The Centre for
Sustainable Transportation

Le Centre pour un
transport durable

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In this issue:

THE NEED TO REDUCE TRANSPORT ENERGY USE, AND WAYS TO DO IT

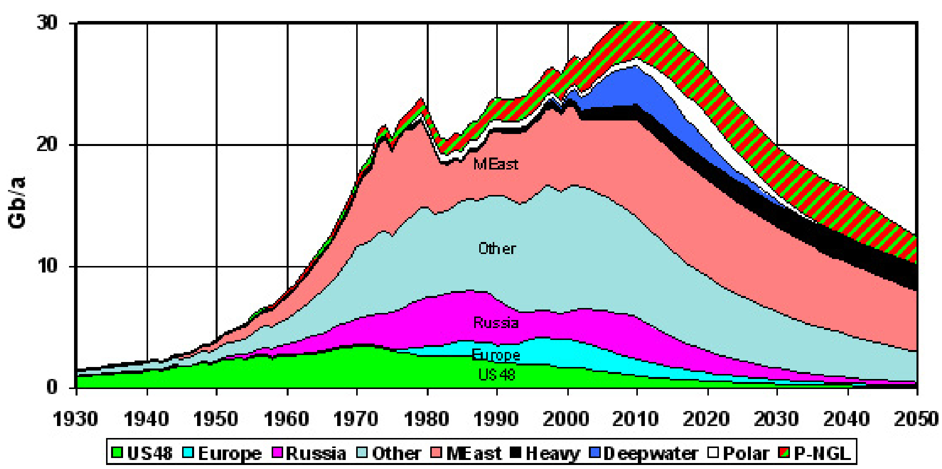
This issue of the *Monitor* first updates energy matters discussed in previous *Monitors*. The updating concludes that reducing transport fuel use should be the overriding goal of Canada's transport policies, more important than reducing greenhouse gas emissions, and perhaps a better strategy for making progress towards sustainable transport.

This issue then discusses three of the many ways in which transport fuel use could be dramatically reduced. The first would allow short-term gains. It is to make more efficient use of trucks on the road. The second would have its main impacts in the medium term. It is to achieve major reductions in fuel use by new personal vehicles. The third is for the longer term. It is to secure much greater use of tethered vehicles (which get their energy from a rail or wire rather than from an on-board source such as a gasoline tank, a hydrogen storage device or a battery).

ENERGY UPDATE: OIL

The February 1999 issue of the *Sustainable Transportation Monitor* explored the transport implications of what was called 'the end of cheap oil'. This phrase came from the title of a 1998 article by geologists Colin Campbell and Jean Laherrère.[1†] These authors

Box 1. World production of regular oil (by region), and of non-conventional oil, and natural gas liquids, actual and estimated, billions of barrels per year, 1930-2050 (see text on Page 2 for explanation of the legend)



Source: Uppsala Hydrocarbon Depletion Group (see Note 4)

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 † The superscript numbers in the text refer to 96 reference notes on Pages 15-22.

argued that worldwide production of *conventional oil* would peak within a decade, when about half of extractable conventional oil had been recovered. Conventional oil, which today comprises almost all oil production worldwide, is oil that can be easily procured from readily accessible locations. 'Non-conventional oil'—which comprised about 30 per cent of Canadian oil production in 2003[2]—includes oil from polar and deep-sea sources and oil from oil sands. The *Monitor* item concluded that "the energy aspects of sustainable transport are as important as its other aspects and require as much attention as transport's impacts on the local and global environment".

Box 1 suggests that production of conventional oil—labelled 'US48', 'Europe', Russia', 'MEast', and 'Other'—may already be at its peak. Growth in production of liquid petroleum products is being sustained chiefly through the use of natural gas liquids, labelled 'P-NGL',[3] and increasingly through use of non-conventional oil, labelled 'Heavy', 'Deepwater', and 'Polar' in Box 1, with 'Heavy' mostly representing oil from Canada's oil sands.

Box 1 suggests moreover that total production of liquid petroleum products—conventional, non-conventional, and natural gas liquids—will peak around the year 2012.[4] This, with continued strong potential demand for oil, which now fuels 95 per cent of transport worldwide,[5] could result in very high prices for transport fuels.

At the least, the possibility of such high prices should be taken into account in developing strategies for progress towards sustainability. Perhaps more important, unanticipated high prices could unravel the very fabric of our transport-dependent society, particularly its economic aspects. (Note that Box 1 does not suggest that oil will run out soon, only that the highest level of production will be reached soon.)

This perspective has influenced the Centre's approach. Indeed, the April 2003 issue of the *Monitor* suggested that dealing with the prospect of very high fuel prices may be a more important challenge for Canadian society than meeting its potential Kyoto obligations: "… the main challenge for transport policy-making over the next several years should perhaps not be how to meet specific GHG emission-reduction targets … or even how to make progress towards sustainable transport. **The main challenge may be that of helping energy-dependent and transport-dependent Canadians prepare for inevitable energy constraints and very high fuel prices.** In reality, reducing GHG emissions, making progress towards sustainable transport, and preparing for an era of energy constraints all amount to the same thing: drastically reducing fossil fuel use."

The Centre's expressions of concern about possible energy constraints have encountered considerable opposition. The force of this opposition appears to be moderating as apprehension about such constraints becomes more widespread. During 2003, the prospect of an early peak in world oil production became the subject of intense debate among oil geologists and oil economists, reflected in a series of articles in the most influential of the oil professionals' journals.[6] The first few months of 2004 have seen several media and other examinations of the prospect of an early peak in world oil production.[7] The prospect has been discussed at several notable forums.[8]

Perhaps the strongest contribution to the discussions has been a readily available, 103-page paper prepared by the Danish Board of Technology and the Society of Danish Engineers,[9] which makes four key points:

There will be a peak in world oil production. Differences among projections are basically differences in the timing of the peak, which in turn reflect different estimates of the extent of oil reserves and of their recoverability.[10] Geologists, influenced by their understanding of what is in the ground, are inclined to believe that the oil production peak will occur before 2020; some say as early as 2007 or before.[11] Economists, influenced by their understanding of how incentives make human ingenuity flourish, are inclined to believe that the peak will occur after 2020.[12]

If a later peak is possible, which is far from clear, it will be achieved only by making huge investments in the oil sector, which may well be wasted (as discussed below) A wiser course, according to the Danish paper, would be for society to invest such amounts in means of reducing oil consumption than in means of possibly postponing the peak in oil production. This implies (i) withdrawal of all subsidies for oil exploration and recovery; (ii) higher taxes on oil products; (iii) use of proceeds of the reduced expenditures and increased taxes to provide incentives for reducing oil use. As well, some of the proceeds could be invested in sustainable energy systems.

An earlier peak will be "less unfortunate" for humanity than a later peak. This is proposed for two reasons.[13] The first is that the sooner the peak the less the overall dependence on cheap oil and thus the easier the weaning from the dependency. The second reason is more technical. A later peak would likely be achieved in part by heightened recovery from reserves, a process that results in a steep decline in production once the peak has been reached.[14]

Governments should work to ensure that the peak in oil use occurs before the peak in oil production. This requires (i) identification of the likely date of the peak, and (ii) development and implementation of an appropriate plan for reducing oil use through efficiency, use of alternatives, and reduced motorized activity, using proceeds from diverting investment. The result will be a relatively 'soft landing' when the peak occurs. Few missions of government may be more important than preparing Canadians for peaks in fuel production, notably transport fuels.

Those who believe a later peak is possible believe it can occur for two reasons. The first, they claim, is that there are sufficient reserves in the ground, discovered and undiscovered, to support a later peak. The second, they argue, is that continually improving extraction techniques result in increased recovery of oil, both oil from previously and currently exploited sources and oil from sources that are to be exploited.[15]

Whether there are sufficient reserves to support a later peak is a matter of controversy. Box 2, prepared by an oil company,[16] shows that annual discoveries of oil peaked worldwide around 1960 and have been running well below annual consumption of oil since about 1980. It might in theory be possible for the long-term decline in worldwide discoveries to be reversed, but the evidence from production in individual countries is not encouraging in this respect.[17]

Those who say that more could be discovered themselves note the huge amounts of investment that would be required. For example, the International Energy Agency has identified the need to add production capacity totalling more than 200 million barrels a day by 2030 (present production capacity is 75 mb/d), at a cost of US$3.1 trillion (in 2000$).[18] Of this amount 72 and 7 per cent respectively would be for exploration and development for conventional and non-conventional oil, 13% would be for crude oil refining, and 8 per cent would be for tankers and pipelines. An Exxon vice-president has said that meeting demand will require added capacity of 80 mb/d by 2010, requiring an investment of about one trillion U.S. dollars, "substantially more than industry is spending today".[19]

In the meantime, the Centre is inclined to give the most credence to the projections in Box 1, which point to a worldwide peak in oil production in about 2012. Note that this is a middle position in that many experts believe the peak will be earlier and many believe it will be later.[20] Oil prices will likely rise slowly as the peak is approached, i.e., during the next decade, as more expensive oil (e.g., from oil sands) replaces conventional oil in the production mix. Soon after the peak is reached, i.e., within the next two decades, prices could rise more steeply because of the growing imbalance between supply and potential demand.

The factors that could result in a production peak much later than about 2012 are not in place. There is insufficient successful exploration, as already discussed,[21] and there is also insufficient reserve growth, i.e., upward restatement of the capacity of particular reserves as more information becomes available and as improvements in technology allow more of the oil in each well to be recovered. On the latter point, previously reported reserves are being revised downwards[22] and recovery factors have been declining.[23] In any case, there could be merit to the argument in the Danish paper that an earlier production peak could be "less unfortunate" for humanity.

Meanwhile, consumption of transport fuels continues to rise, driven chiefly by growth in economic and transport activity in China and other industrializing countries,[24] contributing to higher-than-anticipated prices.[25]

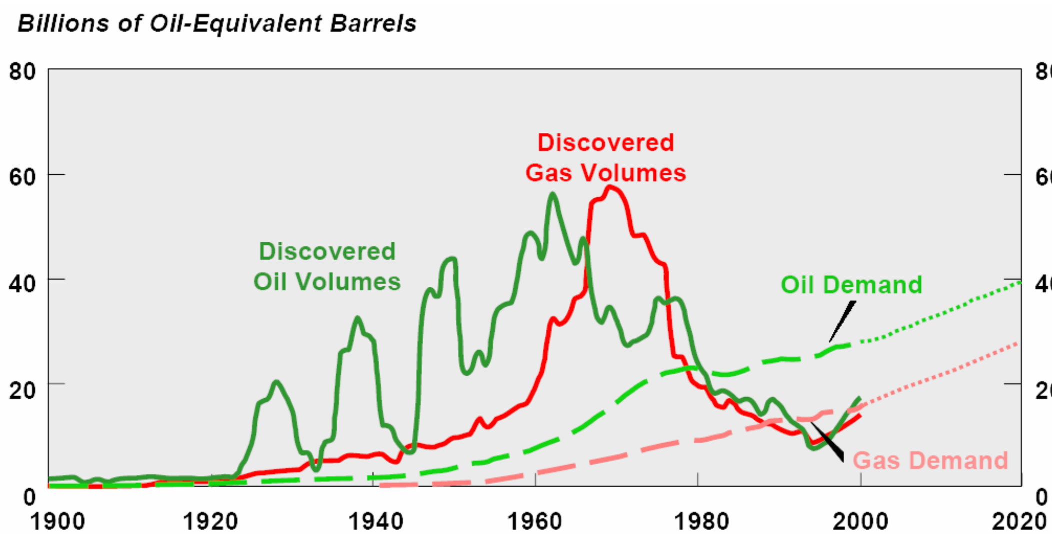
ENERGY UPDATE: NATURAL GAS

The February 1999 issue of the *Monitor* hardly touched on the matter of natural gas, but there are two reasons to pay more attention now.

The first is that supply of natural gas in North America provides a useful object lesson for consideration of oil supply worldwide. It's difficult to move natural gas between continents, and so the market for this resource is essentially continental rather than global. **North American production of natural gas appears to have already peaked**,[26] resulting in large increases in wholesale and retail prices.[27]

There is hope that the imbalance between supply and demand can be re-

Box 2. World discovery of and demand for oil and natural gas, 1900-2000, and projected potential demand until 2020



Source: Exxon Mobile Corporation (see Note 16) duced by massively increasing imports of liquefied natural gas (LNG) from Algeria, the Middle East, Russia, Trinidad and Tobago, and elsewhere, where for the moment supplies remain plentiful.[28] However, shipment of LNG is considered to be hazardous.

There are four LNG receiving terminals in North America, one near Boston. A consultant advised that, "The US Coast Guard requires a two-mile moving safety zone around each LNG tanker that enters Boston Harbor, and shuts down Boston's Logan Airport as the LNG tanker passes by. … These extraordinary precautions are taken out of concern for spectacular destructive potential of the fire and/or explosion that might result from a LNG tank rupture."[29] A local plebiscite recently stopped an attempt to locate a fifth terminal in the remote community of Harpswell, Maine, and several other proposals for terminals in the U.S. and Mexico have been recently withdrawn on account of local opposition.[30]

As of December 2003, LNG terminals had been proposed for 32 locations in North America, including 21 in the U.S., six in Mexico, three in the Bahamas, and two in Canada.[31]

As with oil, *world* production of natural gas may well reach a peak in the foreseeable future. Box 2 suggests that the peak in world discovery of natural gas occurred near 1970, about 10 years later than the peak in discovery of oil. To the extent that a peak in discovery presages a peak in production, it may be reasonable to expect world supplies of natural gas to peak soon after 2020.

The second reason for paying more attention to natural gas is that expectations have grown that it will play a major role in transport. At present, very little transport activity is fuelled by natural gas, although several observers favour greater use.[32]

There is much more excitement about future roles of hydrogen,[33] which can be used in fuel cells as well as in combustion engines.[34] At present, nearly all hydrogen in the U.S. is produced from natural gas,[35] and there seem to be no low-cost alternatives.

Thus, however great the enthusiasm for hydrogen as a transport fuel, its actual use may be constrained by availability of natural gas, production of which is already limited in North America, and may be limited worldwide before children born in 2004 reach middle age.

ENERGY UPDATE: CONCLUDING COMMENTS

Canada's vast size and extensive international trade make us more dependent on transport than most affluent countries.[36] Without adequate preparation, Canada could suffer inordinately from greatly elevated fuel prices, whether for conventional transport fuels based on crude oil or for fuels required by emerging technologies, including hydrogen for fuel cells.

Accordingly, addressing potential constraints on the availability of transport fuels could well become a national policy priority, perhaps of equal or greater importance than that of meeting the transport challenges posed by Canada's Kyoto commitment.

The time is ripe for a national debate on the prospects of imminent energy constraints and for serious consideration of their possibility in every aspect of planning by governments and the private sector.[37] The Government of Canada may do well to consider the advice in the Danish paper discussed above: first figure out when the world oil production peak will be, and then work to ensure that Canada's oil use peak occurs first.

At first sight, this may appear to be far-fetched advice, especially if the peak is determined to be in or near 2012, as suggested by Box 1. On examination, however, the advice is compatible with current relevant policy, even if the peak is as early as indicated.

Current relevant policy is dominated by implementation of plans directed at meeting Canada's potential commitment pursuant to her ratification of the Kyoto Protocol on greenhouse gases.[38] Whether or not the Kyoto Protocol comes into effect, **it would be a relatively easy matter to refocus relevant policy towards ensuring that Canada's peak in oil consumption occurs before the world peak in oil production**. Then, oil use in Canada would already be on a firm downward trajectory when post-peak high oil prices occur.

Indeed, current plans for meeting Canada's Kyoto targets for GHG reductions appear to contemplate at least a plateauing of oil consumption after years of almost uninterrupted annual increases.[39] Thus, all that would be required could well be no more than a somewhat stronger focus on moderating oil use than is presently proposed.

The commitment to reduce greenhouse gases could be maintained, and may even be enhanced by a special emphasis on reducing oil consumption. It may be easier to induce people to reduce oil consumption now to soften the blow of looming high prices than it has been to induce them to reduce present greenhouse gas emissions to avoid the prospect of warmer winters.[40]

Oil use for transport comprises about 70 per cent of all oil use in Canada (and transport is 99-per-cent fuelled by oil products).[41]

The balance of this *Monitor* discusses three ways in which oil use for transport could be reduced, one for each of the short, medium, and long terms. The methods for the short and medium terms—raising truck load factors and reducing the fuel consumption of personal vehicles—were highlighted by participants in four workshops held by the Centre for Sustainable Transportation in 2001 and 2002 on Canada's transport policy options for the period until 2025.[42]

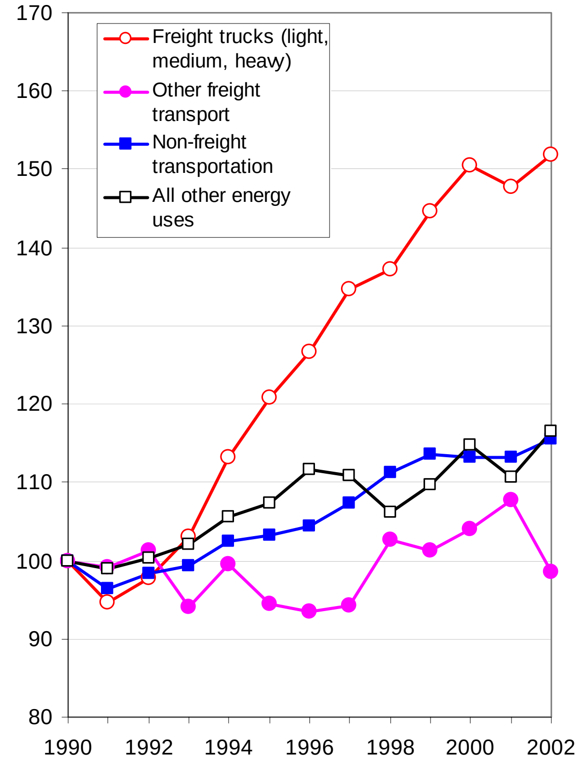
THE REMARKABLE RECENT GROWTH IN ENERGY USE FOR TRUCKING

Among the most rapidly growing energy uses in Canada since 1990 has been use of energy for trucking. This is shown in Box 3, where it can be seen that energy use for trucking grew by 52 per cent between 1990 and 2002, while energy use for other freight transport *fell* by one per cent and energy use for other transport and for all non-transport purposes grew by 16 and 17 per cent.[43]

Put another way, trucking comprised about 18 per cent of Canada's oil use in 1990 and about 24 per cent in 2002. It accounted for 70 per cent of the *growth* in Canada's oil consumption between 1990 and 2002.[44]

The increase in trucking activity has been even greater than the increase in fuel use for trucking. Vehicle-kilometres performed by trucks increased by 75 per cent between 1990 and 2001. However, because of improvements in fuel efficiency across this period (specifically, an average reduction of 11 per cent in the number of litres of fuel used per 100 kilometres travelled), fuel use by trucks increased by 'only' 59 per cent.[45] However viewed, the recent rise in trucking activity has been extraordinary. Any reasonable attempt to reduce the amount of this activity, or even to moderate its growth rate, should be considered.

Box 3. Changes in energy use for transport modes and other purposes, 1990-2001 (1990 values = 100)



Source: Natural Resources Canada (see Note 43)

REDUCING OIL CONSUMPTION BY IMPROVING THE EFFICIENCY OF TRUCK USE

Reduced energy use for trucking can be achieved by improving the fuel efficiency of trucks or by reducing the amount of truck activity. Much attention is being paid to the former strategy,[46] but, as noted in the previous paragraph, the huge growth in truck fuel use arises from growth in truck activity. Almost the only means proposed for reducing truck activity is shifting some freight movement to rail or marine modes.[47] There has been little consideration of other means, notably raising load factors so that fewer trucks are used to carry the same amount of freight.

Load factor is the percentage of a truck's capacity that is used. An empty truck has a load factor of zero per cent; a one-quarter-full truck has a load factor of 25 per cent. Other things being equal, a higher load factor means that more freight is moved for each unit of fuel used.

Increasing load factors has been relatively neglected as means of reducing fuel use and GHG emissions. For example, one of the research papers prepared for the Transportation Table of the federal government's Climate Change Process dealt with the topic.[48] Its authors surveyed the operators of five trucking fleets and concluded that all had attempted to reduce fuel use by matching vehicles to loads for longer trips; and by reducing the need for trips when empty. All had reported success in using "improved dispatch" to reduce fuel use. Specific instances of the effectiveness of measures directed at raising load factors were noted. Nevertheless, this type of measure is absent from the list of actions discussed in the Table's *Options Paper*[49] and is not mentioned in the federal government's current climate change plan.[50]

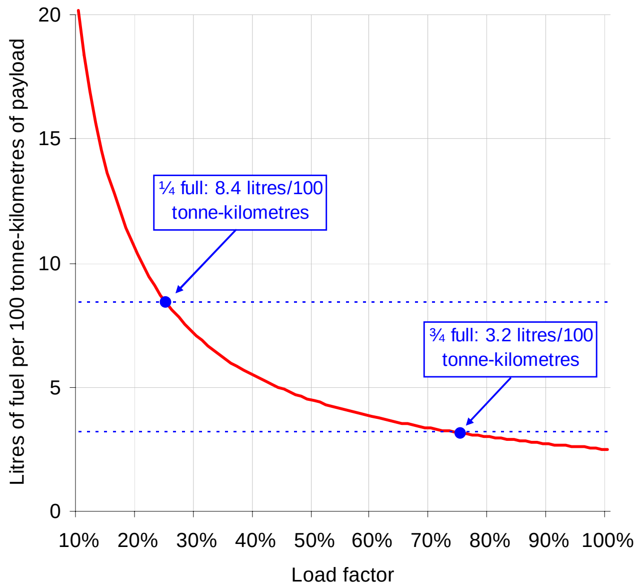
Part of the reason why strategists have not focused on load factors may be lack of understanding that most truck fuel goes towards moving the truck rather than moving its payload, even when the

Box 4. Fuel use for empty and full trucks, and the share of fuel used to move the vehicle, as opposed to its cargo, when the truck is full

	Tare weight in tonnes	Payload in tonnes	litres/ 100 km empty	litres/100 km full load	Share of fuel moving the vehicle (with a full load)
Truck, distribution traffic	5.5	8.5	20-25	25-30	82%
Truck, regional traffic	10	14	25-30	30-40	79%
Tractor and semi-trailer, long-haul traffic	14	26	22-27	30-37	73%
Truck with trailer, long-haul traffic	20	40	28-33	45-55	61%

Source: Volvo Truck Corporation (see Note 51)

Box 5. How fuel use per unit of payload varies with load factor for a tractor and semi-trailer in long-haul traffic



Source: Based on data from Volvo Truck Corporation (see Note 52)

truck is fully loaded. This is illustrated in Box 4, based on data provided by a truck manufacturer.[51] The consequence is that the energy use required per tonne of payload is disproportionately large when loads are small.

The kind of relationship that exists between fuel consumption per tonne of payload and load factor is shown in Box 5, which is based on data in Box 4 for 'Tractor and semi-trailer, long-haul traffic'.[52] In this example, fuel consumption per tonne of payload with a 10-per-cent load factor is about twice the consumption with a 20-per-cent load factor, which in turn is about twice the consumption with a 45-per-cent load factor, which in turn is about twice the fuel consumption when the truck is full. In this example, when the truck is full 73 per cent of the fuel moves the truck, even though the payload (26 tonnes) is almost twice the truck's unladen weight (14 tonnes).

Put another way, the example in Box 5 shows that more than two and a half times as much fuel is required to move a tonne of payload over 100 kilometres when a truck is one-quarter full than when it is three-quarters full (8.4 vs. 3.2 litres in this example).

The important aspect of load factor is not so much the estimated energy use per payload tonne-kilometre but the opportunity to consolidate loads, use fewer trucks, use less fuel, produce fewer emissions, and cause less congestion on the road. The key point is not that a one-tenth-full truck uses about eight times as much fuel per tonne of payload as a full truck. It is that ten of the near-empty trucks could—in theory—be replaced by one full truck, thereby saving seven-eighths (88 per cent) of the fuel used. Whether they can be replaced in practice requires careful investigation in each instance.

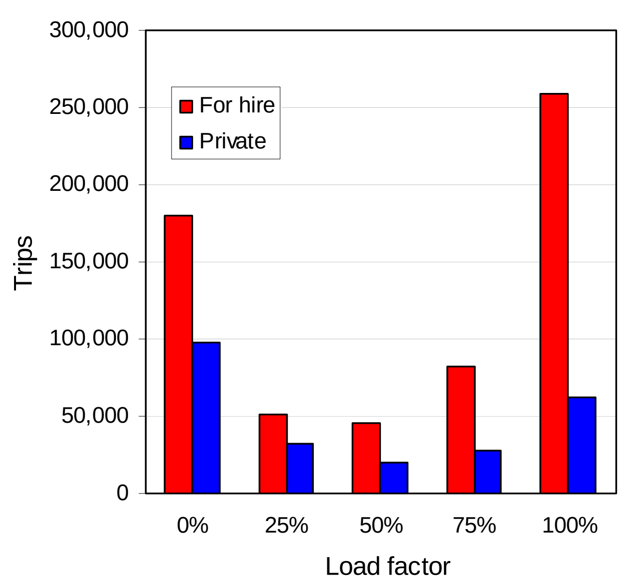
Even quite small increases in load factor can result in significant reductions in fuel use, provided appropriate consolidation can be achieved. For the example in Box 5, increasing the average load factor from 30 to 40 per cent reduces fuel use per payload tonne-kilometre by almost a quarter (from 7.1 to 5.4 litres per 100 tonne-kilometres). Increasing the average load factor from 50 to 60 per cent reduces fuel use by 15 per cent. The next question is whether there is scope for increasing load factors. Are trucks on the road mostly full or mostly empty?

ACTUAL LOAD FACTORS FOR INTER-CITY TRUCK TRAFFIC IN CANADA

In 1991, 1995, and 1999 (but not in 2003), the federal and provincial governments conducted an extensive survey of heavy-duty cargo trucks moving along Canada's main inter-city highways.[53] The 1999 *National Roadside Study* (NRS) sampled truck traffic at 238 sites spread along the 25,200 kilometres of roads that are the main components of the network used by trucking outside urban areas. There was a seven-day truck count at each site and 65,052 interviews with operators of randomly selected trucks at the sites, supported by truck inspections. Interviews and inspections categorized trucks into empty, one-quarter full, half full, three-quarters full, and full. (The question as to whether 'full' means by 'full by space' or 'full by weight' is addressed below.)

Results of the 1999 NRS suggest that about half of such trucks on the road were half full or less. Box 6 shows the actual distribution of trips by load factor, showing 'for-hire' trucks and 'private' trucks separately.[54] A considerably higher proportion (42 per cent)

Box 6 Distribution by load factor of inter-city heavy-duty, truck trips in 1999, according to type of ownership



Source: National Roadside Survey, 1999 (see Notes 53 and 54) of the for-hire trucks were full than the private trucks (26 per cent), a matter returned to below.[55] Conversely many more of the private trucks were empty (41 per cent vs. 29 per cent for for-hire trucks).

Box 7 shows how the full trucks were full.[56] Trucks were more likely to be full by space ('cubed out') than by weight ('weighted out'). Just over a quarter of trucks were full by both space *and* weight. The 1999 NRS documentation is unclear as to whether trucks carrying less than a full load were, for example, half full by space or by weight. Analysis of cargo weights suggests that partial loads may have been even more likely to have been characterized by space than by weight.[57]

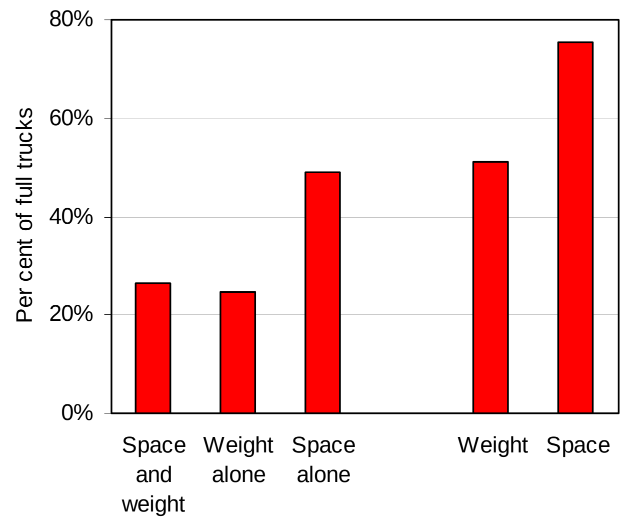
Box 8 confirms the indication in Box 6 that for-hire trucks were more likely to be well loaded than private trucks.[58] It shows too that load factors increased quite steeply with trip distance, especially in the case of for-hire trucks. Put another way, full and nearly full trucks were likely to be on long-distance trips, and less full trucks were more likely to be on shorter-distance trips.

Because less full trucks travelled shorter distances, the expected reduction in energy use and emissions from load-factor improvements could be lower for lower load factors. This is illustrated in Box 9, which shows both the shares of all trips that had load factors of 75 per cent or less and the shares of potential capacity, weighted for distance travelled, for the six largest provinces, the Atlantic provinces, and Canada.[59] The weighting for distance travelled reduces the potential for improvement considerably, from a Canada-wide average of 63 per cent (trips three-quarters full or less) to 33 per cent (unused capacity weighted for distance). However, even after the correction for distance travelled, the potential for better loading of intercity trucks remains considerable.

Many more trucks are on Canadian roads than the intercity trucks that were the subject of the NRS surveys. The scale of this activity may be indicated by the following estimate: in the mid-1990s the value of private trucking exceeded that of for-hire trucking, even though the 1999 NRS, for example, recorded 2.6 times as many trips by for-hire trucks (see Box 6). The estimate is set out in Box 10, which shows the values of for-hire and private trucking according to the type of trip (urban, intra-provincial, etc.).[60] Private trucking appears to predominate within urban regions (truck movement within which was substantially underestimated in the NRS surveys).

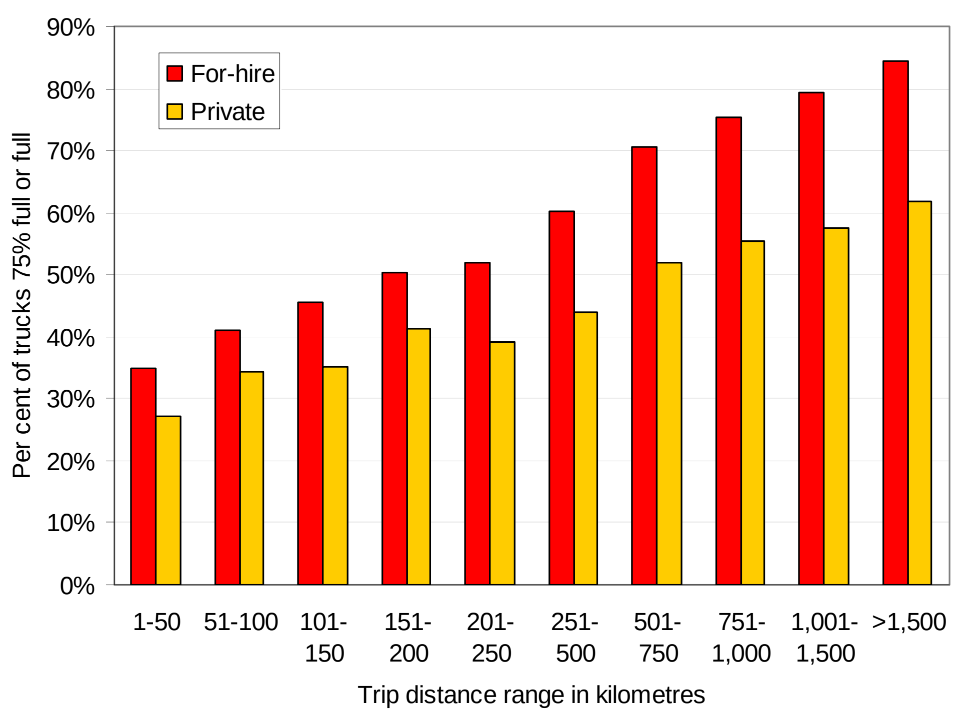
Indeed, in terms of *numbers* of trips (as opposed to tonne-kilometres per-

Box 7. How full trucks were full by space or weight or both, Canada, 1999



Source: National Roadside Survey, 1999 (see Notes 53 and 54)

Box 8. How the load factor of trucks varied with trip distance, Canada, 1999



Source: National Roadside Survey, 1999 (see Notes 53 and 54) formed), there may be very much more urban than inter-urban truck traffic. An indication of this comes from the Edmonton Region Commodity Flow Survey, which showed that 93 per cent of commercial movements in the Edmonton Region stop and start within the region and that 36 per cent were for the movement of goods rather than the provision of services.[61]

In conclusion, the available evidence suggests that the potential for reducing energy use and GHG emissions by increasing truck load factors may be large. The more productive opportunities could lie with private trucks travelling shorter distances, in and near urban areas. However, longer-distance trucking should also be addressed. Even though longer-distance trucks are more likely to have high load factors, there may be a sufficient number with low load factors to warrant measures to ensure further consolidation of loads, particularly for private trucking.

RAISING LOAD FACTORS

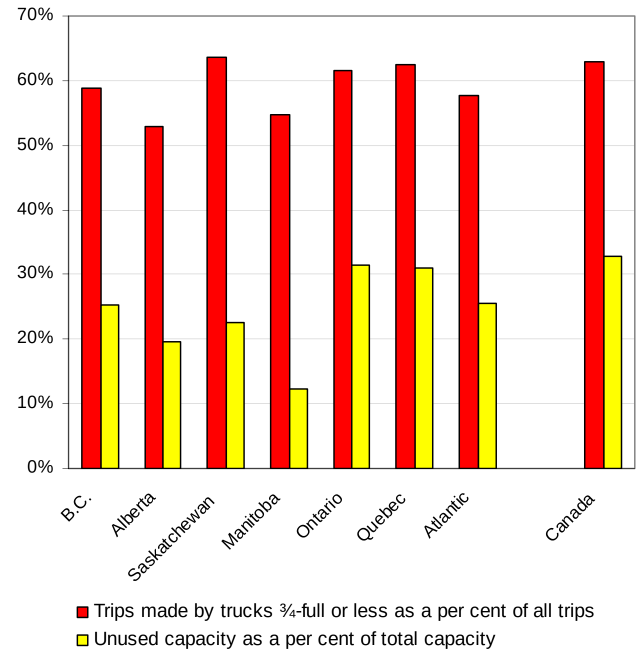
There are practical limits on the extent to which load factors can be raised. For example, a carrier moving drilling equipment for extended use at a remote site is unlikely to find an early return load. Practical limits can be made more severe by laws and regulations concerning cabotage[62] and security.[63] Nevertheless, efforts to raise load factors warrant consideration because of the potential for relatively easy and early reductions in fuel use.

In Europe and Japan there have been numerous attempts to reduce the number of trucks moving within urban areas by establishing public- or private-sector distribution centres that consolidate loads, rationalize pick-ups, and optimize loading and routing of the vehicles employed.[64] The experience is mixed. Such services can be successful in reducing truck activity, energy use, and emissions, but they can also raise costs, deterring use of them when there are alternatives.

An outstanding example of a successful attempt to reduce truck activity in a congested area is the establishment of the Heathrow Airport Retail Distribution Centre, near London UK, managed by Exel, a logistics company. Suppliers' vehicles go to the distribution centre, and only the logistics company's vehicles enter the airport. **The result appears to have been a reduction by 90 per cent in the number of vehicles servicing retail operations within the airport**. In addition to the reduced congestion and environmental impacts, the following advantages have been noted:

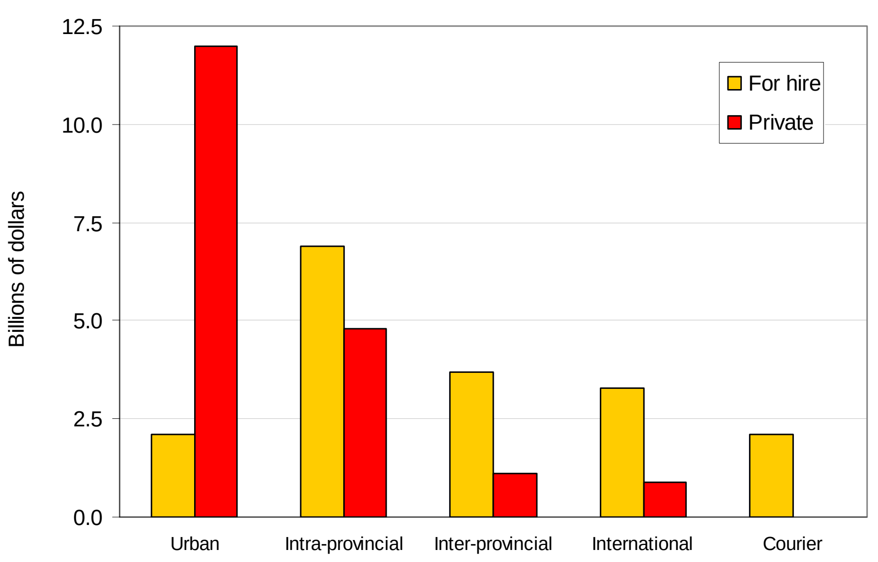
- Major cost savings by suppliers.
- A reduction in the number of less experienced drivers on airport roads.
- More frequent and better scheduled deliveries to terminal buildings,

Box 9. Trucks not full as a per cent of all trips and unused capacity as a per cent of all capacity (weighted for trip length), Canada and provinces, 1999



Source: National Roadside Survey, 1999 (see Notes 53 and 54)

Box 10. Value of services provided by for-hire and private trucking by area of operation, Canada, mid-1990s



Source: *Profile of Private Trucking in Canada*, 1998 (see Note 60) enabling retailers to know more accurately when goods will arrive.[65]

The system was introduced in part to reduce internal traffic and in part to reduce security risks. It illustrates the potential for reductions in truck energy use and GHG emissions. It may also illustrate the essential requirements for the success of such a scheme: a high level of freight transport activity within a relatively small area, complete control over roads in the area, and the prohibition of other means of freight movement in the area.

It's hard to find assessments of efforts to increase the load factors of trucks operating over longer distances. The apparent popularity of Internet-based load-matching services suggests that there may be considerable interest in raising load factors.[66] However, the interest may be driven by factors other than fuel savings and reductions in GHG emissions. A recent prospective view of trucking and logistics during 2004 suggested that load factors are increasing but more in response to overall capacity constraints than to particular concerns about fuel use or GHG emissions.[67] Several possible causes for the capacity constraints were indicated (not in order of importance): (i) reduction in effective rail capacity; (ii) growth in economic activity, particularly in the U.S.; (iii) carrier bankruptcies and consolidations during the recent economic recession in the U.S.; (iv) shortages of truck drivers; (v) cross-border security programs; (vi) new U.S. hours-of-service rules for drivers, and forthcoming new Canadian rules; and (vii) higher insurance premiums and uncertainty about fuel costs that have made operators reluctant to add equipment.

Thus, an ongoing trend towards higher load factors could be an almost incidental effect of the prospect of higher fuel costs. The challenge may be to convey that much higher fuel prices may be imminent, as discussed in earlier sections of this *Monitor*, and that rearrangement of loading and shipping practices so as to raise load factors would be an effective remedy.

Increased load factors could be achieved quite quickly. They require no changes in vehicle or infrastructure, or even much change in systems of freight movement. Thus they could provide a timely response to the rapidly rising use of oil for trucking illustrated in Box 3.

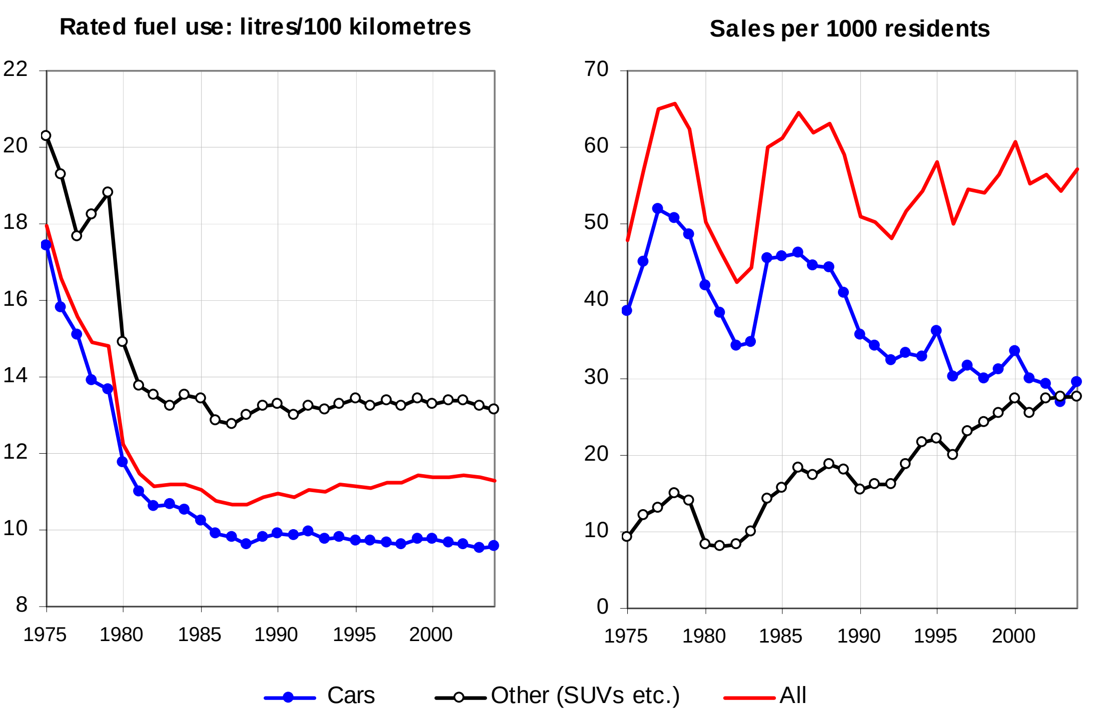
One possibly easy way to raise load factors could be to discourage private trucking, which is associated with lower load factors than for-hire trucking (see Box 6 and Box 8). When private trucks operate in a for-hire mode, they have load factors similar to for-hire trucks.[68]

For a broad discussion of improving the efficiency of commercial vehicle management, which touches on several of the points raised above, see the Freight Transport Management section of the Victoria Transport Policy Institute's *Online TDM Encyclopedia*.[69]

REDUCING FUEL USE BY PERSONAL VEHICLES

In Canada and the U.S., the average fuel intensity—i.e., fuel use per 100 kilometres—of new personal vehicles fell sharply between 1975 and 1982, less sharply between 1982 and 1987, and has increased slightly since then. These trends are shown in the left-hand panel of Box 11, which concerns vehicles sold in the U.S. only.[70] Personal vehicles include regular automobiles, on the one hand, and what are generi-

Box 11. Weighted average rated fuel use (left panel) and weighted sales per capita (right panel), light-duty vehicles sold in the United States, 1975-2004 model years



Source: U.S. Environmental Protection Agency (see Note 70) cally known as 'light trucks'—sport-utility vehicles (SUVs), passenger vans, and pick-up trucks—on the other hand.

What is clear from Box 11 is that, given sufficient impetus, the average fuel intensity of vehicles sold can fall quite steeply. The U.S. average fell by more than a third in just six years, between 1975 and 1982.[71] The impetus was the 'oil crises' of the 1970s, which resulted in a tripling of the real price of crude oil between 1973 and 1974 and a further doubling between 1978 and 1979.[72] In response, real U.S. pump prices rose by 23 per cent between 1973 and 1974, and by 22 per cent in each of 1978-1979 and 1979-1980.[73]

Real retail gasoline prices fell steeply in the early 1980s, returning to pre-crisis levels by 1986, where they stayed with minor fluctuations until this year. Real crude oil prices fell to about twice the pre-crisis level by 1986, again staying there with rather larger fluctuations until this year's upwards trend.

Even though gasoline prices fell in the early 1980s as sharply as they had risen in the late 1970s, the average fuel intensity of personal vehicles did not increase because the U.S. government introduced Corporate Average Fuel Economy (CAFE) standards, with effect from the 1978 model year. The CAFE program required average fuel intensity to decline by about a third between 1978 and 1985 to approximately the current level, with separate standards for regular cars and light trucks (i.e., SUVs, minivans, and pick-up trucks).[74]

The left-hand panel of Box 11 shows a slight increase in average fleet fuel use since the 1985 model year, even though the individual averages for automobiles and light trucks did not increase. The increase in average fuel use resulted from the change in the mix of the new-vehicle fleet, shown in the right-hand panel of Box 11, whereby the share held by light trucks grew from 25 per cent for the 1985 model year to 51 per cent for the 2003 model year.

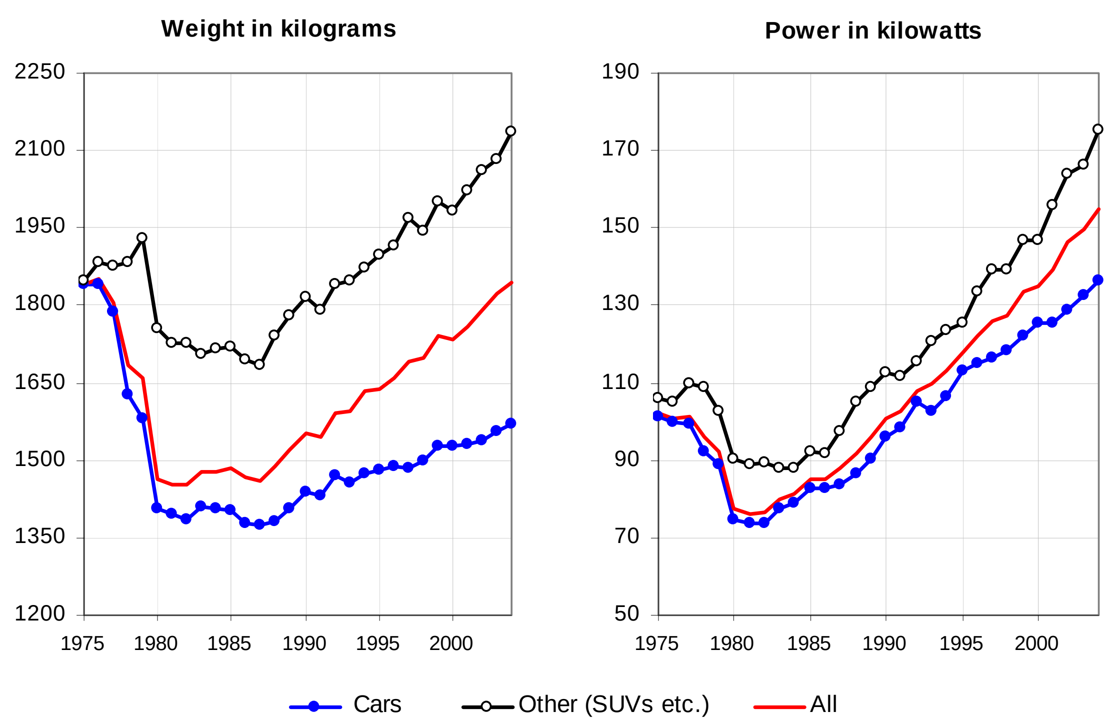
Box 12 shows that the sharp declines in fuel use between the 1975 and 1982 model years were achieved through dramatic reductions in vehicle weight (21 per cent overall; left panel) and engine power (25 per cent overall; right panel). Since the 1987 model year, weight has increased by 26 per cent, i.e., back to near the 1975 level. Power has increased by 76 per cent. This has all been achieved while maintaining more or less constant fuel efficiency (as required by CAFE standards).

Remarkable technological achievements since 1987 have allowed vehicle weight to increase by 25 per cent and engine power to increase by 76 per cent, while hardly increasing fuel intensity. If the achievements had instead been applied to reducing fuel use, the average fuel consumption of new personal vehicles could be 55 per cent less than the current level (i.e., 5.1 rather than 11.3 litres per 100 kilometres). The vehicles would, of course, weigh less and be less powerful but they could also be no less comfortable or safe, and, for almost all purposes, no less practicable than the present vehicles on the market.

According to vehicle manufacturers, vehicle weights and power have risen in response to consumer demand.[75] Box 11 suggests that given the right incentives (e.g., higher fuel prices), consumer demand can change rapidly.

Thus, the good news is that there is much scope for dramatic improvements in the fuel efficiency of new vehicles.

Box 12. Weighted average vehicle weight (left panel) and engine power (right panel), light-duty vehicles sold in the United States, 1975-2004 model years



Source: U.S. Environmental Protection Agency (see Note 70)

Manufacturers were able to adjust quite quickly to a rapid change in consumer demand in the 1970s. Today, with more flexible manufacturing processes,[76] the adjustment could perhaps be more rapid.

The bad news is that although the new-vehicle fleet could change quickly, changes in the whole personal-vehicle fleet could take considerably more than a decade. At current replacement rates, seven years would be required to replace half the light-duty vehicles on the road and 12 years to replace three quarters of the total.[77] Turnover could be accelerated by an incentive program.[78] If a replacement vehicle does not have at least 15-per-cent better fuel efficiency than what it is replacing there could be a net increase in life-cycle energy use.[79]

Manufacturers may argue that 'forcing' consumers to buy vehicles they do not want would reduce sales. But, history suggests that the move to smaller, less powerful vehicles in the 1970s was associated with a major *increase* in sales (see the right-hand panel of Box 11). With an effective incentive program, the increase in sales could be even greater.

Markedly improving the fuel efficiency of personal vehicles may well not have such an early impact on overall oil consumption as increasing the load factors of trucks on the road. However, to ensure that it would have as strong an impact as possible by the time world oil production peaks, perhaps in 2012, measures to ensure improved fuel efficiency should be introduced as soon as possible.

TETHERED VEHICLES FOR AN ERA OF ENERGY CONSTRAINTS[87]

A longer-term effective response to high oil prices could be much wider use of tethered vehicles—i.e., electrically powered vehicles fuelled via rail or wire—including trains, streetcars, trolley buses, and even trolley trucks.

Tethered vehicles have three relevant advantages over comparable untethered vehicles: (i) they can have remarkably low energy intensities; (ii) their primary fuels can include a wide range of renewable and non-renewable sources; and (iii) for the most part they involve familiar, tried, tested, and available technology.

They also have four major disadvantages: (i) they are confined to routes with appropriate infrastructure (i.e. rails and/or wires); (ii) this infrastructure is dangerous to pedestrians (high voltage) and must be elevated or confined to a separate right-of-way; (iii) without special provision, they are operationally constrained in that the inability to pass reduces speeds to that of the slowest vehicle on the system; and (iv) they rely on continuously available, centrally provided power.

The superior performance of tethered passenger vehicles with respect to energy use is illustrated in Box 13.[88] In each of the three categories of vehicle, tethered vehicles show lower *operational* energy use.

Overall (primary) energy use can be much greater than operational (secondary) energy use, according to how the energy is supplied. For example, electricity produced by a combined-cycle gas turbine generator requires expenditure of about 90 per cent more primary energy in the form of generator fuel than is available in the

Box 13. Energy use in megajoules per passenger-kilometre by various modes. Tethered modes are shown in colour

Vehicle type	Fuel	Occupancy (pers./veh.)	Energy use (mJ/pkm)
Personal vehicles:			
SUVs, vans, etc.[80]	Gasoline	1.70	3.27
Large cars[80]	Gasoline	1.65	2.55
Small cars[80]	Gasoline	1.65	2.02
Motorcycles[80]	Gasoline	1.10	1.46
Fuel-cell car[81]	Gasoline	1.65	0.92
Hybrid electric car[82]	Hydrogen	1.65	0.90
Very small car[83]	Diesel	1.30	0.89
Personal Rapid Transit[84]	Electricity	1.65	0.49
Public transport between cities:			
Intercity rail (U.S.)[85]	Diesel		2.20
School bus[80]	Diesel	19.5	1.02
Intercity bus[80]	Diesel	16.8	0.90
Intercity rail (U.S.)[85]	Electricity		0.64
Public transport within cities:			
Transit bus (U.S.)[86]	Diesel	9.3	2.73
Trolleybus (U.S.)[86]	Electricity	14.6	0.88
Light rail (streetcar, U.S.)[86]	Electricity	26.5	0.76
Heavy rail (subway, U.S.)[86]	Electricity		0.58

Sources: See notes referenced within the table secondary energy in the electricity.[89] Similarly, if hydrogen for a fuel cell is produced by electrolysis, the energy content of the electricity used is about 60 per cent higher than the energy content of the hydrogen produced.[90]

With such conversion losses, it is important to consider the primary energy use; this is a better indicator of the energy burden. However, when the secondary energy—which provides the motive power—can be produced with little intermediate conversion, considerations of primary energy use are less important. Examples are gasoline produced from conventional oil and electricity from wind turbines.

Tethered vehicles can also provide superior energy performance for freight transport. There are no electric freight trains in North America. The comparison in Box 14 is for Finland.[91] Not shown are tethered versions of trucks, known as 'trolley trucks', which like trolleybuses are powered through an overhead wire. They are used extensively in mining and other off-road operations, as illustrated in Box 15.[92] Data on comparative energy use by trolley trucks and regular trucks are not available; the difference between the two is likely comparable to that shown in Box 14 for diesel and electric trains.

The particular features of electric motors that make them more efficient than comparable internal-com-bustion engines are: (i) higher torque at low speeds, thus requiring less fuel use and a smaller motor; (ii) smaller motors mean less weight to carry, also meaning less fuel use; and (iii) electric drive systems can have regenerative braking—motive energy is captured when decelerating rather than lost as friction heat—again resulting in energy savings.

Box 14. Energy use by freight transport in Finland, in megajoules per tonne-kilometre

Vehicle type	Fuel	Energy use (mJ/tkm)
Truck	Diesel	0.45
Train	Diesel	0.20
Train	Electric	0.06

Source: Ecotraffic R & D (see Note 91)

The low energy intensities of tethered vehicles, for passengers and freight, suggest that extensive use of them should be considered as part of the preparation for an era of energy constraints.

Just about as important for sustainability as tethered vehicles' low energy intensity is their versatility in the use of primary energy sources. Any means of generating electricity for the grid can be a primary source of energy for tethered vehicle operations. In this way, wind, sun (thermal and photoelectric), tide, falling water, nuclear fission, and combustion of fossil fuels and biofuels can all be energy sources for tethered vehicles.

As we move towards an energy future whose only certainty may be reduced reliance on fossil fuels, notably oil, the ability to power transport by a wide variety of sources will be advantageous. Moreover, electricity is the most convenient energy currency of many sustainable primary sources, including wind, sun (photoelectric), tide, and falling water.

Tethered electric vehicles have been in practical use for at least 120 years.[93] There were streetcars on Canadian streets before there were automobiles.[94] There has been continuous development of the technology as adoption of these modes has spread throughout the world, and as technical requirements have been enhanced (e.g., for high-speed trains).

Building on this well-established technology, there are many opportunities for further enhancement, especially in the matter of personal rapid transit (PRT, noted in Box 13). Because PRT could provide a convenient, affordable alternative to automobile use in low-density areas, it offers the opportunity to address what may be the most intractable of transport challenges.[95]

Another major challenge concerns road freight transport, noted above as the fastest growing source of oil use. It's possible to conceive of technological development that would allow any truck, and even any road vehicle, to draw motive power from overhead wires, replacing some of it during braking.

DISADVANTAGES OF TETHERED VEHICLES

The most serious disadvantage of tethered vehicles is their infrastructure requirements. At a minimum, they require wires above existing roads, and the means to power them. According to the type of vehicle, they could also require new rails or other guideways.

A similar challenge confronted automobiles 100 years ago. They were mostly confined to summer travel on roads within urban areas. In 1910, the only paved highway in Canada was a 16-kilometre stretch from Montreal to Ste.-Rose. Present levels of route flexibility took many years to develop. Indeed, an automobile was not driven across Canada until 1946, and the Trans-Canada Highway was not completed until the 1960s.[96] Today's automobiles and trucks may be even more confined to laid-out roads than those of a century ago, but the road system is extensive, reaching to most parts of southern Canada.

Widespread adoption of tethered vehicles could well involve continued use of the present road system, with the addition of powered overhead wires that can be shared by all. However, vehicles run more efficiently on rails or tracks than on roads, and energy constraints, plus operational and safety challenges, may favour trains and other vehicles confined to special-purpose rights-of-way.

Tethered systems may have less immediate resilience than cars and trucks be-

Box 15. Trolley truck operating at the Quebec Cartier iron ore mine, Lac Jeannine, 1970s

Source: Hutnyak Consulting (see Note 92)

cause the latter carry their own fuel. However, both depend ultimately on heavily centralized systems of energy distribution. Toronto's streetcars and subway trains stopped during the blackout on August 14, 2003, but cars and trucks kept on rolling, at least for a time. Then they were slowed or even stopped in traffic jams caused by non-functioning traffic signals and by line-ups at non-functioning gas stations.

Greater dependence on tethered transport systems would stimulate designs for greater resilience involving more distributed generation of electricity and greater redundancy. These would in any case be likely features of a more sustainable system of energy supply.

A major shift towards tethered transport systems would require several decades. However, if tethered systems do indeed offer the best option for sustaining effective transport in an energy-constrained world, an early start on conversion would be advisable. Initial elements of the conversion strategy could include electrification of existing rail lines, upgrading of heavily used bus routes to trolley bus or streetcar service, and focused exploration of applications of personal rapid transit.

SUMMARY OF THIS ISSUE OF THE *MONITOR*

This issue of the *Sustainable Transportation Monitor* has reinforced the need to achieve early reductions in oil use for transport. Such reductions could be necessary to avoid the severe economic hardship that would occur soon after a peaking of world oil supply, perhaps early in the next decade. Without adequate preparation, Canadians would be left to the rigours of the marketplace, which could make much necessary transport unaffordable. Adequate preparation would mean much reduced dependence on oil at the time of the peak, and thus much less vulnerability to high prices of gasoline and diesel fuel.

Three of many ways to reduce dependence on transport fuel have been discussed. Their main impacts would be respectively in the short, medium and longer terms, although early action with respect to each measure should be considered.

The short-term measure addressed the main cause of Canada's recent growth in oil use: trucking. There seems to be considerable potential for reducing oil consumption through more efficient use of trucks on the road, specifically by raising load factors.

The measure for the medium term concerns fuel use by new personal vehicles. History suggests that dramatic changes could be achieved very quickly by applying some of the remarkable technological achievements of the last few decades to reducing the fuel intensity of vehicles rather than increasing their power and weight. Because less than ten per cent of the personal vehicle fleet is replaced each year, more than a decade would be required to reap the full benefit of this measure.

The measure for the long term concerns the very nature of our vehicles. In an era of profound energy constraints, reliance on *tethered* vehicles may make sense because they have inherently low fuel use and because they can make use of a wide range of renewable and other energy sources.

Making progress in these matters will require strong political leadership backed by solid research, which the Centre for Sustainable Transportation would be pleased to contribute to.

THE CENTRE FOR SUSTAINABLE TRANSPORTATION

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

The mission of The Centre for Sustainable Transportation is to work proactively in achieving the sustainable transportation of persons and goods in Canada through co-operative partnerships, relevant and timely research; projects; the communication and dissemination of balanced information; and the monitoring and supporting of sustainable transportation activities.

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 tenth issue of the Sustainable Transportation Monitor, published annually from 1998 to 2000 and now twice a year. All issues of the Monitor are available at the Centre's Web site, as are the Centre's other publications (visit www.cstctd.org). The Monitor provides evaluation of progress towards or away from sustainable transportation and discussion of related matters.

This issue has been written by Richard Gilbert, the Centre's research director. The content has been approved for publication by the Board of Directors acting as individuals rather than as representatives of the organizations with which they are affiliated.

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 to become a corporate or individual member of the Centre.

REFERENCE NOTES

1. Campbell CJ, Laherrère JH, The End of Cheap Oil, *Scientific American*, March 1998, Pages 78-83. The cover story of the June 2004 *National Geographic* magazine has the same title (see Note 7).
2. For the share of synthetic crude oil in Canada's oil production, see Figure 4.7 of *Canada's Oil Sands: Opportunities and Challenges to 2015*. National Energy Board, Ottawa, May 2004, available at the URL below.
   1. http://www.neb.gc.ca/energy/EnergyReports/EMAOilSandsOpportunitiesChallenges2015/EMAOilSandsOpportunities2015Canada2004_e.pdf. Accessed June 5, 2004.
3. Natural gas liquids are compounds such as propane and butane that become available during extraction of natural gas. They become liquid under small increases in pressure or reductions in temperature, and can replace oil derivatives in many of their uses.
4. Box 1 was taken from the Web site of the Uppsala Hydrocarbon Depletion Group at the URL below.
   1. http://www.isv.uu.se/uhdsg/. Accessed June 5, 2004.
5. According to Page 411 of International Energy Agency, *World Energy Outlook 2002* (IEA, Paris, France, 2002), 95.5% of the energy used for motorized transport worldwide in 2000 came from oil, i.e., 1,696 out of 1,775 million tonnes of oil equivalent.
6. The debate surfaced most of all in a series of six articles in what may be the most influential of the oil professionals' journals. The first of these articles was Williams B, Debate over peak-oil issue boiling over, with major implications for industry, society. *Oil & Gas Journal*, 101(27), 18-29, July 14, 2003. The other five articles are in the subsequent issues of this weekly publication. Associated articles appear in several of the issues.
7. Among several recent media treatments of peak oil are the following [numbers in square brackets refer to the URLs at the end of this note]:
   •Michael Meacher, Plan now for a world without oil. *Financial Times* (London, UK), January 5, 2004. [1]
   •Paul Roberts, Running out of oil—and time. *Los Angeles Times*, March 6, 2004. [2]
   •James Flanigan, Pump prices just a drop in the bucket of fuel woes. *Los Angeles Times*, March 7, 2004. [3]
   •Stella Farrington, Oil over a Barrel: Goodbye to Cheap Oil from 2010? *Dow Jones Newswires*, March 8, 2004. [4]
   •CBC Radio, Quirks & Quarks, March 13, 2004. [5]
   •Jeffrey Rubin, Oil market tightness is likely long term. *Globe & Mail*, March 15, 2004. [6]
   •Jacqueline Doherty, Crude Calculations. *Barrons*, March 15, 2004. [7]
   •Jeffrey Rubin, Why sky high oil prices are no blip on the radar. *Globe & Mail*, March 22, 2004. [8]
   •Yves Cochet, Vers la pétro-apocalypse. *Le Monde* (Paris, France), March 31, 2004. [9]
   •Joan Lowy, The end of the age of oil? Opinions vary. *Scripps Howard News Service*, April 7, 2004. [10]
   •World oil crisis looms, *Jane's Foreign Report*, April 21, 2004. [11]
   •Paul Krugman, The oil crunch, *New York Times*, May 7, 2004. [12]
   •Mathew Ingram, Crude oil price surge sends shivers down investors' spines, Globe & Mail, May 8, 2004. [13]
   •Richard Gilbert, Don't gripe about gas prices, *Globe & Mail*, May 11, 2004. [14]
   •Tim Appenzeller, The end of cheap oil [cover story], *National Geographic*, June 2004 [15]
   •Jim Lemon, Running out of gas: Can alternative sources replace the fossil fuels we depend on? *Literary Review of Canada*, May 2004
   Four recent books on the topic are:
   ✱Richard Heinberg, *The Party's Over: Oil, War and the Fate of Industrial Societies*. New Society Publishers: Gabriola Island, BC, 2003.
   ✱David Goodstein, *Out of Gas: The End of the Age of Oil*. W.W. Norton & Co.: New York, 2004.
   ✱Stephen Leeb, Donna Leeb, *The Oil Factor: How Oil Controls the Economy and Your Financial Future*. Warner Books, New York, 2004.
   ✱Paul Roberts, *The End of Oil: On the Edge of a Perilous New World*. Houghton Mifflin Co., New York, 2004.
   Also of interest is the February 2004 paper *Invest in the Oil Sands: High Oil Prices are Here to Stay* by John Mawdsley, Jenny Mikhareva, and Craig Espey of the Calgary office of Raymond James Ltd. (available from john.mawdsley@raymondjames.ca).
   1. http://www.btinternet.com/~nlpwessex/Documents/WATworldwithoutoil.htm. Accessed June 5, 2004.
   2. http://www.commondreams.org/views04/0307-02.htm. Accessed June 5, 2004.
   3. http://www.latimes.com/business/la-fi-flan7mar07,0,3823964.column. Accessed June 5, 2004.
   4. http://www.culturechange.org/fall_of_petroleum_DowJones.html. Accessed June 5, 2004.
   5. http://radio.cbc.ca/programs/quirks/archives/03-04/mar13.html. Accessed June 5, 2004.
   6. http://www.globeandmail.com/servlet/ArticleNews/TPStory/LAC/20040315/RRUBIN15/TPBusiness/Columnists. Accessed June 5, 2004.
   7. http://www.smartmoney.com/barrons/index.cfm?Story=20040315. Accessed June 5, 2004.
   8. http://www.globeandmail.com/servlet/ArticleNews/TPStory/LAC/20040322/RRUBINOIL22/TPBusiness/Columnists. Accessed June 5, 2004.
   9. http://www.lemonde.fr/web/article/0,1-0@2-3232,36-359335,0.html. Accessed June 5, 2004.
   10. http://www.shns.com/shns/g_index2.cfm?action=detail&pk=NOMOREOIL-04-07-04. Accessed June 5, 2004.
   11. http://www.janes.com/business/news/fr/fr040421_1_n.shtml [part article only]. Accessed June 5, 2004.
   12. http://www.pkarchive.org/column/050704.html. Accessed June 5, 2004.
   13. http://www.theglobeandmail.com/servlet/ArticleNews/TPStory/LAC/20040508/RSTOC08/Columnists/Columnist?author=Mathew+Ingram. Accessed June 5, 2004.
   14. http://www.globeandmail.com/servlet/ArticleNews/TPStory/LAC/20040511/COGAS11/Comment/Idx. Accessed June 5, 2004.
   15. http://magma.nationalgeographic.com/ngm/0406/feature5/index.html [excerpt only] . Accessed June 5, 2004.
8. Here are three recent forums where peak oil has been discussed:
   ★On December 10, 2003, the Society of Danish Engineers and the Danish Board of Technology held a conference in Copenhagen entitled 'Oil Demand, Production and Cost—Prospects for the Future'; details are at the first URL below. (The conference considered the first draft of the paper detailed in Note 9.)
   ★On February 24, 2004, the Center for Strategic and International Studies held a conference in Washington DC entitled

'Future of Global Oil Supply: Saudi Arabia'; details are at the second URL below.
★On February 27, 2004, the Swiss Federal Office of Energy held a workshop in Berne entitled 'Availability of fossil fuel resources'; details are at the third URL below.
1. http://www.ida.dk/oilconference/. Accessed June 5, 2004.
2. http://csis.org/energy/events.htm. Accessed June 5, 2004.
3. http://www.energie-schweiz.ch/internet/03252/index.html?lang=fr. Accessed June 5, 2004.

9. This March 2004 paper, prepared by Klaus Illum and entitled *Oil-based Technology and Economy*, is available at the URL below.
1. http://www.ida.dk/oilconference/Oil-based_Technology_and_Economy.pdf, Accessed June 5, 2004.

10. As the Danish paper detailed in Note 9 observes, even oil-supply 'optimists' project or imply a projection of a peak in oil production. The key part of the discussion concerning the position of one of these optimists, the International Energy Agency, is on Page 50 of the Danish paper. The key part of the discussion concerning another optimist, the Energy Information Administration of the U.S. Department of Energy, is on Page 84 of the paper.

11. Two recent analyses point to a 2007 peak in world oil production. One is by A.M. Samsam Bakhtiari, senior planner with the National Iranian Oil Company, in the April 26, 2004, issue of *Oil & Gas Journal*. It is entitled 'World oil production capacity model suggests output peak by 2006-2007'. The other is byChristopher Skrebowski, editor of the influential UK journal *Petroleum Review* (Oil field mega projects 2004, *Petroleum Review*, January 2004, available at the URL below). Skrebowski did not quite assert that world oil production will peak for all time in 2007 but concluded that after 2007 the volumes of new production will be "well below likely requirements". One authoritative source points to an even earlier peak, in 2005 (Deffeyes KS, *Hubbert's Peak: The Impending World Oil Shortage.* Princeton University Press, 2001).
1. http://www.odac-info.org/bulletin/documents/MEGAPROJECTSREPORT.pdf. Accessed June 5, 2004.

12. A recent example of the economists' position is Maugeri L, Oil: Never cry wolf—why the petroleum age is far from over. *Science*, 304, 1114-1115, 21 May 2004. This author, an oil company executive, argued that the concept of supply reflects "an unjustifiable faith in geology and does not consider technology and cost/price functions".

13. The discussion as to why an earlier peak would be better is on Page 50 of the Danish paper detailed in Note 9.

14. The discussion as to how a later peak might be associated with a steeper post-peak fall in production is on Pages 50 and 84 of the source detailed in Note 9.

15. For a brief elaboration of this position, see the source detailed in Note 12.

16. Box 2 is from a presentation by Harry J. Longwell, Executive VP, Exxon Mobil Corporation at the Offshore Technology Conference, Houston, Texas, May 7, 2002, available at the URL below. Also see Note 21 for data for 2001-2003.
1. http://www2.exxonmobil.com/Corporate/Newsroom/SpchsIntvws/Corp_NR_SpchIntrvw_Houston_070502.asp. Accessed June 5, 2004.

17. According to Smith MR, *World Oil Supply Report*, 3rd edition, Douglas-Westwood Ltd., 2004, as reported in Anon, Study: World oil forecast beset with reserves shortfalls. *Oil & Gas Journal*, April 12, 2004, 99 countries have produced or can produce significant volumes of oil. Of these, 52, including the U.S., are already well past their production peak, and another 16, including Australia, China, Norway, and the UK, are at or close to their peak.

18. The IEA document is *World Energy Investment Outlook: 2003 Insights*, International Energy Agency, Paris, France, 2003, available for a fee from the URL below.
1. http://library.iea.org/dbtw-wpd/bookshop/add.aspx?id=145. Accessed June 5, 2004.

19. The quotation is from the source detailed in Note 16. To put this amount into perspective, if the trillion dollars created 10 years of production at 80 million barrels a day, the cost per barrel would be US$3.42, less than one tenth of the current oil price per barrel of about US$40. It amounts to about US$28 per person worldwide per year for six years, i.e., about 0.3% of per-capita GDP. (For world-wide GDP, see the URL below.)
1. http://www.j-bradford-delong.net/TCEH/1998_Draft/World_GDP/Estimating_World_GDP.html. Accessed June 5, 2004.

20. For experts forecasting an earlier peak, see Note 11. For experts forecasting a later peak, see Note 10 and 12.

21. Box 2 shows discoveries only until 2000 and may suggest they were then on the rise again after a long decline. Data for subsequent years show this is not the case. According to the report referred to in Note 17, discoveries in 2000, 2001, and 2002 were respectively 13.05, 4.02, and 3.34 billion barrels. According to energy consultants IHS, 2003 may be the first year since the beginning of the modern oil industry in which there were no large oil discoveries at all (see the news release of their report at the URL below). The results for 2003 have been described by the editor of *Petroleum Review* as "little short of horrifying".
1. http://www.ihsenergy.com/company/press/pressreleases/arc2004/pr_011204-activity03.jsp. Accessed June 5, 2004.

22. The matter of the January 2004 downwards reclassification of the proven reserves of the Royal Dutch/Shell oil company is very much in the news at the time of writing (see Callus A, McBride J, Shell executives hid shortfall for years. *Globe & Mail*, April 20, 2004, at the first URL below, and Cahill T. Shell cuts oil reserves for the fourth time in 2004. *Globe & Mail*, May 25, 2004 at the second URL below). There are indications that overstatement of oil reserves may extend beyond this company (see Brought to book, *Economist*, April 1, 2004).
1. http://www.globeandmail.com/servlet/ArticleNews/TPStory/LAC/20040420/IBSHELL20/TPBusiness/International. Accessed June 5, 2004.
2. http://www.theglobeandmail.com/servlet/ArticleNews/TPPrint/LAC/20040525/IBSHELL25/TPBusiness/. Accessed June 5, 2004.

23. In his presentation at the December 2003 Copenhagen conference (see Note 8), Francis Harper noted that estimates of recovery factors for individual oil fields tend to grow, but that overall there has been a decline as smaller fields with low recovery factors have come into production. He concluded, "There are potentially large volumes available from increases in recovery factor, but realizing them will be expensive, difficult and slow".

24. According to the June 2003 issue of the *BP Statistical Review of World Energy*, available at the first URL below, China passed Japan in 2002 to become the world's second major user of oil after the U.S. Over the previous decade, use of oil in China had increased by 99%. Use of oil in Canada and the U.S. had increased respectively by 17% and 16%. Use of oil in Japan had declined by 3%. According to *Monthly Oil Market Report*, International Energy Agency, Paris, France, May 12, 2004, available at the second URL below, consumption of oil products in China

during the first quarter of 2004 was 19% higher than consumption during the same quarter of 2003; net imports of crude oil and oil products were 46% higher.
1. http://www.bp.com/subsection.do?categoryId=95&contentId=2006480. Accessed June 5, 2004.
2. http://omrpublic.iea.org/currentissues/full.pdf. Accessed June 5, 2004.

25. An example of the lack of anticipation of high oil prices may be the projections of Natural Resources Canada, which advised the U.S. Energy Information Administration in August 2003 that it expected world oil prices to remain more-or-less constant until 2020 at US$22.57 a barrel in 2002 dollars (see Table 9 of *International Energy Outlook 2004*, Energy Information Administration, U.S. Department of Energy, April 2004, available at the first URL below). According to the State of Alaska's Tax division, at the second URL below, the average monthly spot price for West Texas Intermediate Oil has been at least 25% above this price in every month since August 2003 and in May 2004 was 73% above this price (i.e., US$38.98 in 2002 dollars, or US$40.31 in current dollars).
1. ftp://ftp.eia.doe.gov/pub/pdf/international/0484(2004).pdf. Accessed June 5, 2004.
2. http://www.tax.state.ak.us/programs/oil/prices/index.asp. Accessed June 5, 2004.

26. For an informed view that North American natural gas production may have already peaked, see the presentation by Matthew Simmons, *The Natural Gas Riddle: Why Are Prices So High? Is a Serious Crisis Underway?* at the mini-conference of the International Association for Energy Economics, Houston, Texas, December 11, 2003, available at the first URL below. Matthew Simmons is a member of the National Petroleum Council (NPC), an industry body established to advise the U.S. Secretary of Energy. In September 2003, the NPC had issued a report, *Balancing Natural Gas Policy*, available at the second URL below, that included the following: "North America is moving to a period in its history in which it will no longer be self-reliant in meeting its growing natural gas needs; production from traditional U.S. and Canadian basins has plateaued."
1. http://www.simmonsco-intl.com/files/IAEE%20Mini%20Conf.pdf. Accessed June 5, 2004.
2. http://www.npc.org. Accessed June 5, 2004.

27. The Alberta Gas Reference Price increased more than 3.5-fold between February 1999 and February 2003, from $1.90 to $6.83 per gigajoule (see the URL below). Over the same period, the price Toronto consumers paid for natural gas rose by about 70%.
1. http://www.energy.gov.ab.ca/gmd/gas/monthlyref.asp. Accessed June 5, 2004.

28. LNG contributed about 1% of total U.S. natural gas supply in 2002, projected to rise to over 20% of total supply by 2010 (see Page 39 of *Annual Energy Outlook*, Energy Information Administration, U.S. Department of Energy, January 2004, available at the URL below). According to the International Energy Agency (see Pages 110 and 114 of the source detailed in Note 5), North America was responsible for 31% of world natural gas consumption in 2000 but had only 5% of proven natural gas reserves.
1. http://www.eia.doe.gov/oiaf/aeo/pdf/0383(2004).pdf. Accessed June 5, 2004.

29. The quote about Boston Harbour is from Powers B, *Assessment of Potential Risk Associated with Location of LNG Receiving Terminal Adjacent to Bajamar and Feasible Alternative Locations*, at the URL below. This source suggests that LNG shipment becomes economically feasible when the wholesale natural gas price is above about Can$4.40 per gigajoule (see Note 27).
1. http://www.borderpowerplants.org/pdf_docs/lng_position_paper_june2002_english.pdf. Accessed March 14, 2004.

30. For information about the Harpswell plebiscite and plans for new LNG terminals see Cox K, Tiny Maine town kills LNG project. *Globe & Mail*, March 11, 2004, at the first URL below. For other recent withdrawals of proposals, see Romero S, Fears drain support for natural gas terminals, *Trinidad Express*, May 21, 2004, available at the second URL below.
1. http://www.globeandmail.com/servlet/ArticleNews/freeheadlines/LAC/20040311/RTRANS11/international/International. Accessed June 5, 2004.
2. http://www.trinidadexpress.com/index.pl/article_opinion?id=23063499. Accessed June 5, 2004.

31. This information is from the source detailed in Note 28. A third proposal for a Canadian terminal is for Beaumont, near Quebec City (see Gibbens R, Gaz Metro faces fight over LNG plant. *Financial Post*, May 20, 2004, available for a fee at the first URL below). See also Spears J, Enbridge scrambling to meet gas demand. *Toronto Star*, May 6, 2004, available at the second URL below.
1. http://www.fpinfomart.ca. Accessed June 5, 2004.
2. http://www.thestar.com/NASApp/cs/ContentServer?pagename=thestar/Layout/Article_Type1&c=Article&cid=1083795010531&call_pageid=968350072197&col=969048863851. Accessed June 5, 2004

32. One author favouring greater use of natural gas as a fuel for combustion engines in vehicles is Matthew Wald (Questions about a hydrogen economy, *Scientific American*, pp. 66-73, May 2004), who argued that natural gas has "very few technical details to work out" compared with hydrogen fuel cells and, in any case, "hydrogen cells may not appear in great numbers in driveways, where cars have a total energy requirement of about 50 kilowatts apiece by may run only an average of two hours a day—a situation that is exactly backwards from where a good engineer would put a device like a fuel cell".

33. According to the International Energy Agency, "In the long term, perhaps the most promising path for virtually eliminating the direct use of petroleum fuels … is the hydrogen fuel cell. Once all vehicles operate on hydrogen fuels, they will be potentially renewably fuelled (if a renewable source of hydrogen is developed), and will produce water as their only emission." (Pages 168-169 of *Towards a Sustainable Energy Future*, IEA, Paris, France, 2001). In January 2003, U.S. President George Bush announced the FreedomCAR and Fuel Initiative "to reverse America's growing dependence on foreign oil by developing the technology needed for commercially viable hydrogen-powered fuel cells", detailed at the first URL below. Also see Sperling D, Ogden J, The Hope for Hydrogen, *Issues in Science and Technology*, pp. 82-86, Spring 2004, available at the second URL below.
1. http://www.eere.energy.gov/hydrogenfuel/. Accessed June 5, 2004.
2. http://www.its.ucdavis.edu/publications/2004/UCD-ITS-RP-04-19.pdf. Accessed June 5, 2004.

34. Hydrogen can be used as fuel for internal combustion engines, but its use in fuel cells is said to offer "significantly greater potential" (see the URL below).
1. http://www.initiative-brennstoffzelle.de/en/ibz/live/nachrichten/detail/104.html. Accessed June 5, 2004.

35. According to Amory Lovins in *Twenty Hydrogen Myths* (Rocky Mountain Institute, 2003, available at the URL below), "U.S. hydrogen production is at least one-fifth and probably nearer one-

third of the world total, is equivalent to ~1.8% of total U.S. energy consumption, and comes ~95% from natural gas at ~99% purity from steam reforming and associated cleanup processing." Data on production of hydrogen in Canada are not readily available. It's possible that current and future reliance on natural gas for hydrogen production could be less in Canada than in the U.S.
1. http://www.rmi.org/images/other/Energy/E03-05_20HydrogenMyths.pdf. Accessed June 5, 2004.

36. Figure 17 (Page 29) of *Measuring the New Economy: Trade and Investment Dimensions* (Organization for Economic Cooperation and Development Document No. TD/TC/WP(2001)23/FINAL, October 2001) sets out 1999 data on trade and GDP for 25 OECD and east European countries, at the URL below. Among the listed countries, Ireland (125%), Hungary (110%), and The Netherlands (86%) had trade as a higher share of GDP than Canada (72%).
1. http://www.olis.oecd.org/olis/2001doc.nsf/LinkTo/td-tc-wp(2001)23-final. Accessed June 5, 2004.

37. Consideration of the implications of peak oil is already being fiercely opposed. An example is the editorial by Peter Foster entitled "The great fake oil-shortage scare" in the *Financial Post* (*National Post*) on April 28, 2004. His argument is based chiefly on a book by Danish statistician Bjørn Lomberg (The Skeptical Environmentalist, Cambridge (UK), 2001) the key points of whose thesis seem to be that "new fields will be continuously added as demand rises" and that there will be much reserve growth. Indeed, Lomberg claims "there is oil enough to cover our total energy consumption for the next 5,000 years".

38. The Kyoto Protocol is an amendment to the United Nations Framework Convention on Climate Change (UNFCCC) adopted at the Third Conference of the Parties to the UNFCCC, held in Kyoto, Japan, in December 1997. The Protocol concerns reductions in emissions of six greenhouse gases (GHGs), i.e., gases whose concentration in the earth's atmosphere influences the mean temperature of the earth's surface by affecting the rate of energy loss of the earth (see the first URL below). The Protocol is binding on the 38 countries listed in Annex 1 to the UNFCCC, i.e., most of the industrialized countries, including those with economies in transition (former Soviet Union and eastern European countries). The Protocol comes into effect when two criteria are met: (i) it has been ratified by 55 Parties to the UNFCC, and (ii) it has been ratified by Annex 1 countries responsible for 55% of the total 1990 GHGs emitted by Annex 1 countries (see the second URL below). The first criterion has been met. Regarding the second criterion, 29 Annex 1 countries have ratified the Protocol, representing 44% of 1990 Annex 1 GHG emissions (see the third URL below). Significant non-ratifiers of the Protocol are the U.S., responsible for 33% of the 1990 Annex 1 total, and Russia, responsible for 17% of the total. Russia has not yet refused to ratify the Protocol, and may be moving towards ratification (see Nick Paton Walsh, Putin throws lifeline to Kyoto as EU backs Russia joingin WTO. *The Guardian*, London, UK, May 22, 2004, at the fourth URL below). Canada, responsible for 3% of the total, ratified the Protocol on December 17, 2002. When the Protocol comes into effect, Canada's obligation will be to reduce its GHG emissions so that the average during the five years 2008 to 2012 is 6% below the 1990 level. As well, "demonstrable progress" must be made by the ratifying Annex 1 countries by 2005 (see the second URL below).
1. http://unfccc.int/resource/iuckit/fact02.html. Accessed June 5, 2004.
2. http://unfccc.int/resource/iuckit/fact21.html. Accessed June 5, 2004.
3. http://www.unfccc.int/resource/kpstats.pdf. . Accessed June 5, 2004.
4. http://www.guardian.co.uk/international/story/0,3604,1222190,00.html. Accessed June 5, 2004.

39. The federal government's plan to meet its potential Kyoto obligation is set out in *Climate Change Plan for Canada*, Government of Canada, November 21, 2002, available at the first URL below. In brief, the plan speaks to reducing annual GHG emissions from an anticipated 'business-as-usual' (BAU) average level for the years 2008-2012 of 809 million tonnes (mt) of carbon dioxide equivalent to 571 mt, i.e., 6% below the actual level of 607 mt in 1990, i.e., an overall reduction by 29% form the estimated BAU level. The 2001 level was 720 mt, i.e., just slightly *above* the value to be expected from a BAU trend between 1990 and 2001. The actual 1990 and 2001 levels are from *Canada's Greenhouse Gas Inventory 1990-2001*, Environment Canada, 2003, available at the second URL below. According to this source, about 80% of Canada's GHG emissions in 2001 arose from the burning of fossil fuels, and about 32% of this source was contributed by transport (26% of total GHG emissions). According to Appendix 3 of *Canada's Energy Future: Scenarios for Supply and Demand to 2025*, National Energy Board, Ottawa, 2003, available at the third URL below, oil accounted for 33% of primary energy use in Canada in and transport accounted for about 70% of oil use (with oil fuelling over 99% of transport). Thus, it's clear that to meet the federal government's Kyoto target there would have to be a peaking of overall *fossil fuel* use in 2001 or soon after, although it's less clear that *oil* use would also have to peak. For example, if GHGs from non-fossil-fuel sources were reduced by 50% and those from non-oil fossil fuels by 40%, both compared with BAU trends, the target could be met while allowing for growth in oil consumption throughout the Kyoto period until 2012. However the government's *Plan* does speak to a reduction in emissions from transport by at least 10% from the BAU level of 206 mt to approximately the 2001 level, i.e., 187 mt. Thus, it may be reasonable to conclude that the *Plan* speaks to an approximate plateauing in oil use between about now and 2012.
1. http://www.climatechange.gc.ca/plan_for_canada/plan/pdf/full_version.pdf. Accessed June 5, 2004.
2. http://www.ec.gc.ca/pdb/ghg/1990_01_report/1990_01_report_e.pdf. Accessed June 5, 2004.
3. http://www.neb-one.gc.ca/energy/supplydemand/2003/English/SupplyDemandAppendices2003_e.pdf. Accessed June 5, 2004.

40. According to Green K, The 'fatal conceit' of Kyoto. *Toronto Star*, April 25, 2004, available at the URL below, "A suppressed report by the federal government evaluating the effectiveness of spending $500 million since the year 2000 to reduce emissions of greenhouse gases has shown—surprise!—that the spending was largely wasted, producing neither a reduction in gas emissions, nor the development of new 'cleaner' technologies."
1. http://www.thestar.com/NASApp/cs/ContentServer?pagename=thestar/Layout/Article_Type1&c=Article&cid=1082758210897&call_pageid=968256290204&col=968350116795. Accessed June 5, 2004.

41. The sources of the information about oil use for transport is detailed in Note 39.

42. The workshops were held in Vancouver, Brampton, Montreal (in French), and Halifax. The workshops were attended by 266 Canadians with a deep interest in transport issues, including more than 200 transport professionals. They are described in Issue No. 8 of the *Sustainable Transportation Monitor*, available at the URL below. See also Note 78.
1. http://www.cstctd.org/CSTadobefiles/STM8%20English1.pdf. Accessed June 5, 2004.

43. The data in Box 3 are from the *Comprehensive Energy Use Database* maintained by the Office of Energy Efficiency of Natural Resources Canada, available at the URL below. Note that Canada's population growth between 1990 and 2002 was 13.4%. Thus, per-capital energy use for trucking increased by 34%, while per-capita energy use for all other transport—freight and passenger—declined by just over two per cent.
1. http://oee.rncan.gc.ca/neud/dpa/comprehensive_tables/index.cfm?Text=N&PrintView=N. Accessed June 9, 2004.

44. The data on the trucking's share of Canada's growth in oil consumption are from the source detailed in Note 43.

45. The estimates of truck activity—vehicle-kilometres travelled—are from the 2003 version of the source detailed in Note 43, hence the use of the period 1990 to 2001 rather than 2002. (The 2003 version was used because of a possible lack of internal consistency in the 2004 version that is being explored.) A vehicle-kilometre (vkm) is performed when a vehicle moves through one kilometre. Ten vkm are performed when one vehicle moves through ten kilometres or two vehicles each move through five kilometres.

46. For example, almost all of the awards to date concerning trucking in Transport Canada's Freight Sustainability Demonstration Program (see the first URL below) concern reducing fuel use through improving vehicle performance or driver behaviour. Two of the awards are for programs in which a minor objective is improved vehicle routing. Another federal government program that focus on improved fuel efficiency is Natural Resources Canada FleetSmart program, described at the second URL below.
1. http://www.tc.gc.ca/programs/Environment/Freight/FETI/fsdp/menu.htm. Accessed June 5, 2004.
2. http://oee.nrcan.gc.ca/fleetsmart/about/about.cfm?PrintView=N&Text=N. Accessed June 5, 2004.

47. The following is on Page 21 of *Climate Change Plan for Canada*, detailed in Note 39: "Given that freight activity is expected to increase by 60 percent by 2020, increasing fuel efficiency within each mode and better integrating freight services to make greater use of low-emission vehicles and modes will be critical to meeting Canada's climate change objectives." The *Plan* also speaks to encouraging more use of biodiesel fuel, which could reduce GHG emissions without reducing truck activity. Other means of reducing truck fuel use, not addressed in the *Plan* or here, include reducing idling requirements and harmonization of provincial regulations concerning truck lengths weights and lengths.

48. The paper prepared for the Transportation Table's Trucking Sub-Group that dealt with improving load factors was prepared by L-P Tardif & Associates Inc. and entitled *Environmental Awareness and Outreach Measures to Reduce GHG Emission*s (August 1999). It is available at the URL below.
1. http://www.tc.gc.ca/programs/environment/climatechange/subgroups1/truck/study1/final_report/final_report.htm. Accessed June 5, 2004.

49. The November 1999 *Options Paper* produced by the Transportation Table of Canada's Climate Change Process is available at the URL below. Truck tracking (which could contribute to raising load factors) is discussed as a possible action, but rated as a "less promising measure".
1. http://www.tc.gc.ca/programs/environment/climatechange/subgroups1/Options_Paper/English/default.htm. Accessed June 5, 2004.

50. The *Climate Change Plan for Canada* is detailed in Note 39.

51. The information in Box 4 is from Table 4 of the document *Emissions from Volvo's trucks (standard diesel fuel)* produced by the Volvo Truck Corporation in November 2003, available at the first URL below. The last column was calculated using the mid-points of the ranges in the previous two columns. These estimates of the share of fuel used to move the truck rather than its load may be on the low side. For example, Bridgestone, a tire company, has suggested that as a rule of thumb for a truck with semi-trailer each tonne of payload reduces fuel use by one per cent, with the difference between a full and empty truck being 21.1 per cent of the energy used to carry a full load (see the second URL below). Bridgestone's analysis thus assumes that almost 79 per cent of the fuel is used to move the vehicle, as opposed to its cargo, perhaps a higher value than that shown in Box 4. Another estimate of how fuel use varies with load factor concluded that a diesel truck tractor with a single trailer together weighing 11 tonnes when empty uses 28.3, 38.1, and 41.4 litres of fuel per 100 kilometres when carrying cargo weighing 0, 19.0, and 25.3 tonnes, respectively. It follows that when the largest weight of cargo was being carried, 68 per cent of the fuel was being used to move the vehicle, also perhaps a higher value than that shown in Box 4. (See Figure 31 on Page 73 and also Page 89 of Muster T, *Fuel Savings Potential and Costs Considerations for US Class 8 Heavy Duty Trucks through Resistance Reductions and improved Propulsion Technologies until 2020*, Energy Laboratory, Massachusetts Institute of Technology (Report MIT EL 00-001), May 2000, available at the third URL below.)
1. http://www.volvo.com/NR/rdonlyres/EF65E6D8-BF98-4BBF-B539-18C925B53844/0/Emis_eng_20640_03017. pdf. Accessed June 5, 2004.
2. http://www.trucktires.com/us_eng/technical/bftechnical/fuel_economy_f.asp. Accessed June 5, 2004.
3. http://lfee.mit.edu/publications/PDF/el00-001.pdf. Accessed June 5, 2004.

52. A payload tonne-kilometre is one tonne of payload moving through one kilometre. Box 5 is based on the same source as Box 4, as detailed in Note 51.

53. Only the results of the 1999 *National Roadside Study* (NRS) are publicly available, from the Canadian Council for Motor Transport Administrators (CCMTA) at the first URL below. Users should be warned that although the documentation for the 1999 NRS speaks to the possibility of analysis by data collection site, such analysis is not possible using the version available from CCMTA. This is pursuant to an agreement between the federal and provincial governments whereby the complete database of the 1999 NRS is not available to the public. The available database does allow analysis on a provincial and Canada-wide basis in respect of a large number of characteristics of trucks, operators, cargo, and trips.
The much less extensive 1995 NRS seems no longer to be ordinarily available. The Centre has a copy of the data file and supporting material, and would be pleased to make this available on request. (Enquiries can be sent to richardgilbert1@csi.com.) The 1995 NRS does not appear to have been designed to allow analysis at the level of the data collection site. Several comparisons of the 1995 NRS data and the 1999 NRS data conducted by the Centre suggest that, notwithstanding the considerable increase in volume (see Box 3), the essential features of truck traffic were similar in the two years. If anything, load factors fell, but by only a little, and in any case the differences between the two surveys preclude ready comparisons.
The detailed results of the 1991 NRS seem unavailable. The most extensive mention of this *Study* is in the 1998 document *Profile of Private Trucking in Canada*, available at the second URL below. The 1999 NRS concerned only cargo-type trucks with a gross weight of more than 4.5 tonnes—including tractors, tractor-trailer

combinations, and straight trucks with six or more axles—and travelling for at least part of their journey on the 24,134 kilometres of Canada's National Highway System or on 1,061 kilometres of other roads considered to be of significance to inter-city truck traffic. Trip data concerned all travelled roads and ferries, including those outside Canada.
1. http://www.ccmta.ca/english/publicationandreports/publicationandreports.html. Accessed June 5, 2004.
2. http://strategis.ic.gc.ca/epic/internet/ints-sdc.nsf/vwGeneratedInterE/fd01101e.html. Accessed June 5, 2004.

54. Box 6—and the other analyses here based on the 1999 NRS (detailed in Note 53)—represents only trips for which cargo capacity, trip origin, and trip destination were all known. These trips totalled 85% of the actual 65,052 trips covered by the 1999 NRS, thus representing about 85% of all qualifying trips in Canada. For-hire trucks are operated by companies in the business of carrying freight for other companies. Private trucks are owned by the businesses that ship the freight. In the present analyses, trucks normally classified as private that are carrying other businesses' freight are counted as for-hire trucks; these amounted to about 6% of all trucks identified as carrying cargo in the 1999 NRS.

55. One clear difference between the results of the 1995 and 1999 National Roadside Studies was the increase in the number of private trucks found operating on a for-hire basis (from 4.2% to 12.9% of private trucks). The share of private trucks on the road (including those operating on a for-hire basis) increased slightly between 1995 and 1999, from 31.4% to 32.6%. Thus, the growth in the share of for-hire trucking over the four years did not comprise growth in the for-hire trucking industry so much as growth to the extent to which other businesses with trucks to spare operated in a for-hire mode.

56. Box 7 is based on the 1999 NRS, as detailed in Notes 53 and 54.

57. Average cargo weights for full, ¾-full, ½-full, and ¼-full trucks were respectively 18.6, 14.4, 7.0, and 3.1 tonnes. Thus, a ½-full truck on average carried less than half the cargo carried by a full truck, suggesting that they were even more likely to be ½-full by space than full trucks were full by space.

58. Box 8 is based on the 1999 NRS, as detailed in Notes 53 and 54.

59. Box 9 is based on the 1999 NRS, as detailed in Notes 53 and 54. Potential capacity was estimated by assuming that each truck carried the average cargo weight of full trucks for the respective jurisdiction(s). Weighting for trip distance was achieved by estimating actual and potential total payload tonne-kilometres and calculating the difference between the two as a percentage of potential total tonne-km. Note that the data points for Canada refer to all eligible trips and those for the individual provinces refer to trips that touch the respective provinces. Thus, the values for Canada are not the same as the unweighted or weighted means of the provincial values.

60. Box 10 is based on Exhibit 3.1 of *Profile of Private Trucking in Canada*, 1998, detailed in Note 53. The statement that private trucks predominate for distances shorter than about 200 kilometres is based on Exhibit 3.2 of that document. Statistics Canada stopped collecting data on private trucking in 1998, so little is known about what likely continues to be both a key aspect of freight transport and an important component of the Canadian economy. A recent report produced by Transport Canada (Nix F, *Trucking Activity in Canada: A Profile*, Transport Canada, March 2003, available at the URL below) suggests that in 2000 private trucking was still economically more important than for-hire trucking ($21.8 billion vs. $20.8 billion) but this estimate seems to have been no more than a scaling up of the mid-1990s value set out in Box 10.
1. http://www.tc.gc.ca/pol/EN/Report/TruckActivity/Truck%20Activity%20in%20Canada.pdf. Accessed June 5, 2004.

61. The Edmonton Region Commodity Flow Survey is described in Hunt JD, Brownlee AT, Ishani M, Edmonton Commercial Movements Study. In *Transport Revolutions: Proceedings of the 39th Annual Conference*. Canadian Transportation Forum, 2004.
As well, the document by Fred Nix detailed in Note 60 offers an indication of the scale of freight movement within urban areas. It notes that perhaps two billion tonnes of freight moves annually within urban areas, perhaps four times the intercity truck movement. If this is the case, intercity movement would still constitute more transport *activity* (i.e., tonne-kilometres) because intercity truck journeys are likely more than four times longer on average than truck journeys within urban regions.
An earlier source suggested that perhaps 14% of truck tonne-kilometres occur in urban areas, using 44% of fuel used by trucks on the road and thus responsible for a similar share of GHG emissions (Delcan Corporation, *Assessment of Freight Forecasts and Greenhouse Gas Emissions*, prepared for the Freight Sub-Table of the Transportation Table of the National Climate Change process, June 1999, available at the first URL below). The authors of this report noted that "there is very little statistical basis for estimating the percentage of tonne-kilometres served in urban areas" (p. 32).
If freight movement as a whole is being considered, what is often the final link in the chain, the shopping trip, could also be noted. According the box on Page 6-18 of *Mobility 2001: World Mobility at the end of the 20th Century and its Sustainability* (World Business Council on Sustainable Development WBCSD, Geneva, Switzerland, available at the second URL below), "the amount of fuel used by consumers in going to the store to pick up the groceries is five times as great as the fuel consumed by trucks and trains to get the groceries to the store". In the analysed example, breakfast cereal, a reasonably allocated share of shopping trips accounted for 83% of the field-to-table transport energy use.
1. http://www.tc.gc.ca/programs/environment/climatechange/subgroups1/freight/study1/Final_Report/Final_report.htm. Accessed June 5, 2004.
2. http://www.wbcsd.org/DocRoot/uu8taBpoTDXkvBiJHuaU/english_full_report.pdf. Accessed June 5, 2004.

62. 'Cabotage' refers to the point-to-point movement of people or goods. Canadian and U.S. trucks cannot engage in cabotage in the other country except as may be incidental to international goods movement. Cabotage rules can reduce truckers' ability to maximize load factors while in the other country. U.S. cabotage rules for Canadian operators are at the URL below.
1. http://www.fmcsa.dot.gov/rulesregs/cabotagerules-web.pdf. Accessed June 5, 2004.

63. Expedited customs clearance processes to pre-authorized drivers, carriers, and importers are available at the 12 border crossings through the Free and Secure Trade (FAST) program. Details from a Canadian perspective are available at the URL below. A registered carrier seeking to make use of expedited clearance may find it harder to assemble a full load because not all exporters or importers may be registered with FAST.
1. http://www.cbsa-asfc.gc.ca/import/fast/menu-e.html#eligible. Accessed June 5, 2004.

64. For a review of urban load consolidation, see *Delivering the Goods: 21st Century Challenges to Urban Goods Transport*. Organization for Economic Cooperation and Development, Paris, France, 2003, (ISBN 9264102809). See also the examples referenced in the source detailed in Note 69.

65. See *Heathrow Airport Retail Consolidation Centre*. Good Practice Case Study 402, Action Energy, UK Government, May 2002, at the URL below.
1. http://www.transportenergy.org.uk/downloads/GPCS402.pdf. Accessed June 5, 2004.

66. A visit to the first URL below gives an indication of the extent of Internet-based load-matching activity. One operator (Transcore), not listed at this URL, manages about 300,000 matches a day for some 50,000 users (Stastny P, Trucking. *Canadian Transportation Logistics*, 106(11), pp. 46-, Nov./Dec. 2003.). The authors of a paper prepared for the Trucking Sub-Group of the Transportation Table of the National Climate Change Process suggested that Internet-based load-matching may be of limited effectiveness because it does “nothing more than what was done in years gone by with people sitting at a telephone with card indexes … however, doing it faster, cheaper and more thoroughly”. Their conclusion was that enhanced load matching would produce no more than a 0.3-per-cent reduction in truck GHG emissions by 2010. (Taylor GWR, Nix F, Delaquis M, *The Potential for GHG Reductions from Improved Use of Existing and New Truck Technology in the Trucking Industry*, June 1999, available at the second URL below.)
1. http://dmoz.org/Business/Transportation_and_Logistics/Trucking/Truck_Transport/Freight_Matching_Services/. Accessed June 5, 2004.
2. http://www.tc.gc.ca/programs/environment/climatechange/subgroups1/truck/study2/final_report/FINAL_TRUCK_TECH.doc. Accessed June 5, 2004.

67. See the article by Paul Stastny detailed in Note 66.

68. This is a finding from the 1995 and 1999 NRS surveys. See Notes 54 and 55 for more information about private trucks operating in a for-hire mode.

69. The Freight Transport Management section of the *Online TDM Encyclopedia* is available at the URL below.
1. http://www.vtpi.org/tdm/tdm16.htm. Accessed June 5, 2004.

70. Box 11 is based on data on new vehicles sales in Table 2 of *Light-Duty Automotive Technology and Fuel Economy Trends: 1975 Through 2004*, U.S. Environmental Protection Agency, Washington DC, 2004, available at the first URL below. (The values in the left-hand panel are metric conversions of so-called ‘adjusted 55/45’ values.) Less detailed data are available about vehicles sold in Canada, which generally conform to the same fuel consumption standards. The only readily available comparable source on Canadian vehicles is Schingh M, Brunet É, Gosselin P, *Canadian New Light-Duty Vehicles: Trends in fuel consumption and characteristics (1988-1998)*. Natural Resources Canada, Ottawa, 2000, available at the second URL below. Comparing data for the 1998 model year, the latest year covered by both reports, the Canadian automobile fleet used on average slightly less fuel than the U.S. fleet (9.2 vs. 9.6 L/100 km, in the terms of Box 11) as did the light truck fleet (13.1 vs 13.4 L/100 km). For that model year, 45% of light-duty vehicles sold in the U.S. were light trucks, compared with 43% in Canada. Note that the category of light-duty vehicles includes all vehicles weighing less than 3,856 kilograms (8,500 pounds). The vast majority of these vehicles are used for personal transport, but a very few cars and (in Canada in 2001) about a quarter of light trucks are purchased for commercial purposes.
1. http://www.epa.gov/otaq/cert/mpg/fetrends/420r04001.pdf. Accessed June 5, 2004.
2. http://oee.nrcan.gc.ca/english/programs/pdfs/Doc5e.pdf. Accessed June 5, 2004.

71. The paper by Schingh et al detailed in Note 70 suggests that the Canadian average fell at least as steeply, declining by 27% during the three years from 1979 to 1982.

72. For historical world crude oil prices, see the source detailed in Note 24.

73. For historical U.S. retail gasoline prices, see Table 6 of *How much we pay for gasoline*. American Petroleum Institute, October 2002, at the URL below
1. http://api-ec.api.org/filelibrary/howmuchwepay2002.pdf. Accessed June 5, 2004.

74. The standards set in Canada’s corresponding voluntary program—the CAFC (Company Average Fuel Consumption) program—generally track the CAFE standards. For information about the CAFC program, see the URL below. The program is also called the Corporate Average Fuel Consumption program.
1. http://www.tc.gc.ca/securiteroutiere/asfbb/FCpgm/en/cafc/page1_e.htm. Accessed June 5, 2004.

75. See for example General Motors of Canada’s case for eliminating the CAFC program in favour of a carbon tax: Smith BA, Wakefield TA, *A Review of Canada's Corporate Average Fuel Consumption (CAFC) Program & the Case for a Carbon Tax* (undated), partial text available at the URL below. This document includes the following: “Since the technology is not available to achieve radical improvements in fuel efficiency, the only way manufacturers would be able to meet more stringent standards would be through a massive down-sizing of the fleet, principally through a shift to smaller vehicles, a shift which is presently inconsistent with consumer needs and preferences.”
1. http://catf.vizonscitec.com/Index/1C73EC0FC16FA08788256976006BEBEC!OpenDocument. Accessed June 5, 2004.

76. For example, in the Ford Motor Company’s 2002 *Corporate Citizenship Report*, Chairman Bill Ford wrote “It is also a key part of our transformation to lean, flexible manufacturing processes that will make us more efficient, more competitive and more able to respond to changing demands” (see the URL below). In the same document, Mr. Ford explained why his company could not keep its commitment to improve the fuel efficiency of SUVs by 25%: “we were not able to make the investments in the products and technologies needed to meet the goal, nor were some of the technologies as mature as we thought”.
1. http://www.ford.com/en/company/about/corporateCitizenship/principlesProgressPerformance/our-perspective/letter-bill-ford.htm. Accessed June 5, 2004.

77. According to the Canadian Vehicle Survey (Statistics Canada, *CANSIM II*, Table 4050044), 51% of light-duty vehicles (less than 4.5 tonnes) on the road in the fourth quarter of 2003 were seven years old or less and 76% were 12 years old or less.

78. A proposal for such an incentive scheme was set out in *Background Paper for a Post-Kyoto Transport Strategy* prepared for the four workshops held by the Centre in 2001-2002, as follows: “The kind of program in mind is one in which a $1,000 per litre/100 km improvement is rebated for each vehicle replacement or retire-ment, together with a $200 per litre/100 km annual tax on each vehicle in use. Such a program would require regular certification of the fuel efficiencies of all vehicles on the road. It may be simpler to provide the rebates but raise fuel taxes to even higher levels than is proposed here.” The *Background Paper* is available at the URL below. (The workshops were noted earlier in this *Monitor* in connection with Note 42.)
1. http://www.cstctd.org/CSTadobefiles/Background%20paper%207.pdf. Accessed June 5, 2004.

79. This estimate is based on data in Van Wee B, Moll HC, Dirks J,

Environmental impact of scrapping old cars. *Transportation Research Part D*, 5, 2000, pp. 137-143, and in Das S, et al, Automobile recycling in the United States: energy impacts and waste generation. *Resources, Conservation and Recycling*, 14, pp. 265-284, 1995.

80. The data in this row are derived from the source detailed in Note 43.
81. The fuel-cell-car data are for the 2004 Honda FCX subcompact, as posted by U.S. Department of Energy at the URL below.
1. http://www.fueleconomy.gov/feg/fcv_sbs.shtml. Accessed June 5, 2004.
82. The data for a hybrid gasoline-electric car are those for the 2004 Toyota Prius midsize car, as posted at the URL below.
1. http://www.fueleconomy.gov/feg/hybrid_sbs.shtml. Accessed June 5, 2004.
83. The data for the 'very small car' are those for Volkswagen's Lupo 3L, a two-seater-plus diesel car available only in Europe and described by the manufacturer as the "first 3L vehicle in production" (see Klaus-Peter Schindler, *The future of the Diesel engine in passenger cars*. Presentation at the 7th Diesel Engine Emissions Reduction Workshop, Portsmouth, Virginia, August 2001, at the first URL below). Manufacturer's energy-use data are given here, i.e., 2.99 litres/100 km, equivalent to 0.89 mJ/pkm for an occupancy of 1.30 (this author's estimate). In Slide 10 of the cited presentation, a rate of 0.75 mJ/pkm is given for "average rate of occupation" "in urban traffic under 75 km", which suggests an average occupancy of 1.54 or higher. Testing of the Lupo 3L by Transport Canada indicated highway fuel use of 3L/100 km and city fuel use of 3.8L/100 km (*Advanced Technology Vehicles Program, 2001-2002 Annual Report*, Road Safety and Motor Vehicle Regulation, Transport Canada, January 2003, at the second URL below).
1. http://www.osti.gov/fcvt/deer2001/schindler.pdf. Accessed June 5, 2004.
2. http://www.tc.gc.ca/roadsafety/atvpgm/reports/annual/atvp0102.pdf. Accessed June 5, 2004.
84. Personal Rapid Transit (PRT) is a generic term for concept systems comprising fully automated small vehicles carrying 1-6 passengers running on guideways at, above or below ground, providing direct origin-to-destination service. A useful review of these and other innovative technologies can be found at a Web site maintained by Jerry Schneider of the University of Washington, at the URL below. The energy use shown in Box 13 represents the average of several developers' estimates.
1. http://faculty.washington.edu/jbs/itrans/. Accessed June 5, 2004.
85. There are no electrically powered intercity trains in Canada, and so U.S. data are provided for this type of vehicle. Amtrak's Northeast Corridor is the only electrified part of the intercity rail system in the U.S. About 2.63 billion passenger-kilometres (pkm) were performed in this corridor in 2000 and about 6.34 billion pkm in the rest of the system (the Centre's estimates based on several sources, notably Report No. GAO/RCED-96-144 by the U.S. General Accounting Office, *Northeast Rail Corridor: Information on Users, Funding Sources, and Expenditures*, 1996, at the first URL below, and Table 9.12 of Davis SC, Diegel SW, *Transportation Energy Data Book 23*, Oak Ridge Tennessee: Oak Ridge National Laboratory, 2003, at the second URL below). According to Table A.16 of the latter source, 470,170,000 kilowatt-hours of electricity and 94,968,000 U.S. gallons of diesel fuel were used respectively to provide this service.
1. http://ntl.bts.gov/data/rc96144.pdf. Accessed June 5, 2004.
2. http://www-cta.ornl.gov/data. Accessed June 5, 2004.
86. The data in this row are derived from data on U.S. systems provided by the American Public Transportation Association (APTA), available at the URL below. (Data on Canadian systems in the source cited in Note 43 are not provided by mode. However, in aggregate they seem roughly comparable to the APTA data.) Note that one incidental conclusion from this table could concern the superior fuel efficiency of cars compared with buses. Such a conclusion is very sensitive to vehicle occupancy levels, as are others to be drawn from this table. Canadian bus occupancies may well be higher than those indicated for the U.S., but data necessary for this comparison are lacking.
1. http://www.apta.com/research/stats/. Accessed June 5, 2004.
87. The balance of this issue of the *Monitor* is based on a paper presented at the 39th Annual Meeting of the Canadian Transportation Research Forum, Calgary, May 9-12, 2004, by Richard Gilbert and Mee-lan Wong entitled *How energy constraints could ensure a major role for tethered vehicles in Canada's next transport revolution*.
88. The sources for the estimates in Box 13 are in the corresponding end notes. Box 13 shows *end* or secondary energy. As noted in the subsequent paragraph, primary or full-cycle energy use can be much greater.
89. For generator efficiency see, for example, Wei A, *Technologies for Next Generation Turbine Systems*. Presentation at the Turbine Power Systems Conference and Condition Monitoring Workshop, Galveston, Texas, February 2002, available at the URL below.
1. http://www.netl.doe.gov/publications/proceedings/02/turbines/wei.pdf. Accessed June 5, 2004.
90. For the efficiency of electrolysis, see Page 171 of Committee on Alternatives and Strategies for Future Hydrogen Production and Use, National Research Council, *The Hydrogen Economy: Opportunities, Costs, Barriers, and R&D Needs*. (Washington DC, National Academies Press, 2004), available at the URL below.
1. http://books.nap.edu/books/0309091632/html/index.html. Accessed June 5, 2004.
91. The freight transport data in Box 14 are from the source at the URL below. In Finland, electric freight trains appear to use less than one third of the operational energy per tonne-kilometre (tkm) used by comparable diesel freight trains, which in turn use less than half of the energy used by trucks. Note that the reported energy use by Finnish trucks (0.45 mJ/tkm) is very much lower than the use estimated even for heavy Canadian trucks in the source detailed in Note 43 (2.41 mJ/tkm). However, the Finnish and Canadian sources present similar estimates of energy use by diesel freight trains (respectively 0.20 and 0.25 mJ/tkm).
1. http://www.ecotraffic.se/pdf/et.pdf. Accessed June 5, 2004.
92. The trolley truck photo in Box 15 is at the URL below.
1. http://hutnyak.com/Trolley/trolleyphotos.html. Accessed June 5, 2004.
93. For notes on the history of tethered vehicles see, for example, the URL below.
1. http://mikes.railhistory.railfan.net/r066.html. Accessed June 5, 2004.
94. Filey M, Howard R, Weyerstrahs H, *Passengers Must Not ride on Fenders*, Toronto, Ontario, Green Tree Publishing Co., 1974)
95. PRT has detractors. For an example, see the URL below.
1. http://www.avidorstudios.com/PRTisaJoke.html. Accessed June 5, 2004.
96. Nichol J, *The All-Red Route* (Toronto, Ontario, McArthur and Co., 1999).