The world's energy needs and the nuclear power option

Is nuclear energy's role really too small to make a difference?

by Hans Blix

Energy is the lifeblood of our societies. An enormous increase in the use of oil, coal, gas, and hydropower has been a major means of raising the standard of living in a few countries to unprecedented levels. There has been a clear relationship between the level of economic development and energy consumption. The differences have also been enormous between, say, the average North American who uses 7200 kilograms of oil equivalent per year and the average Chinese who uses 590 kilograms, or the average Indian who has to make do with 280 kilograms of oil equivalent (of commercial energy). Even after the oil shocks, the countries of the Organisation for Economic Co-operation and Development (OECD) — with one-sixth of the world's population — consume almost one-half of the world's primary energy.

The oil price shocks in 1973 and 1979 changed what had until then been a steady trend in the OECD countries towards ever increasing energy use. The consumption of primary energy stagnated while the gross domestic product (GDP) rose by more than 30% by 1986. The use of electricity, on the other hand, continued to rise although at a slowed rate in an almost one-to-one relationship with GDP. Two things are worth noting:

- Firstly, that the industrialized countries were able to achieve a saving in primary energy use of some 30-40%, or 2-2.5% per year, between 1973 and 1987 (which is the latest year for which we have global data). In North America, the per capita consumption of primary energy actually dropped by 13% between 1973 and 1987.
- Secondly, that the saving of primary energy was at least partly achieved through a shift in energy end use from oil and coal to the refined and more efficient secondary energy form of electricity.

Energy needs of developing countries

The energy situation in the developing countries was and is very different. In spite of the serious economic problems which many of them have encountered since the oil price shocks, their use of both primary energy and electricity has continued to expand at a rate of 4–5% per year and sometimes faster than the growth in GDP. This does not necessarily mean that the developing countries are using energy in a wasteful manner. They simply have tremendous needs which have gone largely unfulfilled.

Developing countries show a much faster increase than industrialized countries in the use of electricity. In the past 15 years the increase has been around 8% annually, or a total of almost 200%. Again, these countries have a demand for all the electric energy that can be produced.

Electricity and development

It seems very likely that the future availability and use of electricity will turn out to be a determining factor for development. Electricity has great flexibility in use and can be controlled with precision to provide heat or power just where it is needed and in the amount needed, whether in residential, industrial or commercial uses.

It may also be predicted that — barring some dramatic developments including drastic actions by governments — the global demand for more energy, particularly electricity, will increase in the future. However, this demand is now standing face-to-face with fears about the environmental consequences of even present levels of energy use.

Dr Blix is the Director General of the IAEA. This article is an abridged version of his address in October 1989 at the Massachusetts Institute of Technology, USA, where he was invited to present the 1989 David J. Rose Lectureship. The full text is available upon request from the IAEA Division of Public Information.

Environmental concerns

Seventeen years after the first United Nations conference on the environment in Stockholm in 1972, we are becoming painfully aware that, despite efforts made, environmental problems have escalated from local to regional level and now pose global threats. I am, of course, referring especially to the greenhouse effect.

- In June 1988, a Conference with scientists and politicians in Toronto warned about the changing composition of the atmosphere and recommended, *inter alia,* a reduction of 20% in carbon dioxide emissions by 2005.
- In November 1988, the Intergovernmental Panel on Climate Change (IPCC) was sponsored by World Health Organization (WHO) and United Nations Environment Programme (UNEP). This panel remains the forum in which the community of States analyse the problem of global warming, the consequences it may have, and ways of countering it.
- In April 1989, a ministerial conference in the Hague called for the establishment of a new international body with authority to take binding decisions even in the absence of a full consensus on some environmental matters.
- In July 1989, the Paris summit meeting of the seven most industrialized nations devoted 5 of the 19 pages of its communiqué to questions of protection of the environment.

Let me also note that in 1992 a second UN Conference on the Human Environment is expected to deal, *inter alia,* with global warming.

There is thus at present certainly no lack of awareness that the world is facing a grave environmental problem in the greenhouse effect and there seems also to be an understanding that far-reaching action must be taken. But what action?

International co-operation

It is clear that we can hope to reduce or contain global carbon dioxide emissions only through international action and that at least one of these actions will have to involve limiting the burning of fossil fuels. Such a limitation will raise formidable political problems. Just think of the needs of the developing countries. Two examples: for its development, China has plans to double its use of domestic coal between 1985 and 2000. India plans to treble its coal use in the same period of time. If these two countries — with then more than one-third of the world's population — implement their plans, they will use more coal than all of the OECD countries together in 2000 — and it is forecast that the OECD countries will use 35% more in 2000 than in 1985.

This brings me to the question what concrete international action can realistically be proposed if we are to face up to the threat of global warming. An international convention against climate change is a major proposal at present. But what concrete measures are to be agreed upon in such a convention? There are some important question marks and some formidable problems. We still do not know what an acceptable level of global carbon dioxide emissions is. The Toronto Conference last year called for a reduction by 20% from present levels, but there is scant evidence that this would be the right level. Let us hope that the IPCC deliberations which are supposed to be concluded by the end of next year (1990) might give some more solid guidance. Nevertheless, whatever the desired reduction of carbon dioxide emissions is, there remains the main problem of how to achieve it — and by whom it is to be achieved.

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Hydro and nuclear power

There are now only two energy sources which are technically and economically proven on a large scale and which can produce large amounts of energy without adding significantly to sulphur dioxide, nitrous oxide, or carbon dioxide emissions. These are hydroelectric power and nuclear power.

There is still a very large hydro capacity in the developing world, and this should certainly be used where environmental concerns can be met. In industrialized countries there is a limited exploitable potential left.

This leaves us with nuclear power. It now provides 17% of the world's electricity and 5% of its primary energy. This is just a few per cent less than hydroelectric power. The importance of nuclear power is, however, very different in different countries. In the USA, the fraction of electricity generated by nuclear power plants is 20%, but it is much higher in some areas, for instance in New England and around Chicago. France is the world leader with 70% of its electricity coming from nuclear power, which means in practice that oil has been fully replaced by nuclear power for electricity generation. In July this year, the figure was almost 80% in France as the spring and summer had been very dry. Through its large nuclear power capacity, France now generates more electricity than it needs itself, and exports electricity valued at more than US $1 billion per year to its neighbours. Belgium gets 65% of its electricity from nuclear plants, the Republic of Korea 50%, and Sweden 45%. There are now 11 countries which get more than 30% of their electric energy from nuclear power. Of the Eastern European countries, Hungary at present has the highest fraction of nuclear-generated electricity — 49%.

There is at present considerable doubt about the future of nuclear power, even among the big users of it. In Sweden, the phasing out of nuclear power by 2010 has been decided upon by Parliament, and the Government has announced that the first two plant shutdowns are to take place in 1995 and 1996, reducing the present park from 12 to 10. For me, as a Swede, it is somewhat ironic that in the same 2 years, the Republic of Korea plans to put its plants numbers 11 and 12 into operation.

The present nuclear outlook is bleak in several countries. In Italy even the existing nuclear plants are no longer in use following a referendum. Switzerland, the Federal Republic of Germany, Belgium, and the Netherlands have a *de facto* moratorium for new plants. Several countries like Austria, Denmark, and Ireland have renounced nuclear power entirely, even though they need more electricity-generating capacity. Against these negative trends, I may mention the expanding nuclear programmes in France, Japan, Great Britain, and Eastern Europe.

The Chernobyl accident had a serious effect on public opinion everywhere, including the Soviet Union itself and the countries of Eastern Europe. The Soviet Union closed two nuclear plants in Armenia after the earthquake there. It also stopped construction on several plants, and abandoned plans to use a number of sites for nuclear plants. Although there is evidently a considerable anti-nuclear opinion in the USSR, as in most industrialized countries, the USSR still plans to double its nuclear power plant capacity from the present 34 000 megawatts by 2000. In a recent interview, President Gorbachev said "... An opinion has grown in the world, and I share this opinion, that one cannot do without nuclear energy. What place it is to take in our overall electricity production is another question. And, naturally, safety should be guaranteed. But we won't survive without nuclear power." There are, in fact, nuclear power plants in operation or under construction in every one of the East European countries, and operating plants in, for instance, Bulgaria and Hungary consistently show very good performance.

In the USA, no plant ordered since 1973 has been completed, and no new orders are expected for several years, in spite of the fact that many utilities need new generating capacity sooner rather than later.

Future prospects for nuclear power

The prospects for nuclear power thus appear very uncertain at the moment. Yet we are facing a situation in which a revitalization of the nuclear option seems to be of crucial importance and seems to be desired by many governments. New plants need to be ordered to meet demand. However, although strong reasons speak for nuclear power, opposition is strong. The main arguments are well known:

- Nuclear power is said to increase the risk of proliferation of nuclear weapons;
- The risks of accidents with serious consequences are said to be unacceptable;
- The waste problem is said to be unsolved; and
- Finally, the use or non-use of nuclear power is said to be irrelevant to the greenhouse problem because its share in the energy supply is small.

How serious are these objections?

First, non-proliferation. Unlike, for instance, the dissemination of chemical technology, the transfer of nuclear power technology has from the beginning been based on schemes for international co-operation with built-in checks and controls against the risk of proliferation of nuclear weapons. The Atoms for Peace programme which led to the creation of the IAEA within the UN system was based on the philosophy that technology, material, and equipment would be made available against commitments that they would only be used for peaceful purposes. The verification that these commitments are upheld is now being provided through the IAEA safeguards system, the first international on-site inspection system; it now costs about US $50 million per year and has some 200 inspectors regularly visiting some 60 countries. Some 95% of all fissionable material outside nuclear-weapon States is under safeguards control. The fears which were common 25 years ago that many States would acquire nuclear weapons have not materialized. The risk of proliferation exists, but I think we can confidently state that the development of civilian nuclear power does not significantly contribute to it. None of the present nuclear-weapon States began with nuclear power. The weapons came first.

Second, safety. The TMI and especially the Chernobyl accident have increased the attention in many countries to the safety of nuclear reactor operations not only at home but also in other countries. The awareness that a nuclear accident anywhere in the world would have considerable psychological fallout, even if the physical fallout were to be negligible, has similarly directed attention to the need for some international guarantees of nuclear power safety. There have been some demands for the adoption of binding international safety rules and inspection of their implementation. However, governments are not at present ready to accept the primacy of any international body in the field of nuclear safety. An extensive international role would also require a considerable apparatus. The international regime that governments are introducing through the IAEA and a few other international organizations is more subtle — it seeks to give good models for national safety regulations and assistance and support to regulators and plant operators. This regime is expected to be effective, not because regulators, suppliers, or operators are legally obliged to respect it, but because they find it in their interest to respect it and rely on it.

Already in the early 1970s, the IAEA served as an instrument for building an international consensus on

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safety standards and practices. The Nuclear Safety Standards Programme — the so-called NUSS programme — produced five Codes of Practice covering the essential safety aspects of governmental organization, siting, design, operation, and quality assurance. The Codes are supplemented by 56 Safety Guides recommending how these safety requirements could be implemented... Member States have used the Codes extensively to elaborate national regulations. To take an important example, China, with its emerging nuclear power programme, has adopted the NUSS standards as the basis for its national regulatory requirements. Several Member States have directly adopted the Code for quality assurance. Out of the 31 IAEA Member States which have nuclear power plants in operation or under construction, 20 have informed us that their national safety regulations are consistent with the NUSS standards.

The Agency has also established an International Nuclear Safety Advisory Group with the task of looking independently into fundamental safety questions. This was the group that produced a report on the Chernobyl accident and in a publication last year it has also set out "Basic Safety Principles for Nuclear Power Plants" — not as regulatory standards, but as objectives for power plant designers, constructors, and operators to aim at — objectives which should be at a higher level than regulatory authorities would use.

While standards and regulations are indispensable to ensure nuclear safety, they are not enough. Equal attention must be paid to operational safety in the some 430 nuclear power plants which are now operating in the world and the 100 or so plants which will soon be put into operation. To assist its Member States in this regard, the Agency is offering several services which are being increasingly used.

Firstly, Operational Safety Review Teams (OSARTs) are sent to a nuclear power plant in response to a request. The teams are composed of experts from both the Agency and Member States and their reviews are certainly not cosmetic. Over a period of several weeks they thoroughly review plant operations management and procedures. Since Chernobyl the reports of most of the OSARTs which the Agency has performed have been published by the authority which requested the OSART, in order to inform the public. Industrialized countries pay the full cost of such visits; developing countries pay all local expenses. Secondly, the Agency offers expert teams (ASSETs) to help a nuclear plant operator assess safety significant events and define the real root causes. Thirdly, the Agency can arrange for reviews of regulatory organizations by peers from other countries. This can help to improve the functioning of the organizations and strengthen confidence in them. We have carried out the first review of this kind this year.

Safety is never static, and the broadest possible information exchange must be organized so that the best experience can be adopted by all. The Agency's Incident Reporting System (IRS) is the only worldwide service for exchanging information on operational safety experience. The IRS collects and analyses reported events to create a better understanding of problems that may be common to specific plant types or generic to all plants.

So much for international action related to operational safety at existing nuclear power plants. What about the future plants which are supposed to be safer and more tolerant of human errors than the ones which were subject to accidents at TMI and Chernobyl?

I must preface my remarks about future reactors by the comment that today's nuclear power reactors are designed to tolerate a great deal of human error. Their safety systems have much built-in redundancy. Moreover, they rely on decades of proven technology and engineering practices reflecting the high standards and strict regulations of the nuclear industry. In the TMI accident, the containment worked in spite of several operator errors. The accident at Chernobyl occurred because several safety systems had in fact been deliberately switched off. A strengthened safety system which has been introduced for that reactor type now makes it harder to do so.

The industry now seems ready to present advanced versions of the currently most common reactor types, with standardized and simpler design, more "passive" safety features and often smaller sizes. This could make them attractive for the industrialized countries seeking to meet the current lower rate of increase in electricity demand. Moreover, through lower total capital costs these reactors could help to improve the management of investment risks. Such features might also make them interesting for some developing countries. The emergence soon of these new reactors should not and does not preclude R&D work on radically new types of power reactors. When the cost of development of new technology is very high and the chances of sales very uncertain, it would be unrealistic to expect the nuclear industry to work alone to develop new reactors. In most cases, government support will be needed for the development and construction of prototypes. From the Agency's side, we are seeking to promote renewed co-operation on this subject between governments and industry, also internationally.

In covering the subject of nuclear power safety, I must, of course, mention the international agreements which were reached after the Chernobyl accident on measures that are designed to contain and mitigate the consequences of an accident, notably early notification and assistance in the case of radiological emergencies.

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Notification has actually been given in two cases since the Chernobyl accident, although it was not strictly required under the convention. Assistance has likewise been organized twice in the same period, not in connection with nuclear power accidents however, but to help victims of accidents involving large radiation sources for medical and industrial uses.

In this discussion of safety I have focused exclusively on nuclear power. I submit to you that the safety philosophy and concepts that have been developed for nuclear power are such that there would be great advantage if other energy-producing industries emulated them. Although no accidents in the history of mankind have had greater publicity than the ones at TMI and Chernobyl, accidents which have occurred in recent years with fossil fuel cycles show much higher death tolls.

Let me now turn to the third argument commonly raised against the use of nuclear power, namely the allegedly unsolved problem of radioactive waste disposal. It is a symptom of the difficulty of conveying correct information that probably a majority of people accept this allegation. In no other way is there any substance in it, however, than in the sense that so far disposal facilities for high-level waste have not actually been built. This is not explained by any lack of ability to construct facilities in which the waste will be safely stored for thousands of years. Rather, the reasons are two: first, that it is *desirable* to delay ultimate disposal of waste — or unprocessed spent fuel — for some 30–50 years to allow it to lose much of its heat and radioactivity before packaging it and depositing it. The second reason is that the public and political organs elected by it are unwilling to consent to the use of *any possible sites*. Dr Herbert Kouts, chairman of the IAEA's International Nuclear Safety Advisory Group, summed up the situation when he said, "The 'unsolved' problem of radioactive waste is more political than technical and will require more guts than brains to solve."

Internationally agreed criteria for the safe disposal of low- and intermediate-level radioactive waste have existed for some time, and a number of actual repositories for this kind of waste are already working well.

In September 1989, the IAEA's Board of Governors approved international criteria also for the safe disposal of high-level wastes. It should be noted that in devising standards for the disposal of any radioactive waste, one requirement has consistently been that the waste disposal shall take place in such a way that both present and all future generations shall be protected against any radiation risks higher than we would accept today. The civilian nuclear industries accept these requirements, and I think one might safely say that if other industries had had as prudent a waste philosophy and practice as the civilian nuclear industry, the world would look very different today.

The argument is also not correct that this generation is enjoying the benefits of nuclear power and leaving the burden of waste disposal to our children. In a good number of countries, the current users of nuclear-generated electricity are actually paying for future waste disposal and decommissioning of plants by a special fee built into the cost of each kilowatt-hour.

Too small to be of significance?

I should like to conclude with some comments on the argument that holds that nuclear power has such a small share of the world's energy supply that the absence of any carbon dioxide emissions from nuclear power plants has no significance for the greenhouse threat. Some facts may be of interest: Last year, nuclear power worldwide produced 1800 terawatt-hours of electric energy. If that had instead been produced by coal-fired power plants, which would have been the economically competitive alternative, it would have meant a 9% increase in the carbon dioxide emissions resulting from the worldwide burning of fossil fuels.

Some 25% of the world's total carbon dioxide emissions come from public utility electricity generating stations. In the United Kingdom, where 20% of the electricity comes from nuclear stations, the average carbon dioxide emission per kilowatt-hour produced was 0.78 kilograms. In France, where nuclear plants generate 70% of the electricity, the corresponding figure was 0.09 kilograms. This gives a perspective not only on what can be achieved, but also on the potential problems in negotiating a convention to reduce carbon dioxide emissions worldwide.

It is somewhat ironical that the argument that nuclear power is too small a factor to be of significance in the efforts to contain or reduce emissions of carbon dioxide should come from some of those who maintain that a rapid development and deployment of new renewable sources of energy, together with conservation, must be the main answer to the greenhouse threat. As I noted a while ago, currently less than 0.3% of the world's primary energy comes from those renewable energy sources, compared to the 5% which nuclear power provides today. In September 1989, the World Energy Conference concluded that solar and wind power cannot be expected to provide any significant global contribution in the foreseeable future. *(See the report on the WEC conclusions that appears in the following article.)* This does not mean, of course, that the world should abandon efforts to develop these energy sources. We should certainly try to accelerate their development, but it would

be irresponsible to count on them in the next few decades as a major factor in countering the greenhouse threat. If demands for energy are to be met today, the real and hard choice is between fossil and nuclear fuel. With some exceptions, developing countries have no real choice. Lack of infrastructure and trained manpower at present obliges them to use fossil fuels — and hydropower when available. The industrialized countries have a choice. And these are the countries that at present are responsible for 80% of the carbon dioxide emissions in the world.

The sooner we face up to the reality, the better the chances are for energy policies to meet the threat of global warming. An international convention committing the world's governments to maximum energy conservation, reforestation, and an expanded use of renewable sources of energy is desirable, but is not enough. I submit to you that we shall not only need to keep the nuclear power capacity which exists, but also to considerably expand it. That this will actually happen is by no means a foregone conclusion. We must ensure that nuclear power performs safely and economically well, that an international nuclear safety culture is established. We must overcome resistance to the construction of facilities for the storage of spent fuel and the disposal of waste. We need to demystify nuclear energy. The graver the threats to the world, the greater the need for rationality. The scientists need to be heard and understood.

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Mihama nuclear plant in Japan. (Credit: Kansai Electric Power Co.)