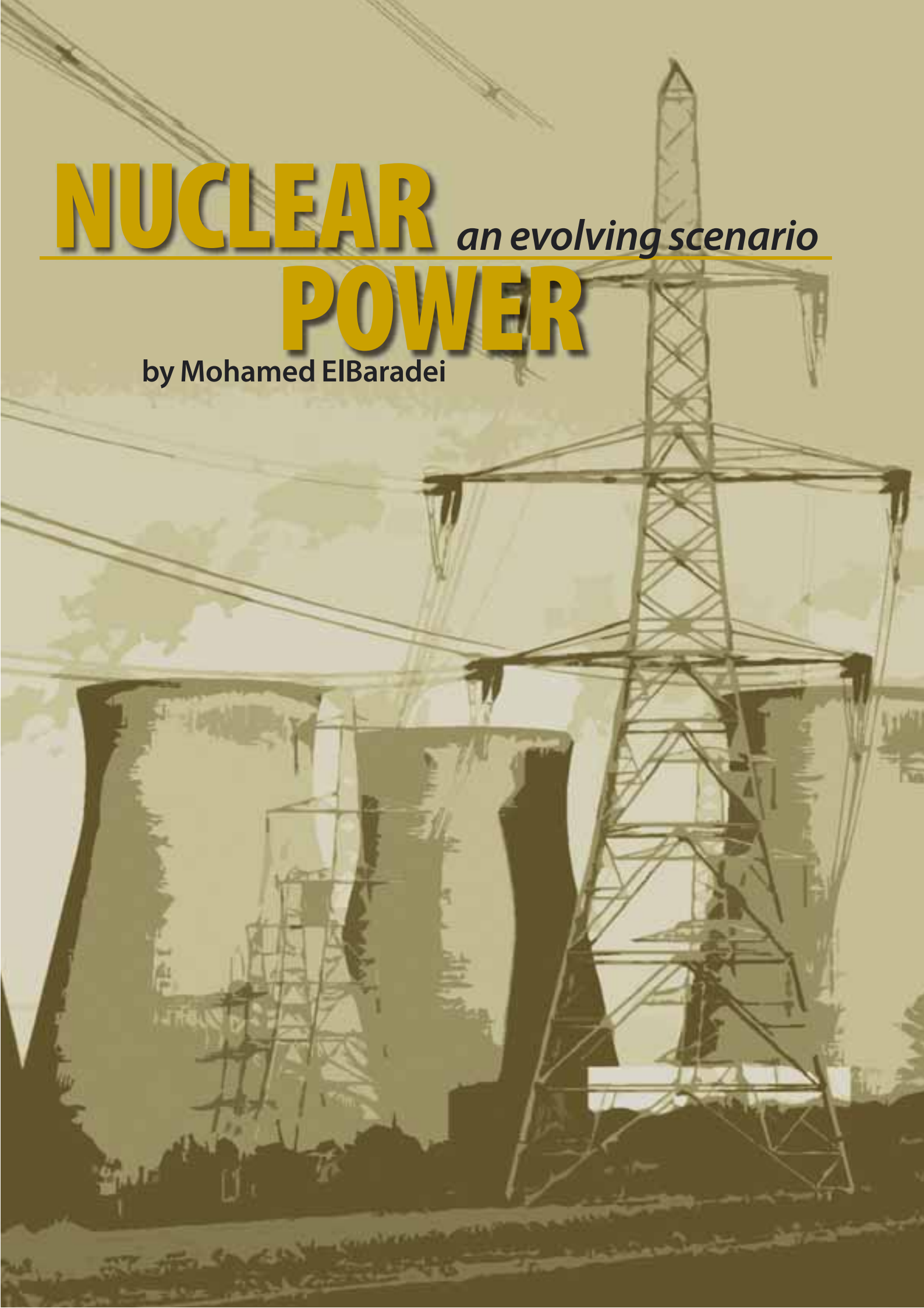
NUCLEAR POWER

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.

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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 exist-

ing 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.

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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.

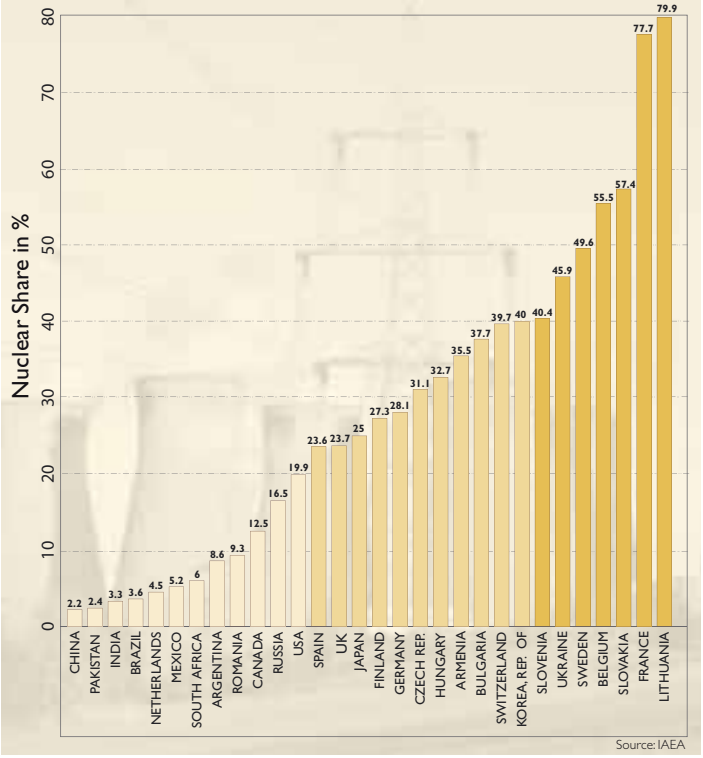
Key Issues For Future Viability

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.

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