INTEGRATED POWER AND WATER PRODUCTION USING CONCENTRATING SOLAR TECHNOLOGY: A RELIABLE SOLUTION.

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Abstract

In the next decades the water demand will constitute a key factor for the economic and social evolution of the developing Countries in North Africa and Middle East and the climate changes will represent the main challenge for the near future.

Starting from these considerations, the paper presents an alternative way to generate electric power and desalinated water using the sun energy as heat supply source.

Two plant configurations have been considered: (1) a small size plant (less than 5 MWe) for rural and isolated application and (2) a large size plant (from 10 to 30 MWe) for industrial – grid connected application.

The small size plant is designed as a standard package, including consolidated equipment like parabolic trough concentrating solar modules (CSP), organic Rankine cycle (ORC) generation set and desalination plant, based on reverse osmosis (RO) technology.

The large size plant is based on a water/steam Rankine cycle.

The study has been based on commercial equipment and an economical model has been developed with the aim to propose a real and feasible solution.

The economics deriving from the two applications have been analysed in order to individuate the application and sustainability range for each kind of plant.

As conclusion a general view of real opportunities will be provided, including different applications like cogeneration (heat and cool) and possible scenario to match different local needs.

Introduction

Middle East and North Africa (MENA) countries are facing high socio-economic development needs, along with rapid population increase and increased urbanisation. As a consequence, energy demand is expected to continue growing (about 6% yearly up to 2020) and, as is expected to do in more rapid trend, electricity (about 7%). While conventional energy resource endowments greatly differ between countries, they all face increasing local and global environmental constraints. In addition, some well-endowed countries are facing a declining hydrocarbon production (in particular for oil) though hydrocarbon exports are the backbone of their economies. As such, their preservation and valorisation are essential to the sustainable development of the region. In this context, renewable energy (RE) can play an important role and address increasing needs, stability and sustainable development concerns.

In addition to energy and environment, water is becoming a major source of pressure in most of the MENA Countries. Indeed, freshwater sources in the region are persistently over-used. This is partially due to a rather low efficiency of water distribution and use, which in many cases does not reach present state of the art. It is also due, as mentioned earlier, to the continuous growth of population and economy of this region, which requires more water for more people and for new cultural, economic and industrial activities. Since about a decade, the exploitation of freshwater in this region has surpassed the available renewable surface and groundwater sources, and the deficit is poorly covered by over-exploiting the groundwater resources (1). Enhanced water management and more efficient distribution and use of water are the core of sustainable supply. However, a pre-requisite for water management is the existence of water to manage. Enhanced water management can delay and hopefully avoid the early depletion of groundwater resources, but it cannot supply new, growing demands.

Thus, new, unconventional sources of water must be found, and possible solutions range from the transport of freshwater to the region by tanker ships to seawater desalination. It is common to all those solutions that they require significant amounts of energy. Moreover, sustainable supply of water requires a sustainable source of energy, sustainable meaning in this context affordable, compatible with society and the environment, and secure. With fossil energy prices exploding by several 100% in the past few years, serious concerns on the stability of the global climate due to carbon emissions and increasing conflicts about energy sources all over the globe, it is obvious that the conventional energy system does not fit to the requirements of a sustainable, secure and competitive supply of water. As a consequence, governments are reluctant to invest in any of the new sources, but instead put increasing pressure on their groundwater, which is however a solution for only a very limited time span, with disastrous results once those resources are depleted.

The MENA region is endowed with a high potential for RE resources, particularly solar and wind. Each square kilometre of land in the region receives every year an amount of solar energy that is equivalent to 1.5 million barrels of crude oil. A technology to harvest, store and convert it to useful energy is state of the art: concentrating solar power (CSP). A CSP plant of the size of Lake Nasser in Egypt-Aswan would harvest the energy equivalent to the present Middle East oil production.

As a consequence, certainty about high solar resources availability increasing needs for both electricity and water in the region naturally lead to conclude that using CSP for water desalination should be seriously considered as one of the adapted solutions and to address these needs in a sustainable manner.

CSP technology

Overview

Many different types of system exist, of which the parabolic trough, the power tower (central receiver), the linear Fresnel and the parabolic dish are the most common.

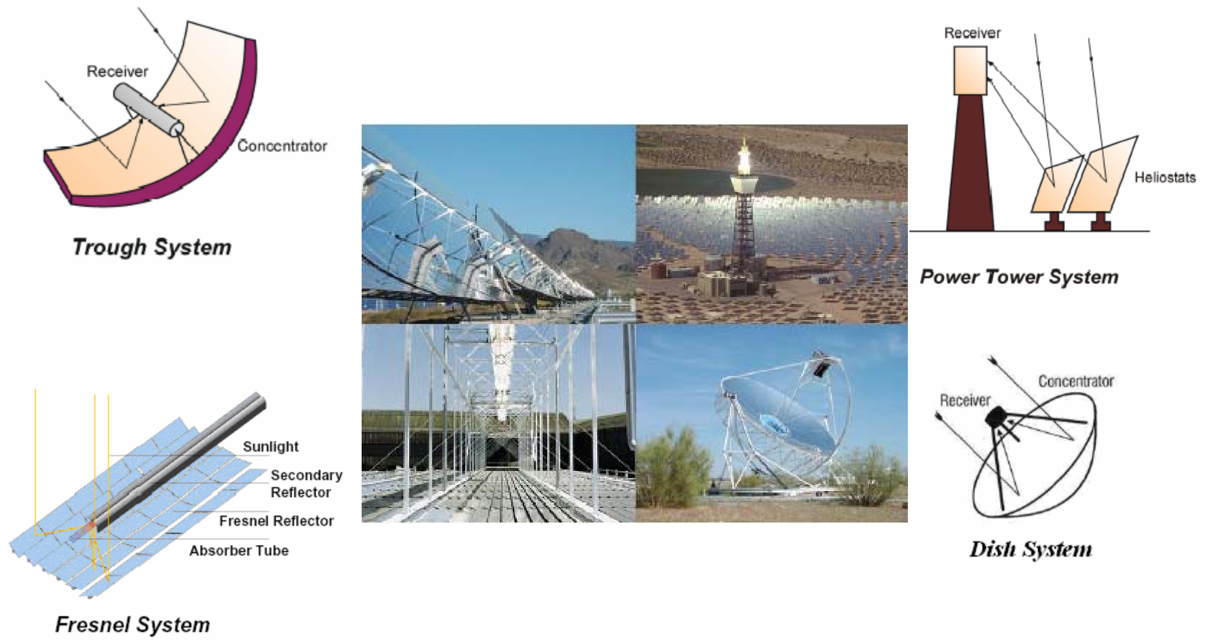


Figure 1 – Different types of CSP technology.

CSP, sometimes also referred to as solar thermal, produces electricity in much the same way as conventional power stations: by raising steam to drive turbines and generators. But instead of burning coal or gas, heat is generated by concentrating sunlight on mirrors. CSP plants work best in sun drenched hot deserts, where large shares of electricity production can be guaranteed.

In reality, CSP technology is not new. The first plant (parabolic) has even been built 100 years in the Mediterranean region, in Egypt, close to Cairo: a parabolic trough produced by then direct solar steam near Cairo, when coal was shipped from England to Egypt. But the availability of hydrocarbon resources at relatively low prices, dramatically slowed down interest to this technology. The first oil crisis in the late 70's gives rebirth to CSP research and interest. In particular, several studies on the use of CSP for electricity production and water desalination have been performed by European research institutions and important efforts are being made to enhance the development of this technology and to move from research to CSP market introduction. The first commercial plants were built in California in the mid 1980's, with unit capacities of up to 80 MW and are thus presently in operation. New plants are being built in Spain and in US today. CSP is mature and established technology.

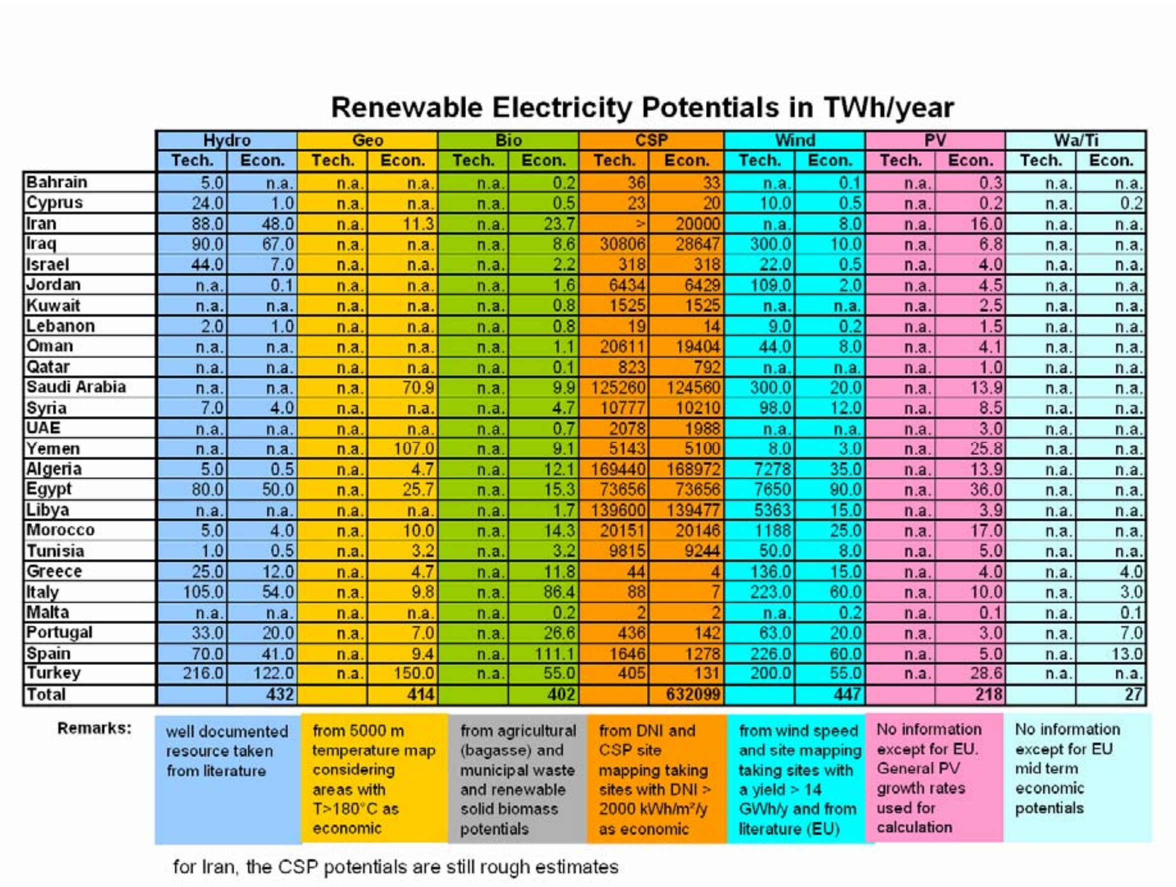
Solar heat can be stored in tanks of melted salts and used to power the steam turbines during the night or on cloudy days. The waste heat from CSP power-generation can be used to desalinate sea water - a vital resource in arid regions - and the shade of the mirrors can provide protected land for agricultural use.

For the purpose of this paper a parabolic trough CSP technology has been selected, coupled with a molten salt thermal storage system.

Potential market

The coastal CSP potential in MENA amounts to 5700 TWh/y, the total potential to 630,000 TWh/y. With one square kilometre of desert land in the MENA countries up to 165,000 m^3/day of desalted water can be produced using CSP technology.

Referring to the Table 1, in the economical potential of CSP have been considered the sites with direct radiation equal or higher than 2000 kWh/m^2/year, while in the technical potential of CSP have been considered the sites with direct radiation equal or higher than 1800 kWh/m^2/year. The result is that in the majority of the MENA countries the CSP technology has the higher value of the technical and economical potential respect the other renewable sources. Additionally in the MENA countries the technical and economical potentials are practically coincident, determining an extremely favourable application of CSP technology.

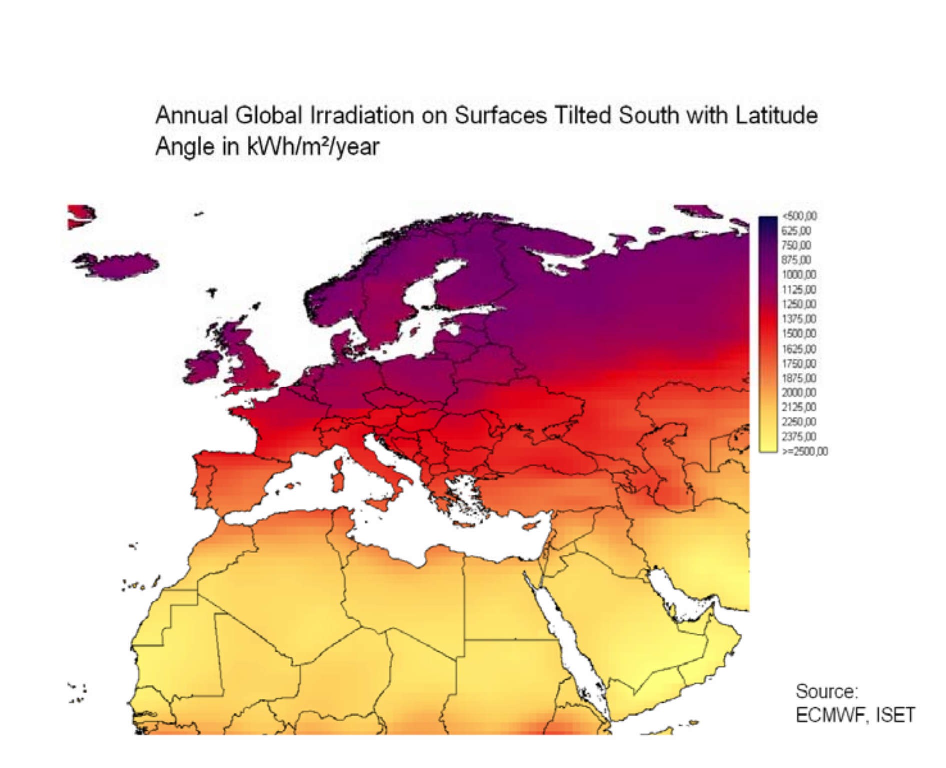


Renewable Electricity Potentials in TWh/year

	Hydro		Geo		Bio		CSP		Wind		PV		Wa/Ti	
	Tech.	Econ.	Tech.	Econ.	Tech.	Econ.	Tech.	Econ.	Tech.	Econ.	Tech.	Econ.	Tech.	Econ.
Bahrain	5.0	n.a.	n.a.	n.a.	n.a.	0.2	36	33	n.a.	0.1	n.a.	0.3	n.a.	n.a.
Cyprus	24.0	1.0	n.a.	n.a.	n.a.	0.5	23	20	10.0	0.5	n.a.	0.2	n.a.	0.2
Iran	88.0	48.0	n.a.	11.3	n.a.	23.7	>	20000	n.a.	8.0	n.a.	16.0	n.a.	n.a.
Iraq	90.0	67.0	n.a.	n.a.	n.a.	8.6	30806	28647	300.0	10.0	n.a.	6.8	n.a.	n.a.
Israel	44.0	7.0	n.a.	n.a.	n.a.	2.2	318	318	22.0	0.5	n.a.	4.0	n.a.	n.a.
Jordan	n.a.	0.1	n.a.	n.a.	n.a.	1.6	6434	6429	109.0	2.0	n.a.	4.5	n.a.	n.a.
Kuwait	n.a.	n.a.	n.a.	n.a.	n.a.	0.8	1525	1525	n.a.	n.a.	n.a.	2.5	n.a.	n.a.
Lebanon	2.0	1.0	n.a.	n.a.	n.a.	0.8	19	14	9.0	0.2	n.a.	1.5	n.a.	n.a.
Oman	n.a.	n.a.	n.a.	n.a.	n.a.	1.1	20611	19404	44.0	8.0	n.a.	4.1	n.a.	n.a.
Qatar	n.a.	n.a.	n.a.	n.a.	n.a.	0.1	823	792	n.a.	n.a.	n.a.	1.0	n.a.	n.a.
Saudi Arabia	n.a.	n.a.	n.a.	70.9	n.a.	9.9	125260	124560	300.0	20.0	n.a.	13.9	n.a.	n.a.
Syria	7.0	4.0	n.a.	n.a.	n.a.	4.7	10777	10210	98.0	12.0	n.a.	8.5	n.a.	n.a.
UAE	n.a.	n.a.	n.a.	n.a.	n.a.	0.7	2078	1988	n.a.	n.a.	n.a.	3.0	n.a.	n.a.
Yemen	n.a.	n.a.	n.a.	107.0	n.a.	9.1	5143	5100	8.0	3.0	n.a.	25.8	n.a.	n.a.
Algeria	5.0	0.5	n.a.	4.7	n.a.	12.1	169440	168972	7278	35.0	n.a.	13.9	n.a.	n.a.
Egypt	80.0	50.0	n.a.	25.7	n.a.	15.3	73656	73656	7650	90.0	n.a.	36.0	n.a.	n.a.
Libya	n.a.	n.a.	n.a.	n.a.	n.a.	1.7	139600	139477	5363	15.0	n.a.	3.9	n.a.	n.a.
Morocco	5.0	4.0	n.a.	10.0	n.a.	14.3	20151	20146	1188	25.0	n.a.	17.0	n.a.	n.a.
Tunisia	1.0	0.5	n.a.	3.2	n.a.	3.2	9815	9244	50.0	8.0	n.a.	5.0	n.a.	n.a.
Greece	25.0	12.0	n.a.	4.7	n.a.	11.8	44	4	136.0	15.0	n.a.	4.0	n.a.	4.0
Italy	105.0	54.0	n.a.	9.8	n.a.	86.4	88	7	223.0	60.0	n.a.	10.0	n.a.	3.0
Malta	n.a.	n.a.	n.a.	n.a.	n.a.	0.2	2	2	n.a.	0.2	n.a.	0.1	n.a.	0.1
Portugal	33.0	20.0	n.a.	7.0	n.a.	26.6	436	142	63.0	20.0	n.a.	3.0	n.a.	7.0
Spain	70.0	41.0	n.a.	9.4	n.a.	111.1	1646	1278	226.0	60.0	n.a.	5.0	n.a.	13.0
Turkey	216.0	122.0	n.a.	150.0	n.a.	55.0	405	131	200.0	55.0	n.a.	28.6	n.a.	n.a.
Total		**432**		**414**		**402**		**632099**		**447**		**218**		**27**
Remarks:	well documented resource taken from literature		from 5000 m temperature map considering areas with T>180°C as economic		from agricultural (bagasse) and municipal waste and renewable solid biomass potentials		from DNI and CSP site mapping taking sites with DNI > 2000 kWh/m²/y as economic		from wind speed and site mapping taking sites with a yield > 14 GWh/y and from literature (EU)		No information except for EU. General PV growth rates used for calculation		No information except for EU mid term economic potentials	

for Iran, the CSP potentials are still rough estimates

Table 1 – CSP potential in MENA countries (2)



Source:
ECMWF, ISET

Figure 2 – CSP potential in MENA region.

The use of desalination technology to produce fresh water is mainly concentrated in the Arabian Peninsula and in North Africa, as reported in Table 2, confirming the very high potential of these regions for the application of an integrated solar desalination plant.

Region	**Country**	**Plants**	**Capacity**	
			Total (100 m^3/d)	%
Persian Gulf	Bahrain	1	272	1,3
	Emirates	19	5700	26,6
	Iran	1	94	0,4
	Iraq	1	130	0,6
	Kuwait	6	1598	7,5
	Oman	1	91	0,4
	Qatar	4	682	3,2
	Saudi Arabia	15	5173	24,2
	TOTAL	**48**	**13740**	**64,2**
Mediterranean	Algeria	5	477	2,2
	Egypt	1	114	0,5
	Israel	9	1234	5,8
	Jordan	2	290	1,4
	Libya	4	560	2,6
	Spain	3	432	2,0
	TOTAL	**24**	**3107**	**14,5**
Far East	China	1	143	0,7
	India	1	300	1,4
	Pakistan	2	189	0,9
	Singapore	3	344	1,6
	TOTAL	**7**	**976**	**4,6**
America	Mexico	1	129	0,6
	Trinidad To.	1	114	0,5
	USA	18	3216	15,0
	TOTAL	**20**	**3459**	**16,1**
	Australia	1	123	0,6
TOTAL		**100**	**21404**	**100,0**

Table 2 – Location of 100 largest desalination plants (3).

With regard to the present energy, water and environment situations in the MENA region and taking into consideration the really favourable site location, this innovative concept and study of the hybridation of CSP and water desalination units will assess a wide replication and potential in the region.

Desalination technology

The principal industrially consolidated desalination technologies are briefly described in the following.

The desalination processes are divided in two mainly families:

- thermal processes;
- mechanical processes.

The most important thermal systems may be used in indirect solar desalination plants are Multi-effect (ME) and Multi-stage flash (MSF) distillation systems.

Mechanical vapour compression (MC) and reverse osmosis (RO) represent the mechanical available processes.

Multi-stage flash

In the MSF process, seawater is heated in a vessel called the brine heater. This is generally done by condensing steam on a bank of tubes that carry seawater which passes through the vessel. This heated seawater then flows into another vessel, called a stage, where the ambient pressure is lower, causing the water to immediately boil. The sudden introduction of the heated water into the chamber causes it to boil rapidly, almost exploding or flashing into steam. Generally, only a small percentage of this water is converted to steam (water vapour), depending on the pressure maintained in this stage, since boiling will continue only until the water cools (furnishing the heat of vaporization) to the boiling point. In this unit, the feed water could pass from one stage to another and be boiled repeatedly without adding more heat. Typically, an MSF plant can contain from 15 to 25 stages. The vapour steam generated by flashing is converted to fresh water by being condensed on tubes of heat exchangers that run through each stage. The tubes are cooled by the incoming feed water going to the brine heater. This, in turn, warms up the feed water so that the amount of thermal energy needed in the brine heater to raise the temperature of the seawater is reduced.

The technology requires the use of chemical products such as acids that need special handling to improve the water quality to make it domestically suitable and industrially adaptable. Combination with other processes, such as using heat energy from electric-power generation plants, may lead to a reduction of the production costs. Installation of high-production capacities avoids high operation costs.

Multi-effect distillation

ME, like MSF, takes place in a series of vessels (effects) and uses the principles of condensation and evaporation at reduced ambient pressure in the various effects. This permits the seawater feed to undergo boiling without the need to supply additional heat after the first effect. In general, an effect consists of a vessel, a heat exchanger, and devices for transporting the various fluids between the effects. Diverse designs have been or are being used for the heat exchanger area, such as vertical tubes with falling brine film or rising liquids, horizontal tubes with falling film, or plates with a falling brine film. By far the most common heat exchanger consists of horizontal tubes with a falling film. There are several methods of adding the feed water to the system. Adding feed water in equal portions to the various effects is the most common. The feed water is sprayed or otherwise distributed onto the surface of the evaporator surface (usually tubes) in a thin film to promote rapid boiling and evaporation after it has been preheated to the boiling temperature on the upper section. The surfaces in the first effect, are heated by Steam from Steam turbines of the power plants or a boiler. The steam is then condensed on the colder heat transfer surface inside the effect to heat. The condensate is recycled to the boiler for reuse. The surfaces of all the other effects are heated by the steam produced in each preceding effect. The steam produced in the last effect is condensed in a separate heat exchanger called the final condenser, which is cooled by the incoming sea water, thus preheating the feed water. Only a portion of the seawater applied to the heat transfer surfaces is evaporated. The remaining feed water, of each effect, now concentrated and called brine, is often fed to the brine pool of the next effect, where some of it flashes into steam. This steam is also part of the heating process. All steam condensed inside the effects is the source of the fresh water product.

The ambient pressure in the various effects in the ME process is maintained by a separate vacuum system. The thermal efficiency of the process depends on the number of effects with 8 to 16 effects being found in a typical plant.

Although there is a similarity between the MSF and ME both in pre-treatment and final treatment requirements, the installed capacity of this technique is limited vs. the MSF.

Vapour compression

The vapour compression (VC) distillation process is generally used in combination with other processes (like the ME described above) and by itself for small and medium scale seawater desalting applications. The heat for evaporating the water comes from the compression of vapour rather than the direct exchange of heat from steam produced in a boiler.

Steam ejectors (thermal vapour compression) and mechanical compressors (mechanical vapour compression) are used in the compression cycle to run the process. The mechanical compressor is usually electrically or diesel driven, allowing the sole use of electrical or mechanical energy to produce water by distillation.

Reverse osmosis

This is a process in which salt water is pumped into a closed container against permeable membranes and forced to overcome the osmotic pressure of the salt solution. This technique requires a pre-treatment to be compatible with the membrane by removing suspended solids and also needs a pH adjustment which depends on the water source and the kind of membrane. The technique is considered as the most promising one, which can be used for brackish and seawater desalination. It is used in a wide capacity range for supply to the domestic sector without any need to add chemicals. The system could be used for supplying the industrial sector if it were integrated within other thermal technology systems.

Although most of the RO plants are used to desalinate groundwater, seawater desalination shares about 43% of the total installed capacity of all RO plants.

The main operational parameter of the above described desalination technology are resumed in the Table 3.

Technology		**MSF**	**ME/TVC**	**MVC**	**RO**
Possible unit size (m^3/day)		76 500	45 500	1 000	8 500
Energy consumption (kWh/m^3)	**Electrical/mechanical**	3.5 – 4	2.5 – 3.0	7 – 16	4 – 6
	Thermal	55 – 120	30 – 120	None	None
Electrical equivalent for thermal energy (kWh/m^3)		8 – 18	2.5 – 10	None	None
Total equivalent energy consumption (kWh/m^3)		12 – 22	5 – 13	7 – 16	4 – 6

Table 3 - Energy requirements of four industrial desalination processes (5).

Utilising thermal desalination systems, MSF and ME, the solar field could drive the distillation plant by both heating the seawater or brine preheated at the plant or by generating steam. Steam generated by the solar collectors and an auxiliary system, if necessary, is not only able to drive a distillation system, but also to generate electricity in order to feed a RO or VC plant.

Considering the energy input required by the different desalination systems and the impact on the solar field extension, the RO and the ME processes have been selected for our purposes.

Integrated solar desalination plant

The engineering of a first plant for the combined generation of electricity, district cooling and desalted water has recently started in Aqaba, Jordan. It will be the first economically competitive solar power station without any financial public support.

Another innovative project is just started in Tripoli, Libya, for the integration of a CSP parabolic trough solar field feeding a desalination unit, based on thermal ME technology.

The present paper would provide a complete and realistic picture of two possible plant configurations, to be adopted in different application scenarios.

Proposed configurations

Two plant configurations have been considered: 1) a small size plant (less than 5 MWe) for rural and isolated application and 2) a large size plant (from 10 to 30 MWe) for industrial – grid connected application.

The small size plant is designed as a standard package, including consolidated equipment like organic Rankine cycle (ORC) generation set and desalination plant, based on reverse osmosis (RO) technology.

The large size plant is based on a water/steam Rankine cycle feeding a conventional steam turbine (ST) and a combined ME/RO desalination plant.

Plant 1) : small size integrated solar desalination plant

The studied plant will consist of a CSP solar field feeding an ORC generation set. The electricity produced by the ORC turbo-set will feed a RO desalination plant. An heat storage system has been foreseen to ensure a 8 h/day operation of the desalination plant. An auxiliary fuel fired heating system will ensure the right operation of the plant during solar field outage periods.

The production of desalinated water will be kept constant during the year, sending to the local electric grid the excess power produced during the higher irradiation period and compensating with burning fuel during the lower irradiation periods.

In the Figure 3 is reported a schematic flow of the plant.

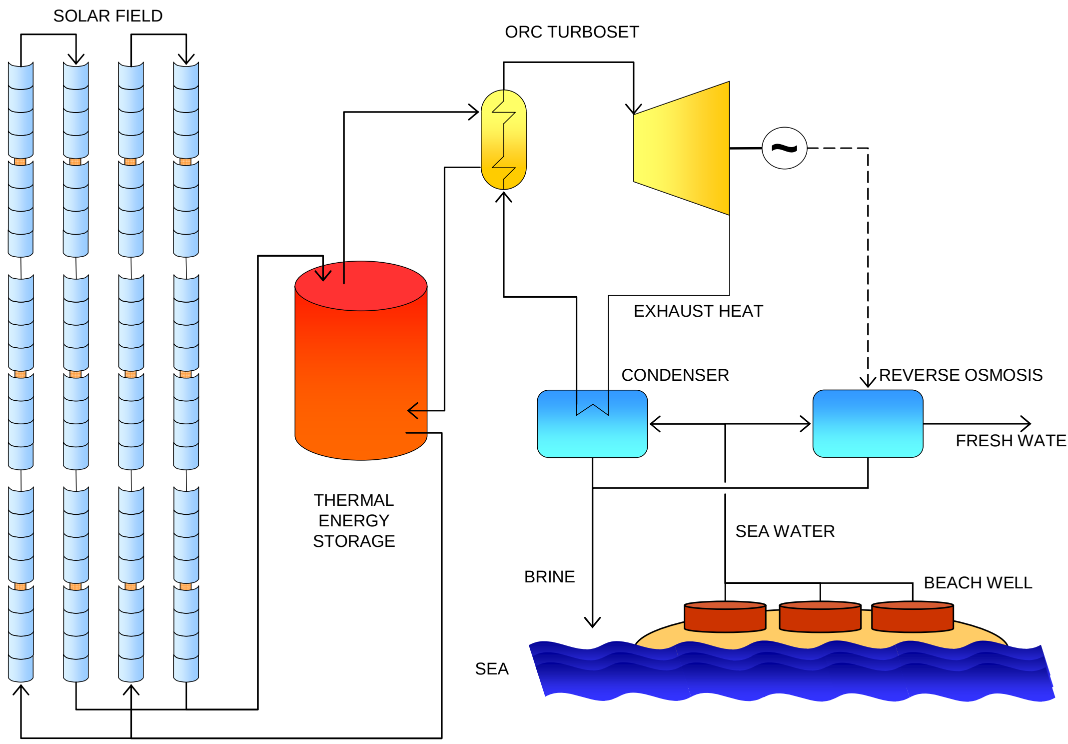


Figure 3 – 1.5 MW plant simplified flow diagram.

It is possible to individuate four functional areas of the plant: the solar field, the heat storage, the turbo-generator and the desalination system.

1 – Solar field

The solar energy is concentrated by 60 collectors and heats the fluid flowing in the receiver tubes. The fluid is heated from 290 °C up to 550 °C.

2 – Heat storage

A single tank thermal storage has the function to smooth the heat delivery to the ORC, avoiding the fluctuation due to the solar irradiation variation, and to ensure the energy necessary to the ORC turbo-set operation during the solar field outage period.

3 – Turbo-generator

The solar fluid is kept via a by-pass at a constant temperature of 320 °C and sent to the ORC pre-heater and then to the evaporator. At the evaporator outlet the solar fluid is sent back to the solar field, while the organic fluid expand in the turbine generating electricity. At the turbine outlet, the organic fluid is condensed in a sea water cooled condenser and then pumped again to the pre-heater.

4 – Desalination system

The desalination unit take out sea water from one or more beach wells, allowing a simplified sea water pre-treatment. Downstream the RO unit, the desalinated water is potabilised for next distribution.

The key data of the plant are the following:

Annual sum of DNI	kWh/m^{2}y	2 200
Annual insolation on solar field	MWh/y	74 712
Nominal electric power	MW$_e$	1.5
Annual electric production	MWh/y	5 345
Full load hours	h/y	3 297
η electrical	%	18
η conversion annual	%	7
Nitrate salts thermal energy storage		Thermocline
Full load hours energy stored	h	8.0
Number of collectors		60
Plant area	m^2	101 178
Annual reverse osmosis production	m^3/y	890 306
Annual water consumption	m^3/y	747
Net annual potable water production	m^3/y	889 559
	m^3/y	
Annual fossil fuel consumption		353
	m^3/y	

Plant 2) : large size integrated solar desalination plant

The second case consists of a large CSP solar field feeding a Rankine cycle generation set. The electricity produced by the steam turbine driven generator feed a RO desalination plant while the exhaust steam condenser heat up the first effect of a ME plant. A two tank molten salt heat storage system has been foreseen to ensure 7.0 h/day operation of the desalination plant.

In the Figure 4 is reported a schematic flow of the plant.

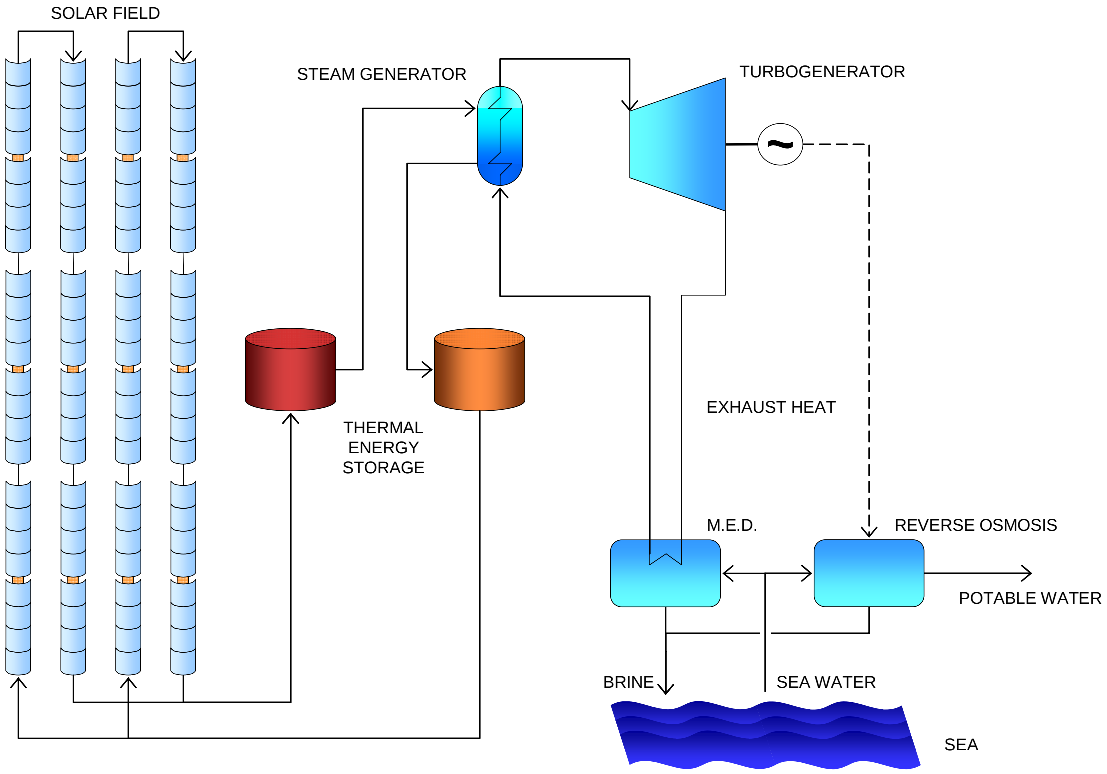


Figure 4 – 30 MW plant simplified flow diagram

It is possible to individuate four functional areas of the plant: the solar field, the heat storage, the turbo-generator and the desalination system.

1 – Solar field

The solar energy is concentrated by 468 collectors and heats the fluid flowing in the receiver tubes. The fluid is heated from 290 °C up to 550 °C.

2 – Heat storage

A two tanks thermal storage has the function to smooth the heat delivery to the ST, avoiding the fluctuation due to the solar irradiation variation, and to ensure the energy necessary to the water/steam cycle operation during solar field outage period.

3 – Turbo-generator

The solar fluid is sent to the steam generator at the maximum available temperature of 550 °C that allow to increase the Rankine cycle efficiency up to 40%. At the evaporator outlet the solar fluid is sent back to the solar field, while the steam expand in the turbine generating electricity. At the turbine outlet, the steam is condensed in the first effect of the ME plant and then pumped again to the steam generator.

4 – Desalination system

The desalination unit take out sea water from a dedicated intake and then is distributed to both RO and ME plants.

Downstream the RO and MED units, the desalinated water is potabilised for next distribution.

The key data of the plant are the following:

Annual sum of DNI	kWh/m^{2}y	2 200
Annual insolation on solar field	MWh/y	874 130
Nominal electric power	MW$_e$	30.0
Annual electric production	MWh/y	124 938
Full load hours	h/y	3 144
η electrical	%	40
η conversion annual	%	16
Nitrate salts thermal energy storage		Two tank
Full load hours energy stored	h	7.0
Number of collectors		468
Plant area	m^2	1 012 569
Annual reverse osmosis production	m^3/y	16 978 600
Annual M.E.D. production	m^3/y	1 646 474
Annual water consumption	m^3/y	5 838
Net annual potable water production	m^3/y	18 618 246
Annual fossil fuel consumption	m^3/y	2 959

Economic evaluation of the projects

The economic evaluation of the 1.5 MW plant has been based on the following parameters:

Period of operations	25	years
Freshwater price	3.00	€/m^3
Fossil fuel price	112.00	€/m^3
Employees	35	
Land cost	not considered	
Development cost	500 000	€
EPC cost	21 900 000	€
Loan interest	6.00	%
Tax on profit	35.00	%

The simplified model utilised is based on a common project financing scheme, where no incentives or subsidies have been considered for water/power production.

The total power production has been considered used for internal consumption and for water production.

The freshwater price has been considered as production cost before distribution and localised in a remote area (higher price).

The main result of the simulation of the 1.5 MW plant are here below reported:

Payback period	19	years
IRR	6.9	%
NPV	3 572 078	€

The economic evaluation of the 30 MW plant has been based on the following parameters:

Period of operations	25	years
Freshwater price	2.00	€/m^3
Fossil fuel price	112.00	€/m^3
Employees	45	
Land cost	not considered	
Development cost	500 000	€
EPC cost	235 500 000	€
Loan interest	6.00	%
Tax on profit	35.00	%

The simplified model utilised is based on a common project financing scheme, where no incentives or subsidies have been considered for water/power production.

The total power production has been considered used for internal consumption and for water production.

The freshwater price has been considered as production cost before distribution and localised in an urban area (lower price).

The main result of the simulation of the 30 MW plant are here below reported:

Payback period	19	years
IRR	7.2	%
NPV	124 336 441	€

Conclusions

The opportunities of CSP

The main advantages deriving from the use of solar energy to desalinate sea water are here below summarised:

1. avoid fuel consumption → CO_2 emission limitation;
2. wide availability of energy also in isolated areas → sustainable growth;
3. reliable solution → with also high efficiency in MENA region;
4. sustainable solution → use of fuel oil for more convenient scopes;

Middle East area project export

This kind of initiatives constitutes a real opportunity for the MENA countries, where the abundance of solar irradiation perfectly match with the increasing demand of electric power and fresh water.

In the MENA countries the conventional fuel fired cycle has been preferred in the past due to low cost and availability of liquid fuels, such as crude oil and heavy fuel oil and of sufficient space. These advantages in addition to a significant growth in electrical consumption have been the driving factors in this area for selecting conventional steam power plants. The trend in the last years toward a preservation of the environment by reducing drastically the pollution and the increased significance of the plant fuel consumption led to a re-evaluation of the use of renewable energy.

Investment analysis & future development

The results of the economical analysis carried out put in evidence the following key aspects:

1. The IRR and NPV values are at the moment positive even not attractive, but there is a wide margin of investment costs reduction, driven by the technological and production improvement of the key components, foreseeable in term of the 20%.

2. In order to reduce the impact of the desalination plant investment cost, it is advisable to utilise the desalination plant for 24 h/d, downscaling the size up to a 60%.

   To allow this continuous operation it is necessary to adopt the following configurations:

  - 1.5 MW plant: to provide an engine generator set, supplying the required power output during solar plant outage;
  - 30 MW plant: to foresee a local grid connection, supplying the required power output during solar plant outage.

In this way the water yearly produced will be kept constant, while the investment costs are drastically reduced:

  - 1.5 MW plant: reduction of solar field and desalination plant size, partially affected by the necessity to install an additional engine generator set.
  - 30 MW plant: reduction of desalination plant size and opportunity to sell the excess energy production during solar plant operation at higher price (peak load) and to buy electricity from the net for water desalination .at lower price (night operation).

In other words an adequate combination of conventional and solar energy sources will allow to find the best investment return and to generate an attractive project since now, even without public subsidies, with the possibility to scale the appropriate plant design from remote applications to industrial needs.

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