DEVELOPMENT OF ENERGY AND THE FUTURE OF MANKIND

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The progress of civilization has been conditioned by mastering sources of energy that are ever more powerful, more concentrated and more manageable. This was illustrated by the industrial revolution of the 18th century, sustained by the opening up of the first coal mines and marked by the invention of the steam engine. In the 19th century, the understanding of electro-magnetic phenomena opened the way for the use of electric and electronic techniques in a multitude of domains (electric power, lighting, heating, communications, data processing, etc.) which change our daily lives at an ever-increasing rate.

The energy used by man today, in one form or another, comes mainly from solar radiation. The only exceptions are the two nuclear energy substances: uranium, produced billions of years ago through the nucleosynthesis in stellar explosions, and deuterium, formed in the primeval fireball a few minutes after the big bang.

The energy consumption of the 5 billion human beings inhabiting the earth today represents the equivalent of 12 billion tons of coal per year, but it is unequally distributed. While each Canadian or Scandinavian uses an average of 10 tons of it, an Ethiopian peasant does not even use 50 kilograms. As long as disparities so intolerable as this are not corrected, there can be no peace and stability in the world.

The population of the earth will have doubled half a century from now. To satisfy its requirements, under conditions that provide for the well being and dignity of each human being, immense resources must be mobilized. No energy sources known today can be forgotten. We must also count on scientific and technical progress to discover new ones in the future.

Nuclear energy is one of these sources. The 400 nuclear plants existing today in the world produced 1,600 billion kWh in 1987, i.e. 16 % of the electricity generated in the whole world. Where they are properly managed, they operate with an exceptional level of availability and reliability.

Nevertheless, a large number of men and women across the world are today extremely worried about the use of nuclear energy. This poses a true problem for society, one which needs to be dealt with seriously, objectively and a clear and straightforward manner.

During the last few centuries, science and technology have bestowed blessings on mankind that would have impossible for our ancestors to imagine. It would be against all reason to want to benefit from the advantages of progress and at the same time refuse to take on any of its constraints. However it is imperative that the potential inconveniences that it includes be defined within boundaries that are acceptable for the health of humanity and the quality of the environment.

The Chereobyl accident was indeed tragic but figures cited thereafter, in a panic situation, regarding the casualties caused by the radioactive cloud which escaped from the plant, are meaningless and must be rejected.

The earth is a fragile ecological niche. The fact that the ozone layer, which at high altitudes is protecting us from the ultraviolet radiation from the sun, is starting to disappear in places, is a real source of worry for us. The steady increase in the proportion of carbon dioxide in the atmosphere, an inescapable consequence of the combustion of coal and hydrocarbons, will possibly lead to harmful, irreversible effects on the climate of our planet within a hundred years' time.

By objectively comparing the long-term effects of the various energy vectors, it would not be scientifically honest to claim that nuclear energy is less ecological than other forms of energy.

The results that have already been obtained regarding its use for the generation of electricity in numerous countries across the world are in fact remarkable. The Japanese program is

exemplary in this light, through its continuity, its consistency, and the quality of its achievements insofar as concerns both the power plants themselves and the various industrial installations of the nuclear fuel cycle.

This is particularly the case in the field of fast neutron breeder reactors (LMEBR), where the Japanese program is not without recalling that of Western Europe. It consists of a series of logically linked steps: the experimental Joyo reactor, followed by the Monju prototype station being built, which will in the future be followed by a first demonstration plant with a power of over 1,000 MWe. The similarity of their technical options and objectives should encourage the creation of a true association between Japan and Western Europe.

Now that the fast neutron breeder reactor systems have demonstrated their industrial feasibility, they must still prove that they are economically competitive with the present-day light water nuclear power plants. Commercial success of the fast neutron reactor is within our reach, but perhaps not for another quarter of a century. In fact, the date that it will occur depends partially on external factors, such as the price of natural uranium on the international market.

Forecasts concerning the future of energy in the world can only be made with the greatest care, since it is impossible to imagine the disruptions that are likely to bring about entirely new discoveries or unexpected improvements in existing techniques.

Mankind will have to use a wide variety of energy resources, both to meet its extremely varied requirements and to ward off the hazards of a monoculture.

For a number of developing countries, where wood is often still the basic fuel, it is undoubtedly through the intensive use of fossil fuels that the transition to easier conditions of life will be made.

It can be predicted that the low-price oil and gas reserves of the earth will be exhausted in a century, but for some uses such as air transport, it is difficult to see how to substitute hydrocarbons in any way.

The world's coal reserves are vast should last several centuries. Their wide utilization however poses some difficulties. The operation of mines might be faced with problems as regards workers and environmental protection. There is generally inadequacy between the location of deposits and the location of use(i.e. industrial and urban concentrations), which poses major transportation problems, whether it be by land, river or maritime transport. Considerable progress is expected in the use of fossil fuels in power plants, through new techniques such as fluidized beds. One basic objective is to considerably reduce the pollution resulting from nitrogen and sulfur oxides contained in smoke and fumes.

Solar radiation is an energy source whose importance should increase in the future, particularly for residential applications and in the commercial sector, and for advanced-technology industrial activities. Its privileged fields of use will depend on its specific characteristics, above all due to the fact that it is present everywhere, but in low concentrations. The processes using direct conversion through photovoltaic cells can be expected to be developed as the yield of these cells increases and their unitary cost goes down.

Controlled thermonuclear fusion in principle offers an inexhaustable source of energy, using the deuterium contained in sea water. We can hope that in the near future the physical conditions of the break-even in a deuterium and tritium plasma will be obtained in an experimental magnetic confinement device. The technological and eoonomical problems to be overcome are nevertheless of such an amplitude that it is not at all certain that it will be possible to achieve the use of the fusion energy on earth at any significant scale.

For a whole list of reasons, we may anticipate that it will be a long time before the

developing countries will be able to take advantage of nuclear fission energy, which would during this time remain the privilege of the most industrialized nations. The advanced countries will have to help the developing ones as much as possible so that these too can take advantage later on of this form of energy. In the mean time, the advanced countries should increase the use that they themselves make of nuclear energy in order to reserve for others energy sources such as oil, gas or coal, which are more immediate and easier to use.

As industrialization increases in the world, the share of the electricity vector will also increase, due to the fact of its versatility and capability of adapting to multiple usages. This fact should enourage the development of nuclear energy, which lends itself particularly well to electricity generation. Nevertheless, nuclear energy should later on play a significant role in the production of heat through modest-sized specific reactors.

The day will come when the peaceful use of nuclear energy will be through power plants equipped with breeder reactors. Mankind will therefore have available an energy able to provide its requirements for many centuries to come. The chemical and nuclear characteristics of plutonium will impose rigid rules, which all countries will have to abide by, controlling its handling, transport and more generally any chain of industrial operations marking the successive steps of its use. The general use of breeder reactors will require that order be present everywhere and at all times, and we can even hope that it will contribute to its implementation.

In all probability, the 21st century will bring with it spectacular progress in terms of space exploration. The propulsion of space vehicles for long periods of time and the energy supply of stations isolated in interplanetary space will require nuclear reactors with specific characteristics. It can be anticipated that the liquid metal-cooled fast neutron reactor will prove to be particularly well adapted to these usages.

The use of fission energy in space will make numerous missions possible, ones whose beginnings we are only catching a glimpse of today. Beyond practical applications, in this I see above all a new step in the adventure of mankind and the innate requirement which, throughout man's evolution, led him boldly down the halls of knowledge to explore the mysteries of the universe.

It is in this that man finds his greatest nobility and may finally be his very reason for existence.