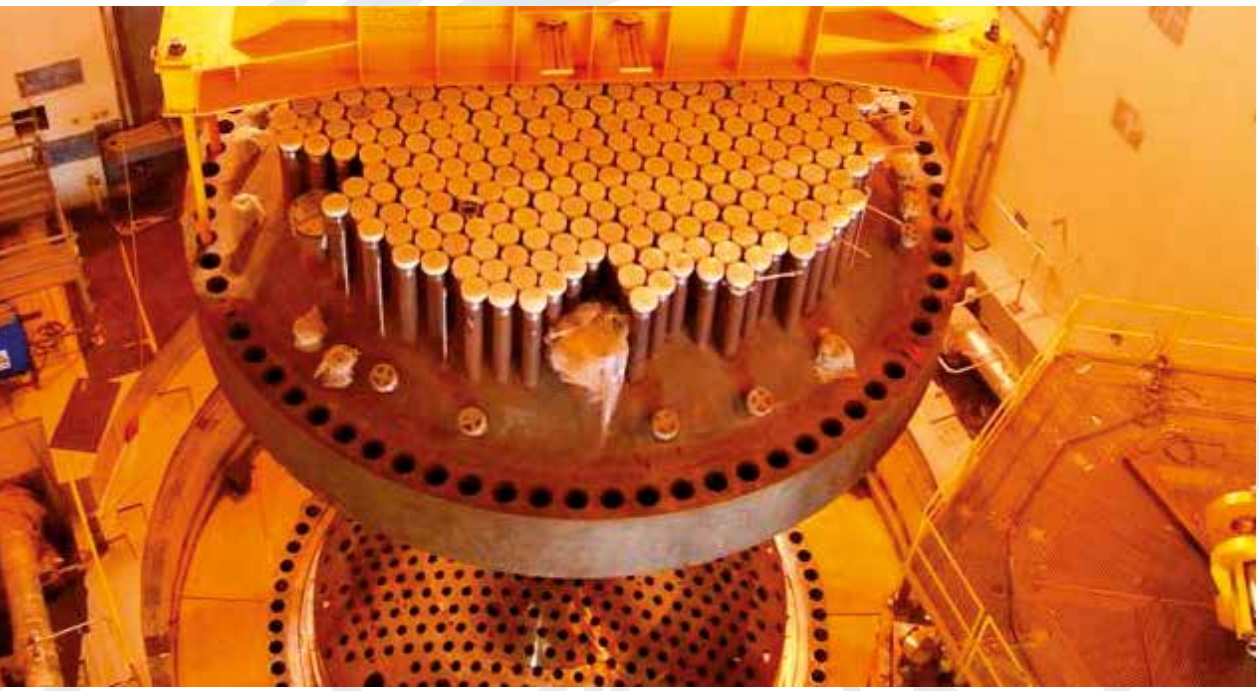
IAEA

INPRO
International Project on
Innovative Nuclear Reactors
and Fuel Cycles



# INPRO — In Brief

## International Project on
## INNOVATIVE NUCLEAR REACTORS AND FUEL CYCLES

Enhancing Global Nuclear Energy Sustainability
www.iaea.org/INPRO

# **INPRO** Members in **2012**

Algeria
Argentina
Armenia
Belarus
Belgium
Brazil
Bulgaria
Canada
Chile
China
Czech Republic
Egypt
France
Germany
India
Indonesia
Israel
Italy
Japan
Jordan
Kazakhstan
Republic of Korea
Malaysia
Morocco
Netherlands
Pakistan
Poland
Russian Federation
Slovakia
South Africa
Spain
Switzerland
Turkey
Ukraine
United States of America
Vietnam
European Commission

# **INPRO** — Enhancing Global Nuclear Energy Sustainability

The world needs to produce huge quantities of energy in the coming decades to meet the needs of a growing population and, at the same time, raise the living standards of billions of people that do not have access to cheap, plentiful electricity. The production of this energy at a reasonable cost, without environmental damage and in a safe and secure manner, will be one of this century's most challenging undertakings. Nuclear energy has the potential to make a significant contribution to meeting the world's growing energy needs.

For nuclear energy to play a substantial role in a sustainable global energy supply, both technical and institutional innovations need to be developed. The results of studies and projects carried out under the **International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO)** can make a contribution and provide added value to a wide range of stakeholders and the nuclear and scientific communities in IAEA Member States.

At the turn of the century, a number of IAEA Member States recognized the need to take action to ensure that nuclear energy was developed in a sustainable manner. As a result, INPRO was initiated in 2000 as an IAEA flagship project, through a General Conference resolution, to help ensure that nuclear energy is available to contribute to meeting the global energy needs of the 21st century — sustainably.

INPRO has made considerable progress; 37 members have joined the project, representing 85% of the world's GDP and more than 75% of its population.

INPRO has a successful history as a collaborative and international project, resulting in a continuously growing membership and acknowledged in numerous IAEA General Conference Resolutions. The INPRO Methodology, INPRO collaborative projects in the areas of innovation and global nuclear energy sustainability and the INPRO Dialogue Forum are ongoing achievements providing a solid foundation for INPRO's activities.

Angra nuclear power plant, Brazil.
(Photo: Electronuclear, Brazil)

# **INPRO** Programme

INPRO's activities are centred on the key concepts of global nuclear energy sustainability[1]. INPRO's holistic approach provides a global view of nuclear energy systems. The pursuit of technical and institutional innovations in nuclear energy through international cooperation will contribute to sustainable nuclear energy.
*(INPRO Development Vision 2017)*

INPRO's activities provide assistance to INPRO Members in:

- **understanding the challenges** of global nuclear energy sustainability through studies and scientific analysis of nuclear energy sustainability, development pathways and their contribution to the broader United Nations goals for sustainable development in the 21st century;
- **developing options** for enhanced sustainability through promotion of technical and institutional innovations in nuclear energy technology through collaborative projects among IAEA Member States;
- **implementing solutions** that assist IAEA Member States to consider the findings of global nuclear energy sustainability studies and to take advantage of anticipated innovations in their national long range strategies for nuclear energy development and deployment.

[1] The World Commission on Environment and Development (the Brundtland Commission, 1987) defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" and identified four essential dimensions: economic, social, environmental and institutional.

GIF/INPRO/IAEA Workshop on Safety Aspects of Sodium Cooled Fast Reactors.


NESA Training Workshop in Indonesia.

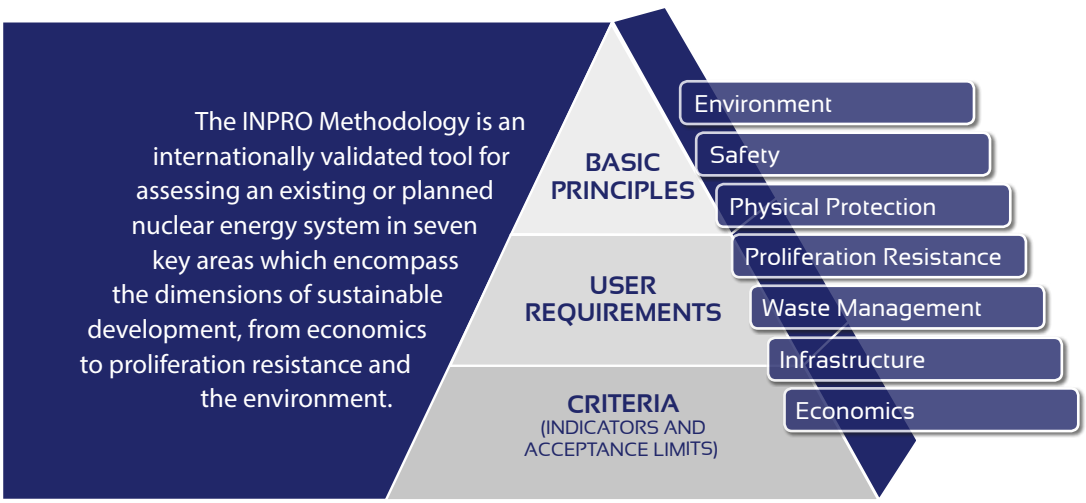
Zaporizhzhe nuclear power plant, Ukraine.
(Photo: Energoatom, Ukraine)

# National Long Range Nuclear Energy Strategies

## The IAEA, through INPRO, assists IAEA Member States in building national long range nuclear energy strategies and making decisions about sustainable nuclear energy development and deployment.

By undertaking national nuclear energy assessments (NESAs) using the INPRO Methodology, national energy planners can make informed decisions on the choice of the most appropriate nuclear system and assess whether their strategic deployment plan is sustainable. The IAEA offers practical support and training in this area. NESAs are supported by the IAEA as an integral part of national nuclear power planning along with IAEA energy system planning models and the IAEA Milestones approach.

Argentina, Armenia, Brazil, India, the Republic of Korea and Ukraine assessed different nuclear energy systems using the INPRO Methodology several years ago. Another eight countries conducted a joint study on an innovative nuclear energy system based on closed nuclear fuel cycles with fast reactors. Now, Belarus, Indonesia, Kazakhstan and Ukraine are applying the INPRO Methodology in national NESAs to guide their strategies for nuclear power programmes.



## Proliferation Resistance

For the safe and responsible use of nuclear power, it is crucial to understand the proliferation resistance of nuclear systems. They must be designed to make any diversion or undeclared production of nuclear material or misuse of nuclear technology by States difficult and detectable. They must be safeguardable and must enable the IAEA to meet its safeguards goals.

The INPRO study PRADA analysed pathways for acquiring or diverting fissile material for a nuclear weapons programme, and made recommendations for assessing the robustness of institutional, material, technical and safeguards barriers against proliferation. A new project, PROSA[3], is now developing a set of tools, in cooperation with the Generation IV International Forum (GIF), to assess proliferation resistance and the safeguardability of nuclear energy systems.

2 PRADA: Proliferation Resistance: Acquisition/Diversion Pathway Analysis.
3 PROSA: Proliferation Resistance and Safeguardability Assessment.

Treatment of radioactive waste.
(Photo: Studsvik, Sweden)

# Global Nuclear Energy Scenarios

By developing global and regional nuclear energy scenarios, INPRO helps newcomers and 'mature' nuclear countries to understand how international collaborations could facilitate the transition to a globally sustainable nuclear energy system and the activities and stakeholders required to achieve this transition.

A study on global scenarios and regional trends in nuclear energy development in the 21st century illustrated the potential contribution of innovative nuclear energy systems employing fast reactors and closed fuel cycles in meeting the global and regional demands for nuclear energy. It also investigated the flow of nuclear material among different regions of the world, based on possible demand scenarios (IAEA Nuclear Energy Series No. NP-T-1.8, 2010).

Considering issues of world heterogeneity, national policies on the nuclear fuel cycle and the role of collaboration among countries in making the transition to a sustainable nuclear energy system, the GAINS[4] project developed an internationally verified framework for the assessment of such transition scenarios. The study concluded that the sustainability of a global nuclear energy system in the 21st century would be more likely if technology holders and users collaborate, in particular on the back end of the nuclear fuel cycle.

One of the most important challenges that many users of nuclear energy will face is to decide which back end fuel cycle strategy to adopt. There are many advantages of the closed nuclear fuel cycle in terms of resource utilization and waste disposal. Still, many challenges remain concerning technical feasibility, assurance of the safety and security of nuclear installations, economic and financing considerations, proliferation risk and environmental implications. In the FINITE[5] project, INPRO Members share strategic options related to the closed fuel cycle that could potentially be implemented.

The natural abundance of thorium in comparison to uranium, its chemically inert nature, superior thermal conductivity and advanced neutron characteristics make thorium based fuel cycles attractive. An INPRO study (ThFC)[6] investigated the potential role of thorium in supplementing the uranium–plutonium fuel cycle under several scenarios that assumed a significant increase in the use of nuclear energy in the world. While thorium fuel fabrication and irradiation experience cannot yet

be considered as commercially 'mature', there is sufficient knowledge and experience today for a technically feasible implementation of a 'once through' thorium fuel cycle (IAEA Nuclear Energy Series No. NF-T-2.4, 2012).

Building on these earlier studies, and in particular on the GAINS analytical framework, the INPRO Collaborative Project SYNERGIES[7] evaluates and identifies mutually beneficial collaborative ('win–win') strategies among nuclear technology suppliers and users, and the driving forces and impediments influencing the achievement of globally sustainable nuclear energy systems. The project will identify short and medium term multilateral collaborations capable of developing pathways to long term sustainability and will examine additional scenarios for the evolution of sustainable innovative nuclear energy systems.

Integrating the outputs of these and other IAEA projects, a new activity entitled ROADMAPS[8] will develop 'roadmaps' (*"who does what, where and when"*), i.e. flowcharts of structured actions, scope of work and timeframes for individual stakeholders in a collaborative scenario that would facilitate a transition to globally sustainable nuclear energy systems.

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4 GAINS: Global Architecture of Innovative Nuclear Systems Based on Thermal and Fast Reactors including Closed Fuel Cycles.

5 FINITE: Fuel Cycles for Innovative Nuclear Energy Systems through Integration of Technologies.

6 ThFC: Further Investigation of the $^{233}$U/Thorium Fuel Cycle.

7 SYNERGIES: Synergistic Nuclear Energy Regional Group Interactions Evaluated for Sustainability.

8 ROADMAPS: Roadmaps for a Transition to Globally Sustainable Nuclear Energy Systems.

China Experimental Fast Reactor, Beijing, China.
(Photo: China National Nuclear Corporation)

# Innovations

INPRO supports national and international efforts by coordinating studies and fostering collaboration on innovations in selected nuclear technologies and in institutional arrangements for developing and deploying innovative nuclear energy systems.

Under the INPRO project AWCR[9], case studies were performed on the advanced heavy water reactor in India, the CAREM-25 reactor in Argentina, and the advanced power reactor plus (APR+) in the Republic of Korea to gain a better understanding of the performance of passive safety systems, which can improve safety reliability and reactor economics.

An important feature of innovative nuclear reactor designs will be the use of coolants at temperatures much higher than those recorded in the current generation of reactors. In the COOL[10] project, INPRO Members jointly investigated the technological challenges of cooling reactor cores that operate at high temperatures in advanced fast reactors, high temperature reactors and accelerator driven systems by using liquid metals and molten salts as coolants.

Decay heat removal after shutdown of a fast reactor is one of the most important safety functions. The INPRO project DHR[11] modelled safety grade decay heat removal systems for liquid metal cooled reactors and concluded that the reactor can be safely shut down and the residual heat can be removed by natural convection in the decay heat removal system in the case of loss of off-site power or station blackout.

Since the Fukushima accident, preventing severe accidents and mitigating their consequences, including release of radioactive material to the environment, are receiving increased attention. A new INPRO study, RISC[12], will examine the safety requirements and related technical and institutional innovations that would ultimately avoid relocation or evacuation of people from the nuclear power plant site.

A key study addressed legal and institutional issues related to the introduction of transportable nuclear power plants (TNPPs). The study results aim to help developers learn about those innovative technologies that could simplify the introduction and deployment of nuclear power and related legal and infrastructure issues, and consider technical design scenarios and options regarding operation and ownership. A case study on export deployment of a small reactor without on-site refuelling is planned.

A new project, LOADCAPS[13], undertaken jointly with other IAEA groups will address the issue of flexible operation of nuclear power plants and identify the requirements of INPRO Members.

9 AWCR: Advanced Water Cooled Reactor Case Studies in Support of Passive Safety Systems.
10 COOL: Investigation of Technological Challenges Related to the Removal of Heat by Liquid Metal and Molten Salt Coolants from Reactor Cores Operating at High Temperatures.
11 DHR: Decay Heat Removal System for Liquid Metal Cooled Reactors.
12 RISC: Review of Innovative Reactor Concepts for Prevention of Severe Accidents and Mitigation of their Consequences.
13 LOADCAPS: Load Following Capability in Innovative Designs.

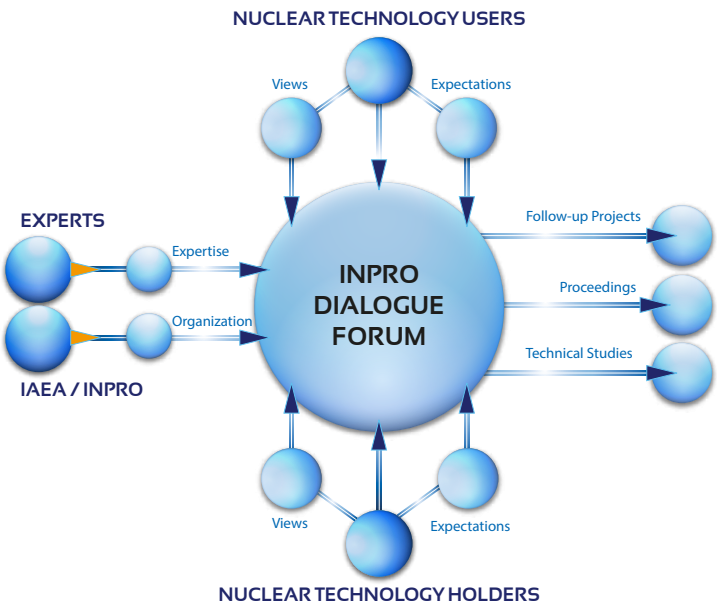
The Deputy Directors General of the Department of Technical Cooperation and the Department of Nuclear Energy attend the closing session of an INPRO Dialogue Forum.

# INPRO Dialogue Forum on Nuclear Energy Sustainability

The INPRO Dialogue Forum offers a platform for technology holders, technology users and other stakeholders to share information, perspectives and knowledge on issues related to sustainable nuclear energy development.

The INPRO Dialogue Forum is open to all IAEA Member States and involves a variety of stakeholders, including governments, national and international organizations, regulators, vendors, operators and researchers. Open discussions between technology users and holders at an early stage in the development of nuclear energy systems facilitate a common understanding of issues, establishment of strategic partnerships between technology users and holders and future deployment of innovative nuclear energy systems in the technology user countries.

The main value of the INPRO Dialogue Forum lies in the opportunity to discuss and share perspectives on issues of common interest, with the goal of reaching consensus and adopting joint policies. The INPRO Dialogue Forum is being implemented in strategic cooperation with other IAEA technical programmes to ensure good coordination and to take advantage of IAEA expertise in different areas. All Dialogue Forums have been supported by the IAEA's Department of Technical Cooperation, which facilitates the participation of developing countries and allows them to benefit from, and engage in, discussions on global nuclear energy sustainability.



Organized for the first time in 2010, the INPRO Dialogue Forum has focused on the following topics since then:

- Socioeconomic and macroeconomic factors, proven technology and safety approaches for innovative nuclear energy systems (February 2010).
- Multilateral approaches to nuclear energy deployment with a focus on institutional challenges (October 2010).
- Common user considerations for small and medium sized reactors (October 2011).
- Drivers and impediments for regional cooperation on the way to sustainable nuclear energy systems (July 2012).
- Long term prospects for nuclear energy in the post-Fukushima era (August 2012, hosted by the Republic of Korea).

In 2010, the IAEA marked the 10th anniversary of INPRO during the 54th IAEA General Conference with participation of Director General Y. Amano and high-level representatives from Member States.


## Membership in INPRO

INPRO is a membership based project. IAEA Member States and recognized international organizations are invited to join the project and contribute to INPRO in the form of financial support, human resources and expertise through participation in INPRO studies and projects. INPRO is funded mainly from extrabudgetary resources.

IAEA Member States wishing to become INPRO Members should address a letter expressing this intention to the Deputy Director General, Head of the Department of Nuclear Energy. After that, a consultative process will be established to determine the details of membership.

## INPRO Steering Committee

In addition to participating in INPRO activities, representatives of INPRO Members also form the INPRO Steering Committee, which guides the project's activities. The Steering Committee meets regularly to review progress and provide guidance on future activities. Every two years, the Committee endorses the INPRO Action Plan which defines detailed tasks and priorities for implementing INPRO activities.

## Project Management

The INPRO Project Manager is the Deputy Director General and Head of the Department of Nuclear Energy. He is supported by the INPRO Group in the IAEA's Division of Nuclear Power, which coordinates activities with INPRO Members. The group comprises regular IAEA staff, cost-free experts provided by INPRO Members and consultants.

## International Collaboration

INPRO is collaborating with other international initiatives and institutions including the European Commission (EC), the Generation IV International Forum (GIF), the International Science and Technology Centre (ISTC), the OECD/Nuclear Energy Agency (OECD/NEA), the European Sustainable Nuclear Energy Technology Platform (SNETP) and the World Nuclear Association (WNA). The aim is to ensure good synergy and coordination of activities.

# A Brief History of **INPRO**

**2000** The 44th IAEA General Conference passes a resolution which leads to the initiation of the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO).

**2001** INPRO is launched to develop and validate a holistic approach to the assessment of innovative nuclear energy systems — the INPRO Methodology. Nine countries and the EC become the first INPRO Members.

**2004** Six national and eight individual case studies on specific nuclear installations test the INPRO Methodology.

**2005** Six countries assess different nuclear energy systems using the INPRO Methodology. Another eight countries undertake a joint study on an innovative nuclear energy system based on closed nuclear fuel cycles with fast reactors.

**2006** World leaders meeting at the G8 Summit in St. Petersburg, Russian Federation, acknowledge the efforts of INPRO and the Generation IV International Forum (GIF).

**2008** The report of an independent commission on *Reinforcing the Global Nuclear Order for Peace and Prosperity: The Role of the IAEA to 2020 and Beyond,* requested by the IAEA Director General, recognizes INPRO's role in bringing together "many states ... to consider approaches to safer, cheaper, more secure, and more proliferation-resistant nuclear systems, with effective management of nuclear waste."

**2009** Eleven INPRO collaborative projects are under way, covering different issues of innovative nuclear reactors and fuel cycles, which support national and international R&D activities. The projects are concluded in 2011.

**2010** The IAEA marks the 10th anniversary of INPRO during the 54th IAEA General Conference. Director General Y. Amano and high level representatives from Member States express appreciation for INPRO's activities during its first decade. The President of the Russian Federation addresses a congratulatory letter to the participants of the 54th IAEA General Conference.

**2011** The INPRO Steering Committee approves the INPRO Development Vision 2017, which guides the project's strategic development over the next five years. INPRO's activities focus on the key concepts of global nuclear energy sustainability.

**2012** Belarus, Indonesia, Kazakhstan and Ukraine undertake NESAs using the INPRO Methodology. Several new collaborative projects are launched. INPRO has 37 Members.

IAEA

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