Resources optimization using Pareto analysis for sea water desalination plants

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ABSTRACT

This study examines the potential of implementing a systematic approach to piloting desalination plants, with the objective of evaluating energy improvements in water desalination processes. The introduction of new reverse osmosis membranes is imperative at the small-scale level. The findings can be extrapolated to inform the operation of large-scale desalination plants. The objective of this approach is to achieve the optimal water quality standard at the lowest possible cost. In this manner, pilot tests are being conducted prior to the determination of whether to alter the reverse osmosis membranes, as this represents a substantial investment. The objective of these tests is to minimise the risk of making an erroneous decision and to ensure optimal results in terms of energy consumption, operating costs and reduction of environmental impact, while complying with the requisite water quality standards. In this instance, the Pareto analysis is utilised to ascertain the two or three most significant causes whose treatment affects more than 80 % of the potential energy savings to be implemented. This article introduces a novel approach to studying a total of 180 desalination plants at the territorial level in the Canaries.

1. Introduction

This study can be used for decision-making in processes related to improving energy efficiency in seawater reverse osmosis plants. Improvements in seawater desalination are studied, based on the reduction of energy consumption in the production of fresh water.

The global scarcity of freshwater resources has significantly influenced the development of desalination technologies, with reverse osmosis emerging as one of the most prevalent and highly regarded methods.

The objective is to introduce improvements to the energy efficiency of reverse osmosis (RO) processes for seawater desalination plants, with the intention of establishing a globally applicable procedure.

The desalination of seawater in water treatment plants has evolved a lot in the last five decades, in which the desalination process and its technology has changed and has become more and more cost-effective and efficient. Initially, the desalination process was a thermal process that has been changing with scientific and technological advances (Liao and Li, 2024; Gabriel Anghel and Ilinca, 2023; Wang, 2022; Dariane,

2021; Kong, 2021; Shi, 2022). It is interesting to consider the design and implementation of pilots in desalination plants, in a systematic way, to evaluate energy improvements in water desalination processes. In this sense, it is proposed to carry out tailor-made pilots according to the situation to make the right decision and execute the investment with the minimum risk. Therefore, in these pilots, an assessment of boron, water quality, a diagnostic analysis of energy, carbon footprint, ecological footprint, environmental sustainability and operation and maintenance costs are carried out (Ruiz et al., 2017; Leon et al., 2021; Kurihara, 2021; Caudle et al., 1966).

Membrane ageing is a decisive factor regarding the energy consumed in the plant, the permeate flow rate and the emissions produced. Therefore, a study methodology is established to make decisions about it. The decision to change membranes is very important for the lifetime of the plant and many variables must be considered, such as working pressure, feed and permeate water quality of the reverse osmosis system, conversion, temperature, etc. With the introduction of state-of-the-art membranes with low energy consumption and high salt rejection, we can produce water of the required quality under more efficient and

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sustainable conditions than with commercial reverse osmosis membranes for sea water desalination (Almadani, 2003; López et al., 2004; Porada et al., 2013; Lee et al., 2006; Li et al., 2008). The primary objective of the improvements studied in seawater desalination is based on the reduction of energy consumption in the production of fresh water. Consequently, reverse osmosis is the most suitable process due to its lower energy consumption per cubic meter of product water, which is why it occupies a privileged position in the sector (Biesheuvel and van der Wal, 2009; Kim and Choi, 2010; Biesheuvel et al., 2011; Bouhadana et al., 2011).

Moreover, it is studied the operation, maintenance, and handling of membranes in detail, due to their importance in energy saving, showing how to optimize all the processes where they are involved with the aim of continuously improving their efficiency (Demirer et al., 2013; Dlugolecki and van der Wal, 2013; Suss et al., 2012; Bouhadana et al., 2011; Jeon et al., 2013; Blair and Murphy, 1960).

The energy efficiency of desalination plants is directly correlated with the quality of the permeate water that is required. In Spain, Royal Decree 140/2003 identifies boron as a significant challenge in the production of drinking water, stipulating a maximum concentration of 1 ppm. This necessitates either a second purification step, which would require the doubling of the number of membranes in the plant, or the use of a more expensive, high-rejection membrane in a single step, but with boron rejection lower than 1 ppm, which would consume more energy. The implementation of a novel reverse osmosis refining process, which is characterised by high costs, or the deployment of high rejection membranes in a single step but with elevated pressures, thus necessitating greater energy consumption, represents a significant variable cost for the installation (Arnold and Murphy, 1961; Murphy et al., 1969; Murphy and Caudle, 1967; Evans and Hamilton, 1966).

The WHO, however, is more flexible with boron requirements for drinking water and allows a maximum of 2.4 ppm. This international regulation is followed in many countries in the world where water desalination is very important and among others we can mention Chile where the plant designs consume less energy because they work at lower pressures since the boron does not have to be less than 1 ppm but less than 2.4 ppm; or in other areas of the planet such as North Africa, the Middle East, etc., where they are also adapting to this regulation. The main objective of this study can be considered for the decision making of actions associated with Energy Efficiency. This article introduces a novel approach to studying a total of 180 desalination plants, at the territorial level in the Canary Islands, specified in annex 1 (Evans et al., 1969; Reid et al; Washington, 1997; Zubieta and Bonert, 2000; Lasia et al; York, 1999).

The present study is concerned with seawater reverse osmosis desalination plants in the Canary Islands. This manuscript aims to optimize the operation of these plants with a view to reducing their environmental impact, namely their energy consumption, water quality, costs, and emissions. The objective is to make this process more efficient and sustainable. It is essential to assess the energy efficiency of desalination plants in terms of the emissions generated the carbon and ecological footprint of the system.

2. Methods

The two most important parameters for describing the separation performance in reverse osmosis processes are the permeate flow rate and the salt rejection. Both quantities are mainly influenced by the following parameters: pressure, temperature, recovery and salt concentration in the feed (Schiller, 1997; EN 62391-1, 2006; EN 62391-2-1, 2006; EN 62391-2, 2006). In annex 1 is shown the real-field data.

2.1. Pressure

The permeate flow rate increases with increasing feed pressure. However, the concentration of salts in the permeate decreases with increasing feed pressure. This corresponds to an increase in the rejection coefficient. The high-pressure pump is the highest energy consumption of the sea water reverse osmosis desalination plant. Due to this is very important to control this. A feed salinity increase affects directly increasing the feed pressure and the energy consumption of the installation. The same occurs when decreases the feed temperature or the plant is dirty due to the bad quality of the feed water and pretreatment. Therefore, all these issues have to be in account to avoid any increase in the energy consumption and due to this in the economic and environmental costs of the installation (EN 62576, 2010; Gualous et al., 2003; Brouji et al., 2008; Conway and Pell, 2001; Fabregat et al., 2003; Burke and Miller, 2009).

2.2. Temperature

Temperature is another very important factor because it directly affects the operation of the RO system. When the temperature drops there is a decrease in the permeate flow rate and conversely when the temperature rises there is an increase in permeate production. The rejection coefficient, R, however, decreases with increasing temperature. This means that more dissolved substances pass through the membrane (Martín, 2014; Texas Instruments, 2018; Arduino, 2018; Arduino, April 2018).

2.3. Pilots

The implementation of pilot tests with the latest generation of reverse osmosis membranes in large desalination plants is becoming increasingly prevalent. This is due to the fact that preliminary experiments are being conducted on the functionality of these new generation membranes, which exhibit enhanced salt rejection and reduced energy consumption. This is done in order to achieve the optimal water quality standard at the lowest possible cost. In this way, pilot tests are being carried out before the decision is made whether or not to change the reverse osmosis membranes, as this represents a significant investment and minimizing the risk of errors in order to ensure the best results in terms of energy consumption, operating costs and reducing the environmental impact while complying with the required water quality (Spark Fun Electronics, 2018; Adafruit, 2018; Texas Instruments, 2018; Adafrui, 2018; Texas Instruments, 2018).

2.4. Use of pilots

The energy consumption is the highest operation cost of the desalination system so we would like to reduce it through the reverse osmosis process which is the most efficient. Due to this, it is mandatory the introduction of RO piloting in a seawater desalination plant for testing and to decrease the energy consumption. This is essential to optimize its resources.

Pilot plant could be equipped with a vessel and the following elements to a full monitoring and control of the operational conditions (pressure and flows of the seawater, brine and permeate flows).

- Feed seawater flow: a control valve at the HPV inlet for the water flow and pressure control, a pressure transmitter, a drop pressure transmitter.

- Permeate flow: a flow meter, a pressure transmitter (the one of the full scale rack).
- Brine flow: three valves, in order to control the brine flow and appropriately make the brine discharge from 65 bars to atmospheric pressure,a flowmeter.

The implementation of reverse osmosis (RO) piloting in a seawater desalination plant, which is characterised by a high energy consumption, could prove advantageous in optimising the utilisation of its

resources. In the absence of a pilot plant, there is a risk of failing to capitalise on the opportunity to test a membrane that optimises energy consumption and improves the quality of the water produced. The selection of the feed water intake is of significant importance, as an open intake is prone to greater contamination than a well intake. Additionally, the temperature range is higher in an open intake, which directly impacts energy consumption. The accumulation of fouling and the reduction in temperature increase the operational pressure required to maintain permeate flow. Furthermore, the use of high rejection membranes increases the operational pressure and consequently influences energy consumption. Therefore, it is essential to utilize low energy consumption membranes if the quality requirements of the client can be met.

Not having a pilot plant can have a very high opportunity cost, as it is not possible to test a membrane that optimises energy consumption and improves the quality of the water produced. This makes it possible to test its operation on a small scale and then take it to a large scale in the plant, minimising the risk of not meeting the planned objectives. If we do not have such a pilot plant, the cost of which for large seawater plants is not significant compared to the investment that would have to be made in membranes in the installation, we can make a mistake if we choose the wrong membrane for our type of water without first having tested it in situ and lose a large amount of money (Analog Devices, 2018; Texas Instruments, 2018; Zhao et al., 2012; Texas instruments, 2018; Song et al., 2015).

Therefore, having the appropriate tests and the necessary instrumentation in a plant of this type to carry out pilot tests has a direct impact on the energy efficiency of the system. In this sense, different types of tests can be carried out: membrane ageing, piloting or collection depth, among others. In the first of these tests, the membranes are operated in a pressure pipe, in parallel to the rest of the train, and under the same operating conditions as the plant. In this way, the membranes age and we can pilot them a posteriori in more real working conditions, not only in start-up conditions where it is more difficult to find problems. The second test is the actual piloting, where we vary the working conditions of the membrane as we wish to obtain results in different scenarios. Finally, a test of the catchment depth helps to characterise the feed water to the installation in terms of temperature, water quality, etc (Dimitriou et al., 2015a, 2015b).

It is therefore proposed to carry out pilot tests to experiment on a small scale with the operation of new generation membranes with high rejection, but also with low energy consumption, looking for the one that considerably reduces, depending on the type of water in each plant, energy, economic and environmental consumption while complying with the required water quality. Once the best membrane has been chosen for each plant, through the introduction of these pilot tests, the energy, economic and environmental improvement that has been chosen will be carried out on an industrial scale of the entire plant, frame by frame. These economic, energy and environmental assessments are shown in the diagram and are also included earlier in this chapter (García Latorre et al., 2015; Kherjl et al., 2015; Schallenberg-Rodriguez et al., 2014).

If these periodic pilot tests are not carried out with the membranes that are coming onto the market and partial replacements are not made of the membranes that are operating in the plant, over time, these will age and not only will water production decrease, but it will also be of poorer quality and the working pressure will increase, which means higher energy consumption and operating costs for the plant. Therefore, it will be more expensive not to carry out pilot tests than to carry them out with membranes that the manufacturers do not normally leave at zero cost for them to have real information on their operation. Continuing to work with membranes that consume more and more energy to produce the same amount of water or less with worse quality, will also have an environmental cost, represented in an increase in the carbon footprint and the planet's ecological footprint as will be calculated later in chapter 4 of the results (Dow et al., 2016; Mazlan et al.,

2016; Walton, 1989; Boerlage, 2015).

Likewise, working with ERI, DWEER, OSMOREC, etc. energy recovery systems will reduce the energy consumption of the installation compared to working with Pelton or Francis turbines and therefore it is also advisable to rely on these systems that will reduce the environmental cost of the system, the ecological and carbon footprint of the plant.

In this sense, the main factor to comply with, depending on the geographical and political location where we are, will be the drinking water regulations if it is a desalination plant for human consumption, which is the majority of cases throughout the world. If we are in Spain, it is the Royal Decree 140/2003 of 7 February that we must comply with, where the biggest bottleneck is to ensure that the boron rejection of RO elements is sufficiently loose so that the total permeate is below 1 ppm. This is the main factor to meet, water quality. For this it is studied how boron and hence water quality can vary depending on the use of different RO membranes. This will be carried out later with real data at the Alicante 1 desalination plant (Bilstad et al., 2015; Gude, 2016; Leon and Ramos, 2017).

Therefore, the demand of water quality requires us to work with membranes with high salt rejection and particularly boron to achieve this value, and when it is not possible to do a second osmosis step where we treat the permeate from the first step again with brackish water membranes partially or totally and often incurring the cost of chemical products to raise the pH. We do this so that the boron, which is mainly boric acid, becomes borate, which is a salt, so the membrane is more likely to reject it, as it is designed to reject salts.

Once we meet the water quality, if possible, in one step only, so as not to make the plant more expensive with a second osmosis step in terms of membranes, pressure pipes, pumps, piping, valves and energy consumption; secondly, we seek to keep the pressure required in our system as low as possible by using state-of-the-art membranes with low energy consumption and working at not too low temperatures.

Therefore, we relate water quality to a high salt rejection which means high energy consumption, so we introduce the latest generation membranes to reduce the energy required while maintaining the necessary quality. The pilot tests carried out at the Carboneras desalination plant are along these lines and, using different membranes from various manufacturers, we were able to choose the best one that firstly met the water quality requirements and secondly did so with reverse osmosis membranes at the lowest possible energy consumption (Mahboubeh and Vijay, 2024; Kalhori et al., 2023).

In this sense the water quality is directly linked to the energy consumption of the plant which is also a function of the water temperature. It introduces the necessary tools to identify what energy is needed in our process and calculate it (Khorsandi et al., 2022; Parisa-Sadat and Loáiciga, 2021).

Similarly, we also relate water quality and the energy consumption of the desalination plant to the economic and environmental dimension of the system, since the lower our energy consumption, the lower the monetary and environmental costs of our installation (Parisa-Sadat and Loáiciga, 2015). This methodology is applicable to all seawater desalination plants, which is why we are also going to extend the study to all these installations in the Canary Islands and to the studies carried out in Alicante 1 and Carboneras, as will be seen later. Similarly, the Pareto diagram tool is used to identify which aspects of the desalination plant are the most significant, linked in Fig. 1, and they have the greatest impact on its energy consumption. Therefore, Fig. 1 shows the most important elements to be considered in the installation.

3. Results

3.1. Pareto analysis

Pareto analysis is used to identify the 2 or 3 most significant causes which affect to more than 80 % of the costs. In this sense, Fig. 2 below
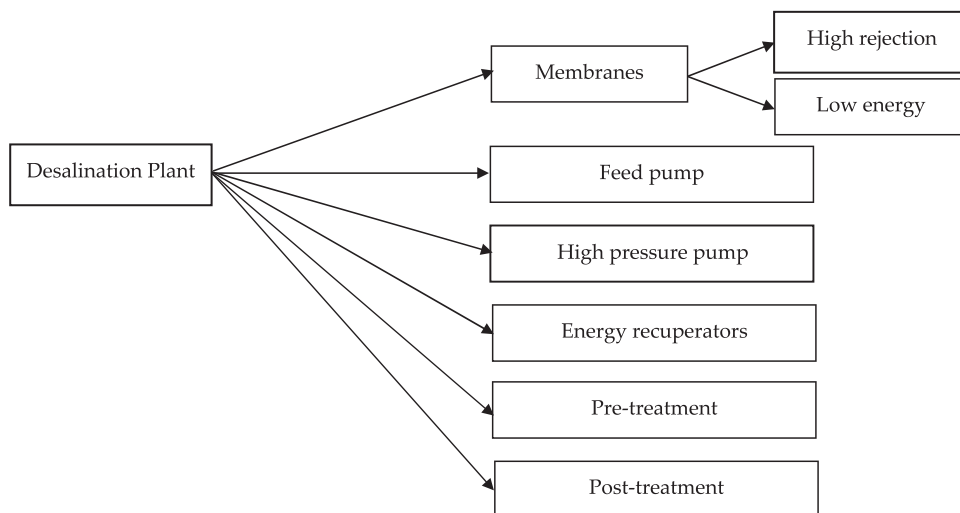
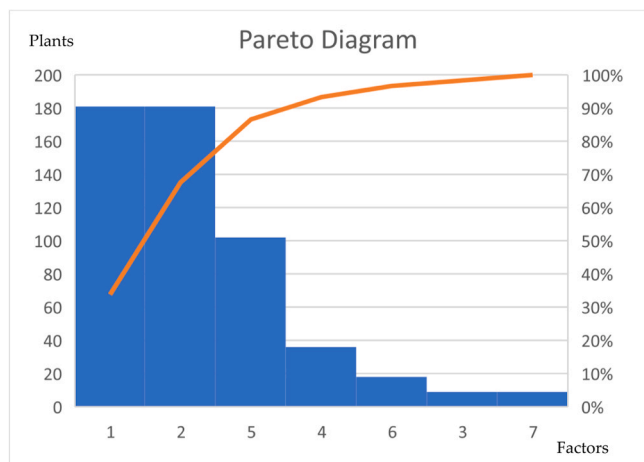**Fig. 1.** Most significant elements of the desalination plant.

Fig. 2. Desalination plant Pareto diagram.

shows the Pareto diagram for the energy improvement of 180 plants in a given territory. A series of factors that can affect this energy improvement have been numbered from 1 to 7, such as the seawater intake, the decision on the membranes, the energy recuperators, the high-pressure pump, the decisions on the pre-treatment, the feed pump or the post-treatment.

The aim is to determine which would be the most significant effects. In this example, it can be seen how the most important decisions are based on factors 1, 2 and 3, which influence 90 % of the possible energy improvement of the system. In this sense, the first two elements will be mainly studied in terms of the decision making on factors 1 and 2 for the installation, which represents between 70 % and 80 % of the influence on the proposed energy improvement. The third factor is also considered, although to a lesser extent, to reach 90 % of the effects on the energy improvement of the desalination plants in the territory to be considered.

Membrane decisions can be made on the basis of a pilot test in the plant, with the specific type of water to be treated, or directly based on the supplier's projections and guarantees. In this sense, the technical specifications of the manufacturer Toray show how, in the case of a desalination plant, an uncertainty of around 20 % in water quality can be expected, due to the safety factors of the very conservative manufacturer's specifications and even more so the system guarantees that may be requested a posteriori depending on each particular project. This

demonstrates the need for piloting in a desalination plant to eliminate this uncertainty at virtually no cost to the operator, as the membranes for these tests are normally supplied free of charge by the supplier avoiding the risk of making a mistake with the membranes, with all the costs that this entails, and are tested in a prepared pipe that is released from the plant for this test. Depending on the size of the plant, we can make a colour coded classification according to the incidence of piloting as shown in Table 1. For example, level 1, green, refers to desalination plants with a production of less than 100 tCO2/day, with a very slight impact, as the percentage of salt rejection and energy consumption is very similar per m3 of product water, as it is a small amount of permeated water, this value is low, but as the product flow of the installation increases, this product shoots up to multiply by a thousand in the case of level 5, red, with a very serious impact on the energy efficiency of the installation, economic and environmental cost (Table 1).

3.2. Territorial Pareto diagram

The Pareto diagram, already discussed before, has been studied at territorial level for the Canary Islands, where a total of 180 seawater desalination plants have been included for this study. Fig. 3 shows the corresponding Pareto diagram.

The most important decision making is based on the decision on the collection of feed water, the membranes and the energy recovery units, which influence 90 % of the possible energy improvement of the system. In this sense, the first two elements will be mainly studied in terms of decision-making on seawater collection and the type of membranes to be chosen for the installation, which represent between 70 % and 80 % of the influence on the proposed energy improvement. The third aspect, energy recovery, is not the subject of this study because it is not subject to possible pilots in the plant, but rather to the installation or not of these, whose operation has been demonstrated in seawater plants. In any case, it is advisable whenever possible to introduce energy recovery equipment of the Dweer or ERI type that makes maximum use of the pressure energy of the brine.

Decisions on membranes can be made based on a pilot test in the plant, with the specific type of water to be treated, or based directly on the projections and guarantees of the supplier. It is demonstrated the need to carry out a pilot test in a desalination plant to eliminate this uncertainty at practically no cost to the operator, as the membranes for these tests are normally supplied free of charge by the supplier, avoiding the risk of making a mistake with the membranes, with the costs of all kinds that this entails, and are tested in a prepared pipe that is released from the plant for this test.

Table 1
Incidence of not using plant pilots.

Production (m³ /day)	Advocacy	Colour
<100	Very Slight	1
100-1000	Slight	2
1000-10000	Moderate	3
10000-100000	Serious	4
>100000	Very Serious	5
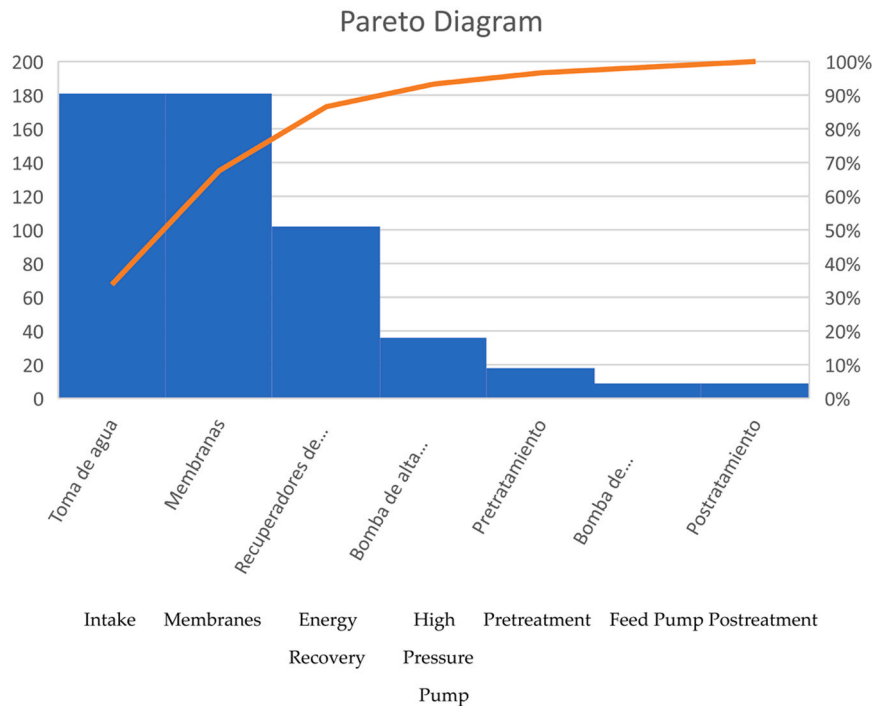
Fig. 3. Pareto diagram of the desalination plant.

Regarding the decision to take decisions on the collection of feed water, if possible, we recommend taking the water from a beach well or borehole to take advantage of the filtration of the ground and improve the quality of the feed water, which is cleaner and less polluted. If this is not possible due to the size of the plant, we would opt for an open intake and in both cases at the appropriate depth to stabilize the working temperature as much as possible. Similarly, the greater the depth, the lower the salinity of the seawater, which reduces the osmotic pressure and consequently the energy consumption of the installation.

In this sense, a deeper intake stabilizes the temperature and reduces its value in the summer- autumn periods when it is higher in the water, improving boron rejection in the most critical months. This helps us, by confirming pilots, to opt for membranes with low energy consumption as opposed to those with high rejection which consume much more. Increasing the depth of the intake also means an economic cost based on the cost of the GRP pipe of around 35 EUR/m and, if necessary, a higher-pressure pump, which in the case of Grundfos means 5.5 % more cost, although normally the same pump is enough. Even so, these costs are quickly amortized against the large energy and economic savings that can be obtained per cubic meter of water produced. This also justifies the importance of the feed water intake.

Energy consumption is calculated multiplying the desalination capacity of each island times the consumption per kWh/m3 of permeate water. This consumption (kWh/m3) is obtained studying the characteristics and different energy recovery systems installed in the desalination plants of each island (http://www.fcca.es).

In this sense, it can be confirmed that for an annual production of desalinated water in the Canary Islands of approximately 660,000 m3/day and considering an average energy consumption of 3.04 kWh/m3, introducing equipment to recover energy from brine, we have a carbon footprint of 1203.84 tCO2/day, which means that there are 439,402 tCO2 per year, as commented on in Section 3. On the other hand, following this same criterion and using a global coefficient of the ecological footprint to calculate it (Suss et al., 2012; Bouhadana et al., 2011; Jeon et al., 2013; Blair and Murphy, 1960), a value of 219701 ha/year of surface area is obtained to compensate for the ecological footprint that we have due to the production of desalinated water in the Canary Islands. This ecological footprint per person divided by the population of Canary Islands (2207,225 habitants), supposes a value of 0.1 ha/person/year and consequently the emissions per inhabitant and year are 0.2 tCO2/person/year.

The carbon and ecological footprints calculated before are only for the desalination in Canary Islands. If we extend this calculation to the total annual consumption in all the sectors of the archipelago in 2019 of 8878271 MWh and considering an average value of 0.6 tCO2/MWh obtained (Blair and Murphy, 1960), it is estimated that 5326,963

tCO2/year can be emitted. It represents 2.4 tCO2/person/year.

A general analysis of energy consumption by plant components reveals that if membrane replacement is not carried out, energy consumption increases progressively. This phenomenon can be observed in Table 2, which was constructed on the basis of the calculations and design specifications of the Toray membrane manufacturers. It is estimated that the average operating flow is 16 LMH, with a beach well intake or pre-treatment with ultrafiltration membranes, along with a recovery rate of 45 % and a feed salinity of 39 g/l, which is typical of the area.

Software Toray DS2 software was employed to run hypothetical projections under different scenarios, utilizing a calculator tool to obtain all the requisite parameters. The most unfavorable scenario in terms of energy consumption was based on the lowest feedwater temperature observed in the Canary Islands (17°C) and the TM820K-440 membrane. This element exhibited high salt rejection (99.86 %) and a permeate flow of 24.2 m3/d under the test conditions of 55.2 bar, a recovery rate of 8 % and feedwater characteristics of 32,000 ppm NaCl. The other element used in the projections, the TM820V-440, resulted in lower energy consumption, with 99.80 % of salt rejection and 37.5 m3/d of permeate flow under the same test conditions. The pore size of the flat sheet membrane in the TM820K-440 is smaller than in the TM820V-440. Consequently, the former produces permeate water of a higher quality, while the latter has a lower energy consumption.

It can be seen from Tables 2 and 3 that, in 5 years of operation, the working pressure is considerably higher at the lowest feedwater temperature (17ºC) than at the highest (27ºC) and that consequently the energy consumption is also higher. In the lower energy consumption case (with the TM820V-440 element), the calculations incorporated an energy recovery system (ERS) to further reduce energy consumption at the highest temperature of around 27ºC (Table 3).

Thus, Table 2 shows, at the lowest temperature (17ºC) and after 5 years of operation, the highest energy consumption (6.274 kWh/m^3) with the high salt rejection element (TM820K-440), and Table 3 shows, at the highest temperature (27ºC) and at start-up, the lowest energy consumption (2.200 kWh/m^3) with the low energy consumption element (TM820V-440).

4. Conclusions

The novelty of this article is to apply Pareto diagram to a study of a total of 180 seawater desalination plants at territorial level in Canary Islands. The introduction of RO piloting in a seawater desalination plant, whose energy consumption is very high, could be beneficial in optimizing its resources. Without a pilot plant, there is a risk of missing out on the opportunity to test a membrane that optimizes energy consumption and improves the quality of the water produced.

The Pareto analysis is used to highlight the 2 or 3 most significant causes whose treatment affects more than 80 % of the possible energy improvement to be implemented.

In this example, it can be seen how the most important decisions are based on factors 1, 2 and 3, which influence 90 % of the possible energy improvement of the system. In this sense, the first two elements will be mainly studied in terms of the decision making on factors 1 and 2 for the installation, which represents between 70 % and 80 % of the influence

Table 2
Pressure, power and energy consumption at 17ºC with the TM820K-440 membrane element.

Year	Pressure (bar)	Power (kW)	Energy consumption (kWh/m^3)
0	71.11	23,511.23	5.643
1	72.77	24,060.57	5.775
2	74.56	24,650.69	5.916
3	76.13	25,171.11	6.041
4	77.62	25,662.76	6.159
5	79.06	26,140.34	6.274

Table 3
Pressure, power and energy consumption values at 27ºC with the TM802V-440 membrane element.

Year	Pressure (bar)	High Pressure Pump Power (kW)	ERS Power (kW)	Booster (kW)	Energy (kWh/m^3)
0	57.69	9168.26	7908.69	479.10	2.200
1	58.07	9226.44	7962.37	480.20	2.214
2	58.45	9285.33	8016.83	481.30	2.229
3	58.77	9334.34	8062.14	482.10	2.240
4	59.06	9378.71	8103.15	482.90	2.251
5	59.34	9420.35	8141.62	483.70	2.261

on the proposed energy improvement. The third factor is also considered, although to a lesser extent, to reach 90 % of the effects on the energy improvement of the desalination plants in the territory to be considered.

The cost and energy required in the process depend on the quality of water required and the type of membrane used. It is confirmed the importance of operational efficiency and cost reduction, due to the highest cost of the installation is the electrical consume of the high-pressure pump. To reduce the feed pressure influences directly in the highest economical cost of the sea water reverse osmosis desalination plant. Feed water collection is important due to an open intake could increase the dirty on the surface of the reverse osmosis membranes and it increases the energy consumption. Moreover, to use high rejection membranes increase the operation pressure and it influences directly in the energy consumption and in the economic cost of the installation. Therefore, it is mandatory to use low energy consumption membranes to get a cost reduction in the operation of the plant.

The study of standard RO elements for a seawater desalination plant helps to choose a reverse osmosis element that lowers the energy consumption, and therefore the operating costs of the plant as energy is the most expensive part of the plant.

Within the total cost of water production, the most important influences are the energy consumed and the type of RO element chosen.

Author statement

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Federico Antonio Leon Zerpa: Writing – original draft, Validation, Software, Project administration, Investigation, Formal analysis, Conceptualization. **Alejandro Ramos Martin:** Writing – review & editing, Visualization, Supervision, Resources, Methodology, Funding acquisition, Data curation. **Carlos Alberto Mendieta Pino:** Writing – review & editing, Visualization, Validation, Resources, Project administration, Investigation, Funding acquisition, Conceptualization. **Nicolau Chrinza:** Writing – original draft, Validation, Software, Project administration, Investigation, Formal analysis, Conceptualization. **Paulino Muguirrima:** Writing – review & editing, Visualization, Supervision, Resources, Methodology, Funding acquisition, Data curation.

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The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.clwat.2024.100054.

Data availability

Data will be made available on request.

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