Combined water and electricity production on industrial scale in the MENA countries with concentrating solar power

Massimo Moser[a], Franz Trieb[a], Jürgen Kern[b]

[a]German Aerospace Center (DLR), Institute of Technical Thermodynamics,
Pfaffenwaldring 38-40, D-70569 Stuttgart, Germany
Tel. +49 711 6862-779; Fax +49 711 6862-747; email: massimo.moser@dlr.de
Tel. +49 711 6862-423; Fax +49 711 6862-747; email: franz.trieb@dlr.de
[b]Kernenergien – the solar power company, Olgastr. 131, D-70180 Stuttgart, Germany
Tel. +49 711 253582-0, Fax +49 711 253582-66; email: j.kern@kernenergien.de

Abstract

This paper presents some results from the EU-financed project MED-CSD in which technical and economic feasibility studies for water and power plants driven by concentrated solar power (CSP) were carried out in specific locations within selected MENA countries. On one hand desalination helps to moderate the problem of water scarcity and represents a valid alternative to overexploitation of underground water resources, on the other hand it has to face energy and environmental problems. The use of solar energy, which is typically abundant in areas affected by water scarcity, is the key for a sustainable water and power supply. Furthermore it has been shown that combined CSP-desalination plants are economically feasible and produce energy and water at a fixed and secure price, compared with the price volatility and the increasing scarcity of fossil fuels.

1. Water scarcity and desalination: substitution of a problem with another one?

Most of the MENA countries experience an increasing water demand driven by population growth and rising industrial and agricultural production. The available natural water resources are often overused or not utilized in an optimal way. The increasing water demand copes with almost constant or in some case decreasing resources, due to unsustainable water use and climate change. As shown in figure 1, in the MENA region the gap between natural water resources (top of blue area) and water demand (top line) is expected to enlarge in the next years [1]. A strategy to develop a sustainable water supply consists in adopting several parallel countermeasures, among them the increase of efficiency in irrigation (drip systems, precision sprinklers) and in municipal water distribution, use of water non-intensive crops [1][8], water cleaning and re-use. But even if all these measures are applied, reaching an optimistic general efficiency in the water end use (see shaded and green areas in figure 1), anyway a water deficit will be present in the MENA region considered as a whole. The two red time lines in figure 1 show that it is important to start now to plan alternatives in order to initiate a structural change in the water supply sector. The decade between 2010 and 2020 is crucial not only for the reached results, but for the preparation and expansion of the necessary production capacities [2].

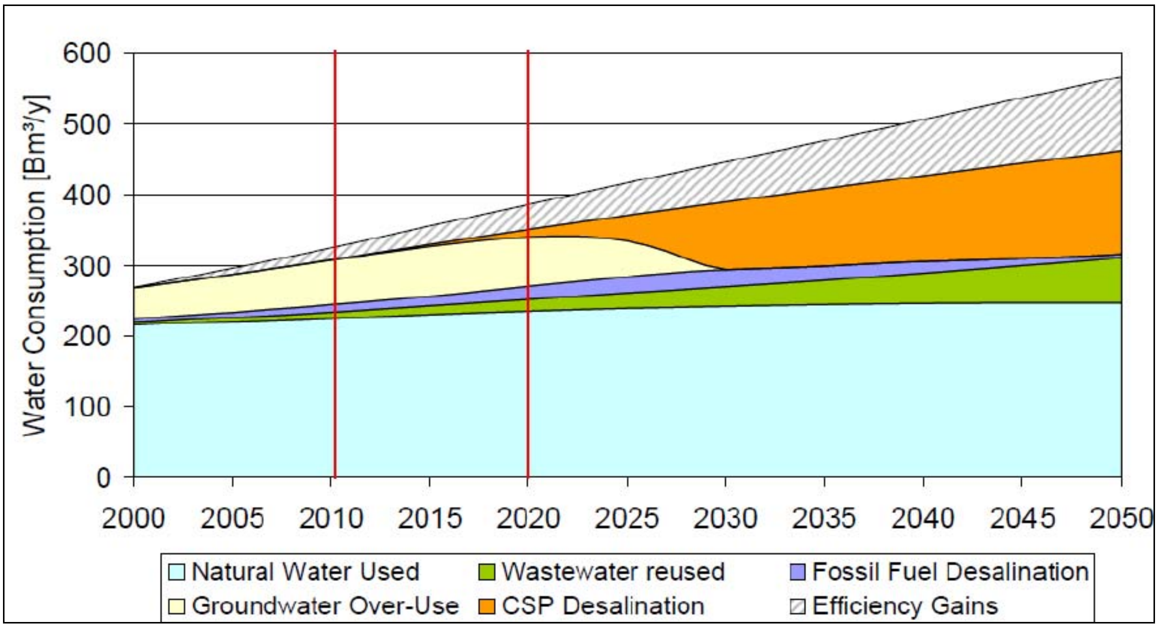


Figure 1: Water demand scenario for MENA until 2050 and coverage of demand by sustainable sources, by unsustainable sources and by solar desalination [1]

The gap between water demand and natural water is covered at the moment by groundwater overuse and desalination driven by fossil fuels, but none of these solutions is sustainable. In most of the MENA countries the overexploitation of underground water resources is a common solution to get potable water (see crème area in figure 1). This practice presents several negative consequences: due to the difference between extraction and replenishment ratio of the aquifer, the water level sinks, contributing to dry out oases and other green areas. Furthermore, the groundwater overuse near the coast leads to saltwater intrusion in the aquifer, making it useless. This is what just happened in Gaza, where now the cost of drinking water delivered by trucks reaches 8-10 $\$/m^3$. On the other hand, desalination is affected by energetically and environmental problems, as summarized in Table 1.

Problem	Negative impact
High energy consumption	Increased and unknown operation cost, availability of competitive fossil fuel in the future
Water intake design	Entrainment of organisms, chemical pre-treatment necessary
Greenhouse gases emission	Contribution to climate change
Brine discharge	Presence of chemicals for water treatment, high salinity. In the case of thermal desalination higher seawater temperature. Local degradation of the marine environment

Table 1: Overview of energetic and environmental problems of desalination driven by fossil fuels

In the following we will focus our attention on the energy problem. In particular we want to show how it is possible to get dispatchable (time-independent available) and relatively inexpensive energy for desalination from renewable energy. The known problem of renewable energy sources is that they all vary in the time on different time scales (daily and seasonal variations). This characteristic conflicts with the constant energy requirement of desalination plants, which are operated optimally at constant load, despite a partial load operation is possible in certain ranges. Given these boundary conditions, the key of the dispatchability of renewable energies is the option of energy storage. Concentrating solar power (CSP) - in contrast to other renewables like photovoltaic (PV) and wind power - offers proven thermal energy storage, together with the option of hybrid operation with fossil fuels in one single plant, thus contributing to stabilize the electricity grid. Nevertheless, our aim is not to propose CSP as exclusive solution on the energetic and water problem. On the contrary, a reasonable solution will be a well-integrated mix of different renewable energy resources.

2. The MED-CSD project

The MED-CSD project is funded by the European Commission - DG Research under the 7th Framework Programme (FP7). The project takes benefit from the results of past and on-going studies [1][4][5]. The main objective of the project is to carry out feasibility studies of water and power plants based on the combination of CSP and seawater desalination in the Mediterranean region. The feasibility studies are performed in selected locations in Cyprus, Egypt, Italy (island), Morocco and Palestine, for a total of 10 locations. For each location 4 configurations are analyzed: 2 types of solar field (parabolic trough (PT) and Linear Fresnel Reflector (LFR) [5]) and 2 types of desalination (multiple effect distillation (MED) and reverse osmosis (RO)) are taken into consideration. In some sites like MOR2, which is a site far from the seashore, the MED doesn't make sense, so this configuration is not analyzed in this particular case.

The principle of CSP consists in using a reflective surface - in form of a parabola or a series of rectangular mirrors - that concentrate the direct normal solar irradiation (DNI) towards a receiver tube which contains a heat transfer fluid (HTF). Because CSP uses only the share of the radiation coming directly from the sun, the mirrors have to track the sun during the day. The thermal energy recovered by the fluid loop is then passed to the water/steam loop via heat exchangers, where electricity is generated in a conventional steam power cycle (Rankine cycle). Surplus energy from the solar field can be stored in the thermal energy storage and delivered to the turbine with the required time delay. A part of the thermal waste energy from the turbine can be also utilized to drive other processes like thermal desalination (option 1). In this case, the MED serves also as condenser. The hot water tank between turbine and thermal desalination has the function to reduce the fluctuations of the available heat to the MED, thus stabilizing the water production to an almost constant value (figure 2).

In alternative, the produced electricity can be then partially or totally utilized to feed a RO system (option 2). In this case, the turbine cooling is provided by a dry cooling system (figure 3).

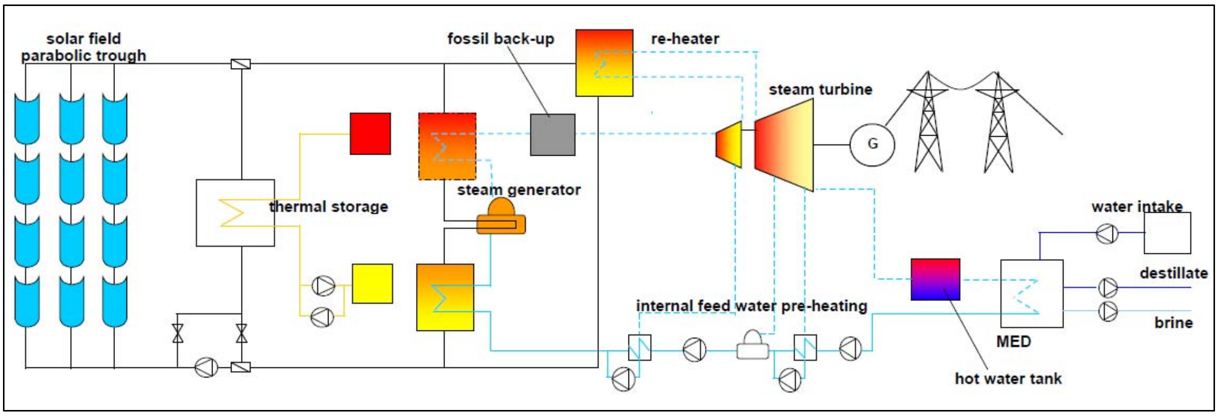


Figure 2: Scheme of PT-MED configuration

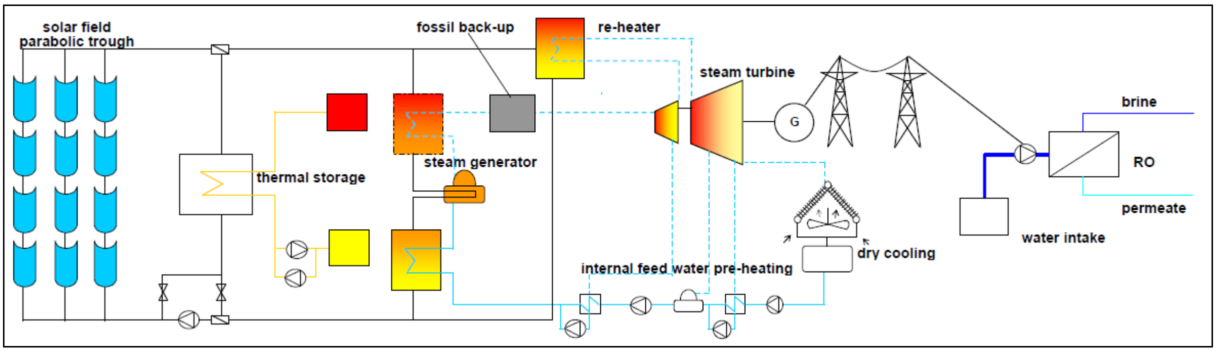


Figure 3: Scheme of PT-RO configuration

Beyond that, each of the 4 configurations is calculated with 2 different DNI models, in order to appreciate the weight of the uncertainty of the solar resources (due essentially to different aerosol models). This is a very sensitive parameter, because the DNI influences design as well as yearly equivalent full load hours of the plant (and therefore also investment and additional fossil fuel costs). For a given location, the differences between the 2 DNI models reach values between 166 and 548 *kWh/m²/year* (figure 4).

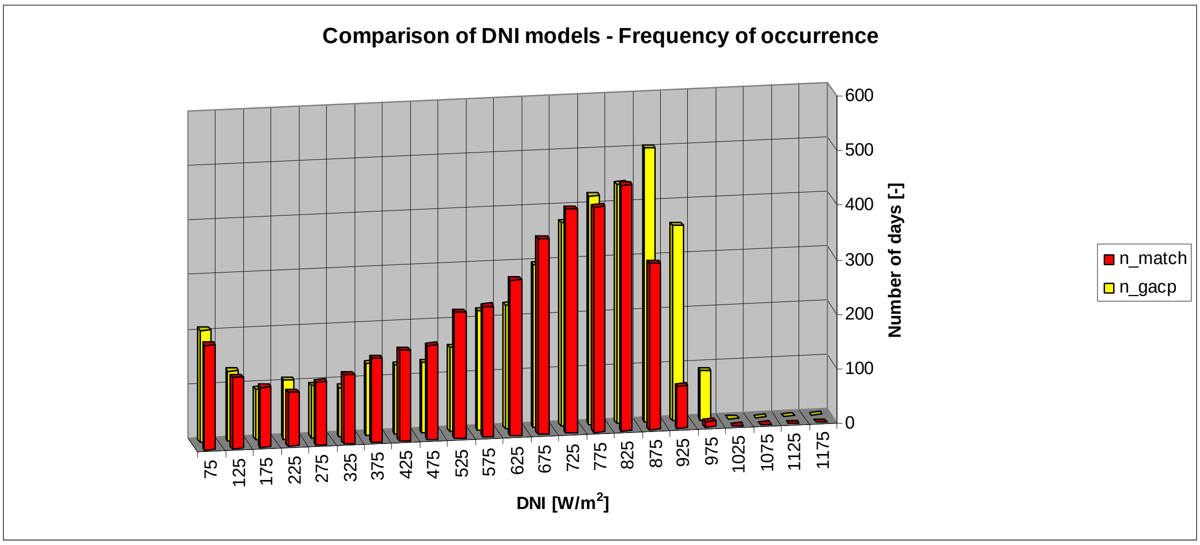


Figure 4: Comparison of the 2 used DNI models (example: Safaga - EGY2)

In the end, 10 locations were simulated with 4 different layouts and 2 DNI models, for a total of 72 model runs. In order to guarantee a high degree of comparability, all plants have almost the same storage and collector size and have to cover the same electricity and water demand. The results show only small differences in the total electricity and water production. One of the most important results of the technical model is the amount of fossil fuel that is used in order to cover the electricity demand when neither solar field nor storage delivers enough energy to the steam turbine.

3. Technical model

The technical analysis is carried out with INSEL v8 [6]. The performed analysis is based on yearly simulation of the plant with hourly resolution. The first information needed by the model is the time (figure 5). Once the time is defined, the input data are read from *.txt* files. The most important required data are direct normal irradiation (DNI), ambient temperature, wind velocity and electricity demand. The time serves also as input for the calculation of the position of the sun. At this point, all required inputs for the solar field are given. In this block the most important result is the amount of collected heat, which results from a detailed heat balance between incoming radiation and thermal losses of the collector field.

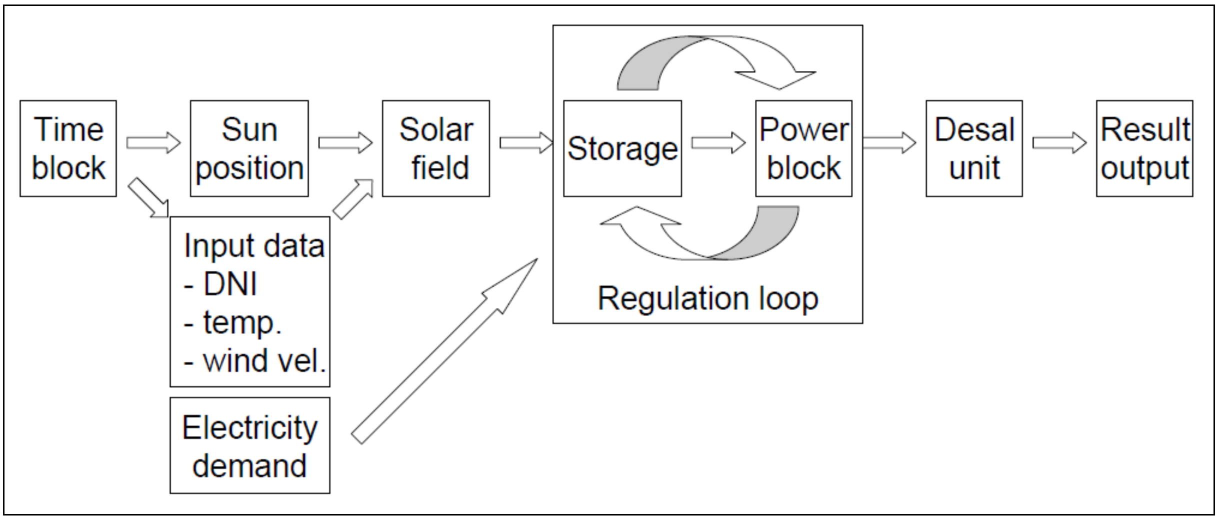


Figure 5: Scheme of the general model structure

In the following of the calculation, the information coming from the solar field flows together with the electricity demand in a regulation loop, which includes the thermal storage, the power block and the fossil fuel back-up. If the solar field produces more energy than required from the turbine, the required energy is delivered to the turbine and the surplus is stored in the thermal energy storage. If the solar field doesn’t produce enough energy, first is checked if the storage still contains energy and - if this conditions is fulfilled - the storage is discharged. If the storage is already completely discharged, the gap between the energy coming from the solar field and the thermal energy required by the turbine is covered by the fossil fuel back-up. In some cases - namely at night and under bad weather conditions - the required energy is delivered totally by the fossil co-firing. The regulation loop is required because the turbine has not only to satisfy the electricity demand, but has also to cover the parasitic from the solar field (i.e. internal electricity consumption due to pumping of the HTF and sun tracking), storage, turbine itself and desalination. The problem is that the values of the parasitics vary every hour and they are not known at the moment of the calculation. Therefore a loop is necessary to meet the desired net electricity production. In the power block the most important result is the net electricity generation. The last block of the plant is the desalination unit. This block needs as input information about seawater temperature and salinity. In the case of the MED, the thermal flux from the hot water tank is also required as information. As last step, the most important results of the simulation are printed in a text file.

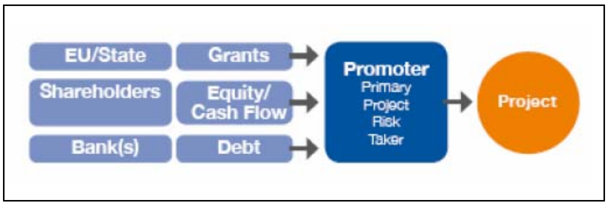
4. Economic model

The results from the design and from the yearly simulation of the technical model serve as input for the economic model. The most relevant economic parameters are land area requirement, plant design (dimensions of solar field, storage, turbine and desalination) with the relative capital expenditures (CAPEX), net electricity and water production and yearly fuel consumption. The results used for the economic model base on the "optimistic" DNI model (GACP). Other inputs are the Engineering, Procurement and Construction cost (EPC), including purchase prices, land cost and civil work. Finally, financial inputs like equity rate of return, debt interest rate, local inflation rate, duration of construction and operating and maintenance costs are included basing on estimations from key partners.

The profitability of a project can be seen from different points of view:

- in the corporate finance (or promoter finance) model, the project is considered as a whole, taking into account all the funds (loan and equity) and all the cash flows during the operating life. Those cash flows are then discounted with the Weighted Average Cost of Capital after tax (WACC), which represents the weighted cost of both debt and equity.
- On the other hand, the priority order dictates that banks must be serviced before the shareholders. This means that the cash flows are primarily addressed to banks before being distributed as dividends, what is essential in the investor's point of view (project finance). In this case the profitability is given by the net present value (NPV) and the internal rate of return (IRR) calculated on the delivered dividends basis. The NPV is defined as the sum in the time of the future cash flows, which in this case are discounted with the minimum equity rate of return for investor's considerations [7]. A positive NPV means that the investment will cause gains for the firm, and therefore the project should be accepted. The project could be accepted also for a NPV = 0; in this case the firm doesn't gain nor loose money, but the shareholders can obtain the required rate of returns.

Figure 6 shows the differences between the 2 finance models: the corporate finance presents a relative high share of equity (ca. 60 %) and a relative lower equity return rate (e.g. 13 %). This structure applies for relatively small projects (typically basic or applied research). In the project finance model the sponsors create a legally independent company in which they are the most important shareholders. The debt share is typically around 60 % - 70 % and due to the more pronounced risk the shareholders claim higher minimum return (e.g. 17 %). The financing model has an important impact on the project feasibility.



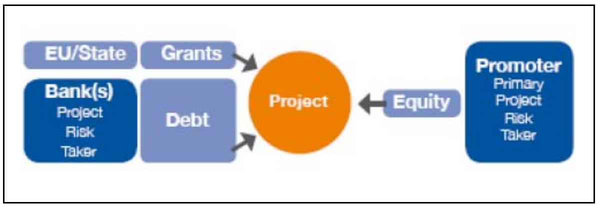


Figure 6: Project financing schemes: promoter finance (left) and project finance (right) [9]

5. Results and discussion

Technical Results

In figures 7 and 8 are represented the most interesting results of the simulation: net electricity production (black line), water production (blue line) and stored heat in the molten salt tanks (red line). A compared analysis of electricity production and DNI (yellow line) shows that the demand is covered at every time, also at days with bad direct solar irradiation, like day 2 in figure 8, which represents a sample winter case. The electricity demand can be always satisfied because of the hybridisation. The storage is charged on sunny days and allows for reduction of fossil fuel consumption and solar operation also in the evening and in summer even in the night. In the case of the MED, due to the presence of the hot water tank (low temperature energy storage), the water production can be kept almost constant, in spite of the fluctuating waste heat coming from the turbine.

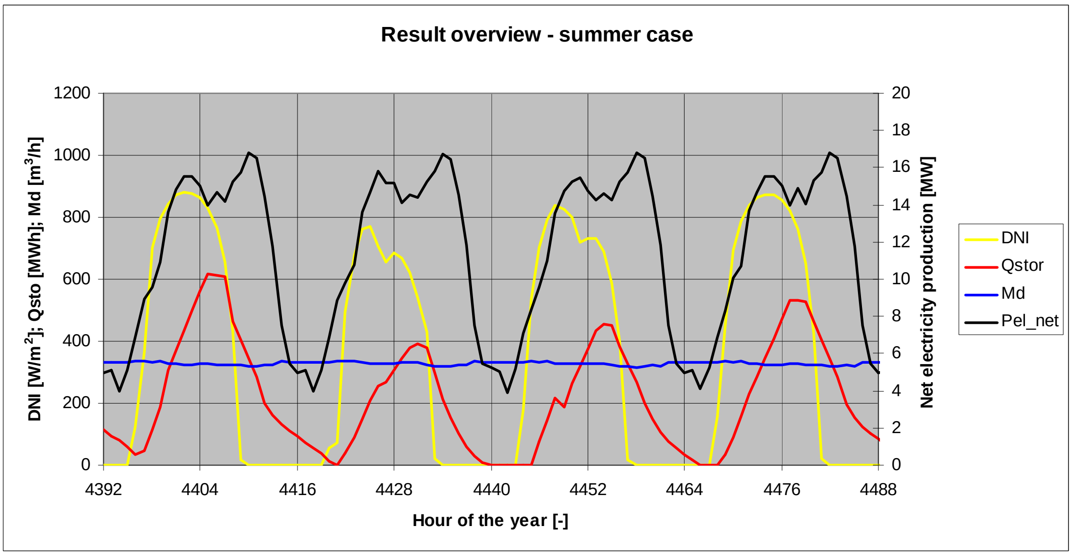


Figure 7: Result overview for 4 sample summer days (EGY2 – GACP/PT/MED)

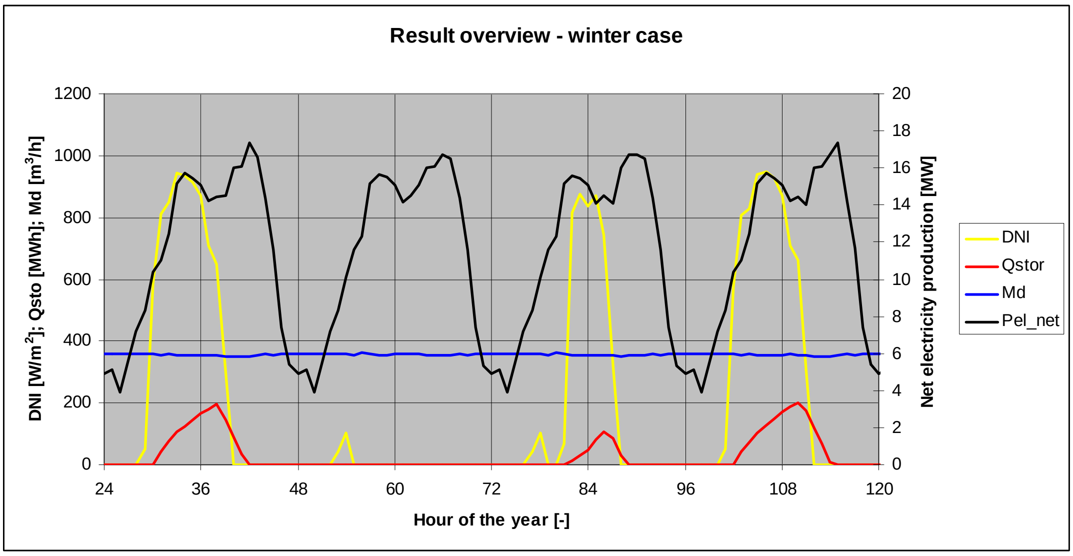


Figure 8: Result overview for 4 sample winter days (EGY2 – GACP/PT/MED)

Concerning the plant design, an analysis among the simulated locations shows that (Table 2):

- The salinity of the seawater influences the internal electrical consumption of the RO; this has an influence on the dimensions of the solar field and of the turbine. Locations with lower salinity like Tan-Tan (MOR1) will be characterised by lower total investment cost in comparison to sites where the salinity is much higher (e.g. Safaga – EGY2).

- The cooling system in the RO-case is a dry-cooling; the design ambient temperature plays here a very important role, since it defines the efficiency of the turbine and in the end the dimension of the solar field (SF). Higher ambient temperatures lead to smaller efficiency and higher investment for the turbine and the SF.

- The MED has a quite stable behaviour, since in this case the design condenser temperature is fixed (80 *°C* and 65 *°C*, depending on the thermal load from the turbine). For this reason the solar field size does not depend on the location. In addition, the internal electrical consumption of the thermal desalination is not influenced by the salinity.

- The solar field for the RO is in the most cases larger than for the MED. This could look strange at first sight, but the higher electrical consumption of the RO overcompensates in most cases the lower thermal efficiency of the turbine of the MED-case.

A particular case is M'sied (MOR2), which has - as inland desert location - a very high design ambient temperature (Table 2). Furthermore, currently there isn't an adequate electrical grid between CSP-plant and desalination site on the coast. It has also been estimated that an eventual additional electrical interconnection would cause the loss of 5 % of the produced electricity, so that the plant in this case is over-dimensioned in order to cover these losses. In the end, the effects of high temperature and electricity losses result in a 10 % higher solar field area.

Cyprus		Trough (SKAL-ET 150)				Fresnel (NOVA1-Oil)			
Site		CYP1 Larnaca		CYP2 Pentakomo		CYP1 Larnaca		CYP2 Pentakomo	
DNI	*kWh/(m²a)*	2,173		2,220		2,173		2,220	
Seawater salinity	*ppm*	38,000		38,000		38,000		38,000	
Desalination technology		MED	RO	MED	RO	MED	RO	MED	RO
Solar field area	*m²*	217,998	224,604	217,998	224,604	312,780	320,800	312,780	316,790
Water production	*Mm³/a*	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07
Power nominal capacity	*MW*	20.6	22.1	20.6	22.0	20.5	21.9	20.5	21.9
Total full load hours	*h*	5,197	5,212	5,206	5,232	5,177	5,208	5,187	5,221
Solar full load hours	*h*	2,904	3,015	2,993	3,104	2,822	2,930	2,912	3,010
Egypt		Trough (SKAL-ET 150)				Fresnel (NOVA1-Oil)			
Site		EGY1 Matruh		EGY2 Safaga		EGY1 Matruh		EGY2 Safaga	
DNI	*kWh/(m²a)*	2,147		2,669		2,147		2,669	
Seawater salinity	*ppm*	38,000		40,500		38,000		40,500	
Desalination technology		MED	RO	MED	RO	MED	RO	MED	RO
Solar field area	*m²*	217,998	221,301	217,998	227,907	312,780	308,770	312,780	308,770
Water production	*Mm³/a*	3.07	3.07	2.98	2.98	3.07	3.07	2.98	2.98
Power nominal capacity	*MW*	20.6	22.0	20.6	22.1	20.6	21.9	20.5	21.9
Total full load hours	*h*	5,188	5,213	5,277	5,331	5,154	5,192	5,251	5,293
Solar full load hours	*h*	2,916	3,005	3,743	3,907	2,936	2,979	3,700	3,765
Italy		Trough (SKAL-ET 150)				Fresnel (NOVA1-Oil)			
Site		ITA1 Lampedusa		ITA2 Pantelleria		ITA1 Lampedusa		ITA2 Pantelleria	
DNI	*kWh/(m²a)*	2,123		1,970		2,123		1,970	
Seawater salinity	*ppm*	38,000		38,000		38,000		38,000	
Desalination technology		MED	RO	MED	RO	MED	RO	MED	RO
Solar field area	*m²*	217,998	221,301	217,998	224,604	312,780	312,780	312,780	320,800
Water production	*Mm³/a*	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14
Power nominal capacity	*MW*	20.3	21.9	20.5	21.8	20.6	22.0	20.6	22.0
Total full load hours	*h*	5,256	5,236	5,190	5,229	5,139	5,170	5,120	5,141
Solar full load hours	*h*	2,746	2,813	2,503	2,627	2,607	2,680	2,378	2,480
Morocco		Trough (SKAL-ET 150)				Fresnel (NOVA1-Oil)			
Site		MOR1 Tan-Tan		MOR2 M'sied		MOR1 Tan-Tan		MOR2 M'sied	
DNI	*kWh/(m²a)*	1,978		2,692		1,978		2,692	
Seawater salinity	*ppm*	35,000		35,000		35,000		35,000	
Desalination technology		MED	RO	MED	RO	MED	RO	MED	RO
Solar field area	*m²*	217,998	221,301	217,998	247,725	312,780	300,750	312,780	328,820
Water production	*Mm³/a*	3.18	3.18	3.16	3.16	3.18	3.18	3.16	3.16
Power nominal capacity	*MW*	20.6	21.9	20.6	22.4	20.6	22.2	21.0	23.4
Total full load hours	*h*	5,174	5,208	5,559	5,573	5,131	5,078	5,385	5,232
Solar full load hours	*h*	2,505	2,589	3,874	4,023	2,439	2,396	3,530	3,585
Palestine		Trough (SKAL-ET 150)				Fresnel (NOVA1-Oil)			
Site		PAL1 Gaza		Pal2 West Bank		PAL1 Gaza		Pal2 West Bank	
DNI	*kWh/(m²a)*	2,189		2,208		2,189		2,208	
Seawater salinity	*ppm*	38,000		15,000		38,000		15,000	
Desalination technology		MED	RO	MED	RO	MED	RO	MED	RO
Solar field area	*m²*	217,998	224,604	217,998	231,210	312,780	312,780	312,780	320,800
Water production	*Mm³/a*	3.07	3.07	3.35	3.35	3.07	3.07	3.35	3.35
Power nominal capacity	*MW*	20.6	22.1	20.8	21.9	20.5	21.9	20.7	21.6
Total full load hours	*h*	5,196	5,218	5,218	5,172	5,194	5,227	5,212	5,183
Solar full load hours	*h*	3,056	3,189	3,048	3,216	3,081	3,160	2,996	3,131

Table 2: Extract from the result's overview of the technical model

Another particular case is West Bank (PAL2), where - despite the high design ambient temperature - the solar field is only 3 % larger than in the reference case. This is due to the fact that the water to be desalinated is brackish water (salinity = 15,000 *ppm*) and the electrical consumption for the RO is much lower than for typical seawater salinity (38,000 *ppm* for the Mediterranean Sea).

The equivalent solar full load hours are among the most relevant results. They are calculated simply by dividing the yearly amount of produced electricity by the nominal capacity. They depend on the yearly sum of DNI and to a lesser extent on the design of the solar field. The results show that there is an almost linear relation between the DNI and the solar full load hours, so EGY2 and MOR2 are the best locations from this point of view. Another way to rise the solar full load hours and to consequently reduce the fossil fuel consumption is to increase the solar multiple (dimension of solar field and storage). This option is not taken into account in the MED-CSD project.

Economic results

Considering the corporate finance model, in some locations all proposed configurations reach the profitability, while in other cases only the best configurations present a positive NPV. Figure 9 shows the break-even lines (lines corresponding to a NPV equal to 0). On the x-axis is represented the levelized electricity cost (LEC, [*€/MWh*]), on the y-axis the levelized water cost (LWC, [$€/m^3$]). It can be intuitively understood that - for a given NPV - high LWC corresponds to low LEC and vice versa. The slope of the line array is the same, but the different configurations have a different interception point on the x and y axis. The lower the value of the intercept, the higher is the attractiveness of the project. The blue and the orange lines represent the maximal prices that a utility would pay for the produced water and electricity, respectively. These prices are higher than the ones paid by consumers, because in most of the MENA countries these prices are subsidized. As a result, blue and orange lines divide the diagram in 4 quadrants. If a result line has one or more points within the first quadrant (bottom, left), then this configuration generates profit. If a configuration doesn't have any point in the first quadrant, a grant or a higher tariff are necessary to reach the minimum feasibility point, which is the interception of blue and orange lines (green line).

Considering now the project finance model (private investor point of view – red line), without incentives like grants or specific feed-in tariffs, none of the proposed projects presents a positive NPV. However in Italy, where feed-in tariffs are assumed in the model, just a small grant is still required, whereat few adjustments in the input parameters could lead the project to breakeven without any grant. In the purpose of making a project profitable, the available options are to add grants, to benefit from feed-in tariffs for water and electricity (public policies or private contracts) or to negotiate from bankers and investors a lower cost of capital. Palestine, Egypt and Morocco are actually more likely to benefit from a grant and/or a debt with an attractive interest rate than European countries (Cyprus, Italy) which have yet attractive feed-in tariffs. As regard to equity rate of return, the more risky the country is, the higher the rate will become. In some regions of Egypt or Palestine, it is actually difficult to make the project profitable from the investor point of view, mainly because of high values of equity return (from 15% to 20% in the model assumptions). At last, it is also interesting to increase the share of debt among the total capital required because its cost is cheaper than the cost of equity [7].

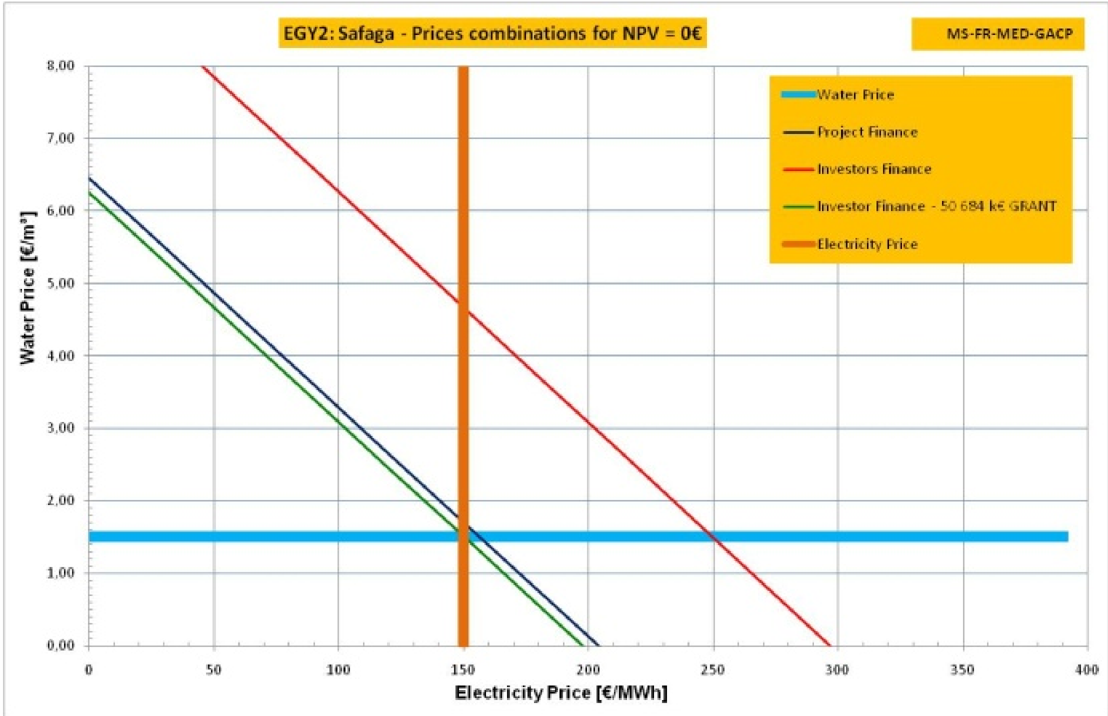


Figure 9: Project break-even lines as function of LEC and finance model

6. Conclusions and outlook

The actual water supply in most of the MENA countries, basing on groundwater overexploitation and desalination driven by fossil fuels is not sustainable. Particularly severe negative consequences are salt water intrusion in coastal areas and falling groundwater levels due to intensive pumping. In order to mitigate this problem several measures have to be taken as soon as possible. Management and efficient use of water, enhanced distribution and irrigation systems and reuse of wastewater are important measures for sustainability, but they will be able to avoid only a part of the long-term deficit of the MENA region.

Due to energy storage and hybrid operation with fossil fuel, concentrating solar power (CSP) plants can provide sustainable and dispatchable energy which is suitable for industrial scale desalination either by thermal or membrane processes. In the case of plants producing combined water and power, the adding of a hot water tank between turbine and thermal desalination unit allows reaching an almost constant water production in spite of a fluctuating electricity demand profile. The option of dry cooling makes possible to produce electricity also in desert locations, which typically offer best solar conditions. The electricity can be transported to the coastal regions and used to drive membrane desalination.

In the end, the techno-economic results of the MED-CSD project show that if on one side the technologies to build a sustainable alternative are available and proven, on the other side - depending on the financing boundary conditions - the construction of combined power and water plants requires adequate economic conditions like feed-in tariffs or grants in order to attract investors. More and more realized demonstration plants will highlight the technical and economical appeal of this multi-purpose solar power and water solution.

References

[1] Trieb, F., Gehrung, J., Viebahn, P., Schillings, C., Hoyer-Click, C., Kern, J., 2007 “AQUA-CSP: Concentrating Solar Power for Seawater Desalination”, German Aerospace Center (DLR), Study for the German Ministry of Environment, Nature Conservation and Nuclear Safety, November 2007, Stuttgart, http://www.dlr.de/tt/Portaldata/41/Resources/dokumente/institut/system/projects/aqua-csp/AQUA-CSP-Full-Report-Final.pdf

[2] Trieb, F., Müller-Steinhagen, H., Concentrating solar power for seawater desalination in the Middle East and North Africa, Desalination, 220 (2008), 165-183

[3] Trieb, F., Schillings, C., Kronshage, S., Viebahn, P., May, N., Paul, C., Klann, U., Kabariti, M., Bennouna, A., Nokraschy, H., Hassan, S., Georgy Yussef, L., Hasni, T., Bassam, N., Satoguina, H., 2005, “MED-CSP: Concentrating Solar Power for the Mediterranean Region”, German Aerospace Center (DLR), Study for the German Ministry of Environment, Nature Conservation and Nuclear Safety, Stuttgart, http://www.dlr.de/tt/desktopdefault.aspx/tabid-2885/4422_read-6575/

[4] Trieb, F., Schillings, C., Kronshage, S., Viebahn, P., May, N., Paul, C., Klann, U., Kabariti, M., Bennouna, A., Nokraschy, H., Hassan, S., Georgy Yussef, L., Hasni, T., Bassam, N., Satoguina, H., 2006, “TRANS-CSP: Trans-Mediterranean Interconnection for Concentrating Solar Power”, German Aerospace Center (DLR), Study for the German Ministry of Environment, Nature Conservation and Nuclear Safety, Stuttgart, http://www.dlr.de/tt/desktopdefault.aspx/tabid-2885/4422_read-6588/

[5] Trieb, F., Müller-Steinhagen, H., Kern, J., Scharfe, J., Kabariti, M., Al Taher, A., Technologies for large scale seawater desalination using concentrated solar radiation, Desalination, 235 (2009), 33-43

[6] [Online] 2010, [Cited: 13.07.2010], http://www.insel.eu/

[7] MED-CSD Final Report, D2.1, “Methodology and main results of the economic and financial pre-feasibility studies of CSP plants with thermal storage coupled to desalination unit”

[8] Mimi, Z.A., Jamous, S.A., Climate change and agricultural water demand: Impacts and adaptations, African Journal of Environmental Science and Technology, 4 (2010), 183-191

[9] EIB, “Funding CSP projects – The EIB’s view”, [Online] 2010, [Cited: 20.07.2010], http://ec.europa.eu/energy/res/events/doc/cervino_eib.pdf