ORIGINAL PAPER

USING RENEWABLE ENERGY FOR SEAWATER DESALINATION AND ELECTRICITY PRODUCTION IN THE SITE OCP MOROCCO

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***Abstract**. OCP is the world's largest exporter and producer of phosphate rock, In this context, OCP has adopted a new improvement plan which proposes to develop production of phosphate rock from 28 to 47 million tons in 2020. The horizon industrial advancement program of OCP excepted to increase water consumption of 73 to 181 million m3 / year for its various operations. In this paper we will do a feasibility study to achieve a positive energy balance due to the energy collected generated by an exothermic system for sulfuric acid production in two chemical processing sites (Jorf Lasfar and Asfi) and renewable energy integration in two mining operation sites: Khouribga, Ben Guerir for meet the growing needs on energy.*

The principal purpose of this article is to develop an innovative idea of a desalination plant to produce fresh water from seawater by using renewable marine energy, principally hydrokinetic and wave energy. The main achievements will be connected with the environment protection, low maintenance and its accessibility to small communities.

***Keywords**: renewable energy, seawater desalination, electricity production.*

1. INTRODUCTION

The gap between water resources and water demand is expected to be filed by global developments such as population and economic growth and climate change. However, a series of technical approaches exist in order to decrease water poverty [1].

OCP plans to increase its production capacity from 30 to 50 million tons, as well as increase its production of downstream fertilizer through strategic partnerships, especially in Jorf Phosphate Hub (JPH) where infrastructures are in the process be developed to accommodate 10 additional units. This Plug and Play platform will provide common infrastructure at low cost, and will be connected through a slurry pipeline to the largest phosphate deposit in the world located in Khouribga, ensuring a secure supply. Present in five geographic areas of the country (3 mining operation sites: Khouribga, Youssoufia, Ben Guerir, Laayoun and two chemical processing sites: Safi and Jorf Lasfar), OCP is a regional development vector and important national (Fig. 1).

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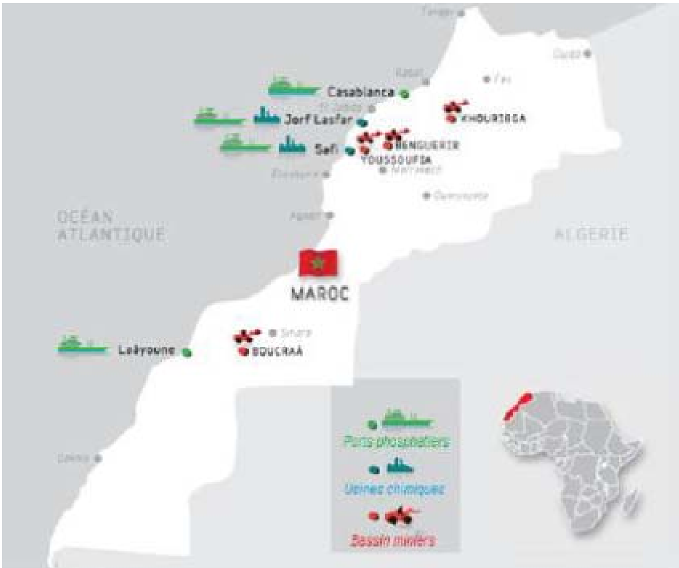


Figure 1. Map of the main OCP implantation sites in Morocco. of the selected locations in Morocco.

Access to water is a vital issue for the realization of the industrial strategy of the OCP Group: The effort to increase the production capacity is naturally accompanied by increased water requirements ranging from 66 million m3 / year currently to over 158 million futures (Fig. 2).

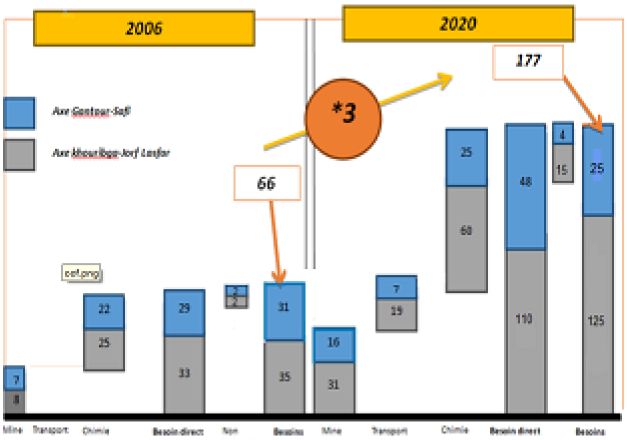


Figure 2. Evolution of the water needs of the OCP.

Renewable energy sources have been accepted worldwide as sustainable sources of energy, and are introduced to the energy sector with an annual growth rate of over 25 % per year [2-4]. From all available energy sources, marine energy is the one that correlates best with the demand for water, because it is obviously the main cause of water scarcity.

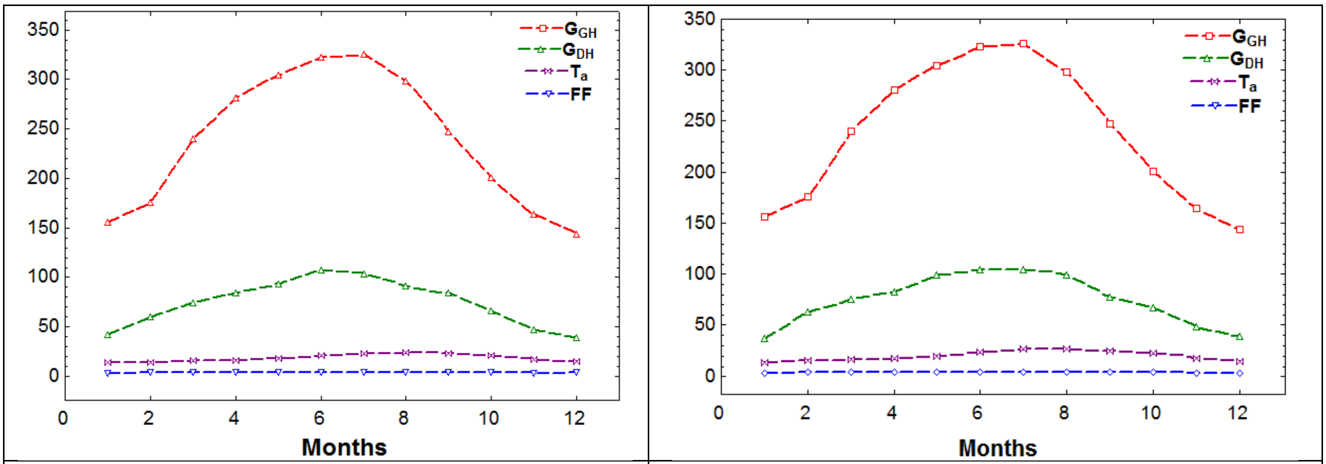
2. EVALUATION OF POTENTIAL CLIMATE IN OCP MOROCCO

To determine the potential use of renewable energy for seawater desalination and electricity generation in OCP Morocco, one has to look first at the geographical and climatic conditions. The geographic location of Morocco has several advantages for the extensive use of solar energy. Morocco is situated in the North West of the continent of Africa, between latitudes 21°- 36°N and longitudes 1°-17° W, and it has an area of 710,850 km². The Sahara represents 36, 57% of the area of the country. The climate in the north is warm Mediterranean, cold semi-arid and cold desert in the west and center, warm desert in the south.

In our study, we will do a feasibility study to integrate renewables energies (solar, wind, marine) into the OCP sites depending on weather data [5]. We selected two sites for the sea water desalination and two sites for electricity production according to the geographic location on the map [6].

2.1. SITES FOR THE SEAWATER DESALINATION

Jorf Lasfar: Latitude [°] = 33.210, Longitude [°] = -8.500, Altitude [m] = 0
Safi: Latitude [°] = 32.300, Longitude [°] = -9.250, Altitude [m] = 0



Jorf Lasfar | **Asfi**

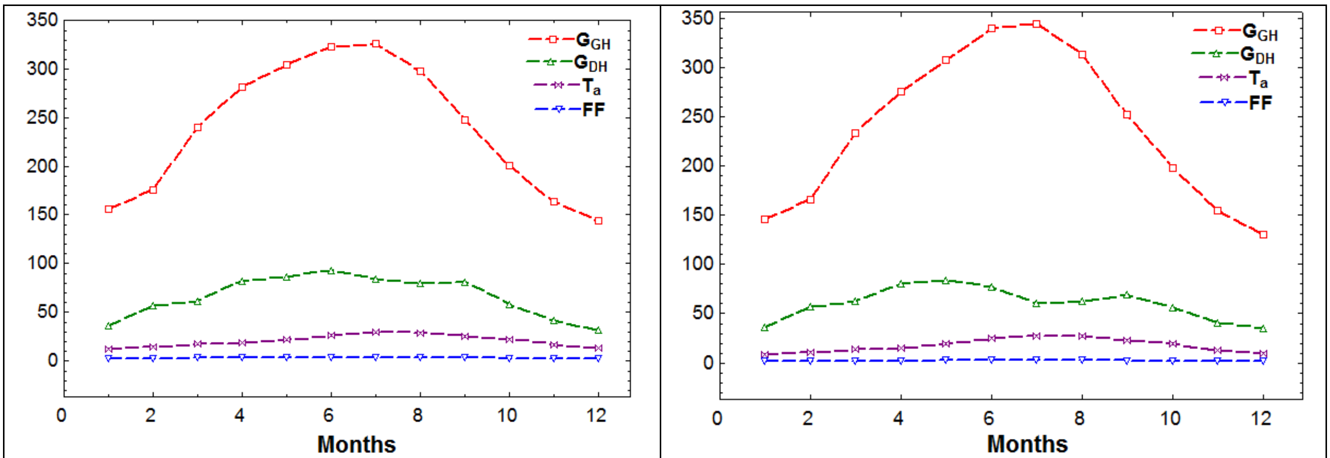
G_Gh: Irradiance Avg. the ray. Overall horiz. **FF**: Wind Speed
G_Dh: Irradiance of horizontal diffuse radiation. $\mathbf{T_a}$: Air temperature

We found that the cities (Jorf Lasfar, Safi) are placed next to the sea (Fig. 3) so the wind speed is more important than solar radiation, therefore, better to use wind power and marine energy [7] and heat recovery during the production of sulfuric acid to desalinate seawater.

Figure 3. Location of the Industrial Site (Jorf Lasfar, Safi).

2.2. SITES FOR ELECTRICITY PRODUCTION

Ben Guerir : Latitude [°] = 31.617, Longitude [°] = -8.033, Altitude [m] = 466
Khouribga: Latitude [°] = 32.900, Longitude [°] = -6.950, Altitude [m] = 774



Ben Guerir	Khouribga

G_Gh: Irradiance Avg. the ray. Overall horiz. **FF**: Wind Speed
G_Dh: Irradiance of horizontal diffuse radiation. $\mathbf{T_a}$: Air temperature

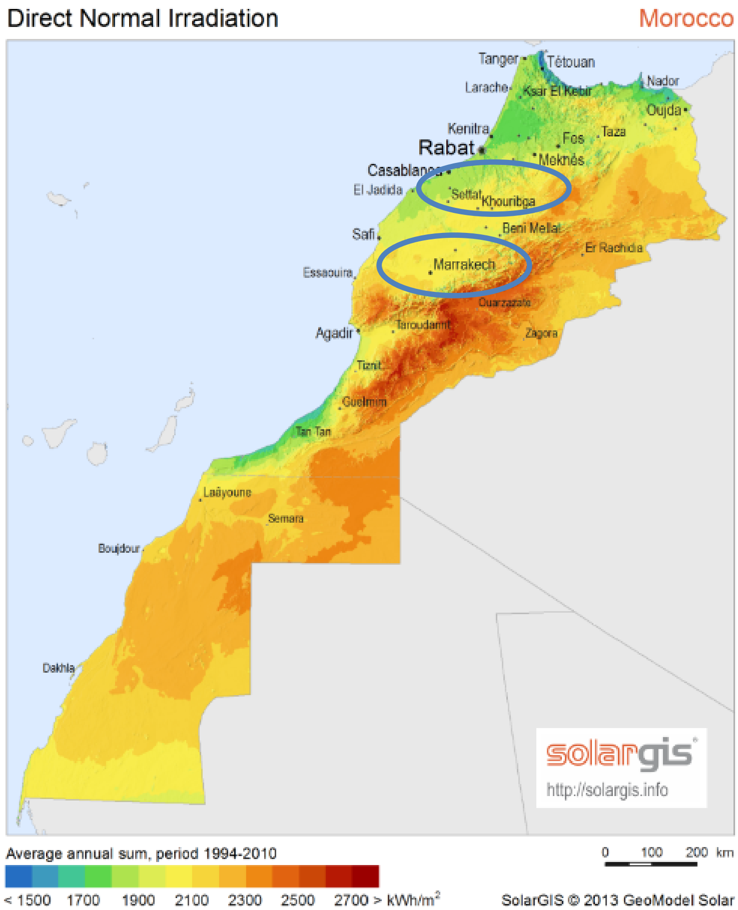


Figure 4. Climate illustration map.

3. HYBRIDIZATION SYSTEM OF DESALINATION

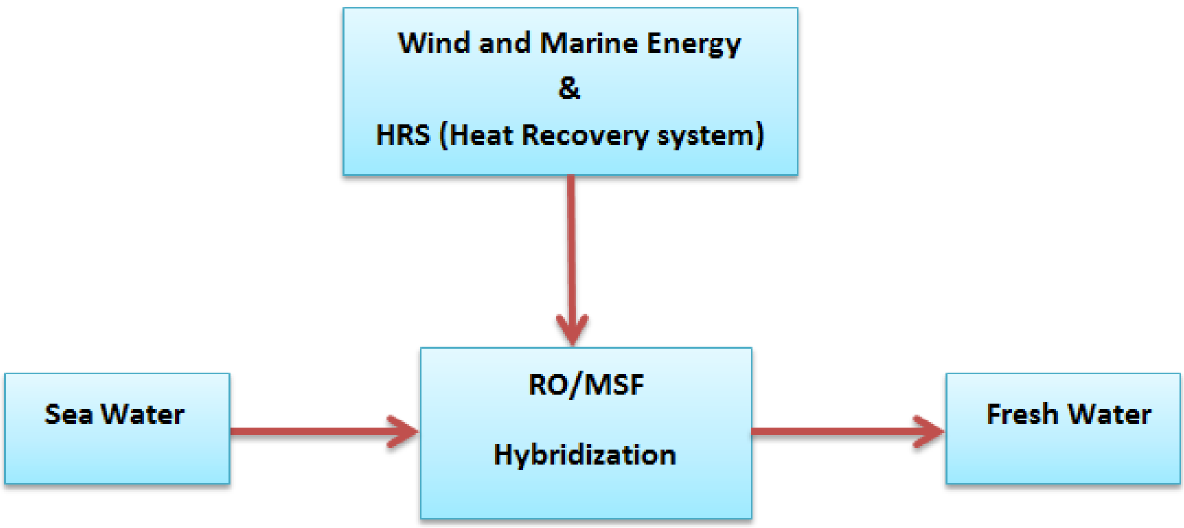


Figure 5. Components of hybridization system of desalination.

3.1 MARINE RESOURCES AND RENEWABLE ENERGY FOR ELECTRICITY GENERATION AND DESALINATED WATER PRODUCTION

The purpose of this investigation is to estimate the marine currents potential, as the source of renewable energy [8], in the area of the Canal of Jorf Lasfar and Safi for desalination seawater. The principal object of the planning methodology developed in this research is to estimate and describe this means in order to agree on the potential for the energy extraction of an order of Technical Energy Conversion System (TECS) and to assure that the tidal resource possible is not over-extracted [9].

Tidal turbine

Already the velocity distribution in the region of interest has been evaluated, it can be used to the TECS' power curve to calculate the annual energy output. The other components required are as follows:

- Power generated in each velocity bin P (Ui)
- Efficiency of the device (η_R)
- Rated velocity
- Electrical efficiencies

Hypothesis

The rotor efficiency (ηR) can be considered to rise from 38 % at cut-in speed to reach 45 % at the rated velocity

The cut-in velocity is the minimum velocity required for device operation and is assumed constant at 0.5 m s^{-1}

Technical assessment of the system

Produced energy from ocean power projects can be transformed into electrical or mechanical energy, which can, in turn, be applied as a driving force collectively with the desalination and water treatment by reverse osmosis processes [10],. All those parameters will be employed to measure the electrical power produced in each velocity bin as follows:

$$P(U_i)=P_{AV(i)}\cdot\eta_R$$

where

$$_{(i)}=0.5\cdot\rho\cdot A\cdot U_i^3$$

ρ : water density (Kg m^{-3});
A : the rotor swept area (m^2);
Ui : the central velocity value (m s^{-1}) .

The rotor diameter considered in this study is 25 m. This is the currently maximum diameter for a standard horizontal axis turbine. Therefore, the swept area A is 490,625 m^2.

The average Mean Spring Peak Velocity VMSP must be estimated to obtain the maximum velocity that would occur during an average month [11].

In this investigation the mean spring peak velocity is estimated by: 2.1 m/s.

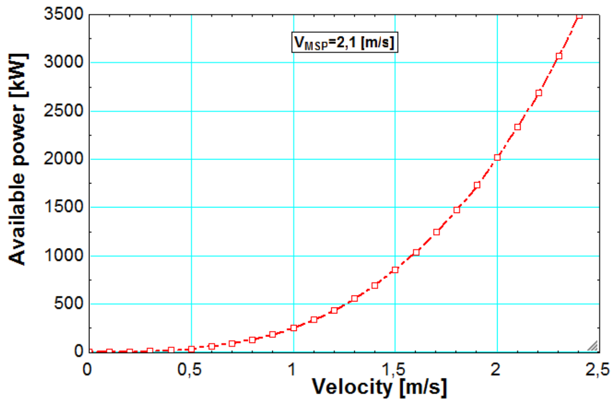


Figure 6. Available power vs Velocity.

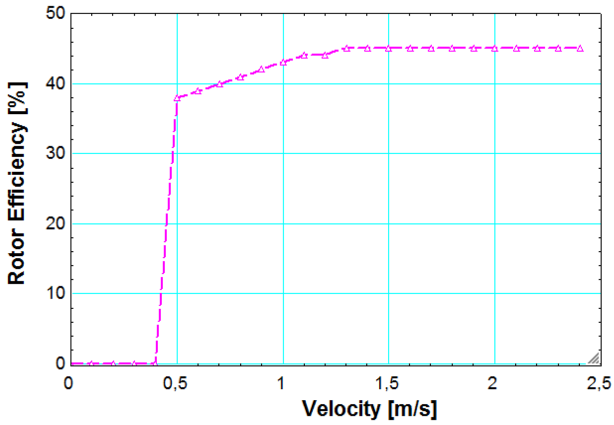


Figure 7. Rotor efficiency vs Velocity.

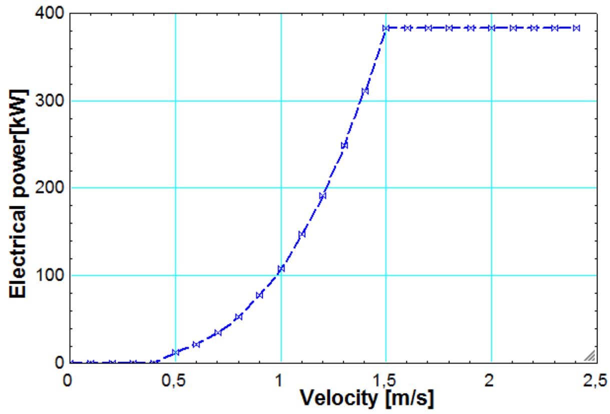


Figure 8. Electrical power vs Velocity.

Wave energy

In order to calculate the quantity of energy obtained by an Ocean Power Converter (OEC) [12], additional wave or tide conditions necessity be considered, but further the device features, the power take-off system, and the control strategy to name a few. The power included in the wave incident to a device [13]:

$$P_n = \frac{\rho * g}{16} H_s^2 C_g(T_e, h)$$

where, Pn is wave power (kW/m), ρ is sea water density (1,028 kg m^{-3}), g is gravitational acceleration (9.8 m s^{-2}), Hs is significant wave height (m), and Cg is wave group velocity (m s^{-1}) as a function of wave energy period, Te (sec), and water depth h(m) (Cornett 2008). Cg can be estimated as

$$C_g = \frac{\left(1 + \frac{2kh}{\sinh(2kh)}\right)\sqrt{\frac{g}{k}\tanh(kh)}}{2}$$

where the wave number k is calculated using a dispersion relationship expressed as a function of wave frequency (w=2π/Te) and water depth h:

$$w^2 = gk * \tanh(kh)$$

Similarly, the generation of electricity through the power of tidal currents, the potential energy is calculated by :

$$\Delta w = \int_{0}^{T} \frac{1}{2} C_P \rho \, S_{Turbine} v(t)^3 dt$$

where C_P is the power coefficient

$S_{Turbine}$ is the transversal area of the turbine;

$v(t)$ is the speed sinusoidal of the current.

The flow of desalinated sea water, depending on the energy converted from the sea and made to the system can be estimated by integrating the van't Hoff formula for the osmotic pressure. This energy converted by the converter device serves as a driving force, allowing the seawater admission and pumping it to a reverse osmosis module [14].

$$\Delta w = -\int_{V1}^{V2} P \, dv = NRT \, Ln\left(\frac{V1}{V2}\right)$$

Δw : the required energy per pump cycle

N : the number of moles of salt in seawater

R : the universal gas constant

T : the temperature in Kelvin

V1 e V2 are the initial and final volumes of the pump piston, their difference represents the volume of water actually pumped.

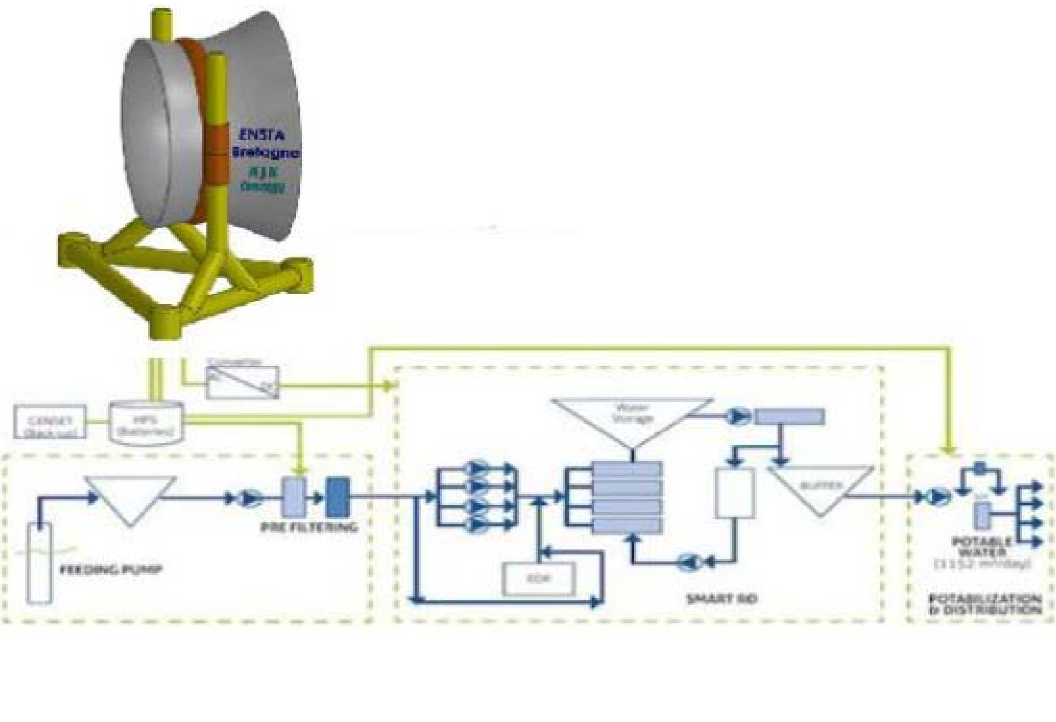
The energy required to pump a volume through a semi-permeable membrane can be calculated by :

$$\Delta w = \int_{V1}^{V2} (P_S + \Delta P) dv = \left[\frac{P_{sea}(1-\alpha/2)}{(1-\alpha)} + \Delta P\right] \Delta V$$

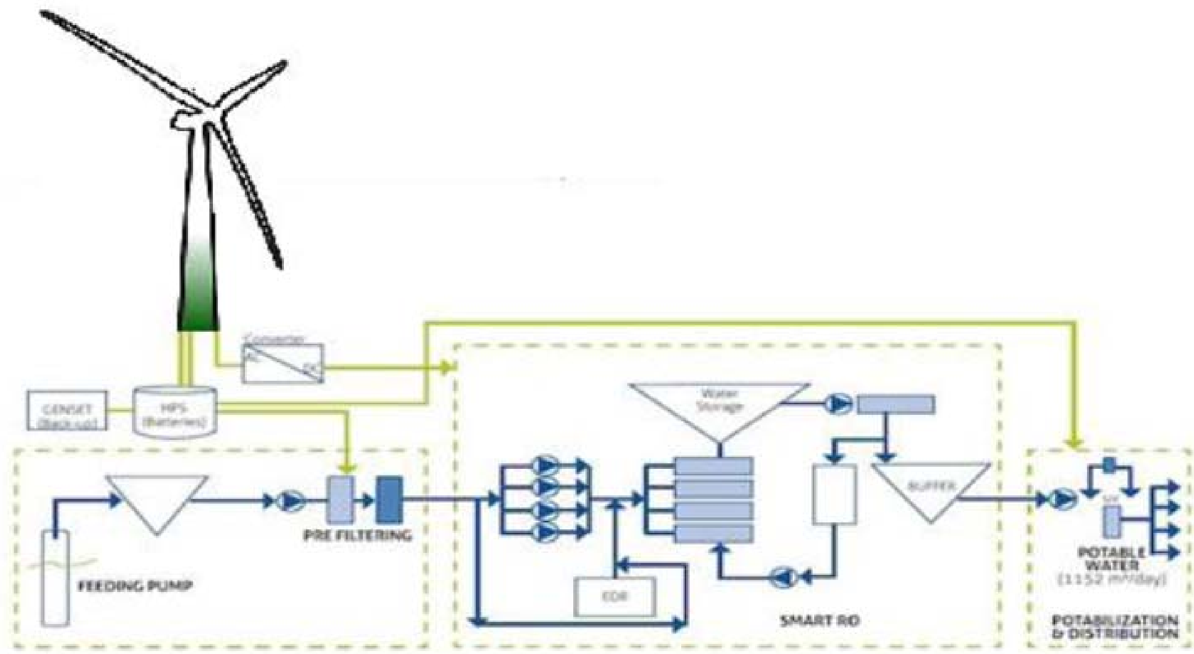
where α is the recovery rate of the desalination system.

The systems diagrams that can be used for desalination water sea with the integration of renewable marine energy

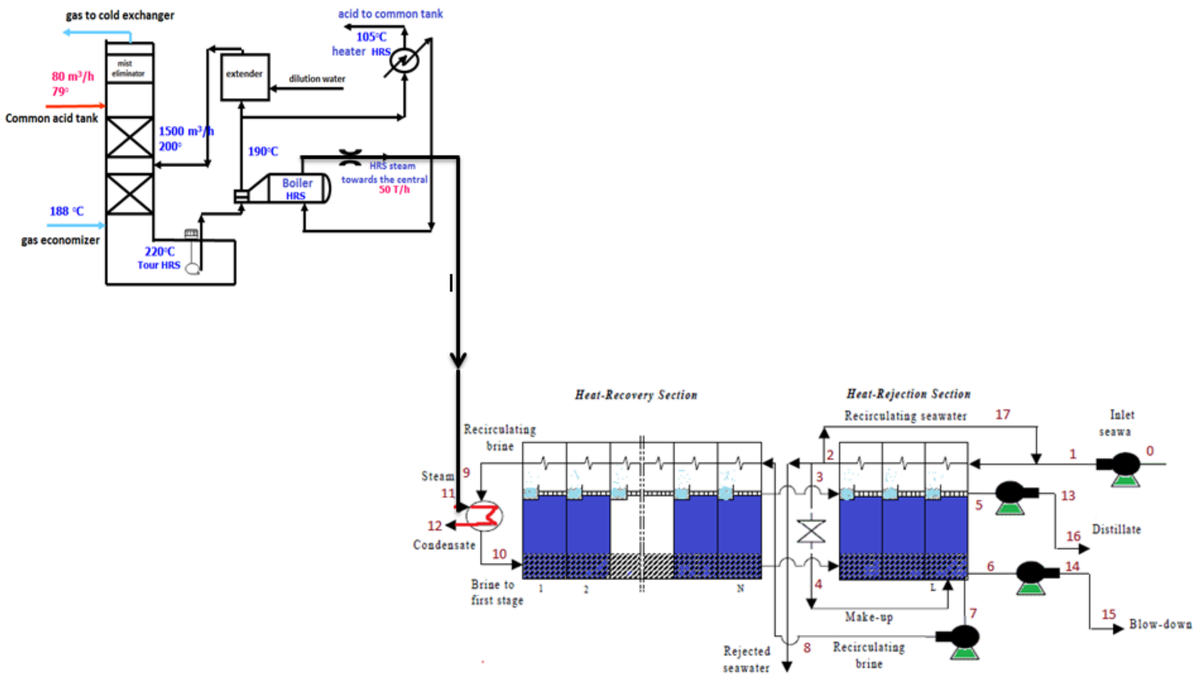
Tidal Turbine for desalination sea water



Wind energy for desalination sea water [15-16]

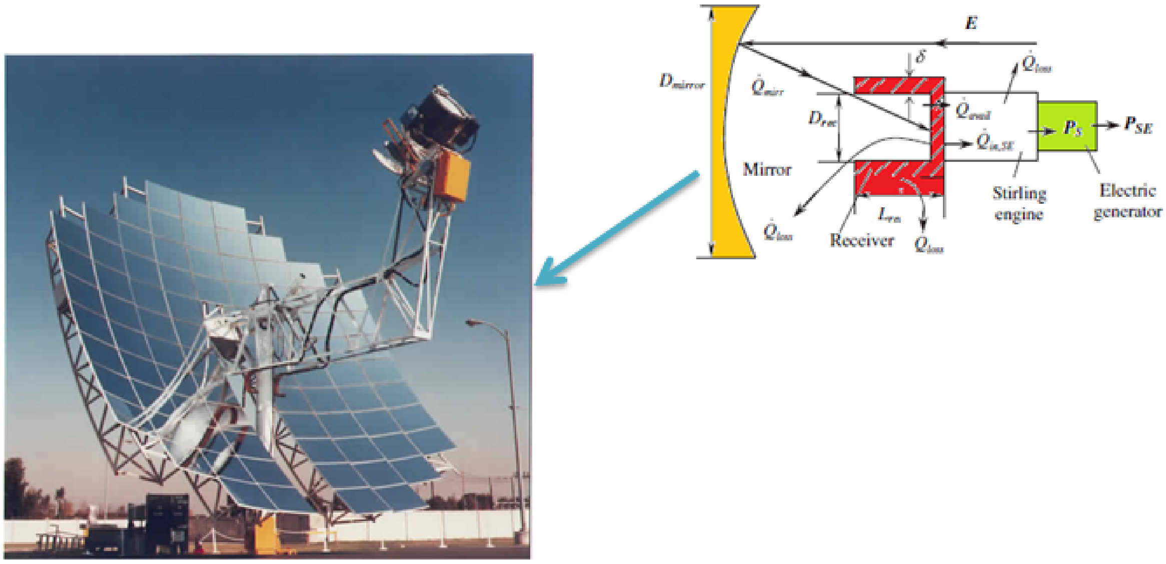


Heat recovery system for desalination sea water



3.2. *SOLAR ENERGY FOR ELECTRICITY PRODUCTION*

The other one can determine the efficiency with to investigate the impact of direct solar irradiation on the energy output of the Dish Stirling system [17],



The direct normal irradiation for several of the three localities chosen in Morocco is used as the input for the performance prediction of the Dish Stirling System, as presented in the following 3rd-order pronominal equation:

$$P_{net,elec} = -2{,}341.10^{-08}.(DNI)^{03} + 3{,}46.10^{-05}.(DNI)^{02} + 3{,}19.10^{-04}.(DNI) - 2{,}047358$$

The global efficiency of a Dish Stirling system is given by:

$$\eta_{SE} = \frac{P_{net,elec}}{A \cdot DNI}$$

with A is the concentrator area (m²)

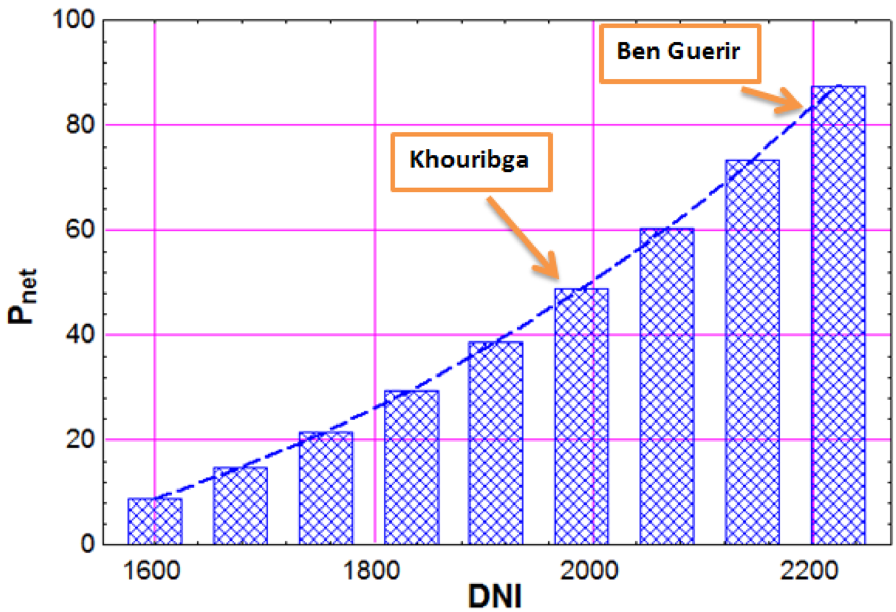


Figure 9. The net power in function of direct normal irradiation.

The net power P_{net} increase with the direct normal irradiation (DNI) for each city: Khouribga, Ben Guerir. The maximum power can be reached is 89 W for Ben Guerir, and the minimum power is 50 W for Khouribga. Also, the performance of Stirling engine varies linearly with the direct normal efficiency and the net power. Ben Guerir reaches an efficiency about 0, 4 % (Fig. 10).

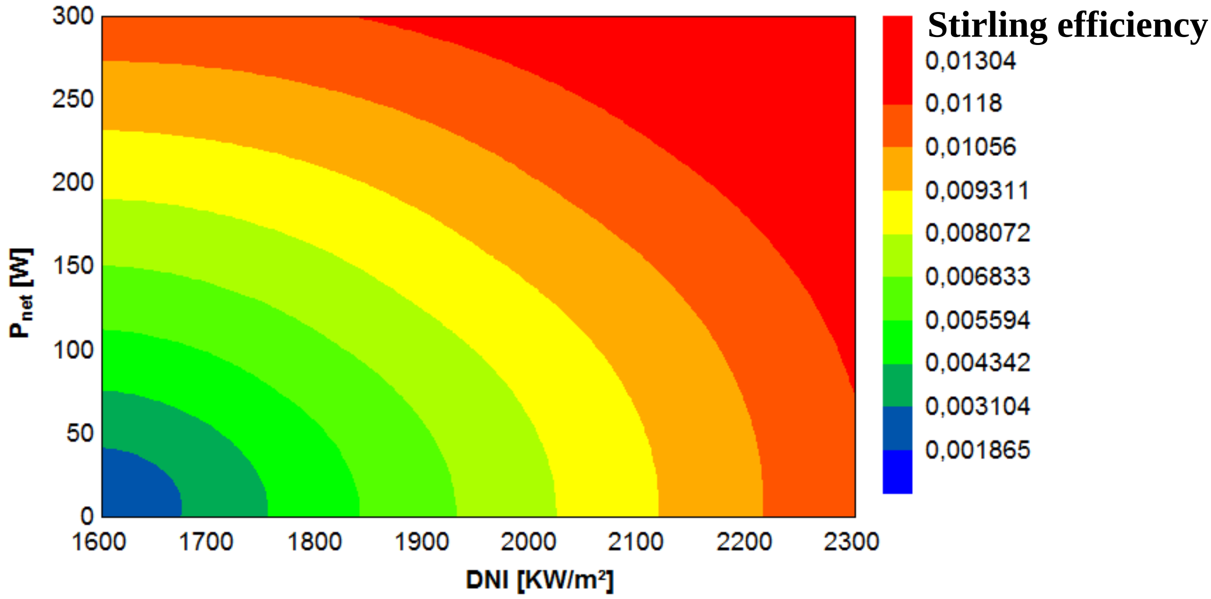


Figure 10. The Stirling efficiency in function of direct normal irradiation and the net power.

CONCLUSIONS

The desalination of sea water allows in particular to increase the resource in fresh water available, to provide a solution in the event of drought and to respond to situations of shortages and crises with use of a hybrid system that is to say Integration of Renewable Energies Marines and recovery of the heat during the production the sulfuric acid.

The desalination of water has an impact at both the positive and negative impact on the environment. And as a perspective for any project of desalination of sea water, it is necessary to carry out a study of the impact of the desalination plant which must focus in particular on the two aspects most critical: the rejection of the brines on the marine ecosystem and the increase of energy consumption, compared to the other alternatives of drinking water resources. Energy consumption, compared to the other alternatives of drinking water resources.

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