المؤسسة العامة لتحلية المياه المالحة
Saline Water Conversion Corporation (SWCC)

Capital Cost Elements In the Desalination

“we race the future where life is”

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Introduction

Organizations in various industries have been striving to achieve continuous success in their core business, and these results mainly rely on the development and maturity of the organization's readiness to the intersections of events against the stakeholders' and the shareholder's expectations.

In the field of economic impact, opportunities for continuous improvements and cost reduction is huge, while preserving the efficiency and the highest quality.
with regards to desalination industry, as an important industrial sector, it has a critical role of ensuring the sustainability of water supply, especially with the continuing water scarcity and climate change challenges.

Capital cost reduction in desalination is a crucial aspect in making desalination technologies more affordable and accessible. Several strategies and advancements have been explored to achieve this goal.
In the report, the author will highlight the relationship between water capital investment and economic growth, the evolution of water capacity building cost reduction over the years by technologies and finally, the capital cost breakdown analyses.

The Relationship Between Water Capital Investment and Economic Growth

Overall, economic impact occurs as a result of growth in the production of goods and services. Increased spending expanded international trade, and businesses increased their investment in capital spending can all influence the level of production of goods and services in an economy [1].
Investments that contribute to water sustainability bring significant benefits to society, the economy, and the environment. "Water investments" encompass a wide range of investments, including spending on infrastructure, long-term assets, and services that contribute to the delivery of water and sanitation services [2].

Since water is a vital resource, the size of capital investments increases due to the continuous rise in water demand across all sectors, such as urban, agriculture, industry, and the environment.

The interrelated relationship between water capital investment and economic growth includes the following areas: investment in water infrastructure, investment in desalination capacity construction, and investment in operation, maintenance, and services.
These areas have a direct impact on the gross domestic product (GDP) in various aspects, such as local spending on water capacity building, local labor compensation, local procurement of goods and services, and local depreciation of capital assets [3]. Subsequently, as water is an essential requirement for life, and a key driver of every human need, it is also the sixth goal of the Sustainable Development Goals (SDGs), which is quoted as "Ensure availability and sustainable management of water and sanitation services for all."[4] Therefore, the economic benefits of investing in water could exceed hundreds of billions of dollars annually in order to achieve the objectives of the SDGs.

The Evolution of Water Desalination Technologies Economics

The evolution of water desalination technologies has had a significant impact on the economics of desalination projects. Advancements in technology, improved efficiency, economies of scale, and increased market competition have all contributed to the reduction in the cost of producing desalinated water.

Here is an overview of the evolution of desalination technology economics:

Early Years: In the 1960s and 1970s, desalination was an expensive and energy-intensive process. The high capital and operational costs limited its widespread adoption.

Technological Innovations: Research and development efforts focused on improving desalination technologies, such as reverse osmosis (RO), multi-stage flash (MSF), and multi-effect distillation (MED). (RO) desalination, which is a much more energy-efficient process than traditional thermal desalination technologies. Advancements in membranes, energy recovery systems, and plant designs gradually reduced the costs associated with desalination.

Economies of Scale: As desalination technology matured and deployment increased, economies of scale played a significant role in cost reduction. Larger desalination plants benefit from spreading fixed costs over a larger water production capacity, resulting in lower capital costs per unit of water produced.

Energy Efficiency Improvements: Energy consumption is a major component of operational costs in desalination. Significant improvements have been made in energy efficiency through the development of energy recovery devices, which help recover energy from the brine stream and reduce overall energy requirements.

Reduction in Membrane Costs: The cost of RO membranes, a critical component in desalination, has significantly decreased. Advances in manufacturing techniques, economies of scale, and increased competition among membrane manufacturers have contributed to the reduction in costs.

Technological Integration and Innovation: Integration with other water treatment processes and technological innovations, such as forward osmosis and membrane distillation, is being explored to increase efficiency and reduce costs.

Global Experience and Knowledge Sharing: With the expansion of desalination projects worldwide, experience and best practices were shared and implemented, leading to improved efficiency and cost-effectiveness.

It is important to note that the cost evolution of desalination technologies can vary depending on regional factors, project scale, energy costs, feed water quality, and other site-specific considerations. Fluctuations in material costs, energy prices, and regulatory requirements can also influence project costs.

Overall, the evolution of desalination technologies has led to continuous improvements and cost reductions, making desalination a more economically viable solution for addressing water scarcity challenges in many regions.

Seawater Reverse Osmosis Desalination CAPEX Breakdown

This section reviews the capital cost of desalination based on an actual database of about four large projects desalination plants. To be more representative of the latest cost data, desalination plants built over the past three years have been selected for the analysis.

The capital cost includes sixteen main components that summarize the desalination capital project as follows:

#	Components	Weight (With Regards to The Total CAPIX Cost)
1	Site surveys and studies	2.80%
2	Sea water intake	5.45%
3	Pretreatment system	5.24%
4	Membrane cleaning and flushing	0.62%
5	RO system	30.16%
6	Chemical systems	0.63%
7	Waste water system	0.50%
8	Post treatment system	2.73%
9	Product water pumping station	0.97%
10	Tanks	2.01%
11	Outfall	2.81%
12	Heating, Ventilation and Air Conditioning	2.10%
13	Firefighting systems	0.86%
14	Electrical works	12.03%
15	Instrumentation, control and automation works	3.97%
16	All civil works	27.13%
		100%

The SWRO desalination process consists of three main components: pre-treatment, RO membrane, and post-treatment systems. Seawater typically contains various dissolved solids, suspended solids, and organic and inorganic compounds. The pre-treatment process is designed to eliminate the suspended solids and organic and inorganic compounds. The RO system is responsible for removing the dissolved solids from seawater to produce fresh water. The post-treatment system utilized to adjust the pH of the fresh water and remineralize it to meet the criteria for drinking water quality and transportation.

In the following section we will review in detail the sixteen main components that impact the capital cost as the following;

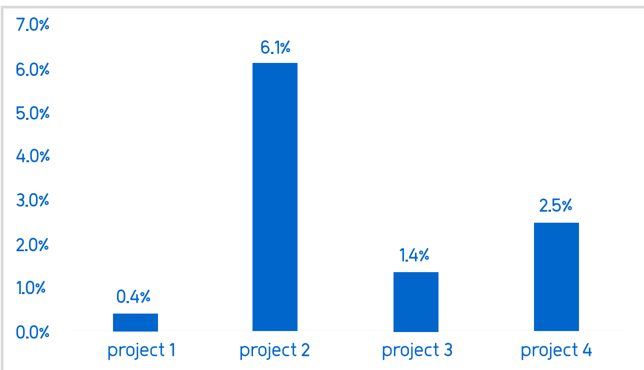
Site surveys and studies

Technical View:

Site surveys and studies are vital in the capital project process. They entail visiting the project site to observe and assess potential hazards, physical features, access points, and other essential information. These observations play a crucial role in determining the success of the project. By conducting a thorough site survey, project planners can gather valuable insights that inform decision-making, risk mitigation, and project design. Understanding the site's characteristics and challenges enables effective project execution it ensures that the project is tailored to the specific conditions of the location, setting the stage for a successful outcome.

Financial View:

FIGURE (1): THE WEIGHT SITE SURVEYS AND STUDIES COST FOR THE SELECTED PROJECTS



The costs associated with site survey and studies for civil works are subject to variation, contingent upon the level of complexity of the site being examined and surveyed. For example, in (Project 2) the weight is (6.1%) due to the nature of the geographies of the site being examined, and the challenges comes with it, the available sites close to the seawater, the status of the distance needed to find the suitable sea depth for the intake systems etc.

In this study, this particular capital cost element holds a weight average of approximately (2.8%). These expenses are a crucial investment, ensuring comprehensive understanding of the site's characteristics and enabling effective project planning and execution.

2- Sea Water Intake

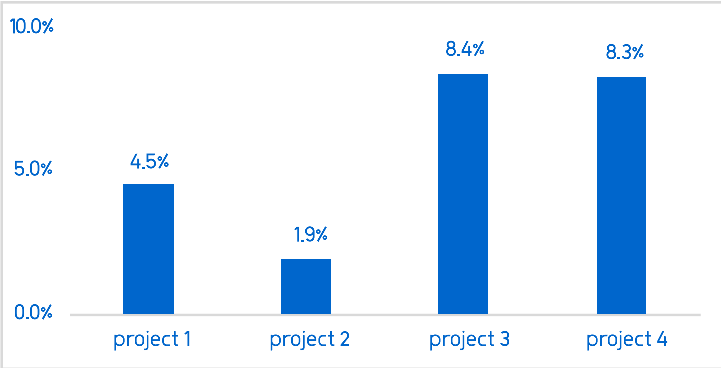
Technical View:

The intake system design for the SWRO desalination plant is critical for plant sustainability. The optimum intake design system will result in better SWRO performance and lower foulant species on membrane surfaces. There are two main types of intake systems. Open water intake and subsurface intake.

Open water intake is widely used in desalination plants because of its volume capacity suitable for large SWRO plants. Open intake can be surface or submerged. The open surface intake consists of an active screen & traveling screen for debris and solids removal. The subsurface intake system uses sea wells for seawater collection. It is used for small SWRO plants.

Financial view:

Figure (2): THE WEIGHT OF THE INTAKE SYSTEM COST FOR THE SELECTED PROJECTS



Note: the weight of the intake system for each project is the cost of the component with regards with the total cost of the project

The cost-weight range of the intake system in SWRO desalination plants falls between (1.9% - 8.4%) of the total capital cost. On average, the intake system represents approximately (5.45%) of the total capital cost without the civil works at the intake. The management of this cost can be approached in various ways, depending on the condition of the existing infrastructure.

The cost of the intake system varies due to several factors. For instance, in (Project 2) the weight is (1.9%) because of the Maximized benefit of the given infrastructures via using the existing intakes for the new plant, which results in lower capital cost for the intake system. For (Project 3) the weight of the intake system is high due to the mandatory requirements being added to the intake system, like Seawater electro chlorination pumps and the Firefighting pump, unlike (project 1), which benefits from the available systems in the given area. Also, the variance of the nature of water in (project 3), which has a highly moving sand that demanded a large distance of the intake pipes and a lower depth than (Project1). In (project 4) the reason for the high intake share is the requirement to build new intake infrastructure, which requires high capital cost.

Generally, in the case of SWRO desalination plants, it is preferable to locate the plant as close to the seawater intake source as possible this helps to avoid higher costs associated with lengthy intake pipelines and complex intake constructions. One of the main challenges that impact the water intake cost are the quality of water, the level of the various dissolved solids, suspended solids, and organic and inorganic compounds in the seawater.

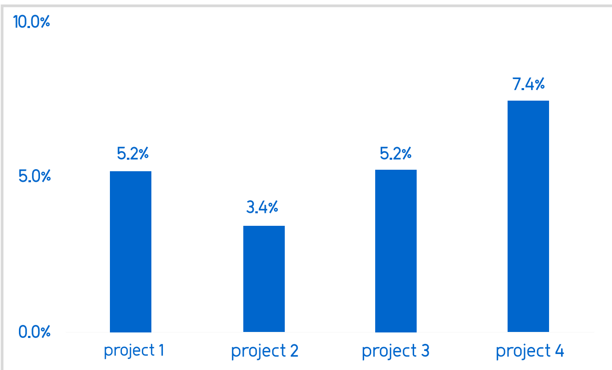
3- Pretreatment system

Technical View:

The aim of the pretreatment system is to sufficiently eliminate foulants from the seawater and to secure a steady and effective performance of the reverse osmosis membranes. The pre-treatment process is used to remove the large particles & solids. It consists of a Dissolved Air Floatation (DAF), Dual Media Filtration (DMF) or Microfiltration (MF) /Ultrafiltration (UF), and Cartridge Filter (CF). Depends on the requirements of the given project.

Financial View:

Figure (3): THE WEIGHT OF THE PRETREATMENT SYSTEM COST FOR THE SELECTED PROJECTS



The pretreatment system represents a (5.24%) of the total capital cost of SWRO desalination plant. Pretreatment costs are defined by the type and complexity of the pretreatment system. The type of pretreatment required depends on the raw water quality at the project site.

Some raw seawater or brackish surface water sources have a high level of organics and biological activity like project (3) and (4) which require more robust pretreatment technologies, such as DAF (Dissolved Air Flotation) and UF (Ultrafiltration). Other raw water sources that use submerged intakes or well-based intakes may require less pretreatment, such as a single-step media filtration or MF (Microfiltration).

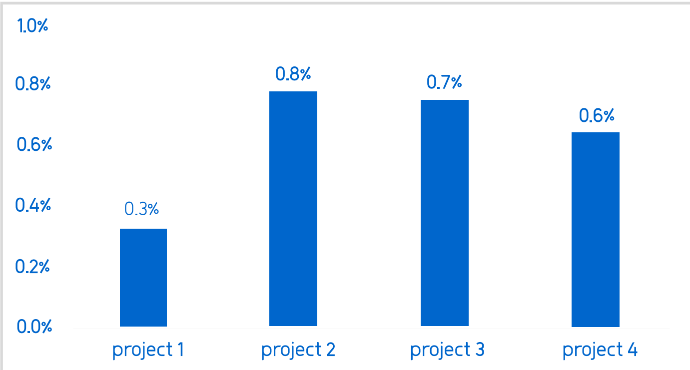
4- Membrane Cleaning and Flushing

Technical View:

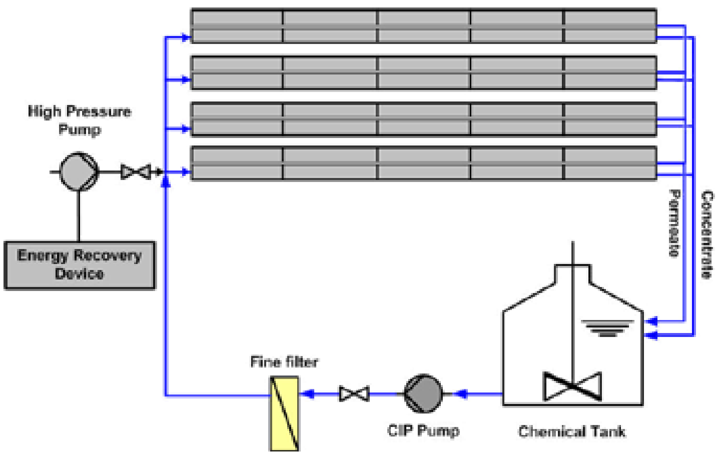
RO membranes accumulate foulants in the feed/brine spacer cavities over time, which causes differential pressure increase and have to be cleaned periodically in order to maintain their performance and useful life. The purpose of membrane cleaning is to dissolve and remove inorganic scales, dislodge and remove particulate and colloidal foulants.

Financial View:

Figure (4): THE WEIGHT OF MEMBRANE CLEANING AND FLUSHING COST FOR THE SELECTED PROJECTS



The membrane cleaning and flushing has a weight of (0.62%) of the total capital cost of SWRO desalination plant. One of the lowest cost elements that impact the capital cost, however it has a great role of ensuring and keeping the full life span of the membrane's equipment.



Source: https://www.lenntech.com/processes/desalination/membranes/general/membranes-cleaning.htm

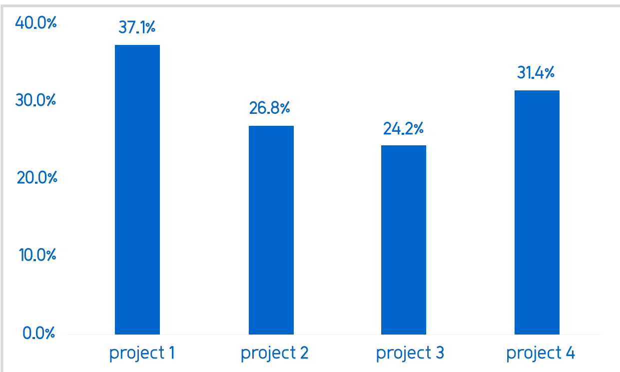
5- RO System

Technical View:

After pretreatment, the feed water is introduced to the RO system, where dissolved solids are removed, and freshwater is produced. The three main components in the RO process are the high-pressure pumps (HPP), energy recovery device (ERD), and RO membranes.

Financial View:

FIGURE (5): THE WEIGHT OF RO SYSTEM COST FOR THE SELECTED PROJECTS



The RO system has the highest share of the capital cost, on average it has more than (30%) of the total capital cost of SWRO desalination plant.

RO system is the core element of desalination. The cost will vary due to the level of complexity of the specifications of the systems, which depends on many factors. For example, Project (1) and (4) have a higher set of equipment for the high-pressure pumps (HPP) than Project (2) and (3) by (24%), which has a high impact on the capital cost. Another indicator is the difference in the number of equipment used in the Variable Frequency Drive (VFD) for HPP, which impacts the capital cost. Overall, the cost will be affected due to how many phases the seawater will go through the membranes.
How much pressure do we need to apply depending on the water TDS levels.

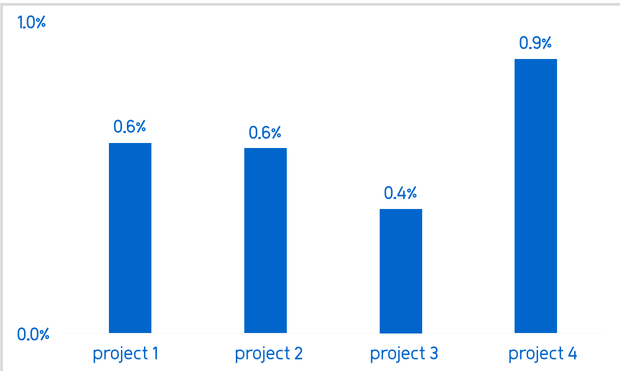
6- Chemical Systems

Technical View:

Pretreatment chemicals used for brackish and seawater desalination include pH adjusters, coagulants and flocculants, deposit control agents (Antiscalants, dispersants), biocides and reducing chemicals. In post-treatment, chemicals include chlorine, anti-corrosion additives and compounds for remineralization.

Financial View:

FIGURE (6): THE WEIGHT OF CHEMICAL SYSTEMS COST FOR THE SELECTED PROJECTS



Alongside membrane cleaning and flushing, chemical systems play a vital role in water treatment. Despite their importance, these systems typically have a relatively low capital cost, representing an average weight of approximately (0.63%) of the total capital cost. Their cost-effectiveness underscores their significance in maintaining optimal water quality and system performance.

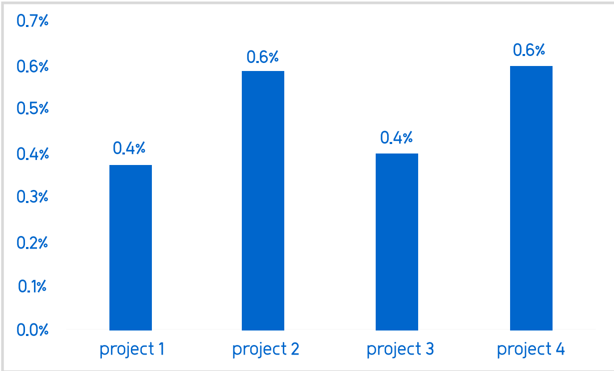
7- Waste Water System

Technical View:

This system used for treating the waste of water which resulted from all the process in the desalination plant.

Financial View:

FIGURE (7): THE WEIGHT OF WASTE WATER SYSTEM COST FOR THE SELECTED PROJECTS



The waste water system, on average, represents a relatively small portion, accounting for approximately (0.5%) of the total capital cost. Despite its modest share, this component plays a critical role in managing and treating the discharged water effectively and responsibly.

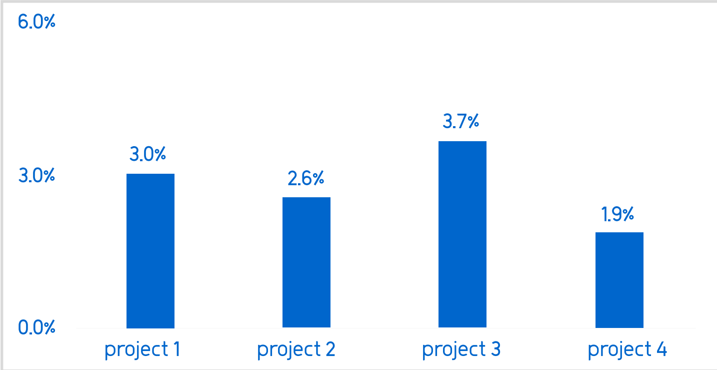
8- Post Treatment System

Technical View:

It is mainly used to reduce the corrosiveness of SWRO permeate stream. It increases its hardness and alkalinity. The primary post-treatment process is stabilization, corrosion control, disinfection, and air stripping for $CO2$ & $H2S$ removal. Three main parameters are necessary for stabilization: pH, alkalinity, and calcium carbonate. Sodium hydroxide, potassium hydroxide, carbon dioxide, lime, and soda ash could be used for pH adjustment.

- **Financial View:**

FIGURE (8): THE WEIGHT OF POST TREATMENT SYSTEM COST FOR THE SELECTED PROJECTS

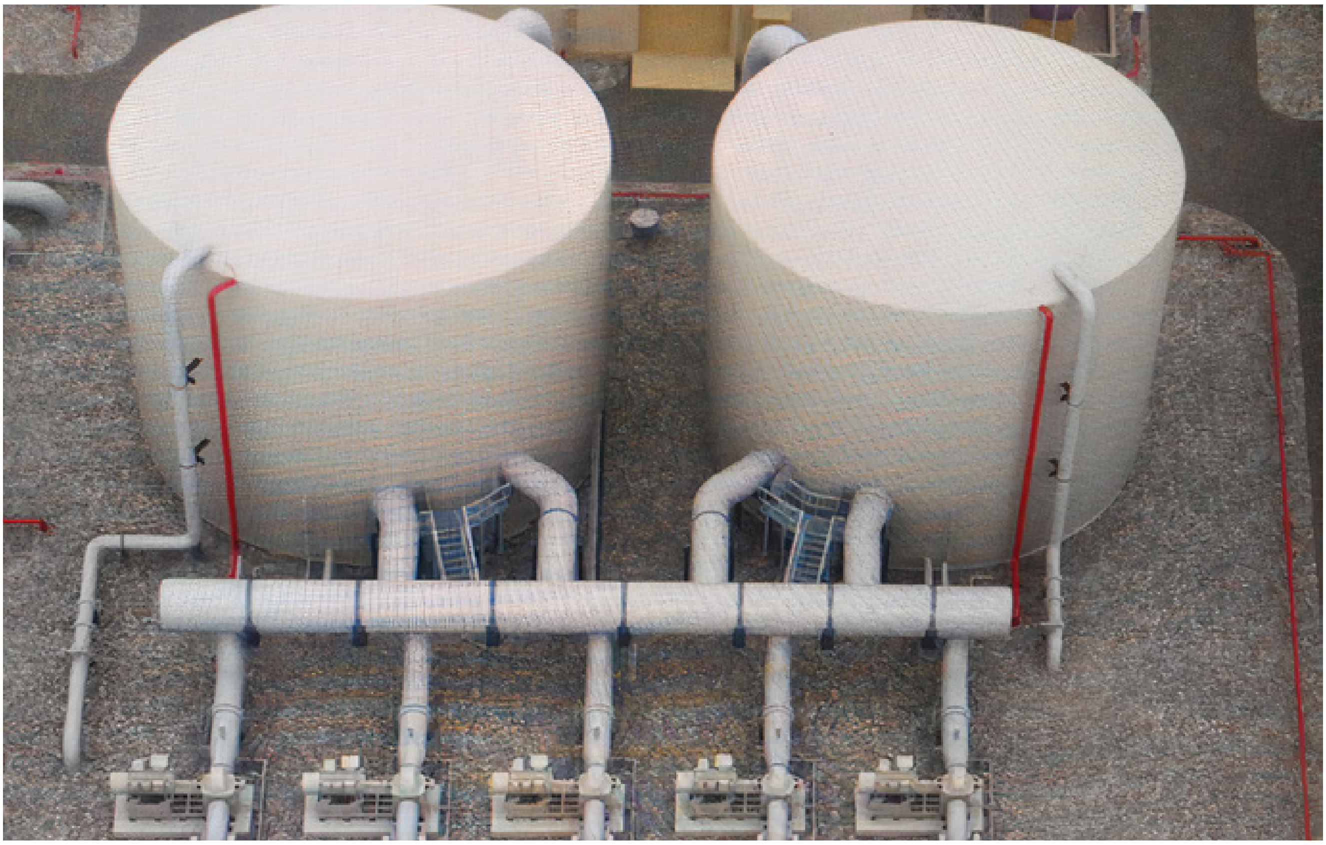


The stabilization of product water often necessitates pH adjustment, with the cost of post-treatment being determined by the configuration of the RO system and the number of passes. In the given data, the average weight of the post-treatment system is (2.73%) of the total capital cost.

9- Product Water Pumping Station

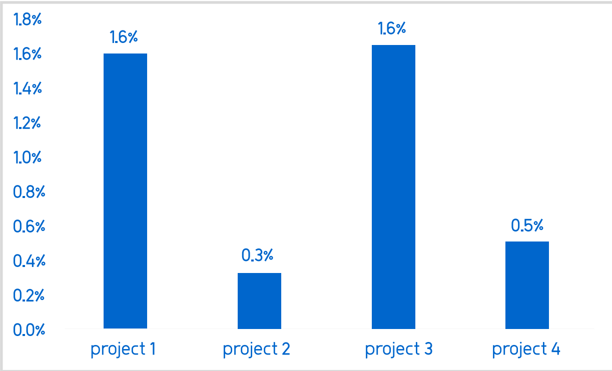
- **Technical View:**

It is the station where the product of water produced is ready to move to the operational tanks in order to be transmitted.



Financial View:

FIGURE (9): THE WEIGHT OF PRODUCT WATER PUMPING STATION COST FOR THE SELECTED PROJECTS



Within the total capital cost of a SWRO desalination plant, the product water pumping station represents a relatively small portion, with a weighted average of approximately (0.97%). Despite its low contribution, this component is vital in facilitating the distribution and transportation of the desalinated water to its intended destination.

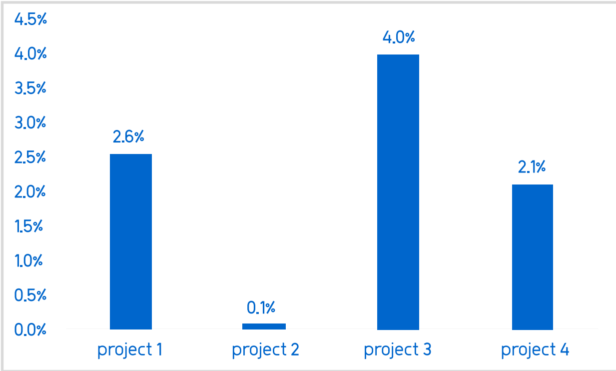
10- Operational Tanks

Technical View:

Water desalination tanks, also known as operational tanks, fulfil the essential function of storing the produced water. They serve as a crucial intermediary step in the desalination process, allowing the freshwater to be readily available for distribution through transmission lines to meet the water supply needs.

Financial View:

FIGURE (10): THE WEIGHT OF TANKS COST FOR THE SELECTED PROJECTS



The operational tanks account for an average weight of (2%) of the total capital cost of a desalination project. The exact cost varies based on the number of tanks required, which is directly influenced by the size of the desalination capacity.

These tanks play a critical role in storing and managing the produced water, ensuring a consistent and reliable water supply. Properly sizing and implementing these tanks contribute to the overall efficiency and effectiveness of the desalination plant's operations.

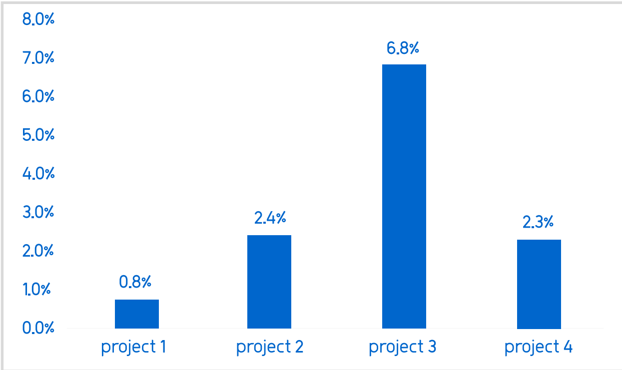
11- Outfall

Technical View:

The outfall system handles the safe discharge of treated wastewater back into the environment. Outfalls utilized to dispose the seawater when it is used in applications such as desalination plants.

Financial View:

FIGURE (11): THE WEIGHT OF OUTFALL COST FOR THE SELECTED PROJECTS



The total average weight of capital cost of the outfall is (2.8%), as the intake the outfall cost varies in relation with structure and the distance of the intake and the outfalls from the seawater.

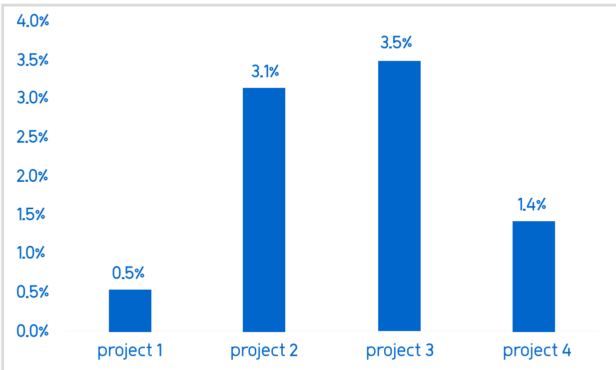
12- Heating, Ventilation and Air Conditioning (HVAC)

Technical View:

It is used to describe a complete internal comfort system that can be used to heat and cool the facilities, as well as provide improved indoor air quality.

Financial View:

FIGURE (12): THE WEIGHT OF OUTFALL COST FOR THE SELECTED PROJECTS



The total average weight of the capital cost of the HVAC is (2.1%). The cost's weight change depends on the size of the building's constructions and the complication of the air flow inside the constructions.

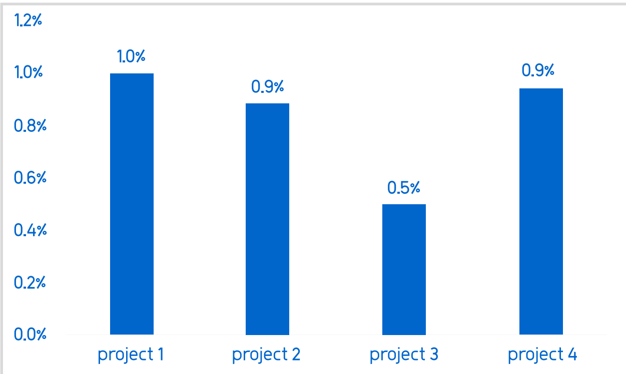
13- Firefighting Systems

Technical View:

Firefighting Systems, are very important to detect, control, extinguish and alert facilities to fire or smoke. Fire protection systems include sprinkler systems, standpipe systems and fire alarm systems. They are required in the desalination plants.

Financial View:

FIGURE (13): THE WEIGHT OF FIREFIGHTING SYSTEMS COST FOR THE SELECTED PROJECTS



The total average weight of the capital cost of the Firefighting Systems is (0.9%).

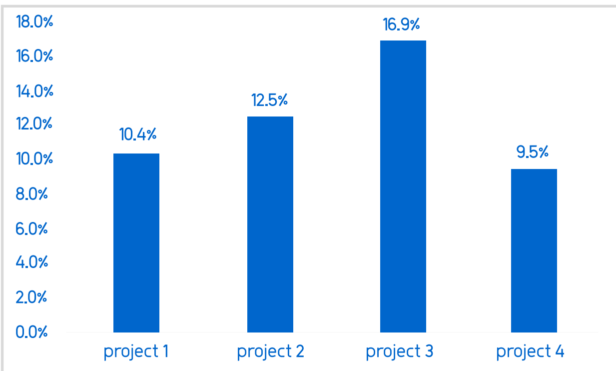
14- Electrical works

Technical View:

Reverse osmosis (RO) membrane separation, which uses a membrane barrier and pumping energy to separate salts from the water. Electrical energy here is used for membrane-based systems.

Financial View:

FIGURE (14): THE WEIGHT OF ELECTRICAL WORKS COST FOR THE SELECTED PROJECTS

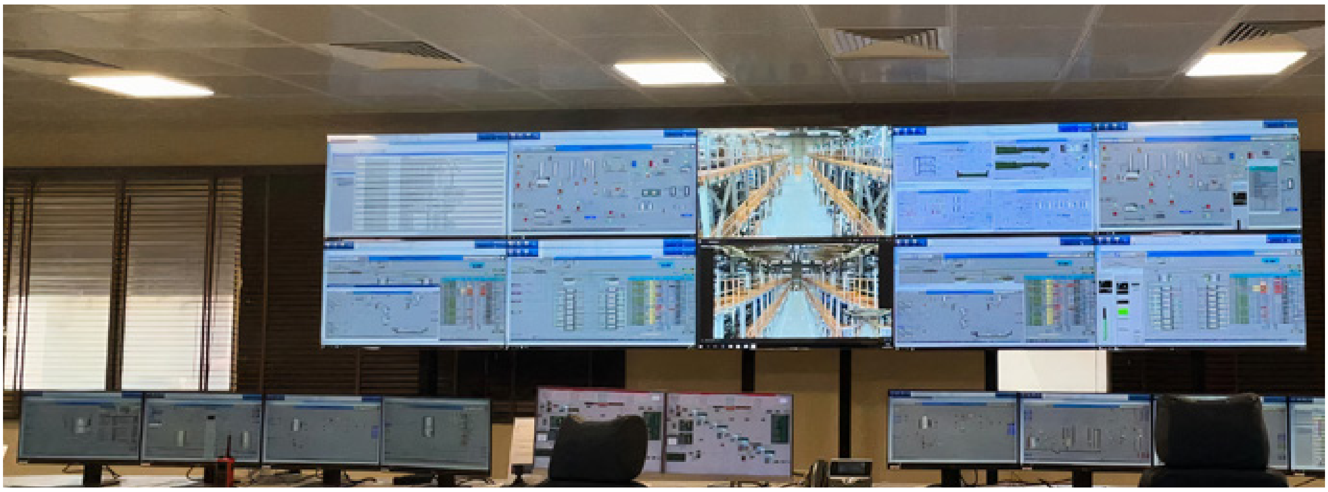


Current energy prices, transmission distance, at the proposed location of the desalination facility play an important role in determining the supply price for connected power. In this study, the Electrical works have a weight of (12%) of the total capital cost.

15- Instrumentation, Control and Automation (ICA) Works

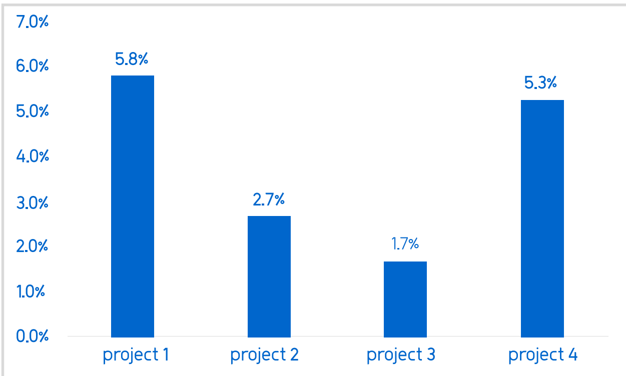
Technical View:

Instrumentation and control systems entitle controlling, monitoring and the full automation of the plants operation.



Financial View:

FIGURE (15): THE WEIGHT OF ICA WORKS COST FOR THE SELECTED PROJECTS

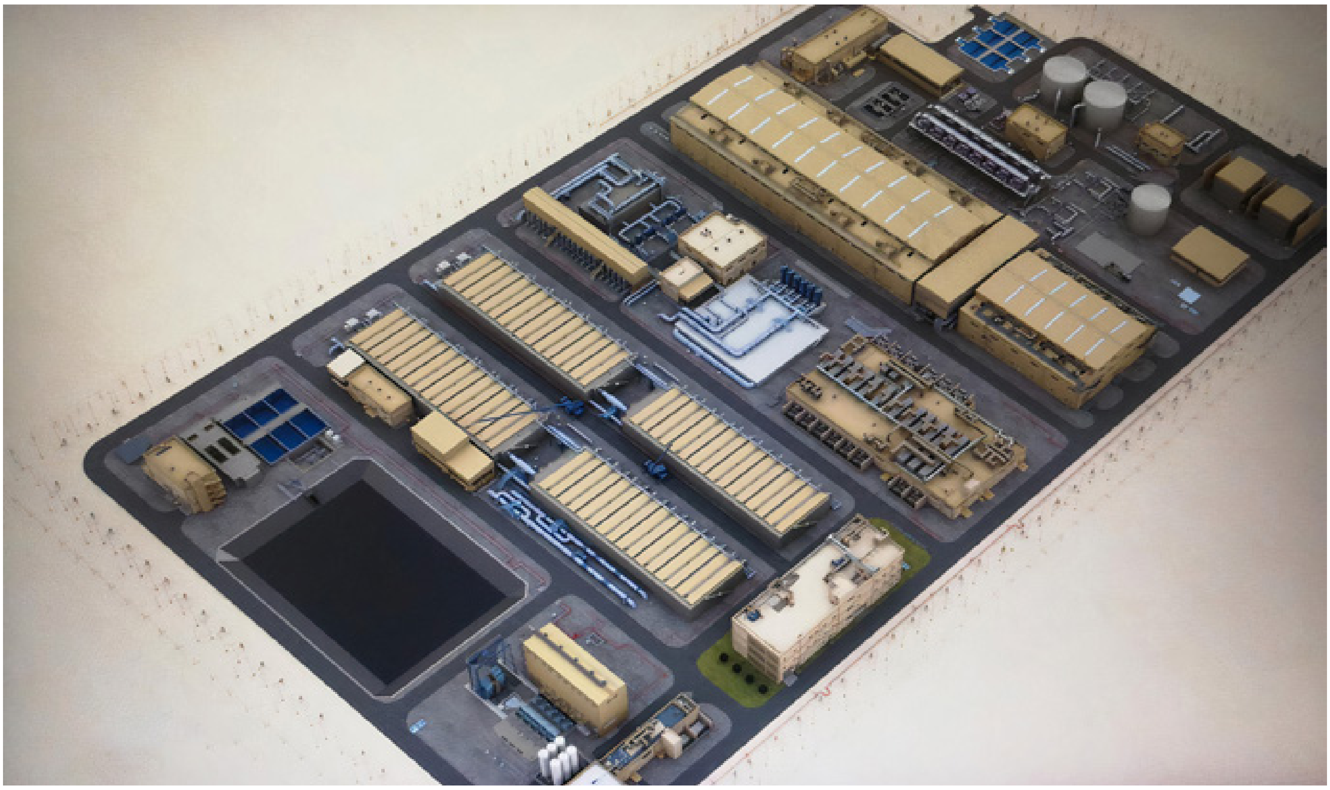


The total average weight of the capital cost of the ICA is (3.97%). This cost varies depend on the level of features and advanced system used for supervision and control.

16- All civil works

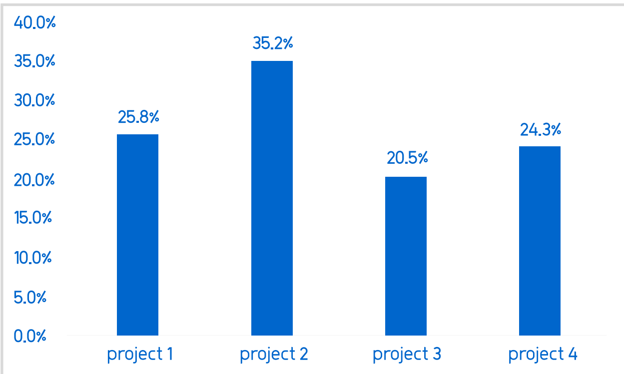
Technical View:

All civil works include building foundations for the process equipment as well as establishing buildings to house the electrical and instrumentation facilities, the various stores and workshops, the administration, the social facilities, etc.



Financial View:

FIGURE (16): THE WEIGHT OF ALL CIVIL WORKS COST FOR THE SELECTED PROJECTS



This capital cost element is the second highest capital cost share among all the elements at (27.1%). These costs change depending on the status of the geographic of the plant locations and the cost of the equipment used. As the first capital cost element, the site and survey (Project 2) have the more challenging geographic site, quality of water and the high level of TDS of the seawater.

Conclusion

The importance of desalination capital planning is ensuring sustainable economic growth and effective water resource management. The relationship between water capital investment and economic growth is evident, as adequate access to clean and reliable water sources is crucial for various industries and societal well-being.

Effective water capital planning governance is essential to prioritize and allocate resources efficiently, ensuring that investment aligns with long-term goals and sustainability objectives.

Understanding the breakdown of desalination CAPEX is crucial for decision-making. Analyzing the different components of capital expenditure Stakeholders can identify areas for optimization and efficiency improvement. This breakdown also allows for better financial planning and risk management, ensuring the long-term sustainability and affordability of desalination projects.

In conclusion, desalination capital planning plays a vital role in addressing water scarcity challenges and promoting economic growth. Adopting effective governance models and practices, such as those employed by SWCC, and understanding the breakdown of desalination CAPEX, stakeholders can make informed decisions that balance economic, environmental, and social considerations. Investing in sustainable water infrastructure and technologies will secure a prosperous future where access to clean water is guaranteed for all.

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