Nuclear energy for seawater desalination: Updating the record

Results of IAEA-supported studies show a range of combinations and options for tapping the earth's seas and oceans

by
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Worldwide availability of potable water greatly exceeds the amounts needed and used, but resources are not evenly distributed. There are regions where water is scarce, and where the population is already at the mercy of inadequate supplies. Seawater constitutes a practically unlimited source of supply. When desalted, it can contribute to the solution of growing water problems, wherever the sea is accessible. Desalination, as all industrial processes, requires energy.

Fossil energy resources are limited, however, and their increasingly intensive use raises environmental concerns, including the threat of a gradual climate change with far-reaching consequences. At the same time, worldwide demand for energy is steadily growing, and adequate solutions are needed. Nuclear energy contributes significantly to the world's existing supply of energy, and it has the potential to do even more. Realizing this potential, however, is not an easy challenge.

This article reviews the national and global interest in using nuclear energy in seawater desalination processes. It further reports on recent IAEA studies examining the possibilities and potential of nuclear desalination today.

The early years

Combining the use of nuclear energy with the industrial process of supplying potable water by seawater desalination has been considered as far back as the 1960s. Indeed, it was characterized at that time by great optimism regarding the use of nuclear energy. Several studies were undertaken by individual countries, organizations, and nuclear industries. At the request of its Member States, the IAEA performed several technical and economic studies between 1964 and 1967, which were issued in the Technical Reports Series (Nos. 24, 51, 69 and 80).

At that time, there was considerable interest in promoting the use of nuclear energy for a variety of applications in addition to generating electricity. Applications included ship propulsion, district heating, energy supply to remote locations, industrial process steam supply, and seawater desalination. The idea of large agro-industrial-nuclear complexes was also pursued.

At a time of strong public and political support, these nuclear energy applications did not remain at the study stage, but proceeded to prototypes and demonstration projects. For seawater desalination, the design and construction of the Shevchenko complex (now Aktau in Kazakhstan) was launched by the former Soviet Union. The BN-350, a liquid-metal-cooled fast reactor, went into operation in 1973, and since then has provided both electricity and heat for the production of potable water.

What happened after the early efforts and achievements is now history. Developments in the nuclear field were concentrated in large power reactors for electricity generation, and the BN-350 is still the only power reactor in the world being used to supply heat for industrial-scale desalination. In Japan, several small-scale seawater desalination plants have been installed in large nuclear power stations for producing feedwater and miscellaneous services. There are also about 16 small desalination plants installed on Russian nuclear icebreakers and other nuclear-powered ships.

No further projects have been undertaken regarding the combination of nuclear energy and seawater desalination. Major developments, however, have taken place in both nuclear power and in desalination technologies, and several studies have been done.

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Renewed interest

At the 1989 session of the IAEA General Conference, renewed interest was expressed in the potential of nuclear reactors for seawater desalination. The Conference adopted a resolution [GC(XXXIII)/RES/515] which requested the IAEA to assess the technical and economic potential of nuclear desalination. Since then, this subject, under the title "Plan for Producing Potable Water Economically", has remained on the agenda of every General Conference, and successive resolutions have directed the Agency to further pursue relevant activities.

The importance of having adequate supplies of clean potable water for growing populations — coupled with the magnitude of problems involved in satisfying this need — is now globally recognized. Less known is that desalination, which during the 1960s constituted an emerging technology with a status comparable to nuclear reactors for electric power at that time, has become an established commercially available process, with further potential for improvements.

Nuclear reactors for electric power have also matured. Even though they have become a technically proven and economically competitive source of energy which supplies about 17% of worldwide electricity consumption, they have been plagued by problems of public and political acceptance in many countries. With reduced prospects for further penetration into the electricity supply market when compared to earlier expectations, interest in other applications, in particular seawater desalination, has reappeared.

A number of other factors are propelling the technology of nuclear desalination forward. They include growing concerns about the environmental effects of burning fossil fuels; recognition of the benefits of diversification of energy sources; the development of new advanced reactor concepts in the small- and medium-power range; and interest in achieving higher efficiency in energy consumption processes.

Since the renewal of the IAEA's activities concerning nuclear desalination, a growing number of countries and international organizations have expressed interest, participated in meetings, and provided information and support. The assistance and support, involving more than 20 countries, has included the provision of expert services and funds totalling US $570,000.

Recent IAEA reviews and studies

Following the 1989 General Conference, the IAEA took steps to update its review of available information on desalination technologies and the coupling of nuclear reactors with desalination plants. Results were reported in a 1990 technical document (TECDOC-574), *Use of Nuclear Reactors for Seawater Desalination.*

After the status review, the IAEA prepared and issued a report in 1992 entitled *Technical and Economic Evaluation of Potable Water Production through Desalination of Seawater by Using Nuclear Energy and other Means* (TECDOC-666). This report contained an assessment of the need for desalination based on recent analysis of the world's potable water resources; information on the most promising desalination processes and energy sources; and a review of nuclear reactor systems proposed by potential suppliers. It specifically evaluated the economic viability of seawater desalination by using nuclear energy in comparison with fossil fuels. The study encompassed a broad range of both nuclear and fossil plant sizes and technologies in combination with various desalination processes. Other aspects, such as environmental and institutional issues, were also discussed. The IAEA is continuing to collect and analyse relevant information on suitable nuclear reactors, desalination processes, coupling aspects, and potable water demand.

In 1991, in response to a request for assistance submitted by five North African States (Algeria, Egypt, Libyan Arab Jamahiriya, Morocco, and Tunisia) a regional feasibility study on nuclear desalination was launched. This study was presented to the participating countries this year.

Saudi Arabia has also requested IAEA technical assistance for a feasibility study on nuclear desalination. Work on this study was started in 1993, and is expected to be concluded by 1996.

Other work is being carried out in response to a resolution of the 1993 General Conference concerning demonstration facilities of nuclear desalination. As a first step, a study is being perfomed to identify, define, and characterize a practical set of options from which one or more demonstration facilities might be chosen. Work on this "options identification programme" started in 1994, and is expected to be concluded by 1996.

These activities, studies, and reports are not isolated efforts. Rather, they have been performed in a combined way, following a logical sequence, and complementing each other. They illustrate the IAEA's roles of facilitating the exchange of information and the transfer of knowledge and experience. In this way, it can serve as a catalyzer, organizer, or co-ordinator of nuclear desalination projects, and as a provider of technical assistance. The IAEA cannot, however, take a leading role for practical applications of nuclear desalination, nor can it design, build, own, or operate nuclear desalination complexes.

Combinations, options, and prospects

There are various regions in the world, and many specific locations in a number of countries, where water demand exceeds supply and where seawater desalination constitutes the only or the best available supply option. There are, however, no reliable databases which would permit global quantitative estimates of water deficits.

The IAEA's studies have found that the North African and Gulf regions are characterized by overall water scarcity. As an input to the North African feasibility study, the region's participating countries analyzed their respective water demand and supply situations and available options for increasing supply. They identified a series of specific locations, with production demands for seawater desalination ranging from 20,000 to 720,000 cubic meters per day by the year 2005. Indeed, the countries of the region already have had to use fossil-fueled energy for desalination to supply their growing needs for potable water. Presently, there is an installed desalination capacity of the order of a million cubic meters per day in the region. In Saudi Arabia, the water supply is even more dependent on seawater desalination; the currently installed capacity is around four million cubic meters per day.

Though better knowledge of the current situation and more precise forecasts of the evolution of demand and supply are needed in these regions, there is no doubt that desalination will be required in increasing amounts to complement surface and diminishing groundwater resources.

Due to the relatively high cost of seawater desalination independent of the energy source used, this option is currently only relevant for the supply of potable water for personal, domestic, and industrial use. For widespread irrigation in agriculture, the costs are still too high. This restriction is expected to prevail for at least several decades. Among available desalination processes, three have been selected for study. These are the RO (reverse osmosis) process, the MED (multi-effect distillation)

More countries are interested in desalting water from the world's oceans.

process, and the MSF (multi-stage flash distillation) process.

It has been found that there are no technical impediments to the use of nuclear reactors as an energy source for seawater desalination. Nuclear reactors could provide electricity or heat, or both, as required by the desalination processes. Regarding nuclear safety, the same principles, criteria, and measures would apply as to any nuclear power plant. An additional requirement is that the product water would have to be adequately protected against any conceivable contamination.

Practically any type of nuclear reactor could provide the energy needed for desalination. Technical, and in many cases also economic information, was collected on about 20 reactor concepts from potential vendors. These concepts correspond to different stages of design and are mostly in the small- and medium-power range. The amount of energy — either in the form of heat or electricity or both — that can be supplied by nuclear reactors in this power range is typically more than enough even for very large seawater desalination plants. For example, a desalination plant with a capacity of one million cubic meters per day could supply an urban concentration of three to four million people with sufficient potable water for domestic use. Such a desalination plant using the RO process would require a nuclear plant having an installed capacity of about 300 megawatts-electric. This same urban concentration of people also would require between 4000 to 6000 megawatts-electric of installed capacity to provide their corresponding electricity needs. Hence, nuclear power plants in the upper end of the small- and medium-size power range, and certainly the large-size nuclear power plants, would only constitute suitable choices when they are intended to supply electricity to consumers in addition to energy for seawater desalination. Thus, there is no reason why nuclear reactors could not supply both requirements simultaneously, and take advantage of the economic benefits accruing to large-size nuclear plants.

In the North African feasibility study, it was assumed that the nuclear reactors would be integrated into the electric grid system, and the size of the reactors would only be limited by the grid size, i.e. not larger then 10% of the interconnected capacity. With this assumption, the options considered were in the small- and medium-power range, except in Egypt, where even large-size reactors could be utilized.

With the methodology applied and the assumptions adopted, the economic assessment in the 1992 IAEA generic study has shown that the use of nuclear reactors as an alternative option to the use of fossil fuelled plants would in general be economically competitive for medium- and large-size nuclear plants supplying electricity only or electricity and heat that are integrated into the electric grid system. Water production costs would generally be between US $0.7 and $1.1 per cubic meter. Combinations with plants supplying only heat result in considerably higher water production costs.

The economic assessment performed within the scope of the North African feasibility study confirmed these earlier results. In this assessment, the economic data provided by the potential vendors were used, instead of the parametric values adopted in the generic study.

The results obtained in such assessments are considered suitable for indicating economic feasibility. However, firm prices as contained in formal tenders would be needed prior to investments.

The studies performed have shown that a very large number of possible combinations exist between the many different reactor concepts, the various desalination processes, and the different coupling schemes. The options identification programme now under way is expected to identify the most practical approaches, and determine the associated demonstration requirements.

The institutional issues regarding nuclear desalination are fundamentally those corresponding to any nuclear power project. In particular, the development of suitable local infrastructure constitutes a challenge to any country starting a nuclear programme. Experience has shown that this can be done, though it does involve major efforts sustained over a relatively long period of time.

The North African feasibility study has shown that it is possible to perform such a study in co-operation with countries on a regional level. It has also shown that there are mutual benefits, if a common approach and joint efforts are applied. Several subject areas appear to be of particular interest for regional co-operation. These include the development of databases, and activities related to technology transfer; nuclear safety; regulatory infrastructure; local participation; and the development of human resources .

The work done within the framework of the IAEA's nuclear desalination programme over the past 5 years has shown what can be achieved through cooperative approaches involving active national participation and related technical and financial support.

All the results so far illustrate that the application of nuclear energy to seawater desalination is a realistic option. The challenge ahead is to demonstrate its use by proceeding with effective development and practical applications. ❒