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IAEA BULLETIN

INTERNATIONAL ATOMIC ENERGY AGENCY

Energising the Future
The Power of Innovation

China's Challenging Fast Track

Nuclear's "Second Wind"

Blackouts & Dollars

Deep Waste Repositories • Inspections Work • Nuclear Scenarios

IAEA
ATOMS FOR PEACE

The International Atomic Energy Agency is the world's centre of nuclear cooperation. Created in 1957 as the intergovernmental "atoms for peace" organization within the UN system, the IAEA contributes to global peace, development, and security in essential ways — helping to prevent the spread of nuclear weapons, and fostering safe, secure and peaceful uses of beneficial nuclear technologies for human development.

The IAEA mission covers three main pillars of work, with authority rooted in its Statute:

❶ **Safeguards & Verification,** including safeguards inspections under legal agreements with States to verify the exclusively peaceful nature of nuclear material and activities.

❷ **Safety & Security,** including the establishment of safety standards, codes, and guides and assistance to help States apply them.

❸ **Science & Technology,** including technical and research support for nuclear applications in health, agriculture, energy, environment and other fields.

The work is multi-faceted and engages multiple governmental and other partners at national, regional and international levels in and outside the UN system. IAEA programmes and budgets are set through decisions of its own policymaking bodies — the 35-member Board of Governors and the General Conference of all Member States. Reports on IAEA activities are submitted periodically or as cases warrant to the UN Security Council and UN General Assembly.

The Agency is headquartered at the Vienna International Centre in Vienna, Austria. Operational field and liaison offi-ces are centred in Toronto, Canada; Geneva, Switzerland; New York, USA; and Tokyo, Japan. The IAEA runs or supports research centres and scientific laboratories in Vienna and Seibersdorf, Austria; Monaco; and Trieste, Italy.

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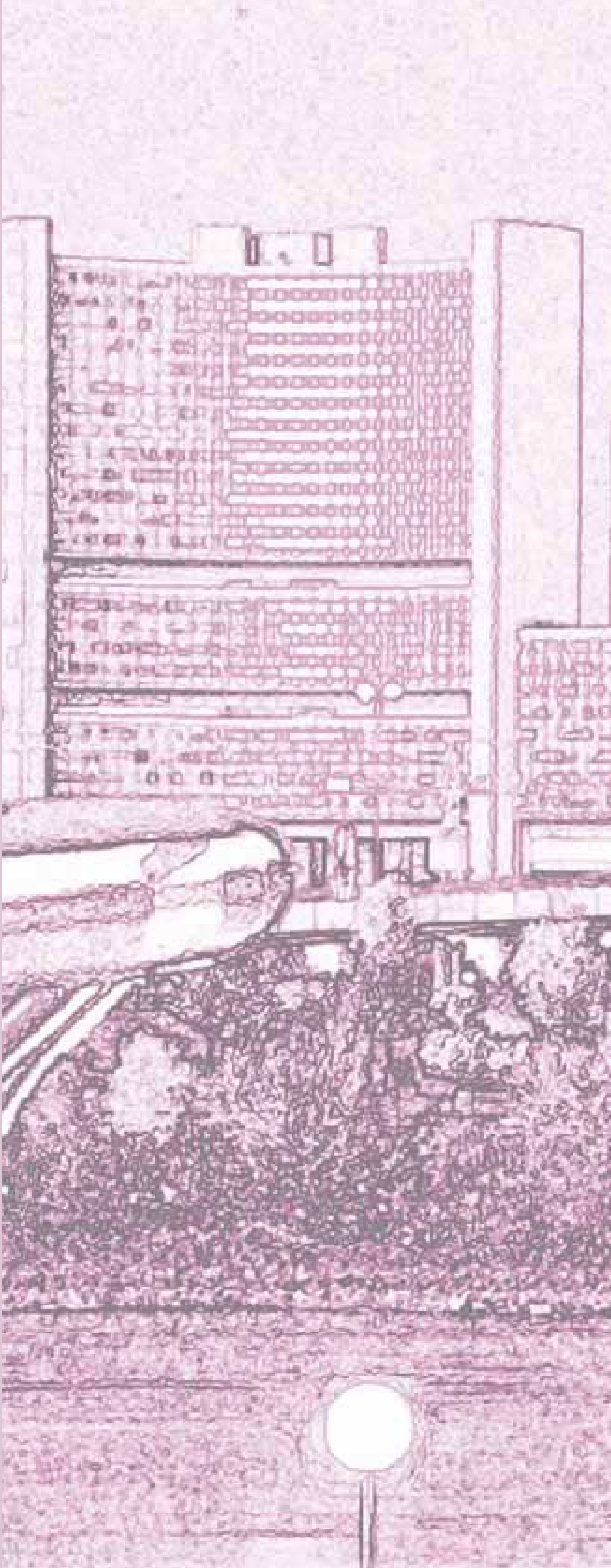

Too Cheap to Meter What?

50 years ago, at 17:30 hours, 26 June 1954, in the town of Obninsk, near Moscow, the first nuclear power plant sent electricity to residences and businesses. Atomic energy had crossed the divide from military uses to peaceful ones, demonstrating the potential to fuel civilian electric power plants. The milestone is being marked this year at an IAEA international nuclear power conference in Obninsk. Past experience will be reviewed, but the focus is on meeting future challenges.

Though it has come a long way in 50 years, nuclear energy today finds itself in a struggle of the fittest to carve a niche over the next fifty — in the marketplace and in the public eye. Clichés and sound bites tell part of the nuclear story. Visionary talk by nuclear proponents in 1954 was about future energy sources that would be "too cheap to meter", a phrase critics pounced upon. Today in 2004 the "too cheap to meter" phrase occasionally haunts the atom, but pops up more often than not in promotional ads for anything from wind power to web sites. Talk of nuclear energy now is of a "renaissance" and "second wind." New nuclear plants are most attractive where energy demand is growing and resources are scarce, and where energy security, air pollution and greenhouse gases are priorities, IAEA Director General Mohamed ElBaradei points out.

In cities, towns, and villages, reality is different, or too much the same, depending how you see and live it. Cheap or not, nuclear energy today supplies one-sixth of the world's electricity in some 30 countries. Still, it does not produce enough power. Neither does any other energy source. More than 1.5 billion people have *no electricity* to meter whatsoever — not from renewables, solar, nuclear, biomass, wind, coal, oil, gas, firewood, or hydrogen, the publicized promise of tomorrow.

So what will it take? Maybe bigger blackouts or hotter days than the world has seen. Certainly needed are more attention, action, and money. In dollar terms, energy analysts say trillions of dollars must be invested in fuels that are clean, affordable, and sustainable. In Asia, where energy demand and populations are fast rising, nuclear is growing, as in China where plans are ambitious. Outside the region, the story is mixed, with some countries rejecting the option outright on safety and waste grounds.

Whatever the choices, the world can ill afford to ignore bringing more power to people. As eminent Indian scientist Homi Bhaba noted a half century ago, "No energy is as expensive as no energy." Time will tell how long his message resonates.

— Lothar Wedekind, Editor-in-Chief

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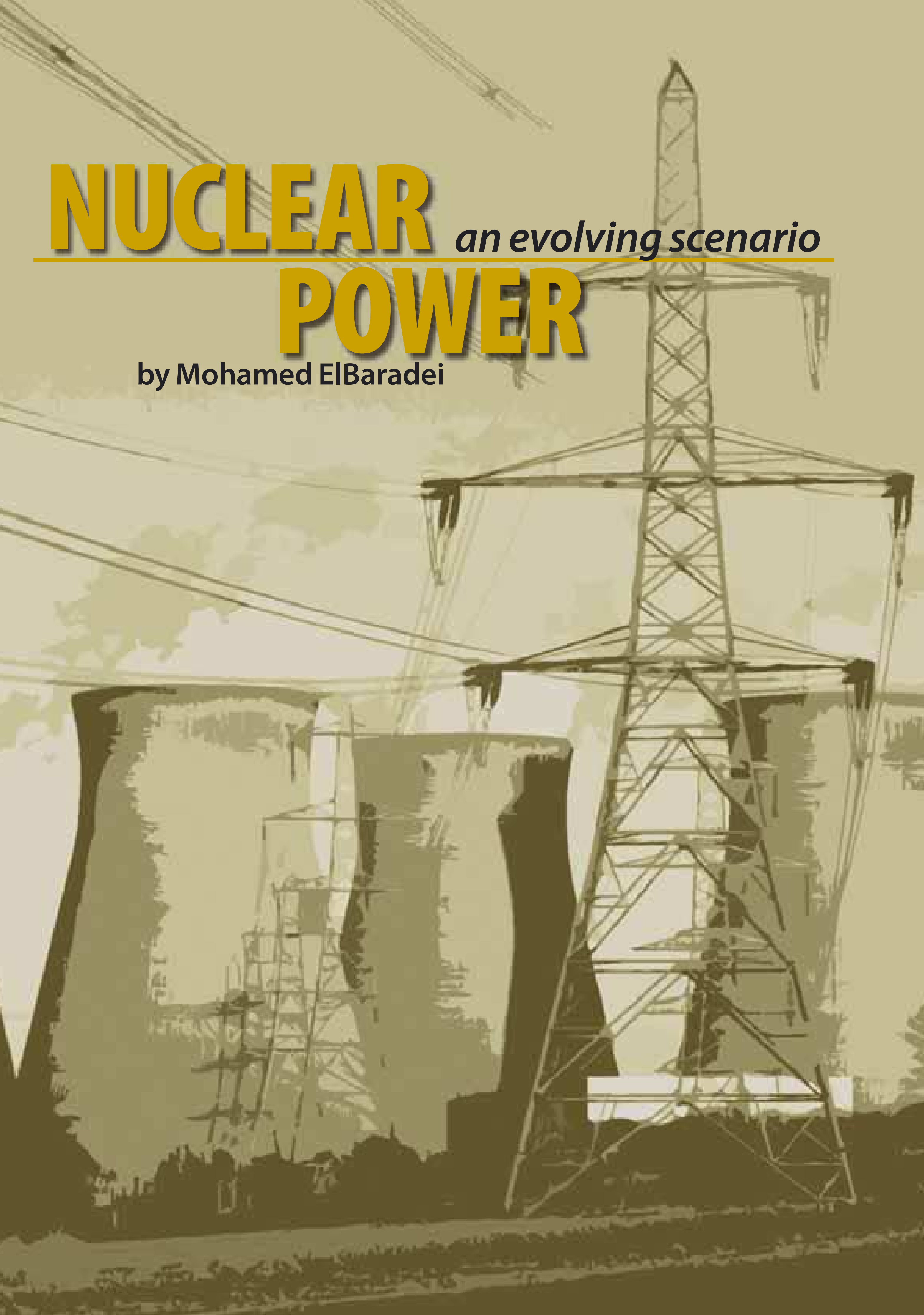
NUCLEAR POWER *an evolving scenario*

by Mohamed ElBaradei



The past two years have found the IAEA often in the spotlight — primarily because of our role as the world's 'nuclear watchdog', as we are sometimes referred to on the evening news. This heightened focus has enabled governments and the public at large to appreciate the even-handed approach we try to bring to our verification activities, by relying exclusively on hard evidence. This, in turn, has given the IAEA a reputation for objectivity and independence. We apply this same approach to the other side of our "Atoms for Peace" mission: using nuclear technology for economic and social development.

Atomic energy can also be harnessed to serve more basic human needs. One of the gratifying experiences of my professional life has been to witness the increasing array of nuclear and isotopic techniques that have been used to address daunting challenges — particularly in the developing world — to generate crops with better yield in arid climates, to study child malnutrition, to manage drinking water supplies, to increase industrial productivity, to eradicate disease-bearing pests, and to solve many other problems related to hunger, poverty and inadequate health care.

The most visible, and often controversial, peaceful nuclear application is the generation of electricity, the focus of this article largely from a European perspective.

The Dynamic Picture

The state of nuclear power remains a very mixed picture — but with some signs that change could be on the horizon.

At the end of last year there were 440 nuclear power units operating worldwide. Together, they supply about 16% of the world's electricity. That percentage has remained relatively steady for almost 20 years — meaning that nuclear electricity generation has grown at essentially the same rate as total electricity use worldwide.

Nuclear electricity generation is concentrated in developed countries. More than half of the world's reactors are in North America and Western Europe, and fewer than 10% are situated in developing countries — which is nonetheless where this century's greatest growth in energy demand will likely occur. Many developed countries generate substantial portions of their electricity from nuclear fission: including Russia, at 16%; Germany, at 30%; or Japan, at 35%. By contrast, for large developing countries such as Brazil, India and China, the percentages are only 4%, 3.7% and 1.4%, respectively.

New Construction

Expansion and growth prospects for nuclear power are centred in Asia. Of the 31 units under construction worldwide, 18 are located in India, Japan, South Korea and China — including Taiwan. Twenty of the last 29 reactors to be connected to the grid are also in the Far East and South Asia.

That is probably more active construction than most Europeans would guess, given how little recent growth has occurred in the West. For Western Europe and North America, nuclear construction has been a frozen playing field — the last plant to be completed being Civaux-2 in France in 1999. That should raise a question: with little to no new construction, how has nuclear power been able to keep up with other energy sources, to maintain its share of electricity generation?

Improved Safety Performance and Increased Availability

Interestingly enough, the answer is tied directly to efforts to improve safety performance. The accident at Chernobyl in 1986 prompted the creation of the World Association of Nuclear Operators (WANO), and revolutionized the IAEA approach to nuclear power plant safety. Through both organizations, networks were created to conduct peer reviews, compare safety practices, and exchange vital operating information to improve safety performance. A more systematic analysis of risk was used to ensure that changes made were in areas that would bring the greatest safety return.

With little to no new construction, how has nuclear power been able to keep up with other energy sources, to maintain its share of electricity generation?

Although the focus of this international effort was on improving safety, the secondary benefit was a steady increase in nuclear plant availability and productivity. In 1990, nuclear plants on average were generating electricity 71% of the time. As of 2002, that figure had risen to 84% — an improvement in productivity equal to adding more than 34 new 1000-megawatt nuclear plants — all at relatively minimal cost.

The result is that existing well-run nuclear power plants have become increasingly valuable assets. Although the front-loaded cost structure of a nuclear plant is high, the operating costs have become relatively low and stable. While these improvements to safety and economics have not been well publicized — and have not yet had a significant impact on the public's opinion of nuclear power — they have not escaped the notice of investors. They have been a strong factor in decisions to extend the licences of existing plants — for example, in the United States, where 19 plants have received 20-year licence extensions in the past five years.

Change On The Horizon?

Some analysts believe the case for new nuclear construction in Europe is gaining new ground, for a number of reasons.

Carbon Emissions

The first is the result of the clear position Europe has taken in global efforts to limit greenhouse gas emissions and reduce the risk of climate change.

Nuclear power emits virtually no greenhouse gases. The complete nuclear power chain, from uranium mining to waste disposal, and including reactor and facility construction, emits only 2-6 grams of carbon per kilowatt-hour. This is about the same as wind and solar power, and two orders of magnitude below coal, oil and even natural gas. Worldwide, if the 440 nuclear power plants were shut down and replaced with a proportionate mix of non-nuclear sources, the result would be an increase of 600 million tonnes of carbon per year. That is approximately twice the total amount that we estimate will be avoided by the Kyoto Protocol in 2010, assuming Russian ratification.

Security of Supply

A second reason is the current emphasis in Europe on the security of energy supply. The Green Paper on Europe's supply security estimated that business-as-usual would increase dependency on imported energy from around 50% today to around 70% in 2030. A similar concern drove nuclear power investment during the 1970s oil crisis, an investment that contributes significantly to the security of Europe's energy supply today. Large European uranium resources are not a necessary condition for this security. Rather, it is based on the diverse roster of stable uranium producers, and the small storage space required for a long term fuel supply.

Comparative Public Health Risk

What about safety and public health? For nuclear power, significant health impacts arise only from major accidents, of which there has been just one — Chernobyl — caused by serious design flaws coupled with serious operator mistakes. Chernobyl was a light water graphite-moderated reactor (RBMK reactor), and there are still 15 RBMK reactors operating in Russia, plus two in Lithuania that are scheduled for closure in 2005 and 2009, according to accession agreements. Due to improvements made since 1986, none of these reactors poses the threat of Chernobyl, nor are more RBMKs being built.

More to the point, Chernobyl is not the prototype for new nuclear plants — European or otherwise. For evaluating the performance of future plants, a much better model would be the European Pressurized Water Reactor (EPR) that TVO in Finland just selected for its new Olkiluoto-3 plant. When engineering analysts examine the public health risk from these new nuclear designs — or, for that matter, the safety record of the world's nuclear plants over the past decade of operation — they find nuclear related risks to be among the lowest in the energy industry.

Making the Choice

Clearly, however, energy decisions cannot be made on a "one-size-fits-all" basis. Each country and region faces a different set of variables when choosing its energy strategy. For example, Europe does not face the dual pressures of population growth and the need for economic development that are present in some parts of Asia. With two-fifths of the world's population, China and India are among those countries that face enormous energy demands, driven by the need to combat poverty and hunger.

Energy choices are also strongly affected by public perceptions — including perceptions of risk. Despite the engineering analyses I just mentioned, and despite the array of measures that have been put in place to offset the possibility of a severe nuclear accident, such a risk can never be brought to zero — and the memory of Chernobyl continues to weigh heavily on public perceptions in some countries. In Austria, for example, where I live, and where there are no nuclear power plants, I would expect the overwhelming majority to be against nuclear power. Finland, by contrast, has a long and positive experience with nuclear power, and a majority of its public continues to support nuclear power expansion. Yet in other countries, such as Germany and Sweden — even where considerable experience with nuclear power has not been accompanied by significant safety concerns — anti-nuclear sentiments have led to decisions to phase out nuclear power.

Clearly, however, energy decisions cannot be made on a "one-size-fits-all" basis. Each country and region faces a different set of variables when choosing its energy strategy.

How countries balance the risk of a nuclear accident against other factors — such as air pollution, dammed rivers, mining accidents, or dependency on foreign fuel supplies — are matters of complexity and of legitimate debate. At the IAEA, we do our best to provide the most objective information possible to support a country's decisions on energy supply, to ensure that the risks and benefits of nuclear technology are clearly and fairly understood, and to assist those countries that choose nuclear power in operating their facilities safely and securely.

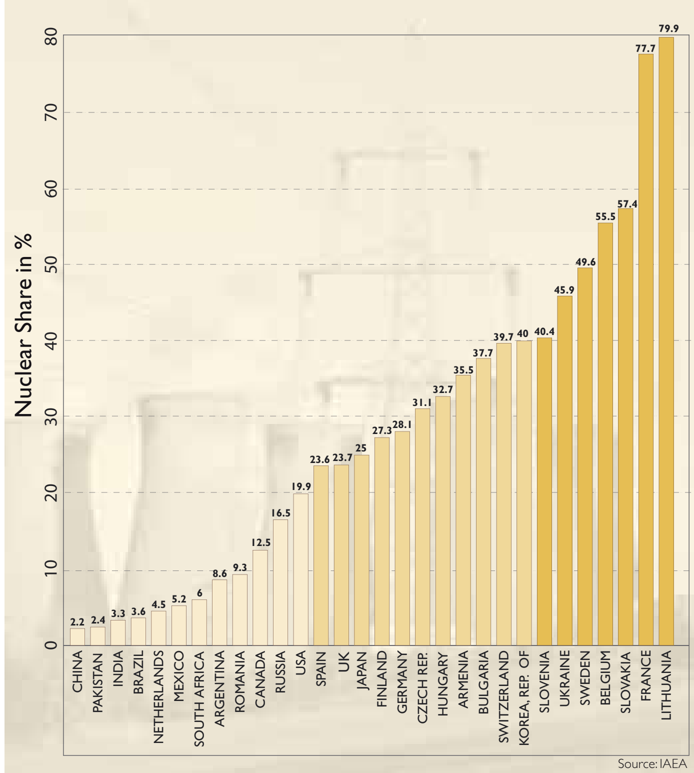
Key Issues For Future Viability

As we look to the future, certain key challenges are, in my view, of direct relevance to the future viability of nuclear power.

Waste Management and Disposal

The greatest challenge lies in the development of clear global and national strategies for the management and disposal of spent fuel and high level radioactive waste. Here in Europe, the Parliament in January approved a draft legislative resolution requiring EU Member States to submit, by 2006, detailed programmes for long term waste management and disposal. Finland has been in the lead in this area; the Finnish Government and Parliament have already ratified a ‘decision in principle’, with solid local support, to build a final nuclear waste repository in a cavern near the nuclear power plants at Olkiluoto. Sweden is also working to finalize the process of site selection. The IAEA has been working hard to help its Member States develop waste management and disposal strategies, and to facilitate international cooperation in waste disposal research and demonstration projects.

NUCLEAR SHARE OF ELECTRICITY
WORLDWIDE, 2003



To visualize the waste issue, analysts sometimes note that the spent fuel produced from all the world’s reactors in a year — even without being processed for re-use — would fit into a structure the size of a soccer field and 1.5 meters high. When this amount — 12 000 tonnes — is contrasted with the 25 billion tonnes of carbon waste released directly into the atmosphere every year from fossil fuels, the volume of spent nuclear fuel seems relatively small. Moreover, disposal technology is fully capable of stabilizing nuclear waste in the form of glass or ceramic, encasing it further in corrosion resistant containers, and isolating it geologically. Further research is underway that would use accelerator driven systems to reduce the volume and radio-toxicity of waste. And new research is being conducted on ways to ensure the retrievability of waste stored in repositories, to allow full use of future advances in technology.

Nonetheless, the public remains skeptical — and nuclear waste disposal will likely remain controversial, possibly until the first geological repositories are operational and the disposal technologies fully demonstrated.

Safety Performance

A second key challenge relates to safety performance. As I have already mentioned, the development of strong international nuclear safety networks over the past two decades has paid off, and I feel confident in saying that nuclear safety has dramatically improved. But we should not rest on our laurels. There are still gaps: in some cases, existing facilities with older design features still require upgrades or compensatory measures to ensure an acceptable level of safety. We are also focused on identifying problems with similar root causes, to prevent recurring events at nuclear facilities: that is, ensuring that lessons learned at one nuclear plant are effectively incorporated into the operational practices of all other relevant nuclear facilities.

I would like to emphasize that, regardless of the energy choices made by a given country or region, it is important that all countries lend their support to ensuring that high safety standards are implemented in nuclear facilities worldwide. Nuclear safety is of common interest and should remain a global priority.

Nuclear Security

The third key challenge — nuclear security — should come as no surprise. The September 2001 terrorist attacks in the United States has naturally led to the re-evaluation of security in every industrial sector, including nuclear power. Both national and international nuclear security activities have greatly expanded in scope and volume; in the past two years, we in the IAEA have worked on every continent to help countries better control their nuclear material and radiological sources, protect their nuclear facilities and strengthen border controls. Here, too, the international community is making good progress; while much remains to be done, nuclear installations around the world have strengthened security forces, added protective barriers, and taken other measures commensurate with current security risks and vulnerabilities.

The risks to nuclear power plants have been much in the spotlight. And while the nuclear industry has been very proactive in addressing security concerns, those efforts should not blind us to the vulnerabilities of other industrial or commercial sectors — which, if subjected to terrorist attack, could have similarly devastating effects.

Nuclear Non-Proliferation

A related but separate challenge is the prevention of nuclear weapons proliferation. Let me say at the outset that no nuclear material placed under IAEA safeguards — whether from nuclear power reactors or other sources — has ever been known to have been diverted for military purposes.

However, as recent events have demonstrated, the non-proliferation regime is under growing stress. This is visible in the failed operation of the export control regime, as evidenced by the recently discovered black market of nuclear material and equipment. It is also evident in the perilous spread of fuel cycle technology. Under the current non-proliferation regime, there is nothing illicit in a non-nuclear-weapon state having enrichment or reprocessing technology, or possessing weapon-grade nuclear material. If a State with a fully developed fuel-cycle capability and highly industrialized infrastructure were to decide, for whatever reason, to break away from its non-proliferation commitments, most experts believe it could produce a nuclear weapon within a matter of months.

To address these vulnerabilities, I have recently proposed that the most proliferation-sensitive parts of the nuclear fuel cycle — the production of new fuel, the processing of weapon-usable material, and the disposal of spent fuel and radioactive waste — be brought under multinational control, perhaps in a limited number of regional centres. Appropriate checks and balances would be used to preserve commercial competitiveness, to guard against the spread of sensitive technology, and to ensure supply to legitimate would-be users. I have also recently proposed a review of the export control regime, with a view to tightening controls to make the regime global and binding. And I have called for the more extensive rules of verification, under the so-called 'additional protocol', to become the global norm, to enable the IAEA to effectively detect undeclared nuclear activities.

In my view, advantages in terms of cost, safety, security and non-proliferation could accrue from this type of multinational approach.

Technological and Policy Innovation

A final challenge is innovation — encouraging the development of new reactor and fuel cycle technologies. To be successful, these innovative technologies should address concerns related to nuclear safety, proliferation and waste generation — and must be able to generate electricity at competitive prices. From a technical standpoint, this implies a greater reliance on passive safety features, enhanced control of nuclear materials through new fuel configurations, and design features that allow reduced construction times and lower operating costs. And the innovation must be more than purely technical: policy approaches must be put in place that enable reliable construction schedules, licensing review procedures, and other factors affecting cost and consumer confidence.

In view of changing market requirements, we are giving particular attention to small and medium-sized reactors, which allow a more incremental investment, provide a better match to grid capacity in developing countries, and are more easily adapted to a broad range of industrial settings and applications such as district heating, seawater desalination, or the manufacture of chemical fuels. Nearly 20 IAEA Member States are currently involved in the development of innovative reactor and fuel cycle designs. The Agency has been promoting innovation through its International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO), and is also working with other national and international innovation projects.

Decisions Down the Line

In conclusion, let me point out that the current 'holding period' for nuclear power in Europe will soon come to an end. In the near future, Europe will be faced with important energy decisions. With an increasing number of nuclear power plants reaching their original design lifetimes, Europe will have to decide how to replace its retiring nuclear power plants.

Making these decisions will depend, to some extent, on where you choose to place your emphasis — for example, on exploring available coal and natural gas resources, improving the performance and cost of renewables, or placing greater reliance on imports. What seems clear is that the only base load option available today with low carbon emissions comparable to nuclear power is large hydropower — and sites for hydropower expansion are somewhat limited in Europe.

At the end of the day, whether your decisions involve decommissioning, extending the life of existing reactors, or building the next generation of European nuclear power plants, the IAEA will be ready to assist efforts to ensure a safe and secure energy supply.

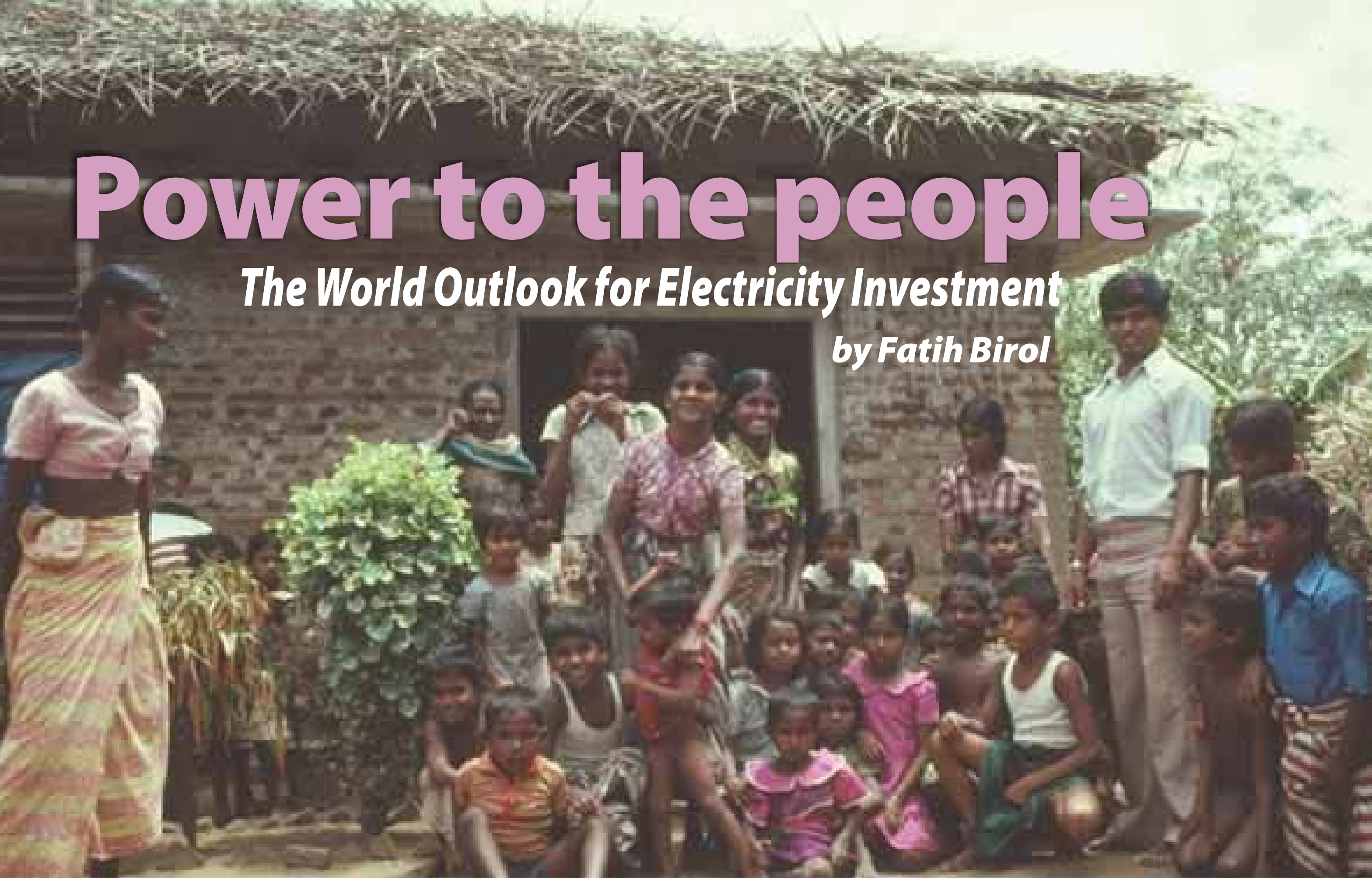
Dr. ElBaradei is Director General of the IAEA. This article is based on his speech at the European Parliament Conference on Energy Choices for Europe, May 2004, Brussels. E-mail: Official.mail@iaea.org

In June 2004, the IAEA launched a global press campaign on nuclear's future. Read more at www.iaea.org.

Power to the people

The World Outlook for Electricity Investment

by Fatih Birol



Electricity blackouts made news in Europe and North America not long ago. Behind the headlines, too much of the world lives with blackouts everyday. About one in four people still have no electricity. How much will it cost to bring the needed power to more people?

Energy analysts are looking at the pace and price of progress — at a time when electricity demand is rising ever higher.

Total investment required for the energy-supply infrastructure worldwide over the period 2001-2030 is expected to amount to $16 trillion, or $550 billion a year. This investment is needed to replace existing and future supply facilities that will be exhausted or become obsolete during the projection period, as well as to expand supply capacity to meet projected primary energy demand growth of 1.7% per year.

Capital needs will grow steadily through the projection period. The average annual rate of investment is projected to rise from around $450 billion in the current decade to $630 billion in 2021-2030. This compares with estimated investment of $410 billion in 2000. Actual capital flows will fluctuate around these levels according to project and business cycles. The power sector will account for the bulk of energy-investment needs, and oil and gas in almost equal measure for most of the rest *(see Figure 1)*.

These are some of the key findings of the *World Energy Investment Outlook* of the International Energy Agency (IEA), based in Paris, France. This article focuses on the power sector. The award-winning report, released in late 2003, assesses, fuel by fuel and region by region, the prospects for and possible barriers to investment in the global energy sector to 2030. The core analysis of investment needs is based on the reference scenario projec-

Figure 1: **Cumulative Investment in Energy**
by Fuel, Worldwide, 2001-2030

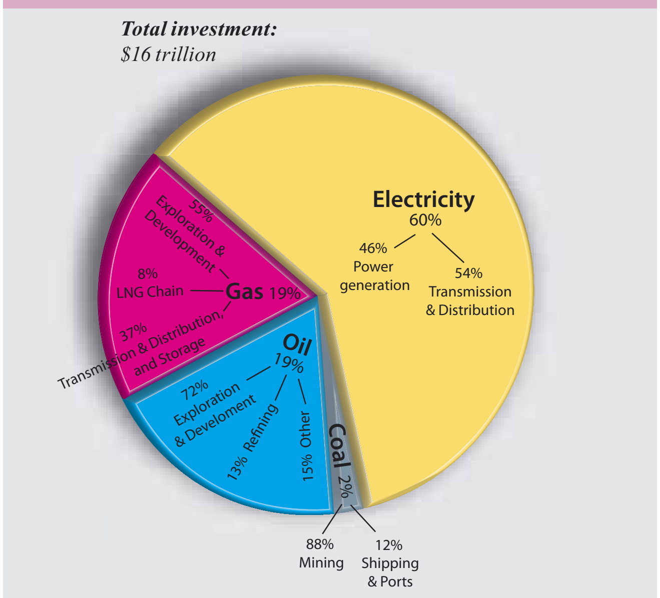
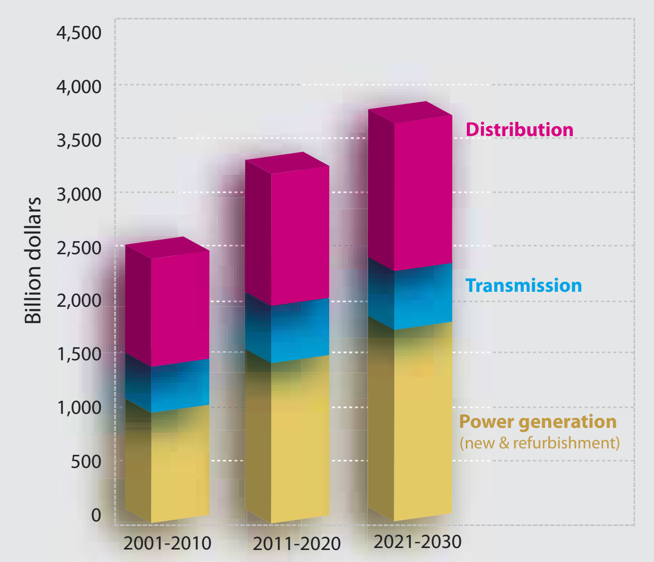


Figure 2: **Investment in Electricity,** Worldwide, 2001-2030



tions of supply and demand contained in the IEA's *World Energy Outlook 2002*.

Although the total sum of investment needs is large in absolute terms, it is modest relative to the size of the world economy, amounting to only about 1% of global GDP on average over the next thirty years.[1] The proportion is expected to fall slightly over the projection period, from 1.1% in the current decade to 0.9% in the decade 2021-2030. But the extent of the challenge differs among regions, ranging from only half a percent in countries of the Organisation for Economic Cooperation and Development (OECD) to 5% in Russia.

Electricity Market Trends

World electricity demand is projected to double between 2000 and 2030, growing at an annual rate of 2.4% *(see Table 1)*. This is faster than any other final energy source.

Table 1: **Electricity Balance,*** Worldwide, 2000-2030

	2000	2010	2020	2030	Average annual growth 2000-2030 (%)
Gross generation (TWh)	**15,391**	**20,037**	**25,578**	**31,524**	**2.4**
Coal	5,989	7,143	9,075	11,590	2.2
Oil	1,241	1,348	1,371	1,326	0.2
Gas	2,676	4,947	7,696	9,923	4.5
Hydrogen-fuel cells	0	0	15	349	n.a.
Nuclear	2,586	2,889	2,758	2,697	0.1
Hydro	2,650	3,188	3,800	4,259	1.6
Other renewables	249	521	863	1,381	5.9
Own use and losses (Mtoe)	**235**	**304**	**388**	**476**	**2.4**

**Includes transport, agriculture and non-specified uses of electricity.*

Electricity's share of total final energy consumption rises from 18% in 2000 to 22% in 2030. Electricity demand growth is strongest in developing countries, where demand will climb by over 4% per year over the projection period, more than tripling by 2030. Consequently, the developing countries' share of global electricity demand jumps from 27% in 2000 to 43% in 2030.

The next three decades will see a pronounced shift in the generation-fuel mix in favour of gas and away from coal — the most widely used fuel today worldwide. The role of nuclear power is also expected to decline markedly, because few reactors will be built and some existing ones will be retired. Nuclear production is projected to peak at the end of this decade and then decline gradually. Its share of global power generation will, therefore, drop sharply from around 17% now to 9% in 2030.

Power Sector Investment Needs

To meet the expected growth in electricity demand through 2030, cumulative investment of $10 trillion in power-sector infrastructure will be needed — equivalent to 60% of total energy-sector investment. If the investments in the oil, gas and coal industries that are needed to supply fuel to power stations are included, this share reaches more than 70% and total power-sector investment over $11 trillion. That is nearly three times higher in real terms than during the past thirty years. As demand for electricity increases, investment needs will gradually rise, from $2.6 trillion in the current decade to $3.9 trillion in 2021-2030 *(see Figure 2)*.

The power sector in developing countries will require more than half of the global investment, exceeding $5 trillion. Two-thirds must flow into developing Asia. China's investment needs will be the largest in the world, approaching $2 trillion *(see Table 2)*. India will need investment close to $700 billion, while East Asia and Latin America each will need investments approaching $800 billion. The electricity industry in OECD countries will need investment of around $4 trillion, while that in the transition economies will need $700 billion of investment, more than half of it in Russia.

Generation is the largest single component of total power infrastructure investment. Investment in new plants over the next thirty years will be more than $4 trillion, accounting for 41% of the total. Most of this investment will go into the development of gas and coal-fired power plants.

Refurbishment of existing power plants over the next 30 years will need investment of $439 billion. Investment in transmission and distribution networks together will take 54% of the total. Network extension, as a component of investment, is more important in developing countries, because of population growth and an increase in the rate of electrification.

Table 2: **Electricity Investment,** Summary for 2001-2030, billion dollars*

	Generation				
	New	Refurbishment	Transmission	Distribution	Total
OECD Europe	645	62	143	501	1,351
OECD North America	717	137	295	728	1,876
OECD Pacific	357	61	131	260	809
Total OECD	**1,719**	**260**	**569**	**1,488**	**4,036**
Russia	157	21	45	154	377
Transition economies	**297**	**41**	**82**	**280**	**700**
China	795	50	345	723	1,913
East Asia	344	22	133	301	799
Indonesia	72	6	33	74	184
South Asia	310	18	142	312	783
India	268	15	119	262	665
Latin America	317	19	128	281	744
Brazil	149	7	54	122	332
Middle East	92	15	47	103	258
Africa	206	13	123	266	609
Total developing countries	**2,064**	**138**	**918**	**1,987**	**5,106**
Total world	**4,080**	**439**	**1,568**	**3,755**	**9,841**

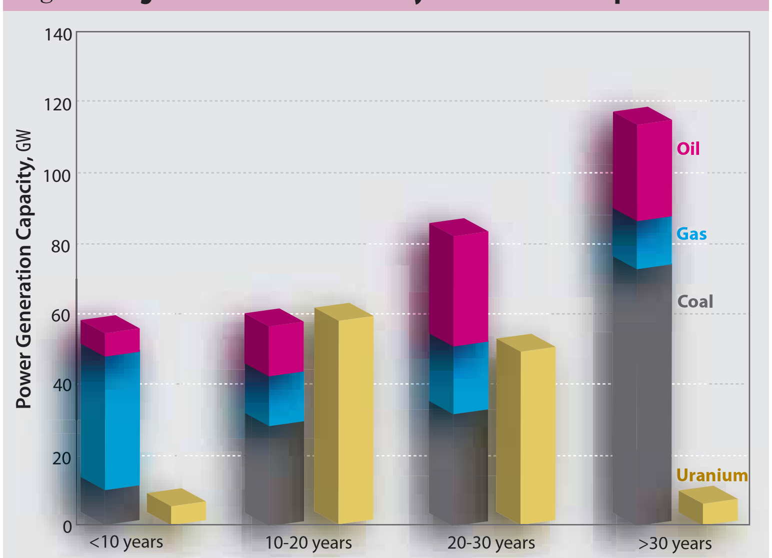
**based on year 2000 US dollars*

In OECD countries, where networks are more developed, most network investment will be needed for refurbishment and replacement of existing equipment. In the European Union, as in the rest of the OECD, investment in new power stations to replace those built in the 1970s and 1980s will need to rise in the coming years *(see Figure 3)*. In developing countries, priority is often given to investment in generation, but a growing share of capital will need to go to transmission and distribution in the future.

Challenges in OECD Countries

Power-sector investment now accounts for less than 0.5% of GDP in most OECD countries, and that figure is expected to drop to an average of 0.3% over the next three decades. Investment has declined somewhat since the mid-1990s for a number of reasons, including high reserve margins in some countries, the lower capital costs of new power plants, low demand growth and uncertainty caused by environmental policies and market liberalisation.

Figure 3: **Age of Power Generation Systems in the European Union**

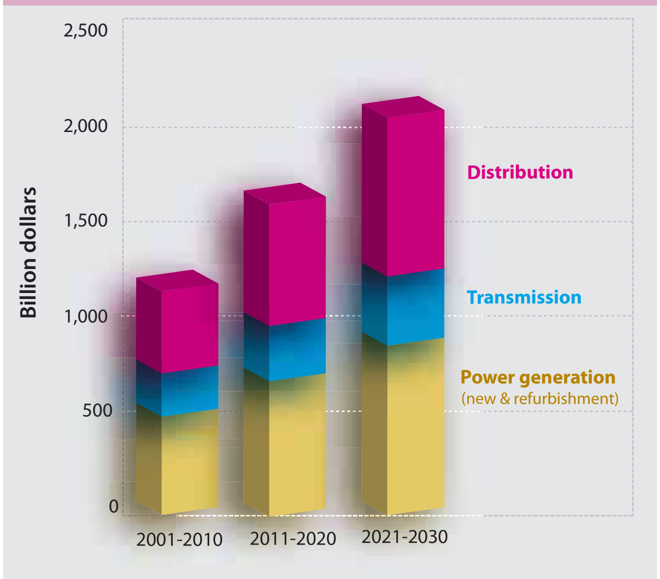


Market liberalisation has created new challenges and uncertainties in OECD countries. There is new concern about the adequacy of investment as markets adapt to the new conditions. Investors in liberalised markets are more exposed to risk than they were in regulated markets and in different ways.

A number of market and regulatory imperfections may lead to under-investment in some electricity markets. Prices may be distorted, for example, by government policies to protect small consumers. And concerns are growing about whether competitive markets adequately remunerate investment in peak capacity. Policymakers in most OECD countries appear to believe that current market designs do not guarantee an adequate level of security of supply, and are considering how to intervene to address this issue.

Environmental regulations, requiring power plants and other industrial facilities to reduce their emissions, are becoming tighter. Uncertainty about future environmental legislation increases investor risk. Existing legislation is directed principally at emissions that have a local or regional impact, such as sulphur dioxide, nitrogen oxides and particulate matter. These emissions depend on the fuel mix used in power generation and tend to be higher in countries where the share of coal in the generation-fuel mix is high. Emission standards for these pol-

Figure 4: **Investment in Electricity,**
Developing Countries, 2001-2030



lutants are tight and are becoming tighter in many OECD countries, which will significantly increase investment requirements.

Challenges in Developing Countries

Capital flows to the power sector will need to rise substantially over the coming decades to meet rapidly rising demand *(see Figure 4)*. Mobilising the capital to build new power stations and add sufficient transmission and distribution capacity may prove an insurmountable challenge for some developing countries. The risk of under-investment is perhaps greatest in many African countries and India. Public utilities are often not profitable and are, therefore, not able to finance new projects themselves. The poor financial health of utilities often results from low electricity tariffs or under-collection due to non-payment or theft.

Investment in power sector infrastructure in developing countries has traditionally been the responsibility of governments, though the 1990s saw an increasing number of countries turning to the private sector for part of the investment needed to finance the electricity sector. Direct government-funded investment in the power sector is likely to continue to decline, due to competing demands on government tax revenues and structural reforms aimed at promoting private participation. Government are, in many cases, also seeking to encourage competition.

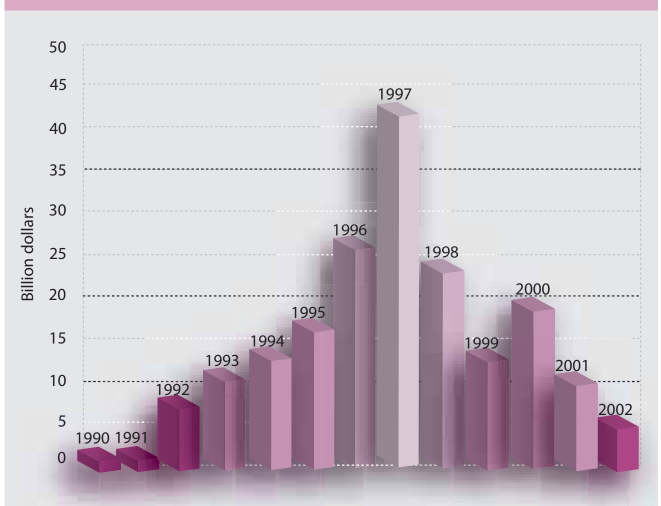
But attracting private capital is enormously challenging. Private investment in the power sector in developing countries has fallen sharply since the late 1990s, due to badly designed market reforms, economic crisis or poor returns on earlier investments *(see Figure 5)*.

Poorly developed domestic financial markets are often a major barrier to domestic investment. Another handicap is growing constraints on their ability to borrow money in international markets. Funds from international lending institutions and export-credit agencies have diminished in recent years. Exchange rate risk can also limit access to international financial markets.

Overcoming these obstacles will not be easy. It will require significant improvements in governance and deeper market reforms. A key challenge will be to reform tariff structures to make prices cost-reflective and improve revenue collection in a way that does not unduly hurt poor consumers who are not able to afford even basic electricity services.

Even if the huge electricity investment needs which arise in developing countries in the IEA's reference scenario are met in a timely fashion, there will still be 1.4 billion people without access to electricity in 2030. It is not that no one is trying. The proportion of the population without electricity will fall by a third in that timescale — but population growth will maintain the absolute numbers very close to their present level. This is morally and economically unacceptable and signals the need for action by industrialised countries to reduce such extremes of wealth and deprivation.

Figure 5: **Private Investment in Electricity**
Developing Countries, 1990-2002



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[1] *Total cumulative investment divided by cumulative world GDP (in year 2000 dollars at market exchange rate) between 2001 and 2030.*

Double or Quits?

The Global Future of Civil Nuclear Energy

Peter Beck & Malcolm Grimston

Among the many disputes in the field of energy, in many countries none appear to be as acrimonious as those surrounding nuclear power. Its supporters are confident that nuclear power will have an important long-term future on the global energy scene, while its critics are equally confident that its days are numbered and that it was only developed to provide a political fig-leaf for a nuclear weapons programme. Both sides believe the other to be thoroughly biased or stupid and there is little constructive debate between them.

As the disputes rage, especially over such issues as the management of nuclear waste, the economics and safety of nuclear power compared with other sources of electricity, the possible links with nuclear weapons and the attitude of the public towards the industry, decision-making is either paralysed or dominated by those who shout loudest. As a result, governments, industry and the financial sector have in recent years found it increasingly difficult to develop policy in this field.

Deciding about future energy developments requires balanced and trustworthy information about issues such as the relative environmental effects of different options, the safety of installations, economics and the availability of resources. This is of particular importance now because world energy use is expected to continue to grow significantly during this century, particularly in less developed countries. In the same period, global emissions of greenhouse gases, especially carbon dioxide, will have to be severely curbed. To meet both these requirements may well involve a step change away from being able to meet growing energy needs by depending on an ever increasing supply of carboniferous fossil fuel.

To address this situation, the Royal Institute of International Affairs undertook a two-year research project, aimed at providing information from the standpoint of an organization with no vested interest in either the pro or the anti camp, but close connections to both. The project has aimed to illuminate the differences, rather than to adjudicate among the various 'sides'.

The question at issue is what role nuclear energy might play in this new world. It could be expanded rapidly and it clearly has the potential to contribute to mitigating climate change. However, as indicated above, the industry presents a number of challenges. The aim of this project has not been to come to judgments as to what role, if any, nuclear power will or should play in future energy supplies, but rather to expound and develop, from an uncommitted standpoint, the arguments used by proponents and opponents of the technology.

Nonetheless, we feel it appropriate to highlight some themes which have emerged:

❶ The nuclear option will always remain 'open', in the somewhat trivial sense that the technology is understood, and records can be maintained even if no more stations are built and existing ones come off-line. To restart such an industry, though, would be a major and lengthy undertaking, while the uncertainties and the size of the challenges associated with the issue of energy and the environment over the next decades are considerable and can emerge rapidly. It can be argued, then, that actions should be taken now to ensure that nuclear power is available as a practical option.

❷ The extent to which such actions should be taken will depend on such factors as perceptions of the size of the energy challenges, the extent to which nuclear technology can evolve and matters of politics and values. However, given the timescales involved, serious consideration must be given to what actions (if any) are required now, and in the near future, if the nuclear option is to be kept meaningfully open for, say, the year 2020.

❸ The track record of nuclear energy, so far, is a matter of dispute between supporters and critics of the technology. To its supporters, nuclear power has largely fulfilled its early promise — it now generates about one-sixth of the world's electricity, having been the fastest growing of the major energy sources in proportional terms throughout the 1970s, 1980s and 1990s. It does so safely (it is among the safest of the major energy sources, according to some studies) and without emitting significant quantities of greenhouse gases. To its opponents, nuclear power has not fulfilled its promises — in terms of economics, the failure to find a waste management route, the potential for major accidents and terrorist attacks, and the way the industry has behaved towards society. They believe that a 'second chance' should only be contemplated in the most extreme of circumstances, if at all.

The reality, we suspect, lies between the extremes.

❹ As regards the future, the extent to which nuclear power will appear attractive will depend on impressions of two main factors — the 'environment' in which it is operating, and its own intrinsic features. Several elements within this environment are largely outside the control of the nuclear industry itself. In a future of energy shortages, disappointing performance of renewables and acute fears about climate change, for example, nuclear power would presumably look more attractive than in a future of limited energy demand, flourishing renewable industries and perceptions that climate change is manageable.

❺ As noted earlier, the nuclear industry itself might be able to take a number of steps to make itself more attractive, for instance by developing smaller and cheaper reactors, but there are potential logjams. Even supposing that acceptable technical solutions, at reasonable cost, can be developed for the major areas of concern, it might nonetheless prove very difficult to reach that state of development. For example:

◆ companies might not be prepared to put in the research, development and commercialization effort necessary to demonstrate cheaper and safer nuclear designs without a reasonable prospect that such designs will find a market, but such a market may not emerge until the designs are ready.

◆ development of novel waste management techniques such as partition and transmutation may only make sense if there is an expanding nuclear industry, but such expansion may be impossible without new ways of managing waste.

Similar problems may be encountered with respect to renewables, carbon dioxide sequestration and perhaps even demand-side technologies. In order to ensure that solutions to the major areas of difficulty become feasible, governments — either alone or in international collaboration — may have to act now, or very soon, to ensure that there are ways of clearing these logjams by providing stimuli for progress.

Perhaps the most difficult issue is over the construction of demonstration plants. If private companies should prove unwilling or unable to build such facilities, the financial risk being too great, then, in our view, governments should be prepared to take steps to ensure that such plants are built. Without them much of the longer-term research effort is likely to be wasted.

❻ Governments will also have to create the circumstances in which there is a sufficient supply of suitably qualified individuals to staff the industry and the regulatory bodies — this is true whether the industry contracts or expands. Governments may also have to act to ensure that sufficient funds are being put aside to deal with waste management and decommissioning in the long term.

❼ Finally, there is the issue of how the industry can make itself more acceptable to the public and how to involve it in the decision-making process. As the industry has lost its favoured position with governments, so it seems to have lost some of its early arrogance. Considerable thought is being given to ensuring that the public is, and feels that it is, contributing to the decision-making process. This trend must continue if the feeling, still prevalent in some circles, that nuclear power is something imposed upon, rather than a part of society, is to be overcome.

In the immediate future, it looks likely that the 'centre of gravity' of nuclear activity will continue to move away from North America and Western Europe and towards South and East Asia. Before long, however, a new understanding between the people, governments and nuclear industries in the industrialized world may be needed. Such an understanding should open the way for proper international appraisal of whether, and in what circumstances, nuclear energy might make a positive contribution to meeting the energy and environmental challenges that the world has to face in the twenty-first century.

This article has been adapted from the Briefing Paper, "Double or Quits? The Global Future of Civil Nuclear Energy" issued by The Royal Institute of International Affairs, April 2002. At the time of the paper's issuance, the late Peter Beck and Malcolm Grimston were Associate Fellows with the Sustainable Development Program at the Royal Institute of International Affairs, also known as "Chatham House," in London. For the complete briefing paper, visit www.riia.org/pdf/research/sdp/Nuclear_Double_or_Quits.pdf and for further information on the Sustainable Development Program please visit the Institute's website at www.riia.org.

Double or Quits? The global future of civil nuclear energy, 2002, by Malcom Grimstone and Peter Beck, RIIA & Earthscan Publications, London, and Brookings Inst., USA. ISBN 1 85383 913 2 (paper).

Passing the Torch

ANENT

The Asian Network for Education in Nuclear Technology

by Fatimah Mohd Amin

Recent trends show that the nuclear industry is poised for expansion for the first time in decades. The greatest expansion is seen in Asia. Out of 15 new nuclear power plants connected to the grid during the period 2000-2002, 12 are in Asia. In 2002, all new nuclear plant construction was in Asia. Besides energy generation, nuclear technology has an important role in meeting basic human needs — clean water, modern health care and food security.

The expansion in the nuclear industry requires a sustainable, qualified and experienced workforce to ensure a high level of safety and performance as well as the next generation of innovative technologies. Even where no expansion is foreseen, it is vital that steps are taken to prevent the loss of accumulated knowledge to ensure that the operation of existing nuclear facilities meets the highest safety requirements and to prepare for decommissioning activities. Ageing of the nuclear workforce in many countries has prompted the nuclear community to initiate various programmes to address the issue of the ageing workforce, which is worsened by the declining interest in the nuclear field among the young.

In 2002, the IAEA General Conference adopted a resolution on "Nuclear Knowledge" (GC(46)/RES/11B), which was reiterated in the 2003 General Conference (GC(47)/RES/10B). These resolutions emphasized the importance of nuclear knowledge management and called on Member States to strengthen their efforts in this activity. In response to the resolutions, the Agency convened a consultancy meeting to prepare the groundwork for the establishment of the Asian Network for Education in Nuclear Technology (ANENT).

ANENT was established in 2004 to promote, manage and preserve nuclear knowledge and to ensure the continued availability of talented and qualified human resources in the nuclear field in the Asian region. The First Coordinating Committee meeting in Febuary 2004 in Kuala Lumpur, Malaysia, marked the official formation of ANENT. Membership is open to universities, research centers, government agencies and other institutions involved in nuclear education and training. As of April 2004, 17 institutions and three collaborating institutions had become participating members.

Sharing the Know-How

ANENT operates based on the principle of cooperation for the mutual benefit of its members. The objective of ANENT is to facilitate cooperation in education, related research and training in nuclear technology through:

✔ sharing of information and materials of nuclear education and training;

✔ exchange of students, teachers and researchers;

✔ establishment of reference curricula and facilitating mutual recognition of degrees; and

✔ facilitating communication between ANENT member institutions and other regional and global networks.

Countries in Asia are diverse with respect to the development and utilization of nuclear technology. Some countries have nuclear power programmes, such as Japan, the Republic of Korea, China, India and Pakistan. Others focus their resources on applying nuclear technology to generate new varieties of crops, generate new industrial products and processes, diagnose and treat diseases, and protect the environment. A few countries that have yet to exploit nuclear technology for power production have plans for the introduction of nuclear power programmes in the near future. On the whole, the penetration of nuclear technology applications is still below optimum in many countries in the Asian region.

Differences in the level of knowledge and resources are observed among countries in Asia, depending on the national development level and usage of nuclear technology. This diversity provides an opportunity for sharing of know-how and experience among ANENT members. On the one hand are countries that have well-developed nuclear power programmes that also have well-established education and training programmes in nuclear science, technology and engineering — they are the potential knowledge donors. For example, there are 14 universities in Japan that offer nuclear and related courses and six universities in the Republic of Korea that offer courses in nuclear engineering.

On the other hand, countries that only now are planning their nuclear power programmes need to acquire knowledge and develop their human resources — they are the recipients. Vietnam, for example, requires between 500-700 graduates with nuclear engineering and related degrees to prepare for the introduction of the nuclear power programme. At the same time, Vietnam is very short of experienced and qualified people to teach in these courses. In this case, through ANENT, the more developed countries can provide teaching staff to conduct courses in Vietnam or offer places for Vietnamese students in their universities.

The exchange of students and teaching staff would be greatly enhanced with the mutual recognition of degrees among ANENT members. This in turn would accelerate capacity building in the less-developed Member States. Human resource development is also vital for the development of innovative technologies through research and development (R&D) activities. Significant innovation could be realized through cooperation, networking and sharing of resources, both for nuclear power and non-power applications.

Through ANENT, members could pool expertise and share facilities, some of which may be beyond the affordable reach of some countries. Basic facilities required for education and training of the nuclear workforce such as research reactors and accelerators require large resources to operate and maintain. ANENT enables institutions without these basic facilities to have access to other institutions for the purpose of education, training and research.

The establishment of basic requirements for reference curricula could contribute towards maintaining the professional standards of nuclear engineers and technicians. It would enhance the mobility of the nuclear workforce as well as widen their career opportunities. Such prospects could draw the young and talented to take up courses in nuclear science, technology and engineering thus overcoming, to a certain extent, the problem of the ageing nuclear workforce.

The Way Forward

A pragmatic and stepwise approach will be adopted in implementing ANENT activities. At the 1st Coordination Committee meeting, five activities were identified for implementation during the first phase beginning in 2004 and ending with the full operation of ANENT at the beginning of 2006. For each activity, an Action Plan was agreed upon and is being implemented, each being led by one lead institution. The activities are:

Activity	Lead Institution and Country
Exchange of information and materials for education and training	Korea Atomic Energy Research Institute (KAERI), Republic of Korea
Exchange of students, teachers and researchers	Malaysian Institute For Nuclear Technology Research (MINT) Malaysia
Distance learning	Philippine Nuclear Research Institute (PNRI), The Philippines
Establishment of reference curricula and facilitating credit transfer and mutual recognition of degrees	Hanoi University of Technology (HUT), Vietnam
Liaise with other networks and organizations	Atomic Energy Authority, Sri Lanka

The first activity that will be implemented involves taking stock of resources and materials for education and training in nuclear technology in the Asian region. Information and material are to be collated and placed on the ANENT web portal, which is expected to be fully operational by the end of 2004. The web portal will — as a key enabling technology — play a central role for networking among ANENT members. Member institutions could then use this information to identify education and training institutions suitable for placement of their staff. At the same time, a working mechanism will be established to support the exchange of students, teachers and researchers, with member institutions encouraged to implement exchange through bilateral cooperation as a starting point for multilateral networking.

The exchange of students and teachers would be greatly facilitated with the mutual recognition of degrees and transfer of credits. Towards this end, ANENT member institutions will exchange and evaluate existing curricula and establish recommended requirements for reference curricula in nuclear science, technology and engineering.

Distance learning would be one of the main approaches used by ANENT to teach and train students from diverse locations. Education and training materials already available will be compiled and distributed on the ANENT website. ANENT will utilize already available material — for example, that produced by the IAEA and other regional networks and associations — and will only consider developing new materials where none exist.

ANENT will seek to learn from experiences of other networks already in operation such as the European Nuclear Education Network (ENEN) and, where appropriate, collaborate with them. ANENT will serve as a facilitator to link its member institutions with other regional and global networks. At the 1st Coordination Committee meeting, representatives of ENEN, the World Nuclear University, the Asian Regional Cooperative Council for Nuclear Medicine and the Asian School of Nuclear Medicine were invited to share with ANENT members their experiences in nuclear education and training.

ANENT will strive to work in synergy with IAEA activities and programmes. By focusing on education, ANENT complements existing IAEA activities and would support IAEA initiatives for the preservation of nuclear knowledge. ANENT is a comprehensive initiative in education and training in that it will give equal importance to energy and non-energy technologies, thus meeting the diverse needs in the Asian region. ANENT aspires to become an important contributor towards national efforts in the development of a skilled and qualified workforce that is critical for the sustainable development of the nuclear industry.

Fatimah Mohd Amin serves as the spokeswoman for ANENT and works at the Malaysian Institute for Nuclear Technology Research (MINT). For more information on ANENT and a full list of participating institutions, please contact the author. E-mail: fatimah@mint.gov.my

Peter Gowin, IAEA Nuclear Knowledge Management Unit, and Scientific Secretary of the first ANENT Coordination meeting and K.W. Han, Republic of Korea, contributed to this paper.

International Conference on

Nuclear Knowledge Management

Strategies, Information Management and Human Resource Development
7-10 September, Saclay, France

Like any highly technical endeavor, the use of nuclear technology relies heavily on the accumulation of knowledge. This includes technical information in the form of scientific research, engineering analysis, design documentation, operational data, maintenance records, regulatory reviews and other documents and data. It also includes knowledge embodied in people — for example, scientists, engineers, technicians.

In recent years, a number of trends have drawn attention to the need for better management of nuclear knowledge. Depending on region and country, they include an ageing workforce, declining student enrollment figures, the risk of losing nuclear knowledge accumulated in the past, the need for capacity building and transfer of knowledge, and recognition of achieving added value through knowledge sharing and networking.

In response to this growing concern, the IAEA along with the Commissariat de l´Energie Atomique (CEA), Government of France will be organizing a conference to address the issue of Nuclear Knowledge Management.

The objective is to reach a clear and common understanding of issues related to nuclear knowledge management for sustaining knowledge and expertise in nuclear science and technology.

The conference will provide a forum for professionals and decision makers in the nuclear sector, comprising industry, governments and academia as well as professionals in the knowledge management and information technology sectors. Aims ares:

› to exchange information and share experience on nuclear knowledge management, comprising strategies, information management and human resource development;

› to identify lessons learned and to embark on the development of new initiatives and concepts for nuclear knowledge management in IAEA Member States;

› to discuss the present status and future developments of the Agency's International Nuclear Information System (INIS).

For more information, visit the IAEA web site: www-pub.iaea.org/MTCD/Meetings/Announcements.asp?ConfID=123

For more information on the IAEA's knowledge management initiative, visit www.iaea.org/km/

China's Challenging Fast Track

Far more energy will have to be produced — and conserved — to power the expanding economy and protect the environment

by Wei Zhihong

China's economy is on a fast track, with growth projected to quadruple in the first two decades of this century. A mix of clean and affordable energy sources will be needed to fuel and sustain development.

Since China opened to outside markets in the 1980s, the national economy has expanded steadily, with an average annual growth rate of 9.6% in gross domestic product (GDP) from 1980 to 2000. Development has stayed strong in this century, and GDP grew 9.1% in 2003, the highest rate in the past six years. For the first time, per capita GDP topped $1000, reaching $1090 last year.

How to best manage and sustain growth is driving energy decisions. Analyses show that China has entered a stage of manufacturing, chemical, and heavy industrial development that is energy intensive. At the same time, demands for energy at home and in businesses are growing among China's population of 1.3 billion people. As consumption grows, so do concerns about air, water, and land pollution in the context of sustainable energy development.

Shortages in Boom Times

China consumes more energy than any country except the United States. Entering this century, the country's energy consumption has grown from 924 million tonnes of oil equivalent (Mtoe) in 2001 to an estimated 1080 Mtoe in 2003.

Alongside energy growth stands energy shortages, especially in electricity generation. Electricity generation does not sufficiently meet the demand for industrial production and people's daily needs in more than 20 Chinese provinces, and demand exceeded supply in five of six regional electricity grids in 2003.

It is not surprising that serious power shortages have arisen, for a number of reasons. Firstly, over the past two years, demand for electric power has grown at a monthly rate of more than 15%. Meantime, new power generation capacity

Photo: Morning traffic in Beijing. Credit: Petr Pavlicek/IAEA has lagged greatly, with annual growth rates falling from 6.8% in 2000 to 5.3% in 2002.

Secondly, production investment has increased rapidly, notably in energy-intensive sectors such as metallurgy, building materials, and chemical industries to support boom expansion of automobile and construction sectors. Today, the production output of steel (210 million tons in 2003), coal (1400 million tons in 2002), and cement has elevated China among the world's top producers.

Thirdly, the country has experienced water shortages in recent years, and especially in 2003. This, in turn, has reduced hydropower generation, which previously accounted for 16% to 20% of total electricity production.

Fourthly, China's coal trade has been reformed in a market-oriented economy, with the State no longer guiding coal prices. The price for coal has risen on average between 10-15 yuan per ton in response to demand and transportation costs. On the other hand, the price of other thermal power sources is still guided by the State, rather than being market driven and responsive to coal price fluctuations. This situation hinders development of coal-fired power generation, which accounts for 80% to 90% of Chinese electric power production.

Energy & Economic Trends

China has a diverse energy base. The country has the world's highest level of exploitable hydropower resources, third highest level of proven coal reserves, and considerable oil and natural gas resources. Coal remains the main fuel, accounting in 2002 for two-thirds of total primary energy consumption. The consumption shares for oil, natural gas, hydropower and nuclear energy were 23.3%, 2.7%, 7.7% and 0.4%, respectively. Renewable sources, mainly wind, solar, and geothermal energy, together accounted for 0.3%.

In terms of energy projections, the electricity shortages of 2003 focused attention on the importance of forecasting supply and demand and steps to improve it. Energy facilities need quite a long time to be built before they can serve consumption centers and end users. Key forecasting factors include social and economic development, such as population, urbanization, GDP, national economic structure, and technological progress.

Because of China's large population pressures, there is no doubt that China will continue to implement its family planning policy over the longer term. It is expected that population will slowly increase from 1.26 billion in 2000 to about 1.475 billion people in 2020. More than half of the population, or 52%, is expected to live in or near cities by 2020, compared to 36% today.

Regarding economic development, an ambitious target was set in late 2002 to have China's GDP quadruple to the year 2020. To reach the target, an annual average growth rate of GDP would be about 7.2% a year. Achieving this target by 2020 would move China's world GDP ranking to third place, behind the USA and Japan, and increase per capita GDP to US $2945, nearly three times today's level.

In terms of technological progress, the aim is to reduce energy intensity, particularly in primary industries. The targets assume that energy intensity will go down continuously, and decrease by 40% to 50% by 2020.

Projections in energy demand foresee that coal's share will decrease from 66% in 2000 to 60% in 2010 to 54% in 2020. At the same time, cleaner energy and non-carbon energy — especially natural gas, nuclear energy and renewable energy — will see great development, as their combined share in total primary energy is projected to grow from 2.9% in 2000 to 15.6% in 2020.

When Less is More

Energy conservation measures are being emphasized as especially important factors to consider. Appeals from research institutes and energy experts call for elevating the energy conservation strategy to a much higher level in national policy. It is estimated that 60% of energy conservation potential in China exists in the industrial sector.

Since 1980, through national policies, great achievements in energy conservation have been obtained, owing to efforts by central and local governments, industrial sectors, and energy end users. Studies indicate that energy-saving measures during the period resulted in a reduction of 773 Mtoe, and contributed to environmental protection by cutting roughly 20 million tons of sulphur dioxide emissions, 263 million tons of cinders, 13 million tons of ashes and dust, and 440 million tons of carbon emissions.

The potential savings and impacts over the next two decades could be considerable. Research teams at Tsinghua University have noted, for example, that energy use per unit of major industrial products in China is 25% to 90% higher, on average, than those in developed countries. It is estimated that the energy saving potential could reach 70 Mtoe in the near term by means of technology improvements. Additionally, up to 210 Mtoe could be saved from structural adjustments in industrial and product sectors.

Realizing potential benefits will have to overcome barriers arising from China's transition to a more market-oriented economy, and the establishment and implementation of rules and legislation, including those in China's Energy Conservation Law promulgated in the late 1990s.

Options & Choices

Oil resources in China are very limited, and oil imports accounted for about 30% to 40% of demand over the past decade. The proportion is projected to reach 52% in 2020,

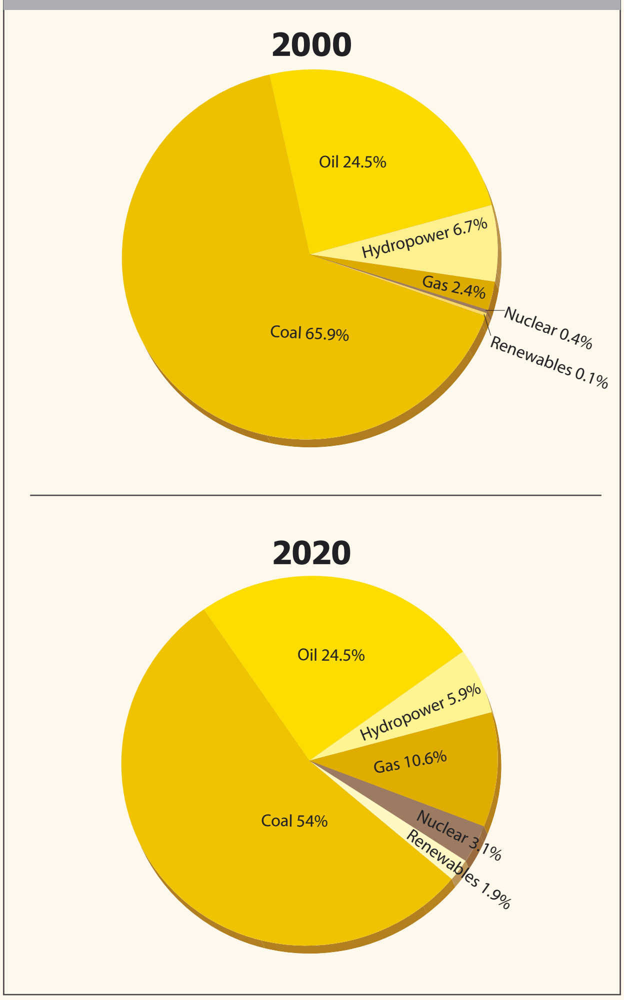
China's Future Energy Demand

Energy demand is rising fast in China, and the mix of energy is changing. Coal's share of total primary energy consumption is projected to decrease in coming decades, with natural gas, nuclear power, and renewable energy sources on the rise.

Looking at nuclear power, China today operates nine nuclear plants and has two more under construction, based on data reported to the IAEA. Nuclear today provides about 1.4% of total electricity generation, and plans call for building enough nuclear plants to produce up to 36 GW of electricity by 2020.

Plans include developing advanced types of nuclear plants. China's Institute of Nuclear and New Energy Technology is hosting topical meetings and workshops in 2004 on high-temperature gas reactors (HTGRs) which the country has developed. They include an IAEA workshop on safety demonstration and market potential for HTGRs in September 2004 in Beijing. For more information, visit the IAEA web pages at www.iaea.org/programmes/ne/nenp/nptds/htgr/.

Energy Consumption



Source:Tsinghua University, Beijing

assuming domestic production capacity of 200 million tons and consumption of 420 million tons.

Natural gas, nuclear power, and renewable energy sources are the most feasible options in an energy substitution strategy.

China's natural gas industry is just in the initial stages, though it grew rapidly over the past decade. Production has doubled since 1990, to reach 32.7 billion cubic meters in 2002. Four major gas fields are developed (Shanganning, Chuanyu, Qinghai and Xinjiang) in west China, and a few fields operate in east China. Plans are to expand natural gas output to up to 150 billion cubic meters by 2020, if pipeline construction proceeds as planned. Even then, however, domestic gas production would fall short of the projected demand of 220 billion cubic meters.

Alongside other initiatives, China is pursuing international cooperation for developing and importing natural gas. An agreement with Russia includes importing natural gas and building a pipeline from northern Siberia to China. Work is expected to start in 2005, with operation planned in 2010.

Nuclear power development still is in early stages, though China started building plants in the late 1980s. Three nuclear power stations where a combined nine units are in operation have a total capacity of 6100 megawatts (MW). All are located in east coastal areas, where the economy is well developed but energy resources are poor.

Nuclear's potential is linked to demands for easing serious power shortages on the east coast and other areas. In 2003, China's National Development and Reform Commission promulgated a long-term programme of nuclear power development that sets a target of 36 gigawatts (GW) in total capacity by 2020. The programme aims to help reduce dependence on coal and contribute to a cleaner energy structure.

In China nuclear power mainly replaces coal-fired power. Cost comparisons in China's east coastal regions show that grid prices of nuclear power now are higher than for coal. However, when the costs of installing desulphurization equipment at coal plants is calculated, then nuclear's price competitiveness improves.

To reach the 2020 nuclear target, strategic measures need to be adopted. They should address attaching priority to development in east coastal regions; investing in the most economic and mature nuclear reactor technologies; and identifying the best funding approaches.

At this time, funding limitations hinder nuclear development, since top priority is given to hydropower and other thermal power sources. Past nuclear financing modes were mainly dependent on domestic investment, but they are not suitable to the current situation. Foreign funds will become a very important financing source, though this has raised, and will continue to raise, issues related to such partnership ventures, including plant ownership.

When it comes to renewable energy, the Chinese government has paid great attention to its research and application since the 1980s, on environmental and other grounds. Next to hydropower, wind energy remains important. By the end of 2002, China had built around 30 wind farms, mainly in Xinjiang Uygur Autonomous Region, Inner Mongolia Autonomous Region, and Guangdong province. Counting smaller wind turbines, the total capacity from wind power was about 485 MW.

Solar and biomass energy also have been developed, with biomass on a larger scale. Currently the total annual output of agricultural residues is 700 million tons (equivalent to 210 Mtoe), 51% of which is used for fuel. About 250 to 300 million tons are consumed per year in rural areas, mainly for space heating and cooking.

Though renewable energy now plays a small role in China, it is important for improving environmental quality and people's living standards in rural areas. New targets for production have been set to 2010 in governmental guidelines.

Future directions emphasize improving the country's institutional management and organization of renewable energy development; expediting hydropower development, notably small and medium-sized projects; enhancing biomass production and use; developing solar technologies; expanding wind power to serve remote areas; and improving the financial framework, including questions of taxation, subsidies, and energy pricing for governmental and private sector involvement.

A Challenging Future

Chinese efforts are accelerating to address environmental protection and global climate change in the context of energy development. Coal's heavy use has resulted in serious consequences. Air pollution is caused by emissions of sulphur dioxide, carbon dioxide, and dust, and studies show that 85% of sulphur dioxide and 76% of carbon dioxide emissions are from coal combustion. China is now the second biggest carbon dioxide emission country in the world, and studies indicate it could rise to the top in decades ahead.

Additionally, areas affected by acid rain have reached about 40% of China, ranking the country among the three main heavy acid rain regions, next to Europe and North America. About one-third of coal is consumed by thermal power plants, but only a small fraction of plants have been equipped with desulphurization technologies.

More efforts are being made to reduce sulphur and carbon emissions, through development of cleaner energy sources

Credit: Vadim Mouchkin/IAEA

Demands for energy at home and in business are growing among China's 1.3 billion people.

and technologies, improved institutional coordination , and governmental policies and directives.

China is also actively pursuing measures in cooperation with other countries to combat global climate change. A white paper on population, environment, and development — called "China's Agenda 21" — incorporates a priority programme of concrete, operational projects. Almost all projects are included in national or local government plans for social and economic development. Development of clean energy and production systems are placed in an important position.

As China moves ahead, many issues will influence the country's sustainable development. The importance of energy strategies cannot be over-emphasized. Apart from other major strategies, such as population control, promoting clean energy is the most important to curb pollution and improve standards of living. Efforts should be focused on energy efficiency improvements, energy substitution of coal with natural gas and nuclear power, and renewable energy development, especially in rural areas of the country.

Some new mechanisms, rules, and policies already are in place to steer China's transition from a centrally planned economy to a socialist market economy. On the energy front, further steps will be needed to assure a path of sustainable development.

Wei Zhihong is Deputy Director of the Institute of Nuclear and New Energy Technology, Tsinghua University in Beijing, China. His article is based on a more comprehensive working paper presented at the 1st KEIO-UNU-JFIR Panel Meeting of the 21st Century Center of Excellence Program on Economic Development and Human Security, held at Keio University in Tokyo in February 2004 and co-sponsored by the United Nations University and the Japan Forum on International Relations. The full paper is published in the proceedings of the meeting, accessible on the Internet at coe21-policy.sfc.keio.ac.jp/ja/event/file/s2-6.pdf.
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Energising africa

'Leapfrogging' energy technologies can help, and so can more investment and partnerships for developing Africa's abundant resources.

by Ogunlade Davidson

The importance of modern energy provision in African development cannot be over-emphasised, as it is the nucleus of socio-economic development worldwide. However, large numbers of Africans depend instead on firewood and charcoal, reflecting the comparatively low level of industrialisation on the continent. Moving out of this stage requires a substantial increase in cost-effective and affordable energy sources, while minimising environmental hazards and ensuring social equitability and sustainability.

For Africa to be competitive, its per capita primary energy needs to be increased. In comparison with the rest of the world, Africans are among the smallest consumers of primary energy. In addition, Africa has multiple energy technologies to satisfy the needs of 30% of the population, in urban areas. The rural areas, where the remaining 70% live, have limited energy choices. It must be a priority for African governments to ensure that the rural majority has access to the same choices as those who live in urban areas.

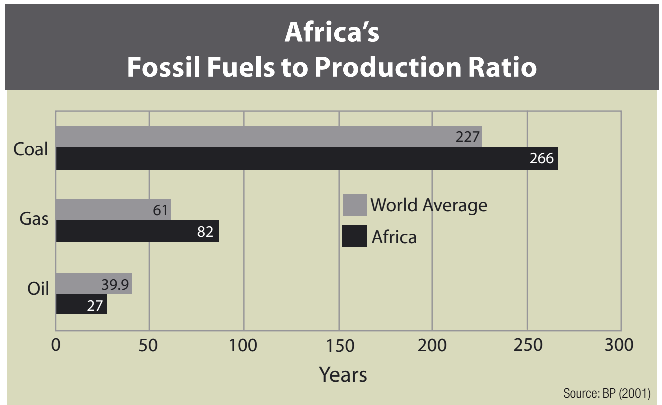
Natural resources

Africa's shares of proven reserves of coal, gas and oil at the end of 2000 were 5.7%, 7.4% and 7.1% respectively, according to British Petroleum data. Exploiting these reserves at current rates, they will be depleted in 266, 82 and 27 years respectively *(see graph, next page)*. These are above the world average for coal and gas (227 and 61 years respectively), and below for oil (39.9 years). It is worth noting that Africa's share of non-renewable resources will rise as a result of recent oil and gas finds.

Africa's huge supply of fossil fuels, presently exploited for exports, has to be used within the continent because as commodity prices continue to either fluctuate or decline, returns from such exports either dwindle or become unpredictable. Developing the downstream end of such resources so as to boost industrialisation on the continent is crucial.

Developing Africa's fossil resources requires a strategy that reflects the skewed distribution of these sources, hence different approaches for the different regions. Northern

Africa, with a large share of oil and gas, will need to exploit these resources, as will western Africa. Central and eastern Africa will need to include geothermal systems (as in Kenya and Ethiopia) and major hydropower systems (as in Uganda), as these are abundant there. Similarly, coal should be included in southern Africa's sustainable energy system — especially in South Africa, which has over 90% of the continent's coal deposits. Fortunately, significant technological progress is being made in developing these resources, resulting in both improved energy and environmental efficiency.



Renewable energy

Africa has significant renewable energy options. Being mainly in the tropics, solar energy is quite pervasive. In addition, agricultural production can lead to large quantities of biomass, as in Mauritius where these practices already contribute significantly to their electricity. Wind is available in selected areas, such as Egypt, Mauritania and Mozambique, but the most available resource in nearly all countries is hydropower. However, the technologies for renewable energy are not ideal.

> African governments need to act collectively in approaching critical energy issues

Solar energy devices are generally yet to be cost effective while wind — where the resource is available — compares well with more conventional systems. Solar water heaters can prove useful in certain niches such as rural areas that are far from the national grid. The use of modern biomass in the industrial, power production and transport industries is supported, as waste products from agricultural processing are good feedstock for such systems.

But it is worth noting that fossil fuels have dominated the global energy scene for more than a century and will continue doing so for at least another generation. Any new energy system will require substantial changes to the entire energy infrastructure and huge capital requirements, as will the costs involved in overcoming the obstacles posed by vested interests.

Financing energy investments is particularly challenging because of limited domestic capacity, which has led to the dominance of foreign financing and continued influence by donors and multilateral institutions. In recent years, the most notable prescription from these institutions has been for Africa to liberalise and privatise the energy sector, as in the cases of Senegal, Côte d'Ivoire and Uganda. While there are advantages in reforming the sector's management, increasing access to affordable, modern energy for poorer communities has been ignored; so has maximising indigenous energy resources. As a result, higher energy prices and energy scarcity have characterised such reforms. A departure from this vicious cycle is advisable.

The search for solutions

Effective transfer of technologies will require partnerships among major stakeholders. African governments will have to formulate and implement measures that will improve the capacities of these countries to better receive technologies, while governments of technology suppliers will need to formulate policies that provide incentives for technology suppliers to find such transfers attractive.

Energy technology "leapfrogging" can have a positive impact on African countries as they move towards a more sustainable development. Leapfrogging involves moving from one technology to another without going through the certain intermediate stages, such as moving from a traditional firewood stove to one using liquefied petroleum gas, while ignoring improved charcoal and kerosene stoves.

But past experience has shown that African governments need to act collectively in approaching critical energy issues and must introduce institutional reforms to facilitate regional joint ventures. Africa's fossil fuels and renewable energy alternatives are abundant but most of these reserves are yet to be exploited due to the lack of capital resources, infrastructure and institutions.

African countries can contribute their abundant energy resources, provided the technological and financial support systems are available, which will require significant external assistance.

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View from Japan

by Shunsuke Kondo

Bridging the transition to a safe & secure energy future

Japan's 52 nuclear power plants supply about a third of the country's electricity, becoming a safe, reliable and competitive energy source. Even if nuclear power rightfully is considered a domestic source of primary energy, Japan's degree of self-sufficiency in primary energy supply is only about 20%, of which 16% comes from nuclear and the rest mostly from hydropower.

Over past years, nuclear power has contributed to the rising percentage of electricity generation from non-fossil fuels from 38% in 1990 to 44% in 2001. By 2010, 49% of total generation is predicted to come from non-fossil fuels.

Japan's environment is benefiting. Though electricity generation rose by more than 21% since 1990, associated carbon dioxide emissions increased less than 7%. By 2010 Japan's electricity demand is predicted to reach 900 billion kWh. The electric utility companies are committed to reducing the CO_2 emissions, and are continuing construction of four nuclear power units and preparing to build six additional ones, though it will take more than ten years before the completion of latter.

Expansion and growth prospects for nuclear power are weak globally with growth predominantly centered in Asia. Of the 36 units under construction worldwide, 20 are located in Taiwan, China; India; Japan; and South Korea.

Why are Asian countries starting and/or increasing the use of nuclear power? In my view, three reasons, mainly. One is that the per capita endowment of energy resources in the region is scarce compared with others. Nuclear power is practically a unique energy source that contributes to making their energy supply portfolio more attractive from the viewpoint of energy supply security. A second reason is the increasing recognition that we have already started to confront adverse environmental effects; the world cannot reconcile human needs and environmental security if we continue the reliance on the burning of fossil fuel for energy production. A third reason is the recognition that nuclear power has reached a technical and institutional maturity.

Nevertheless Asia's relatively positive scene does not mean that nuclear will be a major player for future electricity generation in this region. According to the International Energy Agency's World Energy Outlook of 2002, more than half of the new electrical generating capacity projected in Asia for construction by 2030 will be gas-fired. New nuclear capacity is projected to be about one-tenth that of natural gas.

These predictions seem to be inconsistent with the result of long-term forecasts of energy supply and demand, including that of the International Panel on Climate Change (IPCC) Special Report on Emission Scenarios (SRES). This report indicates that nuclear energy may be a major component of the global energy supply mix in the latter half of this

Photo: Akashikaikyou Oohashi Bridge, Awajisma Island, Japan. Credit: Junichi Higo/IAEA century to curb the accumulation of greenhouse gas in the atmosphere.

Break of Dawn

The Japan Atomic Energy Commission (AEC) believes that we are not at the brink of nuclear power to be a minor electricity supplier but at the break of dawn for nuclear power to become a major player in the world. To this end, the AEC is asking relevant administrative organizations and industries to pursue coordinated strategic efforts, sharing the vision that safe, economical, and reliable nuclear energy technology will contribute as a mainstay of electricity and heat generation technology, fostering economic growth, providing security and fuel diversity, and enhancing environmental quality in many parts of the world.

The AEC has recommended a three-tier strategy — or a well coordinated mix of near-term, mid-term, and long-term plan of actions. The objective of the near-term plan is to continue the most effective utilization of existing nuclear power plants and fuel cycle facilities.

This can be done not only by developing a broad range of technologies that promises enhancement of their long-term performance but also by assuring public acceptance through accountable behavior. Actions toward this objective are, on the one hand, to promote use of the plutonium recovered from spent fuels by reprocessing in light-water reactors (LWRs), securing adequate interim spent fuel storage capacity at-reactor and away-from-reactor facilities, and preparing for the selection of the site for geological disposal of vitrified high-level radioactive wastes.

On the other hand, the AEC also requests to develop and apply advanced technologies for increased output of existing units, longer-term reliable operation of existing units, high burn-up fuel to improve the economy of operation, and economical dismantling of nuclear facilities and management of radioactive wastes generated in the process, adopting risk-informed decision making of inspection and maintenance activities and accountability-conscious quality management systems. These measures are essential to the maintenance of a high level of safety, safeguards and security, continuously improving the economy of the construction and operation of fuel cycle facilities as well as nuclear power units. We request that these activities be promoted with toughness, resolution, and consideration to details, as they directly affect the performance of existing plants and facilities and around 70% of the general public still feels uneasy toward the safety of nuclear facilities, swayed by widespread media coverage of any incident when it occurs.

In parallel with these kind of activities, the nuclear community should prepare relevant measures to mitigate the effects caused by crises that hamper the sustainable use of nuclear energy as well as implement effective measures to prevent the occurrence of such crises. Furthermore, the growing universality of technology now makes successful innovation much more frequently driven by market forces. It is thus important for the nuclear community to pursue the environment shaping strategy that aims at realizing synergistic coexistence of nuclear reactor systems with various industries besides the electricity industry. This entails building networks for mutual learning, knowledge-sharing, and joint deliberation, starting from those utilizing radioactivity and radiation for industrial, medical, scientific and other activities. This will serve to make the man on the street familiar with the application of radiation, radioactivity, and nuclear reactions.

The objectives of the mid-term plan are to develop more economically competitive and "human-conscious" plants that can compete with emerging non-nuclear power technologies for replacement and addition of generation capacity. The need for pursuing this objective is clear. The competitive operation of today's units and facilities by no means guarantees the adoption of the same type of plants and facilities for replacement of retiring units or for the addition of capacity.

In this age of technological innovation, deregulation of the electricity market is sharply altering the financial landscape for utilities, which are no longer guaranteed a fixed return on investment. This makes it extremely difficult to justify the design and construction of capital-intensive plants to stockholders. Added factors are the emergence of innovative and "neighbor–friendly" modular power generation technologies such as renewable energy sources and fuel cells.

Actions to be taken for pursuing this objective are to reduce the capital cost of nuclear power plants by new designs with, for example, innovative concepts and components; to improve robustness of nuclear power plants in safety and reliability by adoption of passive safety features; to minimize environmental impact by reducing volumes of radioactive waste generated during the decommissioning as well as operation of facilities; and to improve the "human consciousness" of nuclear plants by pursuing low occupational exposure to radiation, low workloads in operation, maintenance, and emergency situations.

The major investment for these activities should come from private sectors that operate the plants and facilities. However, government should support research and development for actions of a long-term and/or generic nature. This will ensure that a broad range of technologies is developed that promises to enhance the long-term performance of various types of existing and future facilities.

We believe that the nuclear community should prepare itself better for changes in our society. We are living in a period of "profound transition", according to Peter Drucker, the renowned policy strategist. The evidence to support his assertion is seen in Japanese society:

❶ in the discussion of future energy demand — energy consumption in Japan is predicted to start decreasing before 2030 and most likely at around 2020,

❷ the pursuance of a "zero emission society", which has found momentum by Japan's enactment of the Basic Law for Establishing a Recycling-Based Society; and

❸ the expansion of niche markets for distributed electricity supply systems.

Oil — most of it imported — remains Japan's largest source of energy, but the level of dependence is shrinking. Nuclear energy and natural gas are making up the difference. Since the oil crises in 1973, oil's share of energy consumption has fallen 25%, while the combined shares for nuclear and gas have grown to top 30%.

Photo: Sendai nuclear power plant, Sendai, Japan. Credit: Kyushu Electric Co.

This transition forces us to acknowledge in the strategic plan that over the long term, not just new but truly radically new energy technologies are coming. They will effectively address the challenges of air pollution, climate change and energy supply insecurity while expanding energy service worldwide. During the second quarter of this century many other technologies — such as photovoltaic power, fuel cell cars, hydrogen derived from many sources and di-methyl ether or similar synthetic fuel derived from biomass — will become as commonplace as gasoline cars and coal-fired power plants are today.

It is essential for the nuclear community, therefore, to continue to explore innovative nuclear energy supply system concepts that can compete in such new energy markets. This will make nuclear energy technology sustainable in terms of social acceptability as well as in terms safety, economy, environmental protection, and non-proliferation.

Preparing for the Future

Such system concepts should include nuclear reactor systems that are consistent with the pursuit of a "zero emission" society. Examples are to develop practical technologies to reduce the toxicity of high-level radioactive waste bound for geological disposal and nuclear reactors that can be used for the production of hydrogen as a fuel in the transport sector.

We believe that the government should support exploratory activities for future energy systems. It is important for the government, though, to establish a level playing field to assure fair assessment of various options, nuclear and non-nuclear. This serves to prevent the emergence of public mistrust of the government's energy policy. International collaboration should be effectively implemented to increase transparency and accountability – and to reduce research and development costs.

Finally, the AEC recognizes the importance of successful continuation of nuclear construction activities by fostering competitive plant designs. Without progress, it will become very difficult to maintain qualified suppliers of nuclear equipment and components, contractor and architect engineer/engineering organizations with the personnel, skill, and experience in nuclear design, engineering, and construction. Therefore we consider it our responsibility to ask concerned organizations to review the situation, plan and execute actions to assure the availability of needed experts in various sectors essential to the maintenance of infrastruc-tures for regulation, construction and operation of nuclear facilities.

These and other key aspects of nuclear knowledge management can be effectively pursued in consultation with professional societies, and through global collaboration among the main institutional players. Preserving and cultivating the "know-how" in this way will bridge the transition in the dawn to a safe and secure energy future integrated with the wise utilization of nuclear energy systems.

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Nuclear Snapshots

Perceptions of energy needs drive public opinion on the USA's nuclear future

by Ann Stouffer Bisconti

The United States has the world's largest nuclear power program, with 103 plants supplying about 20% of the country's electricity.

But no new plant has been ordered in the USA in a quarter of a century. Today, a growing need for affordable, reliable, and emission-free electricity is reawakening interest in nuclear energy. *(See box on next page.)*

Where does US public opinion stand on nuclear's future?

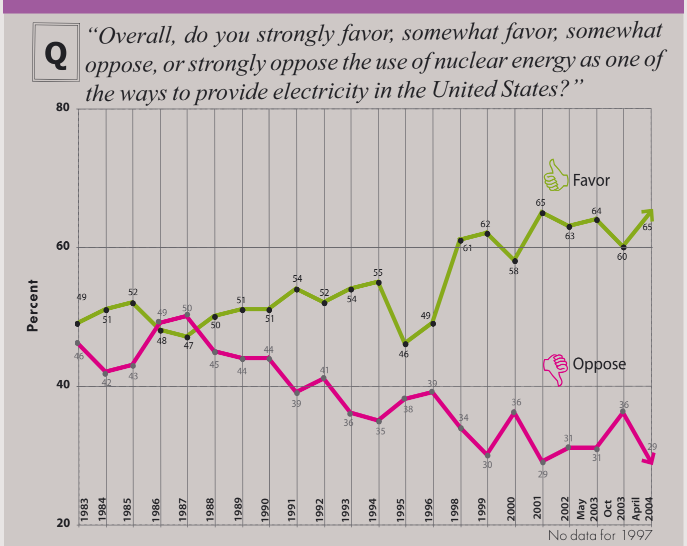
National public opinion surveys sponsored by Nuclear Energy Institute (NEI) have tracked changes in public opinion on nuclear energy issues for 21 years, providing "snapshots" over time of where the public stands. The surveys are conducted by telephone with nationally representative samples of 1,000 US adults and have a margin of error of plus or minus three percentage points.

The latest survey, conducted 16-18 April 2004 by Bisconti Research with NOP World, found that 65% favor the use of nuclear energy — a record high. Also, 64% of Americans now say that it would be acceptable to add a new nuclear power plant at the site of the nearest operating nuclear power plants, up from 57% in October 2003.

These positive changes are closely linked to perceptions of the need for nuclear energy. Focus groups for NEI indicate that electricity reliability is a leading consumer concern, especially in the context of instability in the Middle East region; a major blackout in the US that affected the northeast and midwest in August 2003; and the rising cost and supply volatility of natural gas.

Previously, support for nuclear energy — and for building more nuclear power plants — peaked after energy problems in California were widely reported in 2001. Support for building more nuclear power plants increased again after the August 2003 blackout, especially in those areas that were affected, the northeast and midwest. Between May and October 2003, acceptability of building new nuclear reactors at the nearest existing nuclear plant sites rose 18 percentage points in the northeast (40%

Favor/Oppose Nuclear Energy, Trend in %



We Should Definitely Build More Nuclear Power Plants

to 58%) and 11 percentage points in the midwest (55% to 66%).

On other measures, 54% in April 2004 said that new nuclear plants *definitely* should be built to provide future electricity supply, 69% were in favor of keeping the option to build more nuclear power plants in the future, and 82% supported license renewal for nuclear power plants that continue to meet government safety standards.

The April survey also found that 74% agreed that government and electric companies should work together to develop state-of-the-art nuclear power plants that can be built to meet new electricity demand. This question was asked for the first time in April to assess support in principle for current provisions in US energy legislation that would promote public-private partnerships.

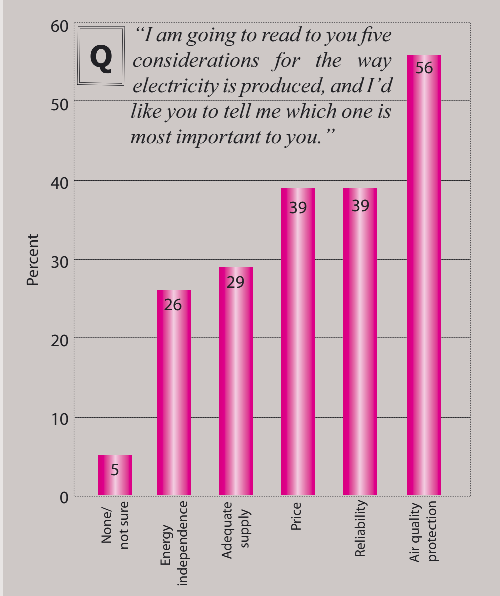
Perceptions of the safety of nuclear power plants continue to be much more favorable than in the 1980s and early 1990s. Sixty percent rated nuclear power plant safety high, and 19% rated safety low. A dramatic shift in perceptions of safety in the past decade (from 34% in 1984 to 60% today) corresponds with measurable improvements in plant performance and efficiency.

Also, perceptions of the nearest nuclear power plant were quite favorable: reliable (82%), safe (73%), and clean (70%). However, residual ambivalence is seen in the fact that 38% still feel uneasy with the nearest plant. Also, the public is divided about equally as to whether the nearest plant is good or bad for the environment.

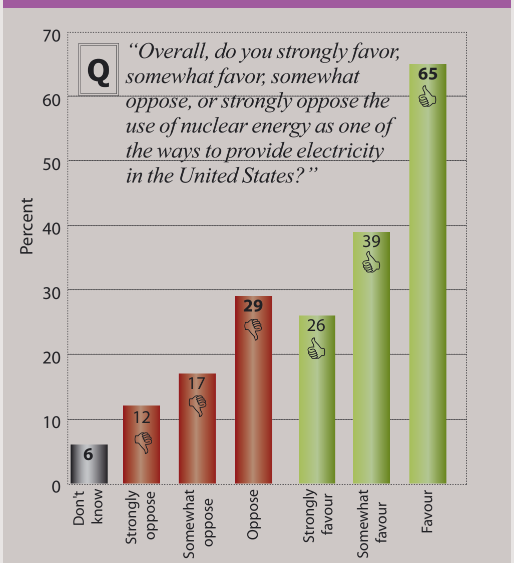
One of the greatest challenges to the nuclear energy enterprise is to increase awareness of the environmental benefits of nuclear energy. Only 27% rated nuclear energy "one of the best" sources of electricity for air quality protection. However, of five considerations in the way electricity is produced — reliability, price, adequate supply, energy independence, and air quality protection — air quality protection was rated most important.

Ann Stouffer Bisconti is President of Bisconti Research, Inc., a public opinion research group based in Washington, DC. Results of surveys are reported on the web site of the Nuclear Energy Institute at www.nei.org. Author E-mail: ann@bisconti.com

Most Important Considerations for the Way Electricity is Produced



Favorability to the Use of Nuclear Energy



Advancing the Nuclear Option

In April 2004, three consortia of global energy partners were formed to test the US Nuclear Regulatory Commission's new process to obtain a combined construction and operating license for advanced nuclear power plants. The consortia include a total of 19 leading energy companies and reactor vendors from the US, Japan, France, and Canada. No commitment is being made to build a nuclear unit at this time.

The new streamlined licensing process was established in 1992 by the US Congress and includes *putting public participation at the front end of the process where it is most meaningful.* Successfully testing the process can reduce some business uncertainty for companies interested in building new nuclear plants.

The consortia plan to complete the licensing application and submit it the NRC in 2008.

New Accents on NUCLEAR ENERGY

Nuclear Energy Among Choices Facing the Bigger EU

Five of the ten countries which officially joined the European Union (EU) on 1 May 2004 — Czech Republic, Hungary, Lithuania, Slovakia and Slovenia — rely on nuclear energy to provide a fourth or more of their electricity needs, based on the IAEA's nuclear databanks.

In total, they have 19 operational reactor units. Their accession means that 13 out of the 25 EU member states produce electricity using nuclear power, and the total number of operational reactor units in the EU now tops 150.

Czech Republic

Six nuclear plants are operating, two at Temelin and four at Dukovany, collectively supplying about a fourth of the country's electricity.

Hungary

Four nuclear plants are operating at Paks, supplying about 33% of the country's electricity.

Lithuania

Two nuclear plants are operating at Ignalina, supplying about 80% of the country's electricity.

Slovakia

Six nuclear plants are operating at Bohunice and Mochovce, collectively supplying about 57% of the country's electricity.

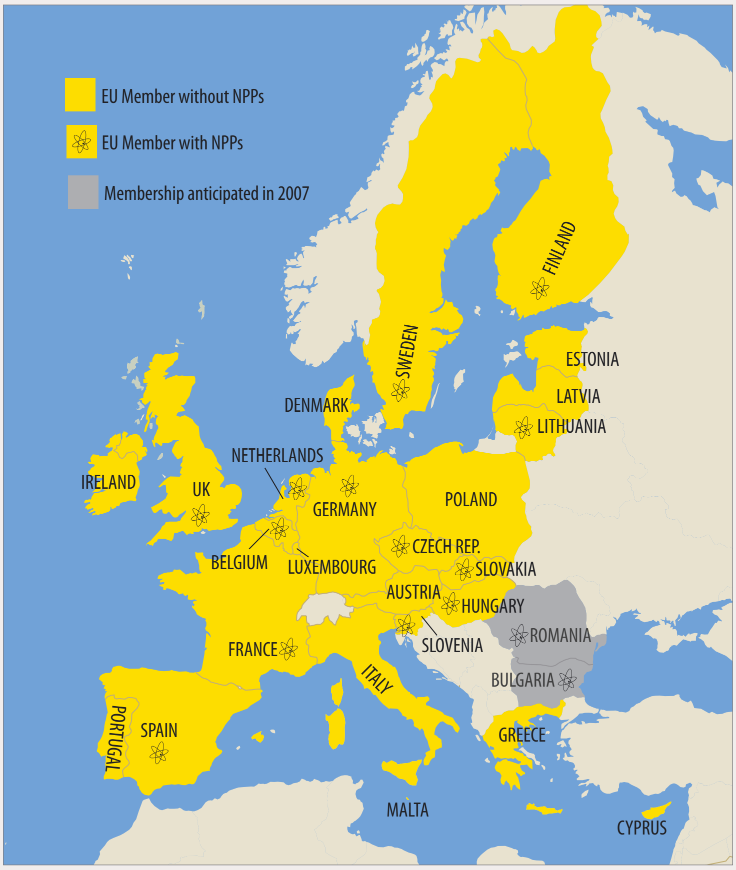
Slovenia

One nuclear plant is operating at Krsko, supplying about 40% of the country's electricity.

The new countries will add to the overall use of nuclear energy by nearly 450 million people in the expanded EU. Before the expansion, about one-third of the world's nuclear-generated electricity was consumed in the EU. Nuclear was also the community's largest single energy source for electricity generation, ahead of coal at 29% and gas at 15%. As noted at a recent European energy conference attended by IAEA Director General Mohamed ElBaradei, nuclear's future is mixed and countries face important choices. Besides the five new EU countries, eight others operate nuclear power plants — Belgium, Finland, France, Germany, Netherlands, Spain, Sweden, and the United Kingdom. Of these, four (Sweden, Germany, Belgium and the Netherlands) have introduced phase-out programmes, while Finland plans to build more nuclear plants.

At the European energy conference, Dr. ElBaradei outlined three critical challenges facing nuclear power's future in Europe and other countries — clear global and national strategies for the management and disposal of spent fuel and radioactive waste; high levels of nuclear safety performance; and upgraded nuclear security.

The IAEA places high priority on addressing the safety of nuclear power plants in the European region, as elsewhere. The EU additionally



Nuclear Energy Status in the EU, 2003

	NPPs In Operation	Nuclear Share of Total Electricity (%)
LITHUANIA	2	79.9
FRANCE	59	77.7
SLOVAKIA	6	57.4
BELGIUM	7	55.5
SWEDEN	11	49.6
SLOVENIA	1	40.4
BULGARIA*	4	37.7
HUNGARY	4	32.7
CZECH REPUBLIC	6	31.1
GERMANY	18	28.1
FINLAND	4	27.3
UK	27	23.7
SPAIN	9	23.6
ROMANIA*	1	9.3
NETHERLANDS	1	4.5

*anticipated membership date: 2007

Source: IAEA, May 2004

has issued a package of safety and related measures to cover the future development of nuclear energy in the enlarged union. Global cooperation on nuclear power and safety issues includes expert peer reviews, the exchange of operating experience, and legal conventions.

All five new EU countries with nuclear plants, for example, have joined the international Nuclear Safety Convention that sets benchmarks linked to IAEA safety standards. Each filed national reports at the last review meeting in 2002.

While EU enlargement means increased nuclear-generating capacity, it also means the shut-down of some reactors as negotiated in the terms of EU accession. Lithuania must close its two units by 2005 and 2009 respectively, while Slovakia must close down two of its six units — in 2006 and 2009 — although it has another two under construction. Bulgaria, which is lined up to join the EU in 2007, faces similar shut-downs as part of its accession deal.

Regarding nuclear safeguards — which are geared to verifying State pledges for the exclusively peaceful use of nuclear energy — the five new EU countries with nuclear power plants are members of the global Nuclear Non-Proliferation Treaty (NPT) and have safeguards agreements with the IAEA. They also have signed or ratified Additional Protocols that grant IAEA safeguards inspectors broader rights of access to sites and information.

EU Background

The new EU countries have expanded the EU's membership from 15 to 25. The new members are Poland, the Czech Republic, Slovakia, Hungary, Estonia, Latvia, Lithuania, Slovenia, Malta, and Cyprus. Romania and Bulgaria are also expecting to join in 2007.

The EU was founded as the European Economic Community (EEC) by the Treaty of Rome in 1957 to promote economic and political integration in Europe. The EEC has expanded from its original six members (Belgium, France, Germany, Italy, Luxembourg, and the Netherlands) to include the United Kingdom, Ireland, and Denmark in 1973; Greece in 1981; Spain and Portugal in 1986; and Austria, Finland, and Sweden (former members of the European Free Trade Association) in 1995.

For more information, please visit: www.iaea.org/NewsCenter/News/2004/energy_eu.html

IN BLACK & WHITE

MEDIA'S ROLE IN SHAPING PUBLIC OPINION

by Choi Yearn-hong

Credit: D.Calma/IAEA

In a modern, democratic society, the newspaper's role is important and critical in shaping citizens' opinions on nuclear power and other issues. Citizens acquire knowledge on current issues in their society, nation, and the world through newspapers. Today, television and internet media is increasingly becoming more popular among citizens, but newspaper media continues to affect intellectual citizens, policymakers and think tanks. Therefore, assessing major daily newspaper editorials covering nuclear issues and affairs is necessary for their sound bridging between nuclear science and engineering and the public. Bridging the two cultures, science and humanities, is an enormous task for modern democratic society.

Ultimately, the public's understanding of nuclear issues should be healthy and sound. In a democratic society, citizens cast their votes for the public servants who they agree with most and for who they believe will influence and change public policy. The citizens also look to their representative government to bring light to issues in the good of public interest. If they are not well equipped intellectually for societal issues, their choice of government representatives and support for certain policy issues can be dangerous. This jeopardizes the success of a modern democracy.

The social implications of risk and the public's understanding of public challenges to modern society and technology have been seriously discussed in the United States and European nations. South Korea is starting to discuss the public's understanding of science and technology issues, including nuclear power plant safety and nuclear waste disposal.

Many daily newspaper editorials on nuclear issues were concentrated on nuclear weapons, non-proliferation, arms reduction talks, and weapons testing bans. The US editorials covered the US-Russia arms reduction talks and implementation of the treaty, North Korean nuclear weapons program, nuclear conflict between India and Pakistan, emerging nuclear power in Iran and Iraq, nuclear lab and spy infiltration of US nuclear science and development information, and IAEA inspection and its role for world peace. The South Korean editorials covered extensively North Korea's suspected nuclear weapons program, long distance missiles, and Japan's possible nuclear armament.

Concentration on nuclear arms is understandable. The mass destruction of human civilization is feasible with a possible nuclear war, or human mishap at nuclear facilities. Concern for nuclear energy, nuclear power plant safety, nuclear waste management, nuclear medicine, and nuclear research and development issues are scarce, because they are, unlike the nuclear arms issue, not at the forefront of concern. This research outcome shows the unbalanced approach by newspaper editorial writers on nuclear issues. Readers of newspaper editorials can be influenced by the concentration on the nuclear weapons issue, and scarcely other issues, resulting in the public's understanding of nuclear issues to be quite skewed.

The US editorial writers defended the scarcity of nuclear issues outside nuclear arms issue saying, "There has been no new construction of nuclear power plants since Three Mile Island. Nuclear power plant safety has been long proven, so that there is no critical issue. Editorials are basically comments on current issues. There are no current issues. That is why." Some writers have also claimed that they were influenced by the anti-nuke environmentalists.

In interviews with more than a dozen editorial writers, I asked a couple of questions: "Is the newspaper educating the public?'' and "Don't you think the newspaper editorials should take a balanced approach toward various nuclear issues?'' The first answer was, "Yes, it does.'' The second answer was, "Yes, they should.'' These answers are normative. Mr. J.W. Anderson, a former *Washington Post* editorial writer and journalist-in-residence at Resources for the Future, an environmental think-tank in Washington, told me, "The newspaper's role as the public educator has been diminishing. Its role is becoming more as that of entertainer like television. Education belongs to the schools and colleges. Don't you think so?'' He added, "All editorial writers attempt to approach evenly on the issues. However, they have their own views and they reflect the newspaper's image.''

Credit: D.Calma/ IAEA

A majority of editorial writers accepted the educational experiences for a better understanding of nuclear science and technology as a part of science policy and/or energy policy. Some frankly told me they were not experts on nuclear issues. They learned things at news sites, in the street or in the field. Their educational backgrounds were diverse. Some studied humanities, some social sciences, and very few the natural sciences and engineering. They were mainly journalists.

Harvard, Indiana and Missouri journalism schools have educated many of the US and foreign journalists, including Korean reporters, editorial writers, and newspaper executive directors. The Korean colleges and universities should create similar programs to educate journalists.

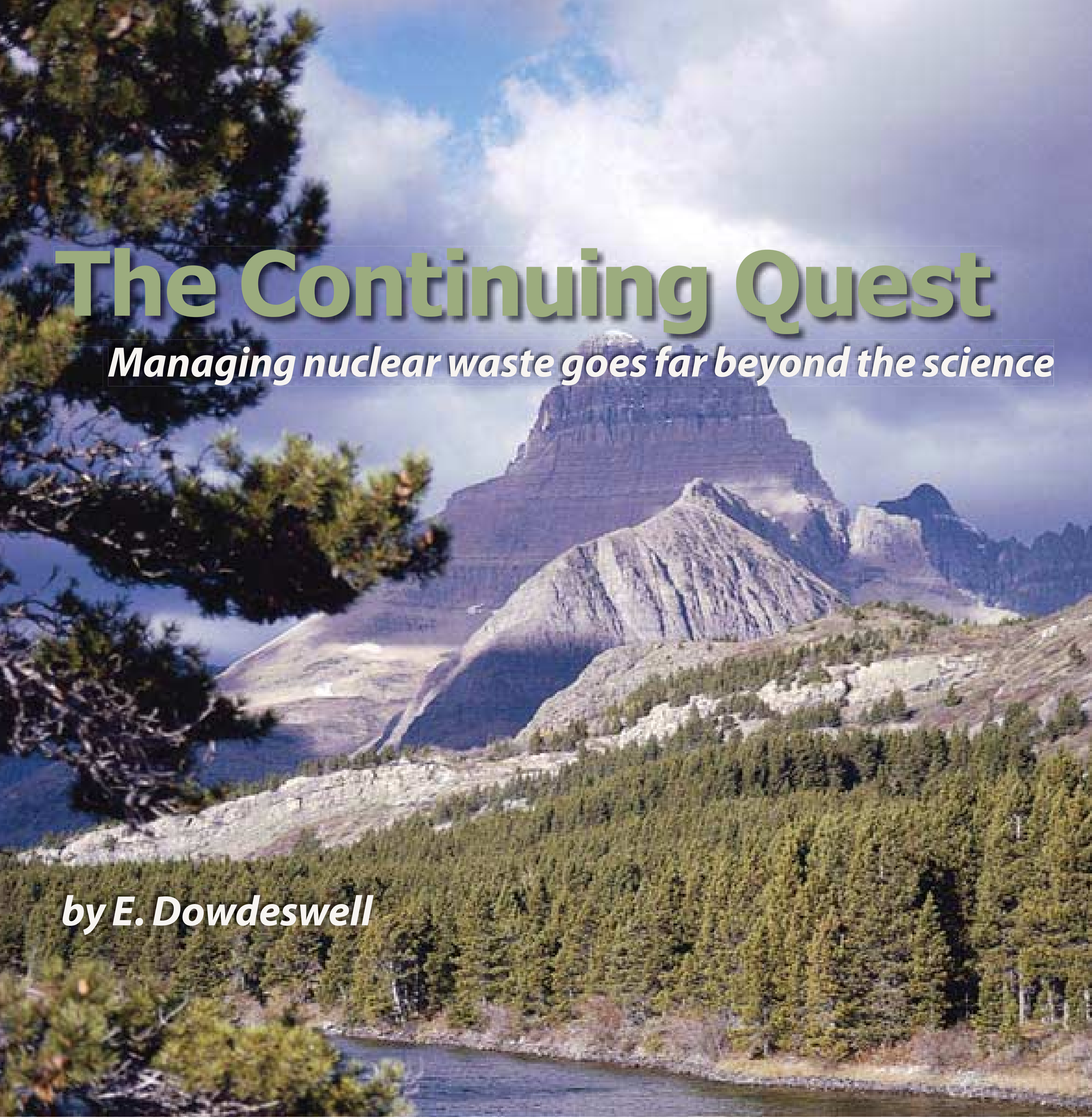
The newspaper's role as a bridge between science and the public is not particularly visible or conspicuously evident. Their role is subdued to populism. Anti-nuclear environmental movements are persuading or forcing the newspaper's role as a middle-of-the-road mediator or fair and objective educator. Newspaper's role as a bridge may be abandoned in the future under popular trends. Korean newspapers report on German and Scandinavian nations' decision to seek alternative energy sources over nuclear power. They do not report on China, India and other Asian nations' search for nuclear power. They do not report on how much energy can be possibly generated from alternative energy sources such as solar, wind or tides in Korea in next 10 or 20 years.

The US reliance on nuclear power is about 10 percent of its total energy consumption. However, South Korean reliance on nuclear power is about 50 percent of all electric power consumption. South Korea's future economic development and energy policy should more seriously and frequently be discussed in the newspaper opinion pages. A more realistic approach toward nuclear energy policy should be discussed in depth.

Choi Yearn-hong is a poet, Professor at University of Seoul and a columnist for The Korean Times. Choi Yearn-hong is one of a group of journalists who participated in the Journalist Seminar in the margins of the International Conference on Fifty Years of Nuclear Power in Obninsk, Russia organized by the IAEA and hosted by the Government of Russia in June 2004. This editorial first appeared in The Korean Times in March 2004. E-mail: yhc@uos.ac.kr

The Continuing Quest

Managing nuclear waste goes far beyond the science



by E. Dowdeswell

In the early years of this new millennium our world is changing dramatically. This is a time of blinding technological change, increasingly interconnected economies and growing alienation between citizens and their institutions. A sustainable world is not an unreachable goal, but any critical environmental, social or economic analysis would certainly raise questions about our current trajectory.

The issue of the long-term management of nuclear waste illustrates well the conundrum that society faces. It is an issue that embodies scientific complexity and uncertainty. It inspires fear and insecurity and polarizes citizens. It is very long-term in character, raising questions of inter-generational equity quite inconsistent with the time frames of elected governments. It raises discussion of trade-offs: energy sufficiency versus significant financial investment and long-term security. In sum, it is an issue that requires much better understanding of resilience, vulnerability and the dynamic interaction between nature, technology and society.

Questions of environmental protection are among those raised for waste management.

All nuclear nations have faced significant challenges in their quest for an acceptable approach for the long term management of the nuclear waste they generate. The story behind that fact illustrates the degree to which the nuclear industry is being shaped by factors much beyond the scientific and technical. Social, ethical and economic considerations are now being recognized as legitimate aspects of the public policy process.

Radioactive waste decisions, once considered the exclusive purview of governments and the nuclear community, are now clearly in the public domain.

Of 32 nations that harness nuclear energy to generate electricity some have declared, or even legislated, that deep geological disposal is their ultimate intent. However, few have progressed to the point of final repository site selection. Over the past decade a number of national management programs have had to be reigned in and re-thought, put on hold, or even abandoned, in the face of public opposition and activist electorates. Radioactive waste decisions, once considered the exclusive purview of governments and the nuclear community, are now clearly in the public domain.

In Canada there may not have been marches in the streets, but the experience was not dissimilar to what happened elsewhere. Interveners made it clear that social acceptability is as important as technical safety.

The Process in Canada

By the late 1980s extensive scientific work had been done by Atomic Energy of Canada Ltd. (AECL) on a concept for geological disposal of used nuclear fuel deep in the plutonic rock of the Canadian Shield. The concept was put to an environmental assessment panel for public review. After a nine-year study the Seaborn Panel concluded that, on balance, from a technical perspective, the safety of the AECL concept had been demonstrated but, from a social perspective it had not. Just as had happened in many other countries, Canadian nuclear waste producers were sent back to the drawing board.

The Nuclear Waste Management Organization (NWMO) was established in late 2002 in response to federal legislation requiring Canada's nuclear energy corporations to create an organization to investigate and develop an approach for the long-term management of their used nuclear fuel. An independent Advisory Council acts as a guarantor of the public interest. The companies were also required to put in place trust funds to ensure that the money will be available to finance the nuclear waste management approach ultimately adopted by the government.

The NWMO has been given three years to study, at a minimum, three approaches including deep geological disposal, storage at the nuclear reactor sites and, centralized storage, either above or below ground. We must examine the risks, costs and benefits, develop implementation plans and consult with Canadians. Once the Government of Canada takes a decision on our recommendations the NWMO will be responsible for implementation.

It is reasonable to ask, "What will make this attempt any different than those of the past?" The answer may lie in our search to understand the deeply held values of citizens and to review our options through a multi-dimensional lens that is in part shaped by citizens themselves.

Sustainable development is our conceptual underpinning. We see as our purpose, to develop collaboratively with Canadians a management approach that is socially acceptable, technically sound, environmentally responsible and economically feasible.

Our approach includes a focus on broad engagement of society; a comprehensive (not just technical) review; a study built around three milestone documents so that we could learn together with citizens – first about the framework for the study itself, then the assessment and finally the recommendations and implementation plan. We provide a forum for recognizing divergent viewpoints and seeking common ground.

From Dialogue to Decision

Our journey from dialogue to decision is well underway. Our first discussion document "Asking the Right Questions? The Future Management of Canada's Used Nuclear Fuel" defines the problem, communicates potential choices and poses a way of assessing the alternatives. Key questions have emerged from our preliminary conversations with a broad cross-section of Canadians. They brought perspectives and ideas that were instrumental in advancing our knowledge and understanding. We listened and learned.

Scenario workshops helped us imagine the future. Workshops with environmental interests, representatives of aboriginal communities and those with technical and scientific expertise contributed insights about expectations and concerns, the knowns and unknowns and suggested possible ways forward. Papers were commissioned to capture the current state of knowledge on a broad range of technical matters as well as evolving concepts related to our work. And of course we benefited from the experiences of other countries around the globe. Throughout, a panel of ethicists reminds us of the ethical implications of our process and thinking.

Ours is a work in progress. Two interrelated tracks of activity are underway: an assessment which thoroughly examines the options and an engagement program through which we are testing our initial observations and refining our thinking. This iterative process of seeking input and exposing our evolving ideas will continue until our task is completed.

A multidisciplinary assessment team has developed an assessment methodology that builds on the framework identified by citizens. It is being applied to each of the alternatives, identifying the risks, costs and benefits and describing the social, economic and ethical considerations associated with each of them. The team is also testing the robustness of different approaches against different time frames contemplated in the earlier scenarios workshops. All of this work will be shared with the public for review before recommendations are developed.

The core of our engagement program is our web site. It is becoming a significant repository of information and an active venue for engagement and exchange. It offers simple polls and short surveys, invites more comprehensive electronic submissions and will host moderated "e-dialogues."

To be able to choose the right technical solutions we must first ask what requirements the technology has to live up to.

An innovative National Citizens' Dialogue has brought together a representative sample of citizens in 12 communities across Canada to learn about nuclear waste in a group setting and think through their views and expectations for its long-term management. In considering the key issues and trade-offs we are trying to identify and understand the core values of the general public.

Additionally, dialogues tailored to the specific needs and requirements of aboriginal peoples, communities that currently store used nuclear fuel and organizations active in social and environmental matters have been organized.

Meeting the Challenge

There are no "right" answers to many of the ethical questions. How do we accommodate the desires of the current generation while recognizing that the decisions we make now may affect the lives of our children, their children and many generations to come? How heavily should we rely on emerging technologies? What forms of institutions and governance inspire trust and confidence?

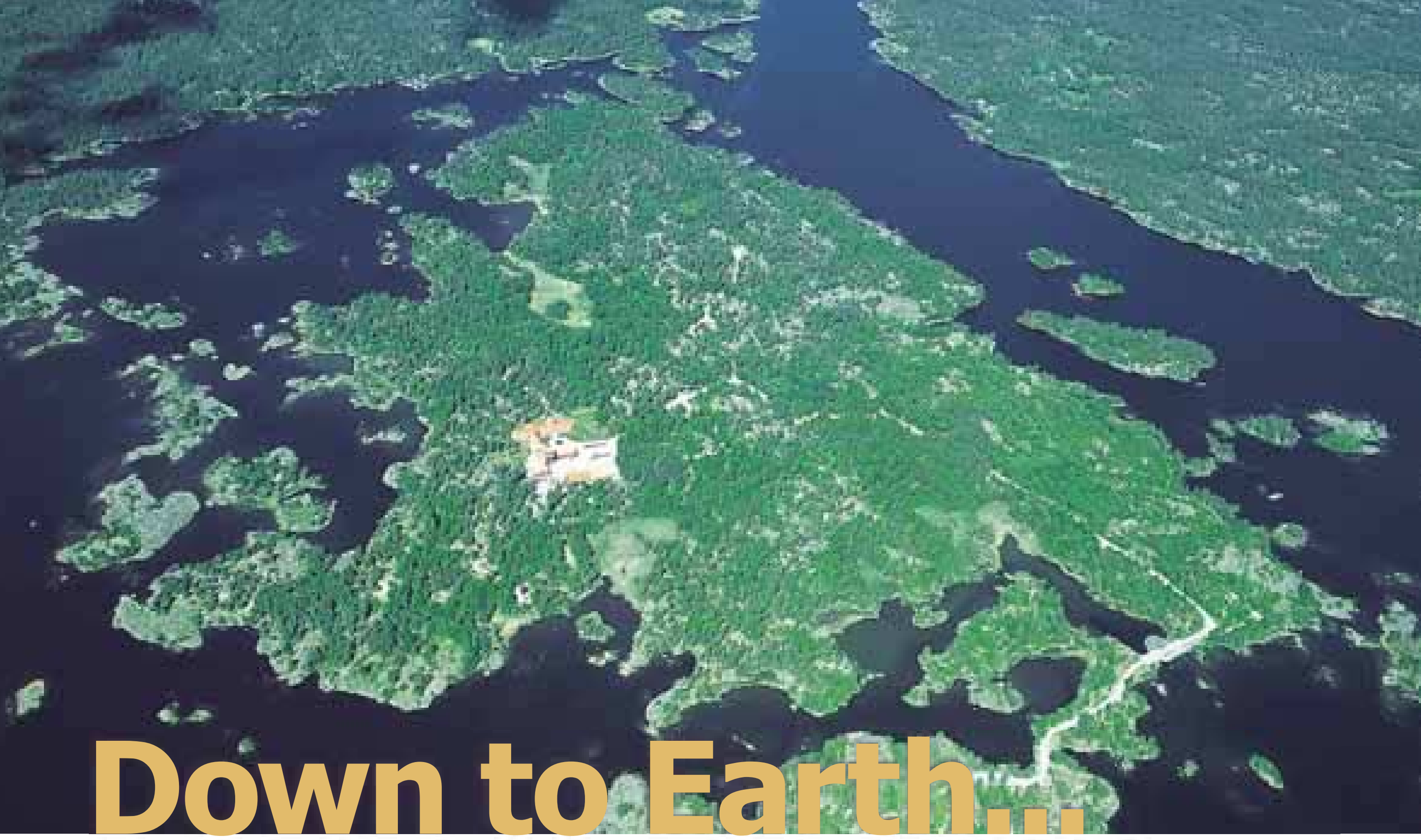
How we approach this challenging public policy issue will say a lot about our values and priorities as a society — how we want to live.

These questions and more are fundamental to meeting the challenge of managing used nuclear fuel in an appropriate and acceptable manner. To be able to choose the right technical solutions we must first ask what requirements the technology has to live up to. Despite the fact that scientific and technical research into waste management options has been going on for decades a solution has eluded us. Perhaps that is because there has been no agreement on the societal values we wish to protect. Perhaps also because we have been arrogant in our assumptions that expertise resides only in the minds of a select few.

Within Canada and internationally, the landscape against which our study is being conducted is shifting. Issues of energy policy, security, health and safety, environmental protection, and good governance are prominent on the public agenda.

How we approach this challenging public policy issue will say a lot about our values and priorities as a society — how we want to live. Fundamentally it is about developing a contract between science and society: a contract that allows us to benefit from technology while managing the risks and respecting the values of Canadians.

Elizabeth Dowdeswell is President of Canada's Nuclear Waste Management Organization (www.nwmo.ca). She has had an extensive career in government, education and international affairs. From 1993 to 1998 she served as Executive Director of the United Nations Environment Program. Before joining the United Nations, Ms.Dowdeswell was Canada's Assistant Deputy Minister of Environment from 1989 to 1992, responsible for the national weather and atmospheric agency. E-mail: edowdeswell@nwmo.ca



Down to Earth... and below

Sweden's Plans for Nuclear Waste

by Claes Thegerström

Significant progress in the area of nuclear waste management has been made in several countries during the last few years. Siting decisions for deep repositories were taken in Finland — with almost unanimous support in the national parliament as well as locally — and in the USA where the Yucca Mountain project enjoyed a majority vote in the US Congress. In Sweden, the final phase of the voluntary siting process has commenced with site investigations in two municipalities. In France, work on the underground research laboratory (URL) at Bure is progressing.

Several other countries have experienced difficulties or significant delays in their programmes. This means that while many countries still have a long way to go in order to arrive at concrete decisions about implementation of deep disposal, some countries such as Finland and Sweden are now approaching the licensing phase. In the case of Sweden, we plan to be able to start the licensing of the deep disposal system within the next few years.

The Swedish System

SKB, the Swedish Nuclear Waste Management Organization, has developed a system that ensures the safe handling of all kinds of radioactive waste from Swedish nuclear power plants for the foreseeable future. The cornerstones of this system are:

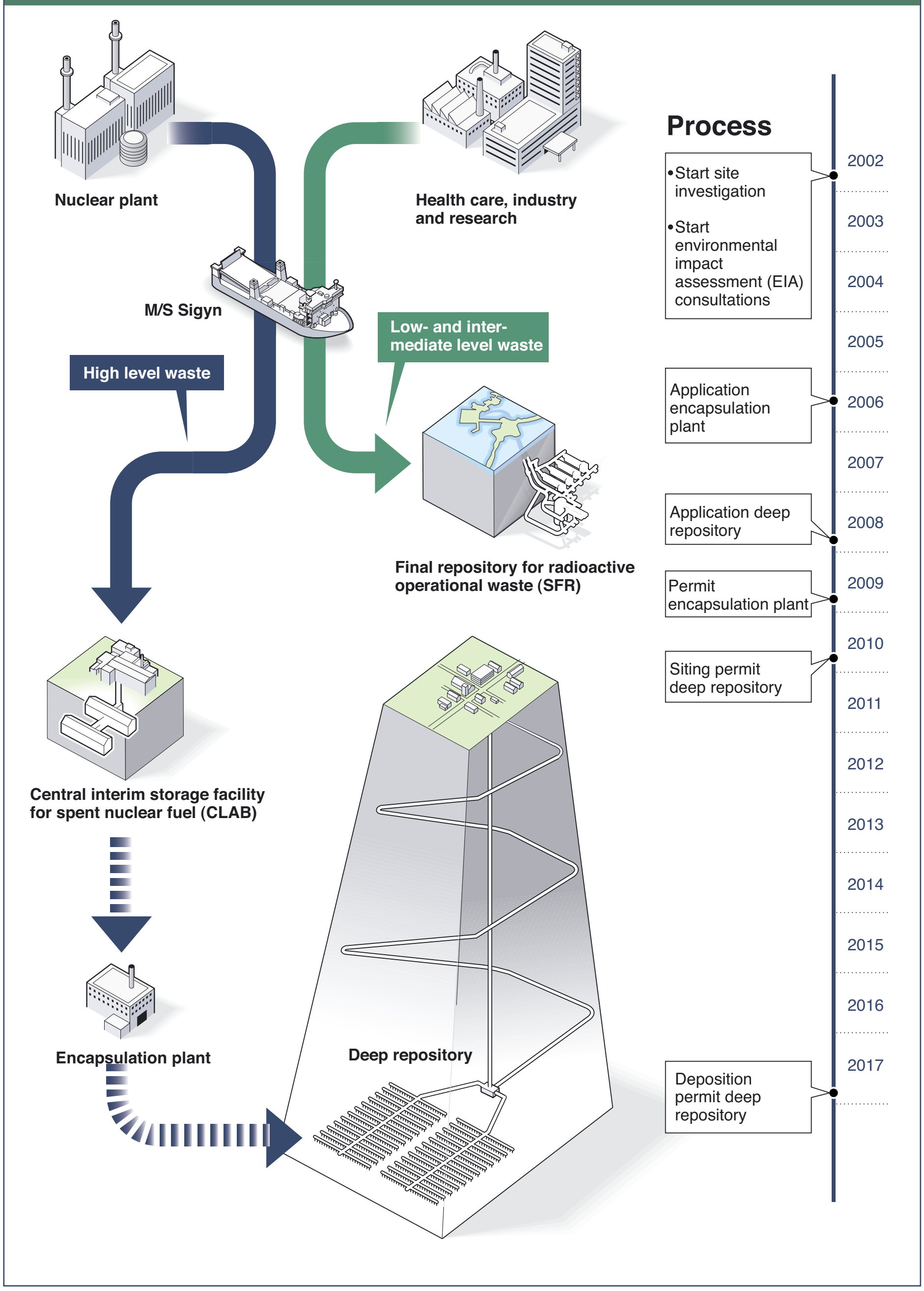
- A central interim storage facility for spent nuclear fuel, called CLAB, which has been in operation since 1985.
- A final repository for short-lived, low and intermediate level waste (SFR), which has been in operation since 1988.
- A shipping transport system (M/S Sigyn) which has been in operation since 1983.

The missing link in the system is the final approval of a method, and the location of a site, for the final disposal of high-level waste, i.e. the spent fuel, as well as a final repository for long-lived intermediate waste.

The plan for the final disposal of spent nuclear fuel is to encapsulate it in durable copper canisters and place

Air photo of the Äspo Hard Rock Laboratory — one of Sweden's laboratories built to research all the processes involved in deep repository storage. Credit: SKB

The Swedish System



it (embedded in betonite clay) in a deep repository approximately 500 metres down in the bedrock (the KBS-3 method). The work on research, development and demonstration of deep geological disposal of spent fuel has been an intensive one lasting for more than 20 years.

Site Investigations and Stakeholder Involvement

Actual siting work on the deep repository began in the early 1990s. SKB concluded that the strong political power of municipalities in Sweden concerning local issues and the special character of the nuclear waste issue will by necessity lead to a need for local understanding and support for the project in order to be able to construct and operate a repository. It was judged necessary to create a participatory and voluntary process in order to achieve such understanding. This approach was well supported by almost all the stakeholders.

In the year 2000, SKB presented an integrated account of the methodology for final disposal of spent nuclear fuel, the selection of sites and programme for the site investigation phase. The proposal was to proceed with site investigations in three of the communities where feasibility studies had been made. After a review by the regulatory agencies, the Swedish Government in 2001 endorsed SKB's proposal. The municipalities of Östhammar and Oskarshamn approved SKB's plans to proceed with site investigations, while the municipality of Tierp rejected further participation in the siting process.

The goal of the site investigation phase is to obtain a permit to build the deep repository for spent nuclear fuel. The permit applications will be based on broad supporting documentation. The investigations of the rock serve as a basis for configuring the underground units of the deep repository. These results will also influence the positioning and layout of the surface units of the repository and provide input for assessment of the environmental impact.

Much experience has been gained by SKB and others over the past 25 years of managing and communicating the nuclear waste programme. They can be summarized as follows:

◆ It is necessary to be clear and open, and it is vital to carefully define the problem to be discussed. Communication should concentrate first on *why* (sharing the problem) and then on *how* nuclear waste should be managed.

◆ Words cannot replace action. Trust or distrust will depend mainly on how an organisation is seen to behave. Thus priority should be given to actions — they speak louder than words. Visits to operational sites are important because people seldom disbelieve what they see with their own eyes, and practical demonstrations of how spent fuel can be handled — like in CLAB, the central interim storage facility — help to enhance confidence in future plans.

◆ It is important to maintain a constant dialogue with all stakeholders and the general public. Trust must be based upon continuity and an open discussion of all issues. Also difficulties and potential problems should be actively communicated to the public and the press by the implementer.

◆ We live in a global village. Events and debates in one country can be picked up literally within seconds by the media in another country. Thus there is a mutual dependence between waste management programmes. For instance, the progress made in neighbouring countries like Finland and Sweden has provided a mutual support between these two programmes. Thus the decision, in principle, in Finland on deep geological disposal (KBS-concept) at Olkiluoto has been most helpful in the Swedish debate. On the other hand some of the international discussions on international or multinational repositories have posed difficulties because such discussions — if they are not well structured — have created doubts about the possibilities of local municipalities to stay in control of the types and origins of the waste to be disposed of in their area.

Multinational Co-operation

However, if it is well structured and focuses on the development of a common basis of knowledge, international co-operation is important and rewarding. For a good number of years, the close international co-operation and co-ordination in R&D as well as safety principles within IAEA and other international fora has been extremely valuable.

I would like in particular to also emphasise IAEA's Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. It provides clear statements about the need for well-defined national waste management strategies and programmes as well as underlining that each country has a responsibility for its nuclear waste. The fact that it requires the presentation and international review of the programme documents will be a significant tool in helping all Member States define and develop their nuclear waste management plans.

Increased International Consensus

On the whole, the nuclear waste management arena is now characterized by positive trends and increased effort. When more people are pulling in the same direction, development gathers pace. I believe that there now is a trend towards focusing on national programmes and an increase in consensus, and I would especially like to emphasize the following issues:

◆ There is an increased consensus that deep geological deposits are required. There are certainly different opinions as to how long spent nuclear fuel or reprocessed nuclear fuel should be kept in intermediate storage. But there is increased consensus that, in the end, long-term safety is found through deep geological disposal.

◆ The multi-barrier principle has gained broad support. Different countries have different geological requirements, which in turn demand varying technical solutions. Despite this, there is a common view that robust safety is a matter of deep geological storage, reinforced with several technical and natural barriers.

◆ The importance of stakeholder involvement is becoming more and more self-evident. Dialogue and transparency is essential for a fair and successful decision process. This can be as much of an important and difficult task as the questions concerning geology and technology.

◆ There is also an increased consensus that focused efforts for implementation of long-term safe disposal should not be postponed to future generations. Even with present nuclear waste management plans, the work from construction of a nuclear reactor to a closed final repository will involve three generations.

◆ And finally, we are happy to note that there is an increased consensus that each country should take care of its own waste. If one chooses to co-operate with other countries, this should be made in a clear and transparent way and on a voluntary basis between countries interested in and open to possibly becoming the host of a multinational solution.

Concluding Remarks

The spent fuel disposal programmes in several countries, including Sweden and Finland, are approaching the phase of industrial implementation. At present there is a stable situation both in terms of scientific/technical capabilities to move forward and a broad social trust and confidence in the programmes. Thus, a real breakthrough is possible within the foreseeable future. This would mean that more than 25 years of investment in scientific/technical work, communication and confidence-building could bear fruit.

This is a golden opportunity to provide concrete results and all efforts are now focused on really making use of it when the resources, the know-how and the commitment needed is available. Among the key components for success are a continuous, high quality of scientific/technical work and a broad and open dialogue with all stakeholders.

Claes Thegerström is the President of SKB, the Swedish Nuclear Fuel and Waste Management Co. He has worked with nuclear waste and environmental protection matters since the 1970s both in Sweden and internationally. He is a member of CNE, the French National Scientific Evaluation Committee. E-mail: claes.thegerstrom@skb.se. For more information on SKB, please visit: www.skb.se.

Nuclear's Second Wind

Innovative "fast" nuclear power plants may be a strategic imperative

by Evgeny Adamov

Nuclear power needed 50 years to gain the same position in global energy production as the one achieved by hydropower over hundreds of years. All those years, proposals for new reactor concepts would come up every now and then alongside mainstream reactor technologies. In the nuclear-friendly 1960s and 1970s, some of those "innovative" concepts even led to demonstration or pilot projects.

Yet for all the diversity of new ideas, nuclear power entered the new century still moving in a rut of older mainstream technologies. Most were devised at the dawn of nuclear engineering, when reactors for production of weapon-grade isotopes and reactors for nuclear submarines propelled development.

Unless we understand the reasons why innovative technologies failed to make any appreciable progress way back then, it is impossible to answer the question of whether there is a need for them now or in the foreseeable future.

Few people, perhaps, may remember that nuclear power was not brought into existence by energy deficiency. Its advent was caused by the Second World War and the associated pressing necessity for increasing the power of weapons. Once the war ended, nuclear plans were fuelled by the intentions of both weapons designers (e.g., Russia's I. Kurchatov who initiated construction of the world's first nuclear power plant in Obninsk and US politicians led by President Dwight Eisenhower's "Atoms for Peace" Initiative in 1953) to counterbalance the military effort by encouraging peaceful nuclear applications.

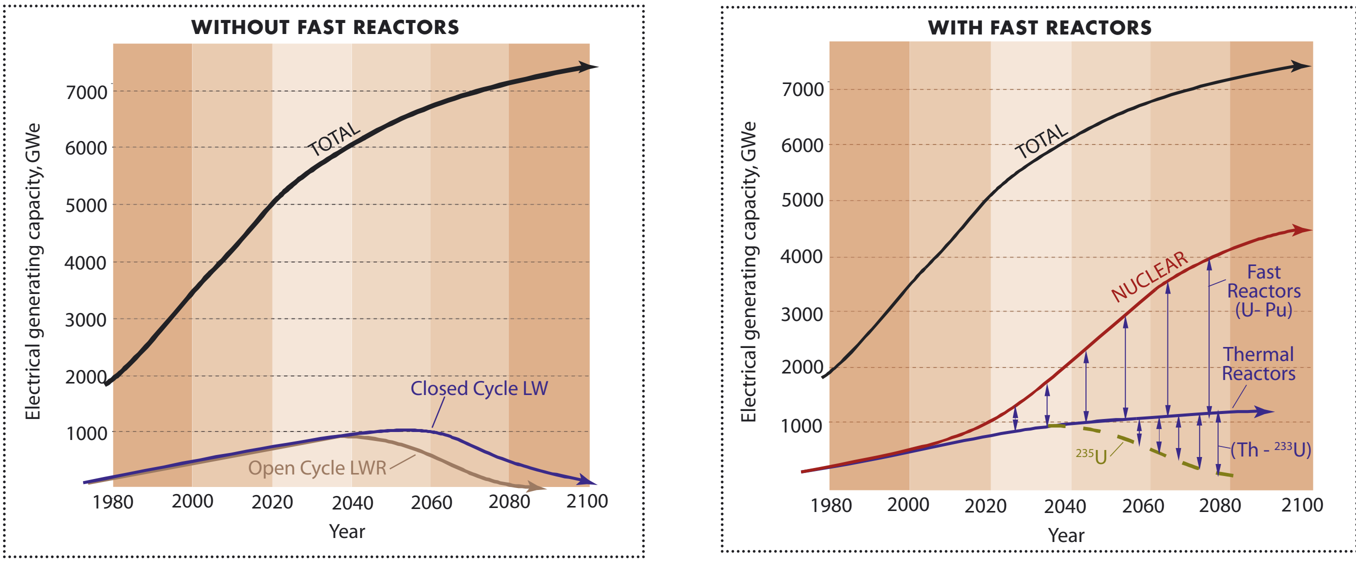
The Changing Context

Today, energy demands still are largely met by fossil fuels, as they were at the outset of nuclear development. In recent decades, zealous supporters of nuclear power have repeatedly referred to the imminent shortages of fossil fuels, though this gloomy prospect will not threaten humanity for another 100 years. That means potential shortages are not the only — or predominant — factor to encourage active search for alternative sources of energy.

Other factors have come more in play. One is the changing environmental context. At the end of the last century, acute environmental awareness demanded a closer look at "green" energy solutions. Nuclear power was assessed and shown to have advantages in terms of environmental protection over the majority of other energy technologies. However, the political enthusiasm of the Kyoto Protocol proponents has recently dropped so low that, with even more convincing evidence of the greenhouse effect hazard, reasons may still be found for taking the problem of greenhouse gas emissions off the priority list. Given the current 6 % share of nuclear in the total energy balance, it is quite reasonable to expect that the overall contribution of the so-called alternative sources (wind, solar, tidal, biomass, geothermal and other forms of energy) may well lead to expulsion of nuclear without noticeable losses to global energy supply.

Another factor is the evolving political framework. In the early period of nuclear power, it was assumed that the commercial industry would develop in the context of bipolar possession of nuclear weapons (NATO with the USA at

Figure 1: **Projected Nuclear Capacity Growth**



Notes: Tentative scenario, assuming potential inexpensive uranium reserves of approximately 10 Mt.

the head *versus* the Warsaw Treaty led by the USSR). As it turned out later, weapons-related technologies would not be confined to the circle of five States declared to belong to the nuclear club. Instead, the problem of non-proliferation acquired a more acute significance compared to developments influencing energy technologies. This was especially so in the context of the energy-saving drive and newly found oil and gas fields — including offshore deposits — which brought down the price of fossil fuels to record-breaking levels.

There is still much room for analysing why nuclear power not only fell far short of reaching generation levels projected in the 1970s, but also why it is very likely to keep losing its share on the energy market during the next 10 to 15 years. Such an analysis has been done in Russia and other countries. With such an approach, the requirements imposed on nuclear power are not subject to normal considerations of the market alone, and nuclear power itself should not be treated as a conventional sphere of commercial activities (as was persistently suggested in the previous decade).

Nuclear's "Second Wind"

The important point is that the necessity for innovative nuclear technologies needs to be assessed in the changing context. It is important to examine the possible conditions that may cause a demand for nuclear power and the circumstances under which the technology may gain its "second wind". For some countries, such as France and Japan, the lack of their own oil or gas resources is in itself a sufficient motive for keeping nuclear in the energy mix. Others may seek diversification of the energy sector or self-sufficiency in energy as a high priority.

Safe nuclear power is also capable of producing hydrogen, for example, and doing it in a profitable way. This use would allow reducing consumption of fossil fuels in electricity generation in the future, thereby saving these resources for other, more expedient applications in transport and energy-intensive industries. Even today, this may be an attractive option for some strong economies.

It is important to examine the possible conditions that may cause a demand for nuclear power and the circumstances under which the technology may gain its "second wind".

Yet paradoxical as it may seem, nuclear's second wind could be fuelled by rising costs and concerns over weapons proliferation and how to manage risks. Until nuclear weapons are totally banned and eliminated, proliferation will remain a risk demanding tight controls to keep nuclear materials and technologies from falling into the wrong hands. Right now, efforts to maintain and develop nuclear technologies, the associated expertise and industrial facilities for the sake of nuclear weapons alone is by far a greater social and economic burden in terms of public spending than if this know-how were channelled and shared for energy production.

In Russia, for instance, activities to remedy the consequences of nuclear-weapons programmes are estimated at tens of billions of dollars, which are yet to be found in the national budget. Meanwhile, reasonable implementation of the strategy for dynamic nuclear power development to the year 2050, already endorsed by the Russian Government, is a way to avoid diverting these weapons-related funds from other sectors of social demand.

In my view, the way forward is to develop advanced nuclear power plants based on technologies that help deter the spread of nuclear weapons. Large-scale nuclear power should be built upon innovative reactor designs and fuel processes that can provide technological support to the nuclear non-proliferation regime, while helping to meet the world's electricity needs.

"Fast" Nuclear Plants

On non-proliferation and other grounds, designs for *fast neutron reactors* offer the most promising option *(See box, Fast Reactors)*. They would burn uranium-238 alone and, hence, allow eliminating uranium enrichment and separation of weapons-grade plutonium from the set of fuel-cycle technologies now used for nuclear power operation. Unlike earlier types, these fast reactors will have no fuel blanket where weapons-grade plutonium could be produced.

This option enables nuclear power development to become more technologically detached from the production of materials useable for weapons. It further would support other elements of the non-proliferation regime, including political and legal arrangements, such as inspections. These could be considerably facilitated, for example, by using satellite systems to watch the configuration of fuel-cycle buildings.

With such an approach, States now shouldering the cost burdens of nuclear proliferation could channel efforts differently. They could define the optimal conditions for sharing the advantages of innovative nuclear energy technologies with countries that have no nuclear weapons and, at the same time, feel a pressing need to develop their own energy production systems.

So, for example, while providing maximum access to nuclear technologies, nuclear States could address the non-proliferation problem, at first, by arranging — all on their own — energy production in needy regions of Asia and Africa. The use of nuclear energy, subsidised in its early development period in these regions, would be essentially non-commercial, and based on international assistance. The initiative thus might become a crucial factor in stabilising the political situation in areas of international conflicts — both known today and likely to appear in the future. At the same time, this initiative would fit excellently into the currently practised "design-build-operate" approaches and may well turn into major business for State-owned or international corporations as energy markets develop.

In my view, the way forward is to develop advanced nuclear power plants based on technologies that help deter the spread of nuclear weapons.

Can Nuclear Meet the Needs?

If nuclear power is to be considered as a strategic imperative for global economic and security, it is necessary to have a clear idea of its potential. Based on today's reactors and using an open fuel cycle (without reprocessing), nuclear power would use up the available reserves of reasonably priced uranium towards the end of this century. The total capacity of nuclear power plants would not rise much higher than the current level of about 350 GWe. By reprocessing and reusing fuel in thermal reactors, as practiced in some countries, a 15 to 20% increase in total power output could be attained. If thorium were used as fuel in addition to natural uranium, nuclear's potential contribution could be doubled at the most.

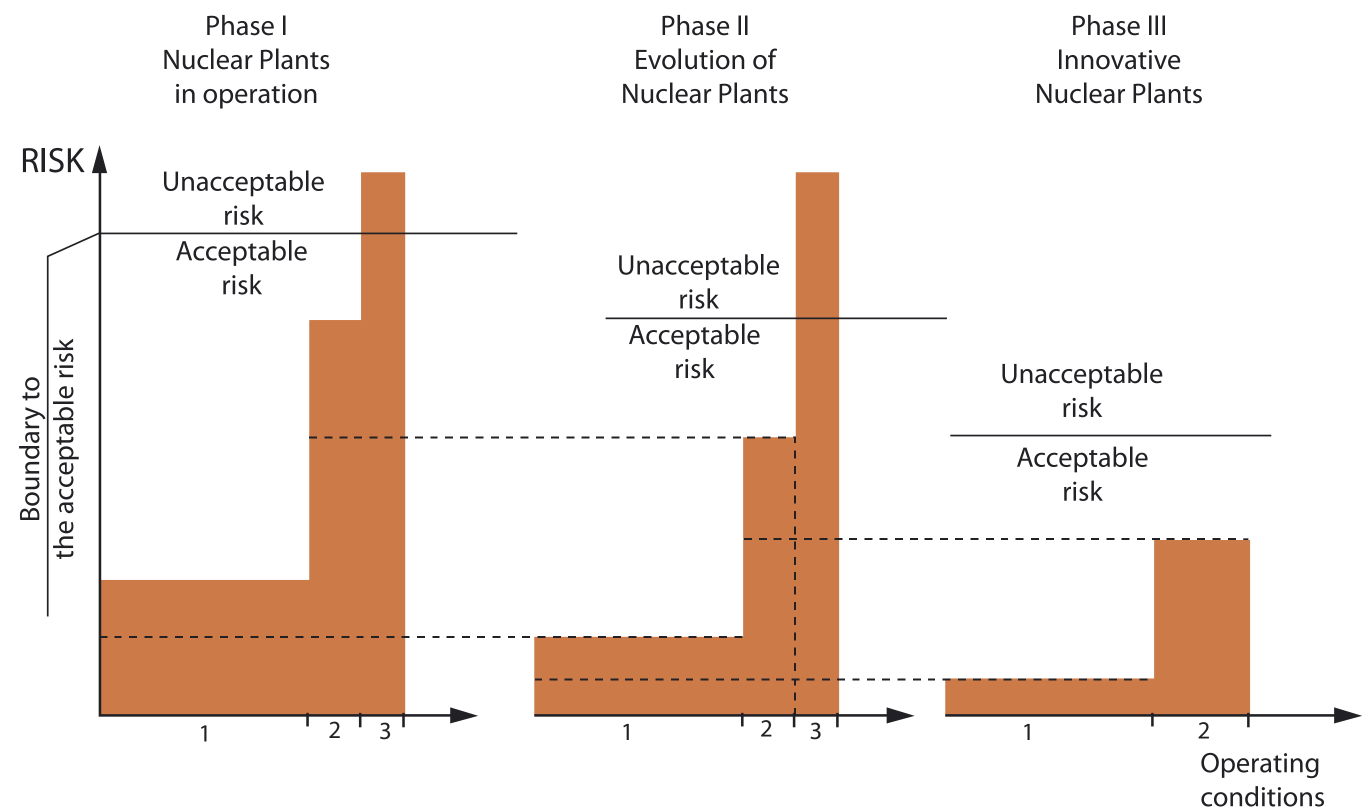
Fast Reactors

Fast reactors are not new, but their development is breaking new ground. Initially they were designed and configured to both consume and produce fuel. Such "breeder" reactors burn uranium fuels and breed plutonium that can be reprocessed and recycled to fuel reactors anew. France, Russia, Japan and other countries developed fast breeder reactors, though only a few generate electricity commercially today. Russia's BN-600, for example, has been supplying electricity to the grid since 1981.

Today's commercial nuclear plants mainly are "thermal" reactors that may or may not include fuel reprocessing. In basic terms, "fast" and "thermal" refer to what's happening inside the reactor core. In all types of reactors, the fission, or chain reaction, that generates heat is kept going by the energetic collision of neutrons with the fuel. In a thermal reactor, the neutrons are slowed down to what physicists call "low energy" by a moderator, such as graphite or water. In a fast reactor, the neutrons from the chain reaction are not slowed down and stay at "high energy".

For more technical information about fast reactors and what countries are doing, visit the IAEA's nuclear energy web pages at www.iaea.org.

Figure 2: **Nuclear Safety in Terms of Risk Categories**



1- Normal Operation; 2- Design-basis accidents; 3 - Beyond-design-basis accidents (including severe accidents)

The projected picture changes significantly if fast reactors are deployed and a closed fuel cycle is followed so that spent nuclear fuel is reprocessed and recycled for energy use. Nuclear then could provide all of the required increase to electric power production foreseen during the next few decades by the World Energy Congress (WEC). At a later point, nuclear would even be able to do away with constraints on fuel resources. The requirements of the Kyoto Protocol would be met automatically in this case and the greenhouse gas emissions of the power industry could be fixed at any predetermined level.

> If large-scale nuclear power is to be considered as a realistic option, there is no escape from the conclusion that the foundation of the industry should be formed by fast reactors.

In recent years, the pessimism of the 1990s has given way to some tendencies towards reinstating nuclear power among the priorities of energy strategies in a number of large countries, such as China, India, Iran, and Russia. The National Energy Policy of the USA also is quite symptomatic in this respect. Nevertheless, whatever the motives for nuclear power revival may be, the primacy of non-proliferation will remain an invariable priority of international politics. If large-scale nuclear power is to be considered as a realistic option, there is no escape from the conclusion that the foundation of the industry should be formed by fast reactors. Down the line, successful solution of the problem of controlled thermonuclear fusion may only add to nuclear's capabilities to meet ever-increasing global energy demands.

Safety & Waste

Beyond energy and proliferation concerns, the issues of nuclear plant safety and radioactive waste disposal are important to consider.

On the waste front, the nuclear engineering expertise built up throughout the years has helped find very efficient ways of radioactive waste disposal. These include various methods of sealing it off from the environment and burying it in carefully chosen geological formations. It is always a problem, however, to demonstrate safety of any storage facility — let alone a spent fuel repository — for a geologically meaningful span of time. This points to the need to develop a fuel cycle that does not add to waste problems, but minimizes them.

A nuclear electricity system based on fast reactors and a closed fuel cycle would make it possible to achieve what has been called "radiation-equivalent management" of nuclear materials. This management involves a process known as "transmutation" of minor actinides and fission products that is being developed as an alternative strategy for reducing and managing long-lived radioactive waste. With a closed fuel cycle for fast reactors, for example, the total activity of nuclear waste would approximate that of mined ore in no more than 150 to 200 years. This is certain to influence public perceptions of waste management.

Regarding plant safety, I cannot but acknowledge impressive achievements in the safety improvement of existing nuclear plants, through the use of probabilistic safety assessments and other measures. However, if we pursue the right innovative nuclear technologies, reactors can be developed that present no chance of severe accidents by virtue of their design, physics and materials. The advantages of such facilities may prove decisive in the public choice.

Such reactors have been referred to recently as "natural safety facilities". They would rely for their safety on laws of nature, rather than on additional engineered safety barriers and extra personnel. For instance, fast reactors can be designed so that their physics would exclude the possibility of serious accidents such as occurred at Chernobyl in 1986 or at Three Mile Island in 1979. *(The differences are illustrated in Figure 2.)*

Global Cooperation & Support

On various grounds then, fast reactors could open up new opportunities for assuring nuclear power's competitiveness. To serve strategic interests for energy and non-proliferation goals, national and international support will be needed for this new chapter in nuclear power development.

Many studies have analysed and defined the basic safety, economic and associated requirements for innovative reactor technologies. These are fundamentally different requirements from those of the 1960s and 1970s. The new requirements were translated into the key principles laid down in the Strategy of Nuclear Power Development in Russia in the first half of the 21st Century and were cited by the Russian President in his Initiative for International Cooperation announced at the UN Millennium Summit in New York in September 2000.

The IAEA General Conference in 2000 additionally gave rise to the so-called INPRO programme (International Project on Innovative Nuclear Reactors and Fuel Cycles), through which many countries are collaborating *(see "Fuelling Innovation" in this Bulletin edition)*. Recent statements of IAEA Director General ElBaradei are largely in accord with President Putin's global initiative.

In parallel, changes in the political attitudes towards nuclear energy, reflected in the US National Energy Policy, drove some countries to join forces through the Generation IV International Forum (GIF) for developing advanced nuclear reactors. Six reactor concepts, including fast reactors, have been selected for more detailed review before a final decision is made.

To serve strategic interests for energy and non-proliferation goals, national and international support will be needed for this new chapter in nuclear power development.

Incidentally, such work was carried out in Russia in the last decade and led to the choice of a lead-cooled fast reactor whose engineering design is in detailed development. The project is in a very advanced stage, and a site has been chosen in the Urals for possible construction of a demonstration plant. During the same period, R&D efforts were completed to support the approach of radiation-equivalent management of nuclear materials. The findings of the studies could serve as a basis for comparison with other reactor concepts and approaches to fulfilment of fuel cycle objectives.

The review of progress through INPRO and GIF has shown that the two could be coordinated, provided that the final goal is harmonised and defined as development of economically competitive large-scale nuclear power based on a closed fuel cycle and proliferation-resistant technologies. In light of rising interest in new approaches for nuclear power, it may be expedient to join INPRO and GIF activities to reach their common objectives through international cooperation. Successful implementation of the International Thermonuclear Experimental Reactor (ITER) fusion project, even though it comes ahead of the actual need for such facilities, is an excellent example of efficient cooperation in tackling the most challenging engineering tasks.

Cheap electricity produced by innovative nuclear power plants is an attractive basis for future economic development. It can help efforts to eliminate the oppressive disparity in regional standards of living and, ultimately, help resolve the basic reasons underlying political tensions and international conflicts.

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Fuelling Innovation

Countries look to the next generation of nuclear power

by Judith Perera

The past few years have seen several multinational initiatives looking at the prospects for the medium- and long-term development of nuclear energy. These include: the US-led Generation IV International Forum (GIF), the IAEA's International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO), and the European Michelangelo network for competitiveness and sustainability of nuclear energy in the EU (Micanet). There have also been two major studies — a joint investigation by the IAEA together with the OECD's International Energy Agency (IEA) and Nuclear Energy Agency (NEA), *Innovative Nuclear Reactor Development; Opportunities for International Co-operation;* and an interdisciplinary study by the Massachusetts Institute of Technology (MIT) on *The Future of Nuclear Energy*.

All these cover much of the same ground, looking at innovative nuclear systems including reactors and fuel cycles. But, while they were prompted by the same set of underlying imperatives, they also differ to some extent, not least in the importance they attach to the nuclear fuel cycle. GIF and INPRO are two initiatives where enhanced international co-operation could emerge.

GIF Initiative

GIF is essentially a US initiative. In 1997, the President's Committee of Advisors on Science and Technology reviewed national energy R&D and drew up a programme to address energy and environmental needs for the next century. This noted the importance of assuring a viable nuclear energy option to help meet future energy needs including properly focused R&D to address the principal obstacles to achieving this option including spent nuclear fuel, proliferation, economics, and safety. In response the US Department of Energy (DOE) initiated the Nuclear Energy Research Initiative (NERI) to address technical and scientific issues affecting the future use of nuclear energy in the US. In 1998, DOE established the independent Nuclear Energy Research Advisory Committee (NERAC) to provide advice to the Secretary and to the Director, Office of Nuclear Energy, Science, and Technology (NE), on the DOE civilian nuclear technology programme.

INPRO Members	BOTH INPRO & GIF	GIF Members
Argentina	Argentina	Argentina
Brazil	Brazil	Brazil
Bulgaria	Canada	Canada
Canada	France	France
China	Republic of Korea	Japan
Czech Republic	South Africa	Republic of Korea
France	Switzerland	South Africa
Germany	**Organisational Member:**	Switzerland
India	European Commission	United Kingdom
Indonesia		United States
Republic of Korea		**Organisational Members:**
The Netherlands		FORATOM
Pakistan		European Commission
Russian Federation		
South Africa		
Spain		
Switzerland		
Turkey		
Organisational Member:		
European Commission		

INPRO status as of June 2004. Observers from Euratom, the IAEA, and the Nuclear Energy Agency participate in GIF meetings.

GIF focuses on the collaborative development and demonstration of one or more fourth generation nuclear energy systems that could offer advantages in economics, safety and reliability, sustainability, and could be deployed commercially by 2030. The aim is to share expertise, resources, and test facilities to improve efficiency and avoid duplication. *(See table for GIF members.)*

The National Energy Policy (NEP), issued in May 2001 by the Vice President's National Energy Policy Development Group, supports the expansion of nuclear energy as a major component necessary to meet growing US energy requirements. In September 2002 the NERAC Subcommittee on Generation IV Technology Planning issued the Technology Roadmap for Generation IV Nuclear Energy Systems. In coordination with GIF, six innovative reactor concepts were selected for further collaborative research and development with the supporting fuel cycles a1nd also to serve as focus areas for innovative NERI-sponsored R&D projects. They include:

- Gas-Cooled Fast Reactor (GFR) — a fast-neutron-spectrum, helium-cooled reactor and closed fuel cycle;
- Very-High-Temperature Reactor (VHTR) — a graphite-moderated, helium-cooled reactor with a once-through uranium fuel cycle;
- Supercritical-Water-Cooled Reactor (SCWR) — a high-temperature, high-pressure water-cooled reactor that operates above the thermodynamic critical point of water;

◗ Sodium-Cooled Fast Reactor (SFR) — a fast-spectrum, sodium-cooled reactor and closed fuel cycle for efficient management of actinides and conversion of fertile uranium;

◗ Lead-Cooled Fast Reactor (LFR) — a fast-spectrum lead of lead/bismuth eutectic liquid metal-cooled reactor and a closed fuel cycle for efficient conversion of fertile uranium and management of actinides;

◗ Molten Salt Reactor (MSR) — produces fission power in a circulating molten salt fuel mixture with an epithermal-spectrum reactor and a full actinide recycle fuel cycle.

They are expected to be deployable within the next three decades. Comparative advantages include reduced capital cost, enhanced nuclear safety, minimal generation of nuclear waste, and further reduction of the risk of weapons materials proliferation. Work has started on four of the selected systems. The goals set for Generation IV nuclear energy systems are:

◗ Sustainability: meet clean air objectives and promote long-term availability of systems and effective fuel utilization for worldwide energy production; minimise and manage nuclear waste and reduce long-term stewardship;

◗ Economics: offer life-cycle cost advantage over other energy sources; offer level of financial risk comparable to other energy projects;

◗ Safety and Reliability: excel in safety and reliability; have a very low likelihood and degree of reactor core damage; eliminate the need for offsite emergency response;

◗ Proliferation Resistance and Physical Protection: represent a very unattractive and the least desirable route for diversion or theft of weapons-usable materials, and provide increased physical protection against acts of terrorism.

GIF studies have defined four classes of nuclear fuel cycle including once through, with partial recycle of plutonium, with full plutonium recycle, and with full recycle of transuranic elements. These were modelled over a century based on nuclear energy demand projections developed by the World Energy Council and the International Institute for Applied Systems Analysis.

The once-through cycle was shown to be the most uranium resource-intensive generating the most waste in the form of spent fuel, but the wastes produced are still small compared with other energy technologies. Uranium resources are sufficient to support a once-through cycle at least until mid-century. However, the limiting factor is the availability of repository space. This becomes an important issue, requiring new repository development in a few decades. In the longer term, beyond 50 years, uranium resource availability also becomes a limiting factor.

Systems that employ a fully closed fuel cycle can reduce repository space and performance requirements, although costs must be held to acceptable levels. Closed fuel cycles permit partitioning of nuclear waste and management of each fraction with the best strategy. Advanced waste management strategies include transmutation of selected nuclides, cost effective decay-heat management, flexible interim storage, and customised waste for specific geologic repository environments. They also promise to reduce the long-lived radiotoxicity of waste destined for geological repositories by at least an order of magnitude by recovering most of the heavy long-lived radioactive elements.

Various reactors could also be combined in symbiotic fuel cycles including combinations of thermal and fast reactors. Actinides from the thermal systems can be recycled into fast systems, reducing actinide inventories worldwide. Improvements in the burn-up capability of gas- or water-cooled thermal reactors may also contribute to actinide management in a symbiotic system. Thermal systems may also develop features, such as hydrogen production in high-temperature gas reactors or highly economical light water reactors as part of an overall system offering a more sustainable future.

GIF studies also found that nuclear energy is unique in the market since its fuel cycle contributes only about 20% of its production cost. They further suggested that adopting a fuel cycle that is advanced beyond the once through cycle may be achievable at reasonable cost.

International Project: INPRO

INPRO was initiated in 2000 in a resolution adopted by IAEA Member States to ensure that nuclear energy will be available, as a sustainable resource, to help to fulfil energy needs in the 21st century. In order for nuclear energy to play a meaningful role in the global energy supply, innovative approaches will be required to address concerns about economic competitiveness, safety, waste and potential proliferation risks. Accordingly, INPRO takes a somewhat longer-term perspective than the other initiatives and is the only one which addresses the problems from the point of view of potential users in developing countries by identifying their specific needs. INPRO defines "users" as including a broad range of groups including investors, designers, plant operators, regulatory bodies, local organisations and authorities, national governments, NGOs and the media as well as end users of energy.

INPRO seeks to bring together all interested IAEA Member States, both technology holders and technology users, to consider jointly the international and national actions required to achieve desired innovations in nuclear reactors and fuel cycles. These should use sound and economically competitive technology based — as far as possible — on systems with inherent safety features that minimise the risk of proliferation and any impact on the environment. The aim is to create a process that involves all relevant stakeholders and that will have an impact on, draw from, and complement the activities of existing institutions, as well as ongoing initiatives at the national and international level.

The scope of INPRO covers nuclear reactors and fuel cycle facilities expected to come into operation in the future together with the associated fuel cycles. While INPRO considers a 50-year time scale for the necessary analysis, this does not mean that the technologies will be implemented during this time. However, a mixture of current, evolutionary, and innovative designs is expected to be brought into service and co-exist within this period. INPRO has not yet addressed any specific technologies.

In 2001-2003, under Phase 1A, INPRO produced sets of Basic Principles (BPs), User Requirements (URs) and Criteria to compare different concepts and approaches with respect to the key issues in the debate concerning the future role of nuclear energy — economic competitiveness, safety, waste, proliferation, security and physical protection, and sustainability. It not only focussed on technological requirements but also made recommendations on institutional, legal and various infrastructure issues, mainly in the context of the process of continuous globalisation. This phase ended in June 2003, having established a methodology and guidelines to assess different concepts and approaches.

Phase 1B, which began in July 2003, includes the validation of the INPRO methodology through case studies and examination of innovative nuclear energy technologies made available by Member States. This examination will be performed by members on the basis of BPs, URs, criteria and methodology established during Phase 1A. It will also include preliminary collection of information on innovative reactors and fuel cycles. Six INPRO Member States offered to carry out National Case Studies by applying the INPRO methodology to selected national INS:

- Argentina: CAREM-X system including CAREM reactor and SIGMA fuel enrichment process.
- India: APHWR reactor and fuel cycle including a FBR and an ADS for transmutation of waste.
- Republic of Korea: DUPIC fuel cycle technology.
- Russian Federation: nitride-fuelled BN-800 reactor family and adjacent fuel cycle in the equilibrium state.
- China: Pebble Bed High Temperature Reactor.
- Czech Republic: Molten Salt Reactor (concept chosen by Generation IV International Forum (GIF).

In addition, several teams consisting of individual experts are performing case studies, which cover those technologies not addressed by the National Case Studies, in order to obtain a validation of the Methodology as complete as possible.

Final results of these studies and several case studies will be reported to the 7th meeting of the INPRO Steering Committee in late 2004. Innovative nuclear reactor and fuel cycle concepts will then be assessed against the requirements and criteria selected. Drawing on the results from the first phase, Phase 2 will look at available technologies and the feasibility of starting an international project.

INPRO has hitherto depended on the political, financial and technical support accorded by IAEA Member States (in particular Russia, which provided the major financial support for project), but from 2004 funding is partly included in the IAEA regular budget. *(See table for INPRO members.)*

The key feature of INPRO's methodology is the information it provides about the potential of nuclear energy and the consequences of its use. It takes into account the development options for society and its energy requirements as well as the associated expenditure in terms of effort, resources and time. This will provide INPRO members with a tool to help in identifying and assessing the components needed for a future nuclear energy system, such as reactors, waste processing facilities, fuel fabrication and recycling facilities. It will also assist States to identify the research, development and demonstration (RD & D) required to improve existing components for future application and to develop new components as required.

In the area of economics, INPRO considers four market scenarios covering possible future developments. These are characterised by various levels of globalisation and regionalisation and differing views of economic growth versus environmental constraints. Provided innovative nuclear energy systems (INS) are economically competitive, INPRO believes they can play a major role in meeting future energy needs. But to keep the total unit energy cost competitive, all component costs (capital costs, operation and maintenance, fuel, etc) must be considered and managed. Limits on fuel costs imply limits on the capital and operating cost of fuel cycle facilities, including mines, fuel processing and enrichment, fuel reprocessing and the decommissioning and long-term management of the wastes from these facilities.

Regarding sustainability, INPRO has set two basic principles, one related to the acceptability of environmental effects caused by nuclear energy and the second to the capability of INS to deliver energy in a sustainable manner in the 21st century. Protection of the environment is seen as fundamental, and to be sustainable the system must not run out of important resources (such as fissile/fertile material or water) part way through its intended lifetime. The system should also use them at least as efficiently as acceptable alternatives, both nuclear and non-nuclear.

Regarding safety, INPRO Principles and Requirements are based on extrapolation of current trends and seek to encompass the potential interests of developing countries and countries in transition. For nuclear reactors, the fundamental safety functions are to control reactivity, remove heat from the core, and confine radioactive materials and shield radiation. For fuel cycle installations, they are to control subcriticality and chemistry, remove decay heat from radionuclides, and confine radioactivity and shield radiation. The development of INS should be based on a holistic life cycle analysis taking into account the risks and impacts of the integrated fuel cycle.

The safety of waste management involves different time scales and, in many cases different source terms and pathways, compared with nuclear installations. The existing nine principles already defined by the IAEA for the management of radioactive waste have been adopted by INPRO without modification.

As the demand for electricity is expected to grow mainly in developing countries, INPRO believes particular attention should be paid to these countries. For countries that need only a small number of nuclear power plants it would not be rational to develop a fully capable domestic supply structure. Internationally operated companies could provide most of the necessary infrastructure for the construction and operation of nuclear power systems and could supply a valuable service.

Need for Global Co-operation

There is a general consensus on the need for international efforts to develop new nuclear technologies. Establishing some kind of co-operation between existing projects has been discussed and is progressing.

GIF technology goals and INPRO user requirements have many similar or identical statements relating to economics, safety, environment, fuel cycle and waste, proliferation resistance, and sustainability. Approaches for screening and selecting candidate innovative concepts also appear to be quite similar. However, there are some significant differences:

- GIF is already in the phase of initiating R&D, while INPRO has only just completed formulation of its user requirements;

- GIF mainly addresses the demands of a few industrially-developed countries, while INPRO offers a more in-depth consideration of nuclear power in general, taking into account country and region specifics;

- INPRO is expected to involve a broader spectrum of technology proposals for innovative reactors and nuclear fuel cycles, which would meet the demands of nearly all countries – and not just nuclear stakeholders.

- INPRO also seeks to address issues beyond technological requirements, particularly the possible advantages of international cooperation in establishing the necessary infrastructure for individual countries, as well as innovations in legal and institutional structures. INPRO is ready to consider the needs of developing countries in this regard.

- GIF limits its consideration to separate nuclear energy systems with reactors of different types and accompanying fuel cycles.

- INPRO considers that the combinations of such systems should be tailored to different scenarios of nuclear power development at national, regional, and global levels.

GIF and INPRO have the basis for closer co-operation since the focus of their efforts is different. GIF members are mainly the holders of technologies and GIF is considering very complex technologies. However, INPRO sees Asia as the future market for nuclear, including developing countries, where more simple but reliable systems are needed. INPRO includes members from developing countries and so can better understand their needs and requirements.

The role of innovation as a crucial factor to the future of nuclear was highlighted at the IAEA's International Conference on Innovative Technologies for Nuclear Fuel Cycles and Nuclear Power held in Vienna in June 2003. The chairman of India's Atomic Energy Commission, Dr. Anil Kakodkar, stressed the importance of nuclear as part of a diversified energy mix. However, he said there was an underlying conflict between the developing and developed world concerning nuclear power. Many developing countries believed that non-proliferation measures had been used largely to prevent a meaningful technology transfer, he said.

At the IAEA General Conference in September 2003, States adopted a resolution stressing the need for international collaboration in developing innovative nuclear technology and high potential and added value that could be achieved through collaborative efforts. It also stressed the importance of identifying synergies with other international initiatives on innovative nuclear technology development.

It is clear that a more collaborative multinational approach is evolving, though some obstacles remain to be resolved. As developments unfold, co-ordination between INPRO and GIF could soon begin.

Judith Perera has 15 years experience as is a writer, editor and consultant on nuclear energy and related areas. This article is adapted from her report in the January 2004 edition of Nuclear Engineering International. E-mail: JudithPerera@aol.com. For more information on the IAEA's work through INPRO see www.iaea.org/INPRO/

South Africa's Nuclear Model

A small and innovative reactor is seen as the model for new electricity plants. The project is nearing the starting blocks.

by Tom Ferreira

Although nuclear power generation has by far the best safety and environmental record of any technology in general use, it has for many years been unable to make any meaningful inroads into the wall of negative perceptions that have arisen against it.

But sentiments are changing rapidly on a global scale. The flare-up of oil prices is a sobering reminder of the volatility in the energy market, the exhaustibility of fossil fuels and the urgent need for stable, reliable, non-polluting sources of electrical power that are indispensable to a modern industrial economy.

Today, new types of nuclear plants are prized, and South Africa is moving ahead. The State energy provider, Eskom, is internationally regarded as the leader in the field of the Pebble Bed Modular Reactor (PBMR) technology, a "new generation" nuclear power plant.

A decision on the PBMR project's future is on the near horizon *(see box, The PBMR Nears the Starting Blocks.)* Should approvals be received in the coming months to proceed to the project's next phase, construction of the PBMR demonstration plant will start in 2006, in which case the reactor will start in 2010 and handed over to the client, Eskom, in 2011. Eskom has conditionally undertaken to purchase the first commercial units.

Pebble bed reactors are small, about one-sixth the size of most current nuclear plants. Multiple PBMRs can share a common control center and occupy an area of no more than three football fields.

More specifically, the PBMR is a helium-cooled, graphite-moderated high temperature reactor (HTR). The concept is based on experience in the UK, United States and particularly Germany where prototype reactors were operated successfully between the late 1960s and 1980s. Although it is not the only high-temperature, gas-cooled nuclear reactor being developed in the world, the South African project is internationally regarded as a frontrunner. The South African PBMR includes unique and patented technological innovations which make it particularly competitive.

Mr. Nic Terblanche, Chief Executive of PBMR (Pty) Ltd, says that the commercial reactors would be sized to produce about 165-MWe each. To maximise the sharing of support systems, the PBMR has been configured into a variety of options, such as an 8-pack layout. "This is the most cost effective layout and allows the modules to be brought on line as they are completed," he says.

The concept allows for additional modules to be added in accordance with demand and to be configured to the size required by the communities they serve. It can operate in iso-

The PBMR Nears the Starting Blocks

South Africa's Eskom has two partners in the PBMR project, namely the Industrial Development Corporation (IDC), and British Nuclear Fuels. The partners have all expressed a desire to proceed to the detailed design and construction phase. This phase involves construction of a demonstration reactor at Koeberg near Cape Town and an associated fuel plant at Pelindaba near Pretoria, where fuel for Koeberg used to be manufactured.

So far, the project's detailed feasibility study, basic design and business case have been completed and the project team is ready to move to the construction phase once the various approvals are received.

Eskom is currently awaiting the final verdict on the Environmental Impact Assessment (EIA) from the Minister of Environmental Affairs and Tourism (DEAT) following an initial positive Record of Decision (RoD) on the EIA reports in June 2003. The DEAT found the project was, with some conditions, acceptable from an environmental impact point of view.

Subsequent to the positive RoD, interested and affected parties were granted two months to lodge appeals with the Minister of Environmental Affairs and Tourism. The appeal period ended in August 2003 and the Minister is currently reviewing the appeals.

In addition to the final verdict on the EIA and approval by the investors, proceeding to the next phase (building of a demonstration module and fuel plant), is still subject to the issuing of a construction license by the South African National Nuclear Regulator and approval by the South African Government.

The project seems to be strongly supported by President Thabo Mbeki and his government. In fact, a South African delegation led by the Department of Trade and Industry met with senior executives of Areva and Framatome in Paris earlier this year to negotiate possible French participation in the project. Areva is one of several international companies who have shown an interest in getting involved in the US $13 billion project.

Design view of the PBMR module concept.

lation anywhere, provided that there is sufficient water for cooling. Dry cooling, although more expensive, is an option that would provide even more freedom of location.

Developments Marking Progress

An exciting new development is PBMR (Pty) Ltd's intention to submit a proposal for the US$ 1.1-billion hydrogen production project at the Idaho National Environmental and Energy Laboratory in the USA. The hydrogen initiative calls for a plant that can generate both electricity and high temperature process heat. Initial conceptual layouts show that, with minor modifications, the current PBMR power plant can meet this requirement.

Participation in the hydrogen project offers clear benefits that can act as a catalyst for the early commercialization of the PBMR technology in the USA. This would lead to the reactor becoming the preferred route as far as HTR technology is concerned.

The PBMR concept is based on the philosophy that new reactors should be small. The reactor consists of a vertical steel pressure vessel lined with graphite bricks. It uses silicon carbide coated particles of enriched uranium oxide encased in graphite to form a fuel sphere or pebble, each containing about 15,000 uranium dioxide particles. Helium is used as the coolant and energy transfer medium.

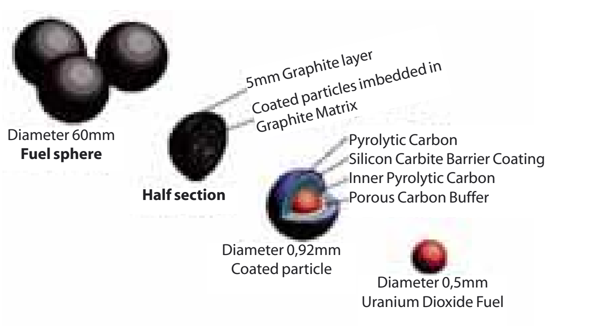
The project achieved a major engineering milestone with the successful starting up of a test rig of the PBMR power conversion system. The test rig represents the first closed-cycle, multi-shaft gas turbine in the world. The model was designed and built by the Faculty of Engineering at Potchefstroom University near Johannesburg, with technical input from the PBMR project team.

The South African Nuclear Energy Corporation, which is under contract from PBMR (Pty) Ltd to develop the fuel manufacturing capability, is in the meantime making good progress. Its focus is on developing the exacting production techniques required for the manufacture of complete fuel spheres.

Demonstrating Safety

The design's fundamental concept is aimed at achieving a plant having no physical process that could cause a radiation hazard beyond the site boundary. In addition, the peak temperature reached in the core during the transient is not only below the demonstrated fuel degradation point, but also far below the temperature at which the physical structure is affected. This will preclude any prospect of a core melt accident.

The safe design was proven during a public and filmed plant safety test at the German AVR power plant, on which the PBMR reactor core concept is based. The Germans stopped



The uranium fuel spheres or pebbles are 60 mm in diameter, which is slightly smaller than a tennis ball. On the right are the coated particles, which are abouts 1mm in diameter. A coated particle consists of a kernel of uranium dioxide surrounded by four coating layers.

the flow of coolant through the reactor core and left the control rods withdrawn just as if the plant was in normal power generation mode.

It was demonstrated that the nuclear reactor core shut itself within a few minutes. It was subsequently proven that there was no deterioration over and above the normal design failure fraction of the nuclear fuel. This proved that a reactor core meltdown was not credible and that an inherently safe nuclear reactor design had been achieved.

"We're trying to change the nuclear culture," says Phumzile Tshelane, General Manager Corporate Services of PBMR (Pty) Ltd. "If the PBMR demonstration module proves to be technically and commercially viable, it could dramatically boost the prospects of nuclear energy on a global scale, fulfilling at last the dream of a non-polluting power source that is safe, competitive and perhaps even popular."

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Joining Forces for Innovation

South Africa already operates two conventional nuclear power plants at Koeberg, which together supply about 6% of the country's electricity, including most of nearby Cape Town's needs. Electricity demands are expected to keep rising in years ahead. About 60% of South Africans today have access to electricity, compared to 30% a decade ago. Nuclear and renewable sources of energy helped fuel the growth, though coal remains the dominant power source, generating 90% of all electricity.

Pebble bed reactors are not new to the nuclear world, though technological innovations now are helping to bring them to market. If built, South Africa's PBMR would be the largest commercial example of the technology.

Both Germany and China have developed PBMRs, and research and development is intensifying in the United States, China and other countries. Recently, researchers at the Massachusetts Institute of Technology (MIT) in the US and Tsinghua University in Beijing, China formed a partnership to collaborate on PBMR development under an international agreement between the US Department of Energy and the China Atomic Energy Authority.

For the past six years, MIT and Tsinghua research teams have been working independently on studies of the reactor. Their joint work now sets up ways for the research teams to exchange technologies and ideas.

"The agreement provides an incredible opportunity for bringing the world together on this promising technology," says Professor Andrew Kadak of the Department of Nuclear Engineering, who leads the MIT research and was instrumental in the three-year effort to get the agreement signed. He is now contacting other pebble-bed researchers in the United States, Europe, South Africa and elsewhere to develop mutual topics of interest. The aim is to form an international effort that will go far beyond the MIT/Tsinghua collaboration and build on worldwide interest in the technology.

One focus of interest is a "plug-and-play" approach to building components of pebble bed reactors. If competitive, researchers say such small, modular plants will be attractive not only to the US market but also to China and other rapidly developing countries that have widely dispersed populations.

Safety For All
the new INSAG

by Richard Meserve & Kenneth Brockman

In 1985, the IAEA Director General identified the need for an advisory committee to the IAEA in the area of nuclear safety. The group that was subsequently chartered was called the International Nuclear Safety Advisory Group (INSAG). The nuclear community knew it over the years for the sage counsel and advice that it provided to, and through, the Agency. Between 1985 and 2002, INSAG membership ranged from 13 to 15 experts from around the world. Individuals whose names are synonymous with a commitment to nuclear safety led the group during these years, including Messrs. A.P. Vuorinen (Finland), H.J.C. Kouts (USA), Z. Domaratzki (Canada), A. Birkhofer (Germany), and A. Baer (Switzerland).

Over these 17 years, INSAG produced numerous studies that provided the foundation for advances in nuclear safety. These studies included evaluations of design and operational safety at nuclear power plants, consideration of the impacts of radiological exposures, and the examination of how best to develop and maintain a proper safety culture.

While INSAG publications were recognized throughout the nuclear community as authoritative and insightful reflections on topics relating to nuclear safety, some believed the Group was limited by its charter obligation to provide advice solely to the IAEA. Other international groups of experts, most notably the International Commission on Radiological Protection (ICRP), evolved with much broader responsibilities. As result, the organization and Terms of Reference for the ICRP were seen to provide a model to emulate if one wanted to have an expert group that could serve all concerned stakeholders. It was in response to this desire that the current INSAG was chartered.

Credit: D. Calma/IAEA

Mr. Brockman and Dr. Meserve at the press briefing in Vienna announcing INSAG's formation.

The New INSAG

While the acronym INSAG has been retained, the proper full name for the group has been subtly, but significantly changed. No longer is the Group an advisory group; now INSAG stands for the International Nuclear Safety Group. This change captures the fact that INSAG is no longer an advisory organ for the Director General and the Secretariat, but instead has been convened to serve all parties concerned with nuclear safety issues — non-governmental organizations, regulatory authorities, the nuclear industry, the public and the media. The opening statement from the new Terms of Reference for INSAG states that "INSAG will provide recommendations and opinions on current and emerging nuclear safety issues to the IAEA, the nuclear community and the public."

While the audience for the new INSAG has expanded, the issues that it will address are now more sharply focused. Given the fact that groups such as the ICRP are operating in areas relating to radiation safety, the new INSAG has been asked to focus on the "safety of nuclear installations — nuclear power plants, research reactors, and other fuel cycle facilities." This narrowing of the areas of concern is not intended, however, to be excessively restrictive. The Director General, in his comments to the group, emphasized that he expected INSAG to approach safety with the widest of perspectives and to be an internationally recognized body that could be called upon to consider any safety issue that were to arise at a nuclear installation in an objective and comprehensive fashion.

The new group is chaired by Dr. Richard Meserve, recently Chairman of the United States Nuclear Regulatory Commission and now President of the Carnegie Institution. Four of the other members served on previous INSAGs — Mr. A. Abagyan (Russia), Mr. A. Alonso (Spain), Mr. A. Birkhofer (Germany) and Mr. S. Matsura (Japan). The other members bring skills from around the globe — Z. Dutra (Brazil), L. Echavarri (OECD/NEA), S. Harbison (United Kingdom), T. Hill (South Africa), C. Kang (South Korea), J. Laaksonen (Finland), A. Lauvergeon (France), J. Ronaky (Hungary), S. Sharma (India), J. Tian (China) and D. Torgerson (Canada).

The members were selected both because of their technical expertise and because of their personal and professional commitment to safety. These individuals represent all of the institutions and facilities involved in ensuring nuclear safety — the power reactor industry, operators of fuel cycle facilities, regulatory authorities, non-governmental organizations, and research and academic institutions. The IAEA serves as a Secretariat for the group, providing it with logistical support and a venue at which to conduct activities. The Director General appoints the members, and the Division of Nuclear Installation Safety serves as the support organization.

The Top Five

To date, INSAG has identified five issues that require the group's immediate focus and attention. First, at the request of the Director General, the Chairman of INSAG, with assistance from the group, will develop a periodic report presenting an opinion on the State of Nuclear Safety. It is anticipated that the first report will be available for the General Conference of the IAEA in September. Second, INSAG will consider the concept of a Global Nuclear Safety Regime, and the challenges arising from the international and intercultural aspects of today's nuclear industry. Third, the group will look at Safety Principles, seeking to determine how best to apply risk insights in the regulatory, design and operational decision-making processes. Four, INSAG will examine Operational Safety, a significant area of focus for the previous INSAGs. To properly serve the public, INSAG recognizes that it must consider whether the current fleet of nuclear installations have been designed and are being operated in a manner that ensures, to the greatest extent reasonable, the protection of the health and safety of the public and the environment. Finally, INSAG will consider how best to address the issue of Stakeholder Involvement. The Terms of Reference for the new INSAG have expanded its audience, and the group will focus significant effort on how best to involve all concerned stakeholders and how best to communicate with them.

The INSAG meets twice per year. However, the individual members work extensively on their own time during the intervening periods. Both individually, and as a group, INSAG seeks to ensure that all countries that choose the nuclear option have properly addressed safety issues. More importantly, INSAG stands ready to serve the world community as an authoritative adviser that is both technically competent and committed to the paramount importance of safety in nuclear facility design and operation.

Past INSAG Safety Reports

The IAEA has issued a collection of reports on nuclear safety under the INSAG framework. They include the world's first authoritative account of the 1986 nuclear accident at Chernobyl, and an update issued in 1993.

Other reports have focused on topics including basic safety principles; safety culture; regulatory decision-making; knowledge management; safe management of radioactive sources; and the defence-in-depth approach to nuclear plant safety.

Many of the reports are issued in non-English language editions, including Russian, Spanish, and French, and can be downloaded on the Internet. For more information, check the Publications pages of the Agency's public web site at www.iaea.org, and enter the word "INSAG" in the search function.

INSAG's Chairman, Richard A. Meserve was appointed the ninth president of the Carnegie Institution in December 2002. He assumed the presidency in April of 2003, after stepping down as chairman of the US Nuclear Regulatory Commission (NRC).

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Illicit Nuclear Trafficking
& the new agenda

by Vladimir A. Orlov

Weapons of mass destruction (WMD) are a serious international concern and have been at least for nearly a century. After World War I, the Geneva Protocol of 1925 prohibited the use of chemical and biological warfare. The advent of nuclear weapons, with their extraordinary destructive capacity, made the proliferation of WMD an even greater concern after the Second World War.

Moreover, during the post-Cold War period the dangers of proliferation of WMD have increased due to regional tensions, the dissolution of the Soviet Union (and resulting looser controls over weapons scientists and dangerous materials), and the ready availability of sensitive technologies. More than ten States have active WMD-related programmes, and probably about ten more have capabilities to start them.

At the same time, non-State actors (transnational organized criminal communities and international terrorist networks) today are seen as playing an increasingly active role in unauthorized access to and proliferation of sensitive materials, technologies, and weapons. After 9/11, the risk of such actors using WMD components as a tool for blackmailing governments has become a real scenario, still with low probability but with highly significant — and disastrous consequences.

The international community has responded to problems and challenges in two major ways. The first has been the elaboration of multilateral international treaty regimes intended to prevent the proliferation of WMD. These include the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), the Chemical Weapons Convention (CWC), and the Biological and Toxin Weapons Convention (BWC). The second approach has been the formation of non-treaty arrangements, generally known as "suppliers' clubs", aimed at preventing the proliferation of technologies and equipment that could be used by a "proliferant" State or non-State actor to develop WMD and/or delivery systems (e.g., ballistic or cruise missiles) associated with such weapons. These organisations are: the Australia Group (chemical and biological technology); the Zangger Committee and the Nuclear Suppliers Group (nuclear); and the Missile Technology Control Regime (MTCR).

A particularly important role in detecting non-compliance to nuclear non-proliferation is played by the International Atomic Energy Agency (IAEA). Its inspection mechanism has proved to be efficient and balanced even in such complex situations as Iraq.

For various reasons, these treaty and non-treaty regimes have been under severe stress in recent years. The situation demands a new international agenda of action against the proliferation of WMD. For example, within the NPT regime, nuclear-weapon States and non-nuclear weapon States frequently disagree over Treaty commitments to negotiations regarding nuclear disarmament and to provisions to prevent the diversion of nuclear materials to nuclear weapons purposes. The Indian and Pakistani nuclear weapon tests of 1998, the de facto nuclear weapon status of Israel, and the North Korean nuclear weapons programme also pose significant challenges to the NPT.

Meanwhile, States parties to the BWC have not achieved consensus on a legally binding protocol to provide the convention with a "verification" mechanism. Despite conclusion of the CWC — which mandates the elimination of an entire class of WMD and establishes an international organisation and detailed verification regime to ensure compliance — many countries are suspected of possessing chemical weapons programmes. Issues of compliance are essential, and the failure to address non-compliance in a satisfactory manner is perceived as undermining the viability of the non-proliferation regime.

The growing perception that these mechanisms have been inadequate to constrain the proliferation of WMD technology and the development of increasingly longer-range missiles has led to alternative approaches. On the one hand, there has been a cooperative international approach to assist countries in the former Soviet Union that have technical and/or financial difficulties living up to their non-proliferation commitments. On the other hand, the US has also begun to place greater emphasis on deterrence and defence against these threats, as evidenced by robust programmes for counter-proliferation, such as the 2003 Proliferation Security Initiative.

The Group of Eight countries (G-8) has become an increasingly important forum for discussing WMD proliferation, notably its prevention and measures aimed at cooperative threat reduction in different regions of the globe, starting with the former Soviet Union. In June 2003, the G-8 launched a Global Partnership Program Against the Spread of Weapons and Materials of Mass Destruction. Since then, cooperative approaches towards proliferation prevention have demonstrated their efficiency, though much more work must be done.

The Threats of Illicit Nuclear Trafficking

The last decade of the 20th century put on the agenda new non-traditional threats to the international regime of nuclear non-proliferation. Among the most serious are illicit trafficking in nuclear material and nuclear terrorism. The emergence of these threats, which are no longer hypothetical but real, were magnified by the terrorist attacks of September 2001.

The threats are determined by similar factors. In the 1960s and later, development of nuclear explosive devices required titanic efforts of an entire State and it was a large-scale and expensive program. Nowadays it is much easier due to scientific and technological progress and more widely spread knowledge and technology.

Political shifts in the post-Cold War world also play a role. Small but ambitious States find it more difficult to achieve their foreign policy objectives, since they can not as easily play one superpower off another. Additionally, as the superpowers have loosened control over regional conflicts, belligerents have more temptation to gain added military and political *trumps*, e.g. with acquisition of WMD. Finally, in most cases, national governments have become less radical and, hence, some groups and political activists try to pursue their goals independently and not through established power institutions.

Other reasons for illicit nuclear trafficking and nuclear terrorism are:

› The release of a considerable number of weapons-grade nuclear materials resulting from the global process of nuclear arms reduction.

› The aggravating conditions of obtaining nuclear materials for non-nuclear weapon States, who are found or suspected of secretly developing their own military nuclear programmes because of restrictions imposed through international systems of export control.

› The growing number, influence and increasing financial capabilities of non-State actors in international relations, such as terrorist groups, transnational organized crime groups, ethnic separatist movements, and extremist religious cults.

The difficulties in adequately responding to such non-traditional challenges are not a headache for one State but for all States, and especially those that possess and must control nuclear weapons or complex nuclear enterprises. At the same time, it is obvious that the risk of illicit nuclear trafficking and unauthorized access to weapons-usable nuclear materials or nuclear weapons with terrorist purposes is considerably high in two States, namely the United States and Russia. They possess the largest stockpiles of nuclear weapons and nuclear materials, sensitive from the standpoint of non-proliferation, and they are engaged in a dynamic process of nuclear arms reduction.

What is Nuclear Trafficking?

The illicit trafficking in nuclear material is intra- or inter-border movement of nuclear materials that are sensitive from the point of non-proliferation (i.e. uranium with 20% enrichment and higher and plutonium, as well as related fuel cycle facilities that might be accessed illegally). Thus, it is mostly the matter of stealing 20% (or higher) enriched uranium and plutonium from nuclear fuel cycle enterprises. Once stolen, the material can be left within the country of origin (i.e. *pure* theft) or illegally transported to another State (i.e. nuclear smuggling). The latter is the most dangerous from the point of non-proliferation.

The theft and smuggling of nuclear materials can pursue different goals. One is commercial, that is, resale to the third party with the purpose of obtaining personal financial profits. Another is terrorist, namely the malevolent use of stolen nuclear materials for terrorism or blackmail. In the case of nuclear material smuggling there is a high possibility that those who acquired nuclear materials from the thief will later use it for developing a military nuclear programme

IAEA Tracks Illicit Trafficking of Nuclear & Radioactive Material

As of December 2003, the IAEA's Illicit Trafficking Database contains 540 confirmed incidents involving illicit trafficking in nuclear and other radioactive materials, which have occurred since 1 January 1993. Several hundred additional incidents (344) that have been reported in open sources, but not confirmed by States, are also tracked in the IAEA database but are not included in the following statistics. The majority of these confirmed incidents involved deliberate intent to illegally acquire, smuggle, or sell nuclear material or other radioactive material. The database also includes some incidents where actions may have been inadvertent, such as accidental disposal or the detection of radioactively contaminated products.

Of the 540 confirmed illicit trafficking incidents about 41% involved nuclear material, and 62% involved radioactive material other than nuclear material. (These figures total more that 100% because some incidents involved both nuclear and other radioactive materials.)

Incidents with Nuclear Material

As of December 2003, the IAEA database includes 182 confirmed incidents since 1 January 1993 that involved nuclear material.

Weapons-usable nuclear material. Of these 182 incidents with nuclear material, less than 10% (18 incidents) involved highly enriched uranium (HEU) or plutonium, materials that could be used for the fissile core of a nuclear explosive device. During the first half of the 1990s, quantities of a kilogram or more of HEU were seized in a few cases, and in one case about 0.3 kg of plutonium (Pu) was seized. By contrast, no confirmed theft or seizure since 1995 has involved more than 1% or 2% of what would be needed for constructing a nuclear bomb. These small quantities are not grounds for complacency, however. Even when small quantities of such material are seized, the question remains whether they might have been samples of larger quantities available for illicit sale. Another concern is that trafficking in such materials might occur undetected.

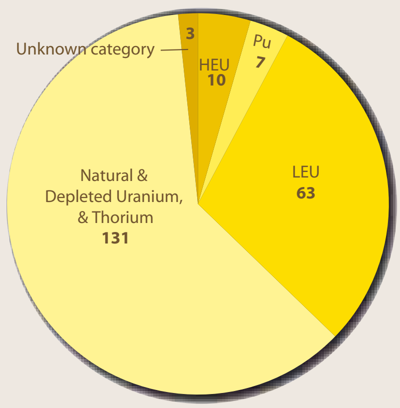
Lower-grade nuclear materials. The overwhelming majority of confirmed nuclear trafficking involved lower grade materials. These include: low-enriched uranium (LEU), usually in the form of nuclear reactor fuel pellets; natural uranium in a variety of forms and purity; depleted uranium, usually in the form of shielding material in containers of the type used to ship or store radioactive sources; and thorium in various forms including ore. While the quantities of these lower-grade materials that have been stolen or seized to date have been too small to be significant for nuclear proliferation, these cases sometimes are indicative of gaps in the control and security of nuclear material.

Other Radioactive Material

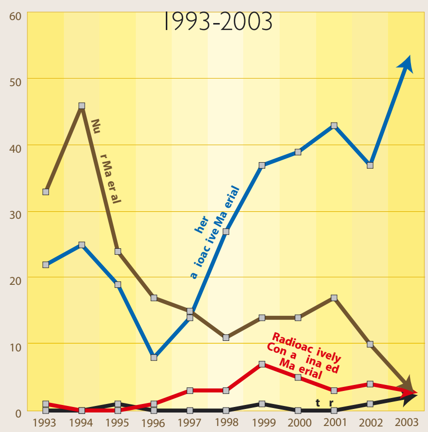
As of December 2003, the IAEA database includes 335 confirmed incidents since 1 January 1993 that involved radioactive material other than nuclear material. In most of the cases, the trafficked radioactive material was in the form of sealed radioactive sources. However, some incidents with unsealed radioactive samples, or radioactivily contaminated materials such as contaminated scrap metal, also have been reported to the illicit trafficking database and are include in the statistics. Some States are more complete than others in reporting incidents, and open-source information suggests that the actual number of cases is significantly larger than the number confirmed to the IAEA.

Radioactive sources involved in confirmed trafficking demonstrate a wide range of activity levels. The vast majority of them have been too weak to cause serious health problems if used for malicious acts.

Distribution of incidents involving nuclear material
1993-2003



Confirmed incidents involving nuclear and other radioactive material
1993-2003



For more information on nuclear security, see the IAEA's web pages at www.iaea.org.

of a State striving for possession of nuclear weapons. At the same time, the buyer may represent a State or a non-State actor willing to acquire nuclear weapons, and after purchasing, it will be the buyer who will carry out contraband supplies of nuclear materials.

In most cases, information about nuclear theft or nuclear smuggling shows that most trafficking involves radioactive substances that are not nuclear materials and cannot be used to produce nuclear weapons. These are primarily natural uranium and uranium dioxide, and sources of ionizing radiation. Sometimes they were intended for resale inside the country where the materials were obtained, sometimes for smuggling abroad. Such cases pose no threat from the point of non-proliferation, though they do raise fears and concerns over what have been called "dirty bombs".

The problem of analyzing illicit nuclear trafficking is complicated by the considerable amount of confidential, unverified, or exaggerated information. To a certain extent, the mass media sensationalize reports, and journalists are not always professional enough to explain to the readers the difference between highly enriched and depleted uranium, for example. In some cases, the problems of illicit trafficking are the targets for political and diplomatic games or the objects of undercover campaigns by intelligence services themselves.

Russia is often identified in the world press as a source of illicit nuclear trafficking. The reason for this was the collapse of the USSR and the suspicions of insufficient physical protection of nuclear materials and weakness of control systems. The first wave of information about nuclear smuggling from Russia dates back to 1992, and many reports were discredited or proven false.

It would be a mistake to connect the problem of illicit nuclear trafficking with any particular state (including Russia). At the same time, it would be wrong to say that there was no illicit nuclear trafficking in Russia, as some officials did in the early 1990s. The problem exists and it is universal. One cannot preclude, for example, that some weapons-usable materials have been smuggled from Western Europe and North America to Pakistan and Israel.

More Cooperation Needed

As stated by the G-8 leaders at the Moscow Nuclear Safety and Security Summit as early as 1996, illicit trafficking in nuclear material poses a global proliferation risk and a potential danger to public health and safety. The criminal diversion of nuclear material could assist States or terrorist groups to bypass the carefully crafted controls of the international nuclear non-proliferation regime and permit them to construct or otherwise acquire a nuclear or radiological weapon. The G-8 leaders admitted that the majority of cases, so far, had involved only small amounts of fissile material or material of little use for weapons purposes, and many apprehended nuclear traffickers had been swindlers or petty thieves. Nevertheless, cases of illicit nuclear trafficking continue to occur. *(See box, IAEA Database on Illicit Nuclear Trafficking.)*

Efforts to prevent illicit trafficking in nuclear material are being reinforced. They include strengthening the first line of defense, i.e. safe and secure storage of nuclear materials and efficient measures of protection, control and accounting to prevent proliferation. They will also need to involve tightening of national export control systems.

International cooperation in this area, sensitive from the point of national security, has its limits. It is understood, however, that without international cooperation, the problem of illicit nuclear trafficking, when involving more than one State, cannot be solved. For instance, in the framework of international cooperation to prevent illicit nuclear trafficking, the G-8 established the Non-Proliferation Experts Group to coordinate its efforts with a range of intelligence, customs, law enforcement and other agencies.

The international community's response additionally should draw upon the existing instruments and organizations of the nuclear non-proliferation regime. These include universal adherence to the NPT and the Principles and Objectives agreed at the 1995 NPT Review and Extension Conference, and to the Convention on the Physical Protection of Nuclear Material, as well as application of the recommendations on physical protection made by the IAEA and the Nuclear Suppliers Group (NSG).

Cooperation within the framework of the Zangger Committee and the NSG is particularly important in the struggle against illicit trafficking. The IAEA plays a special role in international cooperation and has adopted an action plan supporting its programme to prevent illicit trafficking and nuclear terrorism. Recent proposals by the IAEA Director General for greater and more concerted action for stronger controls over nuclear materials are a sign of the challenges before the international community. They merit proactive and urgent attention.

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Parts of this essay are drawn from his work at the Geneva Centre for Security Policy in April 2004, and from a paper he authored on illicit nuclear trafficking.

Hot Spots weak links

Strengthening Nuclear Security in a Changing World

by Tomihiro Taniguchi & Anita Nilsson

Protection against nuclear terrorism is one of the critical issues facing the international community today. New and challenging security dimensions must be met.

During the Cold War, the main international security concern was the fear of a nuclear war and the spread of nuclear weapons. The post-Cold War era presented new security challenges, which recognized the need to strengthen the international regime of physical protection of nuclear materials.

In the post-9/11 period, threat perceptions include the potential terrorist use of an improvised nuclear explosive device, the use of a radiological dispersal device (RDD) and attacks against nuclear facilities, i.e. sabotage. These threats point to the need for an overall strengthening of the global nuclear security regime with attention to "weak links" that may offer soft targets for terrorists or criminals.

This article discusses some of the basic concepts and developments in the field of nuclear security; the legacy of the Cold War and the rise of new challenges to the global nuclear security agenda in the post-Cold War and post-9/11 periods; and efforts of the IAEA to strengthen the global nuclear security regime. The IAEA is filling an important and expanding role, yet more measures are needed.

The Evolving Context of Nuclear Security

The Cold-War Period

During the height of the Cold War, "nuclear deterrence" and "nuclear proliferation" dominated the global nuclear security agenda. In their national security strategies, States considered calculable threats of high-intensity and low-probability — nuclear conflicts based upon the predictable rational behavior of known State-level adversaries (also known as "rational actor theory"). A bi-polar security structure gave rise to the "nuclear deterrence" doctrine.

Concerns that additional States would acquire nuclear-weapon capability ("horizontal" proliferation) led to the conclusion of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) in 1968. While the Treaty prohibited non-nuclear weapon States parties to acquire nuclear weapons, "vertical" proliferation involving the development and deployment of more sophisticated nuclear weapons continued among the five nuclear-weapon States.

The NPT, which has now been in force for more than three decades, is one of the most successful international treaties. In the 1960s, it was feared that the number of nuclear-weapon States could rise to 20 and above, but due in large part to the

NPT, that number has been curtailed to about eight States. While the nuclear disarmament forecast under Article VI of the Treaty has not yet been achieved as expected, bilateral disarmament treaties and the voluntary reductions of nuclear weapons have lessened the global stockpiles of nuclear weapons from their Cold War heights.

The Post-Cold War Period

The end of the Cold War was marked by a shift from a bipolar structure of global security to more complex international relations. An increased risk for low-intensity national and regional conflicts emerged with new and more dispersed threats involving a larger number of actors: criminals or terrorists, which operate with trans-border networks.

The discovery in the early 1990s of clandestine nuclear programmes in Iraq and the Democratic People's Republic of Korea (DPRK) prompted the development and adoption of the Model Additional Protocol to safeguards agreements. In addition, the disintegration of the Soviet Union resulted in a larger number of States being left with nuclear weapons on their territories, and having responsibility for nuclear material. Also, dismantling of nuclear weapons resulted in large quantities of weapons-grade nuclear material in storage facilities.

The many cases of illicit trafficking in nuclear materials triggered an awareness of the need to strengthen the international physical protection regime. In 1999, the IAEA Director General, *inter alia,* convened an open-ended group of experts to examine the need to strengthen the Convention on the Physical Protection of Nuclear Material (CPPNM). The work was completed in 2003, when a report containing a number of proposals to strengthen the Convention was submitted to the IAEA Director General.

The Post 9/11 Period

The events of 9/11 in the USA demonstrated a new scale, dedication and organization of terrorist groups, which prompted the international community to re-evaluate the threat posed by terrorism, including potential threats to civilian nuclear programmes. The willingness of terrorists to sacrifice their own lives in the attempts to cause widespread death and destruction has prompted new nuclear security awareness.

While the threat that terrorists will acquire a nuclear weapon or related materials remains the most grave, the threat of a radioactive dispersal device (RDD) or sabotage of a nuclear facility or transport must also be seriously considered. The potential consequences of sabotage with a release of radioactive substances that could affect neighbouring countries point to a transnational dimension of nuclear security, contrary to the perception during the Cold-War period.

Thus, nuclear security in the post-9/11 period must consider the potential of: a) the theft of a complete nuclear weapon; b) the theft of nuclear material for the purpose of constructing a crude nuclear explosive device with or without the active involvement of a State; c) the theft of nuclear and other radioactive materials to construct an RDD; and d) attacks or sabotage directed against a power reactor, a fuel cycle facility, a research reactor or a nuclear transport.

The prevention of such events requires strong actions at the international, regional, and national levels. An internationally accepted and consistently and comprehensively implemented nuclear security regime in broad partnerships should make malicious acts very difficult to pursue.

What is the IAEA Doing?

The IAEA has adopted an integrated multi-track approach to assisting States in strengthening their nuclear security systems through a comprehensive Plan of Activities for Protection Against Nuclear Terrorism. The Plan covers measures to prevent, detect, and respond to malicious acts involving nuclear and other radioactive materials. It embraces advisory, evaluation, and training services, as well as legislative and technical support.

IAEA Nuclear Security Plan

The IAEA's mandate, technical competencies, extensive experience, and global reach make it a well-suited international organization to effectively assist States in improving their nuclear security systems. To confront the post-9/11 nuclear security threats and to provide nuclear security assistance to States, the IAEA Board of Governors, in March 2002, approved a Plan of Activities for Protection Against Nuclear Terrorism and assigned the highest priority to its coherent and effective implementation. The Plan covers three lines of defense: prevention, detection and response, supplemented with activities in support of information management and co-ordination.

The implementation of the Plan was estimated to require a minimum of $36 million to be funded largely through voluntary contributions made to an extrabudgetary Nuclear Security Fund (NSF). As of January 2004, over $27 million had been pledged by 24 Member States and one organization, of which almost $18 million has been received. In addition, Member States provide substantial in-kind assistance including equipment, and the use of facilities, services, and cost-free experts for the implementation of the Plan.

The main features of the Plan include:

❶ ***Evaluation of need.*** At the core of the Plan is the assessment of States' needs for improved nuclear security. Since 2001, the IAEA has carried out over 60 advisory and evaluation missions to help States identify and remedy their nuclear security needs. The purpose of missions under the newly established International Nuclear Security Advisory Service is to address States' needs across the entire spectrum of nuclear security related activities. The recommendations generated as a result of these missions provide the basis for subsequent targeted, nuclear security assistance, through IAEA programmes or through bilateral support. As a consequence, a joint, long-term workplan for improving security in the host State may be created for implementation in partnerships between the host country, the IAEA and bilateral programmes.

❷ ***Education and training.*** Strengthening nuclear security requires well-prepared staff. The IAEA assigns high priority to training, which it offers in an international, regional, and national context, depending on the subject areas. Several topics are suitable only in a national setting, such as workshops on design basis threat methodology, due to the sensitivity of security-related information and topics. Since 2001, the IAEA has conducted over 80 training courses, seminars, and workshops, which have had a positive impact on development of national cadres of nuclear security specialists in States.

❸ ***Supporting legal instruments.*** The Agency works hard to bring about universal adherence to, and implementation of existing international legal instruments relevant to the enhancement of protection against nuclear terrorism, e.g. the Convention on the Physical Protection of Nuclear Material (CPPNM), the Code of Conduct for the Safety and Security of Radioactive Sources, and safeguards agreements and additional protocols.

To support the implementation of these instruments, the Agency develops and provides guidelines and recommendations. In addition, supporting technical documents have been developed on a range of security related topics. They include design basis threat methodology, vital area identification, categorization of radioactive sources, security of sources, functional specification for detection instruments, the protection against sabotage against nuclear facilities, the due consideration of an "insider" threat, information technology security at nuclear installations, and preparedness and response to malicious acts involving nuclear and other radioactive material. The IAEA Nuclear Security Series of documents will provide a vehicle to reach a broader audience for publications in nuclear security.

❹ ***Co-ordination and cooperation.*** International cooperation is essential for identifying best practices to combat nuclear terrorism and proliferation, knowledge sharing, resource allocation, information exchange and early warning. By working in co-ordination with States and groups of States, such as the European Union, which also provide bilateral security support, the Agency facilitates the provision of physical protection equipment upgrades, as well as of equipment for accounting, and detection of nuclear smuggling. To further support the combating of illicit nuclear trafficking, the IAEA provides nuclear forensics support to Member States for the characterization of confiscated material through dedicated laboratories around the world, and for the upgrading of tools for the detection of radioactive materials in trafficking.

International IAEA conferences such as the International Conference on the Security of Radioactive Sources held in Vienna, Austria (the Hofburg Conference) in 2003, and on National Infrastructures for Radiation Protection held in Rabat, Morocco, are effective means of addressing urgent topics in an international setting. In 2005, an international conference on nuclear security as a whole will be convened as well as an international conference on the safety and security of radioactive sources as a follow-up on the Hofburg conference in 2003.

At an IAEA training course in Cyprus, participants learn about ways to combat illicit trafficking in radioactive materials.

To enhance co-ordination at an international level, the IAEA participates in the meeting of the UN Security Council Counter-Terrorism Committee, and works closely with a number of international organizations, including Interpol, Europol, and World Customs Organization, in a wide range of areas for nuclear security.

Building a Robust Regime

The global nuclear security regime, which is at an early stage of its development, should be strengthened. This process should include both tackling the "hot spots" and eliminating "weak links."

Emphasis is on achieving an effective comprehensive global nuclear security framework that will serve as a reference point for States' efforts and for the Agency's support. Due consideration must be

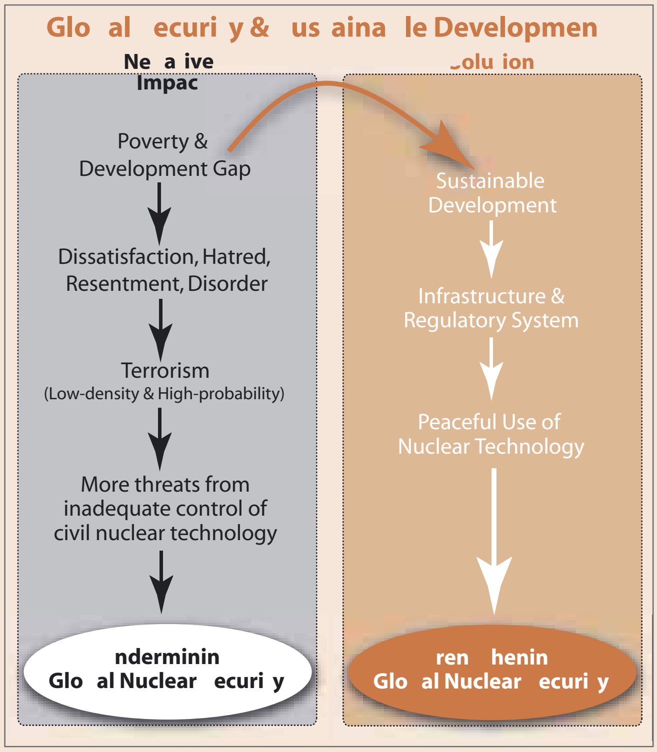
A Comprehensive Approach to Security

The IAEA has adopted a broad conceptual approach to nuclear security by pursuing "*the means and ways of preventing, detecting, and responding to sabotage, theft and unauthorised access to or illegal transfer of nuclear material and other radioactive substances, as well as their associated facilities.*"[1]

While in the past, matters related to nuclear safety, safeguards and, in particular, nuclear security, were each dealt with separately, recent developments have unfolded their overlaps and potential synergies. The 2003 IAEA General Conference[2] acknowledged such linkages and noted, *inter alia*, that strengthening the safety of radioactive sources contributes to enhanced security of such sources. It further noted that safeguards agreements, additional protocols, as well as States' systems of accounting for and control of nuclear materials, contribute to preventing illicit trafficking, deterring and detecting diversion of nuclear materials.

Both developed and developing countries depend on the continued availability of nuclear energy and on the day-to-day access to radioactive materials used in medicine, agriculture and industry. Continued peaceful uses of nuclear and radioactive substances are essential for sustainable development.

It has long been widely recognized that the development and use of nuclear technology require due consideration to human health and safety. There is now a growing awareness that these activities also require adequate security to protect them from malicious acts. Nuclear security and sustainable development, therefore, respectively serve each other's needs and are important mutual prerequisites. An increased focus on and support for the



process of sustainable development and equitable socio-economic relations could have positive impact on efforts to address the root causes of terrorism and thus alleviate threats against peaceful nuclear activities.

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[1]*IAEA working definition of nuclear security adopted by the IAEA Advisory Group on Nuclear Security.*
[2]*IAEA General Conference Resolution, "Nuclear and Radiological Security: Progress on Measures to Protect against Nuclear and Radiological Terrorism," GC(47)/RES/8, September 2003.*

given to international and regional cooperation in efforts to protect against nuclear terrorism. It is essential that issues of nuclear non-proliferation, nuclear safety and nuclear security be dealt with on a comprehensive and integrated basis in order to achieve maximum success for the peaceful, safe, and secure use of nuclear technology.

Major Challenges

There is an urgent need to evaluate and strengthen the global nuclear security regime. Embedded in such an effort is the worldwide need to secure nuclear and other radioactive materials in non-weapon, non-nuclear use. The many storages of research reactor fuel containing highly enriched uranium, which can be used in an improvised nuclear explosive device must be seen in the perspective of the potential consequences should these materials come into the wrong hands. Furthermore, many research establishments with research reactors, laboratories and waste handling facilities require that much more attention be given to security.

The security of transport of nuclear and radioactive materials presents additional issues of concern to the international community. These questions are further complicated by the materials that present both a radiological *and* a chemical hazard. The privatisation of the nuclear power industry, the construction of new generations of nuclear power reactors, as well as of other nuclear fuel cycle facilities, compel expanded security-related responsibilities for the private sector.

It is also clear that robust, tight and internationally accepted nuclear security, which subscribes to a graded-recommendations approach based on risk and potential consequences, is imperative to sustainable development, of which the day-to-day benefit of nuclear energy and nuclear applications is an integral part.

The Holistic Approach

Global nuclear security requires a multi-track and holistic approach. It includes efforts to prevent the spread of weapons of mass destruction and related material; the protection of sensitive equipment and technologies; control of radioactive sources from cradle to grave, the detection of malicious acts involving nuclear and other radioactive materials, and emergency and incident preparedness to respond to and mitigate the consequences of any such acts.

Building a Global Nuclear Security Regime

The top tier of a global nuclear security regime consists of the CPPNM and the Code of Conduct for the Safety and Security of Radioactive Sources. Safeguards agreements and additional protocols are recognized for their contribution to nuclear security. Likewise, the Convention on Nuclear Safety, the Convention on the Early Notification of a Nuclear Accident, the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency, and the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management are recognized as important components of the institutional framework.

It is noted that the CPPNM is one of the twelve conventions that have been identified to contribute to the prevention of terrorism, and therefore, a strengthened CPPNM will significantly reinforce the global nuclear security regime. The proposals made by the open-ended group of legal and technical experts to amend the CPPNM contain broadening of its scope to include: protection of nuclear material in use, storage and transport, and the protection of nuclear facilities against sabotage. Further, universal implementation of the Code of Conduct on the Safety and Security of Radioactive Sources will also strengthen the nuclear security regime.

The global security regime is only as good as its weakest link. Eliminating the "weak links" requires the utmost attention. It is essential to work toward the creation of a critical mass of intellectual and institutional resources in States, which will be able to provide the competencies required to establish and sustain robust nuclear security systems and facilitate their implementation. Cooperation among relevant national authorities is key to forming effective national networks. Enhanced interaction between governments and non-governmental institutions will facilitate the exchange of new ideas and increase public awareness of threats to nuclear security of the nations. Effective intergovernmental networks will support a constructive nuclear security dialogue.

The Agency will work towards establishing longer-term relationships with countries to provide assistance and support in their efforts to improve their nuclear security systems to reach the anticipated holistic goal of strengthened nuclear security. Through longer-term goals and work plans, the coordination of resources available to the Agency, as well as in bilateral and multilateral support programmes, will be facilitated. The nuclear security relevant recommendations and guidelines developed by the IAEA will provide the necessary reference points for the States when establishing their own goals for nuclear security in their countries.

Building an effective global nuclear security regime requires a concerted action by all States. Therefore, the IAEA invites all States to join in efforts to strengthen nuclear security at international, regional, and national levels by making the best use of the Agency's nuclear security related services and by contributing financial and in-kind resources. It's essential that issues of nuclear proliferation and the secure and safe use of nuclear technology be dealt with in a comprehensive and synergistic manner in order to achieve maximum success.

Is Enough Being Done?

The international community has taken important steps to make it much more difficult for any terrorist and/or criminal to use nuclear and radioactive materials to cause death, destruction and panic.

Yet, is enough being done? The consequences of an explosion of *one* crude nuclear device would be catastrophic, and the consequences of the sabotage of a nuclear facility may forever halt the development of nuclear technology for peaceful purposes and thereby hamper socio-economic development. Although an RDD may not cause mass destruction, the disruption and panic caused by the explosion of such a device and the unavoidable, likely vast contamination of and effect on the environment are likely to have unforeseeable consequences.

The Chernobyl catastrophe 18 years ago awakened the world to the fact that the global nuclear safety regime must be strengthened. The international community has now a window of opportunity to take proactive measures to prevent any catastrophic nuclear malicious event that may halt the future use of nuclear technology for the benefit of mankind. There is no room for complacency.

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Return to Sender

Upgrading the Safety & Security of Research Reactors

How the world's nuclear research reactors are fuelled makes a difference. In fact, the type of fuel they use has become a serious concern on safety and security grounds. A focal point is fresh and spent highly enriched uranium (HEU) fuel that remains on site at many shut down research reactors, says the IAEA's Crosscutting Co-ordinator for Nuclear Research Reactors, Mr. Iain Ritchie.

Since 1993 the Agency has worked to help countries upgrade safety and security at research reactors, particularly at shut-down reactors that have no plans for decommissioning and decontamination. The problems are significant, funds limited, and the work ever growing.

Spent Fuel at Reactors

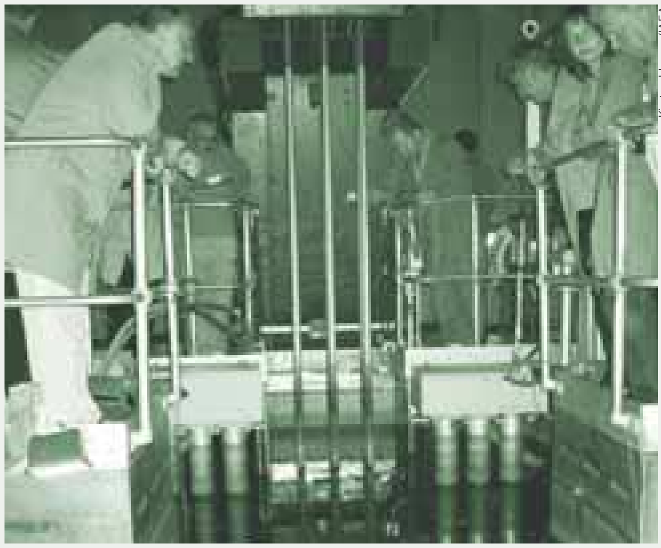
Researchers have long used small nuclear reactors as engines of discovery for everything from lifesaving cancer treatment to electronic gadgetry. But the use and future of research reactors is radically changing in a more economically competitive, and safety-conscious world.

Historically, HEU was the fuel of choice to power research reactors. It is also a key safeguarded material that can be processed and used to make a nuclear weapon. Most research reactors are located in nuclear-weapon States, but some are in countries yet to conclude safeguards agreements with the Agency.

"To have to imagine that all this spent fuel, in all these little research reactors, is scattered all over the world is crazy," says Mr. Allan Krass, Physical Science Officer, US State Department. "We know of a number of countries where the economy is in intensive care, the political situation is completely unstable and yet they have a research reactor with a spent fuel pool," Mr. Krass said.

In the past, the US supplied the bulk of HEU fuel and reactors in North America and the Asia Pacific, while the former Soviet Union supplied enriched fuel and HEU reactors to Eastern Europe. There are various "take back" initiatives underway to return this spent fuel to the countries of origin for safe disposal.

"There is no country that enjoys taking back spent fuel — it's a political headache. Yet it is irresponsible to just imagine that you can leave that where it is indefinitely," Mr. Krass said.



Kirsten Hansen/IAEA

La Reina research reactor in Santiago, Chile.

In some cases stocks of highly radioactive spent fuel are stored in an unsafe manner, corroding away. In other instances, spent fuel had been building up for years, for longer periods, and in large quantities, than originally planned. About one-third of all spent research reactor fuel is HEU spent fuel. The IAEA's research reactor database reveals the extent of the spent fuel problem:

◆ 12,850 spent fuel assemblies of US origin still at research reactors abroad. Most are eligible to be returned under the US "take back" program, as long as they are discharged before 13 May 2006.

◆ 24,803 spent fuel assemblies originally enriched in the former Soviet Union still at research reactors abroad. A Tripartite (IAEA, Russian Federation, US) Initiative to repatriate this fuel is expected to begin this year.

Of the 382 shut down research reactors worldwide, less than half are decommissioned. The IAEA's focus is on the 27 shut down research reactors in developing Member States.

"Of the 27 in question, those with safety concerns and serious spent fuel problems are well known to us and we are trying to improve maters," Mr. Ritchie said. Of particular priority, reactors that have been shut down for more than a year with no plans for decommissioning; and reactors or spent fuel storage pools housing leaking fuel assemblies or exotic fuels that require special management.

The Agency's work in this area includes:

◆ Enhancing the safety of facilities and spent fuel storage, including support for the return of fuel to the country of origin;

◆ Correcting institutional shortcomings through training and guidance, and providing limited monitoring equipment in chronic cases;

◆ Identifying and supporting upgrades to physical security at vulnerable sites;

◆ Developing long-term measures to improve security and creating a common safety culture. This includes encouraging States to sign on to the new Code of Conduct on the Safety of Research Reactors that goes before the IAEA General Conference in September 2004.

Fresh Fuel at Reactors

Stocks of unused, fresh HEU fuel also become a liability when a research reactor shuts down. Fresh HEU fuel — material not yet used in a nuclear research reactor — is low in radioactivity. This makes it far easier for a thief to transport than the highly radioactive spent fuel wastes.

"What we are talking about is weapons-grade material that is not self-protecting - material that is not so radioactive that people can't just pick it up and carry it away," Mr. Krass said.

The IAEA is helping Member States to transfer unwanted fresh HEU stocks back to the country that supplied it. In August 2002 it helped transfer 45 kilograms (enough fissile material to make two nuclear bombs) from Serbia and Montenegro back to Russia, to be blended down to low-enriched uranium (LEU) that cannot be used in a nuclear weapon. Most recently it assisted Libya in March 2004. In December 2003 it assisted Bulgaria and in September 2003, Romania. More return shipments are planned in other countries.

Stop HEU Trade

Currently about 130 research reactors around the world still run on weapons-grade HEU. In an article "A Safer World" published in The Economist, IAEA Director General Mohamed ElBaradei called for an end to trade in HEU.

"Existing facilities around the world that use high-enriched uranium applications — for example, to produce medical radioisotopes — should continue, gradually but irreversibly, to be converted to low-enriched processes."

The Agency is helping countries do exactly that. It actively supports them to convert their research reactors from burning HEU to LEU. In conjunction with the US "Reduced Enrichment for Research and Test Reactors" (RERTR) programme the Agency is helping to reduce and eventually eliminate international commerce in HEU for research reactors.

So far 29 reactors have been fully converted to LEU and a further seven are in the process of converting. Countries seeking IAEA assistance include Brazil and Romania.

Safety and security is a twin challenge of rising proportions as more and more research reactors are shut down or decommissioned this decade. The IAEA stands ready to help but with limited resources improvements come slowly, says Mr. Ritchie. Signs fortunately are pointing to more international support and co-operation in months and years ahead.

— Kirstie Hansen, IAEA Division of Public Information. For more information see the feature series on the IAEA web site www.iaea.org.

Code of Conduct

The Code of Conduct on the Safety of Research Reactors goes before the IAEA General Conference in September 2004 for adoption, having been approved by the Board of Governors at its March 2004 meeting.

The Code establishes "best practice" guidelines for the licensing, construction and operation of research reactors. At its core, "the safety of the public, the environment and the workers," said IAEA Director of Nuclear Installation Safety, Mr. Ken Brockman.

Research reactors were excluded from the Convention on Nuclear Safety when it was drawn-up in the early 1990s. The need for an overarching Code of Conduct came to a head in a resolution at the 2000 IAEA General Conference, prompted by safety concerns as many of the worlds' research reactors approached the end of their originally planned lifespans. Increased fears of terrorist threats following the 11 September 2001 attacks in the United States also helped to fuel desire for a Code of Conduct, Mr. Brockman said. Just less than half of the world's 272 research reactors still operate using highly enriched uranium—a key ingredient for a nuclear bomb.

The Code is a non-binding international legal agreement, where States determine their own level of commitment to its guidance. The Code was derived from more detailed international standards that have been promulgated for the safe day-to-day operation, construction, shutdown and decommission of research reactors, Mr. Brockman said. "It will pave the way for the continued evolution of these standards," he said.

The Agency has already carried out numerous safety and security missions at research reactors which, among other things, has helped to improve the security infrastructure at reactors.

Timeline IRAQ

Challenges & Lessons Learned from Nuclear Inspections

by Jacques Baute

Under a dramatic and far-reaching global spotlight, the International Atomic Energy Agency's experience in Iraq reached a turning point in March 2003. Its nuclear inspection team — together with teams of the United Nations Monitoring, Verification and Inspection Commission (UNMOVIC) and the rest of the UN organisations operating in Iraq — had to withdraw ahead of announced military operations. The diplomatic route to disarming Iraq had reached an impasse.

Today, international inspection teams tracking weapons of mass destruction (WMD) programmes in Iraq work in the wings, ready to resume operations in Iraq at the UN Security Council's call. The mandate of international inspection stands, with the IAEA's Iraq Nuclear Verification Office (INVO) in Vienna in charge of the nuclear file.

The IAEA's nuclear inspection and verification experience in Iraq stretches over a span of three decades, addressing activities from the mine to the weapon. Agency inspectors led the discovery and dismantlement of Iraq's secret nuclear weapons programme in the 1990s, and after the 1990s round of inspections had stopped, they had found no evidence, up to March 2003, that the programme had been revived since 1998.

Since the first Iraq inspections under Security Council mandate in early 1991, the road of nuclear verification in Iraq has proved to be long and hard, and valuable lessons were learned that have benefitted the international community and strengthened the IAEA inspectorate. This article highlights the IAEA's extensive experience in Iraq, the main challenges, and selected key lessons drawn from them.

Limits & Loopholes: The Early Years

Much is known in the nuclear verification community about the limitations of IAEA safeguards in the 1980s and of the corrective steps that were taken. Until then, the nature of the

Photo: The remains of facilities used for Iraq's clandestine nuclear weapons programme. (Iraq, 1991-1998).
Credit: Action Team 1991-1998/IAEA

traditional approach, thought to be adequate by the international community, had enough loopholes for Iraq to begin a clandestine nuclear weapons programme and remain undetected for a decade.

It is unfortunate that in some arenas some continue to portray the early safeguards limitations as an indicator of the IAEA's inability to provide credible assurance of a State's adherence to its obligations under non-proliferation agreements. Iraq had joined the global Nuclear Non-Proliferation Treaty (NPT) in the 1970s as a non-nuclear-weapon State and had concluded the required NPT safeguards agreement with the Agency.

Back then, it seemed that the international community was convinced that NPT non-nuclear-weapon States would remain committed to their pledges, and thus, the Agency's role would simply be the verification of the State's declared nuclear materials and installations. The mistake of the whole community was not to acknowledge that a meaningful verification system must implement measures aimed at detecting if a State was trying to deceive the system via the conduct of undeclared activities.

Addressing these loopholes — i.e. developing the lessons learned of the initial discovery of Iraq's undeclared programme under the tougher inspection regime mandated by the Security Council in the 1990s — was the main objective of the IAEA's programme for strengthening safeguards, and ultimately led, in 1997, to the adoption of the Additional Protocol to NPT safeguards agreements. The Protocol gave IAEA inspectors more authority, broadening the scope of information and access that States had to provide to the IAEA for nuclear safeguards and verification.

If inspectors had such authority in 1991, for instance, Iraq would not have been able to develop most of its clandestine activities in undeclared buildings at its Tuwaitha Nuclear Research Centre, as turned out to be the case. Had the Agency been able to put together and analyse information from an extended declaration required from the inspected country, from the quite numerous open sources in the late 1980s, and from information from other States, they would have known more about Iraq's apparent intentions and the world would not have waited for Iraq's invasion of Kuwait before zeroing in on the clandestine nuclear programme.

Detection & Deception: On the Weapons Trail 1991-95

The adoption of resolution 687 by the UN Security Council, in April 1991, was an important milestone. In this cease-fire resolution of the first Gulf war, the Agency was requested to map out and neutralise Iraq's nuclear programme and ensure Iraq's compliance with its NPT and resolution-related obligations through a far-reaching and ongoing monitoring and verification system.

Could a verification body dream of better conditions than being provided unconditional access to any individual, documents and technology that would help strengthen the conclusions? But despite such excellent conditions, our job was still far from easy.

The challenge at that time started with a learning phase — learning about Iraq's covert programme, including its most sensitive aspects, its weapons development; learning how to use the tremendous rights provided by the resolution; and learning how to team with UNSCOM, the United Nations Special Commission on Iraq. UNSCOM was tasked with a similar mandate for chemical and biological weapons and missiles and was requested to provide "assistance and cooperation to the Agency" (a vague definition, at best, to prevent possible variations on the understanding).

For the IAEA, one challenge was establishing the right structure for tackling Iraq's nuclear file. The first — perhaps too modest — response was to start with an IAEA Action Team made up of three professionals, reporting directly to the Director General, relying on the roster of inspectors from the Department of Safeguards, and calling on Member States to provide the expertise not readily available in-house. Gradually, however, the team grew in order to meet the challenges and, by December 2002, had become the Iraq Nuclear Verification Office (INVO) with more than 20 professional staff members.

Perhaps the biggest misconception was the time the "Iraq project" was expected to last. The timeframe cited by the Security Council in resolution 687 was expressed in days. Apparently, it was generally expected that the task could be completed in no more than a few months. As a result, the team went through a serious struggle when, at the end of 1993, a major turnover of personnel occurred, leaving only the Action Team leader to provide continuity. Newcomers had to rebuild the institutional knowledge with an innovative attitude. Major effort was made to develop a team approach, with a high priority in securing vital information through advanced structured databases, avoiding unnecessary restriction to information circulation, unless its sensitivity demanded a strict "need to know" approach.

That lesson, learned the hard way in 1994, was certainly a pillar of the success of the Agency's resumption of activities in November 2002. By then, staff turnover had once again led to a situation where INVO's Director was almost the only survivor of the senior staff involved in the preceding four (1994-98) years of inspections.

As IAEA inspections moved on in 1991, it became clear that Iraq's initial reaction certainly did not match the expectation in terms of transparency set by the Security Council. During the first months of inspections, Iraq's obvious objective was to hide as much as possible of its past programme. Unannounced intrusive inspections, in an attempt to circumvent concealment actions — such as Iraq's cleanup of enrichment facilities and its efforts to hide sensitive information from inspectors — became a powerful tool that forced Iraq to readjust its approach, and reveal some of its programme components by the summer of 1991. The extent of Iraq's clandestine programme was broadly uncovered, well before Iraq's forthcoming (and revised) declaration in 1995.

This was due to various inspection techniques, including for instance particle analysis of swipe samples, that has become since then one of the most effective verification tools in the nuclear area. Other factors behind the progress made were the realization of Member States that sensitive information provided to the Agency can lead to dramatic discoveries, the thorough and professional approach of experienced safeguards inspectors mixed with experts in non-traditional areas, and the development of systematic and comprehensive analytical approaches, in particular to gain understanding of the depth of Iraq's procurement effort during the 1980s.

The Agency's mandate for the destruction, removal or rendering harmless of Iraq's proscribed materials, equipment and facilities was practically completed by early 1994 (but not in 45 days as foreseen in Security Council resolution 687). At that time, there was no more weapon useable material, i.e. plutonium or high-enriched uranium (HEU), left in the country, no single use equipment was intact (even dual use items linked to the prohibited programme were destroyed) and all buildings with dedicated features had been destroyed. Even facilities that Iraq had not yet acknowledged as being linked to prohibited activities were destroyed, such as Al Atheer, the weaponisation centre, denied to be such until the summer 1995.

In August 1994, after having operated for three years on a campaign mode (sending teams of inspectors from headquarters for inspections that were limited in time), the Agency began its permanent presence in Baghdad. Fully unannounced inspection subsequently became the order of the day. The Agency had the possibility to inspect anyplace, at anytime, which proved to be a far more effective inspection regime.

Conclusions & Credibility: The Coherent Picture Emerges 1995-98

An important event occurred in August 1995 through the departure from Iraq of General Hussein Kamel - the Iraqi President's son-in-law and former supervisor of all WMD programmes. Iraq pre-empted his expected revelations by coming forward with additional declarations. In particular, Iraq provided details on its attempt to recover HEU from reactor fuel and handed over large quantities of documents related to the centrifuge enrichment and weaponisation areas. Additionally, the counterpart demonstrated a level of transparency that was unseen until that point in time. Because we had fully understood Iraq's documentation procedures, we completed our collection of original Iraqi documents by convincing the counterpart that providing the missing original reports was inescapable. They gained access to all relevant Iraqi personnel, while, prior to August 1995, Iraq had tended to give us access only to a "spokesperson" in the relevant technical areas.

Follow-up on Iraq's most damaging concealment action — the unilateral destruction of equipment and documents in the summer of 1991 — was implemented. This led to a campaign of digging in the desert to recover and take inventory of what had been hidden. Member States, or, more specifically, those communities in Member States that worked closely on the "Iraq case", also became more supportive. They had finally realised that the IAEA inspection team was strong in its technical approach, reliable in handling sensitive information, and that the IAEA had become the most knowledgeable organisation on Iraq's past programme and remaining capabilities. A tremendous amount of information of all kinds began to flow to us, allowing the team to become confident that, as all sources of credible information were being consistent, we had reached an accurate understanding of Iraq's nuclear past programme and remaining capabilities.

The lesson to be learned from that period is the following: It is possible for a nuclear verification body to provide the international community with an accurate estimate of the past and present situation provided that:

- the inspection team is technically strong and thorough, in particular in its analysis of documentation down to a detailed level and in its dealings with all relevant personnel;
- the team remains politically independent, i.e. relying on facts only, away from bending to political pressure;
- Member States are supportive of its action, both politically through the support of the Security Council and technically through the provision of information and expertise;
- the inspected State fulfils the verification body's requests.

Although, accuracy can never be 100%, by the end of the 1990s the world had a clear "coherent picture" of what was Iraq's nuclear programme. It was documented in comprehensive reports to the UN Security Council.

Unfortunately, one of the key problems, in retrospect, was that the Agency's approach and results remained unpublicised. In 1997-1998, only UNSCOM, and its problematic relations with Iraq, was reported in the media. In view of this lack of publicity, along with the fact that four years had passed during which, in capitals, many of the staff dealing with the Iraq file had moved on, it was hardly surprising that, by 2002, many people, including policy makers, were more inclined to consider worrisome declarations on major television networks than thorough but rather lacklustre, technical reports to the Security Council. The promoters of the "inspections do not work" line could easily surf on the majority's short and selective memory.

The key lesson for the Agency was that it should not only successfully fulfil its mandate, but also make better use of the media to convey its achievements to the public and decision makers.

Blindspots & Skyshots: The Inspection Gap 1998-2002

In the fall of 2002, the world had not yet come to grips with the ramifications of nearly four years without inspections on the ground in Iraq, following operation Desert Fox in mid-December 1998. Consequently, as the "experimental results" normally provided by field activities were no longer available, every possible speculation, including the most pessimistic interpretation of fuzzy intelligence or worst case scenarios extrapolated from procurement attempts, were taken at face value.

Four years without inspections is certainly of significance in the development of a nuclear programme, especially considering what Iraq was able to do in the four years between 1987 and 1990. On the other hand, it is clear that, contrary to what was possible during the 1980s and early 1990s, sanctions were in place.

Moreover, there is no comparison of Iraq's available assets at the end of 1986 and the situation at the end of 1998. In the absence of inspections, high-resolution commercial satellite imagery which became available at the end of 1999, provided a useful tool to try to remain in contact with the reality in the field (it is now widely used to prepare safeguards inspections worldwide). Overhead imagery had been utilized by the Agency in Iraq since 1991, in the form of photographs from U2 planes. Unfortunately, while allowing us to prepare well for inspections, imagery, as expected, proved to be far from sufficient to assess the existence or absence of nuclear activities.

The use of human intelligence proved to be an even greater challenge, given the possibility for anyone to embellish, if not create stories that end up being unverifiable. How many of the concerns raised by defector's reports, or as the result of imagery observations, could have easily been resolved had inspectors been in the field?

Moreover, while it is difficult to measure the deterrence induced by an inspection regime, the broad conditions provided by Security Council resolution 687 and other resolutions, together with their implementation aimed at optimising inspection effectiveness, were clearly providing a level of deterrence quite effective in preventing any prohibited activity of significant scale.

IAEA Inspectors assess the ruins of a facility used to produce highly enriched uranium. (Iraq, 1991-1998)

The adoption of Security Council resolution 1409, in May 2002, provided the Agency with a new mandate, resulting in developing a novel type of advanced experience: The process of reviewing all contracts to export goods to Iraq in order to identify what items might be of relevance for a hidden nuclear programme would allow the Agency to build an understanding of procurement networks, reflect on what items would be choke points and identify areas of possible concerns, based on the procurement of humanitarian or infrastructure rehabilitation goods.

But again, even that detailed information, compiled with clandestine procurement attempts, was far from enough to assess what was actually occurring in the country.

The Last Round: Under the Magnifying Glass 2002-03

The last period of inspections, between November 2002 and March 2003, was of a quite different nature, with regard to global attention and what seemed to be at stake. Some perceived that war or peace were now firmly resting on the shoulders of the IAEA and UNMOVIC inspectorates.

While it was clear that the decision would ultimately not be in the hands of the inspectorate but in those of the of Security Council members, it was vital that the Agency do its best to provide the Council with all possible facts and reliable conclusions in a timely fashion to support its decisions.

The IAEA relied on four years of preparation, including its comprehensive databases on sites, equipment and personnel, its refined "coherent picture", and former inspectors to benefit from the experience accumulated before December 1998. Thus, the Agency was able, within three months, to address most of the concerns raised by Member States.

IAEA, UN Inspections in Iraq Worked

IAEA and UN inspections of Iraq's weapons of mass destruction programmes worked, *Newsweek* magazine reported in February 2004. The magazine cites the record of international inspections and of the US-led Iraq Survey Group, whose past leader, David Kay, reported his findings.

Newsweek's Fareed Zakaria writes:
"We were all wrong," says weapons inspector David Kay. Actually, no. There was one group whose prewar estimates of Iraqi nuclear, chemical and biological capabilities have turned out to be devastatingly close to reality — the U.N. inspectors. Consider what Mohamed ElBaradei, head of the U.N. nuclear agency, told the Security Council on March 7, 2003, after his team had done 247 inspections at 147 sites: "no evidence of resumed nuclear activities... nor any indication of nuclear-related prohibited activities at any related sites." He went on to say that evidence suggested Iraq had not imported uranium since 1990 and no longer had a centrifuge program. He concluded that Iraq's nuclear capabilities had been effectively dismantled by 1997 and its dual-use industrial plants had decayed. All these claims appear to be dead-on, based on Kay's findings... The real lesson is that international bodies like ElBaradei's can work.

The magazine features an interview with IAEA Director General ElBaradei on the role of IAEA and international inspections.

"I think the sanctions worked, and more importantly, the inspections worked," Dr. ElBaradei says. "A combination of sanctions and inspections managed to disarm Iraq."

Dr. ElBaradei underlined the importance of having IAEA and international inspectors return to Iraq. "We still have a request by the Security Council to verify that Iraq has no nuclear weapons."

On 7 March 2003, Director General Mohamed ElBaradei told the Security Council that the IAEA had found no evidence or plausible indication of the revival of a nuclear weapons programme in Iraq. However, he added that more time was still needed for the Agency to complete its investigations on whether Iraq had attempted to revive its nuclear programme between 1998 and 2002. Neither the changes in Iraq over the past year nor the investigations by the Iraq Survey Group set up to complete Iraqi disarmament have done anything to contradict the Agency's assessment of the situation. However, conclusions should certainly not be drawn before the IAEA team has had a chance to complete its assessment, once the Security Council revisits its mandate, as foreseen in resolution 1483 and 1546, and teams can return to Iraq.

As highlighted in major newspapers and magazine editorials, the IAEA seems to have been right in its assessment of Iraq's nuclear capabilities. In my view, this was no coincidence, but the result of a well thought out and reliable approach. It is the Agency's role to provide the international community, in a timely fashion, with facts and conclusions when, and only when, they become indisputable, and to inform them about uncertainties as long as they exist.

This is what the IAEA's Iraq teams did routinely, but more spectacularly in October 1997 and March 2003. The fact that the Agency has 137 Member States forces it to put great distance from any single political agenda and its associated pressure (which is not the case for national analysts who, at a given point in time, may feel under the pressure, explicit or implicit, from a single political line).

But if the ethics of the approach provide the framework for the work, it does not provide the end product. The methodology that leads to the "credible assurance" that the international community expects from the verification body relies first on assembling top quality personnel, whose contribution is required to be disconnected from any "a priori" belief that would lead to preconceived conclusions. Experts must be of geographical diversity, and redundancy of expertise is certainly mandatory in sensitive areas, again to avoid unwanted bias. Then, it is fundamental to remember that the information that leads to a conclusion cannot be limited to a declaration taken at face value, "the last HUMINT" (human intelligence) or the "last sample analytical result". Rather, it has to include data that is as comprehensive as possible in nature, origin and time. Another key parameter is certainly to keep in mind one's own limitations, to avoid excessive extrapolating far from the facts and forgetting the inherent presence of uncertainties.

Of course, no verification is meaningful, unless the inspectors have, on a continuous basis, the appropriate level of authority that enables drawing credible conclusions while limiting the uncertainties. Absence of inspections, like in Iraq from 1999-2002, turns the whole community blind. Providing the IAEA inspectorate with the right level of authority (even short of the dream conditions as in Iraq) is a win-win situation. It benefits the international community, which receives the level of assurance it seeks, and also the inspected party, which is given the opportunity to demonstrate the reality of its compliance. As proven in Iraq, inspections work, and they have no substitute.

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Seeking the Truth

Hans Blix speaks to CNN's Christiane Amanpour on Disarming Iraq

by Bonnie Azab Powell

Speaking on the anniversary of the United States' invasion of Iraq, originally declared as a pre-emptive strike against a madman ready to deploy weapons of mass destruction (WMD), the man first charged with finding those weapons said that the US government has "the same mind frame as the witch hunters of the past" — looking for evidence to support a foregone conclusion.


Hans Blix spoke with veteran CNN war correspondent Christiane Amanpour at the University of California, Berkeley on 17 March 2004 as part of the Media at War Conference.

"There were about 700 inspections, and in no case did we find weapons of mass destruction," said Hans Blix, the Swedish diplomat called out of retirement to serve as the United Nations' chief weapons inspector from 2000 to 2003; from 1981 to 1997 he headed the International Atomic Energy Agency (IAEA). "We went to sites [in Iraq] given to us by intelligence, and only in three cases did we find something" — a stash of nuclear documents, some Vulcan boosters, and several empty warheads for chemical weapons. More inspections were required to determine whether these findings were the "tip of the iceberg" or simply fragments remaining from that deadly iceberg's past destruction, Blix said he told the United Nations Security Council. However, his work in Iraq was cut short when the United States and the United Kingdom took disarmament into their own hands in March of 2003.

Blix accused US President George W. Bush and UK Prime Minister Tony Blair of acting not in bad faith, but with a severe lack of "critical thinking." The United States and Britain failed to examine the sources of their primary intelligence — Iraqi defectors with their own agendas for encouraging regime change — with a sceptical eye, he alleged.

In the build-up to the war, Saddam Hussein and the Iraqis were cooperating with UN inspections, and in February 2003 had provided Blix's team with the names of hundreds of scientists to interview, individuals Saddam claimed had been involved in the destruction of banned weapons. Had the inspections been allowed to continue, Blix said, there would likely be a very different situation in Iraq today. As it was, America's pre-emptive, unilateral actions "have bred more terrorism there and elsewhere."

Blix has written a new book, *Disarming Iraq,* about the events leading up to the war. During that period he was lambasted by both doves and hawks: by the former for failing to state unequivocally that Iraq had no WMD, and by the latter for failing to find them. As he explained, part of the problem was that he himself had believed the weapons probably existed. "I'm not here to have gut feelings," he said. "But yes, in December 2002 I thought Saddam had weapons of mass destruction." Still, "the objective was to inspect effectively and to report objectively."

The important thing to remember, Blix said repeatedly, was that Saddam was cooperating with the inspections, despite the difficulties they create for a leader. "No one likes inspectors, not tax inspectors, not health inspectors, not any inspectors," Blix chuckled. Not only did Saddam have to endure the indignity of submitting to searches of his palaces, he explained, but the dictator also harbored the valid fear that the inspectors would pass on their findings of conventional weapons to foreign intelligence agencies, providing easy future targets.

Photos: IAEA/UN

IAEA Director General ElBaradei, Dr. Hans Blix and Mr. Al Saadi of Iraq respond to press questions in October 2002 in Vienna.

UN Inspectors and staff prepare for the resumption of inspection in Iraq, 18 November 2002.

Inspectors in Iraq prepare to set out for another day of inspections in January 2003.

Blix tried hard to reassure the Iraqis about this concern. “Inspectors shouldn’t be intertwined with intelligence,” he emphasized. “There should be only one-way traffic: the intelligence groups give the inspectors tips on where to look, but they understand that there is no quid pro quo.”

CNN’s Christiane Amanpour brought up how Blix’s credibility as an inspector had been attacked by Vice President Dick Cheney, among others, for his failure as head of the IAEA to detect Iraq’s advanced nuclear weapons program, discovered only after the end of the 1991 Gulf War. Blix accepted responsibility for that failure, and said that the system of inspections had been vastly improved since then.

“Cosmetic inspection is worse than no inspection at all, because it can lull people into a false sense of security,” he allowed. IAEA practiced a weak form of inspection until 1991, he explained, one that had been designed in the 1970s to check countries like Germany for compliance with non-proliferation laws, not for totalitarian regimes trying to build weapons in secrecy. As a result of the 1991 failure in Iraq, the IAEA had launched a systematic change in its protocols that were formally adopted in 1997.

The primary difficulty with looking for weapons of mass destruction in Iraq, said Blix, was the “problem of proving the negative. For example, how can you prove that there is not a tennis ball in this room? Or that there is no anthrax in all of Iraq?” The United States and the United Kingdom wanted black-and-white answers, and instead they got “lots of shades of gray in the reports.”

What Blix’s inspectors had needed was more time, he emphasized. The Bush administration should have halted its military build-up in the area at 50,000 troops, the point at which the Iraqis had become much more cooperative, providing the lists of scientists and bureaucrats to Blix’s team. “Given time, we would have been able to interview the many people who destroyed weapons of mass destruction after 1991,” he told Amanpour.

Amanpour asked why, if those weapons had been destroyed, would Saddam have continued to let the world believe he still possessed them at the risk of losing his country? Blix surmised that the bluffing was a cheap and effective deterrent. “[The Iraqis] didn’t mind the suspicion from the neighbours — it was like hanging a sign on the door saying ‘Beware of the dog’ when you don’t have a dog,” he speculated.

But instead the Bush administration continued to pour troops into the area, an ominous presence portending war. “Once they got to 250,000 troops sitting in the hot desert sun, there was a momentum built up that couldn’t be halted,” said Blix.

Amanpour pressed him to identify the source of that momentum — in effect, why did the US invasion of Iraq seem in retrospect such a foreordained action? Partly it was because, despite the lack of evidence for remaining WMD, the Bush administration continued to believe in them, Blix said. Although he places some of the blame on a failure of US intelligence processes — the Pentagon relied too much on its own “silo” of sources rather than more heavily vetted intelligence from the CIA and the State Department, as has been documented extensively by Seymour Hersh in the New Yorker — the real problem was the lack of “critical thinking,” he argued.

“In academia, when you write your thesis, you have an opponent on the faculty and you must defend it. And in a court, there is cross-examination from the prosecutor,” said Blix. But in the intelligence arena, because of the confidentiality of the subject matter, it is difficult to find those who will play devil’s advocate. The Bush Administration, he said, did not

Dr. ElBaradei conferring with Dr. Blix and UN Secretary General Kofi Annan in the margins of the UN Security Council meeting, 5 February 2003, New York.

UN Security Council's briefing on the progress of weapons inspections in Iraq, 14 February 2003, New York.

US Secretary of State, Colin Powell, Dr. ElBaradei and Dr. Blix briefing the UN Security Council on Iraqi cooperation, 7 March 2003, New York.

try. "They took away the question marks [in the reports] and put in exclamation points instead!"

Blix did not rule out that even if inspections had been allowed to continue, military intervention in Iraq might still have been necessary. "I am not a pacifist," he said. But he is a lawyer and a diplomat, and he believes that it was the responsibility of the Security Council to uphold its own resolutions regarding Iraq, not the responsibility of one or two Council members acting alone. Had Iraq resisted further inspections, or had they turned up evidence of another nuclear weapons program — the area Blix said that sanctions and inspections had been most effective in squelching — Security Council members Russia and China would most likely have voted for military action, giving it international legitimacy.

Blix speculated that the Bush administration's real motivation for invading Iraq was in reaction to the terrorist attacks of September 11, 2001. "The US was attacked on its own soil. I was here; it was like an earthquake in this country," he said. "It was as if Afghanistan was not enough."

Amanpour asked Blix to respond to a statement by Ahmed Chalabi, the Iraqi defector who along with affiliated sources provided much of the faulty WMD intelligence. "We were heroes in error. Saddam is gone, the Americans are in Baghdad, and that's all that matters," she quoted Chalabi as having said. Blix called it a "cynical" statement, yet admitted that he was troubled by the idea that had he been allowed to continue his inspections, Saddam would probably have remained in power.

How to deal with such tyrants and failed States is the biggest challenge facing the world, Blix stated, echoing many other prominent diplomats and thinkers invited to speak by the Journalism School in the months past. He claimed that a global shift had occurred in the world's tolerance for genocide such as had occurred in Kosovo or Rwanda. Thanks in part to media attention, which brought the world's citizens closer to one another, he said he thought such acts would no longer be considered protected by State sovereignty, and that humanitarian intervention would be more common.

In a press conference shortly before his interview with Amanpour, Blix had elaborated on this topic, citing the need to use the "carrot as well as the stick." Ironically, the man whose name is synonymous with the world's fears of nuclear, biological, or chemical annihilation says he has other concerns on his mind.

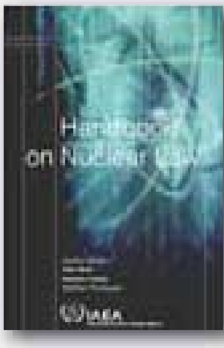
"Part of the hype is that proliferation of weapons of mass destruction is the 'greatest existential threat' — as I think Tony Blair put it," he said. "But to my mind, the North–South divide [between developed and emerging countries], the fact that hundreds of millions of people go hungry, the effects on the global environment, are just as big a threat," said Blix. "I personally am more worried about global warming than I am about WMD."

The university's Graduate School of Journalism and the Human Rights Center organized the three-day "Media at War" conference to foster discussion of the challenges that US, European, and Middle Eastern reporters faced when covering the Iraq war for the past year, and to raise issues they should keep in mind as they report on the ongoing occupation, upcoming international war-crimes trials, and the country's anticipated regaining of sovereignty. For a complete webcast of the interview visit: webcast.berkeley.edu/events/details.html?event_id=132

IAEA Books & Meetings

The IAEA is a leading publisher in the nuclear field. Its scientific and technical publications cover fifteen subject areas. They include proceedings of major international conferences, as well as international guides, codes, and standards. Read more about recently published and upcoming books on the IAEA's web pages at www.iaea.org/Publications/

History of the International Atomic Energy Agency: The First Forty Years



Handbook of Nuclear Law

Advances in Destructive and Non-Destructive Analysis for Environmental Monitoring and Nuclear Forensics

Standards and Codes of Practice in Medical Radiation Dosimetry

The IAEA's major conferences and symposia in 2004 cover a range of topics. For updates on them and other meetings, check the IAEA's web pages at www-pub.iaea.org/MTCD/Meetings/Meetings2004.asp

International Symposium on Quality Assurance for Analytical Methods in Isotope Hydrology
25-27 August, Austria

International Conference on Nuclear Knowledge, Strategies, Information Management and Human Resource Development
6-10 September, France

International Conference on Topical Issues in Nuclear Installation Safety
18-22 October, China

International Conference on Isotopes in Environmental Studies — Aquatic Forum 2004
25-29 October, Monaco

20th IAEA Fusion Energy Conference
1-6 November, Portugal

International Symposium on the Disposal of Low-Activity Radioactive Waste
13-17 December, Spain

Nuclear Energy's New "Funky" Image

To the hip-swaying beat of Lipps' "Funkytown", the French energy giant AREVA unveiled its new global ad campaign. Nuclear energy never looked this funky nor this accessible. AREVA, an energy leader, has tackled the challenge of finding ways of explaining what it does without becoming too technically complex. As the creative director noted, "We focused our initial research on a style that supports the brand well and that's different enough to hold people's interests." The look they settled on is almost comic-strip in style. Education aids, diagrams and illustrations frequently seen in schoolbooks inspire the 45-second TV spots and print ads. The ads aims to recreate this educational atmosphere — but with flair. "This approach lends a certain rhythm to the TV ads as a whole and gives people a real insight into AREVA's activities." Who knew uranium mining could be this fun?

If you missed the ad, take a look on-line: www.areva.com

IAEA Member States

1957 **Afghanistan,** Albania, Argentina, **Australia, Austria, Belarus, Brazil,** Bulgaria, **Canada,** Cuba, **Denmark**, Dominican Republic, Egypt, El Salvador, Ethiopia, **France,** Germany, Greece, **Guatemala,** Haiti, Holy See, Hungary, Iceland, **India,** Indonesia, **Israel,** Italy, **Japan,** Republic of Korea, Monaco, Morocco, Myanmar, Netherlands, New Zealand, **Norway, Pakistan,** Paraguay, Peru, Poland, **Portugal**, **Romania**, **Russian Federation**, Serbia and Montenegro, **South Africa**, Spain, Sri Lanka, **Sweden**, **Switzerland,** Thailand, Tunisia, **Turkey,** Ukraine, **United Kingdom**, **United States**, Venezuela, Vietnam

1958 Belgium, Ecuador, Finland, Islamic Republic of Iran, Luxembourg, Mexico, Philippines, Sudan

1959 Iraq

1960 Chile, Colombia, Ghana, Senegal

1961 Lebanon, Mali, Democratic Republic of the Congo

1962 Liberia, Saudi Arabia

1963 Algeria, Bolivia, Côte d'Ivoire, Libyan Arab Jamahiriya, Syrian Arab Republic, Uruguay

1964 Cameroon, Gabon, Kuwait, Nigeria

1965 Costa Rica, Cyprus, Jamaica, Kenya, Madagascar

1966 Jordan, Panama

1967 Sierra Leone, Singapore, Uganda

1968 Liechtenstein

1969 Malaysia, Niger, Zambia

1970 Ireland

1972 Bangladesh

1973 Mongolia

1974 Mauritius

1976 Qatar, United Arab Emirates, United Republic of Tanzania

1977 Nicaragua

1983 Namibia

1984 China

1986 Zimbabwe

1992 Estonia, Slovenia

1993 Armenia, Croatia, Czech Republic, Lithuania, Slovakia

1994 The Former Yugoslav Republic of Macedonia, Kazakhstan, Marshall Islands, Uzbekistan, Yemen

1995 Bosnia and Herzegovina

1996 Georgia

1997 Latvia, Malta, Republic of Moldova

1998 Burkina Faso, Benin

1999 Angola

2000 Tajikistan

2001 Azerbaijan, Central African Republic

2002 Eritrea, Botswana

2003 Honduras, Seychelles, Kyrgyz Republic

Total Membership: 137 (as of December 2003)

Eighteen ratifications were required to bring the IAEA's Statute into force. By 29 July 1957, the States in bold — as well as the former Czechoslovakia — had ratified the Statute.

Year denotes year of membership. Names of States are not necessarily their historical designations. For States in italic, membership has been approved by the IAEA General Conference and will take effect once the necessary legal instruments are deposited.

Note:
- ♦ *The Democratic People's Republic of Korea (DPRK), which joined the IAEA in 1974, withdrew its membership of the Agency 13 June 1994.*
- ♦ *Cambodia, which joined the IAEA in 1958, withdrew its membership of the Agency 26 March 2003.*
- ♦ *The former Federal Republic of Yugoslavia was changed to Serbia and Montenegro as of 4 February 2003.*

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Further information and registration forms can be obtained at: http://www-pub.iaea.org/MTCD/Meetings/Announcements.asp?ConfID=124