Innovation in nuclear technology

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Innovation has been a driving force for the success of nuclear energy and remains essential for its future. For the continued safe and economically effective operation and maintenance of existing nuclear systems, and to meet the goals set out by projects aiming at designing and implementing advanced systems for the future, efficient innovation systems are needed. Consequently, analysing innovation systems is essential to understand their characteristics and enhance their performance in the nuclear sector.

Many studies on international and national innovation processes have been performed, in particular in OECD countries, as many governments are interested in building on feedback from experience for strengthening their innovation systems. However, until now innovation in the nuclear energy sector had not been investigated in detail, and aspects specific to the nuclear sector had not been thoroughly analysed. The new NEA study on *Innovation in Nuclear Energy Technology* published by the OECD early in 2007 presents a review and analysis of innovation systems in the nuclear sector based on country reports and case studies.

Scope and approach

The scope of the study focuses on analysing the performance of innovation systems applied in the nuclear sector as described in a series of country reports and case studies. Innovation is defined as a process spanning from research to widespread dissemination of an output through demonstration and early deployment. The output of innovation is a new or significantly improved product or process introduced successfully on the market and bringing economic and/or social benefits.

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The feedback from experience provided by 11 country reports and 23 case studies was analysed in a systematic manner according to ten elements, or indicators, selected in the light of their relevance to assessing the performance of innovation systems. Those key elements are:

- demands from the market for innovative products;
- human resources available in support of innovation programmes;
- finances that can be allocated to innovation programmes;
- physical inputs, such as materials, services and equipment, dedicated to innovation;
- innovators' access to science, technology and business best practice;
- ability and propensity of the entity pursuing an innovation programme to innovate;
- availability of institutional and support mechanisms adapted to innovation;
- networks, collaboration and clusters at the disposal of innovators;
- effectiveness of market processes for widespread distribution of the outputs from innovation;
- business environment framing the deployment of outputs from innovation.

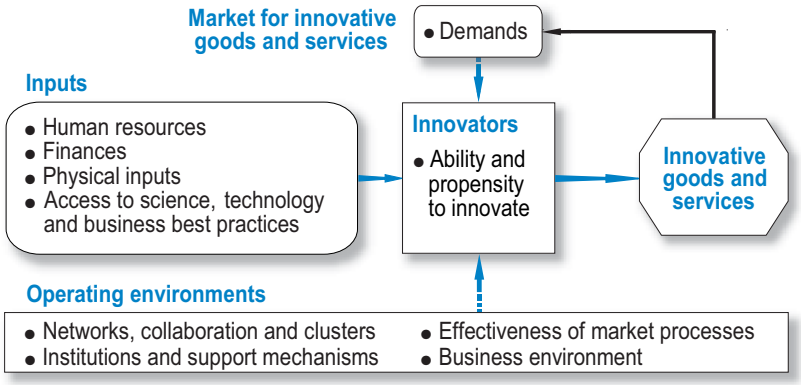
The figure illustrates the links and relationships between those ten elements. The evaluation of the respective contributions of each element to the success or failure of the innovation processes assessed helps identify best practices and provides insights into the reasons why some routes were not successful.

Nuclear innovation programmes

Research and development (R&D) programmes in the field of nuclear energy cover not only the design of new concepts and systems, but also the improvement of current nuclear power plants and fuel cycle facilities. Both domains may include innovation efforts.

Generally, R&D programmes dedicated to enhancing the performance of existing technologies and facilities are undertaken under industry leadership. The role of innovation in such programmes focuses, for example, on improving material characteristics in

Elements determining innovation performance



hostile environments, enhancing process efficiencies or adapting modelling capabilities.

Innovation programmes aiming at the development of evolutionary reactors and fuel cycles, achieving stepwise improvements over existing nuclear systems, may be undertaken jointly by industry and governmental institutes or laboratories. Innovation in that case relates mainly to technology adaptation but may require basic research to identify alternative technical solutions leading, for instance, to better economics or improved resource utilisation.

R&D programmes devoted to the design and development of a new and innovative generation of reactors are more likely to be undertaken in multinational frameworks under the leadership of governmental bodies. Recently, several countries have launched national or international efforts to define goals and roadmaps aimed specifically at the development of innovative nuclear technologies. The Generation IV International Forum (GIF) and the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) are examples of such endeavours.

Innovation is a key element in programmes that have very ambitious objectives requiring the development of entirely new concepts and systems. Innovative solutions will be needed, for example, to improve natural resource utilisation and to minimise waste streams, to eliminate the risk of off-site impacts even in the case of a severe accident, to enhance the competitive margin of nuclear systems, to penetrate non-electricity markets, to reduce the risk of nuclear weapons proliferation and to improve the physical protection of nuclear facilities.

Characteristics of innovation in the nuclear sector

The specific characteristics of the nuclear energy sector have influenced the patterns of nuclear energy development and the innovation systems adopted in various countries for R&D in the field. Nuclear energy characteristics can be grouped under four main headings: high reliance on scientific knowledge and technology know-how; low-volume/high-value market; high financial risk but low marginal production costs; and need for a stable legal and regulatory framework as well as a predictable political context.

While the innovation systems adopted in different countries vary according to their nuclear development patterns – autonomous, relying on technology transfer and adaptation, or relying mainly on foreign supply – all are based to some extent on government support and international co-operation, at least in their initial phases.

The principal driving forces of innovation identified by analysing country reports and case studies may be summarised as follows:

- market drivers, including striving for competitiveness and increasing market shares;
- policy drivers, including responding to global objectives such as environmental protection and social acceptance; and
- technical drivers, including development of enhanced materials, new computer tools and better equipment, increased efficiency and more effective management techniques.

The main actors in nuclear innovation are governmental bodies and institutes or laboratories performing research programmes, and suppliers of materials, equipment and services. Final users of the outputs, in particular utilities, also play an important role.

Governmental bodies are involved in nuclear innovation directly through national R&D policy decisions and support to basic research, and indirectly through national energy policy priority setting and the establishment of infrastructures and regulatory frameworks. In the nuclear energy field, safety authorities and agencies in charge of radiological protection and radioactive waste management, for example, have an important role in setting up the framework for innovation.

Those who perform R&D carry the most responsibility in terms of implementing innovation programmes. For a mature technology like nuclear energy, research centres involved in R&D include a mixture of public and private entities ranging from university laboratories to branches of industrial companies. Co-operation and co-ordination between the various actors are essential for effectiveness, as well as for the ultimate success of the innovation processes.

Suppliers, ranging from small local enterprises providing specific products or technologies to large multinational companies, play an essential role in the innovation process by providing innovative solutions to specific problems and by linking the R&D performed to commercial market realities. The constraints of competitive markets and intellectual property rights are important factors for suppliers that may limit the scope of co-operation between the various actors within an innovation programme.

Although they are the end users of innovation in nuclear energy technology, utilities are not automatically supportive of innovation. In liberalised markets, in particular, utilities tend to favour proven systems that offer guarantees of demonstrated performance. They have nevertheless contributed to certain innovation programmes, in the field of plant-life management for example. Initiatives such as issuing utility requirements provide guidance to innovators on the desired characteristics of end products.

Reasons for the success or failure of innovation processes

Although nuclear energy development and deployment can globally be considered as a successful innovation process, specific approaches to innovation in the nuclear energy sector have been more or less successful. Many reasons for the variable performance of innovation programmes are common to nuclear and other technologies, but some are specific to the nuclear sector.

The economics of the end product of the innovation process is a key element of success. A lack of competitiveness with other products already available on the market is bound to lead to a failure at the dissemination stage. In the case of nuclear technology, this might result from the process itself or from the context, for example, low fossil fuel prices.

Responding to market demand is a prerequisite for the successful deployment of an innovative product. Early analysis of market requirements and potential competitors is essential to assess the opportunities for the product to be adopted by users.

Project management is very important at all stages of an innovation programme to ensure that the objectives and scope of the project are well-defined and kept under control, that the expected budget and schedules are met, and that adequate down-selection of options are completed when needed.

Drastic changes in the overall political and economic context may be very detrimental to the successful completion of innovation programmes, especially in the nuclear energy sector where lead times for the design and development of new products or processes usually exceed a decade.

Concluding remarks

Innovation is essential for the safe and effective operation of nuclear power plants and fuel cycle facilities in service, as well as for the successful development and deployment of the next generations of nuclear systems. In most countries interested in the nuclear option, nuclear R&D programmes are being pursued and dynamic innovation systems are in place to design and eventually deploy innovative reactors and fuel cycles.

Policy makers' renewed interest in the nuclear energy option as a means to address security of supply and climate change threats creates favourable conditions for launching innovation programmes. Taking advantage of past experience, those programmes have the potential to succeed in designing, developing and deploying nuclear energy systems responding to sustainable development goals.

Lessons learnt from innovation programmes that have already been completed can help enhance the effectiveness of future programmes. The analysis of past experience provides a means for identifying causes of failure as well as best practices. Although national and local conditions are important factors, the main drivers for the success of innovative endeavours are common to all countries.

Co-operation and co-ordination among the various actors are major elements promoting success. All interested stakeholders, including research organisations, industrial actors, regulators and civil society, have a role to play in supporting the success of innovation, but governments are an essential trigger, especially for projects with long durations and very ambitious objectives.

Governments have a major role to play in promoting innovation because they are responsible for the overall national energy policy which sets the stage for the eventual deployment of innovative products and processes. Moreover, only governments can create the stable legal and regulatory framework favourable to the undertaking and successful completion of innovation programmes.

International organisations such as the NEA may help enhance the effectiveness of national policies and innovation programmes by providing a forum for exchanging information, facilitating multilateral collaboration and joint endeavours, and offering technical support for the management of innovative programmes. The NEA role as Technical Secretariat of multinational programmes such as GIF is an example of its specific contribution to innovation in nuclear energy technology. ■