DEVELOPMENT OF NUCLEAR REACTORS & FUEL CYCLES

THE NEED FOR INNOVATION

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As the century unfolds, global development and population growth seem certain to challenge the habitability of the Earth. There is especially an increasing sense of urgency to meet the growing needs for electricity and water in ways that protect the environment.

Over the past 50 years, nuclear energy has grown from a new scientific development to become a major part of the energy mix in more than 30 countries. During 1999, seventeen countries relied on nuclear power for 25% or more of their electricity needs. At the same time, more countries are showing interest in developing and demonstrating diversified applications of nuclear energy, such as the use of reactors for desalination of seawater.

Against this background, one would expect to see a rising trend for nuclear power generation. Yet that is not the case, and nuclear power's future contribution to meeting the challenges of sustainable energy development is uncertain. Worldwide, the picture is mixed: no new nuclear power plants are being built in Western Europe and North America. In several countries of Asia and in parts of Eastern Europe, however, nuclear power continues to grow.

Major contributing factors to this mixed picture are concerns and misperceptions related to three types of topical issues:

- safety and security;
- the linkage between nuclear power and nuclear weapons;
- environmental and economic aspects of nuclear power and its fuel cycle.

If nuclear power is to contribute in significant ways to meeting future energy demands, these topical issues must be resolved. In a real sense, the acceptance of nuclear power as a future energy option will depend on the successful application of solutions to the problems encountered during the deployment of nuclear energy in the 20th century.

Each topical issue can be addressed through efforts in three interrelated areas.

- *Technology.* The characteristics of the technology itself determine to an appreciable extent key aspects of safety and security; non-proliferation; and environmental and economic factors.
- *Legal & Institutional Framework.* Commercial contracts, government laws, regulations, and inter-governmental treaties and conventions set the ground rules affecting nuclear power development and implementation.
- *Oversight & Controls.* Controls applied by the owners and operators of nuclear facilities, by local and national governments, by regional and international organizations, as well as concerned citizen groups, serve to ensure that the required oversight structure for nuclear operations is in place and maintained.

In each of these three interrelated areas, diverse efforts have been taken and are being pursued; in fact, the past half-century has produced an industry that has profitably harnessed nuclear energy to the extent that it currently supplies one-sixth of the world's electricity needs. That accomplishment is significant.

But the problems being faced today are different than those encountered over the past

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decades, and they vary considerably in different parts of the world. They are particularly challenging in developing countries that require electricity to mitigate the burdens of poverty and meet the basic human needs of sustainable development. More needs to be done to assist developing countries interested in pursuing the nuclear option for electricity generation.

Very few of the means available for addressing the challenges inherent to each of the three topical issues are amenable to simple or short-term improvements. They will require sustained efforts over considerable periods of time, and they will require working cooperatively toward innovative solutions that satisfy major questions, concerns, and misperceptions.

Given the world's energy situation and the demands of sustainable development, a central aim must be to strengthen the foundation for expanding nuclear power's potential contribution to electricity supply. Such steps can be taken through coherent programmes addressing the technologies, the legal and institutional frameworks, and the oversight regimes required for public and political support.

Throughout its existence, the IAEA has played a key role in establishing and coordinating international efforts for the peaceful applications of nuclear energy. At a time when nuclear power finds itself at a crossroads concerning future development, the Agency's activities in areas of nuclear power and the fuel cycle have taken on added importance. This article reviews the global situation in the context of major challenges being faced and discusses the need for coordinated, long-term actions essential for securing progress in the development of nuclear power as the century opens. As the global energy market is expanding, nuclear energy has the potential to increase its contribution to electricity generation, as well as to non-electric end uses of energy through diversified applications in various fields.

THE GLOBAL SITUATION

The contribution of nuclear energy to future energy supplies depends on several key factors. The degree of global commitment to sustainable energy strategies and recognition of the role of nuclear energy in sustainable strategies will impact its future use. Technological maturity, economic competitiveness, financing arrangments, and public acceptance are other key factors influencing decisions to build new plants. Public perception of energy options and related environmental issues, as well as public information and education, will also play an important role. Continued vigilance in the safe operation of current plants is another highly important factor in preserving the potential of nuclear power to contribute to future energy strategies.

Fundamentally, the challenges to nuclear power require scientific and technical research and development not only to improve current nuclear reactor and fuel cycle technology, but also to develop new innovative reactors and fuel cycles that are proliferation-resistant, and achieve higher efficiency, lower cost, and enhanced safety levels.

Seven Subject Areas. The global prospects for nuclear power can be described in terms of the following seven topics.

Technology. Nuclear power technology has been under development for five decades. Substantial orders for commercial power plants began in the 1960s, and widespread commercial operation began in the 1970s. Currently, nuclear power supplies about 6% to 7% of world primary energy. The majority of operating plants have performed well and continue to improve.

However, problems have been encountered on several fronts and in some cases plants were prematurely shut down or completed but never operated. Construction starts peaked in the 1970s and connections to the grid in the 1980s, with current levels of both far below the values achieved earlier.

Today's activities for technology development within the nuclear power industry can be characterized as taking place within three general categories:

- Currently Operating Commercial Facilities. Improvements in maintenance, operations, engineering support, fuel supply, and life extension.
- Evolutionary Designs. Improvements in design and operation for near-term future deployment, involving moderate changes from

commercial facilities that are operating now.

- Innovative Designs. Advances in design and operation involving major departures from currently operating commercial facilities for long-term future deployment.

In recent years, a host of ideas for new power reactor designs and fuel cycles have sprouted from several countries. Some of these designs could bring about a rejuvenation of nuclear power, but only if they are developed, tried and tested under conditions that encourage their success and lead to commercial fruition. The lead-time for nuclear development is long. The development and testing of a new nuclear reactor concept is expected to require 15 to 20 years, depending on continued political support and the availability of adequate resources. It may be considerably longer before the most promising candidate can be selected and demonstrated to become the instrument for substantial expansion of nuclear power. Vigorous actions are required to maintain and build upon the necessary expertise that has been acquired.

Safety. The present high level of nuclear safety has been achieved by continuous improvements based on the global accumulation of experience. Safety measures have generally been introduced based on a judgment to be "reasonably practical", as noted in the IAEA's Safety Series publication *The Safety of Nuclear Installations*. Some countries use a formal cost/benefit analysis process to decide about improvements. In case of uncertainties it is necessary to make conservative decisions. With the present and future high level of hardware performance, emphasis needs to be given to the management of operational safety.

There is a broad international consensus, including industry and regulatory authorities, on the safety targets for future reactors. They have been suggested by the International Nuclear Safety Advisory Group (INSAG) and basically require that future nuclear plants be safer by a factor of ten compared to the targets set for existing reactors (i.e., targets of 10^{-5} per year for core damage frequency and 10^{-6} per year for large radioactive releases for future plants). It is stated in INSAG-12 that "Another objective for these future plants is the practical elimination of accident sequences that could lead to large early radioactive release, whereas severe accidents that could imply late containment failure would be considered in the design process with realistic assumptions and best estimate analysis so that their consequences would necessitate only protective measures limited in area and in time."

Without changes in technology, these improvements would add to the cost of nuclear power, both in capital and operating expenses. The challenging task for the development and demonstration of future plants, then, is how to improve safety to such ambitious levels and cut costs at the same time to allow for competitiveness in the energy marketplace.

This is of course not an impossible task in principle. Simultaneously improving operating safety and economic performance of technology has always been one of the fundamental drivers of engineering ingenuity and innovation.

Evolutionary designs explore avenues to increase safety which on the hardware side include using modern control technology, simplifying safety systems, making use of advanced designs and extending the required response times for safety systems actuation and operator action. On the software side such solutions have the potential to reduce the burden of demonstrating compliance with requirements. Also, increased technical knowledge and improved computer codes contribute to safe operations. Another element is "risk-informed decision making", which aims to focus efforts on important safety issues; it could lead to tightening requirements in some cases but relaxing others. Attention also is being directed at simplifying the licensing process and increasing its predictability.

Innovative designs make even greater use of features to increase inherent safety. In particular, designs strive to demonstrate that advanced designs or new features can obviate the need for certain safety systems required for today's reactors; they either would not be needed at all or only needed for protecting the investment in the plant, not for protecting public health and safety. In such a case, the equipment could still be installed; however it would not need to be safety graded, which now adds significantly to its cost. Such designs would also greatly reduce the effort needed to develop accident management measures and to prepare for emergencies.

Physical Security. Adequate protective measures and a robust international framework are essential to prevent unauthorized possession of nuclear materials and other dangerous radioactive materials, and to prevent the willful destruction of nuclear installations or the intentional dispersal of such materials in transit.

Spent Fuel & Radioactive Waste Management. Spent fuel and waste management is of continuing concern to the public. Shortage of capacity for spent fuel storage is a major issue in several countries. At the same time spent fuel will have to be stored longer at the same site due to lack of a disposal facility. The absence of demonstration of a permanent waste disposal facility has multiplied the concerns, and has introduced uncertainties regarding future operation, further degrading public support, political willingness and financial viability. Innovative concepts for nuclear fuel cycles with new technologies can help mitigate the environmental burden by reducing nuclear waste volume and toxicity, to enhance safety, proliferation resistance and cost-effectiveness of nuclear power.

Non-Proliferation. The possibility of a potential linkage between nuclear power and nuclear weapons is central to the international non-proliferation regime, and serves as the basis for IAEA safeguards. Fifteen States are known to have developed uranium enrichment methods, and while chemical reprocessing is currently being pursued by only one State which does not possess nuclear weapons, concerns remain that the current and future nuclear power operations could encourage and provide essential technologies related to the acquisition of nuclear weapons.

In the aftermath of events in Iraq and the Democratic People's Republic of Korea, the international non-proliferation regime has been extended and strengthened, including the willingness of States to refrain from assisting potential proliferators from acquiring key technologies and know-how, supplier controls on sensitive materials, facilities and equipment, and strengthened IAEA safeguards -- especially in relation to their ability to detect undeclared enrichment and reprocessing operations. Any State embarking on a programme to acquire nuclear weapons today would encounter significantly greater barriers to international assistance, significantly enhanced prospects for detection before such a programme could succeed, and a greater likelihood of concerted counter-proliferation actions in the event that such a programme were revealed.

Economics. The global trend toward deregulation and enhanced competition in electricity generation -- along with continuing low prices for fossil fuels and an oversupply of baseload generating capacity in developed countries -- have worked against the expansion of nuclear power plants. Although most existing nuclear power plants are profitable, very few new plants are being ordered.

Availability in many regions of the world of cheap natural gas and technological breakthroughs in gas turbine technologies, as well as advances in coal technologies, have narrowed the economic attractiveness of new nuclear power plants to countries with no easy access to natural gas or coal, or which place a high value on energy security.

Studies done by the International Energy Agency (IEA) and Nuclear Energy Agency (NEA) of the Organization for Economic Cooperation and Development (OECD), as well as those done in the USA and at the IAEA, have shown that for the high rates of return and corresponding short pay-back periods commonly expected today, it will be difficult for new nuclear power plants to be competitive in regions with easy access to gas or with domestic coal reserves. High up-front capital costs, relatively long construction times have more than offset the nuclear fuel cost advantage. Today, some natural gas systems can be built at a significantly lower capital cost than an equivalent nuclear power plant and in less than one-third the time. Thus in the near-term, nuclear power capacity is expected to grow only in the limited number of countries that lack indigenous energy resources or natural gas infrastructures.

Public & Political Acceptance. While existing nuclear power reactors operate reliably and safely, concerns and misperceptions arise when safety hinges on complex engineered systems and the skills of operating staff. In spite of the development of evolutionary designs for which improvements in safety characteristics over existing plants have been made, support for nuclear power has diminished in many countries. Greater efforts are required to more effectively communicate advances that are being made and to foster public understanding of nuclear power in the context of global energy demands, comparative energy systems, and the regulatory and technological environments in which electricity generation systems operate.

THE NEED FOR INNOVATION

In the longer term, global power market conditions remain uncertain. But many analyses, including the recent World Energy Council Statement, strongly support the need to retain nuclear power as an option. *(See related article, page 2.)* Continuing growth in population and energy demand, particularly in developing countries, in combination with further experience with and understanding of the global climate change phenomenon, emphasize a global imperative for a rapid and extensive deployment of non fossil-fired plants for electricity generation.

The March 2000 Intergovernmental Panel on Climate Change (IPCC) approved a Special Report on Emission Scenarios (SRES) for the period through 2100. These scenarios expect a large demand for non-carbon energy technologies in the period after 2020.

The projection for nuclear energy deployment is generally quite large. The scenarios foresee a varying nuclear share, but they indicate consistently a great potential for the nuclear growth -- from the current 350 GWe to between 2000 GWe and 5000 GWe by 2050 and 3500 GWe to 10,600 GWe by 2100. *(See related article, page 31.)* In essence, the capacity range for 2050 in these scenarios translates into global nuclear power capacity additions of 50 GWe to 150 GWe per year during 2020-2050.

In light of the challenges already mentioned, it is difficult to foresee a five to tenfold increase in nuclear energy capacity based only on existing evolutionary technologies. Innovative R&D activities are needed to ensure the full participation of nuclear power in the worldwide energy market of the future. Consider the following:

- Cost. There is a need to enhance nuclear competitiveness in the deregulated energy market especially in regions with easy access to gas and/or with small local grids, as well as for non-electric nuclear applications.
- Infrastructure Compatibility. Much of the future increase in electricity demand is projected to take place in countries not very familiar with nuclear power. It is not possible for all of them to develop quickly the needed infrastructure for reactor operation and front end and back end fuel cycle services. Similarly, local safety review and licensing requirements for plant construction and operation should be achievable at reasonable cost.
- Safety. Through ongoing research and development, the safety of future reactors is being further increased. One objective is the practical elimination of accident sequences that could lead to large early releases of radioactivity. In order to reduce costs, this calls for innovative solutions which would increase safety by simplifying systems and making better use of advanced safety designs and features.
- Safeguards. A large worldwide increase in the number of nuclear power plants and consequent increase in the amount of plutonium in spent fuel are concerns for IAEA safeguards. Even moreso, however, would be the spread of critical uranium enrichment and plutonium extraction technologies.

The costs of inspections required to provide an adequate degree of assurance that States continue to honour their non-proliferation undertakings vary widely depending on the nature of the technology employed: if a light water reactor is the baseline, the inspection effort for an on-load power reactor is approximately five times greater; a uranium enrichment plant ten times greater, and a chemical reprocessing plant 100 times greater.

Innovations in reactor designs and fuel cycle arrangements should be

INNOVATIVE TECHNOLOGIES RELATED TO THE NUCLEAR FUEL CYCLE

Attribute	Process & System	Relevant Countries	Features
Fuel Composition & Process	Pyro-process	Japan, Russia, US	Nuclear waste volume is smaller and process facility is simpler than for wet process (expected economical and environmental advantages).
	Vibro-packed fuel	Russia, Switzerland	Fuel particle is directly produced from acid solution from reprocessing (economical merit is expected compared to powder technology).
	DUPIC system	Canada, Republic of Korea	Plutonium is not separated from PWR spent fuel (proliferation resistance is expected).
	Thorium fuel (thorium-uranium, thorium-plutonium)	India, USA	Thorium resource is abundant. Fuel with thorium-uranium composition generates less minor actinides (MA) than uranium-plutonium fuel.
	Inert-matrix fuel	France, Japan, Switzerland	Due to chemically stable oxide, spent fuel is regarded as waste form (environmental mitigation).
Partitioning & Transmutation (P-T) System	Accelerator Driven System	France, Japan, USA	High neutron energy produced destroys MA, long-lived fission products (LLFP). Sub-critical core enhances safety.
	P-T system with Fast Reactor (FR)	Japan, Russia	Existing FR technology is applied for destruction of MA, LLFP.
Reactor System	Lead (+ Bismuth) Fast Reactor	Russia	Enhanced safety with use of lead coolant.

pursued that would allow substantial expansions of nuclear power while minimizing access to nuclear materials in forms which could readily be used in nuclear weapons or other nuclear explosive devices, and to the technologies allowing their production.

■ Resource Availability. Conventional uranium resources may eventually become too expensive to sustain a several-fold increase of global nuclear power based only on traditional thermal reactors. A comprehensive plan should be developed to estimate and meet the future needs.

These are the main reasons why there is a need to work on innovative reactor designs and fuel cycles in addition to the evolutionary reactors.

INNOVATIVE R&D ACTIVITIES

Innovative Reactor Designs. Currently 40% of the nuclear power plants under construction (23% of all capacity under construction), primarily in developing countries, fall into the small (below 300 MWe) and medium (below 700 MWe) size range. They incorporate the basic technologies of the current large nuclear power plants. The smaller evolutionary reactors (such as AP-600, the VVER-640, the PHWR-500, and CANDU-6) are also based on existing plants.

However, the need for innovative R&D has been recognized by the nuclear industry and by countries that believe in the overall benefits, viability and importance of nuclear power for the long term. Currently, significant R&D on innovative nuclear fuel cycle and reactor concepts is being performed in a number of countries, including Argentina, Canada, China, France, India, Italy, Japan, Republic of Korea, Russia,

SMALL & MEDIUM NUCLEAR REACTORS UNDER DEVELOPMENT WORLDWIDE

Small nuclear reactors are being designed and developed in a number of countries. They include:

- Carem-25, 25-MWe pressurized water reactor under development in Argentina. This reactor is being designed with an integral steam generator that could be coupled to a desalination process.
- KLT-40, 40-MWe pressurized water reactor under development in the Russian Federation. This reactor is being designed as a barge-mounted version of a small-sized reactor used in icebreakers for electricity as well as heat generation in the northern part of Siberia.
- PBMR, 114-MWe high-temperature reactor under development in South Africa. This gas-cooled Pebble Bed Modular Reactor is being developed with a once-through fuel cycle and advanced safety features due to the use of ceramic-coated fuel particles with a high heat capacity.
- SMART, 100-MWe pressurized water reactor under development in the Republic of Korea. The conceptual design of this reactor is almost complete and features an integral steam generator for multipurpose applications, including seawater desalination.
- NHR-200, 200-MWth pressurized water reactor under development in China. Also in China, initial criticality of a small 10 MWth high-temperature reactor for non-electric applications is planned for 2001.
- AHWR, 235-MWe heavy-water reactor under development in India. This is a vertical tube advanced reactor that would use a thorium-based fuel and incorporate passive cooling features.
- GT-MHR, 285-MWe gas-cooled reactor being developed through combined efforts in the United States, Russian Federation, France, and Japan.

South Africa, and the USA. *(See table and box.)*

Attention has focused on development of small and medium reactors which have various combinations of relative simplicity of design, economy of mass production, reduced siting costs, long life cores, practically unattended remote operation, and centralized maintenance and refueling services. Russia has demonstrated commercial operation of small reactors for heat and electricity in remote areas. The United States embarked on a Nuclear Energy Research Initiative in 1999 to develop advanced reactor and fuel cycle concepts and scientific breakthroughs in nuclear technology to overcome obstacles to the expanded use of nuclear energy.

Innovative designs directed toward smaller units with shorter construction times and lower capital costs are under study in many countries. The intent is to produce a design that will be economical with enhanced safety and proliferation-resistant features. These are not merely down-sized versions of older designs. On-site construction with factory built structures and components, including complete modular units for fast installation are some of the intended features of these reactors. It is also hoped that these will be easier to finance and suitable for deployment even in regions with modest electricity grids.

From the perspective of innovation, two advanced non-water cooled reactor technologies may be mentioned. These are direct cycle High-Temperature Gas Reactors and Lead/Lead-Bismuth Cooled Fast Reactors. The 114-MWe helium-cooled Pebble Bed Modular Reactor (PBMR) from South Africa has received worldwide attention as it claims to have the desired features (including market competitiveness). The Russians also have made similar claims, although at a larger size, for their lead-cooled fast reactor.

All of these reactors hold the promise of reducing some of the concerns over nuclear power development. It will be important to select those that are the best candidates for future development and demonstration.

Innovative Nuclear Fuel Cycles. From early in the development of nuclear power in the 1960s, the closed fuel cycle scheme with breeder reactor was perceived as the best option for large-scale nuclear energy deployment. However, break-through efforts are now needed to cope with a number of issues emerging from non-proliferation, environmental mitigation, economics, and enhanced safety and security needs.

Desired features of innovative nuclear fuel cycles can be defined in relation to a number of aims:

- Economic competitiveness of fuel cycles.
- Minimization of radioactive waste.
- Furtherance of non-proliferation aims, namely that nuclear materials cannot be easily acquired or readily converted for non-peaceful purposes.
- Further enhancement of safety through technological processes.

Although large-scale programmes on innovative nuclear fuel cycles are not implemented at present, many countries with nuclear power programmes are investigating them,

Again, all of these fuel cycle concepts hold the promise of improving at least some of the concerns over nuclear development. It will be necessary to assure that the overall objectives for nuclear power innovation are met, and ultimately, to concentrate on the fuel cycles which eliminate or minimize concerns.

While current innovative R&D programmes share common goals, their approaches and specific objectives differ. One result is a wide diversity of reactor and fuel cycle concepts. Some programmes are taking a new look at older concepts where improvements in materials and other technologies have made them viable now. Others are attempting to introduce innovative systems in place of more conventional ones in order to achieve substantial improvements. Yet others have decided to explore radically new options.

Innovative R&D today covers practically all major nuclear fuel cycle and power plant types -- Light-Water Reactors, Heavy-Water Reactors, Gas-Cooled Reactors and Liquid Metal Reactors -- with other types also being explored. A worldwide look at innovative R&D shows some 40 to 50 different concepts under development. Some are in the initial conceptual design stages, others are more advanced, in the basic design stage, and a few are proceeding toward construction of prototypes or demonstration units.

A wider diversity also exists for the requirements in such crucial areas as safety, waste management, non-proliferation, resource consumption, and types of energy applications. For example, in the economics area, although all concepts aim to be competitive in the future energy market, there are different opinions as to whether they should become competitive by taking into account potential introduction of CO_2 taxes and increases of fossil fuel prices, or not. In view of these uncertainties, nuclear power should aspire to stand on its own right.

In the safety area some believe that today's advanced light-water reactors are sufficiently safe for large-scale development, because they are neighbor-friendly (no significant release of off-site radioactivity even in the case of a severe accident). Others insist that the public will accept large-scale nuclear energy deployment only if a new reactor type is proposed with no significant fuel failure, as sometimes claimed for modular high-temperature reactors.

In the waste management area, some believe that direct underground disposal of spent fuel is a sufficiently safe option and that to ensure public acceptance, only its practical demonstration is needed. Others insist that the elimination of nuclear long-lived hazardous nuclides, by burning or transmuting them, is necessary to raise public support for large-scale nuclear energy deployment. There are different opinions as to which hazardous elements should be eliminated, and to what extent. Similarly, retrievability of spent fuel is another issue.

In the non-proliferation area, some propose to develop special "proliferation-resistant" reactors and fuel cycle concepts (new types of fuel, new reprocessing technologies without the extraction of plutonium, new concepts of fast reactors, and so on) with increased reliance on intrinsic technical features against possible diversion of nuclear material. There is, however, no consensus among researchers as to how to measure the level of "proliferation resistance" and to what extent we should increase our reliance on technical measures.

The nuclear community must find a way to reduce the multiplicity of options and settle on the few that hold the most promise for successful development.

THE NEED FOR INTERNATIONAL COOPERATION

With limited individual governmental support of R&D and a large diversity of conceptual designs, it is essential that the next crucial 10 to 15 years are spent in producing practical nuclear reactors and fuel cycles which will be successful in the market. In particular, overly ambitious targets in waste management, safety or non-proliferation may lead to excessive increases in the cost of nuclear energy, lowering the competitiveness of the nuclear option.

While technology innovations are being developed, it will also be essential to review and revise commercial, governmental and intergovernmental mechanisms in line with advances being achieved.

These are important issues for the long-term revival of nuclear power and must be addressed as early as possible. One way to make progress and build a consensus on some of these issues is through international collaboration and global coordination of R&D activities. International cooperation among governmental research centres, international organizations such as the IAEA, NEA, and European Commission, and the nuclear industry can expedite progress by pulling resources together for the common goal. For example, the following tasks may be set as joint efforts for these groups:

- Evaluation of future utility needs and the role of nuclear power in different market settings;
- Development of a set of desired characteristics for safety, security, waste management, non-proliferation, and resource consumption for new reactors and fuel cycle technologies;
- International cooperation in the development of the most promising concepts.

These are important to ensure that countries will be able to benefit from the technology of nuclear power as a long-term sustainable energy supply option.

IAEA Activities. The IAEA has longstanding programmes to assist countries in areas related to nuclear power development and the fuel cycle. Efforts now are being directed at improving the coordination of activities and defining common goals in line with the interests of the Agency's Member States. The IAEA's new results-oriented programme and budget approach may help to integrate all its activities into a programme on innovative reactors and fuel cycles to better address the major challenges of energy and nuclear power development that countries are facing. In this framework, the global development of innovative reactors and fuel cycles can be assessed.

As noted in the Agency's Medium Term Strategy, a central objective of efforts is to support and facilitate the exchange of information and the development of new and emerging applications of nuclear technologies. This can be achieved by providing a forum for, and encouraging, the review of developments associated with new nuclear power and fuel cycle technologies, including small and medium reactors for electricity generation and heat production, including seawater desalination; new technological developments relevant to competitiveness, safety, and efficiency; improving the proliferation-resistance in reactors and associated fuel cycles; and reducing the arisings of radioactive waste. Particular types of activities being considered include serving as a central forum for Member States who wish to work on similar design concepts. This would essentially help to pool resources and expertise in the development of innovative reactors and fuel cycles.

Nuclear power today is at a turning point, with no consensus concerning its future role. While it has a proven track record of helping countries to meet their energy needs -- and it holds comparative advantages over other options for generating electricity in the framework of sustainable energy development -- achieving greater public and political awareness and acceptance of its potential contribution is a fundamental challenge. Through new initiatives and integrated actions being put into place to strengthen international nuclear cooperation, the IAEA is planning a more cohesive programme that will better meet the interests of Member States in developing and demonstrating that the nuclear power option is a vital element of the world's energy future. ❐