Some Activities in Member States (2019-2020)

Algeria In response to water scarcity which was experienced by the country over the past four decades, national authorities have implemented a seawater desalination program for taking in charge the increasing water demand expressed mainly by the population. This extensive desalination program is based on natural gas as an energy source. Due to the strong demand on natural gas seen in recent years, another program based on renewable energies is set up recently in order to diversify energy sources.

Nuclear power is expected in this new program related to the diversification of energy sources. To this end, feasibility studies were carried out on the seawater desalination by means of nuclear power. These studies demonstrated that nuclear desalination is an option to consider in the near future. In this communication, it has reviewed briefly the climatic characteristics of Algeria. It is also presented the global strategy developed for conventional and unconventional resources and key indicators related respectively to: water, energy and desalination. A brief description of the program of activities initiated for the short term in the field of nuclear desalination is presented.

Hamma desalination plant, the largest SWRO in Africa [2]

Argentina has established a solid Nuclear Desalination and Integrated Water Management programme in the frame of the IAEA activities. Studies related with the coupling of RO and low-temperature multi-effect evaporation (LT-MEE) plants to SMR have been achieved. For the design of modular plate evaporator in a LT-MEE technology, the interaction between R&D/technical groups and engineering companies was required. A global water management programme is well accepted by NPP engineering authorities. In that sense, the recovery of the Steam Generator Blow Down is under analysis for NPP under operation (Atucha I) and future project as well (CANDU 4th NPP,800 MWe). Also, discussions with NPP authorities/operators show that the reduction in water cost, chemicals consumption, and features of plant availability and life management are taken into account for the selection of the technology for the Demineralized Water Plant. The hybrid RO+ Electrodeionization (EDI) is still seen as not fully reliable for the production of demineralized water. The future activities for ND and WM programme are focus in i) reinforce connections with local companies and international engineering companies (that hired for support NPPS in life management) for ND and WM divulgation, ii) establish a legal framework between engineering companies and designer institutions in the technology transfer. ii) continue encourage engineering authorities from CNEA projects and NPPs in the importance of ND and WM implementation.

Title photo: Construction process of Carlsbad desalination plant in California [1]

Belgium With access to drinking water already a major challenge for as much as one quarter of the world's population, and further forecasts predicting that by 2030, 47% of the global population will face water scarcity, The Global Clean Water Desalination Alliance – H_20 minus CO_2 is one of the few climate initiatives dealing with the water-energy nexus and climate change. As the quest for finding solutions to combat climate change in view of the impacts of global warming on water resources increases, nuclear desalination can offer significant potential to substitute fossil fuel as a source of energy for desalination. The integrated hybrid MED-RO design can make use of warmer seawater discharged from NPP or reject sections final condenser of MED to reduce energy consumption, reduce size of seawater intake and outfall. To minimize energy consumption and reduce power losses of NPP it is recommended to use straight MED with the lowest extractions steam pressure available using straight MED, rather than MED-TVC. In general, there is very important need to educate both parties the NPP and desalination islands about technology implication, operational and maintenance requirements of both. At the same time, continuous public relations campaign is needed to assure the public of safety, explain benefits and reliability of Nuclear Desalination.

Brazil The national development of a small PWR for cogeneration of water and electricity can improve the country capacity to address water shortage issues. Therefore, studies have been initiated aiming to adapt and improve a previously Brazilian designed small PWR in order to optimize it for cogeneration of water and electricity: the DES-SAL reactor. The DES-SAL reactor will meet Generation III and post-Fukushima requirements. Design innovations for the system are sought both in the desalination process and in the coupling of the secondary reactor circuit and the desalination unit. The concept adopted in the project is based on shortening the steam expansion in the turbine, thus stopping the expansion at atmospheric pressure rather than at the very low pressures usually adopted in PWR systems designed for electricity generation only. In the proposed system, steam condensation occurs at 100 C, a temperature sufficiently high to provide the heating required to operate a Membrane Distillation unit. From the 75 MWth generated in DES-SAL, 17 MWe of electricity will be produced and the remainder 58 MWth will be available for the Membrane Distillation process. A prototype of a Membrane Distillation unit will be built at the Instituto de Engenharia Nuclear/CNEN in order to study and optimize the Membrane Distillation process that will be employed in DES-SAL.

China According to a recent research article published in a desalination journal, China has utilized the IAEA's economical assessment programme DEEP, which showed that China has the capability and capacity to eliminate water scarcity using nuclear energy by the year 2030. These claims are based on the predictions of 23.1 billion m^3/year at \$0.86/m^3. The article also states that this technology will be affordable for not only the major cities but also the lower income and rural areas with supply chain costing \$0.99/m^3 to \$1.79/m^3. The comparison to fossil fuel powered desalination plants shows that while in the short run, nuclear is more expensive, it is actually more favourable in the long term.

MED desalination in Tianjin 2ith 200,000 m^3/d [3]

Until now only a RO desalination plant was built in Hongyanhe Nuclear plant. There should be more influence on nuclear power plant authorities. MED system is found to be more efficient compared with RO system in north China, where the temperature of seawater is lower. Research activities on the evaporator design for a MED system used in platform with Nuclear Power Plant were conducted.

Egypt was one of the countries that realized the importance of nuclear power to secure the supply of electricity and fresh water. Several attempts haven't been materialized in the last 3 decades due to different factors. Recently, Egypt has reconsidered the nuclear power as an option to supply electricity and signed cooperation agreement with Russia. The country intended to develop Seawater desalination modules with total capacity up to 170 000 m3/day using hybrid MED/RO technology for each NPP block. The proposal for new seawater desalination modules connected with the new nuclear power plants units was cancelled because of the possibility to cause delays in the construction of the NPP due to the required modifications on the design, as well as not being licensed in the supplier country.

India has demonstrated nuclear desalination and is in regular operation round the clock. In India, there is a requirement for large, medium and small size desalination and water purification units as part of the Integrated Water Resource Management. The 6300 m^3/d Nuclear Desalination Demonstration Plant using hybrid Multi-Stage Flash-Reverse Osmosis technology in Kalpakkam is coupled to Madras Atomic Power Station. High quality distilled water produced from MSF section is supplied to MAPS for high end applications. The rest of it, is supplied to water reservoir along with potable water produced from RO section for augmenting the water supply.

Desalination plant at Kudankulam nuclear reactor site in India [4]

Earlier, a Low temperature desalination plant coupled to a nuclear research reactor at Trombay was demonstrated. With this, India has the experience with different types of coupling mechanisms and isolation loops for nuclear desalination plants. It is planned to integrate 3×800 m^3/d Multi-Effect Distillation Thermal Vapour Compression plant with Advanced Heavy Water Reactor.

Japan has a very extensive nuclear energy program. With all nuclear power plants located on sea shores and utilize the ocean as a heat sink. Eight of these plants are hooked up with desalination plants used mostly for fulfilling the need of freshwater for the boiler of the reactor, but also potable water and household water. These plants have a capacity ranging from 1000-1300 m^3/d and use Multi-Stage Flash Distillation, Multi-Effect Distillation, and Reverse Osmosis. With successful operation over 30 years, there have been no contamination of steam or water and no negative effects on the environment. They are looking at the potential to add more desalination plants in the future.

Pakistan Karachi Nuclear Power Plant, KANUPP has gone through experience of integrating NPP with desalination system, MED type, Low temperature, Low pressure using extraction steam of turbine cycle, operating safely since 2009.

KANUPP Nuclear Desalination Demonstration Plant, Pakistan [5]

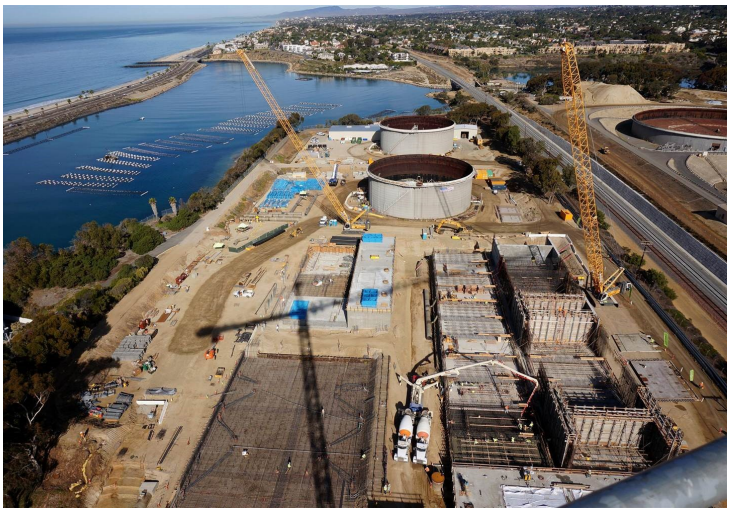
Pakistan is contributing through its experiences with IAEA in various Technical Meetings and Coordinated Research Program and sharing the experiences gained in the field of design, manufacturing, installation and commissioning of the ND Plant. Successful operation of KANUPP NDDP project may be used as evidence regarding technical viability for coupling desalination with Nuclear Power Plant safely in future projects. Feasibility of coupling for deploying Nuclear Desalination Plant for upcoming Karachi coastal projects (PWR: 2×1100 MWe) was also considered.

Kazakhstan Plans of State Corporation Rosatom (Russian Federation) on combining Nuclear Power and Desalination Technologies for constructed worldwide Nuclear Power Plants inspired a renewed interest to experience of Kazakhstan in 20-years operation the largest in the world Industrial Desalination Plant integrated with Fast Breeder Nuclear Reactor BN-350. In the stage of intensive discussions there are plans for cooperation of Kazakhstan and Russian experts for development and testing new ideas and approaches for application of Nuclear Desalination as for NPP Integrated Water Management as for supply with fresh water the population and industry in areas of NPP location.

Russia has developed a business of selling nuclear technologies to other countries. Their technology is currently being considered for Iran's planned nuclear plant Bushehr and is already in use in plants such as in Kazakhstan. In February 2015, Egypt and Russia signed a nuclear agreement considering nuclear desalination plant. While they continue their international relations, they investigate new technologies such as the use of Small Modular Reactors for desalination and the possibility of floating power plant station desalination – proposing that the latter could produce up to 240,000 m^3/d of fresh water.

USA On-site nuclear desalination experience in the US is still quite limited (e.g., the reverse osmosis membrane filtration system for make-up water and on-site general use at the Diablo Canyon nuclear power station is a long-standing example of this). This could very well change in the coming years with the expected deployment of advanced light water small modular reactors (SMRs). The promise of the advanced reactor systems (i.e., non-light water reactors [LWRs] and advanced SMRs) is also seen as gaining momentum, with the current development of several US reactor designs, including fast high temperature gas-cooled, sodium-cooled, molten salt, and others.

Saudi Arabia There is a tremendous demand for fresh water worldwide due to an increase in population, exponential industrial growth and also drastic climate changes. These factors globally lead to great challenges to many countries. In the Kingdom of Saudi Arabia the water demand is expected to increase from 6.5 Mm^3 per day to more than 9Mm^3 per day by 2030. To fulfil the demand of water more and more countries are becoming dependent intensively on seawater desalination. Desalination in kingdom of Saudi Arabia became strategic choice nowadays. Today Kingdom of Saudi Arabia tops in the production of desalinated water which is about 16.5% of



Construction of Carlsbad desalination plant (1)

The general interest in cogeneration and non-electrical applications of nuclear power is also catalysing the specific interest in nuclear power-enabled water production and treatment applications. The US Department of Energy, its national labs and industry (several reactor vendors and utilities) are actively exploring the use of nuclear fission energy beyond the electricity sector, i.e., as hybridized nuclear energy systems. The economic case for any of these applications needs to be demonstrated, and initial indications are that this could be achievable for several of the advanced SMR designs that could potentially be deployed in the next 10 to 25-year timeframe

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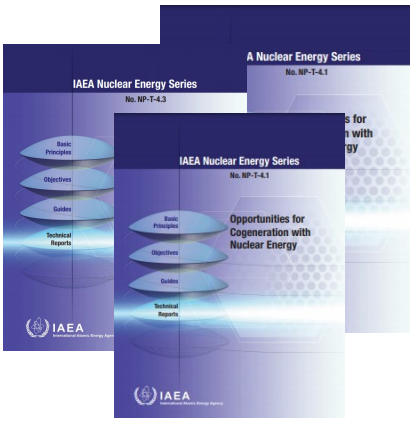
(1) Carlsbad Desalination Project, http://carlsbaddesal.com/
(2) Desalination technology: Algerian plant highlights the challenges of getting drinking water to a parched region, www.sciencebusiness.net/news/76602/
(3) Seawater Desalination: A Promise for China's Future? http://www.waterworld.com/articles/wwi/print/volume-28/issue-4/
(4) Koodankulam Desalination: Looming Calamity for Gulf of Mannar, http://www.dianuke.org/koodankulam-desalination-looming-calamity-for-gulf-of-mannar/
(5) courtesy of Pakistan Atomic Energy Commission

Publications !



Three related Nuclear Energy Series documents were Published:

Guidance on Nuclear Energy Cogeneration (NP-T-1.17)

Cogeneration, i.e. the production of electricity and heat, has proven to be a highly efficient and environmentally attractive option for energy conversion. Nuclear cogeneration could be considered as an option in light of actions on climate change. However, nuclear cogeneration is not widely deployed. This publication provides a quick introduction to the advantages, experience, and future planning for implementation of nuclear cogeneration. It also highlights some demonstration projects that were developed in the past in connection with industries, describing technical concepts for combined nuclear-industrial complexes. The publication is intended to be of interest to users in academia and industry as well as government agencies and public institutions requiring basic information on various aspects of using nuclear power for cogeneration.

(download or order hard copies here)

Opportunities for Cogeneration with Nuclear Energy (NP-T-4.1)

This publication presents a comprehensive overview of various aspects relating to the application of cogeneration with nuclear energy, which may offer advantages such as increased efficiency, better cost effectiveness, and reduced environmental impact. The publication provides details on experiences, best practices and expectations for the foreseeable future of cogeneration with nuclear power technology and serves as a guide that supports newcomer countries. It includes information on systems and applications in various sectors, feasibility aspects, technical and economic details, and case studies.

(download or order hard copies here)

Industrial Applications of Nuclear Energy (NP-T-4.3)

This publication provides a detailed overview of the potential use of nuclear energy for industrial systems and/or processes which have a strong demand for process heat/steam and power, and on the mapping of nuclear power reactors proposed for various industrial applications. It describes the technical concepts for combined nuclear–industrial complexes that are being pursued in various Member States, and presents the concepts that were developed in the past to be applied in connection with some major industries. It also provides an analysis of the energy demand in various industries and outlines the potential that nuclear energy may have in major industrial applications such as process steam for oil recovery and refineries, hydrogen generation, and steel and aluminium production. The audience for this publication includes academia, industry, and government agencies.

(download or order hard copies here)

Upcoming Publication

Technical Report on Vendor and User Responsibilities in Nuclear Cogeneration Projects

The objective of this document is to: analyze responsibilities and requirements of users and vendors involved in nuclear cogeneration plants compared to the ones for standalone NPPs; develop a generic algorithm to define the roles of various stakeholders in nuclear cogeneration project in general, and users and vendors in particular; in consideration of the technology, business models, regulations, public sensitivity, media involvement, scientific groups, etc; and develop guidelines for vendors and users of retrofit and new build projects covering production of electricity and process steam for nuclear cogeneration applications such as desalination, district heating, hydrogen production.

2017 Meeting of Technical Working Group on Nuclear Desalination

The International Nuclear Desalination Advisory Group (INDAG) was established by the IAEA in 1996. INDAG played an active role in the past years, contributed to promotion and stimulation of nuclear desalination activities, and provided a forum for Member States to exchange information on the technological developments , operations, and demonstration of integrated nuclear desalination systems. To enhance its functions, the IAEA has reformed INDAG into a Technical Working Group on Nuclear Desalination (TWG-ND) in 2008. The sixth meeting of the TWG-ND was held from 20-22 Nov 2017 at VIC, Vienna, and was attended by 9 members representing 8 MSs.

The main objectives were to:

- Review activities undertaken by the IAEA Secretariat and Member States in the fields of nuclear desalination and integrated water resources management (IWRM) at nuclear facilities;
- Conduct an objective assessment on the future of nuclear desalination including: near-term deployment, responsibilities of users and vendors, capacity building, localization, socio-economic and environmental aspects, and the potential deployment of nuclear desalination projects as a measure for climate change mitigation;
- Provide a forum for sharing information and knowledge on latest developments on national and international programs in the areas of nuclear desalination and IWRM; and
- Provide advice and guidance on future IAEA activities relating to nuclear desalination and IWRM.

The following conclusions were reached:

- The members of TWG-ND expressed their satisfaction with IAEA's conducted activities on non-electric applications and on nuclear desalination specifically and also expressed their will to participate in the revision of the upcoming documents, mainly on nuclear desalination and water management in NPPs.
- The TWG-ND agreed that nuclear desalination activities present an important and impactful opportunity for nuclear power applications in the future, especially as new nuclear reactors come on line. Advanced HTR type reactors as well advanced SMRs, may provide unique features and operating parameters for electricity generation (e.g., higher temperatures and thermodynamic efficiencies) which could also enable greater deployment of coupled desalination operations. Coupling of the desalination plant (e.g., thermal, mechanical separation, or hybrid operations) should be considered either with extracted heat directly from the power cycle or rejected heat.
- Nuclear desalination should be considered as an important carbon-free generation option for augmenting water resources.
- The members of the TWG-ND agree to proactively engage the IAEA and specifically on nuclear desalination with ideas and concepts for future implementation by the Agency.
- Existing nuclear desalination experience to-date has demonstrated the benefits of nuclear energy beyond electricity production and provides some of the technical basis required for future expansion of similar activities.
- Some of the Members of the TWG showed interest of their MSs to embark on new nuclear desalination installations incorporating existing and emerging desalination technologies.

The TWG-ND recommended the IAEA to:

- Consider initiating a new CRP to examine the specific benefits of SMRs (and particularly advanced HTR) for nuclear desalination and other non-electric applications.
- Consider including select-topics on non-electric nuclear power applications such as industrial heat, hydrogen production, and district heating, in the scope of future TWG-ND meetings.
- Update the relevant data and experience relative to the coupling of NPPs with various desalination systems and their operation and maintenance.
- Conduct technical and information sharing workshops in MSs with relevant experience in nuclear desalination.
- Regularly communicate new and updated relevant IAEA publications, technical studies, and MSs input to the members of the TWG-ND.
- Disseminate nuclear desalination related information in relevant international fora.
- Highlight the benefits of providing fresh water specifically using nuclear energy as a clean and sustainable source of energy to the public.
- Encourage sustained and constructive interaction between vendors, utilities, and various end users in sharing relevant technical information and licensing considerations.
- Assess the importance of licensing issues and related gaps relevant to the coupling of nuclear and water production systems and explore interlinks between comprehensive integrated water resources management and nuclear desalination practices.
- Update the IAEA nuclear desalination guidebook with the latest relevant information and continue updating software tools, such as DEEP, DE-TOP, ND Toolkit as needed.

Meetings Related to Nuclear Desalination and Efficient Water Management 2019 — 2020

Meeting Title	Date	Location
7th Meeting of Technical Working Group on Nuclear Desalination (TWG-ND)	24—26 June 2019	Vienna, Austria
Technical Meeting on Specific Considerations for the Deployment of Nuclear Cogeneration Projects	22—24 July 2019	Vienna, Austria
Technical Meeting on Assessing the Deployment of Small and Medium Sized or Modular Reactors and High Temperature Reactors for Cogeneration Applications	02—24 Sept 2019	Vienna, Austria
Consultants Meeting develop the publication on the responsibilities of users and vendors in nuclear desalination projects	2020	Vienna, Austria
Technical Meeting on Potential Schemes for Licensing Nuclear Cogeneration Plants	01—03 Sept 2020	Vienna, Austria