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Research Paper

Energetic, economic and environmental (3E) study of combined concentrating solar power plant and desalination small scale capacity for arid areas

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ABSTRACT

Water scarcity is a growing global problem affecting millions of people and ecosystems. It is the result of a number of factors, including population growth and climate change. Sustainable water management practices, efficient use of resources, and innovative technologies are essential to address this challenge. By implementing these strategies, we can work towards ensuring a reliable water supply for future generations and mitigating the impact of water scarcity on communities and the environment. This study proposes and investigates a promising solar brackish water desalination system based on reverse osmosis technology powered by a solar organic Rankine cycle. This paper aims to perform a technical and economic study of Organic Rankine Cycle (ORC) powered by concentrating solar Fresnel field combined with desalination units in an isolated region of Algeria (region of Hassi Khebi), taking into account the power fluctuation of the solar plant ensuring an acceptable quality of produced water. In particular, the prediction of the performances of the different components (the power plant and the desalination unit) is achieved through the modeling of the reverse osmosis unit and the simulation of concentrating solar power (CSP). The nominal capacity of the concentrating solar power plant is 1.2 MW based on linear solar Fresnel concentrators, the results have shown that the capacity of the desalination unit under nominal conditions reaches 15000 m3/day; this value represents a capacity factor of 24% according to the solar power availability, while the capacity factor of the solar power plant is around 20% with a solar electric efficiency of 15%. The economic analysis shows that the levelized cost of the water produced is estimated at 0.92 ($/m3), as is the cost of the electricity generated, which is 0.25 $/kWh. Finally, there is the cost amortization period, which is 9.66 years. The established carbon balance shows the importance of this type of system compared to conventional systems.

1. Introduction

Facing the growing demand for fresh water, environmental concerns, water scarcity, and the anticipated shortages, adopting a green water policy has been and continues to be considered a crucial alternative. Today, the production of fresh water through conventional desalination units is widespread, thanks to the large number of power plants built around the world. Commercial units using reverse osmosis technology are the most commonly used. When combined with renewable energy sources, desalination has become a viable and increasingly important solution in response to the rising demand for both water and electricity. Desalination driven by renewable energy is particularly promising in isolated areas. Its feasibility and reliability are supported by numerous implemented designs and practical experiences, mainly focused on small-capacity systems [1–3]. Desalination is the process by which the salt from the seawater or brackish water is removed. There are two types of desalination: filtration (which uses electricity as the main source of energy) and evaporation (which uses heat as the main source of energy). The most important technologies on a large scale within these two categories are reverse osmosis (RO) and multi-effect distillation (MED), respectively. The first one is more widespread around the world. Algeria is one of the countries in the MENA region that has included seawater desalination as part of its non-conventional water resources. Seawater desalination may be considered the most appropriate solution in many regions of Algeria to plug the gap between water demand and supply. The Algerian strategy is to have 1,624 billion m3 per year of water produced with non-conventional water resources, of which 1 billion would be obtained by seawater desalination [4]. Many desalination plants have been installed in Algeria so far, which are distributed in coastal zones of 1500 km of length from the east to the west. The seawater desalination plants that constitute an overall production capacity of around 2,310,000 m^3/day. According to the Algerian press service and the Algerian energy company, four desalination units were started and launched by the Algerian Republic President in 2025, each producing 300,000 m^3/day [5]. The exploitation of renewable energy sources to produce electricity and water is commonly considered a very promising way to reduce pollution and environmental impact. Algeria has important solar potential. The climatic conditions are favorable for the implantation of solar plants, with 2650 hours of sunshine per year and 1700 kWh/m^2 of average energy received in the north zone [6, 7]. Therefore, it seems logical that solar desalination will be one of the solutions to obtaining freshwater in many regions of the country. Several works, both of which analyze the combination of desalination plants and solar plants. Serval work focused on direct solar distillation. Sathish D et al [8] studied the thermal performance of a small, low-cost salt gradient solar pond. The portable pond was designed as a rectangular structure with a volume of $0.5m^2$.

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Nomenclature

CSP	Concentrating solar power	*ACC*	Annual capital cost
ORC	Organic Rankine cycle	*DNI*	Direct normal irradiation (W/m^2)
RO	Reverse osmosis	M_d	Fresh water production (m^3/day)
MED	Multi effect distillation	X_f	Salinity of feed water (g/l)
PCM	Phase change materials	P_{Th}	Thermal power (kWth)
PV	Photovoltaic	P_e	Electric power
SPC	Specific power consumption	*Greek Symbols*	
LEC	Levelized electricity cost	$\eta_{th,ORC}$	ORC Thermal efficiency
LWC	Levelized water cost	$\eta_{sol.ele}$	Solar to electricity efficiency

Polystyrene and high-density polyethylene sheets were used to insulate the walls. A thin glass cover was placed on top of the pond to prevent dust accumulation without hindering solar radiation absorption. Sodium chloride was used as the medium, and three salt gradient regions—lower convective, non-convective, and upper convective were created using an injection filling technique. Temperature and salt gradient data were collected experimentally over a 20-day period in Coimbatore, India. The pond absorbed approximately 65% of the available radiation, reaching a maximum temperature of 49 °C. Regular cleaning of the water surface is necessary to maintain a stable salt gradient. Despite being constructed with low-cost materials, the portable pond showed significant potential for storing solar energy for thermal applications. A.S. Nafey et al. [9] analyzed energy, exergy, and costs for a solar-driven ORC-RO desalination system based on the Sharm El-Sheikh plant. They evaluated different solar thermal collectors and working fluids, comparing organic options with water. Parabolic trough collectors proved to be the most efficient for heat supply. Toluene and water were identified as the best fluids, requiring minimal collector area. These choices resulted in lower specific costs and reduced exergy destruction. N. Ahmad et al. [10] Developed the modelling, simulation and the experimental verification of a small-scale PV-RO system operated by fixed and tracking PV panels for Dhahran, a city in Saudi Arabia. The results revealed that the optimal tilt angle of PV panels was close to 0.913 times the latitude of Dhahran. On the other hand, the yearly permeate gain obtained by single and double axis continuous tracking PV panels was 43% and 62%, respectively. U. Caldera et al. [11] estimated the global cost of seawater desalination using solar PV and wind energy for 2030. They found that the levelized cost of water (0.59 €/m³–2.81 €/m³) will be comparable to current fossil-powered SWRO plants (0.60 €/m³–1.90 €/m³). Bing Xu et al [12] examines the typical research developments in solar desalination systems integrated with phase change materials (PCMs). It evaluates performance assessment methods and the impact of various factors on the efficiency of these systems, such as PCM selection, structural design, and system integration. Additionally, it discusses the challenges encountered in incorporating PCMs into solar desalination systems, offering insights for future research. A.S. Isah et al [13] offers a comprehensive analysis of solar desalination systems, focusing on distillate quality, cost estimation, efficiency, and performance comparison. The results demonstrated an increase in distillate quantity from 4.7 L/m²/day to 19.7 L/m²/day for conventional and modified systems, respectively. The pretreatment system enhanced distillate quality by 10-55% in certain parameters. Cost analysis revealed distillate costs of 0.041$/L for traditional systems and $0.091/L for the improved systems. Comparison with other studies highlighted the exceptional efficiency of this study, with an average improvement of 30%. D.A. Dehmas et al. [14] examined a 5000 m³/day SWRO system driven by a 10 MWe wind power plant in Tenes, Algeria. Their study focused on economic and environmental benefits but did not consider the effects of wind power fluctuations on plant operation. Z. Triki et al. [15] evaluated a 1 MWe wind-powered brackish water RO unit in Adrar, Timimoun, and Tindouf, using batteries to manage wind power fluctuations. The author reported daily water production of 3720 m³ in Adrar, 3315.36 m³ in Timimoun, and 2843.52 m³ in Tindouf, with levelized costs of $0.66/m³, $0.70/m³, and $0.75/m³, respectively. Remlaoui et al [16] modeled, analyzed, and dynamically simulated photovoltaic/thermal (PVT) collectors and direct contact membrane distillation (DCMD) in Algeria using TRNSYS software. There are few works, particularly in Algeria, that focus on the combination of the CSP solar power plant with the desalination unit for isolated areas. In this work, our objective is to study and analyse a micro concentrated solar power plant (FRESNEL collector) with a reverse osmosis desalination unit using an ORC cycle with a nominal power of 1.2 MWe. In the first part, the sizing of the different components of the plant, such as the CSP concentrator field and the reverse osmosis unit, is carried out. The performance of the plant under design conditions (nominal conditions) is also presented. Then, in order to see the dynamic behaviour of the studied system, we have presented the hourly dynamic performances during the year (8760 hours) [17, 18] for the different components of the system (the FRESNEL CSP concentrator field, the ORC power block and the RO desalination unit). In this study, taking into account the intermittent solar resources (fluctuation of the power supply), the strategy previously proven [19] is adopted in this work, which is represented by the switching on/off of the pressure vessels ensuring an acceptable water quality less than 0.5 g/l.

2. Methodology & system description

The system studied consists of a desalination unit using reverse osmosis technology combined with a Fresnel solar CSP plant. The CSP plants are designed to generate the electricity required by the brackish water reverse osmosis (RO) unit to produce fresh water Fig. 1). The solar CSP is based on linear Fresnel collectors and an ORC cycle, while the desalination unit is a reverse osmosis unit with energy recovery. Regarding the localization of the system considered in our study, the selected area is HASSI KHEBI in Tindouf (29°11'9"North and 5°4'32"west). This area is located in the south-west of Algeria, about 1300 km from the capital Algiers. The reason for which the selected site is characterized by the availability of brackish water and the solar potential, for the simulation of the meteorological and radiometric data of this area issued from METEONORME software. The salinity of the water is 3.2 g/l [4, 19]. The solar CSP plant operates only with direct solar radiation, without storage or hybridization, in order to prove the feasibility of a combination of organic solar plant CSP-ORC with reverse osmosis brackish water desalination units. The analysis of the small-scale CSP power plant is carried out through this study. The power block based on organic Rankine cycle TURBODEN TD 12 HRS [20] with a nominal capacity of 1.2MW, on the other hand, a brackish water desalination unit based on reverse osmosis technology and driven with the CSP-ORC plant to produce the fresh water for the population.

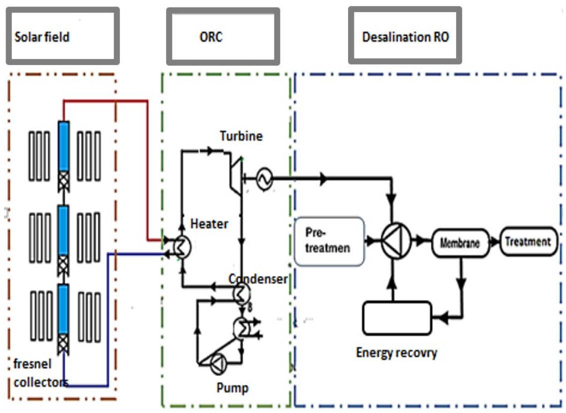


Figure 1. Flow diagram of the combined CSP/RO system studded.

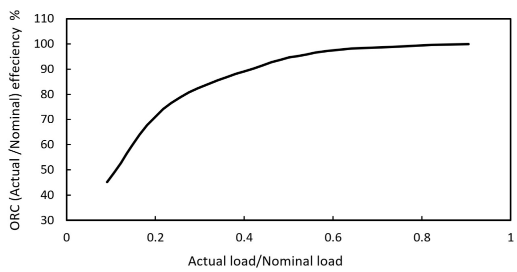


Figure 2. ORC thermal efficiency variation according to thermal load.

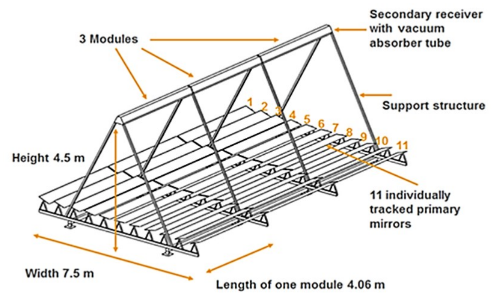


Figure 3. Fresnel collector's characteristics (LF-11 data sheet) [21].

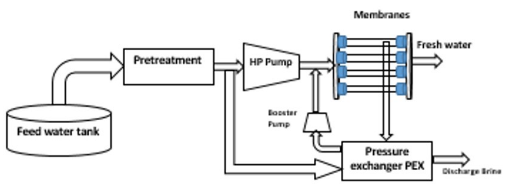


Figure 4. Diagram flow of reverses osmosis unit.

2.1 Organic Rankine cycle

The Rankine cycle is a thermodynamic cycle that converts heat into work Fig. 1, based on the production of electricity from heat, using the heat in the heat source to evaporate the working fluid (organic fluid) in the evaporator. The ORC consists of the thermal cycle, which makes it possible to produce electricity from steam, is used together with the gases that used to be seen from cooling systems, which make it possible to obtain higher pressure steam within the same temperature compared to water steam. The power delivered by the organic Rankine engine varied according to the thermal power availability from the solar field, the dynamic performances are simulated in Engineering Equation Solver (EES). Figure 2 shows the net efficiency of the ORC machine as a function of the thermal load supplied by the solar collectors. In addition, the technical details of the ORC are presented in Table 1.The delivered power by the organic Rankine machine varied according to the thermal power availability from the solar field, the dynamics performances are simulated in engineering equation solver (EES). In Fig. 2, the net efficiency of the ORC machine is displayed as a function of the thermal load supplied by the solar collectors. Moreover, the technical details of the ORC are presented in Table 1.

2.2 Fresnel collectors solar field

The solar field Fig. 1 represents the strongest part of the plant, in which his role is the collection of solar energy at high temperatures to produce the necessary thermal power needed by the organic Rankine machine. The Fresnel mirror collectors are used in this work Fig. 3, in the absorber tube, the heat transfer fluid used is Therminol VP1. The solar field simulated in the selected region using GREENIUS software. The advantages of choosing the Fresnel technology instead of the parabolic trough are the lower cost and simplicity, lightweight, and closer to the ground, Better ground coverage, more compact, and lower capital and maintenance costs.

Table 1. Characteristics of TURBODEN organic rankine [21]

Function mode	Electricity production only
Grosse Power (MW)	1.20
Auxiliary consumption (MW)	0.05
Net power produced (MW)	1.16
Grosse efficiency (%)	25 %
Net efficiency	24 %
Temperature inlet /outlet(°C)	305 / 206
Absorbed thermal power ($MWth$)	4.82
Condenser cooling water temperature (°C)	25 / 35
thermal capacity of cooling water ($MWth$)	3.61
Minimal accepted load ration	10 %
Minimal load	480 $kWth$
Air ambient temperature at design (°C)	15.0

2.3 Reverse osmosis unit modeling

The performance of the desalination unit varies depending on the electrical power supplied by the ORC power unit, while the water flow rate, the pressure applied to the membrane, the quality of water produced, and the specific consumption vary with the fluctuation of electrical power, which is proportional to direct solar radiation. The reverse osmosis desalination (RO) unit, Fig. 4, was modeled based on the models described in the literature [19, 22]. The model is implemented in the environment of the EES (Engineering Equation Solver) software. We have carried out to adapt the RO model to the intermittency of electricity due to the availability of solar irradiation by switching on/off the pressure vessels to ensure an acceptable water quality.

2.4 Economic analysis

The levelized cost of water (LWC), Eq. 1 is calculated as the ratio of the total annual investment cost—comprising the investment cost of the RO unit (ACCRO) and the annual investment cost of the CSP plant (ACC power plant) to the annual freshwater production ($M_{d-annual}$), [23, 24].

$$LWC = \frac{ACC_{RO} + ACC_{power\ plant}}{M_{d-annual}} \quad (\$/m^3) \tag{1}$$

The annual capital cost calculations for the RO reverse osmosis desalination unit and solar power plant are described in the following sections:
Reverse osmosis unit investment cost:
The annual capital cost of RO (ACC_{RO}) reverse osmosis unit and solar power plant are described in the following sections, Eq. 2.

$$ACC_{RO} = \left[\left(1 + \frac{27}{100}\right) \left(C_{equip} + C_{site}\right) \right] A_{f-RO} + C_{o\&m.RO} ACC_{RO} \tag{2}$$

Where A_{f-RO} is the RO unit damping factor and is estimated as Eq. 3.

$$A_{f-RO} = \frac{i(1+i)^{LT_{RO}}}{(1+i)^{LT_{RO}} - 1} \tag{3}$$

Where i is the discount rate (5%) and LT_{RO} is the life time of the RO unit estimated at 20 years. C_{equip} represents the equipment capital (cost intake pump and the retreatment cost, high-pressure pump and membrane cost). This work consists of analyzing the combination of concentrated solar power plants with brackish desalination units. The focused points to be described are: The dynamic performance of concentrated solar power plants, Power cycle characteristics, the reverse osmosis unit, and the economic analysis (calculation of the discounted cost of fresh water produced).

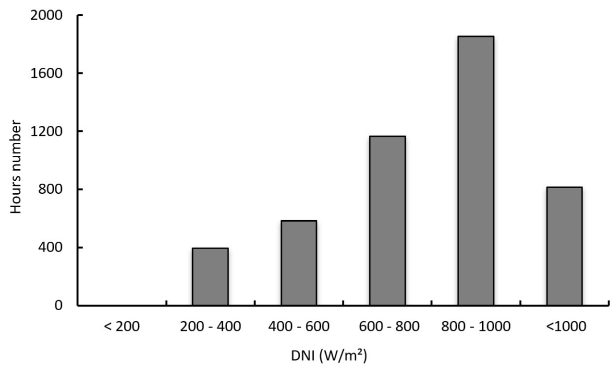


Figure 5. Yearly direct normal irradiation in Hassi khebi TINDOUF area.

3. Results and discussion

The production of electricity and water and the corresponding costs are functions of the energy collected by the solar field and transferred to the heat transfer fluid, which is in turn a function of the optical and thermal losses and the stability of the desalination unit due to the availability of electricity from the concentrating solar plant with an organic Rankine cycle (ORC-CSP) power plant. All these effects have to be studied to explain the behavior of the final energy collected by the fluid, the electricity generation, the water produced by the desalination unit, and the cost of the water. Therefore, numerical calculations have been carried out to estimate and predict the dynamic behavior of both devices, the concentrating solar power plant (ORC-CSP) and the RO desalination unit. We have chosen three days of the year (according to the variation of solar radiation during the seasons) to analyses the performance of our installation and to further clarify the appearance of the different key parameters during the days. These three days are 24th May, 17th July and 19th December.

3.1 Direct normal irradiation potential

In a Concentrating Solar Power plant, the solar field contains the mirrors that collect the solar energy and transfer it to the heat transfer fluid through the receiver. In solar CSP plants, direct sunlight is most important for their operation; it is called direct normal irradiation (DNI). It expresses the solar energy (watts) falling per unit area (m^2). Figure 5 shows the hourly evolution of the direct normal irradiance during the year, as well as the three typical days we have chosen (24 May, 19 July, and 16 December). The Hassi Khebi region is characterized by good radiation (up to 1000 W/m^2 in the Saharan zone). The DNI influences the sizing of the Fresnel collector field.
Figure 5 shows the number of hours for different ranges of direct radiation. It is clear that the number of hours per year where the direct radiation varies between 800 and 1000 W/m^2 is significantly higher than the other ranges (1800 hours/year). In our analysis, have been chosen a value of 850 W/m^2 has been chosen for sizing. This is based on Fig. 6, which shows direct irradiation. We can see that the best day for the best operation is the 24th of May, with 13 hours of sunshine, compared to the 16th of December (with a direct irradiance of more than 800 W/m^2 and 9 hours of sunshine) and the 19th of July (with a DNI of more than 600 W/m^2 and 13 hours of sunshine). The decrease in the DNI is explained by environmental factors such as the sand wind and the overcast sky (atmospheric attenuation).

3.2 Design of the ORC-CSP plant and RO unit

The design results obtained for the different parts of the plant (CSP part, desalination part) are shown in Table 2. The result shows that the total solar field contains 29 rows in each row has 4 modules, and the nominal capacity of the desalination unit is 15000 m^3/day with acceptable quality equal to 9.47 mg/l, the membrane applied pressure in nominal condition is about 26 bar. The desalination unit operates only with the power supplied by the solar CSP plant during sunlight. The performance of the unit varied according to the power fluctuation.

Table 2. Characteristic's Solar Fresnel collectors and reverse osmosis desalination unit.

Parameters	values
Solar CSP-ORC plant	
DNI at design	850 W/m^2
Nominal thermal load	4820 $kWth$
Electric Power	1.2 MW
Efficiency	24%
Solar field total effective area	29 rows (each row contain 4 modules)
Desalination unit	
Unit capacity	625 (m^3/h) (15000 m^3/day)
Membrane applied pressure	25.82 (Bar)
Fresh Water quality	9.47 (mg/l)
Specific power consumption	1.669 (kWh/m^3)

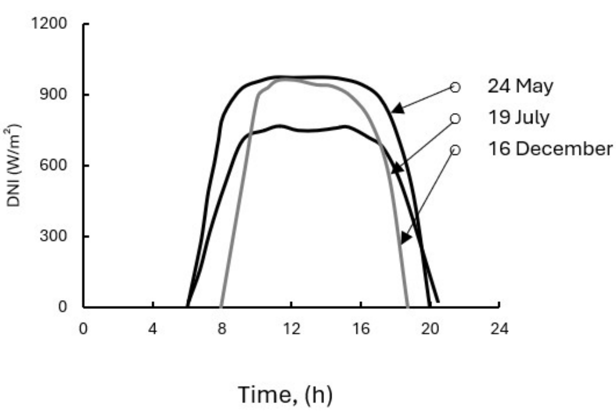
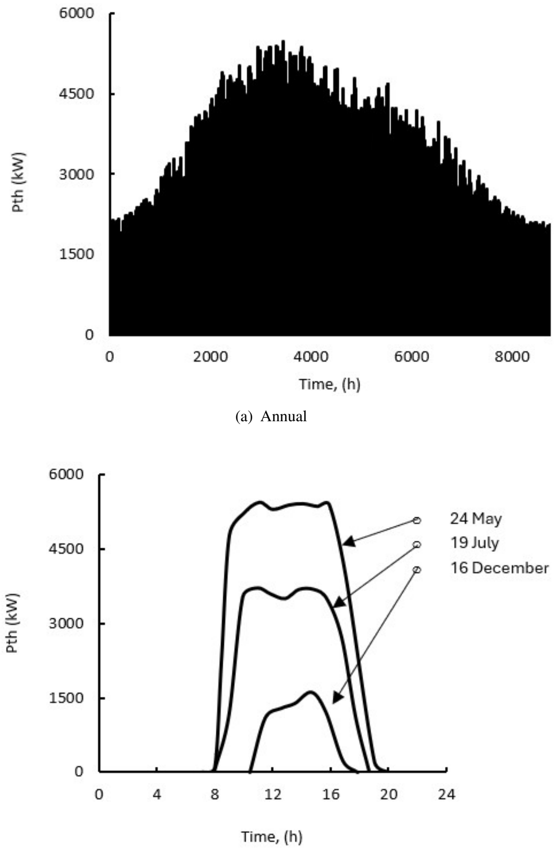


Figure 6. Presentation of direct normal irradiation (DNI) in the selected representative days.



(a) Annual

(b) Three days.

Figure 7. Thermal power produced by solar FRESNEL field (P_{th}).

3.3 Thermal power supplied by the Fresnel solar field (P_{th})

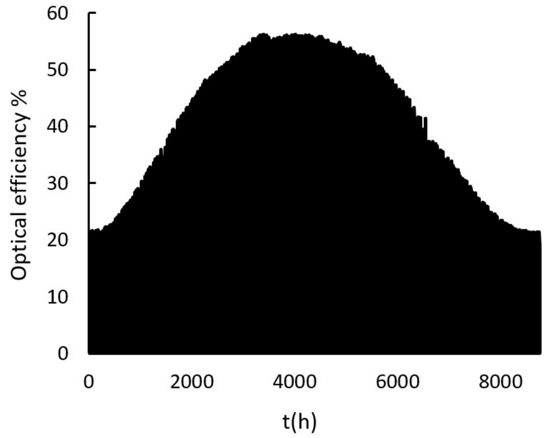
The net power produced by the FRESNEL concentrator field is used to supply heat to the ORC power unit to produce electricity from the turbine, which drives a generator. It should be noted that the power unit starts working at 10% of the nominal load, i.e. 482 kW. During periods when the thermal output is lower than this value, the whole system is shut down (switched off). In Fig. 7 below we have shown the dynamic variation of the thermal power produced by the CSP field during the year and also for the selected days. We can see that the thermal power produced during the day of 24 May is the closest to the nominal power (4820 kW). On the other two days, the thermal power is lower than the nominal value.

3.4 Solar field optical efficiency

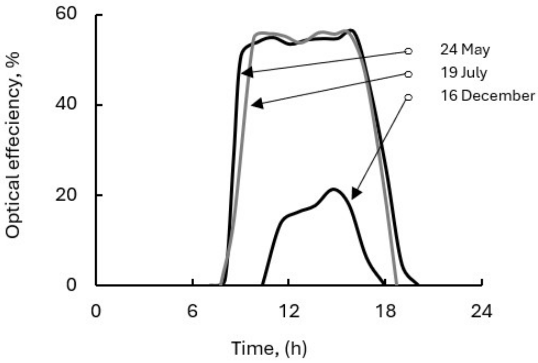
Figure 8 shows the variation of the optical efficiency of the FRESNEL concentrator field. It is quite clear that the optical efficiency is better in the summer period; it exceeds 55%, since the angle of elevation of the sun is maximum in this period, which directly influences the optical losses due to the cosine effect and the losses due to blocking and shading between the mirrors. losses due to the cosine effect and those due to blocking and shading between the mirrors. In the extreme periods of the year (winter), the optical efficiency is around 20%. The optical efficiency of the solar field directly affects the thermal output.

3.5 Electricity production: (P_e)

The electrical energy produced by the ORC is shown in Fig. 9. We can see that it is higher on the 24th of May than on the other days, and this is due to the thermal energy coming from the solar field. From Fig. 10, it is clear that the production of electrical energy by the unit is very low in winter (around 2 MWh), whereas it reaches its maximum in summer, when it reaches 12 MWh/day. This increase is justified by the increase in direct radiation and the duration of sunshine. In our study, the CSP solar plant delivers only 20% of the energy it should deliver under nominal conditions. Therefore, we can say that this installation works with a capacity factor of 20%.

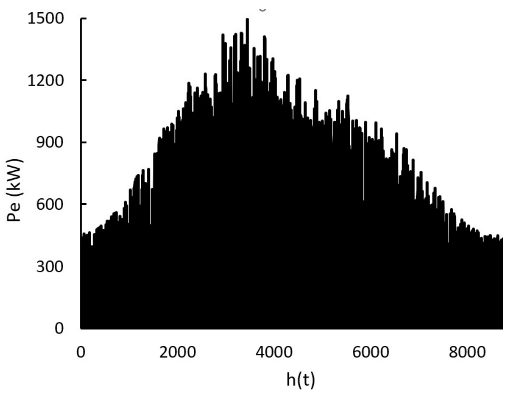


(a) Annual

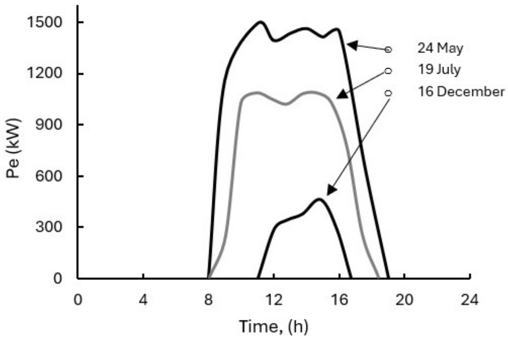


(b) Selected days.

Figure 8**.** Solar field optical efficiency (η_{sol}) evolution.



(a) Annual



(b) Selected days.

Figure 9**.** Thermal power delivered by the Fresnel solar field (*Pe*).

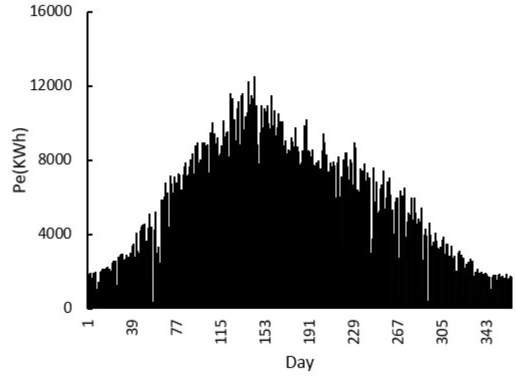
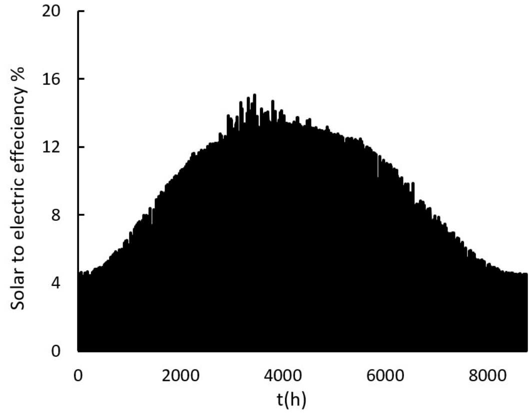
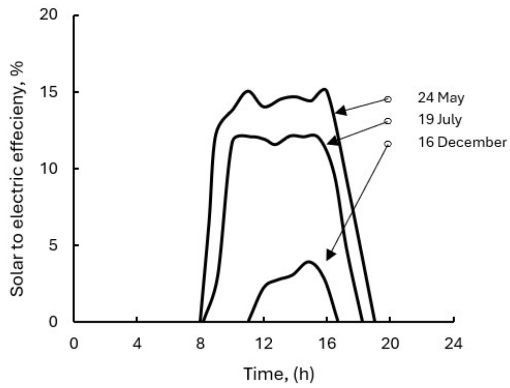


Figure 10**.** Daily production of electrical energy. (*Pe* (kWh)).



(a) Annual



(b) Selected days.

Figure 11**.** Total efficency solar to electric evolution ($\eta_{sola-elec}$ (%)).

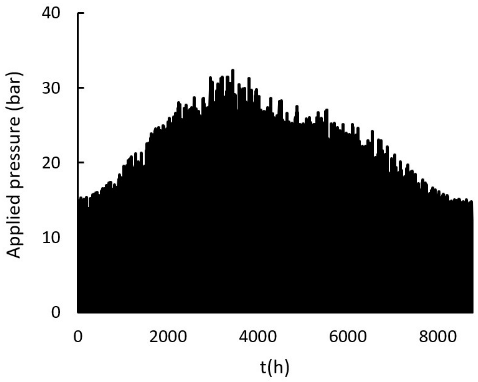
3.6 Total solar power plant efficiency

One of the essential parameters for evaluating a solar installation is the solar electric conversion efficiency; we have presented here Fig. 11 this parameter during the year and for the three days selected (May 24, July 19, and December 16). The conversion rate of solar electric is low in winter (5%) on December 19, but in summer, it is within standards, reaching 15% and 12% on May 24 and July 19, respectively.

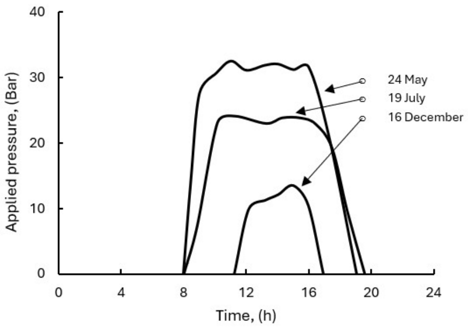
3.7 Performance of reverse osmosis desalination unit

3.7.1 Membranes applied pressure

The pressure applied to the membrane varies according to the electrical power delivered by the ORC turbine; in this section, we have presented the variation in power over the year and for the three days in question Fig. 12. The pressure on the membrane varies between 15 and 32 bar, 15 bar for the winter period (16 December), 23 (Bar) for the summer period (19 July), and 32 (Bar) for 24 May.

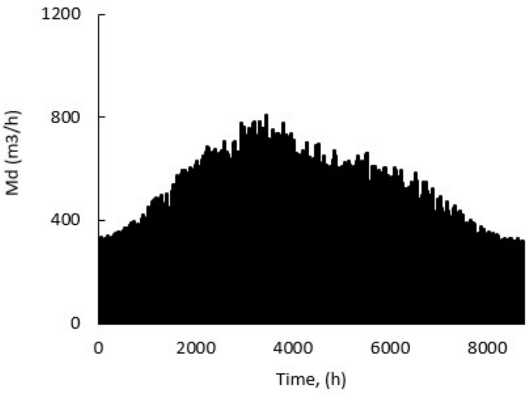


(a) Annual

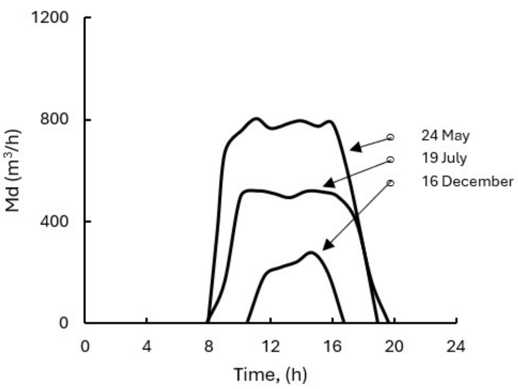


(b) Selected days.

Figure 12**.** Membranes applied pressure.



(a) Annual



(b) Selected days.

Figure 13**.** Hourly fresh water production.

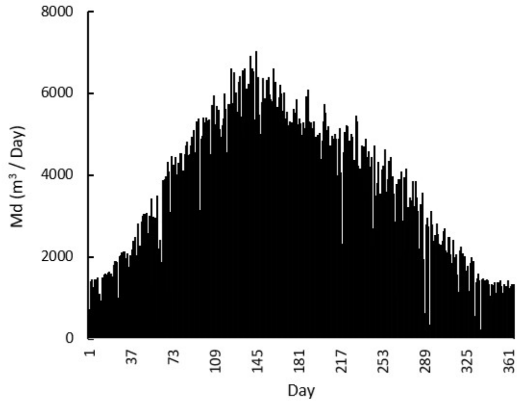
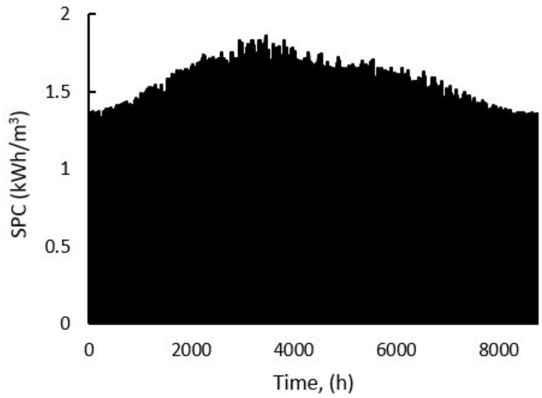
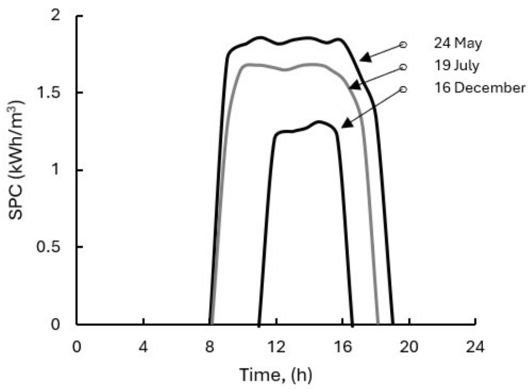


Figure 14**.** Daily water production throughout the year.



(a) Annual



(b) Selected days.

Figure 15**.** Specific power consumption.

3.7.2 Fresh water production

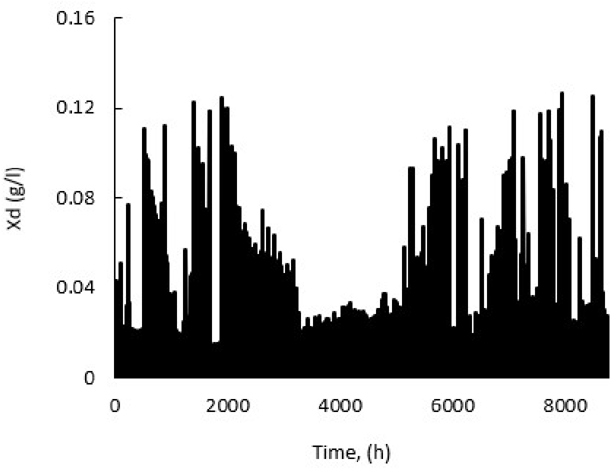
The amount of fresh water produced is shown in the (Fig. 13 and Fig. 14. The hourly flow rate of water produced by the RO reverse osmosis desalination unit reaches 806.1 m^3/h, 520 m^3/h, and 292.76 m^3/h on 24 May, 19 July, and 16 December, respectively. To balance production and demand throughout the year, water storage is essential. The previous figure represents the daily amount of water produced by the *RO* unit for the days of the year (365 days). It is worth noting that the production of water is proportional to the energy produced or to the direct solar radiation; the fluctuation in production is due to the intermittency of the electrical energy supplied by the CSP-ORC plant. In this case, the capacity factor, which is the ratio between the actual production and the nominal annual production, is 24%.

3.7.3 Specific power consumption (SPC)

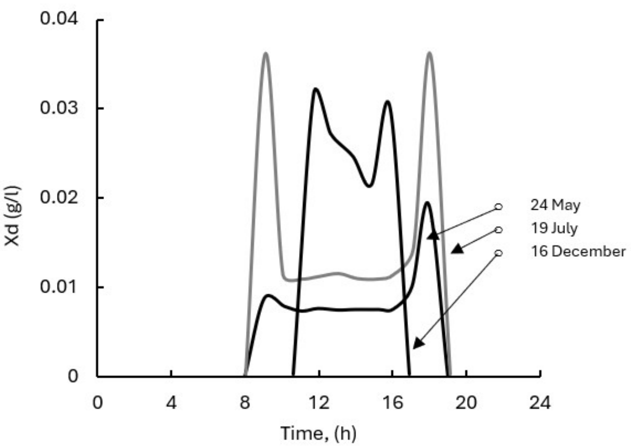
In this section, we have presented the variation of the specific consumption of SPC energy in Fig. 15. This parameter represents the electrical energy required to desalinate 1 m^3 of water. In nominal conditions, the specific consumption is 1,669 kWh/m^3 and in partial conditions it decreases to 1.4 kWh/m^3. At the same time, the quality of the water produced is reduced but remains within the standards.

3.7.4 Fresh water quality

The water quality represents the amount of salts in one litre of fresh water produced; this parameter is shown in Fig. 16. According to the literature, the water remains drinkable up to 500 (g/l) and in nominal conditions, the salt concentration is 9.45 (mg/l). However, under dynamic conditions (as a function of time), the concentration of fresh water varies between 9 (mg/l) and 30 (mg/l). This increase does not affect the quality of the water, as the pressuriser is switched on and off according to the availability of electricity.



(a) Annual



(b) Selected days.

Figure 16. Salt concentration in the produced water.

3.8 Economic and environmental analysis

The Table 4 and Fig. 17 below gives an overview of the discounted costs of electricity and water and the annual production for each of the parts: the solar CSP-ORC and the RO desalination unit. The investment cost of the whole system is around $911,576/year, of which the cost of the desalination unit represents 43% and 57% of the total annual investment cost of the CSP-ORC plant, with an annual production of water and electricity of 1.3 $Mm^3/year$ and 2.07 $GWh/year$ respectively. The discounted costs of electricity and produced water are LEC = 0.25$/$kWh$ and LWC = 0.92$/$m^3$. Comparing the similar work with our results (a discounted cost of water equal to $0.75/$m^3$ and $0.14/$kWh$ of produced energy) of a similar analysis carried out by TRIKI [15] (combination between a reverse osmosis desalination unit and a wind system in the Tindouf region with a power of 1 MWe), it was found that the discounted costs of water and energy produced by our plant are 19% higher than the costs obtained by TRIKI. This cost difference is justified by the high cost of CSP solar power plants, which is higher compared to wind systems, and in the author's hand, the integration of the battery bank in the system witches is benefic in the economic plan but poses environmental challenges for end-of-life disposal or recycling, while, for the presented study, the integration of thermal storage system allow effectively reduce costs without affecting the environment. And we compare with other works in the literature studded combined CSP-RO plants in Table 3, we conclude that (l_e) cost of water produced by the plant is competitive compared with the referenced study. In addition, the or payback period is calculated, which is the ratio between the total cost of the system (CSP-ORC-RO) and the cost of the water produced during the lifetime of the whole installation. In our study, the payback period is 9.66 years.

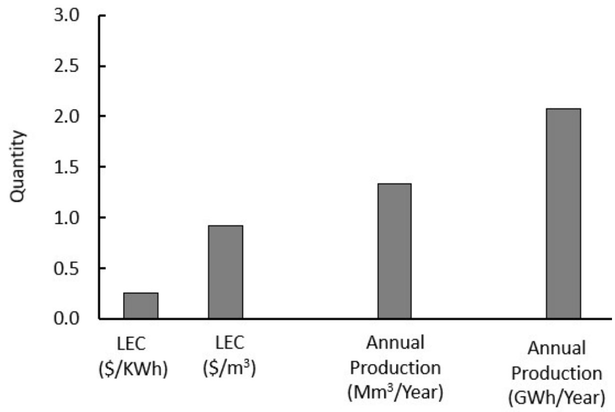


Figure 17. Production quantity and cost of water and energy.

Table 3. Comparison of the LCOW with similar works in literature.

Configuration	Plant Capacity	Net Efficiency	LCOW	Ref.
CSP ORC-RO	1.16 (MWe) 15000 (m^3/day)	13-15%	0.92 $(\$/m^3)$	This work
CSP Parabolic RO	50 (MWe) 35607 (m^3/day)	26.86%	0.93 $(\$/m^3)$	[25]
CSP Parabolic RO	7.58 (MWe) 7344 (m^3/day)	25.00%	1.03-1.18 $(\$/m^3)$	[26]
CSP Parabolic RO	5.00 (MWe) 1067 (m^3/day)	——	1.24 $(\$/m^3)$	[27]

For the environmental analysis, we performed a simple calculation of the amount of carbon dioxide equivalent avoided by harnessing solar energy. We consider that the quantity of toxic gas produced by 1 (kWh) of electricity by conventional means (natural gas) is equal to 0.63 $(kgCO_{2\,eq}/kWh)$ [28, 29], and the quantity of toxic gases ejected during the manufacture of the solar installation CSP is equal to 32.2$(gCO_{2\,eq}kWh)$ [30].

The annual quantity of CO_2 equivalent released by the CSP system (during the construction of the concentrators is evaluated as follows, Eq. 4.

$$CO_{2\,eq-CSP} = 32.2g \times Annual\ Alectricity\ Aroduction \tag{4}$$

And for comparison, we use the quantity of toxic gas produced if the electricity production system uses a conventional fuel such as natural gas, by the Eq. 5.

$$CO_{2\,eq-CSP} = 0.63\ Kg \times Annual\ Alectricity\ Aroduction \tag{5}$$

From there, we conclude that in our case, we have avoided almost 1240 tons of CO_2 per year through our CSP system, which has a considerable influence on climate change. This type of system plays a very important role in the preservation of fossil resources (natural gas and oil) and the reduction of greenhouse gas emissions. Where the allowable voiding of toxic gases is 94%.

Table 4. Summarized table of the energetic, economic, and environmental analysis done.

Parameters	Value
LEC	0.25 ($\$/kWh$)
LWC (takin account the energy cost)	0.92 ($\$/m^3$)
Annual production	1.33 ($Mm^3/year$)
Annual energy	2.07 ($GWh/year$)
Depreciation period	9.66 year
Investment specific cost of CSP	2653.56 ($\$/kW$)
Investment specific cost of RO unit	476,23 ($\$/m^3$)
Product during manufacturing of CSP	32.2g ($CO_{2eq}kWh$)
Carbon production of CSP	67 (tonnes $CO_{2eq}/year$)
Avoid CO_{2eq}	1240 (tonnes $CO_{2eq}/year$)
$CO_{(2eq-convensional)}$	1306.3853 (tonnes/ year)
$CO_{(2eq-CSP)}$	66.77080421 (tonnes/ year) with the reduction of 94%

4. Conclusions

Water scarcity leads to significant health problems, economic losses, food insecurity, and environmental degradation. The use of alternative water sources is an important solution to ensure the stability of society, and this paper aims at the energetic, economic, and environmental analysis of a combined solar Fresnel CSP and desalination small-scale system destined for the isolated Saharan region of Algeria. The work presents a modeling and dynamic simulation for the exploitation of electricity from solar energy using a linear Fresnel collector and ORC thermal cycle in order to produce fresh water by a desalination unit using reverse osmosis technology of brackish water in the region of Hassi Khebi region in TINDOUF, Algeria. For the reverse osmosis unit, the theoretical model was established in the engineering equation solver code, and the GREENIUS software was used to simulate the solar linear Fresnel field and combine it with the ORC thermal cycle. The use of dynamic simulation of a combined solar CSP –ORC and RO desalination unit aims to predict facility behaviour. The following points summarize the most significant conclusions of the simulation study:

- The achievements of this work are the design and simulation of a small-scale solar plant for the production of electricity and desalinated water using a CSP-Fresnel plant and an RO unit, simulated hourly, and performing a technological-economic and environmental analysis. In terms of energy efficiency, water production, environmental analysis, water, and energy costs.
- For the desalination unit, the annual water production is around 1.33 $Mm^3/year$.
- The economic analysis was conducted of the various components of the system (CSP&D), and we found an investment cost for the overall system of around $911,576/year with an annual production of water and electricity supply of 1.3 $Mm^3/year$ and 2.07 $GWh/year$, respectively.
- The objective is to show the potential gains saved in the production of water by renewable energy compared to its production by fossil energy.
- Our results have shown that the DNI is the main factor influencing all the other parameters (thermal power from the solar field, electrical power supplied by the ORC cycle, quality of water produced, etc.), and that the quantity of water produced is sufficient enough (1.33 $Mm^3/year$) to cover the needs of the population of the Hassi Khebi region and to consider other possible uses, such as in agriculture.

This result demonstrates promise in addressing to counter the problems of water shortage, drought, and pollution by limiting greenhouse gas emissions thanks to concentrated solar power plants, which implies good prospects for the technology in the near future, and adequate for small scale unit for isolated area. For the future, we hope to strengthen this study by adding an effective thermal storage system to ensure greater energy and water production, within the framework of improving equity in energy and water security in desert areas.

Authors' contribution

All authors contributed equally to the preparation of this article.

Declaration of competing interest

The authors declare no conflicts of interest.

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This study didn't receive any specific funds.

Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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