



Developing Nuclear Energy Strategies

Innovation is key to the future of nuclear energy — as is the need for nuclear energy to be consistent with the sustainable development objectives of those countries which consider including the technology in their future energy mixes or plan to expand its use. Nuclear energy systems are characterized by complex infrastructures and longevity easily extending over several generations. Also, developing or expanding nuclear energy systems requires extensive lead times and resources, especially for the design and commercialization of new and innovative components.

It is therefore prudent to assess nuclear energy systems holistically, i.e., from all possible angles including the four dimensions of sustainable development: social development, economic development and environmental protection, linked by effective government institutions.

The IAEA assists Member States in capacity building in the area of national and regional energy systems analysis and planning, so they can independently chart out their own national energy strategies. Depending on a country's indigenous resource endowment, its stage of infrastructure development and sustainable development objectives, the energy system analyses may or may not conclude that nuclear energy is part of a country's future energy mix.

The IAEA offers a set of computer models and a methodology to:

- (1) **Develop potential and plausible trajectories of energy demand and corresponding energy supply mixes (technologically neutral);**
- (2) **Conduct a Nuclear Energy System Assessment (NESA) with particular focus on all things nuclear.**

Long range and strategic planning for energy system evolution and the potential role of nuclear energy therein requires a sound understanding of the

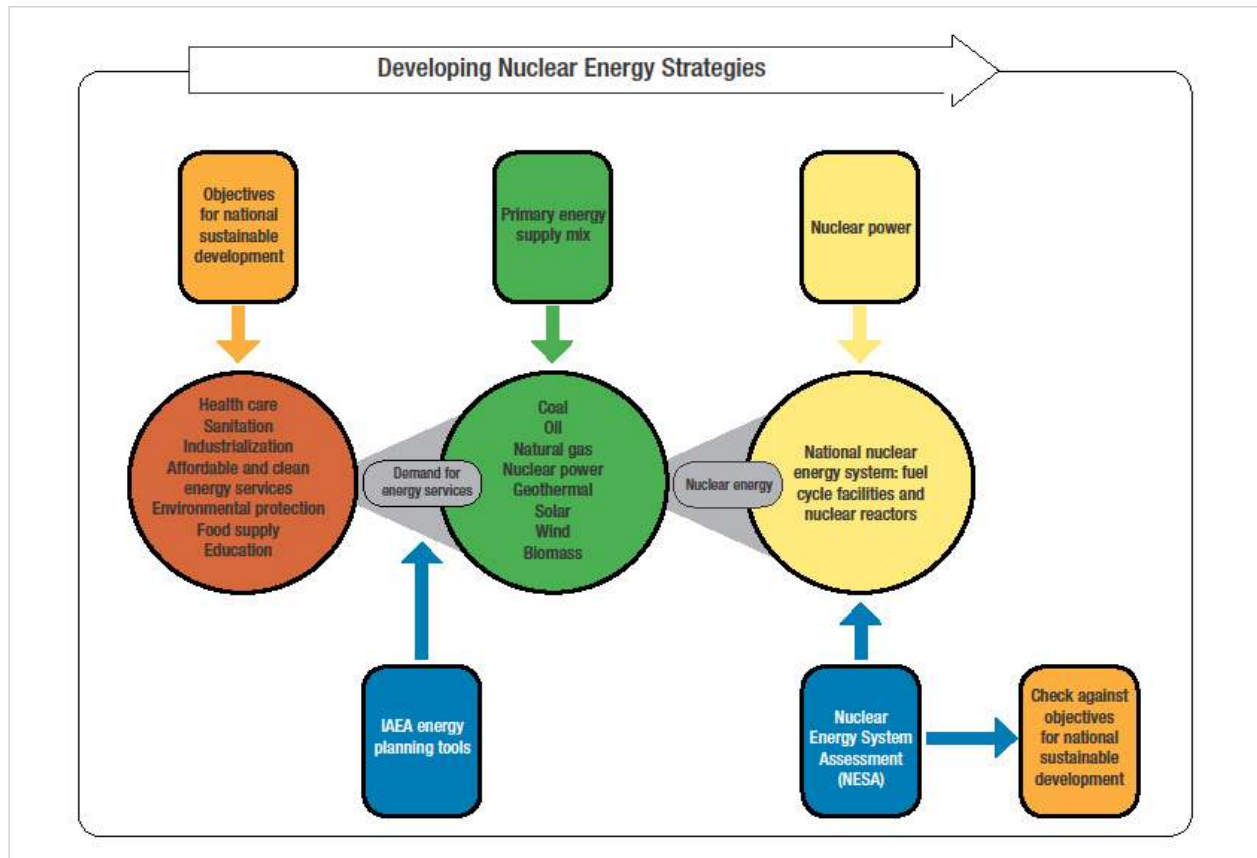
dynamics of technology change and innovation of energy-related infrastructures, social preferences, economic development directions and environmental constraints. In particular, adopting a nuclear power programme has intergenerational implications and obligations extending well beyond 100 years.

A Nuclear Energy System Assessment (NESA) is a holistic approach using an internationally validated tool, the INPRO methodology, to support strategic decision making in Member States that are planning to establish a new nuclear energy programme or expand an existing one.

More specifically, a NESA evaluates:

- All nuclear facilities in a given nuclear energy system, from mining through to final end states for all wastes and permanent disposal of high level waste, and all related institutional measures such as legal framework, regulatory bodies, etc.
- The complete lifecycle of the facility ('cradle to grave'), i.e. design, construction, operation and decommissioning .
- All assessment areas defined in the INPRO methodology, i.e. economics, infrastructure, waste management, proliferation resistance, physical protection, environment and safety.





A NESA can be used both by countries with established nuclear programmes, for example to assess the transition from a current fleet of reactors to a nuclear energy system with innovative technologies, and by ‘newcomers’, wishing to embark on new nuclear programmes. The assessment allows them to consider possible future nuclear systems in a holistic and comprehensive manner to determine whether or not they would meet a country’s sustainable development objectives.

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Assisting Member States in Long-Term Energy Planning & Development

The IAEA offers Member States tools and methods to support long-term energy planning and assessing nuclear energy systems, in its efforts to ensure that nuclear energy is available to contribute, in a sustainable manner, to meeting the energy needs of the 21st century. This includes computer models devoted to energy system analysis and planning, indicators for sustainable energy development, the

INPRO methodology for Nuclear Energy System Assessment (NESA), tools for analyzing nuclear fuel cycle material balance, and guidance in developing a nuclear infrastructure in ‘newcomer’ countries.

In July 2009, 50 representatives from over 40 Member States came together at the IAEA to learn about the integrated use of these tools and methods for national energy and nuclear energy planning and development, listen to feedback from Member States which had applied the IAEA energy planning models and undertaken NESAs, share experiences



From left: I. Videnovic, TC, I. Jalal, PESS, P. Gowin, INPRO, Y. Sokolov, DDG-NE, R. Beatty, INPRO Group Leader



Fifty participants from over 40 countries attended the Workshop at the IAEA Headquarters

and lessons learned and identify needs for support from the IAEA.

Opening the Workshop, Mr Y. Sokolov, IAEA Deputy Director General and Head of the Department of Nuclear Energy emphasized that countries should take a holistic approach and consider their long-term commitment when developing a national nuclear power programme.

Addressing the workshop participants on the last day of the meeting, Ms A.M. Cetto, IAEA Deputy Director General and Head of the Department of Technical Cooperation, gave some examples of TC activities in the sustainable development of nuclear energy around the world. She also stressed that the IAEA is open to consider, for the future TC programme cycle, national projects to perform a NESA using the INPRO methodology in an integrated approach to national nuclear energy planning.

Representatives from developing countries, especially those who are not INPRO members, were able to familiarize themselves with the large range of aspects that have to be taken into account when establishing modern nuclear energy systems. The approach of coupling the assessments for an optimal energy mix and evaluating a planned nuclear energy system was considered to be very useful. Participants emphasized the need to organize similar workshops in Member States, since this would enable many national decision makers to participate. All participants highlighted also the value of direct feedback from the representatives of Brazil, Ghana, India, Ukraine

and Vietnam as users of the tools covered by the Workshop.

The Workshop on *IAEA Tools for Nuclear Energy System Assessment for Long Term Planning and Development*, held at the IAEA from 20-23 July 2009, was jointly organized by the INPRO Group and the Planning and Economic Studies Section (PESS) and supported by the IAEA Department of Technical Cooperation. It was one of the key elements of an IAEA interregional project to promote technology development and the application of future nuclear energy systems in developing countries.

All presentations and workshop documents are available at: www.iaea.org/INPRO/2009-Jul-WS.html

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Transportable Nuclear Installations: INPRO Study on Legal and Institutional Issues

Twenty experts from seven INPRO member states are contributing to a study on legal and institutional issues related to introducing transportable nuclear installations (TNIs). The study, which also benefits from cooperation of the IAEA Office of Legal Affairs, is part of the INPRO programme area on “**Innovations in Institutional Arrangements**”. This programme area fosters collaboration of Member States on innovative institutional and legal ar-

rangements for the use of innovative nuclear systems in the 21st century.

A TNI is a non-stationary nuclear energy unit capable of producing final energy products. It includes the nuclear reactor, balance of plant (e.g. steam generator or turbine) and, if necessary, fuel storage facilities. The complete TNI is factory-fabricated and then moved to its location by rail, truck or ship. Fuel is either already included in the reactor core or transported separately and then loaded at the site.

All TNI reference cases of the INPRO study have in common that they are not designed for, and do not enable operation during transport. All TNIs can be designed for relocation after operation at a selected site, or for remaining at the original site until their final return to the factory.

TNIs are of particular interest for niche applications, especially in areas with limited infrastructure, for countries with small electrical grids, and remote or isolated areas. They can also be used for non-electric applications, such as desalination of sea water and hydrogen production. No operating TNI exists in the world today, although in several countries new technologies are being designed or TNIs constructed.

TNIs will require innovative approaches to institutional and infrastructure arrangements. The IAEA document *Milestones in the Development of a National Infrastructure for Nuclear Power* (IAEA Nuclear Energy Series No. NG-G-3.1) identifies 19 infrastructure issues that are also applicable to TNIs. In the INPRO study, special emphasis has been placed on:

- **Technical, logistic and hard infrastructure implications of the use of a TNI as a battery reactor** (i.e. transport with or without loaded fuel, decommissioning or TNI replacement and use in another site before the end of the core life);

- **Minimum technological level required in the recipient country to deploy a TNI** (i.e. health care system, communication network, possibility of regional assistance, local services and conventional safety culture);
- **Quality assurance and quality control to meet licensing requirements in the supplier/recipient countries** (i.e. international certification of the design and access to the supplier factory for inspection).

Six meetings have been held so far to advance the study which will result in a report to be published by the IAEA. Available legislation and existing regimes for safety, security, safeguards and liability have been considered.



Transportable nuclear reactor designed by SOSNY, Belarus.

The main objective is to help developers learn about technologies that could simplify legal and infrastructure issues, and technical design scenarios and options of operation and ownership that would introduce additional problems.

The report should also enable newcomer countries to recognise the potential advantages of introducing TNIs, since users of TNIs are not obliged to install facilities for the storage and management of fresh and spent nuclear fuel, and waste management is considerably reduced. Since reactors would be factory-fabricated in the supplier country, a Member State installing a TNI would not need to develop construction or maintenance capabilities.

The draft document “*Legal and Institutional Issues of Transportable Nuclear Installations*” will be reviewed by INPRO members in the near future. A technical meeting tasked with finalizing the report is planned for October 2009.

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COOL Moves Forward

Next generation reactors, to be used for hydrogen production and other applications, will need to incorporate innovative approaches to further enhance their reliability and safety for large scale deployment in different regions of the world. An important feature of these reactors will be the use of coolants at temperatures that are much higher than those in current generation reactors. This involves addressing a wide range of issues concerning design and safety of these reactors.

An **INPRO Collaborative Project (CP)** — termed **COOL** — investigates the technological challenges of cooling reactor cores that operate at temperatures up to 1000 degree C in advanced fast reactors, high temperature reactors and accelerator driven systems, by using liquid metals and molten salts as a coolant. The project was initiated by two INPRO Members, the Czech Republic and India.

Representatives of countries participating in this CP, i.e. Brazil, China, Germany, Hungary, India, Italy and the Republic of Korea, recently met at the IAEA to chart the way forward by presenting their experience in this field and interest in the project, defining national contributions and finalizing, adopting and signing new terms of reference for research work to be undertaken.

All participants presented ongoing research activities related to liquid metals and molten salts:

India will play a key role as COOL project leader;

Germany will contribute to the area of materials and the development of barriers for protection;

China and Italy will research thermal hydraulic correlations for liquid metal coolants and computational fluid dynamic (CFD).

Since **Brazil's** interest lies in the area of neutronics, the country will contribute with research on neutronics and CFD.

Hungary will contribute with CFD studies on liquid metals and molten salts.

The Republic of Korea, which presented basic research since there is no R&D project at a national

level, will participate with studies on molten salts for various geometries.

The Czech Republic is expected to add its experience in the area of molten salt coolants.

In addition, it is planned to provide the data generated by the COOL CP to the IAEA Thermo-physical Properties Data Base of Light Water Reactors and Heavy Water Reactors (THERPRO).

The results of the investigation of technological challenges related to the removal of heat from reactor cores operating at temperatures between 600 to 1000 degree C, with a focus on liquid metals and molten salts for use in high temperature reactors, accelerator driven systems, molten salt reactors and advanced fast reactors, will be documented in progress reports and a final report, to be published by the IAEA in 2011.

More information about the COOL CP is available at: www.iaea.org/INPRO/cool.html.

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Performance Assessment of Passive Gaseous Provisions

The objectives of the INPRO Collaborative Project on **Performance Assessment of Passive Gaseous Provisions (PGAP)** are to propose an internationally accepted definition for the reliability of thermal-hydraulics passive systems and a methodology to assess their reliability.

The new methodology will build from existing methodologies developed in Europe, i.e. Reliability Methods for Passive Systems (RMPS) and in India, i.e. Assessment of Passive Systems Reliability (APSRA), and will use the results of a benchmark exercise modelling decay heat removal transients for the CEA gas cooled fast reactor (GFR) design. The benchmark will comprise two phases — deterministic calculations and reliability calculations. For each phase, two transients will be simulated to assess the performance of the decay heat removal system.

Six partners joined PGAP in 2007 when the project was initiated:

CEA of France, which had proposed and is leading the project, SOSNY from Belarus, SCK-CEN from Belgium, NRI from the Czech Republic, FZK from Germany and BARC from India.

In 2008, COMENA from Algeria joined the project after Algeria expressed its desire to join INPRO, and has since become an active partner. The project includes active participants (performing the benchmark exercise) and observers. Integrating Algeria successfully as a new partner during the project has demonstrated the potential for INPRO to collaborate well with new INPRO members. Coordination is also ensured with the IAEA Coordinated Research Project on ‘Development of Methodologies for the Assessment of Passive Safety System Performance in Advanced Reactors’.

Five PGAP partners participated in the second technical project meeting held in mid-June 2009 at the IAEA. The partners performing the benchmark exercise presented their results for the first transient. Although the results appeared to be mainly consistent, some discrepancies were identified in terms of physical parameter evolution against time; certain were due to a misunderstanding of the scenario or of assumptions proposed in the specification, others were due to code features. The participants agreed on a second round of calculations in which most discrepancies are expected to be solved. It will then be possible to start the reliability part of the benchmark (sensitivity study).

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Global Vision: Nuclear Energy in the Context of Global Sustainability

The INPRO Programme Area “**Establishment of a global vision on sustainable nuclear energy**” aims at providing a better understanding of the role of nuclear energy in the context of sustainable development. The objectives of studies undertaken in this area are to develop global and regional nuclear energy scenarios — on the basis of a scientific-technical pathway analysis — that lead to a global vision of sustainable nuclear energy development in the 21st century, and to support Member States in working towards that vision.

An INPRO study on “Global scenarios and regional trends of nuclear energy development in the 21st century” was started in January 2009, with the objective to:

- Analyse, in a generalised manner, the possible development of nuclear energy systems and its impact on sustainable energy supply, taking into account the anticipated development in different regions of the world;
- Develop a broad matrix framework for innovative nuclear energy systems that would be adequate to provide growth rates in nuclear energy to meet the challenges of sustainable development;
- Indicate R&D and institutional directions to be explored in order to achieve innovations required for possible future deployment of innovative nuclear energy systems.

The study builds upon a system of a few reactor and fuel cycles types available today, and those likely to be developed in the future, to illustrate the strength of a modelling approach that would show the role of an inter-regional transfer of nuclear fuel resources in support of a global growth of nuclear energy. Sixteen experts from nine INPRO Member States are participating in this activity. Dynamic simulation is used in modelling nuclear power development. The results will feed into an “INPRO Vision”, which will also take into account input from other INPRO Collaborative Projects such as “*Meeting energy needs in the period of Raw Materials Insufficiency during the 21st century (RMI)*”, “*Investigations of the 233U/Th fuel cycle (ThFC)*” and “*Fuel cycles for Innovative Nuclear systems through Integration of Technologies (FINITE)*”.

At a recent meeting (25-27 August 2009), participants discussed a draft report on “*Global scenarios and regional trends of nuclear energy development in the 21st century*” which will document the study results. The meeting also clarified and refined the national and regional growth scenarios for nuclear energy, to be used and considered in that study. The report is expected to be ready for review by 15th INPRO Steering Committee in November 2009.

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