A Conscious, Smart Site Model for a Solar-Water Energy System

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Abstract. This paper proposes a global model of sustainable desalination in the hydrological context of any river with a reservoir close to the sea. For this purpose, a desalination plant is installed, located on the coast, which transports the pumped water using the course of the river itself and discharges it directly into the reservoir. The concept of sustainability lies in the fact that the energy required to provide for the entire process is obtained by means of a floating photovoltaic park located in the reservoir. The electrical energy generated by this park provides a self-consumption solution for both the desalination plant and the pumping stations, either by injecting and balancing its energy into the electrical grid or directly to the desalination plant. In addition, as a remarkable product in the desalination process, various derivatives are obtained and the project becomes a source of green hydrogen.

Keywords: Sustainable desalination system · Floating photovoltaic park · Circular economy · Green hydrogen

1 Water+S Project

1.1 Introduction

This paper proposes the application of a sustainable desalination cycle in the hydrological context of the Vélez river and the Viñuela reservoir in the municipality of Vélez-Málaga.

The first part of the project requires obtaining desalinated water from the sea. For this purpose, a desalination plant is installed at the mouth of the Vélez river, which discharges the pumped water, using the course of the same river, directly into the reservoir of the Viñuela.

The concept of sustainability lies in the fact that the energy needed to power the entire process would be obtained by means of a floating photovoltaic park located in the reservoir itself (taking into account all the biological parameters necessary for it to have no ecological impact). The electrical energy generated in this park would be justified by

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the self-consumption of the desalination plant and the pumping stations, but it would inject energy into the electricity supply network which would provide energy to users in the area and could even be sized for greater production. In practice, both the desalination plant and the pumping stations would be directly supplied from the general electricity grid, but free of charge, as the same energy would be injected into the system from the photovoltaic plant.

Currently, there are numerous examples of separate installations that follow the presented design, but it has never been considered to combine these models in a joint way, in a way that works with the sustainability concept of the desalination system. Therefore, this proposal would be pioneering at world level, from the technological point of view, and totally replicable in any of the river basins that have a reservoir, close to the coast, from which drinking water is distributed for both irrigation and human consumption.

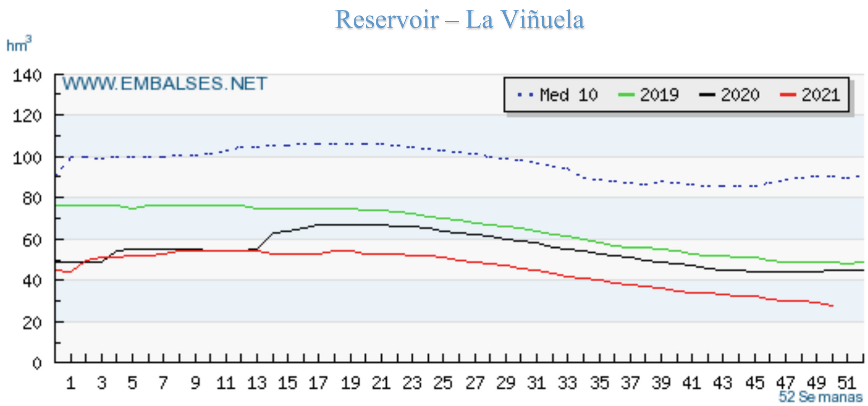
1.2 Project Advantages

This project is proposed because it is of great benefit to all stakeholders involved in the project:

a. Firstly, it will ensure the supply of water to the Viñuela rteservoir, regardless of the rainfall contribution in the area.
b. It will make possible to generate a significant amount of electricity (up to 500 MWh), using renewable energy and without the need to occupy land that can be used for other purposes. In practice, much more energy will be generated globally than is necessary for the operation of the system, making it a very attractive project for the provision of electricity to the general grid.
c. As it has been designed as a modular project, starting from a base corresponding to the production of 10 Hm^3 of water per year, it can be expanded according to the needs that are observed and does not require a gigantic dimensioning from the beginning.
d. At no time is private land used to locate any of the facilities, so no land expropriation would be necessary.
e. The water brought into the reservoir basin will be mixed with the water collected there, so it will not be necessary to mineralise it and, furthermore, it will be channelled through the existing distribution network, so there will be no need to install additional pipelines.
f. Control of the quantity of water stored in the reservoir will ensure the supply to the irrigation network in the area, thus enabling the agro-industrial development of the area without the problem of restrictions that could endanger it.
g. The desalination process under evaluation will allow the production of brine by-products (such as hydrogen, hydrochloric acid and sodium hydroxide).

1.3 Current Situation

Over the last few decades, the agricultural development of the Axarquía region (Málaga) has been exponential. The introduction of subtropical fruits and their confluence with a climate and land adapted to them, has meant the creation of an economic growth pole for Spain. Today, tens of thousands of jobs have been generated and many hectares of productive land that make up a strategic value chain, which has turned this area into one of the richest in Europe. But like all wealth it has its own Achilles' heel, which is the scarcity of water in the area.



It is hard to believe that a place bathed by the Mediterranean Sea would have water problems on such a scale as those suffered by Axarquía today. Certainly, the solution is a rainfall increase, but humans are not yet capable of generating the rainfall they want to recharge the Viñuela reservoir:

Dammed Water (14-12-2021)	**28 hm³**	**16.97 %**
Change previous week	-1 hm³	-0.61 %
Capacity:	165 hm³	
Same Week (2020):	45 hm³	27.27 %
Same Week (Med. 10 Years):	90 hm³	54.55 %

Therefore, more imagination is required in these scarcity moments and that is why the team formed by the **Agrarian Society of Transformation "Trops"** and the **Andalusian Institute of Domotic and Energy Efficiency** propose a solution that is firmly in line with the requirements of the European projects.

1.4 Previous Technical Data Assessed on the Proposed Project

Characteristics of the Viñuela reservoir:

- Area: 565 Ha (5,565,000 m^2)
- Water capacity: 170 Hm^3
- Current water consumption for irrigation: 20 Hm^3/annual

- Volume of storage water (as of 10/12/2021): 28,60 Hm^3
- Daily flow required: 54,794 m^3

The use of the reservoir area should not exceed 30% in order not to influence the food chain. Therefore, the total surface area of photovoltaic panels to be installed could be around 1,669,500 m^2.

It has been demonstrated that floating photovoltaic installations [5] have a 20% higher yield than those located on land. Therefore, considering an output of 350 W/m^2, the potential generation of electrical energy that could be obtained in case of maximum use (which is not our case) in the installation would be of

$$1.669.500 \times 350 = 584.325.000\,\text{KWh} = 584,325\,\text{MWh}$$

the daily light cycle will of course have to be considered.

Total current water needs would amount to some

$$54.794 * 365 = 19.999.810\,\text{m}^3 \cong 20\,Hm^3$$

According to studies and internationally collected data in desalination plants already in operation, it is estimated that between 3 and 6 KWh are required per m^3 desalinated and pumped. Therefore, we consider that the following are required

$$54.794\,\text{m}^3 * 6\,\text{KWh} = 328.764\,KWh/day$$

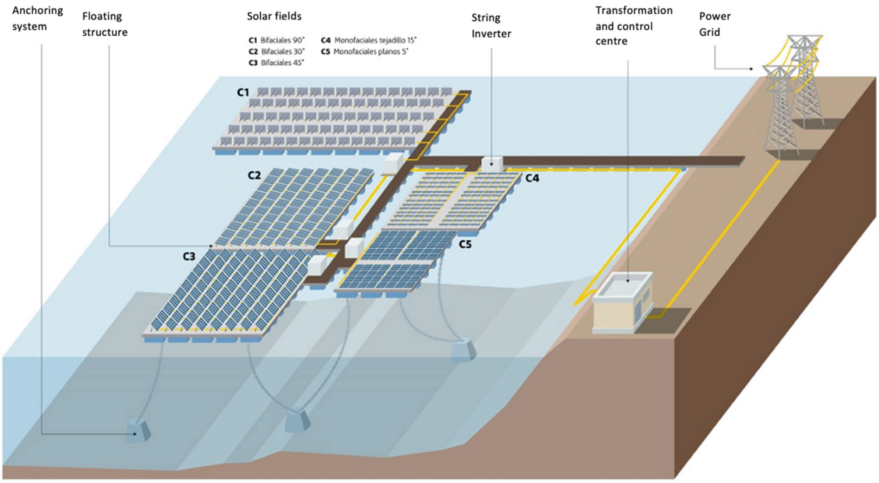
Given that the proposed operation involves the continuous pumping of water 24 h a day (the system is supplied from the general electricity grid), the desalination plant will be dimensioned in the most efficient and energy-efficient way so that it can generate a flow capable of covering the proposed needs.

The electrical power to be installed in the photovoltaic plant can be estimated according to the specifications to be supplied into the grid, but it must always be sized to exceed 328.764 MWh/day during the hours of sunshine.

1.5 Proposed Solution

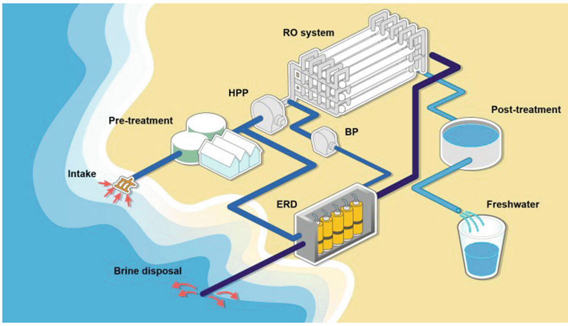
This solution proposes the establishment of three coordinated infrastructures:

1. Floating Solar Photovoltaic Plant: the richness of the agricultural land in the area provides this innovative solution for supplying the energy required for desalination. The floating plants already existing in various places on our planet allow high quality electricity generation on the water, given the permanent stability of both its liquid surface and its average temperature. On the other hand, they protect the reservoir itself from the proliferation of algae that must be removed for human consumption and from atmospheric pollution that may fall on its surface.



2. Pumping stations network: necessary to pump the desalinated water through the course of the Vélez River until it is discharged into the reservoir. This network is sized according to the quantity of water to be pumped, the density it has according to its desalination quality and the distance it travels.

3. Desalination Plant: located near the sea, it would be responsible for desalinating the amount of water necessary to recharge the Viñuela reservoir, this water finally being mixed with water from peripheral rivers and streams. This plant would generate a quantity of brine that would allow a parallel industry for the creation of hydrogen, salt, chlorine and other chemical derivatives of commercial interest.



The development of such a project meets several of the most important indicators for European projects:

1. The solar energy production and the citizens' consumption are synchronous, i.e. both coincide in the peak hours of electricity consumption in our industries and cities. Therefore, this production is the most favourable for the economic interests of all citizens, by providing sources that can reduce the energy price.
2. Solar energy production and desalinated water generation are asynchronous, i.e. desalination can be contracted during the hours of lowest energy prices, thus minimizing operating costs.
3. The energy generation and water desalination system matches to the circular economy [8], generating a zero consumption loop and maintaining the electricity grids and the global energy balance stability.
4. Brine generation would be incorporated into the actions proposed by the European Sea4Value project, which analyses the maximum industrial use of the by-products generated. On the other hand, and thanks to the advances made in recent months in the field of seawater hydrolysis, we are faced with a great source of hydrogen production [9], compatible with the Spanish and European objectives for this energy source.

2 Floating Photovoltaic Plant

2.1 Introduction

Open floating photovoltaic systems offer new possibilities for expanding the capacity to generate electricity using the solar energy. They have many advantages over land-based installations, both economically and in terms of infrastructure, as they have shown up to 20% higher energy yields compared with them (thanks to the dust absence, solar reflection on the water surface and the cooling of the panels due to the water effect), and it is possible to use existing electricity transmission networks in hydroelectric environments (very close to the demand centres) as a means of evacuating the energy generated [4].

This system was initially proposed to reinforce the existing hydroelectric power plants production, normally at the reservoirs foot, to boost their energy yield and help to manage low water availability periods, and even to use this input to condition the need to use stored water for electricity generation on solar input (which could be restricted to night-time hours if necessary).

Work carried out in this respect by prestigious entities such as the National University of Singapore and the International Bank for Reconstruction and Development in 2019, have shown additional advantages [7], which make the use of these systems advisable, such as:

- reduced water reservoirs evaporation due to the protection and shading provided by the solar panels
- improvements in water quality by reducing algae growth
- reduction or elimination of shading that the surrounding plants and terrain could produce on the panels
- elimination of the significant site preparation need (ground levelling, foundations, etc.) compared to land-based installation
- easiness of installation and deployment at sites with low anchoring and mooring requirements as well as a high degree of modularity, leading to faster installations.

The capital costs of floating systems are like those of onshore installations, although they are expected to decrease due to greater scale economies. In 2018 they ranged from €0.7 to €1 per Wp installed, depending on project location, reservoir basin depth and system size [6].

2.2 International Benchmarks for the Implementation of These Technologies

The first FPV system was built in 2007 in Aichi (Japan), followed by several other countries including France, Italy, Korea, Spain and the United States. All of these were for research and demonstration purposes. The first commercial installation took place in 2008 in California (USA) with 175 kW capacity, when the FPV market grew worldwide. By 2020 more than 60 countries implemented these power plants, of which 35 were in operation generating around 2.6 GW of global capacity. The fast increase in the number of these installations reinforces their attractiveness.

The World Bank estimates that by using only 5% of the available surface area of water reservoirs in Latin America, it would be possible to install more than 180 GW of floating solar power, equivalent to the total installed generation capacity of hydroelectric power plants.

The Inter-American Development Bank (IDB) is currently supporting the FPV development in Suriname with a Technical Cooperation funded by Japan Special Funds to study the feasibility of integrating these systems into the Afobaka hydroelectric power plant (which generates 50% of the total electricity consumed in the country). Electricity supply in Suriname is critical during the dry seasons' peak periods, coinciding with the hottest and sunniest periods of the year, also the air conditioning consumption in buildings tends to be higher.

This project will help to supply electricity during these peaks and optimize the management of water resources to hold reserves at critical times. The FPV system can be connected to the same transmission line from the hydropower plant, managing both solar and hydroelectric power generation in an integrated and optimal way for the grid.

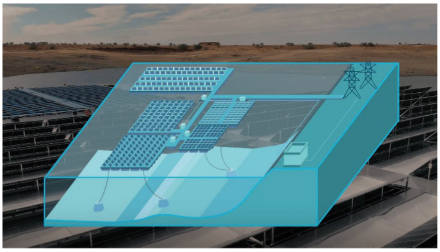
The Technical Cooperation will also analyse the value chain for the supply, installation, operation and maintenance (O&M) of the project and propose recommendations to increase local content and create new local jobs.

According to Energies Market Research (2019), FPV systems are expected to continue to grow and become established in the market, generating between 4 and 10 GW in the next five years.

If countries are truly interested in accelerating the decarbonisation agenda, all technically and economically feasible options should be considered, and VPPs have the potential in Andalusia for a solid contribution to that common goal.

2.3 National Benchmarks for the Implementation of These Technologies

In Spain, experiences with these technologies can be seen, for example, in the Sierra Brava reservoir (Caceres), which for weeks now has housed 3,000 solar panels on the water with an output of 1.1 MW of electricity. The installation expands for 12,000 m^2 within the more than 1,600 hectares of the reservoir, which represents around 0.08% of its surface area. The plant is divided into five zones in which different inclination degrees of the panels and floating systems on the water are tested. The data collected will be used for future installations.



The platform's anchoring system consists of a network of 74 ropes that anchor the platform to the bottom of the reservoir, attached to concrete blocks. The pandemic paralyzed the installation of the plant, which began at the beginning of the year, and was inaugurated at the end of July with the visit of the president of the Junta de Extremadura, Guillermo Fernández Vara. The plant also has an environmental impact on its surroundings, which is rich in bird species such as the great bustard, little bustard and common kestrel. This is why the project caught the attention of the environmental organization SEO Birdlife, who contacted Acciona to work as an independent body and will monitor it to analyse its compatibility with the birds' habitat. Acciona has undertaken to build nesting supports for the birds and the company claims that it would have a minor impact than on dry land because no excavation or earthworks are required.

In the province of Córdoba, the Aquasol complex will be built at the Urrá hydroelectric power plant. It is the first in the country with an installed capacity of 1.5 MW, which, in compliance with Sustainable Development Goal (SDG) 7, Affordable and clean energy, and SDG 12, Climate action, will occupy 1.7 ha of the reservoir. It will be installed using 5,600 solar panels supported by a floating structure.

In the Canary Islands, although it is not a valid example for our approach as it is located in the sea, the construction of a floating photovoltaic plant has been approved by the Norwegian company Fred Olsen Renewables as part of the European Boost project, with a budget of four million euros [10].

3 Pumping Network

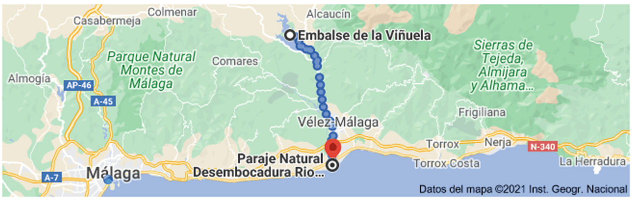
3.1 Introduction

In accordance with the approach taken in the project to discharge the desalinated water into the Viñuela reservoir basin, we must have a network of pumping stations that allow the water to be driven through a pipeline that would run along the course of the Vélez River. This network will be sized according to the quantity of water to be pumped, its density according to its desalination quality and the distance it will travel.

3.2 Location and Distance of the Installation

The distance to be covered from the location of the desalination plant (mouth of the river Vélez) to the Viñuela reservoir is approximately 20 km with a maximum gradient of 285 m at the highest point.

Given the distance, the route unevenness and the losses in the pipeline, it would be advisable to locate a second impulsion block at 12 km from the desalination plant, which is also where the unevenness increases.



3.3 Technical Summary Table for a Desalination Plant of 10 Hm^3/Year

As the project has been designed in a modular way, we have evaluated the technical characteristics of the pumping for a production of 10 Hm^3/year [3].

Flow rate

Sewater flow rate m^3/day	Daily rejection (brine) flow rate m^3/day	Waterflow produced m^3/day	Theoretical capacity produced per year	Actual production capacity per year
63,000 m^3/day	34,000 m^3/day	28,000 m^3/day	10 Hm^3	8 Hm^3

Energy Data

Energy power (Kw)	Working voltage	Specific energy consumption
10 MW	6.6 kV	2.8 KWh/m^3

Further information

Number of reverse osmosis racks installed, for production of 7000 m^3/day (*)	Consumption population benefited	Total built-up area, desalination plant
4 Lines	200.000	3.000 m^2

(*) reverse osmosis for seawater.

The new generation of desalination plants developed by Tesacua's engineers feature advanced technological innovations that allow the desalination of seawater by reverse osmosis, with low energy consumption thanks to the energy recovery systems they incorporate, with an energy efficiency of up to 97%.

3.4 Pumping Stages

Three stages are planned for the water pumping:

- Intake pumps, which will be responsible for supplying seawater to the desalination plant.
- High pressure impulsion pumps, which will oversee carrying the water from the desalination plant outlet to the re-impulsion point.
- Booster pump located about 12 km from the previous one and would push the water to the reservoir, (this stage would be like stage 2).

3.5 Technical Characteristics of the Different Stages

Intake Pumps. They will be responsible for carrying the water from the marine deposit to the desalination plant. It will be necessary to take the water by means of several boreholes of a certain diameter and depth, according to the characteristics of the project and the underwater terrain topography.

The seawater will be collected in an underwater pipeline, by means of suction from the collection pumps and boosting it to the desalination plant. In a first estimate, the water captured should be in the order of 63,000 m^3/day for the estimated 10 Hm^3.

A First Proposal Could Be to Use Blocks of 5 Pumps, so that One of them remains in reserve in the event of a breakdown or reduction in production. The power would be around 250 KW Each, with a Total Pumping Capacity of 0.9 m^3/s. The Pumps Adopted Are Horizontal Centrifugal Pumps, with Mechanical Seal and Independent Priming System for Each One. Adequate Protection Will Be Provided to Prevent Water Hammer.

High Pressure Booster Pumps. They will be responsible for carrying the desalinated water to the reservoir basin. Given the characteristics of the installation, we propose those of the manufacturer IDEAL, model APM-100 (see attached catalogue). For high pressure boosting, groups of turbo-pumps have been planned, with a total flow of 2625 m^3/h and 71.2 kg/cm^2.

The most important features of the APM-100 model are:

- Pumps that are intended for large industrial applications such as desalination plants.
- These are **high pressure multistage centrifugal** pumps for transferring clean or slightly contaminated fluids that do not contain abrasive substances.
- They comply with ISO 9906 Gr II and allow for optimum performance and good NPSH (Net Positive Suction Head) values, also known as Net Positive Suction Head (ANPA).
- Standard rotation direction from the coupling in clockwise direction, but other arrangements are possible depending on customer requirements.
- Working temperature range 90–110 °C (gasket or mechanical sealed construction respectively). For higher temperatures, external cooling or special mechanical seals are used.

1. High pressure booster pumps, they should have the same characteristics as those in Sect. 2, as the flow rate is the same (28.000 m^3 /day).

3.6 Pipeline

According to the technical data of the expected flow, the pipe estimated diameter should be about 500 mm. The recommended material for the piping would be polypropylene, “AWADUKT PP SN10” from Rehau, specially designed for piping systems requiring high resistance.

4 Desalination Plant to Supply Water to the la Viñuela Reservoir

4.1 Introduction

According to the Spanish Association of Desalination and Reuse, **Spain is one of the countries in the world that produces the most desalinated water**. It is currently **the fourth** largest country in terms of installed capacity, i.e. the production capacity of all the desalination plants built in our country, behind only **Saudi Arabia, the United States and the United Arab Emirates** [1]. According to the most up-to-date data available to AEDyR, **around 5,000,000 m^3/day of desalinated water is currently produced in Spain for supply, irrigation and industrial use.**

To get an idea of this figure magnitude, we can say that if all this water were used for human consumption, estimating an average consumption per person per day of 150 L, which is higher than the estimated average (according to the latest data from the National Institute of Statistics in Spain, we consume 132 L per inhabitant per day), it could supply around 34 million people.

Although the main use of desalinated water is for water supply, industrial and agricultural uses are not negligible. In fact, the use of desalinated water for agricultural irrigation is quite remarkable compared to other countries and has spread much more and earlier than in other parts of the world.

A curious fact is that, while large capacity desalination is the best known and often receives the most political and media attention, **small and medium capacity desalination is of great importance in our country since**, if we consider the number of desalination plants of these sizes, the percentage is considerably higher.

How many desalination plants are there in Spain?

There are currently a total of 765 desalination plants installed in Spain with a production of more than 100 m^3/day. Of these, 360 are seawater desalination plants and 405 are brackish water desalination plants.

- In terms of production, 99 are high-capacity plants. Large capacity plants are those with a production of between 10,000 and 250,000 m^3/day. Of these, 68 are seawater plants and 31 are brackish water plants.
- Medium capacity plants, i.e. those with a production capacity of between 500 and 10,000 m^3/day, total 450 (207 seawater and 243 brackish water).
- Finally, small capacity plants, i.e. those with an output of between 100 and 500 m^3/day, total 216, of which 85 are seawater plants and 131 are brackish water plants.

4.2 Existing Problem

The tropical fruit sector in the province of Malaga, and especially in the Axarquía area, has been threatened for years by the lack of water. For example, on 8 October 2021, the regional delegate for Agriculture, Livestock and Fisheries in Malaga, specified that the contribution for agricultural irrigation in the Axarquía region would be reduced by a third, as proposed by the Malaga water resources committee, dependent on the Junta de Andalucia, in view of the extreme drought situation in which the La Viñuela reservoir finds itself. Thus, the irrigation communities' farmers of the Guaro Plan will have from 3,000 to 2,000 m^3 of water per hectare. These irrigation communities have almost 6,300 ha of crops and will have 12.6 hm^3 of water from the reservoir, compared to 18.7 hm^3 in the last hydrological year.

4.3 Followed Objectives

The objective of this proposal is the construction of a scalable seawater desalination system, which can improve water problems that the tropical sector of the Guaro river irrigation community has been experiencing. To this end, a scalable desalination plant will be built in modules of 10 by 10 hm^3.

The construction of this desalination plant will not only ensure the currently cultivated area supply, but with subsequent extensions it will also be able to serve the possible increase in irrigated areas.

On the other hand, we must not lose sight of the service that this reservoir provides for the water supply to the city of Malaga, with which it is interconnected by pipeline.

4.4 Desalination Systems

There are currently a multitude of methods for the separation of water and salt. The following table shows the different technologies and the energy used. Although more than ten types can be seen in the table, not all of them are used to desalinate large quantities of water. The different desalination methods are divided into two groups:

Thermal desalination or phase change, energy input or extraction is needed in order to obtain the phase change.

- Multiple effect distillation (MED)
- Flash Evaporation (MSF)
- Freeze desalination (CO)
- Vapour compression (CV)

Membrane technology.

- Desalination by reverse osmosis (RO)
- Electro dialysis (ED).

Process	Energy	Method	Symbology
Evaporation	Thermal	Flash evaporation	MSF
		Multi-effect distillation	MED
		Thermal vapour compression	TVC
		Solar distillation	DS
Crystallization	Thermal	Freezing	CO
		Carbohydrate formation	FH

(*continued*)

(*continued*)

Process	Energy	Method	Symbology
Filtration and evaporation	Thermal	Membrane distillation	DC
Evaporation	Mechanics	Mechanical Vapour Compression	CV
Filtration	Mechanics	Reverse Osmosis	OI
Selective Filtration	Electric	Electro dialysis	ED
Chemistry	Electric	Exchange	ITI

4.5 Some Interesting Facts

a. Investment and operating costs of different reverse osmosis sea water desalination plants (Source: extended table adapted from Cosin, 2019)

Planta	País	Año construcción	Capacidad (m^3/día)	Inversión (millones €)	Ratio (€-m^3/día instalado)	Tarifa producción (€/m^3)	Tipo de contrato
Larnaca	Chipre	2001	52.000	47	904	0,64	EPC
Ashkelon	Israel	2005	396.000	182	460	0,45	BOT
Singspring	Singapur	2005	136.380	100	733	0,42	BOO
Honaine	Argelia	2005	200.000	194	970	0,65	BOT
Perth	Australia	2006	143.000	333	2329	1,01	BOD
Aguilas	España	2008	210.000	290	1381	0,50	EPC+O&M
Skikda	Argelia	2009	100,00	95	950	0,64	DBO
Beni Saf	Argelia	2010	200.000	132	660	0,60	DBO
Chennai	India	2010	100.000	78	780	0,89	BOT
Limassol	Chipre	2012	40.000	47	1175	0,75	BOT
SSDP (Perth II)	Australia	2012	306.000	517	1690	0,35	Alliance
Quingdao	China	2013	100.000	116	1160	0,61	EPC+O&M
Tuaspring	Singapur	2013	318.500	546	1714	0,31	BOOT
Ashdod	Israel	2014	384.000	320	833	0,46	EPC
Torrevieja	España	2014	240.000	341	1420		EPC+O&M
Tenes	Argelia	2015	200.000	199	995	0,51	DBO
Tuas III	Singapur	2018	136.000	187	1375	0,46	DBOO
Shuqaiq 3	Arabia Saudí	2021	450.000	516	1147	0,45	BOT
Rabigh	Arabia Saudí	2022	600.000	559	932	0,47	DBO
Taweelah	EAU	2022	900.000	473-1.032	526-1147	0,42	BOT

It is very difficult to generalize about the investment costs of desalination as each plant can be very different from the others (due to different collection systems, pre-treatment, civil works type, tanks, sea distance, pumping, etc.) and the costs are very variable depending on the country [2]. From this table, we can draw some interesting conclusions:

- Long-term concession-type contract formats (BOT, BOD, BOO, DBO, DBOO), normally for 20–25 years, are in an international level, the majority for large desalination plants, although these public-private participation formulas have been rarely used in Spain in the water sector, where EPCs (design and construction with or without subsequent operation) have predominated.
- The construction ratios range from 460 to 2,329 euros per m^3/day installed, with an average value of 1,121.
- In these facilities, there are obviously scale economies, although investment costs are more dependent on the country than on the plant size or its year of construction. In countries with high labour costs, investments are much higher in relative terms (as is clearly the case in Australia) than in countries such as the Middle East, North Africa or China.
- In the last 5 years, there has been strong competition in the sector (mainly from Asian or Middle Eastern companies), with desalinated water prices in concession formats below 0.5 €/m^3, including the amortization of the installation.

b. According to the Directorate General for Infrastructures and Exploitation, in its economic study, the rate for the use of water from the Viñuela reservoir for 2011 was 29.85 euros/1000 m^3, i.e. 0.3 €/m^3.
c. While the use of desalinated water for agriculture is a practically irrelevant activity worldwide, representing no more than 2% of total uses (IDA, 2015), Spain is an uncommonness in this regard, being the country with the highest use for this application, with values above 21% (Zarzo et al. 2013).

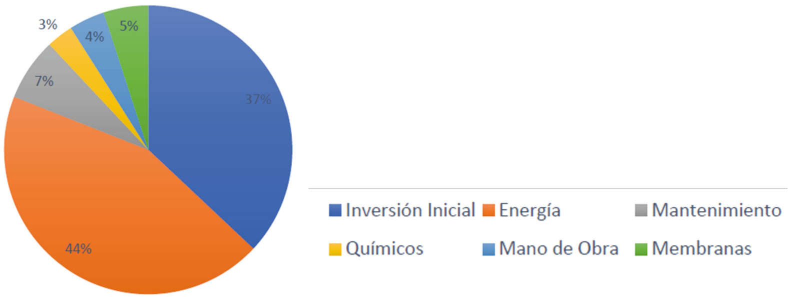
   In Spain, the structural water deficit has led the Irrigation Communities and agricultural companies in the Spanish Levante region to rely on desalination as part of their water resources, integrating surface water from water transfers, groundwater, reused water and desalinated water (brackish and seawater), thus obtaining a reasonable price thanks to the mixture of all these inputs. In addition, the high returns on investment in greenhouse crops, which are high-tech with "out of season" products, make the cost of desalinated water affordable within the production costs for this sector of high-quality products.
d. According to Carlos Cosín (IAGUA) "La evolución de las tarifas en desalación (Parte I)" the average price of the investment needed in Spain for reverse osmosis desalination plants ranges from 0.2 to 0.36 USD per m^3.

   https://www.iagua.es/blogs/carlos-cosin/evolucion-tarifas-desalacion-parte-i
e. The following is a comparison of energy consumption in various reverse osmosis desalination plants in Spain:

	Planta A	Planta B	Planta C	Planta D
PARÁMETROS OPERACIÓN				
Presión de trabajo (Atm)	70,0	67,6	70,0	70,0
Índice de Conversión	45%	45%	45%	45%
RENDIMIENTOS				
Motor eléctrico	95,0%	94,0%	94,0%	94,0%
Bombas alta presión	83,0%	84,0%	83,0%	84,0%
Turbina recuperación	88,0%	90,0%	88,0%	90,0%
Rendimiento global calculado	64,3%	65,1%	63,6%	65,5%
CONSUMOS (kWh/m³)				
Consumo físico ideal	1,97	1,90	1,97	1,97
Consumo industrial óptimo	2,74	2,65	2,74	2,74
Consumo industrial calculado	3,06	2,92	3,10	3,01
Consumo real registrado	3,45	3,26	3,53	3,27
Rendimiento global registrado	57,1%	58,3%	55,8%	60,2%
% Incr. Cons. Registrado/Calculado	13%	11%	14%	9%

Energy consumption in reverse osmosis seawater desalination: current situation and prospects (Antonio Estevan and Manuel García Sánchez-Colomer).

a. Economic analysis. Desalination by reverse osmosis (RO)



Percentage of Reverse Osmosis (RO) desalination costs

4.6 Water Flow in the Plant

1st Seawater harvesting.

The most important aspect to clarify, in the case of new desalination plants, is their location and, linked to this, their collection and discharge system, both highly conditioned, not only by their technical and economic aspects, but also, and especially in the Mediterranean, by their possible environmental effects.

The water volume to be produced is the first and most important determining factor in the abstraction, and entails abandoning the idea of abstraction by means of wells or drains. Following an extensive investigation of the aquifers in the area in its double aspect of guaranteeing the necessary flow and the absence of risks derived from abstraction in the aquifer in terms of zero risk of marine intrusion or lowering of piezometric levels in the existing wells in the surrounding area.

Currently, the main seawater harvesting systems for desalination can be classified as follows:

- Open intakes.
- Vertical wells/boreholes
- Horizontal drains.
- Mixed intakes.

In relation to the qualitative aspect, the open intake generates more uncertainties, as it is more vulnerable to all kinds of polluting discharges, has more variability in quality, and is subject to temperature variations. On the other hand, water from wells and drains, is generally, of better quality and more homogeneous.

However, from the point of view of flow guarantee, the advantages are for the open intake, as experience shows the difficulty of guaranteeing the production flow in water from wells and drains. So that, for medium/high production plants, the open intake of seawater is recommended under normal conditions, although it has the disadvantage of greater complexity of execution and in many cases greater investment in the pre-treatment stage.

2nd Physic-chemical pre-treatment.

To guarantee optimum conditions for the water feed to the reverse osmosis system racks, a physicochemical pre-treatment is usually designed, by adding sodium hypochlorite as a disinfectant and to avoid the precipitation of salts on the membranes. In this way, the pH is corrected by injecting sulphuric acid into the feed water, thus also favouring the disinfectant action of the hypochlorite.

To remove suspended solids and present colloids in the seawater, ferric chloride is added, which results in the formation of flocs that are subsequently removed in the sand filters. After this, to reduce the residual chlorine before the water reaches the membranes, sodium metabisulphite is added in-line. Finally, antiscalant is added to prevent the precipitation of salts on the surface of the membranes.

In physical pre-treatment plants, flocs and other particles in the raw water are removed by passing it through sand filters with silica sand layers of different grain sizes.

3rd Reverse osmosis desalination and energy recovery.

The desalination system consists of lines fed by high-pressure and split-chamber pumps, a reverse osmosis membrane mixer and an energy recovery system.

Energy recovery is usually carried out by one of these systems:

- Inverted pumps
- Pelton Turbines
- Turbo chargers (centrifugal hydraulic converters)
- Isobaric chamber systems.
- Two-way isobaric chambers.
- One-way isobaric chamber.
- Revolver cameras

With the energy recovery system using pressure exchangers, the high-pressure pump pressurises 40% to 45% of the seawater. The rest of the water flow is pressurised through the pressure exchangers, where the high-pressure brine flow is transferred from the low-pressure seawater. At this point, booster pumps fitted with frequency converters increase the seawater pressure at the outlet of the pressure exchangers to match the inlet pressure to the reverse osmosis system. The flow rate of these pumps is coupled with the flow rate of the high-pressure pumps before the water reaches the inlet of the RO system mixers. In this way, lower power high-pressure pumps can be used and considerable energy savings can be achieved. This pressure transfer process occurs by momentary contact of both flows in the rotor tubes of the pressure exchanger, which is located inside two ceramic shells with very precise tolerances, creating an almost frictionless hydraulic sliding bearing when filled with high-pressure water.

4^{th} Post-treatment by remineralisation.

As the last step of the water treatment line, the Langelier index of the RO permeate water is corrected to achieve a final quality suitable for use as drinking water. For this purpose, a post-treatment is carried out, which consists of a remineralisation using carbon dioxide and calcite and adding sodium hypochlorite. The first two agents increase alkalinity and hardness, while sodium hypochlorite is needed to disinfect the water.

5^{th} Brine removal.

Because of the desalination process, a hypersaline reject water or brine is discharged into the sea. The salinity of this discharge is variable, depending on the origin of the catchment and the treatment process. The dumping methods development, brine management tools, studies on the behaviour of the saline plume, etc., has sought to mitigate these effects on marine ecosystems, in addition to the obtaining of by-products that reduce the environmental impact of dumping and help to reduce the time required to recover the investment through the sale of these products. I.e. Useful Waste System.

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10. Comisión Europea: Plan de recuperación para Europa: NextGenerationEU (2020)

Journal of Computational Science- Impact Score, Overall Ranking, h-index, SJR, Rating, Publisher, ISSN, and Other Important Metrics

Last Updated on May 27, 2022

Important Metrics

Title	Journal of Computational Science
Abbreviation	J. Comput. Sci.
Publication Type	Journal
Subject Area, Categories, Scope	Computer Science (miscellaneous) (Q1); Modeling and Simulation (Q1); Theoretical Computer Science (Q2)
h-index	52
Overall Rank/Ranking	4170
SCImago Journal Rank (SJR)	0.991
Impact Score	3.95
Publisher	Elsevier
Country	Netherlands
ISSN	18777503

About Journal of Computational Science

Journal of Computational Science is a **journal** covering the technologies/fields/categories related to **Computer Science (miscellaneous) (Q1); Modeling and Simulation (Q1); Theoretical Computer Science (Q2)**. It is published by **Elsevier**. The overall rank of Journal of Computational Science is **4170**. According to **SCImago Journal Rank (SJR)**, this journal is ranked **0.991**. SCImago Journal Rank is an indicator, which measures the scientific influence of journals. It considers the number of citations received by a journal and the importance of the journals from where these citations come. SJR acts as an alternative to the Journal Impact Factor (or an average number of citations received in last 2 years). This journal has an **h-index** of **52**. The **best quartile** for this **journal** is **Q1**.

The ISSN of **Journal of Computational Science** journal is **18777503**. An International Standard Serial Number (ISSN) is a unique code of 8 digits. It is used for the recognition of journals, newspapers, periodicals, and magazines in all kind of forms, be it print-media or electronic. **Journal of Computational Science** is cited by a total of **2079** articles during the last 3 years (Preceding 2021).

Journal of Computational Science Impact Score 2021-2022

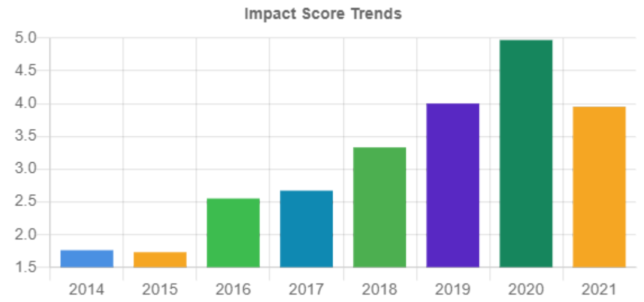
The **impact score** (IS) 2021 of **Journal of Computational Science** is **3.95**, which is computed in 2022 as per its definition. **Journal of Computational Science** IS is **decreased** by a factor of **1.02** and approximate percentage change is **-20.52%** when compared to preceding year 2020, which shows a **falling** trend. The impact score (IS), also denoted as Journal impact score (JIS), of an academic journal is a measure of the yearly average number of citations to recent articles published in that journal. It is based on Scopus data.

Journal of Computational Science Impact Score 2022 Prediction

IS 2021 of **Journal of Computational Science** is **3.95**. If the same downward trend persists, impact score may **fall** in 2022 as well.

Impact Score Trend

Year wise Impact Score (IS) of Journal of Computational Science. Based on Scopus data.



Year	Impact Score (IS)
2022/2023	Coming Soon
2021	3.95
2020	4.97
2019	4.00
2018	3.33

Journal of Computational Science h-index

Journal of Computational Science has an h-index of **52**. It means **52** articles of this **journal** have more than **52** number of citations. The h-index is a way of measuring the productivity and citation impact of the publications. The h-index is defined as the maximum value of h such that the given journal/author has published h papers that have each been cited at least h number of times.

2021	3.95
2020	4.97
2019	4.00
2018	3.33
2017	2.67
2016	2.55
2015	1.73
2014	1.76

Top Journals/Conferences in Computer Science (miscellaneous)

 # IEEE Transactions on Smart Grid
Institute of Electrical and Electronics Engineers Inc. | United States

 # npj Quantum Information
Nature Partner Journals | United Kingdom

 # IEEE Geoscience and Remote Sensing Magazine
IEEE Geosciene and Remote Sensing Society | United States

 # Computers and Education
Elsevier Ltd. | United Kingdom

 # Proceedings - Annual IEEE Symposium on Foundations of Computer Science, FOCS
| United States

 # Proceedings of the IEEE
Institute of Electrical and Electronics Engineers Inc. | United States

 # European Journal of Operational Research
Elsevier | Netherlands

 # ACM Computing Surveys
Association for Computing Machinery (ACM) | United States

 # Proceedings - Annual IEEE Symposium on Foundations of Computer Science, FOCS
| United States

 # Computer Science Review
Elsevier Ireland Ltd | Ireland

See All

Top Journals/Conferences in Modeling and Simulation

 # Structural Equation Modeling
Psychology Press Ltd | United Kingdom

 # npj Computational Materials
Nature Publishing Group | United Kingdom

 # Geoscientific Model Development
Copernicus Gesellschaft mbH | Germany

 # NPG Asia Materials

Impact Score, h-Index, and Other Important Details of These Journals, Conferences, and Books

Journal/Conference/Workshop/Book Title	Type	Ranking	Publisher	h-index	Impact Score
Biotechnology, Agronomy and Society and Environment	journal	15942	Les Presses Agronomiques de Gembloux	39	0.98
Food Science and Technology (United States)	journal	19570	Horizon Research Publishing	3	0.60
Journal of Conservative Dentistry	journal	12803	Wolters Kluwer Medknow Publications	35	1.49
Teanga	journal	20547	The Irish Association for Applied Linguistics	2	0.23
Archives of Acoustics	journal	14419	Polish Academy of Sciences, Committee on Acoustics	26	1.24
Respiratory Care	journal	7243	Daedalus Enterprises Inc.	94	1.79
Journal of Noncommutative Geometry	journal	6162	European Mathematical Society Publishing House	22	0.67
International Review of Financial Analysis	journal	1446	Elsevier Inc.	69	8.00
Journal for the History of Astronomy	journal	23385	SAGE Publications Inc.	17	0.13
Extrapolation	journal	22645	Liverpool University Press	5	0.22

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Journal of Computational Science ISSN

The ISSN of **Journal of Computational Science** is **18777503**. ISSN stands for International Standard Serial Number.

An ISSN is a unique code of 8 digits. It is used for the recognition of journals, newspapers, periodicals, and magazines in all kind of forms, be it print-media or electronic.

Journal of Computational Science Rank and SCImago Journal Rank (SJR)

The overall rank of **Journal of Computational Science** is **4170**. According to SCImago Journal Rank (SJR), this journal is ranked **0.991**. SCImago Journal Rank is an indicator, which measures the scientific influence of journals. It considers the number of citations received by a journal and the importance of the journals from where these citations come.

Journal of Computational Science Publisher

Journal of Computational Science is published by **Elsevier**. It's publishing house is located in **Netherlands**. Coverage history of this **journal** is as following: **2010-2021**. The organization or individual who handles the printing and distribution of printed or digital publications is known as Publisher.

Call For Papers

Visit the official website of the journal/conference to check the further details about the call for papers.

Abbreviation

The IS0 4 standard abbreviation of **Journal of Computational Science** is **J. Comput. Sci.**. This abbreviation ('J. Comput. Sci.') is well recommended and approved for the purpose of indexing, abstraction, referencing and citing goals. It meets all the essential criteria of ISO 4 standard.

ISO 4 (International Organization for Standardization 4) is an international standard that defines a uniform and consistent system for abbreviating serial publication titles and journals.

How to publish in Journal of Computational Science

If your research field is/are related to **Computer Science (miscellaneous) (Q1); Modeling and Simulation (Q1); Theoretical Computer Science (Q2)**, then please visit the official website of this **journal**.

Acceptance Rate

The acceptance rate/percentage of any academic journal/conference depends upon many parameters. Some of the critical parameters are listed below.

- The demand or interest of researchers/scientists in publishing in a specific Journal/Conference.
- Peer review complexity and timeline.
- The mix of unsolicited and invited submissions.
- The time it takes from manuscript submission to final publication.
- And Many More.

It is essential to understand that the acceptance rate/rejection rate of papers varies among journals. Some Journals considers all the manuscripts submissions as a basis of acceptance rate computation. On the other hand, few consider the only manuscripts sent for peer review or few even not bother about the accurate maintenance of total submissions. Hence, it can provide a rough estimation only.

The best way to find out the acceptance rate is to reach out to the associated editor or to check the **official website** of the Journal/Conference.

Credits and Sources

- Scimago Journal & Country Rank (SJR), https://www.scimagojr.com/
- Journal Impact Factor, https://clarivate.com/

Nature Publishing Group | United States

mSystems
American Society for Microbiology | United States

PLoS Computational Biology
Public Library of Science | United States

Mathematical Models and Methods in Applied Sciences
World Scientific Publishing Co. Pte Ltd | Singapore

European Journal of Operational Research
Elsevier | Netherlands

Energy
Elsevier Ltd. | United Kingdom

Journal of Computational Physics
Academic Press Inc. | United States

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Top Journals/Conferences in Theoretical Computer Science

SIAM Review
Society for Industrial and Applied Mathematics Publications | United States

IEEE Transactions on Evolutionary Computation
Institute of Electrical and Electronics Engineers Inc. | United States

ACM Computing Surveys
Association for Computing Machinery (ACM) | United States

SIAM Journal on Optimization
Society for Industrial and Applied Mathematics Publications | United States

Statistics and Computing
Springer Netherlands | Netherlands

IEEE Computational Intelligence Magazine
Institute of Electrical and Electronics Engineers Inc. | United States

Mathematical Programming Computation
Springer Verlag | Germany

Foundations and Trends in Theoretical Computer Science
Now Publishers Inc | United States

Journal of Combinatorial Theory. Series B
Academic Press Inc. | United States

Computer Science Review
Elsevier Ireland Ltd | Ireland

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