Nuclear energy applications: Desalting water from the sea

Through IAEA-supported studies, options have been identified for demonstrating the practical use of nuclear desalination systems

by Toshio Konishi

Water resources in many parts of the world are not sufficient to meet the needs of people living there. In many cases, natural sources of fresh water supply are threatened by pollution and increasing salinity. At the same time, the demand for clean, potable water is growing, particularly in areas of high population growth.

Part of the answer to such pressing water problems may come from the sea's abundant resources. Desalination is one of the most promising alternatives for supplying potable water, and nuclear power plants could be an important part of the picture. The world's collective desalination capacity has increased steadily in the past decades, a trend expected to continue into the next century, and more countries are interested in using nuclear energy to desalt seawater.

The reasons behind nuclear power's use for electricity generation also apply to its potential use for seawater desalination. These reasons are, for example, economic competitiveness in areas which lack cheap hydropower or fossil fuel resources, energy supply diversification, conservation of fossil fuel resources, the promotion of technological development, and environmental protection by avoiding emissions of air pollutants and greenhouse gases.

The IAEA surveyed the feasibility of using nuclear energy for seawater desalination as early as the 1960s and 1970s. But at that time, interest was directed mainly at its use for electricity generation, district heating, and industrial process heat. Since 1989, however, the IAEA's Member States have shown renewed interest in nuclear desalination, adopting a number of resolutions on the subject.* With this support, a growing number of IAEA Member States and international organizations have participated in meetings, and provided relevant expertise and support. The assistance and support, involving more than 20 Member States, has included the provision of expert services and funds. Additionally, the IAEA has performed studies to assess the technical and economic potential of nuclear reactors for seawater desalination.

One study, *The Potential for Nuclear Desalination as a Source of Low Cost Potable Water in North Africa*, was completed in 1996 and published as a technical document (IAEA TECDOC-917). It analyzed the electricity and potable water demands and the available energy and water resources in five countries: Algeria, Egypt, Libyan Arab Jamahiriya, Morocco, and Tunisia. The scope included the selection of representative sites, analysis of various combinations of energy sources and desalination processes appropriate for each site, economic factors, financial aspects, local participation, infrastructure requirements, and institutional and environmental aspects. Other generic studies described in another IAEA publication (TECDOC-666) examined costs for different types of applications. These assessments have shown that nuclear seawater desalination could be technically and economically feasible.

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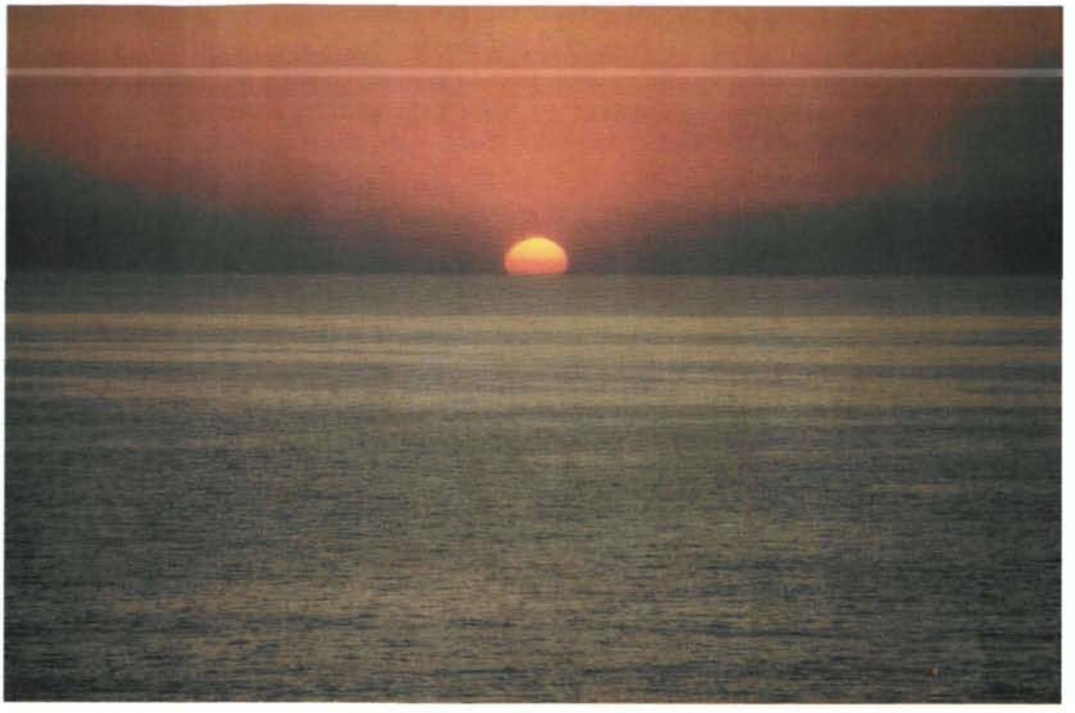
*Nuclear desalination is taken here to mean the production of potable water from seawater in an integrated complex in which both the nuclear reactor and the desalination system are located on a common site, the relevant facilities and services are shared, and the energy used for the desalination process is produced by the nuclear reactor.



Taking the salt out of seawater takes energy.

Assessing global experience

Recent IAEA activities* have focused on helping countries to assess the economic feasibility of using nuclear plants for desalination. Methods have been developed that enable site-specific economic evaluations. A computer programme is available for countries to use in such analyses, and some experts already been trained on the program's use. Now being envisaged is the development of a more detailed computer programme for allocating the costs of dual-purpose plants and determining their optimum coupling.

In 1995, the IAEA convened an advisory group of experts to review global experience with coupling nuclear energy plants and heat application systems like district heat networks and desalination processes. About 500 reactor years of operational experience from nuclear co-generation and heat-only reactors are now available in twelve countries.

Nuclear energy has been used for seawater desalination at locations in Japan and in Kazakstan. While in Japan the desalination plants are mostly for on-site water supply, the Aktau desalination complex in Kazakstan supplies water to a nearby population center.

While most industrialised countries are favouring large nuclear power stations for domestic application, there is a growing interest in smaller reactors (SMRs) in several Member States. These plants would fit better to smaller and weaker electricity grids and would better match the rates of projected growth in power demand. Most countries which are suffering from potable water shortages have grids for which SMRs could be an appropriate choice for electricity generation and for desalting seawater. An SMR survey, published by the IAEA in a technical document (TEC-DOC-881), has found that many different SMR types of plants have been designed. Vendors have offered these reactors as possible options for coupling to desalination processes.

Identifying options

In line with resolutions of the IAEA General Conference, the Agency has further focused on activities related to identifying options for nuclear desalination and demonstrating the technology. A demonstration programme would aim to build confidence, through the design, construction, operation, and maintenance of appropriate facilities, that nuclear desalination can be technically and economically feasible,

*For an option to be "practical", it was regarded to have fulfilled the following conditions: there is no technical impediment to implementation and a suitable site exists; it is technically feasible to be implemented on a certain predetermined schedule; and the investment cost can be estimated within an acceptable range. Nuclear and desalination technologies have promising prospects for future commercial application.

while meeting established safety and reliability criteria. Toward this end, a two-year "Options Identification Programme (OIP)" was initiated with participation of representatives from interested Member States.

The purpose of the OIP is to select from a wide range of possible choices in terms of desalination technologies and reactor types the few most practical candidates for demonstration.* The demonstration options are based on reactor and desalination technologies which are themselves readily available without further development being required at the time of the demonstration.

In the course of identifying practical options for demonstration, the list of available reactors was reviewed and several reactors were identified as being most appropriate. A set of screening criteria based on design and licensing status were used as a filter. Applying them, the reactor technologies currently available or which might become available within a period of approximately the next ten years were identified. Additional screening factors were then considered, which ruled out some options. These included various reactor designs which are not commercially offered; liquid metal-cooled reactors and high temperature gas-cooled reactors, which are unlikely to be commercially available in the near term; large reactors, which are unlikely to fit the electricity grids of most countries facing water shortages; small reactors which currently appear to be economically less competitive (however, they may be feasible at sites with low water demand and where alternative systems for potable water production are also expensive); and boiling-water reactors, which are likely to require installation of additional systems in order to prevent radioactive release to the heat recipient systems.

Consideration was also given to desalination technologies suitable for coupling to a nuclear reactor. Desalination by the processes of reverse osmosis (RO) and multi-effect distillation (MED) appear to be most promising, due to relatively low energy consumption and investment costs, as well as high reliability. Originally, the multi-stage flash (MSF) process was also considered as a candidate. However, the MED process has a lower energy consumption and appears to be less sensitive to corrosion and scaling than the MSF process. Also, its partial load operability is more flexible. Therefore, MSF has been excluded as a candidate, having no inherent advantages over MED.

The desalination processes for demonstration do not need to be implemented at the level of large-scale commercial production. Two or three trains or units could provide design and operational performance characteristics which are fully representative of larger scale production facilities, as the larger plants are simply multiple trains or units operated in parallel.

When combining a nuclear reactor and a desalination process to form an integrated facility, their compatibility was taken into account in the selection process. Scheduling, infrastructure, and investment requirements were also considered for their significance in identifying practical options for demonstration.

As a result of this screening, three options were identified as recommendable, practical candidates for nuclear desalination demonstration. These options use well-proven water cooled reactors and desalination technologies.

Option 1: RO desalination in combination with a nuclear power reactor being constructed or in an advanced design stage with construction expected in the near term. The preferred capacity of the reactor would be in the medium-size range. Two or three RO trains, up to 10,000 cubic meters per day each, would provide a suitable demonstration. A newly constructed reactor would offer the best opportunity to fully integrate the RO and reactor systems, including feedwater preheating and the optimization of system design. Such demonstration could readily be extrapolated to larger scale commercial production facilities.

Option 2: RO desalination, as above, in combination with a currently operating reactor. Some minor design modifications may be required to the periphery of the existing nuclear system. Advantages include a short implementation period, a broad choice of reactor sizes, and the availability of nuclear infrastructures. A reactor in the medium-size range would be preferred, as it provides a system close to that which would most likely be used in commercial production facilities.

Option 3: MED desalination in combination with a small reactor. This would be suitable for demonstration of nuclear desalination for capacities of up to 80,000 cubic meters per day.

It has been concluded that these demonstration options could be implemented, if there is interest from investors. The investment required would be in the order of US $25 million to $50 million for the RO options and US $200 million to $300 million for the MED option, the latter including the cost of the reactor.

The process of identifying and characterizing demonstration candidates during the OIP required considering many issues which must be addressed for the demonstration of nuclear desalination as well as for commercial deployment. A demonstration programme is intended to promote confidence and to confirm specific characteristics or parameters considered to be important in the design, construction, operation, and maintenance of a nuclear desalination facility. A number of subjects were identified for more thorough examination and evaluation, covering technical, safety, and economic issues. Such specific subjects for investigation include the interaction between nuclear reactors and desalination systems; nuclear safety requirements specific to nuclear desalination systems; and the impact of feedwater preheating on the performance of RO systems.

The question of infrastructure requirements for nuclear desalination plants is recognized as a major issue, especially for Member States with no nuclear power experience. A demonstration project, if implemented in such a country, could be a very effective and practical framework for developing its nuclear infrastructure, in particular a nuclear regulatory structure.

Desalination facilities connected to nuclear power plants in Japan and Kazakstan have been producing desalted water for years. In addition to these experiences in nuclear desalination plants, a significant number of Member States have shown interest in this option. Ongoing or planned national and bilateral projects will contribute to international experience in nuclear desalination. Such projects should be useful for commercial deployment, contributing to solve potable water supply problems in the next century. These include programmes and activities in China, India, the Republic of Korea, Morocco, and the Russian Federation. These projects, as well as studies and research and development in some other interested Member States, can contribute to a universal demonstration programme. They can be considered as a basis for international co-operation and support, beneficial also for other interested countries. It will be important to utilize the experience gained from these programmes, and not to duplicate activities.

The growing global interest in nuclear desalination led the IAEA to organize an international symposium on "Desalination of Seawater with Nuclear Energy" in Taejon, Republic of Korea, in May 1997. The symposium was convened in co-operation with other international organizations and provided a forum for the review of the latest technological experience, design, and development of nuclear desalination systems and of its future prospects.

Future directions

Studies performed to date show that seawater desalination using nuclear energy is a realistic option for many countries. The continuing expansion of seawater desalination installations presents a potential market for the introduction and commercial deployment of nuclear desalination systems. The IAEA's two-year OIP has identified a few practical technical options for demonstration of nuclear desalination. The demonstration programme has to concentrate on those issues which are relevant to commercial projects. Some issues, in particular technical features which have a major impact on economic competitiveness and on the overall economics of nuclear desalination, do need demonstration to confirm assumptions and estimates. Since several countries have ongoing activities in nuclear desalination, a Co-ordinated Research Programme is being proposed in 1997.

Over the coming years, it will be important to continue and deepen relevant studies and to assist interested Member States in building their nuclear infrastructures, e.g., through implementation of demonstration programmes. The IAEA will continue to support activities that encourage the active participation of countries, and that emphasize the sharing of technical expertise and the effective use of available financial resources. To facilitate the sharing of knowledge and experience, an International Nuclear Desalination Advisory Group (INDAG) is being established with the participation from Member States which are operating, developing, designing, planning, or are interested in nuclear desalination plants.

Results of this international co-operation so far illustrate that practical options exist for the application of nuclear energy to seawater desalination. But to realize them, it will be important to educate the public and to gain the confidence of investors. Means toward this include continued safe and reliable operation of nuclear plants, factual information on the comparative risks and benefits of nuclear and other energy sources, and conservative cost estimates for nuclear desalination facilities. This will be a sound basis for proceeding with effective development, demonstrations, and large-scale applications to help solve the world's growing water supply problem. ❐