The Potential Impacts of Very High Fuel Prices on Canada's Transport Systems and Cities

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When Energy Demand Exceeds Supply:
Impacts on Transportation and Cities
held by the
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University of Winnipeg
Winnipeg Art Gallery, Brio Hall & Auditorium
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This is the front page of the second, February 1999 issue of the Centre's Sustainable Transportation Monitor. Note the chart's now-familiar portrayal of discovery, production, and consumption.

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SUSTAINABLE TRANSPORTATION AND THE END OF CHEAP OIL

The price of crude oil could rise dramatically during the next 10-15 years. This would help attainment of sustainable transportation but there would also be significant perverse effects. Canada's plans for reducing transport's environmental impacts should allow for the possibility of such a price rise.

Current prices of crude oil are at their lowest level in real terms since the early 1970s.[1] The world market seems awash with oil on account of resumption of sales by Iraq (the oil-for-food program), reduced growth in demand in Asian countries, and high winter temperatures early in 1998.[2] As this issue of the *Monitor* is being prepared, the main news about oil concerns social problems in oil-producing countries resulting from low oil revenues.[3]

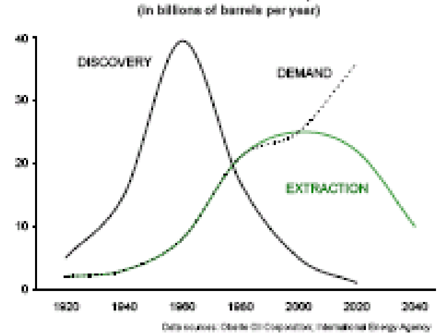
Thus it is with some hesitation that we begin this issue of the *Monitor* by reporting what appears to be **growing agreement among oil experts that we are soon to see the permanent end of cheap oil.**[4] Notable among these experts are those of the International Energy Agency (IEA), whose position on the matter is set out below.

The significant facts are these:

- **World *discoveries* of reserves of conventional oil peaked in the early 1960s** at a rate of about 40 billion barrels a year (bb/y).[5] ("Conventional oil" is oil that can be pumped from the ground, usually under its own pressure. "Unconventional oil" is pumped from seabeds or mined from oil sands or shale. Conventional oil can be recovered at relatively low cost; hence it is also known as "cheap oil." Nearly all of the oil now used in the world is conventional oil.) In spite of massive and highly sophisticated efforts since then, the rate of discovery of conventional oil has declined steadily to an estimated 1998 rate of 6 bb/y, less than one third of the rate of extraction and use (see Box 1).[6]
- **The massive surveying effort means that the total amount of conventional oil in the ground across the world has been more or less identified.**
- Various factors cause the output of an oil field to reach a maximum soon after it is first tapped and to decline when about half of the oil in the field is depleted.[7] When large numbers of fields

Box 1 CST

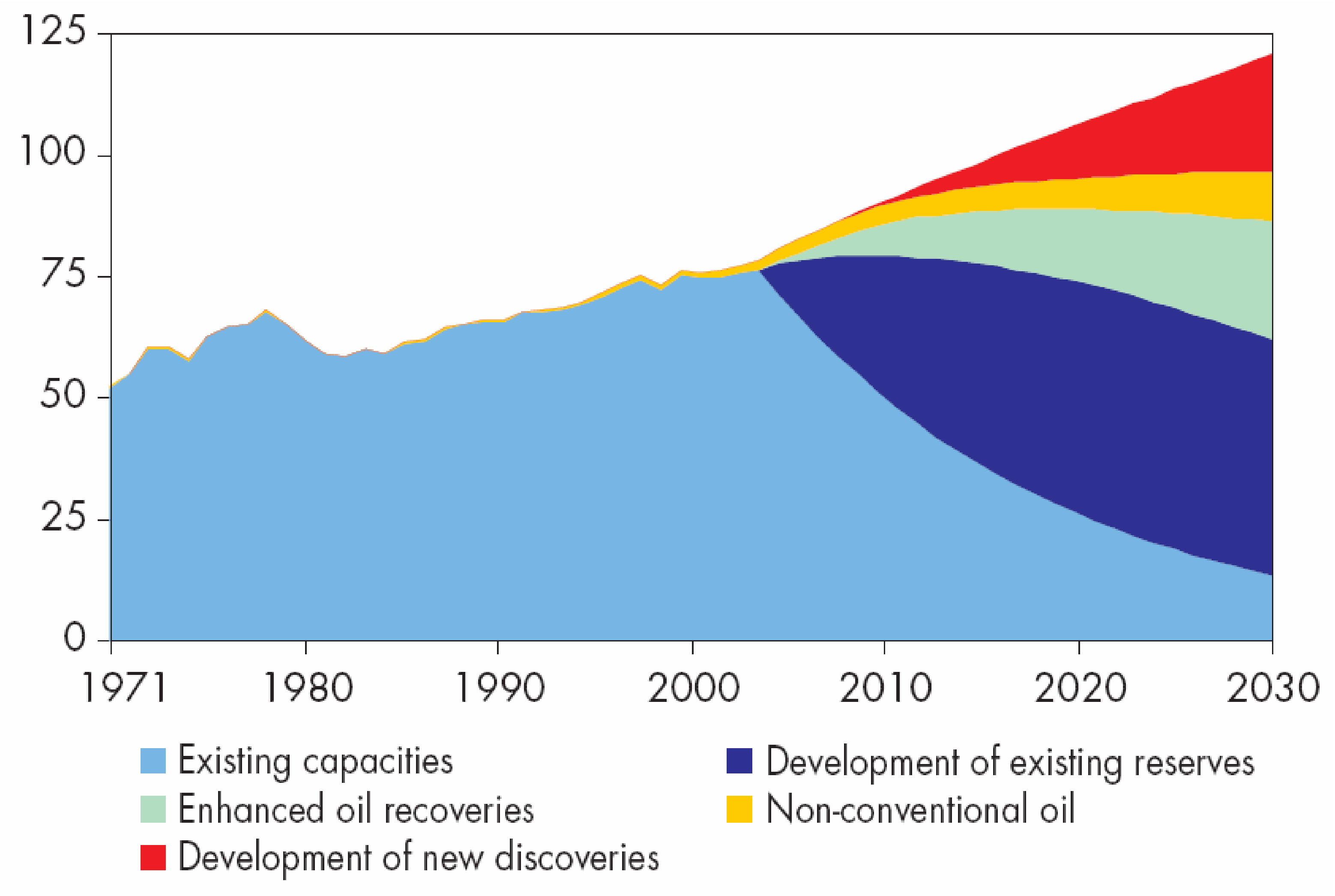
Actual and projected world-wide discovery, extraction, and demand for conventional oil, 1820-2040
(in billions of barrels per year)



The *Sustainable Transportation Monitor* is the collective expression of the Board of Directors of the Centre for Sustainable Transportation. Members of the Board are listed on Page 12. The views and analyses presented here are not necessarily those of the organizations with which members of the Board are affiliated. The superscript numbers in the text refer to reference notes that begin on Page 13.

Here's the most authoritative projection of consumption, and where it is coming from

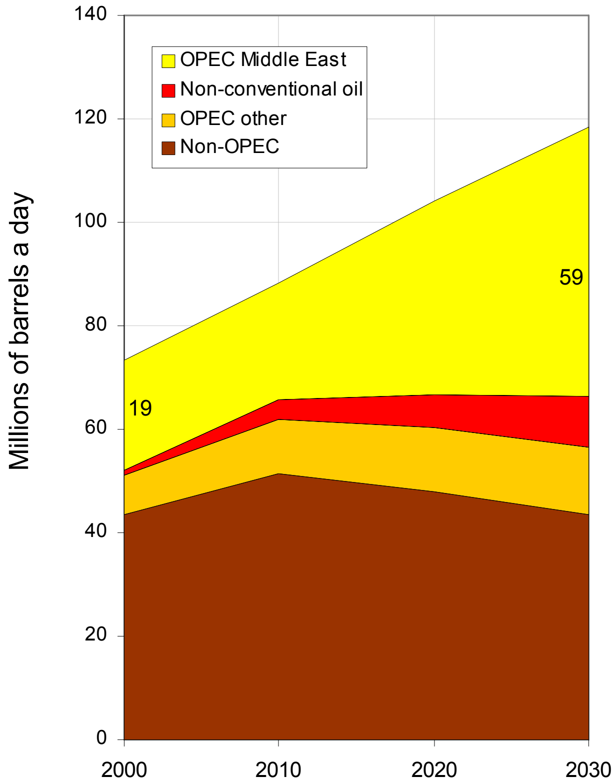
Millions of barrels a day



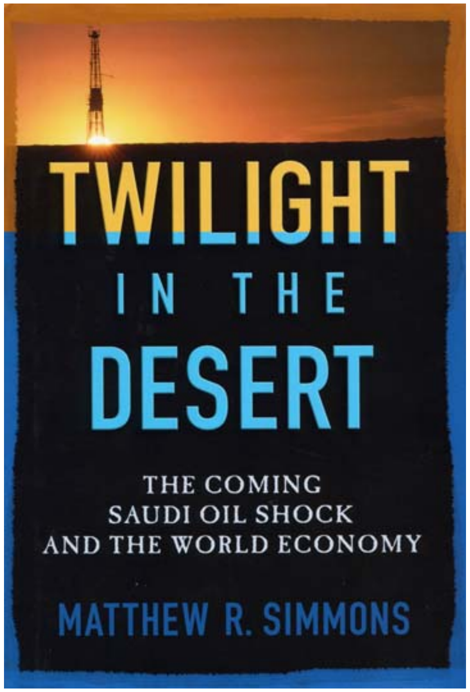
Source: *World Energy Outlook 2004*, International Energy Agency, 2006

IEA says almost all of the new oil from the other three sources—existing reserves, new discoveries, enhanced recovery—will come from the Middle East

IEA's view of world oil production by source, 2000-2030

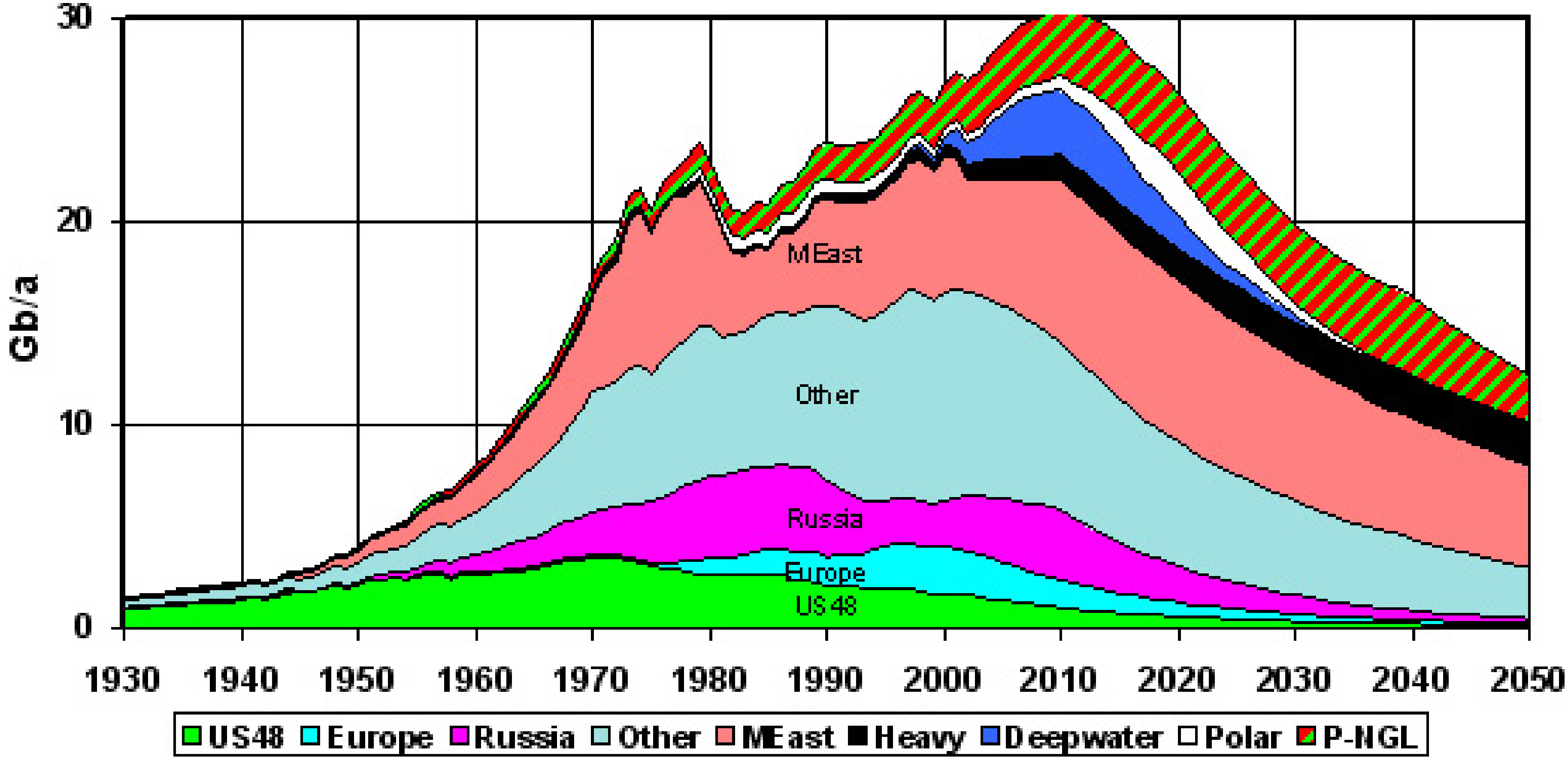


Simmons says there is doubt whether Saudi Arabia can even maintain the current production of 9.5 mb/d.



IEA: "Of the projected 31 mb/d rise in world oil demand between 2010 and 2030, 29 mb/d will come from OPEC Middle East … Saudi Arabia, Iraq, and Iran are likely to contribute most of the increase." On April 10, 2006, according to *Platts Oilgram News,* Saudi Aramco, announced that its "composite decline rate of producing fields" is 2%/year, after "remedial actions and the development of new fields".

Here's the best estimate of when the world peak in liquid hydrocarbon production will occur: about 2012 (black area is oil sands)



Source: Uppsala Hydrocarbon Depletion Group, 2005

An updated analysis by Colin Campbell puts the peak in production of conventional oil in 2005 and the peak production of all liquid hydrocarbons in 2010 (ASPO newsletter, April 2006)

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Small shortfalls can mean big price increases (two analyses)

①

Based on analysis for the U.S. by the Brookings Institution

	Shortfall in crude oil supply			
	0%	5%	10%	15%
Resulting increase in crude oil price	0%	30%	200%	550%
Crude oil price per barrel (US$)	$50	$65	$150	$320
Resulting gasoline pump price (Can$/litre)	$0.85	$1.00	$1.50	$2.50

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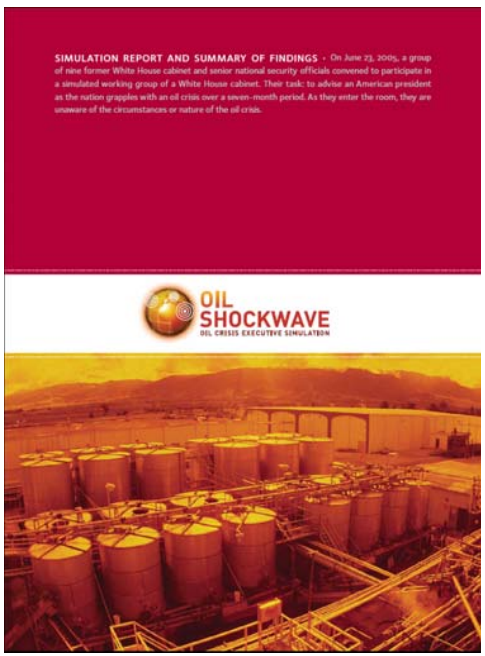
②



The U.S. National Commission on Energy Policy concluded in June 2005 that a "4 percent global shortfall in daily supply results in a 177 percent increase in the price of oil" (from $58 to $161 per barrel).

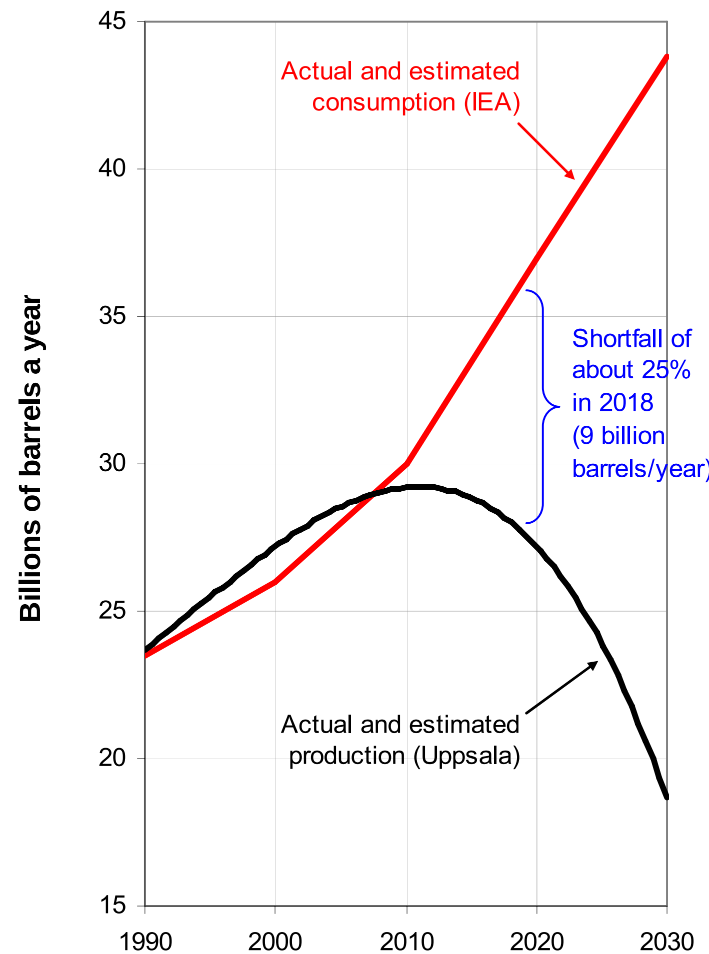
The possibility of fourfold increases in pump prices

- The IEA projection of world consumption and the Uppsala University analysis of production together suggest that in 2018 there could be an oil production shortfall of about 25%.

- Using the more conservative of the above two analyses of the impact of shortfall on price, this translates into an eight-fold increase in oil's 'wholesale' price (i.e., to US$500-600/barrel).

- High prices force down potential demand; and pump prices vary less than crude oil prices (distribution costs, taxes).

- Nevertheless, it may be reasonable to assume that pump prices of transport fuels will be four times higher in 2018 than they are now—similarly for natural gas.



Four-dollar gasoline is an optimistic perspective

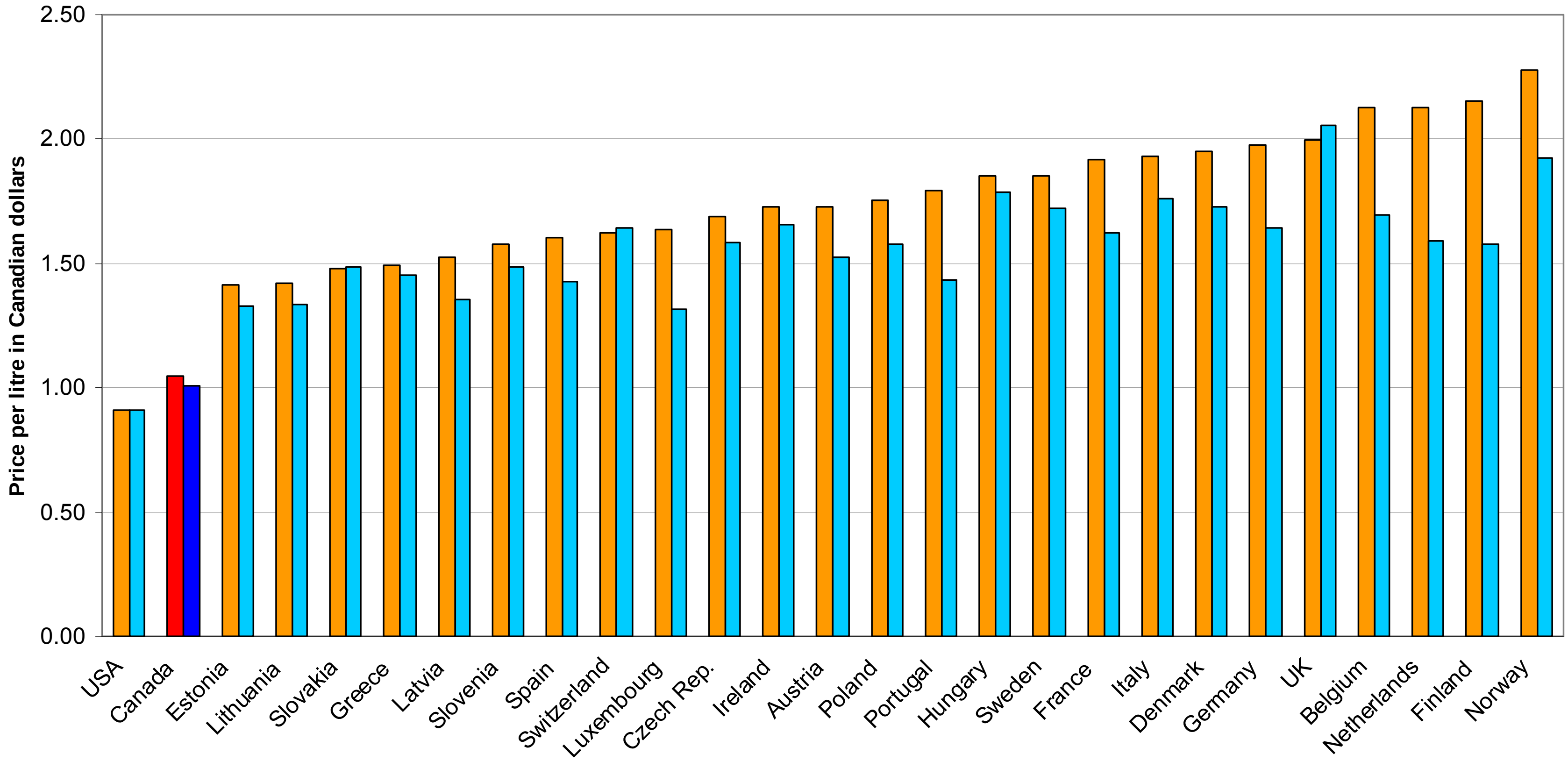
1. One outcome of the end of cheap oil (and natural gas) could be a ‘hard landing’ into economic depression and widespread dislocation.

2. Projecting a reasonably stable price of \$4/L implies that there is still demand for oil, i.e., economic and social life are continuing, albeit within a different framework. \$4/L implies a ‘soft landing’.

3. A reasonably stable \$4/L (and \$2/m^3) also implies an orderly process whereby the long decline in production of oil (and natural gas) is being matched by progressively more efficient use and by a measured transition to use of other fuels.

4. \$4/L and \$2/m^3 are also optimistic in that they are large enough increases to effect real change in how energy is used and produced.

European and other gasoline prices (cheapest posted) are 140-220% of Canadian prices. The diesel fuel price difference is usually a little less. Prices below are for September 19-20, 2005, ranked by gasoline price, using official exchange rates.



Data sources: UK Automobile Association, *Japan Today*, Australian Institute of Petroleum, MJ Ervin & Associates, OANDA.com

The higher fuel prices in Europe have surprisingly little impact on travel, which is overwhelmingly by automobile on both sides of the Atlantic

Including aviation

	Kilometres travelled per person	Share by personal vehicle	Share by surface public transport	Share by aviation
Canada	16,113	81%	9%	10%
EU15	13,397	79%	15%	6%

Ignoring aviation

	Kilometres travelled per person	Share by personal vehicle	Share by surface public transport
Canada	14,529	90%	10%
EU15	12,659	84%	16%

Data sources: Natural Resources Canada, *Energy Use Data Handbook*, 2005; Statistics Canada (population data); European Commission, *Energy and Transport in Figures 2005*

LNG to the rescue for natural gas?

"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."

Powers B, *Assessment of Potential Risk Associated with Location of LNG Receiving Terminal Adjacent to Bajamar and Feasible Alternative Locations*, June 2002

Why biofuels may not fill the liquid transport fuels gap

1. Ethanol and biodiesel have some role as substitutes for present transport fuels.

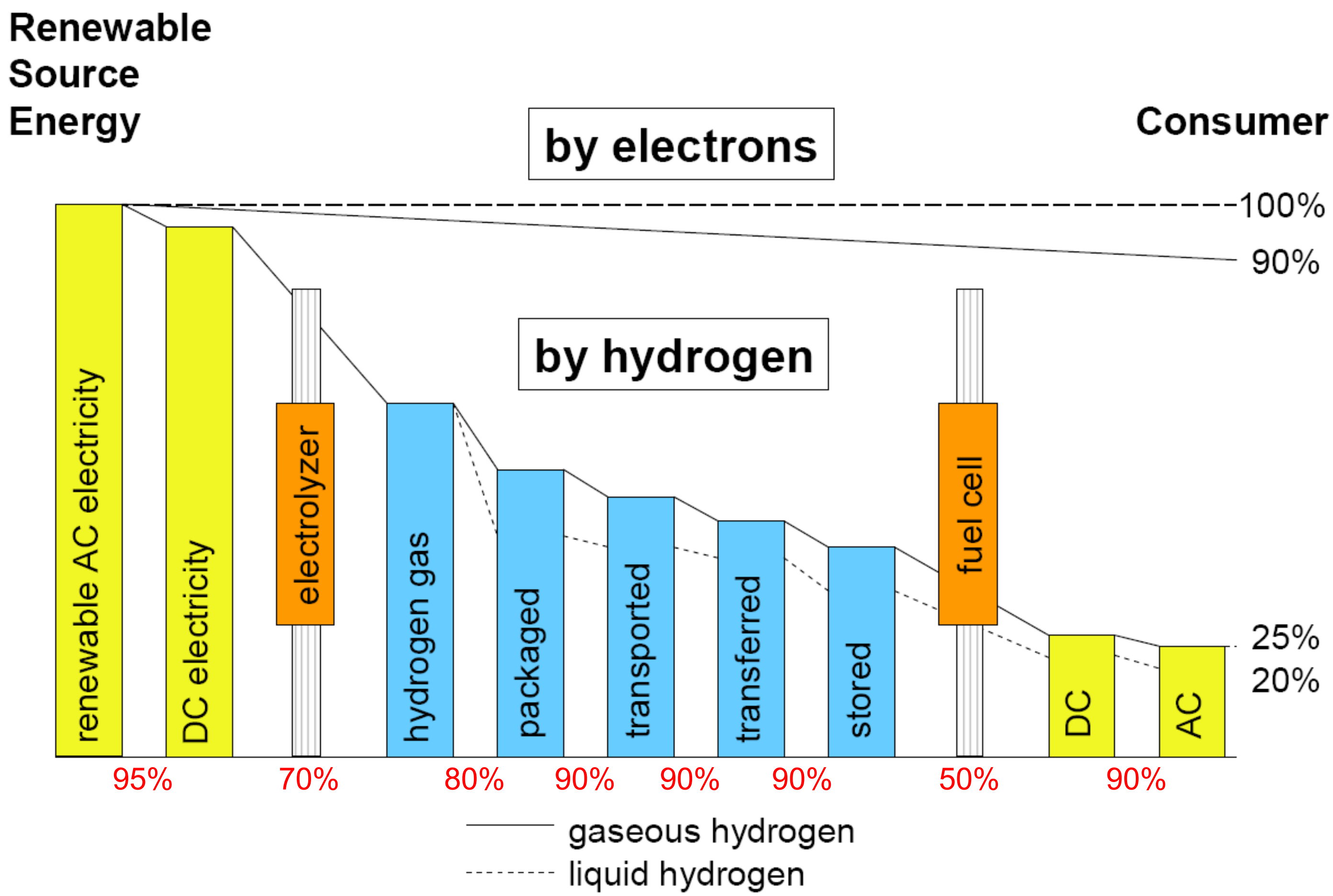
2. Ethanol production raises questions about required energy inputs and land requirements. The new Goldfield plant in Iowa uses about 100,000 tonnes of coal [!] a year to produce about 200 million litres of ethanol from about 600,000 tonnes of corn—harvested from about 1,000 square kilometres of land. The energy in the coal is about 60% of the energy in the ethanol, and more energy is required for farming and transporting the corn.

3. There are fewer questions with production of ethanol from cellulose (Ottawa-based Iogen Corp. is a world leader), using wood, corn, and other wastes.

4. But the land requirement question remains, and a new question: in an energy-constrained world in which fertilizer production is limited by oil and natural gas availability, will not waste materials be needed to replenish land?

5. It usually makes more sense to use biofuels to cogenerate electricity.

Why the hydrogen fuel cell future won't work
(but grid-connected vehicles will)



Source: Bossel (2005)

Approximate efficiencies of processes are in red.

Strategy for analysis, for municipalities and transport

- What are the chances of prices rising fourfold during the next 25 years?
- If the odds seem less than one in four, proceed with business as usual. If they seem between one in four and one in two, have a 'Plan B' that puts energy first.
- If there seems to be a more than even chance of a fourfold rise, use a 'Plan A' should be a plan that puts energy first.
- Fourfold increases appear to have a more than even chance of happening by about 2018, and a higher chance by 2031.

Guidelines for a municipal Plan A by 2018 (transport and buildings, not industry or agriculture)

- Keep household and business energy bills 50% above current levels, with another 50% to go towards new equipment.
- Thus, reduce per-capita energy use by about two-thirds (allowing margin for error, population growth, etc.).
- Keep the total amount of electricity use at about the same level as now, but do much more with it, particularly for transport. Electricity's share of total energy use would rise from about a fifth to about a half.
- Reduce use of oil and natural gas by about 80%.

Here's what the consumption guidelines translate to (for Hamilton, Ontario, population now about 520,000)

Purpose of energy use	Actual in 2003 (petajoules)				Proposed for 2018 (petajoules)				Change in total, 2003-18
	Oil/NG	Electricity	Other	Total	Oil/NG	Electricity	Other	Total	
Movement of people	20.0	0.0	0.0	20.0	3.0	3.5	0.0	6.5	-68%
Movement of freight	11.9	0.0	0.0	11.9	4.0	1.4	0.2	5.6	-53%
In residential buildings	13.9	6.9	1.0	21.8	2.7	5.1	1.1	8.9	-59%
In other buildings	10.0	7.6	0.3	17.9	1.7	4.3	0.5	6.5	-64%
Totals for transport	31.9	0.0	0.0	31.9	7.0	4.9	0.2	12.1	-62%
Totals for buildings	23.9	14.5	1.3	39.7	4.4	9.4	1.6	15.4	-61%
Overall totals	55.8	14.5	1.3	71.6	11.4	14.3	1.8	27.5	-62%

Source for 2003 data: Ontario section of Natural Resources Canada, *Comprehensive Energy Use Data*, 2006;

Additional factors for transport

- Maintain the amount of motorized travel by Hamilton residents (excluding aviation) to near current levels. A 15-20% reduction per capita is proposed, mostly to offset population growth, mostly achieved through shift to walking and bicycling and through shortening of journeys.

- Reduce automobile use by about a third; increase transit use about threefold; introduce personal rapid transport; reduce fossil fuel use for moving people by about 85%; add more electricity use for transport than fossil fuel use.

- Increase the amount of movement of goods in, to, and from Hamilton by about 9%, almost keeping pace with population growth.

- Reduce truck use, and use many electric trucks; increase rail and marine use; reduce fossil fuel use for moving goods by about two-thirds; replace some of this with more use of electricity.

What are grid-connected (tethered) vehicles?

- Electrically driven vehicles that get their motive energy while moving from an overhead wire(s) 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 lighter than internal combustion engines (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., sun and wind).

- Grid-connected systems can use a wide range of fuels and switch among them without disrupting transport activity, allowing smooth transitions towards sustainable transport.

Public transit within cities

Montreal

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

Calgary

Vancouver

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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

Note on Calgary-Edmonton High-Speed Rail

- Recent Van Horne Institute study (Shirocca Consulting) showed: With current fuel price regime, Calgary-Red Deer-Edmonton high-speed electric train (300 km/h; 90-min. C-E trip time; 10 return trips/weekday) would have revenues about $200 million/year, thus covering operating costs (about $120 million/year) and 75% of capital costs ($3.7 billion, or about $130 million/year).

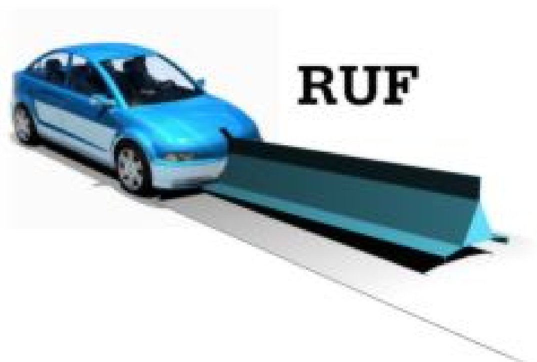
- What if fuel prices rise fourfold and fuel efficiency improves by 50% (air, train) and 100% (car)? Rail use rises to 45% of trips (from 22%). Also, (not in Van Horne estimate) total trips rise by 50% (same people travelling more, as for Paris-Lyon). Revenues now exceed costs by $25 million/year.

- Paris-Lyon TGV (400 km) has double-decked trains running 35 times a day (headways as low as 3-4 minutes, GPS-satellite managed).

Personal vehicles

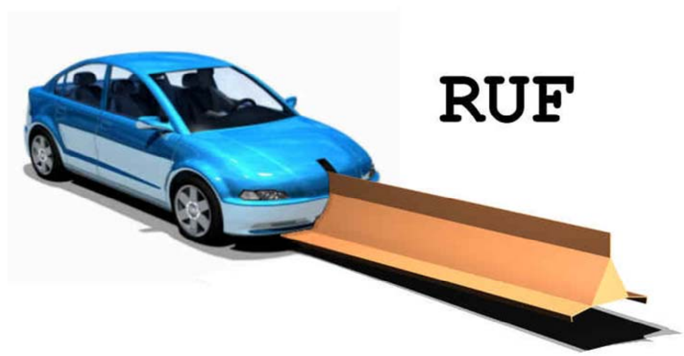
Düsseldorf Airport SkyTrain

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)

More on PRT



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?

Fuel is now >75% of shipping costs. Kites reduce fuel use by about a third. <3-year payback. Coming into use in 2007.

Source: Economist September 17, 2005

Additional guidelines for energy use in buildings

- About the same reduction in overall energy use as for transport (≈60%), and the same level of reduction in fossil fuel use (≈85%), even though more energy is used in buildings than for transport.
- As for transport, there would be a shift to electricity use. Now electricity is 37% of in-building energy use, becomes 61%. Transport energy use is now 0% electricity, becomes 54%.
- Big difference is that buildings but not vehicles can be a source of energy (discussed later).

Here's how *new* buildings could change

House type	Annual energy consumption ($kWh/m^3/year$)
Typical existing house (1970)*	309
Typical new house (2002)*	203
Model National Energy Code house (2002)*	161
R-2000 house*	112
Advanced house (1991)**	33

* 198 m^2 one-story, single detached house, natural gas heating.

** 250 m^2, two-storey, single detached house heated through an integrated mechanical system, in Brampton, Ontario.

Data sources: *??*

Land-use planning principles

- Put energy first (e.g., build land uses around transport and energy production requirements)
- Avoid greenfield development
- Don’t abandon present low-density areas
- Mix uses; foster vibrant centres
- Aggressively pursue ‘brownfield’ development

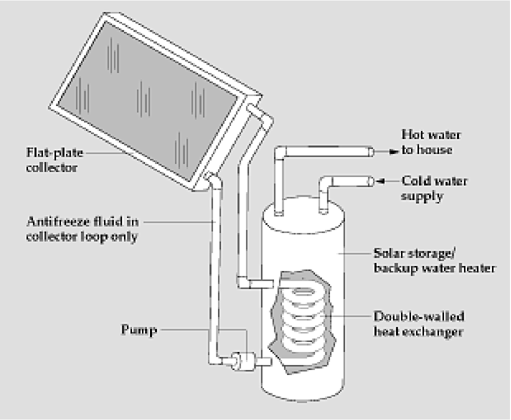
Energy production will be a priority (1)

Hamilton could become self-sufficient in electricity and produce substantial amounts of natural gas and other useful energy:

- Solar energy: electricity and hot water
- Wind energy: electricity
- Deep Lake Water Cooling (DLWC): cold water for air conditioning
- Hydroelectric power: electricity
- Energy from waste: electricity, process steam, hot water
- Biogas production: natural gas (also electricity, etc.)
- District energy: allows buildings to be heated and cooled from numerous sources (including DLWC)
- Local food production: energy for humans, reduces transport and possible shortages

Energy production will be a priority (2): solar electricity and hot water

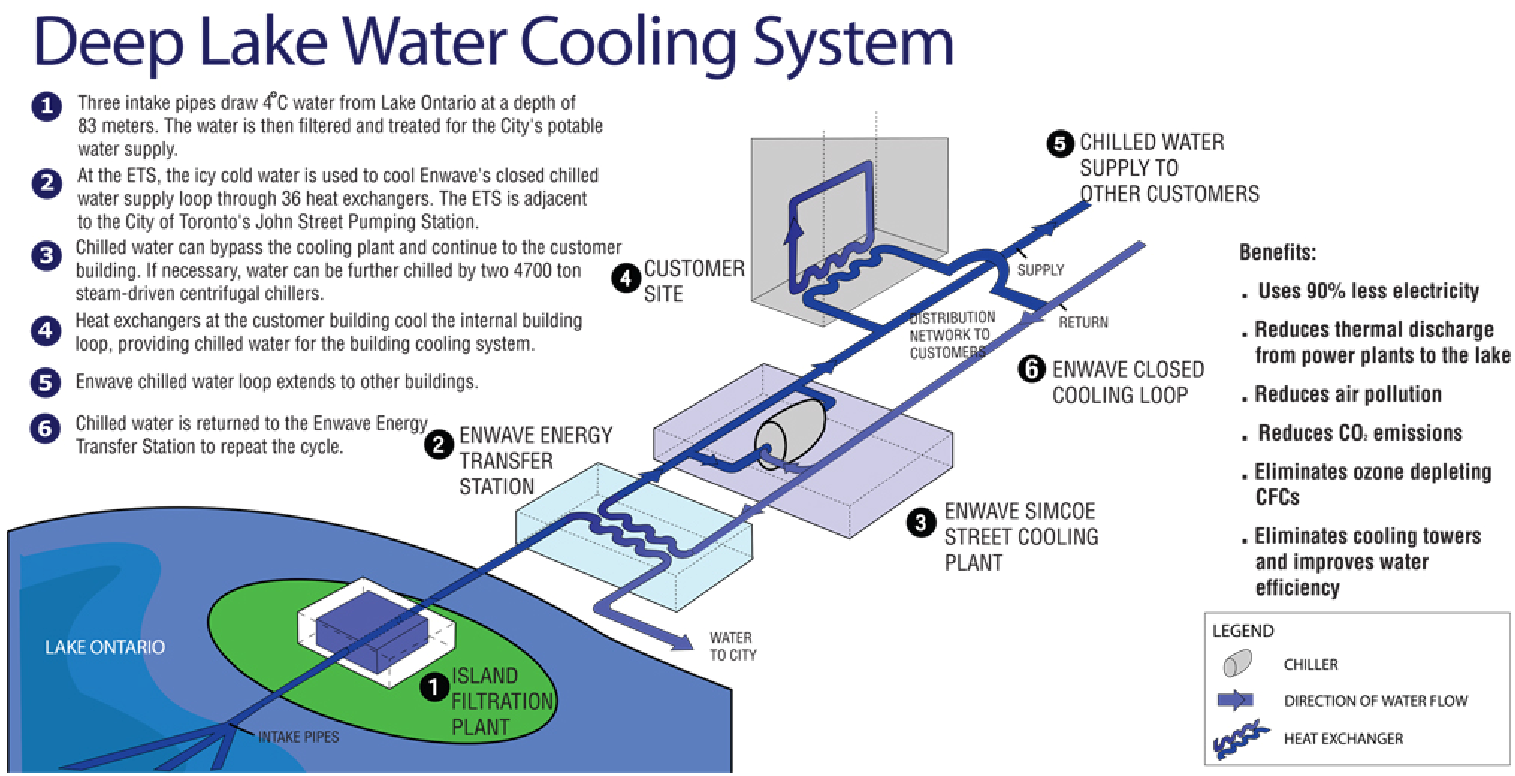
Photovoltaic panels on roofs upper left) and walls (lower left) could provide the equivalent of most of the electricity used within Hamilton's residential buildings and more than that used in commercial buildings (in total, more than half of Hamilton's 2018 consumption). Solar water heating panels (right) could provide most of Hamilton's domestic hot water.



Energy production will be a priority (3): horizontal and vertical wind turbines

Wind turbines, over farmland (left), and especially over water (below), but also—with vertical-axis turbines—in confined spaces (right) could provide the equivalent of about a quarter of Hamilton's electricity use.

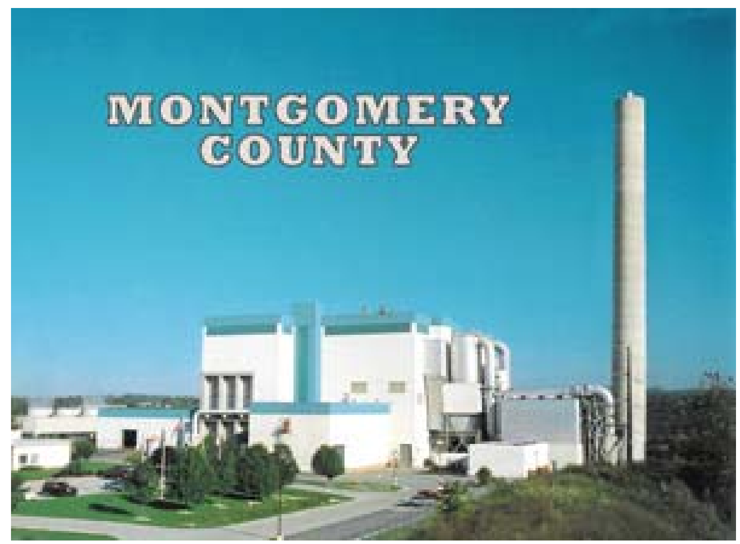
Energy production will be a priority (4):



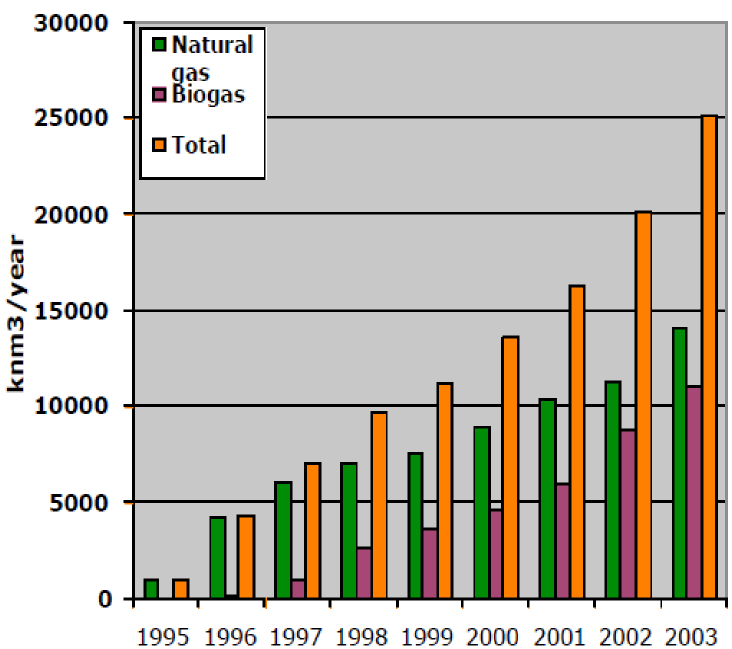
Toronto's system provides the cooling equivalent of 250 megawatts of electric power: annually about 15% of Hamilton's proposed electricity use in 2018. Toronto's downtown is only 5 km from where Lake Ontario is 80 metres deep, Hamilton's is 20 km, but the additional underwater piping cost is relatively small and so is the temperature gain.

Energy production will be a priority (5): Energy From Waste (EFW)

If Hamilton were to manage half of Southern Ontario's solid waste in four plants like the Florida plant on the right, all located on the Stelco site, the product would be over 40% of Hamilton's electricity requirements in 2018, hot water enough to heat *all* Hamilton's buildings (via a district energy system), and some steam for industrial processing. Municipalities and businesses would *pay* Hamilton to take this fuel. Two conditions should be imposed: (i) all non-Hamilton waste arrives by rail or water; and (ii) for more than half of the days of the year the plants act as air cleaners, i.e., the air coming out the stacks is better than the ambient air (which will be better in 2018 than now because there will be fewer internal combustion engines. The plant on the left is in Burnaby, B.C.

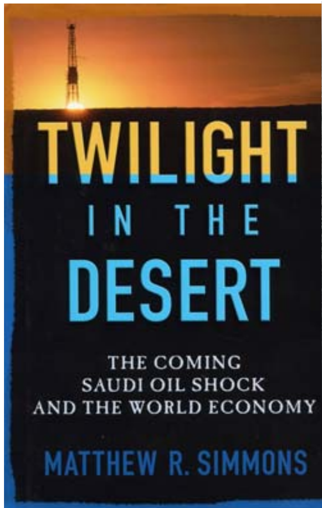


Energy production will be a priority (6): Biomethane from organic wastes



Municipalities, businesses, and farms would also pay Hamilton to process biomass, notably animal and vegetable wastes. If the wastes are digested anaerobically and the biogas product upgraded, the result can be 'biomethane', which is essentially the same as natural gas. This is a less well tried process than production of energy from solid waste, but its use is growing rapidly. Sweden is running trains and buses with biogas/ biomethane (see top views), and several thousand cars (chart).

Source: Eliasson (2005)



Calgary

Thanks for your attention!