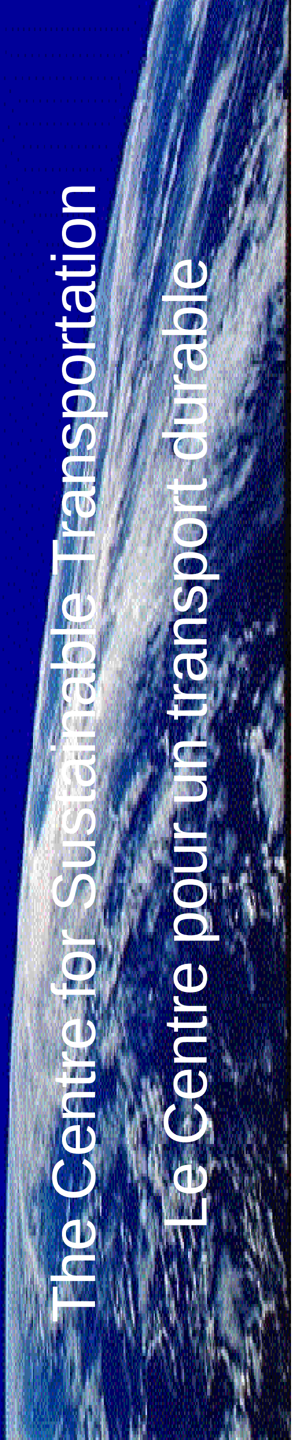
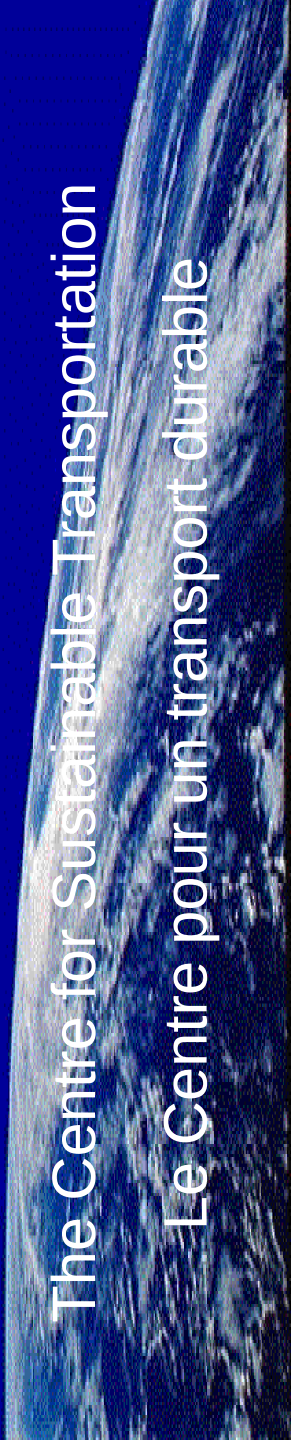


Energy Constraints and Transport Sustainability

Richard Gilbert

Presentation to the
Windsor Workshop
Toronto, June 14 and 17, 2004

Enquiries to Richard Gilbert at richardgilbert1@csi.com or 416 923 8839



What should be the main concerns of transport policy-makers?

- Sustainability? Yes. But it means different things to different people, often quite different; bridging the differences can be a huge challenge.

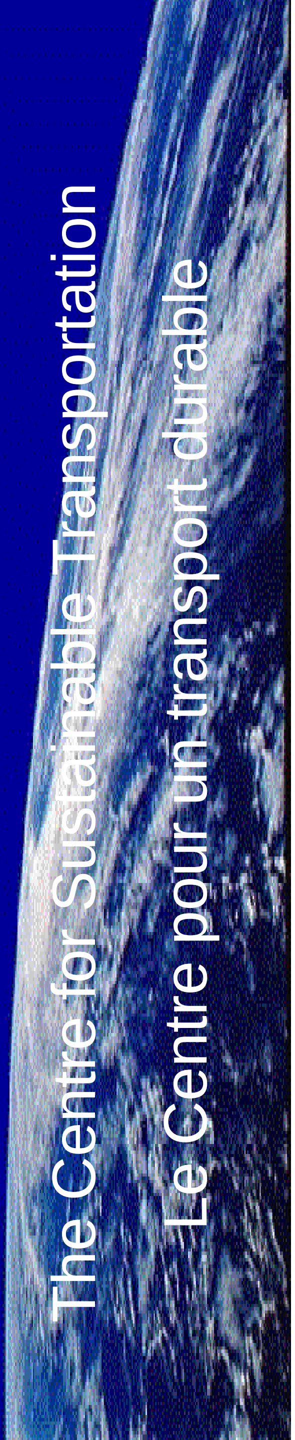
- Kyoto? Yes. But it's hard to persuade Canadians that warmer winters will be a problem, or that they should prevent or prepare for sea-level rise in 2050.

- Energy constraints? Yes. It's hardly on policy-makers' radar, but signs of early—perhaps profound—impacts are clear. Energy concerns should be foremost in our policy-making and shape our approaches to sustaina-bility and climate change.

Energy is IMPORTANT (1)

	Canada and U.S.		Rest of world	
	1900	**2000**	**1900**	**2000**
Primary energy consumption:				
per capita (gigajoules)	113	365	17	52
per unit of GDP (kJ per 2000US$)	21.4	10.0	25.4	7.3
Population *(billions)*	*0.08*	*0.31*	*1.57*	*5.74*
GDP *(trillions of 2000US$)*	*0.43*	*11.38*	*1.05*	*40.77*
GDP/capita *(thousands of 2000US$)*	*5,375*	*36,710*	*670*	*7,105*

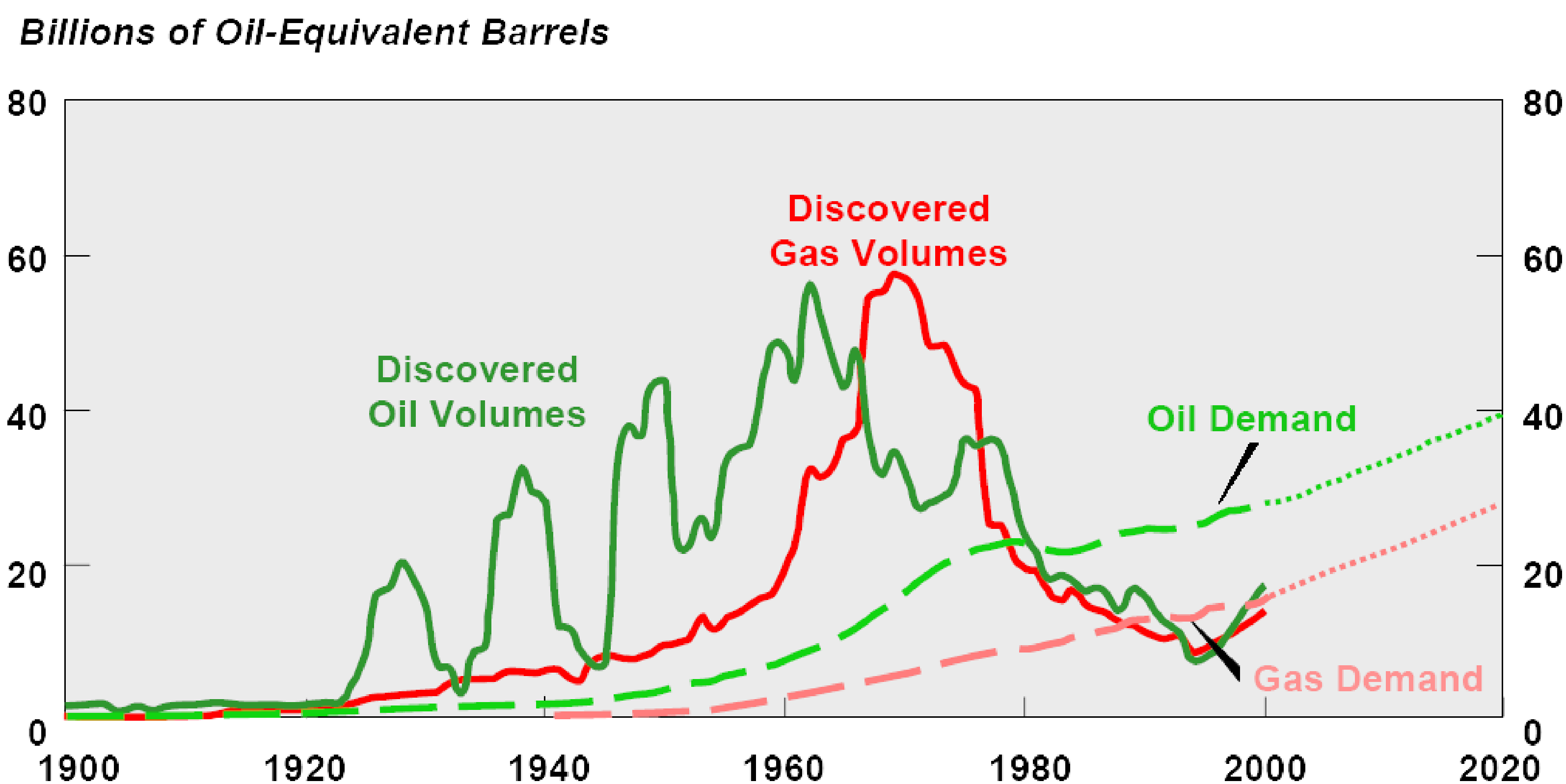
A person's annual manual labour is equivalent to less than one gigajoule of applied energy. Thus, energy use in Canada and the U.S. in 2000—almost all fossil fuels—provided each resident with the manual labour equivalent of at least 365 additional people (our energy slaves).



Energy is IMPORTANT (2)

- Without ample supplies of inexpensive added energy, modern civilization as we know it may not be possible.
- Our buildings would be hardly habitable, our transport arrangements would be primitive, and most of our worldly goods would be irreplaceable.
- The most profound impact could be on population, now sustained by energy-intensive agriculture and public health practices.
- Without energy slaves from one-time deposits of fossil fuels, our planet might support a billion ‘slaves to the soil’, rather than six billion humans often living in extraordinary comfort.

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

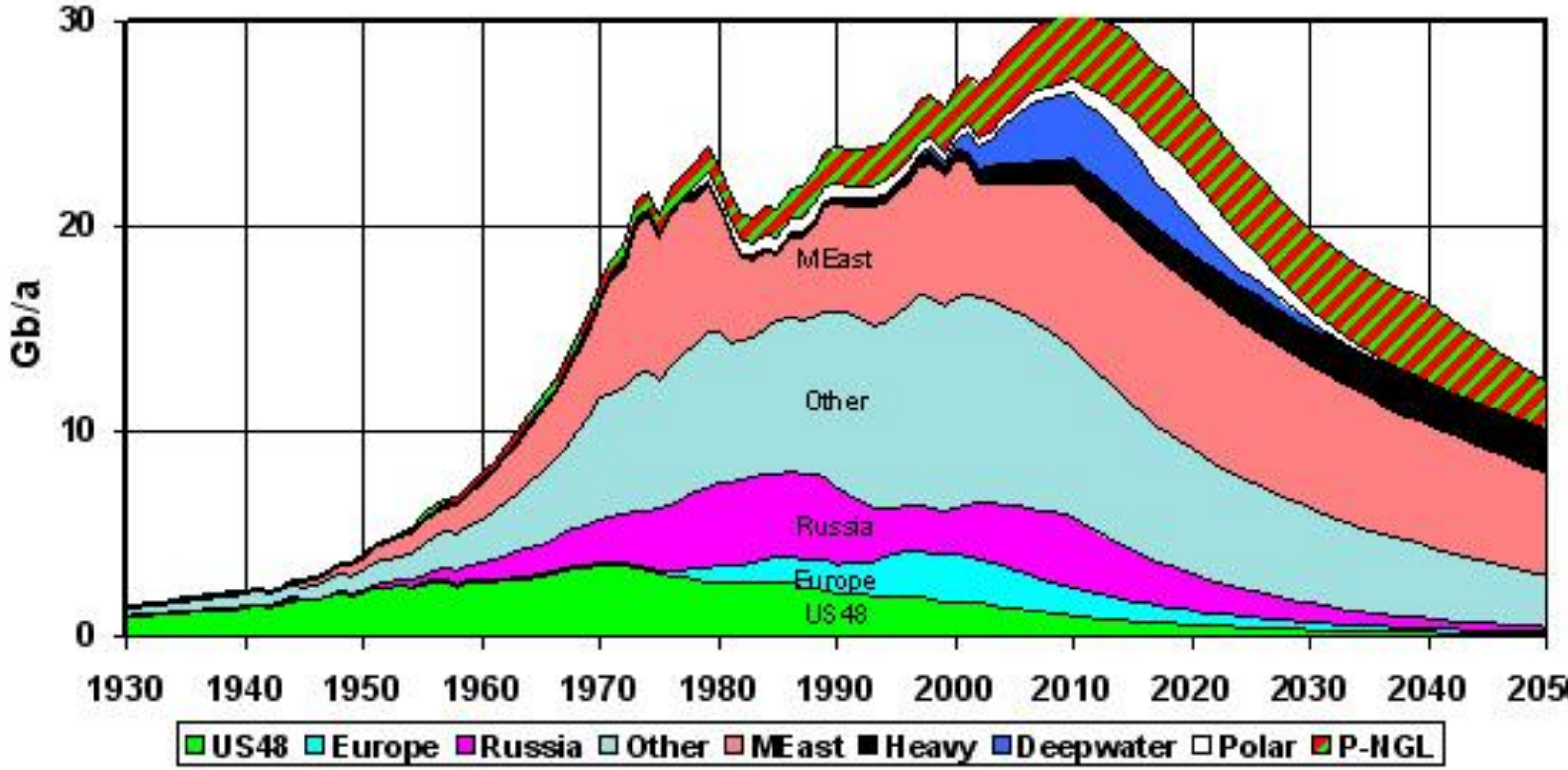


Source: Exxon Mobile Corporation

We haven't been finding the fuel we need to sustain what we depend on. In this decade, we are using more natural gas than we are discovering, and very much more oil.

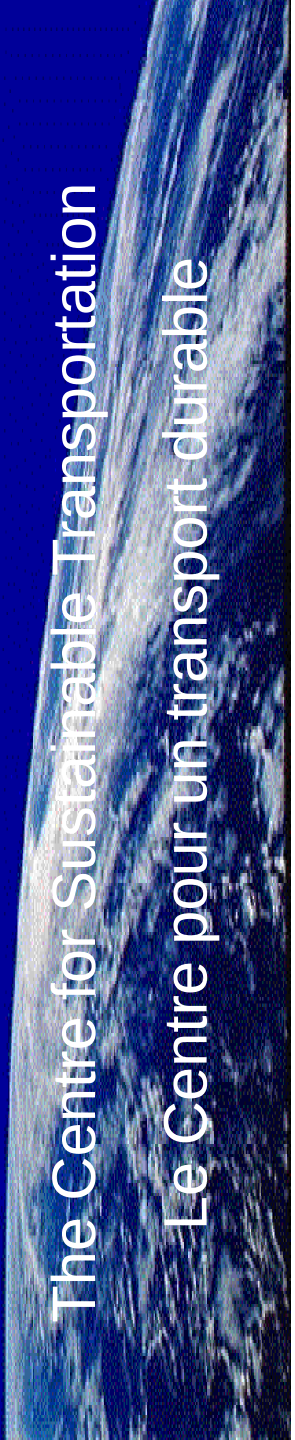
The Centre for Sustainable Transportation
Le Centre pour un transport durable

World production of regular oil by region, non-conventional oil, and natural gas liquids, actual and estimated, billions of barrels per year, 1930-2050

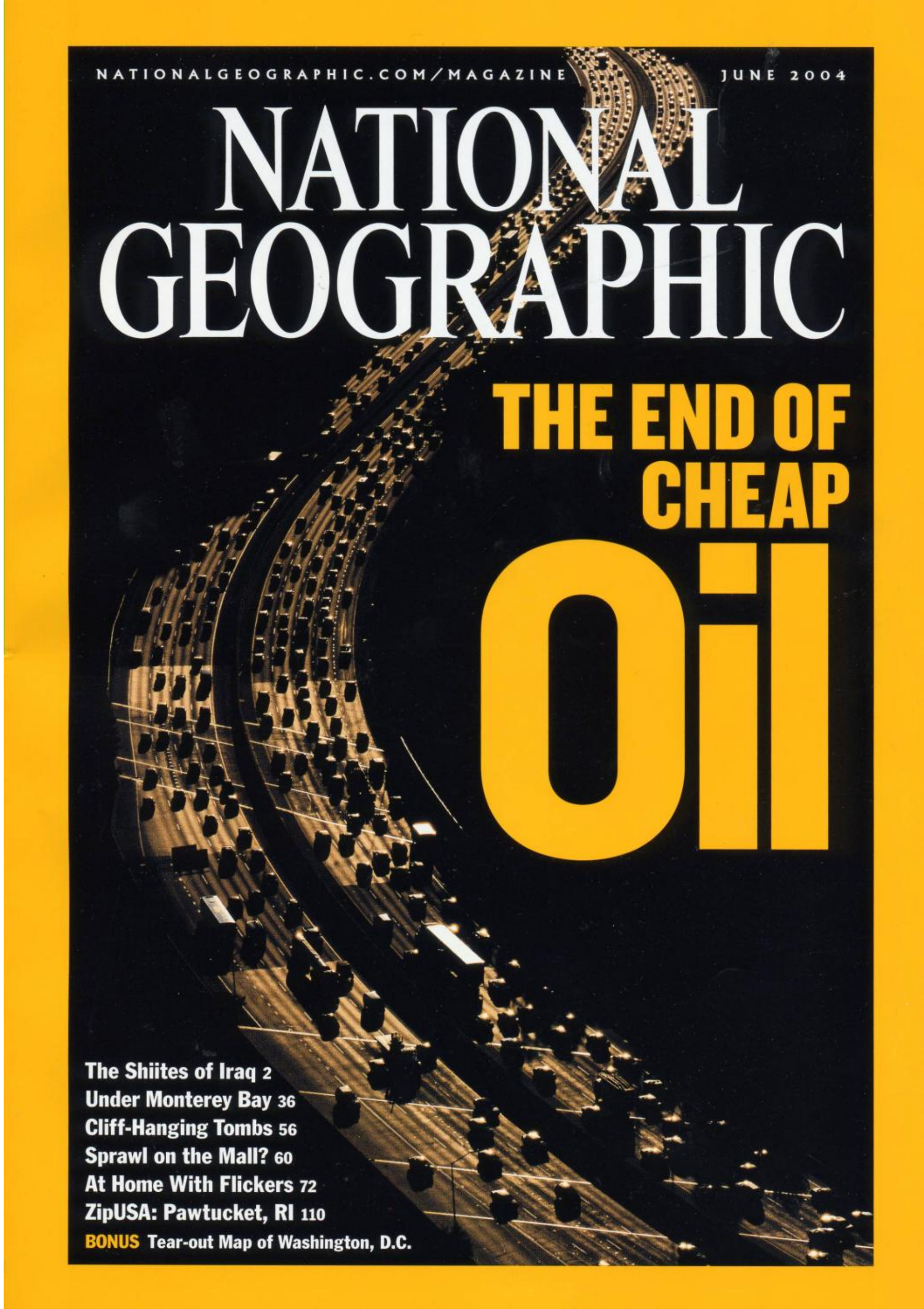


Source: Uppsala Hydrocarbon Depletion Group

Production of crude oil and equivalents—which provide >95% of transport fuels worldwide, >99% in Canada—may peak in 2012, which will mean very high prices unless demand falls first.



This month's NG cover echoes the title of a 1998 *Scientific American* article by Colin Campbell and Jean Laherrère that was initially dismissed as yet another oil scare but is now seen as a seminal step in our under-standing of the future of oil.



David Green and colleagues' qualifying statement

"The authors believe that their analysis has a bias toward optimism about oil resource availability because it does not attempt to incorporate political or environmental constraints on production, nor does it explicitly include geologic constraints on production rates."

The Centre for Sustainable Transportation

Le Centre pour un transport durable

Four points from the Danish paper

(at http://www.ida.dk/oilconference/Oil-based_Technology_and_Economy.pdf)

1. There will be a peak in world oil production.

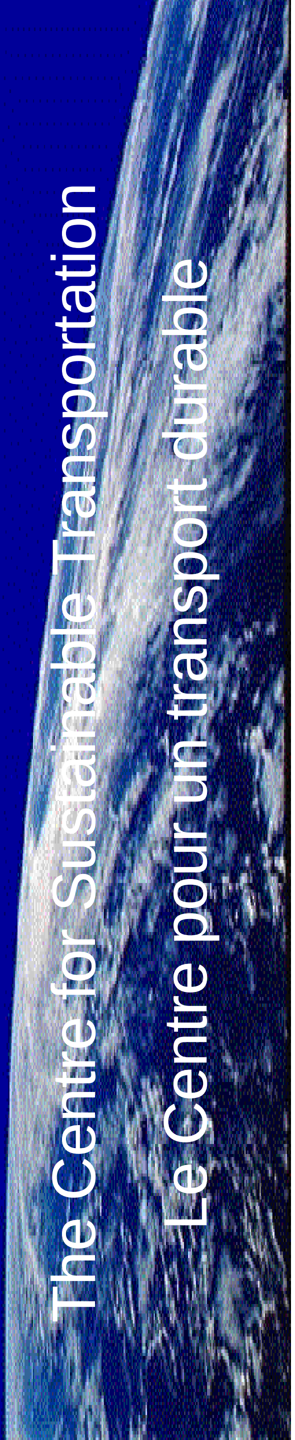
2. If peak later than about 2020 is possible, which is far from clear, it will be achieved only by making huge investments, which may well be wasted.

3. An earlier peak will be "less unfortunate" for humanity than a later peak.

4. Governments should work to ensure that the peak in oil use occurs before the peak in oil production.

1. There will be a peak in oil production

- Estimates of timing vary according to estimates of (a) extent of reserves; (b) their recoverability.
- Geologists tend to say earlier rather than later (before 2020, perhaps as early as 2007, even before), based on what is in ground and extraction experience.
- Economists tend to say later rather than earlier (after 2020, maybe even 2035 or later), based on how price increases stimulate human ingenuity.
- Just about all estimates point to a production peak well within lifetimes of people alive today.
- North American natural gas provides a portent: its production peak may have already occurred.



June 12, 2004

The New York Times

An Oil Enigma: Production Falls Even as Reserves Rise

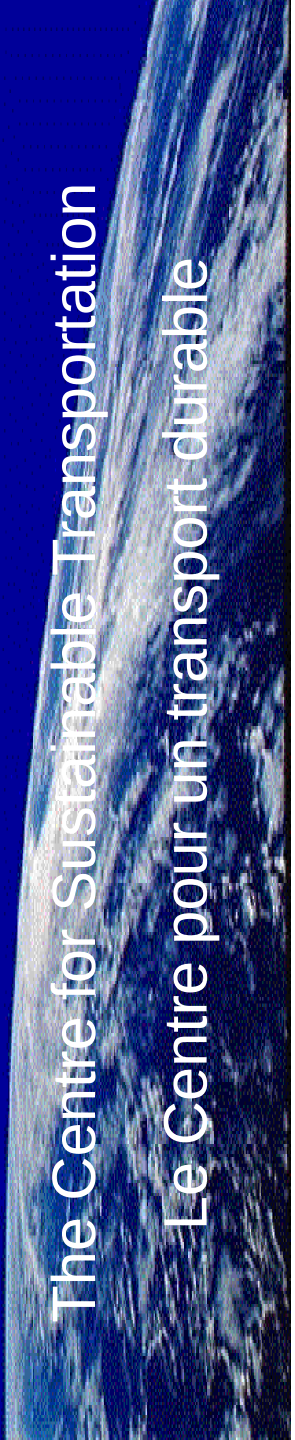
By ALEX BERENSON

For six consecutive years, ChevronTexaco has had good news for anyone worried that the world is running out of oil: the company has found more oil and natural gas than it has produced. Over that time, ChevronTexaco's proven oil and gas reserves have risen 14 percent, more than one billion barrels.

But near the bottom of ChevronTexaco's financial filings is a much less promising statistic. For each of those years, ChevronTexaco's wells have produced less oil and gas than the year before. Even as reserves have risen, the company's annual output has fallen by almost 15 percent, and the declines have continued recently despite a company promise to increase production in 2002.

…. continued

The usual focus on *reserves* seems misplaced. Reserves are important (although often questionable) but production—or rather, ability to produce—may be much more important.



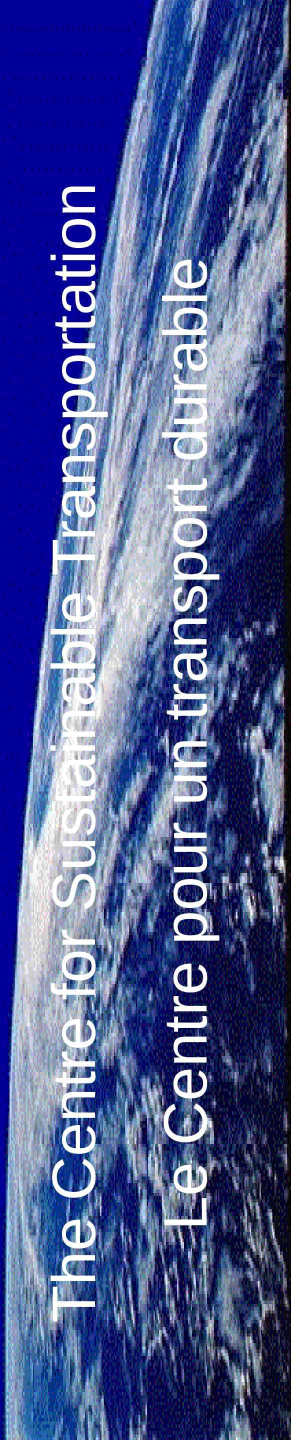
2. A later peak will require much investment

- All who think a later peak is possible also see the need for large amounts of investment in exploration and in extraction technology.

- An example is Exxon Mobil, which points to the need for oil industry investments of one *trillion* U.S. dollars worldwide by 2010 to produce new production capacity of 80 million barrels a day (now worldwide about 75 mb/day).

- IEA says investment of $3.1 trillion needed to add 200 mb/day by 2021 (for exploration, refining, distribution).

- These are much above current rates of investment and a lot of money to waste if oil cannot be found or if recovery rates cannot be increased.



3. Better an earlier rather than later peak

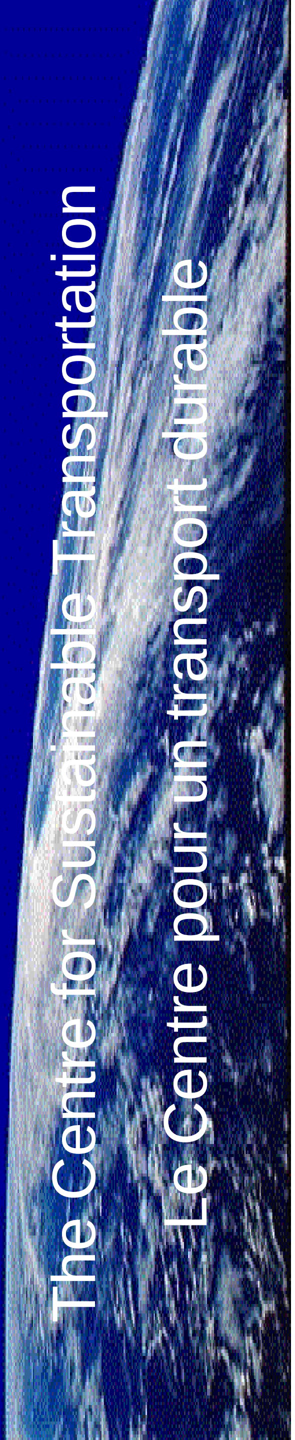
- An earlier peak would be "less unfortunate" for two reasons.
- One is that there will be less dependency on oil worldwide.
- The other is that an earlier peak would be more likely to have a gradual rather than a steep decline in post-peak production.
- Thus, there is a strong case for investing more in reduced oil dependence than in finding and extracting oil.

4. Ensure oil use peaks before production peaks

- Then we will already be reducing oil use and thus have a relatively 'soft landing' when the production peak occurs.
- To do this, first identify the date of the production peak. Then develop a plan to have oil use fall before this peak. Then implement the plan.
- The transition could be helped by use of the proceeds from diverting investment.
- Oil use could be reduced through efficiency, through reduced motorized activity, and through use of alternative vehicle systems and fuels—e.g., tethered vehicles.

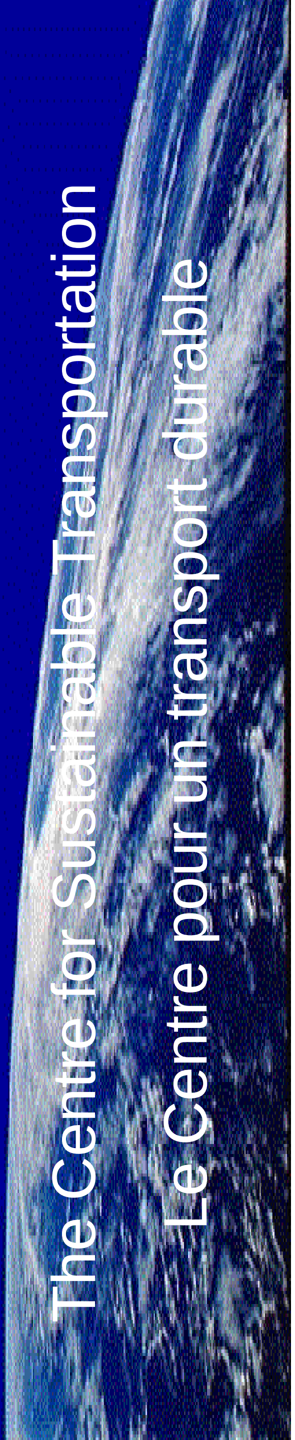
Government's Kyoto plan would plateau oil use

- Kyoto looks more promising with EU backing of Russian accession to WTO.
- *The Climate Change Plan for Canada* appears to favour a plateauing of oil use by 2010, at about the 2001 level. (About 70% of Canada's final oil use is for transport.)
- It would be relatively easy to refocus relevant policy to start pushing oil use down, within the Kyoto framework, so Canada becomes economically as well as environmentally sustainable.



Actions need for short, medium, and longer terms

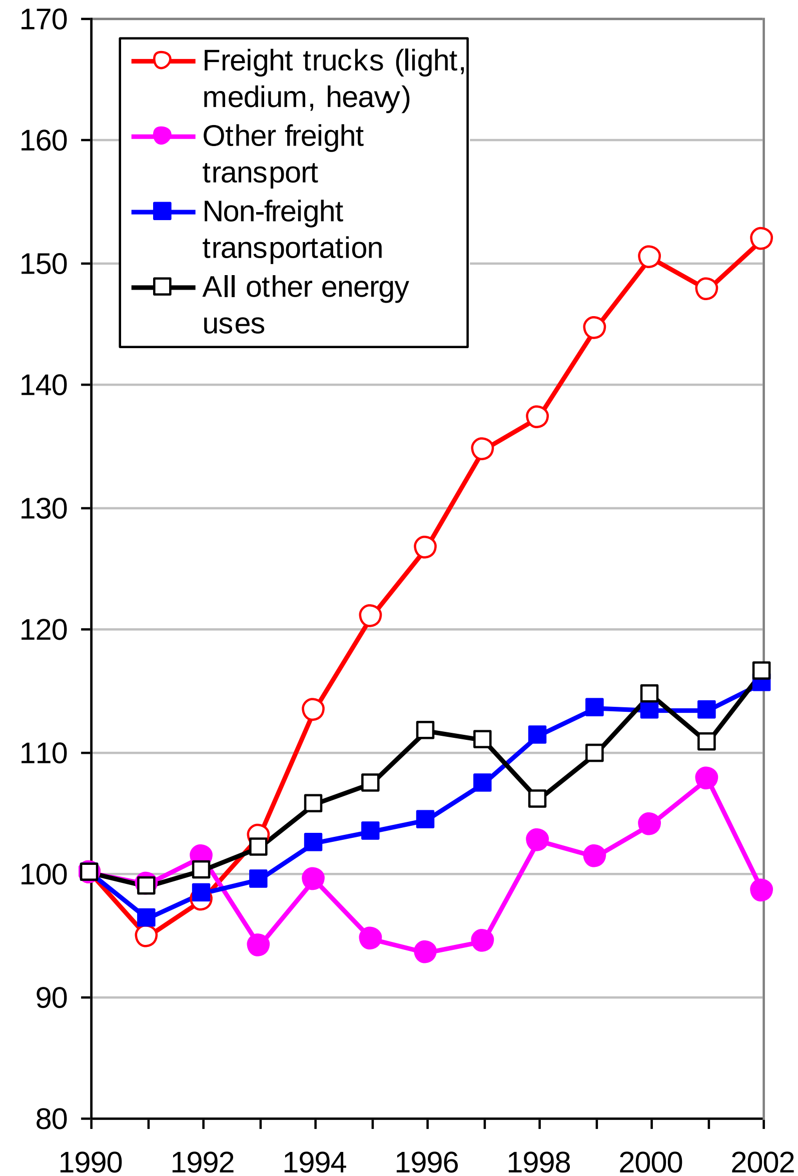
- **Short-term** actions are the most important, to get oil use moving down before the oil production peak (in 2012?). A focus on trucks' load factors may produce the biggest gains.
- **Medium-term** actions are required to keep pushing oil use down further after the peak (and to help in the short term). A focus on new-vehicle fuel consumption may produce the biggest gains.
- **Longer-term** actions are required to help reduce oil use much more, while maintaining mobility and advancing sustainability. For this, adoption of tethered vehicle systems may offer the best strategy.



Energy use for freight movement by truck in Canada grew >50% during 1990-2002. It fell for other freight movement, increased 16% for other transport and 17% for all other uses. (Population growth was about 14%.)

Trucking accounted for about 70% of Canada's *growth* in oil use between 1990 and 2002.

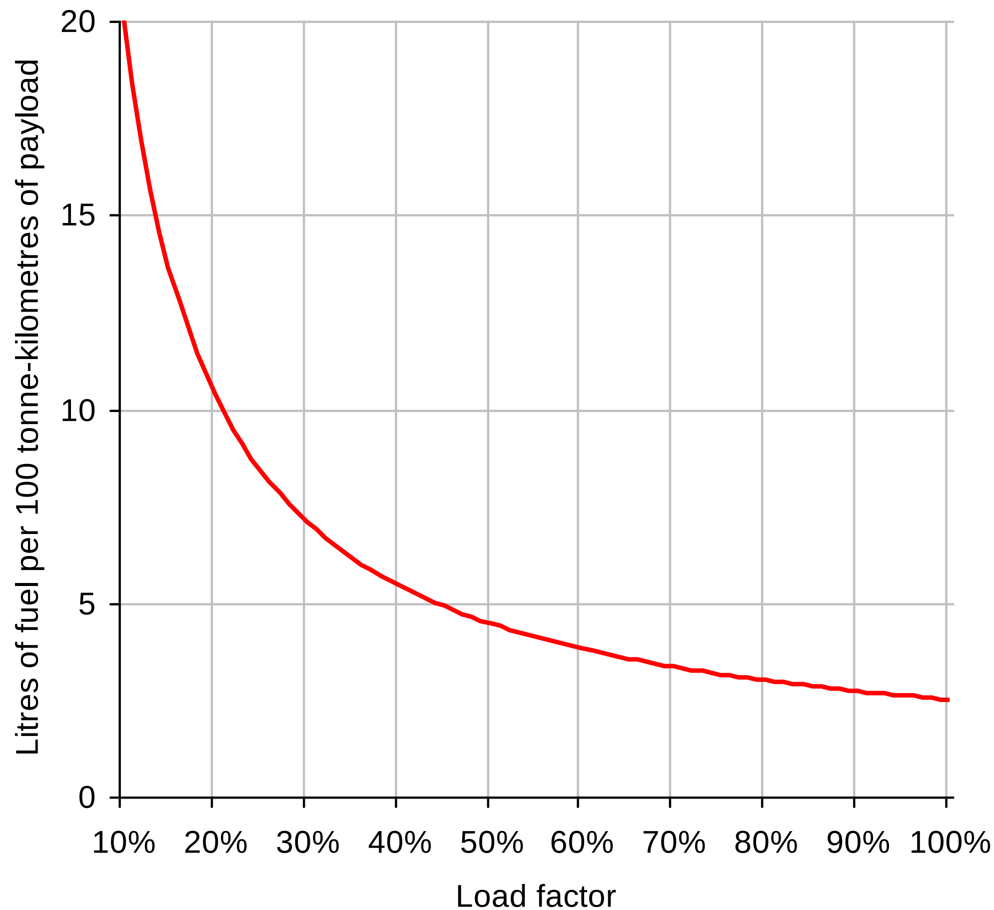
Thus, reducing trucking's oil use should be the short-term focus.



Source: Natural Resources Canada, *Energy Use Data Handbook, 1990 and 1996 to 2002*

How fuel use per payload-tkm varies with load factor

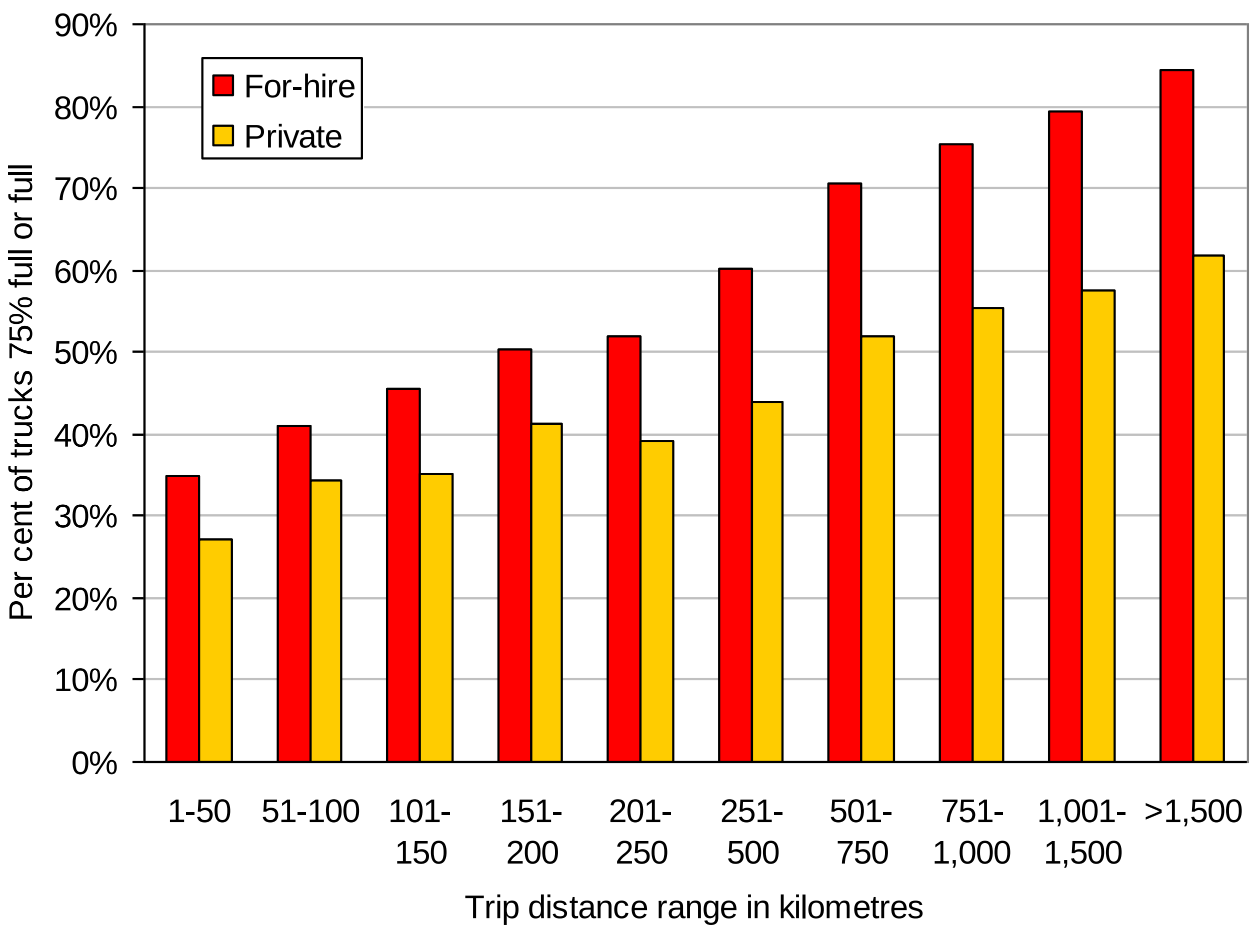
2½ times as much fuel is required to move a tonne of payload over 100 km when a truck is ¼ full than when it is ¾ full.



Source: Based on data provided by Volvo Truck Corporation

The Centre for Sustainable Transportation
Le Centre pour un transport durable

Focus on raising load factors of trucks making shorter trips, and private trucks



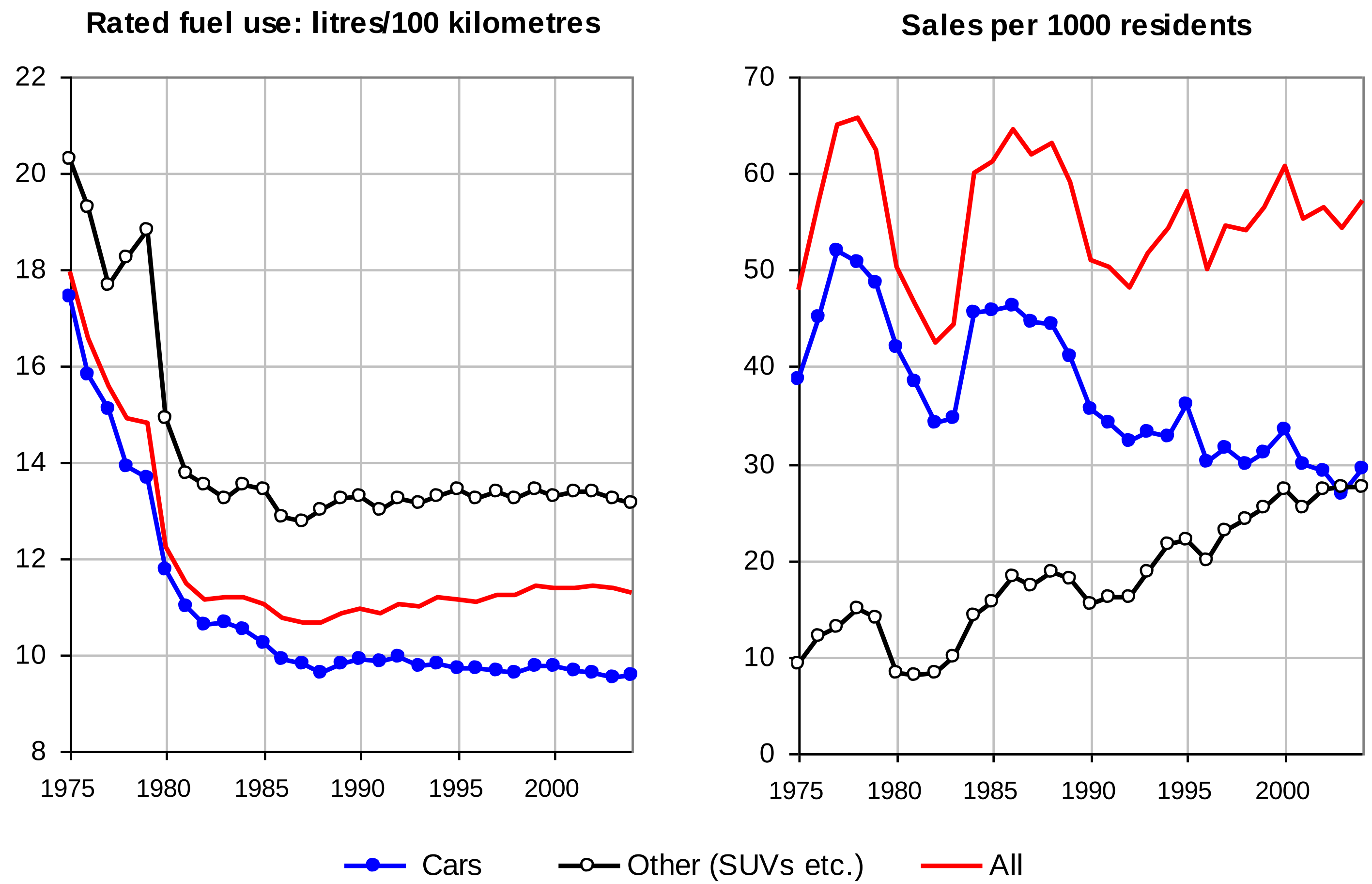
Source: National Roadside Survey, 1999

Improving trucks' load factors

- Education: chiefly of shippers—who make the decisions—rather than carriers, but also carriers.
- Taxes: higher fuel taxes might help. Or higher costs generally (which force efficiencies).
- Regulations: access limits for vehicles half-empty or less.
- Regulations: removing cabotage rules and differences in provincial regulations.
- Consolidation: distribution centres that consolidate loads, rationalize pick-ups (Heathrow Airport: 90% reduction in truck traffic for store deliveries and pick-ups).

The Centre for Sustainable Transportation
Le Centre pour un transport durable

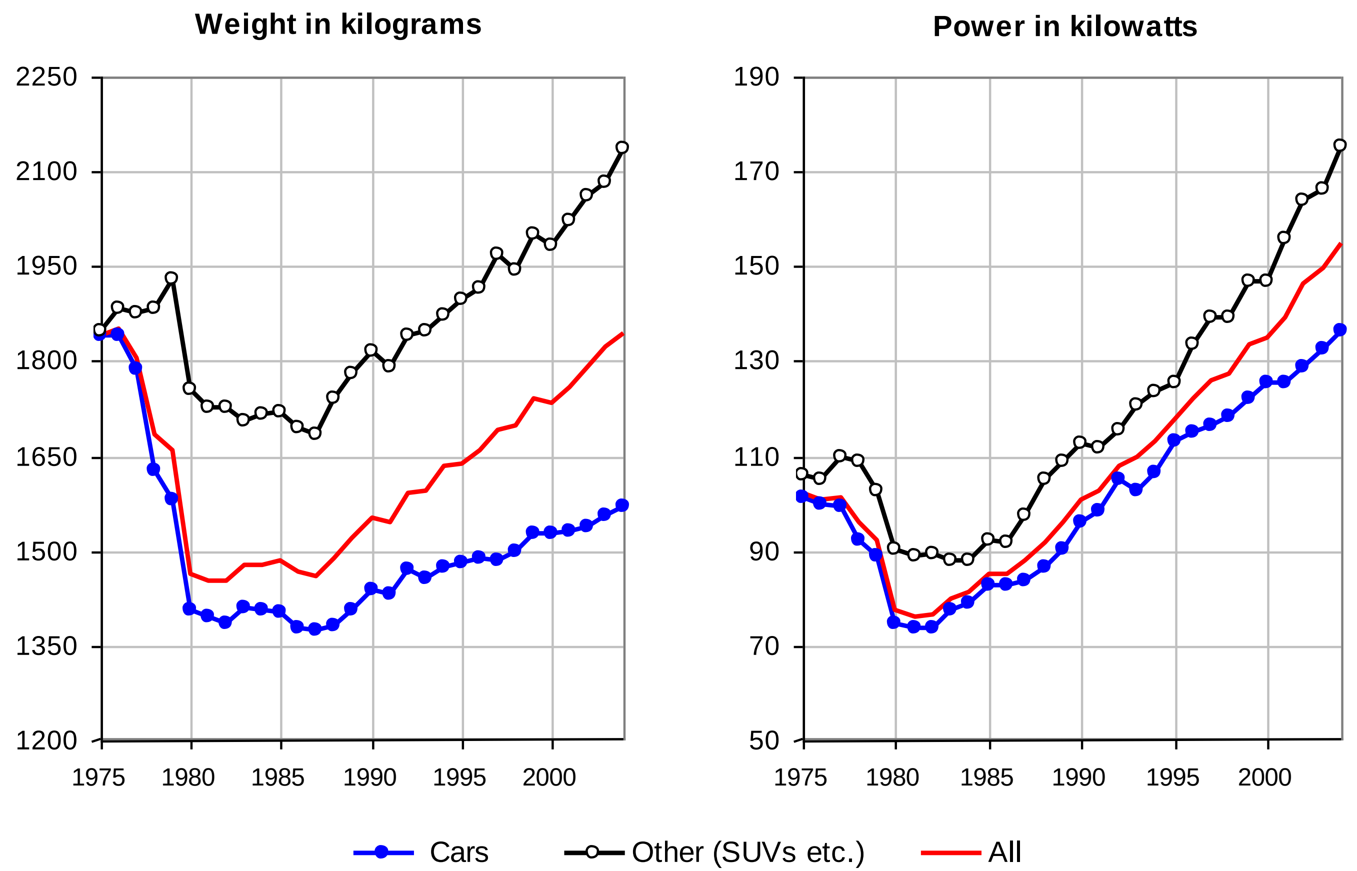
Weighted average rated fuel use (left) and sales per capita (right), light-duty vehicles sold in the U.S., 1975-2004 model years



Source: U.S. Environmental Protection Agency, 2004

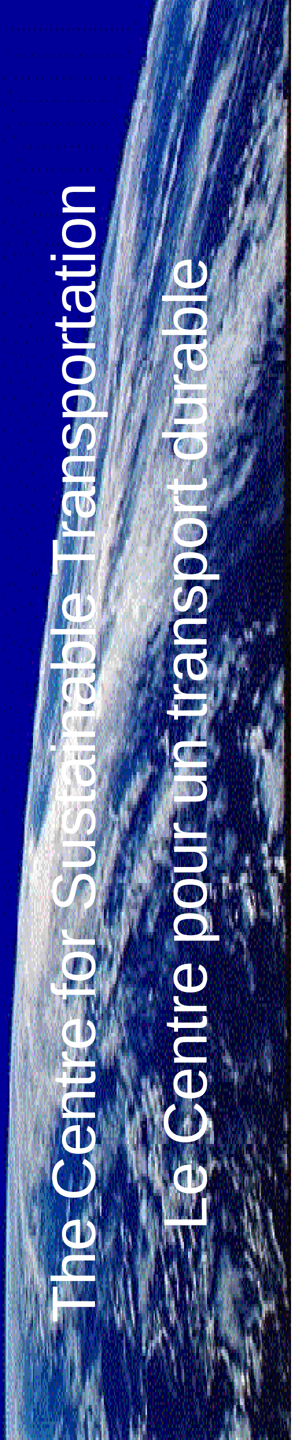
Note rapid adjustment to 1973 oil shock, and CAFE's control of fuel use.

Weighted average vehicle weight (left and engine power (right), light-duty vehicles sold in the U.S., 1975-2004 model years



Source: U.S. Environmental Protection Agency, 2004

Note how all technology gain since mid-1980s has gone to 25% weight increase and to 76% increase in engine power. If weight and power had remained the same, fuel use would be 55% lower (5.1 vs. 11.3 L/100km).



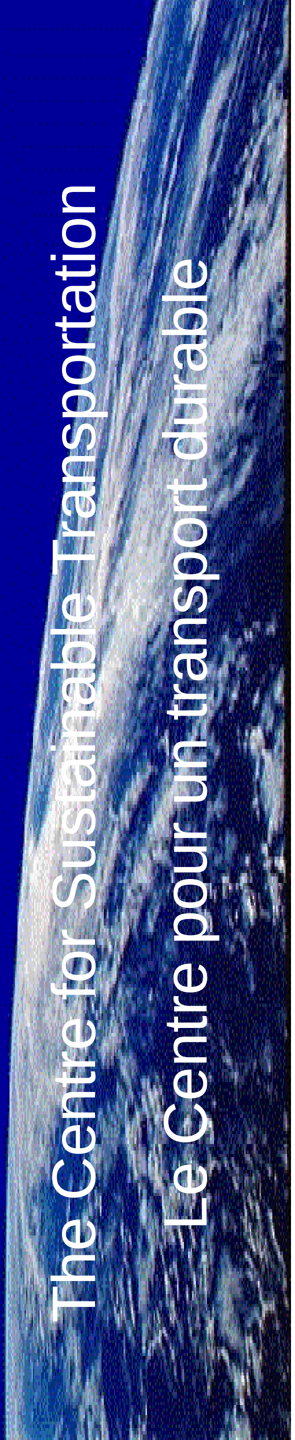
Replacing Canada's personal vehicle fleet

- Manufacturers can be nimble if consumers demand (see late 1970s); therefore educate consumers, and manufacturers. Higher fuel prices would help change demand.

- Challenge is that at current replacement rates it takes seven years to turn over half the fleet (12 years for 75% of the fleet).

- Incentives could help speed the turnover, including rebates and feebates. Higher fuel prices might speed things up too.

- Problem: if replacement vehicle has not at least 15% lower fuel use, early replacement could result in added energy use because of energy used to manufacture and distribute vehicles.



What are tethered vehicles?

- They are electrically driven vehicles that get their motive energy from an overhead wire or wires (or third rail) rather than from an on-board source.

- They have high ‘wire-to-wheel’ fuel efficiency for four reasons:
  - >95% of applied energy is converted to traction
  - electric motors are intrinsically lighter than ICEs
  - constant torque at all speeds means no oversizing
  - there is no fuel to carry.

- Overall efficiency and environmental impacts depend on the distribution system (perhaps a 10% loss) and the primary fuel source, which can range from inefficient and dirty (e.g., coal) to efficient and clean (e.g., wind).

- Tethered systems can use a wide range of fuels and switch among them without disrupting transport activity, making for smooth transitions towards sustainable transportation.

Public transit within cities

Vehicle type	Fuel	Occupancy (pers./veh.)	Energy use (mJ/pkm)
Transit bus (U.S.)	Diesel	9.3	2.73
Trolleybus (U.S.)	Electricity	14.6	0.88
Light rail (streetcar)	Electricity	26.5	0.76
Heavy rail (subway)	Electricity		0.58

Montreal

Calgary

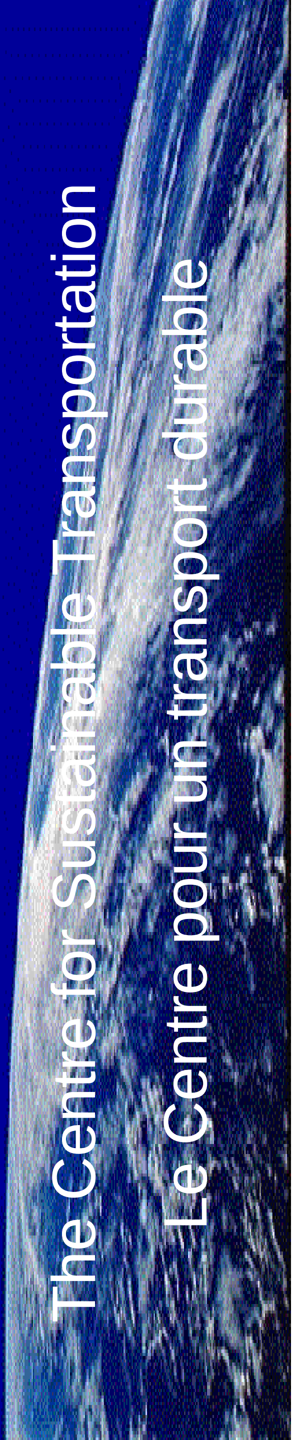
Vancouver

Public transit between cities

Vehicle type	Fuel	Occupancy (pers./veh.)	Energy use (mJ/pkm)
Intercity rail	Diesel		2.20
School bus	Diesel	19.5	1.02
Intercity bus	Diesel	16.8	0.90
Intercity rail	Electricity		0.64

Amtrak Acela at Boston South station

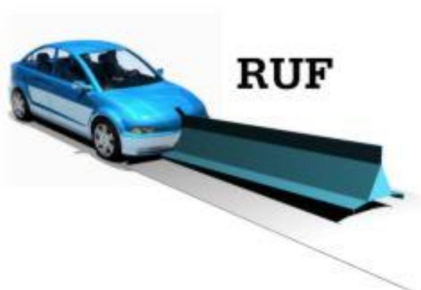
German ICE



Personal vehicles

Düsseldorf Airport SkyTrain

Vehicle type	Fuel	Occupancy (pers./veh.)	Energy use (mJ/pkm)
SUVs, vans, etc.	Gasoline	1.70	3.27
Large cars	Gasoline	1.65	2.55
Small cars	Gasoline	1.65	2.02
Motorcycles	Gasoline	1.10	1.46
Fuel-cell car	Hydrogen	1.65	0.92
Hybrid electric car	Gasoline	1.65	0.90
Very small car	Diesel	1.30	0.89
Personal Rapid Transit	Electricity	1.65	0.49



Skyweb Express (Cincinnati concept)

Freight transport

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

Vehicle type	Fuel	Energy use (mJ/tkm)
Truck	Diesel	0.45
Train	Diesel	0.20
Train	Electricity	0.06
Truck	Electricity	0.15?

The Centre for Sustainable Transportation
Le Centre pour un transport durable

Tethered vehicles and the next transport revolution (1)

- The main contexts for the next transport revolution could be super-high oil prices and little in the way of availability of hydrogen or uses for it.
- The main transport concerns will be (i) getting the most movement for the least energy use; (ii) taking advantage of the widest possible range of energy sources.
- Much more than other systems, tethered vehicle systems meet both of these needs.
- We should invest now in rails, wires, and other infra-structure for tethered vehicles. Sustaining our transport-dependent way of life may well depend on it.

Tethered vehicles and the next transport revolution (2)

Era	Approxi-mate dates	What drives wheels	What provides electricity
Steam Age	1820-1890	External combustion engine	N.A.
1st Electric Age	1890-1910	Electric motor (EM)	Battery, tether
ICE Age	1910-2010	Internal combustion engine (ICE)	N.A.
Hybrid Age	2010-2020	ICE and EM (or EM alone)	Battery charged by ICE
2nd Electric Age	2020-??	Electric motor	Fuel cell, battery, tether

If the fuel cell doesn't become a practicable choice for road vehicles—because of too high costs of vehicles, refuelling infrastructure, and fuel—the primary challenge could be to develop tethered systems that provide the convenience of today's personal vehicles and trucks.