NEA News

2001 – No. 19.1

Issue on sustainable development:

Sustainable energy for future generations

Energy and sustainable development: issues and options

Energy system sustainability worldwide

Nuclear energy economics in a sustainable development perspective

Radioactive waste management and sustainable development

Measuring the sustainability of energy systems

Sustainable development and nuclear liability

AEN NEA

NUCLEAR • ENERGY • AGENCY

NEA News

2001 – No. 19.1

contents

Sustainable development

NEA News is published twice yearly in English and French by the OECD Nuclear Energy Agency. The opinions expressed herein are those of the contributors alone and do not necessarily reflect the views of the Organisation or of its Member countries. The material in *NEA News* may be freely used provided the source is acknowledged.

All correspondence should be addressed to:

The Editor
NEA News
OECD Nuclear Energy Agency
12, boulevard des Îles
92130 Issy-les-Moulineaux
France
Tel.: +33 (0) 1 45 24 10 10
Fax: +33 (0) 1 45 24 11 10

The OECD Nuclear Energy Agency (NEA) was established in 1958 as the OEEC European Nuclear Energy Agency and took its present designation in 1972 when its membership was extended to non-European countries. Its purpose is to further international co-operation related to the safety, environmental, economic, legal and scientific aspects of nuclear energy. It currently consists of 27 Member countries: Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States. The European Commission takes part in the NEA's work and a co-operation agreement is in force with the International Atomic Energy Agency.

For more information about the NEA, see:

www.nea.fr

Editorial board:
Jacques de la Ferté
Cynthia Picot

Co-ordination/photo research:
Solange Quarmeau
Annette Meunier

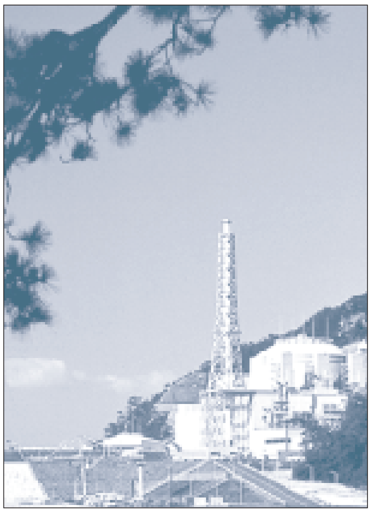
Design/layout/graphics:
Annette Meunier
Andrée Pham Van

Cover page: The Monju nuclear power plant, Japan (credit: PNC); radioactivity measurements near the Saint-Laurent-des-Eaux NPP, France (credit: EDF); main control room of the Ulchin NPP, Korea (credit: KEPCO); a TRUPACT-II transportation system near Carlsbad, New Mexico, United States (credit: USDOE); children sporting Sellafield paraphenalia, United Kingdom (credit: BNF plc).

4 Sustainable energy for future generations

8 Energy and sustainable development: issues and options

12 Energy system sustainability worldwide



14 Nuclear energy economics in a sustainable development perspective

18 Radioactive waste management and sustainable development

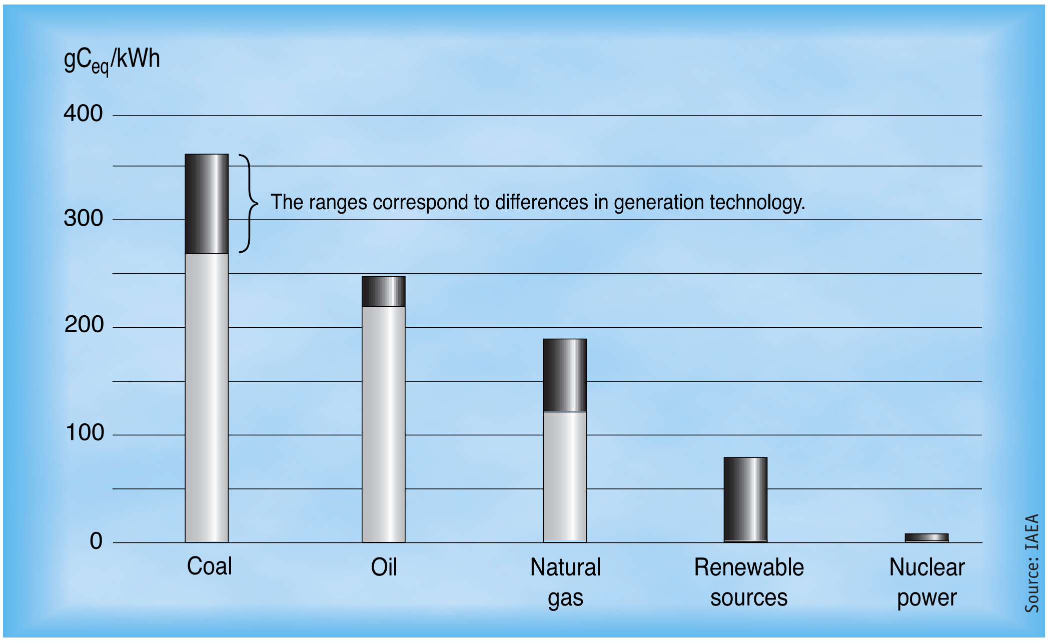
21 Measuring the sustainability of energy systems

25 Sustainable development and nuclear liability

27 New publications

editorial

Greenhouse gas emissions from electricity generation by different sources



Sustainable development

This issue of NEA News *has been prepared in conjunction with the OECD Forum 2001 on "Sustainable development and the new economy". OECD Forum 2001 is an international public conference which brings together Ministers, heads of international organisations, and participants from business, labour, non-governmental organisations and civil society at large. A series of round tables on sustainable development is being organised at the Forum and will provide input to the special session on sustainable development, to take place at the OECD Ministerial being held on the day after the Forum.*

Readers will find in the following pages a range of individual contributions on the subject of nuclear energy and sustainable development, covering its economic, social and environmental aspects. They outline the role that nuclear energy may be able to play in helping to promote sustainable development in OECD Member countries and beyond. This role arises from two of nuclear energy's most important assets: namely, that it produces negligible amounts of greenhouse gas emissions and provides a stable supply of baseload electricity which is not vulnerable to volatility in fuel prices. We hope that the articles in this issue of NEA News *make a positive contribution to informed debate on the potential role of nuclear power in sustainable development.*

Luis E. Echávarri
NEA Director-General

D. Johnston*

Sustainable energy for future generations

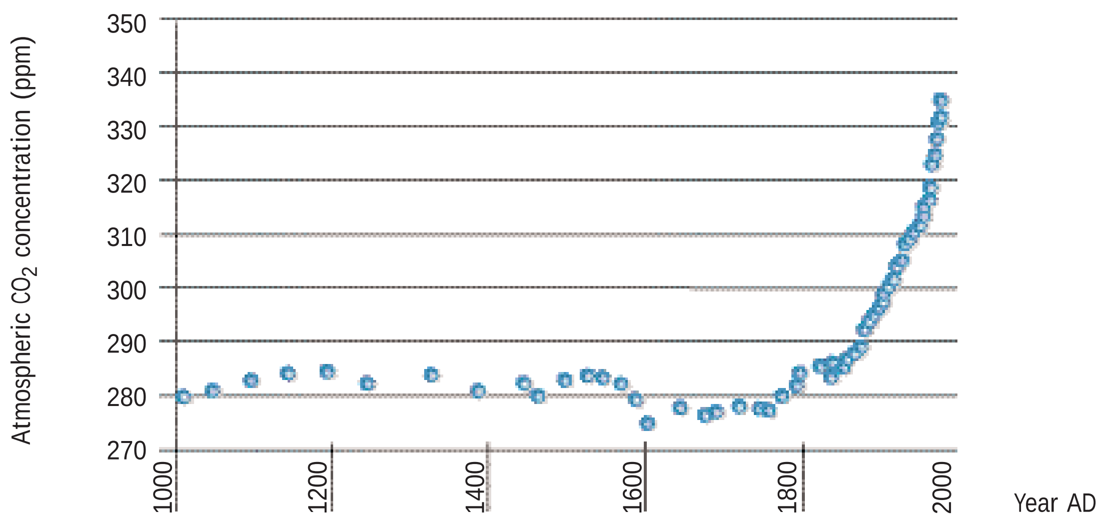
Energy is a key to the future of the planet. Greenhouse gas emissions and global warming, combined with a growing population, are putting us on a fast track to frightening consequences. If we want sustainable development, we must solve our future energy needs without burning up the environment. Indeed, according to Burton Richter, a Nobel Prize-winning physicist, *"It is our responsibility, both on ethical grounds and on grounds of self-interest, to develop technologies that will allow the rest of the world to increase their standard of living without at the same time destroying the environment of the planet."* For the moment, there is no serious discussion on how we are going to do this.

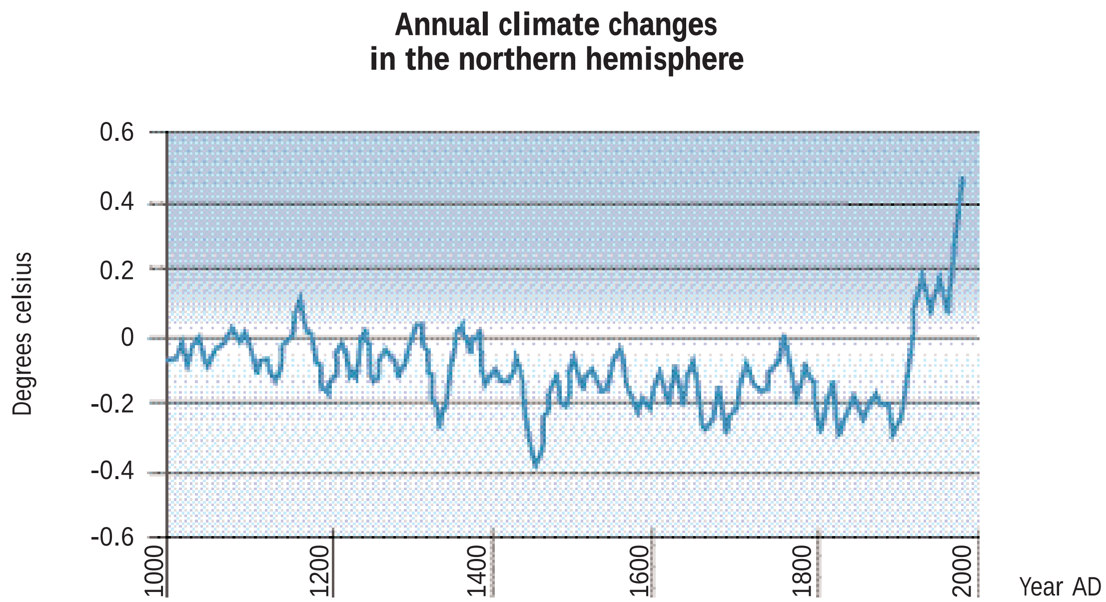
In the 1987 Report of the World Commission on Environment and Development (the Brundtland Report) entitled "Our Common Future", sustainable development was defined as "...development that meets the needs of the present without compromising the ability of future generations to meet their own needs".

This definition is as suitable as any because, taken in its broader sense, it combines environmental, social and economic considerations.

** The Honourable Donald J. Johnston is Secretary-General of the OECD. This article is adapted from a column published by the author in the* Globe and Mail *(Canada). It represents a personal opinion and not an official position of the Organisation.*

Average atmospheric carbon dioxide concentrations over the last millenium





"At a minimum," states the report, "...sustainable development must not endanger the natural systems that support life on earth: the atmosphere, the waters, the soils and the living beings". The erosion of any of these elements, and certainly the absence of any of these elements, make any consideration of the social and economic objectives of sustainable development irrelevant.

Yet the world finds itself on an unsustainable energy path that threatens to lead to catastrophe. One of the most important sets of indicators showing the dangerous direction in which we are headed is that pertaining to the concentration of greenhouse gases in the atmosphere, and the contribution that human activities are making to those concentrations.

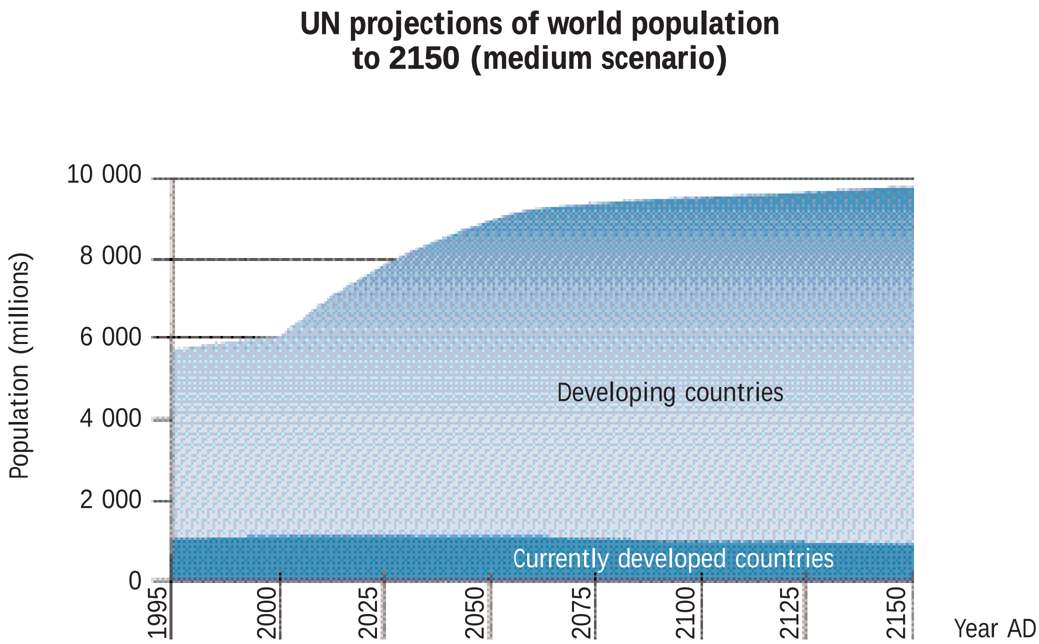
The gases that contribute to the greenhouse effect include carbon dioxide (CO_2) and a large number of other, often more complex and less common gases. CO_2 is not the most powerful of the greenhouse gases, but it is the most abundant – accounting for the bulk of the human-induced warming effects. And because of its pathways through nature, it is the gas for which historical concentrations are the easiest to reconstruct.

Emissions of carbon dioxide from the burning of fossil fuels increased seven-fold during the 20th century. Since 1900, temperatures have risen steeply, and the rate of increase has accelerated over the past 25 years. Current average temperatures are believed to be close to 0.8° C above normal. In the Antarctic, average temperatures have risen by 2.5° C over the past 25 years. The Intergovernmental Panel on Climate Change believes that global temperatures could rise by as much as 6.1° C over this century.

We are engaged in a perilous experiment with nature that is unprecedented in the history of humankind. Global warming means damage to ecosystems and biodiversity. Rising sea levels will render uninhabitable the world's low-lying seacoasts. Tropical diseases will spread. If current trends continue, this could begin within the lifetime of our children.

Can we do something to turn around the situation? Yes, of course we – that is, the developed, industrialised countries of the world – can. Our populations have stabilised, and we are probably rich enough and smart enough to develop clean, safe energy technologies that can deliver our current level of material welfare while cutting emissions – if we rise to the challenge. But there is a major obstacle to success: poverty and population growth in the rest of the world. According to the United Nations' latest projections, global population will increase by 50 per cent between now and 2150. Virtually all of that growth will occur outside the OECD area.

Globalisation is paving the way for the emergence of a worldwide middle income class of 4 to 5 billion people, with the same aspirations for comfortable homes, a range of choice in foods



and consumer products, and opportunities for education and travel that form the accoutrements of our modern civilisation. But these all depend on one vital input: energy.

If the rest of the world were to have the current standard of living of the OECD area, energy production would have to increase by a factor of 30. No one expects such a jump to happen suddenly, but even if increased demand for energy happens gradually, how is it to be met?

Let us look at fossil fuels – the fuels largely responsible for anthropogenic emissions of greenhouse gases. Many experts expect that production of petroleum-based oils will peak some time before mid-century and start to decline thereafter. Coal, which will remain abundant, can easily fill the gap. For geological reasons, natural gas is more abundant than oil and its use can be expected to increase in absolute terms and then stabilise. Under this "business-as-usual" scenario, the International Institute for Applied Systems Analysis (IIASA) predicts that the use of fossil fuels will double over the next century.

Given the strong links between fossil-fuel combustion and growth in atmospheric CO_2 concentrations that we have seen already, can we actually envisage continuing to burn fossil fuels at current or expanding levels over the next century? The consequences for global warming and climate change would be intolerable.

What about clean renewable sources of energy like solar or wind or harnessing the ocean currents? There is certainly room to further develop wind power and solar panels, and perhaps ocean currents and tidal power, but as contributors to basic energy needs they are likely to remain largely insufficient. If we are to hand on to future generations a planet that will meet their needs as we have met ours, it can only be done by incorporating the nuclear energy option. Nuclear power can be abundant, even unlimited; it produces no greenhouse gases of any consequence.

In the mid-1950s, at the time of President Eisenhower's "Atoms for Peace" initiative, nuclear energy was seen as a godsend for both the developed and the developing world. Fossil fuels were understood to have a finite life, which of course they still do, although it has been modestly extended beyond estimates of that day. But fossil fuels were not seen at the time as harbouring the potential for irreversible damage to the biosphere which we now believe to be the case.

Today, the atmosphere is being choked by greenhouse gas emissions, global temperatures are rising dramatically, and the global population has more than doubled since 1955, most living in poverty in the developing world. Yet we seem to be denying ourselves the nuclear option which was seen over four decades ago as the way forward!

What happened to change public, and hence political, attitudes towards nuclear energy? Of course, the accidents at Three Mile Island a little over 21 years ago, and more recently Chernobyl, have had a major negative impact on the evolution of the nuclear industry. The tendency of the nuclear industry to secrecy, probably inherited from national defense orientations of nuclear research, made things worse. No new nuclear facilities are currently planned within the OECD countries except in Japan and Korea. In fact others, following Germany's lead, may opt to phase it out.

There is concern about the health risks associated with nuclear energy, both in terms of functioning nuclear power plants and in relation to radioactive waste. As for the latter, the OECD Nuclear Energy Agency, in a collective opinion developed by its Member countries, confirmed that the disposal of long-lived radioactive waste in deep geologic formations can be designed and implemented in a manner that is sensitive and responsive to fundamental ethical and environmental considerations.

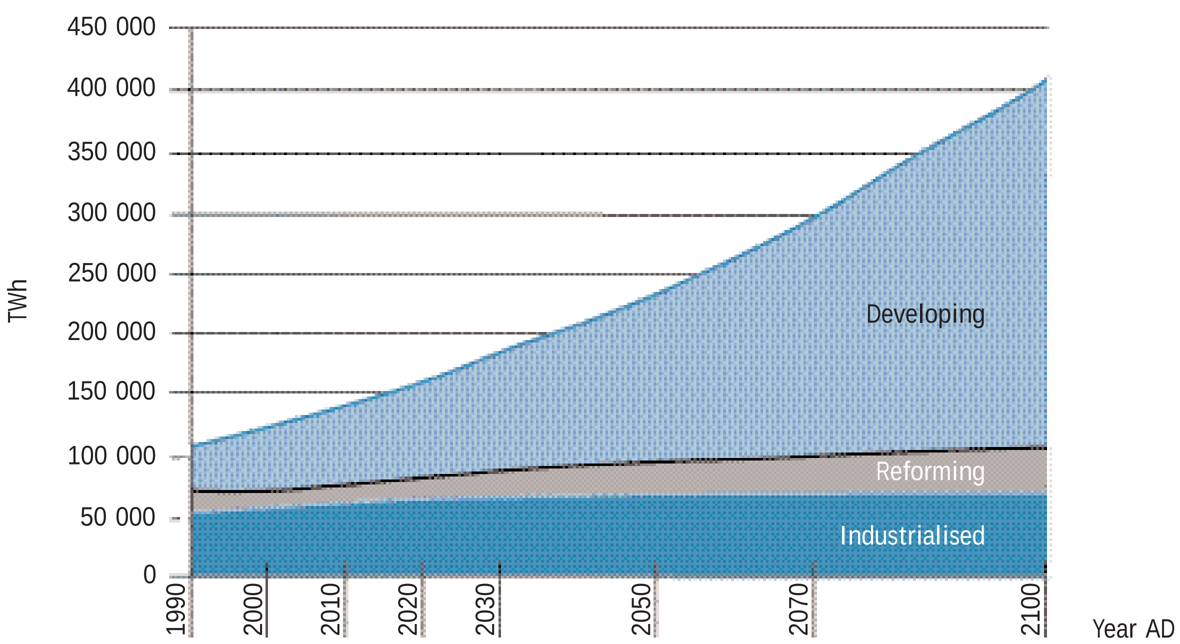
Of course, no energy source is free from risk. Risks are an inherent part of decision making in public policy. When we look at nuclear power, there are obvious ones, but compared to what alternatives? Are we to abandon it on the strength of a few accidents? Between 1918 and 1965, 42 major dam failures caused substantial loss of life. Did we stop building dams as a result? Did we abandon coal because of the high risks associated with coal mining? No. We worked at making technologies more reliable and safety measures stricter.

Those of us who do believe that the future has a constituency must prove it by urgent action. Ideally, a campaign should be led by political and civic leaders who have no vested interests in any particular energy option. This campaign should be based on an honest assessment of the risks and benefits of nuclear, and solutions to solve problems.

The future of energy is not the future of any one part of the globe: it is the future of the fragile planet Earth. To safeguard this future, we must mobilise scientific expertise and material resources in support of accelerated energy research in all areas. Let us together, from every corner of the global village, join forces to ensure that our planet survives in a condition hospitable to human life. That must be our promise to future generations.

Total primary energy consumption by region

(IIASA reference projection scenario B)



O. Appert*

Energy and sustainable development: issues and options

Future development needs to be sustainable in all of its dimensions if it is to continue to fully contribute to human welfare. In the achievement of this objective, the manner in which energy is produced and consumed is of crucial importance. In the wake of these insights, first attempts begin to provide concrete options for steps towards sustainability in the energy sector.[1] Two criteria can be identified for developing sustainable development policies. First, such policies need to strike a balance between the three dimensions of sustainable development – economic, environmental and social – acknowledging that all three are intrinsically linked. Second, policies in the energy sector need to reduce exposure to large-scale risks and improve the resilience of the energy system through active risk management and diversification.

In the energy sector, these two criteria will have to prove themselves in the face of several potential challenges to sustainable development:

- The growing importance of non-OECD countries in global energy consumption has important consequences for global supply security and greenhouse gas emissions. In addition, 2 billion people lack access to electricity.
- Climate change remains a top priority for industrialised countries, while developing countries need to address local and regional pollutants.
- Assuring the security of energy supply is becoming an increasingly difficult challenge as the dependency of OECD countries on a dwindling number of suppliers for their oil and gas imports grows.
- The institutional environment for energy policy making is changing fast. On the one hand, market reform, privatisation and increasingly vocal NGOs decentralise decision-making power; on the other hand, more and more issues require regional or global co-ordination.
- Technical progress – in particular, improvements in energy efficiency and cost reductions of renewable energy sources – holds great potential for making progress in several areas of sustainable development; however, it will not be realised on its own.

A number of initiatives testify that policy makers are responding to these challenges. Both the Ninth Session of the Commission on Sustainable Development (CSD) in New York (April 2001) and the Meeting of IEA Energy Ministers in Paris (May 2001) have energy and sustainable development as their principal theme. The three-year OECD horizontal project on sustainable development provides a reference for a large number of policy efforts aimed at improving sustainability.

The International Energy Agency (IEA) is fully contributing to these efforts. For several years, the IEA has committed itself to an integrated approach to energy policy making. Its Shared Goals of 1993 state:

> *Member countries of the IEA seek to create the conditions in which the energy sectors of their communities can make the fullest possible*

* *Mr. Olivier Appert is Director of the Office of Long-Term Co-operation and Policy Analysis of the International Energy Agency (e-mail: olivier.appert@iea.org).*

contribution to sustainable economic development and the well-being of their people and of the environment.[2]

This orientation is now developing into a full-scale commitment towards sustainable development. The IEA looks forward to participating in the emerging discussion on energy and sustainable development in collaboration with the OECD and the NEA.

The global energy picture

The quest to assure sustainable development in the energy sector is challenged by a projected fossil fuel future and an increasing concentration of oil and gas suppliers. In the Reference Scenario of the IEA's *World Energy Outlook 2000*, world total primary energy demand for commercial fuels is estimated to increase by more than 57% between 1997 and 2020, or at an average annual rate of 2%.

The bulk of the projected increase in world energy demand over the next 20 years is expected to come from regions outside the OECD. Consequently, the current 54% share of OECD countries declines to 44% by 2020, while that of developing countries rises to 46% from the current 34% share.

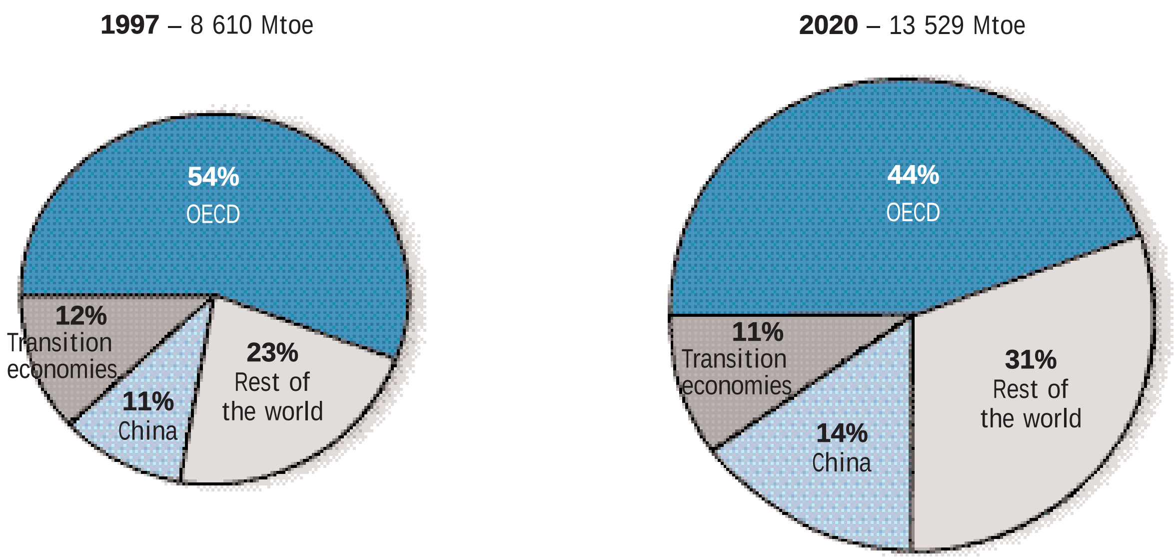
Oil remains the dominant fuel with a share of almost 40% in 2020, increasing with total energy demand at an annual 2% growth rate. Oil demand growth is driven by the transportation sector, which increases by 2.4% per annum. Natural gas is the second fastest growing energy source after non-hydro renewable energies with 2.7% per annum over the projection period. As a result, its share in world primary energy demand increases from 22% today to 26% in 2020. The expected demand increase for gas, however, has raised the issue of gas security.

Over the outlook period, world coal demand is projected to increase by only 1.7% per annum, thus reducing its share of total primary energy supply. China and India, countries with rich coal bases and high electricity demand growth prospects, are expected to contribute more than two-thirds to the increment in world coal demand over the projection period.

Nuclear power, which accounted for 17% of the world's electricity in 1997, is projected to decline by the end of the outlook period after 2010 to 9% in 2020. Nuclear power output increases only in developing countries, while a significant number of the currently operating reactors in the OECD are expected to be decommissioned.

Hydropower is, with 18% of global electricity production, the world's second largest source of electricity after coal and contributes approximately 3% to the global energy supply – a share that is anticipated to remain stable. Non-hydro renewable energies are expected to be the fastest growing energy source in the global energy mix, with an annual growth rate averaging 2.8% until 2020. Despite this rapid growth, their share will only reach 3% by 2020. This projection is raising a fundamental question: Are we on a sustainable energy path? The obvious answer is no unless there are considerable changes.

World primary energy supply by region



Source: IEA (2000), *World Energy Outlook 2000*, Paris.

Elements of sustainable development in the energy sector

Sustainable development contains a strong future orientation. The Brundtland Report of 1987 defines it as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". The concern over the long term is particularly relevant for the energy sector, as impacts from energy production and consumption can reach into the future for many generations to come.

Globalisation, regulatory change, new technical developments, increased awareness of environmental issues and the availability of new information and communication technologies constantly change the complex context in which the energy sector evolves over time. In some cases, such structural change permits progress in all three dimensions of sustainable development at once. For instance, the advent of the combined-cycle gas turbine (CCGT) has allowed several OECD countries to combine economic efficiency gains with reductions or limitations in greenhouse gases.

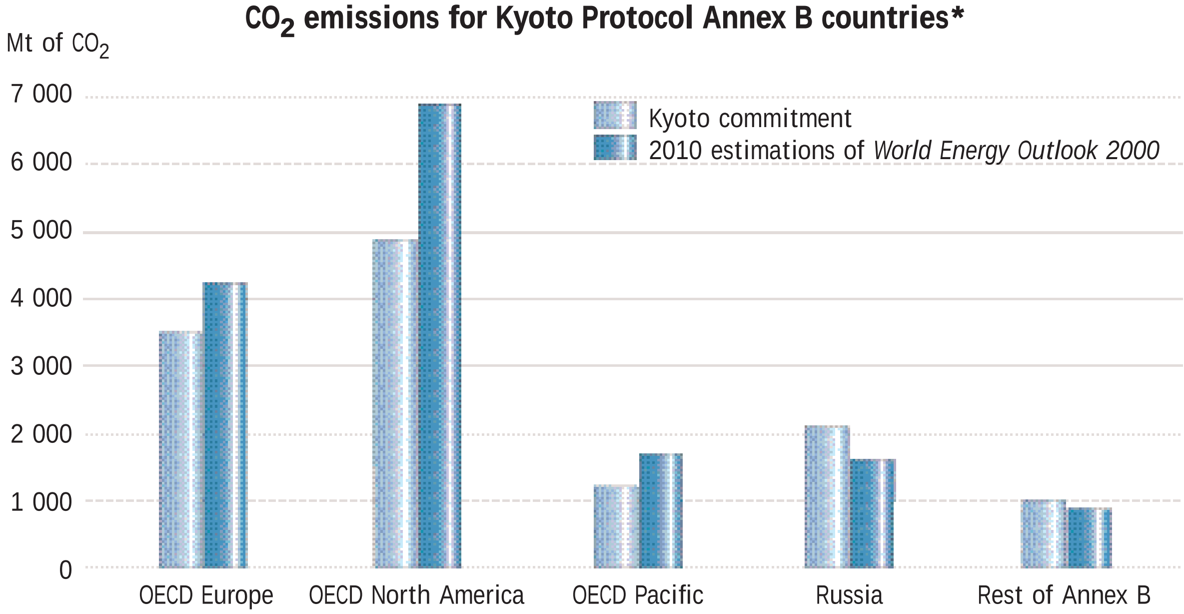
As long as such win-win opportunities do not arise in sufficient quantities in the short term, progress towards sustainability in the energy sector requires careful trade-offs between the different dimensions of sustainable development; for example, when maintaining per capita welfare for future generations. As long as the substitutability between different dimensions is guaranteed, this implies that losses in one dimension – say the environmental one – shall be substituted by at least equivalent progress in another one – say the economic one.

Often trade-offs cannot be made and institutional processes need to determine quantitative thresholds. Environmental regulations primarily aimed at local and regional airborne emissions such as particulates and sulphur dioxide (SO_2) have achieved considerable success in OECD countries. Unfortunately, the same progress has not yet been made in developing countries where the impacts of solid fuel use (coal, dung and biomass) is responsible for about 2 million premature deaths a year.[3]

One of the most challenging policy efforts towards sustainable development in the energy sector is constituted by the efforts of the Kyoto Protocol Annex B countries to reduce greenhouse gas emissions, approximately four-fifths of which result from the combustion of fossil fuels. The graph below indicates the magnitude of this challenge by setting the commitments of Annex B countries against the emissions projected in the Reference Scenario of the IEA World Energy Outlook 2000.

While much of the debate on sustainable development has focused on the interplay between economics and the environment, there is a social dimension that must be included. In the case of energy, the social dimension is multifaceted: it includes not only energy security but also the issue of access to energy services, employment issues in the energy sector, disruption to societies that can

CO_2 emissions for Kyoto Protocol Annex B countries*



* Annex B countries are those countries that have committed to quantified greenhouse gas emission limitations and reductions.

Source: IEA (2000), *World Energy Outlook 2000*, Paris result from price shifts in the energy sector and issues such as the social implications of energy-related land use. None of these factors can be considered individually – each has links to the economic dimension, and many also have links to the environmental dimension.

Other than the pursuit of clearly defined public goods such as in the environmental or the social areas, governments also have an obligation to create the appropriate framework conditions for well functioning and competitive markets. Regulatory reform offers significant potential benefits in terms of improved economic efficiency, lower prices for consumers, improved risk allocation and stimulus to economic growth and competitiveness.

Finally, all three dimensions of sustainable development will require the absence of disruptions that could pose systemic risks. Only by avoiding irreversible breakdowns can economic, social and environmental options of future generations be preserved. Risk management is particularly important in the energy sector due to two factors. First, energy sources such as electricity or oil only have limited substitutability – their absence would imply large burdens on society. Second, the energy sector is characterised by long timeframes of planning, operation and decommissioning of energy installations and infrastructures. The inertia and rigidity that result from these factors limit the flexibility of energy systems and expose them to shocks.

Towards sustainable energy policies

Energy policy makers have the choice either to be leaders or followers in the discussions about sustainable development. The choice to participate or not no longer exists. Future-oriented policy integration of different dimensions and risk management have been identified as the principal features of a coherent approach to sustainable development in the energy sector. Given that unexpected shocks will certainly arrive and that there is no such thing as “zero risk”, sustainable energy policies will also need to maintain response options when such shocks do arrive in order to ensure sustainable development.

In light of the issues mentioned earlier, a number of policies can be identified that enable progress towards sustainable development. While their implementation may vary from country to country, their combined thrust is common to all countries interested in developing comprehensive energy policies towards sustainable development:

- safeguarding energy supplies through diversification of energy sources and the co-ordination of flexible response mechanisms in the face of unexpected supply shortages;
- balancing climate change risk and the risk to interrupt economic growth through the setting up of appropriate targets and the creation of economically least-cost, market-based instruments;
- promoting the internalisation of environmental externalities of energy production and consumption through the clear assignment of responsibilities as well as the removal of energy subsidies that are detrimental to public-good objectives;
- ensuring the operation of energy equipment, plants and infrastructures under the highest safety standards and the creation and maintenance of appropriate emergency response mechanisms to ensure against accidental risk;
- promoting the research and development of new energy technologies in areas which have the clearly identified potential to contribute to sustainability objectives;
- continuing the liberalisation of energy markets with stable and predictable frameworks concerning environmental performance and social compatibility;
- creating appropriate conditions for the involvement of the private sector to participate in the effort to provide electricity for the 2 billion people currently without access through investment and technology transfer;
- sponsoring research, learning and information dissemination on issues related to sustainable development, thus acknowledging the need to address the intrinsic complexity of sustainable development;
- creating broad and transparent decision-making processes that allow the involvement of all stakeholders and reflect societal changes in order to foster policy integration and the achievement of balance between the three dimensions of sustainable development.

These are guidelines for moving in the right direction. It is inevitable that it will be an immense challenge to reach a sustainable development path, and that strong political determination will be necessary. ■

Notes and references

1. See, for instance, IEA (2001 forthcoming), *Working Towards a Sustainable Energy Future*, Paris.
2. IEA (1995), *The History of the International Energy Agency*, Volume III, Paris.
3. UNDP, UNDESA and WEC (2000), *World Energy Assessment*, Vienna.

G. Doucet*

Energy system sustainability worldwide

Anti-globalisation marches on the World Bank, the IMF and the World Trade Organisation seem to be saying liberalised markets are bad for prosperity and equal opportunity. I do not agree, but markets alone are not enough. On the one hand, it is folly to think that the supplementary financing of about US$ 30 billion per annum to achieve the goal of eradicating energy poverty wherever it exists (in addition to about US$ 400 billion per annum in investments in current infrastructure improvements or extensions) will come from governments or the taxpayer. On the other hand, it is a gross injustice to think that poor people do not now pay for the non-conventional energy they need to cook or to warm their families: they pay an excessive amount with their hours of wood collection and the heavy health impact of the inefficient and polluting systems they often use.

At its World Congress in Houston, Texas in September 1998 WEC concluded that, with one-third of the world's population having no access to affordable, commercial energy supplies, it is a business priority not just a social duty to do something about the situation. WEC also took up the challenge of the CEO of ABB, Göran Lindähl, to collaborate in technology transfer and investments to remove one billion tonnes of CO_2 from the atmosphere by 2005.

It was in this context that WEC published a Millennium Statement in April 2000 (see www.worldenergy.org) that shows how sustainable energy systems can be achieved in a global, competitive market. It also partnered, for the first time, with the United Nations Development Programme (UNDP) and the United Nations Department of Economic and Social Affairs (UNDESA) in publishing the *World Energy Assessment* in September 2000 as the basis of the Conference on Sustainable Development that the UN will hold in 2001. The Assessment establishes the ways in which reaping the benefits of market reform in energy systems, coupled with appropriate regulations, regional energy co-operation and a diversified energy portfolio, will achieve a satisfactory sustainable path by 2020.

This work was undertaken against the backdrop of the recent tripling of oil prices, which has created severe exchange rate pressure in developing countries that import large amounts of oil or natural gas. However, it is not the adequacy of supply or the price of oil that is the fundamental challenge; fossil fuels will continue to be a big part of the total primary energy mix well into the

> The World Energy Council (WEC) is a global, multi-energy body supported by the energy interests, both government-owned and private, in over ninety countries. Since 1923 when WEC was created to help rebuild the electricity grid after World War I, it has combined the business of efficient and profitable energy systems, covering the full range of exploration, production, transmission, distribution and utilisation issues, with government concerns for prosperity and the well-being of people in their daily lives. The sustainable production and use of energy for the greatest benefit of all is its mission, supported by over 4 000 engineers, economists, policy makers and executives who believe that affordable, sustainable energy is one of the keys to address poverty, inequality and environmental degradation in every corner of the earth.

* *Mr. Gerald Doucet is Secretary-General of the World Energy Council (e-mail: info@worldenergy.org).*

21st century. It is the focus on cleaner technologies and how to cover the real cost of fuels and energy services that will matter most in the sustainability work WEC is now carrying out.

Action not words

Today WEC's regional programmes in Asia, Africa, Latin America and the Caribbean, and Central/Eastern Europe are focused on providing access to a minimum of 500 kWh of reasonably priced and purchased electricity, or its equivalent, to every person in the world by 2020. This does not have to be grid-based electricity, but it is a commercial undertaking nonetheless; not being a gift from the gods, energy must be priced to cover full costs and the payments systems have to work effectively. WEC has also established the only global, multi-energy greenhouse gas emissions reduction database to track over 400 *real* energy projects which will bring commercial energy to a new market in a developing country in a manner which quantifiably reduces harmful emissions. This database is public for anyone to verify.

Markets go hand in hand with sensible and impartial regulation to address efficiency standards, full fuel cost accounting, market power and trade in energy. The Kyoto Protocol has put greenhouse gas emissions on the political radar screen, but developing countries are right to focus on energy poverty and local pollution before they begin to worry about the imperfect science of global warming. We must nevertheless get on with the job of linking energy accessibility investments in developing countries with quantifiable emissions reductions using the latest technologies. It is competition and customer choice, coupled with appropriate regulation, which will promote the acceleration of technology transfer to achieve this. Time is of the essence.

This message has largely penetrated the thinking of political leaders in developing countries, the energy utilities and service executives with whom they work. How they manage the public debate on security, ownership and pricing issues is critical, but they seem to realise that there is a need to act now rather than postpone difficult decisions until later. Energy companies have moved to implement business strategies to manage harmful emissions and carbon in a sustainable way, not just in the developing countries but in their own backyards. Fostering financial partnerships between developed and developing countries, in the form of sound business investment in energy infrastructure


Ledru and Martel, UNESCO

The sustainability of energy systems varies from one country to another.

or distributed generation systems to achieve environmental goals, is a big piece of the sustainability puzzle.

These are practical steps to link the goal of energy accessibility with the goal of energy acceptability wherever the opportunity arises. Efficient energy systems matter greatly to health, environmental and emerging issues such as water resources, the objective of a major study called *Living in One World* which will be released by WEC at its 18th World Congress in Buenos Aires in October 2001. Addressing the problem of ethics and energy system governance, along with new technologies and liberalisation transition issues are other key topics for the Congress.

New focus needed

The WEC has invited the World Bank and the United Nations to focus on these issues. Reaping the benefits of market reform with appropriate regulation is not enough in those countries with serious urban or rural poverty; the political risk of investments needs to be addressed by the World Bank and other financial institutions through a global co-insurance scheme for energy projects to ensure that *force majeure* and other special burdens are addressed in a balanced way. According to the *World Energy Assessment* referred to above, cleaner fossil fuel technologies, hybrid renewable energy systems linked to baseload electricity, and safer nuclear power must be nurtured through sound policy and business strategy as part of the energy mix to meet the growing global demand for reliable and sustainable energy by 2020, perhaps 50% higher than it is today, especially in developing countries. ■

E. Bertel, R. Morrison*

Nuclear energy economics in a sustainable development perspective

In order to contribute effectively to sustainable development goals, a technology option must meet the test of economic efficiency to justify its use of scarce capital. However, in a sustainable development perspective, this test should be considered in a broad context, taking into account the need to preserve capital assets of all kinds: natural, man-made, human and social. Assessments of competitiveness in this context should be based upon comparisons of full costs to society of a product or a service.

At present, many of the costs associated with the supply of goods and services are not reflected in their market prices. In the power sector, for example, the production and use of electricity creates costs external to traditional accounting practices, such as damages to human health and the environment, that are not borne by producers or consumers. Those "external" costs are supported by society as a whole, now or in the future.

Economists are looking for ways of valuing these costs and incorporating them into prices, i.e. internalising the externalities. Within a sustainable development framework, getting the prices right so that market mechanisms can operate efficiently implies taking into account social and environmental costs for present and future generations. On that basis, the comparative assessment of alternative technologies will become an effective policy-making tool.

* *Dr. Evelyne Bertel is a member of the NEA Nuclear Development Division (e-mail: bertel@nea.fr). Dr. Robert Morrison is former Chairman of the Steering Committee for Nuclear Energy (e-mail: robertmorrison@home.com).*

Economic characteristics of nuclear energy

Nuclear energy has a number of unique economic characteristics that affect its attractiveness from a sustainable development perspective. Nuclear energy programmes imply long-term commitments from policy makers and investors, so financial risks and future liabilities arising from nuclear activities deserve careful consideration. Nuclear power plants are capital-intensive, but have low and stable marginal production costs. The nuclear industry sector requires a comprehensive infrastructure, including highly qualified manpower that contributes to increasing human capital assets. It uses limited amounts of natural resources and helps to provide security of supply.

The construction time of current nuclear units, around 5 years or more, and their expected technical lifetimes, up to 60 years or more, may raise some issues for private investors and power plant owners facing deregulated markets, but are consistent with the long-term perspective adopted by decision makers aiming at the implementation of sustainable development policies. It takes a long time, generally more than two decades, to amortise the capital invested in a nuclear power plant. The need to run the plant at a high rate of utilisation for many years before the investment is paid back raises financial risks associated not only with potential technical failures, but also with uncertainties about the stability of regulation and the growth of market demand.

Investment typically represents some 60% of the total generation cost of nuclear electricity. The capital cost of a 1 GWe nuclear unit is roughly

US$ 2 billion. Once built, on the other hand, nuclear plants have rather low fuel and operating costs, compensating for the need to amortise their capital investment. Since the cost of uranium represents only some 5% of the cost of electricity from nuclear plants, even a significant rise in the cost of uranium would have little impact on the total cost of nuclear-generated electricity.

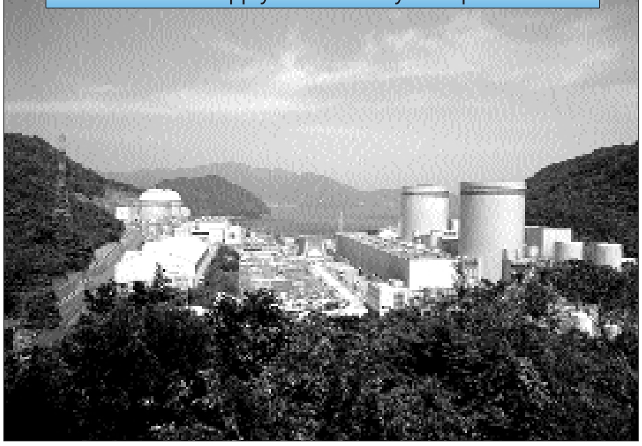
The large size of uranium resources and their balanced geopolitical distribution worldwide ensure long-term security of supply. Uranium, and thorium, another potential nuclear fuel, are generally not useful for other significant purposes. The recovery of their energy content decreases the demand for other, more versatile energy resources, thereby contributing further to sustainable development. Because of the high energy density of nuclear fuel, nuclear energy requires a very small flow of energy materials, in mass or volume terms, and makes small demands on the natural resource base and the environment. This also means that nuclear fuel can be stockpiled for several years at reasonable costs, decreasing concerns about energy security in the short term.

Economically recoverable uranium resources are large enough to cover demand for many decades at current rates of consumption. Moreover, if demand was to increase, higher prices could bring still more resources on stream. Advanced fuel cycles, in particular those taking advantage of fissile material recycling, could allow the resource base to be further extended by a factor of sixty or more, ensuring a nuclear fuel supply for centuries to come, even if the use of nuclear energy is greatly expanded.

The nuclear energy sector requires R&D and education infrastructures as well as comprehensive legal and institutional frameworks. Requirements for a high level of technical and managerial know-how create demand for highly qualified manpower, bringing macroeconomic and social benefits. The spin-off benefits of nuclear energy activities are widespread and enhance its contribution to the economic and social goals of sustainable development. Nuclear power plants and fuel cycle facilities contribute to the man-made asset passed on to future generations, while experience in operating the nuclear fuel cycle adds to the human and intellectual capital base.

Future financial liabilities arise from the need to cover the costs of decommissioning nuclear facilities and disposing of long-lived radioactive waste. Those liabilities were recognised at an early stage. Measures taken by the industry and governments to establish and guarantee adequate funds for these liabilities are consistent with the objective of not passing undue burdens on to future generations. The high energy density of nuclear fuel and the large amount of electricity that it produces allow for adequate funds to be generated from a small surcharge on the price of electricity to consumers.

Nuclear power provides close to 40% of the supply of electricity in Japan.



Takahama NPP, Kansai Electric Power Co., Inc., Japan

Competitiveness of nuclear power

Existing nuclear power stations tend to have low operating and fuelling costs as noted above. This makes them highly competitive on a marginal cost basis. Recent experience, in the United States, the United Kingdom, Sweden and Finland for example, demonstrates that nuclear power plants perform well in deregulated markets. Existing nuclear power plants that were built at low original costs, or where the initial costs have been largely amortised, can be very competitive and profitable. They are expected to continue operating well beyond the time required to amortise the investments that were made in them.

Most existing nuclear power plants have improved their technical performance significantly over the past decade. The availability factors of nuclear units exceed 80% in most OECD countries. Simultaneously, operation and maintenance costs have been reduced, taking advantage of feedback from experience, as demonstrated by the figures published by US and German operators for example. This has led to a drastic improvement of the overall economic indicators of nuclear power plants.

The possibility of improving the technical performance of existing nuclear power plants, as well as increasing their power capacities and

Nuclear electricity generating costs

Country	Discount rate %	Investment %	O&M %	Fuel %	Total cost US cents/kWh
Canada	5	67	24	9	2.5
	10	79	15	6	4.0
Finland	5	59	21	20	3.7
	10	73	14	13	5.6
France	5	54	21	25	3.2
	10	70	14	16	4.9
Japan	5	43	29	27	5.7
	10	60	21	19	8.0
Korea (Republic of)	5	55	31	14	3.1
	10	71	20	9	4.8
Spain	5	54	20	26	4.1
	10	70	13	17	6.4
Turkey	5	61	26	14	3.3
	10	75	17	9	5.2
United States	5	55	27	19	3.3
	10	68	19	13	4.6

extending their lifetimes, offers prospects for enhanced competitiveness in the coming years and decades. Many countries, even those with moratoria on further construction, have increased their installed nuclear capacity through upgrading existing plants. Lifetime extension is cost-effective in most cases, even if some upgrading may be required to meet current safety standards.

For new power plants, the data in *Projected Costs of Generating Electricity* (OECD/NEA, 1998) show that nuclear power is seldom the cheapest option. In a deregulated market context, meaning high discount rates, and with the present prices of hydrocarbons, natural gas is a very strong competitor. However, these studies do not take account of the recent increases in the price of oil and natural gas. In the case of North America, natural gas prices have gone up by a factor of three or four in the last two years. While prices may not hold at current levels, it now looks as if they will be maintained at a higher level than was anticipated in the late 1990s.

In the longer term, nuclear power plants will have to compete not only with state-of-the-art, fossil-fuelled plants but also with renewable energy technologies that are expected to improve their performance and reduce their prices through scientific and technical progress and commercial development. In this context, there is a need in most cases to ensure that the capital cost is reduced, along with the planning and construction times. Some reactor designers and manufacturers plan to reduce capital costs by 30 to 40% for designs that are available now or will be in the next few years, and to reduce construction times to five years or less. Planning would be helped by a standardised and predictable approach to regulation.

The relative competitiveness of alternative options for electricity generation depends strongly on the discount rate used to calculate cost estimates. With a 5% discount rate, nuclear power plants that would be built today would compete favourably with alternatives in many countries, but with a 10% discount rate gas-fired power plants would be the winner nearly everywhere. High discount rates, in line with the economic objectives of private investors in deregulated markets, enhance the competitiveness of technologies that are not capital-intensive, such as gas turbines. On the other hand, low discount rates, which reflect a preference for a future consistent with sustainable development goals, favour capital-intensive technologies such as nuclear power and renewable energy sources.

External costs

The health and environmental external costs of electricity are limited by norms, standards and regulations aiming at reducing residual emissions and burdens from fuel cycles for electricity generation. In the case of nuclear energy, the industry is operating under stringent safety regulations, tight limits on atmospheric emissions and liquid effluents, and commitments to contain radioactive waste. The industry is also supporting the corresponding costs of these responsibilities, thereby internalising the expense.

A significant proportion of nuclear energy cost is due to safety features designed to prevent nuclear workers and the public from receiving radiation doses in excess of permitted levels, in conformity with stringent environmental and safety regulations. The internalisation of external costs extends to long-lived radioactive waste disposal and plant decommissioning through the establishment of funds to cover future financial liabilities. The liability in the event of major accidents is also internalised, although in most cases the total liability of the industry is effectively capped, and governments do carry the residual risk that constitutes an externality. Some countries have unlimited liability, but since the ability of the industry to pay is limited, governments still end up with the residual risk. Most other industries are only beginning to think about liability regimes for long-term impacts.

Comparative studies carried out recently, such as the ExternE project implemented under the auspices of the European Commission, show that alternative options for electricity generation, including fossil and renewable sources, have not fully internalised their respective external costs. There are no generic conclusions since impacts of energy fuel cycles are often site-specific, but generally speaking, nuclear energy fuel cycles have lower external costs than alternative options, even when the possibility of accidental releases is considered.

The adoption of environmental protection regulations has led to the implementation of cleaner technologies. State-of-the-art, fossil-fuelled power plants include pollution abatement devices which, at a cost, reduce atmospheric emissions to levels thought to be harmless. The notable exception is the risk of global climate change resulting from carbon dioxide and other greenhouse gas emissions.

Although it is not possible to assess with a reasonable degree of certainty the value of global climate change damages in the long term, it is a major risk that should be avoided within a sustainable development framework. Passing on to future generations the burdens associated with climate change that arise from activities that benefit the current generation is certainly not consistent with sustainable development objectives.

Cruas-Meysse NPP, Henri Cazin, EDF, France

Not passing on burdens to future generations is an essential element of sustainable development.

Conclusion

Nuclear power plants in operation, including those in deregulated markets, are generally competitive since their marginal costs are low as compared with alternatives. Furthermore, experience shows a continued trend towards improving operating performance of existing reactors as well as economic performance.

The research, development and design efforts being made by reactor designers could lead to significant reductions in capital costs and construction times for the next generation of reactors. These reductions will be essential in order to lower financial risks associated with nuclear energy and to attract investors.

The economic goals of sustainable development require that the full costs of a given technology be factored into the price of its product. The nuclear energy sector has gone a long way in this direction and its present costs reflect a fairly complete integration of environmental and social burdens associated with nuclear electricity generation. Therefore, the internalisation of external costs for all technologies and energy sources would likely enhance the competitiveness of nuclear energy. However, this is likely to take some time. Meanwhile, the nuclear industry must be active in reducing its costs in a competitive environment, while ensuring that high standards are maintained with respect to health, safety and environmental impacts. It must convince investors and the public that nuclear energy is a good investment for the future in the broadest economic, environmental and social terms. ■

J. Lang-Lenton León*

Radioactive waste management and sustainable development

The concept of sustainable development emerged at the end of the 1980s in response to the need to find a balance between economic development and the conservation of ecosystems. The Brundtland report defines sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs".

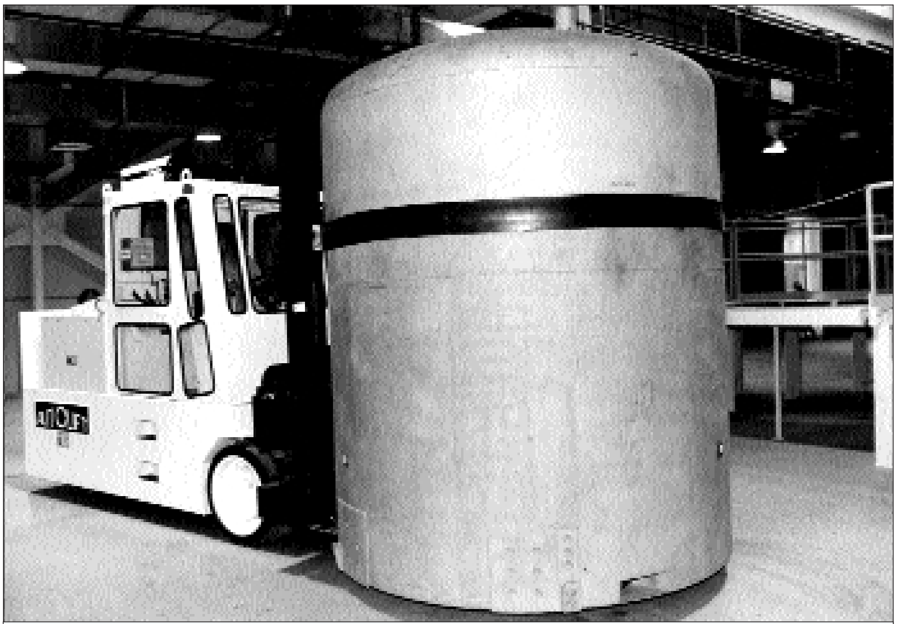
Energy is an essential part of economic development, and contributes to increasing social stability by improving the quality of life. In order to achieve such improvement in the developing countries and to maintain it in the developed world, important increases in energy production will be required. Furthermore, it is probable that electricity production will increase more than that of other forms of energy, since it is convenient, versatile and clean at the point of use. As energy production and use will continue to increase, its effects on health and the environment must be controlled, in an attempt to reduce these effects to the extent possible, and thus meet the goals of sustainable development. Energy sources that do not pollute because of combustion gases, such as nuclear power and renewable energy sources, may be of vital importance as regards the reduction of emissions, but they are required to compete on a market in which fossil fuels are particularly abundant and at relatively low costs.

Radioactive waste is an unavoidable by-product of the application of ionising radiation in diverse areas, such as nuclear medicine, industrial applications and the conservation of foodstuffs, but is particularly important in electricity production due to its high level of radioactivity. However, the radioactive waste produced by the use of nuclear energy represents a very small volume – normally less than 1% – of the total toxic wastes generated in those countries that use nuclear energy to generate electricity.

In most OECD/NEA countries, short-lived, low- and intermediate-level wastes are disposed of using systems that guarantee the safety of people and the environment during the time that these wastes maintain their radioactivity. These wastes are duly conditioned and stored in facilities isolated from the environment by engineered barriers. High-level waste is first deposited in temporary storage facilities, under strict safety conditions, for several decades. These installations may be of the wet or dry storage type, and may be for a single nuclear power plant or for all those in a given region or country. Consideration should also be given to uranium mining tailings and to the waste materials from uranium concentrate manufacturing plants, which although not considered to be radioactive waste as such, are conditioned at the installations themselves and protected from meteorological agents by means of layers of different isolating materials.

Although there are no economic, technical or environmental incentives to speed up or hasten the construction of final disposal facilities for radioactive waste, temporary storage is not a permanent solution. In the interests of coherence with

* *Mr. Jorge Lang-Lenton León is Director of Communication at ENRESA (e-mail: JLAL@enresa.es).*


USDOE, United States

A transuranic package transporter on a forklift
in the WIPP waste handling building in the United States.

the principles of sustainable development – of not passing burdens on to future generations – it is essential that the development of final disposal facilities be addressed.

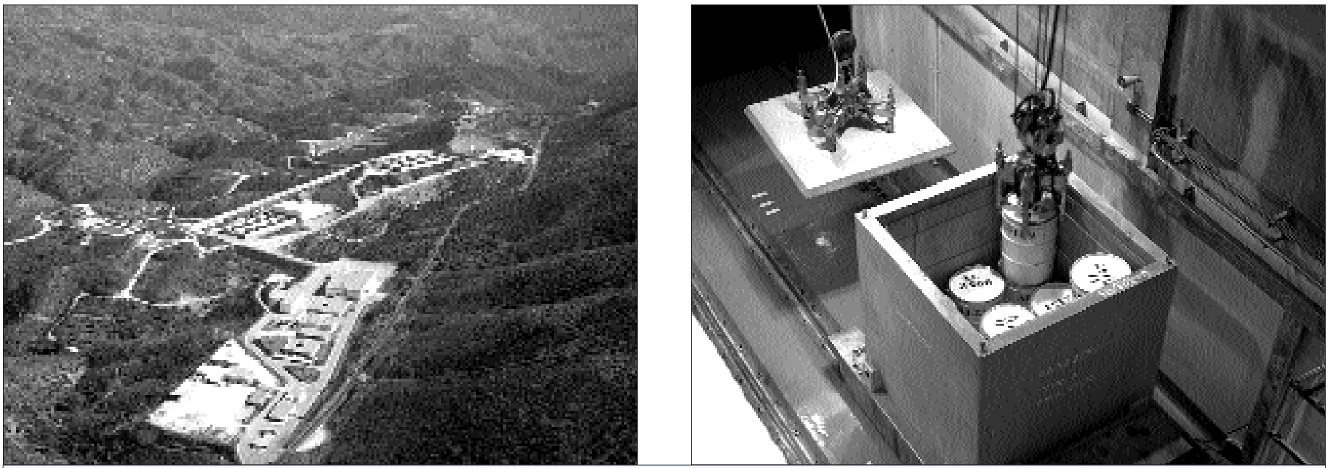
The technology known as "deep geologic disposal" is now available for the final disposal of high-level waste. This is based on the stability and impermeability of certain of the geological formations in the Earth's crust, in which the conditioned waste is placed, remaining isolated from the biosphere by a set of barriers, among them the geological barrier, for a sufficient period of time for its radiological activity to decay to harmless levels. The waste can be recovered, at least during the initial phase of the repository, and also during subsequent phases, albeit at increased cost.

The safety of geologic disposal has been demonstrated in nature itself. Almost two thousand million years ago a natural reactor operated discontinuously for millions of years, moderated by natural currents of water, at a uranium ore deposit in Gabon. The fission products produced during the nuclear reaction hardly moved from their original location. The first man-made geologic disposal facility for long-lived waste started operation in the United States in March 1999 and will provide industrial experience.

Furthermore, both the activity of long-lived radioactive waste and the time that it remains active might be considerably reduced by using partitioning and transmutation (P&T) techniques. With this technology, the transuranic elements and long-lived radionuclides present in the waste, having been isolated, are transformed by neutron bombardment into other non-radioactive elements or into elements having shorter half-lives than the original ones. This option is being investigated by certain countries, but has not yet been developed, and it is not known when or whether it will become available on an industrial scale.

As pointed out above, one of the main objectives of sustainable development is to prevent the transfer of undesirable burdens to future generations. If the nuclear industry did not set aside adequate funds, the financial burdens associated with plant dismantling and radioactive waste disposal would be passed on. In OECD/NEA countries, the costs of dismantling nuclear power plants and of managing long-lived wastes are included in the electricity generating costs and applied to the end consumers; in other words, they are internalised. Although the cost of radioactive waste management is quite high in absolute terms, it does not represent a significant component in the cost of nuclear power generation.

The suitable management of radioactive waste implies the application of advanced technologies, the development of which requires qualified training and R&D programmes. This generates employment and provides a transfer of knowledge to future generations. Scientific and industrial development takes place under strict control, as a result



ENRESA, Spain

The El Cabril site in Spain: the drums of radioactive waste are introduced into the concrete container before being disposed of into the repository vaults.

of which in practically all countries in which activities relating to nuclear energy are carried out, standards have been developed to guarantee the health of the general public, the workers involved and the environment. Likewise, institutions specifically responsible for nuclear and radioactive issues have been set up, and have been provided with human and material resources as well as the necessary legal authority to ensure high levels of safety control.

However, although radioactive waste management must first be based on rigorous science and technology, the solution must also be socially and politically accepted. In sustainable development, social equality and representation count as much as science and technology.

The dissemination of adequate information is essential, but not sufficient in itself. Communication is a two-way process, and confidence in this process often appears to be more important than the specific technical information actually provided. Overpowering information may be seen as offensive if it involves the audience having to accept it as an act of faith, and if harbouring doubt is considered to be indicative of ignorance.

In order to bring about a sufficient degree of acceptance, it is necessary to understand the mechanisms that govern the social perception of risk. There are many factors that affect the perception of risk, such as the level of control, familiarity with the technology, the degree of uncertainty, concern for the consequences, the degree of credibility of the institutions, the decision-making process and the ideas and values of the community in which people live.

Addressing the public's concerns and negotiating acceptable solutions will be an important challenge. A decision-making process should be set up step by step, and all the affected groups should be allowed to participate. The role of governments will be crucial in defining this process, and they should act as a source of objective information. They should also dedicate adequate resources for this purpose.

Finally, it should be borne in mind that international collaboration, accomplished mainly through the co-ordination and directives of organisations such as the OECD/NEA and the IAEA, is allowing for the promotion and globalisation of activities relating to nuclear safety, the development of standards, training, R&D and surveillance of compliance with non-proliferation treaties.

Conclusions

Radioactive waste management, as currently carried out in OECD/NEA countries, is fully consistent with the principles of sustainable development. It allows present generations to progress without leaving burdens for those of the future, while transferring to the latter a corpus of knowledge, standards and structures of international relations that will facilitate their own development.

Nevertheless, achieving public acceptance is essential if we are to attain the objectives of sustainable development. With this in mind, and in view of public opinion regarding the nuclear risk, it is necessary to provide impulse and include public participation in decision making.

W. Kröger*

Measuring the sustainability of energy systems

Today's energy policies are characterised by a contradictory position. In theory, there is a clear will to respond to emerging threats, e.g. evidence of man-made climate change, irresponsible use of limited resources, geopolitical discrepancies with unbalanced satisfaction of vital needs. In practice, decision making is dominated by economic competitiveness and maximisation of short-term profit. The use of fossil fuels is unbroken and still increasing. A recent Green Paper concluded that the EU countries have to reduce growing structural weaknesses by limiting dependence on fuel imports and to give priority to energy systems that do not emit global warming gases.[1]

As a matter of principle, our energy supply must reach a higher degree of sustainability. The major goal must be to stop carbonising and finally decarbonise the current worldwide energy systems as much as possible. This huge task can only be achieved in a stepwise approach. For the transition phase, the "most sustainable" options among the fossil energy systems must be identified and used. Non-fossil options need to be further developed and implemented. But the use of carbon-free energy systems (hydro, nuclear, new renewables) also has to be balanced in a way that optimally and equally fulfils economic, ecological and social criteria as elements of sustainability. For this purpose, appropriate tools and suitable attributes are needed to assess technological options, both to strategically choose the most adequate energy mixes and to foster, guide and control necessary technological developments.

Assessment matrix

To make the concept of sustainability operational and to provide technical input for decision-making processes we need to transfer the somewhat abstract idea into principles. This can only be done for a defined field of application or sector. The Swiss *Paul Scherrer Institut* has developed a set of sector-specific indicators with which different options for electricity supply can be evaluated. They are applicable both to different technologies and to different levels of development (current – advanced – potential) within a single technology. These indicators must be determined comprehensively on the basis of whole energy chains. Besides life cycle analyses (LCA), environmental impact assessment (EIA) and risk assessment (RA) provide the methodological framework. The proposed indicators (see Table 1) correspond to a restricted number of criteria derived from sustainability principles. They are mostly independent and unaggregated to ensure sufficient transparency. In addition, they aim to be quantifiable, although a few will probably remain at least semi-qualitative. At the same time they are representative of the much larger number of attributes used in current sustainability assessments.

The first principle "no exhaustion of resources" includes natural resources like fuels but also other materials. Following a broad interpretation, it covers not only the environment, but also human resources like public health as well as social peace and economic welfare. In detail, safety aspects

* *Prof. Wolfgang Kröger is Director of the Nuclear Energy and Safety Department at the Paul Scherrer Institute (e-mail: wolfgang.kroeger@psi.ch).*

Table 1: Assessment matrix for different energy systems, each considering the same level of development

Principles	Criteria	Indicators	Units of measure
"no" exhaustion of resources	use of fuel /	availability of reserves [1]	years
	other materials (example: Cu ore)	consumption	tons *
	extent of land losses	plant operation	km^2 *
	effects on water (example: pollution by Zn)	pollution or consumption	tons *
	environmental impact through emissions	climate relevant gases	kilotons CO_2 equiv. *
		gases damaging the ozone layer	tons FCKW equ. *
	impact on human health	normal operation	years of life lost *
		accidents / collective risk	fatalities *
	impact on societal aspects	risk aversion	land losses (km^2)/ fatalities per accident [2]
		work opportunities	Δ persons/year *
		proliferation threat	qualitative
	economic efficiency	internal and external costs	currency unit/kWh
"no" production of non-degradable waste	produced amount of hazardous substances		m^3 *
	necessary confinement times [3]		years
"no" high sensitiveness to social and environmental factors	supply and disposal security	foreign dependency	qualitative
		technology availability [4]	currency unit *
	robustness, i.e. no necessity for...	...rapid external interventions [5]	hours
		...socio-political / financial stability	qualitative

* per GWa_e or GWh_e.
1) Under the assumption of a stabilisation at today's production level.
2) Maximum value identified through risk analyses for a 1 GW(e)-plant.
3) Necessary to achieve "natural levels".
4) Expected costs for R&D up to commercialisation.
5) Time period following an abnormal event, before human corrective actions become necessary.

are accounted for in "collective risk" (as expected value for fatalities caused by undesired events and corresponding frequencies), and in maximum losses due to the worst conceivable accident. Economic competitiveness is considered through both internal (production) and external (environmental damage) costs.

The second principle of "no production of non-degradable waste" is specified by the amount and the necessary confinement times (based on the evolution of waste toxicity or radiotoxicity over time). The degree of public acceptance is not treated as a specific criterion; instead, other aspects that may influence the social perception of technology (risk aversion, jobs, threats, etc.) are explicitly considered.

The principle of "no high sensitiveness to social and environmental factors" is hard to specify; security of supply and robustness of technical systems have been selected as criteria.

Cross comparison of indicators

Comprehensive analyses made to date show that most of the proposed indicators can already be quantified. Corresponding results reveal the strong and weak points of the different energy chains (see Table 2 for a subset of quantified indicators).

The fossil-fuel systems are subject to limited energy resources. They show the well-known problematic ecological characteristics and also relatively unfavourable risk features; natural gas is the best performer among them. Hydropower shows an excellent performance but the cost range is broad, as new hydro plants are expensive. The "new" renewables (solar and wind) are environmentally superior to fossil sources. They also have the highest potential for technical improvements. However, they need large amounts of non-energetic (material) resources and, in the short to medium term, they only have a strongly constrained potential to become major suppliers of electricity at competitive prices.

Challenges for nuclear energy

Nuclear energy is not only characterised by low levels of emissions, but within the Western world, also by an excellent safety record. This is reflected in comparatively low estimated collective risks for both normal operation and severe accidents.

Table 2: Selected (example) indicators for current energy systems

Applies for every option: the upper row shows a range of values for current systems; the lower row gives the corresponding values for the best future systems under Swiss conditions (time horizon approximately 20 years). All data are based on life cycle analyses.[1]

	Fuel reserves	Material consumption (copper ore)	Greenhouse gases	Sulphur dioxide	Inorganic waste in repository	High- and intermediate-level rad. waste	Production costs	External (environmental) costs
	Years	kg/GWh_e	$t(CO_{2\text{-eq}})/GWh_e$	$kg(SO_x)/GWh_e$	kg/GWh_e	m^3/GWh_e	Rp^*/kWh_e	Rp^*/kWh_e
Hard coal	160-2 300	14-19 59	950-1 200 770	920-25 000 520	5 800-54 000 4 000	0.13-0.20 0.04	5.7-7.4 6.3	3.1-15.8 5.1-8.6
Natural gas	70-170	16 8	530 390	260 150	1 500 1 100	0.04 0.004	4.7-5.8 4.7-8.2	0.8-5.5 2.5-4.2
Nuclear	120-400	7-9 4	8-29 6	56-150 33	650-1 200 600	9.0-11.0 2.4	5.1-7.5 5.7-7.2	0.2-1.3 0.3-0.4
Hydro storage	∞	< 1 < 1	4 4	8-10 7	30 30	0.006 0.002	4-21 12-16	0-1.2 0.1
Photovoltaic	∞	270-1 600 350	110-260 44	700-3 600 160	4 900-10 000 1 600	0.6-1.2 0.06	70-140 45	0.1-1.5 0.5-0.7

* Rp: Swiss cents.
1. PSI/ETH Zurich: Energie-Spiegel Nr.3, Sept. 2000.

Catastrophic events with releases of radioactive substances have not happened in power plants of Western design; studies show a potential for high-consequence events at extremely low frequency levels.

For fossil and hydro plants statistics show numerous serious accidents, a few with even more than 1000 immediate fatalities (the latter due to oil fires and dam failure in non-OECD countries). The evaluation of statistical data for OECD countries leads to average risk figures in the range of $7x10^{-2}$ (gas) to $4x10^{-1}$ (oil) fatalities per GW(e)•a. For nuclear power the accidental risk is dominated by latent effects following large releases of radioactive substances in the course of core-melt accidents combined with early containment failure. Based on probabilistic analyses (PSA level 3), up to several tens of thousands of late fatalities must be accounted for, although the frequency of such catastrophic events is extremely small ($<<10^{-7}$ per reactor year). The multiplication of these two parameters leads to calculated risk figures in the range of 10^{-1} down to 10^{-3} late fatalities per GW(e)•a for Western plants of differing designs and site conditions. If nuclear power has to play a major role in a future and more sustainable energy mix, these figures should (and can) be further reduced by technical means.

The potential for high-consequence events is perceived as a Damoclean type of risk: although their frequency is almost negligible, a large part of the public reacts adversely and refuses acceptance.[2] Therefore, improved protection against severe accidents is one of the biggest hurdles nuclear power plants have to surmount without falling into the "economy trap". Built-in design measures should allow the possibility of excluding catastrophic events and eliminating the need for off-site emergency planning. Besides strengthening the containment (e.g. for the European pressurised water reactor – EPR), other ways should be explored to enhance the use of inherent safety features and/or passive systems, both for reactivity control and after-heat removal (e.g. small, modular, high-temperature, gas-cooled reactors or passive, advanced light water reactors). Apart from their considerable innovation potential, they could offer possibilities for plant simplification and further increased availability, and therefore play an important role within a cost-reduction strategy.

Moreover, a sustainable use of nuclear energy should include the closure of the fuel cycles and strategies for waste volume reduction. Innovative technologies need to be pursued to reduce secured confinement times to historical scale, as well as the potential danger of man-made intrusion. Promising solutions are the partitioning and transmutation of minor actinides and long-lived fission products partly in novel dedicated systems. For this purpose, the option of reprocessing must remain open. The plants involved should ideally be part of an integrated system, mainly to avoid or control undue transport and proliferation risks; their safety standards must be equivalent to those outlined before.

Partitioning and transmutation (P&T) aims at reducing the potential long-term impact of high-level nuclear waste in geological disposal sites by eliminating many of the actinides (long-lived radioactive isotopes) it contains. In order to eliminate these actinides, the spent nuclear fuel needs to be reprocessed – separating the elements that can be used again from those that will need to be disposed of directly – and then "recycled" by making new nuclear fuel and burning it in a nuclear reactor (preferably a fast neutron reactor). Multiple recycling can lead to a reduction in the mass of actinides going to final geological disposal by a factor of 100. The drawback, however, is that the fuel to be handled in such a recycling scheme becomes more highly radioactive, possibly demanding new reprocessing and fabrication techniques.

New debate

To introduce sustainable development as a guiding principle into decision-making processes, consensus needs to be reached among all participating groups about which criteria and indicators are to be applied, and, in addition, on how they can be aggregated and weighted.

Nuclear energy can only play a major role if one succeeds in increasing societal acceptance. This can be achieved only partly with technical solutions and innovative developments; it is just as important to convince society of the benefits of nuclear energy and to regain trust.[2] This also means that new forms of debate need to be found with stakeholder participation and reliable technical information as transparent input.

References

1. CEC Green Paper "Towards a European strategy for the security of nuclear energy supply", COM (2000) 769.
2. The TRUSTNET Framework, EUR 19139, 2000.
3. PSI/ETH Zurich: Energie-Spiegel Nr.3, Sept. 2000.

J. Schwartz*

Sustainable development and nuclear liability

The third party liability regime for nuclear energy is unique in many ways and addresses a number of relevant issues in the context of sustainable development. Although the high safety standards of the nuclear industry mean that the risk of an accident is low, the magnitude of damage that could result to third parties from such an accident is considerable. It was thus recognised from the very inception of the nuclear power industry that a special legal regime would need to be established to provide for the compensation of victims of a nuclear accident.

The ordinary rules of tort and contract law were simply not suited to addressing such a situation in an efficient and effective manner. If ordinary law were to be applied, victims would likely have a great deal of difficulty determining which one of the many entities potentially involved in the nuclear accident was actually liable for the damage caused. Also, without a limit on the amount of liability imposed upon the liable entity, that entity would not be able to obtain financial security (such as insurance) against that risk, thereby leaving victims with claims that could not be realised. In addition, accounting principles would prevent the operators of nuclear installations and the suppliers of nuclear goods and services from carrying such potentially large liabilities on their books, regardless of how unlikely a severe accident might be.

Special nuclear liability regimes were therefore established to overcome these disadvantages and now assure the following benefits: providing adequate protection to the public from possible damage; ensuring that the growth of the nuclear industry, from which this same public benefits, will be protected from excessively burdensome liabilities; marshalling international insurance market resources to ensure that sufficient financial security would be available to satisfy potentially large claims; and ensuring that liability and compensation mechanisms address the transboundary nature of nuclear damage. In order to provide these benefits, these regimes had to be based upon the following principles: a nuclear operator's strict and exclusive liability; limitations upon the time and amount of a nuclear operator's liability; and the nuclear operator's obligation to financially secure its liability.

National regimes reflecting these principles are implemented through legislation in most OECD Member countries, and progressively in non-member countries. The current international regimes which reflect these same principles are established by the following Conventions: the 1960 Paris Convention on Third Party Liability in the Field of Nuclear Energy established under the auspices of the OECD and to which 14 OECD Member countries from Western Europe are Contracting Parties; and the 1963 Vienna Convention on Civil Liability for Nuclear Damage established under the auspices of the International Atomic Energy Agency, which is worldwide in character and to which four OECD Member Countries[1] are Contracting Parties. These two Conventions are themselves linked by the 1988 Joint Protocol on the Application of the Paris Convention and the Vienna Convention.

Since the Chernobyl accident, the international nuclear community has recognised the need for extensive revision of the international regimes to enhance their provisions for protecting victims and to promote a global regime attractive to all countries. Those efforts resulted in the adoption, in 1997, of two new instruments: the Protocol to Amend the Vienna Convention and the Convention

* *Mrs. Julia Schwartz is a member of the NEA Legal Affairs Section (e-mail: julia.schwartz@oecd.org).*

on Supplementary Compensation for Nuclear Damage. Each instrument is designed to accord better protection to nuclear accident victims in all affected countries on a more equitable basis. In addition, ongoing negotiations to revise the Paris Convention and the Brussels Supplementary Convention, again with the objective of providing enhanced protection to victims of a nuclear accident, are expected to be completed in 2001.

The liability limit imposed upon nuclear operators under national legislation varies considerably between OECD Member countries. These variations result from the differing limits imposed under the various existing international nuclear liability instruments, from the extent to which these countries utilise nuclear power for energy production, and from other political and economic factors.

A few countries have adopted national legislation providing for the unlimited liability of their nuclear operators for nuclear damage. Of course, the corresponding financial security limits are, of necessity, limited, since no private or public resource is either able or willing to guarantee a totally unlimited amount of liability. The argument against limiting the liability of the operator is that the operator is subsidised by not having to face the full value of an accident, and will have less incentive to ensure safety, thus making an accident more likely. Yet on this specific safety issue, most OECD Member countries take the position that both the operator and the operating staff have a strong self-interest in plant safety, and that the operators are strictly regulated by competent, independent organisations.

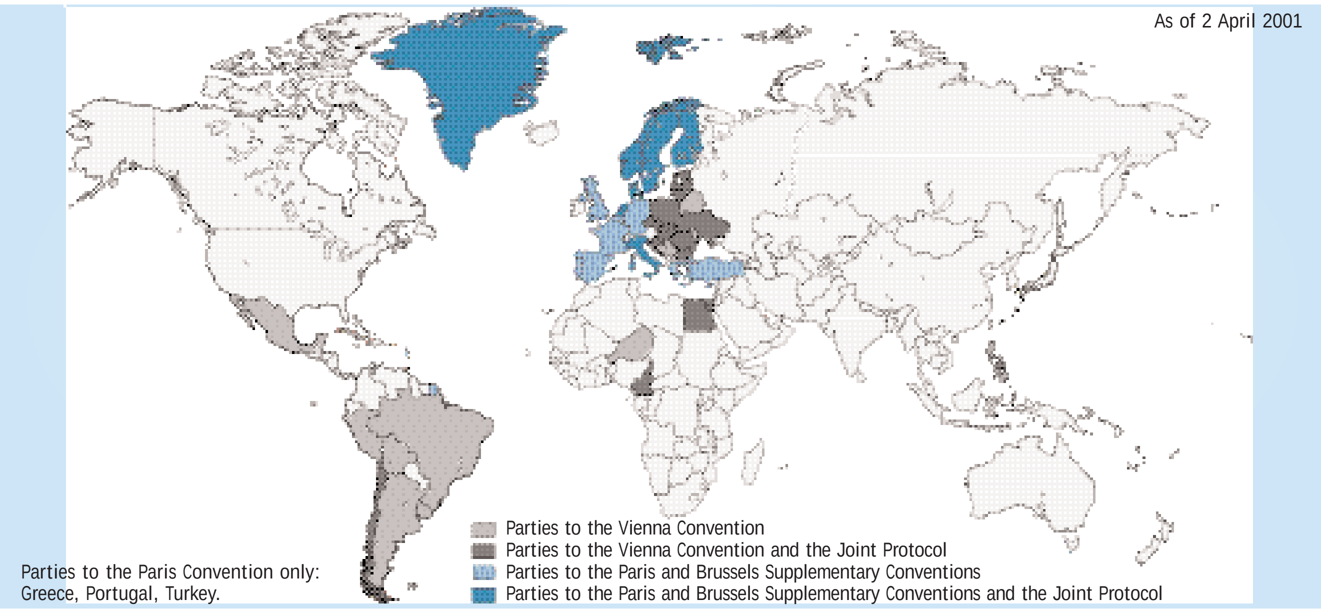
Conclusion

It is important to remember that the nuclear industry is one of the most highly regulated industries in modern-day society. In most OECD countries with developed nuclear power programmes, and even in those which possess only small research reactors, there are strict legislative requirements in place to ensure the health, safety and security of the public, including industry workers, as well as the protection of the environment. While this does not automatically mean that the goals of sustainable development are explicitly incorporated into the nuclear regulatory regimes of all such countries, it would be safe to say that such goals will have been taken into account to a significant degree. To the extent that a country's nuclear regulatory agency enforces such an interpretation, then that country is well on its way to achieving its sustainable development goals in relation to nuclear energy production and utilisation. If such a country adheres to a national or international third party liability regime designed to ensure equitable, adequate and realisable compensation to victims of a nuclear incident, it will have gone that much further. ■

Note

1. The Czech Republic, Hungary, Mexico and Poland each acceded to the Vienna Convention prior to becoming Member countries of the OECD.

Ratifications of nuclear third party liability conventions



New publications

Nuclear development

Actinide and Fission Product Partitioning and Transmutation

Sixth Information Exchange Meeting, Madrid, Spain, 11-13 December 2000

ISBN 92-64-18466-X – 132 pages – Free: paper or web versions.

The objective of the OECD/NEA Information Exchange Programme on Actinide and Fission Product Partitioning and Transmutation (P&T), established in 1989, is to enhance the value of basic research in this area by facilitating the exchange of information and discussions of programmes, experimental procedures and results. The Information Exchange Meetings form an integral part of the Programme and are intended to provide a biennial review of the state of the art in P&T. This book and its enclosed CD-ROM contain the proceedings of the 6th Information Exchange Meeting held in Madrid (Spain) on 11-13 December 2000. Recent developments and achievements and the new challenges in P&T are reported in four overview papers. Details are provided in the 79 papers that were presented during the meeting. The conclusions highlight some of the main aspects to take into consideration when planning future research and development on P&T.

Nuclear regulation

Improving Nuclear Regulatory Effectiveness

ISBN 92-64-18465-1 – 48 pages – Free: paper or web versions.

Ensuring that nuclear installations are operated and maintained in such a way that their impact on public health and safety is as low as reasonably practicable has been and will continue to be the cornerstone of nuclear regulation. In the past, nuclear incidents provided the main impetus for regulatory change. Today, economic factors, deregulation, technological advancements, government oversight and the general requirements for openness and accountability are leading regulatory bodies to review their effectiveness. In addition, seeking to enhance the present level of nuclear safety by continuously improving the effectiveness of regulatory bodies is seen as one of the ways to strengthen public confidence in the regulatory systems. This report covers the basic concepts underlying nuclear regulatory effectiveness, advances being made and future requirements. The intended audience is primarily nuclear safety regulators, but government authorities, nuclear power plant operators and the general public may also be interested.

Investing in Trust: Nuclear Regulators and the Public

Workshop Proceedings, Paris, France, 29 November-1 December 2000

ISBN 92-64-19314-6 – 324 pages – Price: € 60, US$ 54, £ 37, ¥ 6 050.

Good governance and efficiency in decision making by governmental authorities are increasingly dependent upon mutual trust and confidence between those authorities and the public. This workshop provided an opportunity to exchange information and views on how national nuclear regulatory organisations can improve their interface with the public.

Nuclear Regulatory Challenges Arising from Competition in Electricity Markets

Bilingual – ISBN 92-64-08460-6 – 34 pages – Free: paper or web versions.

In recent years a worldwide trend has been developing to introduce competition in electricity markets. As market competition unfolds, it produces a wide range of safety challenges for nuclear power plant operators and regulators. Nuclear regulators must be aware of the potential safety challenges produced and consider whether new regulatory response strategies are warranted. This report describes many of these challenges, their implications and possible regulatory response strategies. The intended audience is primarily nuclear safety regulators, although government authorities, nuclear power plant operators and the general public may also be interested.

Assuring Future Nuclear Safety Competencies

Specific Actions

ISBN 92-64-18462-7 – 58 pages – Free: paper or web versions.

In many countries, retiring nuclear safety experts are not being replaced by younger counterparts. This risks creating a shortfall in the number of experts available to ensure the effective regulation of the nuclear power industry. It could also result in the loss of much of the present nuclear safety knowledge base. This report discusses specific ways to maintain future nuclear safety competencies in nuclear regulatory authorities and the nuclear industry.

Nuclear safety

Nuclear Safety Research in OECD Countries

Major Facilities and Programmes at Risk

ISBN 92-64-18463-5 – 64 pages – Free: paper or web versions.

Major nuclear safety research facilities and programmes are facing increasing budgetary constraints, and in many cases are being closed or terminated. This report identifies major facilities of vital interest to the international nuclear safety community and makes recommendations for their continued operation in an international framework, either as joint projects or centres of excellence.

Radiation protection

Second International Nuclear Emergency Exercise INEX 2

Final Report of the Hungarian Regional Exercise

Bilingual – ISBN 92-64-08640-4 – 82 pages – Price: € 28, US$ 24, £ 17, ¥ 2 670.

The Nuclear Energy Agency (NEA) initiated its programme of International Nuclear Emergency Exercises (INEX) by a table-top exercise (INEX 1) which allowed the 16 participating countries to examine how their response mechanisms addressed the international aspects of a large-scale nuclear emergency. Based on the experience thus gained, a series of more realistic exercises, INEX 2, was organised by the NEA. These exercises used as a basis a national-level emergency exercise at an existing power plant, and aimed to achieve three international objectives: the real-time exchange of information, public information and decision making based on limited information and uncertain plant conditions. This report summarises the experience gained and lessons learned during the third INEX 2 regional exercise which took place in Hungary.

Experience from International Nuclear Emergency Exercises

The INEX 2 Series

ISBN 92-64-18464-3 – 42 pages – Free: paper or web versions.

In case of a nuclear emergency, countries need to be well prepared to manage a crisis situation. In order to help countries improve their emergency planning, preparedness and management, the OECD Nuclear Energy Agency (NEA) organised a series of international nuclear emergency exercises called INEX 2. This report summarises the lessons learned from all four exercises in the series, which took place in Switzerland (1996), Finland (1997), Hungary (1998) and Canada (1999), in the areas of: decision making based on limited information and on uncertain plant conditions; real-time exchange of information; public and media communications; and preparation and conduct of emergency exercises on an international level. The report will be of interest to both policy makers and technical managers in the nuclear emergency field.

Radioactive waste management

Nuclear Waste Bulletin

Update on Waste Management Policies and Programmes – No. 14 – 2000 Edition

ISBN 92-64-18461-9 – 136 pages – Free: paper or web versions.

The NEA *Nuclear Waste Bulletin* is prepared by the Radiation Protection and Radioactive Waste Management Division of the OECD Nuclear Energy Agency in order to provide a means of communication amongst the various technical and policy groups within the radioactive waste management community. It delivers concise information on current activities, policies and programmes in 18 NEA Member countries and 3 international organisations. It also provides biennial updates of progress in the development of technologies for the management and disposal of radioactive waste.

Confidence in Models of Radionuclide Transport for Site-specific Assessments

Workshop Proceedings, Carlsbad, New Mexico, USA, 14-17 June 1999

ISBN 92-64-18620-4 – 312 pages – Price: € 96, US$ 84, £ 58, ¥ 9 100.

GEOTRAP is the OECD/NEA Project on Radionuclide Migration in Geologic, Heterogeneous Media carried out in the context of site evaluation and safety assessment of deep repository systems for long-lived radioactive waste. Performance assessment of proposed waste disposal sites requires models of radionuclide transport through the geosphere. To be used in repository planning and development, these models must have the confidence of both national waste management programmes and the wider scientific community. The fourth GEOTRAP workshop, "Confidence in Models of Radionuclide Transport for Site-specific Performance Assessments" held in June 1999, addressed the issue of technical confidence building and provided an overview of current developments in this field. Proposed approaches to confidence building and approaches that have already proven successful were presented and discussed. In addition to the material presented during the workshop, this publication includes a technical synthesis reflecting the discussions that took place as well as the conclusions and recommendations made, notably during the working group sessions.

Gas Generation and Migration of Radioactive Waste Disposal

Safety-relevant Issues, Workshop Proceedings, Reims, France, 26-28 June 2000

ISBN 92-64-18672-7 – 190 pages – Price: € 45, US$ 39, £ 27, ¥ 4 300.

In underground repositories for radioactive waste, significant quantities of gases may be generated as a result of several processes. The potential impact of gas generation, accumulation and migration on the performances of the various barriers and, ultimately, on the long-term safety of a repository, should therefore be assessed in the development of safety cases for underground repositories. It was in this context that the EC and the NEA organised a workshop on "Gas Generation, Accumulation and Migration in Underground Repository Systems for Radioactive Waste: Safety-relevant Issues" in Reims, France on 26-28 June 2000. This book includes the texts of the invited presentations, the reports of the deliberations held in the five working groups, as well as the main conclusions of the workshop.

Using Thermodynamic Sorption Models for Guiding Radioelement Distribution Coefficient (Kd) Investigations

A Status Report

ISBN 92-64-18679-4 – 190 pages – Price: € 50, US$ 45, £ 31, ¥ 5 050.

A general consensus has been reached among technical experts that high-level radioactive waste can safely be disposed of in deep geological repositories. Safety studies are carried out to evaluate the overall capacity of a particular disposal site to confine waste and minimise radioactive releases. Since the principal way in which radioactive elements might eventually reach the biosphere is by transport of dissolved radionuclides in groundwater, the safety study calculations must be able to estimate their rate of transfer through each of the barriers surrounding the repository. It is well known that, for many radioelements, sorption reactions can lead to a reduction of the amount of radionuclides present in the solution phase. How best to take radionuclide sorption reactions into account in repository performance assessment models is the subject of this book.

Pressurised Water Reactor Main Steam Line Break (MSLB) Benchmark

Volume II: Results of Phase I on Point Kinetics

ISBN 92-64-18280-2 – 136 pages – Free: paper or web versions.

The benchmark is based on a well-defined problem concerning a PWR main steam line break, which may occur as a consequence of the rupture of one steam line upstream of the main steam isolation valves. This event is characterised by significant space-time effects in the core caused by asymmetric cooling and an assumed stuck-out control rod during reactor trip. It is based on reference design and data from the Three Mile Island Unit 1 Nuclear Power Plant (TMI-1). It includes a description of the event sequence with set points of all activated system functions and typical plant conditions during the transient. This report summarises the results contributed by international participants concerning Phase I of the exercise: point kinetics simulation to test the primary and secondary system model responses.

Pyrochemical Separations

Workshop Proceedings, Avignon, France, 14-16 March 2000

ISBN 92-64-18443-0 – 332 pages – Price: € 77, US$ 66, £ 46, ¥ 7 230.

The industrial treatment of spent nuclear fuel is presently performed using different wet chemical processes. Alternative dry processes, using pyrochemical methods, have received some attention due to their potential advantages in terms of plant design and criticality safety, as well as radiation dose. Recent progress in the transmutation of long-lived fission products and minor actinides has brought renewed interest in pyrochemical methods, as effective transmutation will be based on multi-recycling of the fuel with very high burn-up and short cooling times, conditions under which pyrochemical methods offer various advantages over wet processes. Studies of pyrochemical processes have so far been carried out at laboratory level. Considerable R&D work is still required in order to upgrade these processes to the current level of industrial aqueous processing.

Evaluation of Speciation Technology

Workshop Proceedings, Tokai-mura, Ibaraki, Japan, 26-28 October 1999

ISBN 92-64-18667-0 – 436 pages – Price: € 80, US$ 70, £ 49, ¥ 7 600.

It has been widely recognised among researchers that speciation data are essential for proper and reliable modelling of radionuclide behaviour, which is studied *inter alia* in the context of radioactive waste management. Participants at the OECD/NEA workshop on "Evaluation of Speciation Technology" reviewed the various techniques used to identify different species of actinide and fission product elements present in nuclear waste and nuclear reprocessing streams. The review takes into account the advantages, disadvantages and limitations of the various methods in relation to their field of application. Recommendations for future R&D are also provided. These proceedings will primarily be of interest to chemists specialised in separation techniques and radioactive waste management experts.

Shielding Aspects of Accelerators, Targets and Irradiation Facilities – SATIF 5

Workshop Proceedings, Paris, France, 18-21 July 2000

ISBN 92-64-18691-3 – 426 pages – Price: € 84, US$ 75, £ 52, ¥ 8 450.

Over the last 50 years particle accelerators have evolved from simple devices to powerful machines, and will continue to have an important impact on research, technology and lifestyle. Today, they cover a wide range of applications, from television and computer displays in households to investigating the origin and structure of matter. It has become common practice to use particle accelerators for material science and medical applications. In recent years, requirements from new technological and research applications have emerged, giving rise to new radiation shielding aspects and problems. These workshop proceedings review recent progress in radiation shielding of accelerator facilities, evaluating advancements and discussing further developments needed with respect to international co-operation in this field.

Nuclear Production of Hydrogen

First Information Exchange Meeting, Paris, France, 2-3 October 2000

ISBN 92-64-18696-4 – 244 pages – Price: € 55, US$ 49, £ 34, ¥ 5 550.

Hydrogen has the potential to play an important role as a sustainable and environmentally acceptable energy source in the 21st century. However, hydrogen does not exist as a gas on earth and thus has to be produced from, for example, water or natural gas by different separation techniques. One way to do so would be to use nuclear-produced energy or heat in this separation process. The present publication gives an overview of the advancements in the scientific and technological fields related to the nuclear production of hydrogen.

CD-CINDA 2000

Index to Literature and Computer Files on Microscopic Neutron Data

CD-ROM – Free on request.

Published on behalf of the USA National Nuclear Data Center, the Russian Nuclear Data Center, the NEA Data Bank and the IAEA Nuclear Data Section.

Where to buy NEA publications

For customers in North America

OECD Washington Center

2001 L Street NW, Suite 650, Washington DC 20036-4922, USA
Tel.: +1 (202) 785 6323 – Fax: +1 (202) 785 0350
Toll-free number for orders: +1 (800) 456 6323
E-mail: washington.contact@oecd.org – Internet: www.oecdwash.org

For customers in Asia

OECD Tokyo Centre

Landic Akasaka Bldg, 2-3-4 Akasaka, Minato-ku, Tokyo 107-0052, Japan
Tel.: +81 (3) 3586 2016 – Fax: +81 (3) 3584 7929
E-mail: center@oecdtokyo.org – Internet: www.oecdtokyo.org

For customers in Central and South America

OECD Mexico Centre

Av. Presidente Mazaryk 526, Colonia: Polanco,
C.P. 11560, Mexico D.F., Mexico
Tel.: +52 (5) 281 3810 – Fax: +52 (5) 280 0480
E-mail: mexico.contact@oecd.org – Internet: rtn.net.mx/ocde/

For customers in the rest of the world

OECD Paris Centre

2, rue André-Pascal, F-75775 Paris Cedex 16, France
Tel.: +33 [0(1)] 45 24 81 67 – Fax: +33 [0(1)] 45 24 19 50
E-mail: sales@oecd.org

Online Ordering: www.oecd.org/bookshop

Secure payment with credit card.

Where to order free NEA publications

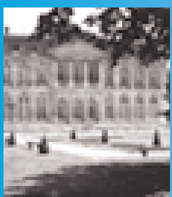
NEA Publications

12, boulevard des Îles, F-92130 Issy-les-Moulineaux, France
Tel.: +33 [0(1)] 45 24 10 15 – Fax: +33 [0(1)] 45 24 11 10
E-mail: neapub@nea.fr – Internet: www.nea.fr

Online Ordering: www.nea.fr

Employment Opportunities

OECD Nuclear Energy Agency



Vacancies occur in the OECD Nuclear Energy Agency Secretariat in the following areas:

- Nuclear Safety
- Radioactive Waste Management
- Radiation Protection
- Nuclear Energy Economics
- Nuclear Science
- Nuclear Law
- Nuclear Engineering
- Computing

Qualifications:

Relevant university degree; at least two or three years of professional experience; very good knowledge of one of the two official languages of the Organisation (English or French) and ability to draft well in that language; good knowledge of the other.

Vacancies are open to candidates from NEA Member countries. The NEA is an equal opportunity employer.

Initial appointment:

Two or three years.

Basic annual salary:

From FF 332 000 (Administrator) and from FF 476 000 (Principal Administrator), supplemented by allowances depending on residence and family situation.

Applications, in English or French (specifying area of specialisation and enclosing detailed curriculum vitae) should be marked “NEA/NL” and sent to:

Human Resources Management
OECD
2, rue André-Pascal
F-75775 Paris Cedex 16, France

Radwaste Solutions

THE MAGAZINE OF RADIOACTIVE WASTE MANAGEMENT AND FACILITY REMEDIATION

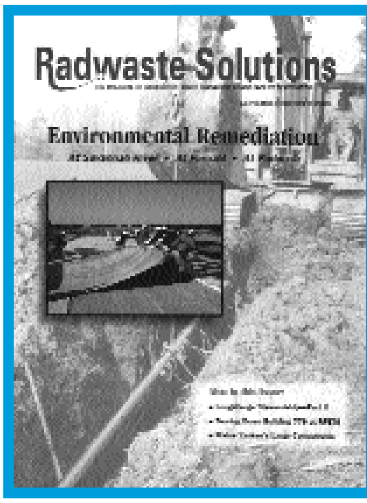
– *Don't miss an issue!*

Don't miss an issue of *Radwaste Solutions*, formerly *Radwaste Magazine*, which focuses on practical solutions to everyday problems and issues in radioactive waste management.

Published by the American Nuclear Society, the magazine covers all sectors – government, utility, private – that deal with radioactive waste. Also, it covers all elements of this work, including processing, packaging, storing, decommissioning, reutilization, transporting, and final disposal.

With each issue of *Radwaste Solutions* you get progress reports on cleanup/remediation/decommissioning projects; news and views from industry leaders and professionals; coverage of industry conferences you can't find elsewhere; and technical information that can help your project.

Look at some of the articles that the magazine's recent issues have presented to our readers:



- Low- and intermediate-level waste management in Spain
- Everything you ever wanted to know about the Hanford waste tanks
- The end of an era: Decommissioning four German fuel cycle facilities
- Bringing new technologies to the D&D toolbox
- Radwaste management at U.S. nuclear power plants: Where we are today (and how we got there)

On top of great content, we make it easy to subscribe. Take your choice: Give us a phone call (708/579-8208); send us a fax (708/579-8314); or zip us an e-mail (accounting@ans.org). We'll get the process moving so that you start receiving your own copy of *Radwaste Solutions*.

Please enter a 2001 subscription to *Radwaste Solutions* for:

Name ______________________________

Company ______________________________

Street Address ______________________________

City______________ State/Province ______________

Postal Code__________ Country ______________

Tel.__________ Fax__________ E-mail______________

Add $25 for each overseas subscription
Add $30 for funds drawn on non-U.S. banks
(All orders must be prepaid in U.S. dollars.)

Payment method:

❍ Check (payable to ANS) ❍ Money order ❍ MasterCard
❍ Visa ❍ AMEX ❍ Diners Club

Acct. no.______________________ Exp. date ______________

Signature______________________________________

Check one:

❍ Yes! I want to subscribe to *Radwaste Solutions* at $35.00 per year. (I am a member of the American Nuclear Society.) ANS Membership ID no.______________

❍ Enter my library subscription at $355.

Send to:
Radwaste Solutions
American Nuclear Society
P.O. Box 97781
Chicago, IL 60678-7781
USA
(Make check payable to American Nuclear Society)

Credit card orders:
Facsimile 708/579-8314
ANS members call 708/579-8266
Nonmembers call 708/579-8208

OECD PUBLICATIONS, 2 rue André-Pascal, 75775 PARIS CEDEX 16
PRINTED IN FRANCE
(68 2001 01 1 P) ISBN 92-64-19107-0 – No. 51903 2001
ISSN 1605-9581