ENERGY OPTIONS: Preparing for an Uncertain Future

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1. Introduction

A cardinal issue in the world today is that of energy supply. It is an immediate problem for many and a long term concern for all. The human race is not in equilibrium. Our population is growing, our vital resources are decreasing and our environment is deteriorating. Some of the world's population are affluent while many others are starving or living in poverty. Changes must be made if more are to share the affluence of the few. Failure to change will lead to unnecessary suffering and death, increased international tensions, and possibly to wars. Our long term survival demands a sustainable society with an adequate standard of living. Humanity is fortunate that it can see the perils ahead and that it has the knowledge to devise solutions and, hopefully, the wisdom to implement them.

"Energy Options" is an important initiative of the Federal Government to examine the energy question in toto, to look beyond our traditional preoccupation with fossil fuels to our many other options for future energy supplies. This is a timely endeavour because the 21st century will see massive changes and perilous shortages in the conventional sources of world energy. The present period of relative calm is precious; we must use it to prepare for the unstable times ahead. We must look beyond the short-term fluctuations to the inexorable long-term trends. Decisions must be made on the basis of fact and conservative expectations rather than on unrealistic hopes and unfounded fears. A sustainable world energy system in the post-fossil-fuel era will require rigorous and objective analyses of every energy option and the deployment of all that prove viable.

This brief has been prepared on behalf of the Chalk River Branch of the Society of AECL Professional Employees (SAPE). Our present and past membership, representing many fields in science and engineering, have from the beginning played major roles in the underlying and applied research for the Canadian CANDU nuclear power option. As professionals with scientific and technical knowledge of nuclear issues, we believe that all energy options should be examined with the same thoroughness that has been applied to nuclear power, so that honest and objective comparisons can be made to determine how best to meet our long-term energy needs.

Our submission addresses the major criteria by which we believe energy options should be judged: sustainability, security of supply, and safety. These are not independent criteria and may be weighted differently in different situations and time frames. The overriding consideration must always be the survival of society as it progresses towards a sustainable state. In succeeding sections we discuss the nature of a sustainable energy system, energy security in terms of fuel supply and technical reliability, and safety issues. The brief ends with a summary and conclusions.

2. Sustainability

An energy supply is sustainable if it is renewable or if it exists in such quantities as to be available on a time scale comparable to the lifetime of the sun. Needless to say, on this timescale, cataclysmic events will likely have occurred that will render concerns about energy supplies irrelevant.

Presently most of our energy is supplied by the combustion of fossil fuels - in particular coal, natural gas and oil. These originated from solar energy captured by photosynthesis and preserved as hydro-carbons by geological processes acting over millions of years. By contrast their combustion is being achieved in a few hundred years. Fossil fuels are a once-only option in the history of man. Their cheapness and convenience have supported the dramatic flourishing of humanity through both industrial and scientific revolutions. Their exhaustion will have far-reaching and irreversible effects on the human condition. If our present civilization were to be lost, future generations would find it much more difficult to advance without the aid of cheap and abundant fossil energy. Even now ours is a very fragile society. Because of the finite amount of fossil fuels, and because our rate of use exceeds their rate of formation by many orders of magnitude, a sustainable society must look to survival without them in the long term.

Available energy on earth can be derived from five possible sources: the result of nuclear fusion in the sun; primordial and radioactive decay heat within the earth; the gravitational energy of the earth-moon-sun system; fission either of existing fissile elements or of those that can be bred from fertile elements; and possibly fusion of light elements on earth if present research is successful. There is absolutely nothing known to science today that promises any radically new, presently unknown, source of energy.

Our possible long-term options are renewables derived from solar energy and nuclear energy based on fission and maybe fusion. Conservation must also be practised, but it must be remembered that this only moderates the amount of energy needed; it does not eliminate the need for energy. Some long term options, like hydroelectricity and nuclear fission, are widely used; others, like photovoltaic, modern windmills, wave and tidal power, are in the early stages of development. Nuclear fusion remains to be demonstrated as a practicable energy source under terrestrial conditions. Some of these sources are referred to as renewables but in fact all of the above may be considered inexhaustible on the many billion year time-scale of the lifetime of the sun.

Nuclear fission, with advanced fuel cycles, is an inexhaustible energy source because the vast energy yield from a small mass of fissile material makes even very dilute sources economically accessible in the long term. Enormous quantities of uranium and thorium are found in dilute but recoverable amounts in the oceans and elsewhere. Nuclear fission is the only presently proven, economical and practical long-term energy source that can be deployed anywhere, at anytime and in the amounts required for the local region - points that are often forgotten in the debate over energy options.

3. Security

3.1 Security of Supply

In the near term fossil fuels will inevitably play an important role in the energy budget. As stated in the recent study of the World Energy Conference (1), the pessimistic scenarios of a few years ago are the most probable today. The study points out that just to hold oil consumption at 1978 levels with a pessimistic economic growth scenario (called the "increasing international tension" scenario) the following must be achieved between 1978 and 2020:

Coal	increased by a factor of 2.5 to 4.4 GTOE*/a
Natural Gas	increased by a factor of 2.0 to 2.4 GTOE/a
Hyroelectricity	increased by a factor of 2.5 to 1.0 GTOE/a
Nuclear	increased by a factor of 10.0 to 1.6 GTOE/a
New Sources	increased by a factor of 100.0 to 0.8 GTOE/a
Wood	increased by a factor of 1.4 to 0.7 GTOE/a
Waste	increased by a factor of 1.6 to 0.4 GTOE/a

*Giga tons of oil equivalent

A key component of a healthy population and economy in Canada is a strong electrical system. The Canadian electrical system is relatively isolated from international energy markets based as it is on hydroelectricity, coal and nuclear fission. Canada is a world leader in technologies of electrical generation and usage. Prudence demands that we foster and develop this capability through electrical substitution where feasible and through development of vital new technologies such as more efficient batteries and hydrogen usage for transportation. An ample supply of reliable economic electricity is, and will increasingly be, a major Canadian competitive advantage.

The transition from our present unsustainable system to a sustainable one will be fraught with so much social, political and economic turmoil that our very survival may be in question. Already the activities in the Persian Gulf should be a warning of what will happen when nations see their energy supply jeopardised. The world energy situation is likely to get much worse before it gets better.

Wise energy planning for Canada must balance the long-term realities against those of the near-term. It is not selfish for Canada to look to its own energy sustainability. The harsh Canadian climate and the long distances that have to be travelled within the country demand large quantities of energy. The maintainence of our own economic strength is essential if we are to help those less fortunate than ourselves.

3.2 Technical Reliability

A secure energy conversion system requires both a ready supply of feedstocks (fossil fuel,uranium or renewable energy sources) and proven, reliable technology. Some key players in the present energy debate are attacking

existing technologies of established reliability and advocating their replacement with as yet unproven alternatives. This is particularly hazardous as we enter an era of profound change in the energy supply as discussed in Section 3.1. It is therefore essential to examine all proposed options critically to judge whether they can provide the same reliable and economic flow of energy that we enjoy today.

Central power stations fueled by coal or uranium or having hydro as a source have generally proved to be very reliable provided there is a reasonable reserve margin to compensate for equipment failures and maintenance. There have been freezing conditions which have interfered with coal handling between storage piles and combustion units. (Nuclear stations are not subject to such problems since very small amounts of fuel need be transported). Large scale hydro is dependable although year-to-year variations in output can be considerable depending on precipitation levels.

One of the difficulties in the energy debate is to grasp the magnitude of the problem of meeting our requirements. Some critics of present technologies are suggesting alternatives that are neither practical nor proven. A review of some of the "soft energy" alternatives lays bare some of the technical difficulties.

The use of biomass is well established. For example the pulp and paper industries generate substantial amounts of their energy today, however it is not very practical for very large energy production despite the strong advocacy. It is a sobering thought that the total energy fixed by green plants in the USA represents only about 75% of the commercial energy used in that country. Furthermore about 50% of the energy fixed in the USA is already harvested through agriculture and forestry (2). Thus the potential impact of biomass is limited by supply, present use, and the magnitude of the demand.

A recently discussed concrete example is the proposed replacement of the generation of the 800MW Maine-Yankee reactor by a power station burning forest biomass(3). It would require 10-million tons of wood annually from 5-million acres of forest (about one-quarter the size of the State of Maine) to match the energy output from the nuclear power station. This would entail about 400000, 25-ton truck loads of chips per year (one load per minute around the clock) and 5-billion gallons of water. The result of the combustion would be 110000 tons of ash, 1400 tons of particulates,420 tons of SO-2, 14000 tons of CO, 7500 tons of nitrogen oxides and 4500 tons of volatile organics. Edwin White,Professor of Forest Soil Science at Syracuse University, notes that use of biomass is a case in which technological advances in the harvesting of wood "far outstripped research and knowledge on the environmental impacts". Can operations of this magnitude be considered "benign" when the impacts on highway safety, air quality, soil erosion, water retention, wild life habitat and other uses for wood are largely unknown?

For the past few years the annual increase in electrical energy demand in Ontario has been equivalent to about one reactor at the Darlington Station (about 10% larger than the Maine-Yankee reactor). Forest wastes should not be "wasted" but it is clear that biomass cannot even hope to meet the growth in our requirments let alone make a major contribution to our present needs.

Solar power and wind energy are frequently cited as major long term options to replace nuclear energy. The solar situation has recently been reviewed by the National Research Council of Canada(4). Their conclusions are summarised in the following quotes:

> State of the Art Active Solar: "Without subsidies or tax credits of some form this [cost performance figure] is far too high to give any significant market penetration in Canada or elsewhere" (page 19)
>
> State of the Art Passive Solar: "A state-of-the-art passive solar design with cost effectiveness in mind simply emphasises south-facing windows without adding window area beyond that which is aesthetically desired." (page 34)
>
> "The major application for photovoltaics is in remote locations where grid power is not available. For example the approximate cost for a 20 Watt unit at $8 per peak-watt would be about $1280 plus battery and regulator. Grid electricity at $0.05/kwh would be about $9 per year" (page 39)

The economics of solar energy in the USA is illustrated by the following report(5):

> "with lower oil prices and particularly the expiration of tax credits, sales of thermal solar systems have dropped by 80%. Many companies are out of business. For example, Servamatic Solar of Concord, California, that had sales of $100 million and a workforce of 4000, is in liquidation. Survivors have diversified into, for example, satellite dishes, water purification and residential air conditioning."

Another frequently quoted soft-energy option is windpower. Like solar power this too suffers from the same problems of low energy density and intermittent and unreliable availability. A wind machine's output varies as the cube of wind speed over the operating range of the device so that siting is very important. At present in Canada the only economic application is hybrid wind-diesal systems in remote locations(6). Windmill technology has proven difficulties with finding strong, resilient materials that will withstand the constant buffeting over the economic lifetime of the machine. At present most machines of over 1 MW capacity are out of service because of fatigue problems(7).

4. Safety and Environmental Concerns

A guiding principle in energy production and distribution must be to maximize benefit and minimize harm to humans and the environment. In much of the world, the problems of poverty and suffering are directly related to shortages of energy, whereas in more affluent areas concerns are centred on the hazards associated with the production of energy.

The use of fossil fuels has both short and long term implications for human health and the environment, in addition to the previously discussed problems with shortages of supply. Widespread air pollution and acid rain are serious concerns today; climatic change from the "greenhouse effect" is a

major danger of unknown proportions for the long term. Anything that can be done to reduce the use of fossil fuels now will moderate the environmental impacts and buy precious time for the necessary transition to the post-combustion era.

Wind and solar have been called benign technologies, but to be significantly useful they must be largescale. Vast quantities of material are required and it has been pointed out that the air pollution resulting from their manufacture is about 60 times that for materials needed in the building of a nuclear power station of equivalent energy output(8). Large windmill farms will cause problems because of visual aesthetics and noise pollution and there is potential for harm to local bird populations and disturbance to other wildlife. An honest comparison cannot ignore such technical, economic and environmental factors.

Conservation also has associated risks. The most topical example is indoor air pollution in tightly sealed homes, particularly the widespread radon problem, the radiological impact of which far exceeds that of nuclear power stations.

Nuclear power too has dangers although, from both experience and risk analyses, its hazards are no greater and, in fact, generally smaller than those of alternative sources of energy. The normal operation of a nuclear power station poses negligible risk to its workers, the public and the environment. The overall harm from uranium mining is much less than that from coal mining for equal energy outputs. (An additional safety factor of about 50 in mining will be gained for nuclear over coal with the introduction of advanced fuel cycles). All evidence to date suggests that the disposal of high level radioactive waste is a scientifically and technically soluble problem with the main features of a satisfactory solution in hand. The problem is made easier by the small amount of waste; its location and easy accessibility at the power site; and the steady decrease of its toxicity with time because of its radioactive decay.

Only in accident situations can any major harm arise from the nuclear option. The tragedy of Chernobyl demonstrated that people can die in accident situations; but even in this case, with one of the worst accidents imaginable, it has not been the unrecoverable world disaster that had been predicted by some critics. The deaths of 32 workers were tragic but the death toll was not abnormal compared to other types of accidents in our society: the total assumed death toll from both acute and delayed radiation doses to the evacuees is less than two days average highway deaths in the USA. It has been estimated that the replacement of 1000MW(e) of coal burning with nuclear power saves about 70 lives per year(9). Accordingly the harm to the general public from the burning of coal to replace the nuclear energy from Chernobyl Unit 4 is comparable to the predicted worldwide delayed deaths from Chernobyl fallout. By the same reckoning, far more lives are saved every year by the use of nuclear power than will be lost as a result of the nuclear accident over the next 50 years or so. As a result of Chernobyl new safety reviews have been carried out by many nations. No surprises have been found that imply that properly designed stations, operated on wellestablished principles, pose significant danger to those living near them. This is certainly the case for the CANDU reactors.

5. Summary and Conclusions

Canadians will continue to need energy for survival, for transportation and to fuel our industries. This brief has dealt with some longer term aspects of the energy debate, particularly those concerning nuclear power. Fossil fuels will play a major role in our energy budget in the short term but, for reasons concerning sustainability, security and environmental safety, we must begin now to plan and implement their replacement.

The adequacy of energy supplies will be an increasing concern both nationally and globally in the coming decades. Oil and natural gas will cease to be large scale energy sources within the experience of many now alive. The remaining resources should be used prudently to facilitate the transition to more permanent technologies. Security of supply does not loom large in the public mind at present, but given the massive investment required, the period of energy crisis will bring unnecessry suffering and hardship if there is inadequate preparation.

Canadians are very fortunate in having many energy sources at their disposal. Few sources however are capable of supplying the vast amount of energy that is required. The only options that can play a greater, major role in the not too distant future are hydro, coal and nuclear. As has been stated elsewhere, the soft energy options are not reliable. We cannot control the shining of the sun or the blowing of the wind. Supply of soft energy is too sensitive to storms, fire and, in the case of biomass, disease. If we were to become too dependent on these options we would be surrendering our energy system to the vagaries of nature - a totally unacceptable state of affairs. In spite of the present shortcomings of renewables we must continue research and development to improve them as well as to clearly establish their limitations. As an Ashanti proverb states "No one tests the depth of a river with two feet". We too must not cast aside proven technology on the basis of unfounded fears and unsubstantiated alternatives.

A cornerstone of energy security, and one largely isolated from unstable international markets, is a strong and resilient electrical system. Electricity is central to modern, efficient technologies and, if available, it offers important opportunities for oil and gas substitution through electrification of transportation and hydrogen technology. Surplus capacity is often criticized, but a short-fall in supply will cause industrial chaos and undermine our flexibility in dealing with shortages in other sectors.

Nuclear power through the fission phenomenon is one of the best energy sources; it is capable of a sustainable energy supply; it has proven technology that already exists in Canada through the CANDU system; it already has competitive economics; and the harm to the environment and to man himself is among the smallest of all competitive systems.

Canada is fortunate among nations in having present prosperity, a strong educational, scientific and technical base and rich resources. We can look forward to a relatively secure future if we utilize all our options wisely with due regard to both short-term considerations and long-term realities.

References

1. "Energy 2000-2020: World Prospects and Regional Stresses" ed. J.-R.Frisch, published by Graham and Trotman Ltd,London 1983. Pages 108-113.
2. "Fuels for Biomass" by W.Vergass and D.Pementel in "Advances in Energy systems and Technology" Vol 1,(1978), Academic Press,New York. Pages 126-169.
3. Maine Times Vol 20,#1, Oct 2,1987. Special Energy Issue. Published in Topsham,Maine.
4. Canadian Solar Energy Review, March 1986. National Research Council of Canada #25713.
5. Energy Daily, Feb 26,1986.
6. Alternative Energy Technology in Canada,1986. National Research council of Canada #26612. Page 53.
7. Energy Daily, Nov 12,1987.
8. Ottawa Citizen, June 3, 1985. Page A10
9. Access to Energy, Vol 15,#5, Jan 1988.