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The Nuclear Power Alternative
1988 Energy Day, Helsinki
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The title of this paper is based on the premise that the world needs more electricity and that nuclear power represents one alternative among the conceivable sources. This point of departure is by no means uncontroversial. According to a view put forward with strong feelings by certain groups, the era of nuclear power is an unfortunate interlude which must be brought to a close as soon as possible. These groups consider nuclear power to be more dangerous than all other sources of electricity, despite the fact that the number of people who have met death as a result of electricity generation by nuclear means is very small compared with that of persons who have died in connection with energy production by gas and hydro power plants, for example. This line of thought sometimes also argues that nuclear power is so expensive that it would be advantageous to shut down nuclear power plants long before they have reached the end of their service life. It is considered impossible to manage the waste from them, despite the fact that its volume is so limited that it can be isolated from the biosphere, and in this differs radically from the immense volume of waste from fossil fuel that to a large extent is discharged into the earth's atmosphere and contributes to the damaging of forests and lakes and to threatening our climate. Nuclear power is also viewed as particularly fraught with fatal consequences for peace, since it is believed that it inevitably leads more countries to acquire nuclear weapons. This in spite of the fact that the declared nuclear weapon States are still only five in number and that over 130 States have given an undertaking not to acquire nuclear weapons, in return for which they are able to share in peaceful atomic technology, and despite the fact that the part of the world characterized by the greatest tension is where the greatest oil resources are to be found, namely, the Middle East. And lastly, it is stated that nuclear power is unnecessary: nuclear energy as well as a large amount of our oil, coal and gas consumption can be done without, it is said, if we save more energy and make more extensive use of such renewable sources as wind power, solar cells and biomass.

A message that promises us the possibility of avoiding all risks with nuclear power plants and nuclear waste and also of drastically reducing the burning of coal, oil and gas and thereby reducing the emissions from these fuels, is a seductive one. With due respect for the good intentions of those who propagate this message, I would maintain that this represents the romantic approach to energy policy. Earlier on, during the Swedish referendum, we heard the slogan "What should go away? Barsebäck. What should come in? Sun and wind!" Today, eight years later, Swedish nuclear power plants are producing approximately half of all the electricity in Sweden. Solar cells make no contribution to the electricity network and wind power from a small number of experimental facilities makes a marginal contribution of 0.004% to electricity production. The contribution of the renewable sources to the generation of electricity in Sweden, with the exception of water power, is insignificant, not because no efforts are made to exploit sun and wind, but because thus far it has proved difficult to utilize these sources rationally and economically.

A wish-dream policy in the energy area can perhaps be successfully propagated until its character of wishful thinking becomes obvious through an electric power deficit. In any case, the message of such a policy is in many places still sufficiently attractive to make it difficult to pursue a policy which calls for costly investments and a certain amount of risk but which in return ensures a significant additional contribution of electric power. To refrain from the timely provision of sufficient capacity also involves risks in the form of future electric power shortages with consequences for employment, competition, standard of living and quality of life.

Permit me to illustrate my thesis that the world will require more energy, especially electricity, in the next few decades.

It is not difficult to understand how the opposite point of view could arise in some quarters. During the 1960s and early 1970s, consumption of both primary energy and electricity increased very greatly and a direct connection appeared to exist between increased consumption of energy and economic growth. This was the point of departure for the planners in the 1970s and their calculations for the 1980s. The oil-price shocks of 1973 and 1979 led meanwhile to tremendous changes. In part, they contributed to an extended economic slump with lower economic growth and energy consumption than had been calculated, in part they gave a strong impetus to the saving of oil, the most important source of energy. We have seen how the national product in the western industrial coun-

tries increased by 40% since 1973 while the consumption of primary energy stagnated. A significant saving of energy was thus possible. Nor does anyone deny that there is room for extensive improvement in the efficient use of energy and that this must be utilized.

In a situation where it is desired, for vital environmental reasons, to limit or reduce the burning of the predominant fossil fuels, it is tempting to assume that economic growth can continue with unchanged or even reduced expenditure of energy. The Brundtland Commission set up by the United Nations, in its report last year, presented a scenario with continued economic growth but with a primary energy contribution which would by the year 2020 have dropped to half of present-day consumption. However, the realism of such a scenario is very much open to doubt. The trend in recent years has, on the contrary, been in the direction of a definite increase in primary energy consumption. Between 1974 and 1986, primary energy consumption in the world as a whole increased by 2.1% per annum and even in Western Europe we have had an increase of approximately 1% per annum during the last two years.

If we then consider the consumption of electricity in particular, we find that it consistently increases in step with increases in the gross national product. Before 1973, the increase ranged from 6 to 7% per annum. Thereafter, the figure was around 3%. Two important conclusions can be drawn. First, that savings in primary energy oil and coal were facilitated by the increase in the use of electricity, which is often more effective in end use. Second, that the calculations of a marked increase in electricity requirements, which in the 1970s were made in the light of earlier experience, resulted in too large a planned electricity capacity. During the 1980s, large numbers of power plants were eliminated from the plans. Thus, since 1972, in the United States, orders for no fewer than 117 nuclear power plants and 65 coal-fired plants were cancelled or deferred. In the case of a total of 47 nuclear power plants, construction work which had already begun was halted or postponed.

Despite the fact that the expansion of capacity was thus greatly reduced in relation to the planning for the 1970s, in some respects the capacity for electricity production during the first half of the 1980s was abundant in relation to requirements and, against this background, it is not difficult to understand how some opponents of nuclear energy arrived at the argument that increased electricity production is not required or even at the conclusion that nuclear power plants can be shut down. However, this thesis overlooks essential facts and the

great variations existing between different countries. France, which at present exports 8000 million francs' worth of electricity per annum, could obviously shut down a few nuclear power plants without its own electricity requirements having to suffer. For Switzerland and Italy, both of which have a de facto moratorium on the expansion of nuclear power and which import electricity from France, a halt in French exports would be cause for concern.

While it can be said that France and Germany have an adequate electricity supply for a number of years, that does not apply at all to the industrial countries in general and even less to the developing countries. Even with the 3% increase in the consumption of electricity, the ceiling of expanding capacity is being reached in many places. An additional consideration is that some old power plants have completed their service life and need to be replaced. In this way we see how ceiling capacity was reached in many regions of the United States last summer, with so-called brown-outs, which occurred despite imports of electricity from Canada. In England, the Netherlands, Belgium and Finland it is now considered necessary to plan for increased capacity in electricity production. In all these countries nuclear power is one possibility, with coal as the principal alternative. Renewable sources of energy are not expected to make any significant contribution.

As far as the developing countries are concerned, it is not difficult to understand that they are planning for increased electricity production and that in most cases only financial constraints are holding back expansion. In many areas, e.g. in China, India and Pakistan, the shortage of electricity is a significant factor in preventing industries from operating at full capacity.

Let me give a few figures on electricity consumption in various countries by way of providing specifics and material for comparison. Norway led in electric power consumption for 1986 with 23 000 kWh/person/year, nearly all of it provided by hydro power. For Finland, the figure was 9600 kWh. France has increased its consumption from about 3500 kWh/person/year in 1973 to 6200 kWh at present through a large-scale expansion of nuclear power. In Italy, where construction was recently stopped on some nuclear power plants and some others that were in operation were shut down, consumption is 3200 kWh/person/year and planning now has to be started on increased electricity production with fossil fuel. China uses approximately 400 kWh/person/year, India about 250, Indonesia about 175, Sudan and Bangladesh about 50. China is planning to increase its installed capacity by 100 000 MW by the year 2000.

Of this, 70 000 MW are expected to come from coal-fired plants. Even in India, where work is under way on an ambitious expansion of nuclear power, an even greater expansion of coal-based electricity is planned.

The areas in which we can observe a great expansion in electricity production by nuclear means are, on the one hand, in the intensively expanding Far East, Japan, Korea, Taiwan (China) and South-East China along with Hong Kong, on the other hand, in the Soviet Union and Eastern Europe, where Bulgaria is at present already producing approximately 30% of its electricity (around 2600 MW) from nuclear energy.

We all accept the idea that electricity should everywhere be utilized as effectively as possible. Transmission losses must be kept as low as possible, and electrical equipment should be built for maximum efficiency. However, savings are progressively harder to achieve. We can perhaps save electricity by using a refrigerator with low energy consumption, but people will not agree to save it by doing without a refrigerator. The conclusion to be drawn from data for the most recent years is that the gains made in efficiency do not cover the increased demand. An increase in capacity of varying often significant orders of magnitude is predicted in many areas. The question is: how will this electricity be generated?

We have several possible sources: fossil fuels (coal, oil and gas), hydroelectric power, nuclear power, renewable sources such as wind, sun and biomass, geothermal power. Of course, all these sources will be used but the proportions in which the various types come into play are of importance from the economic and environmental point of view. Energy from nuclear fusion for commercial use is considered to be decades away.

In the following discussion, I must touch very briefly on hydroelectric power. In some of the developing countries, considerable hydro power continues to be available for use and this will surely be drawn on where it is economical. In the industrialized countries there isn't much more to draw on. Besides, environmental consequences create opposition to a number of conceivable projects, e.g. those relating to the Danube.

Nowhere do the authorities reckon that the renewable sources of energy wind, solar power and biomass will be able to make any significant contribution to the production of electricity within a foreseeable time. In Denmark there is an ambitious programme for wind-generated electricity. In 1987, wind generators covered 0.5% of electricity requirements while thermal power plants, up

to 97% coal-fired, covered 86.4%. Denmark has resolved to set up 10 wind-power plant parks and had reckoned with obtaining 100 MW(e) from them by 1990. However, the programme has been delayed. By comparison, it may be mentioned that 500 MW of coal-fired thermal power plants will be coming into operation in Denmark between 1989 and 1990.

Solar cells supply electricity to satellites, clocks and calculators, where costs are not a major factor, but despite the progress which has been made, it is not expected that solar cells will be able to provide significant amounts of electricity economically before the turn of the century. This is undoubtedly a technology to which substantial research and development resources should be allocated.

In the world of experts and planners, there is hardly any division of opinion as to the fact that the real alternatives for increased electricity production at present are nuclear power and fossil fuels, above all coal.

From the economic point of view, it is reckoned that the alternatives of coal and nuclear power are not essentially different. Reasonable construction times of about six years are calculated for nuclear power plants. Also included are the costs of handling nuclear waste from the plant and for its decommissioning and, in the case of coal-fired plants, for modern systems to separate dust, SO_2 and NO_2.

In most, but not in all, countries where nuclear energy is used, it has been extremely important for their economic development. In France, where 70% of electricity is generated by nuclear means and in Sweden, where the figure is 50%, cheap nuclear power and old hydro power have resulted in stable and low production costs. These systems for supplying electricity have doubtless been of great importance to the competitive capacity of industry and, in addition, made it possible to replace oil when the price of oil went up. Domestic nuclear power has been a blessing for the Swedish balance of trade. In the case of Korea, nuclear power was of strategic importance for its rapid industrialization. It has also advanced high standards of quality in its own industry, which, to an ever increasing extent, has become a supplier for projects. It may be worth mentioning that at approximately the same time as Sweden is planning to reduce the number of its nuclear power plants from 12 to 10 in the middle of the 1990s, Korea is planning to link reactors 11 and 12 to the national grid.

Great differences exist with respect to infrastructure requirements for coal and nuclear power. In countries like Sweden and Finland, we are obliged to cal-

culate on the basis of locating coal-fired power plants on the coast and near harbour facilities in order to take delivery of the considerable amounts of coal required. In countries like China and India with their own coal deposits in the "wrong place", so to speak, the railways even now are overloaded with the transportation of coal. Nuclear fuel, on the other hand, is extremely modest in volume and can easily be transported, even by aircraft.

Gas can be transported either cold in liquid form or in pipelines. In no case is the infrastructure problem insurmountable, but the pipelines require very large investments.

The producers of electricity want to ensure that they have a reliable source of power. Coal is produced in many countries and the risk of a market cut-off is small. The quantities involved are so large, however, that storage cannot be carried out for any fairly long requirement periods. Any disruptions in supply can therefore constitute a risk. As far as gas is concerned, the consumer sitting at the end of the gas line is of course exposed to and dependent on conditions along the pipeline and at the sources. This dependence can perhaps be reduced by making use of two or more sources and pipelines. Gas cannot be stored for any fairly long period of demand either.

Nuclear fuel, on the other hand, affords great assurance of supply. Several producers are available and storage for many years' consumption is possible. For energy-poor industrial nations like Japan and France, this is an essential aspect.

As far as operational reliability in coal- and gas-fired plants and in nuclear power plants is concerned, no major differences can be observed. In Europe, somewhat fewer unplanned shutdowns in operation are recorded in nuclear power plants than in coal-fired ones. In Japan, with 36 nuclear power plants, it has proved possible to reduce unplanned operational shutdowns to fewer than one per reactor-year. There are reactors in Japan which have not experienced any unplanned shutdown for several years. Generally speaking, development has been in the direction of steadily improving operational results in nuclear power plants, with a routine availability of over 80% in countries like Sweden, France, Canada and, above all, Finland, which has long been at the top as far as operational data are concerned. South Korea, until recently a developing country, last year had a reactor with an extraordinary availability of 99.6% and an average of 88% for all the country's reactors. Nuclear power plant staff are being exposed to ever lower doses of radiation far below the limits set, and thi:

despite the fact that, with increasing age, the plants are becoming more contaminated. These good results are due to careful operation.

Of course, for the public at large the disposal of nuclear waste and the risk of accidents in nuclear power plants are more the centre of interest than economic questions. The Three Mile Island accident, where no human being was injured and where the emission was insignificant, and the Chernobyl accident, where 31 persons met death, a few hundred received high radiation doses and significant amounts of radioactivity were released, these things are imprinted in people's memory, whereas they are surely unable to remember the name of the gas platform in the North Sea which last summer experienced an accident with 160 deaths, or the name of the coal mine in West Germany where earlier in the year 57 miners lost their lives.

It is difficult to make precise comparisons between risks in different fields of activity. We know that hydro power has taken thousands of lives when dams have burst; we know that the big gas explosions in Barcelona and Mexico City each took hundreds of lives, and we frequently read accounts of accidents in coal mines. A comparison between the risks to life and health in electricity produced by gas, by coal and by nuclear energy should necessarily begin at the mines and the gas deposits, as the case may be; it should follow the transport of the raw material, its conversion, its use as a source of energy and, lastly, evaluate the health hazards in the handling of waste. Some studies of this kind have been made. It is my conviction that the more comprehensive studies of the question, which will soon be available, will confirm the results of the studies already carried out, indicating that nuclear power, per amount of electricity produced hitherto, has had very little impact on life and health. I feel more uncertain as to whether such conclusions will affect people's attitude. Most people are more afraid to fly than to ride in automobiles, although the risks both per trip and even more per kilometer travelled are much greater in the case of automobile travel. Our reason is unable to prevail over our feelings. Perhaps only experience over a longer period of time is able to do so. People have been afraid of trains, automobiles and electric ovens but despite fear and the occurrence of accidents, they have made use of these things because their reason has told them that the advantages are worth the risks. Only gradually have they become accustomed to the new technologies and their risks and ceased calling their application into question. Once our feelings have accepted a technique, e.g., the burning of fossil fuel, it seems none the less to take a long time for our reason to engage feelings for the dangers disclosed by a new analysis.

The conclusion I want to draw for nuclear energy is by no means that all we have to do is wait and see. On the contrary, we must endeavour to give as correct a picture as possible of risks and of damage that has occurred. We must also make efforts to reduce these risks and this damage still further in the future. The public surely realizes that no form of energy can be produced entirely without risk and that even abandonment of energy production has its disadvantages. In my opinion, it is the duty of engineers, scientists, planners and politicians to contribute facts which can help the public make comparisons between the advantages and risks of various types of energy. It is unacceptable that nuclear power should be rejected with the argument that "people's anxiety must be taken seriously". Perhaps such an attitude might be understandable in some cases as party politics with a view to minimizing losses of votes, but it is not an attitude calculated to minimize the risks for society in the production of electricity.

After this introduction, let me say that it is important that a correct picture should emerge from the serious accident at Chernobyl, which has undoubtedly had a strong influence on attitudes to nuclear power. From the very first days following the accident, the IAEA tried to contribute to such a picture and these efforts are continuing. I myself visited Chernobyl on three different occasions, once immediately after the accident, once in January 1987 and lastly, in May of this year.

We now know a great deal about the accident and the Soviet Union is keeping the world continuously informed of new findings. Between 200 and 300 persons operational and fire-fighting staff received high doses which resulted in radiation sickness. Around 30 of them died, but most of the others are back in productive work after hospital treatment. Over 100 000 persons were evacuated from their homes and settled in other areas. In the restricted zone that was established within a radius of 30 km around the power plant, comprehensive decontamination was carried out and, with the exception of the area within 10 km from the plant, the region was gradually re-opened. By now, quite a few people have returned there.

Close to one million persons from the region around Chernobyl have undergone medical examinations and no damage has been observed, apart from the psychological reaction which the Soviets call radiophobia. Approximately 100 000 persons are being followed up in a large-scale epidemiological examination designed to determine whether any delayed effects on health, especially cancer, occur. The estimates one sometimes sees regarding the number of

cancer cases that could be caused by radioactive fallout are all based on the unproven hypothesis that if one knows that a high radiation dose to a person represents a certain risk of future cancer, it can be assumed that one tenth of that radiation dose gives one tenth of the risk applicable to the high dose. This can also be expressed in such a way that every additional dose however small represents, according to the hypothesis, an additional cancer risk. This is the hypothesis which also forms the basis of speculations to the effect that an increase in the radon content of the household constitutes a risk of an increase in the number of lung cancer cases.

This hypothesis has been developed and applied as a basis for preventive radiation protection measures and we must be aware that there is no empirical corroboration that this really holds true for low doses. On the contrary, studies in areas with relatively high radiation from radon made in various places in the United States and Austria, and studies in areas with thorium-containing monazite sand in India and Brazil did not show any especially high cancer frequency. The hypothesis can thus not be used to *predict* future cases of cancer caused by low doses. Certain studies which are going on may possibly one day show whether low radiation doses give rise to medical consequences and, if so, which ones. What can be predicted with certainty is that any increase in cancer cases as a result of Chernobyl would be very small in comparison with the millions of cancer cases which have other causes.

No authoritative figures are available as to how much radioactivity increased in various areas as a result of the Chernobyl accident. UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation) has calculated that the population of Europe, including the European part of the Soviet Union, during the first year after the accident, received on average an additional radiation dose due to fallout that was less than a third of the dose that is received naturally from the atmosphere and the environment. For the most exposed population, in White Russia, the additional dose was still less than one year's natural dose. These low average values must not, however, lead us into overlooking the tragic fact I have already referred to, namely, that a number of people in the vicinity of Chernobyl received much higher doses.

It may also be worth mentioning UNSCEAR's recent calculation that, on average, every person receives an annual radiation dose of 2.4 millisieverts from natural sources, mainly radon. Even those who are not familiar with measurements in millisieverts can have an interest in knowing that medical applications

of radiation result on average in an annual increase of one millisievert for every person, whereas all the radioactivity in the world connected with nuclear power results in an average dose of 0.0002 millisievert to each and every one of us. UNSCEAR makes a further calculation which may perhaps appear surprising, namely, that the operation of a coal-fired power plant results on average in a higher amount of additional radiation than a nuclear power plant for the production of the same amount of energy. The explanation lies in the fact that the coal contains small amounts of thorium and uranium which are released during burning and give off radiation to the environment while uranium fuel and its waste are isolated from the environment.

Giving the right proportions to the Chernobyl catastrophe by making the facts available has been an important task for the IAEA. An equally important task has been, and still is, to enable all countries to learn from this accident and this is happening, too. In the Soviet Union a number of measures have been taken at all reactors of the type that was destroyed at Chernobyl in order to make a repetition impossible. A change in organization has also been introduced, with better training for operational personnel and tightened supervision. In other countries, too, impetus has been given to new measures designed to reduce the risk of accidents still further. It is worth noting that, at the same time, plans are laid for ways of avoiding consequences *outside* a nuclear power plant if, in spite of everything, a severe accident should occur at the plant. An example is the installation of safety valves with filters on the containment (vented containment), so that any overpressure can be released while the radioactivity discharged in the reactor building is held back in the filters.

A number of international programmes have also been introduced or expanded by the IAEA for the purpose of enhancing the safety of nuclear power plants throughout the world. Agreement has been reached on comprehensive revised and strengthened safety standards (NUSS) which should be respected by all. Through the IAEA's International Nuclear Safety Advisory Group (INSAG), under Finnish chairmanship, a systematic and integrated safety concept has been presented and from this recommendations have been formulated which, if they are followed by designers, operating personnel and supervisory authorities, will with time lead to a further increase in safety. A new service for Members is that the IAEA, upon request, sends international teams of experts for a period of a few weeks to review operational safety at a nuclear power plant, hold discussions with the staff and give advice. Nearly all our Member States

that have nuclear power plants make use of this service and they pay for it. Such a visit was recently completed in Japan; one is going on in Hungary and soon the first visit to a Soviet nuclear power plant is to take place. Similar visits have been made to Finland, Sweden, Germany, France, the United States and many other countries.

I shall not prolong this account of what is going on internationally to enhance safety and generally reduce the risk of accidents in nuclear power plants. However, one point remains to be dealt with, namely, the question whether new types of nuclear power plants can be expected to be even safer than those now in operation. The answer to this is that, with respect to nuclear power plants as well as to aircraft and automobiles or any other technology, safety is never a static concept. The new models which are now proposed for pressurized-water and boiling water reactors are improved and simplified and, from the point of view of safety, a stage of development ahead of their predecessors which are found all over the world. A considerable amount of work is also going into the construction of new types of nuclear power plants with a greater measure of passive safety. Discussion relating to these types e.g. the high-temperature reactor and the Swedish PIUS is certain to be lively. An important question is who in the present-day world is willing to pay the costs for building the prototypes that will be required before an as yet unproven model can be marketed.

It remains for me to make a comparison between the nuclear power alternative and the fossil fuel alternative from the environmental point of view. The term "alternative energy" has been propagated for a long time but in reality it is not solar cells, wind-driven power plants or biomass but rather fossil fuels which are today the alternative to nuclear power. Incidentally, it would be appropriate to coin the expression "alternative waste". Which waste do we prefer? Small amounts of radioactive waste that can be isolated practically 100% from the biosphere, or huge amounts of emissions or waste on the ground when coal, oil or gas are used? I have no hesitation as to what answer I shall give. It was the realization that the damage to lakes, forests and the land were related to the burning of coal and oil that led me fifteen years ago to prefer nuclear energy. From an environmental point of view, it should be regretted that the expansion of nuclear power in the industrial countries was not more rapid and more comprehensive than it actually was. Let me give an example. In Belgium, the emission of SO_2 from power plants decreased from over 400 000 t in 1973 to around 200 000 t in 1983, or by 60% per kilowatt-hour. Increased use of

nuclear power was a principal factor in this reduction although conversion to higher quality oil also made a contribution. Here in Finland, the total emission of SO_2 decreased by 45% between 1980 and 1986, the reduced emission from power plants having made an important contribution. In France, the total emission of SO_2 decreased by over 50% between 1980 and 1986, mainly as a result of the conversion to nuclear energy. The emission of NO_x from power plants decreased by 60% during the same period and helped neutralize the increase that would have otherwise occurred as a result of greater volume of automobile traffic.

It is now possible through new technology to reduce by at least 90% the emission of SO_2 and NO_x from coal- and oil-fired power plants. We have reason to want this technology introduced as soon as possible, even if it is expensive. The poisonous heavy metals that are released in the combustion of coal arsenic, mercury, vanadium, lead, nickel and chromium are not neutralized, however, but remain behind in our environment forever. Nor can anything be done about the enormous amounts of CO_2 that are formed in the burning of all fossil fuels — more in the burning of coal, less in the combustion of gas — and which contribute to increasing the content of CO_2 in the earth's atmosphere and where, together with methane and some other gases, they cause a rise in temperature, the so-called greenhouse effect.

Already now, there is speculation as to which regions can conceivably gain or lose by a rise in the temperature of the earth's atmosphere. I shall not go into these speculations. The now generally accepted thesis that the temperature of the earth's atmosphere will rise and that climatic changes will follow a continued increase in the atmosphere's content of CO_2 and certain other gases, should lead and has already led to discussion of how the process can be moderated, and with time, halted through reduced emission of greenhouse gases. Even now there seems to be agreement that there must be a reduction in the use of fossil fuels producing CO_2. A conference organized last summer under the sponsorship of the Canadian Government recommended that total emissions of CO_2 up to the year 2005 should be reduced by 20% of the present level. The conference offered three prescriptions as to how this should come about: States should: (1) Switch to fuel emitting less CO_2; (2) Review strategies for introducing renewable fuels; (3) Examine the nuclear power alternative once again.

The hot and dry summer in the United States last year led to a lively discussion of the greenhouse effect. Increased use of nuclear energy is beginning

to be advocated by certain prominent friends of the environment in the American Congress. I cannot avoid the conclusion that a new and highly significant argument has emerged in favour of the nuclear energy alternative. Not so that nuclear energy can become a universal remedy against the greenhouse effect, but the increased use of nuclear energy, *together* with a number of other measures can have a moderating effect on the frightening development we are now facing. Obviously, use must be made of *all* means that are effective. In the long term, reforestation can bind carbon; deforestation, which increases CO_2, must for this and other reasons be checked; a transition to greater use of electrical means of transport, trains and trolley buses, must be promoted; automobiles must be made less petrol-greedy; high thermal efficiency must remain a primary objective for new housing and we must, in general, strive to improve utilization of the amounts of energy in fossil fuels; measures must be taken with respect to the other gases which contribute to the greenhouse effect.

Opponents of nuclear energy are already busy explaining why it is completely meaningless to convert from coal power to nuclear power in order to reduce the emission of CO_2 which results from the burning of coal but not from nuclear fission. Their prescription against the greenhouse effect is the same as against nuclear power, namely, saving energy and using renewable fuels.

There is every reason to support these recommendations but there are good grounds for believing that the savings which can be achieved by better utilization of fossil fuels will, as is the case at present, be offset by increased energy requirements, not least in the developing countries, which will not be making use of nuclear power to any greater extent. As far as the renewable fuels are concerned, there has been no breakthrough which makes any of them promising in the short term.

Opponents of nuclear power today try to assert that nuclear power is such a small part of the world's energy balance that the absence of CO_2 in nuclear power is of no significance in relation to the efforts to reduce the emission of CO_2 and the greenhouse effect. Considering that nuclear power now produces 5% of the world's energy and the commercially usable renewable fuels (excluding hydro power) contribute 0.3%, it is rather curious to maintain that nuclear power is too small a source of energy to play any part and at the same time to insist that increased use of the renewable fuels should be one of the main methods for reducing the emission of CO_2! At least within the next ten to twenty years, it will certainly be considerably easier, with reasonable

economy, to increase the production of energy by nuclear means than with renewable fuels.

Even when we look at concrete figures, it is difficult to understand the assertion that present-day nuclear power is too small a factor to be of relevance as regards CO_2 emissions and the greenhouse effect. The total emission of CO_2 from the burning of fossil fuels is at present approximately 25 000 Mt per annum. The Toronto Conference proposed a reduction of 20%, or 5000 Mt. If the 16% of the world's electricity that was produced with nuclear power in 1987 had been generated instead by the burning of coal, it would have required approximately the same amount of coal that the United States produces in one year (640 million tonnes) and the burning would have resulted in some 2000 Mt of CO_2. Compared with the 5000 Mt which the Toronto Conference wants to eliminate over a 17 year period these 2000 Mt CO_2 that we do not release into the atmosphere would not seem to be insignificant. Nor does it require any fantasy to realize that an increase in nuclear power instead of its elimination could help us forego a fair amount of coal, gas and oil based electricity generating capacity emitting CO_2. In the United States, which today generates half of its electricity through the burning of coal, the replacement of obsolete coal power plants with modern nuclear power plants would be a meaningful way of reducing CO_2 emissions.

Let me close this treatment of the subject by saying that the relation between CO_2 and the greenhouse effect is a further significant reason for an expanded use of nuclear energy. Unfortunately, there are no signs at present indicating that any States have resolved to forego an expanded use of fossil fuels because of the greenhouse effect. On the other hand, it is completely obvious that the principal alternative to nuclear power today is the increased burning of fossil fuels, mainly coal and gas.