Ex-Post Evaluation of The Algerian SWRO Desalination PPP Program

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Abstract

The ever-increasing population and a decrease in available freshwater resources have resulted in continued water scarcity globally. The situation is worse in certain areas than others, especially in countries and regions with limited water resources. Being a desert country that lacks many rivers and other natural water resources together with continuous increase in population, Algeria faces significant challenges in accessing fresh water. The gap in the demand and supply of water affects households and agriculture, which significantly depends on irrigation for successful operations.

The impact of the water supply deficit is being felt across the country and in major cities, such as Algiers and Oran. Although Algeria has employed desalination technology to meet the water shortage challenge in the past, most of the water produced using the technology has only been able to meet the water needs in the oil and steel industries. The objective of this study is to evaluate the impact of some of these large-scale investments and assess them in light of their effectiveness in teams of their cost and their ability to meet the water supply shortages in Algeria.

Keywords: Algeria, Cost-Benefit Analysis, Water Desalination, Public Private Partnership (PPP), Water Shortage

JEL Classification: D61, I38, L95, O55, Q25

EXECUTIVE SUMMARY

The ever-increasing population and a decrease in available freshwater resources have resulted in continued water scarcity globally. The situation is worse in certain areas than others, especially in countries and regions with limited water resources. Being a desert country that lacks many rivers and other natural water resources together with a continuous increase in population, Algeria faces significant challenges in accessing fresh water. The gap in the demand and supply of water affects households and agriculture, which significantly depends on irrigation for its successful operations.

The impact of the water supply deficit is being felt across the country and in major cities, such as Algiers and Oran. For instance, in 2002, there were acute water shortages in Algiers; water was only available to residents every other day; the use of jerry-cans and tanks became commonplace as some households were reported to go several days without access to water. At the height of the emergency, water had to be trucked into the city (World Bank, 2004). Over the years, Algeria has employed reservoirs, dams and water transfers to balance the supply and demand for water, but this has not solved the water challenges, especially in periods where the country has experienced droughts.

Although Algeria has employed desalination technology to tackle the water shortage challenge in the past, most of the water produced using this technology has been to meet the water needs in the oils and steel industries. However, since the early 2000s, the Ministry of Water Resources (MRE) has responded to the dire water supply shortage by employing non-conventional water supply technologies to produce freshwater for households in urban cities along the coast. In 2003, several emergency intervention initiatives were taken, and investments were made in 21 small scale Reverse Osmosis (RO) desalination plants with a total capacity to produce 50,000 m^3 of water per day went into service in the Wilaya's of Algiers, Boumerdes, Tipasa, Skikda and Tlemcen to tackle the water shortages experienced in the summer of 2002 (World Bank, 2004). However, lessons from the small-scale desalination plants' commissioning show that they are not an optimal solution for the country's widespread water shortages. As a result, the Government initiated investments in large-scale desalination infrastructure through private sector participation. The Algerian Energy Company (AEC) has led the development of desalination plants through the Public-Private Partnership (PPP) model.

The objective of this study is to evaluate the impact of some of these large-scale investments and assess them in light of their effectiveness in terms of their cost and their abilities to meet the water supply shortage. The plants and their corresponding capacities are presented in Table 1 below:

Table 1: Plants and their Capacities

Plant Name	Capacity (m^3/ day)
Hamma	200,000
Skikda	100,000
Beni Saf	200,000
Souk Tlata	200,000
Fouka	120,000
Mostaganem	200,000
Cap Djinet	100,000
Honaine	200,000

Tenes	200,000
Magtaa	500,000

The study involves two major components. (a) a benchmarking analysis of how the costs of the plants compare with similar plants commissioned elsewhere; and (b) a cost benefit analysis of one of the plants.

BENCHMARKING ANALYSIS: This analysis is used to compare the Algerian desalination infrastructure's performance against similar projects in terms of nature, scope and scale, that have been commissioned elsewhere. A good understanding of the cost and performance of the desalination program in Algeria relative to other countries is envisioned to result in a positive contribution to decision-making on capital expenditure and the improvement in operational efficiency and effectiveness in delivering future investments in desalination infrastructure. The evaluation metrics that were included in the benchmarking analysis are:

i. Capital Costs.
ii. Operating and Maintenance Costs.
iii. Water Tariff.

These metrics were evaluated using pants of different sizes. Three capacity ranges were constructed that mirror the various plant capacities that exist within the set of Algerian plants included in this analysis. The capacity ranges are as follows.

Plants with a 100k – 150k M^3/day capacity: Comparing the capital cost per m3 of the capacity of Skikda, Cap Djinet, and Fouka against that of the other 23 plants results in a capital cost that ranges between a minimum of 876 USD/m^3 and a maximum of 2,608 USD/m^3, with an average of 1,341 USD/m^3. All the Algerian plants' capital costs are below the average. Similarly, the operation and maintenance costs of the three plants that fall into this category were found to be below the average of the data sample used for the analysis. In fact, their O&M costs rank as the 1st (Skikda – 0.22 USD/m^3), 3rd (Fouka – 0.30 USD/m^3), and 4th (Cap Djinet – 0.31 USD/m^3) least expensive out of all the plants assessed in this sample. The Algerian desalination plants likely have significantly lower O&M costs due to the desalination plants' lower energy cost as a result of an implicit subsidy on electricity. In terms of the water tariff, not only are the Water Tariffs of Skikda, Cap Djinet and Fouka below the average observed for this data sample, their desalinated water ranks as the 3rd (Skikda – 0.64 USD/m^3), 4th (Cap Djinet – 0.75 USD/m^3), and 6th (Fouka – 0.77 USD/m^3) least expensive out of all the plants assessed in this sample. The results indicate that Algeria's desalinated water is reasonably priced relative to the other countries and regions considered in the sample.

Plants with a 200k – 250k M^3/day capacity: comparing the capital cost per m^3 of Hamma, Beni Saf, Souk Tlata, Mostaganem, Tenes, and Honaine against that of the other 11 desalination plants in the data sample results in a capital cost that ranges between a minimum of 739 USD/m^3 and a maximum of 2,117 USD/m^3, with an average of 1,149 USD/m^3. The analysis showed that all the Algerian plants' capital costs are below the average. Out of the 17 plants in the 200k – 250k m^3/day capacity range, the Algerian plants rank 2nd (Beni Saf – 893 USD/m3), 3rd (Mostaganem – 903 USD/m^3), 4th (Tenes – 931/m^3), 5th (Hamma – 987 USD/m^3), 7th (Souk Tlata – 1,029 USD/m^3), and 8th (Honaine – 1,044 USD/m^3) in terms of the least expensive plants with respect to their capital costs. The O&M costs for the plants studied in this category range from 0.12 – 0.47 USD/m^3 with an average O&M cost of 0.28 USD/m^3. The O&M costs of Beni Saf, Mostaganem, Tenes, Souk Tlata, and Honaine were found to be below the average O&M of the observed data in this category. Their O&M costs rank as the 2nd (Souk Tlata – 0.17 USD/m^3), 3rd (Tenes – 0.20 USD/m^3), 4th (Mostaganem – 0.23 USD/m^3), 5th (Beni Saf – 0.23 USD/m^3), and 6th (Honaine – 0.23 USD/m^3), least expensive, out of all the plants assessed in this sample. On the other hand, the Hamma desalination plant seems to be slightly more expensive to operate and maintain, at the cost of 0.31 USD/m^3, which is slightly above average, and relatively more costly than the other Algeria desalination plants. The analysis also indicates that the Algerian Plants Water Tariffs are reasonably priced relative to the other plants in the sample as their Water Tariffs are below the sample average (0.98 USD/M^3). The Algerian plants have the 2nd (Mostaganem – 0.75 USD/m^3), 3rd (Beni Saf – 0.77 USD/m^3), 4th (Souk Tlata – 0.77 USD/m^3), 6th (Honaine – 0.85 USD/m^3), and 7th (0.88 USD/m^3) least expensive Water Tariffs within the sample.

Plants with a 385k – 625k M^3/day capacity: The results of the analysis indicate that relative to the other plants in the sample, Magtaa is more expensive with regards to its capital cost, as it has a capital cost that is higher than the observed average of 792 USD/m^3, and it defies the general trend of economies of scale. It should be noted that at the time when Magtaa was constructed, it was the largest desalination plant in the world; this is likely why it is more expensive than all the other plants. Out of the 4 plants with a 385k – 625k m3/day capacity, O&M costs could only be established for two of the plants; that is Magtaa and Sorek. The O&M costs for Magtaa are equal to those of Sorek (0.22 USD/m^3 of water). Given that there are very few data samples to benchmark the performance of Magtaa, there is little that can be inferred with regards to the operational efficiency of such a large plant in comparison with plants of an equivalent capacity. However, Magtaa's O&M costs fall within the range of other plants in Algeria. In fact, Magtaa is relatively cheaper to operate and maintain than the Hamma, Beni Saf, Mostaganem, Honaine, Cap Djinet, and Fouka desalination plants, all of which have a small production capacity. This observation points to the possibility of operating and maintenance economies of scale as the size of the desalination plant increases. Furthermore, the analysis indicates that though the Water Tariff of Magtaa is slightly pricier than that of Sorek, Magtaa's Water Tariff is reasonably priced relative to the other plants within the Mediterranean region, which fall in the range of 0.64 – 1.62 USD/m^3 of water.

COST-BENEFIT ANALYSIS: The objective of the cost-benefit analysis is to compare the benefits generated by the project to its costs. The study was carried out using the integrated investment approach, which integrates financial analysis, economic analysis, stakeholder analysis and risk analysis. The financial analysis is mainly concerned with assessing the financial revenues and costs of the projects from the perspective of the different stakeholders and estimating the financial feasibility of the project. On the other hand, the economic analysis assesses how the plant has improved the welfare of Algerians. The stakeholder assesses the losers and the gainers and quantifies the losses and/or benefits.

The analysis assumes two alternative scenarios:

a. The first scenario assumes that the status quo situation is already a deficit of water in urban areas. In this scenario, the water is supplied to meet the deficit in the households.

b. In a situation when water supply is limited, the demand for water from urban areas will be satisfied first, with the remaining water being delivered for agricultural use. Therefore, while desalination plants supply water directly to the urban areas, from an economic point of view, the incremental impact is that more water from other sources is now available for agricultural use, i.e., the incremental quantity of surface water is being released for irrigation.

The financial analysis of the Hamma desalination plant shows that the project generates positive returns for the investors. The financial costs of the project include the investment, operation and maintenance costs of the project. The investment costs are financed by debt and equity. 26.2% of the investment cost is financed by equity, and 73.8% of the investment cost is financed by debt. The source of the financial revenue of the project is the tariff charged by the SPV to the off-taker for the water supplied to it by the plant. Using the required return on equity of 15% as the discount rate, the project generates a financial net present value (from the equity perspective) of 1,382 million DZD (2008 prices) and an IRR of 17.09%. In addition, the project generates enough cash flow to meet its debt obligation. Though the ADSCR for the first repayment period was lower than the threshold of 1.30, the ADSCRs in subsequent years are much higher than the threshold.

Furthermore, the financial analysis was used to estimate the project's fiscal impact since this is a PPP project. In the first scenario, where the water produced by the plant is supplied to the households, the present value (in 2008) of the net fiscal impact of the project, at a discount rate of 8 percent, is estimated to be -51,597 million DZD (USD 799 million) in 2008 prices. For the second scenario, the PV of the net fiscal impact at an 8 percent discount rate is -45,954million DZD (USD 711 million) in 2008 prices.[1]

The economic analysis of the project involves the analysis of the economic costs and benefits of the project. The economic analysis begins with the estimation of the economic benefit of the water supplied by the plant to the end-user. The averting expenditure technique was used to estimate the benefit of water to the users. In the first scenario, when the water is supplied to households, the economic benefit of water to the end-user was estimated to be 2.19 USD/m^3. This benefit was compared with the levelized economic opportunity cost of water, estimated to be 2.03 USD/m^3. The economic cost is estimated by adjusting for different distortions like taxes and subsidies that are part of the financial costs and include the distribution cost and water losses. In the first scenario, the project generates economic benefits greater than the economic costs with a benefit-cost ratio of 1.08. Using a discount rate of 8 percent, the project has an economic net present value (ENPV) of 7,830 million DZD (USD 121 million) in 2008 prices in the first scenario.

In the second scenario, where the incremental water produced by the plant goes to the farmers for agricultural purposes, the economic benefit of water was estimated to be 0.095 USD/m^3. Furthermore, the economic LCOW in this scenario is 1.42 USD/m^3. In this case, the economic benefits generated by the project are less than the economic LCOW and results in a benefit-cost ratio of 0.07, with an ENPV (at 8 percent discount rate) of -44,116 million DZD (USD -683 million) in 2008 prices. Therefore, even though the net fiscal impact of the project is greater in the first scenario, the project is only economically viable when the water produced by Hamma desalination plant is supplied to households. Other cheaper alternatives should be found to meet the deficit in the agricultural sector.

[1] The economic opportunity cost of capital (EOCK) or simply put, the economic discount rate is a parameter that should be computed for each country and used consistently in the evaluation of all projects. Computing the EOCK is time consuming and expensive and falls outside of the scope of the evaluation of the desalination plants. In assessing projects from countries that do not have an EOCK estimate, we usually use 12% as this is the rate prescribed by Harberger, A.C, and Jenkins, G.P in their paper published in 2015, titled "Musings on the Social Discount Rate". Initially, we were using 12% as the EOCK, however, after discussions with public officials from Algeria we realized that 8% is more commonly used as EOCK in appraising capital projects. Hence, we adopted 8% as the discount rate for the evaluation of the Algerian desalination plants.

1. BACKGROUND

1.1. WATER RESOURCES IN ALGERIA

Algeria faces challenges in accessing freshwater. A significant proportion of the country lies in hot, arid, and desert regions with freshwater scarcity. Algeria mainly relies on ground and surface water for drinking, agricultural, and industrial purposes. Surface water sources are not always fully replenished due to the seasonality and low levels of rainfall experienced in the country. Furthermore, the rate at which groundwater sources are being exploited is twice that of the recharge rate (Sleet, 2019). As the country's population continues to increase and the number of urban dwellers continues to proliferate, water demand has outpaced supply and put the country in a precarious position. Water shortages have been experienced across the country and in major cities, such as Algiers and Oran. For instance, in 2002, there were acute water shortages in Algiers; water was only available to residents every other day; at the height of the emergency, water had to be trucked into the city (World Bank, 2004). Over the years, Algeria has employed reservoirs, dams and water transfers to balance the supply and demand for water, but this has not solved the water challenges, especially in periods where the country has experienced droughts.

1.2. ALGERIA'S WATER DESALINATION PPP PROGRAM

Algeria is bordered to the North by the Mediterranean Sea and has a coastline of 998 kilometers (EC, 2011). Various major cities and ports are located along Algeria's Mediterranean coastline; these include Algiers and Oran. Algeria has quite a long history with desalination. Algeria's experience with desalination plants spans as far back as the 1960s; most plants built over a period of four decades were strictly to support the oil and steel industries (World Bank, 2004). However, since the early 2000s, in response to water shortages, the Ministry of Water Resources (MRE) has been employing the use of non-conventional water resources (brackish water and seawater) to produce freshwater for households in urban cities along the coast. In 2003, as a result of an emergency public investment program, 21 small scale Reverse Osmosis (RO) desalination plants with a total capacity to produce 50,000 m^3 of water per day went into service in the Wilaya's of Algiers, Boumerdes, Tipasa, Skikda and Tlemcen to tackle the water shortages experienced in the summer of 2002 (World Bank, 2004). Lessons from the small-scale desalination plants' commissioning show that they are not an optimal solution for the country's widespread water shortages. As a result, the Government initiated investments in large-scale desalination infrastructure through private sector participation. The Algerian Energy Company (AEC) has led the development of desalination plants through the Public-Private Partnership (PPP) model.

Algeria's inaugural PPP seawater desalination plant, Kahrama began supplying water to the city of Arzew in 2008. The plant was implemented as an Independent Water and Power Plant (IWPP) that will operate for 25 years. The Multi-Stage Flash (MSF) desalination plant was developed by the Kahrama Spa, a joint venture between the AEC and Black and Veatch (BV). The Kahrama desalination plant has a capacity to supply 86,880 m^3 of water and 320 MW of electricity per day. The water produced by the plant is supplied to the sole off-taker, Sonatrach, the state-owned oil company, while the electricity is supplied to Sonelgaz, the state-owned electricity utility.

Over the period spanning 2008 to 2013, AEC has developed ten PPP Seawater Reverse Osmosis (SWRO) desalination plants. A summary of the technical parameters and the contractual arrangements of these SWRO desalination plants is presented in Table 2. Sonatrach is the sole off-taker of all the water produced by the Hamma, Skikda, Beni Saf, Souk Tlata, Fouka, Mostaganem, Cap Djinet, Honaine, Tenes, and Magtaa desalination plants. The water produced by the desalination plants is then distributed by the National Agency of Dams and Transfers (ANBT) to various national water utilities responsible for providing various cities and regions within their area of service with drinking and irrigation water.[2]

Table 2. SWRO PPP Desalination Plants

Plant Name	Capacity (m^3/day)	Procurement Model	Commissioning Year	SPV
Hamma	200,000	BOO – 25 yrs	2008	HWD SPA (General Electric - 70%, AEC - 20%)
Skikda	100,000	BOT – 25 yrs	2009	ADS SPA (Geida Skikda SL - 51%, AEC - 49 %)
Beni Saf	200,000	BOT – 25 yrs	2009	BWC SPA (Geida Beni Saf SL - 51%, AEC - 49%)
Souk Tlata	200,000	BOT – 25 yrs	2010	AAS SPA (TDIC - 51%, AEC - 49%)
Fouka	120,000	BOT – 25 yrs	2010	MT SPA (AWI SL - 51%, AEC - 49%)
Mostaganem	200,000	BOT – 25 yrs	2011	STMM SPA (INIMA & AQUALIA - 51%, AEC - 49%)
Cap Djinet	100,000	BOT – 25 yrs	2011	SMD SPA (INIMA & AQUALIA - 51%, AEC - 49%)
Honaine	200,000	BOT – 25 yrs	2012	MBH SPA (Geida Tlemcen SL - 51%, AEC - 49%)
Tenes	200,000	BOT – 25 yrs	2015	TL SPA (Befesa Agua Sau - 51%, AEC - 49%)
Magtaa	500,000	BOT – 25 yrs	2015	TMM SPA (MENASPRING - 47%, ADE - 10%, AEC - 43%)

1.3. OBJECTIVE OF THE EX-POST EVALUATION OF THE SWRO DESALINATION PPP PROGRAM

The Algerian SWRO desalination PPP program has added desalination infrastructure worth US$ 2.48 billion to the country's water infrastructure portfolio (AEC, 2013). The objective of the ex-post evaluation of Algeria's SWRO desalination PPP program is to establish the effectiveness and efficiency of investments in desalination infrastructure through the private participation model in meeting the goal of providing water to the Algerian people and stemming the water shortage challenges the country has been facing for the last couple of decades. It should be noted that the evaluation of the PPP program only encompasses the SWRO desalination plants listed in Table 2.

[2] The water utilities include SEAAL, SEOR, SEACO.

2. EVALUATION OF ALGERIAN PPP DESALINATION PLANTS

2.1. PROJECT DEVELOPMENT

From the moment a decision is made to construct a desalination plant to when it is commissioned, the project undergoes several development and approval phases. These phases range from the invitation to tender, submission and selection of technical and commercial proposals, selecting the winning bid, negotiating the Water Supply and Purchase Agreement (WSPA), finalizing the deal for financial closure that leads to the beginning of the construction of the plant, and finally testing the technical capability and commissioning of the desalination plant. The project's commissioning phase has been broken down into two distinct stages for the purposes of this evaluation, that is, the commissioning of the first desalination unit and the full plant commissioning, which represents the commissioning of all desalination units. This was done to account for the delays encountered during the commissioning phase due to a number of challenges.

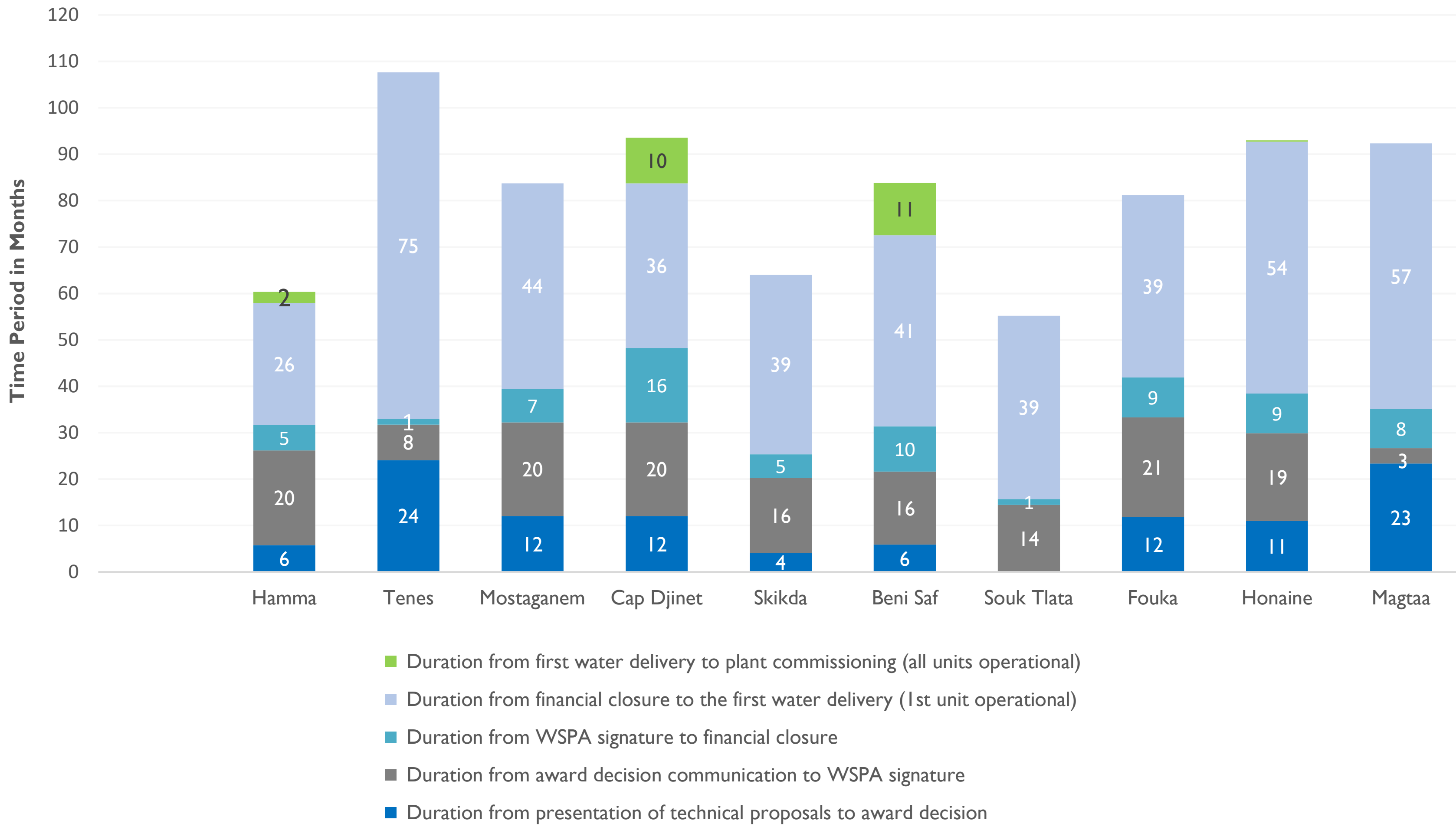
The objective of assessing the project development cycle is to compare the time it took for all the desalination plants from inception to full plant commissioning. This analysis aims to highlight any inefficiencies experienced in procuring the Algerian Desalination PPP Plants. The total time it took to procure each of the Algerian desalination plants is summarized in Figure 1.[3] Out of all the plants, Souk Tlata, Hamma, and Skikda took the least time to procure, with each plant taking a total time of 55 months (4.6 years), 60 months (5 years) and 64 months (5.3 years), respectively from project bidding to the commissioning of the project. However, it should be noted that Souk Tlata did not employ a competitive bidding process; rather, it was procured using the direct negotiation model. On the other hand, it took Tenes 108 months (9 years) to deliver its first water consignment. The average procurement duration of the desalination program is 81 months or 6.8 years. Hence, the procurement processes of Hamma and Skikda resulted in water being delivered 1.6 years earlier than the rest of the plants that used the competitive bidding model. The procurement framework and arrangements of Hamma and Skikda should be examined carefully and, where feasible, be used as templates for future desalination projects to ensure that they are delivered on time to meet the water needs of the Algerian people and avoid water shortages such as those experienced in the summer of 2002.

From the little data available to assess the issues around project development and procurement, it is evident from Figure 1 that the time period from project inception to commissioning can be optimized by addressing the bottlenecks experienced during the evaluation of project bids, negotiation and signing of the WSPA, and the financial closure and construction of the desalination plants. Improving the AEC's institutional capacity to manage the procurement process more efficiently by removing unnecessary bureaucracy could reduce the time it takes to develop projects. Furthermore, thoroughly vetting project developers' institutional and financial capacity will likely cut back on the time required to construct and commission the desalination plants. A more robust analysis needs to be conducted to identify the issues that were faced by plants such as Tenes, Cap Djinet Honaine and Magtaa that resulted in the long lead

[3] It is worth noting that the bidding process information was not available for certain plants, specifically Fouka and Honaine. The commercial proposals tender dates were missing for these plants.

time from project inception to the delivery of freshwater; such an analysis would require significantly more data than was provided for this ex-post evaluation.

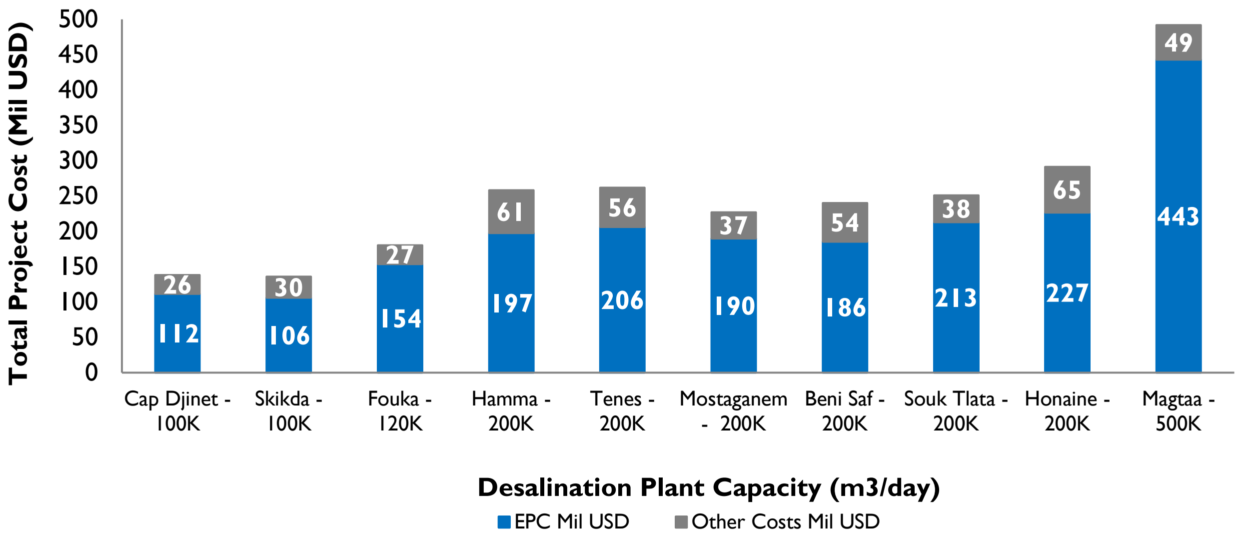
Figure 1. Project Procurement Timeline



2.2. CAPITAL EXPENDITURE

Capital expenditure (CAPEX) consists of two main components, which are direct and indirect costs. In the context of this evaluation, the direct costs refer to the costs incurred in the Engineering, Procurement and Construction (EPC) of the desalination plants. They comprise expenditures such as site development, buildings and structures and equipment, amongst other items. On the other hand, indirect costs refer to the expenditures incurred to finance the project, such as financing fees and interest during construction. In direct fees may also include expenditure categories such as administrative costs, preliminary feasibility studies, legal fees, permits, and contingencies. Figure 2 below summarizes the direct and indirect costs of the Algerian SWRO desalination plants.

Figure 2. Capital Expenditure on SWRO Desalination Plants [nominal values][4]

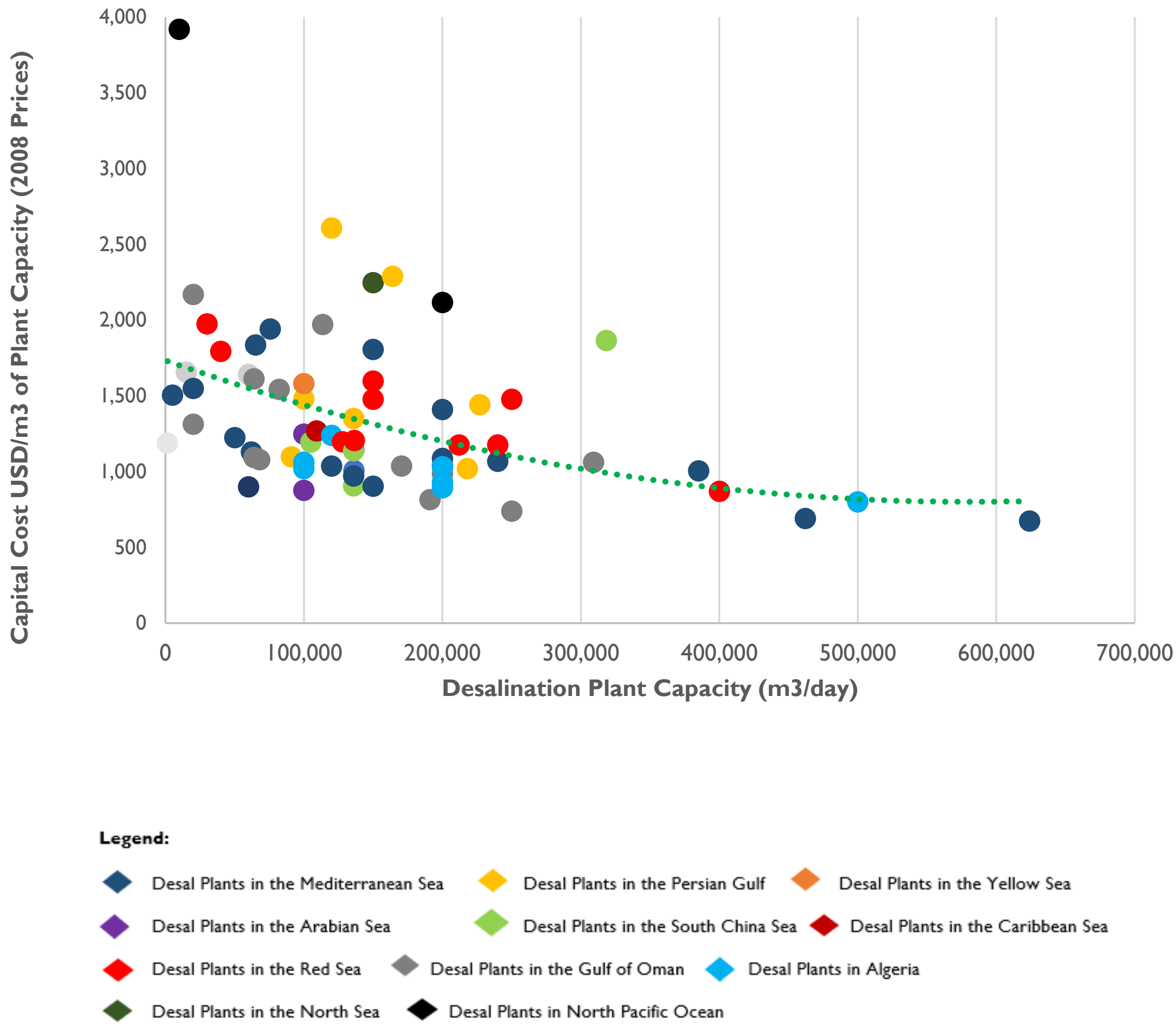


It is estimated that the direct costs of infrastructure projects, i.e., EPC costs, typically range between 50 – 85% of the total CAPEX (Advisian , 2020). The average EPC costs of the Algerian SWRO plants are around 81% of the total CAPEX. The Algerian SWRO PPP program has several plants that are of an equivalent capacity. For instance, the Cap Djinet and Skikda plants both have a daily water production capacity of 100k m^3. In contrast, the Hamma, Tenes, Mostaganem, Beni Saf, Souk Tlata, and Honaine plants each have a daily water production capacity of 200k m^3. Despite having the same technical ability to produce an equivalent quantity of desalinated water, these plants' CAPEX is not similar. Some plants are more expensive than others. For instance, at a capacity of 200k m^3, the costliest plant is Honiane, and the least costly plant is Mostaganem, at capital costs of US$ 292 million and US$ 227 million, respectively, representing a total CAPEX difference of 29%. However, the average variance between the CAPEX of the desalination plants with a capacity of 200k m^3 is 12%. Though a significant disparity was observed for plants with a capacity of 200k m^3, a small variance of 2% was observed for plants with a water production capacity

[4] All figures were sourced from the AEC Activity Report (AEC, 2013).

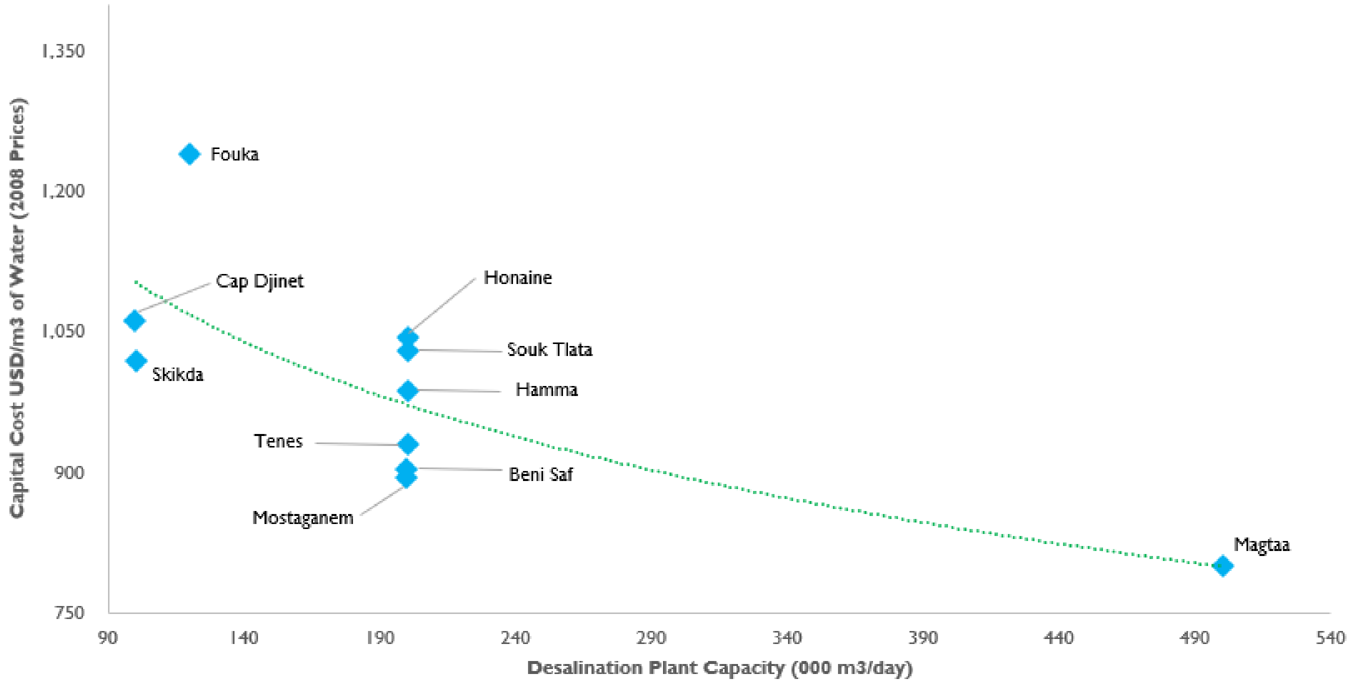
of 100k m³. Some of the factors that determine CAPEX disparity even for plants with an equivalent capacity are site-specific factors that affect the plant's technical and engineering design. Financing terms and contractual agreements, equipment suppliers, contractors, and technological advancements, delays, and budget overruns can all influence the project's overall cost.

Figure 3. Capital Expenditure per Unit of Water Production Capacity - Global Comparison



A comparison of the CAPEX based on a unit of production capacity shows that there are economies of scale; as illustrated in Figures 3 & 4, these economies of scale increase significantly as the desalination plants' water production capacity increases. This result suggests that value for money to be derived from large-scale plants such as the Magtaa desalination plant, where demand warrants constructing a desalination plant of such a capacity. Figure 3 compares the CAPEX of Algerian plants versus other plants in the world, whereas Figure 4 compares the desalination plants in the Algerian PPP program.[5]

Figure 4. Capital Expenditure per Unit of Water Production Capacity – Algerian PPP Program [6]



The Algerian Desalination PPP Program commenced in the early 2000s, its first desalination plant, Hamma, came online in 2008. Followed by two plants that were commissioned in 2009, Skikda and Beni Saf. In 2010, two additional plants came into operation, that is, Souk Tlata and Fouka. 2011 saw the addition of two more plants to the country's portfolio of desalination plants, with the commissioning of Mostaganem and Cap Djinet. In 2012, Honaine came online, and in 2013, Tenes and Magtaa were commissioned. An analysis of the capital costs of the Algerian desalination plants over the course of the period from when the first plant was commissioned to when the last plant was brought online reveals that the desalination plants' capital cost has tended to decrease over time. This decline in the cost of capital over time,

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[5] A composite list of the plants used to in the analysis as well as the sources of data can be found in Annex C.

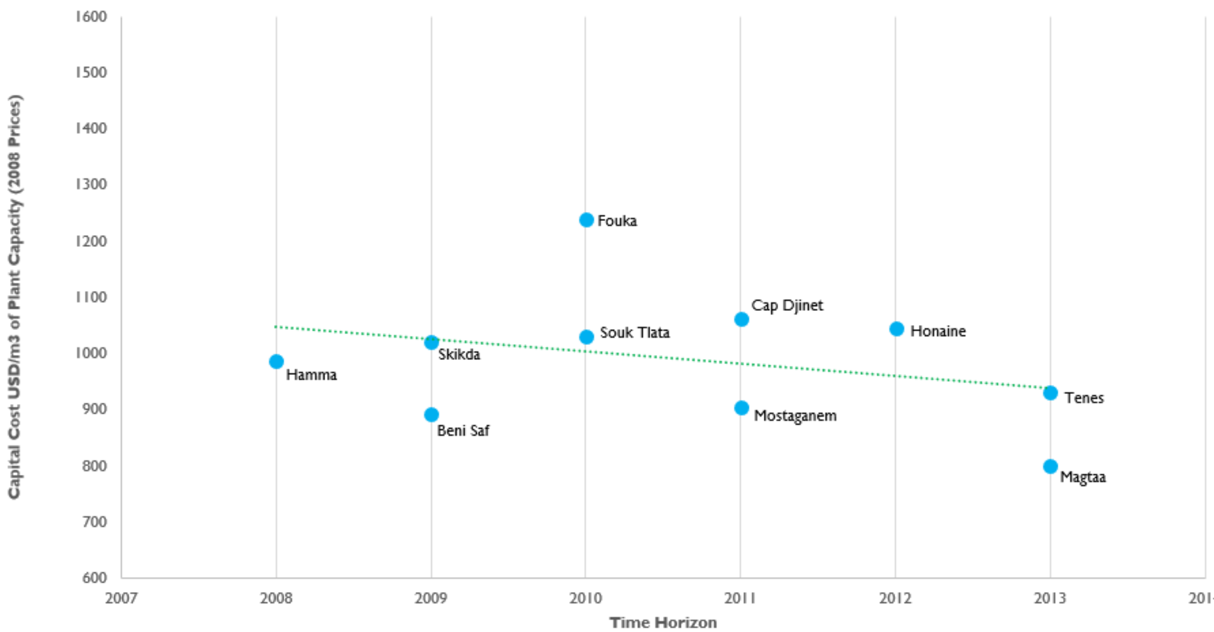
[6] The CAPEX per unit of water production capacity is derived by dividing the real total CAPEX of each plant by its daily water production capacity. Where the real cost is reflected in terms of 2008 prices by apply the appropriate price index. Computing the costs as of the same year (i.e., 2008) allows for an accurate comparison between costs by removing the impacts of inflation. In algebraic terms the real CAPEX per unit of water production capacity can be represented as follows:

$$C_r^t = \frac{C_r^t}{P_i^t} \times \frac{1}{PC}$$

where:

C_r^t = the real CAPEX per unit of water production capacity, C_i^t = the nominal total CAPEX, P_I^t = the price index in period (t), PC = the daily water production capacity of the plant illustrated in Figure 5, is likely attributable to the technological improvements of SWRO that have resulted in the technology becoming cheaper.[7]

Figure 5. Comparison of Algerian Desalination Plants CAPEX over Time[8]



However, there are instances where the capital costs of some plants have defied the general trend observed above. For instance, 4 out of the 10 Algerian plants in this sample have capital costs that are much higher than plants commissioned earlier as well as later periods over the course of the desalination program. Looking at Honaine as an example. The plant was commissioned in 2012, and its capital cost is estimated to be 1,044 USD/m3. It is 17% more expensive than Beni Saf, which has an equivalent capacity to produce 200k m3 of water per day and was commissioned four years prior to Honaine at a cost of 893 USD/m3. Factors such as budget and time overruns due to lengthy contract negotiations and contract disputes can affect the overall capital cost of a project. Hence, without detailed knowledge of the various components and factors that influenced each plant's capital cost, it is difficult to draw any concrete conclusions about the effect of technological change on the capital expenditure of desalination plants in Algeria. However, it seems that the general trend points to cheaper capital expenditure with each successive year of the desalination program.

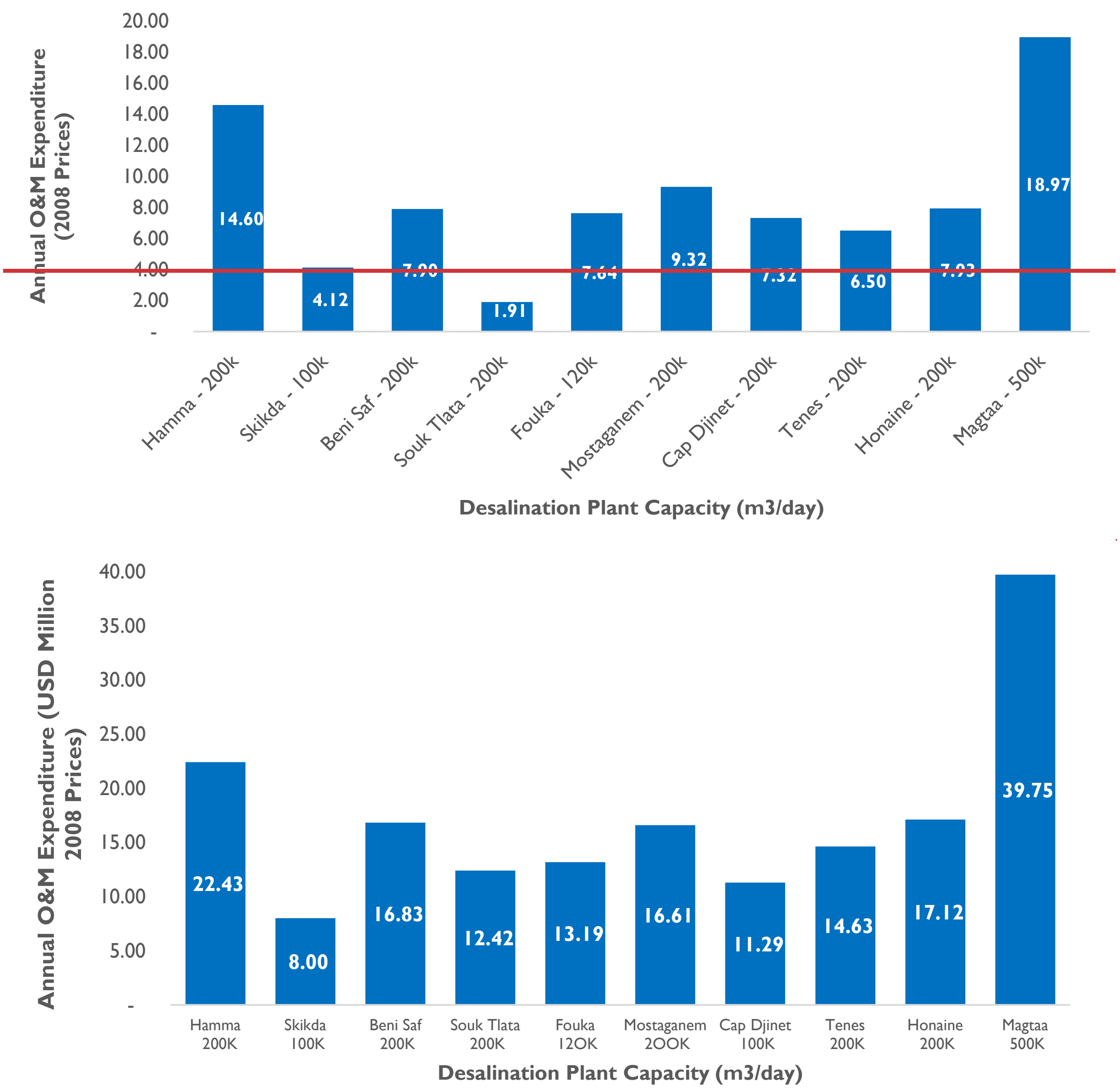
2.3. OPERATING AND MAINTENANCE EXPENDITURE

Operating and Maintenance (O&M) expenditure consist of two main components: fixed and variable costs. The fixed costs are largely comprised of expenditures on the replacement of desalination membranes and

[7] The investment costs represent the costs incurred by the EPC contractor. The EPC costs were sourced from the report produced by AEC, (AEC, 2013). It should be noted that these costs were quite different from those observed in the project contracts. Annex B provides a comparison of EPC costs reported by AEC and those found in the projects' EPC contracts.
[8] All figures were sourced from (AEC, 2013). For details refer to Annex C.

equipment and labor and administration. In comparison, the variable costs consist of expenditures on things such as energy, chemicals, and various types of consumables. Figure 6 below summarizes the total annual O&M costs of the Algerian SWRO desalination plants. The documents reviewed during the evaluation did not provide sufficient data to determine the fixed and variable components of annual O&M costs of the Algerian desalination plants.

Figure 6. O&M Expenditure on SWRO Desalination Plants [nominal values][9]



[9] All figures were sourced from (AEC, 2013), (Water Global Practice, 2019), and (GWI, 2021). For details refer to Annex C.

What is evident from Figure 6 is that there are significant disparities between the O&M costs of the plants. Souk Tlata has by far the lowest O&M expenditure of US$ 1.91 per annum, which is significantly lower than the other plants of an equivalent water production capacity. The O&M costs of plants such as Beni Saf, Mostaganem, Cap Djinet, Tenes, and Honaine, which all have the same capacity to produce 200k m^3 of water per day are, 4.1x, 4.9x, 3.8x, 3.4x, and 4.2x more expensive to operate and maintain, respectively. It is unclear why Souk Tlata has such as low O&M cost compared to its peers. It may be attributable to good governance that has led to a lower administrative burden and O&M expenditures. It is hard to draw a conclusion without an in-depth investigation into the disaggregated O&M cost structures of each desalination plant, an analysis that would require a lot more data than was supplied for this evaluation. However, it should be noted that an attempt was made to verify the O&M costs from the AEC 2013 activity report by comparing them to the O&M costs stated in the projects' O&M contracts. This comparison is provided in Annex B, and it shows that there is a slight disparity in the O&M costs reported by the AEC and those stated in the O&M contracts. However, it should be noted that for evaluation and benchmarking of the desalination plants, we utilized the O&M costs provided in the AEC report, even though some of the figures did not seem to make sense, as is the case of Souk Tlata.

Various factors influence the overall O&M cost faced by each plant. The main determinants of the O&M costs apart from those mentioned above are:

i. The salinity of the feedwater,

ii. The required quality of the product water, and,

iii. The cost of electrical energy.

As the desalination plants all draw their feedwater from the same source, i.e., the Mediterranean Sea, the water's salinity is expected to be roughly similar across the board. It is estimated that the Mediterranean Seawater salinity ranges between 37.5 – 39.5 psu (UN Environment , 2017). The quality of the plants' product water will most likely be of a similar quality as they will be regulated by the standards put in place by the state-owned water and sanitation utilities. Hence, the only factor apart from other fixed and variable O&M cost components that will have a pronounced impact on the total O&M cost is the cost of electrical energy. Figure 7 summarizes each plant's energy cost based on its efficiency to convert saline feed water into freshwater.[10]

[10] The guaranteed specific energy charge (SEC) measures how efficient the desalination is in turning saline water into fresh water.

Figure 7. Cost of Electrical Energy per m³ of Water Produced[11]

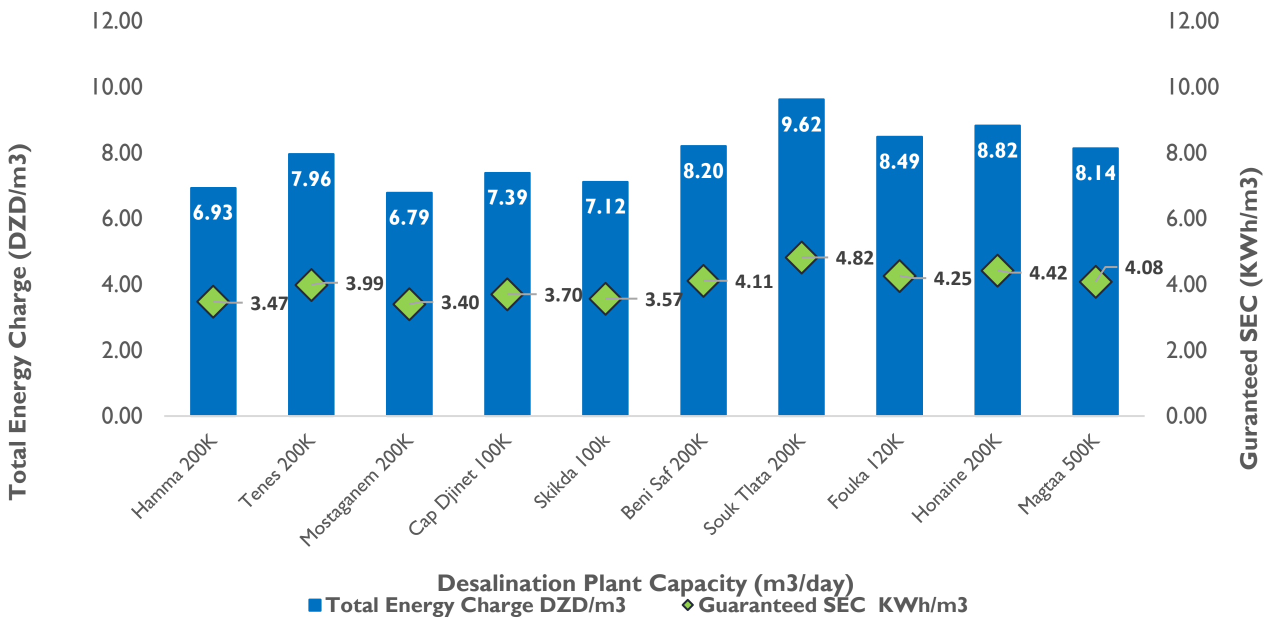
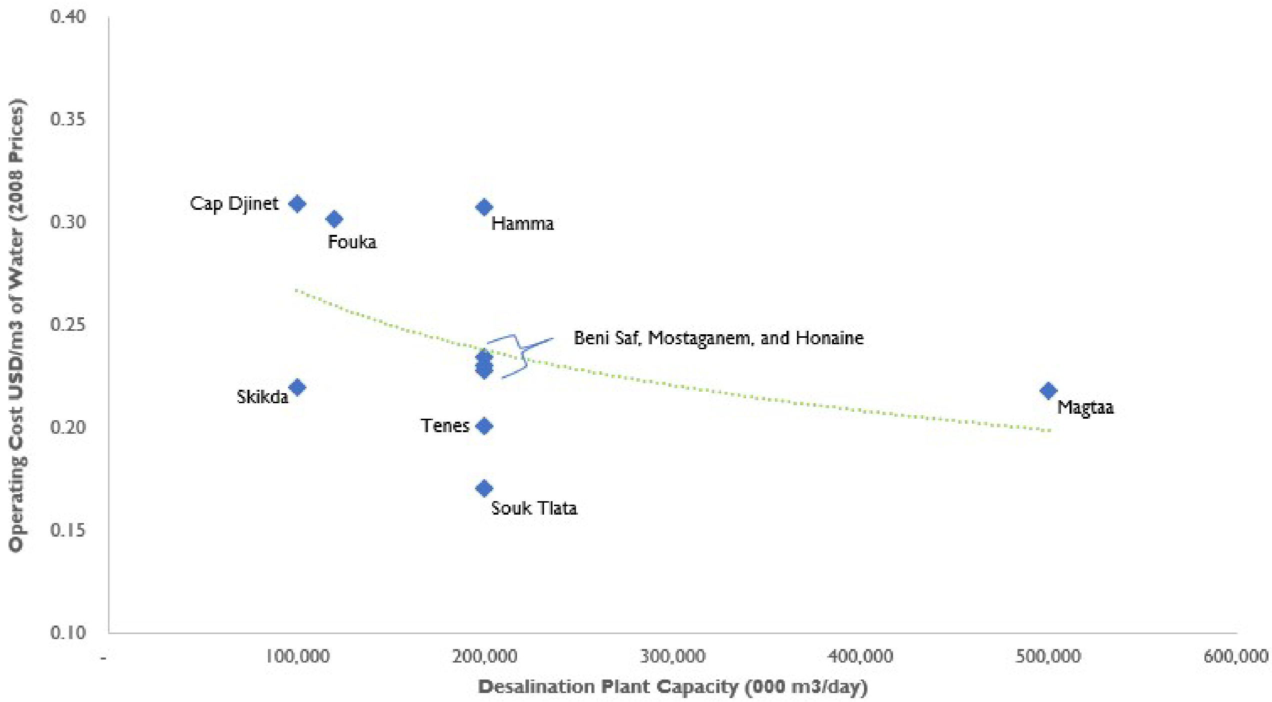


Figure 7 shows that Mostaganem is the most energy-efficient desalination plant. It consumes the least amount of energy and at just 3.40KWh/m³ of water produced, translating to an energy cost of 6.79 DZD/m³. On the other hand, Souk Tlata is the least energy-efficient desalination last and consumes 1.4x more energy than Mostaganem and consequently has an energy cost of 9.62 DZD/m³.

[11] The cost of electrical energy is derived as follows: $\text{Electricity Charge} = \text{SEC} \times \text{Price of a KWh of Electricity}$. All figures were sourced from (AEC, 2013), (Water Global Practice, 2019), and (GWI, 2021). For details refer to Annex C.

A comparison of the O&M Costs based on a unit of production capacity shows that there are economies of scale; as illustrated in Figure 8, these economies of scale increase significantly as the desalination plants' water production capacity increases. This result suggests that there is value for money to be derived from operating and maintaining large-scale plants such as the Magtaa desalination plant instead of smaller plants, in the cases where demand justifies the need for desalination plants with a large capacity.

Figure 8. O&M Expenditure per Unit of Water Production Capacity[12]



[12] The O&M per unit of water production capacity is derived by dividing the real annual O&M cost of each plant by its daily water production capacity. Where the real O&M cost is reflected in terms of 2008 prices by apply the appropriate price index. Computing the costs as of the same year (i.e., 2008) allows for an accurate comparison between costs by removing the impacts of inflation. In algebraic terms the real O&M cost per unit of water production capacity can be represented as follows:

$$OM_r^t = \frac{OM_r^t}{P_I^t} \times \frac{1}{PC}$$

where:

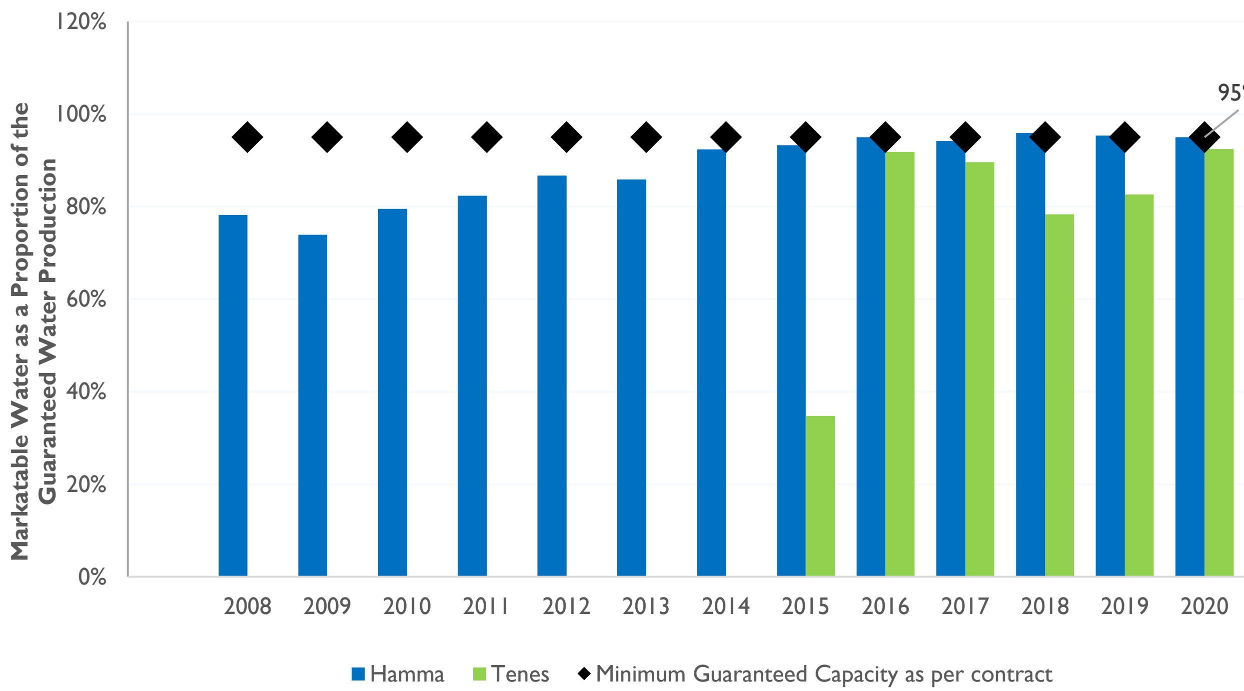
OM_r^t = the real O&M cost per unit of water production capacity, $O\&M_i^t$ = the nominal annual O&M cost, P_I^t = the price index in period (t), PC = the daily water production capacity of the plant.

All figures were sourced from (AEC, 2013), (Water Global Practice, 2019), and (GWI, 2021). For details refer to Annex C.

2.4. WATER DELIVERIES TO THE OFF-TAKER

One of the key measures for assessing the desalination plants' operational efficiency is their ability to supply water to the off-taker as per the contractual arrangements of the WSPA. In the Algerian desalination program, the desalination plants are obligated to supply the off-taker with marketable water equivalent to at least 95% of the guaranteed capacity. The guaranteed water production capacity refers to the marketable water that each desalination plant agrees to make available to the off-taker. In contrast, marketable water is the actual quantity of water produced by the desalination plant and delivered to the off-taker.

Figure 9. Marketable Water Delivered to the Off-Taker



As illustrated in Figure 9, based on the water production schedules reviewed in the case of the Hamma and Tenes desalination plants, it is clear that plants struggled to meet their production quotas during the first few years of operation. In the case of the Hamma desalination plant, it took eight years for the plant to reach the marketable water delivery quantities agreed upon in the WSPA. On the other hand, Tenes has also faced challenges in ramping up production to meet the off-taker's requirements. After six years since the plant was commissioned, its marketable water production has failed to meet the guaranteed water production capacity as per the WPSA. Given the limited information provided, it is hard to say what the causes are behind the Hamma and Tenes plants failing to operate as per the provisions of the WPSA.

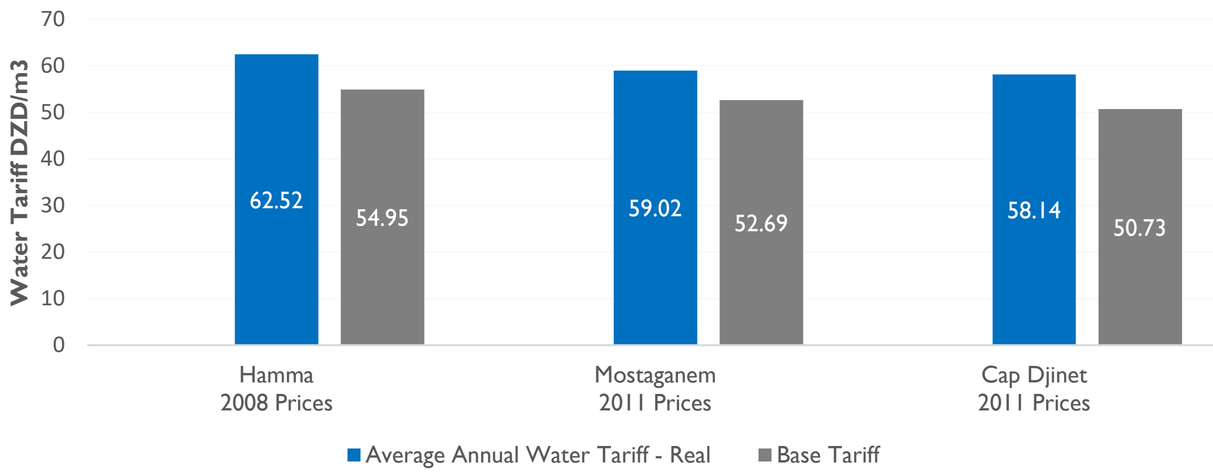
It would be interesting to see whether the other desalination plants in the program, for which water production schedules were not provided, exhibit the same difficulties observed in the case of Hamma and Tenes with respect to discrepancies between the water production plan and the marketable water delivered and billed to the off-taker.

2.5. VALUATION OF WATER PRODUCED BY THE DESALINATION PLANTS

2.5.1. WATER TARIFF

The water tariff represents the price at which the off-taker purchases desalinated water from the plants. The water tariff compensates the desalination plants for the costs incurred to produce desalinated water (O&M costs). It enables them to recoup their CAPEX, repay any financing provided to the plant, and provide a reasonable rate of return to their shareholders. In order to ensure that the value of the water tariff is not materially impaired over the concession period, the base water tariff is indexed annually to factor in changes in various economic variables such as inflation and exchange rates that may change the real value of the project company's earnings.[13] Figure 10 summarizes the average real value of the Hamma, Mostaganem, and Cap Djinet desalination plants' water tariffs and compares them against the base tariffs (i.e., the tariffs when the desalination plants first came online). It should be noted that this analysis could not be completed for the other seven plants in the desalination program as there was not enough data provided.

Figure 10. Average Water Tariff vs. Base Water Tariff [real values]



As shown in Figure 10, the value of the average annual water tariff is higher than the base tariff in the case of all three desalination plants. The average difference is estimated to be 12%. The variation between the average annual water tariff and the base tariff is caused by the average annual growth rate of the tariff being higher than the average inflation rate and exchange rate appreciation and depreciation over the concession period.[14] This implies that the indexation being applied by the project companies is substantially higher than what is necessary for them to ward off the effects of changes in the economy on their required rate of return. This directly impacts the budget as the off-taker, a state-owned enterprise, ends up paying more than initially anticipated for the water delivered by the desalination plants.

2.5.2. FINANCIAL LEVELIZED COST OF WATER

[13] A detailed outline of how the water tariff is projected and indexed over the concession period is provided in Annex A.

[14] The average annual growth rate refers to compound effect of the indexation applied to the base tariff over the concession period.

From Sonatrach's perspective, as the off-taker of the water produced by the desalination plants, there is a cost associated with purchasing water from the plants. Hence, a performance metric that can be used to compare the cost of water purchased from one of the desalination plants against the cost of other plants in the PPP program is the Levelized Cost of Water (LCOW). The LCOW enables the comparison of the desalination plants based on the average cost per cubic meter of water produced by each plant and is, therefore, a measure of the cost-effectiveness of obtaining water from each of the ten desalination plants in the PPP program (Jenkins, 2014).

The financial LCOW is computed as follows:

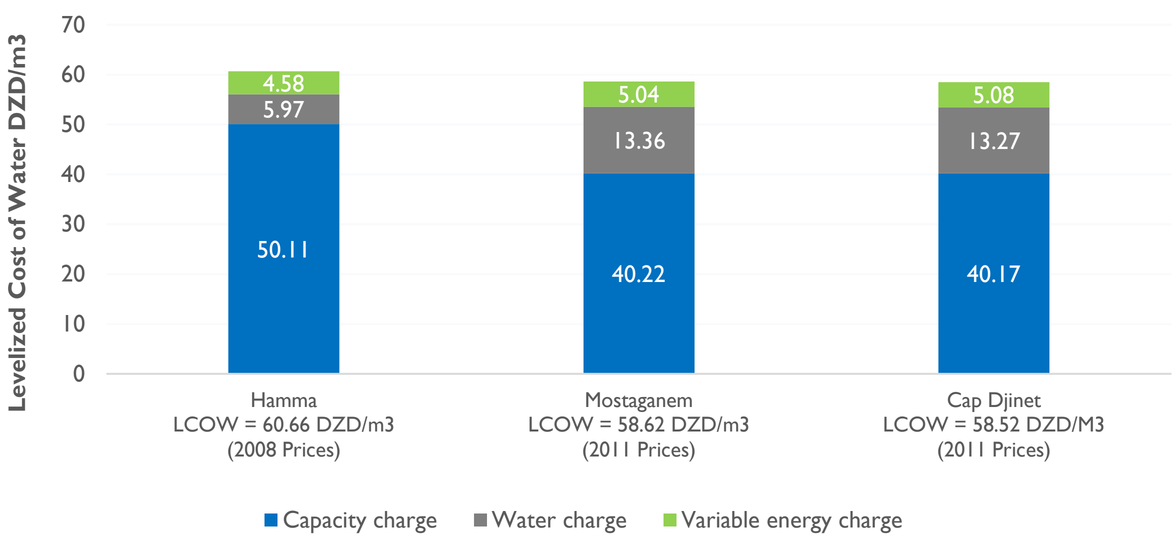
$$FLCOW_r^t = \frac{PV\ of\ the\ total\ water\ payment\ made\ over\ the\ concession\ period}{PV\ of\ the\ total\ water\ delivered\ to\ the\ off\ taker\ over\ the\ concession\ period}$$

where:

$FLCOW_r^t$ = the real value of the financial levelized cost of water in period (t), PV = the present value at an 8% discount rate

Figure 11 summarizes the financial levelized cost of the Hamma, Mostaganem, and Cap Djinet plants. A similar analysis could not be conducted for the rest of the desalination plants as not enough data was provided.

Figure 11. Comparison of Financial Levelized Costs of Water[15]



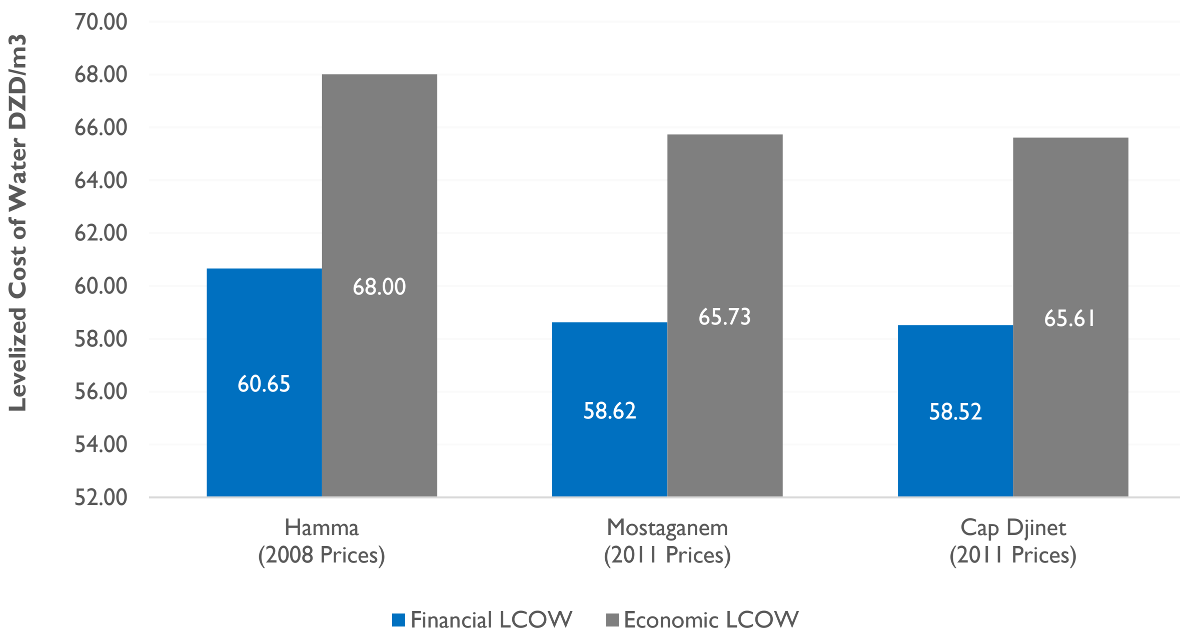
[15] The LCOW for Mostaganem and Cap Djinet were estimated based on the observations of water production and water tariff for a 3-year period reported in the 2013 AEC activity report. Utilizing this data and a couple of assumptions we were able to forecast the water production and water payments to derive an approximation of the LCOW for these plants. It should be noted that the method used provides a rough estimate, and more accurate estimates will require actual data with respect to the water production and water tariff schedules for Mostaganem and Cap Djinet.

Out of the three plants shown in Figure 11, Cap Djinet has the lowest financial LCOW, followed by Mostaganem and Hamma. Hence, the least expensive source of desalinated water is the Cap Djinet desalination plant. The Government effectively saves 0.10 DZD/m^3 and 2.14 DZD/m^3 of water purchased from the Cap Djinet plant as opposed to the Mostaganem and Hamma plants, respectively.

2.5.3. ECONOMIC LEVELIZED COST OF WATER

The economic LCOW is computed in the same way as the financial LCOW described in the preceding section. However, the water payments from an economic perspective are adjusted to remove distortions such as taxes and subsidies, which are considered transfers rather than actual payments. The elimination of distortions brings about a difference in the economic value of LCOW compared to its financial equivalent.

Figure 12. Comparison of Financial vs. Economic Levelized Costs of Water



The economic LCOW is substantially higher than the financial LCOW; the percentage difference between the two in the case of the Hamma desalination plant is 12%. This difference is accounted for by taxes such as import duties and corporate income taxes and the implicit subsidy on electrical energy, all of which are shown in Table 3.[16] The desalination plants currently pay an electricity tariff of around 2.5 USDc/KWh, while the cost-reflective tariff is around 10 USDc/KWh.[17] Hence, the desalination plants obtain the energy

[16] Given a lack of data with regards to the taxes and duties applicable to the Mostaganem and Cap Djinet desalination plants, their economic LCOW was estimated assuming that the percentage difference in the financial and economic LCOW will be more or less equal to that observed in the case of the Hamma desalination plant. Hence, their economic LCOW was derived by multiplying their financial LCOW by 1.12.

[17] Note that these values are based on estimates provided by the World Bank Global Water Practices from work that they are currently doing on assessing the reforms that need to be made to the water tariff in Algeria.

they require for the desalination process at a quarter of the actual cost of that energy to the Government of Algeria. The text box below provides further information on the electricity subsidy.

Explicit and Implicit Electricity Subsidies

In the framework of the support to the Ministry of Finance for the development of a strategy to reform energy subsidies, the World Bank estimated in 2018 explicit (ES) and implicit (IS) subsidies for electricity consumption. The ES affects on the one hand electricity consumers from the wilayas of the South and the Highlands who receive a partial refund of their bills, and on the other hand budget transfers to Sonelgaz for public investment programs (rural electrification, extension of the gas network). IS account for about 97% of total subsidies to the sector. They are present in upstream (production), downstream (transportation, distribution, etc.), and in taxation. IS stems from (i) the sale of crude oil and natural gas on the Algerian market at a price below international prices (upstream subsidies), (ii) from the sale of energy products (oil products, city gas, electricity) at final prices that do not cover the costs of activities (downstream subsidies), and (iii) reduced tax rates that are applied to certain energy products (tax subsidies). According to this analysis, the average total subsidy (ES plus IS) in 2017, excluding tax subsidies, was 616 cDA/KWh, or 150.1% of the average tariff actually applied in 2017 (407 cDA/KWh).

Table 3. Economic LCOW - Hamma

		Value in 2008 Prices (USD/m³)
	Financial LCOW including Duties and Taxes	62.56
(-)	Duties and Taxes	4.54
(+)	Electricity Subsidy	9.98
	Economic LCOW for Hamma	**68.00**

The economic LCOW highlights that the economic cost of water is substantially more than the financial cost, meaning that the Government is spending considerably more resources from an economic perspective to obtain freshwater from the desalination plants. One of the big items that cause this inefficiency is the implicit subsidy on electricity provided to the desalination plants. Cutting down or eliminating this subsidy will save the Government considerable resources.

It should be noted that one of the components of the economic LCOW is the environmental impacts of the project. However, one of the limitations of this study is that these impacts are not included in estimating the economic LCOW. This limitation is discussed in greater details in section 4.2

3. BENCHMARKING ANALYSIS

The benchmarking exercise's objective is to compare Algerian desalination infrastructure's performance against that commissioned elsewhere that is similar in nature, scope, and scale. A good understanding of the cost and performance of the desalination program in Algeria relative to other countries is envisioned to result in a positive contribution to decision-making on capital expenditure and the improvement in operational efficiency and effectiveness in delivering future investments in desalination infrastructure.

The benchmarking was conducted by analyzing data on various key cost and performance metrics of desalination projects. The evaluation metrics that were included in the benchmarking analysis are:

i. Capital Costs.
ii. Operating and Maintenance Costs.
iii. Water Tariff.

Various factors influence the capital costs, operating and maintenance costs, and desalination plants' water tariff. Among the main determinants of these metrics are;

i. The salinity of feedwater,
ii. The required quality of the product water,
iii. The cost of electrical energy,
iv. The capacity of the plant, and,
v. The technology utilized by the desalination plant.

To keep the analysis consistent and compare "apples to apples", the analysis was structured such that.

i. Only projects that utilize the Sea Water Reverse Osmosis (SWRO) technology were used as reference points in the analysis.
ii. Only desalination plants with comparative sizes (i.e., similar capacity to produce desalinated water) were utilized in the analysis. Three capacity ranges were constructed that mirror the various plant capacities that exist within the set of Algerian plants included in this analysis.
The capacity ranges are as follows.[18]

   a. 100k – 150k m^3/day.[19]
   b. 200k – 250k m^3/day.[20]
   c. 385 – 625k m^3/day.[21]

[18] It should be noted that in some cases, the capacity ranges were increased a little due to a lack of sufficient data on reference desalination plants that are closer matched in capacity to those observed in Algeria. However, where possible the capacity ranges were kept in line with the actual plant.
[19] This range closely matches plants such as Skikda (100k m^3/day), Cap Djinet (100k m^3/day), and Fouka (120k m^3/day).
[20] This range closely matches plants such as Hamma, Beni Saf, Souk Tlata, Mostaganem, Tenes, Honaine; which all have a capacity of 200k m^3/day.
[21] This range closely matched the Magtaa plant, which has a capacity of 500k m^3/day.

iii. To ensure compatibility based on the salinity of feedwater, where possible, the plants were compared based on the source of their feedwater (i.e., based on the body of water they draw from for the desalination process).

Data for the analysis was obtained from the following sources.

i. World Bank. (Water Global Practice, 2019).
ii. Global Water Intelligence (GWI) - Desal Data. (GWI, 2021).
iii. Algerian Energy Company Spa. (AEC, 2013).
iv. Various web sources.[22]

A composite data sample of 72 desalination plants from across the globe was constructed using information collected from the sources mentioned above. A list outlining the numerous details and parameters about the plants is provided in Annex C. What follows is an in-depth benchmarking analysis of the capital costs, operating and maintenance costs, and the water tariff of the Algerian desalination plants in comparison to other plants within the data sample.

3.1. BENCHMARKING: PLANTS WITH A 100K – 150K M^3/DAY CAPACITY

The following subsection assesses how Algerian desalination plants that have a capacity of producing 100k – 150k m3 of water per day compare with other plants similar in size from a global and regional perspective. Algeria has three plants that fall in this category, namely.

Skikda and Cap Djinet (both plants have a capacity to produce 100k m^3 of water per day).

Fouka (this plant has a capacity to produce 150k m^3 of water per day).

The aforementioned Algerian desalination plants are compared to other plants from across the world and the Mediterranean region, based on three metrics.

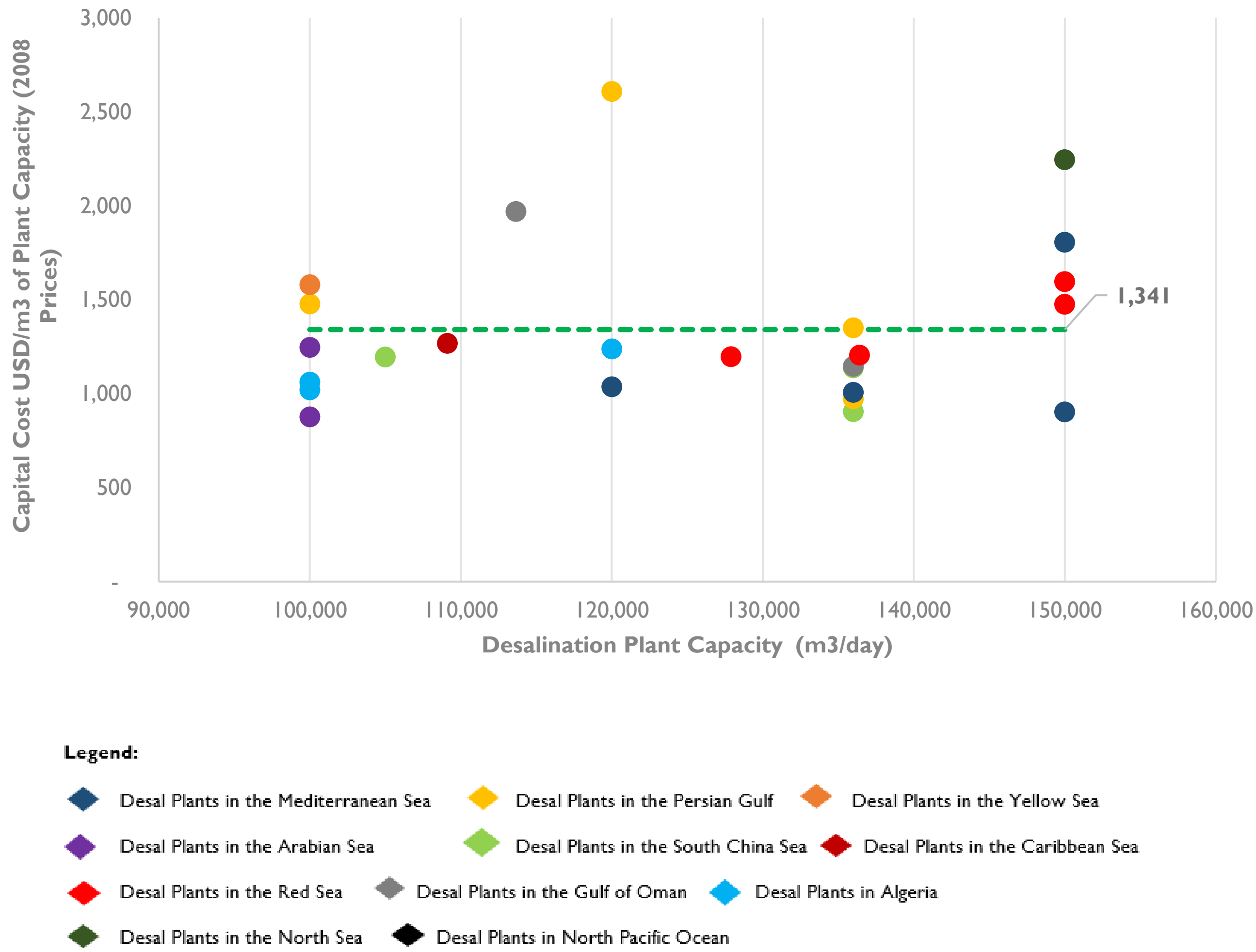
i. Capital costs,
ii. Operating and maintenance costs, and,
iii. Water Tariff.

3.1.1. CAPITAL COST BENCHMARKING: PLANTS WITH A 100K – 150K M^3/DAY CAPACITY[23]

The data sample has 25 plants within the capacity range of 100k – 150k m^3/day. 3 of these 25 plants are from Algeria. Hence, excluding the Algerian plants, the total number of comparators is equal to 22.

[22] A comprehensive list of these sources is provided in the Annex C.
[23] The capital costs represent the EPC costs of the projects.

Figure 13. Capital Cost Comparison (100k - 150k m³/day Capacity)[24]



As illustrated in Figure 13, comparing the capital cost per m3 of the capacity of Skikda, Cap Djinet, and Fouka against that of the other 23 plants results in a capital cost that ranges between a minimum of 876 USD/m³ and a maximum of 2,608 USD/m³, with an average of 1,341 USD/m³. All the Algerian plants' capital costs are below the average. The range of capital costs observed in Figure 13 is relatively similar to that observed in the Mediterranean Sea region of between 800 – 2,200 USD/m³ with an average of 1,200 USD/m³ (Water Global Consultants , 2016).

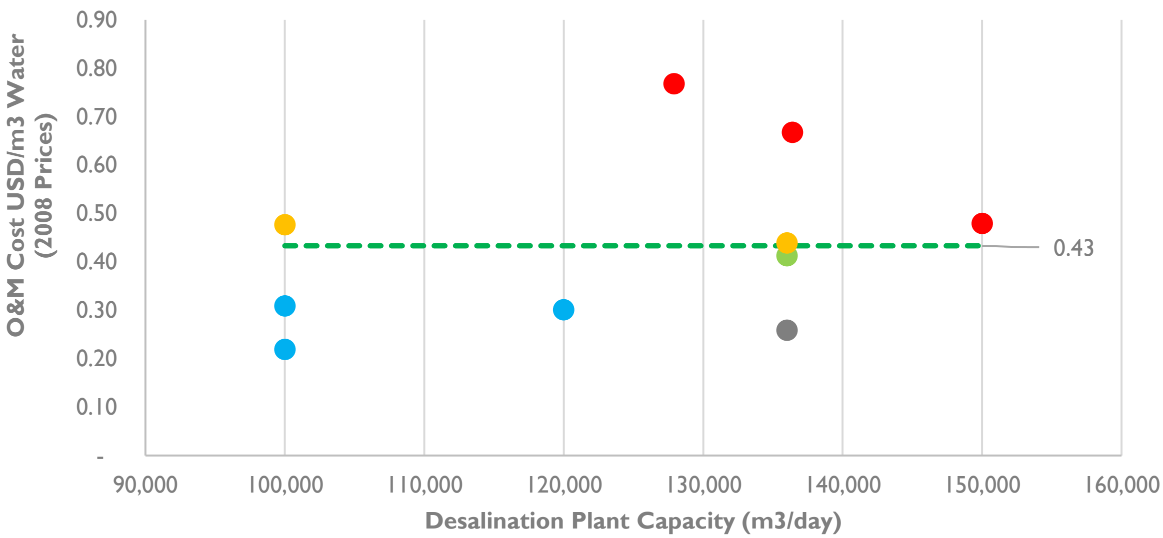
[24] **Reference Plants in the Sample:** [1,478 USD/m³ – Al Jubail, KSA, 100k m³/day], [1,580 USD/m³ – Qingdao, China, 100k m³/day], [1,247 USD/m³ – Minjur, India, 100k m³/day], [876 USD/m³ – Chennai, India, 100k m³/day],[1,970 USD/m³ – Jebel Ali, UAE, 113k m³/day], [2,680 USD/m³ – Barka II, Oman, 120k m³/day], [1,036 USD/m³ – Carboneras, Spain, 120k m³/day], [1,197 USD/m³ – Yanbu Phase 1, KSA, 127k m³/day], [1,137 USD/ m³ – Singspring, Singapor, 136k m³/day], [1,145 USD/m³ – Fujairah 2, UAE, 136k m³/day], [1,351 USD/m³ – Shuwaikh, Kuwait, 136k m³/day], [906 USD/m³ – Tuas 1, Singapore, 136k m³/day], [972 USD/m³ – Az Zour South, Kuwait, 136k m³/day], [1,008 USD/m³ – Valdelentisco, Spain, 136k m³/day], [1,206 USD/m³ – Jeddah 1&2, KSA, 136k m³/day], [2,246 USD/m³ – Beckton, UK, 150k m³/day], [1,597 USD/m³ – Shuaibah 3, KSA, 150k /m³/day], [1,806 USD/m³ – Palmachin Exp 3&4, Israel, 150k m³/day], [903 USD/m³ – El Almein, Egypt, 150k m³/day], [1,477 USD/m³ – Shoiba 3 Exp, KSA, 150k m³/day]. All figures were sourced from (AEC, 2013), (Water Global Practice, 2019), and (GWI, 2021). For details refer to Annex C.

In fact, out of the 25 plants in the 100k – 150k m³/day capacity range, the Algerian plants rank 6th (Skikda – 1,020 USD/m³), 8th (Cap Djinet – 1,061 USD/m³), and 15th (Fouka – 1,239/m³) in terms of the least expensive plants with respect to their capital costs. The results in Figure 13 indicate that the Algerian plants are relatively cheaper than other desalination plants of a similar capacity around the globe and within the Mediterranean region from which the plants draw their feedwater.

3.1.2. O&M COST BENCHMARKING: PLANTS WITH A 100K – 150K M³/DAY CAPACITY[25]

Unlike in the case of capital costs, there is fewer data available on the operating and maintenance (O&M) costs of desalination plants with a capacity of 100k – 150k m³/day. The data sample used for the benchmarking of O&M costs of plants within the capacity range of 100k – 150k m³/day consist of 10 reference points. 3 out of the 10 plants are from Algeria. Hence, excluding the Algerian plants, the total number of comparators is equal to 7.

Figure 14. O&M Cost Comparison (Plant Capacity of 100k - 150k m3/day)[26]



[25] O&M cost per m³ = $\frac{Annual\ O\&M\ cost}{Annual\ Water\ Production}$. The O&M costs per m³ were computed assuming that the desalination plants produce water at full capacity as data on actual water production was limited. The O&M costs represent the total costs as reported by the various sources utilized in the analysis. These O&M costs were not disaggregated into their various components. It is assumed for the purposes of this analysis that these costs are inclusive of the cost of electricity which makes up a big portion of the total cost.

[26] [0.48 USD/m³ – Al Jubail, KSA, 100k m³/day], [0.77 USD/m³ – Yanbu 1, KSA, 128k m³/day], [0.41 USD/m³ – Singspring, Singapore, 136k m³/day], [0.26 USD/m³ – Fujairah, UAE, 136k m³/day], [0.44 USD/m³ – Shuwaikh, Kuwait, 136k m³/day], [0.67 USD/m³ – Jeddah 1&2, KSA, 136k m³/day], [0.48 USD/m³ – Shuaibah, KSA, 150k m³/day]. All figures were sourced from (AEC, 2013), (Water Global Practice, 2019), and (GWI, 2021). For details refer to Annex C.

As illustrated in Figure 14, the O&M costs for this sample of desalination plants range from 0.22 – 0.77 USD/m^3 of water, with an average O&M cost of 0.43 USD/m^3 of water. What is particularly intriguing about the results shown in Figure 14 is that not only are the O&M costs of Skikda, Cap Djinet and Fouka below the average observed for this data sample. Their O&M costs rank as the 1st (Skikda – 0.22 USD/m^3), 3rd (Fouka – 0.30 USD/m^3), and 4th (Cap Djinet – 0.31 USD/m^3) least expensive out of all the plants assessed in this sample.

The Algerian desalination plants likely have significantly lower O&M costs due to the desalination plants' lower energy cost as a result of an implicit subsidy on electricity (La Banque Mondiale, 2019).[27] Data on the O&M costs of the Algerian desalination plants were obtained from the Algerian Energy Company Activity Report (AEC, 2013).[28] Given the data obtained from the AEC Report, it seems that the Algerian plants perform much better than their counterparts in this sample.

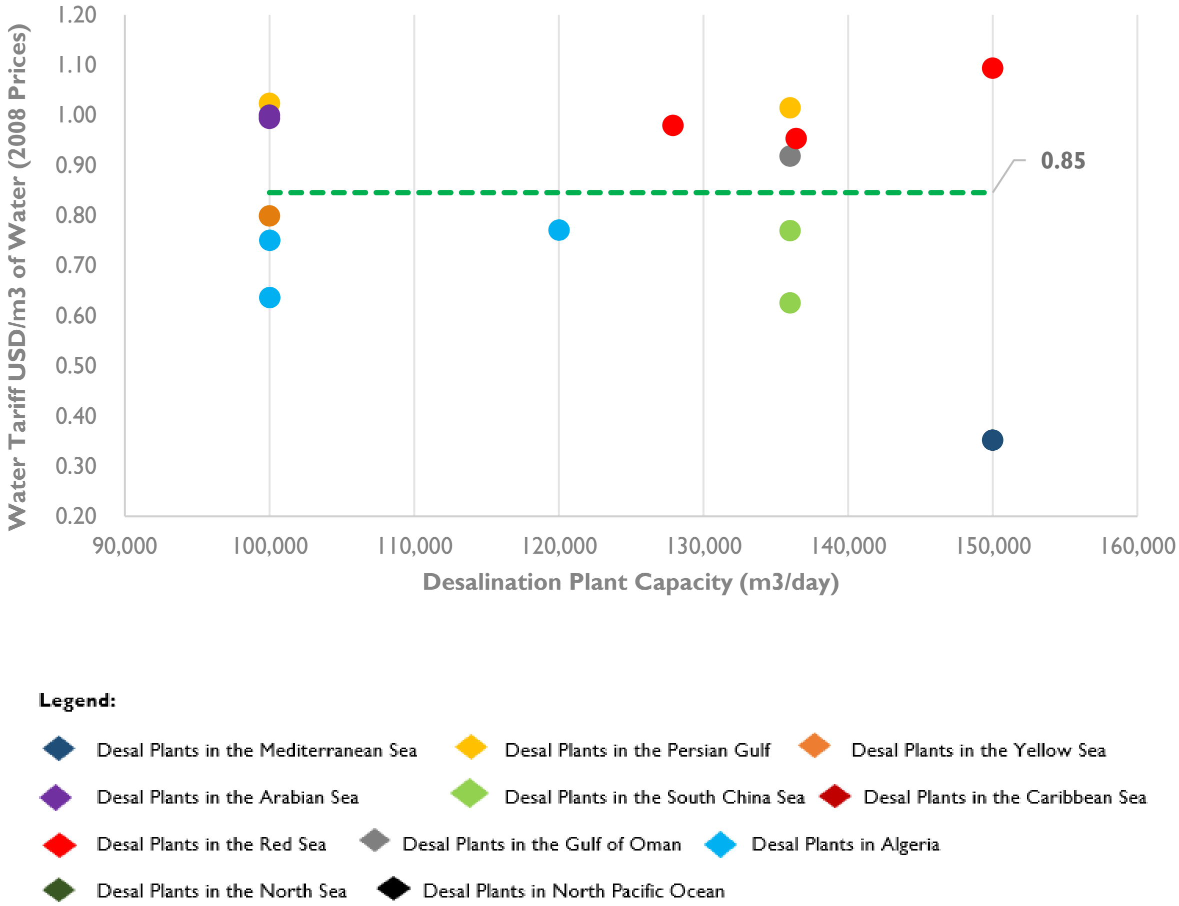
3.1.3. WATER TARIFF BENCHMARKING: PLANTS WITH A 100K – 150K M^3/DAY CAPACITY

The data sample used for the benchmarking of Water Tariffs for desalination plants within the capacity range of 100k – 150k m^3/day consist of 15 reference points. 3 out of the 15 plants are from Algeria. Hence, excluding the Algerian plants, the total number of comparators is equal to 12. As illustrated in Figure 15, the Water Tariffs for this sample of desalination plants range from 0.35 – 1.14 USD/m^3 of water, with an average tariff of 0.85 USD/m^3 of water. As a comparison, the Water Tariffs in the Mediterranean Sea are in the range of 0.64 – 1.62 USD/m^3 of water, while the average is 0.98 USD/m^3 (Water Global Consultants , 2016). What is particularly interesting about the results shown in Figure 15 is that not only are the Water Tariffs of Skikda, Cap Djinet and Fouka below the average observed for this data sample. Their desalinated water ranks as the 3rd (Skikda – 0.64 USD/m^3), 4th (Cap Djinet – 0.75 USD/m^3), and 6th (Fouka – 0.77 USD/m^3) least expensive out of all the plants assessed in this sample. The results indicate that Algeria's desalinated water is reasonably priced relative to the other countries and regions considered in the sample.

[27] It was observed that the desalination plants pay around 2.5 USDc/KWh of electricity, when in fact the real cost of electricity is around 4x the tariff that the desalination plants face, i.e., the cost reflective electricity tariff is 10 USDc/KWh

[28] Refer to Annex B for a detailed outline of the O&M costs outlined in the case of the Algerian desalination plants.

Figure 15. Water Tariff Comparison (Plant Capacity of 100k - 150k m3/day)[29]



3.2. BENCHMARKING: PLANTS WITH A 200K – 250K M^3/DAY CAPACITY

The following subsection assesses how Algerian desalination plants that have a capacity of producing 200k – 250k m³ of water per day compared with other plants similar in size from a global and regional perspective. Algeria has six plants that fall in this category, namely.

i. Hamma,
ii. Beni Saf,
iii. Souk Tlata,
iv. Mostaganem,
v. Tenes, and,

[29] **Reference Plants in the Sample:** [1.02 USD/m^3 – Al Jubail, KSA, 100k m^3/day], [0.98 USD/m^3 – Yanbu 1, KSA, 128k m^3/day], [0.77 USD/m^3 - Singspring, Singapore, 136k m^3/day], [0.92 USD/m^3 – Fujairah, UAE, 136k m^3/day], [1.01 USD/m^3 – Shuwaikh, Kuwait, 136k m^3/day], [0.95 USD/m^3 – Jeddah 1&2, KSA, 136k m^3/day], [1.09 USD/m^3 – Shuaibah, KSA, 150k m^3/day], [0.80 USD/m^3 – Qingdao, China, 100k m^3/day], [1.00 USD/m^3 – Minjur, India, 100k m^3/day], [0.99 USD/m^3 – Chennai, India, 120k m^3/day], [1.09 USD/m^3 – Shuwaikh, Kuwait, 136k m^3/day], [0.63 USD/m^3 – Tuas 1, Singapore, 136k m^3/day], [0.35 USD/m^3 – Palmachim, Israel, 150k m^3/day]. All figures were sourced from (AEC, 2013), (Water Global Practice, 2019), and (GWI, 2021). For details refer to Annex C.

vi. Honaine.

All the Algerian plants mentioned above have a capacity to produce 200k m^3 of water per day. These Algerian desalination plants are compared to other plants from across the world, based on three metrics.

i. Capital costs,
ii. Operating and maintenance costs, and,
iii. Water Tariff.

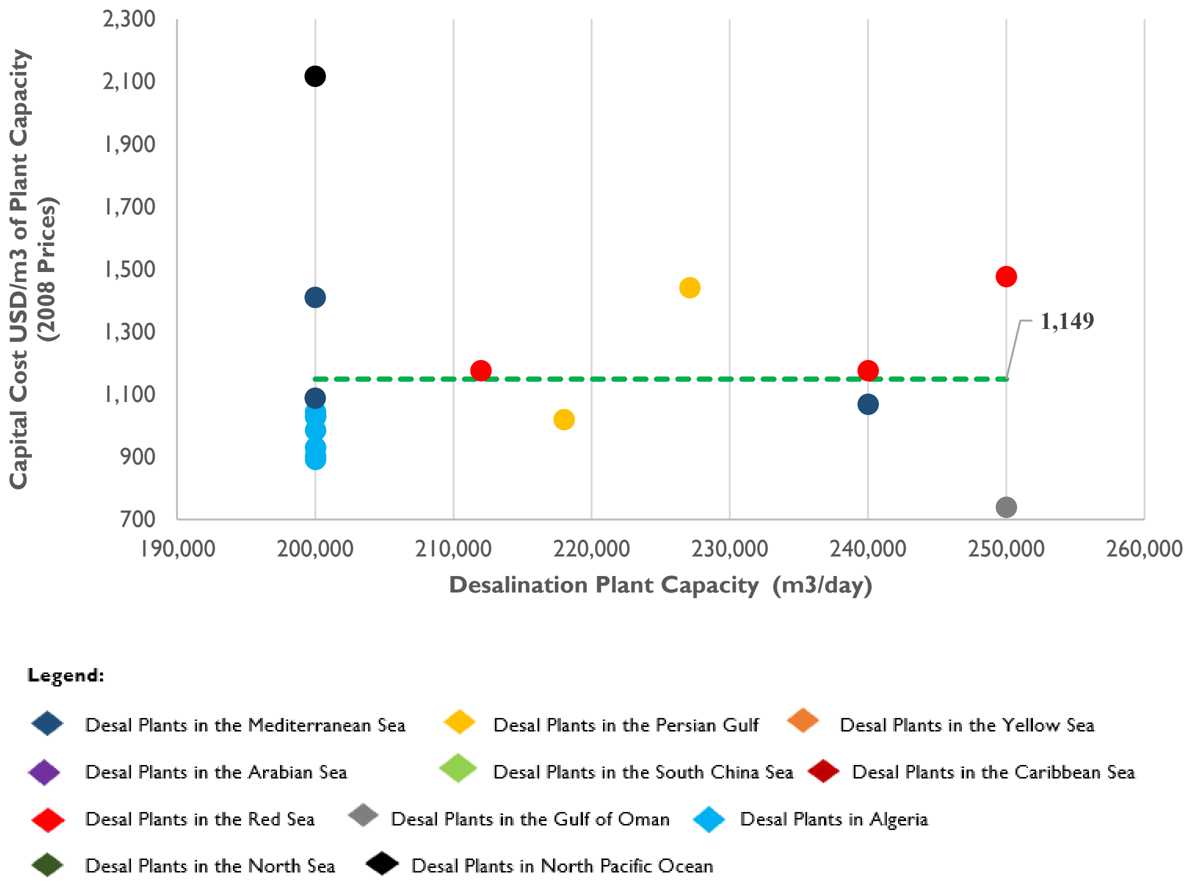
3.2.1. CAPITAL COST BENCHMARKING: PLANTS WITH A 200K – 250K M^3/DAY CAPACITY[30]

The data sample has 17 plants within the capacity range of 200k – 250k m3/day. 6 of those 17 plants are from Algeria. Hence, excluding the Algerian plants, the total number of comparators is equal to 11. As illustrated in Figure 16, comparing the capital cost per m^3 of Hamma, Beni Saf, Souk Tlata, Mostaganem, Tenes, and Honaine against that of the other 11 desalination plants in the data sample results in a capital cost that ranges between a minimum of 739 USD/m^3 and a maximum of 2,117 USD/m^3, with an average of 1,149 USD/m^3.

All the Algerian plants' capital costs are below the average. The range of capital costs observed in Figure 16 is quite similar to those observed in the Mediterranean Sea region of between 800 – 2,200 USD/m^3 with an average of 1,200 USD/m^3 (Water Global Consultants , 2016). In fact, out of the 17 plants in the 200k – 250k m^3/day capacity range, the Algerian plants rank 2nd (Beni Saf – 893 USD/m3), 3rd (Mostaganem – 903 USD/m^3), 4th (Tenes – 931/m^3), 5th (Hamma – 987 USD/m^3), 7th (Souk Tlata – 1,029 USD/m^3), and 8th (Honaine – 1,044 USD/m^3) in terms of the least expensive plants with respect to their capital costs. The results in Figure 15 indicate that the Algerian plants are relatively cheaper than other desalination plants of a similar capacity around the globe and within the Mediterranean region from which the plants draw their feedwater.

[30] The capital costs represent the EPC costs of the projects.

Figure 16. Capital Cost Comparison (Plant Capacity of 200k - 250k m^3/day)[31]



3.2.2. O&M COST BENCHMARKING: PLANTS WITH A 200K – 250K M^3/DAY CAPACITY[32]

The data sample used for the benchmarking of the O&M costs of plants within the capacity range of 200k – 250k m^3/day consists of 11 reference points. 6 out of the 11 plants are from Algeria. Hence, excluding the Algerian plants, the total number of comparators is equal to 5. The results of the analysis are quite different from those obtained in a study that revealed that the O&M costs in the Mediterranean Sea for desalination plants are in the range of 0.25 – 0.74 USD/m^3 of water, while the average O&M cost is 0.35 USD/m^3, (Water Global Consultants , 2016).

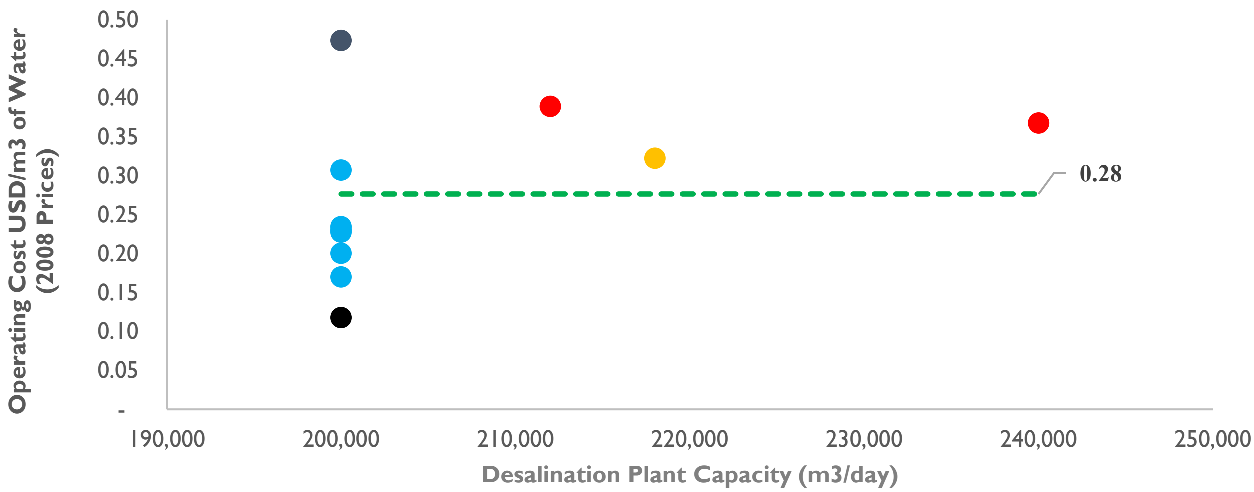
[31] **Reference Plants in the Sample:** [739 USD/m^3 – Sohar 3, Oman, 250k m^3/day], [1,019 USD/m^3 – Al Dur, Bahrain, 218k m^3], 1,032 USD/m^3 – Qurayyat, Oman, 200k m^3/day], [1,068 USD/m^3 – Torrevieja, Spain, 240k m^3/day], [1,411 USD/m^3 – Barcelona, Spain, 200k m^3/day], [2,117 USD/m^3 – Carlsbad, USA, 200k m^3/day], [1,088 USD/m^3 – Llobregat, Spain, 200k m^3/day], [1,176 USD/m^3 – Jeddah 3, KSA, 240k m^3/day], [1,176 USD/m^3 – Shuqaiq, KSA, 212k m^3/day], [1,442 USD/m^3 – Kuwait SWRO, Kuwait, 227k m^3/day], 1,477 USD/m^3 – Shoiba 250k m^3/day]. All figures were sourced from (AEC, 2013), (Water Global Practice, 2019), and (GWI, 2021). For details refer to Annex C.

[32] O&M cost per m^3 = $\frac{Annual\ O\&M\ cost}{Annual\ Water\ Production}$. The O&M costs per m^3 were computed assuming that the desalination plants produce water at full capacity as data on actual water production was limited. The O&M costs represent the total costs as reported by the various sources utilized in the analysis. These O&M costs were not disaggregated into their various components. It is assumed for the purposes of this analysis that these costs are inclusive of the cost of electricity which makes up a big portion of the total cost.

What is striking about the results shown in Figure 17 is that not only are the O&M costs of Beni Saf, Mostaganem, Tenes, Souk Tlata, and Honaine below the average observed for this data sample. Their O&M costs rank as the 2nd (Souk Tlata – 0.17 USD/m^3), 3rd (Tenes – 0.20 USD/m^3), 4th (Mostaganem – 0.23 USD/m^3), 5th (Beni Saf – 0.23 USD/m^3), and 6th (Honaine – 0.23 USD/m^3), least expensive, out of all the plants assessed in this sample. On the other hand, the Hamma desalination plant seems to be slightly more expensive to operate and maintain, at a cost of 0.31 USD/m^3, which is slightly above average, and relatively more costly than the other Algeria desalination plants.

It is likely that the Algerian desalination plants have significantly lower O&M costs due to the lower energy costs incurred by the desalination plants on account of a subsidy on electricity (La Banque Mondiale, 2019).[33] Data on the O&M costs of the Algerian desalination plants were obtained from the Algerian Energy Company Activity Report (AEC, 2013).[34], Given the data obtained from the AEC Report, it seems that the Algerian plants perform much better than their counterparts in this sample.

Figure 17. O&M Cost Comparison (Plant Capacity of 200k - 250k m^3/day)[35]

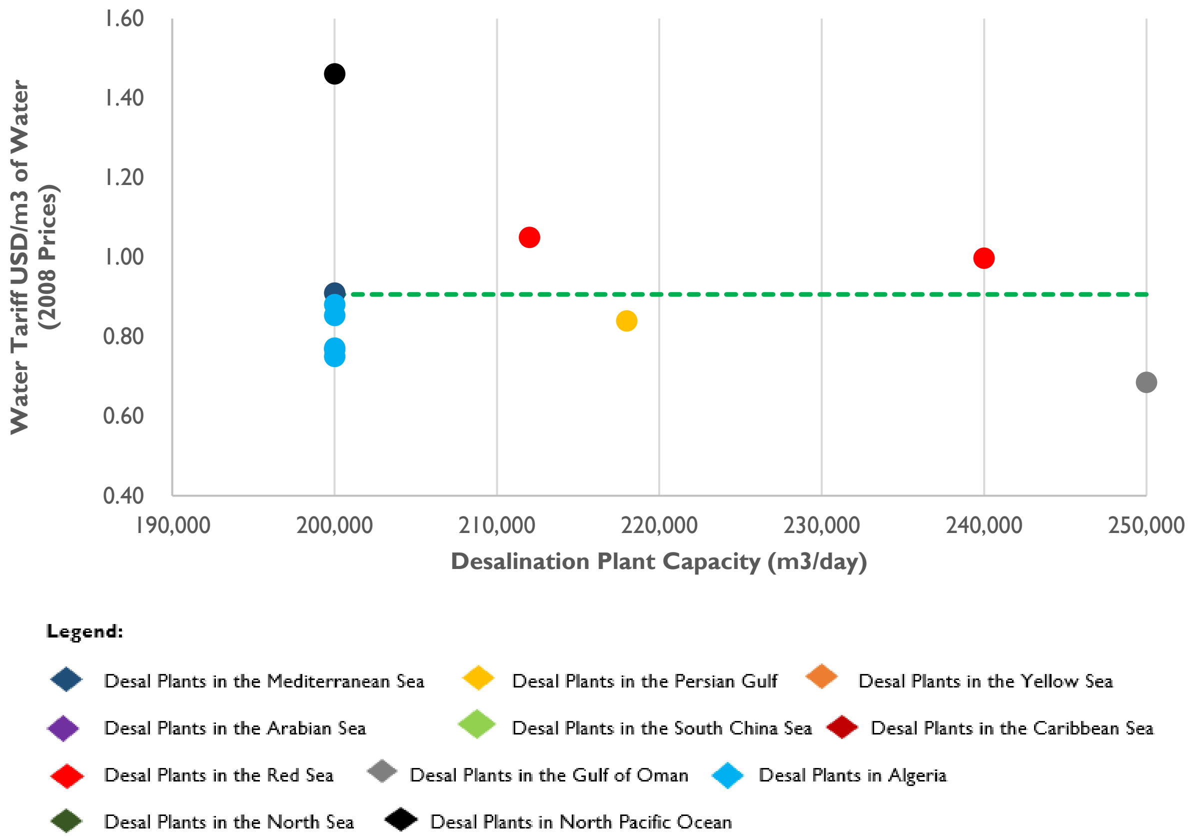


[33] It was observed that the desalination plants pay around 2.5 USDc/KWh of electricity, when in fact the real cost of electricity is around 4x the tariff that the desalination plants face, i.e., the cost reflective electricity tariff is 10 USDc/KWh.
[34] Refer to Annex B for a detailed outline of the O&M costs outlined in the case of the Algerian desalination plants.
[35] **Reference plants in the sample:** [0.47 USD/m3 - Barcelona, Spain, 200k m3/day, 2009], [0.12 USD/m3 – Carlsbad, USA, 200k m3/day, 2015], [0.39 USD/m3 - Shuqaiq, KSA, 212k m3/day, 2010], [0.32 USD/m3 - Al Dur, Bahrain, 218k m3/day, 2012], [0.37 USD/m3 - Jeddah 3, KSA, 240k m3/day, 2013]. All figures were sourced from (AEC, 2013), (Water Global Practice, 2019), and (GWI, 2021). For details refer to Annex C.

3.2.3. WATER TARIFF BENCHMARKING: PLANTS WITH A 200K – 250K M^3/DAY CAPACITY

Based on the data provided for the Algerian desalination plants, the Water Tariff was established for 5 out of the 6 Algerian plants that have a capacity between 200k – 250k m^3/day, namely; Hamma, Beni Saf, Souk Tlata, Mostaganem, and Honaine.

Figure 18. Water Tariff Comparison (Plant Capacity of 200k - 250k m^3/day)[36]



[36] **Reference Plants in the Sample**: [0.91 USD/m^3 – Barcelona, Spain, 200k m^3/day], [1,46 USD/m^3 – Carlsbad, USA, 200k m^3/day], [1.01 USD/m^3 – Shuqaiq, KSA, 212k m^3/day], [1.00 USD/m^3 – Jeddah 3, KSA, 240k m^3/day], [0.69 USD/m^3 – Sohar 3, Oman, 250k m^3/day]. All figures were sourced from (AEC, 2013), (Water Global Practice, 2019), and (GWI, 2021). For details refer to Annex C.

As illustrated in Figure 18, comparing the Water Tariff of these 5 Algerian desalination plants against 6 other plants with a similar capacity shows that the Water Tariff of the sample ranges from a minimum of 0.69 USD/m^3 of water to a maximum of 1.46 USD/m^3 of water, with an average of 0.91 USD/m^3 of water.

As a comparison, the Water Tariffs in the Mediterranean Sea are in the range of 0.64 – 1.62 USD/m^3 of water, while the average is 0.98 USD/m^3 (Water Global Consultants , 2016); this is not too far off from the result presented in Figure 18. The analysis indicates that the Algerian Plants Water Tariffs are reasonably priced relative to the other plants in the sample due to the fact that;

i. Their Water Tariffs are below the sample average.

ii. They have the 2nd (Mostaganem – 0.75 USD/m^3), 3rd (Beni Saf – 0.77 USD/m^3), 4th (Souk Tlata – 0.77 USD/m^3), 6th (Honaine – 0.85 USD/m^3), and 7th (0.88 USD/m^3) least expensive Water Tariffs within the sample.

3.3. BENCHMARKING: PLANTS WITH A 385K – 625K M^3/DAY CAPACITY

The Magtaa desalination plant is the largest plant out of the 10 desalination plants from Algeria included in this benchmarking exercise. At a capacity of 500k m^3/day, it is 5x bigger than Skikda, Cap Djinet, and Fouka and 2.5x larger than Hamma, Souk Tlata, Mostaganem, Honaine, Tenes, and Beni Saf. Across the globe, there are very few desalination plants with a similar capacity to that of Magtaa; however, none of them are of an equivalent scale. The three plants that are similar in capacity to the Magtaa desalination plant are the Ashdod, Hadera, and Sorek desalination plants in Israel, which have capacities of 385k m^3/day, 462k m^3/day, and 624 m^3/day, respectively.

The following subsections assesses how the Magtaa desalination compares to the Israel plants based on three key performance metrics.

i. Capital costs,
ii. Operating and maintenance costs, and,
iii. Water Tariff.

3.3.1. CAPITAL COST BENCHMARKING: PLANTS WITH A 385K – 625K M^3/DAY CAPACITY[37]

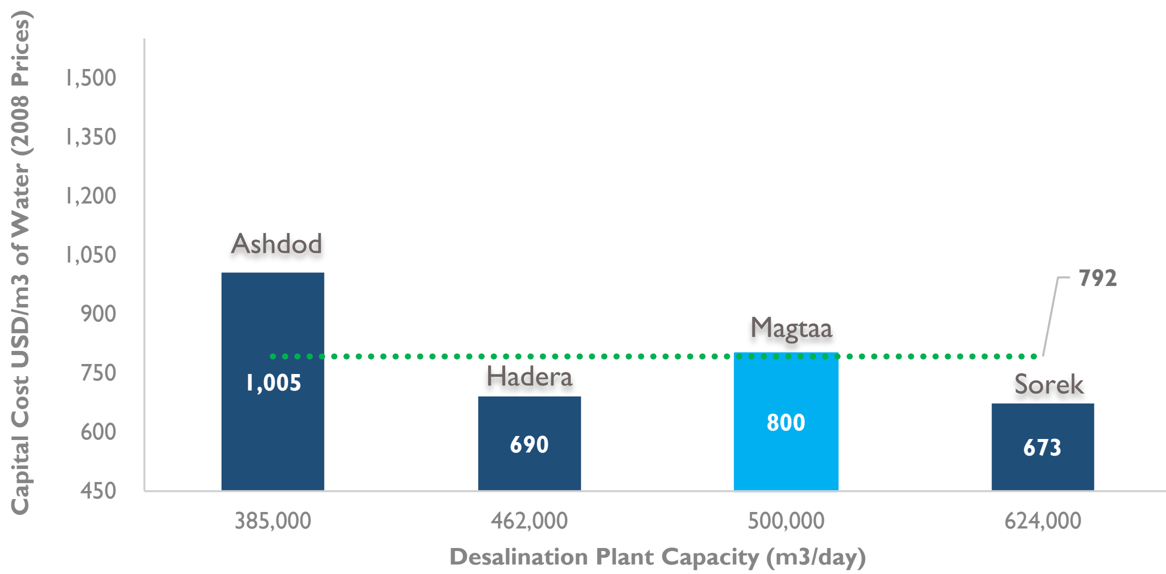
As illustrated in Figure 19, comparing the capital cost per m^3 of the capacity of Magtaa against that of the 3 Israeli desalination plants in the data sample results in a capital cost that ranges between a minimum of 673 USD/m^3 and a maximum of 1,005 USD/m^3, with an average of 792 USD/m^3.

What is evident from Figure 19 is that:

[37] The capital costs represent the EPC costs of the projects.

i. Economies of scale exist as capacity increases for the desalination plants in this sample.
ii. The Magtaa desalination plant defies this general trend of economies of scale.
iii. The Magtaa desalination plant's capital cost is above the average observed in this sample.

Figure 19. Capital Cost Comparison (Plant Capacity of 385k - 625k m³/day)[38]



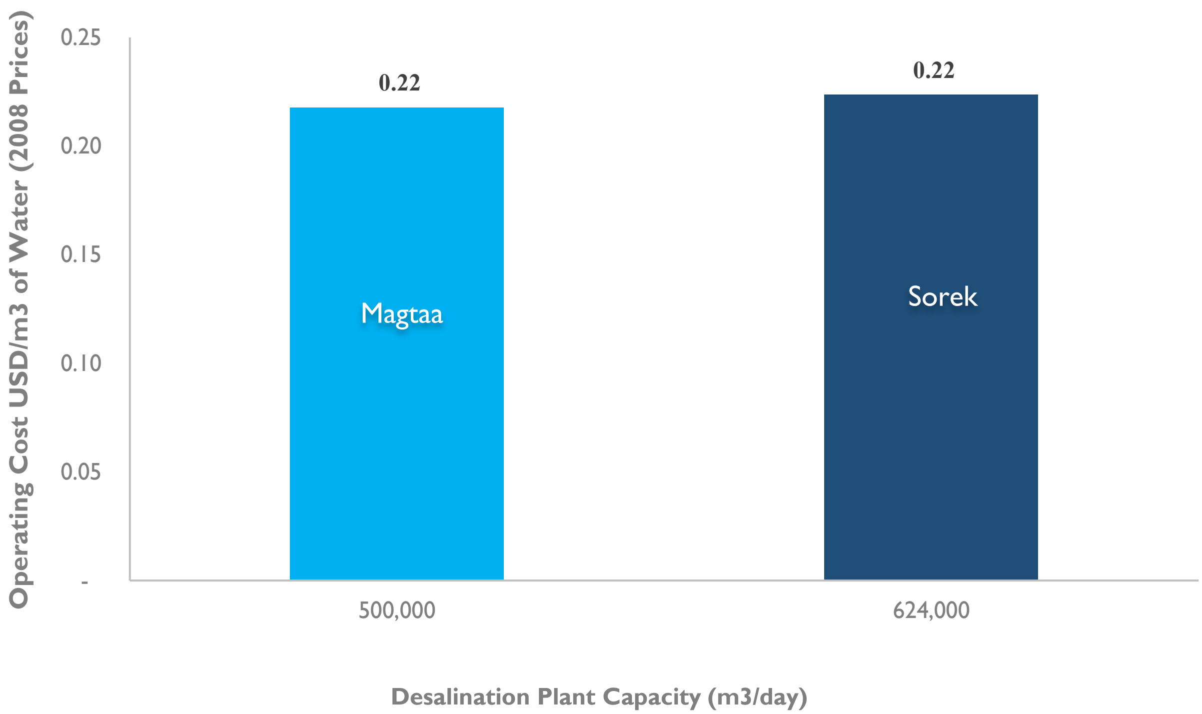
The Magtaa desalination plant is 16% more expensive than the Hadera desalination plant, which has 0.92x the capacity of Magtaa. Magtaa is also 19% more expensive than the Sorek desalination plant, which has 1.25x the capacity of Magtaa. Hence, the results of the analysis indicate that relative to the other plants in the sample, Magtaa is more expensive with regards to its capital cost. It should be noted that at the time when Magtaa was constructed, it was the largest desalination plant in the world. This is likely the reason it is more expensive than Sorek, even though Sorek is a much larger plant.

[38] **Reference plants in the sample:** [1,005 USD/m3 - Ashdod, Israel, 385k m3/day, 2011], [690 USD/m3 – Hadera, Israel, 462k m3/day, 2007], [673 USD/m3 - Sorek, Israel, 624k m3/day, 2013]. All figures were sourced from (AEC, 2013), (Water Global Practice, 2019), and (GWI, 2021). For details refer to Annex C.

3.3.2. O&M COST BENCHMARKING: PLANTS WITH A 385K – 625K M^3/DAY CAPACITY[39]

Out of the 4 plants with a 385k – 625k m3/day capacity, O&M costs could only be established for two of the plants; that is Magtaa and Sorek. As illustrated in Figure 20, the O&M costs for Magtaa are equal to those of Sorek (0.22 USD/m^3 of water). Given that there are very few data samples to benchmark the performance of Magtaa, there is little that can be inferred with regards to the operational efficiency of such a large plant in comparison with plants of an equivalent capacity. However, Magtaa's O&M costs fall within the range of other plants in Algeria. In fact, Magtaa is relatively cheaper to operate and maintain than the Hamma, Beni Saf, Mostaganem, Honaine, Cap Djinet, and Fouka desalination plants, all of which have a small production capacity. This observation points to the possibility of operating and maintenance economies of scale as the size of the desalination plant increases.

Figure 20. O&M Cost Comparison (Plant Capacity of 500k - 625k m^3/day)[40]



3.3.3. WATER TARIFF BENCHMARKING: PLANTS WITH A 385K – 625K M^3/DAY CAPACITY

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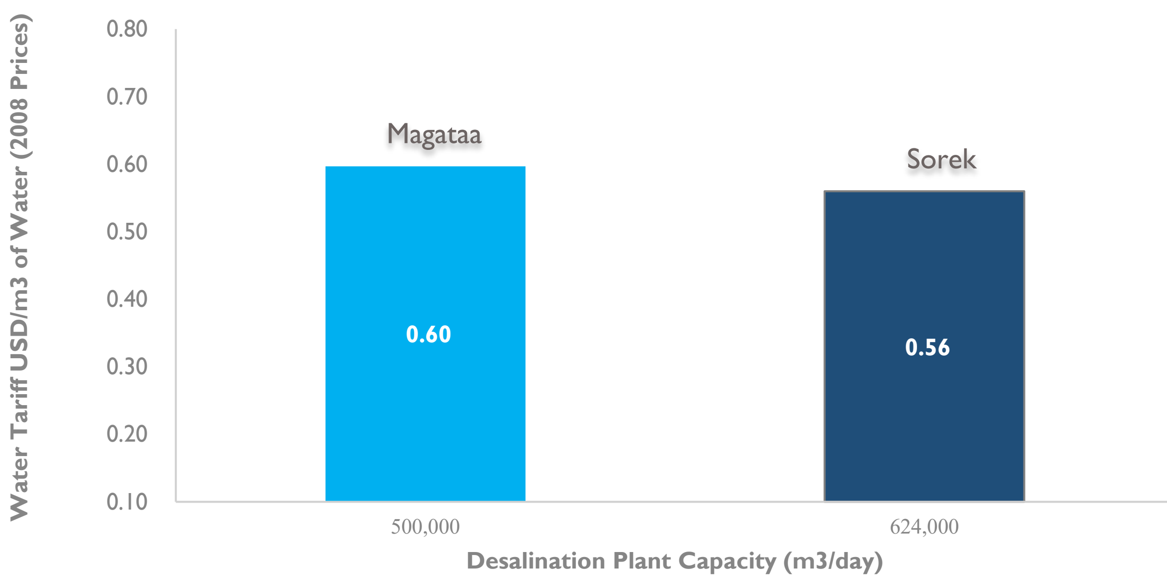
[39] O&M cost per m^3 = $\frac{Annual\ O\&M\ cost}{Annual\ Water\ Production}$. The O&M costs per m^3 were computed assuming that the desalination plants produce water at full capacity as data on actual water production was limited. The O&M costs represent the total costs as reported by the various sources utilized in the analysis. These O&M costs were not disaggregated into their various components. It is assumed for the purposes of this analysis that these costs are inclusive of the cost of electricity which makes up a big portion of the total cost.

[40] All figures were sourced from (AEC, 2013), and (GWI, 2021). For details refer to Annex C.

Out of the 4 plants with a capacity of 385k – 625k m3/day, Water Tariffs could only be determined for two plants; that is Magtaa and Sorek. As illustrated in Figure 21, the Water Tariff for Magtaa (0.60 USD/m^3 of water) is higher than that of Sorek (0.56 USD/m^3 of water). Magtaa's Water Tariff is 7% higher than that of Sorek.

As a comparison, the Water Tariffs in the Mediterranean Sea are in the range of 0.64 – 1.62 USD/m^3 of water, while the average is 0.98 USD/m^3 (Water Global Consultants , 2016). The Water Tariff of both Magtaa and Sorek fall below the average observed in the Mediterranean Sea. Furthermore, their Water Tariffs fall below the minimum tariff observed within the range. The analysis indicates that though the Water Tariff of Magtaa is slightly pricier than that of Sorek, Magtaa's Water Tariff is reasonably priced relative to the other plants within the Mediterranean region.

Figure 21. Water Tariff Comparison (Plant Capacity 500k - 625k m^3/day)[41]



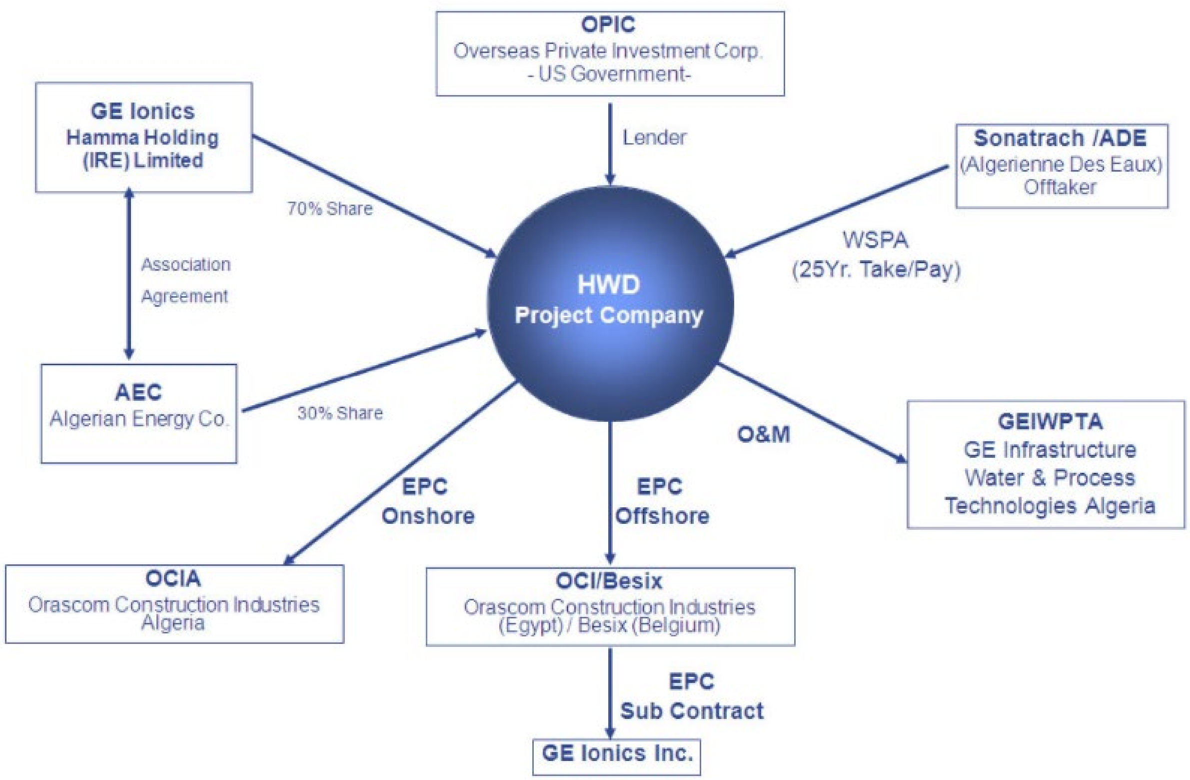
[41] All figures were sourced from (AEC, 2013), and (GWI, 2021). For details refer to Annex C.

4. CASE STUDY: CBA OF THE HAMMA DESALINATION PLANT

4.1. INTRODUCTION

The Hamma desalination plant located in Algiers, Algeria, was the first plant to be commissioned under Algeria's PPP Desalination Program to acquire critical infrastructure to supply the people of Algeria with freshwater. The plant was put into service in the first quarter of 2008 (AEC, 2013). The desalination plant, which uses the SWRO technology, has a capacity to produce 200,000 m^3 of water per day and is estimated to meet the water needs of up to a quarter of the residents of Algiers (or approximately 1.5 million people (General Electric, 2016). The project was procured using the Build, Own and Operate (BOO) PPP model, with a concession of 25 years. The structure of the project and the various stakeholders involved are outlined in Figure 22.

Figure 22. Hamma Desalination Plant - Project Structure



Source: Hamma Desalination Spa.

A total of US$ 258 million was invested in the project (AEC, 2013). Hence, the objective of the Cost-Benefit Analysis (CBA) of the Hamma desalination plant is to assess the economic viability of the Government's decision to invest a significant amount of public resources to supply water to its population using desalination technology.

4.2. LIMITATIONS OF THE STUDY

This section highlights several limitations of the study and how they can affect the outcomes of the analysis.

1. The economic benefit of water is underpinned by the willingness of end-users to pay for the improved water supply. The study uses an estimate obtained in a CRI study in North Cyprus as a proxy for the WTP for water supply in Algeria. While the conditions and coping mechanisms for intermittent water supply are similar in Algeria and North Cyprus, it must be said that the estimate obtained for North Cyprus might not fully reflect the unique situation of Algeria. The accuracy of the estimates of the economic benefit used in the study and the conclusions reached in the study will improve if there is an estimate of the willingness to pay for water by households and industries in Algiers.
2. The economic evaluation of water supply alternatives is typically conducted using the "least alternative cost" principle. There are several reasons for this, including (a) water is considered as an essential "public good" that must be made available for everyone, and (b) in a situation of scarce water supply, willingness to pay for water is very high. Therefore, the analysis of a water project is not usually centered around whether or not the project should be implemented. Instead, the purpose is to identify the alternative (technology) that produces the required volume of water at the least cost. The least-cost principle states that one should not attribute to a project a value of benefits that is greater than the least alternative cost one would have to incur by providing an equivalent benefit stream in a different way. For example, access to good quality, potable water results in a reduction in water-borne diseases, which is of tremendous value to the project beneficiaries. The least-cost principle states that the value of health benefits should not be used as it is likely to lead to the approval of a highly expensive alternative for potable water supply, while other cost-effective solutions might be available. However, this study only considers the desalination technology as the only alternative for water generation, as other alternatives and their respective costs are not known to the authors.
3. Although desalination technologies have been successfully used to provide reliable water supply, irrespective of natural ecosystems, there are still significant concerns about the potential negative impacts the technology has on the environment (Elsaid et al., 2020). The environmental impacts of the two major desalination technologies (Membrane and Thermal Desalination) are typically attributed to brine discharges, which can potentially impair coastal water quality and affect marine life by increasing water, salinity as well as water current and turbidity. They also force fish to migrate while enhancing the presence of algae, nematodes and tiny molluscs (Heck et al., 2018; Panagopoulos et al., 2019; Al-Mutaz, 1991). Another significant environmental impact of desalination technology is the greenhouse gasses due to the high energy demand of the processes involved in desalination (Elsaid et al.,2020b, Liu et al., 2013; Mabrouk et al., 2019, Zhou et al., 2013; Kim et al., 2019). The impacts of these emissions are even more significant in a country like Algeria, where about 90 percent of its energy is generated using fossil fuel (Commission for Energy and Gas Regulation, Algeria, 2019). However, it must be mentioned that the brine discharge from thermal desalination technology might have a higher negative impact on the environment because it is released back to the water at higher temperatures relative to the ambient. Elsaid et al. (2020) and Van der Bruggen et al. (2002) argue that the volume of brine stream released by the thermal desal plants, which can be up to five times that of membrane desalination for the same desalination capacity, despite being less in terms of salinity might be responsible for the increased impact on the aquatic life when the thermal desalination technology is employed. Table 3 below compares some of the environmental impacts of desalination technology and wastewater reuse.

Desalination Technology	Water reuse Technology
Brine Discharge: Technology leads to brine discharge and negatively impacts the environment. This happens by increasing water salinity, the release of dis-infection by-products, and chemical additives, etc. These discharges can potentially impair coastal water quality and affect marine life by increasing water salinity and water current, and turbidity. They also force fish to migrate while enhancing the presence of algae, nematodes and tiny molluscs. etc	Liberation of water for the environment through substitution with wastewater has been widely promoted as a means of reducing anthropogenic impacts of other water supply technologies.
Greenhouse gas emissions: The technology uses energy and releases GHG into the atmosphere when non-renewable energy generation technologies are employed. The volume of GHG emitted depends on the energy need of the technology. Thermal desalination technology is known to consume more energy, and as a result, emit more GHG.	Wastewater reuse provides a route for the entry of organic xenobiotics and heavy metals into the environment. This happens due to the uptake of xenobiotics released through wastewater reuse being taken up by soil, plants and the potential impacts on groundwater. Studies have shown that treated wastewater contains elements like Phosphorus and Nitrogen, which are essential nutrients for plants. However, these elements are found in large quantities and sometimes surpass the P and N needs of plants, thus, leading to the accumulation of plant nutrients and heavy metals in the soil to levels that are toxic for plants. Furthermore, application. not corresponding to the various plant growth phases, may contribute to a nitrates (NO_3) surplus, which may be leached towards the lower horizons, causing its accumulation in the groundwater and therefore leading to NO_3 pollution

Sources: Frank et al., (2019), Kress (2019), Petersen et al., (2018), Petersen et al., (2019), Zhou et al. (2013), Hamilton et al. (2005), Schneider (2008), Jimenez-Cisneros (1995), Asano & Pettygrove (1987), Bower & Idelovitch (1987), NRC (1996), Fatta-Kassinos et al. (2011),

CBA involves the monetization of costs and benefits of the project. Therefore, to incorporate some of the environmental impacts into the analysis, such as impacts of brine discharge, one would need to identify and estimate the cost of the mitigation measures and include this as a part of the cost components of the project. The CBA of the case study (Hamma desalination plant) carried out in this study does not include the environmental impacts of the desalination plant. This is because it is not enough to identify the potential environmental impacts of the plant. To accurately quantify the environmental impact of this plant, the analysis must be carried out on an incremental basis. This would be achieved by taking the difference between the impacts of the Hamma desalination plant and the impacts of the next best alternative source of generating water. However, the authors do not know what the next alternative source of generating water in Algeria is.

4.3. CBA METHODOLOGY

The methodology employed for the CBA combines the financial, economic, stakeholder, and risk analyses of the program in an approach called the integrated investment appraisal approach (IIA). The analysis starts with the assessment of the financial viability of the Hamma plant from the perspective of the equity investors. On the other hand, the Economic cost-benefit analysis goes further to determine whether the Hamma Desalination Plant yields increased welfare for Algerians. Next, we proceed with the assessment of the fiscal impacts resulting from the Hamma project.

4.4. FINANCIAL ANALYSIS

The purpose of the financial analysis is to assess the financial impacts of the projects from different perspectives. The Hamma desalination plant was procured as a PPP project. The SPV has ownership of the plant over the concession period and is responsible for building, operating and maintaining the plant. The concession period is set at 25 years. In this period, Sonatrach/ADE (Algerianne Des EAUX) is the sole off-taker (on behalf of the Government) of the water produced by the plant, with a take/pay obligation. The analysis was carried from 2006 to the end of the concession period in 2032. Actual figures were obtained and used for the analysis between 2006 and 2020. These figures and other project parameters were then used to forecast the financial cash flows of the project from 2021 to the end of the project in 2032.

The total capital expenditure of the project is USD 258 million. The construction was completed in two years, with 50% completion achieved in 2006, and the construction fully completed in 2007. Full project operations began in 2008. 26.2 percent of the project's capital expenditure is funded through equity, and the remaining 73.8 percent is financed through debt. 70 percent of the equity contribution of the project was provided by the private entity through GE Ionics – Hamma holdings (IRE) Limited, and the government provided the remaining 30 percent through Algerian Energy Co. (AEC). Operations began with the plant sometimes operating at capacities below 95 percent (which was the agreed minimum capacity requirement) until 2020. In subsequent years, i.e., from 2021 till the end of the concession period in 2032, the plant is expected to operate at 95 percent capacity. The actual operating capacity of the plant from the beginning of operations in 2008 to 2020 is presented in Table 3 below.

Table 4: Operation Capacity achieved by Hamma Desalination Plant

Year	Plant Actual Capacity
2008	78%
2009	74%
2010	79%
2011	82%
2012	87%
2013	86%
2014	92%
2015	93%
2016 - 2020	95%

The financial analysis was conducted to assess the ex-ante bankability of the Hamma project and estimate equity returns to the SPV (a private entity with 70 percent equity) and the AEC(with 30 percent equity). The following sections describe the results of these analyses.

4.4.1. EX-ANTE HAMMA BANKABILITY

The primary objective of the analysis of the project's bankability is to assess the likelihood of the project to meet its debt obligations (principal and interest payments). One of the indices used to measure the ability of the project to meet these obligations is the annual debt service coverage ratio (ADSCR)[42]. The ADSCR measures the number of times the cash flow available for debt service in a period can service the project's debt obligation in the said period. The minimum ADSCR required by many financial institutions is 1.30 over the debt repayment period.

The analysis shows that in the first year of the debt repayment, which coincides with the first operational year of the plant, the ADSCR was estimated to be 1.26, which is slightly below the threshold. However, that is the only year in which the ADSCR is less than the minimum requirement, as the ADSCR is higher than the minimum requirement in subsequent years. It is, therefore, safe to say that the project was expected to meet its debt obligations.

4.4.2. FINANCIAL ANALYSIS FROM EQUITY PERSPECTIVE

The total equity injection is estimated at USD 67.6 million (i.e., 26.2% of 258 million), with GE Ionics equity of USD 47.3 million (2006 prices). The GoA invested the remaining USD 20.3 million. The SPV sells desalinated water to the off-taker at a tariff that has three components:

- Fixed capacity charge payable based on the installed capacity;
- Volumetric tariff which is dependent on the volume of water supplied to the off-taker;
- The compensation for energy use.

The total financial net present value, in 2008 prices, discounted at the required rate of return on equity of 15%, from the equity perspective is 1,382 million DZD (USD 21.4 million). Of this value, the private entity (GE Ionics) gets a return of 967 million DZD (USD 15 million) and an internal rate of return (IRR) of 17.09%. Similarly, the AEC gets a net benefit of 414.6 million DZD (USD 6.4 million) and an IRR of 17.09%.

It must be stated that the RAM report indicates that the projects include a late payment penalty to the builder (EPC Contractor), builder's claims, and buyers (Off-taker) late penalties. However, these penalties and claims are reported as single figures without any details on when these penalties occur. In the absence of more detailed information about when, why, and what remedies were put in place to avoid future charges, it is challenging to incorporate such figures into the analysis. Therefore, these figures are not included in the financial and fiscal analysis of the project.

4.5. ECONOMIC ANALYSIS

Economic costs and benefits can differ from financial costs and benefits. On the cost side, adjustments need to be made to the financial costs of the plant itself to account for taxes and subsidies. On the benefit side, the starting point in determining the project's economic benefits is estimating people's willingness to

[42] The ADSCR is obtained by dividing the cash flow available for debt servicing by the total debt obligation in a given period

pay the end-users for the improved water supply. In contrast, the financial analysis only considers project revenues: financial payments made to the project by the GoA.

The economic evaluation of water supply alternatives is typically conducted using the "least alternative cost" principle. This principle states that one should not attribute to a project a value of benefits that is greater than the least alternative cost one would have to incur by providing an equivalent benefit stream in a different way. Thus, from an economic standpoint, the employment of any desalination technology will be attractive in circumstances where the alternatives are more costly and the need for improved water supply dire.

The following key assumptions were made in the economic analysis of the plant:

1. There is no change in the water pricing policy to manage the water demand; hence, the marginal value of water to consumers is equal to the price per cubic meter.
2. The desalination plants program offered the only viable solution to deal with the extremely high water scarcity in the early 2000s.

4.5.1. COST-EFFECTIVENESS ANALYSIS

Cost-effectiveness analysis (CEA) is an appraisal technique used to analyse projects when the objective is to select the investment of projects to deliver a specific quantity of a good or service at minimum cost. The economic Levelized Cost of Water[43] (LCOW) is a cost comparison metric used in CEA of water projects. The alternative water generating technology with the least LCOW is the most preferred. As mentioned above, LCOW is a standard measure used to decide on investments in water supply. This is because water is an essential good and, in most instances, Governments assume full responsibility in providing reliable access to good quality potable water. The LCOW for Hamma project is 68 DZD/m^3 (1.05 USD/m^3). This cost shall be compared with the cost of other alternatives to provide a reliable potable water supply of the same quality. However, the alternatives and their respective costs are not known to the authors. Additional analysis is required to make evidence-based decisions on the effectiveness of Hamma project compared to other alternatives. Therefore, the study proceeds to the next step, where we evaluate the effectiveness of the Hamma project using cost benefit analysis (CBA).

4.5.2. COST-BENEFIT ANALYSIS

Unlike CEA, cost-benefit analysis (CBA) involves the comparison of the benefits generated by the project to its cost. It starts with estimating the economic benefit of the project and then comparing it with its economic costs. When estimating the economic benefits of water, it is important to consider the incremental use of water from the plant. The analysis, therefore, assumes two alternative scenarios:

a. The first scenario further assumes that the status quo situation is already a deficit of water in urban areas. In this scenario, the benefits of the desalination project are estimated as the value of water for households.

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[43] $LCOW_r^t = \frac{PV\ of\ the\ total\ water\ payments\ made\ over\ the\ concession\ period}{PV\ of\ the\ total\ amount\ of\ marketable\ water\ produced\ over\ the\ concession\ period}$

b. When water supply is limited, the demand for water from urban areas will be satisfied first, with the remaining water being delivered for agricultural use. Therefore, while desalination plants supply water directly to the urban areas, from an economic point of view, the incremental impact is that more water from other sources is now available for agricultural use, i.e., the incremental quantity of surface water is being released for irrigation.

The CBA for this study begins with the estimation of the benefits generated by the project in the first scenario. To estimate the value that households put on the improved water supply as a result of the project, the averting expenditure methodology is employed. The averting expenditure method is done by accounting for averting expenditures (coping costs) that households incur through the design and operation of their water supply systems to achieve an acceptable level of service. The basic premise of this methodology is that households undertake different actions to cope with a deficient municipality water supply and improve the quality of the water they consume. These actions typically involve purchasing goods and services that improve the desired service. For instance, households improve the quality of drinking water by making expenditures for drinking water from stores or by boiling the water provided by the public water utility. Because these goods are substitutes for a better service, their purchase might be used to reveal the buyers' willingness to pay for an improved service (Korman, 2002). The concept of households' willingness to pay for improved water supply encapsulates the value that households place on improved water supply. Numerous studies[44] have shown that factors such as the health benefits of water as perceived in the quality of water, reliability of water services, ease of obtaining water as informed by the location of the source of water and nature (tap or otherwise), time savings, the volume of water available/supplied, among others, when compared with the next best alternative play a significant role on the consumer's WTP for improved water supply.

It is important to point out that estimating consumer's WTP from their averting expenditures is a lower bound estimate of the true WTP by consumers for an improved service. This is because the methodology underestimates the true benefits of the policy, as it does not capture the value of the disutility (discomfort) associated with the intermittent and low quality of water supply that still exists after the averting expenditures are made (Korman, 2002; Nirmala, 2014; Wu & Huang, 2001). This underestimation, however, is insignificant as WTP captures the main benefits, including health benefits and a very high share of time-saving benefits, reliability benefits, etc. Other methodologies that can be used to estimate the willingness to pay for water are presented in Table 5 below.

Table 5: Methodologies for WTP Estimation

			Suitability to Scenarios	
Methodology	**Pros**	**Cons**	**Households**	**Farm Perimeter**

[44] (Adenike & Titus, 2009) (World Bank, 1993) (Ahamad, Haq, & Mustafa, 2008) (Olajuyigbe & Fasakin, 2010)

Contingent Valuation (Stated Preference): Widely used for "goods" that do not have established monetary value. It is a social survey method where the individuals are presented with information regarding specific water quality changes, the value which cannot be accounted for in real economic markets	• It is reasonably flexible • It has been widely used for the valuation of non-market goods, especially ones that involve natural resources	• It May be subject to hypothetical bias • Inaccuracy in WTP due to the free-rider problem	Can be used estimate WTP for water by households	It can be used to estimate WTP for water by farmers
Averted Expenditure (Revealed Preference)	• Based on data and observed behavior • Not subject to hypothetical bias • Contingent on availability of data, easy to carry out	• Potentially underestimates the economic benefits	Applicable	Applicable
Indirect Approach (crop-water production function analysis): Involves the analysis of the operations and maintenance costs of the consumer. Particularly used for consumers that use water for commercial production.	• Based on data • Not subject to hypothetical bias	• Accuracy depends on the accuracy of data used in the analysis	Not applicable	Applicable

Source: Khan et al., 2014; Carson et al., 2001; Alvarez-Farizo et al., 1999; Aadland et al., 2003; Bennett, 1984; Mitchell et al., 1995; Abdalla et al., 1992.

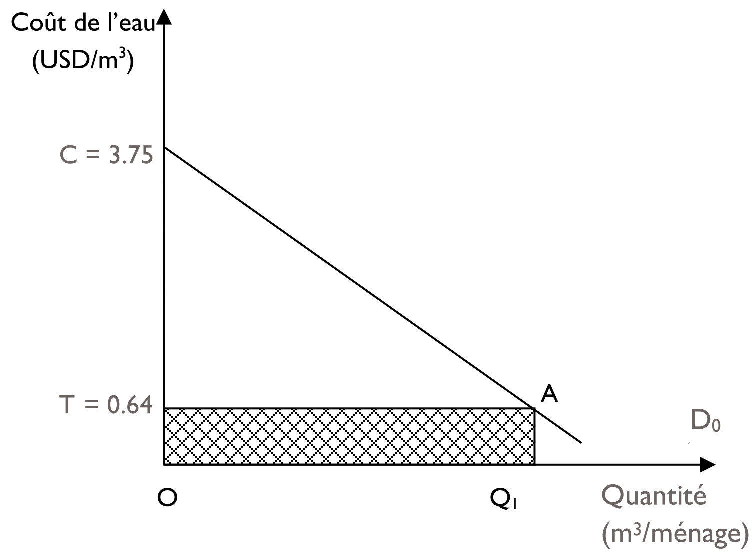
The choice of the methodology to employ when estimating the willingness to pay for water is underpinned by the time constraints, the availability of data, the nature of consumers, and the funds available for the study (Christoph, Michael, & Thomas, 2006). Whatever methodology is selected, the conclusions reached by the different approaches should be the same.

In this study, the averting expenditure was adopted to estimate the willingness to pay for water because it empirically shows how much the consumers would be willing to pay for improved water supply, given the coping costs they already incur as a result of inconsistent water supply. In the second scenario, two approaches that resulted in the same conclusion were employed. The first involved the use of direct interviews of the farmers in the selected area, and the second is an indirect method that considers the maximum amount farmers would be willing to pay for water in order to break even, given their other production costs.

To illustrate how the intermittent water supply transmits into increased coping costs, we consider a similar case in North Cyprus. It is worth mentioning that the CRI study in North Cyprus was compared to a study by Bessedik (2006) that reports how Algerians cope with water shortages and intermittent water supplies in Tlemcen. We conclude that just as in Cyprus's case, the residents of Algeria utilize water storage tanks to ensure a supply of water when they experience interruptions from the utility. Therefore, the two countries are similar in terms of residents' coping strategies where water from the utility is intermittent. However, the study by Bessedik does not delve into the estimation of the willingness to pay for water, given the coping mechanisms currently utilized by residents. In addition, Bessedik reports a wide range of values for different water storage system components. For instance, a water storage system in Tlemcen with a capacity of between 2 – 3 m^3 costs around 316 – 1,579 USD for galvanized steel tanks. Therefore, in our analysis, we adopt the willingness to pay value from the CRI technical report for North Cyprus. The study found that households had a total willingness to pay, including coping costs, of 3.75 USD/m3 (expressed in prices of 2008).

Figure 23 below presents the estimation of the economic benefit of water to households.

Figure 23: Valeur économique de l'eau pour les ménages



Source: Jenkins, G.P., Kuo, C.Y., and Harberger, A.G., Cost-Benefit Analysis for Investment Decisions (2014).

Assuming the water generated by the Hamma Desal plant is directed towards meeting the households' need for water, the figure above represents the average willingness to pay (economic value) for the improved water supply as a result of the project by households in Algiers.

- "C" (3.75) represents the households' maximum willingness to pay for improved water supplied. This is derived using the averting expenditure approach. Synopsis of the Cyprus study used and how this number was estimated are presented in Box 1.
- "T" (0.64) represents the tariff paid by the households to get an uninterrupted water supply. Since with the project, households no longer incur coping costs. The volumetric tariff used in the analysis was estimated as the ratio of the total revenue of the SEAAL and the volume of water sold. It should be pointed out that the revenue includes a fixed proportion and a variable (volumetric) portion. Since the goal is to estimate the volumetric tariff paid by households per cubic meter of water, the volumetric portion of the revenue was extracted by subtracting the fixed portion of the total revenue from the total revenue. The resulting revenue (including the water resource management fee, Water Resource Management Fee, Water quality management fee (Percentage of Base Volumetric Tariff), Water economy fee (Percentage of Base Volumetric Tariff) and the VAT (9,587 million DZD) was then divided by the annual average volume of water consumed by households (232.2 million DZD) to obtain 41.3 DZD.m^3 (0.64 USD/m3).

Therefore, on average, the economic value of the water supplied to households is the area under the curve OCAQ1 which, when estimated, gives a value of 2.19 USD/m^3. Next, adjusting the LCOW for the technical losses and the cost of distributing water to households, we arrive at LCOW at the household tap of 2.03 USD/m^3. Table 6 below presents the estimates of the LCOW at the households.

Table 6: Estimation of Economic LCOW at households Tap

		Value in 2008 Prices (USD/m^3)
	Financial LCOW @ 8% discount rate	0.97
(-)	Duties and taxes	0.07
(+)	Electricity subsidy	0.15
	Economic LCOW @ 8% discount rate (At the plant)	**1.053**
(+)	Cost of distribution[45]	0.103
(+)	Cost of water losses[46]	0.87
	Economic Levelized cost of water at household	2.03

Therefore, we conclude that if all the incremental water released due to the Hamma project is used for household consumption, the benefit-cost ratio is 1.08. This suggests that water desalination for households' use is economically viable. However, a caution should be taken as if less costly alternatives of providing reliable water supply are available in Algeria, resulting in even higher cost benefit ratios.

It is worth pointing out that typically, the customers of the Utility comprises households, industrial, commercial and institutional water users. The willingness to pay for water for all the clients(residential and industrial) of the Utility should be estimated following the same procedure used to estimate the WTP of households. This involves the analysis of each of the clients separately. Using the averting expenditure approach, each client should be analysed individually to understand and estimate their coping costs as these costs will vary from one client to another. For example, Bessedik, 2003, found that some water consumers bought steel tanks that cost between 316-1,579 USD while some concrete tanks (which are expected to last longer and contain more volume of water) ranged between 766-4,786 USD. Industrial users usually tend to enjoy economies of scale and might have a coping cost per cubic meter less than the ones obtained in the households, thus resulting in a lower willingness to pay relative to households.

Box 1: Synopsis of the CRI Cyprus Study

North Cyprus, a country on the northern part of Cyprus, has a population of about 350,000, with a per capita income of about 14,000 USD in 2018 in North Cyprus (State Planning Organization). North Cyprus has suffered from continuously growing water scarcity in terms of its quantity and quality for at least 5 decades. Due to leaking municipal water distribution pipes and low-quality bulk water supplies, the supply of public utility water to households in the towns of North Cyprus has been intermittent, unpressurized and not potable. The objective of the study is to estimate the willingness to pay (WTP) of households for reliable water supply by measuring their averting expenditures.

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45 The distribution cost is estimated as the incremental cost of distributing water from the off-taker to the households. The figures were obtained from SEAAL34a_001, page 55.

46 The technical losses between year 2006 and 2017 were obtained from the SEAAL annual report. These figures were used to estimate the average annual technical decline in technical losses. This average annual decline is then used to estimate the annual technical losses for the remaining years in the concession period. The model sets a condition that the water losses would never go below 20 percent (i.e., technical optimal level of losses). This 20 percent threshold is achieved by 2030. Note that 2031 is the last year of the concession period.
The value of the losses is then estimated by obtaining the difference between the economic LCOW with and without the losses.

Estimating the willingness of households to pay for improved water supply includes the identification of averting expenditures (coping costs) that households incur through the design and operation of their water supply systems to achieve an acceptable level of service, estimating them and presenting them in terms of the levelized costs per cubic meter of water consumed.

The averting actions taken by households include:

- *Buy and maintain a water tank of one cubic meter on the roof of their houses*
- *Buy and maintain a water tank of two cubic meters on the ground floor of their houses*
- *Buy, maintain and operate a water pump of one horsepower*
- *Buy, maintain and operate a water booster pump (if necessary)*
- *Buy bottled water for drinking and cooking*
- *Invest in water purification systems*

The present value (@10%) of the total coping cost of households and total volume of water consumed was estimated to be about USD 132 million and about 42.4 million cubic meters. Therefore, the levelized coping cost without the tariff paid to the utility is 3.11 USD/m3. If this figure is added to the households' volumetric tariff of 0.64 USD/m3(the value in the Hamma study), the maximum willingness to pay becomes 3.75.

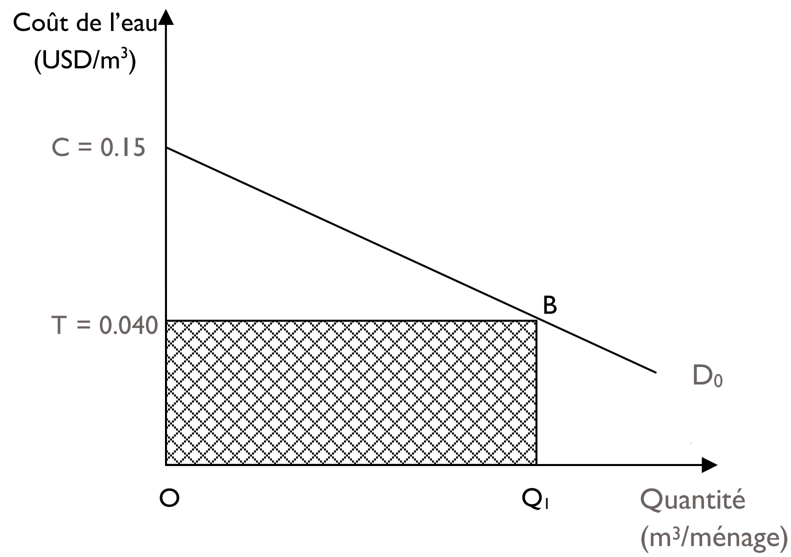
Next, we move to the second scenario when the water deficit is observed in the agricultural sector. The approach used in the estimation of the economic value of water for agricultural purposes is also the measurement of the willingness to pay for improved water supply by farmers. Different factors can potentially influence the willingness of farmers to pay for irrigation water. One of these factors is the productivity and profitability of the crop. Numerous studies[47] show that the higher the productivity and profitability of crops, the higher the farmers' willingness to pay for irrigation water. Other factors include the farm's size, water availability or scarcity, access to alternative sources of water, quality of water, water supply reliability etc.

In their study on farmers' willingness to pay for surface water in the West Mitidja irrigated perimeter, Northern Algeria (Azzi, Calatrava, & Bédrani, 2018) found that nearly 80 percent of the farmers they surveyed were willing to pay an increased price for adequate quantity, quality and reliable supply of surface water to meet their farming needs. The average willingness to pay for surface water was estimated to be 4.11 DZD/m3, equivalent to 0.035 USD/m3. Furthermore, they found that the decrease in average water volume demanded accelerated for prices greater than 5 DZD/m3 and that the demand for water turned to zero at an unidentified price above 10 DZD/m3.

Since the area that was studied is close to Algiers, which is where Hamma water plant supplies water, the estimation, the maximum willingness to pay that was estimated by Malika et al. was used to estimate the economic value of water supplied by Hamma plant to farmers in the Algiers region. The maximum willingness to pay is 10 DZD/m3, which is equivalent to 0.15 USD/m3 (2018 prices). Figure 24 below illustrates the economic benefit of water to farmers.

[47] (Calatrava et al., 2005;, Garrido et al.,, 1996.; Chebil et al., 2007), (Weldesilassie et al., 2009; (Giannoccaro, et al.,, 2016).

Figure 24: Valeur économique de l'eau pour les ménages



Source: Jenkins, G.P., Kuo, C.Y., and Harberger, A.G., Cost-Benefit Analysis for Investment Decisions (2014).

If all the water generated by the Hamma Desal plant is directed towards meeting the Agricultural water needs, Figure 24 above represents the average willingness to pay (economic value) for water supply as a result of the project by farmers (for agricultural use) in Algiers.

- C' (0.15 USD) is the maximum willingness to pay to cultivate the top farm produce export of Algeria. It is derived following the steps described above
- "T" (0.040 USD) represents the tariff paid to use water for agricultural purposes. Same as the first scenario, the objective in the second scenario is to obtain the volumetric tariff charged to farmers to use water for irrigation purposes. (Journal Officiel N°05 du 12 janvier 2005 et selon de tableau ci-dessousv as well as Azii et al., 2017) reports the volumetric tariff charged to farmers in 2017 is 2.5 DZD/m3 (0.04 USD/m3), using the 2008 exchange rate.

Therefore, on average, the economic value of the water supplied to farms for agricultural use is the area under the curve OCBQ1, which, when estimated, gives a value of 0.095 USD/m3. Next, adjusting the LCOW for the technical losses, we arrive at LCOW at the farm perimeter of 1.42 USD/m3. Table 7 below presents LCOW at the farm perimeter:

Table 7: Estimation of Economic LCOW at Farm Perimeter

		Value in 2008 Prices (USD/m^3)
	Financial LCOW @ 8% discount rate	0.97
(-)	Duties and taxes	0.07
(+)	Electricity subsidy	0.15
	Economic LCOW @ 8% discount rate (At the plant)	**1.05**
(+)	Cost of distribution	0

(-)	Operating Cost savings (Water transfer cost savings)[48]	0.02
(+)	Cost of water losses[49]	0.38
	Economic Levelized cost of water at farm perimeter	**1.42**

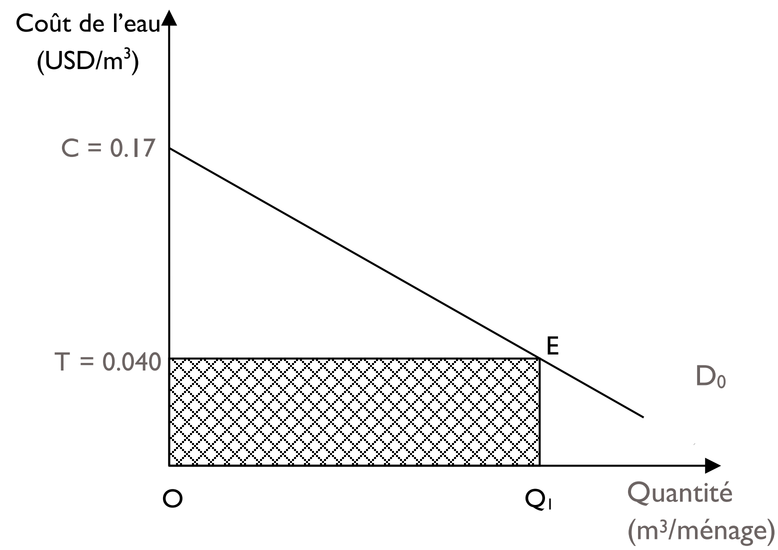
Therefore, we conclude that if all the incremental water released due to Hamma project is used for irrigation, the benefit-cost ratio is 0.07, suggesting that water desalination for irrigation is economically unviable and should not be continued.

Given the outcome of the analysis in the second scenario (if the water is supplied for farmers for agricultural purpose), another approach was employed to estimate the maximum willingness of farmers to pay for improved water supply. The willingness to pay for water for agricultural purposes is directly related to the profitability of the crop for which it is used. Therefore, farm budget analysis was used to test the maximum price of water farmers can afford to break even on their operations. For the analysis, we selected dates as a crop that is one of the top export crops in Algeria, and it has a comparatively high value in relation to the quantity of water used in production. The estimate of the maximum willingness to pay for water started with a typical farm budget for growing dates in the Middle East and North Africa (Zaid, 2002). Based on FAO data, given a yield of 70 kg per tree, and 125 trees, assuming the price of dates is 1 USD/kg, the gross revenue is expected to be 8,750 USD per hectare. The net revenue without including the cost of meeting the water requirements is 2,538 USD/ha. Given a water requirement of about 15,000 cubic meters per hectare (FAO), to break even, the maximum that a farmer would be willing to pay for water will be about 0.17 USD/m3.

[48] The study assumes that if surface water is supplied to households, one of the major variable cost ANBT incurs into is the energy cost of pumping water from the dams to drinking water distribution systems. This cost would be avoided if the water is instead supplied to the farm perimeters, most of which are located downstream of the dams. These savings was estimated by dividing the total energy expenditure (about 2,092 million DZD) of the ANTB by the volume of water dispatched to drinking water distribution networks in 2017. The value in 2008 prices is 1.18 DZD/m3.

[49] The logic is the same with the second scenario. However, in this case, the annual technical loss by releasing the water to the farmers is 27 percent of the water delivered to the off-taker (Bilan ONID 2017).

Figure 25: Valeur économique de l'eau pour les ménages



Source: Jenkins, G.P., Kuo, C.Y., and Harberger, A.G., Cost-Benefit Analysis for Investment Decisions (2014).

- "C" (0.17 USD) is the maximum willingness to pay to cultivate the top farm produce export of Algeria. It is derived following the steps described above
- "T" (0.040 USD) represents the tariff paid to use water for agricultural purposes.

Given the maximum willingness to pay for improved water supply, and the tariff charged to farmers to use water, the economic benefit of water is estimated to be 0.105 USD/m3. If the economic cost of supplying water to farmers remains unchanged at 1.42 USD/m3, the benefit-cost ratio remains approximately 0.07. Hence the conclusion remains the same.

In the first scenario where water is supplied to households, the economic net present value (in 2008), using a discount rate of 8 percent, was estimated to be 7,830 million DZD (USD 121.3 million) in 2008 prices. On the other hand, if the water produced by the plant is supplied to the farmers for agricultural use, the economic NPV (in 2008)[50] of the project at an 8 percent discount rate is -44,116million DZD (USD -683 million), in 2008 prices.

4.6. FISCAL IMPACT ANALYSIS

Although the project is mainly financed by debt and equity contribution by the private entity, the project still has financial implications for the government. The cash outflow from the perspective of the government includes:

[50] The ENPV is estimated using the Azzi et al study on the maximum willingness to pay for water by farmers.

1. **The contribution towards equity**: The government through AEC contributed 30 percent to the equity financing of the project. The present value (in 2008) of the contribution at an 8% discount rate is 1,814.3 million DZD (USD 28.1 million) in 2008 prices.
2. **The payment for the water supplied by the plant:** The water tariff represents the price at which the off-taker purchases desalinated water from the Hamma desalination plant. From 2008 when plant operation started to the end of the concession period, 2032, the average payment by the off-taker for the water produced by the plant is about 7,497 million DZD (nominal prices). The present value at 8% discount rate (in 2008) of the total payment made to the SPV for the water supplied by the plant over the concession period, in 2008 prices is 45,842.2 million DZD (USD 710 million)
3. **Electricity Subsidy:** The government provides an implicit electricity subsidy for the operation of the plant. Over the project's operational life, the average electricity subsidy given to the project in nominal terms is 1,180 million DZD. The present value (in 2008) at an 8% discount rate of the subsidy given for the operation of the plant over the concession period, is 7,108.8 million DZD (USD 110 million) in 2008 prices.

The present value of the total cash outflow (negative fiscal impact) from the government's perspective is therefore -54,765.3 million DZD (USD -848 million), in 2008 prices.

The project is also expected to generate cash inflow, from the government's perspective. The elements of the positive fiscal impacts are.

1. **Taxes and Duties:** The SPV is expected to pay appropriate taxes and duties as required by the Algerian Tax Laws. Over the concession period, the average value of the taxes and duties paid by the SPV, in nominal terms, is 445 million DZD. The present value (in 2008) of the taxes and duties paid by the SPV at a discount rate of 8% is 3,235.3 million DZD (USD 50 million) in 2008 prices.
2. **Share of Free Cash Flow:** Since the AEC contributes 30% of the equity funding of the project, the AEC is expected to get 30 percent of the free cash flow (after the O&M and debt obligations have been met). The present value (in 2008) of this cash inflow to the AEC discounted at 8 percent is estimated to be 4,687 million DZD (USD 72.6 million), 2008 prices

The present value (in 2008) of the total cash inflow from the perspective of the government (positive fiscal impact) of the project, using the EOCK as the discount rate, is 7,922.2 million DZD (USD 122.7 million).

In 2008 prices, the present value of the net fiscal impact of the project – the difference between the positive and negative fiscal impact of the project, at an 8 percent discount rate is -46,843 million DZD (USD 725.4 million).

It is worth noting that there are two components of the project's fiscal impact that depend on the end-user of the water produced by the Hamma Desal Plant. This is the distribution costs and the water transfer cost savings as a result of the project. If the water is supplied to households, the off-taker will incur additional distribution costs of for distributing the water produced by the plant. The present value (in 2008) of the distribution cost over the concession period, discounted at 8 percent, is 4,754 million DZD (USD 73.6 million). Therefore, if the water produced by the plant is supplied to households, the present value (in 2008) of the net fiscal impact of the project at 8 percent is -51,597 million DZD (USD 799 million).

On the other hand, if the water is supplied to farmers for agricultural use, it is expected that the distribution costs would be zero and that there would be a water transfer cost savings as a result of the project. The present value (2008) of the operating cost savings resulting from the project, discounted at 8 percent, is 889.5 million DZD (USD 13.8 million). Therefore, if the water produced by the plant is supplied to farmers for agricultural use, the present value (2008) of the net fiscal impact of the project at an 8 percent discount rate is -45,954 million DZD (USD 711.6 million).

Table 8: Summary of Fiscal Impacts

	Farmer's Scenario PV @ 8% (Million DZD)[51]	Households Scenario PV @ 8% (Million DZD)
POSITIVE FISCAL IMPACT (INFLOW)		
Taxes and Duties	3,235.3	3,235.3
Share of Free Cashflow	4,687	4,687
Operating Cost Savings (Water transfer cost)	889.5	0
Total Positive Fiscal Impact	**8,811.8**	**7,922.3**
NEGATIVE FISCAL IMPACT (OUTFLOW)		
Contribution to Equity	1,814.3	1,814.3
Payment to SPV for water supplied	45,842.2	45,842.2
Electricity Subsidy	7,108.8	7,108.8
Water Distribution Cost	0	4,754
Total Negative Impact	**54,765.3**	**59,519.3**
NET FISCAL IMPACT	**-45,953.5**	**-51,597**

A significant portion (about 85%) of the negative fiscal impact of the project (cash outflow) is the payment made to the SPV as stipulated by the take/pay contract. The nominal[52] annual water payments and the volume of water delivered to the off-taker from the desalination plant are presented in Table 9.

Table 9: Components for Calculating the Financial Levelized Cost of Water for the Hamma Desalination Plant

Year	Annual Quantity of Marketable Water delivered to the off-taker from the Hamma Desalination Plant53 million m3 per annum	Real Annual Water Payments made by the off-taker to the SPV54 million DZD
2008	25.14	1,465.21
2009	53.88	3,486.71
2010	57.93	3,992.79
2011	60.01	4,065.49
2012	63.38	4,486.21
2013	62.58	4,653.99
2014	67.32	5,084.65

[51] All figures are in 2008 prices
52 Real values are nominal values that have been adjusted for inflation.
53 Computed using equations 3, 4, and 7.
54 Computed using equations 5, 6, and 7.

2015	68.01	6,273.49
2016	69.42	6,989.48
2017	68.66	6,863.06
2018	69.92	7,417.52
2019	69.48	7,518.33
2020	69.43	8,332.01
2021	69.24	8,504.82
2022	69.24	8,667.48
2023	69.24	8,845.69
2024	69.43	9,065.08
2025	69.24	9,252.32
2026	69.24	9,482.77
2027	69.24	9,732.84
2028	69.43	10,031.24
2029	69.24	10,297.17
2030	69.24	10,614.44
2031	69.24	10,957.40
2032	69.43	11,358.99

4.7. SENSITIVITY ANALYSIS

As stipulated earlier, the analysis involves analysing actual data from previous years and involves forecasting subsequent years. The purpose of the sensitivity analysis conducted in this study to assess the impact of a change in some of the key variables of the project on the outputs of the project.

Change in Willingness to Pay for Improved Water Supply (Base Value = 0%)

The economic benefit of water is significantly dependent on the willingness of the consumers to pay for an improved water supply. Suppose the maximum willingness of households to pay for improved water supply decreases by 20%. In that case, the economic benefit of the water supplied to them reduces by over 16 percent (from 2.19 USD/M3 to 1.82 USD/m3), the benefit-cost ratio reduces to about 0.95. The ENPV (first scenario) becomes less than zero. If the willingness to pay reduces by 16 % (of 3.74 USD/m^3), the benefits generated by the project will just be equal to the economic cost of the project, and the benefit-cost ratio will be 1. The same logic holds if the second scenario is considered. If the willingness of farmers to pay for improved water increases by 50% (of 0.085 USD/m^3), the economic value of water to the farmers increases by about 33% (to about 0.08 USD/m^3). Even in this case, the project still has costs that are greater than its benefit.

Table 10: Change in Willingness to Pay for Improved Water Supply

Change in WTP	Economic Benefit of Water - Households (USD/m^3)	Economic Benefit of Water – Farmers (USD/m^3)	Economic NPV[55] – 1st Scenario (M'DZD)	Economic NPV – 2nd Scenario (M'DZD)
-50%	1.26	0.03	(18,242.98)	(45,495.2)
-40%	1.44	0.04	(13,028.30)	(45,219.3)
-30%	1.63	0.04	(7,813.62)	(44,943.5)
-20%	1.82	0.05	(2,598.94)	(44,667.6)
-10%	2.01	0.05	2,615.74	(44,391.7)
0%	**2.19**	**0.06**	**7,830.42**	(44,115.8)
+10%	2.38	0.06	13,045.11	(43,839.9)
+20%	2.57	0.07	18,259.79	(43,564.1)
+30%	2.76	0.07	23,474.47	(43,288.2)
+40%	2.94	0.07	28,689.15	(43,012.3)
+50%	3.13	0.08	33,903.83	(42,736.4)

Change in Cost Reflective Electricity Tariff (Base value = 0.063 USD/Kwh)

The government provides an implicit electricity subsidy to the SPV. This reflects in the economic cost of water and the fiscal impact of the project. The higher the cost-reflective electricity tariff, the higher the amount of subsidy provided to the project, and the consequently the higher the economic costs of the project. If the cost-reflective tariff increases by 3 % (from 0.063 to 0.065), the economic LCOW at the

[55] ENPVs are estimated at 8 percent discount rate and in 2008 prices.

plant increases by about 1% (1.05 to 1.06 USD/m³), the economic NPV in the first scenario reduces by about 4% (7,830 to 7,495 million DZD).

Table 11: Change in Cost-reflective Price of Electricity

Cost-reflective Tariff	Economic LCOW at the Plant (USD/m³)	Economic NPV – 1st Scenario (M'DZD)	Economic NPV – 2nd Scenario (M'DZD)
0.0650	1.06	7,495.03	(44,451.21)
0.0640	1.06	7,662.73	(44,283.51)
0.0630	1.05	7,830.42	(44,115.81)
0.0530	1.02	9,507.41	(42,438.83)
0.0430	0.98	11,184.39	(40,761.85)
0.0330	0.94	12,861.37	(39,084.87)
0.0230	0.91	14,538.35	(37,407.88)
0.0130	0.87	16,215.34	(35,730.90)
0.0110	0.86	16,550.73	(35,395.51)
0.0100	0.86	16,718.43	(35,227.81)
0.0050	0.84	17,556.92	(34,389.32)

Change in Marketable Water Delivered to Off-taker

The main purpose of the project is to meet the water supply deficit. Therefore, the feasibility, especially from the economic point of view of the project, depends partly on the plant's ability to supply water. Suppose for example, during the forecast period, the annual marketable water delivered to off-taker (percentage of total production) reduces by 30% (95% to 65%). In that case, the average annual water payment to the SPV reduces by about 20%. However, the same reduction in the marketable water delivered to the off-taker brings about an increase of about 4% in the economic LCOW at the plant, since it now costs more to produce less water (note that the economic LCOW at the plant includes the economic value of the capital costs, subsidies as well all other operation and maintenance costs of the project).

Table 12: Change in Marketable Water Delivered to Off-taker

Change in Marketable Water	Average Annual Water Payment to SPV (M'DZD)	Economic LCOW at the Plant (USD/m³)
-30%	6,022.07	1.100
-20%	6,513.90	1.083
-15%	6,759.82	1.075
-10%	7,005.73	1.068
-5%	7,251.65	1.060
0%	7,497.57	1.053
+2%	7,595.93	1.050
+3%	7,645.12	1.049
+5%	7,743.48	1.046

5. CONCLUSIONS AND RECOMMENDATIONS

The objective of the analysis is to assess the impact and cost-effectiveness of the desalination plants. The study involves (a) a benchmarking analysis of how the costs of the plants compare with similar plants commissioned elsewhere; and (b) a cost benefit analysis of one of the plants, used to compare the benefits of the plant to the costs.

The benchmarking analysis reveals the water tariff, capital costs, operation and maintenance costs of the Algerian desal plants are below the average of plants of similar technologies, sizes and capacities. Therefore, from the effectiveness of the procurement point of view, it can be concluded that Algeria's desalination program was a successful one.

Next, the study proceeds to assess the economic viability of Hamma project to reveal some light on the overall economic viability of the desalination program. That is to compare the benefits generated by the project to the costs the Algerian economy paid for it. This is done using both CEA and CBA. The LCOW at the plant (Hama) is estimated to be 68 DZD/m^3 (1.05 USD/ m^3) in 2008 prices. This cost can be compared to the cost of producing water using other available alternatives.

CBA revealed that the economic viability of the Hamma depends on the use of incremental water released due to the desalination program. We conclude that if all the incremental water released is used for household consumption, the benefit-cost ratio is 1.08, suggesting that water desalination for households' use is economically viable. Under this scenario, the economic net present value (ENPV) of Hamma project at an 8 percent discount rate is 7,830 million DZD (USD 121 million) in 2008 prices. In a scenario where the incremental water is used for irrigation, we conclude that the benefit-cost ratio is 0.07, suggesting that water desalination for irrigation is economically unviable and should not be continued. The total economic loss, ENPV, at an 8 percent discount rate in this scenario is -44,116 million DZD (USD 683 million) in 2008 prices.

Finding economically viable and sustainable solutions to supplying Algiers' residents with an adequate water supply that meets their day-to-day requirements is of paramount importance. Hence, future investments in water supply should be evaluated ex-ante to ensure that they address water scarcity in Algiers and do so in a cost-effective manner. In particular, the cost benefit analysis results are highly sensitive to the technical loss rate observed in the water distribution network. Reduction of such high technical losses will improve returns from desalination programs and save tremendous public resources by delaying the need for the program expansion.

Given that various water supply alternatives will be explored as potential solutions to the water challenges, these options must be assessed in terms of their efficiency and effectiveness in meeting the objective of supplying Algiers' residents with sufficient water. Apart from desalinated water, other options to tackle the water crisis in Algiers and indeed the rest of Algeria should be explored using the techniques outlined in this report – for example:

i. Rehabilitating and upgrading water supply infrastructure. This could entail attending to water leaks in the supply network.
ii. Increasing the tariff faced by household consumers and farmers. This increases the average benefit per cubic meter consumed because users cut back on their consumption by reducing lower-value uses.

iii. Employing water demand strategies to incentivize consumers to allocate and use water more responsibly and cut back on unnecessary consumption.
iv. Wastewater reuse.

Calculating and comparing the levelized economic cost of water can be useful in planning future water supply. Given all the alternatives that may be put on the table to deal with future water needs, the LCOW for each of the alternatives can be utilized to develop the least-cost plan by ranking the alternatives based on their cost-effectiveness in achieving the intended outcome. Therefore, investments producing the least costly water would be undertaken first, with the most expensive alternatives only being implemented if the cheaper alternatives fail to address the water challenges in their entirety.

ANNEXES

ANNEX A: WATER TARIFF INDEXATION AND PROJECTIONS

A1. WATER TARIFF INDEXATION

Indexation involves the process of adjusting the base water tariff values by the price index estimated for each successive year after the base year to account for the growth in economic variables such as inflation. The WSPAs of the desalination projects specify the economic variables against which the water tariff is to be indexed. This annex, therefore, discusses the following issues:

i. Definition and sources of the indexes.
ii. Estimation of indexes for the concession period of desalination plants.
iii. Application of indexes and changes in the exchange rate to the water tariff.

A1.1. DEFINITION AND SOURCES OF INDEXES

The indexes cover a wide variety of revenue and cost components of the desalination plants that need to be escalated to keep up with the growth in prices. Overall, there are 13 indexes covered by the WSPA. 9 are foreign indexes that correspond to the foreign currency components of the water tariff. The U.S. indexes were retrieved from the U.S. Bureau of Labor Statistics (BLS).[56] The remaining 4 indexes pertain to the water tariff's domestic currency components and were retrieved from the Algerian Office National des Statistiques (ONS).[57]

The U.S. BLS indexes are defined as follows:

I. **Index IA1**
Index: Employment Cost Index, annual without adjustment
Sector: Private Sector, Wages and Salaries
Code: N/A

II. **Index IA2**
Index: Producer Price Index, annual without adjustment
Sector: Engineering design, analysis and consulting services
Code: PCU8711#2

III. **Index IA3:**
It is a weighted average of the following 4 indexes:
- Index: Producer Price Index, annual without adjustment
  Sector: Turbines and turbines generator sets
  Code: PCU3511#
  Weight: 15%

[56] Source of information for the foreign indexes. Official website of the U.S. Bureau of Labor Statistics https://data.bls.gov/cgi-bin/srgate
[57] Source of information for the Algerian indexes. Official website of the Office National des Statistiques https://www.ons.dz

- Index: Producer Price Index, annual without adjustment
  Sector: Pumps and pumping equipment
  Code: PCU3561#
  Weight: 50%

- Index: Producer Price Index, annual without adjustment
  Sector: Electrical and electronic machinery, equipment, and supplies
  Code: PCU36_#
  Weight: 15%

- Index: Producer Price Index, annual without adjustment
  Sector: Fabricated metal products, Ex machinery and transportation equipment
  Code: PCU34_#
  Weight: 20%

IV. Index IA4:

Index: Consumer Price Index, annual without adjustment
Sector: Other goods and services
Code: CUUUROOOOSAG*

V. Index IA5:

Index: Consumer Price Index, annual without adjustment
Sector: U.S city average
Code: CUUROOOOSAQL1E

VI. Index IA6:

Index: Producer Price Index, annual without adjustment
Sector: Chemicals and applied products
Code: PCU28_#

The Algerian ONS indexes are defined as follows:

I. Index IB1:

Index pertaining to the Index of the production costs in the industrial sector excluding hydrocarbons.

II. Index IB2:

Index pertaining to the Index of the production costs in the industrial sector excluding hydrocarbons.

III. Index IB3:

Index pertaining to the index of electricity prices.

IV. Index IB4:

Index pertaining to the weighted average of the indices used, taking into account the weight of each component in the Availability Premium.

A1.2. ESTIMATION OF INDEXES FOR THE CONCESSION PERIOD OF DESALINATION PLANTS

Each of the indices outlined in section A.1.1. was estimated for each period (i.e., year) of the concession of the desalination plants. For illustrative purposes, only index IA1 for the Hamma desalination project will be used as an example to run through the process of estimating the indexes.

Given that the Hamma desalination plant commenced operations in 2008 and would cease in 2032 at the end of the concession, the challenge was to determine the value of each of the indexes over 25 years, given that data on the values for the indexes was only available for June 2020.

Data from the Bureau of Labour Statistics (BLS) and the National Statistics Office (ONS) were used to build a replica of the indexes observed in the invoice submitted to the off-taker in June 2020. The objective was to estimate as close as possible the indexes applied in the June 2020 invoice to estimate the index values for the entire concession period. Our estimates of the indexes derived by applying the indexation formulas stipulated in the WSPA and the data from the BLS and ONS for June 2020 closely match those reported on the water supply invoice for June 2020, as illustrated in Figure 26. Interestingly, our estimates of index values do not differ materially from those observed on the invoice. All the index estimates, except IA6 and IB4, had an almost perfect match with those on the invoice. Though the difference between these two indexes is insignificant, it is difficult to ascertain the causes of the variance.

The indexes from 2008 to 2020 are based on historical data collected from BLS and ONS and computed using the indexation formula as stipulated in the WSPA.58 Whereas the indexes from 2021 to 2032 are forecasted using the average growth rate of each index from the period 2007 to 2020. To estimate the value of the index projections in a particular year, the previous index is adjusted using the average growth rate. For instance, index 1A1, the employment cost index, has an average growth rate of 2.69% between 2007 and 2020. The value of the index in 2020 is equal to 1.5350. Hence to find the value of the index in 2021, the following formula is applied:

$$PI_n^t = PI_{n-1}^t * (1 + AvgGR)$$

where:

- PI_n^t = price index in the period in question
- PI_{n-1}^t = price index in the previous period
- AvgGR is the average growth rate of the index between 2008 and 2020

Hence:

$$PI_{2021}^t = PI_{2020}^t * (1 + AvgGR_{2008-2020})$$

[58] A detailed description of how to compute each index can be found in the Hamma WSPA, June 2005.

$$PI_{2021}^{t} = 1.5350 * (1 + 0.0269)$$

$$PI_{2021}^{t} = 1.5763$$

Figure 26. Indexation Estimates for Hamma – June 2020[59]

Indexation Components	Hamma Invoice	Financial Analyst's Estimate	Variance
Indexation from federal BLS (U.S.A)			
IA1 Employment Cost Index - Utilities	1.535	1.535	0.000
IA2 Producer Price Index - Nonbuilding Related Eng.	1.427	1.426	0.001
IA3 Weighted Average Producer Price Index	1.461	1.463	-0.002
IA4 Consumer Price Index - Other Goods & Services	1.517	1.518	-0.001
IA5 Consumer Price Index - All Items Less Food & Energy	1.363	1.363	0.000
IA6 Producer Price Index - Chemicals & Allied Products	1.884	1.825	0.059
Indexation from ONS (Algeria)			
IB1- Production Costs Index - Industrial Sector Excluding Hydrocarbons	1.600	1.616	-0.016
IB3 Electricty Price Index	0.000	0.000	0.000
IB4 Weighted Average for Availability Charge	1.269	1.244	0.025

A1.2. APPLICATION OF INDEXES AND CHANGES IN THE EXCHANGE RATE TO THE WATER TARIFF

The water tariff for the Algerian desalination projects is broken down into 3 components, each encompassing specific characteristics. As defined by the WSPA contract, these 3 water tariff components are:

A. **Availability premium or capacity charge**: represents the bulk of the tariff and consists of all the fixed costs pertaining to the production and return on investment. This tariff component is broken down into 2 sub-components:

   i. Costs in foreign currency expressed in Dinars, which comprise of costs items such as expatriate personnel, operating and maintenance subcontracted services, spare parts, membranes, cleaning chemicals, insurance in foreign currency, return of investment, and other operating costs in foreign currency.

   ii. Costs in Dinars which comprise the cost of Algerian personnel, expatriate personnel, subcontracted services, insurance, corporate income taxes, customs duties, fixed energy charges, and other operating costs in Dinars.

B. **Water charge:** represents the amount of the variable operating and maintenance charges associated with the quantity of Marketable Water produced.

[59] A detailed description of how to compute each index can be found in the Hamma WSPA, June 2005.

C. **Electrical power (energy) charge**: represents the costs of the share of electricity used by the plant for water production.

When the Hamma desalination plant came on stream in 2008, its base tariff was 58.29 DZD/m[3] or 0.903 USD/m[3]. Table 13 summarizes the disaggregated water tariff based on the components discussed above.

Table 13. Hamma Base Water Tariff – 2008 Prices

Tariff Component	Value in Dinars (DZD/m^3)	Value in US Dollars (USD/m^3)
Capacity Charge	47.243	0.732
Water Charge	4.502	0.070
Energy Charge	6.544	0.101
Base Water Tariff	**58.288**	**0.903**

The water tariff in Table11 is the baseline tariff used to estimate the nominal water tariff of Hamma over the life operational of the project. As already discussed in section A.1.2. above, indexes play a crucial part in determining the inflation-adjusted values of the water tariff. Using the indexes derived for the Hamma desalination plant, indexes were applied to derive the nominal values of the water tariff from 2020 to 2032. Just as in the case of indexes, the appreciation and depreciation of exchange rates also affect the value of the water tariff over time. Hence, the calculation of the nominal water tariff also incorporated adjustments for changes in the exchange rate over the project's operational life. Changes in the exchange rate were computed by finding the difference percentage difference between the exchange rate applicable in each period under analysis and the exchange rate when the project began; in the case of Hamma, that is 2006, when the project's construction commenced. The exchange rates percentage appreciation or deprecation can be expressed mathematically as follows:

$$E_n^t = \frac{E_i^t}{E_r^b}$$

where:

E_n^t =exchange rate appreciation or depreciation in period (t), E_i^t= the nominal exchange rate in period (t), E_r^b = the real exchange rate in the base year.

The overall calculation of the water tariff with indexation and adjustments of the exchange rate can be summarized as follows:

$$WT_n^t = BWT_r^t \times P_I^t \times \frac{E_i^t}{E_r^b}$$

where:

WT_n^t = the nominal water tariff in period (t), BWT_r^t = the real value of the base water tariff at the commencement of the project annual, P_I^t = the appropriate price index in period (t), E_i^t= the nominal exchange rate in period (t), E_r^b = the real exchange rate in the base year.

ANNEX B: COMPARISON OF CAPEX AND O&M COSTS

During the analysis we found some inconsistencies with investment and operation and maintenance cost data. For instance, data reported in AEC's 2013 activity report is slightly different from that found in the projects' contractual documents. As can be seen in the figure below, the EPC costs reported by AEC for Hamma, Mostaganem, and Cap Djinet are higher than those found in the projects' EPC contracts, while that of Cap Djinet is equivalent to that statated in the contract. We could not establish the reason for the disparity. However, it should be noted that with respect to the analysis we utilized data from the AEC report.

		EPC Cost (USD million)	
Plant	**Plant Capacity (m3 per day)**	**AEC**	**EPC Contract**
Hamma	**200,000**	**197.30**	**189.90**
Mostagnem	**200,000**	**190.00**	**182.00**
Cap Djinet	**100,000**	**111.60**	**107.47**
Tenes	**2,000,000**	**206.00**	**206.00**

Similarly, data on O&M costs in the AEC report differs slightly from that found in the projects' O&M contracts, as shown in the figure below. A review of the projects' O&M contracts indicates that the O&M contractor is not responsible for energy costs. Hence, it is our assumption that both the O&M costs provided in the AEC report and the projects' O&M contracts do not include the cost of energy. Given that data was available on how much each energy each desalination plant utilizes to produce a unit of water as well as the cost of a unit of energy. We were able to estimate the total cost of energy assuming that the desalination plants produce water at full capacity. These energy costs were added to the projects' O&M cost, as energy constitutes the biggest portion of O&M expenditures. Furthermore, the benchmarking exercise would be consistent as the O&M costs of the reference plants are inclusive of the cost of energy. It should be noted that with respect to the evaluation of the desalination plants, particularly the benchmarking exercise we utilized AEC O&M cost data from the 2013 activity report plus the estimated cost of energy that we computed.

		Annual O&M Cost (USD million 2008 Prices)				O&M Cost per m3			
Plant	**Plant Capacity (m3 per day)**	**AEC Report (excl. energy)**	**AEC Report (incl. energy)**	**O&M Contract (excl. energy)**	**O&M Contrac t (incl. energy)**	**AEC (excl. energy)**	**AEC (incl. energy)**	**O&M Contrac t (excl. energy)**	**O&M Contrac t (incl. energy)**
Hamma	**200,000**	**14.60**	**22.43**	**13.89**	**21.73**	**0.20**	**0.31**	**0.21**	**0.32**
Skikda	**100,000**	**4.12**	**8.00**			**0.11**	**0.22**		
Beni Saf	**200,000**	**7.90**	**16.83**			**0.11**	**0.23**		
Souk Tlata	**200,000**	**1.91**	**12.42**			**0.03**	**0.17**		

Fouka	**120,000**	**7.64**	**13.19**			**0.17**	**0.30**		
Mostaganem	**200,000**	**9.32**	**16.61**	**9.80**	**17.47**	**0.13**	**0.23**	**0.13**	**0.24**
Cap Djinet	**100,000**	**7.32**	**11.29**	**7.75**	**11.93**	**0.20**	**0.31**	**0.21**	**0.33**
Tenes	**200,000**	**6.50**	**14.63**	**6.00**	**15.00**	**0.09**	**0.20**	**0.08**	**0.21**
Honaine	**200,000**	**7.93**	**17.12**			**0.11**	**0.23**		
Magtaa	**500,000**	**18.97**	**39.75**			**0.10**	**0.22**		

It should be noted that we were only provided with four of the desalination plants' contractual documents, namely, Hamma, Cap Djinet, Mostaganem and Tenes. Hence, we could only compare the costs in the AEC report for these four projects.

ANNEX C: COMPOSITE DATA SAMPLE

Country	Plant Name	Capacity	Source of Feed Water	First Year of Operation	CAPEX	O&M Expense	Water Tariff	Source
					USD Mil	USD Mill	USD/m3	
South Africa	Sedgefield	1,500	South Atlantic Ocean	2009	1.78	No Data	No Data	Web
Canary Islands	San Nicolas	5,000	Mediterranean	2001	5.95	1.22	1.55	WB - WGP
USA	Santa Barbara	10,000	North Pacific Ocean	2016	11.89	2.44	2.19	WB - WGP
South Africa	Mossel Bay	15,000	South Atlantic Ocean	2011	17.84	No Data	No Data	Web
Cyprus	Moni	20,000	Mediterranean	2009	23.78	4.87	1.42	WB - WGP
Oman	Sohar	20,000	Gulf of Oman	2013	23.78	4.87	1.68	WB - WGP
Oman	ROI Majis	20,000	Gulf of Oman	2014	23.78	4.87	1.10	WB - WGP
KSA	Yanbu	30,000	Red	2016	35.67	7.31	1.49	WB - WGP
KSA	Kaust	40,000	Red	2017	47.56	9.75	1.40	WB - WGP
Tunisia	Djerba	50,000	Mediterranean	2019	59.45	No Data	No Data	Web
Cyprus	VPS Desal Plant	60,000	Mediterranean	2012	71.35	No Data	No Data	Web
Ghana	Befesa	60,000	South Atlantic Ocean	2015	71.35	No Data	No Data	Web
Cyprus	Larnanca 2	62,000	Mediterranean	2009	73.72	15.11	1.10	WB - WGP
Cyprus	Larnanca 1	64,000	Mediterranean	2001	76.10	15.60	0.84	WB - WGP
UAE	Palm Jumeirah	64,000	Gulf of Oman	2008	76.10	15.60	1.35	WB - WGP
Spain	Alicante II	65,000	Mediterranean	2009	77.29	No Data	No Data	Web
UAE	Ghalilah	68,200	Gulf of Oman	2015	81.10	16.62	1.33	WB - WGP
Morocco	Jorf Lasfar	75,800	North Atlantic Ocean	2013	90.13	18.47	0.96	WB - WGP
Oman	Sur	82,200	Gulf of Oman	2010	97.74	20.03	1.04	WB - WGP
Kuwait	Hamriyah	91,000	Persian Gulf	2014	108.21	No Data	No Data	Web
KSA	Al Jubail	100,000	Persian Gulf	2014	118.91	24.37	1.02	WB - WGP
Algeria	Skikda	100,000	Mediterranean	2009	118.91	24.37	0.64	AEC
Algeria	Cap Djinet	100,000	Mediterranean	2011	118.91	24.37	0.75	AEC
China	Qingdao	100,000	Yellow	2013	118.91	No Data	0.80	GWI-Desal
India	Minjur	100,000	Arabian	2010	118.91	No Data	1.00	GWI-Desal
India	Chennai Nemmeli	100,000	Arabian	2013	118.91	No Data	0.99	GWI-Desal
Taiwan	Formosa	105,000	South China	2019	124.85	No Data	No Data	GWI-Desal
T&T	Point Lisas	109,104	Caribbean	2002	129.73	No Data	No Data	GWI-Desal
UAE	Jebel Ali RO	113,650	Gulf of Oman	2007	135.14	No Data	No Data	GWI-Desal

Country	Plant Name	Capacity	Source of Feed Water	First Year of Operation	CAPEX	O&M Expense	Water Tariff	Source
					USD Mil	USD Mill	USD/m3	
Algeria	Fouka	120,000	Mediterranean	2010	142.69	29.25	0.77	AEC
Oman	Barka II SWRO	120,000	Persian Gulf	2009	142.69	No Data	No Data	GWI-Desal
Spain	Carboneras	120,000	Mediterranean	2002	142.69	No Data	No Data	GWI-Desal
KSA	Yanbu Phase I	127,900	Red	1995	152.08	31.17	0.98	WB - WGP
Singapore	Singspring	136,000	South China	2005	161.72	33.15	0.77	WB - WGP
UAE	Fujairah 2	136,000	Gulf of Oman	2010	161.72	33.15	0.92	WB - WGP
Kuwait	Shuwaikh	136,000	Persian Gulf	2010	161.72	33.15	1.01	WB - WGP
Singapore	Tuas I	136,000	South China	2005	161.72	No Data	0.63	GWI-Desal
Kuwait	Az Zour South	136,000	Persian Gulf	2011	161.72	No Data	No Data	GWI-Desal
Spain	Valdelentisco	136,000	Mediterranean	2007	161.72	No Data	No Data	GWI-Desal
KSA	Jeddah 1 & 2	136,400	Red	1994	162.19	33.24	0.95	WB - WGP
UK	Beckton	150,000	North Sea	2010	178.36	No Data	No Data	Web
KSA	Shuaibah 3	150,000	Red	2011	178.36	36.56	1.09	WB - WGP
Israel	Palmachim Exp 3&4	150,000	Mediterranean	2013	178.36	No Data	0.35	GWI-Desal
Egypt	El Almein	150,000	Mediterranean	2019	178.36	No Data	No Data	GWI-Desal
KSA	Shoiba 3 Exp	150,000	Red	2009	178.36	No Data	No Data	GWI-Desal
Qatar	Ras Abu Fontas 3	164,000	Persian Gulf	2015	195.01	No Data	No Data	Web
UAE	Fujairah 1	170,500	Gulf of Oman	2004	202.74	41.56	0.89	WB - WGP
Oman	Ghubrah	191,000	Gulf of Oman	2018	227.12	No Data	No Data	Web
Spain	Barcelona	200,000	Mediterranean	2009	237.82	48.75	0.91	WB - WGP
USA	Calsbad	200,000	North Pacific Ocean	2015	237.82	48.75	1.46	WB - WGP
Algeria	Hamma	200,000	Mediterranean	2008	237.82	48.75	0.88	AEC
Algeria	Beni Saf	200,000	Mediterranean	2009	237.82	48.75	0.77	AEC
Algeria	Souk Tlata	200,000	Mediterranean	2010	237.82	48.75	0.77	AEC
Algeria	Mostaganem	200,000	Mediterranean	2011	237.82	48.75	0.75	AEC
Algeria	Tenes	200,000	Mediterranean	2013	237.82	48.75	No Data	AEC
Algeria	Honaine	200,000	Mediterranean	2012	237.82	48.75	0.85	AEC
Spain	Barcelona Llgobgregat	200,000	Mediterranean	2009	237.82	No Data	No Data	GWI-Desal
Oman	Qurayyat	200,000	Gulf of Oman	2019	237.82	No Data	No Data	GWI-Desal
KSA	Shuqaiq	212,000	Red	2010	252.09	51.67	1.05	WB - WGP
Bahrain	Al Dur	218,000	Persian Gulf	2012	259.22	53.13	0.84	WB - WGP

Country	Plant Name	Capacity	Source of Feed Water	First Year of Operation	CAPEX	O&M Expense	Water Tariff	Source
					USD Mil	USD Mill	USD/m3	
Kuwait	Kuwait SWRO	227,100	Persian Gulf	2018	270.04	No Data	No Data	GWI-Desal
Spain	Torrevieja	240,000	Mediterranean	2013	285.38	No Data	No Data	Web
KSA	Jeddah 3	240,000	Red	2013	285.38	58.49	1.00	WB - WGP
Oman	Sohar 3 IWP	250,000	Gulf of Oman	2019	297.27	No Data	0.69	GWI-Desal
KSA	Shoaiba 3 Exp 2	250,000	Red	2019	297.27	No Data	No Data	GWI-Desal
KSA	Ras Al Khair	309,100	Persian Gulf	2014	367.55	75.34	0.74	WB - WGP
Singapore	Tuasspring	318,500	South China	2013	378.72	No Data	No Data	Web
Israel	Ashdod	385,000	Mediterranean	2011	457.80	No Data	No Data	Web
KSA	Shoaiba 4	400,000	Red	2014	475.64	No Data	No Data	Web
Israel	Hadera	462,000	Mediterranean	2010	549.36	No Data	No Data	Web
Algeria	Magtaa	500,000	Mediterranean	2013	594.54	121.86	0.60	AEC
Israel	Sorek	624,000	Mediterranean	2013	741.99	152.08	0.56	WB - WGP

ANNEX D: LIST OF WEB SOURCES

Country	Source
Cyprus	https://www.water-technology.net/projects/larnaca-swro-desalination/
	http://www.moa.gov.cy/moa/wdd/wdd.nsf/page23_en/page23_en?opendocument
	http://www.moa.gov.cy/moa/wdd/wdd.nsf/All/F549633FB495865AC2258288002C3E7A/$file/Desalination_Manolis.pdf?OpenElement
	https://www.eac.com.cy/EN/NonRegulatedActivities/desalinationstation/Pages/default.aspx
	http://documents1.worldbank.org/curated/en/476041552622967264/pdf/135312-WP-PUBLIC-14-3-2019-12-3-35-W.pdf
Israel	https://www.gov.il/BlobFolder/generalpage/desalination-main/he/Ashkelon.pdf
	https://www.water-technology.net/projects/israel/
	https://www.water-technology.net/projects/sorek-desalination-plant/
	http://www.water.gov.il/Hebrew/Planning-and-Development/Desalination/Documents/Desalination-in-Israel.pdf
	https://www.water-technology.net/projects/ashdod-desalination-plant-ashdod/
	http://documents1.worldbank.org/curated/en/476041552622967264/pdf/135312-WP-PUBLIC-14-3-2019-12-3-35-W.pdf
Oman	https://www.ferrovial.com/en-ca/business/projects/desalination-plant-oman-al-ghubrah/
	http://www.sacyr.com/es_en/Channel/News- Channel/news/featuresnews/2019/Inauguracion/20191003_Inauguracion_Desaladora_Oman.aspx
	http://www.sacyrindustrial.com/es_en/Actividad/Water/Oman/sohar-SWRO-desal-plant/default.aspx
	http://documents1.worldbank.org/curated/en/476041552622967264/pdf/135312-WP-PUBLIC-14-3-2019-12-3-35-W.pdf

Country	Source
	https://www.sharqiyahdesalination.com/sur-desalination-plant
	https://www.veolia.com/middleeast/our-services/our-vision/our-references/reference-desalination-plant-gulf-region
	https://www.veolia.nl/sites/g/files/dvc2496/files/document/2014/05/sdc_contract.pdf
Qatar	https://www.acciona.com/projects/swro-ras-abu-fontas-3/
	https://www.water-technology.net/projects/ras-abu-fontas-raf-a2-seawater-desalination-plant/
Saudi Arabia	https://www.acciona.ca/projects/water/desalination-plants/
	https://www.waterworld.com/drinking-water/treatment/article/16207660/desalination-plant-in-al-jubail-saudi-arabia-aims-to-cut- energy-costs
	https://www.waterworld.com/international/desalination/article/16203012/saudis-shoabia-4-desalination-project-to-be-supervised-by-pyry
	https://www.veolia.com/middleeast/our-services/our-vision/our-references/fujairah-2-reverse-osmosis-desalination-plant-united-arab
	https://www.accsal.com/projects/fujairah-f2-independent-water-and-power-plant/
	https://www.veolia.nl/sites/g/files/dvc2496/files/document/2014/05/fujairah_contract.pdf
UAE	https://www.arabianbusiness.com/khor-fakkan-desalination-plant-commissioned-84726.html
	https://www.dupont.com/content/dam/dupont/amer/us/en/water-solutions/public/documents/en/45-D02441-en.pdf
	https://informedinfrastructure.com/16775/aquatech-completes-15-migd-desalination-project-for-fewa-in-ras-al-khaimah/
	https://www.aquatech.com/project/aquatechs-15-migd-desalination-plant-helps-the-united-arab-emirates-reduce-dependence-on-groundwater/
	https://www.desalination.biz/news/0/FEWA-to-triple-capacity-at-Ghalilah-desalination-plant/8810/

Country	Source
	https://www.globalwaterintel.com/global-water-intelligence-magazine/8/8/general/hamriyah-swro-goes-to-aqua-engineering
	https://membranes.com/wp-content/uploads/Documents/Technical-Papers/Application/IMS/Hamriyah-SWRO-Desalination-Plant.pdf
	https://www.waterworld.com/drinking-water/infrastructure-funding/article/16222308/uaeaustrian-team-gets-121m-desal-deal
Ghana	https://www.waterworld.com/drinking-water/treatment/article/16200019/first-desalination-plant-in-west-africa-officially-inaugurated#:~:text=On%20Friday%2C%20April%2017%2C%20Abengoa,and%20the%20West%20Africa%20region
	https://www.water-technology.net/projects/accra-sea-water-desalination-plant/
	https://www.miga.org/project/seawater-desalination-project-ghana
	https://www.dme-gmbh.de/ghana-water-buying-desalinated-water-at-about-125-em%C2%B3-from-abengoa-sub-company-ghana-teshie-nungua/
Morocco	http://www.semide.org/documents/meetings/events/international-conference-desalination-sustainability-casablanca-morocco-01-03/jorf-lasfar-largest-swro-desalination-plant-morocco/download/1/MOR12-012_Martinez.pdf
	https://newsroom.ferrovial.com/en/press_releases/cadagua-to-build-desalination-plant-in-morocco-60-million-euro/
	https://openknowledge.worldbank.org/bitstream/handle/10986/29190/122698-WP-v2-PUBLIC-anneces-to-sections-2-to-4.pdf?sequence=5&isAllowed=y
Tunisia	https://www.desalination.biz/news/0/Tunisia-officially-opens-its-first-desalination-plant/9017/
	https://www.kfw.de/stories/environment/natural-resources/tunisia-desalination-of-sea-water/
South Africa	http://www.veoliawatertechnologies.co.za/vwst-southafrica/ressources/files/1/32048-Mossel-Bay-Desalination.pdf
	https://www.mosselbay.gov.za/mossel-bay%E2%80%99s-desalination-plant-gets-top-award
	http://www.wrc.org.za/wp-content/uploads/mdocs/TT%20638-15.pdf

Country	Source
Spain	https://www.acciona.ca/projects/water/desalination-plants/canal-de-alicante-desalination-plant/
	https://ec.europa.eu/regional_policy/EN/projects/best-practices/ALL/1613
	https://www.water-technology.net/projects/barcelonadesalinatio/
	https://www.typsa.com/en/proyectos/torrevieja-desalination-plant/
	https://www.acciona.ca/projects/water/desalination-plants/torrevieja-desalination-plant/
	https://www.tedagua.com/en/project/escombreras-desalination-plant
	https://www.dupont.com/content/dam/dupont/amer/us/en/water-solutions/public/documents/en/45-D02265-en.pdf
	https://www.acciona.ca/projects/water/desalination-plants/san-pedro-del-pinatar-i-and-ii-desalination-plant/
Kuwait	https://www.water-technology.net/projects/shuwaikh-ro-project/#:~:text=The%20Shuwaikh%20RO%20Project%20involves,located%20near%20Shuwaikh%20Port%2C%20Kuwait.
	https://www.doosanenpure.com/content/downloads/doosan_water_bg_brochure.pdf
	https://www.veolia.com/middleeast/our-services/our-vision/our-references/az-zour-south-kuwait
	https://www.watertechonline.com/process-water/article/16199439/az-zour-kuwait-desalination-plant-recycles-power-station-cooling-water
UK	https://www.acciona.com/projects/swro-beckton/
	bbc.com/news/10213835
Singapore	https://www.kepinfratrust.com/portfolio/waste-and-water/singspring-desalination-plant/
	https://www.waterworld.com/international/desalination/article/16201921/landmark-project-in-singapore

Country	Source
	http://environment.asean.org/wp-content/uploads/2013/07/awgrm/Managing-PPP-Contractors-(2Nov2012)(PUB).pdf
	https://www.water-technology.net/projects/tuaspring-desalination-and-integrated-power-plant/#:~:text=The%20total%20cost%20for%20the,%24890m%20(%24635m%20approximately).
	https://www.waterworld.com/international/article/16209929/water-price-set-out-for-singapores-second-desalination-facility
World Bank Study	http://documents1.worldbank.org/curated/en/476041552622967264/pdf/135312-WP-PUBLIC-14-3-2019-12-3-35-W.pdf

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