World Nuclear Association Annual Symposium
5-7 September 2001 - London

Development of Innovative Reactors and Fuel Cycles: The IAEA Role

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Introduction

Over the last 15 years, nuclear power's share of new capacity additions in the world has not kept up with either its share of electricity generated or its share of installed capacity. Last year (i.e. calendar 2000) six new power reactors were connected to the grid - three in India and one each in Pakistan, Brazil and the Czech Republic. Together they equal a little over 3000 MW(e) - or 3 GW(e) of new capacity. But that's only about 3% of the world's estimated total capacity additions in 2000. That 3% share of capacity *additions* compares with nuclear's 10% of global *installed capacity* today and 16% share of actual electricity generated. The shares of generation and capacity differ of course because nuclear facilities run at higher load factors than fossil-fuel plants, so their share of generation is always higher than their share of capacity.

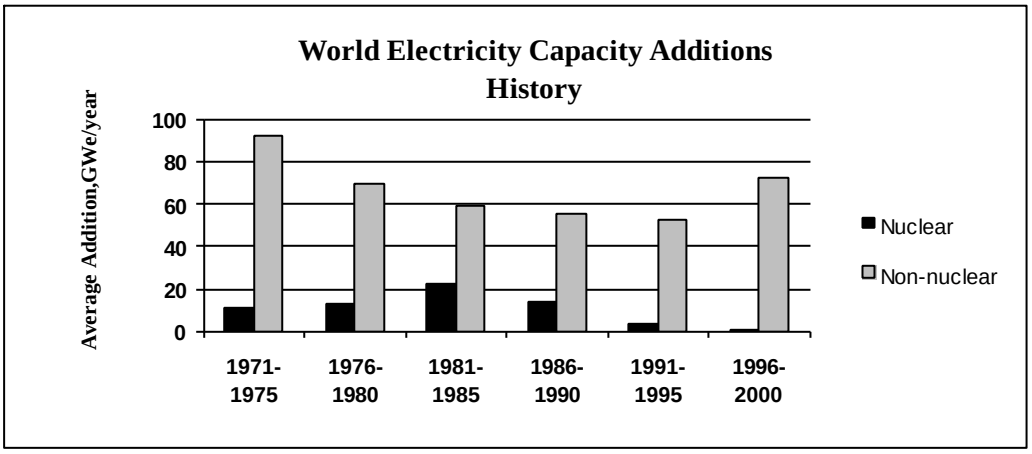

Figure 1

Figure 1 shows that 2000 was not just an unusual year, but unfortunately part of a trend that has been going on for a while. And in the intermediate term, it is a trend that is projected to continue. Our IAEA projections are shown in ***Figure 2*** and have nuclear's share of global capacity dropping to between 6% and 8% by 2020, and its share of

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electricity generation dropping to between 9% and 12%. The good news might be that five of the six nuclear power plant additions in 2000 were in developing countries, exactly where long-term energy scenarios project large growth in energy demand. But as you can see in ***Figure 3***, nuclear additions in developing countries, even in recent years, have been generally swamped by additions of fossil and hydro capacity.

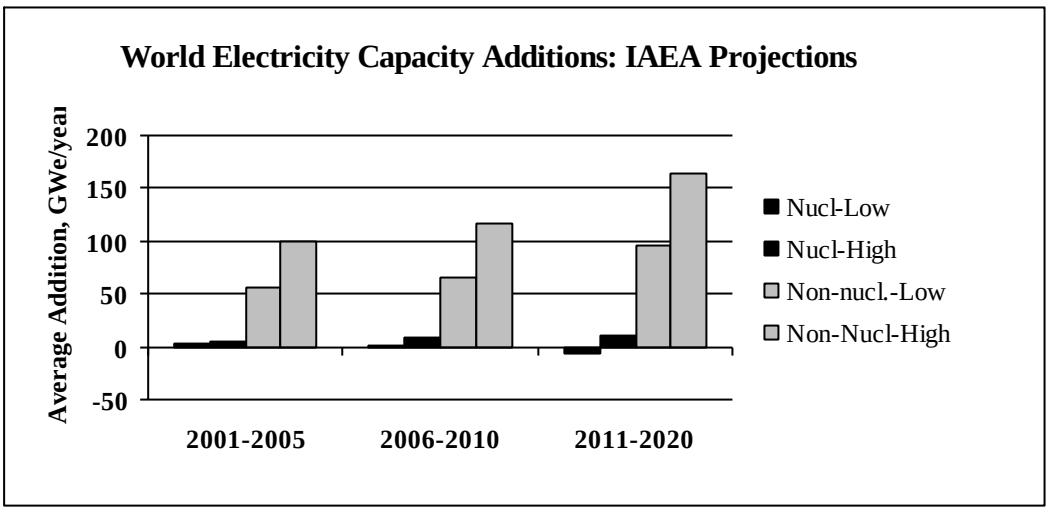

Figure 2

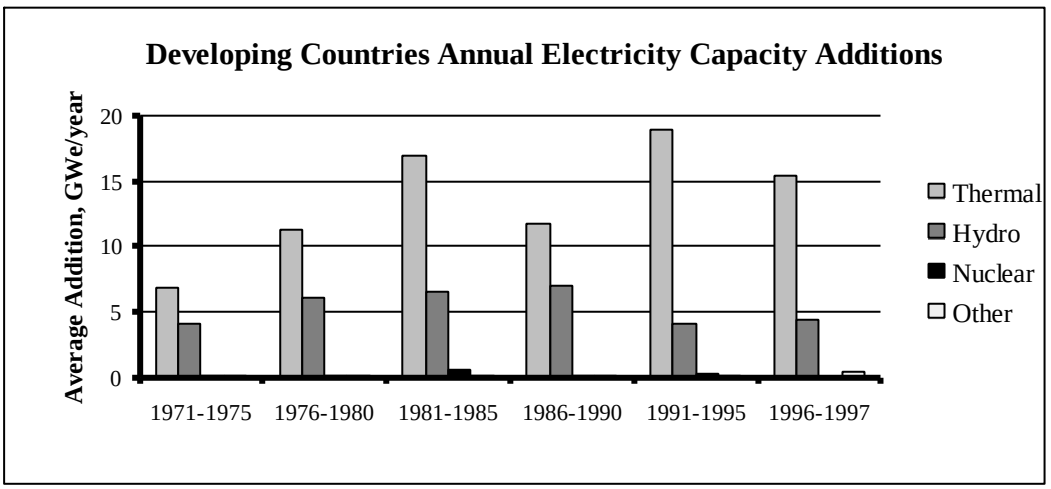

Figure 3

But while it is important to be realistic and fully aware of the data and trends shown in these figures, the future is never simply an extrapolation of current trends. At the same time that we learn from the past, we must apply that experience to prepare for what will be new and different in the future.

First, long-term projections for nuclear power diverge from near-term projections. Long-term energy scenarios - including those analysed in detail and published last year by the Intergovernmental Panel on Climate Change (the IPCC) - generally project increasing - not shrinking - nuclear contributions, even if there is first a near-term dip. The nuclear

shares in the IPCC scenarios are shown in ***Figure 4***. Long-term expansion happens in most of these scenarios because they assume that nuclear technologies, like other technologies, are not static. They improve as we gain experience; as new materials, designs, components and management techniques are developed; and as the nuclear community applies these new developments in a changing power market. It is a reasonable assumption, *but* it is not going to happen by itself. It requires initiative and action.

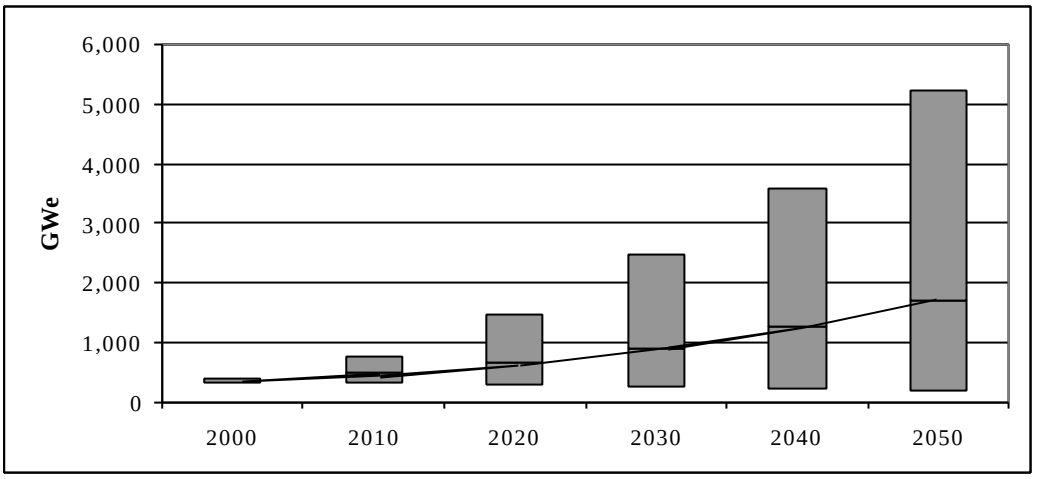

Figure 4: *Range of nuclear power in SRES scenarios, 2000-2050. Solid line represents median. Source: IPCC, 2000*

I see six major challenges that we must deal with successfully if nuclear power is to measure up to some of the more bullish long-term projections. These are: the economic competitiveness of new NPPs; the successful demonstration of effective nuclear waste management; responsiveness to public safety concerns; the preservation and maintenance of nuclear expertise, responsiveness to proliferation concerns; and building public support.

In the remainder of my time, I propose to elaborate a bit on each of these six challenges and report briefly on how we at the IAEA see our role, and what we are doing. A common theme throughout will be the importance of continual innovation - a theme that we are particularly focused on in a new Agency-wide initiative begun in the past year. It goes by the acronym of INPRO, for International Project on Innovative Nuclear Reactors and Fuel Cycles, and I will return to it a bit later in this talk.

Addressing challenges.

Waste management. Here the challenge is to develop clear global strategies for the disposition of spent fuel and high level radioactive waste. Experts judge geologic disposal to be safe, technologically feasible and environmentally responsible, but much of the public at large remains sceptical. The Agency' s role is principally one of facilitating international co-operation in research and development and demonstration projects. We also initiate and participate in conferences and other forums to maintain an

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international focus on this issue, to achieve concrete plans of action, and to bridge the perception gap between technical experts and much of the public.
In connection first with the United States, the Agency recently completed an international peer review of the biosphere modelling programme for the proposed geologic repository site at Yucca Mountain. We are currently engaged, jointly with the OECD/NEA, in an international peer review of the total system performance assessment in support of the site recommendation that may be made to President Bush later this year.

Last year Canada offered to make its underground laboratory at Lac du Bonnet available to the Agency as a facility for international training in, and demonstration of, geologic disposal technology. Belgium has now made a similar offer regarding its Underground Research Laboratory at Mol, and, in October, the Agency will convene a meeting to establish an international Network of Centres of Excellence in geologic disposal, involving these facilities, and to define an initial programme of demonstration and training.

Beyond these initiatives, in which the Agency has been involved, there has been significant progress elsewhere in the field of long-term waste management this year. In Finland in May, the Parliament ratified the government's decision "in principle", taken last December, to construct a deep disposal facility for spent fuel at Olkiluoto. In Sweden, the number of candidate sites being investigated for a spent fuel repository was narrowed from six to three, with detailed geologic investigations to begin in 2002. And just last month (in August) the US Department of Energy concluded that the Yucca Mountain site meets the Environmental Protection Agency's long-term standards, so there is real movement there.

The new legislation in the Russian Federation on the import for indefinite storage and reprocessing of spent nuclear fuel is also very significant. In the near-term it has important positive implications for countries with Russian-origin research reactor fuel and reinforces a tripartite initiative (involving the IAEA, US and Russia) on the possible return of Russian-origin fuel currently at foreign research reactors. More generally in the longer term, regional or international spent fuel storage facilities and/or geologic disposal facilities could have comparative advantages from both safety and efficiency perspectives.

The safety challenge. Here the challenge is to remain vigilant in ensuring the continued safety of operations at nuclear facilities. While safety is a national responsibility, international co-operation on safety-related matters has proven to be indispensable. The continuing positive results from international collaboration towards safety upgrades at nuclear installations in Eastern Europe are an important case in point.

The present international safety regime consists of three major components: international conventions, a body of internationally agreed safety standards, and mechanisms for applying these standards. To date, the Agency has developed conventions that cover the safety of power reactors, radioactive waste and spent fuel management, early notification, assistance and physical security. The Agency continues to identify areas in which binding norms are needed, such as in the safety of research reactors and of fuel cycle facilities.

From an evolutionary perspective, it is important to appreciate that safer reactors are more profitable reactors, as continued experience and good management improve

performance and capacity factors. Safety improvements are also a principal objective driving innovation in design, management and regulatory oversight.

Assuring the continuity of nuclear expertise. Another challenge is to assure the continuity of nuclear expertise. Qualified, highly trained personnel are essential not only to operate nuclear plants safely, but also for waste management, power plant life extension and decommissioning. In recent years, it has become increasingly clear that a substantial portion of the knowledge base in the nuclear industry will soon be vulnerable to loss through retirement. On the supply side, most countries with advanced nuclear programmes report a decrease in the number of new graduates in nuclear related fields. Slow growth in the nuclear industry, political controversy and the resulting uncertainty about its future weaken the incentives for young people to choose a nuclear career.

At the IAEA we are considering ways in which we can help address this problem. Specifically, we intend to promote co-operative strategies that link relevant organizations - nuclear facilities, university programmes, nuclear professional training centres and prospective donor organizations - to develop specific initiatives to attract young people to nuclear careers. In this context, I am pleased to note that the Republic of Korea will host the second Youth Nuclear Congress in 2002, to follow the inaugural Congress held in Slovakia last April. This is a significant forum for the younger generation to exchange views and understand the importance of nuclear energy technologies.

Public Acceptance. I welcome the greater visibility of nuclear power in the energy policy debates that have begun, among other places, in the United States and several EU countries, as well as in international forums such as the UN's Commission for Sustainable Development. I believe that a full discussion can only clarify issues, increase public involvement and result in conclusions with wider support based on a broader understanding. At the IAEA, we have focused increased attention on reaching out to our many constituencies, in keeping with a new Agency policy that aims to engage both traditional and non-traditional partners. An encouraging indication of the value of this new approach is the large number of non-governmental participants in the Scientific Forums held during our two most recent General Conferences. We have also sponsored very useful meetings with senior managers from nuclear research centres and with representatives from the nuclear industry. In all cases, these are valuable opportunities for different groups to exchange views with the Agency on issues of mutual interest. The Agency has also arranged several regional public information seminars that have attracted wide attendance, and have served as successful forums for a continuing dialogue among technical experts, the media and members of civil society.

Non-proliferation. Proliferation resistance is of course a special focus of the Agency, given our unique role, and one which has seen significant progress in the last decade. We will continue to encourage Member States to become party to and implement the Additional Protocol to strengthen the international safeguards regime, and I hope everyone in the nuclear community will support us in that. Strengthening safeguards is in everyone's interest. We also recognize our unique position and responsibility in taking into account safeguards issues in innovative work on new reactor designs and fuel cycles. Designing proliferation resistance into new ideas from the beginning is better than adding it after the fact. Given our special role in this regard, the first international workshop under the INPRO project was a symposium this July in Italy on "Proliferation-Resistance in Innovative Reactors and Fuel Cycles".

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The Need for Innovation

Finally, there is the need to improve the economic competitiveness of new NPPs, and this leads most directly to the need for innovation.

Let me start by saying that I believe what we are doing to address the above challenges in the framework of traditional activities is very important at least to keep nuclear power alive, but it is not enough. If the nuclear power sector is to increase its role, it cannot simply continue to do what it has been doing and expect that factors outside its control, such as fossil fuel prices or environmental taxes, will change to make nuclear power's prospects more favourable. To reach a different outcome than that indicated by current near- and intermediate-term trends, something must be done within the nuclear community to generate new technological solutions. The challenge is to look to the future, to identify what innovations and new directions - that build upon and make good use of existing expertise and accomplishments - are most promising for helping nuclear power capture a *growing* share of a growing market.

At the national level, work on innovative approaches to nuclear energy reactor design and fuel cycle concepts is proceeding in several IAEA Member States. At the international level, OECD/IEA, OECD/NEA and the IAEA are co-operating in a review of ongoing R&D efforts on innovative reactor designs and to identify options for collaboration. The US Department of Energy is promoting the Generation IV International Forum (GIF) initiative, in which both the IAEA and OECD/NEA are participating as observers. And President Bush's new National Energy Policy explicitly identifies the importance of both nuclear power and nuclear innovations in meeting America's future energy needs. President Putin, at the Millennium Summit, also highlighted the importance of innovation in nuclear technology, calling upon IAEA Member States to join together to explore innovative nuclear technologies to further reduce nuclear proliferation risks and resolve the problem of radioactive waste.

INPRO. Member States with an interest in new future applications of nuclear power have increased in recent years, leading to a resolution by the 2000 General Conference inviting "all interested Member States to combine their efforts under the aegis of the Agency in considering the issues of the nuclear fuel cycle, in particular by examining innovative and proliferation-resistant nuclear technology" and inviting Member States to consider contributing to a task force on innovative nuclear reactors and fuel cycles. In response to this invitation, the IAEA initiated an "International Project on Innovative Nuclear Reactors and Fuel Cycles", INPRO.

The objectives of INPRO, as defined in the Terms of Reference, are:

- to help to ensure that nuclear energy is available to contribute in fulfilling, in a sustainable manner, energy needs in the 21st century;
- to bring together all interested Member States, 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 that

use sound and economically competitive technology, are based – to the extent possible – on systems with inherent safety features and minimise the risk of proliferation and the impact on the environment;
- to create a process that involves all relevant stake holders that will have an impact on, draw from, and complement the activities of existing institutions, as well as ongoing initiatives at the national and international level.

The Project will be implemented in two phases. Phase I was initiated in May 2001 at an initial Steering Committee meeting. In this first phase, work will proceed in five areas recognised as important for the future development of nuclear energy technology: Resources, Demand and Economic Requirements; Environment; Spent Fuel and Waste; Safety; and Non-proliferation. Two crosscutting groups will address Criteria and Methodology; and Institutional, Infrastructure, Social and Sustainability Requirements.

Upon successful completion of the first phase, taking into account advice from the Steering Committee, and with the approval of participating Member States, a second phase of INPRO may be initiated. Drawing on the results from the first phase, it would examine, in the context of available technologies, the feasibility of an international project including the identification of technologies that might appropriately be implemented by Member States within such an international project.

INPRO is very much open to, and welcomes, co-operation with other national and international stakeholders and initiatives to ensure effective co-ordination, for example, with the Generation IV International Forum (GIF). INPRO has already received input from other international organizations, with the Three-Agency Study, a study conducted jointly by OECD/IEA, OECD/NEA and IAEA on specific innovative nuclear reactor developments being one particularly useful joint input of all three Agencies. In GIF, the IAEA is represented, as an observer, at the Policy and Experts Group, and IAEA experts participate in the technical meetings of GIF. At the same time, GIF and INPRO have their distinct strengths, with GIF serving as essentially a designers' initiative and INPRO including other current and potential user countries; with INPRO incorporating IAEA safeguards considerations more directly; and with INPRO's longer time horizon.

INPRO is implemented using mostly extra-budgetary resources offered by interested Member States. As of September 2001, the following are members of INPRO: Argentina, Canada, China, France, Germany, India, Russian Federation, Spain, The Netherlands, Turkey and the European Commission. In total, 14 cost-free experts have been nominated by their respective governments or international organizations.

In conclusion I would like say that INPRO's global character, encompassing both designers and end users and their user's requirements, its long time horizon, its consideration of the changing energy sector and its broad based input through IAEA membership all make it a valuable forum for the assessment of perspectives for nuclear in the 21st century.

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