ENERGY OPTIONS

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(The author is to be the discussant for a session with the above title that is to be part of the Royal Society of Canada's Symposium entitled 'Energy, Environment, and Society: Making Choices', to be held at the Canada Museum of Science and Technology, November 25, 2003. The session will have three speakers: Donald Johnston on nuclear power, David Sanborn Scott on hydrogen energy systems, and Allan Amey on opportunities in the hydrocarbon sector. This requested note provides the discussant's perspective on these topics *before* reviewing or hearing the speakers' presentations.)

The remarkable changes in human societies during the 20th century were built on ever-increasing use of added energy to do things beyond what humans could otherwise do (see Box 1). This added energy made possible fourfold growth in world population, huge increases in industrial production, and massive expansion of motorized movement of people and goods.

Box 1. Primary energy other than food, sun, and wind: consumption and efficiency of use, 1900 and 2000

	Canada and U.S.		Rest of world	
	1900	2000	1900	2000
Primary energy consumption:				
per capita (gigajoules)	113	365	17	52
per unit of GDP (kilojoules per 2000US$)	21.4	10.0	25.4	7.3
Population *(billions)*	*0.08*	*0.31*	*1.57*	*5.74*
GDP *(trillions of 2000US$)*	*0.43*	*11.38*	*1.05*	*40.77*

Sources: International Energy Agency and others (details available on request)

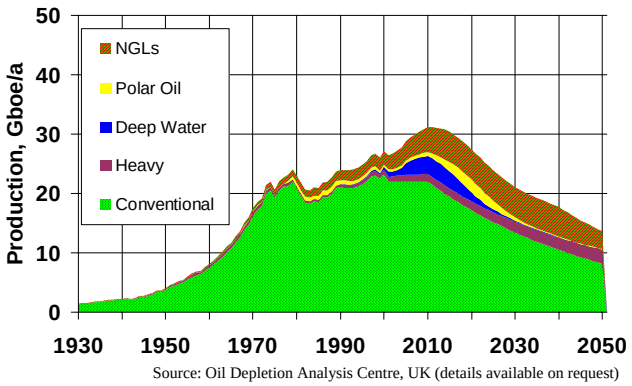
Worldwide, per-capita primary energy use grew more than threefold during the 20th century. Total energy use grew by more than a factor of 11, from 37 to 411 exajoules. The U.S. and Canada used about seven times as much as the rest of the world in both 1900 and 2000. Energy use per unit of GDP fell by more than half in the U.S. and Canada, and by more than two thirds elsewhere; thus, effective per-capita energy use increased by a factor of seven to eleven, respectively. A person's annual manual labour is equivalent to less than one gigajoule of applied energy. Thus, energy use in Canada and the U.S. in 2000 provided each resident with the manual labour equivalent of at least 365 additional people.

In 1900, coal and wood were the predominant fuels. Today they are oil, coal, and natural gas. Most coal is used to produce electricity. Oil and natural gas serve as feedstocks for plastics, fertilizers, pharmaceuticals, and numerous other manufactured products, and well as providing heat and electricity. Just under half of oil production fuels transportation of people and goods.

Civilization as we know it depends on continuing supplies of these fossil fuels: coal, oil, and natural gas. **Availability of the last two is in question.** It's not a matter of their literally running out. Large amounts remain to be extracted. The main challenge is that of production not keeping up with demand. This seems to be happening now for natural gas in North America, and could well happen within a few decades for oil worldwide. Box 2 provides the best estimates of recent and future production; it shows declining production after 2012. The rate of new discoveries has fallen steeply; production from existing wells cannot be increased enough to offset their depletion. When demand exceeds supply, prices rise steeply if demand cannot be reduced.

Current plans would replace oil with hydrogen, mostly for use in fuel cells. Today, almost all hydrogen is made from natural gas, production of which in North America is already not keeping up with demand. Practicable alternative means of producing large quantities of hydrogen are not available; distribution would present major challenges. Widespread use of fuel cells seems several decades away, especially for transport purposes**.** Liquid fuels can be made from coal, but only in ways that are energy-intensive and polluting. Nuclear energy could be massively expanded to generate electricity for production of hydrogen by electrolysis, but this inefficient process comes with strong waste-management challenges.

Box 2. Actual and projected world production of petroleum liquids, 1930-2050



Source: Oil Depletion Analysis Centre, UK (details available on request)

Conventional oil can be pumped inexpensively from readily bored wells. **Heavy oil** is produced from tar sands and other bitumen deposits. **Natural gas liquids**, notably propane, are a by-product of extraction of natural gas.

A sustainable strategy would minimize use of added energy for heating and cooling and use electricity produced from wind, sun, and other renewable sources to power industry and transport. The latter would mostly comprise tethered vehicles using energy from wires or rails, which provide the most energy-efficient transport.

In the energy-constrained world of the 21st and subsequent centuries, continuation of civilization as we know it could well require measured reversion to the energy-use levels of 1900 or earlier.