Nuclear energy & the environmental debate: The context of choices

Through international bodies on climate change, the roles of nuclear power and other energy options are being assessed

by Evelyne Bertel and Joop Van de Vate

Environmental issues are high on international agendas. Governments, interest groups, and citizens are increasingly aware of the need to limit environmental impacts from human activities. In the energy sector, one focus has been on greenhouse gas emissions which could lead to global climate change. The issue is likely to be a driving factor in choices about energy options for electricity generation during the coming decades. Nuclear power's future will undoubtedly be influenced by this debate, and its potential role in reducing environmental impacts from the electricity sector will be of central importance.

Scientifically there is little doubt that increasing atmospheric levels of greenhouse gases, such as carbon dioxide (CO_2) and methane, will cause climate change on a global scale. However, the natural climate variability is still larger than the estimated anthropogenic contributions to climate change.

Despite uncertainties, the threat of climate change remains a serious long-term global risk. Scenarios with time horizons of 2100 and beyond have to be developed, requiring insight into long-term development of life-styles, socio-economics, and technology. Such scenarios are of a normative character and therefore are inherently subjective. What is known is that energy consumption is one of the major sources of greenhouse gases, and nuclear power nowadays avoids more than 8% of the worldwide CO_2 emissions.

Two major international bodies are involved in climate change matters: the Conference of Parties to the Framework Convention on Climate Change (CoP/FCCC), which had its First Session in March/April 1995, and the Intergovernmental Panel on Climate Change (IPCC), which has been active since 1988. Since the energy sector is responsible for the major share of anthropogenic greenhouse gas emissions, international organisations having expertise and mandate in the field of energy, such as the IAEA, are actively involved in the activities of these bodies. In this connection, the IAEA participated in the preparation of the second Scientific Assessment Report (SAR) of the Intergovernmental Panel on Climate Change (IPCC).

The IAEA has provided the IPCC with documented information and results from its ongoing programmes on the potential role of nuclear power in alleviating the risk of global climate change. In particular, the IAEA prepared, jointly with the Nuclear Energy Agency of the Organization for Economic Co-operation and Development (OECD/NEA), sections on nuclear power of the SAR chapter dealing with energy supply mitigation options. This chapter includes a description of different options to reduce greenhouse gas emissions; a presentation of illustrative low CO_2 emission energy supply scenarios; and a discussion on measures for implementing low carbon emitting technologies and strategies. The IAEA and OECD/NEA also prepared a supporting document to the SAR, *Nuclear Power in the Context of Alleviating Greenhouse Gas Emissions*, which was published in the IAEA TECDOC series in April 1995.

This article describes the main functions of these two international bodies and reports on the IAEA's contribution to the IPCC's second Scientific Assessment Report, which is being submitted in early 1996 to the CoP/FCCC.

Global bodies related to climate change

In 1992, the UN Conference on Environment and Development (Earth Summit) in Rio dealt with the sustainability of the Earth in terms of

Mr. Van de Vate is a staff member of the IAEA Planning and Economics Studies Section in the IAEA Division of Nuclear Power. Ms. Bertel, a former staff member of the Section, is now on the staff of the Nuclear Energy Agency, Organization for Economic Co-operation and Development in Paris.

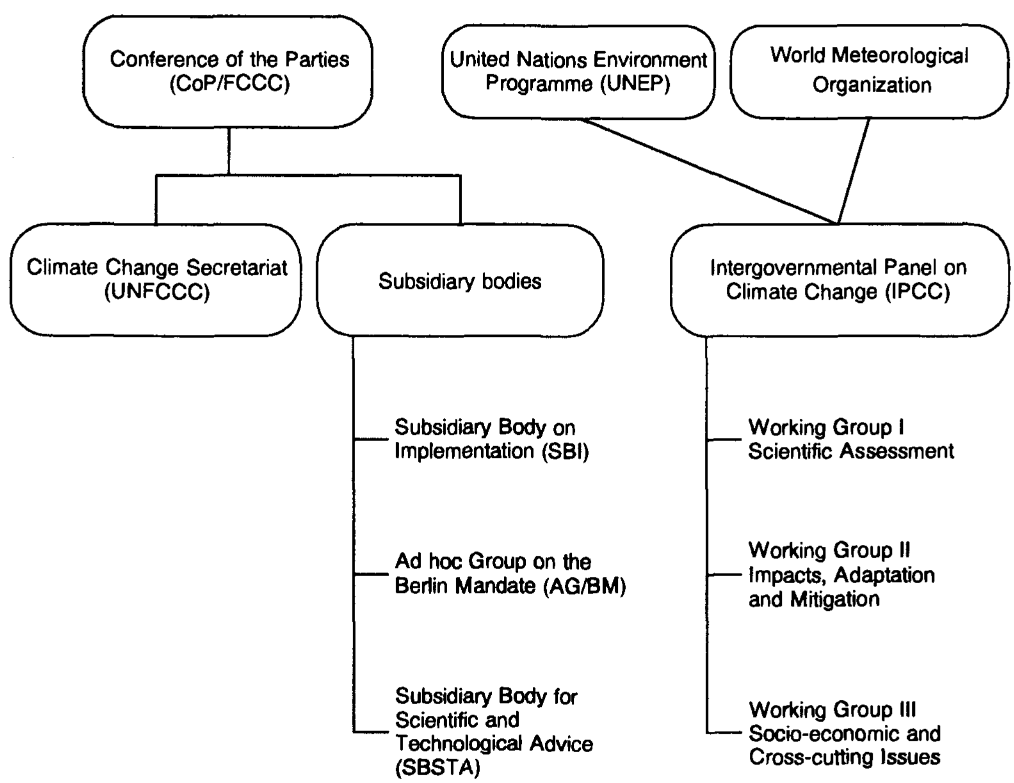
avoiding climate change, environmental pollution, and resource depletion. In Rio, the Framework Convention on Climate Change (FCCC) was signed. It entered into force in 1994 after being ratified by more than 50 countries. The FCCC's objective is to lower the atmospheric greenhouse gas concentration to non-hazardous levels. This will require draconian measures, especially by the industrialized countries where *per capita* CO_2 emissions are more than ten times those of developing countries. Industrialized countries will have to compensate for the increased CO_2 emissions that are inherent to the socio-economic development and rising populations of the developing countries. This equity consideration, laid down in the FCCC, is a frequent political discussion point in inter-governmental meetings related to climate change.

The CoP/FCCC, the supreme body of the Convention, was established by the Earth Summit in 1992 and had its first session in Berlin, in March and April 1995. It reviews the implementation of the FCCC and makes decisions necessary to promote the Convention's implementation. Several subsidiary bodies also have been established: the Convention established the Subsidiary Body for Implementation (SBI) and the Subsidiary Body for Scientific and Technological Advice (SBSTA). In Berlin, the CoP/FCCC set up the Ad hoc Group on the Berlin Mandate (AG/BM) to draft a protocol for the period beyond 2000. SBI will develop recommendations to assist the CoP in its review and assessment of the Convention's implementation. SBSTA will be the link between the scientific and technological assessments and the information provided by international bodies on the one hand, and the policy-oriented needs of the CoP on the other hand. The IAEA will be involved in activities carried out by these FCCC-related bodies.

The IPCC is an independent, scientific, and technical body with a mission to help policymakers mitigate global climate change. As part of its work, the IPCC produces Scientific Assessment Reports on climate change. Its first report was published in 1990 and updated in a supplement in 1992. The second report was endorsed in late 1995 at the IPCC meeting in Madrid, and is expected to be published in early 1996. A third assessment report is scheduled for 1998.

In a co-operative project with the OECD, the IPCC has also produced *Guidelines for National Greenhouse Gas Inventories*. They will assist gov-

Organizations related to the Framework Convention on Climate Change



ernments in reporting regularly to the CoP/FCCC about the implementation of the national measures to lower their emissions of greenhouse gases.

The Scientific Assessment Reports are drafted by experts from a broad spectrum of scientific disciplines. They are subject to review by national and international experts before being submitted for approval by plenary meetings of IPCC and its three Working Groups. Working Group I, on Scientific Assessment, deals with climatology. Working Group II, on Impacts, Adaptation and Mitigation, covers topics such as the rise of sea levels, energy, and desertification. Working Group III, on Socio-economic and Cross-cutting Issues, assesses socio-economic literature related to climate change. Working Groups I and II have evaluated CO_2 emission scenarios with time horizons up to 2100.

In contributing to these evaluations, the IAEA has emphasized the potential role of nuclear energy in the context of comprehensive comparative assessments.

The context of choices

All electricity generation options involve some environmental impacts. However, when they are fitted to state-of-the-art technologies, the options are able to deliver electricity at relatively low risks to the environment. In particular, a number of technical options exist for alleviating or mitigating greenhouse gas emissions from the power sector. Policy measures such as taxes, subsidies, and emission permits can also be used as a means to reflect the estimated full cost to society of alternative options. The challenge for decision-makers in the power sector is to design and implement timely strategies based upon energy mixes that aim towards minimizing adverse environmental, health, and social impacts at the lowest total cost for society.

The technical options that can be considered in the power sector range from efficiency improvement to CO_2 sequestration through shifting to fuels with low or no carbon content. However, at the decision-making level, technico-economic factors and barriers to implementation have to be recognized and taken into account. Energy efficiency improvements are not infinite and have a cost which tends to increase very rapidly once the straightforward savings have been achieved.

Some technological options — which might seem extremely attractive on scientific grounds — are far from having reached the stage of industrial development or even technical feasibility demonstration. Therefore, these options are not likely to make any significant contribution to reducing greenhouse gas emissions or other health and environmental burdens in the short and medium terms. For example, carbon dioxide capture and disposal in deep oceans, or energy systems based upon hydrogen as a carrier, might contribute substantially to greenhouse gas reduction in the long term. But they will by no means be industrially mature and economically competitive within the coming decades. Renewable sources, with the notable exceptions of hydropower and biomass, do not offer realistic prospects for large-scale baseload electricity generation.

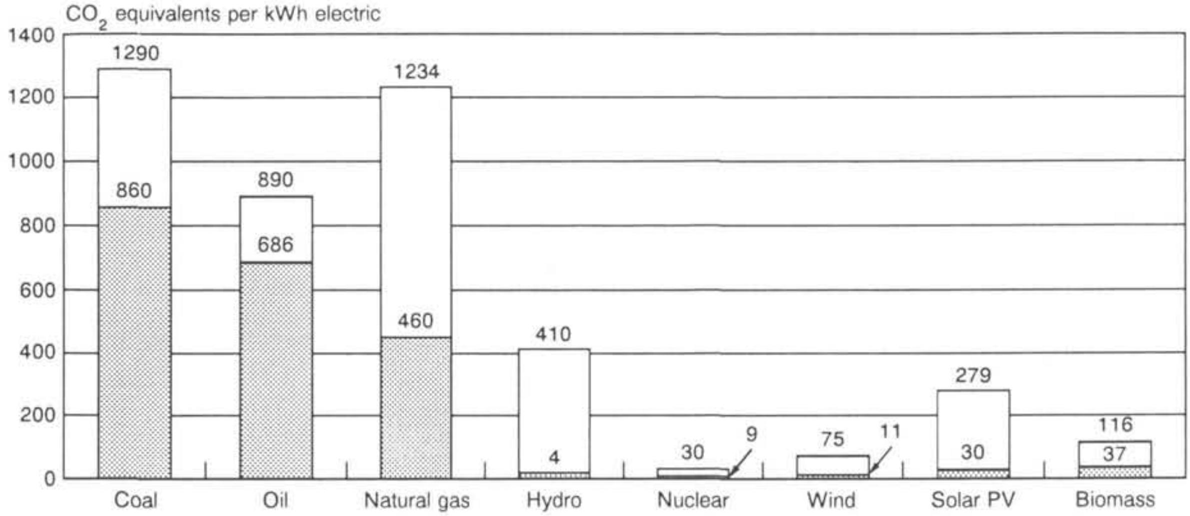
Nuclear power and electricity options

Nuclear power is a proven technology available today that can contribute significantly to reducing greenhouse gas emissions and other environmental burdens from the energy sector and to meeting environmental protection objectives. In the long term — as the executive summary of the SAR chapter on energy supply mitigation options states — "nuclear energy could replace baseload fossil fuel electricity generation in most parts of the world, if generally acceptable responses can be found to concerns about reactor safety, radioactive waste disposal, and proliferation".

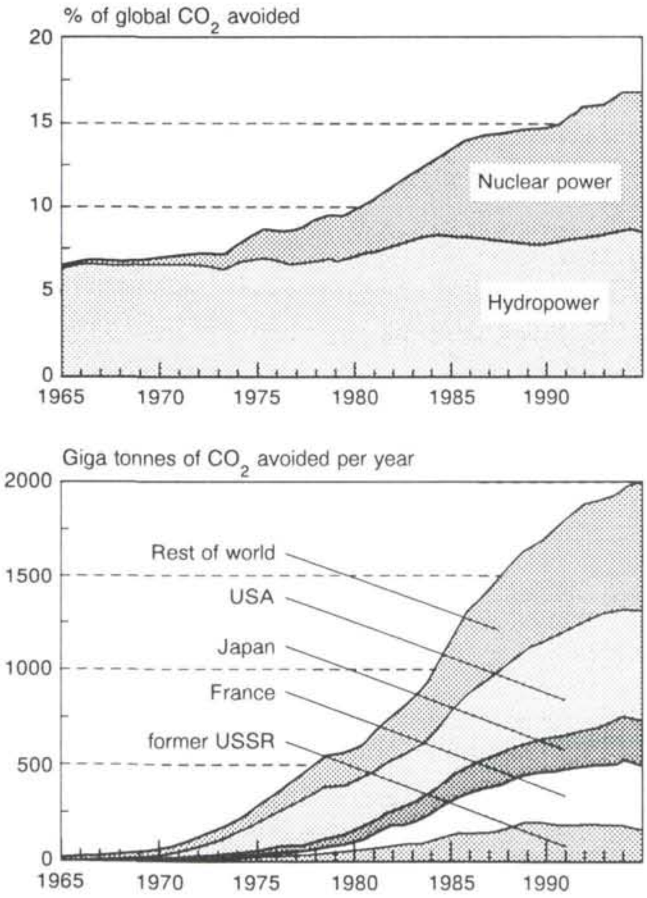
The use of nuclear energy for electricity generation dates back to the late 1950s and it has reached a stage of industrial maturity. At the end of 1994, there were 432 nuclear units connected to the grid with a total installed capacity of some 340 gigawatts-electric (GWe). In 1994, the nuclear electricity generated worldwide exceeded 2300 terawatt-hours (TWh), supplying 17% of the total electricity consumption. The accumulated operating experience of nuclear power plants is now over 7200 reactor-years and the average operating performance is improving continuously with an energy availability factor above 70% since the mid-1980s. This experience places nuclear power among the technologies that decision-makers can consider for sustainable electricity system expansion in the coming years and decades.

While environmental concerns are likely to be major driving forces in choices about electricity generation, the economic competitiveness of options will remain a cornerstone in assessing and choosing alternative sources. Although there are indications that technical breakthroughs could reduce significantly the costs of electricity generated by some renewable energy sources other than hydropower, such as solar photovoltaic and wind power, these options are unlikely to be competitive with fossil fuels or nuclear power for baseload generation before the second or third decade of the next century. In most

CO_2 Equivalent Emission Factors of Different Energy Sources (full energy chain; maximum and minimum values)



Avoidance of Global CO_2 by Nuclear and Hydropower



Trends in CO_2 Emission Rates 1965-93

	Emission rate in 1993 (Pg/y)	Annual increase (Pg/y per year)	Percentage increase (%)
European Union	3.5	0.025	0.8
OECD countries	12.1	0.15	1.4
Non-OECD Europe	5.5 (1988)	0.11 (1965-88)	2.6 (1965-88)
Less developed countries	7.7	0.21	4.4
World	24.0	0.39	2.1

Trends in CO_2 emission rates vary regionally, reflecting differences in development of nuclear power programmes since the mid-1960s. Overall, nuclear power production has increased much faster than hydropower, and their present contributions to avoidance of CO_2 are nearly equal. Comparing the emission of all greenhouse gases from all energy sources reveals low emission factors for nuclear, hydro, and wind power. The top bar graph shows maximum and minimum values as compiled from studies conducted by the IAEA and other organizations. The low CO_2- equivalent emission factor for nuclear power is an international consensus value.

Source: British Petroleum Statistical Review of World Energy, 1995.

countries, oil is not considered for baseload electricity generation owing to the volatility of market prices and concerns on security of supply. Therefore, in most countries the choices for baseload electricity generation plants to be commissioned within one or two decades will essentially be limited to fossil fuels, mainly coal and gas, nuclear power, and, where favourable sites exist, hydropower.

The relative costs of electricity generation by coal, gas, nuclear, and hydro power plants vary from country to country and are highly dependent on local conditions, discount rates, and expectations regarding the future coal and gas price trends. Coal is and will remain an economically attractive option in a number of countries having access to cheap domestic resources. As a result of the development of highly efficient combined cycle technologies, gas has become competitive for baseload electricity generation in a number of countries. However, gas-generated electricity costs are very sensitive to gas prices that might increase significantly if market demand grows rapidly. Where favourable sites exist, hydropower projects offer opportunities for low-cost electricity generation. However, the number of these sites is limited and, in many countries, social and environmental impacts of large dams are preventing the implementation of hydropower plants. Moreover, recent publications indicate that hydropower generation could be unfriendly to the climate because of emissions of greenhouse gases from the water reservoirs.

In spite of their high investment costs, nuclear power plants compete favourably with fossil-fuelled units in most countries. This is especially the case where nuclear programmes have been soundly implemented and managed and where fossil fuels are not accessible at low prices. Ongoing research and development is expected to bring further enhancement of the performance of nuclear power plants that will lead to lower costs of nuclear electricity generation. Moreover, owing to the comprehensive approach adopted for calculating nuclear electricity generation costs, the non-internalized social, health, and environmental costs are very small relative to the direct estimated costs, and they are much smaller than in the case of fossil-fuelled systems. Factoring in these costs should reinforce nuclear power's competitive margin.

Environmental Impacts. With regard to environmental impacts, nuclear power offers specific benefits. In routine operation, nuclear power plants and the fuel cycle facilities do release small quantities of radioactive materials. However, the rules developed and implemented several decades ago for limiting radioactive emissions satisfy criteria for protecting human health and are more than adequate to protect the environment. The other emissions, residuals, and burdens from nuclear power plants and fuel cycle facilities are lower than those arising from fossil-fuel electricity generation chains and comparable or lower than those from renewable energy systems. Taking into account the entire upstream and down-stream energy chains for electricity generation, nuclear power emits 40 to 100 times less carbon dioxide than currently used fossil-fuel chains. Greenhouse gas emissions from the nuclear chain are due mainly to the use of fossil fuels in the extraction, processing, and enrichment of uranium and to fuels used in the production of steel and cement for the construction of reactors and fuel cycle facilities. These emissions, which are negligible relative to those from the direct use of fossil fuels for electricity generation, can be reduced even further by energy efficiency improvements. Such improvements at the enrichment step include, for example, replacing the gaseous diffusion process by less energy-intensive processes such as centrifugation or laser isotope separation.

The role that nuclear electricity already plays in alleviating the risk of global climate change is notable. It is illustrated by the fact that if the nuclear power plants in operation worldwide would be substituted by fossil-fuelled power plants, the CO_2 emissions from the energy sector would increase by more than 8%. This level — which almost equals the avoidance of emissions by hydropower — has been achieved in a number of countries in about two decades of nuclear power development.

The analysis of statistical data in different countries over the last 20 years shows that countries which implemented large nuclear programmes, such as Belgium, France, and Sweden, achieved simultaneously significant reductions of their CO_2 emissions. In France, for example, both CO_2 and sulphur dioxide emissions were reduced by more than three between 1982 and 1992, although electricity production nearly doubled, owing to the share of nuclear power in electricity supply. In the United States, if nuclear energy would not have been used between 1973 and 1994, some additional 1750 million metric tons of CO_2 would have been released in the atmosphere. Countries and regions which do not deploy nuclear power on a large scale — for example, developing countries — had a relatively high increase rate of CO_2 emissions.

A long-term perspective

Over the long term, nuclear fuel resources and existing industrial infrastructures can support a broad deployment of nuclear power programmes in many countries. If the barriers to the implementation of nuclear power were alleviated, nuclear electricity generation could grow steadily from now on and throughout the next century. The long-term nuclear scenario developed by the IAEA in co-operation with the OECD/NEA for the IPCC illustrates this point.

This scenario was set up in the context of the global energy and electricity demand projections outlined in IPCC's SAR chapter on energy supply mitigation options. It assumes that nuclear power would be deployed widely for alleviating the risk of global climate change and would penetrate the market on grounds of its economic competitiveness. It implies that the present policy barriers to nuclear power deployment — such as moratoria on construction of new nuclear power plants and political decisions to ignore the nuclear option — will be progressively removed, and that nuclear projects in developing countries will be facilitated by enhanced technology adaptation and transfer, and financial support from development banks.

The assumptions adopted for estimating the penetration rates of nuclear power in different regions reflect the need for diversity of supply and the availability and competitiveness of alternative options. The options include oil and gas in the Middle East and, in the long term, biomass and other renewable sources. Potential uses of nuclear power for heat and hydrogen production have not been taken into account because of the uncertainties regarding the competitiveness of nuclear power for such applications.

By 2100 in this scenario, the share of nuclear power in total electricity generation would range from less than 20% in Africa, Australia and New Zealand, and the Middle East to 75% in Western Europe. The total installed nuclear capacity would grow from the present 340 GWe to some 3300 GWe in 2100 and nuclear power would provide 46% of the worldwide electricity consumption, as compared to 17% today.

The technical constraints taken into account in estimating potential nuclear capacity growth rates include construction lead times and industrial capabilities for building nuclear power plants and fuel cycle facilities. The availability of sites for nuclear installations, including radioactive waste repositories, was also considered by region, taking into account seismicity, cooling water requirements and the need to build nuclear facilities in areas with relatively low population density. The availability of natural resources for nuclear fuel would not place any major constraint on the development of nuclear power, taking into account known uranium and thorium resources and expected technological progress in fissile material utilization. This scenario would require the deployment of breeder reactors by 2025 in order to support nuclear electricity generation over the period up to 2100 with the presently known uranium resources. However, within that time frame, additional uranium resources would likely become available whenever necessary. Moreover, other types of nuclear power plants, such as thorium fuelled reactors, hybrid systems, and even fusion reactors, might be developed and commercially deployed.

The implementation of this nuclear scenario would allow reductions in carbon dioxide emissions worldwide by a factor of three as compared to the present level. A similar reduction would be feasible without nuclear power only if renewable energy sources, which have not yet reached the level of commercial development, would enter into the market early in the next century and would be deployed at very high rates throughout the next century.

Sustainable energy development

The years ahead will see increasing demand for energy, and in particular the need for additional electricity generation capacity. These challenges will be combined with the necessity to reduce the health and environmental burdens induced by the burning of fossil fuels. Taken together, they call for the development of all available energy sources and technological options that can meet environmental protection and economic efficiency goals in the short, medium, and long term.

Nuclear power is one option for reducing emissions and residuals from electricity generation and for mitigating health and environmental impacts from the energy sector. In order to make a significant contribution in the implementation of sustainable electricity supply strategies worldwide, nuclear power should reinforce its competitiveness versus fossil-fuel based systems and, in the long term, versus renewable sources. The barriers to nuclear power deployment should be alleviated by continuing demonstration that reactors and fuel cycle facilities can be operated in a reliable and safe manner and that technical solutions already existing for final disposal of all radioactive wastes can be implemented wherever needed.

Continuing progress is being achieved in terms of technical performance, safety, and competitiveness of nuclear power plants. These advances should enhance the viability of the nuclear option in an increasing number of countries. The continuation or renaissance of nuclear power programmes in all countries where it is a viable option — based upon the assessment of its economic and environmental benefits as compared to alternative energy sources — would contribute significantly to enhancing the sustainability of energy supply systems. ❐