International Atomic Energy Agency

BOARD OF GOVERNORS
GENERAL CONFERENCE

GOV/2855-GC(40)/4
8 May 1996

GENERAL Distr.
Original: ENGLISH

PLAN FOR PRODUCING POTABLE WATER ECONOMICALLY

Report by the Director General to the Board of Governors and to the General Conference

1. Last year, the General Conference had before it document GC(39)/12, which summarized the progress of various studies and other actions initiated by the Agency on the topic "Plan for producing potable water economically." The document also included a summary of the first phase of the **"Options Identification Programme (OIP),"** which was initiated in 1994. Following discussions based on information provided in this document (GC(39)/12), the General Conference adopted resolution GC(39)/RES/15.

2. Noting the continuing interest of a number of Member States in seawater desalination using nuclear energy and stressing the importance of adequate water supplies for mankind, the General Conference, in resolution G(39)/RES/15, requested the Director General to continue relevant activities and consultations, and called upon Member States to provide expert services and extrabudgetary resources in support of the activities relating to seawater desalination using nuclear energy. The Director General was further requested by the General Conference to report on the progress made in the implementation of the resolution. The present document has been prepared in fulfillment of that request and is being issued for the attention of both the Board of Governors and the General Conference.

Activities Undertaken Relevant to Nuclear Desalination

3. The study "Nuclear desalination as a source of low cost potable water in North Africa" and previous studies have led to the conclusion that small and medium reactors (SMRs) are most suitable for nuclear desalination applications in the countries where electricity grids are relatively small. To discuss the status and recent progress made in the development, deployment and application of SMRs, to review the past experience of the introduction of SMRs and discuss options, models and constraints for introducing SMRs in developing countries, an Advisory Group Meeting (AGM) was held in October 1995. A status report containing up-to-date technical information on most of the SMRs being developed, designed or already commercially available has been completed and was sent for publication.

4. Recent results and advances in technology development and design of integral reactors were discussed and the existing experience along with safety and economic aspects were reviewed at a Technical Committee Meeting (TCM), held in October 1995.

5. In order to review the global experience of coupling nuclear plants with district heat networks and desalination processes, an AGM was held in December 1995 and a consultancy was held in February 1996. During these meetings, it was confirmed that radioactivity levels in the heat consuming parts of these industrial complexes have always stayed within regulatory limits. It was also reported that about 500 reactor-years of operational experience from nuclear co-generation and heat-only reactors are available. The largest part of this accumulation stems from the operation of WWER type reactors in the former Soviet Union and the Eastern European countries. Nuclear energy for seawater desalination plants has been used at locations in Japan and in Kazakhstan. While in Japan the desalted water is mostly consumed at the nuclear power plants, in Kazakhstan the desalination complex supplies water to a near-by residential area.

Finalization of Feasibility Studies

6. In the North African regional feasibility study, which was initiated in 1991, emphasis was placed on analyzing the electricity and potable water demand and the available energy and water resources in the participating countries. The scope of the study included the selection of representative sites, analysis of site specific economics for various combinations of energy source and desalination process appropriate for each site, financial aspects, local participation, infrastructure requirements and institutional and environmental aspects. These activities were performed by the relevant institutions in the participating countries, with assistance provided by the Agency. The study report is in the process of publication.

7. The development of a computer code, which enables site-specific technical optimization and economic evaluation has been completed, and the code is now available to interested Member States. A training course on the operation of the code has been held for a group of North African experts. A more detailed computer code for allocating the costs of dual-purpose plants and determining their optimum coupling has been developed by the Agency and applied for a reference site. The results will be published in 1996.

Nuclear Desalination Programmes in Member States

8. Several bi-lateral and national programmes on nuclear desalination are in progress, either with or without the Agency's involvement.

9. Morocco is about to undertake a joint "Pre-project study on demonstration plant" with the People's Republic of China. The Agency has continued to provide assistance to the Government of Morocco since 1995, within the framework of a technical co-operation project. In the study, a multi-effect distillation (MED) process is to be selected for desalination and connected to a 10 MWth heat-only reactor which will be supplied later by China to produce 8,000 m^3/day.

10. Indonesia intends to undertake a feasibility study on the application of a high temperature gas reactor for the combined production of methanol and desalinated water, in addition to production of electricity, for the Natuna gas field. Agency's assistance in provision of expert services and training has been requested. Indonesia has also expressed interest in nuclear desalination in general, which might contribute to the supply of potable water to some of the islands and regions where supply of fresh water is difficult or inadequate.

11. Egypt has expressed an interest to undertake a pre-project design study on coupling a reverse osmosis (RO) systems to a nuclear facility for the desalination of seawater. The objective of this pre-project study is to acquire ability to plan and design RO systems and their coupling to nuclear power sources. Agency's assistance in provision of expert services and training has been requested for performing this study.

12. In the Republic of Korea, the conceptual design of a 330 MWth multi-purpose nuclear plant is in progress for demonstration of co-generation of electricity and heat as well as seawater desalination. India is carrying out activities concerning the demonstration of nuclear desalination using a 200 MWe pressurized heavy water reactors. The Russian Federation has designed a floating nuclear desalination complex using a power reactor for icebreakers.

Consultations with International Organizations and Member States

13. Acting on resolution GC(39)/RES/15, the Secretariat invited comments from the competent organizations of the United Nations system and other relevant intergovernmental organizations, concerning: (i) the main conclusions of the IAEA TECDOC on "Technical and economic evaluation of potable water production through the desalination of seawater by using nuclear energy or other means", and (ii) the progress made during the first phase of the OIP.

14. As of April 1996, four international organizations have responded. FAO has provided a relevant data base on water resources and rural water use in Africa. WMO is sharing the Agency's position that nuclear water desalination offers important possibilities for overcoming critical water shortages in certain regions of the world. OECD/NEA and UNIDO have also responded.

15. Similarly, in response to the resolution, the Secretariat has sent letters to international organizations and prospective donor countries, requesting support in the form of cost-free expert services and extrabudgetary funds, in order to complete the second phase of the OIP in 1996. Twenty-two Member States and two international organizations have expressed their specific support, since the Agency's activities on the subject of nuclear desalination of seawater was resumed, as shown in Table 1. The Agency has received a total of US$ 670,000.00 as extrabudgetary funds, as summarized in Table 2. In addition, several cost-free experts have been made available to the Agency. For completion of the second phase of the OIP, cost-free experts who have worked on the first phase of the OIP continue to be available. US$ 65,000.00 as extrabudgetary funds has been pledged as of April 1996.

16. The Secretariat has continued consultations with interested Member States concerning the main conclusions of the above mentioned TECDOC and the subsequent progress. In addition, the Secretariat has undertaken several consultations, such as "Review of experience with nuclear heat applications: district heating, process heat production and desalination," for the implementation of the main recommendations of the Advisory Group on Demonstration Facilities, which were made in 1994. A number of Member States supported the Agency's activities by participating in meetings and by providing consultations.

17. The status of the Agency's activities on nuclear desalination as of March 1996 was presented to the interested Member States for review and comments on 18 April 1996 at VIC, Vienna. Nineteen representatives from 18 Member States were in attendance at this presentation and provided their interests and comments.

Activities Included in The 1997/98 Agency's Programme

18. The Agency's 1997-1998 Programme and Budget includes proposals for tasks to be undertaken in Sub-programme A3.06 (Co-generation and heat application), most of which are related to nuclear desalination. Considering the vital importance of producing potable water, several new tasks with specific goals have been proposed. The progress in the Agency's activities on nuclear desalination and the results of feasibility studies have been considered in planning and will be implemented once they ar approved. These new tasks are related to:

- User requirements for nuclear seawater desalination plants,
- Technology, design, and safety aspects of non-electrical application of nuclear energy,
- Local participation in nuclear seawater desalination plants, and
- Institutional aspects of nuclear seawater desalination plants.

19. The Agency is examining the possibility of including a follow-up study on the North African regional feasibility study in its 1997/98 programme and budget as part of technical cooperations in this region, to provide expert services for a review of the regional infrastructure capabilities and to identify any necessary improvements for the deployment of nuclear desalination plants. Training in the utilization of relevant computer programmes is also being considered.

20. Considering the growing international interest in nuclear desalination of seawater, as well as ongoing programmes in some Member States, the Agency will hold an international symposium on the subject in 1997. The Republic of Korea has expressed a strong interest to host this symposium. For detailed preparations of the Symposium, a Steering Committee has been established with representatives from nine Member States and relevant international organizations. The European Commission, the Global Technology Development Center, the International Desalination Association, UNIDO, WHO and WMO have expressed their willingness to support the Symposium in various forms, such as financial support, participation in the Steering Committee, presentation of papers or participation in panel discussions.

Status of the Options Identification Programme

21. The General Conference endorsed in resolution G(XXXVIII)/RES/7 of its 1994 session the recommendation of an AGM that there is a need to establish a programme for identifying a practical set of options for coupling desalination processes to nuclear reactors, from which one or more demonstration facilities with well-defined objectives might be chosen. The objective of a demonstration programme is to build confidence, through the design, construction, operation and

maintenance of an appropriate facility or facilities, that nuclear desalination can be successfully accomplished technically and economically, while meeting established relevant safety and reliability criteria. Thus, as a first step, a two-phase programme, the OIP has been initiated.

22. The purpose of the OIP is to select candidate reactor and desalination technologies that could serve as practical demonstration of nuclear desalination of seawater, supplementing the existing know-how and experience. As this programme was not intended to serve as either a reactor or a desalination process development programme, demonstration options were to be based on reactor and desalination technologies which are themselves readily available, without further development being required at the time of the demonstration.

23. The work has been performed by a Working Group, consisting of representatives from interested Member States and Agency staff. The group, under the Agency's co-ordination, has taken the responsibility for defining and performing all activities necessary to identify and fully characterize a set of practical demonstration options. It has carried out its activities through a combination of periodic meetings and individual work assignments. Throughout the duration of the programme, peer review meetings have been convened by the Agency through AGMs, TCMs and consultancies to address specific technical issues.

24. During the first phase of the OIP, the future market survey of desalted water demand revealed that large water production facilities, each producing 200,000 to 500,000 m^3/day of desalted seawater, could be constructed. For examining the reactor types to be coupled with desalination technologies which might be deployed in the near term for nuclear desalination projects, the list of worldwide reactors was reviewed and screened for potential availability depending upon the status of the design and licensing of each concept. Several candidate combinations were narrowed down to those which were thought to have the greatest potential for yielding technical, operational and economic data having the broadest general applicability. The progress of the first phase of the OIP activities was reported as an interim report to the General Conference of 1995 for endorsement.

25. The second phase of the OIP has been devoted to a detailed analysis of the most practical options for demonstration. To provide a basis for a user to proceed with a project implementation, issues regarding the project planning and implementation of demonstration and commercial deployment have been analyzed. To accomplish the goal of the second phase of the OIP, a variety of activities have been performed including consultancies. Activities in the second phase have addressed, in particular, the following:

- Review of current technical status and prospects of reverse osmosis technology;

- Review of experience with nuclear heat applications: district heating, process heat production and desalination;
- Recommendations to OIP from the experience with nuclear heat applications;
- Progress review of the OIP activities;
- Survey on development trends of desalination processes;
- Review of cost parameters of seawater desalination plants.

This second phase of the OIP is expected to be finalized before the end of 1996.

Major Findings of the Options Identification Programme

26. A market survey indicates worldwide demand for desalination will double every eight to ten years during the next decades. Most of the demand is in the Gulf and the North African regions, but will expand to other regions as well. It is expected that most desalination plants to be built will be in three distinct size ranges, i.e. small (the capacity of less than 10,000 m^3/d), medium (up to 100,000 m^3/d) and large (up to 500,000 m^3/d). Due to the relatively high transport cost of water, plants larger than 500,000 m^3/d would not be economically feasible.

27. Large scale commercial deployment of nuclear desalination will mainly depend on economic competitiveness with available alternative options, and adequate confidence in this application. Should these conditions be satisfied, there seems to be no reason why nuclear desalination plants could not penetrate the potable water market. It could and should be commercially deployed in situations, where it can offer adequate incentives. The continuing and increasing interest shown by the Agency's General Conference is a clear indication of growing interest in nuclear desalination.

28. In the course of selecting 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 status and licensing status was used as a filter. Applying these criteria, the reactor technologies currently available or which might become available within a period of approximately the next ten years were identified. Medium size pressurized light water reactors and pressurized heavy water reactors have been considered as most suitable reactor types. Small reactors might be also feasible at sites with low water demand and where alternative systems for potable water production are expensive.

29. Consideration was also given to the desalination technologies suitable for coupling to a nuclear reactor. Desalination of seawater by the RO and the MED processes appear to be most promising, due to relatively low energy consumption and investment costs, as well as high reliability

as compared with the multi-stage flash (MSF) process. Furthermore, the MED process appears to be less sensitive to corrosion and scaling than the MSF process. Therefore, MSF has been excluded, having no inherent advantages over MED.

30. When combining a nuclear reactor and a desalination process to form an integrated complex, the compatibility in combination was taken into account in the selection procedure. Inter alia, timing, infrastructure and investment requirements were considered for their significance in identifying the practical options for demonstration.

31. As a result of the above-mentioned narrowing down process, three options were identified as recommended practical candidates for further consideration as nuclear desalination demonstration projects. These options, using well-proven water-cooled reactors and desalination technologies, are:

Option 1: RO desalination plant having limited size of water production capacities (two or three trains of up to 10,000 m^3/d each) in combination with a medium-size nuclear power reactor being constructed or in an advanced design stage with construction expected in the near term. This combination will be easily applied to larger commercial water production facilities.

Option 2: RO desalination plant of limited size as above, in combination with a currently operating reactor with some minor modifications for integration. Again this combination will be straightforward to extrapolate to commercial size production facility.

Option 3: MED desalination in combination with a small reactor to be newly constructed, which would be suitable for water production capacities of up to 80,000 m^3/d.

32. More than a dozen nuclear power reactors, which would be suitable for Option 1, are under construction on the seashore. Several other units are also in an advanced design stage, and their construction is expected to start in a relatively short time. Among nearly 70 nuclear power plants which are currently operating on the seashore worldwide, several reactors suitable for demonstration for Option 2 as defined above would be available. From among small reactors being developed, several reactors suitable for Option 3 could be available.

33. The investment required for a demonstration RO facility would be about US$ 30 million for two RO trains of 10,000 m^3/d each. Modest costs are also expected for some minor modifications

of the secondary circuit of the nuclear power plant. Option 1 and Option 2 could thus be implemented with a relatively modest investment. A small reactor with integrated MED desalination, as proposed for Option 3, would cost about US$ 200 to 300 million.

Issues for of Nuclear Desalination Demonstration

34. Desalination facilities connected to NPPs in Kazakhstan and Japan have been producing desalted water for years. This valuable experience would have to be taken into account in order to determine what issues should be specifically addressed in other ongoing or planned activities and projects on nuclear desalination.

35. Several technical items were identified as possible subjects needing more thorough examination and evaluation, covering technical, safety and economic issues. Such specific subjects for investigation include:

- interaction between nuclear reactors and desalination systems;
- nuclear safety requirements specific to nuclear desalination systems;
- the impact of feed-water preheating on the performance of RO systems.

36. Currently, there are ongoing activities in Canada, the People's Republic of China, India, the Republic of Korea, Morocco, and the Russian Federation. Studies in some other interested Member States may also lead to the implementation of further projects. These national and bilateral projects will contribute to international know-how and experience in nuclear desalination, and can be considered as a basis for international co-operation and support which could be beneficial also to other interested Member States.

37. For the ultimate objective of facilitating and promoting commercial deployment, the demonstration programme has to be directed to those issues which are relevant to commercial projects. These issues are technical, economic, financial, safety, reliability and institutional, covering a wide spectrum. Some issues, in particular those technical features which have a major impact on economic competitiveness do need demonstration.

38. The infrastructure requirements for nuclear desalination plants are primarily determined by what is required for nuclear industries. These requirements are major issues for any Member States without having previous nuclear power experience. A demonstration project, if implemented in such a Member State, could be a very effective and practical framework for developing its nuclear infrastructure, in particular its nuclear regulatory structure.

Issues for a Commercial Production Facility

39. There could be a number of issues related to commercial production facilities. Most of the technical aspects could be addressed through the mechanism of demonstration and would ultimately enhance the level of confidence in commercial deployment. There could be issues which would be particularly important and should be thoroughly addressed before commercial deployment, such as: (i) Site selection and site qualification, scheduling, manpower and organizational requirements, (ii) User requirements, or (iii) Local and national infrastructure development.

40. National policies, such as (i)National energy plan, (ii)National potable water supply assurance plan, (iii)Policies concerning international relations, or (iv)Financing, governmental involvement and promotion policies, are also important to proceed with nuclear desalination deployment.

41. For the success of commercial nuclear desalination deployment, firm governmental commitment based on sound national policies and plans, and with adequate international arrangements is of crucial importance. Other essential factors to be met include: (i) Regulatory issues to be resolved before the start of construction, (ii) Efficient project management with tight control of quality, costs and schedule, and (iii) Secured financing.

Possible future actions

42. The next step for proceeding with a nuclear desalination demonstration programme should be for one or more Member States to proceed with preparatory actions for demonstration projects, including site selection and qualification, identification of user requirements, project specifications and the development of infrastructures as may be required for project implementation.

43. It is also important to continue and deepen relevant studies, to exchange information, and to promote international co-operation and collaboration in the subject area. On request, and with the support of the Member States, the Agency would continue its related activities. In order to effectively co-ordinate such continuing activities, one possible framework could be to set up an advisory body to the Agency's activities on nuclear desalination with the participation of interested Member States that are developing or designing nuclear desalination plants or are considering their deployment. This body would facilitate the exchange of information on national and international programmes, projects and experience, and identify and review relevant key issues for nuclear desalination deployment.

Table 1 Support to the IAEA plan for producing potable water economically

	Response to	Nature of response	Type of support
Algeria	general	official, user	participates in feasibility study
Argentina	RES/592	official, vendor	provided funds for overall activity, offered experts
Canada	RES/592-617	official, vendor	provided funds for overall activity
China	RES/592-617	official, vendor/user	provided partly cost-free-expert, offered nuclear island
Cuba	RES/617	official, user	has interest
Egypt	general RES/592	official, user informal	participates in feasibility study, offered partly cost-free experts
Germany	RES/617	informal, vendor	offered floating desalination facility
India	RES/592-617	official, vendor/user	offered partly cost-free experts
Indonesia	RES/617	official, user	has interest
Israel	general	informal, vendor	offered desalination facility
Japan	RES/617	informal, vendor	offered nuclear equipment
Jordan	RES/592	official, user	provided funds for overall activity
Korea, Repulic of	RES/7	official	provided funds for Options Identification Programme, offered to host Symposium'97.
Libyan Arab Jamahiriya	RES/617 general	informal official, user	offered financing for project participates in feasibility study, provided funds and cost-free experts for overall activity
Mauritius	RES/617	official, user	has interest
Morocco	general	official, user	participates in feasibility study
Peru	RES/617	official, user	offered site
Russia	general	official, vendor	offered floating nuclear desalination plant
Saudi Arabia	general RES/592	official, user official	participates in feasibility study offered experts
Tunisia	general	official, user	participates in feasibility study
Turkey	RES/617	official, user	has interest
United States of America	RES/592-617	official, vendor	has interest, provided funds for Saudi Arabian feasibility study
Arab Atomic Energy Agency	RES/592	official	provided funds for overall activity
Global Technology Development Centre	general	official	offered funds for Symposium'97

Table 2 Extrabudgetary Funds for Activities on Seawater Desalination using Nuclear Energy, US$

	1991	1992	1993	1994	1995	TOTAL	note
Argentina			10,000	5,000		15,000	
Canada				18,657		18,657	*1)
Jordan			2,800			2,800	
Korea, Republic of					100,000	100,000	
Libyan Arab Jamahiriya	100,000	53,100		50,000		203,100	
USA				325,000		325,000	*2)
Arab Atomic Energy Agency				6,000		6,000	
TOTAL	100,000	53,100	12,800	404,657	100,000	670,557	

*1) Canadian $ converted to US$

*2) Support for Saudi Arabian feasibility study