CLEAN DEVELOPMENT MECHANISM

CDM-MP86-A01

Information note

Technical note on desalination technologies

Version 1.0

United Nations
Framework Convention on
Climate Change

TABLE OF CONTENTS **Page**

1. Procedural background

1. A request for new methodology “Energy-saving through the use of the reverse osmosis technology in the water desalination process” (NM0377) was submitted by ACCIONA AGUA, SA QATAR BRANCH (the stakeholder) in July 2019.

2. The Methodologies Panel (MP) at its 84th meeting (MP 84) recommended to the Executive Board of the clean development mechanism (CDM) (hereinafter referred as the Board) that the Board approve the methodology. The Board at its 110th meeting (EB 110) considered the proposal from the MP 84 and requested the MP to further work on the methodology. The Board noted that specifically the underlying assumption that project plant, especially greenfield unit, will always displace existing desalination capacity of the water-grid, needs further analysis in the context of the growing demand for potable water in many regions.

2. Purpose

3. The purpose of this note is to respond to the mandate from the Board, by analysing the characteristics and status of the desalination technologies globally, but more specifically in the Middle-East and North Africa (MENA) region, which hosts the proposed project activity submitted along with the proposed new methodology.

3. Key issues and proposed solutions

3.1. Global overview of desalination technologies

4. By 2019, globally, there were about 16,000 operational desalination plants with an aggregate capacity of 95 million m^3/day, of which the MENA region accounted for nearly half of the capacity with 45 million m^3/day output.[1]

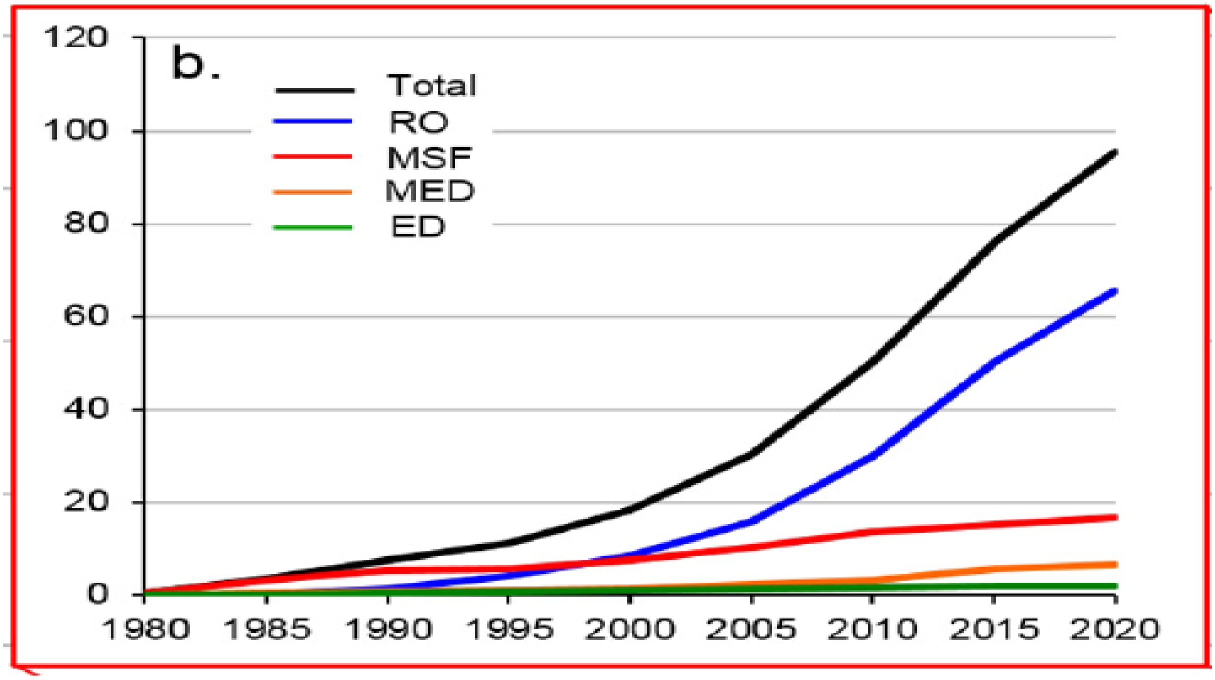
5. Prior to the 1980s, over 80 per cent of all global desalinated water was being produced by thermal technologies such as multistage flash (MSF) and multiple effect distillation (MED), as seen in Figure 1.

6. After 1980, however, the rise in the use of membrane technologies, in particular reverse osmosis (RO) membranes, gradually shifted the dominance away from thermal technologies. By 2000, desalination by thermal and RO technologies were almost equal in capacity. As per the most recent available data, about 70 per cent of global capacity is RO, while thermal technologies such as MSF and MED make up most of the remaining (see figure 1 below). This is primarily because RO has accounted for over 90 per cent of capacities added since 2000.

[1] Jones E, Qadir M, van Vliet M, Smakhtin V and Kang S. 2019. The state of desalination and brine production: A global outlook. *Science of the Total Environment*. 657: pp.1343–1356.

7. Thermal technologies continue to have a relatively higher share in the MENA region. It was reported in 2015 that thermal technology was slightly more prevalent than RO (53 per cent vs 47 per cent),[2] and the region currently accounts for roughly 90 per cent of the global thermal desalination capacity, led by the United Arab Emirates and Saudi Arabia. However, the market share of thermal technologies and RO is not uniform across countries in the MENA region. Share of RO in Saudi Arabia is about 50 per cent; it is below 30 per cent in UAE, Qatar and Kuwait, while it is above 90 per cent in Egypt and Algeria[3]. Most of the RO capacity has been added since 2000. For example, in Qatar, RO capacity in 2000 was negligible. Since 2010, out of the total 172 million gallons/day (i.e. 0.65 million m3/day of desalination capacity added), RO accounted for 96 million gallons/day (i.e.0.36 million m3/day), about 56 per cent of total capacity addition.[4]

Figure 1. Trends in global desalination operational capacity in million cubic meters per day (y-axis) (*source: adapted from Jones et al., 2019*[1])



Source: Adapted from Jones et al., 20191)

[2] World Bank Group's Water Global Practice. 2019. *The Role of Desalination in an Increasingly Water-Scarce World*. Washington D.C.: The World Bank. Available at https://openknowledge.worldbank.org/bitstream/handle/10986/31416/W18059.pdf.

[3] Global Water Intelligence. 2017. *Market insight: global water market 2018*. Available at: https://www.globalwaterintel.com/products-and-services/market-research-reports/global-water-market-2018.

[4] Rahman H and Syed Javaid Z. Desalination in Qatar: Present Status and Future Prospects. *Civil Engineering Research Journal*. 2018; 6(5): 555700. DOI: 10.19080/CERJ.2018.06.555700. Available at https://juniperpublishers.com/cerj/CERJ.MS.ID.555700.php.

8. 2019 World Bank report cited earlier highlighted that the average costs of water production from MSF and RO are comparable, with RO being marginally cheaper. The report, based on a 2016 study, stated that the principal drivers of costs are the interrelated factors of technology choice, plant size, and location, as well as project delivery and environmental regulatory regimes. Project capital, operation and maintenance (O&M), and overall desalinated water production costs depend not only on the primary technology choice made and on plant size but also on a number of other factors, most of which are specific to location, feedwater quality, target product water quality, environmental impacts and regulations, and energy use[5]. Table 1 below includes an extract on costs from the above-cited report.

Table 1. Summary of worldwide seawater desalination costs

Desalination method		**Capital costs (million USD/MLD)**		**O&M costs (USD/m³)**		**Cost of water production (USD/m³)**	
		Range	Average	Range	Average	Range	Average
MSF		1.7-3.1	2.1	0.22-0.30	0.26	1.02-1.74	1.44
MED-TVC		1.2-2.3	1.4	0.11-0.25	0.14	1.12-1.50	1.39
SWRO Mediterranean Sea		0.8-2.2	1.2	0.25-0.74	0.35	0.64-1.62	0.98
SWRO Arabian Gulf		1.2-1.8	1.5	0.36-1.01	0.64	0.96-1.92	1.35
SWRO Red Sea		1.2-2.3	1.5	0.41-0.96	0.51	1.14-1.70	1.38
SWRO Atlantic and Pacific Seas		1.3-1.76	4.1	0.17-0.41	0.21	0.88-2.86	1.82
Hybrid	**MSF/MED**	1.5-2.2	1.8	0.14-0.25	0.23	0.95-1.37	1.15
	SWRO	1.2-2.4	1.3	0.29-0.44	0.35	0.85-1.12	1.03

Note: Costs are at 2016-values. MED-TVC = multiple effect distillation with thermal vapor compression; MLD = million liters per day; MSF= multistage flash distillation; O&M = operation and maintenance; SWRO = seawater reverse osmosis

9. Table 2 below compares desalination technologies with regard to energy consumption based on a study published in 2018.

Table 2. Comparison of desalination technologies[6]

Technology	**Specific energy consumption**
MSF	63.89 to 83.05 kWh_ther/m³
MED	42.23 kWh_ther/m³
RO	3.89 to 16.95 kWh_elec/m³

[5] In the case of thermal technologies factors such as the availability of steam from the combined cycle will also influence the costs. When steam is assigned little cost, then thermal technologies such as MSF become cheaper than RO, and vice versa, i.e. pricing policies and practices of the national utility will have a bearing on the production costs.

[6] Saadat A. H. M., Islam M. S., Parvin F., Sultana A. in Desalination Technologies for Developing Countries: A Review. *Journal of Scientific Research (2018)*

10. Furthermore, the decisions of the utility to “dispatch” power and/or water from different plants in the region, based on diurnal or seasonal fluctuations and other considerations, will also influence efficiencies of the operation of the plant (e.g. part load vs full load) and hence the cost of production. Moreover, the choice of technology and technical specifications or configurations of added capacity or of a new plant are influenced by the relative growth of water demand against the demand for electricity.

11. According to an analysis by the International Energy Agency (IEA) analysis[7], the highly subsidized cost of oil and gas and the prevalence of cogeneration facilities for power and water have led to a unique situation in the MENA region, i.e. relatively higher share of thermal technologies compared to the rest of the world. In the MENA region, thermal desalination technologies have been used only with the cogeneration facility and no stand-alone thermal desalination technology has been constructed in the recent past. More recently, however, RO technology is gaining ground in the region, as stated earlier, and almost all the plants currently under construction in the region are based on RO technology.[8]

12. The shift to RO in the MENA region is likely to continue due to the decline in the cost of RO membranes. The climate change policy driven by the Paris Agreement is also likely to accelerate this trend, since renewable energy technologies such as solar and wind technologies are being introduced at scale. Such a transition can also reduce the water intensity of power generation.

13. Despite the increasing share of RO-based desalination, it is possible that thermal processes using fossil fuels will continue to be used in some part of the MENA region to some extent where steam from power plants is available. The above-cited World Bank report attributes this to two factors: one related to physical operating conditions, in that the regional seas are highly saline and warm and periodically have high concentrations of organics, which are challenging conditions for membrane desalination technology;[9] and the other related to policy on subsided cost of energy. Both factors have significant cost implications.

14. 2019 IEA analysis cited earlier, based on present policies of the countries in the MENA region, predicts a marked shift in fossil fuel use in desalination, i.e. from about 50 per cent share in 2016 to about 20 per cent in 2040 under the New Policy Scenario. The report

[7] International Energy Agence (2019). *Desalinated water affects the energy equation in the Middle East* available at: https://www.iea.org/commentaries/desalinated-water-affects-the-energy-equation-in-the-middle-east.

[8] Based on various news articles: https://www.idom.com/en/project/shuqaiq-3-water-desalination-plant-450000-m3-day; https://constructionreviewonline.com/news/uae-to-construct-worlds-largest-sea-water-ro-desalination-plant; https://energy-utilities.com/kuwait-tenders-doha-phase-2-desalination-plant-news114051.html; https://www.webuildgroup.com/en/media/press-releases/new-webuild-win-in-plant-construction-two-desalination-contracts-in-oman; https://water.fanack.com/bahrain/water-infrastructure-bahrain; https://www.greenprophet.com/2020/11/desalination-emirates-bahrain.

[9] Recent technological advances have increased the share of RO in sea water (SW) desalination. According to Jones et al., 2019,[1] SW desalination accounts for 61 per cent of produced water globally. Fifty per cent of the desalinated water that is produced from RO desalination plants (accounting for 34 per cent of the global desalination capacity) originates from SW. Comparatively, thermal technologies are used almost exclusively for low-quality (highly saline) feedwater types. A total of 96 per cent of MSF plants and 80 per cent of MED plants use feedwater with >20,000 ppm total dissolved solids (TDS), the vast majority of which use sea water.

cites several factors, such as the declining cost of membrane-based technologies, anticipated reforms to energy-pricing, high solar irradiation, and rapidly declining costs for solar projects in the region. These factors would alter the energy mix (from the present 1 GW solar and 90 GW oil-fired generation to increasing share of renewable energy (RE).

15. National policies of the countries in the MENA region in relation to desalination increasingly refer to RO-based desalination and augmenting renewable energy supply (see appendix for details). Furthermore, emission inventories of countries in the region (e.g. inventory of Qatar for 2019) showed the large of dominance cogeneration plants and that the use of the remaining old and inefficient plants is declining rapidly. In the particular case of Qatar, annual power and water demand have been increasing roughly at the rate of 5 per cent per annum over the last five years.

16. In conclusion,

(a) RO is the dominant technology where steam from a power plant is not available; in the MENA region 100 per cent of the additional plant capacity in such a situation has been RO. All the thermal desalination plants added in the recent past are based on use of steam from power plants. This creates two distinct market segments in desalination water supply, with RO being the technology of choice where no steam from a power plant is available for desalination;

(b) The decreasing cost of RE and the push from the Paris Agreement-compatible policies are likely to see an increasing trend in RE+RO based desalination. This will be especially be the case in regions with high solar radiance.

3.2. Response to issues raised by EB 110

17. As noted above, EB 110 requested the MP to further work on the draft methodology addressing the following issue: *"The underlying assumption of the methodology that the project plant, especially the greenfield unit, will* ***always displace the existing desalination capacity of the water-grid*** *needs further analysis in the context of the growing demand for potable water in many regions."*

18. In response to above issue, besides the analysis presented in the earlier sections, the MP also assessed the trends in the demand for potable water in the MENA region. Indeed, the demand is growing (e.g. in the specific case of Qatar, where the proposed project of NM0377 is hosted, there was an average 5.2 per cent annual growth between 2015 and 2019).[10] Also in Qatar, there is significant storage capacity as compared to daily water production. This would mean that hourly/daily demand/supply of water will not demand a similar response in the water supply system, as would the case with an electricity grid. Therefore, modelling these impacts of annual growth and storage accurately in water grid emission factor approach may need different algorithms than those of the electricity grid.

19. Following the analysis above, and taking into account uncertainties and the impending decarbonization of the desalination sector in the MENA region and elsewhere, the MP is of the opinion that the other approaches in paragraph 48 of CDM modalities and procedures (M & P) may need to be explored to determine the baseline emissions, besides

[10] Qatar General Electricity & Water Corporation "KAHRAMAA". 2020. *Statistic Report 2019*. Doha: Planning & Quality Department in collaboration with KAHRAMAA Departments. Available at: https://www.km.qa/MediaCenter/Pages/Publications.aspx.

the water grid emission factor approach that was previously proposed. However, it is possible that under such alternative approaches (e.g. paragraph 48 (c) of CDM M&P), the proposed project under NM0377 may not be able to claim emission reductions. In that context, the MP seeks guidance from the Board as to whether to continue to work on the methodology, i.e. on a top-down basis even if it may not be applicable to the project proponent of NM0377.

4. Recommendations to the Board

20. The MP recommends the Board to take note of this information note and provide further guidance regarding the work related to consideration of the proposed new methodology NM0377.

Appendix. National policies on desalination in the MENA region

1. Below are examples of national policies in the MENA region related to decarbonization of the desalination sector:

   (a) **Kuwait:** Higher-efficiency systems such as the RO system in water production are planned;

   (b) **Morocco:** Establishment of a wind farm with a power of 40 MW for the energy supply of the station Dakhla seawater desalination plant is planned;

   (c) **Qatar:** Urban water supply is mostly from seawater desalination in the country, often using MSF & RO methods. Recently Qatar has made significant progress in reducing the emissions from the power and water sector by introducing its first 800 MW solar power plant, which will be operational soon. It is the goal of the State of Qatar to expand these efforts and transform renewable energy into a key driver for ecological and commercial benefits;

   (d) **UAE:** Desalination is the largest source of potable water in the UAE, which traditionally relied on power and water cogeneration plants for desalinated water. To reduce the environmental impact of desalination, and to address inefficiencies in cogeneration due to operational attributes and seasonal variation in demand for power and water, the UAE is developing and scaling up independent water projects based on RO technology and making efforts to expand the share of renewable energy in desalination. UAE aims to increase the share of RO-based desalinated water to over 50 per cent of the potable water supply mix by 2036;

   (e) **Tunisia:** Installation of mini seawater desalination plants using renewable energies is planned.

- - - - -

Document information

Version	*Date*	*Description*
01.0	1 October 2021	MP 86, Annex 1 To be considered by the Board at EB 112.

Decision Class: Operational
Document Type: Information note
Business Function: Methodology
Keywords: data collection and analysis, technical aspects, water