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I am not going to suggest to you that nuclear power is the solution to the environmental damages and threats which our excessive and careless use of fossil fuels have led to: acid rains, dying lakes and forests and global warming. It is a fact, however, that nuclear power reactors emit no sulphur dioxide (SO_2), no nitrogen oxides (NO_x) and no carbon dioxide (CO_2). The wastes to which they do give rise are minuscule in volume compared to the wastes of the fossil fuels and they can be isolated almost in their entirety from the biosphere. My aim is to show that a continued and expanded use of nuclear power must be **one** among several measures, all of which must be relied on to restrain our use of fossil fuels and thereby to limit the emissions which their burning gives rise to, including those of carbon dioxide.

Energy is the lifeblood of our societies. An enormous increase in the use of hydropower, coal, oil and gas has helped to raise the standards of living in many countries to unprecedented levels. The difference in the levels of energy consumption between the states with the highest living standards and those with the lowest is staggering. The electricity consumption of Norway is about 23,000 kWh per capita and year, while that of Bangladesh is 50 kWh per capita and year. Still, when we are now examining the environmental consequences of the accelerated use of energy by the rich countries with increasing alarm, we must note, sadly, that low per capita energy use has by no means protected developing countries from severe environmental damage. Rapid population growth has led to an ever growing total use of firewood, and to deforestation and desertification. More and more people have to seek their fuel from an ever less plentiful supply. Thus, when we focus on the environmental threats caused by the rich countries' consumption of energy, we must remember that there is another environmental crisis caused by energy use in many parts of the underdeveloped world.

The insignificant risks posed to future generations by the wastes arising from the civilian nuclear power industry have been the subject of much discussion. It is to be welcomed that attention is now devoted also to

the very real and imminent dangers which are posed in particular to the global climate by the burning of fossil fuels at present levels. Are we creating a greenhouse for ourselves, our children and grandchildren? If so, what can we do to avoid it? A conference of twenty-four heads of State and government at the Hague last spring went so far as to call for the creation of a new international authority with power, if need be, to decide on measures even if these were not unanimously supported. In the United Nations General Assembly last autumn, the Soviet Foreign Minister called for a United Nations Council capable of taking effective decisions to ensure ecological security. The United Nations Environment Programme and the World Meteorological Organization have offered a forum for examination of the issue of climate change and recent statements have called for an international convention to combat climate change. The Government of the United Kingdom is among those that address the issue most actively.

The proposals we have seen are evidence of the concern that exists at the highest levels in our various governments. They are welcome as far as they go. However, an international convention must embody some agreement on effective action and an international authority, whatever competence is given to it, must be able to take decisions which result in effective action. What measures can be taken to counter global warming?

Let us note with satisfaction that one of the actions needed is already being taken. Under agreements that have recently been reached the chlorofluorocarbons (CFCs) which have been identified as responsible both for destructive effects on the world's ozone layer and for about 20% of the greenhouse effect, are likely to be largely phased out in the next decade.

It is when we look beyond this measure that we see, so far, relatively little basis for common action. The methane emissions that are judged to account for another 20% of the greenhouse effect cannot be easily limited, as they are mainly linked to rice cultivation and cattle rearing. With a continued increase in the world population, neither of these activities is likely to stagnate. Methane also gets into the atmosphere as a result of leakage of natural gas. A gradual switch from the use of coal to the use of gas, sometimes advocated because it would result in less CO_2 for the same quantity of energy generated, is thus in practice advantageous in terms of

greenhouse response only if leakages of methane can be kept very low — less than one to two percent of the quantity of gas used.

Attention is naturally concentrated on the emissions of carbon dioxide (CO_2). About 50% of the greenhouse effect is attributed to the increasing carbon dioxide levels in the atmosphere. A smaller part of these emissions are the result of deforestation. Forceful programmes for reforestation and a halt to deforestation are desirable measures. We should remember, however, that such programmes may not be easy to implement in poverty stricken countries with rapid population growth. There remains the major emissions for which the industrialized countries carry the greatest responsibility, namely the emission of CO_2 through the burning of fossil fuels, e.g., for heating, transportation and electricity generation. These emissions cannot be prevented by technical means, as can be done with emissions of SO_2 and NO_x, which have been linked to acid rain and dying forests. CO_2 emissions can only be reduced by limiting the burning of coal, oil and gas.

More scientific research is needed to clarify what level of global CO_2 emissions might be tolerable. There seems to be a widely held scientific view, however, that present levels are too high. We may take note of the conclusion of the Conference on the Changing Atmosphere that was held in Toronto last year to the effect that a 20% reduction in present CO_2 levels by the year 2005 should be set as a goal. Others have proposed more severe limitations. Since present CO_2 emissions from the burning of fossil fuels are around 20,000 million tons per year, the reduction under the Toronto proposal would have to be around 4,000 million tons. It is when we raise the question of **how** a reduction of this magnitude is to be achieved that the answers become unconvincing and certainly not yet adequate as a basis for a convention or an international decision to protect the world's climate.

For more than a decade, most environmentalists have been advocating two main responses to the environmental threats from energy use, whether acid rains, dying forests or the arrival of the greenhouse, and these are energy conservation and an expanded use of renewable energy sources, in particular solar power, wind power and biomass.

At the time when I participated in the Swedish public debate before the referendum on nuclear power in 1980, the opponents proposed an immediate halt to the construction of further nuclear plants and a closure of operating plants by 1990. They denied that any increased fossil fuel use would be required and argued that energy conservation, solar and wind power and biomass could be used instead. Today Sweden uses 35% more electricity than in 1980. About 45% of the total electricity generation comes from nuclear power, and about 50% from hydro power. Solar and wind power provide 0.004%. Biomass in the form of wood chippings and other waste products is used by industry, but mainly for heating purposes. A victory for the anti-nuclear option in 1980 would have been an unmitigated environmental and economic disaster for Sweden.

When we are now faced with the contentions that conservation, solar power, wind power, biomass use and various other energy sources are adequate to enable us both to reduce the burning of fossil fuels and to do away with nuclear power, let us have a full-scale public discussion of these options to determine their real value — and to discard their illusory value. We cannot plan substantial reductions in the use of coal, oil or gas on the basis of dreams. We need to escape from the greenhouse, yes, but we need also to escape from the dreamhouse! Let us respect those who withdraw to the countryside to cultivate biodynamic carrots and get their electricity from a windmill. But don't let us believe that they have the recipes for the rest of us.

I shall start by discussing conservation, which is a significant, realistic and necessary element in any effort to reduce the burning of fossil fuels. Conservation embraces both a more efficient and a more discriminate use of energy. In both respects much can be achieved, but it must also be recognized that some means of achieving conservation may be unacceptably costly and others — like tax penalties, for example, on CO_2 production — may be unpalatable. How much can conservation realistically contribute to a reduction of CO_2 emissions? It is easier to gain support for squeezing more miles out of a gallon of petrol than for restricting driving.

Since the automotive sector is significant and often focussed on, let me add some comment on it. It may well be that we should stimulate the

use of the electricity powered means of communication, like trams, trolley buses and trains and thereby, hopefully, somewhat restrain the use of oil-based means of transportation. If the electricity were produced by hydro power or nuclear power, such policies would help restrain CO_2 emissions. More efficient engines in cars would have the same effect. However, the total emissions of CO_2 from fossil fuel burning would be reduced — it has been calculated — by only some 4.5%, or 900 million tons per year, if all cars, trucks and buses in the world could be changed overnight to the best engine performance standards which now exist. Even more could be achieved, of course, if the fuel economy were to improve even further. However, none of these changes occur overnight and the chances are that even with promotion of electrically driven transport and more energy efficient engines, the number of cars in the world will increase to such an extent that total emissions do not fall. This does not, of course, speak against the measures I mentioned. Without them there would be further increases in the emissions.

If predictions about future energy savings are necessarily hypothetical, we do have some past experience to go by. The first oil price shock in 1973 caused a fundamental change in the energy demand in the industrialized Western countries. Primary energy demand — mainly for oil — had up till then followed the increase in the gross domestic product very closely, but since then, it has remained almost constant in spite of an increase in GDP of more than 30% between 1974 and 1986. This means that it was possible, through higher oil prices and government encouragement, to save more than 30% of the primary energy during 12 years in industrialized countries. Worldwide, the picture was different. Globally, primary energy use continued to increase by 2% per year.

During the same period, another significant change occurred in industrialized countries: electricity use began to grow with GDP in an almost one to one ratio. Electricity became the preferred form for energy use in many industrial processes and heating applications. Through its precision in achieving effects exactly where wanted, and in the quantity wanted, it also became a significant factor in achieving the savings in primary energy uses. This was true for those industrialized countries which could most easily use and adopt advanced technologies.

When we now look at actual national plans for the future, we find that they do not generally foresee a decreasing primary energy use — particularly not in the developing world. Indeed, there is a pathetic gap between the frequent claims as to what conservation can achieve and actual energy plans. China, for instance, already the world's biggest burner of coal, plans to double its coal use from the mid-1980s to 2000, and India plans to triple its coal use. These two nations, with more than one third of the world's population, will then use more coal than all of the OECD countries together, including the USA , the UK and the FRG. They are typical of many countries in the Third World, most of which are not able to use advanced and demanding technologies. I am not saying that there is no room for greater energy efficiency in developing countries. I am only saying that the plans of these countries are for a sharp increase in the use of fossil fuels. This means that if we are to succeed in diminishing the greenhouse effect, the industrialized countries must make the major effort.

My conclusion is that although there may be a significant potential for saving both primary energy and electricity, especially in high-consumption countries, we must prepare to face increasing global demands. Knowledgeable organizations — even taking conservation measures into account — forecast 30-45% higher primary energy demand in 2000 than in the mid-1980s, 60-70% higher electricity demand, and about 40% increase in the use of coal alone over the same time period. These forecasts may be wrong, as earlier forecasts have often been. A prospect of catastrophe might affect them. Nevertheless, we must tackle the question particularly whether and how we can contain, indeed, reduce the share of CO_2-producing fossil fuels in the world's energy balance.

Let me turn first to the scope for an expanded use of renewable energy sources. If you except hydro power, these sources now contribute less than 0.5% of the global energy supply — and a major part of that is geothermal energy which is important for instance in Iceland and some parts of Italy and the USA. Solar and wind energy have so far shown little promise of economic competitiveness.

As to solar power, there have been promising developments in photovoltaic cells, but their price is still too high to make them economically

acceptable, except for use in satellites, isolated locations, watches, calculators, etc. It might also be noted that in order to produce the same amount of electric energy as a 1000 MW(e) power station operating at 80% load factor, some 90 square kilometers would need to be covered by solar cells, assuming that they were to be placed in Central Europe and that the best existing types of cells were used.

There exists a long experience with wind generators. In California alone, there are some 15,000 wind generators now in operation. They seem to have an optimum size in the range of 100 to 200 kW. Larger units in the range of 1 to 3 MW have so far proved unsatisfactory. Experience shows that even in very favourable locations, a load factor of 30% from a wind generator is a very good result. That means that it would take at least some 13,000 wind generators of 200 kW capacity each to provide the same electric energy as a 1000 MW(e) thermal power station (with 80% load factor). The surface needed would again be of the order of 100 square kilometers.

It seems clear that much work is still needed to reduce the costs of solar and wind generators considerably if they are ever to become generally economically competitive. I am not surprised that Mrs. Helga Steeg, Director General of the International Energy Agency in Paris, recently stated that "the contribution of renewable energies, besides hydro power, in most of the IEA countries (i.e. most of the Western industrialized countries) for the year 2010 can be estimated to be a maximum of 5%". This does not negate the fact that these energy forms can be very important in specific regions or situations. Nor do present modest results suggest that we should withhold research and development funds for these energy sources. But they do suggest that it would be irresponsible to count on major global contributions from energy systems that have so far not turned out to be viable on a large scale. To suggest that they can replace fossil-fired plants to any major extent during the next decades is as unrealistic today as it was when similar forecasts were being made ten years ago.

My conclusion is that conservation and renewable energy forms certainly should be supported, but they alone will not be sufficient to counter the greenhouse effect. Before focussing on the relevance of nuclear power,

I must briefly discuss hydrogen, which is sometimes mentioned as an alternative to electricity for use in heating and transport. There is a large body of experience with hydrogen. City gas, which has now been replaced by natural gas in many cities, was a mixture of hydrogen and carbon monoxide. In the Soviet Union, an aircraft has been propelled with hydrogen as fuel, and reports reach us that automobile makers experiment with cars fuelled by hydrogen. This is all very understandable and interesting. Petrol will have to be replaced one day. Cars may well have to run on electricity or hydrogen. However, hydrogen has to be produced industrially and for that, either electricity or very high temperatures are needed. Both could be achieved through nuclear reactors. Ideas of producing hydrogen by the use of electricity from solar cells covering large areas in the Sahara seem fanciful and, at any rate, decades away. And even if we were to succeed in producing large quantities of hydrogen, there would still remain the major safety problems of transporting, storing and using it.

Now let me turn to nuclear power. It is recognized that nuclear power plants are capable of producing very large amounts of electric energy without adding CO_2 or SO_2 and NO_x to the atmosphere. Yet, a number of arguments are now mobilized to try to convince the world that nuclear power is totally irrelevant to our needs to generate energy without generating CO_2. Let me discuss some of these arguments.

We hear, for instance, that electricity now only accounts for 29% of the total energy consumption and that fossil-fired power plants today contribute only some 12-15% to the greenhouse effect. It is implied that it is not worthwhile doing anything in this sector, except saving electric energy.

I submit that this is an uncaring attitude. I shall not claim that a continued and expanded use of nuclear power is a panacea for the problem of CO_2 emissions, but I shall try to show that it can make a contribution that, along with others, is most helpful to contain those emissions. Let me point out in the first place that if the electric energy that was generated from nuclear power last year had instead been produced by coal-fired power plants, this would have given rise to additional emissions of about 1600 million tons of CO_2. This figure is not small when you compare it with the 4000 million tons which the Toronto Conference recommended as a target

for reductions by 2005. Let me point out, in the second place, that electricity is a constantly growing part of energy consumption and that it is helpful in efficiently substituting for the direct use of fossil fuels. Even extreme low energy scenarios assume that we will use about twice as much electricity in the world around 2020 as we use now. That would require an **addition** of a 1000 MW(e) plant every 4.4 days on the average [2500 GW(e)]. There would further be a need for replacements for old and obsolete plants — both nuclear and fossil-fuelled. It is not without interest from the viewpoint of CO_2 emissions whether these new plants and replacement plants will be fuelled by coal, gas, uranium or driven by hydro where available. If all the additional electricity that is assumed in the low energy scenario to be needed by 2020 were to be generated by coal, there would be an annual added emission of some 16,500 million tons of CO_2. If, instead all of this new electricity were to be by nuclear power or hydropower, there would be no further CO_2 emissions. Such extreme scenarios are not realistic, of course. Both among additional plants and replacement plants there will be a mix of coal, nuclear, gas and hydro. The figures help to clarify, however, that it is of considerable importance how this mix is made. The more fossil, the more CO_2, the more nuclear and hydro, the less CO_2.

A current standard objection to nuclear power's relevance for CO_2 abatement is that it would require a new nuclear power plant to be put into operation every 2.5 days over 35 years to replace coal-fired plants. Such a perspective is evidently meant to deter everybody from devoting a further thought to the possible relevance of nuclear power. As I said a moment ago, however, there will be a mix and it matters how it is constituted. Let me also remind you that in each of the years 1984 and 1985, 33 new nuclear power plants actually came into operation, or one new plant every 11 days on the average. There exists a capacity to build many more nuclear plants than we do today.

A further objection to future increased reliance on nuclear power is that the world's uranium resources should be too limited to permit nuclear power to be anything but a short parenthesis. The reality is that already known low-cost uranium resources are sufficient to sustain a much larger nuclear power sector than we now have. If we include the resources which geologists consider likely to exist, we might well fuel ten times more reactors

than we now have over their whole lifetimes, even with the present type of reactors and without plutonium recycling.

A perennial argument is that nuclear power plants are unacceptably expensive. There are indeed cases of plants which have become very expensive. The nuclear industry is not the only one in which this happens. Moreover, the statement conveniently overlooks the highly successful and economic nuclear programmes in, for example, Canada, Belgium, France, Japan, Sweden and Switzerland. There have also been studies of the economics of nuclear power by the Nuclear Energy Agency of the OECD in Paris, in co-operation with the Union of Producers and Distributors of Electricity (UNIPEDE) and the IAEA. The results show that nuclear power remains competitive in most OECD countries. Nuclear plants generally cannot compete economically with coal-fired plants built near coal-mines.

My conclusion is that the arguments which have been advanced against the use of nuclear power in the face of the CO_2 problem and which I have cited are all thin and contrived. The reality which is becoming increasingly recognized by all who do not choose to close their eyes is that a continued and expanded use of nuclear power will be an indispensible contribution to the efforts to restrain CO_2 emissions.

The real objections to nuclear power — present or expanded — are not new. They relate to safety, waste disposal and the risk of proliferation of nuclear weapons. Let me deal with them in the reverse order.

The proliferation risk exists whether we have a nuclear power industry that is of today's size or larger, or none. Even a worldwide closing of nuclear power stations would not eliminate the risk and probably not significantly reduce it. Let me remind you that all nuclear-weapon States had their weapons first and power reactors second. Further disarmament, on the other hand, may well promote a fuller commitment to non-proliferation, verified by the IAEA. It should also be remembered that the current nuclear power use, apart from relieving the world of huge quantities of CO_2, reduces the pressures on oil resources. It would take the peak oil production of Saudi Arabia of 1974 to generate the electricity we obtain from nuclear power today (about 400 Mtoe). This effect is not insignificant in a world where

competition for oil resources is a major security issue — like the risk of proliferation.

Let me now turn to the question of wastes. All fuel cycles give rise to wastes, for instance, tailings from uranium mining, slag heaps from coal mining, leakage of methane gas, oil spills in the ocean, ashes, etc.

In the nuclear fuel cycle, the amounts of highly radioactive wastes are small. To be a bit provocative, one might say that the wastes are one of the great assets of nuclear power compared to other energy sources. The limited quantities make it possible for us to safely manage and dispose of practically all the waste that arises, and certainly all that is hazardous, in a controlled manner. The operation of all nuclear power plants in the world last year gave rise to some 7000 tons of spent fuel. If the electricity generated by that fuel had been generated by the combustion of coal, it would have resulted — as I have already mentioned — in the emission of 1600 million tons of CO_2 and tens of millions of tons of SO_2 and NO_x, even with the best flue gas cleaning equipment available. In addition, there would have been some 100,000 tons of poisonous heavy metals, including arsenic, cadmium, chromium, copper, lead and vanadium. These, of course, remain poisonous forever, and are not isolated from the biosphere.

It is often argued by opponents of nuclear power that we do not know how to isolate the nuclear waste safely. That is not correct. Detailed designs for packaging the wastes, whether in the vitrified form after reprocessing, or as compacted spent fuel assemblies, have been worked out and have been approved by safety authorities. When most countries have decided to store such spent fuel for some 30 to 50 years before either disposing of it as waste or reprocessing it, it is for the reason that allowing the radioactivity to decay simplifies the design of both the waste container and the storage and makes it easier to achieve the safe isolation which is required for a very long time period.

It is sometimes suggested that our generation is reaping the benefits of nuclear power, while leaving the financial cost of waste disposal to succeeding generations. However, in several countries there is a legal requirement to add to the price of the nuclear kWh a charge covering the

future costs of the management and disposal of the radioactive wastes, and also of future decommissioning of the plants. Here in the UK, the kWh cost includes a charge for these purposes. These costs are not overwhelming. In Sweden, the addition to the kWh price is two hundredths of a Swedish Crown per kWh, or about 10% of the total price. The estimates of the costs are not very different in other countries.

Let me end my comments on nuclear waste by saying that if other industries had as good methods for waste management and disposal as the nuclear power industry does, the world would have far fewer environmental problems.

The concern mostly voiced about nuclear power relates to safety. In the Chernobyl accident large amounts of radioactive substances were released. Some 200-300 persons — operational and firefighting staff — received high doses and suffered radiation sickness. Twenty-nine of them died of their radiation injuries, but most of the others are back in productive work after hospital treatment. Over 100,000 persons have been evacuated from their homes and have been settled in other areas. In the restricted zone that was established within a radius of 30 km around the power plant, comprehensive decontamination has been carried out. Some people have moved back, but no general return has been authorized.

Chernobyl was a grave and extremely costly industrial accident by any standard but it was certainly not unique in the number of deaths or injuries. Other ways of generating energy also take their tolls. The oil platform that exploded last year in the North Sea took 165 lives. An explosion in a coal mine in the Federal Republic of Germany, likewise in 1988, killed 57 miners. A gas explosion in Mexico City in 1984 left some 450 dead and thousands of people injured. A dam that burst in India in 1979 killed 15,000 people. And last month, an explosion caused by a leak from a gas pipeline destroyed two trains in the Soviet Union and caused more than 600 deaths.

Yes, people will say, but what about the cancer cases that may be caused by the radioactive fall-out? We shall probably never know how many additional cases there may be, if any, as a result of the fall-out from Chernobyl, because the number of cancer cases from other causes in the

same population is so high that a small addition will hardly be discernible. Even for the most exposed population in White Russia, the average additional dose of radioactivity caused by Chernobyl was less than one year's natural dose. These low average values must not, of course, conceal the fact that a number of people in the vicinity of Chernobyl received much higher doses.

Although the Chernobyl reactor was very different from most power reactors operating in the world, and this kind of release is implausible on reactors which, like the Three Mile Island reactor, have containments designed to stop releases into the environment, no one contends that there are **no** risks in using nuclear power. However, these risks should be compared to the risks and damage connected with the main alternative way of generating the electricity, namely through the use of fossil fuels.

We should, of course, compare the whole fuel cycles. The health and environmental consequences of the mining of uranium must be compared with those of the mining of coal and the extraction of gas and oil; one should also compare the transportation of each, the fission of the uranium with the burning of fossil fuels and the emissions from the burning of these fuels with the disposal of nuclear waste. One should compare the number of casualties and health injuries and the amount of environmental damage per quantity of electricity generated. Such examinations are, in fact, underway and from what we have seen so far, they point to a positive picture for nuclear power.

Whether such rational comparisons will help to overcome anxiety about nuclear power is less certain. We have not accepted and tucked away the risks of nuclear power in our minds as we have done with, say, the risks of coal mine accidents. Perhaps the ambition need not be to eliminate all anxiety. After all lots of people rationally accept flying despite feelings of anxiety. We certainly need to demystify nuclear power — but this may take time. Meanwhile perhaps we should be content merely to get broad acceptance of the use of nuclear power. The anxiety which continues to exist should continue to spur all those who are connected with nuclear power to reduce even further the risks of significant accidents. There must be an increased awareness, however, that if broad acceptance is **not** achieved

for nuclear power, we shall have to face the risks that are connected with the alternatives — including their environmental consequences.

Let me conclude: Nuclear power can help significantly to meet growing needs of electricity without contributing to global warming, acid rains or dying forests.

A responsible management and disposal of nuclear wastes is entirely feasible.

The safety of nuclear power, like the safety of any other industrial activity, must be continuously strengthened through technological improvements and methods of operation.

There is a dire need for more factual information to narrow the gap between the real and the perceived risks of nuclear power and to demonstrate the risks of the alternatives.