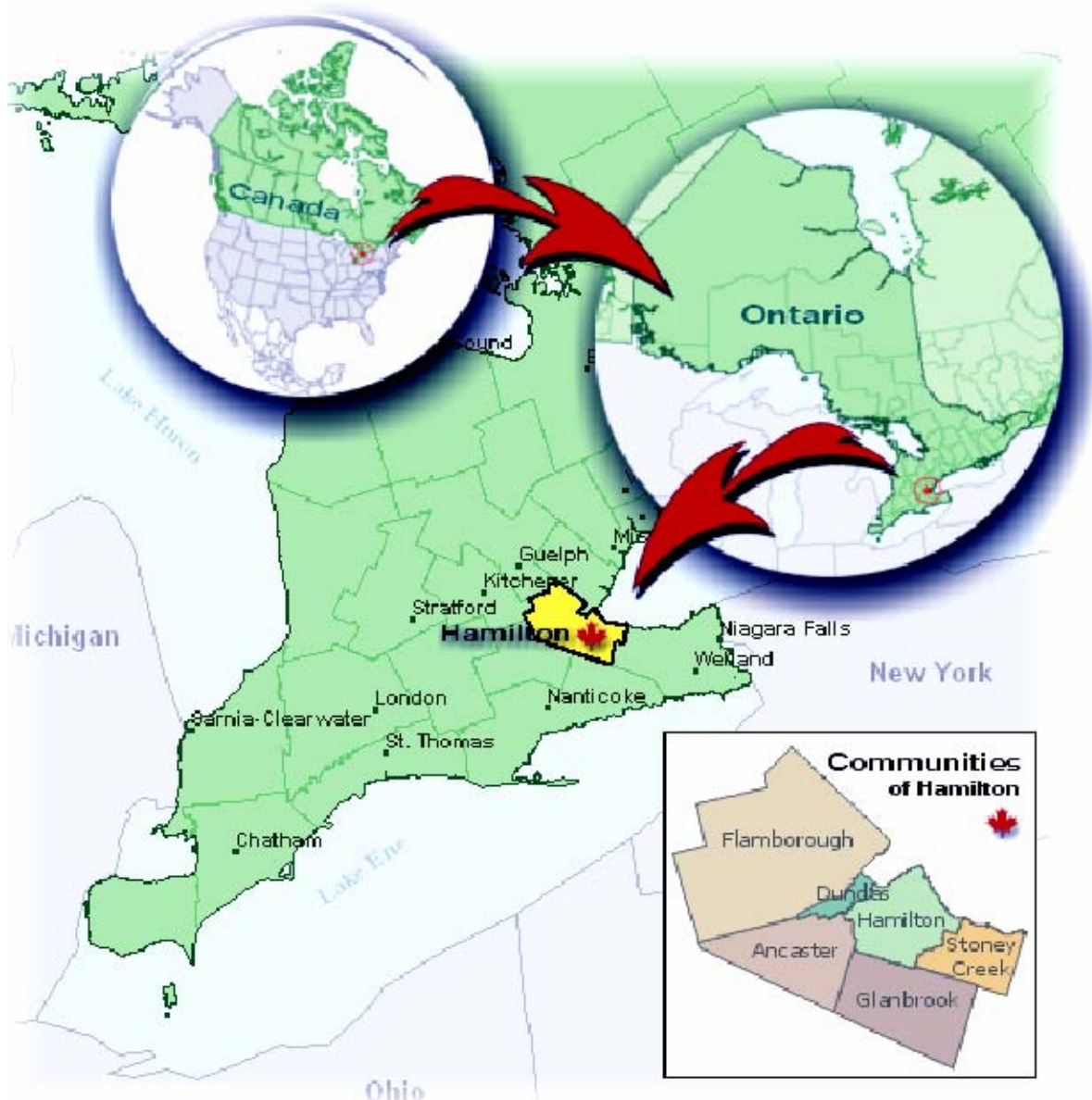


HAMILTON: THE ELECTRIC CITY

April 13, 2006



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Summary

The City of Hamilton is engaged in a major planning exercise for the period until 2031, embracing most aspects of municipal responsibility. Questions have arisen as to how much regard the exercise should have for possible steep increases in the prices of oil and natural gas during the planning period, and what form the regard might take. This report responds to these concerns.

Two price points are taken to illustrate ‘very high fuel prices’: \$4.00/litre for gasoline/diesel fuel and \$2.00/cubic metre for natural gas (in today’s dollars). Both are about four times current all-in prices paid by end consumers. There is a more than even chance that prices will reach such levels during the planning period, even during the first half of the period. Prices will reach these high levels because worldwide and North American production of these fuels will fall far short of desired consumption, and substitutes will not be available in sufficient quantities.

Stable high prices can be regarded as an optimistic outcome of forthcoming convulsions in world and North American energy markets. Alternatives—including low prices arising from a glut in fuels—could be associated with economic and social collapse.

Experience elsewhere suggests that little will change until fuel prices reach two or three times current levels. Most journeys will continue to be made by cars as we know them. Most activities will occur in buildings such as we have now. Patterns of energy production and consumption be similar to now, with more energy continuing to be used in buildings than for transport. However, more will be spent on fuels by individuals and businesses—and less on other goods and services—offset to a degree by improved efficiencies. Above threefold increases, particularly when prices reach \$4/L for transport fuels and \$2/m³ for natural gas, there will be major changes in society, and energy will be a key factor in all decision-making.

The prospect of such high prices provides imperatives to reduce energy use substantially, shift energy use from fossil fuels to renewable resources, and generate as much energy as possible locally. The concerns would be for the City’s operations and for every facet of life and business in Hamilton.

Reasonable planning objectives could be to lower energy use in Hamilton by two thirds and generate most of what is used from renewable resources and waste materials. Implicit in this energy transformation would be extensive use of geo-thermal resources and district energy applications for heating and cooling buildings and electric traction for vehicles. Energy sources would include the widest array of renewable production of electricity, cold and hot water, steam, and biogas.

Given the likelihood of such high prices, energy use and production could become the organizing principle of the City's strategic planning, particularly for land use, transport, and economic development. Land uses would be arranged so as to strike balances between maximizing energy production—e.g., from solar arrays—and minimizing in-building energy use and associated energy use for transport. The movement of people and goods would be guided towards use of radically less energy and towards being powered more by electricity than by fossil fuels.

In engaging in planning of various kinds, the City of Hamilton is exercising one of its principal roles: that of a community builder that seeks to sustain the economic, social, and environmental welfare of Hamilton's residents and businesses. The City has another relevant role: providing services many of which consume fossil and other fuels. The present report also touches on how this role can be exercised in an era of energy constraints, focussing on the City's transit system and its vehicle fleet. As well, in response to City Council's direction, the report touches specifically on the aerotropolis proposal and on freight transport issues.

As a leader in facing future energy realities, Hamilton would be well positioned to become Canada's research and development hub for the new energy paradigm with emphases on local power generation, electric transport, low-energy buildings, and associated information technology. The main focus would be on the use and production of electricity, to be the main fuel in the era of energy constraints.

In the 1880s, Hamilton was one of the first cities in the world to have widespread electric light—for streets, homes, and businesses. It was known as 'The Electric City'. Hamilton could again be 'The Electric City', in the forefront of the transition to electric transport and new electricity generation.

1. Background to this report

Since 2003, the City of Hamilton has been developing a Growth Related Integrated Development Strategy. “GRIDS is an integrated planning process to identify a broad land use structure, associated infrastructure, economic development strategy and financial implications for the growth options for the City of Hamilton over the next 30 years by achieving a balance among social, economic and environmental considerations.”^{1†} A key input into GRIDS is the Transportation Master Plan, also under development. GRIDS in turn will be a source document for the City’s new Official Plan, which will frame the City’s future actions with respect to land use and transportation.

Hamilton's
Growth Related
Integrated Development
Strategy
(GRIDS).

Another key input into GRIDS is the Economic Development Strategy, updated in 2005.² This document presents “a twenty-year vision in which Hamilton will possess a diversified, sustainable economic base consisting of globally competitive, wealth creating companies that employ a highly skilled, well-educated labour force”.³ To achieve this vision, the document recommends that the City concentrate on the development of “eight industry clusters and a ‘Quality of Life’ component that focuses on community attributes such as health care and education”.⁴ Of the eight clusters, the aerotropolis—“a master planned community that develops around an airport”—was identified as “the number one strategic priority for economic development in Hamilton”.⁵

In June 2005, at a public meeting on the aerotropolis concept, and at a subsequent meeting of City Council’s Planning & Economic Development Committee,⁶ several deputants raised concerns about how potential energy constraints might affect the unfolding of the concept. As a consequence, on June 29, City Council directed staff to “prepare an analysis to establish a strategy to deal with the potential fossil fuel crisis (e.g., Oil peak) and the potential impact on our aerotropolis, goods movement future initiatives, fleet, and HSR”.⁷ The present report was commissioned in response to Council’s direction.

City Council's
direction.

Subsequent discussion with City officials suggested a strategy for addressing Council’s concerns. It would be to prepare a more general report that assessed the likelihood of future energy constraints and how the City might best address them. The report would deal with the broad range of

[†] Superscript numbers refer to 114 reference and other notes found on Pages 59-75. Several of these notes provide in-depth analysis of points made in the main text of the report.

land use, transportation, and economic development issues, and would pay special attention the matters identified by City Council.

In particular, the report should address the City's two roles with respect to the issues under discussion: as energy user and as community builder. In the first role, the City strives to minimize its own costs. In the second role, the City seeks to sustain the economic, social, and environmental welfare of Hamilton's residents and businesses.

This report provides a preliminary consideration of these topics.

The present report provides no more than preliminary consideration of this broad range of topics. It suggests that severe energy constraints are likely within the horizon of the City's ongoing planning exercise, i.e., before 2031. It suggests too how the City of Hamilton might prepare for such constraints and even take advantage of them. This report does not provide definitive answers as to what is likely to happen and what should be done, but it does indicate numerous directions that could well be pursued in more depth.

Previous energy references in GRIDS work.

The prospect of severe energy constraints had already been noted in documentation produced for development of Hamilton's Transportation Master Plan. The *Transportation Energy Use and Greenhouse Gas Emissions Policy Paper*, prepared by IBI Group and dated January 2005, had concluded that "a dramatic increase in fuel costs beginning before 2015 is very likely".⁸

GRIDS has also benefited from a brief and constructive discussion of energy in its background paper on climate change, produced in September 2004. That paper anticipated some of the directions proposed here, notably the potential for energy-related economic development: "Renewable energy also presents a tremendous manufacturing and employment opportunity for Hamilton: steel for wind towers, installation expertise, and incorporation into new construction or upgrades."⁹

2. Oil prospects

More than 95 per cent of transport in North America and elsewhere is fuelled by products of petroleum—mostly gasoline and diesel fuel—laid down by geological and other processes acting over many hundreds of millions of years. About 60 per cent of oil is used for transportation. The remainder is used for electricity generation, heating, and lighting, and also as feedstock for a wide range of chemicals: notably plastics, fertilizers, and pharmaceuticals.¹⁰

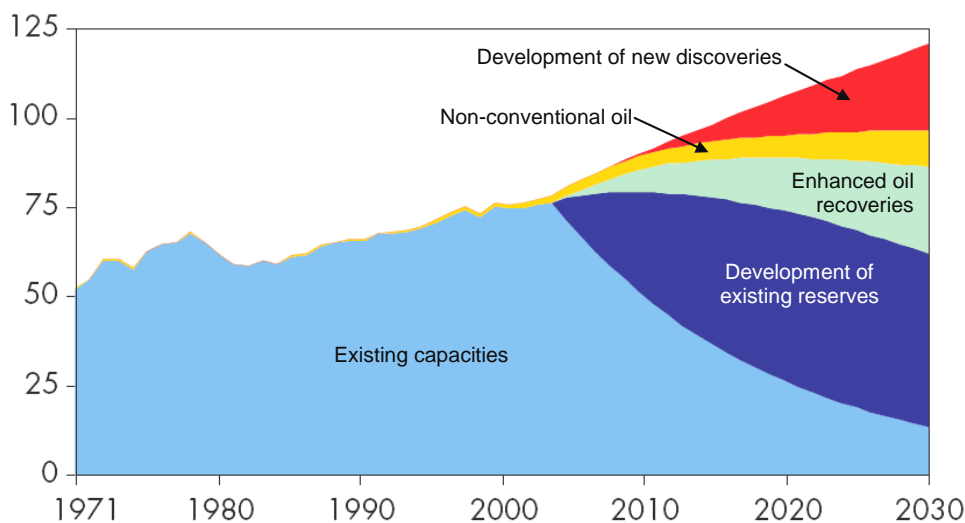
Nearly all the world's transport uses oil, and about 60 per cent of oil use is for transport.

Finding, extracting, processing, transporting, and selling oil products are huge businesses. Three of the four largest public companies in the world, by revenues, are oil companies (BP, Exxon, Shell). However, more than 90 per cent of the world's oil is controlled and produced by private, state-owned companies of which by far the largest is Saudi Aramco.¹¹

World consumption of oil increased enormously between 1945 and 1975, from less than 10 to more than 60 million barrels a day. There have been more modest increases during the last 30 years, to about 85 million barrels a day, but the rate of growth in consumption during 2004 was more like that during the 1960s than that during the 1990s as China moved rapidly into second place among consuming nations.¹²

China has moved rapidly in second place among consuming nations.

The most authoritative source of information about energy production and consumption is the Paris-based International Energy Agency (IEA). Every two years, IEA publishes its *World Energy Outlook*. The chart in Box 1 is from the latest regular edition, published in October 2004.¹³ It shows



Source: International Energy Agency

Box 1. World oil production by source, 1971-2030 (in millions of barrels per day).

Three of the four proposed sources of new oil have been sharply questioned.

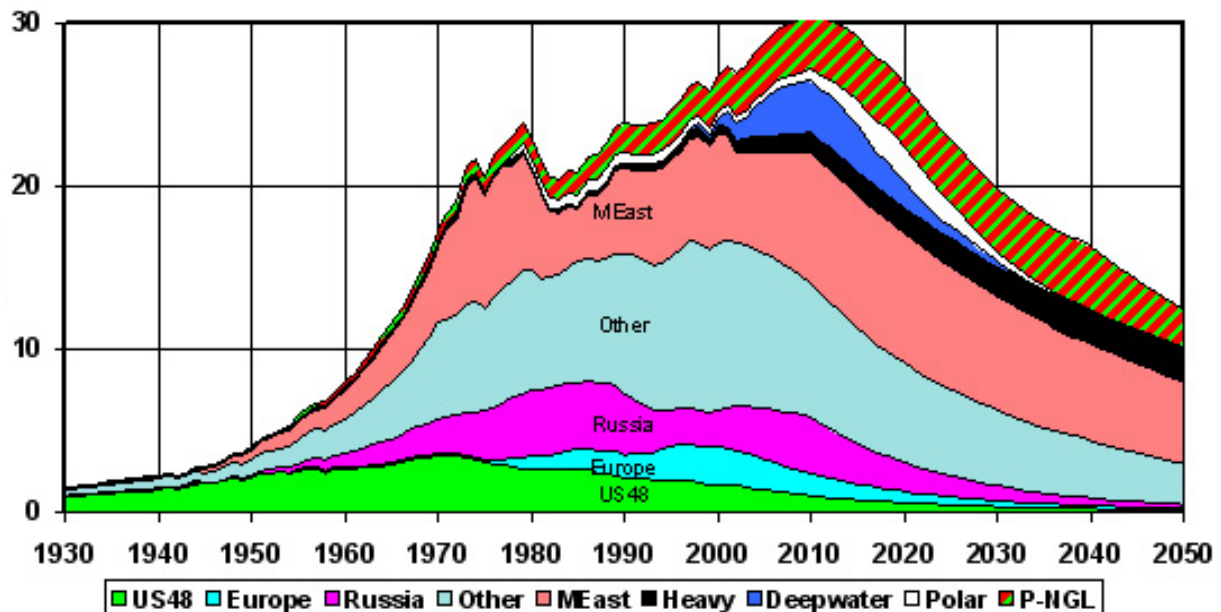
production—and thus consumption—of oil rising to more than 120 million barrels a day by 2031, almost 50 per cent above the current level. It shows too that production from existing wells is set to dry up rapidly beginning this year and that additional production is to come from four sources.

Only one of these four sources is not disputed: the smallest one, labelled ‘non-conventional oil’. This is chiefly oil from Alberta oil sands. The other three proposed sources of new oil have been sharply questioned, particularly the assumption that most of such an increase in growth in oil production could come from Saudi Arabia.¹⁴

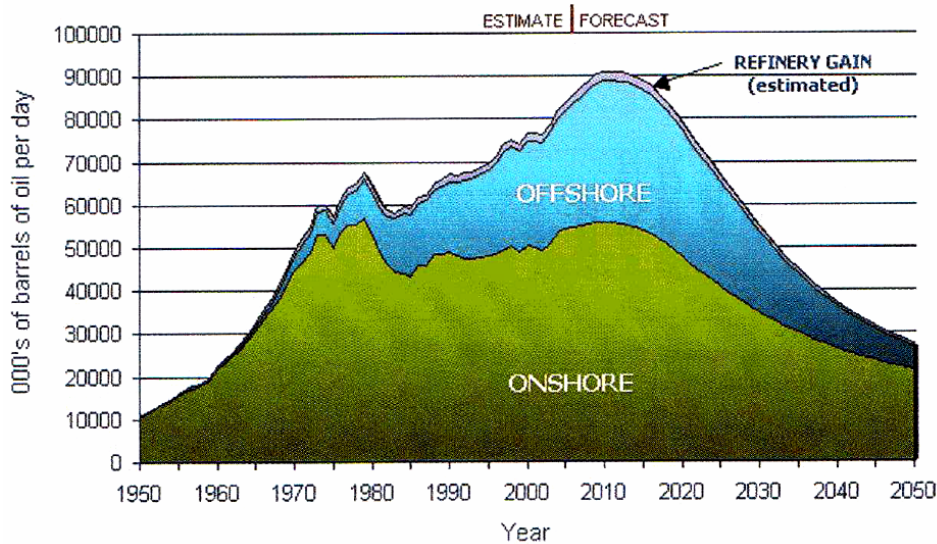
IEA itself appears to be recognizing that its 2004 projection makes little sense. In March 2005, in response to rapidly increasing oil prices, it held an expert seminar under the title ‘Saving oil in a hurry’. In September 2005, in a media interview in connection with the then forthcoming special issue of *World Energy Outlook*, IEA’s director of economic studies said, “Oil is like a girlfriend. You know from the outset of your relationship she will leave you one day. So that she doesn’t break your heart, it’s better you leave her before she leaves you.”¹⁵

Expert opinion may now be coalescing around the rather different projection in Box 2,¹⁶ which suggests that production of liquid petroleum resources will peak in about 2012. A completely different analysis reaching the same conclusion is represented in Box 3.¹⁷ Beyond this point of ‘peak oil’, production will inevitably decline because it will be physically im-

Box 2. 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



Box 3. World oil production by source, 1971-2030 (in millions of barrels per day).

possible to extract more in any year. It's always more difficult to extract oil from a well in the second half of the well's life because pressures are lower, water contamination is more likely, and remaining oil is increasingly in hard-to-reach parts of the reservoir system. Cumulating this difficulty across large numbers of wells results in the kind of production curve in Box 2. Thus, the issue is not so much that oil will run out but that production will not be able to keep up with what people want to consume, i.e., with the kind of consumption trend shown in Box 1.¹⁸

Some experts believe that even the peak in Box 2 is unrealistic, that peak production of oil will occur earlier than 2012 and may even be occurring now.¹⁹ Other experts are more sanguine. For example, a leading U.S. firm of energy analysts has argued that "global oil capacity is set to increase dramatically over the rest of this decade". It "rejects the current fear that a near-term 'peak' in world oil production and a coming exhaustion of supply is near".²⁰

Some experts believe that peak production of oil may even be occurring now. Others are more sanguine.

The debate becomes very technical. For every opinion there is a counter-opinion, and there are many disagreements over admittedly poor information about well depletion rates and discoveries. On balance, however, it's difficult to avoid the impression that the weight of expert opinion is moving more towards the kind of scenario implied by Box 2 and Box 3 than that set out in Box 1.²¹

If potential consumption is represented by Box 1 and probable production is represented by Box 2 and Box 3 the most likely result will be sharply higher prices. How high can prices go? According to the U.S. National Commission on Energy Policy, reporting in June 2005, "a roughly four-

Small shortfalls in production can result in large price increases.

per-cent global shortfall in daily supply results in a 177 percent increase in the price of oil (from \$58 to \$161 per barrel)”.²²

Making specific
predictions
about energy
prices may be
unwise.

However, making specific predictions as to the date of the peak or as to particular price increases could be unwise. One expert suggested that gasoline prices in the U.S. could reach \$10/gallon during the winter just passed winter, equivalent to about Can\$3.25/litre,²³ but prices stayed below \$3/gallon or \$1/litre.

Equally unwise could be the kind of prediction issued by the Ontario government to the effect that oil prices will decline and then remain stable. The government’s long-term economic outlook is predicated on the view that in real terms world oil prices will fall by about a quarter by 2010 and then remain constant until 2025.²⁴

The present paper does not make specific predictions about the date of peak oil, or about what the price of gasoline will be on a particular date. The actual approach used is described in Section 4 below.

3. Natural gas prospects

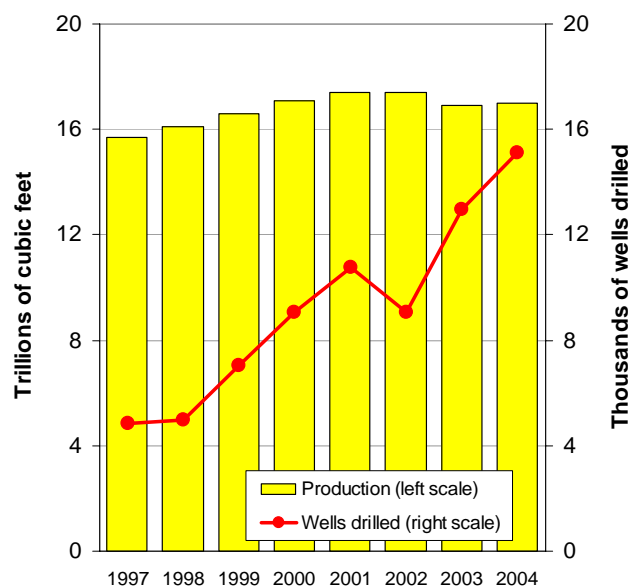
Oil prices did not reach their highest ever levels during 2005, but natural gas prices did. The wholesale price for natural gas rose from US\$5.79 in November 2004 to above \$14 per million BTUs in September and October 2005, causing this winter retail prices to be 25-50 per cent above those for the previous winter. The winter has been unusually warm, and prices have fallen to below US\$7.00/mmBTU.²⁵

Natural gas prices have been at their highest ever levels.

Prices rose so steeply mostly because North American production of natural gas peaked in 2001-2002.²⁶ Canadian production, which is mostly exported to the U.S., also peaked in those years, as is shown in Box 4.²⁷ Production peaked even though drilling for natural gas, also shown in Box 4, continued to increase. Indeed, the number of wells drilled in Canada increased more than threefold between 1997 and 2004, while consumption across this period increased by only eight per cent.

Part of the reason prices have risen so steeply has been the growing use of natural gas to replace coal for electricity generation. In Ontario, for example, coal is being phased out and largely replaced by natural gas,²⁸ thereby contributing to growing potential demand. Unlike oil, it's hard to ship natural gas between continents. Natural gas remains more plentiful and cheaper elsewhere, and at present price differences, it's economical to liquefy it and move it across oceans.

However, three difficulties impede rapid expansion of liquefied natural gas (LNG) imports: (i) a shortage of vessels designed to carry LNG; (ii) a shortage of terminals designed to receive LNG; and (iii) movement of LNG is regarded as hazardous. Consider the following, written in connection with one of the four LNG terminals in the U.S.: "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



Box 4. Canadian production of natural gas and natural gas wells drilled, 1997-2004.

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

The underlying problem is that discoveries of oil and natural gas both peaked decades ago.

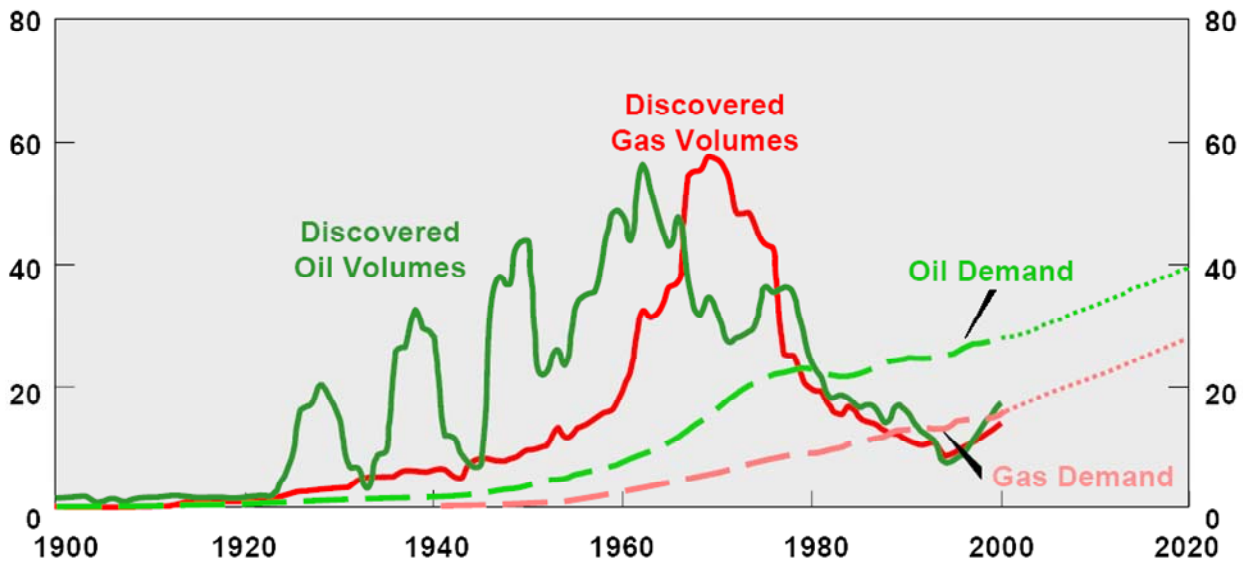
On an energy equivalence basis, about the same amount of natural gas is used in Ontario as oil (diesel fuel, gasoline, and heating oil). Some 85 per cent of oil is used here for transport, while a similar share of natural gas is used for space heating in homes and businesses. Both oil and natural gas are important feedstocks for a wide range of industrial chemicals, pharmaceutical, fertilizers, and plastics.

Little natural gas is used directly for transport, but it is important for transport in two ways. The first is that natural gas is a key resource used in the production of gasoline and diesel fuel, particularly from Alberta’s oil sands. The second is that natural gas is the main source of hydrogen, which is a favoured replacement for present transport fuels when oil becomes scarce.

Box 5. World discoveries and consumption (demand) of crude oil and natural gas, actual and estimated, 1900-2020 (in billions of oil-equivalent-barrels per year).

Unless there is rapid expansion of LNG imports—unlikely for the reasons given—the North American natural predicament will continue to be even worse than the oil predicament. In any case, a world natural gas problem may not be far behind. The underlying problem for both natural gas and oil is that new discoveries of these resources peaked several decades ago and are now well below actual consumption, as illustrated in Box 5.³⁰

Even experts who are optimistic about oil are pessimistic about natural gas. One such oil optimist testified in September 2005 before a committee



Source: ExxonMobil

of the U.S. House of Representatives that although drilling for gas in the U.S. had increased by over 175 per cent since 2002, production was down by two per cent.³¹ This unproductive drilling, similar to what is illustrated in Box 4 is an illustration of what happens when production of a resource peaks.

Some people argue that Canada has so much oil and natural gas we should not be concerned about problems elsewhere. Indeed, Canada is a net exporter of both oil and natural gas. However, most of the oil used in Eastern Canada is imported from Europe. Thus, Canadians are fully exposed to world oil prices.

Canada exports most of its oil production to the U.S., and imports most of what it uses from Europe.

The North American Free Trade Agreement (NAFTA) requires Canada to maintain energy exports to the U.S. Currently, these amount to 70 per cent of our oil and 55 per cent of our natural gas to the U.S. NAFTA also makes it difficult to charge lower prices for Canadian energy use. Thus, Canadians are fully exposed to high North American natural gas prices.³²

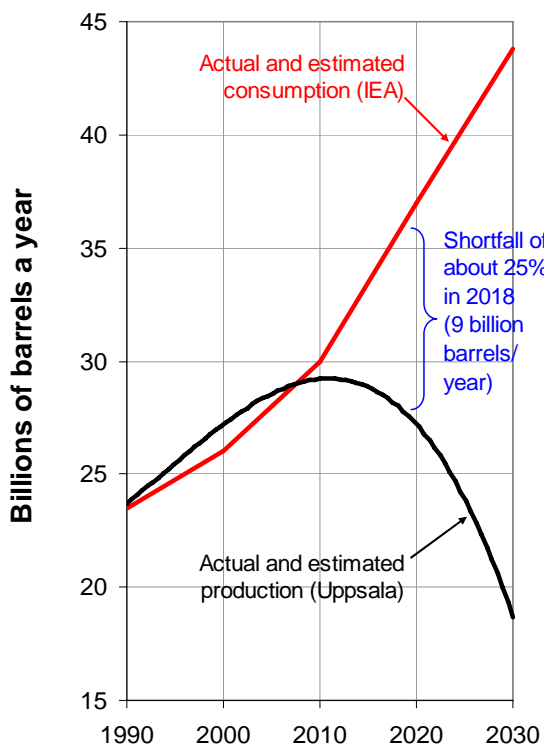
4. Prospects for high oil and natural gas prices

Prices rise when a resource becomes scarce in relation to how much of it people want to use. The higher prices curb consumption by causing people to give up less essential use and to use the resource more efficiently, and also by turning them towards alternatives. Higher prices can also mean that more of a resource is produced or imported, although that kind of option now seems limited in the cases of both oil and natural gas.

that reflects the tension between what people want and what can be produced. It's hard to anticipate with any confidence where the present tensions will lead other than to generally higher prices. A key factor is the strong dependence on oil and natural gas that results from where and how we live. Another key factor is the sheer convenience and usefulness of both fuels, and the consequent difficulty in finding ready replacements. A third factor is the remarkable effect on prices of quite small degrees of scarcity.

Box 6. Shortfall between projected world consumption of oil (International Energy Agency) and projected production (Uppsala University). ▼

Box 6 puts together the projected world consumption of oil in Box 1 and the projected production in Box 2. This points to a potential shortfall of more than 20 per cent by 2018. In Section 2, an authoritative source was quoted as suggesting that a four per cent shortfall could result in an increase in a 177-per-cent increase in crude oil prices.³³



increase in a 177-per-cent increase in crude oil prices.³³ A more conservative analysis suggests that a 10-per-cent increase would result in a threefold increase and a 15-per-cent shortfall would result in more than a sixfold increase.³⁴ Application such analyses to the kind of potential shortfall illustrated in Box 6, while allowing that pump prices tend to move less than crude oil prices (because of more constant taxes and refining and distribution costs), suggests nevertheless that fourfold real increases in pump prices can be expected by 2018. Similar considerations could apply to natural gas. Thus, in each case a rough quadrupling in price is taken to be where we could be headed, i.e. to about \$4 per litre in the gas of gasoline and diesel fuel and \$2 per cubic metre in the case of natural gas, in today's dollars.

These new equilibrium price points should not be taken to be accurate predictions but rather as illustrations of a new pricing reality that could

apply in the foreseeable future. How soon? For oil the challenge will come when world production can no longer be increased, which seems set to happen during the next decade. For natural gas, the crisis may already be arriving.

Movement to new price equilibrium points that are four times present levels may seem a dismal prospect, but there is an important sense in which it would be a positive outcome of what are likely to be inevitable convulsions in oil and gas markets. It would mean that market forces were still working, that our industrialized society was still functioning, and that economic and social life were continuing, albeit within a different framework.

One alternative response to fuel scarcity could be the 'hard landing' of economic and social collapse. Oil and natural gas are so essential to our way of life, the argument could go, civilization as we know it could not continue if their use has to be restrained. Collapse could mean that these fuels become unobtainable, perhaps because distribution channels are no longer working. Collapse could also mean that prices become low again; production and distribution of the fuels would still be working, but there would be much less work and travel and consequently much less consumption.

High prices could be better than the 'hard landing' of economic and social collapse.

This paper considers only the positive outcome of a new equilibrium of high, stable fuel prices. The negative outcome is difficult to plan for.

Three alternative scenarios were considered in preparing this paper. One is that there is a less than 25-per-cent chance that such high prices will occur. If this scenario were thought the most likely, there would not be strong reason for the City of Hamilton to give undue weight to energy considerations. The second scenario is that the odds of such high prices occurring are between 25 and 50 per cent. In this case it could be prudent for the City to continue with its present planning arrangements but to develop a 'Plan B' that could be implemented if prices rise steeply.

This report is predicated on the third scenario: that the odds of such high prices occurring are more than 50 per cent. Choice of this scenario was reached after consideration of all the above and several more factors. The key factors were likely major shortfalls from expected oil production from Saudi Arabia;³⁵ and inability to replace declining production of North American natural gas with sufficient imports or new production.

This report is predicated on the most extreme of three scenarios.

A further factor is the lack of substitutes for oil and natural gas, or prospects for them. The substitute most talked about for oil as a transport fuel

is hydrogen, to be used with fuel cells. Today, almost all hydrogen is produced from natural gas. From the foregoing, there are obvious challenges in expanding this production.

There are no adequate substitutes for oil and natural gas.

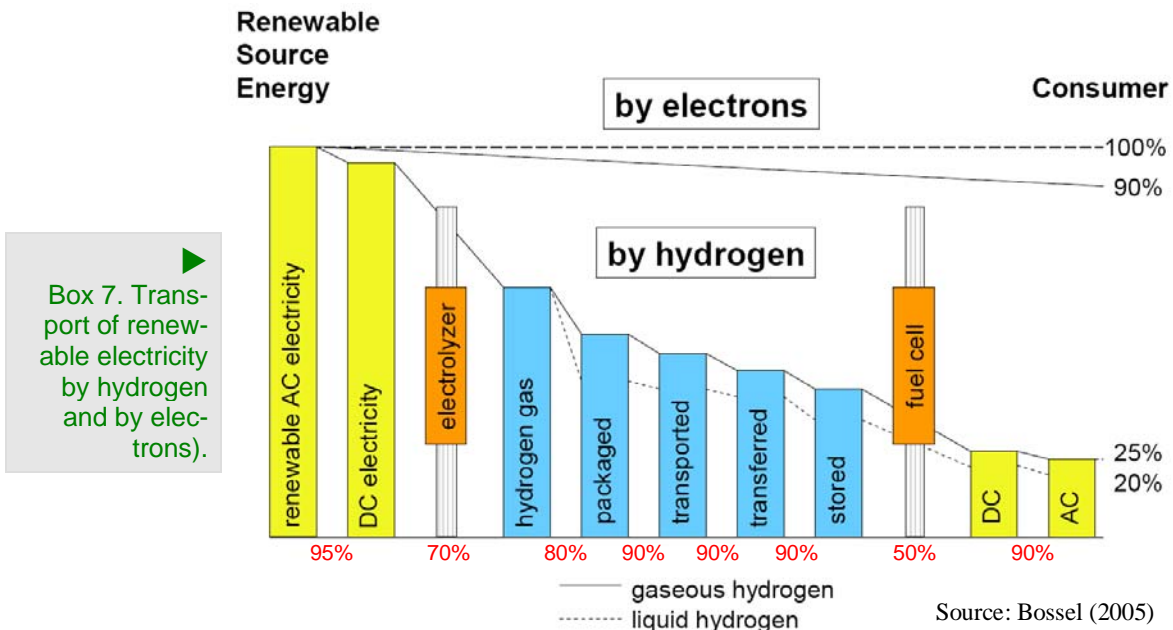
Hydrogen can also be produced by electrolysis. The challenge here is that **in an energy-constrained world it will make more sense to use electricity directly rather than to use it to make hydrogen that is then used in a fuel cell to make electricity.** In the first case, the energy loss is about 10 per cent, chiefly line losses during distribution. In the second case, the energy loss is 75-80 per cent.

The huge difference in energy loss illustrated is in Box 7 for the cases where electricity from a renewable source—e.g., wind or photovoltaic cells—is used to power a streetcar ('by electrons' resulting in a 10-per-cent energy loss) and a fuel-cell car ('by hydrogen', resulting in a 75 or 80-per-cent loss, according to whether gaseous or liquid hydrogen is transported).³⁶

Fuel-cell systems are too inefficient for widespread use in an energy-constrained world.

There are also major challenges in the use of fuel cells, which are presently far too expensive and unreliable for use in everyday transport applications.³⁷ However, the full life-cycle inefficiency of hydrogen-fuel-cell systems illustrated in Box 7 is a sufficient reason to rule out widespread use of these systems in future transport arrangements.

Other substitutes for petroleum oil include liquid fuels from agricultural sources (e.g., ethanol and biodiesel). This production can require large amounts of energy and land,³⁸ which may not be readily available. Oil can



be manufactured from coal, but at considerable cost to the environment.³⁹ Notwithstanding the challenges, some use of these alternative liquid fuels can be expected, along with some continued use of present transport fuels.

The main substitute for natural gas is coal, which can perform most of the tasks for which natural gas is used, again at considerable cost to the environment.

The writing of this paper began with the expectation that the second scenario would be pursued (see Page 15), and that the paper would be setting out the elements of a 'Plan B' for Hamilton for use as an alternative to current planning processes. Renewed consideration of all the issues led to the conclusion that very high prices—e.g., \$4/L and \$2/m³—are more likely than not.

If this argument that higher prices is accepted—and it warrants far more elaboration than there is space for here—a reasonable conclusion is that the City of Hamilton should transform rather than merely add to its current planning processes. The transformation should be one that puts energy concerns first and centre in all its planning. How this could be done is discussed below.

Even if the argument that fuel prices are likely to be very high is not accepted, the City may find there is good reason in what follows to give more attention to energy conservation and production.

Again, the particular prices chosen here—\$4/L and \$2/m³—should not be taken as predictions but more as an illustration of what we might be dealing with. Also, they are considered likely rather than certain. More specifically, what follows is based on the assumption that there is a more than even chance that such prices will occur during the first half of the City's planning horizon, i.e., sometime before 2018.

Equally, the date of 2018 should not be taken as prediction that oil and natural gas oil production will peak then or earlier. The date is noted only because it is halfway through Hamilton's present planning period, which is until 2031. Prices will rise steeply when potential demand for the fuels exceeds production. Production could still be rising, although a mismatch would be evidently more likely if production were falling. What may well happen is that there is an uneven plateau in production, with some annual increases and some decreases but little change overall across a period as long as a decade. If potential production rises when there is such a plateau, prices could rise steeply.

If the argument about high prices is accepted Hamilton should give more attention to energy conservation and production.

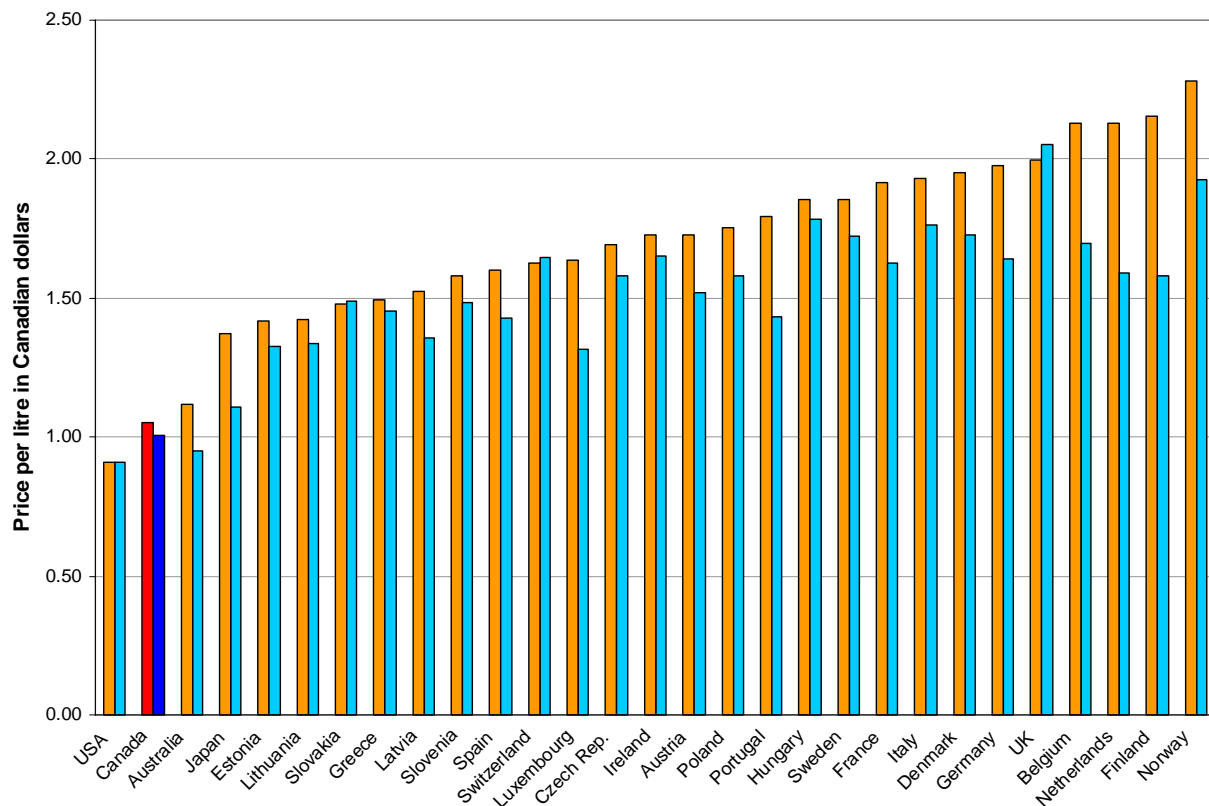
5. Impacts of fuel price increases

We've never had prices as high as \$4/L and \$2/m³—nor has any one else—so we can't be sure what will happen.⁴⁰ In some comparable countries, pump prices are more than double Canadian prices—as shown in Box 8⁴¹—but transport patterns are not much different. It's often believed there is much less automobile use in Europe, for example, than in Canada, but this is not the case.

Box 8. Gasoline (cheapest posted) and diesel fuel prices for 29 countries, Sept. 2005, ranked by gasoline price, using official exchange rates.

Box 9 on the next page shows that Western Europeans travel almost as much by car as Canadians.⁴² They travel about 40 per cent more by surface public transport (urban and interurban) and only half as much by air, but the key fact is that in both cases about 80 per cent of motorized travel is made by private vehicle (cars, SUVs, motorcycles, etc.). Box 10—also on the next page—shows the same data as Box 9, but without aviation. The similarities in the data for private vehicle travel are still evident.

Not shown in Box 9 or Box 10 are data on non-motorized travel, chiefly walking and bicycling. Comparative data on non-motorized modes are



Based on data provided by the Automobile Association (UK) and other sources

	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%

Source: Natural Resources Canada and European Commission

Box 9. Motorized travel within Canada and within the European Union, 2002.



less available. There appears to be more walking and bicycling in parts of Europe, but this may be more to do with local settlement patterns, geography, and climate rather than fuel prices. Even where there are higher rates of walking and cycling, most travel seems to be made by car.

A reasonable conclusion from the above could be that increases in transport fuel prices up to about \$2.50 a litre in current Canadian terms will not result in radical changes in transport activity. People will drive a little less, buy cars that use less fuel, use public transport more often, and overall spend somewhat more on transport and somewhat less on other goods and services. Travel by air is generally more sensitive to price and would likely be more strongly affected by a doubling or more in fuel prices.

We know even less about high space heating costs. In Europe, consumers on average now pay about 10 per cent more per unit for natural gas than Canadians,⁴³ rather less than the difference for transport fuels shown in Box 8. Moreover, space heating is more often managed centrally, whether in apartment buildings or through district heating systems that serve individual homes. As well, homes are smaller and generally cooler in winter.

In the absence of information as to how Canadians might respond to higher home heating prices, it's reasonable to assume something along the lines of the responses to higher transport fuel prices.⁴⁴ Canadians will mostly continue living much as before, but maybe turn the thermostat down a little, add some insulation, and perhaps bring forward the purchase of a high-efficiency furnace. Again, because more will be spent on home heating bills (and space heating for businesses, schools, etc.) less will be available for spending in other areas.

We know even less about the impacts of very high space-heating costs than we do about the impacts of very high transport costs.

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



Box 10. Surface motorized travel within Canada and within the European Union, 2002.

Perhaps around
\$2/litre and
\$1.25/m³, there
will be more
radical changes
in how we live
and how we
travel and move
goods.

Electricity prices would also rise. This would happen in part because increasing amounts are generated from natural gas, but chiefly because consumption could increase as people try to find alternative means of transport and space heating.

At some point, perhaps around \$2.50/L and \$1.25/m³, things could begin to change more radically. Continuation of business as usual will become unaffordable. A household may just be able to live with a doubling of expenditure on gasoline and natural gas compared with today's levels, the result of a 150-per-cent increase in fuel prices, offset by a 20 per cent reduction in use. But beyond that point, perhaps too many sacrifices would have to be made by households and businesses. As important, a large amount of money would now be leaving the Hamilton economy to purchase the fuels brought into Hamilton.

Prices of \$4/L and \$2/m³ could be clearly above the point at which price increases can be accommodated within present arrangements. If such prices are expected, as assumed here, radical changes in many aspects of society should also be expected. We will travel differently because everyday use of present kinds of automobile will be unaffordable. We will live differently because the heating and cooling of present types of building will be unaffordable. We will eat differently because importing our food from afar will be unaffordable (and because artificial fertilizers, made from and with oil and natural gas, will be much more expensive).

The remainder of this paper sets out how the City of Hamilton could help its residents and businesses prepare for the anticipated radical changes. This can be done by putting energy use and production as the primary considerations in all planning.

Hamilton is one
of the first
municipalities to
consider the
implications of
future severe
energy con-
straints.

What is proposed here could be opposed as being outside municipal responsibility.⁴⁵ However, as we enter an era of severe energy constraint energy considerations will become *so* important they will permeate every aspect of our household and business activities. Municipalities will have to be involved because they control, to a considerable extent much of what will have to change, notably transport arrangements and how land is used.

Hamilton has no stronger reason to focus on energy challenges than any other city, and the considered civic choice may well be to wait and see what happens, and then act as may be appropriate. However, Hamilton does happen to be one of the first municipalities to consider the implications of future severe energy constraints.⁴⁶ The City could use this head start to position Hamilton as a leader in understanding and preparing for the era of energy constraints.

6. Strategic planning objectives for energy constraints

An advantage of putting energy considerations front and centre in a city's strategic planning is that *quantitative* targets for energy use and production can be set. Establishing such targets as overarching considerations for the planning of transport, land use, and economic development gives the exercise a refreshing concreteness and allows for ready evaluation of progress. This section derives several provisional quantitative targets for energy use and production, **for the year 2018**, i.e., halfway towards the City's planning horizon of 2031.

The importance of quantitative targets for energy use and production.

As almost always, the City of Hamilton's role would be that of enabler, i.e., creating the conditions for particular activities to occur rather than requiring them to happen. This is Hamilton's primary role in land-use planning: to facilitate development rather than carry out development.

Significant feature of the scenario sketched out in previous sections are fourfold increases in retail prices of transport fuels and natural gas *and* continuing slow declines in their availability. A possibly reasonable target for action by City Council with respect to energy would be to help ensure that residents' and businesses' expenditures on energy for transport and heating and cooling buildings—overwhelmingly the main functions for which oil and natural gas are used—on average rise to no more than 50 per cent above current levels in real terms. Thus, in the simplest possible formulation, energy use for these purposes would have to be reduced to just below 40 per cent of current levels.⁴⁷ An energy-reduction target of two thirds would allow some margin for accommodating declines in availability or provide for lower expenditures on energy.

Accordingly, the first strategic objective proposed here is to reduce per-capita energy use by two-thirds, for transport and in residential, commercial, and institutional buildings.

Reduce per-capita energy use by two thirds, for transport and for heating and cooling buildings.

Note that this objective and those below do not apply to industrial and agricultural energy use (other than associated transport use). Appropriate objectives would have to be set for these sectors, but doing so would require a more detailed analysis than can be done for this report.

Hamilton is not static. Indeed, one of the main objectives of the current planning exercise is accommodation of a population increase of one third, from about 525,000 today to about 700,000 by 2031.⁴⁸ This could correspond to a population of approximately 600,000 in 2018, or about 14 per cent above the current level. If per capita energy use declines by two-

thirds, but there are 14-per-cent more people, total energy use will be about 60 per cent less than current use.

Plan for electricity to comprise a much larger share of Hamilton's energy mix.

As will be spelled out in later sections, Hamilton's fuel mix will likely change towards considerably greater use of electricity, both in buildings and for transport. If use in Hamilton is typical of Ontario (again excluding industrial and agricultural uses), electricity today comprises about a fifth of total end-use energy, with oil comprising nearly half of the total and natural gas almost a third.⁴⁹ It might be reasonable to expect that electricity's share will rise to be half of energy use by 2018. This expectation is illustrated in Box 11, which proposes that total electricity consumption would be almost unchanged between 2003 and 2018. Meanwhile, consumption of oil and natural gas (NG in Box 11) would fall by almost 80 per cent, from 55.8 petajoules⁵⁰ in 2003 to 11.4 PJ in 2018.

It should be stressed that Box 11 is no more than illustrative, both of actual consumption in 2003 and proposed consumption in 2018. Good data on Hamilton's energy use are not readily available. Both the 2003 estimates in Box 11 and the corresponding targets for 2018 are based on available Ontario data, prorated by population.

One thing that should be noted in Box 11—if these estimates of 2003 energy use have some validity—is that **the energy used in buildings (residential and commercial) is about 25 per cent more than the energy used for transport**. This difference would be more-or-less sustained through to 2018. Transport is often considered the most important challenge in terms of reducing energy use. It may be the most difficult challenge, but the higher use levels for buildings justify similar attention being given to this aspect of energy consumption.

The much higher *relative* use of electricity in 2018 will arise chiefly because of *new* uses, notably for transport but also in buildings, all to be described below. Existing uses, including lighting, will be the target of strong conservation measures designed to secure a two thirds reduction in

Box 11. Estimated energy use by fuel by Hamilton residents and businesses in 2003 and proposed use in 2018. ▼

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%

energy use. Thus, of the 14.3 petajoules of electricity to be used per capita in 2018 (see Box 11), 4.9 PJ will comprise current uses by the same population (down from 14.5 PJ), 7.3 PJ will comprise new uses by the same population, and 2.1 PJ will result from population growth.

In Ontario, electricity generation is a special concern. This has arisen because of the unreliability and cost of nuclear generation, the commitment to stop generation from coal, and the rising cost of coal's main replacement fuel, which is considered to be natural gas.⁵¹

Thus, greater use of electricity could make Hamilton especially vulnerable if it is pursuing a strategy involving more relative use of electricity and if it also has to rely on central production of electricity in Ontario. An alternative would be generation of electricity *within* Hamilton, as is discussed in Section 10. That section will demonstrate that, on a net basis, all Hamilton's electricity could be generated within the city, even with the indicated expansion in electricity's share of energy consumption. (The phrase 'on a net basis' means that Hamilton would still be part of the Ontario grid, but would sell as much to the grid as it purchases.) The largest part of this generation would be from renewable sources, including wind and solar generation.

*Generate all
Hamilton's elec-
tricity consump-
tion within Ham-
ilton.*

Accordingly, the second strategic objective proposed here is to generate the total amount of Hamilton's electricity consumption within Hamilton, while continuing to trade with the Ontario grid.

Other fuels—chiefly oil and natural gas, or their replacements—would continue to be used within Hamilton, although at only 20 per cent of current per-capita use (see Box 11). There is scope for energy production other than electricity within Hamilton, as will be detailed below, although this could be more challenging than the production of electricity.

Regarding trading with the grid, various arrangements are possible in theory, although the specifics would depend on the arrangements with the grid operator (the Independent Electricity System Operator) and other involved agencies such as Hydro One. The simplest arrangement might involve unfettered exchange with the rest of the grid, with producers in Hamilton providing about as much as would be consumed in Hamilton, and pricing that helped ensure that Hamilton collectively sold as much to the rest of the grid as it purchased. At the other extreme, Hamilton could become an electricity 'island', trading with the rest of the grid only under specific circumstances.

Accordingly, the third strategic objective proposed here is to generate half of Hamilton's non-electrical energy use within Hamilton.

Produce half of
Hamilton's non-
electrical energy
within Hamilton.

A key consideration is that these objectives be met in ways that are affordable to Hamilton's residents and businesses. At the beginning of this section, the guideline that household and energy expenditures rise to not more than 50 per cent higher than current levels was used to help set the strategic objectives. Then, a shift towards electricity was proposed. Even at current prices, electricity is considerably more expensive than oil (which has roughly a 25-per-cent lower retail price per energy unit) or natural gas (roughly 50 per cent lower). The next objective allows for this shift.

The fourth strategic objective is that the cost of implementing the first three objectives should result in no more than a doubling in real direct household and business expenditures on energy.

This objective would be within the framework of an overall fourfold increase in energy prices. Thus unless at least the first objective is adopted and met, households and businesses in Hamilton could well be paying more than double present amounts paid for electricity.

These four objectives would both define a civic mission for Hamilton and act as a prism through which to view other initiatives. Does this proposal contribute to the energy use objectives? Does it contribute to the energy production objectives?

The objective of substantially reducing energy use makes evident sense if the assumptions about future energy price levels are accepted, and perhaps even if they are not. By contrast, the objectives concerning energy production may well seem far-fetched. Would it not be better, a reasonable person might ask, to continue to rely completely on outside sources for our energy? This person might note that energy concerns are not really the City's business and, in any case, the cost of buying the energy would likely be lower, because of economies of scale.

In response, it could be said that energy—including such conservation and production as can be achieved—will become so important it will be everyone's prime business. Moreover, the City, through its ownership of Hamilton Community Energy (HCE), is already in the energy production business. The plant at Bay and York produces hot and chilled water for building heating and cooling, and electricity, all from natural gas. HCE plans to produce electricity from numerous renewable resources, and both electricity and hot water or steam from municipal waste. HCE also plans to help reduce consumption of electricity and other forms of energy through development of programs of demand-side management, energy audits, and retrofits.⁵²

Indeed HCE, with its parent company Hamilton Utilities Corp. and its sister companies Hamilton Hydro and FibreWired Hamilton, could be good vehicles through which to implement some of what is proposed below. The following proposals, however, go far beyond the present plans of these organizations, and new managerial and administrative structures may be required for full implementation. These matters are discussed in what follows.

Existing companies could implement some of what is to be proposed here.

Transport and new buildings are two examples of areas in which there will be major changes—if the objectives proposed here are adopted—but are not presently addressed by the institutions noted in the previous paragraph. Given present trends, about a quarter of the buildings standing in Hamilton in 2018 will have been constructed since 2005.⁵³ The changes in transport could be correspondingly greater. These and other matters are addressed in subsequent sections of this report.

In considering whether the City should focus on energy production as well as energy use, there is also the consideration that the two can be intimately linked. For example, the optimal orientation of a building for energy conservation may be different from the optimal orientation for energy production (e.g., from photovoltaic cells). What may be optimal overall will depend on how much emphasis is put on each of energy use and production.

Local production of energy can mean greater efficiency and reliability.

A further advantage of local production is that distribution losses can be minimized. Line losses for electricity are not usually a major factor, but it is nevertheless true that they are minimal when generation is where the electricity is used. In an energy-constrained world, avoidance of distribution losses could become more important.

Yet another advantage is reduced vulnerability to large-scale system failures, which may become more common as energy constraints tighten. During the black-out of August 2003, Hamilton City Hall was one of the few buildings in southern Ontario with electric power, produced at HCE's cogeneration plant.

7. Reducing energy use by Hamilton's transport

This section focuses on the movement of people. The movement of freight is discussed in Section 13.

7.1. Travel targets for passenger transport

Estimates of current motorized travel by Hamilton residents and associated fuel use are provided in the table in Box 12,⁵⁴ together with possible targets for 2018. Box 12 is an elaboration for motorized travel by Hamilton residents of how the target set out in Box 11 could be achieved.

A key assumption in constructing Box 12 is that there will be only a modest reduction in the amount of motorized travel per capita. The total declines by only three per cent, from 8,250 to 8,000 million person-kilometres. Per capita, this would amount to a decline by about 18 per cent, because of the expected growth in Hamilton's population by 2018.

The decline in motorized travel would arise chiefly from two factors that are as much to do with land-use planning as with transport arrangements. They are:

- a shift to travel using non-motorized rather than motorized means.
- a reduction in the amount of travel because trip origins and destinations are closer together.

These matters are discussed in Section 9, which concerns land-use planning issues.

Energy use for transport can be reduced in three other ways:

- reduce the amounts of fuel that vehicles consume to travel each kilo-

Box 12. Current motorized travel and associated fuel use by Hamilton residents, and travel and fuel use targets for 2018 (not aviation).



Mode	2003				2018			
	PKM (millions)	Fuel use/ PKM (MJ)	Total petroleum use (PJ)	Total electricity use (PJ)	PKM (millions)	Fuel use/ PKM (MJ)	Total petroleum use (PJ)	Total electricity use (PJ)
Car (ICE)	7,500	2.5	19.0	0.0	1,500	2.0	3.0	0.0
Car (electric)	0				1,500	1.0	0.0	1.5
PRT	0				2,000	0.5	0.0	1.0
Transit	750	1.3	1.0	0.0	2,000	0.5	0.0	1.0
Totals	8,250		20.0	0.0	8,000		3.0	3.5

Note: PKM = Person-Kilometre. ICE = Internal Combustion Engine. PRT = Personal Rapid Transport. MJ = MegaJoule. PJ = PetaJoule

metre.

- reduce the number of vehicles required to perform particular transport tasks by increasing their occupancy or loading.
- avoid motorized travel by not making trips

These three means are discussed in this section in relation to the proposed targets for 2018 set out in Box 12, one in each of the following subsections. First, some of the other features of Box 12 are noted.

Box 12 represents travel in Canada, not including aviation, which, as noted in Box 9 currently accounts for about 10 per cent of domestic travel by Canadians. As will be discussed in Section 12, travel by air can be expected to decline steeply if petroleum fuels become very expensive. A few minor forms of travel, e.g., by taxicab, are not covered by the data in Box 12. Transit includes both local and intercity travel by bus and rail (and perhaps by water in 2018).

Of present non-aviation travel, about three quarters in terms of person-kilometre is local, i.e., performed within about 60 kilometres of home. Most of the other travel is presently done by automobile. With the anticipated energy constraints in 2018, it's likely that an even higher share will be local, but how much has not been estimated. Travel opportunities to and in places other than Hamilton could well be limited. The targets for 2018 in Box 12 should nevertheless be taken to include some intercity travel.

Travel by automobile is proposed to decline from 90 per cent of local travel in 2003 to just over a third in 2018.

Of the travel in 2003 by Hamilton residents represented in Box 12, 90 per cent is by personal automobile. This is to be reduced substantially by 2018, to just over a third of travel in that year. Also, only half of this automobile travel will be fuelled by gasoline or diesel fuel. The remainder will be fuelled electrically, either in all-battery vehicles or in 'plug-in hybrids' discussed below.

Part of the balance of the travel will be taken up by conventional public transit—mostly local but some intercity—all of which will be electrified. Transit ridership will almost triple between 2003 and 2018, although accounting then for only a quarter of total travel.

The remaining third of motorized travel, all in and near Hamilton, will be done by an entirely new form of public transport, known as Personal Rapid Transport (PRT), discussed below.

The net results of these dramatic changes in how Hamiltonians travel will be a reduction in energy use for travel by just under 70 per cent and a reduction in fossil fuel use by 85 per cent (in both cases more if aviation

were to be included). These reductions are more than the two thirds reduction proposed above in Section 6 as an overall strategic objective for Hamilton. This is proposed to allow for the possibility of lesser reductions in energy use for other transport purposes, notably freight movement and emergency vehicles, discussed in the last part of this section.

7.2. Using more efficient, mostly electric vehicles

Fuel use by the present transport system in Hamilton, which chiefly comprises movement of personal automobiles and trucks, could readily be reduced by an average of about 50 per cent by (a) reducing vehicles' weight and power, and (b) using hybrid drive trains in which an electric motor drives the wheels as well as a gasoline- or diesel-fuelled internal combustion engine (ICE).⁵⁵

Whether or not such a reduction is achieved is largely outside the City's control, and in any case it would be insufficient for attainment of the energy-reduction objective.

More certain ways of reducing vehicles' fuel use, particularly use of fossil fuels, would be to effect as much of the transport as possible by grid-connected vehicles, i.e., electric vehicles such as streetcars that are powered directly from a third rail or overhead wire.

The discussion in Section 4, in connection with Box 7, has already highlighted how much more efficient moving power directly to an electric motor is compared with a fuel-cell-based system. Using an electric motor is a much more efficient way of achieving traction than an internal combustion engine (ICE). This is why hybrids—which provide for some substitution of a vehicle's ICE by an electric motor—use less fuel than regular ICE-only vehicles.

The main problem with all-electric vehicles is that they either run from a

Box 13. A
Renewably
powered light
rail train in
Calgary and a
trolley bus in
Vancouver.
▼



battery, which means carrying a heavy weight around and frequently recharging, or directly from the grid, which means that the vehicle has to move alongside a live rail or wire.

Where vehicles can run alongside a wire, they are much more efficient. According to the American Public Transportation Association, trolley buses use less than half the energy used by comparable diesel buses. Streetcars use even less, and electric trains use even less than streetcars.⁵⁶ Data from Vancouver's transit system suggest that trolleybuses can be even more efficient in stop-and-start conditions than electric trains (perhaps because their low weight offsets the higher drag from the tires).⁵⁷

A Vancouver trolleybus and a vehicle from Calgary's grid-connected system are portrayed in Box 13. Calgary's light-rail system is of special interest because it is powered by renewable energy, hence the slogan 'Ride the Wind'. Streetcars provided most of the transit service in Hamilton from 1892 to 1949, and for most of this period were also renewably powered, although in this case from hydroelectric rather than wind resources. The name of Hamilton's transit operation, Hamilton Street Railway, is a legacy of this period.⁵⁸ Further discussion of HSR is in Section 15 below.

Calgary's light-rail system is of special interest because it is powered entirely by renewable energy.

Perhaps the most imaginative and controversial use of grid-connected vehicles would be for personal rapid transport (PRT, sometimes known as 'personal automated transport').⁵⁹ PRT is a generic term for transport systems with the following characteristics:

1. Fully automated vehicles capable of operation without human drivers.
2. Vehicles captive to a reserved guideway.
3. Small vehicles available for exclusive use by an individual or a small group, typically 1-6 passengers, traveling together by choice and available 24 hours a day.
4. Small guideways that can be located above, at or below ground.
5. Vehicles able to use all guideways and stations on a fully coupled



◀ Box 14. Conceptual Personal Rapid Transport (PRT) system.

PRT network.

6. Direct origin-to-destination service, without a necessity to transfer or stop at intervening stations.
7. Service available on demand rather than on fixed schedules.

If successfully developed, PRT systems could mostly resolve the challenge of providing electricity efficiently to personal vehicles, albeit vehicles constrained to operation on a guideway.

If successfully developed, PRT systems could mostly resolve the challenge of providing electricity efficiently to personal vehicles, albeit vehicles constrained to operation on a guideway. Potential developers of PRT systems claim that infrastructure and fuel costs would be low enough to provide widespread penetration, even in quite low-density areas. Box 14 and Box 15 illustrate such systems.

PRT systems are proposed as a low-cost alternative to both public transport and the automobile, in terms of both infrastructure cost and operating cost, particularly energy cost. However, because no system is in operation, rigorous comparison of costs with conventional systems is not possible.

Some versions provide for off-guideway, battery-powered operation for the ‘final kilometre’ between guideway and destination. Box 15 shows the system that comes closest to bridging public transit and the automobile.⁶⁰ RUF and other PRT systems mostly share the ability to self-assemble vehicles into trains, thereby reducing wind resistance, the main factor in vehicle energy use during movement at constant speed.

Evolution towards a dual-mode PRT system could occur from a development in hybrid ICE-electric vehicles known as ‘plug-in hybrids’, mostly in California.⁶¹ A plug-in hybrid is a regular hybrid that has been converted by the owner or a third party by replacing the manufacturer’s battery with a larger-capacity battery that can be charged from a household socket. Gasoline use is reduced by as much as 100 per cent—but is typically 50 per cent—according to distance travelled between charges and kind of traffic.⁶²

Provision of charging opportunities along highways—accessible through

Box 15. Conceptual dual-mode Personal Rapid Transport (PRT) system.



a retractable grid-connector on the vehicles—would add to a vehicle’s ability to run on its electric motor, perhaps to the extent that the internal combustion engine would not be used. With opportunities to charge while in motion available along some highways, battery vehicles could be used more widely. As ‘powered highways’ grew in extent, batteries would be used less, to the extent that the grid-connected mode would be the norm.

It’s a leap to suggest that an unproven technology could be providing Hamilton residents with two billion person-kilometres of travel by 2018, as proposed in Box 12. Nevertheless, the imperatives for this kind of development, and the technical ingredients for successful implementation, notably sophisticated, reliable control systems, appear to be in place. PRT seems to be waiting for a community of Hamilton’s size to embrace it. With the right kind of civic commitment, the investment could follow.

7.3. Improving occupancies

Few things are more important for energy-efficient transport operation than to have well-occupied vehicles. For most journeys, a full vehicle uses only a little more fuel than one carrying only the driver. A diesel bus typically uses about six times as much fuel as a car, which typically carries close to two people. Thus, if the bus has fewer than about 12 passengers, the car is more fuel efficient and can have a lesser effect on the environment. (Of course, if the car has only one passenger, as do most cars during rush hour, and the bus has 30 passengers, the bus is very much better.) Looked at another way, if six people use four cars to get to work, they are using twice as much fuel, and causing twice the impact, than if they used two cars.

Few things are more important for energy-efficient transport operation than to have well-occupied vehicles.

It follows that successful programs to increase occupancies of private and public vehicles could make an important contribution towards reducing energy use. Hamilton is already a strong participant in Smart Commute, a Toronto region program to promote ride-sharing and transit use.⁶³ A Hamilton-based city-wide ride-sharing program that extended beyond commuting travel, say to shopping, could well be part of a concerted effort to reduce transport fuel use. Installation of High Occupancy Vehicle (HOV) lanes within Hamilton could also help to increase occupancy.⁶⁴ Energy savings through improved occupancy are not included in the projections in Box 12, because good assessments of the impacts of such programs are not available. The savings may nevertheless be considerable. Savings realized through higher average occupancies would be a bonus and a safeguard in case elements of the transport target could not be realized.

7.4. Avoiding motorized travel

It almost goes without saying that avoiding motorized travel is a potentially effective method of reducing transport energy use. As fuel prices rise, Hamilton residents will travel less, but the effect is well known to be small.⁶⁵ Nevertheless, a doubling in fuel prices could well produce a decline in motorized travel by 15 per cent or more. Changes in urban design—e.g., adding bicycle infrastructure—could add to motorized trips avoided, or at least provide better amenity to residents who were forgoing motorized travel.

FibreWired Hamilton, for example, could have a role in load control, whereby numerous electrically powered operations such as air conditioning are managed so as to reduce peak demand and consumption overall.

Another contributor to trip avoidance is telework. This is facilitated by good Internet connections. If Hamilton became a city where high-quality Internet connection, by wire or wireless, were inexpensively or even freely available, there could be numerous beneficial consequences, not the least of which would be more working at home and less travel.

A connected city would allow ready implementation of programs such as Smart Commute, discussed above, and of building energy efficiency programs, discussed below, and there are numerous other energy-related applications. Thus, the City's FibreWired Hamilton, noted already as a division of Hamilton Utilities, could be a key actor in a strategy for aggressive energy conservation. FibreWired Hamilton, for example, could have a role in load control, whereby numerous electrically powered operations such as air conditioning are managed so as to reduce peak demand and consumption overall.⁶⁶

7.5. Other transport activity

The above discussion does not cover several other types of vehicle for which switching modes or switching to grid-connection could be difficult. Such vehicles include many emergency vehicles, some construction vehicles, and some service vehicles. In total, these use only a small part of the fuel used for transport. It is nevertheless a very important part, and the possible need for such vehicles to use conventional arrangements should be protected. Later down the road, we may need—and have available—electric police cars and ambulances.

8. Reducing energy use in Hamilton's buildings

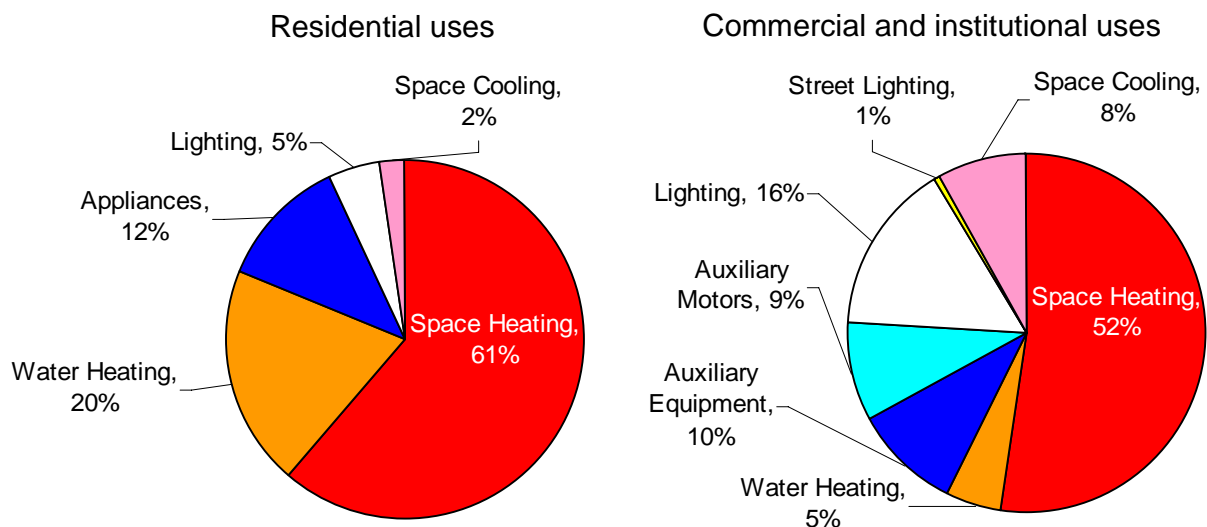
As noted in Box 11 on Page 22, more energy may be used in Hamilton's residential and commercial buildings than for transport within Hamilton. The present section considers how energy consumption in these buildings could be reduced. Buildings—unlike vehicles—also offer many opportunities for energy production at the building, or elsewhere on the land occupied by the building. These energy production opportunities are considered in Section 10.

Box 16 shows how energy is used in Ontario for residential and for commercial and institutional purposes.⁶⁷ In both types of building, almost all space and water heating is by natural gas. The fuel for almost all other uses—lighting, air conditioning, elevator operation, appliances, office equipment, etc.—is electricity.

How total energy use may have been shared between the fuels in 2003 is illustrated in the table in Box 11 on Page 22. This table also sets out proposed targets for reduction in energy use by 2018. As for transport, the targets are based on reductions in overall per capita energy use by about two thirds with a correction for population increase, resulting in a reduction by just over 60 per cent. As for transport, there is a marked increase in electricity's share of total energy use: from just under 40 per cent in 2003 to just over 60 per cent in 2018. An expanded version of the part of the table in Box 11 that concerns buildings appears in Box 17

A fundamental guide in concluding that energy use in buildings can realistically be reduced by about two thirds is the authoritative *Handbook on*

Box 16. Shares of uses of energy by purpose, for residential purposes and for commercial and institutional purposes.



Low-Energy Buildings and District Energy Systems by Professor L.D. Harvey of the University of Toronto, to be published in 2006.⁶⁸ Professor Harvey concludes, “An achievable but ambitious target for new high-performance housing is to reduce the heating and cooling energy use by a factor of four compared to conventional practice, whatever the country and climate under consideration”. He also concludes, “Conventional but aggressive retrofits of residential and commercial buildings that are in need of refurbishment should achieve at least a 50-per-cent savings in annual energy use. In many cases, a savings of 75 per cent can be achieved. There are documented cases where savings of 90 per cent have been achieved.”

Two things are proposed: that new buildings in Hamilton be constructed to a very high energy-efficiency standard and that a massive retrofit program be undertaken for all existing buildings.

In 2018, about 25 per cent of Hamilton’s building stock is likely to be new with the remainder comprising buildings that are standing in 2005.⁶⁹ Thus, two things are proposed. One is that new buildings in Hamilton be constructed to a much higher energy-efficiency standard than presently applies.⁷⁰ The other is that a massive retrofit program be undertaken for all existing buildings. Energy use per building would be reduced by an average of about two thirds. With the net increase in the number of buildings, roughly corresponding to the population growth, overall energy use in buildings would decline by just over 60 per cent (see Box 11 and Box 17).

Use of oil and natural gas (NG) in buildings would fall by just over 80 per cent; but electricity use would fall by less than 40 per cent. The amount of electricity used for space and water heating and space cooling would actually increase, because of widespread use of ground-source (sometime known as ‘geothermal’ or ‘geoexchange’) heat pumps for heating and cooling. The ground several metres below grade is considerably cooler than surface temperature in summer and considerably warmer in winter. Ground source heat pumps can exploit this difference, resulting in substantial reductions in energy required for heating and cooling.

Box 17. Energy use in buildings in Hamilton, 2003, and targets for energy use, 2018.

Another increase in fuel use proposed in Box 11 and Box 17 concerns

	Actual in 2003 (petajoules)				Proposed for 2018 (petajoules)				Change 2003-18
	Oil/NG	Electricity	Other	Total	Oil/NG	Electricity	Other	Total	
Residential									
Space/water heating/cooling	13.9	3.2	1.0	18.1	2.7	3.7	1.1	7.6	-58%
Other	0.0	3.7	0.0	3.7	0.0	1.4	0.0	1.4	-61%
Commercial									
Space/water heating/cooling	10.0	1.6	0.3	11.9	1.7	1.9	0.5	4.1	-66%
Other	0.0	6.0	0.0	6.0	0.0	2.4	0.0	2.4	-61%
Totals	23.9	14.5	1.3	39.7	4.4	9.4	1.6	15.5	-61%

‘other’ sources of energy. At the moment this is mainly use of wood for heating. Some wood use may continue, although it is generally inefficient in domestic buildings and likely to be a source of considerable pollution. The ‘other’ columns in Box 11 and Box 17 refer mainly to waste heat distributed through district energy systems, and to chilled water derived from the large renewable reservoir of cold water in the depths of Lake Ontario, also similarly distributed. These are discussed further in Section 10. For the moment, it can be noted that widespread installation of district energy systems in Hamilton could make a considerable contribution towards reducing energy use in buildings.

Most of the reduction in building energy use will come from changes in the buildings themselves. The scope of reductions possible for new buildings is not well appreciated. It is illustrated in Box 18,⁷¹ which shows that an ‘advanced house’, with a larger-than-average floor area, uses less than one sixth of the energy for heating as a typical new house. Savings in energy for heating commercial buildings can be even larger, in part because the buildings are typically larger and in part because more heat can be captured from activities within the buildings.

Part of the reduced energy use is achieved through better insulation, part through more effective energy delivery and management systems, and part through taking advantage of available natural factors. The last category includes roof colour and materials and use of awnings and other shading arrangements.

Retrofitting existing buildings to reduce energy use is much more challenging (and expensive) than building them to use low levels of energy. Nevertheless, as noted above, Professor Harvey concludes from his exhaustive review of available literature and techniques that savings of more than 50 per cent can be achieved through well-tried conventional means. He goes further and argues for use of ‘solar retrofits’ as follows: “Solar retrofits involve measures such as construction of a second, transparent

An ‘advanced house’, with a larger-than-average floor area, uses less than one sixth of the energy for heating as a typical new house.

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 m² one-story, single detached house, natural gas heating.

** 250 m², two-storey, single detached house heated through an integrated mechanical system, in Brampton, Ontario.

Box 18. Annual use of energy for heating in houses constructed to different standards.

façade over the existing façade of a building, integrated with the ventilation system of the building; installation of building-integrated solar collectors; advanced glazing of balconies and integration with the ventilation system; and use of transparent insulation, either for heating only or for heating and daylighting. Solar retrofits provide additional savings beyond whatever could be achieved through conventional retrofits alone. Construction of a second façade can be used to protect buildings with water problems that might otherwise need to be demolished or undergo expensive future repairs, or to improve the appearance of ugly buildings.”

This section has focussed on space and water heating in buildings because these are overwhelmingly the major energy uses (see Box 17). However, opportunities for other energy savings in buildings are also considerable. These include use of improved appliances, equipment, and lighting, and use of buildings in energy-conserving ways. The latter includes thermostat settings, climbing stairs, avoidance of energy-intensive activities such as leaving doors and windows open in winter and refrigerator doors open at any time of the year, and switching off unnecessary lighting. Space precludes detailed exposition as to how these non-heating energy uses could be substantially reduced. A longer exposition would note, for example, evidence reviewed in Professor Harvey’s book as to how lighting energy can be reduced by 80 per cent in commercial buildings and by more than 50 per cent in residential buildings.

9. Land-use planning for energy constraints

In considering the contribution of land-use planning to the achievement of aggressive reductions in transport and in-building energy use, the following principles are proposed:

1. Make energy use and production the principle determinant of land-use decisions.

This is the most fundamental principle, from which the others follow. Adoption of such a principle can also help define the culture of a community, which can influence actions across the board and help ensure appropriate investment in the community.

2. Give ‘greenfield’ development low priority.

To the extent possible, all new development should occur within the existing urban boundary.⁷² Doing this contributes to intensification, and thus more compact building forms, which are inherently more energy-sparing. Intensive development, compared with alternatives, also reduces transport energy use by shortening trip lengths, making public transit more feasible, and making non-motorized travel more feasible. Intensive development also makes district energy systems more feasible, and reduces the energy cost of infrastructure generally. Also important in an era of energy constraints will be preservation of agricultural land, the main loss when greenfield development occurs. Food imports would become expensive (through transport costs) and even unavailable, causing greater reliance on locally produced items.

Seven land-use
planning principles.

3. No abandonment of existing low-density areas.

Severe energy constraints could result in abandonment of existing low-density areas on the grounds that their required high levels of automobile use cannot be sustained and serving them with public transport may not be feasible. However, selective intensification and judicious use of transport systems—e.g., PRT—suited to low-density areas could maintain the viability of such areas and avoid the extreme social and economic distress that could result from abandonment.

4. Plan for a mixing of uses.

If intensification is achieved, and yet homes, jobs, stores, and other destinations are still separated, travel will be incurred that could be avoided in part if land uses are mixed. Moreover, if individual buildings contain many uses, there are often synergies in energy use and production that can be exploited. For example, operations within an office building may generate more heat than can be used for office purposes. If the building has a residential component, that heat may be less likely to be wasted. Simi-

larly, seniors living above a shopping mall could benefit from the excess heat generated by mall activities, and have the mall close at hand.

5. Aggressively pursue ‘brownfield’ development.

This is development on previously used land that may be contaminated but not to the point that remediation is impossible. Hamilton contains many such sites within its urban boundary whose redevelopment could contribute greatly to more intensive land use and associated benefits.

6. Foster vibrant centres.

The most conspicuous of these is the Downtown, which is becoming more vibrant but has far to go before being acknowledged as a true centre of Hamilton’s economic and social fabric. Hamilton has several lesser centres, each of which if substantially strengthened could reinforce intensification with consequent social and economic benefits in an energy constrained world. The massive retrofit program contemplated in the previous section could have an initial focus on these centres, giving them architectural distinctiveness that could reinforce their attractiveness.

7. Arrange that development supports low-energy transport

Application of many of the above principles will support transit and non-motorized movement of people and goods, including giving low priority to greenfield development and fostering vibrant centres. Because of transport’s key role in energy use, particularly use of fossil fuels, a specific principle concerning the relation between land use and transport may be helpful. Historically, transport planning has served land-use planning. Current practice is to integrate them so that both occur together. For an energy-constrained world, it may be expedient to plan transport first and then arrange land uses to serve the transport activity. A transport objective could be, for example, that half of all commuting occurs on foot or by bicycle. Land uses would then be proposed that would facilitate attainment of this objective.

For an energy-constrained world, it may be expedient to plan transport first and then arrange land uses to serve the transport activity.

10. Energy production opportunities

The strategic objectives concerning energy production may well be the most controversial proposed here. The present section sets out several opportunities that could contribute to producing all the electricity Hamilton uses (on a net basis) and half of the other energy. As already noted, considerable thought is already being given to energy production in Hamilton, much of it associated with Hamilton Community Energy and sister organizations. What is proposed here takes this thinking much further.

Transport offers almost no opportunities for energy production, but buildings offer many, some of which are noted below. As in the section on buildings, considerable reliance has been placed in this section on Professor Harvey's forthcoming *Handbook on Low-Energy Buildings and District Energy Systems*, which as well as detailing how much less energy can be used in buildings also discusses energy production.

10.1. Solar energy

Very much more solar energy falls on Hamilton in a typical day than the energy of all kinds that is used in Hamilton,⁷³ although only a very small portion of this can be harnessed. Nevertheless, one paper notes that placement of currently available photovoltaic (PV) arrays on the roofs of residential buildings in Canada could provide across the year an average of 45 per cent of the electricity used within these buildings. Similar placement plus use of south-facing walls could provide all the electricity used within commercial buildings.⁷⁴ If this were done in Hamilton, electrical output from this source alone would amount to more than the consumption proposed in buildings in Box 17. Residential buildings would generate less than their consumption (3.1 vs. 5.1 petajoules per year) while commercial buildings would generate more (7.6 vs. 4.3 petajoules).

Very much more solar energy falls on Hamilton in a typical day than the energy of all kinds that is used in Hamilton.

PV arrays can be free-standing. Where residential lots are large, as in lower density parts of the city, additional PV arrays could bring the residential total to more than the residential consumption.

Of course, power is not available from PV arrays at night, when much electricity is used. PV sources would have to be balanced with other sources, within and outside Hamilton. Even though Hamilton could be producing an amount of electricity equivalent to total consumption, the concept is always that this would be done on a *net* basis. Widespread PV installation in Hamilton could nevertheless be appealing to operators of the Ontario grid, which experience peak loads during daylight hours.

Solar radiation also provides heat energy. Solar water heaters, perhaps combined with PV collectors, could provide up to half of the residential water heating in Canada.

10.2. Wind energy

Perhaps as many as 100 four-megawatt turbines could be located within Hamilton and in adjacent waters.

After solar (photovoltaic) energy, wind energy is the fastest growing source of renewably produced electricity worldwide, and has been reported to be already cost effective in relation to more expensive conventional means of production.⁷⁵ Wind energy can be even more intermittent than solar energy, but can nevertheless make a valuable contribution to the output from a multi-source system. Wind turbines could be distributed across Hamilton's agricultural lands (as they are across agricultural lands in many parts of Northern Europe). They are generally more effective, however, over water. The relatively shallow part of Lake Ontario near Hamilton could be the location of several more turbines.

Perhaps as many as 100 four-megawatt turbines could be located within Hamilton and in adjacent waters. This would provide an annual total of about 4.0 petajoules,⁷⁶ i.e., more than a quarter of current and proposed use for transport and buildings (see Box 11).

10.3. Deep Lake Water Cooling (DLWC)

DLWC involves use of cold water piped in from the depths of Lake Ontario. Below 80 metres, this water is permanently at close to 4°C. It is a renewable resource, provisioned by the sinking of cold surface waters during winter. The huge volume of cold water at the bottom of this very deep lake (maximum depth 244 metres) makes the resource essentially inexhaustible unless winter surface temperatures cease to fall below 4°C.

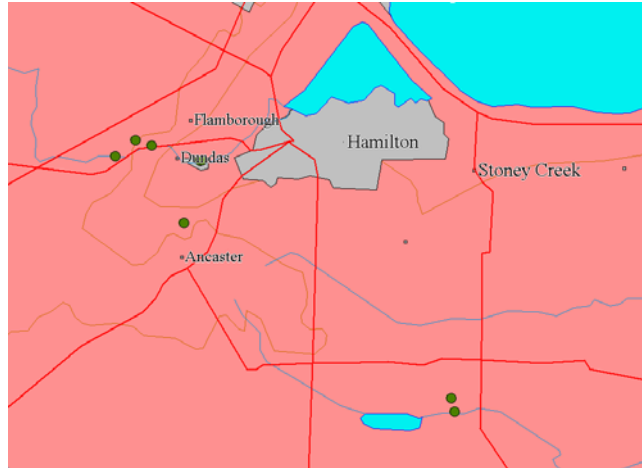
In Toronto, the capacity of the existing DLWC system is the cooling equivalent of 264 megawatts of electric power.⁷⁷ Used for a quarter of the year, this capacity would provide about 2.1 petajoules of energy. If a district energy system were available in Hamilton, piping chilled water around the city, a system of this size could displace most of Hamilton's electricity needs for air conditioning.

Lake Ontario's 80-metre isobath reaches within five kilometres of downtown Toronto, but it is 20 kilometres from downtown Hamilton. However, the cost per distance of laying the necessary underwater pipes is relatively small (compared with the pipe-laying setup cost) and the temperature gain per kilometre of movement of cold water through such a pipe is also

small.⁷⁸ Given a suitable distribution system, DLWC could work for Hamilton.

10.4. Hydro-electric power

The *International Small-Hydro Atlas* identifies several opportunities for achieving ‘micro-hydro generation’, noted in Box 19.⁷⁹ Together these would provide a maximum output of about 600 kilowatts, equivalent over a year to about 0.01 petajoule.⁸⁰ This is an insignificant amount in terms of total use, but could comprise relatively inexpensive base load, and exploitation could well be justified in an era of energy constraints.



Box 19. Potential small-hydro sites in Hamilton.

Hamilton Community Energy is developing a 165-kilowatt ‘run-of-the-river’ hydroelectric facility at an unidentified location.⁸¹

10.5. Energy from waste

Approximately seven million tonnes of municipal, commercial, and industrial waste requiring disposal are generated in south-central Ontario.⁸² If half of this were incinerated for energy recovery in Hamilton, the energy yield would be close to seven petajoules of electricity with a similar amount of useful heat. The electricity would be almost half of Hamilton’s proposed use for transport and buildings. The useful heat would be more than enough to meet all Hamilton’s remaining space heating needs. The balance of the output could be delivered as process steam in nearby industry or as hot water for greenhouses in agricultural areas. (Hot water can be piped several tens of kilometres without significant loss of temperature.)

Other municipalities and businesses would pay Hamilton to accept a large amount of energy each year.

The advantage of this source of energy is that it would be essentially without cost. Other municipalities and private sector interests would pay Hamilton to manage their waste, which fees could cover all the costs of constructing and operating the plant and even some of the costs of the hot water or steam distribution system.

Should Hamilton position itself as south-central Ontario's energy-from-waste centre, it would be prudent to adopt two special rules. One would be that the facility's emission standards be especially stringent, such that for more than half the year the plant is required to emit air that is cleaner than ambient air, i.e., the facility would be mostly an air cleaner not a polluter. The second special rule would be that no waste enter Hamilton other than by rail or barge. Waste management experience suggests that overwhelmingly the main practical issue is truck traffic.

Two unusually strict environmental safeguards: no trucks be used (except for local waste) and that the facility act as a *air cleaner* for most of the year.

Existing or future under-used lands in Hamilton's Port Industrial Area could be ideal for such an enterprise because of their long-standing association with heavy industry and their excellent rail and water access. No other area in Hamilton would appear to be so appropriate. A site east of Toronto is being proposed for a similar purpose.⁸³

Two energy-from-waste proposals for Hamilton are presently under discussion. One is a proposal to incinerate Hamilton's and Niagara Region's municipal solid waste, in Hamilton or in Niagara Region.⁸⁴ This proposal is for the disposal with energy recovery of about 160,000 tonnes annually, i.e., about one twentieth of what is proposed above, which would involve waste from other jurisdictions and from the commercial and industrial sectors.

The other proposal is for the Liberty Energy Centre, to be located on a Strathearne Avenue site. The plant would gasify about 470,000 tonnes of "difficult to compost" biomass annually, including sewage sludge, grass and garden clippings, clean dimensional lumber, urban forest waste, and horticultural waste from a variety of sources. The resulting gas would be used to generate electricity in a steam turbine.⁸⁵

Neither proposal incorporates the kind of unusually strict environmental safeguards proposed for the much larger operation, namely that no trucks be used (except for local waste) and that the plant act as a *air cleaner* for most of the year.

10.6. Biogas production

Agricultural and other animal and plant waste can provide another source of energy, notably from anaerobic digestion of the material to produce biogas, which is approximately 50-per-cent methane, the main constituent of natural gas. South-central Ontario has a major problem with management of this waste, very little of which is used productively. Anaerobic digestion is a well-tried technology, used for example in Sweden and Germany to produce substantial quantities of transport and other fuel.⁸⁶

Hamilton could position itself as a major manager of such waste, again taking advantage of others' willingness to pay for delivery of an energy resource.

Considering manure from cattle, pigs, and poultry alone: Ontario produces about 30 billion litres of this material annually. Anaerobic digestion could convert this into biogas or natural gas equivalent with an energy value of approximately 20 petajoules.⁸⁷ If one quarter of this conversion were to occur in Hamilton, the result would be a substantial portion of the oil and natural gas consumption proposed for Hamilton in 2018 (see Box 17).

One quarter of southern Ontario's farm manure could produce a substantial portion of the oil and natural gas consumption proposed for Hamilton in 2018.

The rule proposed for importation of solid waste could also apply to this waste: that none enter Hamilton by truck, only by rail or water. Again, the Port Industrial Area could be a good location for this industrial process.

There are several uses for the biogas product of anaerobic digestion. It can be readily upgraded to natural gas and sent through the existing distribution system. It can fuel gas turbines that generate electricity, process steam, and hot water for heating. It can be used as a transport fuel, preferably in its upgraded form.

10.7. District energy

Hamilton already has a small district energy system, providing hot water for space heating to several buildings in the west downtown. The source of the hot water is a natural-gas fired cogeneration plant that produces about 0.1 petajoule of electricity a year and hot water with a roughly similar energy value. The district energy system allows waste heat from the generation of electricity to be used productively, raising the efficiency of the process from about 40 per cent to above 70 per cent.

In many European cities just about every building is heated via a district energy system that makes use of waste heat from several processes. In Malmö, Sweden, for example, the district energy system receives waste from the electric power station, a smelting plant, the sewage treatment plant, a sugar refinery, a carbon black factory, a dung-fired boiler at the race track, and the pet crematorium.

An incidental point about Malmö is the energy supply to its Western Harbour district, which uses renewable energy—solar, wind, biogas, deep sea water—for all its buildings and much of its transport.

District cooling is less common than district heating, but may become relatively more important with climate change. One of the world's largest

The district heating system in Malmö, Sweden, receives waste heat from the electric power station, a smelting plant, the sewage treatment plant, a sugar refinery, a carbon black factory, a dung-fired boiler at the race track, and the pet crematorium.

district cooling systems is emerging in Toronto, fed by deep lake water. As noted above, this opportunity could exist for Hamilton.

Buildings may become so efficient in Hamilton there will be no justification for widespread heating and cooling networks. If added heating and cooling are required, a widespread district energy network allows for the use of energy sources that would otherwise be difficult to exploit, thereby markedly raising the efficiency of several processes.

10.8. Local food production

Food is energy for humans, and its availability may be especially threatened if transport becomes expensive. Presently, almost all of the food eaten by Hamilton residents is imported from other places, often across great distances (e.g., fresh fruit flown in from South America). Hamilton also has some of the best agricultural land in Canada, much of which is unused and some of which is vulnerable to development.

Food is sufficiently important to the well being of Hamilton residents to warrant a separate report that would address the following:

Food is sufficiently important to the well being of Hamilton residents to warrant a separate report.

- Where it now comes from, and the transport energy component of each item.
- How availability and price might change with energy constraints.
- Opportunities for enhanced local production, including greenhouse production for out-of-season items.
- Methods of operating greenhouses in Hamilton's climate using little added energy.⁸⁸

A constant flow of food into Hamilton's supermarkets, kitchens, and restaurants is presently taken for granted. A sharp increase in the cost of transport energy could disrupt this flow. The consequences could be severe, especially for households without means to grow some of their own food, or to purchase food that has become considerably more expensive. Examination of the implications of high transport prices for the food supply could be prudent.

11. Economic and social development through preparing for energy constraints

If Hamilton were to follow the path proposed here, there could be substantial advantages from an economic development perspective. To the extent that the projections concerning future energy constraints and prices presented here is correct, many communities around the world will be looking to transform the ways in which they produce and consume energy. Hamilton would be a pioneer in distributed energy production and in radically reducing energy use.

Businesses would establish in Hamilton to be close to and even participate in the dramatic focus on energy concerns.

Businesses would establish in Hamilton to be close to and even participate in the dramatic focus on energy issues—which may dominate economic and social life for much of the rest of this century—Hamilton could be energy’s ‘Silicon Valley’: the seedbed of research, innovation, development, and marketing.

Hamilton would thrive not only because of the additional economic activity but also because it would be saving and producing energy. It would have more secure and lower cost energy than most communities. Moreover, Hamilton as a community would be paying for very little energy, and would thus be able to retain what would otherwise be spent for its own use.

The slogan ‘Hamilton: The Electric City’ is proposed as a way of characterizing what Hamilton could strive to become. ‘Electric’ is an apt characterization, referring both to the increasingly predominant energy use as energy constraints take hold and to the excitement and challenge of leading the transition to a new era.

The slogan ‘Hamilton: The Electric City’ is proposed as a way of characterizing what Hamilton could strive to become.

Hamilton was known as ‘The Electric City’ 120 years ago, in the 1880s, when it was one of the first cities in the world to have widespread electric light—for streets, homes, and businesses.⁸⁹ Hamilton could again be the ‘The Electric City’, in the forefront of the transition to electric transport and new electricity generation.

Positive social development would likely accompany the anticipated economic development, both because Hamilton would be relatively wealthier but as much because Hamilton would have a clear mission: to adjust smoothly and productively to the new era of energy constraints and to show the world how to do it.

Even if the present case is not accepted, there could be reason to foster the expansion of energy interests in Hamilton by identifying energy industry as the ninth economic development cluster.

If Hamilton were to follow the path proposed here, substantial economic development would likely follow whether or not facilitating action were taken by the City. However, the City could help this along by establishing and fostering an energy research and development area, much as the City of Toronto, for example, is fostering development of its Discovery District around four teaching hospitals along University Avenue.

Hamilton's Economic Development Policy is entitled *Hamilton's Clusters of Innovation*. The policy is presently structured around eight industry clusters, with the aerotropolis concept (see next section) as the first priority. If the argument in this report is accepted, there would be good reason to establish an energy cluster as the first priority. Even if it is not accepted, there could be reason to foster the expansion of energy interests in Hamilton by identifying energy industry as the ninth economic development cluster.

12. Matters raised by City Council: Aerotropolis

In directing that this report be prepared, City Council requested consideration of four matters: “our aerotropolis, goods movement future initiatives, fleet, and HSR”. This section and the next three sections focus respectively on these four topics.

The term ‘aerotropolis’ was coined to refer to “a new aviation-linked urban form” comprising “corridors, clusters, and spines of airport-induced businesses ... based on low density, wide lanes, and fast movements”.⁹⁰

Hamilton’s aerotropolis concept concerns expansion of activity at the John C. Munroe Airport, particularly freight movement, and development of “an industrial, commercial and residential community around the Hamilton International Airport, that exists and grows in support of the airport’s and the City’s economic development objectives”. Hamilton’s *Economic Development Strategy* refers to aerotropolis as “the number one strategic priority for economic development in Hamilton”.⁹¹

The aerotropolis concept is linked closely to prospects for air freight, and less directly to prospects for passenger travel by air. Air freight and passenger travel are related in that worldwide about 40 per cent of air freight is carried in passenger planes.⁹² Hamilton Airport would focus more than usual on all-cargo planes, but usage of these is sensitive to passenger movements as carrying freight in passenger planes is usually much more cost-effective for an airline.⁹³

Rosy statements about aviation's future are not consistent with recent statements about the effects of high fuel prices.

There have been recent rosy forecasts of growth in air traffic. For example, in June 2005 Boeing forecast that over the next 20 years passenger traffic will grow by 4.8 per cent annually worldwide and 4.1 per cent in North America, equivalent to increases by 155 per cent and 134 per cent respectively. The cargo forecast was for annual growth worldwide of 6.2 per cent (no North American breakdown), equivalent to an increase by 233 per cent (i.e., more than a tripling of air cargo traffic).⁹⁴

Other industry assessments have been less sanguine, particularly on account of high fuel prices. For example, in September 2005, Giovanni Bisignani, director-general of the Montreal-based International Air Transport Association (IATA), observed that what he described as “extraordinary fuel prices” were having a stronger effect on freight transport than on passenger transport. Prices of aviation fuel were about 50-per-cent higher during the first half of 2005 than during the first half of 2004, and yet passenger traffic worldwide grew by 8.8 percent. Freight growth, by contrast, was only 3.4 per cent.⁹⁵

If oil prices rise steeply, the aviation industry could be especially vulnerable, particularly freight movement, putting the aerotropolis concept at risk, to the extent that it depends on air freight.

An alternative view of the aerotropolis concept is that it could be a 'Highway 6 Business Park' that has no particularly strong relationship to the airport and to air freight activity. Hamilton needs more employment lands for its projected population growth, and to redress the trend whereby Hamilton residents increasingly work outside Hamilton (see Box 20).⁹⁶ The airport area presents an opportunity to provide for new employment lands, because lands surrounding an airport are not generally suitable for residential purposes.

The economic development strategy implied in the concept of 'Hamilton: The Electric City', would suggest that such a business centre be oriented towards energy efficiency, conservation, and production. This would include connecting the new employment area with energy efficient transport for employees and protecting corridors that could be developed for rail freight and even for grid-connected freight systems. The aerotropolis could be developed with a focus on air freight in the short term but in ways that would allow for a future transformation to a wide range of energy-efficient forms of goods manufacture and freight movement.

Hamilton needs more employment lands for its projected population growth, and to redress the trend whereby Hamilton residents increasingly work outside Hamilton.

Box 20. Balance of workforce and employment in Hamilton, 1986 and 2001.

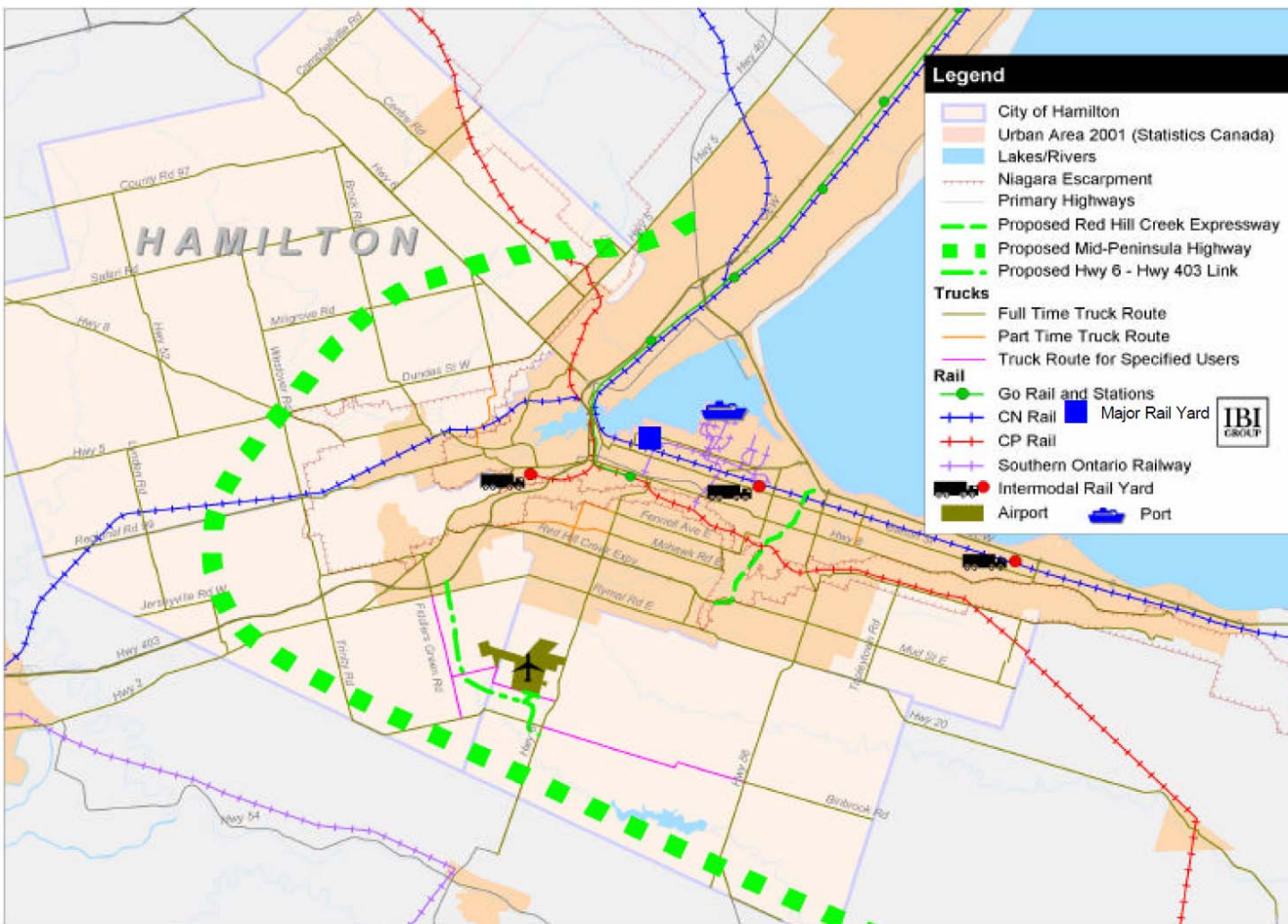
Increase in working population resident in Hamilton, 1986-2001	15.5%
Increase in the number of jobs in Hamilton, 1986-2001	2.4%
Jobs in Hamilton as % of workers resident in Hamilton, 1986	91.1%
Jobs in Hamilton as % of workers resident in Hamilton, 2001	80.8%
Workers leaving Hamilton for work, 1986 (% of resident workforce)	17.9%
Workers leaving Hamilton for work, 2001 (% of resident workforce)	31.2%
Jobs in Hamilton held by workers living elsewhere, 1986	9.8%
Jobs in Hamilton held by workers living elsewhere, 2001	14.8%

13. Matters raised by City Council: Goods movement

Goods movement is often neglected in transport planning, even though—as noted in IBI Group’s *Goods Movement Policy Paper* prepared as part of the work for the City of Hamilton’s *Transportation Master Plan*—the movement of freight has been growing at a higher rate than the movement of people.⁹⁷ According to the *Policy Paper*, freight traffic in Canada is expected to increase by 60 per cent by 2020, a projection that assumes no major changes in fuel availability or price.

The *Policy Paper* notes that “Hamilton is a major transportation centre in Ontario. It is a major port, serves as an air cargo hub for express packages (i.e., courier companies), and it is strategically located for road and rail routes that serve both domestic and trans-border trade. ... These are natural advantages that have developed over time. The key issue for future policy and planning is to preserve and enhance those advantages in an increasingly competitive context.”⁹⁸ Box 21 provides an overview of the

Box 21. Hamilton’s transportation network, noting some key focuses of freight transport activity.



present transport network, illustrating its variety and complexity.⁹⁹

If fuel prices are expected to rise steeply, planning for freight transport should focus on expanding use of the port and of rail facilities, and on developing other alternatives to conventional truck use, particularly for freight movement within the City of Hamilton.

We know less generally about the movement of freight than about the movement of people, particularly the movement of freight in cities, and particularly energy use for freight movement.

It's hard with present knowledge to draw up a table for the movement of freight such as the one in Box 12, which concerns the motorized movement of people. Here's why:

- We know less generally about the movement of freight than about the movement of people, particularly the movement of freight in cities, and particularly energy use for freight movement.¹⁰⁰
- Estimates for Ontario, from which estimates for Hamilton have to be derived, are affected by a considerable amount of through traffic between Quebec and the U.S.
- The movement of freight has been changing much more than the movement of people. In Ontario, energy use for freight transport grew by 43 per cent between 1990 and 2003. Energy use for the movement of people grew by 16 per cent (actually less than the population growth, which was close to 20 per cent).¹⁰¹

For Ontario, transport other than the movement of people accounts for about 40 per cent of transport energy use. Of this 40 per cent, the overwhelming share—about 80 per cent—is truck traffic. Rail, performs about the same number of tonne-kilometres (TKMs) of freight movement in Ontario as trucking, accounted for only five per cent of freight transport energy use. Trucks use about 15 times as much fuel per TKM as trains. They use about seven times as much per TKM as ships, which carried only about a third of the amounts moved by trucks or trains, and accounted for only four per cent of freight transport fuel use.

Box 22. Freight movement by mode for Hamilton residents and businesses and proposed targets for 2018.

Mode	2003				2018			
	TKM (millions)	Fuel use/TKM (MJ)	Total petroleum use (PJ)	Total electricity use (PJ)	PKM (millions)	Fuel use/PKM (MJ)	Total petroleum use (PJ)	Total electricity use (PJ)
Truck (ICE)	3,300	3.2	10.7		1,250	2.5	3.1	0.0
Truck (electric)					1,000	1.0	0.0	1.0
Rail	3,200	0.2	0.7		4,000	0.1	0.0	0.4
Marine	2,000	0.4	0.5		3,000	0.3	0.9	0.0
Totals	8,500		11.9		9,250		4.0	1.4

Note: TKM = Tonne-Kilometre. ICE = Internal Combustion Engine. MJ = MegaJoule. PJ = PetaJoule

There are several challenges in applying these results to Hamilton. Freight transport depends considerably on the nature of businesses in a location and the supporting infrastructure, which are not evenly spread. Hamilton has one of Ontario's largest concentrations of heavy industry and its largest port, meaning at least that it has a disproportionately large share of Ontario's shipping. Notwithstanding the major challenges, an attempt has been made in Box 22 on the previous page to assess current freight movement in and to and from Hamilton, and to set targets for 2018.

Hamilton has one of Ontario's largest concentrations of heavy industry and its largest port.

Many of the same assumptions and limitations apply to Box 22 as to Box 12. Aviation is not represented, nor is movement of freight outside Canada that might be done on behalf of Hamilton residents or businesses. The estimate of current marine activity in Box 22 is especially questionable.

The targets for freight movement in 2018, unlike those for the movement of people, assume an overall *increase* in the amount of freight transport, from 8,500 to 9,250. This is in part because more local production of food is assumed (see Section 10.8) and in part because of the proposal that Hamilton become a centre for the conversion of waste into energy (see Section 10.5). However, this increase by about nine per cent would actually represent a slight decline in freight movement per-capita, because of the expected population increase.

A reduction in the amount of trucking is assumed, to be picked up by increases in rail and, particularly, marine transport. Almost half of trucking is assumed to be electrically powered, because the trucks are plug-in hybrids, battery only, or grid-connected. These would be used mostly within Hamilton. As opportunities for grid-connection grow outside Hamilton, there could be further shifts away from the use of ICE trucks.

Rail is assumed to become mostly electric, with corresponding reductions in energy use. Marine has less opportunity for grid connection, but it can make use of wind, as illustrated in Box 23 on the next page,¹⁰² thereby reducing fuel use by a third. (This is represented in the 'Other' column in Box 11.) Movement by water also has more scope for reducing energy use by reducing speed. The increase in fuel use with increasing speed is much steeper for movement through water than for movement on land.

For local goods movement, the City of Hamilton could promote the use of more energy-efficient forms of transport including bike couriers and small electric trucks.

For local goods movement, the City of Hamilton could promote the use of more energy-efficient forms of transport including bike couriers and small electric trucks. Local distribution and assembly of goods moving to and from Hamilton movement could be made more efficient by establishing freight terminals and load consolidation centres. For example, a food terminal could be established at the edge of the urbanized area to which farmers could bring produce for shared transport to the Farmers Market.

▶
Box 23.
Freighter
pulled by kite.



14. Matters raised by City Council: City fleet

The City of Hamilton's vehicle fleet includes numerous emergency, service, freight and passenger vehicles. As noted in Section 7.5, emergency vehicles and some service vehicles should always have priority in the use of conventional fuels and transport systems.

If an energy strategy is pursued, the City's fleet should be a key focus in order to set an example, reap resulting benefits, and gain the knowledge of systems that comes from use of them.

The above analysis suggests that transport will depend mostly on electric motors, with the electricity provided from batteries or by grid-connection in motion. (See Section 7 above.) Steps in these directions include use of hybrid vehicles and plug-in hybrids. (See Section 7.2.)

The challenge for a municipal administration in taking the lead in matters such as the purchase of hybrid vehicles is that such early adoption comes with two kinds of penalty. One is the higher initial cost of a vehicle that is not in widespread use. The other is the potential for less than adequate reliability of a vehicle that has not been in production for a long time and may in some respects still be experimental.

On the other hand, if Hamilton were to position itself as a leader in transitioning to an era of energy constraints, the character of the municipal fleet could be a strong indication of that leadership.¹⁰³ Moreover, the need for systematic testing of new vehicle types in circumstances similar to those that can be provided by municipal fleet management could lead manufacturers and provincial and federal governments to make the required investments.

If Hamilton were to position itself as a leader in transitioning to an era of energy constraints, the character of the municipal fleet could be a strong indication of that leadership.

Also, as conventional transport fuel prices increase, hybrid and other electric vehicles will become increasingly cost-effective.

At present, more progress is being made in respect of hybrid passenger vehicles than hybrid freight vehicles. However, development and testing of hybrid ICE-battery electric trucks of all sizes and other heavy-duty vehicles is a very active area with a strong Canadian contribution.¹⁰⁴ Such development and testing seems poised to attract considerable federal government support.

15. Matters raised by City Council: HSR

Hamilton Street Railway began in 1874 with horse-drawn cars on rails. These were replaced by electric streetcars from 1892, which in turn were replaced by diesel and electric buses in years around 1950.¹⁰⁵ Electric trolley buses—one is shown on the front of this report—ran from 1950 until 1992.¹⁰⁶

The first move towards reducing transport energy use in Hamilton could thus be replacement of existing bus routes by light rail or streetcars, or by trolley buses, according to levels of ridership.

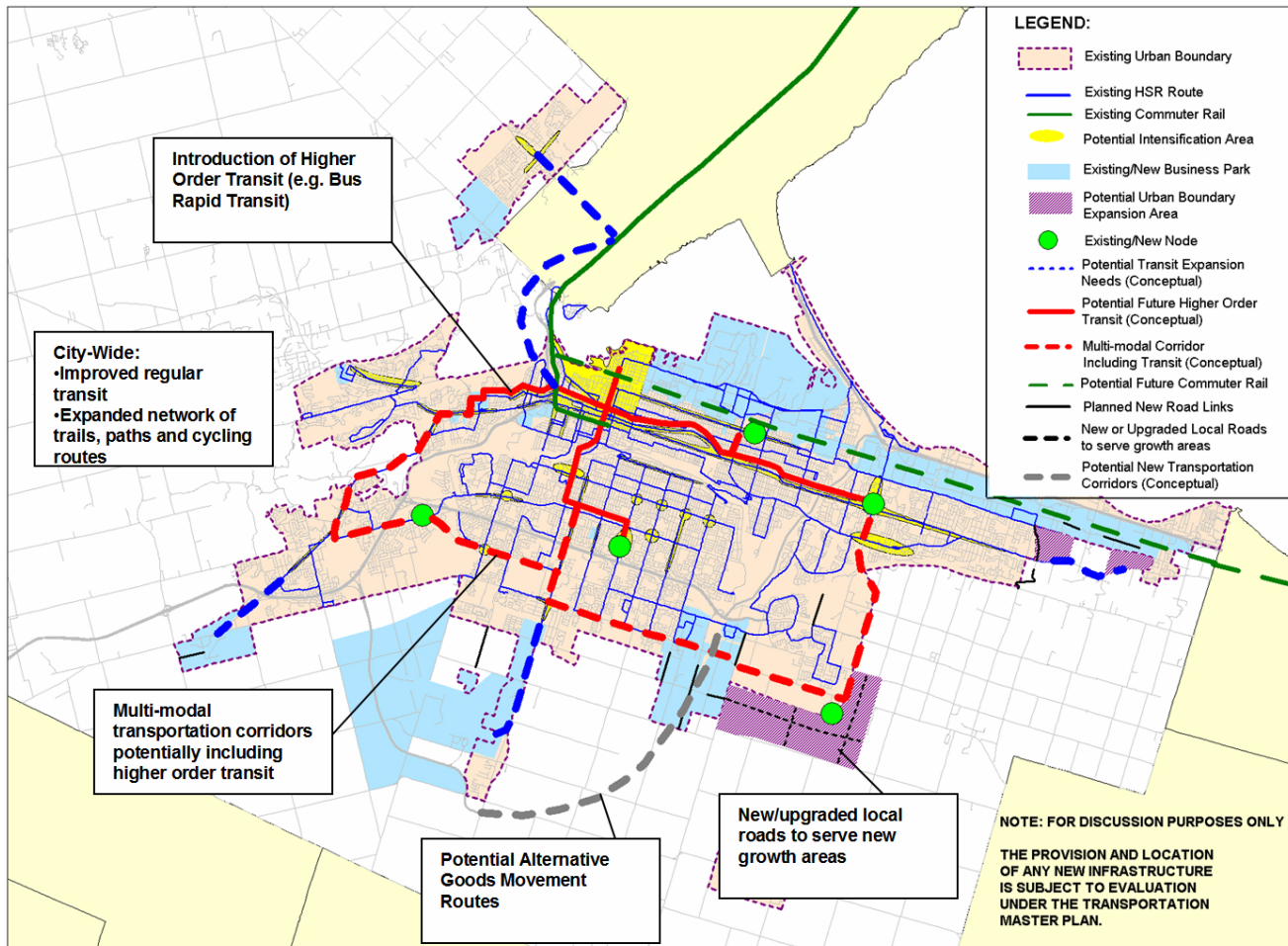
The last trolleybuses operating in Hamilton, on the Barton route, were dual-mode vehicles. They were equipped with small diesel engines for operation when power from overhead wires was not available. However, they were not hybrid vehicles in the present sense of the term. The diesel engine did not charge a battery that could drive the electric traction motor.

Streetcars and then trolleybuses were withdrawn because operation of buses with internal combustion engines appeared to be more cost-effective to transit system operators and funders.

As the price of liquid transport fuels rises, the balance will shift in favour of electric vehicles. The first move towards reducing transport energy use in Hamilton could thus be replacement of existing bus routes by light rail or streetcars, or by trolley buses, according to levels of ridership. (A light rail route can carry more than three times as many passengers per hour as a trolley bus route, even if the latter is mostly operating in its own right-of-way.) The technologies could initially be introduced into the McMaster to Eastgate corridor and the Downtown to Limridge corridor, both of which are identified in Phase 2 of the Hamilton's emerging *Transportation Master Plan* as potential higher order transit corridors (see Box 24 on the next page).¹⁰⁷

The *Plan* includes a proposal for introduction of bus rapid transit or light rail (streetcars) along the designated transit corridors. The above rationale would support this direction except that bus rapid transit would not involve diesel buses but rather trolleybuses, as are used in Edmonton and Vancouver and in numerous other cities around the world. If diesel buses are to be used, perhaps they should be diesel hybrids, of the kind being purchased by the Toronto Transit Commission.¹⁰⁸

Most of the increase in transit ridership proposed in Box 12 on Page 26 would be accommodated by increased levels of service along existing routes, although new routes would also be established where warranted by increases in residential and employment densities.



Also proposed above is a wholly new kind of public transport: Personal Rapid Transport (PRT, see Section 7.2). This system could be integrated with the regular transit, although there could be a premium charge when its routes follow transit routes. PRT could be under the same management as the rest of the transit system or run separately.

Electrically driven incline railways were a feature of Hamilton for several decades,¹⁰⁹ and remain a feature of cities with similar topography, such as Valparaiso, Chile. Trolleybuses are well suited to climbing steep hills; light rail is less well suited. If light rail were to prevail as the main transit mode, reintroduction of incline railways could be advantageous. They would not be needed if a PRT system were introduced.

▲ **Box 24. Transit connections between nodes and corridors will be a key feature of Hamilton's Transportation Master Plan.**

16. How an energy-based strategy could be paid for and its components approved

An inevitable response to the foregoing is that it is all very well and good, and possibly wise, but how could it all be managed and paid for?

In-depth answers to this question will have to wait for a subsequent report. In the meantime, the following can be said.

A community that offers itself as a testbed for advanced energy conservation and production could well be the recipient of an extraordinary amount of private-sector investment.

To the extent there is an expectation of very high fuel prices, opportunities will be sought to develop and demonstrate a range of responses suitable for a real urban environment. A community that offers itself as a testbed for advanced energy conservation and production could well be the recipient of an extraordinary amount of private-sector investment as well as research and development funds from public agencies.

To give three examples:

1. If the City were to call for expressions of interest for the construction of a city-wide Personal-Rapid-Transport (PRT) system, at no cost to the City, a range of appealing responses would likely be received giving confidence to move towards a call for proposals.
2. If the city were to issue a call for proposals for an energy from waste plant and associated district energy system, serving a large part of southern Ontario, and applying the two key conditions noted in Section 10.5, at no cost to the City except a modest cost for disposing of its own waste, a range of appealing responses would likely be received.
3. If the City (or Horizon Utilities Corp.) were to issue a call for expressions of interest for massive installation of photovoltaic collectors on Hamilton buildings, indicating what order of subsidy would be required, a range of appealing responses would likely be received that could form the basis for an approach to a provincial agency and the federal government for appropriate contributions.¹¹⁰

Costing most of the implied ventures in the strategy will be difficult because of the extreme nature of what is proposed and the extraordinary fuel price regime that may be presumed to apply.

Nevertheless, if Hamilton were to indicate that it is 'open for energy business' perhaps along some of the lines indicated here, many ears could perk up and interest could mount (see Box 25 on the next page).¹¹¹

Much of what is proposed here involves reducing energy use within existing buildings. A potential mechanism exists for municipal involvement in achieving this objective: Local Improvement Charges (LICs). A municipality attached a temporary charge to a property that is used to pay a contractor to achieve energy savings that offset repayments to the municipality.¹¹² In Ontario, LICs may be used for improvements to private property but not presently to reduce energy use in buildings.

An enormously costly and time-consuming part of the kind of massive urban makeover proposed here would be conducting the required environmental assessments and securing approvals of them. This could be considered paradoxical because the objective in every case would be to reduce fossil fuel use dramatically, and yet the numerous proposals would be treated in much the same way as projects that have less benign principal objectives.

Moreover, the scale of what is proposed could cause such congestion in the conventional approvals as to preclude almost any of the actions required to move Hamilton towards the goal of becoming the 'The Electric City'. Much provincial cooperation and support would be required to expedite assessments and to streamline approvals.

A particular challenge would be securing the funds needed to engage in energy-first planning, to evaluate many of the suggestions in this report and others, and to develop appropriate implementation strategies. There are two sources of funding for such work. One is the federal government's \$550-million Green Municipal Fund program managed by the Federation of Canadian Municipalities.¹¹³ A specific energy-related Request For Proposals closed on April 12, 2006, but there will be further opportunities. The other opportunity could be the Toronto Atmospheric Fund, presently available only within the City of Toronto, but in the process of expanding its geographic scope.¹¹⁴

An enormously costly and time-consuming part of the kind of massive urban makeover proposed here would be conducting the required environmental assessments and securing approvals of them.

Box 25.
November 2005 news item on how radically new urban arrangements could be magnets for investment.

British engineers will this week sign a multi-billion contract with the Chinese authorities to design and build a string of 'eco-cities'—self-sustaining urban centres the size of a large western capital—in the booming country. ...

The eco-cities are regarded both as a prototype for urban living in over-populated and polluted environments and as a magnet for investment funds into the rapidly growing Chinese economy. ...

The eco-cities are intended to be self-sufficient in energy, water and most food products, with the aim of zero emissions of greenhouse gases in transport systems. ...

[Project director Peter] Head said: 'It is no gimmick. It is being led at the highest levels of the Chinese government. They are very committed to developing a new paradigm of economic development.'

One international property group, Dublin-based Treasury, has already signed up ... for a €1 billion investment in the Dongtan project.

17. Next steps for Hamilton: The Electric City

It would be appropriate to both deepen and broaden the treatment of every aspect of this report.

If there is interest in pursuing the general direction set out in this report, the first step should be to commission a more in-depth and robust analysis of the matters covered here. The present report aims to give no more than a taste of what could be to come. It was written in a relatively short period with limited resources.

It would be appropriate to both deepen and broaden the treatment of every aspect of this report, and some related matters that have not been considered here. For example, to give just two examples, there has been little consideration here of (i) the condition of Hamilton's current building stock, and (ii) the legislation that Hamilton would require to implement much of what is proposed.

This more in-depth report could be completed in four months and would give Hamilton a good basis for deciding whether to pursue an energy strategy. The present report is *not* a sufficient basis for such a decision. It merely raises several matters for consideration.

After consideration of a more substantial report, City Council could engage ideas such as those in the present report at several levels, ranging from complete embrace to complete rejection. For example, Council may decide that the city should plan for an era of energy constraints, but that preparation for such constraints should not become the main planning objective.

If Council decides not to proceed with a more substantial report, or commissions such a report and then decides to do nothing, prudence would nevertheless suggest that the issues be revisited in two or three years. Energy considerations will become a more important feature of every aspect of life in Hamilton. What is in doubt is only how much more important and how quickly.

The present report has begun elaboration of a vision of Hamilton that again becomes The Electric City. Complete embrace of such a vision could transform not only Hamilton but municipalities across North America.

Notes

- ¹ The quotation is from the ‘GRIDS update’ submitted to Hamilton City Council by the City Manager and dated February 16, 2005. Available at <http://www.myhamilton.ca/nr/rdonlyres/30f3e12d-8332-42aa-ba7d-b29489eea954/0/gridsupdateno2v6.pdf> (accessed April 10, 2006).
- ² *Economic Development Strategy*, 2005. Available at <http://www.myhamilton.ca/nr/rdonlyres/ed4f0e97-34b2-4374-ad24-db034885ecb5/0/ecdevstrategyfinal2005.pdf> (accessed April 10, 2006).
- ³ The quotation is from Page 6 of the source detailed in Note 2.
- ⁴ The quotation is from Page 6 of the source detailed in Note 2.
- ⁵ The quotations are from Page 7 of the source detailed in Note 2.
- ⁶ The specific topic of the meetings was proposed amendment of Official Plans “to recognize and expand the existing airport influence area and to create a special policy area for employment purposes” (from the Minutes 05-13 and 05-15 of the Planning & Economic Development Committee).
- ⁷ The quote is from the Minutes of the June 29, 2005, City Council meeting at [http://www.myhamilton.ca/Hamilton.Portal/Inc/PortalPDFs/ClerkPDFs/council/2005/Jun29/Mi notes.pdf](http://www.myhamilton.ca/Hamilton.Portal/Inc/PortalPDFs/ClerkPDFs/council/2005/Jun29/Mi%20minutes.pdf) (accessed April 10, 2006).
Note that ‘Oil peak’ refers to the notion of peak oil production, discussed later in this report, ‘fleet’ refers to the City’s vehicle fleet, ‘HSR’ refers to Hamilton Street Railway, the name of the City’s transit system.
- ⁸ *Transportation Energy Use and Greenhouse Gas Emissions Policy Paper*, IBI Group, January 2005. Available at <http://www.myhamilton.ca/NR/rdonlyres/0456EB3D-7C02-414A-A025-D77B4534F421/0/7EnergyandGHGJan2005.pdf> (accessed October 3, 2005).
The above paper is one of 24 policy papers prepared in connection with the development of Hamilton’s City-wide Transportation Master Plan. The titles of the other 23 are: Access Management, Accessibility, Air Quality, Background on Land Use and Travel Trends, Economic Development, Funding and Financing, Goods Movement, Level of Service, New Technologies, Noise, Parking, Provincial Highway Initiatives, Road Classifications, Road Transfers, Rural Road Standards, Traffic Calming, Transportation Targets and Transit Strategy, Travel Demand Management, Urban Design, Urban Structure and Land Use, , Walking and Cycling, Warrants, and Summary of Proposed Recommended Policies.
Two more of these papers are referred to in this report. The Goods Movement paper is referred to in Notes 97 and 100. The paper on Transportation Targets and Transit Strategy is referred to in Note 107.
- ⁹ The quotation is from Page 22 of Ormond P, *GRIDS Background Study: Hamilton’s Vulnerability to Climate Change*, September 2004, at

<http://www.vision2020.hamilton.ca/NewVision2020pdf/Background-Study-Final.pdf> (access October 20, 2005).

- 10 The data in this paragraph are from *World Energy Outlook 2004*, International Energy Agency, 2004.
- 11 A recent analysis in *The Economist* (April 28, 2005) concluded that of the 928 billion barrels of reserves held by largest 20 oil companies, 90% are controlled by large national state-owned companies. Saudi Aramco alone is reported to control more than a quarter of these reserves. However, questions have been raised about the accuracy of reserve reporting by these companies.
- 12 According to issues of the International Energy Agencies *Oil Market Report* (available at <http://omrpublic.iea.org/>, accessed April 12 2006), Chinese imports of oil and oil products were 43% higher in 2004 compared with 2003. Imports fell by 5% in 2005. In January 2006, they were 52% above the January 2005 level, and 19% above the average for 2004.
- 13 Box 1 is based on Figure 3.20 on Page 103 of the source detailed in Note 10.
- 14 See in particular Simmons M, *Twilight in the Desert: The Coming Saudi Oil Shock and the World Economy*, Wiley, New York, 2005.
- 15 Interview in *Le Monde*, Paris, September 19, 2005. Fatih Birol's words were, "Le pétrole, c'est comme une petite amie, vous savez depuis le début de votre relation qu'elle vous quittera un jour. Pour qu'elle ne vous brise pas le coeur, mieux vaut la quitter avant qu'elle ne vous quitte." It should be noted too that the International Energy Agency appears to speak with more than one voice. The organization also produces a Fact Sheet entitled *Resources to reserves: Oil and gas technologies for the energy markets of the future*, available at http://www.iea.org/textbase/papers/2005/fs_resources.pdf (accessed April 10, 2006). This document notes that "the world contains at least 20 trillion boe [barrels of oil equivalent] of oil and [natural] gas", that "some 5-10 trillion are technically recoverable today", and that roughly 1.5 trillion boe will be required to meet demand over the next 25 years". By contrast, the IEA's flagship publication, detailed above in Note 10, notes that the amount of "ultimately recoverable" oil—at the beginning of 1996—was 1.7-3.2 trillion barrels (Table 3.4 in that document, Page 102). The same document notes that "ultimate [natural] gas resources" amount to 436 trillion cubic metres (Page 136), or about 2.7 trillion boe. Together these total about 5.1 trillion boe, far short of the "at least 20 trillion boe" suggest in the Fact Sheet. According to the *BP Statistical Review of World Energy 2005* (at <http://www.bp.com/genericsection.do?categoryId=92&contentId=7005893>, accessed April 10, 2006), *proved* reserves of oil and natural gas at the end of 2004 were 1.2 and 1.1 trillion barrels of oil equivalent, respectively.
 Experts themselves are confused by such an array of contradictions. In any case, the basic 'peak oil' issue is not so much the amount in the ground as how much of it can be feasibly extracted in any given period.
 The November 2005 special issue of *World Energy Outlook* noted in this paragraph focussed on resources in the Middle East and North Africa. It adds breadth and depth to the conclusion on Page 110 of *World Energy Outlook 2004* that "Of the projected 31 mb/d rise in world oil demand between 2010 and 2030, 29 mb/d [million barrels a day] will come from OPEC Middle

East ... Saudi Arabia, Iraq, and Iran are likely to contribute most of the increase.” There is a useful commentary on *World Energy Outlook 2005* in the April 2006 newsletter of the Association for the Study of Peak Oil and Gas, available at http://www.peakoil.ie/downloads/newsletters/newsletter64_200604.pdf (accessed April 11, 2006).

- 16 Box 2 is Figure 20 in Aleklett K, *IEA accepts peak oil: An analysis of Chapter 3 of the World Energy Outlook 2004*, available <http://www.peakoil.net/uhdsg/weo2004/TheUppsalaCode.html>. Accessed April 10, 2006. A new analysis, closely linked to this one, puts the date for peak production of all petroleum liquids at 2010. See http://www.peakoil.ie/downloads/newsletters/newsletter64_200604.pdf, accessed April 12, 2006.
- 17 Box 3 is Figure 1 in Smith MR, Putting paid to unrealistic demand predictions. *Petroleum Review*, October 2005.
- 18 A critical matter is the steepness of the post-peak decline in oil production. A recent examination of how oil production peaked in Texas, North America, the United Kingdom, and Norway led to the conclusion that “the onset of peaking can occur quite suddenly, peaks can be very sharp, and post-peak production declines can be comparatively steep (3-13%).” (Hirsch R, Shaping the peak of world oil production, *World Oil*, October 2005, available at http://www.worldoil.com/magazine/MAGAZINE_DETAIL.asp?ART_ID=2696&MONTH_YEAR=Oct-2005, accessed April 13, 2005.)
- 19 See, for example, Deffeyes KS, *Beyond Oil: The View from Hubbert’s Peak*. New York: Farrar, Straus and Giroux, 2005. Providing support for this position is an article in the October 2005 issue of the industry journal *Petroleum Review*, indicating that production of petroleum liquids by four of the largest five public oil companies was down in the first half of 2005 compared with 2004, and down in eight of the largest eleven companies. The article is at <http://www.odac-info.org/bulletin/documents/PetReviewOct2005.pdf> (accessed April 10, 2006).
- 20 The quotations are from a June 21, 2005, press release issued by Cambridge Energy Research Associates (CERA), *Oil & liquids capacity to outstrip demand until at least 2010: new report*, at <http://www.cera.com/news/details/print/1,2317,7453,00.html?> (accessed April 10, 2006). Several commentators also have a more sanguine view. For example, David Frum has written, “The world’s supply of oil is not finite. It is more like a supermarket’s supply of canned tomatoes. At any given moment, there may be a dozen cases in the store, but that inventory is constantly being replenished with the money the customers pay for the cans they remove, and the more tomatoes the customers buy the bigger the inventory the store will carry.” (Don’t worry about running out of oil. *National Post*, January 13, 2005). Even more extreme is a book by Peter W. Huber and Mark P. Mills, *The Bottomless Well: The Twilight of Fuel, The Virtue of Waste, and Why We Will Never Run Out of Energy*. New York: Basic Books, 2005. These authors argue that our energy supply is infinite and demand for energy will never go down. The CERA report has been contradicted by a later article in the industry journal *Petroleum Review*, which projects supply shortfalls in production of 4-6% in each of the years 2006-2010 (Prices set firm, despite massive new capacity, October 2005).

- 21 So, also, does other opinion appear to be moving in this direction. For example, a recent lead article in a major U.S. newspaper suggested that “there will come a day when oil production ‘peaks’, when demand overtakes supply (and never looks back), resulting in large and possibly catastrophic price increases that could make today’s \$60-a -barrel oil look like chump change” (Robert B. Semple Jr., *The End of Oil*, *New York Times*, March 1, 2006).
Among recent analyses accepting ‘peak oil’ is one by the U.S. Army Corps of Engineers, which included the following: “Peak oil is at hand ... Once worldwide petroleum production peaks, geopolitics and market economics will result in even more significant price increases and security risks. ... Oil wars are certainly not out of the question. Disruption of world oil markets may also affect world natural gas markets as much of the natural gas reserves are collocated with the oil reserves.” (Eileen T Westervelt, Donald F. Fournier, *Energy Trends and Implications for U.S. Army Installations*, Report ERDC/CERL TN-05-1, September 2005, available at <http://stinet.dtic.mil/cgi-bin/GetTRDoc?AD=ADA441046&Location=U2&doc=GetTRDoc.pdf>, accessed April 12, 2006.)
- 22 *Oil Shockwave: Oil Crisis Executive Simulation*. U.S. National Commission on Energy Policy, June 2005, available <http://www.energycommission.org/ewebeditpro/items/O82F6801.pdf> (accessed April 10, 2006).
- 23 The expert is Matthew Simmons, energy investment banker and advisor to the U.S. president on energy issues. In a recent presentation at the University of Wyoming, he was reported as saying, “We could be looking at \$10-a-gallon gas this winter”. See Klobnak-Ball J, *Matt Simmons issues a wake-up call*, at http://www.planetjth.com/klobnak/klobnak_2005_09_28_energy.html (accessed April 10, 2006).
The indicated Canadian equivalent assumes an 85¢ Canadian dollar and 15¢ higher taxes per litre in Canada than in the U.S.
- 24 See the chart in Section IV.2 of *Toward 2025: Assessing Ontario’s long-term economic outlook* at http://www.fin.gov.on.ca/english/economy/ltr/2005/05_ltr.html#l2_5b (assessed March 7, 2006). These oil price projections are based on the work of Calgary-based Sproule Associates Ltd. The author of the present paper asked Sproule for the basis of its prediction. The response from Nora Stewart was “A combination of increased production and world demand will contribute to a decline in the oil price. We also take into consideration the full-cycle cost of incremental supplies. We select a long term outlook that we consider reasonable and hold it flat. It is impossible to forecast the future. To forecast variations in the long term outlook would be too presumptuous. Excel spreadsheets are used to generate the forecasts.” (e-mail from Diana Berry, February 14, 2006).
- 25 There’s more variability in what consumers pay for natural gas than oil. All-in prices in October 2005 (including delivery charges, administration, and GST) appear to be about 25% higher than the average for last winter, with the prospect of a further, perhaps larger increase at the beginning of 2006.
- 26 For North American production of natural gas, see the tables on Pages 22 and 23 of *BP Statistical Review of World Energy 2005*, available at <http://www.bp.com/genericsection.do?categoryId=92&contentId=7005893> (accessed April 10, 2006).

- 27 Box 4 is from data at the Web site of the Canadian Association of Petroleum Producers at http://www.capp.ca/default.asp?V_DOC_ID=690 (accessed April 10, 2006).
- 28 See Ontario Power Authority's *Supply Mix Advice Report*, December 9, 2005, at <http://www.powerauthority.on.ca/Page.asp?PageID=924&SiteNodeID=157> (accessed April 10, 2006).
- 29 The quotation is from Powers B, *Assessment of Potential Risk Associated with Location of LNG Receiving Terminal Adjacent to Bajamar and Feasible Alternative Locations*, available at http://www.borderpowerplants.org/pdf_docs/lng_position_paper_june2002_english.pdf. (accessed April 10, 2006)
- 30 Box 5 is from Slide 4 of a presentation by Harry J. Longwell, Executive VP, Exxon Mobil Corporation at the Offshore Technology Conference, Houston, Texas, May 7, 2002, available at http://www.exxonmobileurope.com/Corporate/Newsroom/SpchsIntvws/Corp_NR_SpchIntrvw_Houston_070502.asp (accessed April 10, 2006). The continuing failure to replace reserves through discoveries, at least among *public* companies, is highlighted in a recent report *Exploration Strategy and Performance* by consultants Wood Mackenzie, available at http://www.woodmacresearch.com/cgi-bin/wmprod/portal/energy/highlightsDetail.jsp?BV_SessionID=@ @ @ @0081086032.1143220360 @ @ @ @ &BV_EngineID=cccdaddhgejkghgcflgcegjdfjdgig.0&oid=697482 (accessed April 10, 2006).
- 31 The expert was Michael Zenker of Cambridge Energy Research Associates, the consulting firm with the bullish views about short-term oil prospects (see Note 20 and associated text). Mr. Zenker's testimony is at <http://www.cera.com/news/details/print/1,2317,7605,00.html>? (accessed April 10, 2006).
- 32 Nationalization of Canada's oil and natural gas resources has been proposed as a remedy for Canada's energy predicament. However, very few would regard this as a politically feasible option. The question of nationalization and the issue of security of Canada's supply of petroleum resources are linked to considerations of the North American Free Trade Agreement (NAFTA). These complexities are touched on in the author's op-ed piece 'Let's Reroute our Energy Strategy' *Globe & Mail*, October 17, 2005, at <http://www.theglobeandmail.com/servlet/ArticleNews/TPStory/LAC/20051017/CONAFTA17/TPComment/TopStories> (accessed April 10, 2006).
- 33 The source is detailed in Note 21.
- 34 The more conservative analysis is in Perry GL, *The War on Terrorism, the World Oil Market and the U.S. Economy*. Analysis Paper #7. Washington DC: The Brookings Institution, October 24, 2001, available at <http://www.brookings.edu/views/papers/perry/20011024.htm> (accessed April 12, 2006).
- 35 See, in particular, the source detailed in Note 14.

- ³⁶ The chart in Box 7 was adapted from Figure 9 of Bossel U, *Does a Hydrogen Economy make Sense?* Paper presented at the European Fuel Cell Forum, Lucerne, Switzerland, July 4-8, 2005, available at <http://www.efcf.com/reports/E13.pdf> (accessed April 10, 2006).
- ³⁷ One indication that the hope for fuel cells for mobile applications may be running out of steam is the failure of the Canadian Transportation Fuel Cell Alliance to allocate more than a small part of the \$23 million (now \$33 million) with which it was established in 2001 to provide in support of worthwhile projects. See the CTFCA's Web site at http://www.nrcan.gc.ca/es/etb/ctfca/index_e.html (accessed April 10, 2006). Another indication is that General Motors recently put the development of its Sequel fuel cell concept vehicle on hold. See English A, You take the hydrogen road. *Daily Telegraph* (London, UK), October 1, 2005, at <http://motoring.telegraph.co.uk/motoring/main.jhtml?xml=/motoring/2005/10/01/mflarry01.xml> (accessed April 10, 2006).
- ³⁸ A new plant in Goldfield, Iowa, appears to require 100,000 tonnes of coal a year to produce about 200 million litres of ethanol from about 600,000 tonnes of corn—harvested from what is likely 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. See Mark Clayton, Carbon cloud over a green fuel, *Christian Science Monitor*, March 23, 2006, at <http://www.csmonitor.com/2006/0323/p01s01-sten.html> (accessed April 12, 2006).
- ³⁹ A brief and useful account of coal-to-liquid technology is Bensaid B, *Alternative Motor Fuels Today and Tomorrow*, Institut Français du Pétrole, 2005, at http://www.ifp.fr/IFP/en/files/cinfo/IFP-Panorama05_06-CarburantsalternatifsVA.pdf, accessed April 11, 2006. The author notes the high emissions of greenhouse gases from available processes. In the U.S., strongly supported by the federal government, the FutureGen Industrial Alliance is seeking “to design, build, and operate, the world’s first coal-fueled, ‘zero emissions’ power plant” by 2013. See <http://www.futuregenalliance.org/>, accessed April 11, 2006.
- ⁴⁰ As noted in Section 4, the reference prices of \$4/L and \$2/m³ are *real* prices, i.e., they are stated in 2005 dollars rather than the dollars of the day.
- ⁴¹ Box 8 is based on data for the period September 19-22, 2005, mostly provided by the UK Automobile Association at <http://www.aamotoringtrust.com/index.asp?pageid=31&newsid=56> (accessed October 1, 2005). Australian data are from the Australian Institute of Petroleum’s Web site at <http://www.aip.com.au> (accessed October 1, 2005). Canadian data are from MJ Ervin & Associates Web site at http://www.mjervin.com/WPPS_Public.htm (accessed October 1, 2005). Japanese data are from <http://www.japantoday.com/e/?content=news&cat=3&id=350083> (accessed October 1, 2005). Currency conversions were done through <http://www.oanda.com/convert/fxhistory> (accessed October 1, 2005).
- ⁴² The transport data for Canada in Box 9 and Box 10 are from Natural Resources Canada’s *Energy Use Data Handbook Tables* at http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/handbook_tables.cfm?attr=0 (accessed April 10, 2006). Population data for Canada are from Statistics Canada at <http://www.statcan.ca/english/freepub/98-187-XIE/pop.htm#53> (accessed April 10, 2006). Data

for Europe are from *Energy and Transport in Figures 2005* (Eurostat and European Commission) at http://europa.eu.int/comm/dgs/energy_transport/figures/pocketbook/doc/2005/etif_2005_whole_en.pdf (accessed April 10, 2006).

⁴³ The all-in average price in EU15 is about €13.00 per gigajoule (see Table 2.5.8 of the last source detailed in Note 42). This is equivalent to about Can\$18.00/GJ or about 67 cents per cubic metre.

⁴⁴ We don't have good Canadian data on responses to price increases in gasoline. There are good U.S. data at the Web site of the U.S. Department of Energy at http://www1.eere.energy.gov/vehiclesandfuels/facts/2005/fcvt_fotw364.html (accessed April 10, 2006). They go back to the time of the first oil embargo, in the 1970s, when crude oil and pump prices changed considerably. There were substantial increases in the real retail price of gasoline compared with the previous years in 1974 and 1979, when it rose by 22% and 23%, respectively. These were also the only years in the 1970s in which per-capita gasoline consumption declined, by 2.0% and 5.1%, respectively. The largest real increase before 2005 was 28% in 1980, when per-capita consumption fell by 5.8%. Economists refer to the relationship between price and consumption as elasticity. The price elasticity of demand for gasoline in the U.S. over the period 1960-2002 is -0.14, meaning that on average a 0.14% change in consumption occurred for each 1.0% change in price, in the opposite direction. Thus, at least in the short term (up to a year), gasoline consumption is fairly *inelastic*, i.e., it does not change much with changes in price. In general, price elasticities of demand for transport fuels and natural gas appear to both be low in the short term and higher in the longer term, with the latter tending to be somewhat less elastic. (See, for example, <http://www.mackinac.org/article.aspx?ID=1247>, accessed April 10, 2006.)

A point of interest regarding gasoline prices in the 1970s and early 1980s is that they were not evidently related to crude oil prices. A chart provided by the Government of Canada's Department of Finance shows that before 1986 Canadian pump prices varied independently of crude oil prices, but that since 1986 they have changed more or less in lock-step. Pump prices reached their highest levels in real terms in the summer of 2005 even though crude oil prices had been higher in real terms in the early 1980s. What happened in 1986 to align pump prices with crude oil prices is unclear. (See *Background: Oil and Gas Prices, Taxes and Consumers*. Ottawa: Department of Finance, 2005, at http://www.fin.gc.ca/toce/2005/gas_tax-e.html, accessed April 13, 2006.)

⁴⁵ Energy management is recognized as a potential municipal responsibility in Ontario's *Municipal Act*. Section 147(1) of the *Act* reads:

A municipality may provide, arrange for or participate in an energy conservation program in the municipality to encourage the safe and efficient use and conservation of all forms of energy including, but not limited to,

- (a) the improvement of an energy system in a building;
- (b) the substitution of one form of energy for another form of energy;
- (c) the improvement of the capacity of a building to retain heat;
- (d) the reduction of energy use through more efficient use of energy; and
- (e) the shifting of electrical loads from times of high demand to times of low demand.

Section 147(2) reads:

Subsection (1) does not authorize a municipality to lend money out of its own funds as part of an energy conservation program.

(See http://www.e-laws.gov.on.ca/DBLaws/Statutes/English/01m25_e.htm, accessed April 11, 2006.)

The November 2005 *Proposed Growth Plan for the Greater Golden Horseshoe*, which, when adopted, will become official provincial policy and thus bind municipalities in the covered geographic area, says in Section 4.2.4:

Municipalities will develop and implement official plan policies and other strategies in support of the following conservation objectives ...

b) Energy conservation including

- i. Energy conservation for municipally owned facilities
- ii. Identification of opportunities for, and where possible locations for, alternative energy generation and distribution
- iii. Energy demand management to reduce energy consumption
- iv. Land-use patterns and urban design standards that encourage and support energy-efficient buildings and opportunities for co-generation.

(See

http://www.pir.gov.on.ca/userfiles/page_attachments/Library/4/PGPENGfullIPP.pdf?N_ID=4, accessed April 11, 2006.)

⁴⁶ The only other municipality in Canada to address the matter of high oil prices so far may be Burnaby, British Columbia. A staff report entitled *Global Peak In Oil Production: The Municipal Context* was considered by Burnaby City Council in January 2006. These were its major findings:

- The consumption of energy is essential to economic vitality.
- Oil is a finite resource. It will run out. Long before it runs out, production will peak and decline. Prices will rise, and consumption will be forced to decline. This will have a profound affect on our society.
- The date of the peak is a matter of considerable debate. Most projections fall in the range of 2008 to 2037, generally closer to the earlier date. However, in view of the time needed for mitigation, even 2037 is very soon.
- We are an energy-intensive society. There is much that we can do to reduce consumption. Actions fall into three categories: develop other energy sources, increase efficiency, and change consumption patterns.
- To minimize the impact on our economy and society, all levels of government and the corporate sector should begin preparations well before the peak. This is because our current consumption patterns are imbedded in our infrastructure (for energy production, transmission, and consumption) which can only be amended through a substantial investment of time and money.

The Burnaby report is available at

<http://burnaby.fileprosite.com/contentengine/launch.asp?ID=1056> (accessed April 10, 2006). It includes a tabular appendix entitled ‘Possible Municipal Actions to Address Peak Oil’.

⁴⁷ If there is a fourfold increase in price, 150% of current expenditures will buy 37.5% ($=4/1.5$) of what was bought before the price increase.

⁴⁸ The current (2006) population figure of 525,000 is based on the table in Schedule 3 of *Places to Grow: Proposed Growth Plan for the Greater Gold Horseshoe*, Ontario Ministry of Public In-

frastructure Renewal, November 2005, available at http://www.pir.gov.on.ca/userfiles/page_attachments/Library/4/PGPENGfullPP.pdf?N_ID=4 (accessed April 10, 2006). This source also estimates that Hamilton's population will be 660,000 in 2031. The City of Hamilton has been working on the basis that its population will be 700,000 in 2031 (see the source detailed in Note 1). A November 2005 City document sets out five growth options, one of which (No Expansion to the Urban Area Boundary) speaks to a 2031 population of 666,000 and the others to a 2031 population of 700,000. More precisely, these options speak to population increases of 150,000 and 190,000 respectively. Given that the population is now about 525,000 (see the beginning of this note), even the lower increase would mean that the present provincial projection for Hamilton's 2031 population would be exceeded. The November 2005 document is entitled *G.R.I.D.S. Growth Options (CM05038)* and is available at <http://www.myhamilton.ca/NR/rdonlyres/F87781DF-8E05-4D49-B058-C034C515FF98/0/20GRIDSStaffReport.pdf> (accessed April 10, 2006).

- ⁴⁹ Box 11 and the information in this paragraph are based on Natural Resources Canada data *for Ontario* in 2003, at http://www.oee.nrcan.gc.ca/corporate/statistics/neud/dpa/comprehensive_tables/index.cfm?attr=0 (accessed April 10, 2006). Note that about 14 per cent of energy end use in Ontario uses fuels other than electricity, oil, and natural gas, chiefly coal products and wood waste used by industry. This fuel use is not considered in the present analysis.
- ⁵⁰ One petajoule is the usable energy in about 278 gigawatt-hours of electricity, or 26 million litres of diesel fuel, or 29 million litres of gasoline, or 27 million cubic metres of natural gas. See the National Energy Board's conversion tables at http://www.neb-one.gc.ca/Statistics/EnergyConversions_e.htm (accessed April 10, 2006).
- ⁵¹ A recent thorough discussion of these matters is in the source detailed in Note 28. This report proposes that Ontario continue to rely on nuclear energy for about half of its electricity generation, and notes that to achieve this just about all of the province's existing nuclear capacity will have to be replaced by 2025. The report also suggests that "Changes in the Ontario electricity sector over the past few years make it possible to better manage the major risks of nuclear construction, which are cost overruns and delays. ... Significant progress has been achieved on the issue of spent nuclear fuel management."
- ⁵² Information about Hamilton Community Energy in this paragraph is from HCE's Web site at <http://www.hamiltonce.com> (accessed April 10, 2006).
- ⁵³ The rough estimate that 25% of floor space in Hamilton in 2018 will have been constructed since 2005 is based on data in the first source in Note 42 indicating that residential floor space *in Canada* increased by 29% between 1990 and 2003 and commercial-industrial floor space increased by 25%. Similar rates of growth are assumed for 2005-2018, and also that about 5% of the stock will be demolished during that period. Hamilton's rates are assumed to be similar to Canada's.
- ⁵⁴ The estimates for 2003 in Box 12 are based on Natural Resources Canada's estimates for Ontario, detailed in the source in Note 49, except for the breakdown between car and transit passenger-kilometres, which is based on data from the Transportation Tomorrow Survey for 2001,

available at <https://www.jpint.utoronto.ca/> (site of the Joint program in Transportation, University of Toronto, accessed April 10, 2006).

- 55 According to *Consumer Reports*, April 2006, available for a fee at <http://www.consumerreports.org/cro/cars/new-cars/high-cost-of-hybrid-vehicles-406/hybrids-vs-all-gas.htm> (accessed April 11, 2006), the following savings in fuel consumption can be expected from the six most popular hybrid models, in comparison with their closest equivalent all-gasoline models: Ford Escape (31%), Honda Accord (8%), Honda Civic (24%), Toyota Lexus (22%) Toyota Highlander (14%), Toyota Prius (34%). The average savings (not sales weighted) is 22%.
To achieve the target in the text of a 50% reduction in fuel use, the vehicle would also have to be downsized by 34%, i.e., be 34% smaller or have 34% less power, or a combination of the two that resulted in 34% less fuel use, other things being equal.
According to the U.S. Environmental Protection Agency, between 1987 and 2005, the weights of personal vehicles increased by about 25% and the engine power by about 75% with hardly a change in fuel intensity. (See *Light-Duty Automotive Technology and Fuel Economy Trends: 1975 Through 2005*, U.S. Environmental Protection Agency, Washington DC, 2005, available at <http://www.epa.gov/OMS/fetrends.htm>, accessed April 11, 2006.) If the achievements had instead been applied to reducing fuel use, the average fuel consumption of new personal vehicles could be 55% less than the current level. Thus, a reduction by 34% is entirely achievable, if consumers seek smaller, less powerful vehicles and manufacturers provide them.
- 56 The comparisons in this paragraph are based on data on U.S. systems provided by the American Public Transportation Association (APTA), available at <http://www.apta.com/research/stats/> (accessed April 11, 2006).
- 57 TransLink, which operate the Vancouver region's transit system, has provided the author with data suggesting that Vancouver's trolleybuses use considerably less electricity per passenger-kilometre than the SkyTrain system.
- 58 See *Industrial Hamilton: A Trail to the Future* at <http://collections.ic.gc.ca/industrial/dominion.htm> (accessed April 11, 2006).
- 59 A University of Washington Web site provides useful information about PRT, and links to numerous other sites. It is at <http://faculty.washington.edu/jbs/itrans/> (accessed April 11, 2006).
- 60 The illustration in Box 15 are of the Danish RUF (Rapid Urban Flexible) system. The RUF Web site is at <http://www.ruf.dk/> (accessed April 11, 2006).
- 61 For information about plug-in hybrids, see <http://www.iags.org/pih.htm> (accessed April 11, 2006). Also see the Web site of the California Cars Initiative at <http://www.calcars.org/> (accessed April 11, 2006).
- 62 Data on plug-in hybrids at the second source in Note 61 suggest that regular overnight charging of one vehicle at current rates and conditions in Ontario would raise household electricity use by between a third and a half and cost about 90¢ a night for about 50 kilometres of electric-only driving the next day. Note that a reduction by 100% means that no gasoline is used

- ⁶³ The Smart Commute Web site is at <http://www.smartcommute.ca/> (accessed April 11, 2006).
- ⁶⁴ Since December 13, 2005, HOV lanes have been open on Highway 403, in both directions between Highways 407 and 401, and southbound on Highway 404 from Highway 7 to Highway 401.
- ⁶⁵ See the discussion of elasticities in Note 44.
- ⁶⁶ An example of load control is Toronto Hydro's new peakSAVER program, described at <http://www.torontohydro.com/electricsystem/powerwise/peaksaver/faq/index.cfm#q14> (accessed April 11, 2006). Control over residential central air conditioning units and other equipment is assigned to Toronto Hydro. Using radio signals, they can be switched off briefly so as to reduce peak loads. Participating households are given \$25 on signing up, and the chance to win prizes, but receive no other benefit. For many decades until forbidden to do so by Ontario's *Energy Competition Act 1998*, Toronto Hydro rented water heaters that could be switched off during peak periods by a signal down the power wire.
- ⁶⁷ Box 16 is based on data in the source detailed in Note 49.
- ⁶⁸ The full title of this book is *A Handbook on Low-Energy Buildings and District Energy Systems: Fundamentals, Techniques, and Examples*. It is scheduled to be published by Earthscan/James & James (London, UK) in June 2006. See <http://shop.earthscan.co.uk/ProductDetails/mcs/productID/616> (accessed April 11, 2006).
- ⁶⁹ See Note 53 for the analysis supporting this projection.
- ⁷⁰ In respect of this proposal, it can be noted that in Marshall Homes' Copperfield development in Oshawa, energy consumption will be 79% below the standard through use of a solar geoexchange system that uses solar energy and underground heating and cooling. See <http://www.marshallhomes.ca/housewarming/> (accessed April 11, 2006).
- ⁷¹ The information source for the first four listed houses in Box 18 is Figure 3-4 on Page 18 of *Improving Energy Performance in Canada: Report to Parliament under the Energy Efficiency Act For the Fiscal Year 2002-2003*, Ottawa: Office of Energy Efficiency, Natural Resources Canada, 2005, at <http://oee.nrcan.gc.ca/Publications/statistics/parliament04-05/pdf/parliament04-05.pdf> (accessed April 12, 2006). The information for the 'Advanced house' is from *Energy-Efficient Advanced House with Integrated Mechanical System*, Ottawa: Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADET), Natural Resources Canada, 1992, at <http://oee.nrcan.gc.ca/Publications/infosource/Pub/ici/caddet/english/pdf/D025.pdf> (accessed April 12, 2006).
- ⁷² The discussion in Note 48 suggests that Hamilton's projected population increase can be comfortably accommodated within the existing urban boundary.
- ⁷³ The amount of solar energy bathing Hamilton is in the order of 10 petajoules a day. This conservatively assumes a mean annual insolation rate of 3 kWh/m²/day (see http://www.apricus-solar.com/html/insolation_levels_canada.htm, accessed April 11, 2006, for a yearly average of

3.44 kWh/m²/day for Toronto) and that Hamilton's land area is 1,000 square kilometres (actually 1,112.98 sq. km, according to the City's Web site). Box 11 notes that Hamilton's current energy use is about 72 petajoules a year, say 100 petajoules if industrial and agricultural uses are included. Thus, the sun's rays bath Hamilton with about 36 times as much energy as is used in Hamilton.

- 74 Islam, Mazharul, Amir Fartaj, David S.-K. Ting. (2004). Current utilization and future prospects of emerging renewable energy applications in Canada. *Renewable and Sustainable Energy Reviews*, 8, pp. 493–519.
- 75 For an authoritative review of renewable energy worldwide, see *Renewables 2005: A Global Status Report*, available from the Worldwatch Institute at <http://www.worldwatch.org/brain/media/pdf/pubs/ren21/ren21-2.pdf>, accessed April 11, 2006. (Notes and references for this report are available at <http://www.worldwatch.org/brain/media/pdf/pubs/ren21/ren21-2-notes.pdf>, accessed April 11, 2006.)
- 76 A capacity factor of 33% is assumed. This may be a reasonable average value for a mix of land and water installations of large wind turbines. (See, for example, Paul Chernick, Brian Tracey, Susan Geller, *Costs and Environmental Effects of Wind Turbines and Natural-Gas Generation*, Resource Insight, Inc., June 2003, at http://www.capelightcompact.org/pdfs/FIN_WIND-NATURAL_GAS_REPORT.pdf, accessed April 11, 2006.)
- 77 According to Enwave Energy Corporation, which manages Toronto's district cooling system, the current capacity is 75,000 tons of refrigeration. See <http://www.enwave.com/enwave/view.asp?dlwc/energy>, accessed April 11, 2006. A refrigeration ton is equivalent to 3.517 kW (see <http://www.unc.edu/~rowlett/units/dictT.html>, accessed April 11, 2006).
- 78 Communication with Kevin Loughborough, Vice-President, Major Projects, Enwave eEnergy Corporation, August 2005.
- 79 The *International Small-Hydro Atlas* is available at <http://www.small-hydro.com> (accessed April 10, 2006).
- 80 This assumes a capacity factor of about 50% over the year. This appears to be a reasonable world average for hydroelectric facilities. (See http://www.worldenergy.org/wec-geis/publications/default/tech_papers/17th_congress/3_1_10.asp#Heading6, accessed April 11, 2006.)
- 81 See Hamilton Community Energy's Web site at http://www.hamiltonce.com/html/static/current_projects.shtml, accessed April 10, 2006.
- 82 This estimate assumes generation of 0.5 tonne of municipal waste per person and 0.5 tonnes of commercial industrial waste—all not suitable for recycling or reuse—for a population of seven million.

- ⁸³ A proposal similar to that in this section has been made for the never-used and mothballed Wesleyville Generating Plant in Clarington. The proposal “envision[s] Wesleyville as the site of an advanced energy-from-waste facility - a high-tech incinerator - capable of processing all the municipal solid waste from Cornwall to Niagara Falls to Windsor, which would otherwise end up in Michigan or local landfills. Not only would the site theoretically solve a major crisis for Toronto - what to do if Michigan decides to close its border to Canadian trash - but it would also contribute hundreds of megawatts to Ontario's electricity system at a time of tightening supply, caused in large part by the shutdown of provincial coal-fired plants.” (Tyler Hamilton, A burning desire for power, *Toronto Star*, February 12, 2006, at http://www.thestar.com/NASApp/cs/ContentServer?pagename=thestar/Layout/Article_PrintFriendly&c=Article&cid=1139699409673&call_pageid=968332188492 (accessed March 7, 2006)). If the notion of a major energy-from-waste plant takes hold, there could well be competition among municipalities to host such a plant. In the meantime, Ontario Power Generation, which owns the Wesleyville plant, has been reported as considering converting it into a nuclear generating station. (Martin Mittelstaedt, Ontario utility eyes two sites for nuclear reactors. *Globe & Mail*, February 14, 2006, at <http://go.mobile.globeandmail.com/generated/archive/RTGAM/html/20060214/wxnukes14.html>, accessed April 11, 2006.)
- ⁸⁴ The proposal is: McViro Consultants Inc. and Jacques Whitfield Ltd, *Evaluation of “Alternatives To” and Selection of a Preferred Disposal System: Draft Report*, December 5, 2005, at http://www.wasteplan.ca/library_wasteplanreports.cfm (accessed April 11, 2006).
- ⁸⁵ Liberty Energy's Web site is at <http://www.libertyenergy.ca/> (accessed April 11, 2006).
- ⁸⁶ See, for example, See Eliasson G, *Biogas as a transportation fuel*. Paper presented at the Ökosociales Forum Österreich, Grax, Austria, January 2005, available at 1. http://www.oesfo.at/static/mediendatenbank/root01/Veranstaltungen%20Downloads/Mitteuropa%20C3%A4ische%20Biomassekonferenz%202005/Votr%C3%A4ge/Eliasson_long.pdf. Accessed April 11, 2006.
- ⁸⁷ For an overview of manure production in Ontario and shares from cows (57%), swine (35%), and poultry (8%), see Ken McEwan, The lowdown on manure production in Ontario, *Agri-food research in Ontario*, Spring 2001, at <http://www.omafra.gov.on.ca/english/research/magazine/spring01/pg6.htm>, accessed April 11, 2006. The following conversion factors were used to litres of biogas: cow manure, 33%; swine manure 39%, chicken manure, 100%. In estimating energy value, the resulting biogas was assumed to be 50% methane.
- Also see Daid Layzell, Jamie Stephen, and Susan Wood, *Exploring the Potential for Biomass Power in Ontario*, BIOCAP Canada, February 2006, at http://www.biocap.ca/files/Ont_bioenergy_OPA_Feb23_final.pdf, accessed April 11, 2006, which estimates the annual energy value of biogas from animal manure as being 21.0 PJ. A further useful source is Ken Rich and several others, *Biomethane from Dairy Waste: A Sourcebook for the Production and Use of Renewable Natural Gas in California*, July 2005, at http://www.calstart.org/info/publications/Biomethane_from_Dairy_Waste_Full_Report.pdf, accessed April 11, 2006.

- ⁸⁸ One method—developed near Perth, Ontario—that may be promising involves constructing greenhouses with double plastic walls and pumping soap bubbles into the wallspace, using geo-thermal exchange to warm the bubbles in winter and cool them in summer. Construction costs are about three times higher than a conventional greenhouse (about \$12,000 for a 110-square-metre structure, vs. \$4,000), but heating costs are estimated to be 87% lower: \$90 vs. \$700. Thus, the simple current payback period is about 13 years. If the price of propane or other fuel were to rise by a factor of four, the payback period would be just over three years. The system is described in Peter Benner, Bubbles, Tiny Bubbles: Bubble Greenhouse Technology. *Canadian Organic Grower*, Winter 2005, pp. 18-21. See also <http://www.tdc.ca/bubblegreenhouse.htm>, (accessed April 12, 2006).
- ⁸⁹ According to the brochure *Connecting a Community*, produced by Hamilton Hydro Inc., “Electric power came to Hamilton in the 1880s. It was introduced so quickly that some citizens soon claimed the title ‘The Electric City’.” The initial generation, in 1884, used waste steam from the printing presses of the *Hamilton Spectator*. Three early documents have the title ‘Hamilton: The Electric City’: *Hamilton: The Electric City: History, Government, and Prosperity of the Birmingham of Canada*, Industrial Recorder Company, 1901 (University of Toronto Library, microfiche78084); *Hamilton: The Electric City*, Seavey, 1907? (McMaster University Library, Call no. FC 3098.37 .H354); *Hamilton: The Electric City of Canada*, Souvenir Edition of *Magazine of Industry and Daily Times*. Hamilton, December 1910, cited in the source detailed in Note 58. See also Ian Vincent, *Hamilton: The Electric City of Canada*, Master of Museology thesis, University of Toronto, 1974.
- ⁹⁰ The quotations are from John Kasarda, Logistics and the rise of aerotropolis, *Real Estate Issues*, 25, 4, 43-48 (2001), which is a version of the article in which the term was introduced. The full context of the quoted phrases is given in the following:
- Emerging corridors, clusters, and spines of air-port induced businesses are giving rise to new urban forms as much as 15 miles from major airports. These represent the beginnings of the aerotropolis. In response to the new economy’s demands for speed and reliability, the aerotropolis is based on low density, wide lanes, and fast movements. In other words, form is following function.
- Although aerotropolis have so far evolved largely spontaneously—with previous development creating arterial bottlenecks—in the future they will be improved through strategic infrastructure planning. For example, dedicated expressway links (aerolanes) and high-speed rail (aerotrails) will efficiently connect airports to nearby and more distant business and residential centers. Special truck-only lanes will likely be added to airport expressways, as well. Seamlessly connected multi-modal infrastructure will accelerate intermodal transfers of goods and people, improving logistic system effectiveness and further influencing business location and resulting urban form. ...
- While multiple transportation modes will continue to shape metropolitan growth, substantial evidence is accumulating that major airport are generating concentrations of commercial activities that are leading to a new aviation-linked urban form—the aerotropolis. Real estate professionals who recognize this megatrend can select strategic sites near gateway airports and position investment to be leveraged by air commerce. Planners and developers who design and build infrastructure and facilities that are consistent with the new form and function of the aerotropolis can contribute substantially to the economic competitiveness of urban areas and to the emerging needs of business.

- ⁹¹ The quotations are from Pages 53 and 7 of the City of Hamilton’s May 2005 *Economic Development Strategy* (2005), which is at <http://www.myhamilton.ca/nr/rdonlyres/ed4f0e97-34b2-4374-ad24-db034885ecb5/0/ecdevstrategyfinal2005.pdf> (accessed April 11, 2006).
- ⁹² According to Airbus S.A.S, Global Market Forecast 2004-2023, December 2004, at http://www.airbus.com/store/mm_repository/pdf/att00003033/media_object_file_GMF2004_full_issue.pdf (accessed April 11, 2006), 41% of air freight tonne-kilometres worldwide were performed in passenger aircraft in 2003. This share is expected to decline to 34% by 2023. Almost all other air freight is carried in dedicated air freighters.
- ⁹³ In some aviation statistics, freight and passengers are noted interchangeably, with one tonne of freight being equivalent to about 11 passengers. See, for example, the June 2005 press release of the Montreal-based International Civil Aviation Organization at http://www.icao.int/icao/en/nr/2005/pio200506_e.pdf (accessed April 11, 2006).
- ⁹⁴ These forecasts are in *Current Market Outlook*. Boeing Commercial airlines, June 2005, at http://www.boeing.com/commercial/cmo/pdf/cmo2005_OutlookReport.pdf (accessed October 25, 2005).
- ⁹⁵ See also the September 2005 statement by James May, President and CEO of the Air Transport Association of America, whose airline members move more than 90 per cent of air passenger and cargo traffic in the U.S., before a committee of the U.S. Senate (see <http://commerce.senate.gov/pdf/katrina-aviationhrg-091405.pdf>, accessed April 11, 2006):
Over the last four years, the industry – in total – has recorded over \$32 billion in net losses ... Eleven of the 12 passenger airlines rated by Standard & Poor’s are considered “speculative” investments, also known as “junk bond” quality. ... If the price of oil stays high ... I expect more jobs lost, more flights cut and more airlines in crisis. ... the airline industry is one of the most severely hurt by the soaring price of oil. Since we have no other options, airplanes will be burning refined oil long after other modes of transportation have moved beyond it. Not because we want to but because the principles of aircraft design rule out alternatives.”
- ⁹⁶ Box 20 is based on data in the source detailed in Note 54. The same source indicates that the Regions of Halton and Peel, by comparison, showed larger increases in jobs than workforce over the same period. The respective increases were 33.6% and 57.4% for Halton and 61.1% and 82.5% for Peel.
- ⁹⁷ For the IBI Group’s January 2005 *Goods Movement Policy Paper* see <http://www.myhamilton.ca/NR/rdonlyres/34265E2F-DFC0-435A-8658-1F989BDD175D/0/8GoodsMovementJan2005.pdf> (accessed April 11, 2006).
- ⁹⁸ The quotation is from Page 2 of the source detailed in Note 97.
- ⁹⁹ Box 21 is taken from Exhibit 3.1 on Page 12 of the source detailed in Note 97.
- ¹⁰⁰ IBI Group on Page 3 of its *Goods Movement Policy Paper* (see Note 97) noted, “The City of Hamilton does not have complete information on freight transportation, although data collected for the Hamilton Perimeter Road assessment is a start (this is a general and chronic issue on a

national scale). Lack of freight data is a critical issue for transportation planning and for solving traffic congestion problems.” An illustration of this challenge is that the only data IBI Group was able to include in *Policy Paper* on goods movement by truck concerned movement of goods to and from Hamilton in for-hire trucks only. There are several indications that most truck movement in Canadian cities involves movement with the cities, rather than between cities, and is performed by private trucking, i.e., in vehicles owned by the owners of the goods being transported.

- ¹⁰¹ The energy use estimates are from the source detailed in Note 49. The population estimates are those of the Ontario Ministry of Finance at <http://www.fin.gov.on.ca/english/demographics/cenpe0311.html> (accessed April 11, 2006).
- ¹⁰² Box 23 is from Sailing ships with a new twist, *The Economist*, September 15, 2005. Beluga Shipping GmbH (Bremen, Germany) will install a SkySails system on the multi-purpose heavy cargo freighter MS Beluga SkySails, to be in operation in 2007, with hopes for regular sales of the system to begin in 2008. See <http://skysails.info/index.php?id=16&L=1> (accessed April 11, 2006).
- ¹⁰³ According to City officials (e-mail communication from the City Manager’s Office sent on April 5, 2006), “The City has a fleet of about 1,400 vehicles. It has already decided it will be a leader in the adoption of new automotive technology that significantly reduces fuel use. Its fleet of hybrid light-duty vehicles is one of the largest in Canada with 40 hybrid vehicles now in service. The City’s actions have intended to send a compelling signal to the auto manufacturers that a market exists for more fuel-efficient vehicles and is committing to their production by placing firm orders for them.”
- ¹⁰⁴ See, for example, the Web site of Vancouver-based Azure Dynamics at http://www.azuredynamics.com/about_azure.htm (accessed April 11, 2006).
- ¹⁰⁵ For this history of the HSR, see <http://www.trainweb.org/elso/hsr.htm> (accessed April 11, 2006).
- ¹⁰⁶ The photo of the Hamilton trolleybus on the front of this report is from <http://transit.toronto.on.ca/streetcar/4751.shtml> (copyright Joseph Testagrose; accessed April 11, 2006). For further information about Hamilton’s trolleybuses, see <http://home.cc.umanitoba.ca/~wyatt/alltime/hamilton-on.html> and <http://www.trainweb.org/elso/hsr-tc.htm> (both accessed April 11, 2006).
- ¹⁰⁷ See IBI Group, *Transportation Modal Share Targets and Transit Strategies Policy Paper*, January 2005, for Phase Two of the development of the City of Hamilton’s Transportation Master Plan, at <http://www.myhamilton.ca/nr/rdonlyres/1e948d30-2773-4d70-a3c0-45c6883ada6b/0/18transportationtargetsandtransitstrategyjan2005.pdf> (accessed April 11, 2006).
- ¹⁰⁸ The Toronto Transit Commission has ordered 150 hybrid diesel-electric buses for delivery in 2006 from Orion Bus Industries of Mississauga, Ontario, a unit of DaimlerChrysler. According to the manufacturer, these will provide about a 30-per-cent improvement in fuel economy com-

pared with regular diesel buses. See <http://www.orionbus.com/orion/0,,0-11-9892-1-486926-1-0-0-0-0-0-150-9892-0-0-0-0-0-0-0,00.html> (accessed April 11, 2006).

- ¹⁰⁹ Among the best-known books on Hamilton, John Weaver's *Hamilton: An Illustrated History* (National Museums of Canada, 1982) has a 1903 photograph of the Hamilton & Barton incline railway on its front cover.
- ¹¹⁰ While this report was in preparation, the Ontario government announced a massive level of subsidization of grid-connected photovoltaic generation. The Ontario Power Authority will purchase electricity so produced for 42 cent/kilowatt-hour. See Premier Dalton McGuinty's press announcement at http://www.energy.gov.on.ca/index.cfm?fuseaction=english.news&body=yes&news_id=124 (accessed April 11, 2006).
- ¹¹¹ The text in Box 25 is excerpted from Frank Kane, British help China build 'eco-cities', *The Observer*, November 6, 2005, at <http://observer.guardian.co.uk/business/story/0,6903,1635188,00.html> (accessed April 12, 2006).
- ¹¹² For a full discussion of the potential application of Local Improvement Charges to enhancing the energy efficiency of the existing building stock, see Roger Peters, Joanne Whitmore, and Matt Horne, *Using Local Improvement Charges to Finance Energy Efficiency Improvements: Applicability Across Canada*, Pembina Institute, Drayton Valley, Alberta, June 7, 2005, at http://www.pembina.org/publications_item.asp?id=197 (accessed April 11, 2006).
- ¹¹³ For information about the Green Municipal Fund, see <http://www.fcm.ca/english/gmf/gmf.html>, accessed April 11, 2006.
- ¹¹⁴ For information about the Toronto Atmospheric Fund and the proposal for expansion see the report at http://www.toronto.ca/taf/pdf/gtaf_proposal.pdf (accessed April 11, 2006).

About the author

Richard Gilbert is an urban issues consultant who focuses on transportation, waste management, energy systems, and urban governance, with recent or current clients in North America, Europe, and Asia. He serves or has recently served as transport consultant to the Paris-based Organization for Economic Cooperation and Development (OECD) and to Civic Exchange, a Hong Kong-based think tank, as part-time research director of the Toronto-based Centre for Sustainable Transportation (CST, in the process of moving to the University of Winnipeg), and as adjunct professor in the University of Sherbrooke's Faculty of Administration (Centre d'études en réglementation économique et financière).

Richard Gilbert has a 1966 PhD in experimental psychology and in an earlier career was a psychology professor and researcher, teaching at universities in the 1960s and 1970s in Ireland, Scotland, the U.S., Mexico, and Canada, and associated with the then Addiction Research Foundation of Ontario from 1968-1991. He held registration as a clinical psychologist in Ontario from 1974-2001. In the 1990s, he taught graduate courses in planning and urban governance at York University's Faculty of Environmental Studies, and he will teach a graduate course in urban governance at Simon Fraser University during 2006.

He served as a member of the then City of Toronto Planning Board from 1973 to 1976, of the councils of the City of Toronto and Metropolitan Toronto from 1976-1991, and as president of the Federation of Canadian Municipalities in 1986-1987. On retiring as a municipal politician, he became the first president and CEO of the Canadian Urban Institute, from 1991-1993, and has worked as an independent consultant since then.

Major reports published during the last few years include *Electrifying Hong Kong: Making Transport Sustainable* and *Hong Kong's Freight Transport* for Civic Exchange; *Soft Measures and Transport Behaviour* for Umweltbundesamt, the German Federal Environment Agency and OECD; *Energy and Smart Growth* for the Neptis Foundation and the Government of Ontario; *Policy Instruments for Achieving Environmentally Sustainable Transport* for OECD; *Globalisation, Transport, and the Environment* for OECD; *Sustainable Transportation Performance Indicators* for CST (supported by four departments of the Government of Canada), *Energy and Transport Futures* for Canada's National Round on the Environment and the Economy, and *Globalisation, Transport, and the Environment* for the OECD. He was the lead author of *Making Cities Work: The Role of Local Authorities in the Urban Environment* (Earthscan), one of three books commissioned by the United Nations Centre for Human Settlements for the Habitat II conference held in Istanbul in June 1996. With Anthony Perl, he is writing a book with the title *Transport Revolutions: Making the Movement of People and Freight Work for the 21st Century*, to be published by Earthscan/James & James in 2007.