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Cover: Public Information plays an important role in the Japanese nuclear power programme. The visitor’s center at the Hamaoka nuclear power plant contains a life-size reactor model to demonstrate how nuclear energy works.

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The OECD Nuclear Energy Agency (NEA) was established in 1957 under the name of the OEEC European Nuclear Energy Agency. It received its present designation on 20th April, 1972, when Japan became its first non-European full Member. NEA membership today consists of all European Member countries of OECD as well as Australia, Canada, Japan and the United States. The Commission of the European Communities takes part in the NEA’s work and a co-operation agreement has been concluded with the International Atomic Energy Agency.

The purpose of the NEA is to further the development of the peaceful uses of nuclear energy by sponsoring economic, technical and scientific studies and projects, and by contributing to the optimisation of safety and regulatory policies and practices.
These tankers are anchored in Prince William Sound, Alaska, waiting for shipping lanes to open, following the worst ecological disaster in U.S. history.
In the 28th January issue of New Scientist, energy analyst and writer Walter Patterson recommends to those who crave adventure, but are "bored with hang-gliding and alligator wrestling", to try energy planning. This sage advice emerges from his review of what has actually happened in the energy field over the past two decades in contrast to prevailing opinion of the early 1970s. Twenty years ago, forecasters and planners were envisioning scarcities of oil and natural gas and ever-upward prices; the fading of coal as the primary electricity source in favor of cheap, clean nuclear power; and economic growth moving in lockstep with energy demand. And, it is not clear that anyone foresaw the renaissance of "environmentalism" in the late 1980s, driven by growing public concern about prospects of a breakdown of the earth's basic life-support systems.

Thus, Patterson’s counsel to those who would try to predict what lies ahead for energy in the 1990s is: "As you reflect on the implications of the greenhouse effect versus cheap oil and gas; of coal versus acid rain; of nuclear power versus Chernobyl; and of energy efficiency versus fuel supply; cling to one consoling thought: you can always go back to wrestling alligators".

There is, however, at least one sure thing: that energy-environment issues will be high on the agenda of the scientific community and public officials in the 1990s. This is virtually guaranteed by the intrinsic importance of the issues as they impact on economic growth and quality of life, and the array of international conferences and meetings scheduled over the next three years that will be devoted to them. The latter includes: the World Energy Conference in Montreal this September; a meeting of the European Council of Ministers of Transport on Environmental Issues in November; the Second World Climate Conference in 1990; a series of regional follow-up conferences on the Report of the World Commission on Environment and Development being planned for 1990 and 1991; and a major United Nations conference on environment and development to be organized for 1992.

These events will most likely give rise to extensive media reporting and a stream of policy initiatives and programme proposals, thus serving to keep the spotlight on the energy-environment interface. They will also, to varying degrees, set the direction and pace of future energy research and development, shape public attitudes and perceptions vis-à-vis choices among potential sources of energy, and influence governmental policies concerning trade-offs between the costs of energy supply versus environmental protection.

The decades of the '90s, for example, may be marked by public support for governmental policies which would have been unthinkable just a few years ago. Who would have dared venture, even two years ago, that major world leaders would join in calling for a complete ban on chlorofluorocarbon chemicals to save the atmospheric ozone layer? Or that a plan to phase out gasoline and diesel-powered automobiles beginning in the year 2005 would be undergoing serious debate in Southern California as the region struggles with the type of growing air pollution problem that many other large metropolitan areas around the world also share.

THE CHANGING FACE OF ENVIRONMENTAL CONCERNS

It does not seem all that long ago that nations were preparing for the first of the United Nations "mega-conferences" — the 1972 UN Conference on the Human Environment in Stockholm. Industrialised nations were pressing for attention to such problems as marine pollution from oil spills, air and water contamination by manufacturing plants and electric utilities, acid mine drainage and reclamation of strip-mined lands, and the ecological impacts of large dam projects and other major construction works.

At the time of the Stockholm Conference, the developing nations were, at one level, arguing that "environment" was another subterfuge to keep them from developing, or at least that it would serve to divert them from economic progress. Concurrently however, some developing nations were expressing deep concern about certain environmental threats. These included in particular what was later to become known as the "Third World's energy crisis" — the loss of fuelwood — as well as the undesirable side effects of industrial operations, many involving energy production and use, and urban air pollution from aging fleets of automobiles, buses and trucks. Some twenty years later, virtually all of these problems persist, in both the developed and developing worlds, evidenced by the recent oil tanker spill off the coast of Alaska.

The "good news" is that important strides have been made in elevating public awareness, in expanding scientific understanding, in providing technological solutions, and, most important, in implementing successful remedial actions in many cases. Indeed, at least in the OECD region, one detects today a widespread sense of optimism that most, if not all, environmental problems can be dealt with successfully through effective mobilization of technological and
financial resources, coupled with political commitments. In other parts of the world, however, in the face of the overwhelming scope and severity of the environmental challenges, solutions still have to be found.

Over the past two decades major changes have occurred in the nature of environmental problems, and in the way they have been perceived and addressed. One of the principal trends of particular relevance to the energy sector is the expansion of pollution from a local-level problem to one which has regional and even global-scale implications. At the time of the UN Conference in Stockholm, acid rain and other regional-scale, transboundary air pollution problems were known, but hardly the subject of scientific inquiry and international diplomacy that they became during the late 1970s and early ’80s. With coal-fired power plants indicted as the principal source of the sulfur and nitrogen oxides being carried for thousands of miles across national borders, the energy sector was soon in the front lines of the battle.

In 1988 the public discovered the “greenhouse effect”. For years, the scientific community had been warning that the buildup in the atmosphere of certain gases — notably carbon dioxide — could trigger a significant increase of global mean temperature along with more substantial latitudinal variations in temperature and increased severity of seasonal weather and extreme events. What made the situation suddenly ripe for the recent surge of media reporting, expressions of public concern and political-level conferences is that the experience with ozone depletion during the same period offered evidence that humankind is indeed capable of altering inadvertently the very life-support systems on which its existence depends, and the governments of the world, if properly motivated, can together find workable and equitable solutions for the common good. Admittedly, addressing ozone depletion appears to be a much simpler matter than coping with climate change: the scientific cause-effect relationship is more straightforward, and the economic and societal costs of remedial actions are likely to be orders of magnitude less. Nevertheless, there is sufficient guidance and inspiration coming out of the ozone depletion experience to suggest to many that it does indeed provide a “model” for the application of science and public policy in the climate change arena.

A NEW CONCEPTUAL FRAMEWORK

As one considers how energy-environment relationships might evolve over the coming decade, a variety of new factors may dictate how efforts will be rationalised to meet society’s need for sufficient and affordable energy with the desire for a clean, healthy environment over the long term.

In this regard, the World Commission on Environment and Development (the “Brundtland” Commission) may prove to be especially influential. This is, in fact, rather ironic since the Commission’s Report in 1987,

There is now a clear need to discuss at the international level the world-wide implications of the build up of combustion gases from fossil fuel-fired power facilities.
"Our Common Future", was sharply criticised for its treatment of energy, especially by the energy industry.

In advancing the call for "sustainable development" as the only solution to the new environmental "problematique", the Commission emphasized that achieving such a future is predicated on continued economic growth. This has turned aside the vestiges of "no growth" or "slow growth" schools of thought, and concentrated the debate on such issues as...how much growth do we need?... how can we maintain a high quality of growth?... and what is the necessary energy component?

During the 1970s and '80s, the approach to environmental problems evolved from one of "identity and redress" to one of "anticipate and prevent". The Commission, however, by arguing for the imperative of sustainability, has asked us to extend our vision — to look into the future, decide on what type of quality of life and natural environment we want, and then design our technologies, programmes and policies to achieve and maintain that condition. In so doing the Commission has also elevated important intergenerational and equity issues for public debate. These involve the responsibility of present generations for the stewardship of the Earth's resources that will be required by the generations to follow, and the matter of how to deal with the disproportionate distribution of resources within the world of today.

This all has important implications for the energy sector. First, the World Commission has reinforced the need for economic growth, and also the importance of growth in energy as a key driving force. Even leaving aside the Commission's view that the direct linkage between economic growth and energy demand needs to be broken (as it had been in OECD countries following the oil crises of the 1970s), energy supply will have to be increased on a worldwide basis to fuel economic and social progress. A key question is, where will the additional energy come from? One of the problems of answering this is that, at the moment, none of the energy sources in itself looks to be capable of meeting all the needs. Each, including coal, oil, nuclear and even the "soft energy path", has its shortcomings, including substantial environmental costs.

Consequently, what one is looking at in terms of energy "futures" is, not surprisingly, developing the best mix of energy sources of supply which, it is to be hoped, fully integrates environmental values. The proper "mix" will clearly be determined by: technological advances, the particular economic situation and natural resource endowment of individual countries; public attitudes and perceptions; and the value assigned to protection of the environment including perceived responsibility for global ecosystems. Diversity and balance in the result can be expected to provide greatest resilience in ecological, energy security and economic terms.

**THE THIRD WORLD CONNECTION**

Energy-environment issues in the 1990s are virtually certain to require coming to grips in more imaginative ways with the conditions and needs of the developing world. The problems that developing nations face in meeting their rapidly growing energy requirements are well-documented: their special vulnerability to OPEC decisions; the disappearance of fuelwood in the face of population growth; serious air pollution due to use of low-quality fuels for residential heating; the sociological impacts of large hydroelectric power projects; and the loss of agricultural productivity as animal manure is burned for fuel rather than recycled as fertilizer.

There is also an important new dimension that is beginning to attract considerable attention in both the developing and developed world. It involves the responsibilities of the Third World with respect to global environmental problems. Let us remember that some of the largest developing countries — large in terms of both population size and economic growth potential — also possess some of the world's greatest reserves of coal, lignite and peat. Those people who are already urging rapid action by the international community to stabilize or reduce carbon dioxide emissions to counter global warming must quickly confront this fact.

Thus, the North-South dialogue on energy during the next decade may take on a new character linked to concern about global climate change. For the developed world, policies and strategies for assisting developing countries with energy supply will undoubtedly place less emphasis on coal and other fossil fuels where alternatives exist. Those Third World nations with large coal resources will clearly require, and demand, financial technical assistance and other concessions if the rest of the international community wishes them to do their part to curb carbon dioxide accumulation in the atmosphere.

Even without climate change to reshape the debate, the environmental toll exacted by current energy strategies and systems in the Third World will by itself require a rethinking of present policies and approaches. Key issues include:

- How will developing countries be able to meet their energy needs in less polluting ways?
- Can an economic framework be established to promote the development and introduction of new energy technologies in the Third World?
What mechanisms can facilitate the transfer of clearer and more efficient technology from developed to developing countries, and under what terms, if this is intended to serve also the environmental objectives of the industrialised nations?

WHERE WILL NUCLEAR GO?

Attempting today to assign a value to nuclear energy in the energy-environment equation of tomorrow is virtually an impossibility. Viewed through an environmental "prism", nuclear power looms as the siren of the sea: alluring but also quite deadly. While some observers seem to be dismayed that the spectre of climate change from carbon dioxide has given nuclear power a "second life", most people, I believe, want nuclear to succeed.

Certainly, if one assesses energy source options for fueling sustainable development, or to cut back on greenhouse gas emissions, one is quickly led to safe nuclear power as a significant part of a long-term solution. Recent reports of promising possibilities for smaller, more reliable nuclear systems appear to strike a resonant chord among even many long-time critics of the nuclear industry.

At the same time, the challenges for the industry are enormous. Former detractors who today voice a willingness to give nuclear a "second chance" couple this, however, with an admonition that the nuclear industry must first demonstrate an improved ability to maintain safe facilities, that it should manage the waste disposal problem in an environmentally sound fashion, and that strong weapons non-proliferation safeguards must be in place. No small order.

Unfortunately, at the time when the nuclear industry appeared to be gaining momentum toward a safety record that will capture public support, the Three Mile Island or Chernobyl accidents resulted in a serious loss of credibility. The pathway to success must therefore be through technological innovation, fail-safe systems and ultra-tight security and management systems that will all but rule out the possibility of major risks to human health and the environment.

Having said this, it is only fair to point out that the nuclear industry has, over the years, demonstrated a strong concern for environmental safety — this being a matter of economic survival if nothing else. The quality and extent of the environmental research and development it has carried out, and the sophistication of the safety controls it has introduced is unmatched elsewhere in the energy or other technology development sectors. Further, the insights produced through this effort with respect to, e.g., movement and behaviour of chemicals in the environment, the assessment of environmental risk, and the design of pollution control technology have advanced the state-of-the-art of environmental protection at all levels.
However, despite the commitment to environmental protection, and data to show that risk levels relative to most other environmental threats are quite small, the public well understands that the extent and longevity of the results of any nuclear accident with a significant release of radioactivity — however infinitesimal may be the chances of any single occurrence — will likely far exceed the impact of any other type of energy-related incident. Moreover, despite the considerable amount of scientific and technical work devoted to ensuring safe disposal of long-lived radioactive waste, this question, as well as plant decommissioning, does not escape the elevated concern of the public about the potential risks to future generations.

THE TASKS AHEAD

The spectre of global climate change on top of long-standing energy-related environmental threats will certainly keep the spotlight on energy policy in the decade ahead and quite dramatic changes in the way energy is supplied, transported and used may be pressed by the general public, legislatures and political leaders.

The "design for a sustainable future" advocated by the World Commission on Environment and Development is also likely to attract growing support, including from industry which is already perceiving attractive economic opportunities. This may result in the development of technologies specifically designed to achieve, for instance, highly energy efficient societies, and "clean" industrial processes that minimise the production of waste and pollutant emissions, while conserving energy and raw materials.

The debate on the role of government intervention versus non-regulatory approaches to achieving environmental objectives will undoubtedly continue. It may be, however, that governments find that the only way they can cope effectively with major environmental risks is to intervene directly and heavily. This could take the form of the outright banning of certain patterns of behaviour (e.g., driving cars into the centers of cities). Or it might establish technology-forcing targets or limits for industry (e.g., banning the production of chlorofluorocarbons; phasing out gasoline-burning motor vehicles). It could even mean reforming existing tax structures. While such radical steps were virtually unthinkable just a few years ago, these examples and others have either been accepted today or are the subject of serious study in a growing number of countries.

The climate change issue will be a particularly difficult one for individual governments and the international community as a whole to address. Unfortunately, new definitive scientific data on the extent of the global warming problem are unlikely for at least eight to ten years. Meanwhile, policy is likely to be driven by public perceptions.

In mid-1990, an Intergovernmental Panel on Climate Change, established jointly by the World Meteorological Organisation and the United Nations Environment Programme, will be finishing an eighteen-month assessment of what is known about global warming, what its impacts are likely to be, and what governments can do about it. The findings will be targeted at the World Climate Conference next year. It is quite likely that the results of this work will lead to an intensification of calls for governments to provide a "safety net" in the face of continuing scientific uncertainty. This would involve adopting policies to stretch out and lessen the societal impact of any future climate change by slowing down the emission and atmospheric buildup of greenhouse gases. One can speculate already that the strategy will emphasize the early elimination of chlorofluorocarbons — an important greenhouse gas as well as ozone depleter; the protection of forest cover, particularly in the tropics, combined with rapid acceleration of afforestation programmes; and intensified efforts to improve energy conservation and efficiency. How much the pressure may build for the establishment of international targets for the actual reduction of greenhouse gas emissions — and/or for the taxing of potential emissions from energy sources — is not clear.

Coping successfully with the environmental dimensions of energy production, transport and use in the 1990s will require more purposeful pursuit of integrated energy and environmental policies. Together they must address the sources of energy supply, the patterns of energy consumption and the associated environmental risks. Decreased energy consumption; reduced emissions of pollutants; careful choices among coal, oil and natural gas; progress on nuclear plant safety and permanent waste disposal; accelerated development and wider use of non-fossil energy technologies; and better transportation and land-use planning — all are aspects of the energy-environment challenge.

Finally, confronting this challenge in an effective, efficient and responsible manner will require substantially more attention to the economics of the various technologies, strategies and policies being advocated to cope with global climate change, transboundary air pollution and other environmental impacts of energy production, transport and use. This is an area where the OECD, including the International Energy Agency and the Nuclear Energy Agency, should be able to make important intellectual contributions.
THE ROLE OF REACTOR CONTAINMENT IN CONTROLLING SEVERE ACCIDENTS
H. J. Teague

Following the accident at Three Mile Island, a Senior Group of Experts under the NEA's Committee on the Safety of Nuclear Installations (CSNI) reviewed the subject of severe accidents and reported its conclusions to the CSNI in 1982. An expanded and updated version was published by NEA in 1986, shortly after the Chernobyl accident.

The Senior Group began by defining a severe accident as one which exceeds the design basis* to the extent that the core can no longer be cooled by normal means. Although the wide range of possibilities inherent in such accidents is daunting, the Group concluded that existing technology, including the understanding of the physical phenomena involved and the application of probabilistic safety analysis, could be applied to good effect. That was not to say that all aspects were fully understood and amenable to precise evaluation but that certain broad conclusions could be formed with some confidence.

* The "design basis" comprises basic specifications which are defined for the designer in order to ensure the capability of the plant to undergo a specified range of operational events, accidents, and external hazards within strictly limited radiological protection requirements. The design basis usually includes the specification of challenging events, important assumptions, and in some cases particular methods of analysis.

An important conclusion is that although nuclear plants are designed specifically to meet conditions foreseen in design basis accidents, it is customary to provide such substantial margins, in order to meet the design specification with adequate assurance, that the capabilities of a well-designed plant in practice extend well beyond the design basis. It is that feature which gives great scope for intervention at all stages of a hypothetical accident from its earliest initiation to its final stages. Intervention may halt the progression at any stage from initiation onwards or mitigate the effects of releases if earlier measures prove unsuccessful.

It follows that accident management, as the totality of intervention measures is called, is of supreme importance in enabling nuclear plants to survive the effects of severe accidents with minimal consequences to public safety. The Senior Group drew attention to the vital contribution that the containment system can make to accident management, as the accident at Three Mile Island showed.

ROLE OF CONTAINMENT IN SEVERE ACCIDENTS

Since 1986, the Senior Group has continued its examination of severe accidents by reviewing in greater depth and detail what benefit may be...
There are indications of a growing consensus that failure core detonation can be avoided on some existing designs. Containment atmosphere from a primary circuit overpressurisation is sometimes considered a danger of a severe accident, but sudden failure core meltdown is not considered unlikely if dry contact between core melt and concrete takes place. However, the release of fission products by this route would be relatively low compared to more direct paths. Moreover it may be practicable to use water to cool the debris and concrete. The Senior Group drew attention to that possibility as an area which has hitherto received comparatively little study.

With regard to failure to isolate the containment, its potential significance has been well-recognised and much progress has been achieved by paying detailed attention to potential small leaks. The scope for using adjoining buildings for supplementary confinement of fission products has also been appreciated.

By-pass accidents, such as steam generator tube-failures, remain a significant concern, although unacceptable consequences may be avoided by appropriate management action.

Apart from the dramatic effects of gross failures of containment, it is important not to overlook smaller but less improbable releases of activity, such as those from small leaks. Related topics include: the degree to which fission products may be trapped in cracks through which they pass; the chemical forms of iodine; re-emission of radioactivity within the containment as conditions change. A better understanding of the phenomenology of fission product transport within the plant boundary is considered to be an objective of high priority.

**ACCIDENT MANAGEMENT TOOLS**

Considering the status of current designs, what possibilities exist for accident management? Time is a dominant factor. The late failure of containment generally reduces considerably the release of fission products compared to an early failure, and the additional time allows countermeasures to be prepared and implemented.

Apart from the general significance of the time factor, more specific possibilities are highly dependent on the specific plant design. The size of containment, its degree of sub-division into compartments, the quantity and distribution of water within it, all have a strong influence on the thermal and mechanical loads which would act on the containment.

Nevertheless, the Senior Group were able to agree on a number of general goals for accident management measures in order to secure maximum benefit from the margin of strength built into the containment. Because the possibilities for managing an accident increase as it progresses farther and farther beyond
the design basis, a “symptom-oriented” approach is more appropriate than the “event-oriented” approach more common in dealing with design basis accidents. Moreover, in assessing the significance of symptoms and devising appropriate management actions, the analysis should be realistic, not pessimistic.

It is of course for national competent authorities to set quantitative goals for the reduction of risk in their respective countries. However, there appeared to be a general need both for some relationship between what is regarded as an acceptable level of release and its probability of occurrence and for the implementation of any reasonable and practicable ways of attenuating releases in severe accidents.

Plant instrumentation needs to be examined for ways to improve and possibly supplement it, thereby extending its ability to cover the range of variables which would need to be measured during a severe accident. In addition the more severe physical conditions to which instrumentation may be subjected during such an accident should be borne in mind, particularly the need to function for long periods, when maintenance might not be possible. Additional instrumentation, not required within the design basis, would be valuable for accident management, to indicate, for example, major physical variables within the containment atmosphere, valve positions and radiation levels at key locations.

To achieve maximum help in devising management actions, the operators should be provided with computer aids to assist accurate diagnosis based on information derived from the instrumentation and interpreted in relation to plant characteristics. The purpose would be to provide prompt descriptions of current plant status and a basis for analysing the past progression of the event and estimating its future development.

GENERAL PERFORMANCE GOALS FOR CONTAINMENT

In seeking to identify appropriate general guidance for management actions, the sensitivity of many aspects of severe accidents to detailed features of the wide variety of designs presents a difficult problem. The Senior Group therefore tried to specify general performance goals for containments in relation to severe accidents. The goals need to be interpreted in the light of specific plant designs. The proposed goals are:

1. Reduce the potential for pre-existing openings in the containment boundary and between wetwell and drywell for containments with pressure suppression systems.
2. Reduce the potential for early containment failure.
3. Reduce the potential for late containment failure.
4. Develop the ability to foresee long-term requirements and the flexibility to meet them.

Continuing attention to detail and increased experience through periodic containment testing have reduced the potential for pre-existing openings. Sustained vigilance is nevertheless necessary and there is a need for updated risk analysis, using more dependable data from experience accumulated during testing to improve this aspect of containment performance during severe accidents.

The possible causes of early containment failure depend strongly on both the specific design of the plant and on the accident sequence. They include general pressurisation caused by gas produced in small containments, direct containment heating, thermal attack by molten debris on steel walls or penetrations, hydrogen combustion, and penetration by large missiles generated by steam explosions within the primary vessel. Some of these are now considered very unlikely, such as the last-named. Others can be made more unlikely. For example, direct containment heating might be avoided by primary circuit depressurisation or by impeding communication between the pressure vessel cavity and the upper containment. Hydrogen detonation can be prevented by inerting small containments or by providing igniters or recombines for large ones. Thermal attack could be prevented through the use of suitable shields.

Late failures would best be avoided by using water to cool the heat-producing debris. For this purpose, the design basis containment spray system may need to be augmented by independent supplies of both water and power. Cooling would need to be maintained for long periods and it is not certain how efficient such cooling would be, particularly of molten debris.

Some countries have decided to provide controlled filtered venting as a means of preventing failure by overpressure, should attempts at cooling fail. Not surprisingly, venting has generated keen debate. However, a special meeting on the topic held in Paris in May 1988 attracted a large attendance and many high quality papers. There is a recognition that the decision whether and when to vent is likely to be finely balanced. Nothing must be allowed to detract from observance of the design rules for the entire installation nor to aggravate the accident. So far decisions have been made to install filtered venting in PWRs and BWRs in the Federal Republic of Germany, France, Sweden, and Switzerland and variants of it in some of the reactor types in the U.S.
LONG-TERM CONTROL OF ACCIDENTS

Long-term control of the accident may last many months and in addition to the problems encountered in the earlier stages, some novel problems need to be faced. For instance, as the containment cools condensation of steam could result in an underpressure, particularly if non-condensable gases have been vented, with consequent risk of failure by implosion. Similarly, loss of steam, which is an effective inhibitor of hydrogen combustion, could lead to a combustible atmosphere with the risk of a hydrogen burn.

Other long-term measures may include the addition of high boron concentrations in circulating water to avoid re-criticality and the adjustment of water pH to prevent re-evolution of iodine. High radiation fields may cause deterioration of components in the long term and maintenance problems could lead to consideration of innovative measures, such as robotics. Finally continuing provision must be made for monitoring dose levels, radiation, releases and the inventory of activity distributed throughout the plant.

In summary, there is a marked convergence of views in most OECD countries that accident management provides a practical means beyond the normal design basis for preventing excessive loads on the containment which would jeopardise its integrity. Present understanding is thought adequate for defining preliminary guidelines for corrective action, based on a state-by-state or symptom-oriented approach. In the event of a failure of initial actions, further measures to limit environmental consequences might differ from country to country depending on, among other things, whether or not filtered venting was adopted. The availability of such systems increases the range and flexibility of accident management even well in advance of the final stage where monitored venting could be implemented, since the operator would derive confidence from the knowledge that venting was available as a last resort. However it is an option to be used only when all other means have failed; priority must always be given to preserving containment integrity.

CONCLUSION

Current research activities which focus on containment technology and its relation to severe accident management are reasonably extensive and well-served by international specialist meetings, conferences and other interchanges between experts. However, a problem remains in harnessing the knowledge of the specialists and ensuring that its content and significance are fully available to and appreciated by designers and operators who are called upon to make wider-ranging decisions.

The development of the nuclear industry has provided many examples of the importance of appreciating and applying the lessons of experience in operation. This is no less true in relation to the management of severe accidents. Accordingly, in analysing unusual operating incidents, possible implications for the ability of the containment and associated equipment to perform their functions in a severe accident should be borne in mind. In analysing accident precursors these aspects should be specially addressed, and the results of analyses exchanged and widely discussed.
Nuclear power was welcomed enthusiastically in the 1950s and 1960s for its perceived and anticipated benefits. In countries like France and Canada, the economic benefits are clear for all to see. Yet in many countries their realisation has fallen well short of early expectations; so much so that some have questioned whether nuclear power has been a worthwhile investment at all.

To appreciate fully the impacts of nuclear power development, one has to look further than the simple comparison of electricity generation costs. There are wider impacts not only on the economy but also on social welfare and the environment. These have not been studied extensively, and remain largely unknown to the public.

Most attempts to examine the significance to the economy of alternative energy investments have been forward looking. Many have involved the construction of large and complex mathematical models on a global, regional or national scale. Inevitably the conclusions arising from such forward-looking models are sensitive to the input assumptions on which there is no general consensus and past studies have not survived the passage of time.

Two questions can be asked which focus attention on the impacts of nuclear power more clearly than modelling exercises have so far done. They are:

- What would the world have been like had the laws of physics precluded nuclear fission? and
- What would be the consequences of phasing out nuclear power?

The answers to both are necessarily subjective because they involve the development of hypothetical scenarios concerning events in which political decisions would have had (or will have) a major effect. Nevertheless some general ideas can be developed that set the importance of nuclear power in context.

**WHAT IF THERE HAD BEEN NO NUCLEAR POWER?**

**GENERAL EFFECTS**

Had there been no such phenomenon as nuclear fission, the world would be a very different place. Almost certainly the duration of World War II would have been extended with even greater loss of life. The succeeding “cold war” could also have developed along very different lines in the absence of mutual nuclear deterrence. World dependence on oil in the early 1970s would have been greater and the global economy would have been more vulnerable to the impacts of the 1973 and 1979 oil crises.

Additionally man’s ability to produce radioactive isotopes would have been greatly reduced, seriously hampering the study of chemical and biochemical reactions, the tracing of ground water flows and pollutant movements in the atmosphere and surface waters, and one basis for monitoring and controlling industrial processes.

Progress in many fields would have been very much slower. This would have been particularly harmful within the field of medical science where radioisotopes have helped understanding, diagnosis and treatment which, *inter alia*, would have meant that many tens of thousands of lives, if not hundreds of thousands, would have been lost prematurely.

**FUEL SAVINGS**

Nuclear power contributes about 5 per cent of total primary energy consumption each year. This saves the equivalent of 550 million tonnes of coal or 350 million tonnes of crude oil annually. Cumulatively nuclear electricity has saved around 4,400 million tonnes of coal or 2,800 million tonnes of oil. This is not large compared with total world reserves of these fuels but the world’s known reserves of low cost uranium are themselves equal to 10 billion tonnes of coal if they are used in fast reactors, sufficient in principle to meet all the world’s energy needs at current consumption rates for around 1,000 years.

**ENVIRONMENTAL EFFECTS**

Use of coal in place of nuclear power over the past 30 years would have produced additional emissions to the atmosphere of some 10,000 million tonnes of carbon dioxide and in the region of 200 million tonnes of acid gases, together with smaller quantities of heavy metals and organic combustion. These quantities, though large, are still small in relation to the quantities emitted annually and their relative importance in relation to road vehicle exhaust and to domestic and industrial use of fossil fuels is a matter of debate. The acid gas emissions contribute to the acid rain phenomenon which is associated with widespread damage to lake and river life (in Europe and North America), damage to forests and physical damage to buildings.
The world's known reserves of low-cost uranium are equal to 10 billion tonnes of coal if they are used in fast reactors. The photo shows a uranium ore processing plant in Australia.

The global costs of these effects cannot be calculated because of our inadequate understanding of causal relationships, because of the problems of measuring and valuing the damage, and because they vary considerably from locality to locality.

Efforts have been made to quantify the damage done in specific countries. In the United Kingdom, a 1972 study set the overall detriments of fossil fuel emissions, including those to health and buildings, at around £2,500 million per annum (1988 £s). Whatever the total cost, the damage caused by burning coal for electricity production would be 17 per cent higher in the United Kingdom and 30 per cent higher in Europe were it not for nuclear power.

Attention is now focussing on the production of carbon dioxide and other greenhouse gases. There is a growing consensus that the greenhouse effect is a reality, and attempts have been made to assess the consequences of the predicted global warming. The Australian Commission for the Future has put the costs at 3 to 4 per cent of the world’s gross domestic product in 30 years’ time to pay for the need to adapt to higher sea levels and lost agricultural output. The United Kingdom National Environmental Research Council has identified land areas at risk in Britain and put the costs of coastal defences at between £5,000 million and £8,000 million. In the United States the Environmental Protection Agency has calculated that 18,000 km² might be flooded despite the erection of $100,000 million of sea defences. It is still not clear that the fears over climate are real but should they prove to be so, the effects on the world economy would be enormous and on a scale never before witnessed.

Nuclear power has only contributed so far in a minor way to the reduction of carbon dioxide emissions. Nevertheless in combination with energy conservation and the use of renewable sources, it can help to reduce emissions greatly, particularly if electricity is substituted for direct fuel use and through the direct use of nuclear heat. Nuclear’s contribution can only be built up gradually, however, and will inevitably be confined mainly to the industrial nations in the medium term.

HEALTH

Fossil fuel combustion also affects health. American studies in particular have tended to assume that public illness and mortality arising from such diseases as bronchitis, emphysema and lung cancer are in direct proportion to emissions, whereas British authors have taken the view that there is a threshold level of pollution below which significant effects on human health are unlikely to occur. In consequence U.S. sources put the number of premature deaths arising from electricity production in coal-fired or
oil-fired plants at around 10 per gigawatt year per annum or higher, with non-fatal effects of around 2,000 or more per gigawatt year; much higher than those from nuclear power. Studies by the U.K. Health and Safety Executive concentrate entirely on the differential number of largely occupational deaths in mining and transport between coal and nuclear powered stations and conclude that this is around 1.6 per gigawatt year. Even on this basis, cumulative electricity production from nuclear sources would have saved some 2,000 lives worldwide from accident avoidance alone and some 100 times as many non-fatal injuries.

These savings in lives and illness take no account of nuclear accidents. However, the only accident in a civil nuclear plant leading to direct deaths was Chernobyl in 1986. 31 short-term deaths occurred among those fighting the fire, and 300 others on the site at the time of the accident suffered acute radiation sickness. The total number of people in the Soviet Union and Europe who may suffer delayed effects due to radiation released in the accident could amount to several thousands. Nevertheless this would only add 0.05 per cent to the natural cancer incidence in the European regions of the Soviet Union.

The costs of the Chernobyl accident have been put at $14,000 million, including compensation for property losses. This compares with the $2,000 million cost of the Three Mile Island accident where the radioactivity was safely contained.

FUEL PRICES

The 550 million tonnes of coal equivalent being saved per year by the use of nuclear power is large compared with the 150 million tonnes currently traded by sea in international markets. Consequently relatively small changes in demand, such as that arising during the miners' strike in the United Kingdom in 1984 have produced significant observable increases in traded fuel prices.

The use of nuclear energy was one factor which helped halt the rise in world oil prices and their subsequent sharp fall in 1986. The drop in world coal and oil prices averaged some $10 per tonne for coal and $15 per barrel for crude oil. This corresponds to a total cost reduction of $350,000 million per annum. The reasons for the reduction are complex; substitution of cheaper fuels for more expensive ones is only one factor, but it represents a sizeable cumulative benefit to the world's industrial economies.
Direct cost savings from the use of nuclear power vary from country to country. France and Canada have been particularly successful in this regard. Both have benefited from replication and co-location of reactors which yield valuable construction and operational cost savings.

Other direct economic benefits can arise. For example, nuclear power contributed 47 TWh to U.K. supply during the miners' strike there in 1984/85. Had this not existed there would have been an electricity shortfall amounting to nearly 20 per cent of supplies. Based on the values attached to shortfalls in electricity supply, the cost to the U.K. economy would have lain between £10,000 million and £110,000 million, depending on how the power cuts were implemented.

In practice a protracted power shortfall would have led customers to make compensating adjustments. Nevertheless the consequences of shortfalls would not only be immediate losses of production but also loss of confidence on the part of customers, an effect that could persist well beyond the period of the strike. A shortfall of 20 per cent in a country's electricity supply over one year could very easily cut gross domestic product by several per cent, and 1 per cent of the U.K.'s GDP is over £3,000 million. Costs measured in terms of tens of billions could not be considered an excessive estimate under such circumstances.

WEALTH-PRODUCING ACTIVITY

The development of nuclear power has led to the creation of a major world industry involving mining, fuel manufacture, plant design and construction and spent fuel management. This industry has an annual turnover of some $40,000 million and is a major employer in the developed world and those parts of the less developed world that supply uranium.

DEVELOPMENT COSTS

These benefits have not been won without the expenditure of large sums by the industrial nations on power reactor and nuclear fuel development. Nevertheless when the wider benefits described above are taken into account, there seems no doubt that the investment has been worthwhile.

THE COSTS OF ABANDONING NUCLEAR POWER

It is obvious from the preceding discussion that fossil fuels are far from benign, and authoritative studies have shown that renewable non-fuel-burning sources are not capable of matching global energy requirements.

Nevertheless some countries have taken formal decisions not to deploy nuclear power, while Sweden has decided to phase out its existing plants. The politicisation of environmental issues, and in particular nuclear power, has affected many other countries in recent years including Italy, Finland, the Federal Republic of Germany, the Netherlands and the United Kingdom.

Calls to phase out nuclear power have been accompanied by studies which show that there are considerable costs whose magnitudes would be dependant on the manner and speed with which the phase-out were to be undertaken.

NUCLEAR MORATORIA

Studies in Sweden and the United Kingdom have shown that phasing out nuclear power over a period of a few years would have a crippling effect on the economy. Alternative electricity supplies could not be introduced, and intensive use of existing non-nuclear plants would not prevent major shortfalls in electricity supply.

In Sweden these would approach 30 per cent and would be coupled with large increases in electricity prices. In both countries major industrial power users would be forced to shut down and domestic and commercial users would face a mixture of power cuts and price rationing. The effects would be immediate and so severe that they could not be seriously contemplated.

A phase-out of nuclear plants spread over a decade would allow for the construction of some replacement capacity. In Sweden it was concluded that this would still require a major reduction in electricity consumption of around 20 per cent and a doubling of electricity prices to meet the costs of necessary investment in replacement capacity. The steel, pulp and paper industries, which are major contributors to the Swedish economy, would be hard hit with possible plant closures, unless the government were prepared to provide subsidies to keep them internationally competitive.

In the United Kingdom a similar strategy would lead to supply problems in the mid-1990s. It would also require a massive expansion of the U.K. coal industry or improbably large coal imports. 45 million tonnes per annum of additional coal would be needed by the year 2000 to replace the nuclear contribution and to
compensate for the closure of worked-out mines. This compares with the 90 million tonnes that are currently produced annually in the U.K.

The costs of the phase-out strategy in the U.K. have been estimated at £500 million per annum in the short term. Additionally several thousand million pounds would be needed for the capital investment to replace the prematurely retired nuclear capacity. Total electricity prices could rise by 15-25 per cent by the year 2000. In Sweden the costs of phase-out have been estimated at some $1,000 million per year over ten years. The replacement fuel would be mainly oil which would add significantly to Sweden's import bill and also add significantly to the emission of atmospheric pollutants, a matter that is of great concern in all Scandinavian countries. The overall impact is equivalent to a drop in Swedish GDP of about 1 per cent.

Studies in the Federal Republic of Germany have suggested that a rapid phase-out of nuclear power could lead to costs in the region of $100,000 million and lead to electricity price rises of the order of 40 per cent. A moratorium that phased out existing plants at the end of their useful lives would, on the other hand, lead to cost rises of only 5-6 per cent.

In Italy, with its small nuclear share, it has been estimated that abandoning the future use of nuclear power would cost $80,000 million if the alternative were to be oil or gas, or half this amount if the alternative were to be coal.

All the studies anticipate considerable detrimental effects on employment from the abandonment of nuclear power. Increases in the numbers employed in the other fuel industries and in the construction of replacement plant would be outweighed by the negative impact energy shortfalls and higher energy prices would have on international competitiveness and domestic demand.

The direct savings involved are large and growing. They still represent a comparatively small part of the overall level of economic activity (less than 1 per cent), although this is equivalent to a much larger proportion of the discretionary income left after essential expenditures are met. These savings release resources for alternative uses: for investment, for improved social welfare; for aid to the less fortunate sections of the community or to poorer nations; or for leisure or sponsorship of the arts and science. The existence and maintenance of the nuclear option provides the means; society at large decides what use should be made of them.

The effects of abandoning nuclear power can be far greater. On a short timescale it is unthinkable because of the effects on national economies. Even with slower abandonment on a global scale, the impacts would be enormous due to the pressures on alternative fuel supplies. Recession, unemployment and international conflict could be foreseen with consequences which would dwarf the direct costs of a non-nuclear future. Those least able to protect themselves, the developing nations, would suffer most.

There is no guarantee that the availability of nuclear power will be able to avert the consequences of burning fossil fuel but without it there is little hope of maintaining and improving lifestyles while preserving the environment of the planet on which we live.

Opponents have concentrated their attacks on claimed risks to the environment and to safety. Both are matters on which it is far easier to get emotional commitment and for which the seemingly small direct financial savings from electricity production using nuclear power seem poor recompense.

This paper has sought to make clear the far greater benefits that nuclear power has brought and continues to offer for the future. Some of these have financial implications that far exceed the direct cost savings but, more importantly, several relate to the major issues of safety, social stability and environment where nuclear, far from being detrimental, has large advantages over the credible alternatives.

This is a message that the nuclear industry has so far failed to get across to the public at large. However, the tide may be turning in nuclear's favour as growing awareness of the risks of fossil fuel are beginning to be reflected in the media.
Countries operating nuclear power plants have long recognised the fact that the process of learning from experience is one of the most essential steps towards the improvement of nuclear power plant safety and reliability. It is for this reason that Members of the OECD Nuclear Energy Agency instituted, in 1980, an Incident Reporting System (IRS) whose broad objectives are the collection and dissemination of sufficiently detailed information on incidents of safety significance in nuclear power plants, as soon as practicable, and feedback of appropriate conclusions from such incidents.

Since its inception, the NEA/IRS has undergone several evolutionary changes in the areas of reporting content, format and frequency, in the domains of data classification, retrieval and utilisation, and finally in the quality of the general system and the overall enhancement of the information exchange process.

The focus in this article is on the aspect of data utilisation; hence, a description will be given of how the NEA addresses the fundamental question: "What is the most effective means of using the data accumulated through ten years of incident reporting?"

DATA UTILISATION

Use of the data accumulated through the classification and storage of the information contained in the IRS reports falls broadly into four categories:

- Single event assessment;
- Analysis of groups of events;
- Generic studies; and
- Identification of precursors or potentially serious event sequences.

Each of these areas will now be described in detail.

1. An equipment failure occurs at a nuclear plant.
2. The failure is observed in the control room.
3. A report of the incident is analysed by the NEA.
4. Feedback of the incident allows utilities to take action to prevent occurrence of the failure elsewhere.
SINGLE EVENT ASSESSMENT

This constitutes the first basic element of data use. As event reports are disseminated, recipients examine the information contained in the individual reports for applicability to any of the nuclear installations in their respective countries. Initial accounts are frequently followed by more detailed descriptions as more ample and precise information becomes available to the originator. Conversely, a recipient may wish to request from a particular coordinator (either directly or through the NEA) additional details concerning specific aspects of a certain incident; this approach has also proved to be quite viable. Single event assessment is especially valuable in the case of major events.

ANALYSIS OF GROUPS OF EVENTS

The second level of data utilisation is the identification of groups of events that represent similar failures or sequences. Examples are breaches of containment due to malfunctioning of airlock doors or incidents involving hydrogen ignition due to the formation of hydrogen pockets in portions of piping. Many such studies have been performed by participating countries, and the results disseminated (in a manner similar to individual reports). These types of analyses are very useful in addressing problems that have resulted in or could lead to common cause failures or multiple failures.

GENERIC STUDIES

Data stored in the NEA-IRS data base is scanned periodically by members, as well as by the Secretariat, to identify issues that may warrant conducting generic studies, holding specialist meetings, forming task forces, or any combination thereof. The distinction between this type of work and the previous category should be Underlined, in that the incidents analysed here may not necessarily be similar. An example of such a study, completed in 1988, is the "loss of containment functions" study; here, many dissimilar events were considered but they all formed part of the picture of "containment performance", e.g. personnel error resulted in both doors of an airlock being open thus causing a breach of containment; elsewhere, some containment isolation valves failed during a routine test. Both of these incidents constitute containment problems which would form part of the generic study on "containment performance". However, each type of event may have recurred several times and may have been studied under the "Groups of events" category.

The NEA has co-ordinated several other activities which can be grouped under the general umbrella of "Generic Studies". One domain of particular significance is that of the human factor. Aspects in this field include specialist meetings (e.g. Training of Reactor Personnel, Orlando, 1986), questionnaires (e.g. Handling Events involving Human Errors) and task forces (e.g. Task Force on Misinterpretation by Operators of Control Room Indications).

PRECURSOR IDENTIFICATION

Perhaps one of the most important goals of learning from experience is to be able to identify potentially serious failure modes or event sequences such that preventive measures can be taken before such occurrences should materialise. In an attempt to achieve this objective, staff of the Canadian Atomic Energy Control Board developed a computer programme "SECT" (for Significant Event Compilation Tree) whose purpose is to link seemingly unrelated events, or parts of events, that could have occurred at different points in time and/or at various nuclear power plants. Such a software tool generates a large "experience" tree which aids the user in identifying potential paths or scenarios that:

☐ May not have been foreseen in the accident analysis (hence this application includes fault tree verifications);
☐ Could lead to a certain failure; or
☐ Could have been caused by a certain initiating event (which may have ended or been terminated at an earlier stage).

These applications may also be used to:
☐ Show that operating experience confirms analysts' predictions; or
☐ Identify cross links that were not considered by the designer and/or analyst.

The basic idea of SECT can be illustrated using the following event sequences. The first two are independent of each other, except that each sequence contains the event A. They could have occurred at a different time and at different plants. The third sequence is a potential result of linking the first two using the SECT method.

Sequence 1: A coded sequence of events which actually occurred, in which event A is caused by initiating event X.

\[ X \rightarrow A \rightarrow B \rightarrow C \rightarrow E \rightarrow D \]
Sequence 2: A second coded sequence of events which actually occurred and which included the same event A that took place in Sequence 1, although in this case, event A was caused by initiating events J and G.

Postulated Event Sequence as a result of linking Sequences 1 and 2.

This SECT linking thus shows that the combination of initiating events J and G could produce not only the result H, observed in the actual event sequence 2, but could also hypothetically produce the result E. At the same time, initiating event X could hypothetically produce the result H. Thus results of operating events can be identified which might not have been considered through the study of just one sequence of events.

A group of experts, co-ordinated by NEA, is exploring the viability of using SECT in conjunction with the IRS.

CONCLUSION

An adequate level of safety and reliability in generating nuclear electricity largely depends on mechanisms to ensure the feedback of operational experience. This essential process starts by documenting and reporting failures and by the willingness of utilities and regulatory bodies to co-operate and exchange information on an international scale. Furthermore, every possible avenue which could contribute to the learning curve must be pursued. Analyses of single events and groups of events have been shown to be feasible and rewarding; generic studies constitute an equally necessary process. Finally, identifying potentially serious failure paths or event sequences is essential in developing preventive approaches to problems, as opposed to developing corrective measures.
Emergency planning and preparedness is considered a necessary part of the support for any nuclear installation to protect the staff, the public and the environment in case of an accident leading to releases of radioactive substances. However, the primary contribution to this protection should come from the installation itself through good design, quality in construction, competence of staff in operation and maintenance and proper site selection. These reduce both the probability of an accident and the potential magnitude of its consequences. Despite these measures, the occurrence of accidents cannot be entirely excluded and emergency planning is therefore to be regarded as a secondary level of protection needed to mitigate the consequences should an accident occur.

The accident at Three Mile Island in 1979 was a milestone for studies and actions in the area of nuclear safety and emergency planning. Increased attention was paid to developing strategies and methods for preventing severe accidents and mitigating their consequences. Subsequently, many actions of paramount importance to the protection of the population have been taken, for example by giving the operators extended possibilities to manage an emergency situation (training, new procedures, additional safety systems).

Many improvements have also been made concerning off-site arrangements as a consequence of the TMI accident, in order to facilitate the protection of the population near nuclear sites. This accident certainly emphasized the fact that emergency preparedness must be ensured at all times, by having valid emergency plans, exercised periodically, and an emergency organisation where coordination of interventions and responsibilities are clearly defined. Most of these post-TMI actions focussed on the areas close to the plants — the emergency planning zones — and less consideration was given to aspects related to transboundary releases.

Then came the Chernobyl accident in 1986, the second milestone in the area of emergency planning. Showing that a severe nuclear accident can influence areas far beyond the emergency planning zones, the Chernobyl accident stressed the importance of national and even international coordination of emergency response activities. There is no doubt that the Chernobyl accident, its development and the ways in which its consequences were managed have offered a number of lessons to be learned. Further
improvements of public protection measures will largely depend on an in-depth reflection on these lessons, a process which is being actively pursued by national authorities and international organisations.

**REVIEW OF NATIONAL EMERGENCY PLANS**

To contribute to this process, the NEA conducted, in 1987-1988, a critical review of national emergency planning practices and criteria. The review, which concerned the off-site part of emergency planning only, showed that the Chernobyl accident had a strong influence on national practices, particularly in those countries which were most heavily affected by the fall-out of radioactive substances released from the damaged reactor.

Nuclear emergency arrangements in the past have been largely focussed on the so-called near-field aspects, i.e., on the site itself and areas close to it. As a consequence of the Chernobyl accident, however, the scope for nuclear emergency planning is being extended to cover more extensively the far-field or aspects related to large-scale contamination by either a domestic or a foreign nuclear installation. Therefore, it is particularly important in this respect:

- To update and upgrade the organisational structure for emergency planning and preparedness in order to better handle large-scale impacts. Some countries are considering the nomination of a “lead” organisation to set priorities among and to coordinate the first actions taken by the authorities at various levels concerning monitoring, assessment and information activities, as well as to support the emergency services provided at a local level.

- To further develop the regulatory framework for managing a radiological emergency, and to adopt strategies for implementing intervention criteria for protective actions on a large scale, such as the control of contaminated food. The importance of the establishment of intervention levels agreed upon internationally has been demonstrated by the impact of the Chernobyl accident. Apart from intervention levels for food, guidance concerning international travel and transport and the protection of occupationally exposed groups are also being developed and introduced in the emergency response plans.

- To expand the surveillance, monitoring and assessment capabilities.

In order not to be taken by complete surprise by the arrival of a radioactive cloud from an unknown source, arrangements have been made nationally and internationally to alert national authorities in case of a nuclear accident. Firstly, the Emergency Response System of the IAEA has been put into operation to rapidly notify responsible national authorities about nuclear accidents having potential transboundary consequences. Secondly, most countries have upgraded existing or established new national early warning systems intended to alert national authorities when and where a radioactive cloud may enter the country.
The early warning systems include a network of continuously operating radiation monitors capable of detecting any increase of environmental radioactivity at the particular places, often at meteorological stations, where they are located. The maps show the geographical distribution of the stations of the networks in the United Kingdom and in Sweden. In case of an accidental release of radioactivity, the network should register the levels of radioactivity, warn the national emergency centre and give an initial rough estimation of the radiological situation in the country. Precipitation, temperature, wind speed and direction are other important parameters measured at the stations and transferred to the emergency centre.

In addition to this, the capabilities for large-scale mobile monitoring as well as for consequence assessment are being extended. For example, aerial survey systems for the mapping of deposited radioactivity proved useful during the Chernobyl response and will therefore become part of the emergency equipment in many countries.

To improve the strategies and methods for informing the public about nuclear incidents and accidents. Communication with the public, the media and organisations with a special role in a radiological emergency, was identified by most countries as an area where improvements of accident management systems are necessary. In case of a situation similar to the impact of Chernobyl, the need for information will be enormous and preplanned resources, both centrally and locally, are needed to cope with the situation. Some Member countries are considering, for instance, computerised data banks, electronic mail and data transmission systems in their on-going review of the whole complex of questions related to this subject.

Furthermore, the countermeasures adopted by public health authorities during the Chernobyl accident raised difficulties in terms of public understanding and acceptance due, in part, to the perception of discrepancies in national, regional or local response to the accident, but also to a more basic lack of comprehension of the complex radiation protection considerations involved. Therefore, work is going on nationally and internationally to analyse appropriate methods and language to be used when explaining to the public scientific concepts underlying radiation risks and radiation protection, and the technical rationale for the choice of protective actions in an emergency.

The Chernobyl experience also showed the need to disseminate information to the public centrally as well as locally; i.e., there seems to be a tendency, at least in some countries, to decentralise part of the information services to local authorities. The handful of national authorities assigned to this task would be unable to handle all questions from the public. For example, one country reports that the national radiation protection authority registered 30,000 telephone calls during one day at the time of the Chernobyl accident.
APPROACH TO EMERGENCY PLANNING

The NEA review also showed that national emergency planning is based to a large extent on guidance and recommendations developed internationally and the plans appear rather homogeneous. There exist areas, however, where differences in national practices are obvious and progress remains to be made, nationally and internationally, towards diminishing these diverging national practices. One such area concerns basic assumptions used for off-site emergency planning. For example, in some countries, the level of release of radioactive substances for which a plan is needed is not specified; instead a general planning basis is used for all nuclear power plants. Other countries, however, are using reference "source terms" for the purpose of determining the resources needed for emergencies. Partly due to this diverging policy, the extent of detailed planning around the nuclear power plant varies from country to country. In some countries evacuation is planned in detail up to a distance of 5 km, in others up to 20 km. This difference does not mean, however, that evacuation cannot be carried out beyond the detailed planning zones, only that the time needed to do so will be longer.

An attempt was made in the NEA review to identify the rationale for the national approaches in the area of off-site emergency planning, and to demonstrate, if possible, that some of the differences in practices may be more apparent than real and that the practices may have a consistent technical aim leading to a uniformly high level of protection of the population. In some cases this was possible, and in others, difficult. The various national approaches are not always very transparent and it seems quite clear that socio-economic and political considerations are behind many of the decisions in the field of nuclear emergency planning, complicating the ability to make direct comparisons of practices in different countries. However, efforts are being made to overcome this and to assist Member countries in reaching better mutual understanding of the criteria and rationale which lie behind the emergency planning approaches. One such effort is made by the NEA in organising a meeting in June 1989 to discuss recent developments in nuclear emergency planning and the rationale for their adoption.

CONCLUSION

Past experiences from nuclear accidents have clearly shown the importance of being prepared to handle different types of emergency situations, from simply informing the public and the media about a possible release, to applying countermeasures on a nationwide basis. The NEA survey showed that most Member countries rapidly analyse the experience received from these accidents and adjust their practices in order to be well prepared for possible future events. It showed as well that international cooperation and assistance in this field are essential to ensure similar levels of protection of the population in case of a nuclear accident.
The fact that there is currently a marked degree of stagnation in the development of nuclear energy programmes tends to obscure the overall technical and safety performance of the nuclear industry which, given its accumulated operational experience of over 4,000 reactor-years, has been rather impressive by any measures, compared to other industries, such as chemical or mining. There are well over 500 nuclear units, worldwide, whether in commercial operation, under construction or planned, with a combined capacity of approximately 430,000 MWe. A large fraction of these units (about 70 per cent) is already in operation, and their performance records have been indeed remarkable with the unfortunate exception of TMI-2 and Chernobyl-4.

Electric utilities have provided an essential backbone in bringing the nuclear industry to its present state of technical advancement. While in the beginning they were faced with an evolving new technology which presented many stumbling blocks, their commitment to the achievement of good performance has been rewarded in the long run. Their experience and that of other parts of the nuclear industry in all the aspects of planning, construction, operation and maintenance of nuclear power plants and the fuel cycle today offers precious information which deserves to be widely shared.

This is one of the primary objectives of the International Symposium on Achievement of Good Performance in Nuclear Projects, which the Nuclear Energy Agency, jointly with the Atomic Energy commission of Japan (AEC), organised from 17th to 20th April, 1989 in Tokyo in cooperation with the International Atomic Energy Agency. Logistic and technical support was provided by the Japan Atomic Industrial Forum, the Atomic Energy Society of Japan, the American Nuclear Society and the European Nuclear Society.

This Symposium, the main theme of which was "Nuclear Power — Onwards to Even Higher Standards of Good Performance", provided a particularly valuable international forum for people from various sectors of the nuclear industry to present and exchange information on their experience of good performance, with a view to helping all participants in the nuclear industry to raise their operating standards even higher.

The participants reviewed the results achieved to date and current issues facing the nuclear industry, on a regional (selected major nuclear countries) as well as on a global (OECD and the world) basis. While the circumstances may differ from one country to another, the general consensus was that much had been achieved over a relatively short period of time, particularly when compared to other industrial sectors, but that the nuclear industry must strive further to improve the public acceptance of nuclear power, continue to improve the technologies for better safety, economics and reliability and contribute to the creation of a regulatory environment in which high standards encourage investment and the pursuit of excellence.

A cautious optimism emerged from the presentations in the closing session, in which future perspectives for nuclear power were assessed in terms of realities and promises: nuclear power is likely to remain viable for the foreseeable future and contribute to the world's energy needs, but the nuclear industry will have to earn the public trust every inch of the way by maintaining high standards in performance.

The proceedings of the Symposium will be published by the Nuclear Energy Agency later this year.

MR. GEOFFREY STEVENS IS HEAD OF THE NEA NUCLEAR DEVELOPMENT DIVISION.

The nuclear industry will have to earn the public's trust by maintaining high standards in performance.
1988 SITUATION

During 1988, nuclear electricity generation in OECD countries rose by 8.9 per cent from 1313.9 TWh to 1430.2 TWh. Nuclear power provided 23.5 per cent of electricity generated in the OECD area. The number of nuclear power plants connected to the grid in Member countries rose to 320 from 312 at the end of 1987. The total installed nuclear power capacity also increased by around 3.6 per cent to 247.1 GWe.

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(a) Secretariat estimates.

STATUS OF NUCLEAR POWER PLANTS
(as of 31st December 1988)

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(a) Gross data converted to net by the Secretariat.
EDITOR’S NOTE: NUCLEAR TRADE AND NON-PROLIFERATION POLICIES
A HISTORICAL OVERVIEW

The autumn 1988 edition of the Newsletter (Volume 6, No. 2) contained an article entitled “Nuclear Trade and Non-Proliferation Policies: a Historical Overview”, which summarised chapter one of a new study published by the OECD Nuclear Energy Agency under the title “The Regulation of Nuclear Trade: Non-proliferation, Supply, Safety”.

In this article, as well as in Chapter one of this Study, it was stated incorrectly that “... Following the entry into force of the NPT in 1970, the IAEA organised a group of NPT signatories known as the “Zangger Committee” (after its Chairman) to interpret the safeguards clause of the Treaty and agree on common rules for its application”.

It should have been made clear that the Committee met at the suggestion of certain Member States of the IAEA, not at the suggestion of the IAEA Secretariat. The Secretariat of the IAEA did not organise the Committee and has not been associated with its work, but has published from time to time statements of policy at the request of the Member States comprising the Committee.

Chapter five of the Study referred to above deals in greater detail, and correctly, with the work of the “Zangger Committee”.

THE REGULATION OF
NUCLEAR TRADE

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INTERMEDIATE ASPECTS

NUCLEAR ENERGY AGENCY
PARIS 1988
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The impact of the 1986 Chernobyl accident called attention to the need to improve international harmonisation of the principles and criteria for the protection of the public in the event of a nuclear accident. This report provides observations and guidance related to the harmonisation of radiological protection criteria, and is intended to be of use to national authorities and international organisations examining the issue of emergency response planning and intervention levels.

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Following the Chernobyl accident, efforts were made by most countries to better adapt their emergency planning practices and criteria to large-scale accidents having transfrontier consequences. A critical review of the resulting changes, carried out by the NEA, shows the importance that is attached to being prepared to handle different types of accident consequences from informing the media and the public about a possible release of radioactive material up to applying countermeasures on a nation-wide basis.

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(Proceedings of an ad hoc Meeting on The Application of Optimisation of Protection in Regulation and Operational Practices)

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A main requirement in the current ICRP system of radiation dose limitation is that all exposures be kept as low as is reasonably achievable (ALARA), taking social and economic factors into account. This is referred to as optimisation of radiation protection. The NEA arranged for a review of the status of achievements in applying this requirement to various fields of nuclear reactor operations and long-term management of radioactive waste. The review shows that there are areas where the level of protection achieved still offers large scope for optimisation.

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In-situ research and investigations are an integral and essential part of national and international programmes for evaluating geological repositories for radioactive waste. A current topic concerns the potential effects that may be induced in the surrounding geological medium by the construction and development of such a repository. These proceedings present the results of a workshop organised by the NEA and Atomic Energy of Canada Limited (AECL) to review the status of in-situ research on excavation responses, and to evaluate their influence on the safety performance of a geological repository and on the design of engineered barriers that contribute to the isolation of the waste.

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