Energy Technology Options for the 21st Century: Environment, Economy and Society

A Report on the Workshops

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This series was designed as a play in five acts. The first four consisted of one-day workshops — held in January, March, May and June — programmed to deal with broad categories of specific technologies. Workshops 1 and 2 dealt with the supply of energy, the first one focusing on centralized energy systems, the second on decentralized systems. At Workshops 3 and 4 attention shifted to the use of energy: first in buildings, appliances and processes, then in transportation. The wind-up conference on October 1-2, 1992, drew those discussions together and dealt with the broad issues involved in determining our future energy system, issues which cut across the discussions at the workshops.

Linking the workshops and the conference presented us with a challenge. Both the cast and the audience at each workshop were largely different. Except for the MIES organizers and a few other hardy souls who are similarly addicted to the study of energy problems, participation in the workshops was determined by specialized interest and experience. We wondered from the outset whether our objective of capturing the essence of all four workshops in a report of manageable size was really possible, whether it would be viewed as either heroic or presumptuous, especially with limited resources at hand to back up the enterprise. That said, it was still necessary to try. This report is the result.

Each workshop consisted of presentations from technical experts, a panel discussion putting the technological information into a context which reflected the environmental, economic and social constraints to which new technology is subject, and finally, an open discussion among all participants. This report follows a similar format, with the addition of an introduction and a section at the end of the account of each workshop in which we set out some themes that we perceived. Aside from these thematic observations, the bulk of the report consists of our best efforts to convey what we heard at the workshops without imposing our views.

Before proceeding, a special word to those who participated in the workshops. While we have done our best to be true to what you said, we did not have a verbatim transcript of the proceedings. When in doubt we checked supporting documents and, in some cases, contacted the speakers. In those cases where we have missed the mark, our apologies.

In reporting open discussion we have avoided identifying the speaker. In some cases, comments described herein are an amalgam of related ideas conveyed by more than one person.

Introduction

Environmental problems — particularly those associated with air pollution — are now the driving force behind the evolution of our energy system. For those who have worked on energy issues for a decade or more, that involves significant change. Not only has the emphasis on oil, energy security and resource politics receded into the background, the pollution problems themselves have also changed. In the 1970s and before, emissions contributing to photochemical smog and other local pollution dominated our concerns about the link between energy and the environment. In the 1980s acid rain complicated the picture by introducing problems associated with transboundary responsibilities for air pollution. Now ozone and greenhouse gases have brought a frightening global dimension to concerns over pollution. The old local and regional problems were viewed as serious but, rightly or wrongly, as basically manageable; recognition of global environmental damage has pierced our complacency and added a sense of urgency. This in turn has made us more sensitive to the interaction between the energy system and a broader range of physical, ecological, social and institutional problems.

This sense of the environment-as-driving-force shaped the discussion at the workshops more than one might have expected, given that most of the participants were energy specialists rather than specialists on the environment. The engineers and scientists who informed us about new technologies tended to organize their presentations around environmental concerns; discussion by panellists and other participants was led by these concerns to a still greater extent. This involved more than simply viewing the need to reduce aggregate emissions as an argument for increased energy efficiency. At various points it was recognized that there are trade-offs between emission control and energy efficiency, that the dimensions to be considered in choosing energy technologies have increased and become more complex.

A second theme very much in evidence throughout the workshops was the belief that necessary institutional and economic changes present major challenges to the development and application of energy technology. Although technological bottlenecks were discussed, the discussion more often focused on the societal changes required to accommodate new technologies rather than on the technology itself. Complex issues emerged, having to do with the scope for manufacturing new technological hardware at competitive prices, with thorny problems of behavioral change and threshold levels of customer acceptance that must be achieved, with the inertia embodied in existing infrastructure, and with the interaction between key economic organizations (such as electric utilities) and technological change.

Also evident was the tension between government leadership in changing the energy system and the belief that it is better left to the market. The argument here was not merely in terms of ideological positions, but in recognition of the real economic trade-offs involved. It may be desirable to allow different technologies to compete, rather than to try to "pick winners," but doing so may also be at odds with solving threshold problems due to economies of scale and the need for major infrastructure changes. In some cases government may have to lead the way in order to encourage the necessary investment.

While some of the problems alluded to above seem depressingly intractable, this aspect of the discussion was sometimes twinned with a more positive theme. Solving energy problems can bring economic benefits. Participants frequently focused on the question of how to seize the economic advantage potentially involved in producing the goods and services required to deal with energy and environmental problems. If there was some distaste expressed for the kinds of regulations imposed on the provision of transportation in California, there was also the recognition that stringent emission controls, aggressive incentives for electric cars and the like can generate substantial amounts of new industrial activity. Instances in which Canadian companies are developing interesting new products were reported and one could perceive some potential for the development of "green industries."

The latter observation should, however, be kept in perspective. The discussion at the workshops did not leave one with the impression that a coherent and well-supported effort to develop this potential was to be found in either the government or private sectors in Canada. And the same can be said in regard to facing most of the overall challenge of renovating the energy system in response to environmental imperatives.

Workshop 1: Centralized Energy Supply Alternatives, January 23, 1992

Technical Presentations

1. The Use of Coal in the 21st Century — William E. Moore, US Department of Energy

Despite the current pro-nuclear posture of the US Department of Energy, Moore argued that coal-based electricity generation technologies with advanced environmental protection technologies for the removal of SO_2, NO_X and particulates have significant advantages as compared to nuclear energy in the generation of electrical power. These are:

- lower capital and operating costs;
- shorter approval and construction periods;
- fewer intractable problems, such as the risk of a major accident and nuclear waste disposal; and
- greater thermodynamic efficiency, leading to reduced emissions per kWh.

The use of coal carries with it a number of environmental concerns. However, through the use of gasifiers and pressurized fluidized bed combustors (PFBC) coupled with advanced gas turbines and hot gas cleanup, these concerns can be met while providing low-cost highly efficient electrical power generation. For example, the integrated gasification combined cycle (IGCC), as well as the PFBC power systems using the advanced gas turbine and hot gas cleanup technology, are projected to reach system generation efficiencies approaching 55%, with overall capital cost from US$1200/kW for the currently available turbine cycles to less than US$1000/kW for the more advanced designs. Savings in the cost of electricity relative to that produced with existing pulverized coal-fired steam plants are expected to approach 20%.

2. Advanced Nuclear Fission Power Plants — Ralph Hart, Atomic Energy of Canada Limited

The presenter argued that emerging global issues, such as rapid population growth and the greenhouse effect, have created a situation in which the extrapolation of past trends are meaningless with respect to identifying future energy systems. He noted that if, for environmental reasons, the bulk of new electricity supply were to be met from nuclear technology in the next century, this would require on the order of 4000 new generating plants at a cost of US$133 billion per year over the next 30 years. Such an amount is viewed as relatively small compared to other expenditures, such as, for example, the US Defense budget.

Within this context he discussed the prospects for nuclear fission, and made the following points:

- There is no shortage of uranium fuel. For example, even a 100-fold increase in the cost of obtaining uranium from ever poorer resources (e.g., seawater) translates into only a doubling of the delivered price of nuclear generated electricity.
- Near-zero discharge of radioactivity from nuclear reactors is technically feasible and the nuclear waste disposal problem is not insurmountable given that the volume to be handled is comparatively small. Hart is confident of the projected permanent approach to high level waste disposal

in Canada — deep burial in stable geological features.

- The CANDU reactor design — fuelled with natural uranium and moderated with heavy water — offers significant safety features relative to pressurized reactors using enriched uranium and moderated with natural water.
- AECL is focusing on the human error aspects of safety by improving reactor operating information systems and by reducing operator choice situations.
- The CANDU design offers considerable potential for technical evolution over time, including the potential for a "slightly enriched uranium" design and the potential for operating in tandem cycle, whereby spent fuel from light water reactors containing residual uranium is used as fuel for CANDU reactors.

With the current level of uncertainty about future energy requirements and policy, AECL is attempting to maintain a flexible position in terms of future nuclear technology rather than making any major developmental commitment to a particular configuration of nuclear technology. Research by AECL is therefore oriented to defining various possible technical options for the basic CANDU type technology. In general, research on fission technology is active in Europe and North America, absorbing about 50% of all energy R&D funds in IEA countries.

3. Fusion as an Energy Alternative for the 21st Century — Don Dautovich, Canadian Fusion Fuels Technology Project

Fusion power research is being pursued in several nations throughout the world. Significant progress has been made in moving towards net energy production in magnetic confinement systems. The fusion reaction which takes place at lowest temperatures is the deuterium-tritium reaction. Other reactions based on deuterium only are more difficult to achieve but involve no neutrons and therefore lower levels of radiation.

Currently there is about $2 billion in R&D funds being spent annually on fusion research world-wide, of which about $30 million is spent in Canada (one-half at CFFTP and the other half at the Centre canadien de fusion magnétique in Québec).

As compared to fossil fuel or nuclear fission, nuclear fusion offers several significant advantages as a technology for producing electricity in the 21st century, including:

- inexhaustible supplies of fuel in the form of deuterium;
- reduced (but still significant) volumes of radioactive wastes (the deuterium/tritium fuel cycle);
- no CO_2 emissions; and
- lack of danger due to a runaway nuclear reaction, as the fusion reaction instantly stops in the event of major technical problems.

Current expectations are that a commercial magnetic confinement fusion reactor will be large, on the scale of, or larger than, the Darlington nuclear power plant in Ontario. The electricity generated will cost about twice that expected from future fission generating plants.

The development of a practical fusion technology requires advances in a number of scientific fields including materials sciences, robotics, superconductivity, and gas and isotope processing. No small country can hope to develop fusion technology on its own. The current approach is for smaller countries like Canada to specialize in certain technical areas and cooperate with other nations in the overall international effort to develop fusion technology.

The Canadian Fusions Fuels Technology Project has been focusing its research efforts on tritium production and handling technologies, in which it is a recognized world leader, and on robotics. CFFTP provides research, engineering services and hardware to fusion projects outside of Canada and actively seeks to transfer the technologies they develop to existing industries in Canada.

Over the past five years the expenditure of CFFTP has amounted to $58 million: 58% from the federal and provincial governments and Ontario Hydro; 31% from client revenue; and 11% from subcontractors. It directly spends 22% of these funds, with the remainder split between AECL, Ontario Hydro, the universities and other subcontractors.

Without funding limits, it is estimated that the first commercial reactor could be operating in 25 to 30 years. However, in the opinion of the presenter, "the world is not yet serious about developing fusion."

4. Renewable Energy Power Plants — Frank Chu, Ontario Hydro Research

An overview of Ontario Hydro's current demand/supply plan (as of January 1992) was presented as a context for this discussion of renewable energy power plants, which included centralized hydroelectric, photovoltaic, wind and biomass technologies.

Due to the impact of conservation and fuel switching, Ontario Hydro estimates that the need for major new supply facilities has been pushed from the year 2001 to 2010. Current thinking at Hydro regarding new supply technology identifies nuclear (CANDU), gas and coal as the favoured supply technologies.

HYDROELECTRIC POWER PLANTS

It is expected that the contribution of hydraulic power will not increase in Ontario as projects in the Moose River Basin have been cancelled. Moreover, Hydro-Québec's recent experience with its James Bay developments suggests that large-scale hydro projects can no longer be considered environmentally benign due to flooding, methyl mercury pollution and local population relocation problems.

BIOMASS POWER PLANTS

Biomass power plants consist usually of gasification systems using wood waste and/or wood from tree plantations. Plants of 50 MW are proven and 75 MW are possible. The major problem is the amount of land required to provide biomass fuel for such a plant. For example, in Ontario 7000 hectares are required for a 75 MW plant. If Ontario Hydro generated all its electricity from biomass, it would require plantations covering five times as much land as Algonquin Park.

Important advantages of biomass generation include:

- biomass is potentially a renewable energy source, based as it is on sunlight;
- zero or small net CO_2 additions to the atmosphere, providing that the plantations are operated on a sustainable basis;
- low sulphur dioxide emissions; and
- regional employment generation.

The presenter estimated that in Ontario, biomass could produce 100 MW of electricity by 2005, mainly based on wood waste, and 200 MW by the year 2014, at a cost of 9.5¢/kWh (1992$). It has been estimated that as much as 22% of US generation could be from biomass by 2060.

CENTRALIZED WIND GENERATION

There is currently 2000 MW of installed wind generation worldwide, of which 1350 MW are in southern California. Only about 7.5 MW exist in Canada.

The advantages of wind power are that it is renewable, non-polluting and modular. It can be added incrementally and rapidly to the generating system and uses relatively proven technology. Disadvantages are its current requirement for sites with relatively high wind regimes (which places some constraints on southern Ontario with few good, high wind sites) and for relatively large areas for "wind farms," its intermittent availability, adverse effects on birds, and the visual impact of large numbers of towers on the landscape.

Dr. Chu estimated that there would be less than 1 MW of wind generation in Ontario by 2005, with a potential for 10 to 40 MW developed later in the next century.

CENTRALIZED PHOTOVOLTAIC PLANTS

The technology for the photovoltaic production of electricity is a dynamic one, with new, more efficient designs at lower cost emerging steadily. Worldwide about 200 MW of photovoltaic generation exists, with about 0.5 MW located in Canada. The presenter felt that the potential for photovoltaic generation in Canada is limited by the relatively low level of solar radiation.

The advantages of photovoltaic generation include zero fuel cost, low maintenance, modularity, and the absence of pollution in the operating mode. Disadvantages include high capital costs, large land-use requirements, pollution associated with their manufacture and disposal, and the intermittent availability of sunlight.

Given current costs and R&D efforts, an optimistic projection is that photovoltaic generation will provide 50 to 100 MW of capacity in Ontario by 2014. However, with mass production the manufacturing cost of the technology will decline. It is estimated by the Arthur D. Little Company that a manufacturing capacity in the US of 250 MW annually will exist by 2005.

R&D funding for renewables in the US and Canada is quite small compared to that for nuclear and fossil technology. Dr. Chu concluded that, given existing R&D efforts and existing policy, renewable energy technologies will play a minor role in centralized electricity generation in the near term in Ontario, but with environmental constraints becoming more important, their development is important for the long term. The best strategy currently is to continue their development principally for remote and distributed applications, where the technology has a competitive advantage relative to conventional technology.

Panel Presentations

Stephen Blight of the Corporate Policy Group at Environment Canada set out some aspects of the environmental context of the discussion. He drew attention to the new importance of global environmental issues, to a growing toughness in regulations and enforcement procedures, and to the increasing need to merge economic and environmental decision making.

Environmental assessment must be recognized as part of doing business. Inevitably, this implies the need for longer planning horizons to accommodate the time consuming assessment procedures. Despite the problems associated with this in some areas, there is increasing realization within the private sector that clear regulations can be complementary to increasing competitiveness and economic vitality.

Terry Burrell, an environmental economist and law student from Toronto, observed that we are considering energy technology options during a period of conflicting ideas. There is a contradiction between public acceptance of "green values" and the fear that we are lagging in manufacturing growth and competitiveness. Those values are less likely to be acted upon by people who do not feel well off.

Several observations by ***Vaclav Smil*** of the Geography Department at the University of Manitoba reflected his critical view of current and past technological developments. There is too much emphasis on the supply side; yet our understanding of the technology of demand side management is still weak. We have a naive belief that feasible technologies will be economically viable at some time in the future, though the history of engineering provides many examples of physically effective technologies that never came into use. A similar point can be made about the production of saleable by-products; e.g., desulphurization processes.

The case of nuclear fission is especially problematic. Smil believes that the world rushed into the commercial production of nuclear technology too fast and that this has led to substandard engineering and safety. Massive government subsidies of nuclear technology make comparative costs with other technologies meaningless. On the disposal of radioactive wastes, he argued that it is not good enough to blame the persistent absence of a long term solution on an ignorant public.

Plenary Discussion

In the first workshop, participants divided into small discussion groups before winding up the day with a plenary session. The following summarizes some observations reported by group rapporteurs and other comments made at the plenary session.

Environmental Issues

The current regulatory process requires such a long lead time that it causes a bias towards big projects, so that the utility can avoid having to go through the process often. If the regulatory process were streamlined, small projects might be considered. One positive step might be to change the environmental assessment process away from the judicial model currently used in Canada. (It was noted that a new federal bill now pending in Parliament could help to lead the environmental assessment process away from the current judicial model.)

Avoiding global climate change may require a greater role for nuclear power. However, the problem of waste disposal and the mistrust generated by inflated performance claims in the past still pose significant barriers to widespread public acceptance.

Economic Issues

In the past, energy planning has sought to facilitate economic growth. Now, the issue of sustainable development is forcing a rethinking of this energy-economic growth relationship. What are the market incentives that will promote sustainable development?

At several points the need for full cost accounting and pricing, whatever decision making process is in effect, was discussed.

Some participants observed that a continuation of the current movement toward privatization would likely mean the end of large, centralized power systems. This could mean that fusion, new fission and some other centralized technologies will never be operational.

Opposing forces affecting electricity demand in Ontario were noted. There is good reason to believe that it will continue to grow faster than the overall economy as more electricity consuming devices enter the market (e.g., electric pollution abatement equipment, electronics). There is also good reason to believe that demand will decrease through the widespread adoption of energy efficiency measures and the decline of manufacturing in the Ontario economy.

The cost competitiveness of decentralized systems is probably greater than often claimed because important elements in the cost of centralized systems, such as the cost of grid expansion, are often not accounted for.

Social Issues

The degree to which conservation can eliminate the need for new electricity supply is linked, in part, to how fast public perceptions of what constitutes a desirable lifestyle can change. This may be more true for large cars and mobility than for energy efficient appliances and light bulbs.

In one discussion group the question of the basic approach to energy technology decision making was considered. It was argued that normative considerations should be instrumental in driving energy policy. Today's society should decide on what form tomorrow's society should take, and then put in place the policy, research, and economic measures required to achieve that normative society.

Institutional Issues

Large, centralized systems can only function in a stable social and institutional setting. Ten saboteurs could easily knock out the whole Ontario electrical grid.

The use of smaller generation facilities helps deal with planning uncertainty because they can be added in small increments to the system as needed, with shorter lead times, and with fewer regulatory and economic uncertainties. Is the centralized generating plant a dinosaur?

Government Policy

Canadian energy policy will increasingly be influenced by international agreements; for example, agreements with respect to CO_2 emissions/climate change.

In facing uncertainty, a diversity of technical options is desirable. However, a small country like Canada cannot afford to undertake R&D on all energy options. International research linkages can increase the diversity of options available to Canada at a cost less than that of "going it alone." Canada needs to focus on certain areas of energy technology.

Emerging Themes

There was no consensus at the workshop as to what directions energy technology research and development should take to ensure that the best options are available for the 21st Century.

A concern with the need to curtail CO_2 emissions dramatically presents a major constraint on the continued large-scale use of coal, even in high-efficiency power plants.

Taking into account environmental and economic factors, natural gas generation options appear to be more acceptable than any other short and medium term generation options. However, a widespread shift from coal and oil to natural gas may raise natural gas prices and create new environmental problems in terms of the frontier development of resources.

While the advantage of nuclear power in relation to CO_2 emissions was recognized, a major expansion of nuclear generation capacity faces many daunting regulatory, economic, public acceptability and geo-political challenges. An uncertain global economic and political setting seriously challenges such large, capital intensive, long lead time generation projects. Nuclear waste disposal and safety issues remain unresolved in the public's mind. At the same time, it was recognized that Canada had a demonstrated world leadership position with respect to CANDU and related technology.

During the early years of the next century, centralized generation will inevitably continue to be important, but small-scale generation, linked to the grid, will grow more quickly. Barring substantial changes of approach, neither renewables nor fusion generation technology will play a major role in the next few decades.

While significant research developments have recently taken place world-wide in nuclear fusion, and Canada has developed world expertise in the area of tritium production and handling and robotics, it is recognized that Canada must work with other nations in the development of fusion power. It is also recognized that, even with excellent global funding, a commercial fusion reactor will not be available for 30 years, and that the power plants will be large (in excess of 1000 MW) and expensive, thereby encountering all the problems currently associated with large generation projects.

While centralized renewable energy technology has certain advantages in terms of the inexhaustibility of its fuel and the lack of CO_2 emissions, the low energy flux associated with solar energy, current costs of solar photovoltaic technology and the problems of large-scale hydro power challenge a centralized role in Ontario for renewable energy. Other regions of the world are endowed with greater levels of solar flux and wind regimes. However, it was recognized that wind and photovoltaic technology are rapidly developing and will become more cost competitive in the near future. Compared to fission, fusion, and fossil energy technology, only a small amount of R&D expenditure in Canada is currently allocated to solar, wind and biomass energy technologies.

Finally, the importance of addressing both supply and demand sides of the energy balance equation came out in various ways. The potential exists for saving enormous amounts of electricity, thereby obviating the necessity for new generation, avoiding environmental problems and potentially pulling energy demand closer to that which can be met by renewable energy technologies.

Workshop 2: Decentralized Energy Supply Options, March 5, 1992

Technical Presentations

1. The Role of Decentralized Energy Supply Alternatives in the 21st Century — Jeff Passmore, Passmore Associates and consultant to the Independent Power Producer's Society of Ontario

Decentralized supply alternatives should be seen as complementary to a program of improved energy efficiency and demand side management, and not as a substitute. Achievable demand reduction should take precedence to supply alternatives.

Several decentralized supply technologies including cogeneration, biomass/wood energy, landfill gas, municipal solid waste combustion, solar thermal, wind, small hydroelectric, and photovoltaic (PV) electrical generation are available now and, with the exception of PV, they are currently viable at the utility scale. The main constraints on their implementation in Ontario are not economic or technological but rather a lack of appropriate policies.

In California, there is now nearly 10,000 MW of independent power. Wind, solar and small hydro contribute about 2600 MW of generation, supported by institutional measures such as the Public Utility Regulatory Policies Act (PURPA), standard-offer contracts to reduce transaction costs for non-utility generators, tax credits for renewables, air quality standards, and a decision by California not to build further nuclear or large coal facilities. Pacific Gas and Electric has an R&D budget of $10 million for renewables (vs. an Ontario Hydro renewable budget of $0.5 million) and has moved from a system of 100 power plants in 1980 to 600 plants, of smaller average size, in 1991. The decentralized industry (including renewable energy) has provided 293,000 jobs in California with associated multi-billion dollar investments, generated earnings and tax revenue.

Since competitive bidding for power generation has been introduced in the US, the amount of power offered has consistently been greater than the amount needed. The same has been true when proposals have been requested in Ontario, Quebec and BC. One reason independently produced power is economical is that producers are paid on a performance basis — ratepayers do not get stuck with the bill for non-producing technologies.

Why is there less activity in Canada?

- Limited knowledge and misperceptions about new technologies;
- Limited utility experience with renewables;
- No economies of scale, as yet, on technology;
- Lack of policy directives linking environment, energy and business; and
- Too few R&D funds provided for renewables because they are believed to be too expensive, but they are too expensive because insufficient R&D has been undertaken.

What is needed to accelerate decentralized options?

- A national energy and environment strategy;
- A provincial energy policy which encourages decentralized options;
- Explicit energy diversification goals including targets for renewable energy sources; and
- Cost comparisons of renewables with conventional supply options need to take into account the costs of externalities. Then the renewable options look cheap.

There are large potentials for wind, small hydro and biomass energy supply in Canada, but in order to exploit them we need a combination of technology push and market pull, including standards, regulation, consumer information/product labelling, tax incentives, investment tax credits, inclining block rates, and increased R&D.

The one thing we know about the future is that it is very uncertain. This argues for the development of a diverse energy resource base.

2. Renewable Energy Technologies: Status and Outlook — Verne Chant, President, Hickling Corporation, Ottawa

This presentation focused on wind, small hydro, biomass, and solar water heating technologies, based on studies done for the Ontario Ministry of Energy and EMR Canada.

Table 1: Comparison of Commercial Potential for Renewables in Ontario, Two Scenarios — 2005

	Base	Base+2¢
Energy Output (PJ/yr)		
Wind	0	1.4
Small Hydro	5.6	10.8
Biomass	0.2	2.8
Solar	0.6	1.5
	6.3	16.6
Installed Capacity (MW)		
Wind	0	255
Small Hydro	338	655
Biomass	6	113
Solar	299	754
	643	1777

Source: Hickling Corporation

Renewable energy is sustainable and generally environmentally cleaner than conventional energy forms. The technology is smaller and technically simpler, allowing it to be brought on-line rapidly. On the negative side, renewables have low power densities, are intermittent, and have high initial costs. For wind power and small hydro, the production costs rise as the best sites are developed.

The price to be paid in Ontario for energy delivered by decentralized technology, based on 1992 avoided electrical system costs, should be between 4.5 and 6.5 ¢/kWh. The highest price would be appropriate for solar water heating since, being located at the site of demand, it avoids the cost of transmission as well as generation.

At current buy-back rates, only selected small hydro sites are economically attractive. At somewhat higher rates, wind and biomass have significant potential. Scenario analyses indicate that if Ontario Hydro undertook to pay a premium on its buyback rate of 2¢/kWh for wind generated electricity, over 200 MW of wind power could be generated economically. There is also a large potential for biomass. There are large areas of marginal farmland available in eastern Ontario which would be suitable for biomass energy production. The table below compares two scenarios for the year 2005, the base scenario involving Ontario Hydro's current buyback rates (including its 10% premium for renewable sources) and scenario A+2 involving the base rate plus 2¢/kWh.

Such calculations suggest that a renewable energy industry could be created with a small increase in overall electricity rates (which would rise by less than the increase in the buy-back rate). At the same time, assuming reasonable avoidance costs for CO_2, NO_X and SO_2, an addition to the electricity rate to cover emissions control costs of the order of 2¢/kWh is justifiable. This would lead to a shift towards renewables sufficient to reduce Ontario Hydro's emissions by 10%.

In order to promote more use of renewables, a firm statement of government commitment is needed, as well as more specific policies, including: requiring that externality costs be accounted for in energy system planning; committing to higher buyback rates; providing incentives to overcome high start-up costs; and streamlining the energy project assessment and approval process.

3. Experience with Wind Energy, Biomass and Municipal Solid Waste: Application of Decentralized Energy Technologies to District Heating — Rob Brandon, General Manager, PEI Energy Corporation

District heating provides over 40% of the total space heating requirements in some Scandinavian countries, with many systems using combined district heat and power generation systems. In Canada, there are a number of district heating systems, most notably in Edmonton, London, Toronto (cooling only), and in Charlottetown where a municipal solid waste and biomass-fuelled district heating system provides 30% of the space heating requirement, mostly to a small number of large customers (e.g., the University of Prince Edward Island).

Although the burning of municipal solid waste is widespread in Europe, it is controversial in Canada due to perceptions of undesirable emissions and a feeling that it runs counter to recycling efforts.

Although district heating is energy efficient and offers significant environmental and social benefits, barriers to its widespread use prevail. In Canada these barriers include: its high capital costs, which makes it unattractive to independent producers; the complication associated with involving municipal governments, rather than just utilities, in projects; a lack of engineering expertise, which tends to make cost estimates in feasibility studies too high; a lack of supportive government policy; and the absence of "champions" for district heating policy initiatives.

Wind power is an option with significant potential in Canada, especially along the east and west coasts, in the north, and at one location in the interior of Alberta. Already California has an installed wind generation capacity of 1640 MW and Denmark has 360 MW, with plans for a further 1000

Table 2: Wind Power

	Installed MW and Targets		Typical Buy-Back Rates
	1991	2000	
Denmark	360	1000	-
Germany	90	250	17¢/kWh
Netherlands	55	1000	11¢/kWh
Italy	5	300	-
Spain	15	300	-
UK	10	-	22¢/kWh
California	1640[a]	-	-

	Technical Potential	
	MW	%[b]
Newfoundland	661	17
PEI	43	10
NB	785	10
Quebec	9777	15
Ontario	8236	10
Manitoba	1027	7
Saskatchewan	826	10
Alberta	2509	10
BC	3257	-
Yukon	-	
CANADA	27720	11

[a] Refers to 1989
[b] Percent of 1990 power consumption
Source: PEI Energy Corporation

MW. The trend in Europe is to larger wind generators, ranging from 0.5 to 2 MW (as compared to a typical size of 250 kW in the US) because of the shortage of appropriate sites. The UK, Germany and the Netherlands have adopted a policy of offering very high buy-back rates over a limited period in order to "kick-start" a wind generation industry.

4. Fuel Cells: Their Place in the 21st Century — Craig Simpson, Ontario Hydro

The principal advantages of fuel cells are:

- Environmental — fuel cells based on natural gas produce no NO_X or SO_2, and much reduced CO_2 per kWh;
- High efficiency — 60% in simple generation and 80% in cogeneration;
- Modularity — relatively small operating units allow for incremental supply planning;
- Fuel switching flexibility; and
- Decentralized generation reduces costs and problems associated with transmission.

Three major fuel cell technologies are of particular relevance to utilities. They are:

- The phosphoric acid cell (PAFC), which is the most commercially advanced technology. An 11 MW cell in Tokyo is the largest operating unit to date. International Fuel Cells has produced sixty 200 kW units, one of which is being purchased by Ontario Hydro. This technology operates at moderate temperatures (200°C) and will probably be most useful for load management and non-utility generation.
- The molten carbonate fuel cell (MCFC), is a less mature technology operating at higher temperatures (650°C) with greater potential for units in the range 2 to 20 MW or larger. Ontario Hydro is a member of two commercialization groups in the US for this technology.
- The solid oxide fuel cell (SOFC) is an even less mature technology operating at yet higher temperatures (1000°C) with similar applications as the molten carbonate fuel cell. Westinghouse has taken the R&D lead with this technology.

The recommendations of Ontario Hydro's Fuel Cell Task Force are to purchase a 200 kW PAFC now, and to keep involved in high temperature development. Ontario Hydro currently owns a 40 kW PAFC and has options to buy two SOFC's, a 20 kW unit in 1993 and a 100 kW in 1995. They are considering a 2 MW demonstration MCFC in 1997.

It is expected that it will be at least 10 years before a major fuel cell demonstration comes on line in Ontario and perhaps 20 years before fuel cells provide Ontario with significant amounts of power. Public acceptance that fuel cells located within communities are safe and reliable will have an important impact on future developments.

Fuels cells operated by non-utility generators will be in the range 200 kW to 5 MW and will be most useful for office towers and apartment buildings. While some proponents foresee a fuel cell in every house, the capital costs may be prohibitive.

The scale of utility owned units will probably be from 5 to 50 MW and used primarily as a means to deliver power to load growth areas without expanding transmission and distribution facilities. They may also play a role in locations where their waste heat can be used effectively. The time may come when fuel cells replace gas turbines for electrical generation.

How do fuel cells fit into Ontario Hydro's overall planning? The current supply/demand plan does not call for new utility supply capacity until 2009. No fuel cells will be brought onto the Hydro grid until that date, at the earliest. The current "Environmentally Enhanced Supply/Demand Scenario" calls for 600 MW from fuel cells by 2012, and much more later.

5. Electrical Energy From Low Temperature Waste Heat — Nigel Fitzpatrick, Technical Director of Energy Products, Alcan Aluminium Ltd., Kingston

This presentation described work by Alcan on developing cost effective and efficient aluminium heat exchangers which are highly corrosion resistant and suitable for ocean thermal energy conversion (OTEC). Traditionally, such heat exchangers have been fabricated from titanium and have made such generation systems prohibitively expensive. Alcan has teamed with GEC-Marconi to determine whether cost effective, turnkey power generating sets (heat exchangers, turbines and generators) can be produced.

The same basic technology that can be used in ocean thermal heat recovery can be used to produce electricity from industrial waste heat. Alcan has a demonstration plant at a nuclear station in England and is expecting to open a much larger demonstration unit (1 MW) at the Ontario Hydro Pickering nuclear plant in the near future. If all waste heat streams at Pickering were to be used, 400 MW of electricity could be generated. The estimated capital cost of such generation is $1300 per kW. Current designs use ammonia as the heat transfer fluid. No CFCs are involved.

The overall potential for generating electricity from waste heat is large. At an efficiency of 10%, the estimated potential generation from waste heat through such heat exchangers is 1000 MW for Ontario. About 22% of the world's aluminium heat exchanger panels are produced in Ontario.

Panel Presentations

Kevin Cliffe of the Office of Energy Research and Development, EMR Canada, argued that technological issues are not a major impediment to the development of decentralized supply options. The more serious impediments include the scepticism of utility management because of the lack of a technical track record and the fact that renewables have "fallen off the policy agenda" in recent years. There is a need for effective "policy champions" in the decentralized energy supply options area.

There is also a need for local utilities and municipalities to take a more active role in decisions regarding energy supply options; for example, with respect to the use of municipal solid waste as an energy option.

In the context of long-term planning, the costs of renewable technologies need to be compared, not only with those of conventional technologies, but also with other projected technologies, such as clean coal and large fuel cells.

Nilam Bedi, a Senior Economist at the Ontario Ministry of Environment, observed that the realities of government decision making about energy use are complicated by the fact that the related environmental problems exist at three levels: global (e.g., climate change), national or continental (e.g., acid rain) and local. Overlapping jurisdictions greatly complicate the making of decisions.

Policy design for energy systems is more an art than a science. Various types of instruments for change need to be used in a judicious mix. The traditional approach of setting more stringent standards is not always in the public interest. Marketable emissions permits are an example of an important alternative currently being considered.

It is useful to adopt a policy approach which stresses the positive side of environmental improvement. Measures like increased energy prices and carbon taxes are politically unpopular. Perhaps a better approach is to view pollution control as an industry, rather than an additional cost, and to encourage the development of environmentally friendly technologies in Ontario.

On specific policy problems, he noted that declining block pricing mechanisms remain a serious problem in regard to reducing energy use. A change in our attitude with respect to municipal solid waste as an energy form is also called for.

Plenary Discussion

Economic, Environmental and Political Issues

It was observed that much of the discussion involved in the formal presentations has been on late 20th century options rather than 21st century options. To plan for the future we need to take a systems view and identify the technological choices that are most desirable. From this analysis, we can establish consistent policies to give producers a "level playing field." Without this future systems view, there is an inordinate amount of risk coming to bear on decision making.

This argument was further applied to environmental problems. It is necessary to consider the costs of environmental programs in a system wide context. For example, given the health costs attributable to air pollution due to energy production and use, instruments such as tax incentives to reduce the causes of such pollution may actually have a net savings effect.

The role of political will was discussed at various points. Change requires political risks and the unwillingness to take them is easily observable. In this regard the question of federal/provincial jurisdiction came up. One participant argued that energy policy is better made in the provinces, and this can be done in various ways. For example, Alberta has a public utilities commission that is active in policy.

There should not be a return to "made in Ottawa" energy policy. In contrast, someone else argued that energy policy is not inherently regional. The fact that these issues are being regionalized because of the current constitutional debate is a disaster.

The California experience with renewables development was held up as an important source of inspiration. Their approach has been to set goals and accept that there may be some abuses and misallocations involved with achieving them. It was also noted that people may be willing to accept higher electricity rates if the justification is to bring renewables on-line rather than building more nuclear facilities.

A number of comments focused on possible positive aspects of aggressive environmental policies. We are in a period of economic crisis and the resulting structural change represents an opportunity. But we are not taking advantage of this opportunity because the correct signals are not getting to the private sector in terms of investment in "green industries," renewables, and non-utility generation. In Germany, for instance, the experience has been that their environmental rules have made them more competitive on international markets. In California, 400 companies in the environmental field have been founded since 1982. They have over $100 million in export sales.

The traditional claim is that if Ontario strengthens its regulations it will cease to be competitive. This is no longer true. However, there has to be sufficient flexibility in regulations to allow for innovations. An interesting strategy would be to have environmental regulation focus on products: all products manufactured in Ontario should be required to meet strong international energy and environmental standards. This is a way to achieve environmental goals while at the same time improving the chances of exporting from the province.

Societal Issues

Education is important. The success of recycling programs has shown that when people are sufficiently in favour of something, they will make sacrifices. A similar attitude with respect to renewable energy is needed.

Lobbyists who are pushing for alternative energy supply options have very few resources compared to established energy interests.

There is a need to broaden public understanding of what is meant by sustainable development.

Technical Issues

Comments on the formal technical presentations included the following:

- The most important transition that will occur in energy systems is from combustion to electrochemical energy conversion. The main usefulness, however, will be in the area of transport rather than generation.
- We should not be left with the impression that because a supply technology is intermittent it is unreliable. This is not the case if it is properly integrated with the rest of the supply system.
- As buildings become more efficient, the unit cost of delivering the natural gas they use through pipelines becomes greater. In such cases as R2000 houses, the most economical way to heat is with a small oil furnace. In a similar manner, with tighter buildings, it is harder to justify the cost of district heating systems.
- Middle East countries are investing in research on photovoltaic cells. The energy form of the future may be hydrogen produced from photovoltaic generated electricity.
- If Ontario Hydro had more R&D funds for fuel cells, where would they go? Hydro would participate more in the development of new fuel cell technologies and thereby have a greater influence in shaping their final nature. In particular, it would be interesting to explore systems to drive fuel cells through coal gasification.
- Even if decentralized technologies are "mature," considerable R&D may be required to make them work in a Canadian environment and to integrate them into larger systems.

Emerging Themes

A large decentralized energy supply industry based on biomass, wind, small hydro and solar hot water technology could readily be "kick-started" in Ontario by modest increases over current NUG buyback rates, with relatively small impact in overall electricity rates. Based on the California experience, economic and environmental benefits would result.

Public acceptance of such modest rate increases would likely be high, given public concern with environmental quality improvement and with renewable energy.

In sum, the discussion suggested that decentralized, renewable energy technology could make a significant contribution to needed energy system transitions, but that it is unlikely to do so in the near-to-medium term, given the current policy and investment situation.

Workshop 3: End Use Options — Buildings, Processes and Appliances, May 7, 1992

Technical Presentations

1. Energy Efficiency and the Indoor Environment — Steven Carpenter, Intermodal Engineering Ltd., Waterloo

This presentation described "state-of-the-art" energy efficient and low environmental impact residential buildings, addressing design features, space conditioning and healthy indoor environments.

There has been a steady improvement in the technology of energy efficient buildings and an increasing concern with reducing the overall environmental impact of buildings. The results discussed here were based on the Waterloo Green Home, one of a series of EMR-funded "third generation" high-efficiency residential units currently under construction as case studies.

In terms of energy efficiency, the Waterloo house incorporates the following features:

- High levels of insulation;
- Air tight construction methods;
- High insulation value windows;
- Integrated space heating, cooling, water heating, heat recovery (from exhaust air and grey water) and ventilation systems;
- High efficiency appliances and lighting; and
- Solar hot water heating, with a photovoltaic driven water pump.

In terms of reduced environmental impact, the Waterloo House has the following characteristics:

- Low levels of water use;
- Construction materials which are made of recycled materials and can be recycled;
- No ozone depleting chemicals in construction materials, insulation or appliances;
- Low transport energy use in construction;
- Selection of natural gas as heating energy form based on an externalities cost analysis comparison between coal, oil, gas and nuclear energy;
- Landscaping features (trees, no lawn);
- A cistern for yard and garden water; and
- Design features to allow greater living use of the basement area (thereby creating more useable living space per total unit area).

The House will open during the summer of 1992 and is expected to:

- Use half the energy of the R2000 design of house;
- Use one quarter the average amount of water;
- Utilize recycled materials in 50% of its construction; and
- Contain no ozone destroying chemicals.

The Waterloo house is expected to be cheaper to build than a house with equivalent useable floor area and unfinished basement, because of the use of its "basement" area as full living area.

2. Energy Efficient Electrical Appliances — Howard Geller, Executive Director, American Council for an Energy Efficient Economy, Washington, DC

This presentation dealt with trends in, and the current status of, electrical energy efficiency in US appliances. The efficiency of most major appliances has increased significantly during the last five years, reflecting various policies, including energy efficiency labelling, rebates and standards. However, there is still very significant improvement possible in many appliances. Efficiency differences between 1991 stock technology and the best advanced technology range from factors of two to four.

A "Golden Carrot" award has been developed by 10 American electrical utilities in consultation with the Environmental Protection Agency and conservation advocates. This involves rebates from the utilities directly to appliance manufacturers who have produced appliances meeting efficiency levels significantly better than proposed 1993 standards.

Refrigerator technology is being driven by the 1996 phase-out of CFCs which are currently used in compressors. The initial substitute for CFC-12 will be HFC-134a, which will slightly reduce compres-

Table 3: Energy Consumption & Conservation Potential with Major Residential Electrical Equipment — Unit Electricity Consumption (kWh/year)

	1986 Stock	1991 Stock	1991 New	1991 Best	Advanced Technology
Refrigerator	1450	1200	900	710	200-500
Freezer	1050	810	600	430	200-300
Central AC	3500	3000	2750	1600	1200-1400
Room AC	1200	1000	850	590	300-400
Water heating	4000	3800	3300	1200	800-1000
Range	800	770	740	700	400-500
Clothes dryer	1120	1090	1060	920	250-500

Source: American Council for an Energy-Efficient Economy

sor efficiency. It is expected that new CFC substitutes will eventually improve the efficiency of future designs of refrigerators.

Appliance efficiency improvements discussed included the following:

Refrigerators:
- improved efficiency motors, compressors and condensers;
- improved insulation, including hard vacuum steel panel insulation; and
- microprocessor control for greater efficiency.

Laundry and Dishwashing Appliances:
- microprocessor control for cycle time, water level, variable speed;
- designs combining top load convenience with front load efficiency;
- higher clothes washer spin speeds;
- low water dishwasher (new spray systems) designs; and
- microwave dryers which combine microwave/thermal cycles for greater efficiency.

Cooking Appliances:
- induction cooktops which induce heating currents in cooking vessels;
- microprocessor controls; and
- better insulation.

3. Current and Emerging Gas Technologies —

Bill Hawkins, Manager, Engineering/Architectural Service, Consumers Gas

Natural gas is the preferred fossil fuel due to its low emissions of CO_2, NO_X and SO_2. Gas appliances can meet most applications served by electricity.

Current and emerging natural gas technologies described in this presentation included:
- high efficiency furnaces and boilers (90% to 98%);
- electronic spark ignition (now standard in Ontario);
- power vented gas water heaters, vented through an exterior wall;
- gas-fired engine-driven heat pump (cooling capacity of 36,000 Btu/hr, heating capacity of 53,500 Btu/hr);
- the "vertical subdivision" concept involving the integration of gas space heating, water heating and cooking technologies in multi-family buildings, with individually metered units;
- spark ignition/self cleaning gas cooking ranges; and
- gas fired cooling systems, including gas-fired, engine driven compressors (up to 150 tons, with heat recovery), gas-fired absorption chillers (up to 1500 tons) and integrated desiccant/vapour-compression cooling and dehumidification systems.

4. Ultra-low Emission Gas Combustion —

John O'Sullivan, Research and Support Services, Institute of Gas Technology, Chicago

The Institute for Gas Technology is a not-for-profit research organization with close links to the natural gas industry. It has been working on various technologies for reducing NO_X, hydrocarbons and CO emissions from natural gas combustion, primarily in industrial applications. As a technology dissemination strategy, the Institute develops prototypes and then works with potential manufacturers to determine the practicability of the technology.

Overall, the Institute has been successful in devising combustion methods and designs which very significantly reduce NO_X emissions. In some applications, NO_X has been reduced to less than 10 ppm, which is suitable for direct heating in food processing. In general, measures that increase efficiency of combustion tend to increase NO_X, while measures that drive down NO_X increase CO and HC emissions, illustrating that energy efficiency and emissions reduction do not always go hand-in-hand.

Other low emission gas fired technologies under development include fluidized bed, cyclonic incineration of toxic wastes, and municipal solid waste incineration.

5. *Future Process Technology Options — J. Terry Strack, Head of Process Applications R&D, Ontario Hydro Research Division, Toronto*

Ontario Hydro has been working with its industrial customers to test various innovative electrical technologies which are intended to increase productivity and reduce energy intensity and environmental pollution. Examples discussed at the workshop are:

- infra-red pre-heating to speed up plastic products production;
- the use of microwave heating to dry clay products prior to their kiln firing;
- microwave heating of foam/solvent wastes to distil out solvents;
- microwave stripping of solvents from dry cleaning filter cartridges;
- variable speed fans for lumber drying kilns; and
- high efficiency fractional horsepower motors.

In actual industrial settings, the application of these technologies has increased industrial productivity, reduced product energy intensity, or addressed significant environmental waste problems.

The potential electricity savings are very large. For example, there is an estimated 3000 MW of small motor load in Canada typically working at 50% efficiency. Use of improved efficiency motors could raise that level to 70-80%, saving hundreds of megawatts of generation.

The potential for improving drying processes is also very large. Ontario Hydro has established a superheated steam drying test facility at its Research Division to explore ways in which the high efficiencies associated with this drying method can be applied to Canadian needs.

Panel Presentations

Paul Shervill, Manager for Environmental Affairs at Union Gas, observed that the technical presentations demonstrated clearly that much has been, and is being, done in terms of developing energy efficient electrical and gas technologies. However, a major question remains as to how these technologies move from the laboratory to the market.

- Institutional arrangements are lacking to accomplish this speedily. In some cases, decisions regarding energy technology are not made by the final users. For example, in the construction industry decisions are generally made by the architects and builders, rather than by the people who use the energy equipment.
- For the last 10 years, the price of energy has not been high enough to drive widespread innovation and adoption of innovative, energy efficient technology. Weak price signals persist in the gas industry.

John Robinson, Director of the Sustainable Development Research Institute at the University of British Columbia, surveyed a series of problems associated with achieving higher energy efficiency and dealing with environmental problems.

- New energy technologies should not be dismissed based on high initial cost projections, as all such projections over the past 15 years have turned out to be wrong.
- Energy efficiency improvements need to be done as a package. Doing the most cost effective measures first may mean that the less cost effective, but still important, measures do not get undertaken later.
- More effort is needed to understand consumer behaviour regarding energy decisions. Current understanding divides into two camps: pure economic rationality (if the price incentives are right people will adopt new technologies) and the attitudinal approach (education is the key). Neither alone is adequate.
- A mixture of energy efficiency standards and price based policies is needed to drive widespread adoption of energy efficient technology.
- While policy of the 1970s was geared to addressing specific environmental issues, it is now clear that a systems view is needed. How such an approach can be implemented is not clear.
- Market mechanisms fail due to externalities, while political mechanisms fail due to lack of continuity.

Plenary Discussion

The discussion focused strongly on problems associated with leading people to adopt energy saving technology, rather than on problems with the technology itself. For example:

- People cannot be expected to learn all that is needed in relation to energy efficiency retrofits. They need a comprehensive energy retrofit program from an institution they trust. The issue of information availability and overload, and how consumers make decisions on available information, is as important as technical issues.
- Few people are prepared to spend substantial amounts for altruistic reasons. Regulations and standards are required. For example, California's new rule on zero emission vehicles has caused the major car companies to enter the electric car market in a way they would not otherwise have done.
- How can high efficiency light bulbs be gotten into every house? To overcome the high up-front cost, lease the bulb, with payment through the utility bill. Follow up with a visit (perhaps using local service clubs) to do an energy audit and give advice. This will "kick-start" the process.
- Heat pumps are complicated machines. One major breakdown at year five (after the warranty is ended) and all energy savings are lost. This is what the customer fears. A possible solution: leasing or insurance programmes through the utility. Consumers Gas already provides this.
- Install a "negawatt" meter in each house and pay people for the energy they save. A good incentive to buy efficient appliances would be to make people buy four years' worth of energy for an appliance at the time of purchase — then they would not choose inefficient units.
- People selling appliances tend not to stress energy efficiency on the sales floor. Rebates should go to salespersons selling the most efficient appliances as well as to customers.
- Energy efficiency labelling is important. The current use of the label "recyclable" is an example of bad, unregulated, misleading and ultimately counterproductive labelling.

Another theme evident in the discussion was a tension between a piecemeal approach to promoting efficient end use (for the most part, the approach we have now) and a focused strategic approach. There is a need for a broad study of experience in the promotion of new technology with a view to developing strategies.

It was argued that regulation can promote growth of new technologies. There has, for example, been energy efficiency regulation in Canada with respect to windows and ventilation and now Canadian firms are world leaders in production. In Sweden institutional arrangements have been found to be important; e.g., the mortgage system has played a key role in developing a more efficient housing stock. The Canadian Energy Research Institute has found that in the US the most effective policy instruments are tax incentives for manufacturers.

Education of decision makers is also key given a recent study by Consumers Gas that shows that building engineers do not know much about new technologies.

New technologies require skills and organizational arrangements which do not currently exist. Much planning is required to put in place such skills and organizational arrangements. For example, there are several colleges in Ontario which provide special programs for technicians to work on energy technology.

A difficult issue in regard to strategy is whether new technology is prone to create new problems. One participant argued that air tight buildings fall into this category, citing instances of condensation damage or the "sick building" syndrome. Air-to-air heat exchangers are good for removing CO and other construction materials emissions, but do not address spores and mould. Perhaps a slightly leaking building with a high efficiency furnace is a desirable objective. Another participant argued that these problems have been adequately overcome.

An economic issue was raised in relation to the choice of natural gas as the fuel form with minimal environmental impact. Consider a residence that has become very energy efficient, having reduced its need for natural gas and for electricity to very low levels. Given that electricity is essential for certain end use requirements and can also be used for the (small remaining) heating needs, does it make sense in an overall systems context for society to have in place *two* energy systems? Why not only electricity?

Emerging Themes

While energy efficient/low environmental impact technology is increasingly available, there is a great need for the development of more and better programs designed to move the best of this technology rapidly into the market place. Policy, standards, regulation, incentives, rebates and education all have a potential role, and have been tried in various jurisdictions.

There would appear to be merit in an ambitious study which looked at the effectiveness of such methods in the various settings in which they have been tried in order to evaluate them in terms of their effectiveness in a Canadian setting.

Workshop 4: End Use Options — Transportation, June 8, 1992

Technical Presentations

1. Transportation Planning and Traffic Management — Neil Irwin, Managing Director, IBI Group, Toronto

This presentation examined the opportunities associated with land use, transportation planning and traffic management as methods to address the rapidly growing social, economic and environmental problems associated with transportation.

Three major "policy levers" were considered:

- Land use control, involving the coordinated planning of land use (form, density, mix of uses) and infrastructure, to achieve sustainable, convenient and affordable transportation.
- Rail and road transportation networks design and planning, providing effective transportation continuity, coverage and function.
- Management of transportation networks to meet the mobility requirements of people and goods. Management options include: level of service, control of traffic, pricing of transportation, technology, and user information.

Decisions concerning land use, networks and management interact to create an "urban transportation balance," which consists of trade-offs that determine the character of the entire transportation system. These include walking vs. vehicular trips, travel effort vs. opportunities, private autos vs. public transit, movement of goods vs. persons, and transportation energy consumption.

The results of five studies which examined the impacts of various policy options on the transportation sector for the Greater Toronto Area were presented. A number of significant conclusions emerged from these studies:

- Mixed use, high density development focused on downtown Toronto, as distinguished from lower density, "spread" development, leads to significant reductions in rural land consumed, roads constructed, average trip length, energy consumed and automotive emissions. "Nodal" development (i.e., development focused on downtown Toronto plus a number of secondary development nodes), may provide an intermediate strategy, given current suburban lifestyles.
- Land use planning and urban design, including road grids, can be undertaken in a way that maximizes the potential for public transit, as well as walking and cycling. Transit supportive land use is structured (i.e., consists of a system of corridors, nodes and transfer nodes) and compact (i.e., achieves a sufficient residential density to ensure the necessary transit ridership level). Mixed land use along corridors, at nodes and within communities increases the potential for walking and cycling and reduces average trip length.
- A well spaced, continuous road grid consisting of expressways, arterial and collector roads, radial rail/rapid transit lines, and pedestrian-friendly structures are urban design features supportive of transit. At the micro-design level, placement of parking lots behind stores and putting mall entrances near to transit stops or sidewalks, trees, and pedestrian amenities promote public transit and walking.
- Traffic management measures which enhance mobility and energy efficiency while reducing emissions are higher vehicle occupancies/loads, improvements in traffic operations, curb space management, measures to increase the shares of transit and rail, road pricing and more roads, private sector rapid transit funding and more rapid transit, and better information to users on trade-offs involved in transit decisions.

Road pricing could be used to address many transportation problems, including serious financial constraints on road construction and maintenance, supply/demand imbalances, congestion and public transit's low or decreasing ridership share. The theoretical rationale for road pricing is that any underpriced commodity creates excess demand, so that use is rationed by queuing rather than price. This contributes to environmental problems and energy inefficiency. The availability of technology for electronic toll collection makes widespread road pricing possible. The most desirable strategy is to introduce pricing to the most congested roads. While there is generally low public acceptance of road pricing, experience in the US suggests that two-thirds of users would be willing to pay tolls on new roads to accelerate their construction.

In summary, the most important needs are to improve the design of basic road and rail networks, manage transportation systems with the objective of moving people and goods, not vehicles, and in the long run promote structured and compact land use.

2. Alternative Fuels in Light Vehicles — Chris Weaver, Engine, Fuel and Emissions Engineering, Inc., Sacramento, California

This presentation summarized work dealing with energy and environmental aspects of transportation fuel alternatives in California.

The issues affecting the choice of small vehicle fuel technology which are of greatest concern to policy makers are:

- urban air pollution (CO, ozone, NO_X, Volatile Organic Compounds, and particulate matter;
- energy efficiency;
- global warming;
- fuel availability, security and sustainability; and
- social and resource costs of fuel and vehicles.

Issues internal to the use and production of vehicles which affect the choice of fuel technology and are of greatest concern to manufacturers of fuels and vehicles are:

- vehicle/fuel compatibility, including power/weight and power/volume ratios, range, cold starting characteristics, and safety;
- fuelling and storage infrastructure;
- trends in emission regulations;
- fuel economy regulations; and
- familiarity of technology to users and compatibility with existing vehicle components.

Such internal issues relate to the cost of vehicles, fuel and vehicle production capacity, vehicle performance, and market acceptance.

Related to fuel choice is the current variety of fuel-use technologies available:

- Otto Cycle — this cycle is the most widespread form of technology. The most common approach to reducing emissions in this case is through add-on abatement technologies, an approach that the auto industry would like to stay with. "Lean burn" versions would reduce emissions by increasing the air/fuel ratio, but have limited success with achieving acceptable NO_X emissions. The current catalyst technology is efficient in a normal engine operating range, but allows high emissions in the first few minutes of operation and during rapid accelerations. Current US federal testing procedures do not give an accurate assessment of emission because they don't take into account these latter two operating conditions.
- Diesel Cycle — diesel technology has a 20% market share in European automobiles and a higher share in light trucks. This cycle is more energy efficient than the Otto Cycle.
- Gas Turbines — gas turbines have a major drawback of high fuel consumption during idle.
- Electric Motors — electric motors driven by fuel cells and hybrid systems look promising in the longer term. Battery driven electric vehicles continue to experience short range constraints due to battery energy storage limitations.

Factors to be considered in the choice of a fuel include:

- Methanol — pure methanol has cold starting problems. These are less severe with a 15% gasoline mixture (M85), but at a cost of significantly higher emissions. The fuel is expensive and infrastructure requirements are high.
- Ethanol — even more expensive than methanol and with similar problems.
- Natural Gas — good cold-starting performance and emissions reduction. The problem is that storage involves much higher initial cost than for liquid fuels (the gas must be compressed) and so the most economically efficient use is in high mileage fleet vehicles.
- LPG — similar benefits and problems as natural gas, but the long term supply picture is not as good.
- Hydrogen — harder to store than natural gas.

Low octane with correspondingly poor performance characteristics.
- Electricity — problems of range and storage.
- Reformulated Gasoline — this will probably be the primary fuel for the next 10 years or so.

In conclusion:
- Transport systems are not "created," they "evolve" from existing systems.
- The most likely near-term changes to occur in the California transportation system will be the adoption of reformulated gasoline, natural gas and LPG. A mixture of methanol and gasoline is unlikely to play a significant role in California.
- There are major advantages to separating the function of driving the wheels from that of transferring energy from the fuel. In this regard the best technologies are those where the wheels are driven by electric motors, with on-board electricity generation and which allow regenerative braking. Long term promising technologies in this regard are hybrid electric vehicles using natural gas or biomass alcohols, or fuel cell/battery electric vehicles powered by natural gas, biomass methanol or hydrogen.

3. *Alternative Fuels in Public Transit — Ovi Colavincenzo, Manager, Vehicle Technology Office, Ontario Ministry of Transportation*

The Government of Ontario Alternative Fuels Technologies Development Program has been in operation for about 10 years. The Program's objective is to obtain operational experience with various alternative fuels in terms of economic, environmental and implementation issues. A number of projects have been undertaken in cooperation with several local transit authorities, including:
- demonstration of 10 propane buses in Ottawa (1984-87);
- six natural gas demonstration buses in Hamilton (1985-88);
- 50-bus natural gas evaluation in Toronto, Hamilton and Mississauga starting in 1991;
- a methanol bus demonstration in Windsor, beginning in 1991; and
- demonstration of diesel buses with particulate traps (Ottawa 1992).

A life cycle cost analysis was conducted to compare the net present value of diesel fuel technology with other fuel/technology combinations. Estimates for electric trolley vehicles, with and without new overhead wires, were also included. All fuel, equipment, operating, maintenance and fixed costs were included in the analysis.

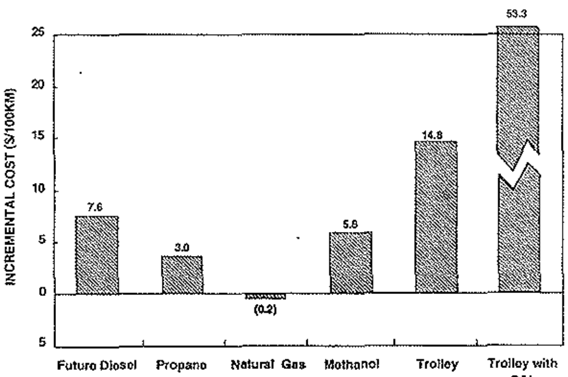

Figure 1: Life-cycle Cost Increment — Relative to 1989 Diesel

To date, the analysis has found that natural gas has by far the lowest fuel cost, but it also has the highest refuelling infrastructure cost because it requires compressors. As well, the fuel cost advantage of natural gas and propane is due in part to the fuel tax structure, which discriminates against diesel fuel. In terms of total life-cycle costs, much of this saving is lost if the comparison is done with fuel taxes removed. Reformulated diesel with traps and methanol are relatively expensive with or without taxes. In the case of the diesel particulate trap, this is due to its very high capital cost. Both types of electric trolley operation are very expensive.

The presentation concluded that:
- The feasibility of operating transit buses using alternative fuels has been demonstrated.
- Alternative fuel buses have demonstrated clear environmental advantages but with significant life-cycle cost increments.
- More suppliers of alternative fuel technology are required to expand the market.
- Government/industry cooperation will be required to develop the alternative fuel technology market.

4. Clean Fuel Commercialization in Southern California — Paul Wuebben, Clean Fuel Officer, California South Coast Air Quality Management District

The California South Coast Air Quality Management District (AQMD) includes a population of 14 million persons. It supports research and development, demonstrations for clean fuel technology, and works with private sector partners in this effort. Currently, the District has the largest fleet of alternative fuels buses in the world.

Commercialization Status of Clean Fuels:

- Electric Vehicles — While expensive, commercial electric vehicles are currently available (e.g., Chrysler's electric van), all of the more advanced vehicles are prototypes. The main problem with such vehicles is the current state of battery technology. To simultaneously meet the goals of low cost, long range, high lifecycle, rapid recharge and high density of energy stored per unit weight will require a "scientific breakthrough" in battery technology.
- Compressed Natural Gas Vehicles — These are technically capable of meeting ultra-low emissions standards. GM and Chrysler have CNG light trucks available. Some of the retrofits available prove under testing to have very high levels of CO emissions. Retrofitting standards need to be tightened.
- Reformulated Gasoline — ARCO claims that their ECX gasoline will be equivalent to an 85% methanol fuel (M85) in terms of emissions. The 6.6¢/l increment figure that is often used is much too high. A more accurate figure is 3.2¢/l. As a short-term step, AQMD supports the efforts of the oil companies to produce such fuels.
- Methanol — One hundred percent methanol fuel has been used to produce the lowest levels of NO_x and particulates ever certified for buses. M85 has higher emissions, but because the reactivity of these emissions is low, the environmental benefits of substituting M85 for conventional gasoline have been underestimated. Furthermore, M85 fuel has lower toxic emissions than gasoline on a "health weighted basis." Disagreeing with the other speaker from California, Wuebben argued that currently quoted estimates of the incremental costs of substituting methanol for gasoline are overstated. Methanol is actually competitive with high octane fuels. California has mandated that all underground filling station tanks that are installed must be methanol compatible.
- Particulate Traps for Diesel — Capital costs are very high. There is probably no viable way to make diesels conform with trends in emission regulations.
- Fuel Cells — Currently capital costs are about $3000 to $5000 per kW, so they are a long way from commercialization.
- Flexible Fuel Vehicles — Ford, Chrysler, Volvo and Mercedes are all marketing flexible fuel vehicles (FFV), able to run on two different fuels (gasoline and some other low emission fuel). The major challenge to commercialization is providing an adequate fuelling station network. California has mandated that, if the auto companies produce 200,000 FFV's, the major oil producers must open 200 stations.

5. Electric Vehicles and Fuel Cell Development — Bill Adams, Director, Electrochemical Science and Technology Centre, University of Ottawa

This presentation addressed recent research in Canada on batteries and fuel cells suitable for electric vehicles.

The recent California mandate for zero emission vehicles has given rise to an acceleration in research on electric vehicles.

Electric vehicles can be shown to have significant environmental benefits, even when the indirect emissions from electricity generation are taken into account. Depending on the time of day battery charging is done, geographical location, and the season, substantial electric vehicle fleets could be accommodated with the existing electrical generating capacity, with much improved capability to control pollution from the point source relative to the dispersed and uncontrollable internal combustion engine (ICE) fleet.

For urban transportation, prototype electric vehicles can now match the performance of internal combustion engines. Projected electric propulsion systems should be capable of surpassing ICE performance within a decade (based on analysis that accounts for reduced operating life-cycle costs).

The key issue is the development of superior battery technologies. Investment in excess of a billion dollars is likely required to develop a battery with the characteristics needed for a generally acceptable electric vehicle. Research and development of this order is under way in the US. Various high energy electrochemical systems have the potential for such battery applications. Research on methods for the recycling of batteries is needed.

Canadian research institutions are working on advanced battery designs (University of Ottawa, Hydro-Québec), fuel cells (Ballard Power Systems in Vancouver and the University of Victoria), and electric vehicle components (Alcan).

Initial production of prototype electric vehicles is beginning to occur this year in Canada and elsewhere. Initial commercialization is slated for 1995 /96 in order to meet the California zero-emission vehicle legislation.

Panel Presentations

Bruce Hutchinson, Professor of Civil Engineering at the University of Waterloo, argued that current road patterns in Toronto are unacceptable in terms of fuel consumption, emissions and other wastes associated with their use. Average commuter trip length has increased about 40% during the last decade. With the increase in labour force participation, the total number of commuter miles has increased tremendously.

By contrast, in Mississauga average trip length has decreased due to sound spatial planning. Per capita transit ridership in Ottawa-Carleton is the highest in Canada, again due to good spatial planning.

Commenting on road pricing, he noted that Singapore has it, but it was not politically acceptable in Hong Kong and the Netherlands. A system was accepted in Denmark only because commuters were promised that funds generated would go to roads. In the UK there is growing support and Stockholm is working on a unified pricing scheme for roads and public transportation.

Peter Reilly-Roe, of EMR Canada, noted that Canada's pledge to cap greenhouse gases implies a very different policy situation from what has existed in the past, and he considered alternative instruments for dealing with it. Canada is hard pressed to do anything independently on the vehicle technology side because it is locked into US standards. There is some evidence that the carbon tax may not work well. While it is clear that differences in energy prices across broad regions (Europe vs. North America) affect consumption predictably, price differences within these regions do not appear to have large effects.

Reilly-Roe suggested that the use of road pricing was unlikely. "Intelligent Highway Systems" encompass a wider variety of options than just road pricing. More work is needed to assess their potential.

A stable policy environment is crucial in relation to the development of alternative fuels. Developing partnerships between governments and producers is important, but governments should not try to "pick winners." It is better to keep options open and let the market decide.

In the view of ***Joel Couse*** of the International Energy Agency in Paris, our high level of mobility, as we currently pursue it, is not sustainable. The most difficult component of the fuel/end use matrix to scale down is the petroleum products/transport sector. Some aspects of this problem are:

- Fuel consumption per vehicle in Europe has not gone down in 10 years, despite significant efficiency gains. This implies that driving behaviour has become more fuel intensive.
- Forecasting firms in Europe have consistently underestimated the demand for cars.
- A study in Holland has predicted that even very large increases in parking rates and high road prices would reduce consumption only in the range of 6 to 7%.
- A neglected part of the sector is air transport, where nothing is happening in relation to alternative, less polluting fuels.

Ralph Torrie, a consultant in Ottawa, questioned whether alternative fuel vehicles will have much effect in light of current trends in population, behaviour and vehicle demand. The current excitement over alternative fuels has shifted attention from transport efficiency improvements, which are more effective. To illustrate the importance of transportation, he presented data on CO_2 production by sector and fuel indicating that the largest single contribution was from oil in transportation.

He discussed the need for an analytical framework in which one can simultaneously evaluate alternative vehicles, land use options and transport efficiency improvements. We need a framework that will help us to decide better what to do first. An illustration of this sort of analysis, developed in Australia, defines factors influencing transport energy demand at different levels of aggregation. The most significant factors were found to be at the level of the "whole city" (urban planning, land use, etc.), while the least significant were "within vehicle" measures, such as emission control devices.

Plenary Discussion

Changes in individual and societal behaviour (for instance, of the sort involved in major land use shifts) were less discussed than improvements in technology. On the other hand, some participants raised the concern that short-term "technical fix" policies could be working against longer-term, ultimately more important "social fix" strategies.

Behavioral Matters

- On influencing commuter behaviour, parking and road pricing are probably more powerful policy levers than fuel prices.
- The change to the two worker household places tremendous time constraints on commuters, and thus limits their ability to use transit.
- Behaviour modelling is important. Leisure trips are increasingly coming to dominate journey to work trips. We need to learn more about them.
- Land use and pricing policies only make sense when alternative, more desirable transport modes are available.

Policy

- In Canada, taxation and other policies have retarded the ability of trains to compete with trucks for intercity freight transport. In Europe, an effort is underway to develop more efficient intermodal freight transfer system to get more freight onto trains.
- High speed rail lines could have a significant impact but the government won't support them, even though it subsidises uneconomic projects like Hibernia.

Technology

- Low emissions do not necessarily correlate well with low energy consumption. The most energy efficient car Toyota builds is illegal in California because of its high NO_x emissions.
- An important factor with respect to switching away from automobile travel is that buses with less than 50 passengers are generally not breaking even in terms of emissions.

Emerging Themes

The day's discussion left one with a strong sense of the importance of the transportation sector in dealing with energy and environmental problems. At present, a wide variety of technological changes is in progress, but at stages insufficiently advanced to make their outcomes clear. In some cases, such as batteries, a substantial breakthrough will be needed before the technology takes hold. In many cases, such as the adoption of various alternative-fuelled vehicles, the development of new infrastructure will be required.

All of this makes it difficult to predict how the transportation sector will evolve as the twenty-first century proceeds. Furthermore, to understand this evolution it is necessary to consider not only vehicle technologies, but also changes in the patterns of roads and urban spaces which determine vehicle usage. Behavioral, political and institutional issues are just as important as technological developments.

Some Reflections on the Process

A satisfying aspect of this series was the extent to which context shaped discussion. People were ready to look beyond their own technical interests and debate the problems associated with developing and implementing energy technology. Our desire to provide a forum for people from diverse backgrounds was fulfilled.

Along with this satisfaction, we are ready to admit to some innocent expectations that were less than fulfilled. During the early planning stages the organizers of this series envisioned each workshop ending with conclusions of a more concrete nature than were in fact achieved. It did not take long for us to see that we were focusing on technological trends and decisions too large for any group of people, however well informed, to agree upon after only a few hours of discussion. Nevertheless, we claim some significant success on the identification of key issues and a corresponding level of cross-disciplinary and cross-professional communication.

In regard to the topics discussed, while we succeeded in dividing the subject into four relatively neat categories, comprehensive coverage was impossible in four one-day meetings. Inevitably some important subjects were not treated sufficiently. For example, even though the global nature of environmental problems influenced much of the discussion, specific technological developments were typically not analyzed in a global context. One can see this, for instance, in relation to the transportation workshop. It was generally assumed that the level of personal mobility currently enjoyed in rich countries would be continued. The question of the desire for similar levels of mobility in the more populous, less-developed regions of the world hardly entered the discussion. If the global environment cannot support the fulfilment of this desire, can we reasonably expect to maintain our own levels of mobility? One can see the need for a new stage of the discussion: an examination of the link between technological options and sustainable development.