ENERGY & ENVIRO

THE DRIVE FOR SAFER, CLEANER D

The world's drive toward safer and cleaner development overcame some big hurdles during the past ten years, only to see more challenges arise. One major question echoed ever louder: how will governments decide to *fuel* and engineer the drive into the next century?

The echo resounded from some events taking place twenty-five years ago. Then, the international human environment conference in Stockholm brought many "green" issues out of scientific laboratories, and the first oil shocks jolted and jaded energy development prospects. In the 1990s, the complex set of challenges seemed to merge on the global conference stage: rising electricity demands in Helsinki in 1991; stark environmental threats in Rio de Janeiro at the 1992 Earth Summit; world population growth rates in Cairo in 1994; problems of over-crowded megacities in Istanbul and hunger in Rome in 1996; and the Earth Summit revisited in New York in 1997. Ahead in Kyoto in early December 1997 is the complex topic of global warming. Governments want a global treaty on climate change and will meet to debate its provisions.

Hovering above it all have been the dramatic political changes in Europe after the breakup of the Soviet Union. These changes opened the window to energy, environmental, and safety problems in countries of the former Soviet bloc.

The overriding message on all these fronts: some important progress has been made, but not enough to celebrate yet. In the political, environmental, and economic flux, ensuring sustainable development will not be easy, quick, or cheap.

At the IAEA, the far-reaching demands became the backdrop for laying a stronger legal and technical foundation to support safe, clean, and competitive nuclear energy development for countries using or thinking of using that option. Countries also sought to demonstrate more clearly how the whole range of nuclear technologies can help solve specific energy and environmental problems. Major platforms built for the new foundation include:

- A strengthened and more integrated global safety regime for key areas of nuclear power, radiation applications, and radioactive waste management. It covers new legal agreements and strengthened safety services. *(See box, page 31.)*
- More specialized technical support to countries for achieving better nuclear power plant performance, upgrading or dismantling older plants, developing advanced types of power reactors, managing growing stockpiles of spent nuclear fuel, and comparing overall energy and electricity options under particular conditions.
- Technical assistance and research projects targeted to help more countries establish and upgrade their regulatory infrastructure for the safe uses of nuclear and radiation technologies, and to improve waste management capabilities in all fields.
- Scientific support of assessments associated with "historical" radioactive wastes from past nuclear practices, and of customized applications of nuclear-based techniques in investigations of climate change, environmental pollution, and marine ecological threats. *(See box, page 37.)*

As the decade opened in 1986, twenty-six countries were getting ready to mark a milestone of nuclear power experience: their 397 electricity-generating plants collectively neared four thousand years of commercial operation. The Chernobyl accident in April changed everything, and ushered in trying times at the IAEA. Within five

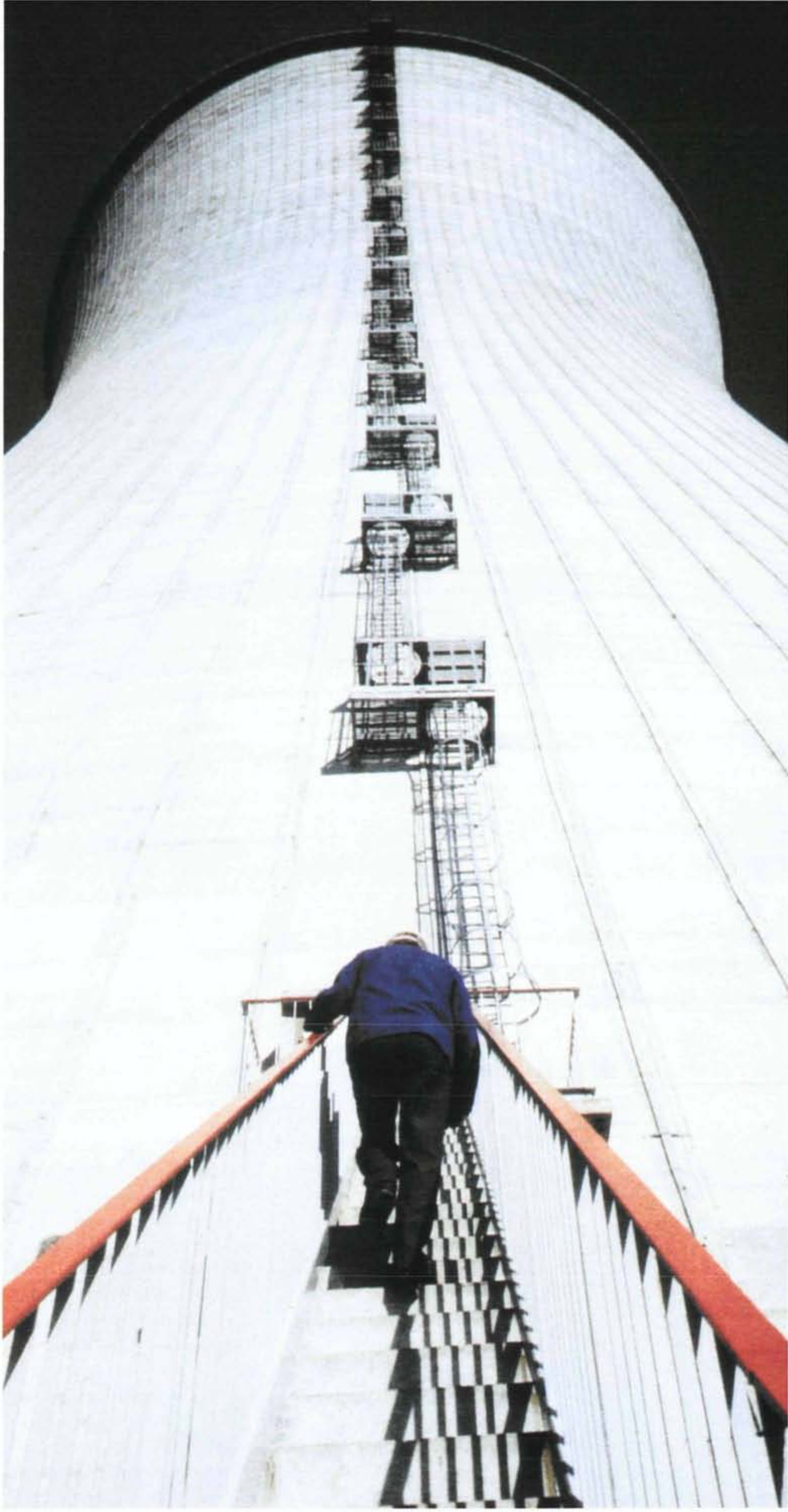
Photo: A climb to the top at Bugey plant in France, where most households, businesses, and industries rely on electricity produced by nuclear energy plants. (Credit: Setboun/Rapho Agence de Press Photographique)

NMENT

EVELOPMENT

months of the accident, States working under the international spotlight at the Agency issued their first responses: they negotiated and adopted two new global legal agreements on nuclear safety, delivered the first authoritative account of the accident, and set in motion plans for expanded safety services and assistance. Throughout the decade, the legal and technical safety regime was reinforced, and today more new elements still are being considered. Just as important, social, health, food, environmental, and nuclear scientists joined together to clarify the actual and potential consequences of the Chernobyl accident. (*See page 24.*)

For nuclear power development, the technical impact of the accident — affecting essentially a small group of Soviet-designed plants operating in only a few countries — extended, like its fallout, well beyond national borders. Lessons learned magnified the imperative of securing an industry-wide "safety culture". Steps to reinforce the safety net quickly gained momentum for business and environmental reasons, and to help win back public support lost in many countries. A few industries and governments sought to phase out their nuclear power programmes, while others suspended or postponed construction and planned projects. On



HOW SERIOUS?

Assessing the seriousness of global warming threats — and evaluating existing and potential responses — has challenged scientists for years. By the mid-1990s, an international scientific consensus had emerged: the 2500 experts taking part in studies of the International Panel on Climate Change (IPCC) issued a report with a guarded but direct message: if energy technologies remain unchanged and demand increases substantially, average temperatures might rise between one and 3.5 degrees Centigrade over the next century. This could cause sea levels to rise fifty centimeters, with ensuing flooding of coastal lowlands and tropical islands, an increase in weather extremes, and damage to forests and croplands. The IPCC outlook has been challenged, but has not been changed.

The issue is complex, and projections harbour considerable uncertainties. To understand more fully and quantify the changing climate picture, scientists need extensive data and powerful analytical tools and models. Among them are isotopic techniques. Using them, scientists examine historical records by taking measurements of ice cores, ancient groundwater, lake deposits and sediments, and estimate the impact of human activities from the results. This information supports forecasting potential effects on forest ecosystems, desertification, and water resources, as well as the possible occurrence of floods and droughts. Isotope methods also prove essential for determining precisely the atmospheric budget of greenhouse gases, especially their sources and sinks, to enable prediction and identification of the impacts of climate change.

Long-term studies also are tracking how carbon moves and sinks in oceans, seas, and lakes. From their laboratories in Monaco, IAEA scientists over the past decade intensified work to investigate the transfer of carbon from its source to ocean depths, work which combines collection and analysis of sinking marine particles with isotope studies.

In support of research, the World Meteorological Organization (WMO) in Geneva and the IAEA operate a global network for tracking and analysis of key isotopes in precipitation. By the mid-1990s, the network contained data from more than 450 locations worldwide.

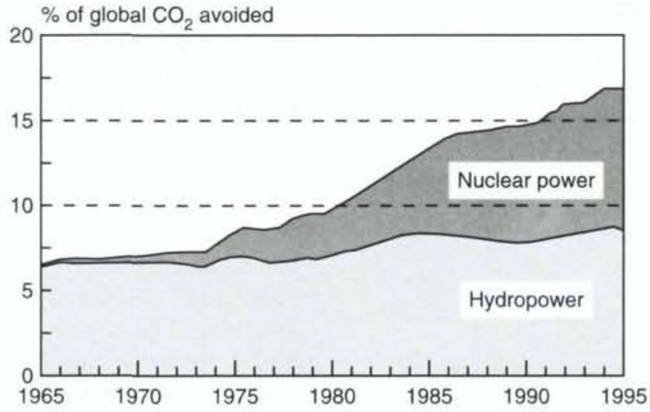
Other IAEA-supported programmes enlist experts in joint evaluations of responses to the threat of global warming, often pro-

record, most governments took a longer, qualified view, staying in favour of nuclear's safe expansion or of steps to keep the option open.

By the mid-1990s, the future of nuclear power looked dimmer. But lights were still on — a good share of them literally powered by nuclear energy. About five new nuclear plants per year — forty-seven altogether — have come on line since 1986, based on reports to the Agency's database. Nuclear's share of total electricity worldwide has held steady, rising only slightly in the 1990s to reach seventeen percent by 1997. Today, more countries than ever are generating one-quarter or more of their total electricity using nuclear power — seventeen States in 1996, seven more than ten years ago (among them Newly Independent States). By 1997, more than 440 nuclear plants were on line in thirty-one countries. They collectively produced about fifty percent more electricity than the Soviet Union produced from all sources ten years ago.

Seen by forecasters, the overall energy picture looked daunting as the years passed. By 1997, projections indicated that world energy demand would grow rapidly into the next century. Analysts said growth would be fastest in developing countries in order to keep up with rising populations and economic growth. Over the longer run, energy demand could climb anywhere between fifty and seventy-five percent in the next twenty-five years, according to the World Energy Council. Any rate of growth will stay closely tied to fossil fuel combustion. In 1997, these fuels continue to provide nearly eighty-five percent of all commercial energy used. When burned to generate electricity, fossil fuels also release carbon dioxide and other greenhouse

AVOIDANCE OF CO_2 EMISSIONS BY NUCLEAR AND HYDROPOWER



viding them with customized computer-based tools for analysis. A multi-agency project called Decades was started in the 1990s to support comparative assessments of energy options, specifically for generating electricity. Results of comparative studies reported over the past decade show far lower emissions of carbon dioxide in countries using nuclear and hydropower extensively than in countries burning large amounts of coal for electricity generation. Globally, nuclear power generates about seventeen percent of the world's electricity. That production has helped countries avoid a good share of carbon dioxide emissions, about eight percent of the world's total in 1995, or roughly as much as hydropower helped avoid.

In addition to nuclear, IAEA projects help develop other "clean" energy sources such as geothermal energy. In countries like El Salvador and the Philippines, Agency-sponsored projects have helped to evaluate and further develop geothermal resources. Nuclear analytical techniques helped to reliably assess temperature and fluid flows deep inside El Salvador's old volcanoes, and to identify potential new fields for development. Data can help save millions of dollars in drilling costs and lead to other savings. Geothermal production in El Salvador is already expected to cut oil import costs by about $9 million.

— Based on reports by Klaus Froehlich, Ms. Lucille Langlois, Ms. Jane Gerardo-Abaya, Florin Vladu, David Kinley, and Murdoch Baxter.

gases into the atmosphere. Less than fifteen percent of total energy comes from carbon-free hydropower and nuclear power, the two main alternative options. At present, only about one percent of all energy used comes from solar and other renewable sources. As environmental issues and notably global warming command closer watch, more people wonder what is in store, and what can be done today. (*See box above.*)

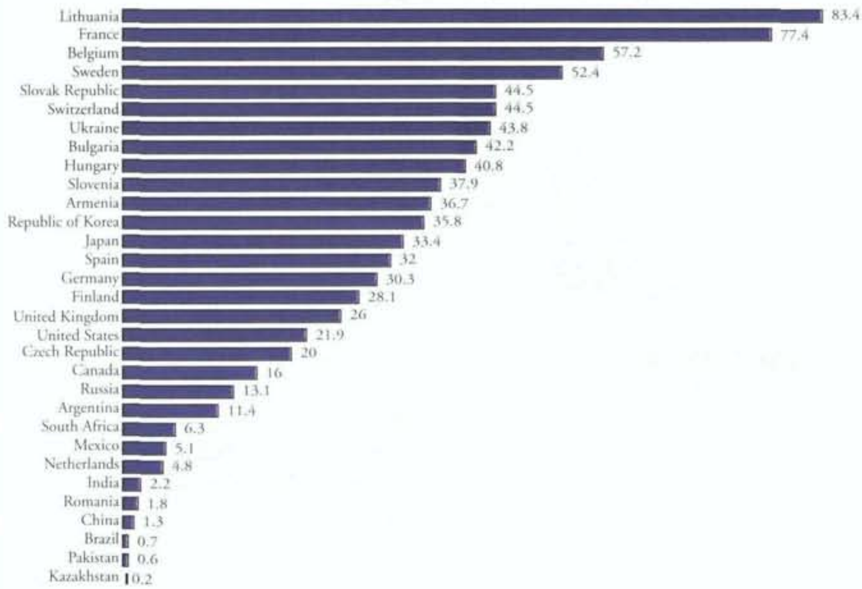
In the energy marketplace of the past ten years, political and economic changes have been influencing directions and thinking, too. Studies still find that electricity consumption and economic growth go hand-in-hand, even as conservation and other efficiency measures have worked to hold down overall energy growth rates.

As the decade moved on, other changes materialized to affect energy trends, including those of nuclear power. In some industrialized countries, "least-cost" generation options became more important in increasingly deregulated electricity markets. One result was greater political and economic pressures on nuclear plant performance. In other countries, confronted with leaner times, a central challenge for the nuclear industry became preserving a cadre of personnel with the necessary expertise and operational experience. In countries with emerging market-oriented economies, the pocketbook became a problem: financing the monthly earnings of highly trained nuclear plant staff raised energy and safety concerns transcending national boundaries.

Worldwide, nuclear industries were nearing another milestone by the mid-1990s: collectively, their plants approached eight thousand combined years of nuclear operating experience.

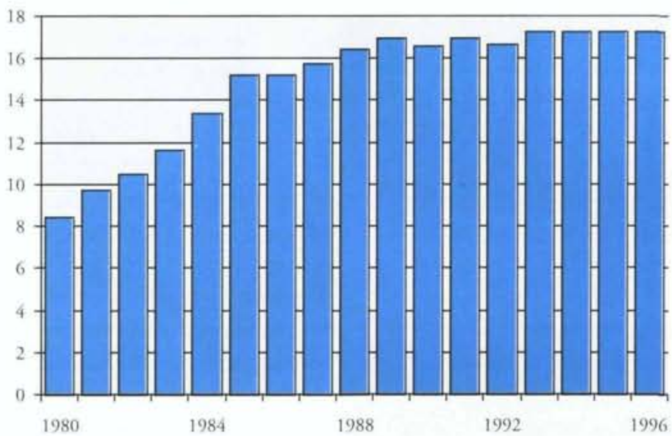
In developing countries, trends in nuclear development stayed mixed. Some States, as those in Asia, invested heavily in nuclear-fueled plants to free

NUCLEAR SHARE OF ELECTRICITY GENERATION, percentage as of January 1997



NUCLEAR POWER GROWTH

1980-1996, percentage of total electricity generation



themselves from dependence and costs of foreign supplies, chiefly oil, or from heavy reliance on coal. China's average electricity use grew ten percent a year during the past decade, and plans call for sixteen large coal and nuclear plants to help meet demands into the next century.

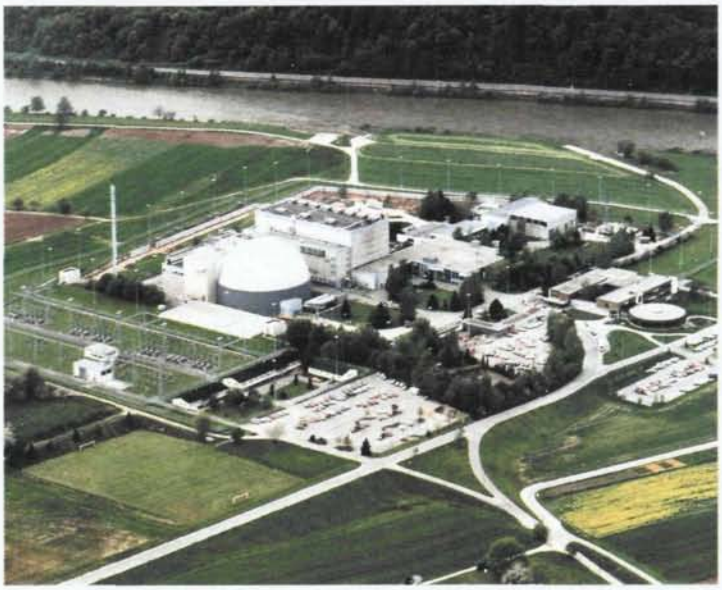
At the start of the decade, in 1986, the World Bank estimated at an IAEA meeting that an investment in electric power then valued at $522 billion (not including interest) would be needed through 1995 to meet projected rising electricity demands in developing countries. That amount represented roughly sixty percent of all the money spent on weapon systems in just one year of the past decade. Even now, the shortage of generating capacity in developing countries persists, and financing any energy project, particularly capital-intensive nuclear projects, remains a stiff challenge. About seven of every ten households in the developing world have no electricity.

Throughout the 1990s, the World Bank, IAEA, and other organizations grappled with the financing picture. Special projects and programmes assisted specific countries in identifying and evaluating different types of financing arrangements. Viable approaches emerged that were applied in several countries.

Other experts took aim at another drawback for many developing countries: the large size of typical commercial nuclear plants compared to the capacity of national grids. They again reviewed the need and market for smaller generating units, and Russia, Argentina and other developing countries emerged as potential suppliers of smaller nuclear power reactors. Possible greater use of such smaller units was studied, though mainly for non-power applications such as the supply of heat for residential and industrial needs, or for desalination facilities. (*See box, page 20.*)

Generally on the economic side, studies showed nuclear power holding its own against competing fuels. Analyses done in association with other organizations showed that nuclear power costs were roughly equal to those of coal, and in some cases to natural gas in terms of generating costs. One aspect of nuclear power — the relatively low cost of fuel — showed an upturn in the 1990s. The uranium market rebounded signif-

SAFETY FIRST



Milestones were achieved over the decade, and others are near, that fortify the global legal framework for nuclear and radiation safety. States put into place new international agreements under Agency auspices that legally bind them to achieve and maintain high levels of safety. Over the past decade, national authorities also increasingly drew guidance from, or entirely incorporated into their regulations, advisory safety standards issued through the Agency's longstanding work. Some of these were newly revised or structured in the 1990s.

The coming challenges for States supported by the IAEA will be to effectively implement the legal agreements, and to secure greater compliance with established safety standards. They are designed to help countries avoid losses from serious accidents. At industrial radiation processing facilities, several serious accidents involving workers occurred over the past decade that could have been prevented. In two new reports, IAEA specialists analyzed the most recent serious accidents and drew attention to specific lessons that should be learned from them.

The strengthened legal framework includes the:

- **Convention on Nuclear Safety**. States adopted this milestone agreement in 1996 that commits them to achieve and maintain high safety levels. They are obligated to meet international benchmarks in major areas of regulation, management, and operation of land-based nuclear power plants. A central feature is a peer review process of national reports on steps States have taken to fulfill their obligations. The first review meeting has been set for April 1999. Through August 1997, forty countries were parties to the Convention, including nearly all States having nuclear power programmes. Sixty-five countries have signed it.

- **Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management.** This agreement — negotiated by States meeting at the IAEA over the past two years — was adopted in September 1997 at a Diplomatic Conference in Vienna. It covers applications in the civilian sector and obliges parties to take appropriate steps for ensuring the safe and environmentally sound management of radioactive waste and spent fuel, and for preventing accidents with radiological consequences. It includes peer reviews of national reports at periodic meetings.

- **Protocol to Amend the 1963 Vienna Convention on Civil Liability for Nuclear Damage and Convention on Supplementary Funding.** States have negotiated these two instruments at the IAEA in the 1990s that together revise the international regime for nuclear liability. They were adopted by States meeting at a separate Diplomatic Conference in Vienna in September 1997.

- **Convention on Early Notification of a Nuclear Accident and the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency.** These two Conventions were adopted in 1986 within months of the Chernobyl accident. The first one establishes an early alert and notification system for potentially severe nuclear accidents that could involve radioactive fallout crossing national borders. Notification is made to the affected States directly, or through the IAEA, which set up an Emergency Response System as its focal point. As its name implies, the assistance Convention obliges States to facilitate emergency support and to notify the Agency of their available experts, equipment, and other materials for providing assistance. As of August 1997, seventy-eight States were parties to the notification Convention, and seventy-four States to the assistance Convention.

Convention on the Physical Protection of Nuclear Material. This agreement, which entered into force in 1987, addresses security of materials during international nuclear transport by obliging parties to ensure the protection of nuclear material within their territory or on board their ships or aircraft. In 1992, the first Review Conference was held in Vienna at which parties reconfirmed their commitments. They also expressed their conviction that it provides an appropriate framework for global cooperation in protection, recovery, and return of stolen nuclear material and in the application of criminal sanctions against those who commit criminal acts involving nuclear material. As of August 1997, fifty-seven States were parties.

The IAEA's advisory nuclear and radiation safety standards include the:

International Basic Safety Standards for Protection Against Ionizing Radiation and the Safety of Radiation Sources (BSS). A milestone was achieved in the mid-1990s when an unprecedented international effort involving the IAEA, WHO, and three other organizations led to revised global radiation standards. The BSS cover general and detailed requirements for a broad range of activities, and are an outgrowth of a vast amount of new scientific information accumulated over the past decade. They follow 1990 recommendations of the International Commission on Radiological Protection (ICRP), which introduced lower radiation dose limits for workers and the general public. The BSS also incorporate the Commission's recommendation that exposures from more than one source of radiation should be taken into account, including potential hazards from accidents. Supplementing the BSS are a range of supporting documents that provide specific guidance in applying the standards.

Nuclear Safety Standards (NUSS). A backbone in the field, the extensive NUSS advisory codes and guides cover nuclear power plants. Topics are related to governmental organization, siting, design, operation, and quality assurance. NUSS codes and some guides were revised over the past decade, steps that included issuance in 1996 of fifteen documents on quality assurance. Separate Agency safety standards cover design and operational aspects of research reactors.

Radioactive Waste Safety Standards (RADWASS). Developed through a programme started in the early 1990s, these standards draw upon extensive safety documentation on waste management issued by the Agency since its formation. They cover an extensive range of topics related to the safe management, including storage and disposal, of wastes from nuclear facilities, hospitals, industry, and research. Also addressed are waste discharges, decommissioning of facilities, and environmental restoration. The leading document was issued in 1995 and establishes the basic principles and concepts for safe radioactive waste management. These are now being elaborated in supporting documents.

Regulations for the Safe Transport of Radioactive Materials. First issued in 1961, these advisory regulations define the basic rules now largely adopted throughout the world for transporting virtually all radioactive material. Their objective is to protect the public, transport workers, property, and the environment from the effects of radiation exposure during transport. A revised edition was issued in 1996. It takes into account the ICRP's 1990 recommendations and the Agency's Basic Safety Standards. It also introduces a new type of package for air transport that must meet more stringent criteria than existing types. A number of safety guides support the regulations.

For all Agency standards, their collective profile was uniformly raised in recent years. A renewed and more uniform preparation and review process was initiated in the mid-1990s under the responsibility of a newly created Department of Nuclear Safety. Also established was a set of five separate advisory bodies. Each has a membership of about fifteen senior governmental officials that work from harmonized terms of reference to review and guide the safety standards programmes.—*Based on reports by Abel Gonzalez, Director of the IAEA Division of Radiation and Waste Safety, and staff of the Agency's Legal Division.*

Photo: One of Germany's nuclear power plants that together provide about thirty percent of the country's electricity.

icantly. Global assessments about its resource base and production also became more thorough. Key data from Russia and other former Soviet-bloc countries were made available for the first time at an IAEA technical meeting.

For the IAEA's involvement in nuclear power, the decade's unfolding economic and environmental realities translated into new challenges and opportunities. Overall, technical programmes became more closely bound to plant safety, performance, and waste-related issues.

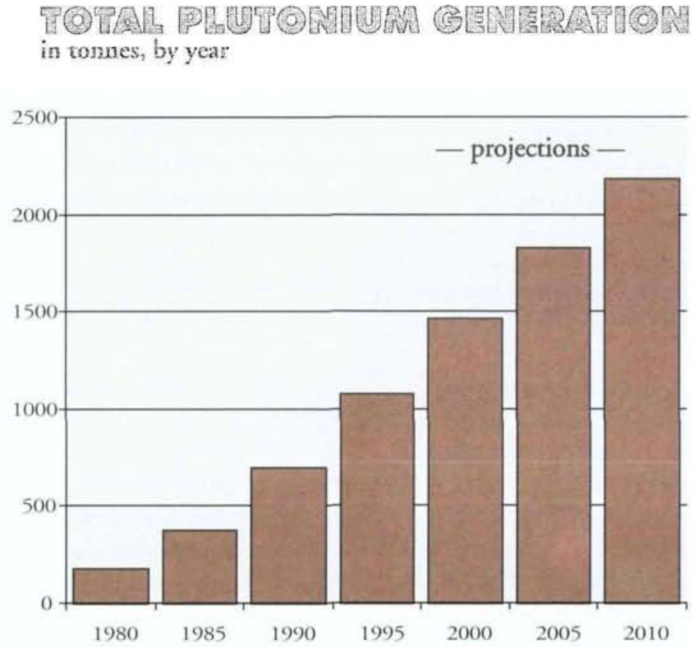
An overriding aim was to assist more countries in building better capabilities for safe and reliable nuclear operations within the framework of the Agency's international standards.

Over the past fifteen years, Agency-supported technical assistance projects invested $100 million in training and hardware support related to nuclear safety. This support went primarily to the seventeen developing countries using or considering use of nuclear power. Agency technical assistance included helping to build an on-site training simulator for nuclear plant operating staff, the first of its kind, in Hungary, for which surplus parts from idled plants in Germany and Poland were used. In the early 1990s, the Agency was one of the first organizations to point out deficiencies at Bulgaria's Kozloduy plant. These findings spurred assistance through the IAEA's expanding safety programmes. The Agency also flagged the need for greater combined efforts to confront problems at that plant and others like it in Central and Eastern Europe. In Bulgaria, technical assistance has since expanded to cover seismic evaluations, as it does in several other countries. The aim is to help make sure nuclear units withstand earthquakes, even those rated higher than the one Japan's reactors withstood successfully during the decade.

Importantly, Agency efforts helped put in place better preventive maintenance and operational controls at nuclear plants over the past ten years. Through programmes to modernize training approaches and instrumentation systems, the work extended beyond the Chernobyl-type units to encompass other reactor types. A far greater share of incidents at plants also were peer-reviewed and technically analyzed for "lessons learned". IAEA-supported or initiated global information networks and safety services linked with national regulatory systems provided a central mechanism.

Worldwide, nuclear plant performance improved throughout the 1990s. Agency evaluations tracked a common indicator — the"energy availability factor", measuring how close to capacity the units perform. The factor rose nearly seven percent in the 1990s, and by 1996 was approaching an eighty percent average. Another indicator — energy losses from plant outages — dropped to below five percent, approximately equal to that of fossil-fuelled plants. Also gaining ground was the operational performance of nuclear fuel at light-water reactors, the predominant type in operation. In the 1990s, IAEA-supported fuel research expanded to twenty-six countries and three international organizations. Technical assistance in fuel behaviour studies was extended to newly independent countries in Eastern Europe and to the types of fuel used at reactors in operation there.

Next generation plants, as they are popularly known, were introduced in some countries during the decade. Common goals for new designs include greater reliability, better economics, and enhanced safety. Annual investment in research and development of different types of advanced nuclear plants grew to an estimated $2 billion in 1996. Most attention focused on "evolutionary" concepts that build upon today's best features and add others. By 1996, some types of advanced reactors came on line or were nearing operation in the Far East, Europe, and North America, while others will take longer to develop and demonstrate. IAEA international working groups on advanced reactor design development are at the forefront of cooperative work. The experts meet periodically to exchange experience and advise the Agency on research needs, particularly involving technical and information links between researchers in developing and industrialized countries. Another type of future nuclear energy system drew more interest over the decade in Japan, France, Russia, and at the European Nuclear Research Centre (CERN). It relies on machines called accelerators that produce high energy pro-



ton currents. An attraction is that these systems, when merged with fission reactor technologies, hold the promise of producing electricity using nuclear fuels, while at the same time destroying plutonium and long-lived radioactive materials.

New realities at the "back end" of nuclear's fuel cycle meant adjustments had to be made. Managing greater amounts of spent fuel became a pressing issue in many countries, and took on high priority at the Agency. In 1985, the world's cumulative inventory of spent fuel was about 30,000 tonnes of heavy metal. Volumes by the turn of the century are now estimated six times that high, and Agency analysts foresee steady though slower growth beyond that time. Although considerable, these volumes are far smaller and more easily isolated from the environment than waste from fossil fuel plants, which is mostly released into the atmosphere. Used nuclear fuel is either reprocessed or prepared for containment in engineered storage facilities. So emplaced for extended time periods, its radioactivity level decays significantly. In support of national efforts to keep fuel safely stored and managed, the IAEA expanded its technical, research, and advisory services. Mainly involved are countries starting up storage facilities or those studying how spent fuel behaves under storage conditions extending beyond fifty years.

For receiving most types of radioactive wastes, more engineered disposal sites had opened or were in planning by 1997. But political decisions slowed progress toward plans for construction of deep geological repositories engineered to hold high-level radioactive wastes and spent fuel. (*See box, page 39.*)

From other directions, the spectre arose of what some called a "plutonium economy". The end of the Cold War saw the dismantling of nuclear weapons and the controlled entry of plutonium into the civil marketplace. The USA has declared fifty tonnes as surplus, and it is assumed Russia will also release as much. Overall, concerns were principally compounded by several factors: an expanded reprocessing industry for the recycling of plutonium, and delays in commercializing more fast-breeder reactors, which are able to burn plutonium. These factors together contributed to rising global plutonium inventories. *(See graph.)*

Action launched through the Agency included setting up a database and methodology to track inventories and reliably project them; developing guidelines for safe handling and storage of large amounts of separated plutonium; and developing a methodology to address concerns related to nuclear proliferation from the standpoint of different fuel-cycle concepts. The IAEA has helped to negotiate controls required to prevent the potential reuse of ex-military plutonium for weapons and to protect the public from its radiation.

Other issues arose just from the industry's advancing age. Countries marked the fortieth anniversary of nuclear power as a commercial energy source in the mid-1990s, and many plants are decades old. Renewed interest surfaced in what the *Financial Times* called "the science of nuclear gerontology". More than one hundred plants worldwide were nearing retirement at a typical age of forty. Many of them are destined to be decommissioned, a process involving site cleanup and restoration. Others are being refurbished and upgraded to extend their lifetimes by about twenty years. More countries began to seek guidance through IAEA channels to learn the best practices being followed in the industry for "life extension" and for experience acquired in decommissioning and site restoration. Importantly, the Agency recently issued interim guidelines for such activities to more fully elaborate its safety standards.

Age-related issues, among others, also affected the world's several hundred research reactors, whose uses range from scientific investigations to the production of radioisotopes used in medicine and other fields. Most of these reactors were built in the 1960s.

A particular technical, as well as political, issue was the disposal and safe storage of used fuel from research reactor facilities. About sixty countries are now operating research reactors. When most of these were built about twenty-five years ago, it was assumed that the spent fuel would eventually be shipped back to its foreign suppliers, chiefly the United States and former Soviet Union.

Agency efforts intensified in the mid-1990s to assess the situation and help operators of research reactors identify and take remedial measures. The work encompassed fact-finding missions, training courses. and advisory technical services on the best ways to store the spent fuel. It also involved working with governmental authorities in the USA, Russia, and other countries on further steps that could be taken. The USA has established a programme to take back any spent fuel it had originally supplied to fuel research reactors, and as the decade closed, authorities in the Russian Federation were being encouraged to do likewise.

What is the outlook at this stage? Long before the decade closed, it became apparent that nuclear power prospects, and the future of related IAEA programmes, would depend on several key factors. As David Fischer writes in his history of the Agency, they include:

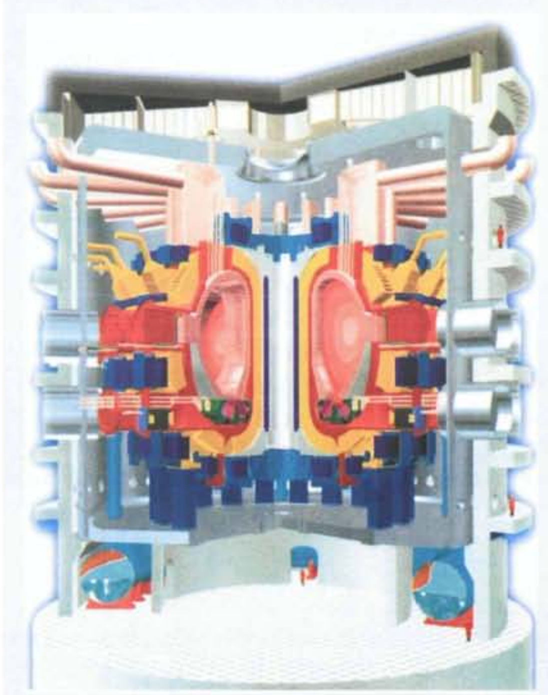
- Future demand for electricity, especially in Asia, where growth trends appear strongest.
- The relative cost of generating electricity by burning fossil and nuclear fuels.
- Stagnating demand for electricity in most countries of North America and Western Europe. In most of these countries, the only rapidly expanding source of energy for electricity generation is natural gas.
- Maintaining a superior safety record for nuclear energy, including its waste products, to counterbalance the memories of Chernobyl.
- Persuading the public that radioactive waste can be disposed of without endangering the health of future generations. The technology is available, but public confidence is lacking.
- And finally, how seriously the world takes the threat of global warming, which stems largely from "greenhouse gases" emitted by fossil fuels. This applies particularly to North America and Western Europe. There, except in France, nuclear energy programmes do not seem likely to flourish unless drastic steps are taken to curb the use of fossil fuel for electricity generation. It also applies to two Asian countries, China and India, where energy consumption and burning of coal seem bound to grow massively in the next century.

At the global level, Mr. Fischer's review finds that world energy development may be going off course if the nuclear option is rejected. The Intergovernmental Panel on Climate Change (IPCC) is the main international body assessing the impact of greenhouse gases on the world's climate. The IAEA provided the Panel with a considerable amount of material, he notes, but in 1994 the IAEA went on record as stating that the draft assessments the Panel made in that year did not "adequately reflect the potential contribution that nuclear energy could make to meeting energy demands while reducing carbon dioxide emissions." Subsequently, the head of the International Energy Agency of the Organization for Economic Cooperation and Development (OECD) noted in a statement to a UN meeting that "nuclear energy [had] accounted for the greater part of the lowering of carbon intensity of the energy economies of the OECD countries over the last 25 years."

Nonetheless, Mr. Fischer concludes, "...the past years have shown how difficult a task it will be to persuade energy authorities and governments, in almost all countries concerned and particularly in developing countries like India and China, to pay the cost of reducing carbon dioxide emissions and to persuade the public that nuclear energy is one of the viable solutions to the problem of global warming. The reluctance of the IPCC to recognize the potentially benign role of nuclear energy was another pointer in this direction."

"MINI-SUNS" FOR ENERGY

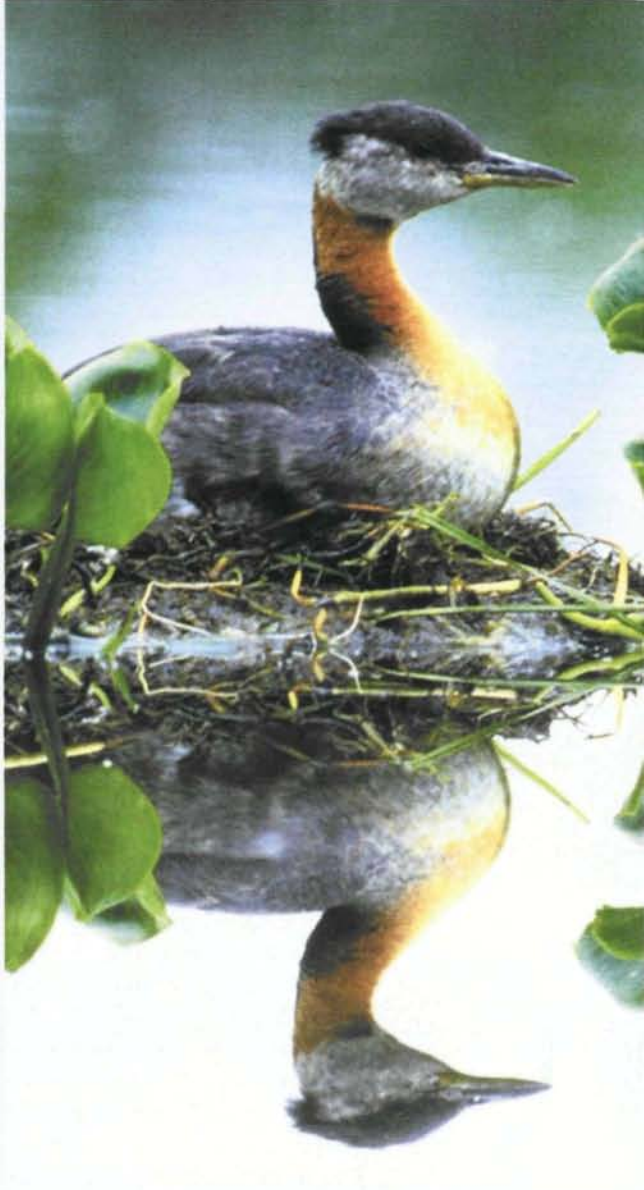
Teams of the world's best and brightest scientists took on major technical challenges during the past decade to move the world closer to demonstrating the power of nuclear fusion, the energy source which powers the sun and stars. Under Agency auspices, global co-operation was expanded in the late 1980s through a four-party initiative that includes Japan, Russia, the European Union, and the United States, and is known as the International Thermonuclear Experimental Reactor, or ITER (see illustration: note the size of the model compared to the people in front of it). The project was set up to confirm the scientific, and address the technical, feasibility of fusion as a potentially safe and environmentally acceptable source of energy. Fusion's main fuels — deuterium and tritium, one extracted from seawater and the other bred from abundant lithium — and its end product, the inert gas helium, are neither toxic, radioactive, nor do they contribute to the "greenhouse effect". In late 1990, scientists successfully completed the conceptual design of the ITER tokamak fusion reactor, and two years later they started an engineering design phase whose intensive work will run through most of this decade. So far, the four parties have not formally committed themselves to build the fusion device, and some technical and financial questions have arisen. Besides the ITER project, other fusion concepts are being investigated internationally, work recorded and shared through IAEA-supported global conferences, research programmes, and the IAEA's scientific journal *Nuclear Fusion.* If technical and economic barriers can be overcome, the decade's extensive efforts could bring the promise of fusion-generated electricity closer to being successfully tested in the 21st century's marketplace.
— *Based on reports by Thomas Dolan, Franz-Nikolaus Flakus, and David Fischer.*



Just where the world's drive for safer, cleaner energy development will lead remains to be seen. Maybe superconduction or commercial thermonuclear fusion (*see box above*) will come true far earlier than now believed possible. Scientists — like those working at the International Centre for Theoretical Physics in Italy run by UNESCO with IAEA support — may achieve breakthroughs in solar energy or other promising energy sources, as they did decades ago with the commercial use of nuclear energy.

For the IAEA, its evolving roles in years ahead almost certainly will be influenced by answers to the big question posed at the outset — how governments decide to fuel and engineer the energy drive ahead. The Kyoto conference on climate change in December, among other events, may help dictate the pace of progress on an important front. — *Lothar Wedekind, based on reports by Dr. Hans Blix, Victor Mourogov, Zygmund Domaratzki, Morris Rosen, Juergen Kupitz, Poong-Eil Juhn, John Cleveland, Boris Guerguiev, K. V. Mahadeva Rao, Iain Ritchie, Ms. Candace Chan-Sands, Bela J. Csik, Viktor Arkhipov, Noboru Oi, James Finucane, Arnold Bonne, Royal Kastens, Ms. Lucille Langlois, Leonard Bennett, Ms. Evelyne Bertel, and David Fischer.*

BY LAND, ATOP MOUNTAINS AND ON THE HIGH SEAS



The past ten years have seen many countries call upon the Agency's scientific and technical expertise for assessments of radiological conditions and environmental pollution threats. Most widely publicized was the response to the 1986 Chernobyl accident. (*See page 24.*) In the early to mid-1990s, countries requested the Agency's assistance in response to some serious concerns:

- IAEA scientists at the Marine Environment Laboratory were called to Kuwait's shores after the Gulf War in 1991 to survey and analyze pollution damage caused by blazing field fires which burned 500 million barrels of gushing oil. Preliminary results were part of the world's first published environmental assessment in the prestigious science journal *Nature*. Surprisingly, they showed that the greatest hydrocarbon pollution was within a radius of approximately 400 kilometers of the sources. By 1992, the oil pollutants had degraded, with only resistant compounds left, and contamination levels dropped to half of 1991 values. The rate of reduction fell by 1993, thought to stem from resumption of commercial tanker traffic and associated "routine" oil spills. Concentrations of oil pollutants in the seas peaked in August 1991, when tests showed significant toxicity to marine larvae, an effect that decreased significantly by 1993. This experience demonstrated how nuclear techniques can be effectively combined with other methods to trace the origins and movement of oil pollution, and help assess damage.

- Along the shores of the Caspian Sea and the Black Sea, in Thailand and other countries, Agency teams confronted other problems over the decade. In the Caspian region, for example, support went to five countries for environmental monitoring campaigns to find out why the sea level is rising, and how to prevent its flooding of cities and farmlands. Another global project with the Swedish International Development Authority includes isotope studies of agricultural pesticide runoff which threatens coastal regions and the livelihood of fisheries.

  About eighty percent of all marine pollution is caused by human activities on land: sewage disposal, industrial wastes, and chemical pollutants. In 1995, States adopted a global action plan hailed as the first programme to lead to more "sustainable interaction" between people and the oceans. The challenge may engage the Agency's expertise. More than a dozen ways in which this expertise might contribute to the action plan's goals and principles have been prepared.

- In countries of Eastern and Central Europe, awareness of radioactive contamination from uranium mining and milling increased and it became a serious health and environmental concern. In 1993 and 1995, the Agency initiated efforts to help countries assess the situation and begin to restore contaminated lands through effective remedial measures. By 1997, fifteen countries were participating in two remediation projects, with some results already published by the Agency. New projects have been initiated in countries including Bulgaria, the Czech Republic, and Slovenia.

In the Arctic Seas, an extensive project from 1993-96 assessed potential health and environmental impacts of radioactive waste dumped in shallow waters near the Novaya Zemlya nuclear test site. The waste included spent fuel in six submarine reactors and in the fuel assembly of an icebreaker ship reactor. Under the auspices of the International Maritime Organization and in accordance with its responsibility under the London Convention to prevent pollution by dumping, the IAEA launched a study involving more than fifty experts from fourteen countries. The study found that the present and future radiological risks to typical local population groups from the dumped wastes are small. It also concluded that, on radiological grounds alone, a remedial action programme was not warranted. Experts noted that limited environmental monitoring should be considered in order to detect any changes in the condition of dumped highly radioactive wastes. In the mid-1990s, IAEA marine scientists were also asked to support studies of past radioactive waste dumping sites in areas of the northwest Pacific Ocean. They joined two scientific expeditions jointly carried out by Japan, the Republic of Korea, and Russia. A report is expected this year.

In Kazakhstan in 1994, an expert group assessed the former nuclear test site known as Semipalatinsk. Of concern were radiological conditions for about 40,000 people living outside but close to the test site boundary, above which radioactive plumes from nuclear tests had passed. The expert group found that people living in these settlements were not at radiological risk. It also found, however, that land very near the test site had not been restricted and was being reoccupied. The team found radiation levels in these areas high enough to justify urging authorities to bar people from settling there for safety reasons.

Heightened concerns over natural radon levels in houses and buildings were loudly voiced throughout the decade, mainly in countries of Europe and North America. Global awareness was further raised at an international conference on high levels of natural radiation in 1990 in Iran. Specialists from thirty countries attended the meeting, which was co-sponsored by the IAEA, WHO, and other bodies. Throughout the early 1990s, the IAEA and European countries sponsored a five-year radon research programme that analytically supported national monitoring campaigns. More than fifty countries took part in fifty-one separate projects which involved the laboratory analysis of radon measurements taken outdoors, at work sites, and in homes.

An advisory group of experts from seven countries, the IAEA, WHO, and United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) was organized in late 1995 to assess questions raised by those Marshall Islanders who had been evacuated from the former nuclear test site at the Bikini Atoll. The Bikini people were relocated to the Marshall Islands before the start of nuclear testing in the mid-1940s. Scientific radiological studies over the past decades, as well as recent patterns of their relocation, had not convinced them that they could safely return to the atoll to live. The advisory group concluded that technically and financially feasible remedial measures could be taken to allow the Bikini people's rehabitation in line with international radiological protection principles. If the measures were taken, the group recommended monitoring of foodstuffs to ensure the strategy's effectiveness. Further Agency-sponsored activities in support of the Bikini people's concerns are under consideration.

An assessment of the present and future radiological situation at the former nuclear test sites at the Mururoa and Fagataufa atolls in the South Pacific was launched in 1996. The study, which was requested and is being principally financed by France, is under the guidance of an International Advisory Committee of global experts. Eleven laboratories in nine countries are participating in the analysis of terrestrial samples, and six laboratories in six countries in the analysis of marine samples. A sampling and surveillance campaign was conducted in July 1996. Closely involved in monitoring and analytical work are scientists of the IAEA's Seibersdorf Laboratories and its Marine Environment Laboratory. As the advisory committee reported at meetings this year, the study is progressing on schedule for completion in the early part of 1998.

— Based on IAEA documents and reports by Ms. Kirsti Sjoeblom, Gordon Linsley, Murdoch Baxter, Ms. Candace Chan-Sands, Pier Roberto Danesi, and Jasimuddin Ahmed.

SHOWING THE WAY

The challenge of demonstrating the safety of radioactive waste storage and disposal assumed greater proportions over the past decade. Most concerns emanated from political decisions to delay plans to build or open repositories engineered to handle highly toxic and radioactive spent fuel and nuclear waste. Some countries initiated expensive cleanup campaigns to counteract past waste storage and disposal practices in military and civilian areas. In most countries, however, more technical progress was quietly being made to demonstrate solutions to both real and perceived problems.

An IAEA survey in the mid-1990s showed that experience is being broadly applied. There are more than one hundred disposal facilities worldwide, ranging from engineered underground vaults to geological repositories for wastes classified as low or intermediate level (LILW). Another forty-two repositories were under development. They all rely on multiple protective measures and operational and institutional controls. Agency efforts focused on assisting countries by promoting the transfer of proven technologies and approaches through technical missions, research programmes, safety services, and other channels. Work also was renewed with some countries interested in setting up regional, or multinational, repositories whereby one country hosts a site accepting wastes from others. The IAEA identified and

reported on both the "pros and cons" of such an approach.

For disposal of high-level radioactive wastes and spent fuel, demonstration plans moved ahead, albeit slowly, often because of lengthy technical and political review processes. Most countries facing the issue do not envisage starting up deep geological disposal repositories until well into the next century. That does not mean there is a backlog of waste piling up. In nearly all these countries, nuclear waste is contained in engineered interim storage facilities that allow it to cool safely over decades. The Agency's technical assistance during the decade included supporting extensive joint research programmes on the performance of high-level waste forms and containers under repository conditions, and safety assessments of underground disposal facilities for other types of wastes.

The Agency broke some new ground when it supported a six-month international assessment of scientific studies analyzing the performance of the Waste Isolation Pilot Plant in the USA, now in the final stages of governmental review. Organized jointly with the OECD Nuclear Energy Agency, the assessment was conducted in 1996-97 by experts in the fields of geology, environmental protection, and nuclear and radiation safety. Their report supported the scientific studies and found them technically sound. The pilot plant is designed to permanently dispose of plutonium and other long-lived wastes generated by defense-related activities, including contaminated tools and clothing. It is engineered more than one kilometer underground at a site in New Mexico. The schedule calls for it to begin receiving wastes in May 1998, pending approval of the US Environmental Protection Agency and the Environment Department of New Mexico.

— *Based on reports by Kyong Won Han, Jorma Heinonen, Ms. Candace Chan-Sands, and Arnold Bonne.*

***Photo:** One of the protective means of safely containing radioactive wastes is known as vitrification (from the Latin "vitrus"- glass). Glass is used to solidify high-level wastes as one protective step before disposal. Here molten glass is shown being poured from a platinum crucible into a steel bar mold.*

BACK TO THE FUTURE: THE CHANGING WORLD AROUND US

1972	1997
POPULATION	
World population stands at 3.8 billion people, over 70% of whom live in developing countries.	Total population hits 5.85 billion, an increase of two billion over 1972, and grows by 81 million people a year. About 80% of the world population now live in developing countries.
URBANIZATION	
About 38% of humanity live in towns and cities, only three of which have more than ten million inhabitants.	About 47% of humanity live in or near cities, eighteen of which have more than ten million inhabitants. Thirteen of these "megacities" are in developing countries.
	AIR POLLUTION
More than 200 million cars, most of them in industrialized countries, aggravate localized pollution problems.	Nearly 500 million cars are on the roads in industrialized and developing countries, where many cities now have hazardous pollution levels. Transboundary pollution has become a regional and global issue.
	THE EARTH & CO_2
About sixteen billion tonnes of carbon dioxide, a gas linked to global warming, are released into the air annually, atmospheric concentration stands at 327 ppm.	CO_2 emissions from burning fossil fuels and other sources are approximately twenty-three billion tonnes per year. Atmospheric concentrations surpass 360 ppm — about 20% higher than levels one hundred years ago.
FRESH WATER	
About 2600 cubic kilometres of fresh water are used annually, mostly for irrigation.	Fresh water use has risen by nearly two-thirds to 4200 cubic kilometres a year. Water problems are severe: 1.4 billion people — one-fifth of the world population — lack access to safe drinking water, and one-tenth lack water for proper sanitation.
ENERGY MIX	
Fossil fuels make up 94% of the world's energy mix.	Fossil fuels account for 90% of the world's energy mix, up 3% from 1991 and indicating a rising trend after the low of the 1980s.
	ELECTRICITY
Electricity accounts for about 21% of total energy production. On a yearly per capita basis, consumption is about 1400 kilowatt-hours (kWh). By region, consumption stands at approximately 8200 kWh in North America, 3100 in Western Europe, 2800 in Eastern Europe, 565 in Latin America, 396 in South East Asia, 240 in Africa, and 143 in the Middle East and South Asia. Total world electricity generation is about 5000 terawatt-hours, of which nuclear power supplied less than 2% (80 TWh).	Electricity accounts for about one-third of total energy production. The world's per capita consumption reaches 2200 kWh in the mid-1990s. By region, disparities still reign: consumption stands at 13,000 kWh in North America, 5400 in Western Europe, 4200 in Eastern Europe, 1500 in Latin America, 1200 in South East Asia, 500 in Africa, and 500 in the Middle East and South Asia. Total electricity generation stands at about 13,000 TWh, with the share of nuclear approximately 2200 TWh, or 17%.
	ARMS CONTROL
Countries spend US $836 billion (at 1995 prices) on arms and armed forces. The five declared nuclear-weapons States conduct 57 nuclear tests. By the end of the year, 70 non-nuclear-weapon States had become Parties to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), which had come into force in March 1970.	Global military spending is about US $800 billion. Before adoption of global nuclear test ban in 1996, seven more tests are carried out, raising the total reported since 1945 to more than 2040. Reductions in arms spending continue, but about 6000 strategic nuclear bombs remain in Russia and the USA. By July 1997, the number of States joining the NPT reaches 185, including 180 non-nuclear-weapon States and all five declared nuclear powers. Cutbacks in military spending yield a "peace dividend" in excess of US $900 billion, the UN reports, but whether surplus funds are being used for social and economic development is difficult to track.

Information based on reports in the *Financial Times*, 4 June 1997, and the *Bulletin of Atomic Scientists*, May/June 1996, IAEA publications, databases.