

Overview of the INPRO Project

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Abstract

During the last fifty years remarkable results are achieved in the application of nuclear technology for the production of electricity. Looking ahead to the next fifty years it is clear that the demand for energy will grow considerably and also the requirements for the way the energy will be supplied.

Within INPRO the future of the energy demand and supply was explored and several scenario's identified. A leading requirement for energy supply is coming up and will play a crucial role: sustainability of the way the energy supply will be realized. Fulfilling the growing need for energy in developing countries is as well an important issue.

Based on these scenario's for the next fifty years, an inventory of requirements for the future of nuclear energy systems has been collected as well a methodology developed by INPRO to assess innovative nuclear systems and fuel cycles. On the base of this assessment, the need for innovations and breakthroughs in existing technology can be defined.

To facilitate the deployment of innovative nuclear systems also the infrastructure, technical as well as institutional has to be adjusted to the anticipated changes in the world such as the globalization.

As a contribution to the conference the main messages of INPRO will be presented.

1. INTRODUCTION

The International Project on Innovative Nuclear Reactors and Fuel Cycles, referred to as INPRO was launched, following resolutions of the IAEA General Conference (GC(44)/RES/21). It followed the Russian Federation's initiative supported by a group of IAEA Member States to join forces in a broad international effort to develop innovative reactor technology and a nuclear fuel cycle which will have the following basic features: unlimited fuel resources, exclusion of severe accidents, environmentally safe energy production without disturbing the natural radiation balance, barring of the nuclear weapons proliferation pathway associated with nuclear power, and economic competitiveness. In 2004 INPRO is partly included in the regular program of the IAEA and gets special support of a growing number of members. Currently INPRO has 21 members: Argentina, Armenia, Brazil, Bulgaria, Canada, Chile, China, Czech Republic, France, Germany, India, Indonesia, Republic of Korea, Pakistan, Russian Federation, South Africa, Spain, Switzerland, The Netherlands, Turkey and the European Commission. These members are contributing to the project by providing funds, experts and studies.

The main objectives of INPRO are to:

- Help to ensure that nuclear energy is available to contribute in fulfilling energy needs in the 21st century in a sustainable manner; and
- Bring together 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.

The 21st century promises the most competitive, globalized markets in human history, the most rapid pace of technological change ever, and the greatest expansion of energy use, particularly in developing countries. For a technology to make a truly substantial contribution to energy supplies, innovation is essential. It will be the defining feature of a successful nuclear industry and a critical feature of international co-operation in support of that industry, co-operation that ranges from joint scientific and technological initiatives, to safety standards and guidelines, and to security and safeguards activities. Innovation is also essential to attract a growing, high-quality pool of talented scientists, engineers and technicians of the calibre and size needed to support a truly substantial nuclear contribution to global energy supplies.

In order to set out the boundary conditions for the desired innovations of nuclear energy systems within INPRO several aspects of the future of nuclear systems were discussed:

- Prospects and Potentials of nuclear power within the next 50 years;
- User Requirements for innovative nuclear energy systems in the area of Economics, Sustainability and Environment, Safety, Waste Management, Proliferation Resistance
- Methodology for Assessment of Innovative Nuclear Energy Systems.
- Considerations on changes in the nuclear infrastructure

This Phase was completed in June 2003 and the results were published in a document: Guidance for the evaluation of innovative nuclear reactors and fuel cycles (Report on Phase 1A of the

International Project on Innovative Reactors and Fuel Cycles (INPRO)-IAEA-tecdoc-1362). Now several Member States are conducting case studies to apply the INPRO methodology to make a judgment on the potential of selected innovative nuclear technologies under consideration for development, to specify corresponding RD&D needs for their development, and to identify improvements in the methodology.

The results of INPRO are outlined below followed by a short description of the current activities.

2. NUCLEAR POWER PROSPECTS AND POTENTIALS

In the area of *Prospects and Potentials* of nuclear power, three topics were evaluated in the project: past developments and the current role of nuclear energy, issues surrounding the use of nuclear power, and the potential role of nuclear energy systems in meeting the demand for energy in the 21st century. Early developments in civilian nuclear power were characterized by the need to keep pace with the high energy growth rates of the post-war period, which gave rise to ambitious plans for thousands of GW of nuclear capacity to be installed by the end of the 20th century. But the deployment of nuclear power slowed, primarily because of a decline in the growth of energy demand in the developed countries. Other factors also contributed, such as serious accidents at Three-Mile Island and Chernobyl and concerns about the long term management of high level nuclear wastes and about nuclear proliferation.

While expansion of the number of nuclear power plants has slowed, one very significant recent development has been the steady improvement in availability factors worldwide, equivalent to the construction of about 33 new 1000 MWe nuclear power plants. The result is that nuclear power has retained its 16% share of global electricity production. Even though currently new additions to nuclear capacity are centred in Asia, signs of revitalization in Western Europe and in the North America are envisaged.

The results of a Special Report on Emission Scenarios (SRES), commissioned by the Intergovernmental Panel on Climate Change (IPCC) in 1996, and published in 2000, have been used to examine the expectations and potential for nuclear energy in the 21st century. The SRES presents 40 reference scenarios, grouped according to four storyline families, extending to 2100. Global primary energy grows between a factor of 1.7 and 3.7 from 2000 to 2050, with a median increase by a factor of 2.5 (see Figure 1). Electricity demand grows almost 8-fold in the high economic growth scenarios and more than doubles in the more conservative scenarios at the low end of the range. The median increase is by a factor of 4.7. Moreover, nuclear energy plays a significant role in nearly all the 40 SRES scenarios, including the four analysed in this project.

This contrasts with near-term projections by the IAEA, International Energy Agency and US Energy Information Agency that show a declining nuclear share in global electricity production in coming decades, and little or no nuclear movement into energy applications beyond electricity. The difference between these more pessimistic near-term projections and a truly substantial future contribution of nuclear energy – one that takes nuclear's percentage of the world's primary energy supply well beyond today's modest share to 20%, 50% or more – is innovation.

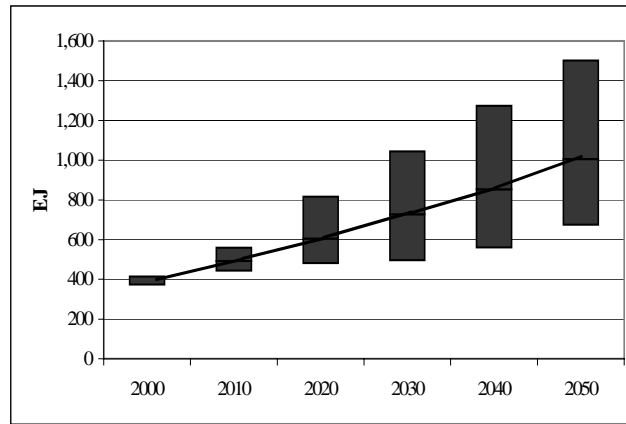


Figure 1. Range of future primary energy demand in SRES scenarios, 2000-2050

Innovative nuclear systems therefore can play an important role in meeting this rapidly expanding world energy demand, consistent with the principle of sustainable development, i.e. meeting the needs of current generations without compromising the ability of future generations to meet their needs. To achieve this objective the issues on which debate concerning the future role of nuclear energy is most often focused need to be addressed. These issues are: economic competitiveness, safety, waste management, proliferation resistance and physical protection, and last but not least sustainability and environment.

3. USER REQUIREMENTS

3.1. Economics

In the area of *Economics* four selected scenarios from the SRES study have been analysed (see Figure 2).

They cover a variety of possible future developments that are characterized by differing levels of globalisation and regionalization and by differing views of economic growth versus environmental constraints

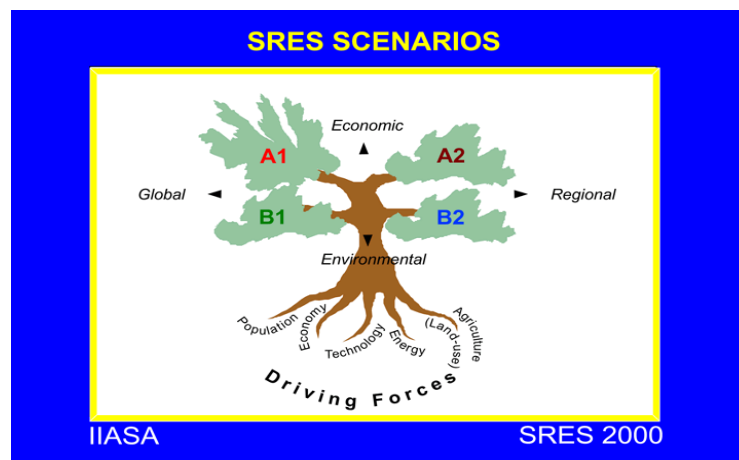
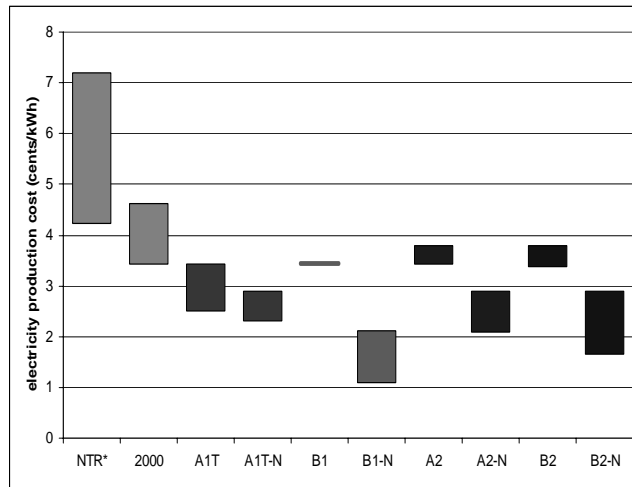


Figure 2 4 SRES Scenarios used in INPRO study

Provided innovative nuclear systems are economically competitive they can play a major role in meeting future energy needs. Economic competitiveness depends on the learning rates (cost reductions as a function of experience) achieved by nuclear energy relative to those of competing technologies. Specific capital costs and electricity production costs (see Figure 3) have been derived that would enable nuclear energy to compete successfully against alternative energy sources within the four selected SRES scenarios chosen.



NTR* = Nuclear Technology Review (IAEA)
2000 = SRES input in the year 2000

Figure 3. Ranges for Electricity Production Costs in 2050 for Nuclear Power Plants

The bar in Figure 3 called A1T shows the SRES cost of electricity by nuclear power in this scenario, the bar named A1T-N shows the necessary range of costs for nuclear to be competitive in this scenario against alternative energy sources.

These costs should be used with caution since they depend on the learning rates for competing technologies implicit in the SRES scenarios. The important message is that for nuclear technology to gain and grow market share it must benefit sufficiently from learning to keep it competitive with competing energy technologies. For such learning to take place experience must be gained and to gain such experience the energy from innovative nuclear systems must be cost competitive with energy from alternative sources and innovative nuclear systems must represent an attractive investment to compete successfully in the capital market place (for an example of the corresponding INPRO Basic Principles, User Requirements and Criteria see Table 1).

Table I. Example for a Basic Principle, User Requirement and Criteria for Economics

Basic Principle 2: <i>Innovative Nuclear Systems must represent an attractive investment compared with other major capital investments</i>		
User Requirement	Criteria	
	Indicator	Acceptance Limit
<i>The total investment required to design, construct, and commission innovative</i>	Total investment.	Investment in innovative nuclear systems enable a return comparable with or better than that required to deploy a competing energy technology of comparable size.

<i>commission innovative nuclear systems, including interest during construction, must be such that the necessary investment funds can be raised.</i>	Project construction and commissioning times.	Times comparable to alternative projects. Schedules met.
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In total, INPRO defined two basic Principles, five User Requirements and several Criteria in this area. To be cost competitive all component costs, e.g., capital costs, operating and maintenance costs, fuel costs, must be considered and managed to keep the total unit energy cost competitive. Limits on fuel costs in turn 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. Cost competitiveness of innovative nuclear systems as well, as meeting the *Principles* and *Requirements* established by INPRO in the areas of safety, waste management, sustainability, proliferation resistance and cross cutting issues will contribute to investor confidence.

3.2. Sustainability and Environment

Internationally there exists strong interest and support for the concept of *Sustainability*. There is a prima facie case that nuclear power supports sustainable development by providing much needed energy with relatively low burden on the atmosphere, water, and land use. Further deployment of nuclear power would help to alleviate the environmental burden caused by other forms of energy production, particularly the burning of fossil fuels. INPRO has set out two Basic Principles (see Table 2) related to sustainability, one dealing with the acceptability of environmental effects caused by nuclear energy and the second dealing with the capability of innovative nuclear systems to deliver energy in a sustainable manner in the future. In addition four User Requirements and several corresponding Criteria were defined.

Table II. Basic Principles for Sustainability and Environment

Principle 1- Acceptability of Expected Adverse Environmental Effects <i>The expected (best estimate) adverse environmental effects of the innovative nuclear system must be well within the performance envelope of current nuclear systems delivering similar energy products.</i>
Principle 2 - Fitness for Purpose <i>The innovative nuclear system must be capable of contributing to the energy needs in the future while making efficient use of non-renewable resources.</i>

Protection of the environment from harmful effects is seen to be fundamental to sustainability. Adherence to the principle that the present generation should not compromise the ability of future generations to fulfil their needs, requires that the future be left with a healthy environment. Notwithstanding the major environmental advantages of nuclear technology in meeting global energy needs, the potential adverse effects that the various components of the nuclear fuel cycle may have on the environment must be prevented or mitigated effectively to make nuclear energy sustainable in the long term. Moreover, efficient and effective use of resources will be necessary

for a nuclear energy system to fulfil its long-term potential. Environmental effects include: physical, chemical or biological changes in the environment; health effects on people, plants and animals; effects on quality of life of people, plants and animals; effects on the economy; use / depletion of resources; and cumulative effects resulting from the influence of the system in conjunction with other influences on the environment. Both radiological and non-radiological effects as well as trade-offs and synergies among the effects from different system components and different environmental stressors need to be considered.

To be sustainable the system must not run out of important resources part way through its intended lifetime. These resources include fissile/fertile material, water (when supplies are limited or quality is under stress) and other critical materials. The system should also use them at least as efficiently as acceptable alternatives, both nuclear and non-nuclear. All relevant factors (sources, stressors, pathways, receptors and endpoints) must be accounted for in the analysis of the environmental effects of a proposed energy system, and the environmental performance of a proposed technology needs to be evaluated as an integrated whole by considering the likely environmental effects of the entire collection of processes, activities and facilities in the energy system at all stages of its life cycle.

3.3. Safety of Nuclear Installations

In the area of *Safety of Nuclear Installations*, INPRO recognizes that extensive work has been done prior to INPRO to establish safety requirements including the Advanced Light Water Reactor Utility Requirements prepared by EPRI, the European Utility Requirements prepared by the European Utilities, IAEA Safety Standards Series, e.g., Safety Guides, and documents of the International Nuclear Safety Advisory Group (INSAG). The Safety Principles and Requirements developed within INPRO 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 sub-criticality and chemistry, remove decay heat from radionuclides, and confine radioactivity and shield radiation. To ensure that innovative nuclear systems will fulfil these fundamental safety functions, INPRO has set out five Basic Principles (see Table 3) but it is also expected that prior work will also be used to the extent applicable.

In total, INPRO defined for these Basic Principles twenty-seven related User Requirements and several Criteria.

INPRO expects that innovative nuclear systems will incorporate enhanced defence in depth as part of their basic approach to safety but with more independence of the different levels of protection in the defence in depth strategy, and with an increased emphasis on inherent safety characteristics and passive safety features. The end point should be the prevention, reduction and containment of radioactive releases to make the risk of innovative nuclear systems comparable to that of industrial facilities used for similar purposes so that for innovative nuclear systems there will be no need for relocation or evacuation measures outside the plant site, apart from those generic emergency measures developed for any industrial facility. RD&D must be carried out before deploying innovative nuclear systems, using e.g., large scale engineering test facilities including possibly pilot plants, to bring the knowledge of plant characteristics and the capability of codes used for safety analyses to the same level as for existing plants. The development of

innovative nuclear systems should be based on a holistic life cycle analysis that takes into account the risks and impacts of the integrated fuel cycle. Safety analyses will involve a combination of deterministic and probabilistic assessments, including best estimate plus uncertainty analysis.

Table III. Basic Principles for Safety of Nuclear Installations

Principle 1: <i>Innovative nuclear systems shall incorporate enhanced defence in depth as a part of their fundamental safety approach and the levels of protection in defence in depth shall be more independent from each other than in current installations.</i>
Principle 2: <i>Innovative nuclear systems shall prevent, reduce or contain releases (in that order of priority) of radioactive and other hazardous material in construction, normal operation, decommissioning and accidents to the point that these risks are comparable to that of industrial facilities used for similar purposes</i>
Principle 3: <i>Innovative nuclear systems shall incorporate increased emphasis on inherent safety characteristics and passive safety features as a part of their fundamental safety approach</i>
Principle 4: <i>Innovative nuclear systems shall include associated RD&D work to bring the knowledge of plant characteristics and the capability of computer codes used for safety analyses to at least the same confidence level as for the existing plants</i>
Principle 5: <i>Innovative nuclear systems shall include a holistic life-cycle analysis encompassing the effect on people and on the environment of the entire integrated fuel cycle.</i>

3.4. Waste Management

The already existing nine principles defined by the IAEA for the management of radioactive waste (see Table 4) have been adopted by INPRO without modification. Thus, waste management is to be carried out in such a way that human health and the environment are protected now and in the future, effects beyond national borders shall be taken into account, undue burdens passed to future generations shall be avoided, waste shall be minimized, appropriate legal frame works shall be established and interdependencies among steps shall be taken into account. These principles in turn lead to the need to specify a permanently safe end state (s) for all wastes and to move wastes to this end state as early as practical, to ensure that intermediate steps do not inhibit or complicate the achievement of the end state, that the design of waste management practices and facilities be optimised as part of the optimisation of the overall energy system and life cycle, and for funds to cover the costs of managing all wastes in the life cycle to be accumulated to cover the accumulated liability at any stage of the life cycle. In total, INPRO has defined six User Requirements and several Criteria in this area. RD&D is recommend to be carried out in a number of areas including partitioning and transmutation and long term human factors analysis to facilitate assessments of long term risks for waste management systems that require long term institutional controls.

Table IV. Basic Principles for Waste Management

Principle 1: <i>Radioactive waste shall be managed in such a way as to secure an acceptable level of protection for human health</i>
Principle 2: <i>Radioactive waste shall be managed in such a way as to provide an acceptable level of protection of the environment</i>
Principle 3: <i>Radioactive waste shall be managed in such a way as to assure that possible effects on human health and the environment beyond national borders will be taken into account</i>
Principle 4: <i>Radioactive waste shall be managed in such a way that predicted impacts on the health of future generations will not be greater than relevant levels of impact that are acceptable today</i>
Principle 5: <i>Radioactive waste shall be managed in such a way that it will not impose undue burdens on future generations.</i>
Principle 6: <i>Radioactive waste shall be managed within an appropriate national legal framework including clear</i>

<i>allocation of responsibilities and provision for independent regulatory functions</i>
<i>Principle 7: Generation of radioactive waste shall be kept to a minimum practicable</i>
<i>Principle 8: Interdependencies among all steps in radioactive waste generation and management shall be appropriately taken into account</i>
<i>Principle 9: The safety of facilities for radioactive waste management shall be appropriately assured during their lifetime</i>

3.5. Proliferation Resistance

In designing future nuclear energy systems, it is important to consider the potential for such systems being misused for the purpose of producing nuclear weapons. Such considerations are among the key considerations behind the international non-proliferation regime. INPRO set out to provide guidance on incorporating *Proliferation Resistance* into innovative nuclear systems. The INPRO results in this area are largely based on the international consensus reached in October 2002 at a meeting held in Como, Italy. Generally two types of proliferation resistance measures or features are distinguished: intrinsic and extrinsic. Intrinsic features result from the technical design of innovative nuclear systems including those that facilitate the implementation of extrinsic measures. Extrinsic measures are based on states' decisions and undertakings related to nuclear energy systems.

Intrinsic features consist of technical features that: a) reduce the attractiveness for nuclear weapons programmes of nuclear material during production, use, transport, storage and disposal, including material characteristics such as isotopic content, chemical form, bulk and mass, and radiation properties; b) prevent or inhibit the diversion of nuclear material, including the confining of nuclear material to locations with limited points of access, and materials that are difficult to move without being detected because of size, weight, or radiation; c) prevent or inhibit the undeclared production of direct-use material, including reactors designed to prevent undeclared target materials from being irradiated in or near the core of a reactor; reactor cores with small reactivity margins that would prevent operation of the reactor with undeclared targets; and fuel cycle facilities and processes that are difficult to modify; and d) that facilitate nuclear material accounting and verification, including continuity of knowledge. Five categories of extrinsic measures are defined, as follows: commitments, obligations and policies of states, such as the Treaty on the Non-Proliferation of Nuclear Weapons and the IAEA safeguards agreements; agreements between nuclear material exporting and importing states; commercial, legal or institutional arrangements that control access to nuclear material; verification measures by the IAEA or by regional, bilateral and national measures; and legal and institutional measures to address violations of measures defined above.

INPRO has produced Basic Principles (see Table 5) that require the minimization of the possibilities of misusing nuclear material in innovative nuclear systems; a balanced and optimised combination of intrinsic features and extrinsic measures; the development and implementation of intrinsic features; and a clear, documented and transparent method of assessing proliferation resistance.

To comply with these Basic Principles requires the application of the concept of defence in depth by, e.g., incorporating redundant and complementary measures; an early consideration of proliferation resistance in the development and design of innovative nuclear systems; and the utilization of intrinsic features to increase the efficiency of extrinsic measures. RD&D is needed

in a number of areas, in particular, in developing a process to assess the proliferation resistance. In total, INPRO defined five User Requirements and several Criteria in this area.

Table V. Basic Principles for Proliferation Resistance

Principle 1: <i>Proliferation resistant features and measures should be provided in innovative nuclear systems to minimize the possibilities of misuse of nuclear materials for nuclear weapons.</i>
Principle 2: <i>Both intrinsic features and extrinsic measures are essential, and neither should be considered sufficient by itself.</i>
Principle 3: <i>Extrinsic proliferation resistance measures, such as control and verification measures will remain essential, whatever the level of effectiveness of intrinsic features.</i>
Principle 4: <i>From a proliferation resistance point of view, the development and implementation of intrinsic features should be encouraged.</i>
Principle 5: <i>Communication between stakeholders will be facilitated by clear, documented and transparent methodologies for comparison or evaluation/assessment of proliferation resistance.</i>

4. METHODOLOGY FOR ASSESSMENT

INPRO has also developed a methodology for evaluating innovative nuclear systems, the INPRO Methodology. It comprises the INPRO Basic Principles, User Requirements, and Criteria, and a set of tables and guidance on their use that can be used to evaluate a given innovative nuclear systems, or a component of such a system on a national, regional and/or global basis. The INPRO Methodology is oriented more to identifying a range of technology alternatives that will fulfill Basic Principles and User Requirements set out for innovative nuclear systems, rather than to selecting a single best solution. It is recognized that the methodology will need to be applied iteratively, that the INPRO User Requirements and Criteria may be supplemented by additional Requirements and Criteria, e.g., taken from existing Standards and Guides. To assess a given nuclear energy system (or a component thereof) the nuclear energy system and its components are specified together with approaches for meeting all relevant Criteria, User Requirements and Basic Principles. Judgments are then established of the potential of the approaches and their constituent components to meet the Criteria, User Requirements and Basic Principles for the nuclear energy system, and a judgment of the entire system is arrived at from the judgments for compliance with all of the Basic Principles, User Requirements, and Criteria. Additional effort will be needed to develop the methodology further for widespread use and to ensure consistency and credibility of the results. Prior to committing to such an effort an assessment of the efficacy of the methodology should be obtained by using it in a number of case studies. To test the methodology, several case studies are being carried out by some INPRO Members for different types of innovative nuclear systems, including a global system with components at the preliminary stage of development, a future system that is already reasonably well developed, and systems being considered for application in different countries or regions.

5. NUCLEAR INFRASTRUCTURE

Issues other than technical requirements are important to potential users of innovative nuclear systems. Many of the factors that will either facilitate or obstruct the on-going deployment of nuclear power over the next fifty years relate to nuclear power infrastructure, international cooperation, and human resources. Nuclear power infrastructure comprises all features/substructures that are necessary in a given country for the successful deployment of nuclear power plants including legal, institutional, industrial, economic and social features/substructures.

The SRES scenarios indicate that the growth of nuclear power will be facilitated by globalization and internationalization of the world economy, and that the growth of demand in developing countries will be a major consideration. Globalization and the importance of developing countries in future world energy markets point to the need to modify infrastructures, both nationally and regionally, and to do so in a way that will facilitate the deployment of nuclear power systems in developing countries.

In a globalizing world with a growing need for sustainable energy, harmonization of regulations and licensing procedures could facilitate the application of nuclear technology. Such harmonization among different markets is in the interest of suppliers and developers of technology as well as users and investors. The development of innovative nuclear systems to comply with the Basic Principles, Requirements and Criteria set out in this project should facilitate such harmonization and could make it possible to change the way the production of nuclear energy is regulated. When, for example, the risk from innovative nuclear systems are ‘comparable to that of industrial facilities used for similar purposes,’ and ‘there is no need for relocation or evacuation measures outside the plant site, apart from those generic emergency measures developed for any industrial facility,’ the requirements for licensing could possibly be simplified. In developing countries that do not have a highly developed nuclear knowledge base and infrastructure, the development of regional or international licensing and regulatory mechanisms and organizations could play an important role. Additional factors that would be expected to favour the deployment of innovative nuclear systems, particularly in developing countries include: optimisation of the overall nuclear energy system by considering component facilities located in different countries as part of an international multi-component system; recognizing the needs of developing countries that have a limited infrastructure and a real but limited need for nuclear energy; vendor countries offering a full-scope service, up to and including the provisions of management and operations.

The life cycle of nuclear power investments, including design, construction, operation, decommissioning, and the waste management, extends well over fifty years in most cases and can easily extend well beyond one hundred years. Thus, a firm long term commitment of the government and other stakeholders is seen as a requirement for the successful implementation and operation of a nuclear power investment and a condition for public acceptance. Clear communications on energy demands and supply options are important to developing an understanding of the necessity for and the benefits to be obtained from such long term commitments. A clear enunciation of the potential role of nuclear energy in addressing climate change concerns in a sustainable and economic manner, together with the performance of existing plants can play an important role in such communications.

The development and use of nuclear power technology requires adequate human resources and knowledge. Globalization brings with it the opportunity to draw on a much broader pool of resources rather than striving to maintain a complete domestic capability across the many disciplines of science and engineering that constitute the range of technologies on which nuclear energy systems depend. International cooperation in science and development can assist with optimizing the deployment of scarce manpower and, just as important, the construction and operation of large scale research and engineering test facilities.

6. HIGHLIGHTS OF PHASE IB AND FUTURE OF INPRO

Six countries, participating in of INPRO offered to apply the results of INPRO as described in the Phase 1A report. Five nuclear systems and their associated fuel cycles were chosen as well one as fuel cycle concept with emphasis on the proliferation resistance.. The main goal of these case studies was to get feed back on the proposed set of basic principles and user requirements and the proposed methodology for assessment. The national case studies concentrated on various innovative technologies (CAREM-X from Argentina, APHWR from India, BN reactor family from Russia, MSR from Czech Republic, HTR-10 from China and the DUPIC fuel cycle from the Republic of Korea). The outcome is currently being analysed as a base for adjustments of the methodology and their different parameters. Separately individual experts have worked on various aspects of future nuclear systems, such as the role of multinational fuel cycle centers. The report was also presented to various interest groups, amongst them the nuclear industry and national regulatory authorities. These groups should be involved in the early stages of innovative developments. In a world where the process of globalisation and internationalisation is ongoing it will be of advantage for suppliers as well as users of nuclear systems to enhance cooperation on common issues. The growing number of INPRO members is an indication of the international interest.

7. CONCLUSIONS

The results of INPRO Phase 1A have been documented in a report published in June 2003 by the IAEA¹⁾. Phase 1A was an important first step to fulfil two objectives of INPRO: to ensure the availability of nuclear energy to help meet growing global energy needs in the 21st century in a sustainable manner and to bring together prospective buyers and sellers of nuclear technology to jointly consider actions needed to achieve desired nuclear innovation for the future energy market. The 21st century promises the most competitive, globalized markets in human history, the most rapid pace of technological change ever, and the greatest expansion of energy use, particularly in developing countries. For a technology to make a truly substantial contribution to energy supplies, innovation is essential. It will be the defining feature of a successful nuclear industry and a critical feature of international co-operation in support of that industry, cooperation that ranges from joint scientific and technological initiatives, to safety standards and guidelines, and to security and safeguards activities. Innovation is also essential to attract a growing, high-quality pool of talented scientists, engineers and technicians of the calibre and size needed to support a truly substantial nuclear contribution to global energy supplies.

To help co-ordinate and guide the development of innovative nuclear systems, INPRO Phase 1A has set out initial Basic Principles, User Requirements and corresponding Criteria in the areas of economics, the environment, safety, waste management, and proliferation resistance. A methodology for assessing innovative nuclear systems has also been created. Several elements of the nuclear infrastructure were reviewed and recommendations for future development made. It complements and builds upon requirements and criteria set out in existing documents such as the IAEA Safety Standards Series. All these outputs, from basic principles to the INPRO assessment methodology, are expected to be steadily sharpened and adjusted based on feedback from early applications and case studies being currently conducted by several IAEA Member States. In a world where the process of globalisation and internationalisation is ongoing it will be of advantage for suppliers as well as users of nuclear systems to enhance cooperation on common issues. The growing number of INPRO members is an indication for the international interest.

Based on results of the first phase of INPRO it can be expected that Innovative Nuclear Systems will be assessed on the base of the basic principles and requirements formulated in INPRO. Need for further R&D will be identified and cooperation to perform R&D can be sought for together with international cooperation to demonstrate the innovations in the nuclear technology that can fulfil the requirements of the society for sustainability of energy supply by nuclear technology.

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REFERENCES

INTERNATIONAL ATOMIC ENERGY AGENCY; Guidance for the evaluation of innovative nuclear reactors and fuel cycles, Report of Phase 1A of the International Project on Innovative Nuclear Reactors and Fuel Cycles, **TECDOC-1362**, IAEA, Vienna (2003).