China is among countries with ambitious plans for nuclear energy. Shown here is the inside of the control room of the Qinshan nuclear plant. Photo: Pavlicek/IAEA

a hazy nuclear renaissance

by Victor M. Murogov

Global initiatives call for developing advanced reactors and promoting nuclear education. The future is far from clear.

As energy issues rise on the global agenda, what role is foreseen for nuclear power over the coming decades? Is enough being done to bring new reactors—and the knowledge to run them safely—on line when they are needed, especially in developing countries where energy demand is growing fastest? There are no easy answers, though some directions are emerging.

Important developments are influencing the changing nuclear workforce, nuclear power technology, and the education of the next generation of leaders. A prime challenge is to preserve the knowledge and experience already acquired in nuclear fields so as to have a solid foundation from which to achieve safe and secure solutions.

Fortunately, some global initiatives can help to pave the road to nuclear power's future and its contributions to sustainable development. They include steps taken by the IAEA—such as the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO)—and the World Nuclear University (WNU). Both initiatives are helping to raise awareness about education and knowledge management and the need for advanced nuclear technologies.

Regrettably in Russia, as in the USA, Western Europe and developing nuclear countries, more attention and support is needed for nuclear education and training—and in preserving decades of nuclear experience that has fed such international initiatives. Opportunities are being lost in my view, leading to a hazy nuclear future. It's worth reviewing the picture.

INPRO & Energy Security

INPRO emerged in response to the call of Russian President Putin for international cooperation in nuclear energy at the

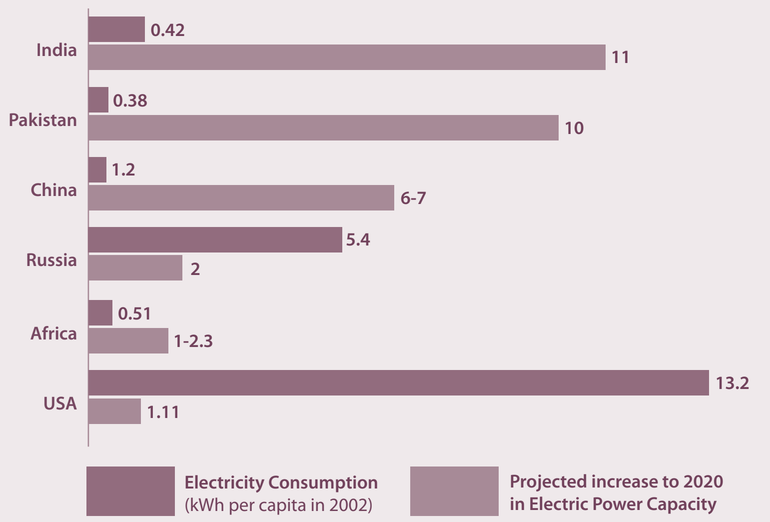
UN Millennium Summit in 2000. It targets the world's energy security and the role of innovative nuclear power plants and fuel cycles that exclude the use of separated plutonium and high-enriched uranium — thereby addressing both safety and proliferation concerns.

INPRO membership today includes 26 countries and organizations: Argentina, Armenia, Brazil, Bulgaria, Canada, Chile, China, Czech Republic, France, Germany, India, Indonesia, Japan, Republic of Korea, Morocco, Netherlands, Pakistan, Russian Federation, Slovakia, South Africa, Spain, Switzerland, Turkey, Ukraine, USA and the European Commission.

- Nuclear medicine in health care;
- Nuclear techniques in food management and agriculture;
- Nuclear applications for quality control in industry;
- Nuclear applications in science, research, and industry (lasers, accelerators, isotope production);
- Nuclear power for potable water supply.

Suffice it to say that — in industrialized countries such as the USA, Japan, and those in Western Europe — non-power applications of nuclear technologies exceed the nuclear power business. This means that nuclear technologies in medicine, industry, agriculture, and other fields have a big impact on industrial economies.

Electricity Needs and Prospects



Source: IAEA

To meet rising demands, countries and regions are projected to increase their installed electric power capacity by factors ranging from just over one in the US to eleven in India by 2020.

The introduction and use of nuclear power, then, can play an essential role in helping countries reach goals of sustainable development. But this can only happen through the realization of innovative nuclear reactors. This thesis was underlined by INPRO's analysis, as well as by experts of the Generation IV International Forum (GIF) initiated by the USA which targets "next generation" nuclear energy systems.

How is the world's energy future unfolding? Estimates show that the global population is rising toward 10-12 billion people by 2050, with general energy consumption expected to double or triple. Electricity consumption is estimated to grow much faster — by a factor of five to seven.

What is important is that about 70% of the growth in energy consumption is attributed to demand in developing countries. Using hydrocarbon fuel to meet this growth is rather questionable, for reasons varying from limited oil resources to concerns about the greenhouse effect. In that light, projections indicate that nuclear's share of the global energy market has to reach 35% by the year 2050.

Global energy trends and developments paint a fairly clear picture, based on an analysis done in the INPRO framework. It shows:

- Steep growth of population and energy demands;
- Severe competition in getting access to limited and unevenly distributed fossil resources;
- Increasing instability in oil-exporting countries;
- Increasing ecological concern and environmental limitations;
- Increasing disparity in energy consumption between rich and poor countries.

The analysis points out the fact that nuclear technology is not only an element of the energy market. It goes far beyond the generation of electricity, penetrating social, political, and economic spheres of industrial societies in many forms. They include:

The structure of energy markets looks to change as well within this century. There is an emerging new market — hydrogen production — that projections show will help to fuel an increase in the use of nuclear power by the end of 21st century. By then, in long-term future, total nuclear power generation could reach 12,000 to 15,000 gigawatts-electric (GWe) compared to today's level of 364 GWe.

In terms of nuclear power research and development, three directions of innovative systems emerge:

One of the most influential conclusions of INPRO and GIF experts is that only a closed nuclear fuel cycle — where plutonium is recycled in fast reactors — can elevate nuclear

power's role to the level required of a global player in the energy market.

New reactors must be developed that are inherently safe and rely on passive safety characteristics.

Nuclear power technology should be diverse — ready to contribute to district heat markets (projected to reach 20-25% of the total energy market) as well as to transportation (currently 30-35% in developed countries) through hydrogen production technologies backed-up by high temperature and "super high" temperature gas-cooled reactors.

As we have seen, more nuclear reactors in the energy marketplace raise concerns related to proliferation — concerns that INPRO is addressing.

INPRO goes beyond accounting and safeguards of fissile materials to consider a broad range of issues:

- Developing the IAEA's existing safeguards system, including national systems of physical protection against sabotage and terrorism;

- Providing engineering and technological barriers against illicit traffic of nuclear materials;

- Providing institutional measures, including international agreement on IAEA-supported international nuclear centres for nuclear reprocessing and waste disposal, uranium enrichment, plutonium recycling on the basis of fast reactors, and low-enriched uranium fuel supply as natural U-235, U-238 now and U-233, U-238 in the future.

To summarize, INPRO is looking to shape a new international regime for the use of nuclear power. Practically speaking, this regime would entail a new international agreement on peaceful use of nuclear energy and a growing role of IAEA as its main guarantor.

It's important to underline international cooperation in the field of innovative nuclear technologies. INPRO's broad membership, for example, now includes China, India and Russia among its two dozen-plus members. Both China and India (who together will have more than three billion people by 2050) are planning ambitious nuclear programmes. This manifests the growing significance of global cooperation and transfer of nuclear knowledge to meet energy and environmental challenges.

Nuclear Education — A Crisis of Development

In the nuclear field, knowledge preservation and transfer to the next generation of leaders is closely linked to global cooperation between north and south, west and east. The World Nuclear University (WNU) was launched in 2004 with the support of the IAEA, World Nuclear Association, Nuclear Energy Agency of the Organization for Economic Cooperation and Development, and the World Association of Nuclear Operators.

WNU brings together the world's nuclear educational programmes and is a logical progression of INPRO in reflecting the need to direct knowledge and experience from industrial to developing countries. The IAEA, for example, possesses the largest database of nuclear-related literature in the area of peaceful use of nuclear energy, the International Nuclear Information System (INIS), and carries out an active international programme of knowledge management. The idea of international cooperation for innovative nuclear systems and knowledge management as a prerequisite for nuclear technology's global role is of great importance.

In the Soviet Union, nuclear education was singled out from the general stream of science and engineering education. Nuclear-related students and university staff had some privileges (increased financial support, salary, scholarships, etc) that had attracted the most talented students to make careers in the nuclear business. This same idea stands behind the WNU. Interested and talented students are carefully selected and promoted as fellows of WNU summer institutes to have the opportunity of face-to-face discussions with world renowned scientists and specialists.

In contrast, nuclear education in Russia is now reduced from the top priority to just an average level of university education. This is regrettable compared to its previous prestigious status. The leading nuclear universities (namely, Moscow Engineering and Physics Institute and Obninsk State Technical University for Nuclear Power Engineering) were moved from RosAtom (the Federal Agency for Nuclear Energy) to the Ministry of Education and Science where they do not have sufficient support that could make nuclear careers attractive to young people.

For example, Russia has been the most developed country in the area of fast reactors and nuclear–related university education. The strategy of nuclear power development in Russia is based on the leading role of fast reactors in a future closed fuel cycle. However, there is no national programme for preservation of knowledge and experience in these particular areas.

Also, until recently, Russia has not participated at the national level in the WNU — the united educational systems of leading nuclear countries. The curious paradox is that the world nuclear community uses advantages of old Soviet experience in organizing nuclear education (realized in the 1960s at the Moscow Engineering and Physics Institute and

the Moscow Institute of Physics and Technology) even as Russia denies its own advantage.

In my view, the situation with Russia's nuclear education must be characterized as critical. There is no more than a five-year period to consolidate and transfer nuclear knowledge and experience to a new generation of Russian nuclear specialists. Without drastic changes in the governmental attitude toward nuclear education, the situation will become catastrophic.

Russia is facing an erosion of nuclear culture, experience and knowledge. The generation gap is a regrettable fact. Though new students are coming to nuclear departments, the quality is inferior to what Russia had two decades ago. An important factor is the low salaries of university staff, which translates to an erosion of the teaching level. On another side is the aging of working force. The age range of leading nuclear specialists is between 60 and 70. There is a lack of the most creative specialists within the 35 to 45 age range. It casts into doubt the federal programme of nuclear development.

But it is not only a problem for Russia. For specialists it is clear that the nuclear community needs to take emergency measures to save nuclear knowledge. Not the least in the list of measures should be economic incentives in the form of financial support for nuclear research, nuclear teaching staff, and scholarships for top students.

Local Initiatives Take Root. Global initiatives for a nuclear renaissance would require institutional and scientific support. Yet it's possible to revive the best national traditions in nuclear education—by organizing centres of nuclear engineering education with university programmes in physics and mathematics, and fostering close collaboration with experimental and technological work of leading national nuclear laboratories. In Russia, such centres are emerging through local initiatives near big research and industrial organizations located in Tomsk, Dimitrovgrad, and Obninsk.

Obninsk—the cradle of Russia's nuclear technology for peaceful uses—provides an excellent opportunity for organizing an integrated Centre of Nuclear Science and Technology. Obninsk hosts 12 nuclear-related research institutions with various experimental facilities. By special Decree of the President in 2000, Obninsk acquired special status as the First Scientific City (in Russian, "Naukograd") of the Russian Federation.

Despite this honourable status, the reality is that Obninsk's experimental base is aging and it hardly can produce frontier scientific results. Without federally-backed research programmes, it is just aging without profitable use. Yet it could provide definitive benefits if it were used for education and training purposes.

Obninsk has a population of about 100,000, and is a city that boasts high levels of education. There are more than 1,100 people possessing the degree of Candidate in Science (analogous to a PhD) and degree of Full Doctor in Science (a special Russian degree). The team of engineers involved in research engineering exceeds 12,000. The student community approaches 8,000. The biggest educational institution is the Obninsk State Technical University of Nuclear Power Engineering. This is the only university in Russia that succeeded in keeping an integrated process of education in a broad spectrum of applied nuclear science, technology and engineering subjects.

In 2005, the first Russian Association of Nuclear Science and Education (RANSE) was registered in Obninsk. RANSE was initiated and promoted by leading scientists of Obninsk University, the Russian Research Centre "Kurchatov Institute" (Moscow), the Medical Research Radiological Centre of the Russian Academy of Medical Sciences (Obninsk), and the Russian Research Centre "Institute of Theoretical and Experimental Physics" (Moscow). RANSE is a non-profit organization which is open to other participants.

In December 2006, RANSE developed and hosted its first nuclear educational session in cooperation with the IAEA and WNU, "Nuclear Technology for Human Life in the 21st Century." International Scientific Sessions were successfully carried out. Scientific sessions are planned in Obninsk on a regular basis.

While RANSE has received some financial support locally, it regrettably has not received any support from federal organizations like RosAtom or the Ministry of Education and Science. This reflects the short term bureaucratic thinking to the problem of retaining competence, knowledge, professionalism and human resources for nuclear development in Russia.

International initiatives launched with the IAEA's support in recent years can be of vital importance for a "nuclear renaissance" that will play a key role in the world's quest to cut poverty and raise standards of living. It is ironic that these initiatives are based on Russian nuclear experience that unfortunately is eroding in Russia. In my view, given more support, there is time to turn around the situation.

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