Convention on Climate Change, February 2000. Also see Note 20.
79. L-P Tardif & Associates Inc., *Environmental Awareness and Outreach Measures to Reduce GHG Emissions From the Trucking Sector*, Report prepared for the Trucking Sub-Group of the National Climate Change Transportation Table, August 1999 (viewed at www.tc.gc.ca/envaffairs/subgroups1/truck/study1/final_report/final_report.htm on March 4, 2000).
80. Most of the account of Swedish practices is from Cairns S, "The Greening of freight transport: The Swedish Green Procurement model." Paper presented at the Annual Meeting of the Transportation Association of Canada, Saint John, New Brunswick, September 1999.
81. See Gilbert R, Sustainable Transportation. In Volume 5 of *Encyclopedia of Global Environmental Change*, Wiley, London, UK, and New York (in press). The main source for Box 10 is Mitchell BR, *International Historical Statistics* (3 volumes). Macmillan, London, UK, 1992-5. Additional sources are: population, from United Nations Environment Program, *Global Environmental Outlook 2000*. Earthscan Publications, London, UK, 1999, Page 6; ocean freight, *European Transport in Figures*. European Commission, Brussels, Belgium, October 1999, Table 9.4; number of automobiles and trucks, from *World Motor Vehicle Data*, American Automobile Manufacturers Association, Detroit, Michigan, 1998, Page 8. Estimates of automobile passenger-kilometres (pkm) and truck tonne-kilometres (tkm) were made by multiplying numbers of vehicles by author's estimates of annual pkm and tkm. The estimates of walk/bicycle activity are also the author's. Box 10 is designed to show relative trends rather than precise data; all estimates are inherently approximate. Data for indicated years may be for a few years earlier.
82. These approximations of relative fuel use are based on several sources, notably the one detailed in Note 78 and the second source in Note 20.
83. The estimate of ocean freight's share of all transport activity comes from *World Energy Outlook*, International energy Agency, Paris, 1998, Tables 7.2 and 7.3.
84. The IMO site—www.imo.org—was visited on March 4, 2000.
85. The promising signs are adapted from the source detailed in Note 73. The author of this report, Michael Walsh, produces a quarterly newsletter, *Car Lines*, which is the best source of up-to-date worldwide information about the technical aspects of regulation of motor vehicles. He can be reached at mpwalsh@igc.apc.org.
86. See the results of Phase 2 the OECD project on Environmentally Sustainable Transport, some of which can be viewed from a link at http://www.oecd.org/env/ccst/est/estproj/estproj1.htm.