nuclear energy and the quality of life

Man's control of nuclear energy came, holding great promise, about 25 years ago. The 'Quality of Life' is a vogue phrase of the last few years, often associated with a fear of losing it. Together these ideas can lead to a future in which each assists the other. In the article which follows Dr. W. Bennett Lewis, a long-standing member of the Scientific Advisory Committees of the Secretary-General of the United Nations and of the IAEA, and Senior Vice-President, Science, of Atomic Energy of Canada Ltd, develops the argument contained in the first paragraph. His text is based upon that of an invited lecture delivered by him at a meeting of the Austrian Physico-Chemical Society, Vienna, in December last year.

By setting up goals for the quality of life and working hard towards them, the endeavour will guide the ways in which we develop nuclear energy (he writes). In its turn controlled nuclear energy will make possible ways of life for all mankind that can have the quality of our ideals.

I will discuss the 'Quality of Life' first because some have doubts, recalling several aspersions on nuclear energy by detractors; in particular, that

- it will cause radioactive pollution
- it will cause thermal pollution
- from the radiation people will die of cancer
- there are terrible genetic hazards
- managing radioactive wastes is an unsolved problem
- there is not enough uranium.

Science can, however, be reassuring about all those points. There is also a false hope that fusion power from deuterium will be so clean and cheap and the supply so inexhaustible that man's energy problems will one day be solved for ever. The true state of affairs appears to be that without the further development of nuclear fission power there would be massively more starvation and malnutrition in the world, and all the diseases that go with them. Fortunately, however, there is no rational argument for stopping or delaying nuclear energy development. Recycled uranium and thorium are effectively inexhaustible sources.

Today we read in our newspapers or hear over the radio or television that a scientist says this and another scientist says that, and often the two are quite incompatible. There is nothing new about this except the rules that govern the western news media, as collectively they are called, combined with a certain respect attached to the name of scientist that entices reporters into the sport of pulling scientists off their pedestals or, perhaps more aptly today, off their platforms.

In the year 1663 the Royal Society of London was granted with its second charter its coat of arms including the motto Nullius in verba, extracted from two lines of the Roman poet Horace:

> "Ac ne forte roges, quo me duce, quo lare tuter,
> Nullius addictus iurare in verba magistri."
>
> - Horace Ep. Book 1, 1, 14

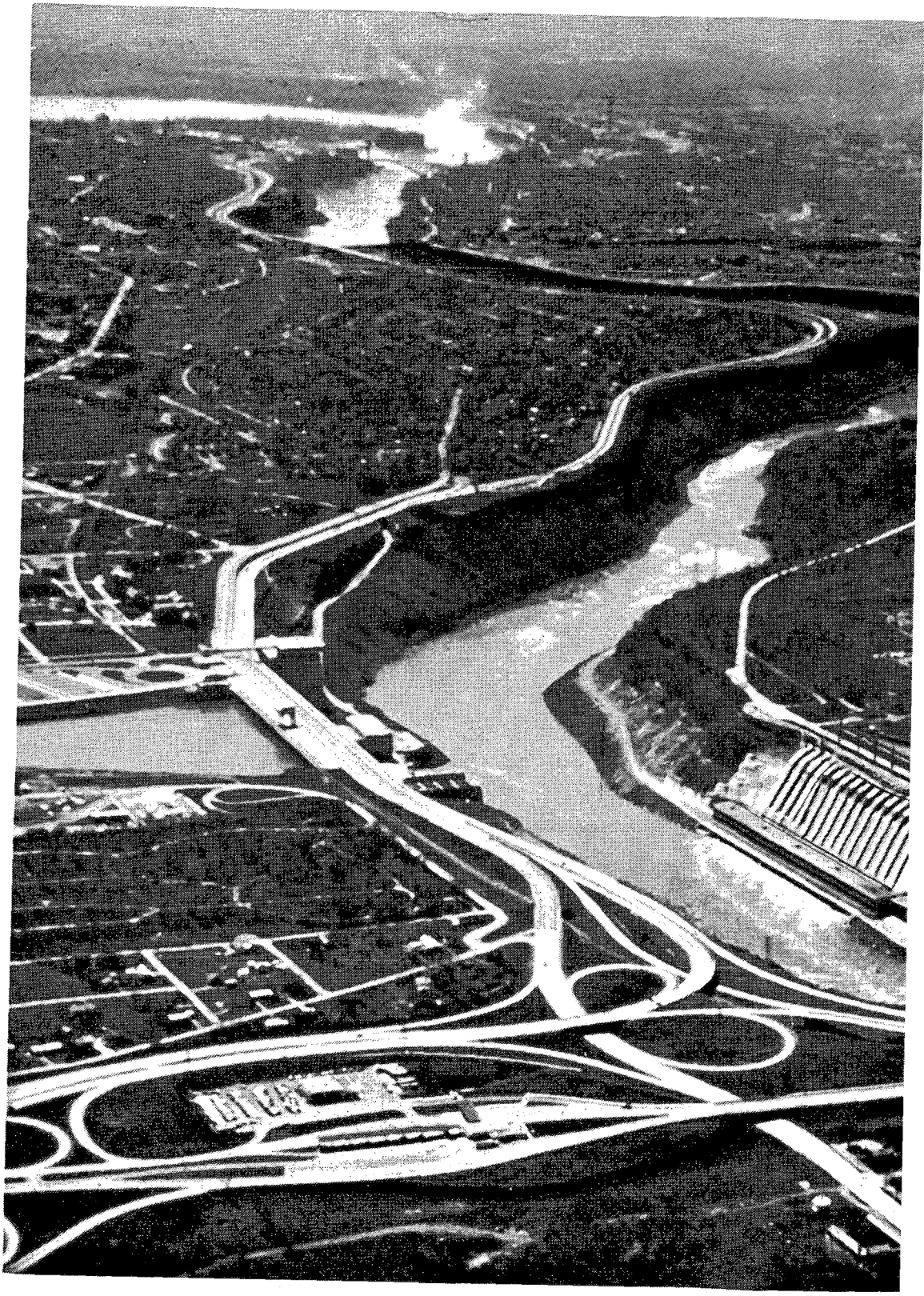
> ("And do not ask, by any chance, what leader I follow or what godhead guards me. I am not bound to revere the word of any particular master.")

The motto, then, means "Nothing is to be held on the word or authority of any particular scientist". Nature is to be the only teacher, not Glenn Seaborg, not John Gofman, not Linus Pauling, not Bennett Lewis, and especially not as reported by the media.

A true student of Natural Science does his best not to mislead. Throughout the world there is justifiable fear of nuclear bombs. If man is ever insane enough to start a nuclear war, no one can tell the ultimate extent of the resulting destruction. Requirement number one in the peaceful development of nuclear energy is to keep away from nuclear war. Because nuclear war would be unquestionably a disaster, some have extrapolated that fear and extended it to nuclear radiation. So deeply ingrained is this fear that in May 1971 a headline appeared as "New wave of cancer from Hiroshima bomb", whereas the account in the original publication in The Lancet, No.7706, pp 927-932, 8 May 1971, from the Atomic Bomb Casualty Commission, showed for one class of atomic bomb survivors a growing slight reduction below the normal incidence of cancer. Table VIII showed that for the total of 15419 children exposed to all radiation levels, 16 cancer tumours were observed, whereas in a control population of 4996 not exposed, 8 cancer tumours were observed. Moreover, in the 10671 children in the group exposed up to a radiation level of 9 rad only 6 tumours were observed. The discussion (p 931) notes that 'These discrepancies are too large to assign to chance'. No generalization was made, nor should it be, from such a limited observation, but that was the fact observed. Another similar fact is that there have been fewer cases of leukemia among atomic energy workers in Britain than the national average. These observations must go into the general store of facts presented by Nature. Now, that great observer of Nature, Charles Darwin, is reported to have observed in mirthful repartee that 'Nature will tell you a direct lie if she can'. The scientist is well aware of this, and has to work long and hard with many facts to arrive at established and later accepted science.

Science has not yet established whether the background level of radiation in the world is good or bad for human life; it could even be essential. Most probably it is beneficial to the majority but detrimental to some. In case you think otherwise, let me remind you of something somewhat analogous that is quite standard in pathology, namely, the effect of sunlight on the skin. Men, especially white men who habitually work with their skin exposed to sunlight, become liable to develop skin cancer. Yet sunbathing is popular and indeed a limited exposure is beneficial in producing Vitamin-D required for calcium and phosphorus absorption in bone metabolism, although in rare cases a cancer may develop.

The level of background radiation varies from place to place in the world. Scientific studies made so far have not found any biological effects on man associated with these different levels. One study was reported from India (Paper P/535) to the 1971 UN Conference on the Peaceful Uses of Atomic Energy in Geneva. It concerned those living in the area of the



Niagara Gorge: the Sir Adam Beck Generating Stations on the Canadian side; spray from the falls may be seen at the

extreme left. Photo: Lewis.

monazite sands in Kerala. Some of those wearing radiation dosimeters were found to have been exposed to more than twenty times the typical radiation background for Bombay. No effects on infant mortality, foetal deaths, fertility or sex ratio at birth were found. Those are biological factors thought likely to be most affected. From the most highly exposed parents, those at over twenty times the normal background, there were slightly fewer surviving children, 82 children from 22 couples. The average expected was 90 children so the difference was not statistically significant. Simple chance or other factors might be responsible.

The increase of background radiation expected from nuclear energy development is only a fraction of the general level now existing.

Thinking of the quality of life, music comes naturally to mind. In my lifetime a very great extension of music to those who appreciate it has come from the electronic reproduction of music from long-playing gramophone records, and tape recordings, from radio broadcasting, from television and, increasingly, recorded television. For the distribution of electric power for broadcasting and television or communication satellites in earth orbit, energy is essential and, for the future, nuclear energy can be its source.

Art and architecture also contribute to enjoyment of life. Probably some of you have seen the highly successful television programme series produced for the British Broadcasting Corporation entitled 'Civilization', in which Sir Kenneth Clark reviewed the development of art in western Europe. That programme itself added to the quality of life which was its theme.

In many lands gardens add much to the quality of life. What a variety there is in gardens.

One and the same individual can feel his physical and spiritual life enriched by music, by art, by gardens and by the wilderness, as well as by wine and companionship. I am not forgetting the joy of alternating effort and rest, of creativity and of learning, of giving service and the joy of faith.

Usually the appeal of the wilderness is felt when alone or with a few congenial companions in a spot one has visited before. This gives rise to resentment when the wilderness is changed by the intruision of a squatter, its crossing by an exposed power line or pipeline, or a highway, or flooding by the work of beavers or of man. One result is that men band themselves together as conservationists and protectors of wilderness parks. Again, the variety is great and real conflicts arise between the protectors and those interested in growing and harvesting forests, clearing the bush, or jungle, to make agricultural land followed sometimes by irrigation schemes. Disputes between rival interests become referred to higher levels of organization.

A good example is the resolution of the conflict achieved at Niagara Falls. One type of spectacle offered by Nature that inspires and delights men is energy going to waste, a great fire or a great waterfall, a storm lashing at rocks on a coast or a thunderstorm at a convenient distance. At Niagara Falls, nature was wearing back the crest of the falls and tourists were leaving their marks behind, Ontario and New York State were hungry to harness their power as electricity. By international agreement, a fair compromise has been achieved and to minimize the tourist damage and enhance the quality of life the Canadian bank has been developed as a park with flower gardens in the summer and conservatories for the winter when the grand spectacle is carved by nature in ice and snow. The great power stations are some miles away down the gorge and quite unobtrusive.

Another invader of the wilderness is the growing settlement that becomes a town or a city. For land to support a large population an agro-industrial-urban pattern of living has developed. A conscious attempt to develop a different pattern through the commune is in progress in certain lands, of which China is the most populous. A city has many aspects: "For some it is where the action is. For others, it's where the jobs are. For all it is a tight, complex mass

"Art and architecture, gardens add much to the quality of life." Here, the Niagara Parks Conservatory. Photo: Lewis.

of humanity" where individuals face "difficult decisions between a desire for identity and the absolute necessity to accomodate to the organization and discipline required for coexistence in close living conditions." (USA National Academy of Engineering Report, June 1971, on Communications and Urban Development.) With the quality of life in mind, many attractive ideas have been put forward for cities of the future. Almost all involve communication systems, both telecommunications and transportation, relying heavily on the use of electricity. More and more this will be generated by nuclear energy. Other essential urban services requiring energy are water and sewage.

Considering the industrial component of the agro-industrial-urban pattern, the power generating station is one essential component, another is factories where materials are converted to the many forms required for food, living and recreation. These factories usually require major services for transportation, energy, waste management and the quality needs of their personnel.

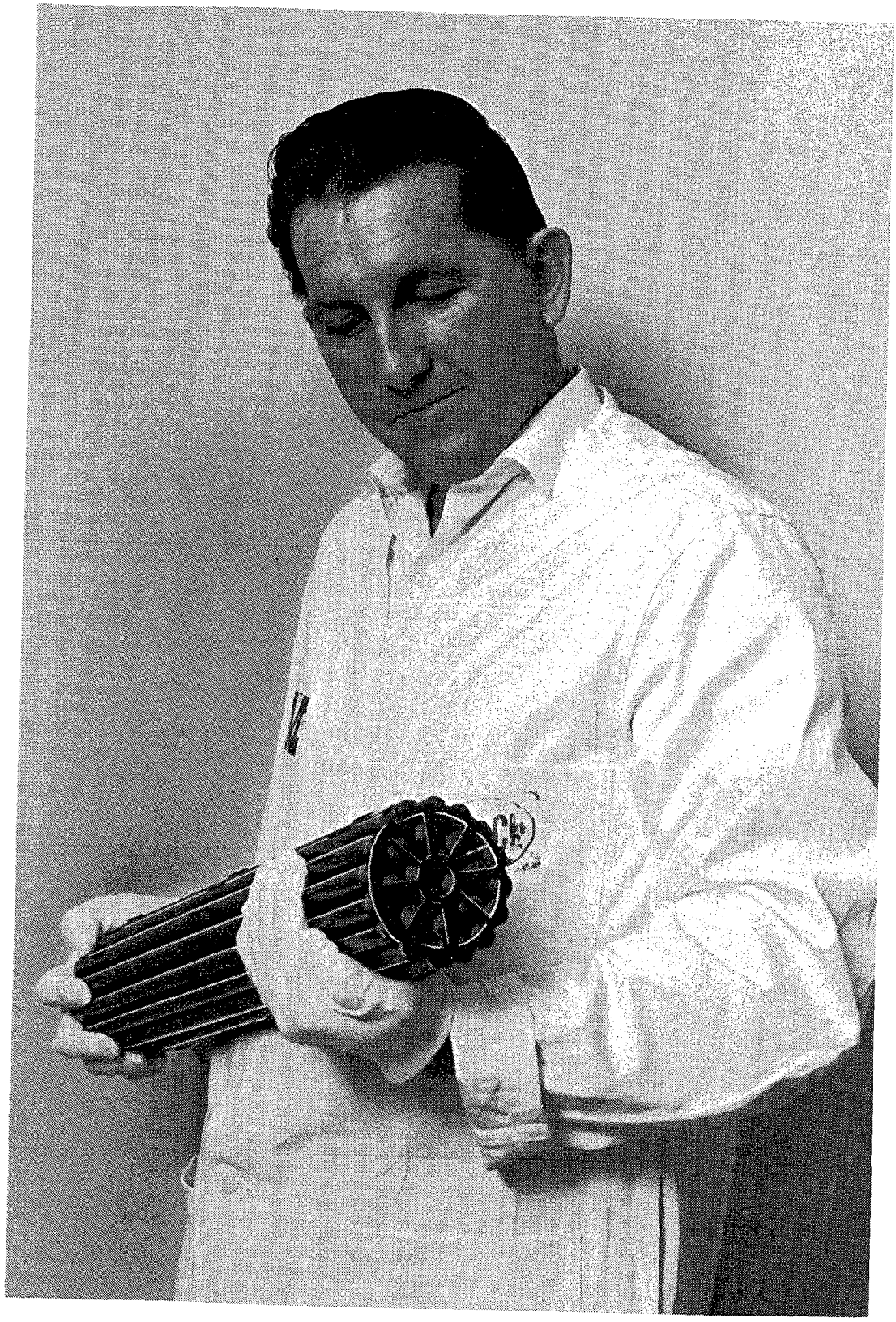
It is popular in these days to see improved quality of life in terms of reduced pollution, but surely much more is needed. Moreover, the word 'pollution' and the phrase 'pollution of the environment' have become too glib on the tongues of the irresponsible. It is amusing to compare some of this modern over-excitement with Shakespeare's Hamlet (Act II, Scene 2). When the prince pretends to explain his pretended madness he says "It goes so heavily with my disposition, that this goodly frame, the earth, seems to me a sterile promontory; this most excellent canopy, the air, look you – this brave o'erhanging firmament, this majestical roof fretted with golden fire, – why, it appears no other thing to me but a foul and pestilent congregation of vapours. What a piece of work is a man! How noble in reason! How infinite in faculty! In form, in moving, how express and admirable! In action how like an angel! In apprehension how like a god! The beauty of the world! The paragon of animals! And yet, to me what is this quintessence of dust? Man delights not me".

Certainly, there are serious major problems caused by concentrations of man, pollution especially of oil on lakes, rivers, seas and coastal beaches, of insecticides on fish and other wildlife, and the contamination of drinking water supplies with products from sewage, insecticides and other wastes, of sulphur dioxide, carbon monoxide and other toxic gases in the atmosphere, and of aerosols and particulates that create smog in certain geographical areas. There are objectionable smells and sounds. These burdens do not fall on one man, one prince, one Hamlet, or one leader to resolve; they are caused by the actions of many men and the ideas and actions of many men can be brought to bear to cure them.

Quite generally, we need to develop ways of recycling wastes. The principles adopted in processing radioactive materials could well form the example and be adopted in some other matters. For radioactive material it has been recognised from the beginning that even the unwanted radioactive materials must be concentrated and contained unless they can be diluted to such a degree with water or air that they may be dispersed to the atmosphere or water without detriment. I am not speaking here of the products of bomb explosions which were at first commonly dispersed into the atmosphere whether they were sufficiently dilute or not. We hope that soon France and China will join the earlier nuclear powers in abandoning atmospheric bomb testing, but of course we hope man will cease from underground tests as well.

Managing radioactive wastes has not proved difficult in Britain; it seems quite normal in Canada even projected to a long term future when we will have much more. Even beautiful gardens have their rubbish pits and compost heaps. They need not be offensive. Radioactive waste management, with recovery and recycling where necessary, does not seem very difficult and also need not be offensive.

A nuclear fuel bundle for the Pickering Generating Station. Photo: Chalk River Nuclear Laboratories, Ontario.



Having abundant energy can remove drudgery, and provide the necessities and the luxuries of life. Another quality of life is needed; the ability to relate to one's neighbour, if not with love, at least in peace, and in verbal peace. What is required is an attitude of mind that both sees and seeks good outside the self and tribe: an attitude that does not proclaim and become preoccupied with imaginary deaths or cancers in the tribe while ignoring the starving millions elsewhere. Harnessed energy may not foster automatically a solution to this problem of human relations, but lack of such resources is blamed for many past wars.

Too many people are not aware of the current science of radiation effects in living organisms. I will quote from the opening paragraphs of the foreword to the Proceedings of an IAEA panel in Vienna in 1966 on 'Genetical Aspects of Radiosensitivity: Mechanisms of Repair'.

"Recent biological and biochemical observations in radiation research have brought about marked advances on the simple, non-biological interpretation held less than a generation ago. Then, the effects of radiation exposure on living systems were viewed as being direct, immediate, irreparable and unmodifiable. Now, it is generally accepted that radiation injury can also be indirect, delayed, reparable and often modified with appropriate radioprotective measures.

"One of the most exciting developments to emerge recently from the multidisciplinary approach to radiobiology is the concept of repair, whereby the observable damage is the net balance of the initial lesions minus the repaired ones."

Let me remind you of one more basic idea in biology. Living cells grow and multiply by feeding on their surroundings. The food does not have to be specific but in the metabolic processes a wide range of compounds are first broken down to simple chemical molecules or radicals and then built up to fit the need. Thermal and chemical disruption called pyrolysis and hydrolysis take part and background radiation provides photolysis and radiolysis as well. There exists an optimum range of temperatures, of hydration and probably also of radiation for these processes, and for their opposites, for example 'photosynthesis'.

When we look around the world today for the rôle of nuclear energy we see that so far it has helped to feed and keep people alive. At the 1971 Geneva Conference already mentioned, Swaminathan of India presented an invited review (P/768) of its effects in agriculture. It has made possible the breeding of varieties of plant with special characteristics such as shorter stems, shorter growing time and higher yield. He showed how a year of 365 days had been stretched by plant breeding aided by radiation and by radioisotope tracers to permit 450 crop growing days on one piece of ground. In therapy, radiation as a weapon against cancer is still increasing in use. Radioisotopes also find more and more use in medicine. Now the world's basic problem is how to limit the growth of population. It now stands at about 4000 million and is doubling in 30 to 40 years. A hundred years hence at that rate it could reach 30 000 million. We find it difficult now to keep the peace and maintain food supplies everywhere. With eight times the population our social organization may have broken down. It is not too soon to start now if we are to converge on a limit of say 15 000 million, together with a system for growing adequate food and keeping at peace. Supposing that is achieved somehow, we ask next how much energy the 15 000 million will need for food, water, warmth, locomotion, synthetic fuels, industry, air-conditioning, local climate modification and any other amenities to meet the quality of life of our ideals. I have suggested the range 5 to 50 thermal kilowatts per head. Taking 20 kilowatts as a median value (also chosen by A. M. Weinberg and P. Hammond, P/033, Geneva 1971) the total is 300×10^{12} watts, or 300 Terawatts or 300 Terawatts or 300 million megawatts. Large, but still only 0.2% of the energy the earth receives from the sun.

TABLE 1 - WORLD ENERGY FLOW

		Ratio Percent
Solar radiation	1.7×10^{14} kW on day hemisphere	100
Heat flow from interior	2.5×10^{10} kW	0.015
Suggested world demand	3×10^{11} kW	0.18
20 kWt $\times$ 1.5×10^{10}	(1.2×10^{11} kWe)	
1966 World Energy consumption rate	4.5×10^{9} kW	0.0026
1.2 kWt $\times$ 4×10^{9}		
Utilization of 1 tonne natural uranium per year at 50 MWd/kg	1.37×10^{5} kW	--

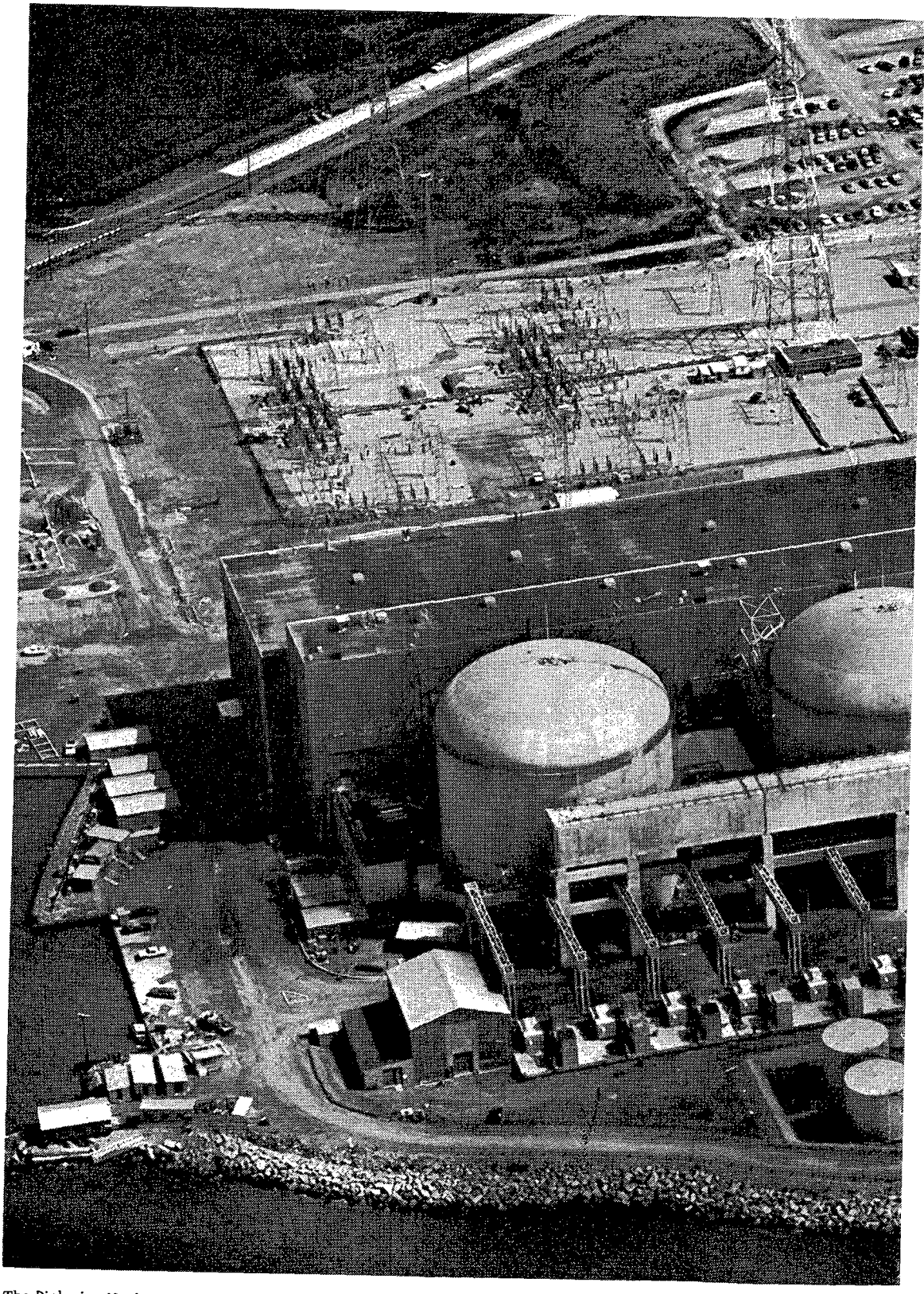
Moreover, there is plenty of nuclear raw material, effectively inexhaustible, whether uranium or thorium for fission or deuterium or lithium for fusion.

TABLE 2 - URANIUM ABUNDANCE

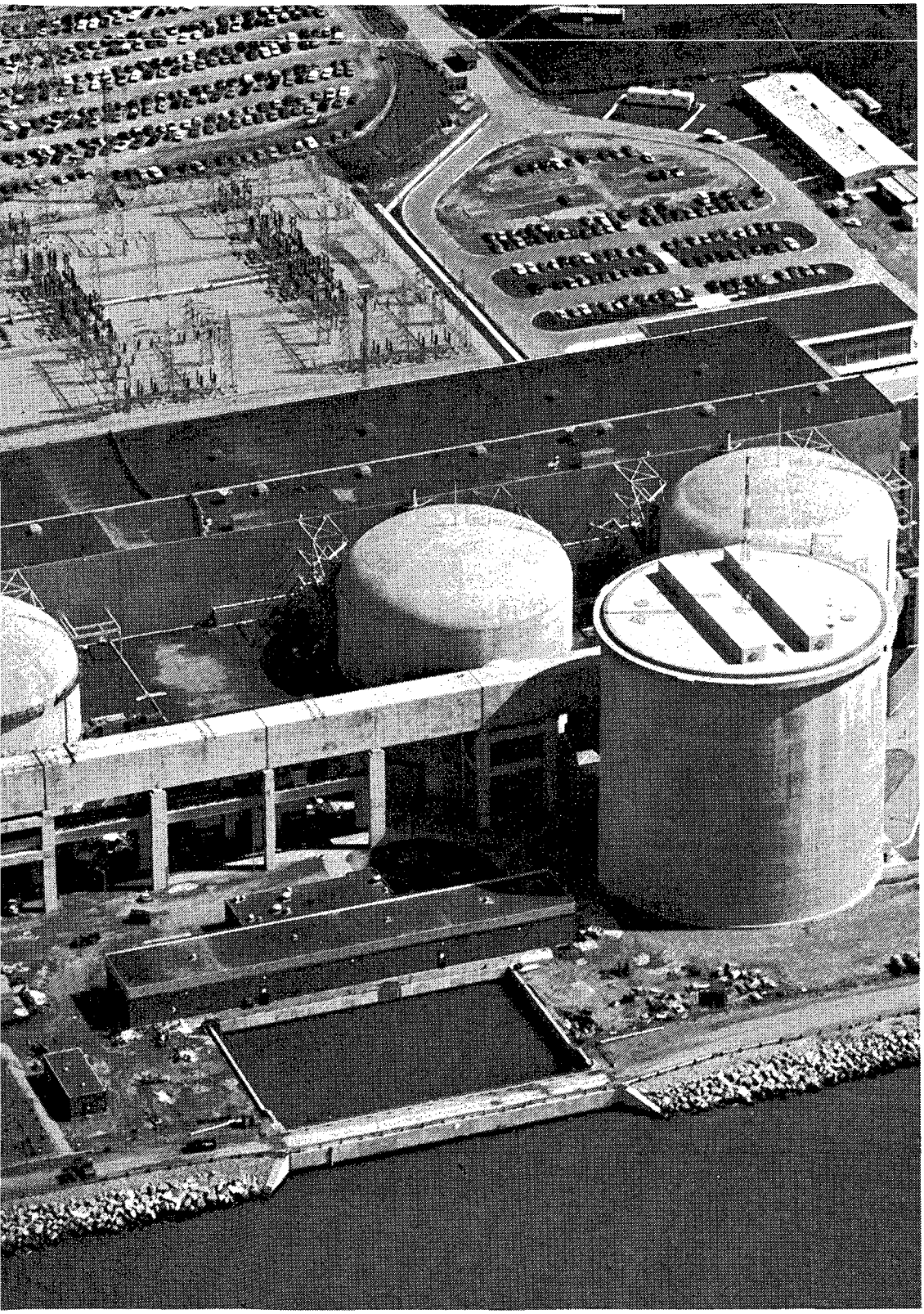
	Million tonnes U
Total in earth's crust	>100,000,000
Within 1 mile of land surface	2,500,000
In oceans	4,500
Canadian low cost ore	0.2

For Future World Demand at 300 TW

Nuclear Energy System	Annual Requirement
CANDU - Thorium + Uranium (50 MWd/kgU)	2.2 U
CANDU - Thorium + Spallation	$\cong$ 0.2 Th or U
CANDU - Thorium + Fusion	$\cong$ 0.2 Th or U
Breeder Uranium or Thorium	$\cong$ 0.2 Th or U



The Pickering Nuclear Generating Station, 2160 MW(e) gross. Three of the four units being built at this installation



were in service at the beginning of June this year. Photo: Chalk River Nuclear Laboratories, Ontario.

Let us not belittle the tremendous technical and organizational effort needed to build and operate the power stations for 300 Terawatts. The effort is so large that not only must the engineering be made simple in the nuclear parts but also in the conversion to harnessed electric or mechanical power or heat that can be utilized for water desalting, chemical processes, etc. These are the problems being tackled by nuclear and other power engineers, as well as by those who finance major works.

I believe that the Canadian route to abundant nuclear power for the indefinite future is much simpler and more practical than those proclaimed by the major industrial nations involving liquid sodium-cooled fast breeder reactors. We would just extend our CANDU heavy-water-moderated reactors to large-scale use of uranium-235 with thorium and recycled uranium-233. I would choose the organic liquid coolant that has been so successful in our 40 megawatt experimental reactor, WR-1, at the Whiteshell Nuclear Research Establishment near Winnipeg. Based on our successful experience with 540 megawatt electric CANDU nuclear power generating units, we would aim at building 1500 megawatt electric units with the organic liquid coolant. Such stations would operate up to 39 or 40% net station efficiency so that the waste heat would not be large by today's standards, so even in hot countries the so-called 'thermal pollution' would not be excessive. In a cold climate with large masses of water, such as Canada, the waste heat could be called more appropriately 'thermal enrichment', so even a lower efficiency could be chosen.

In the papers Canada presented to the 1971 UN Conference, we suggest that CANDU-OCR-1500 megawatt electric units with thorium fuel will be economically competitive with any other proposed system. In the long term, improvements may be developed not only in the conversion and harnessing of the energy as I have suggested, but also by bringing to bear other nuclear reactions that produce neutrons to improve the fuel cycle and even dispense with uranium-235 altogether.

Near breeder reactors such as CANDU thus offer a practical approach immediately and yet allow room for all the ingenuity scientists and engineers may in time apply to simplify operations.

There should be no need to check back over that list of aspersions cast on nuclear energy listed at the outset. If, however, these are checked against the science, knowledge and expectations I have presented, they either disappear completely or fade into insignificance compared with the benefits. Nature, through science, will be the only teacher. In our actions we must keep our attention on our ideals of quality.