E. Bertel, M. Woodruff*

Opportunities for international co-operation in the development of innovative reactors

A number of countries wish to expand their use of nuclear energy or to keep the option open for doing so in the future. Concerns over energy security, the need to reduce emissions of greenhouse gases and other atmospheric pollutants in OECD countries, and a lack of indigenous energy sources adequate to meet increasing demand in non-member countries are key reasons for the interest in nuclear energy. Three international agencies have looked into how this interest may take form in the years to come.

New nuclear power plants will have to face the challenges of privatised and deregulated energy markets coupled with heightened public concern over technological risk. They will have to maintain or surpass current levels of safety and achieve competitiveness with alternative means of generating electricity, especially natural gas combined-cycle plants. Improved ways of dealing with radioactive waste and of addressing non-proliferation concerns will also be important factors for their success.

* *Dr. Evelyne Bertel is a member of the NEA Nuclear Development Division (e-mail: bertel@nea.fr); Ms. Madeline Woodruff works in the Office of Energy Efficiency, Technology and R&D at the International Energy Agency (e-mail: madeline.woodruff@iea.org). Dr. Peter J. Gowin, who contributed to this article, works in the Department of Nuclear Energy at the International Atomic Energy Agency (e-mail: P.Gowin@iaea.org).*

Nuclear fission technologies capable of meeting these demands are being researched today by companies, research institutes, universities and governmental organisations worldwide. In some cases, several research groups are working on the same or similar technologies. International co-operation could potentially help technology developers make the most effective use of the limited research funds available today.

The Three-Agency Study

The "Three-Agency Study",[1] a joint project of the International Energy Agency (IEA), the OECD Nuclear Energy Agency (NEA) and the International Atomic Energy Agency (IAEA), investigated ways in which new technologies are being developed to meet the challenges facing nuclear energy today and tried to identify potential areas for co-operation among technology developers. It also sought to identify "enabling" technologies important to one or several designs that could benefit from international collaboration.

The study focused on "innovative" nuclear fission reactor technologies going beyond the incremental, evolutionary changes to current technology. The approach entailed looking at specific innovative reactor designs in order to identify development teams that could supply technical design data as well as information on R&D programmes; but the main purpose of the study was not to evaluate specific design proposals from particular vendors or designers.

The study was based upon information provided by developers of advanced nuclear concepts in a questionnaire on how the features of their innovative designs contribute to enhanced performance relative to the current generation of reactors. Six characteristics, selected by the study team, were used: safety, economic competitiveness, proliferation resistance and safeguards, waste management, efficiency of resource use and flexibility of application.

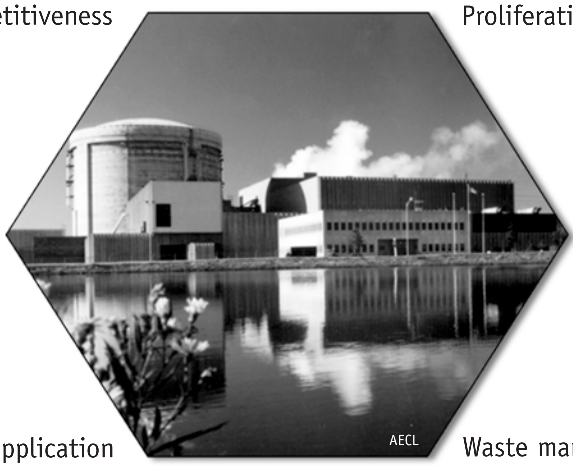
The twelve designs reviewed in the study were selected by the study team according to generic criteria aimed at choosing complete nuclear system designs for which ongoing, funded R&D programmes could be identified, and representing various primary coolants, operating conditions and moderator characteristics as well as different applications of nuclear energy (e.g. electricity generation, district heating, high-temperature applications). In addition to these criteria, a regional and global balance of designs was sought, as was a wide variety of R&D institutions and designers. An attempt was made to reflect the needs of the countries that are members of the participating agencies, considering both the country of origin of each design and countries where the designs might be used.

Main findings

The initial review of innovative reactor designs and their development illustrated the range of technologies from which countries wishing to expand their use of nuclear energy will be able to choose. These designs make use of a wide variety of innovations in an attempt to tackle head-on the challenges facing nuclear energy today. Many of the innovations and innovative approaches are common to several designs.

The Three-Agency Study Approach

Six main characteristics were selected by the study team:



Innovative reactor designs covered in the study

	Name	Country	Type	Capacity	Developer
Light-water reactors	Barge-mounted KLT-40C	Russia	PWR	35 MWe	OKBM
	CAREM-25	Argentina	PWR	27 MWe	INVAP
	MRX	Japan	PWR	Up to 300 MWe	JAERI
	NHR-200	China	PWR	200 MWth	INET
	SMART	Korea	PWR	100 MWe	KAERI
Heavy-water reactors	CANDU X	Canada	PHWR	350-1150 MWe	AECL
Liquid-metal fast reactors	BREST 300	Russia	LMR	300 MWe	RDIPE
	Energy Amplifier	Europe	Hybrid LMR/ Accelerator	675 MWe	CERN
Gas reactors	GT-MHR	USA/Russia	HTGR	286 MWe	General Atomics
	PBMR	South Africa	HTGR	110 MWe	ESKOM
Molten-salt reactors	FUJI	Japan/Russia/ USA	MSR	100 MWe	ITHMSO
Other	RTFR	Russia/USA/ Israel	PWR/ PHWR	Small to large	RCC-KI/BNL/BGU

The methodology applied for the study – reviewing how specific reactor designs deal with the challenges facing nuclear power, and cataloguing the enabling technology and information underlying or beneficial to the full set of designs – was useful for the limited purposes of this study. It could fruitfully be applied to a broader range of designs.

Most of the design activities reviewed focus on the nuclear steam supply system (NSSS). Because the balance-of-plant (BOP), where heat from the nuclear reactor is converted to useful energy, represents a major portion of both capital and operating costs, its design must be given careful attention if economic objectives are to be met.

Specific attention is needed to reduce operation, maintenance and inspection costs, especially for small reactors, although it can be partially addressed by locating several units at a single site and using common support functions and facilities. Owing to their compact design or the type of coolant they use, several of the innovative reactor designs considered present new challenges to the ability to provide efficient, cost-effective and reliable maintenance and inspection of the reactor, the pressure and containment vessels, and other components important to safety. Obstacles to in-service inspection include restricted access and restricted space resulting from very compact configurations, and the presence of obstacles such as insulation or solidified coolant.

All else being equal, economies of scale, which are applicable to capital, operation and maintenance costs, favour large nuclear power plants. To be economically viable, small plants must achieve simplifications in both the NSSS and BOP or offer higher reactor core outlet temperatures that enable higher thermodynamic efficiency and energy utilisation.

Several of the innovative designs considered in this study were developed with a view that in future energy markets, demand may not be driven solely by the need for electricity, but will also arise from needs for process heat, district heating, sea water desalination or hydrogen production. In general terms, taking advantage of co-production options and improving the flexibility of application can improve the competitiveness of nuclear power plants.

Many components and technologies that have been commercialised by the aerospace, automotive, petro-chemical and other industries may be useful in the nuclear industry. Increased co-operation with non-nuclear researchers, and increased tracking of non-nuclear industrial developments, could benefit innovative reactor design efforts.

The information provided by research and design teams in response to the questionnaire indicate that the R&D and design efforts under way on innovative nuclear reactors are funded at very low levels compared with the efforts made in the 1950s, 1960s and 1970s to develop the current generation of reactors, and compared with the R&D expenditures today on maintaining and enhancing the performance of operating reactors. Assuming continuation of these low levels of investment, for most of the designs considered, commercial availability could require 10 to 15 years or longer.

Based on the modest investment in design development, the potential for cross-fertilisation among development efforts, the broad experience upon which development efforts can draw, and the lack of full assimilation of this experience into current efforts, further collaboration in developing innovative reactor designs appears warranted. Such collaboration has the potential to reduce the time and cost required to make technologies commercially available.

Recommendations

The Three-Agency Study offered the following recommendations to reactor design teams for their consideration:

- Make better use of experience to date.
- Increase cross-fertilisation of ideas among reactor types.
- Take greater advantage of components and technologies developed in other industries.
- Increase co-operation in R&D.

The way forward

A wealth of information is available on experience worldwide flowing from several decades of research in the field of nuclear fission and the operation of numerous prototype and demonstration reactors in the 1950s and 1960s. Strong efforts are needed to ensure that previous design and operating experience with relevant coolants, moderators, systems, components, configurations and procedures is fully incorporated into current R&D programmes.

Increased cross-fertilisation of ideas among reactor-type designers could enhance the overall effectiveness of research. Design groups may wish to familiarise themselves thoroughly with the features and technologies that are currently used or proposed by other design groups, and to evaluate potential alternative approaches to meeting their own design requirements. Also, given the low budgets available for innovative reactor research, development and design, it would be worthwhile to take advantage of relevant components and technologies developed by other industries.

Specific "enabling" technologies are good candidates for broad international collaboration because they are relevant to the development of several types of innovative designs, and should be amenable to joint development without necessitating sharing commercially sensitive information or know-how. Candidates for such joint efforts include: technology assessment; natural circulation; high-temperature materials; passive safety devices; in-service inspection and maintenance methods; advanced monitoring and control technologies; delivery and construction methods; and safeguards technologies. Many other enabling technologies would be well suited to more limited co-operation among a few design groups.

Several international projects on nuclear power have been initiated in recent years. For example, the International Atomic Energy Agency (IAEA) recently launched the "International Project on Innovative Nuclear Reactors and Fuel Cycles" (INPRO). Work on innovative nuclear designs is also ongoing within the Generation IV International Forum (GIF), supported by the United States and nine other countries, and through the Michelangelo Initiative Network under the Framework Programme of the European Commission. Such initiatives are appropriate forums for considering the outcomes of the Three-Agency Study and expanding the analysis to more designs. ■

Note

1. The main results from the project are summarised in "IAEA, IEA, OECD/NEA, Three-Agency Study – Innovative Nuclear Reactor Development: Opportunities for International Co-operation, Summary Report", to be published in 2002.