THE MED-CSD PROJECT: POTENTIAL FOR CSP DESALINATION DEVELOPMENT IN MEDITERRANEAN COUNTRIES

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Abstract

Within the MED-CSD project feasibility studies of integrated hybrid Concentrating Solar Power (CSP) and Seawater Desalination (SD) plants were carried out in selected Mediterranean countries (Morocco, Italy, Cyprus, Palestinian National Authority and Egypt). After a review on CSP and desalination technologies, 10 typical locations within the 5 partner countries have been selected. For every location a CSP-desalination plant was modelled. The model bases on hourly time series of solar irradiance, ambient temperature and wind speed and includes local seasonal and hourly load curves for power and water. Surplus energy from the solar field is fed into thermal energy storage, so that operation is possible at night and during cloud transients; gaps between demand and solar power production are covered by co-firing with fossil fuel. Different plant configurations (solar field type, desalination technology) have been compared. In the subsequent step the results of the technical model have been evaluated in a techno-economic model to analyze the economic feasibility and the required financial frame conditions of the projects. Furthermore, an analysis of the market potential of concentrating solar power for sea water desalination in the Mediterranean Region and socio-economic and environmental impact analysis were implemented.

Keywords: concentrating solar power, desalination, solar energy, Mediterranean countries

1. Motivation

Water is the basic commodity for life. Its inhomogeneous distribution on earth in quality and quantity influences human behaviour and in some region of the world its scarcity or its bad quality represents a severe limitation to human life. In some cases like in MENA, water scarcity, increasing water demand and dated water supply systems lead to short-term solutions in order to satisfy the demand of drinking water (e.g. groundwater overuse). In this way it is possible to momentary fill the gap between the increasing water demand and the almost constant available water resources, but this practice is not sustainable because it leads to falling groundwater levels (with consequent drying out of oasis) and salt water intrusion in shore areas. A feasible alternative to this usage is represented by seawater desalination, which however is characterized by high energy consumption (membrane systems uses only electricity, evaporation desalination technologies needs both electricity and heat) and negative environmental impacts (entrainment of marine organisms in the water intake, presence of chemicals in the brine, greenhouse gases emissions). Therefore new desalination capacities should be built taking into account these considerations and looking for sustainable solutions.

An obvious characteristic of most water scarce areas is that they are typically sunny regions. From there the idea to find the solution of the problem in its cause: the sun. In the last decades several technologies and concepts have been developed to transform solar irradiation into heat and electricity. In particular CSP -with the option of thermal storage and hybridisation- allows guaranteeing a flexible operation of power and desalination plants. Despite these encouraging aspects, up to now no integrated power and desalination plant has been constructed. Furthermore, the coupling of CSP and desalination can be seen as an efficiency reduction of the plant (electricity consumption of the RO, minor turbine efficiency in the case of the MED, due to higher steam condensation temperature in the power block). Finally, solar energy and renewable energy sources in general are typically time-fluctuating resources, while desalination plants require almost constant operation, even if they can also work in partial load.

The MED-CSD project deals with these issues and proposes the coupling of CSP and desalination as a feasible and efficient solution, able to produce secure and sustainable water and power in the MENA region [1, final report].

2. MED-CSD Introduction

The MED-CSD is an EU-funded project aimed to carry out feasibility studies of combined CSP and desalination plants in the Mediterranean region. 10 locations have been selected within five countries (Cyprus, Egypt, Italy (island sites), Morocco, and Palestinian National Authority). The first step was a complete review of CSP and desalination technologies, with the aim of choosing representative plant configurations. Location specific input data have been collected. The heart of the project was the implementation of a comprehensive technical and financial methodology to carry out the feasibility study. In parallel, an assessment of water demand and deficit as well as of electricity demand scenario has been conducted for each country. Basing on the results of the techno-economic models, markets potential scenarios for CSP desalination have been performed. In the last step the socio-economic impacts of broad dissemination of CSP water desalination has been described.

3. Technology review and selection of configurations

The aim of the first work package was a technology review for concentrating solar power and desalination technologies, in order to pick out the most representative technologies and the most adapted CSP-desalination combinations. Regarding CSP, 4 technologies were considered in the pre-selection: parabolic trough (PT), linear Fresnel reflector (FR), solar tower and dish Stirling. Table 1 shows that in principle all technologies can be used for electricity generation and can be coupled to desalination systems. Nevertheless, at present the maturity of point concentrating systems is not as high as that of line concentrating systems, and in particular of parabolic trough (figure 1).

Technology		Parabolic Trough	Linear Fresnel	Solar Tower	Dish Stirling
Concentration ratio	-	50-90	35-170	600-1000	<3000
Land use factor	%	25-40	60-80	20-25	20-25
Capacity Range	MW	10-200	5-200	10-100	0.1-1
Installed capacity	MW	480	2	10	trials
Max Temperature	°C	400	400	565	900
Annual efficiency	%	10-16	8-12	10-16	16-29
Storage options		Molten Salt, concrete, PCM	Molten Salt, concrete, PCM	Molten Salt, concrete, PCM	-
Advantages		Long term reliable system, proven storage option	Simple structure and easy field construction, tolerance for slight slopes, DSG proven, lower investment cost, low water consumption for cleaning	High efficiency in the power cycle, slope tolerant system	High efficiency in the power cycle, land slope independent, high modularity
Disadvantages		Limited HTF temperature, high required precision during construction, requirement of flat area, high water requirement for cleaning	Lower optical efficiency, PCM storage is still under development	High maintenance and equipment cost	Not commercially proven, high complexity

Table 1: Comparison of solar thermal power technologies

Up to now, line concentrating systems have clear advantages in comparison to point concentrating technologies due to lower cost, less material demand and simpler construction. Dish Stirling was excluded also because its typical capacity range is clearly below the project requirements (power and water on large scale). In spite of the lower optical efficiency, the Linear Fresnel Reflector represents an interesting option due to the simple structure and to the low water requirement for mirror cleaning. The elevate land use factor provides positive side-effects like high degree of shading below the mirrors, offering the opportunity to use the land for agricultural (figure 2) or other purposes.

Figure 1: Parabolic trough
Figure 2: Linear Fresnel reflector (Source: Solarmundo, greenhouse visualisation by DLR)

In the end, parabolic trough and linear Fresnel reflectors were selected. Concerning the linear Fresnel reflector, a modified design (with synthetic oil in spite of direct steam generation) was chosen. This choice is due to the fact that up to now there isn’t any commercial storage technology suited for the direct steam generation (phase change material (PCM) is still under development). The option of concrete storage was not taken into consideration because there is still not enough experience about the durability of this type of storage. Nevertheless, concrete storage represents definitely an interesting option for the near future. With respect to desalination, potable water can be produced with evaporation or membrane processes, and using thermal and/or electrical energy as driving force. The technologies which can be adopted for industrial scale purposes are different types of evaporation processes (MSF, MED, MED-TVC, MED-MVC) and membrane processes (RO). The mentioned technologies are compared in table 2.

		MED	MSF	MED-TVC	MVC	RO
Raw water quality	-	not critical	not critical	not critical	not critical	very specific pre-treatment
Filter mesh	*mm*	3	3	3	3	<50 *µm*
Distillate quality	*ppm*	<10	<10	<10	<10	stage 1: <300 stage 2: <50
Heat consumption	*kWh/t*	60-100	60-100	50-100	0	0
Heat temperature	*°C*	65-80	120	150	-	-
Power consumption	*kWh/t*	<0.6	3-4	<0.6	8-10	3-6
Maintenance cost	-	low	low	low	low	medium

Table 2: Comparison of desalination technologies (Source: INVEN)

Thermal desalination is ideal for co-generation, because it uses the waste heat coming from the turbine and it allows saving the cost of the condenser. The electrical consumption of these systems is typically low. On the other hand, the relative high required temperatures (70 °C - 150 °C) lead to a reduction of electrical efficiency. Multi stage flash (MSF) represented in the past decades the dominating desalination technology and spread particularly in the Gulf Region. MED (figure 3) is a more recent technology gaining increasing market shares with much lower power consumption for pumps (0.6 kWh/m^3 distillate) and requiring less heat exchange surface. Furthermore, MED is more efficient than MSF in terms of primary energy consumption, because it works at lower temperatures than other thermal processes. The disadvantage of MVC is the higher electrical consumption. Thermal desalination processes are commonly designed for constant operation at full load, even if partial operation is possible. A complication of the design is due to the fluctuating available heat from the turbine (electricity demand and solar irradiation vary in time). The adoption of a hot water tank between turbine and thermal desalination stabilizes the water production and increases the operation grade of the MED. RO (figure 4) present much lower primary energy consumption and slightly lower cost compared to MED. However - as stated before - if MED is coupled to a power plant, it replaces the cost of the condensation unit and partially uses waste heat from power generation for the desalination process. Furthermore, RO systems produce water with higher salinity (< 300 ppm in one stage systems), which would be not adapted for agricultural purposes (ground over-salinization).

Figure 3: Multi effect desalination plant (Source: Entropie)
Figure 4: Reverse Osmosis plant (Source: DME)

In the end, MED and RO were selected for the feasibility study. CSP-MED configuration (figure 5) is adapted only for shore locations (thermal interdependency between turbine and MED), while CSP-RO configuration (figure 6) is more flexible, because the CSP power plant can be located also far away from the desalination plant, for example in inland locations where the DNI is typically higher. For this reason CSP-RO configurations are equipped with dry cooling, the only cooling option for locations without water availability.

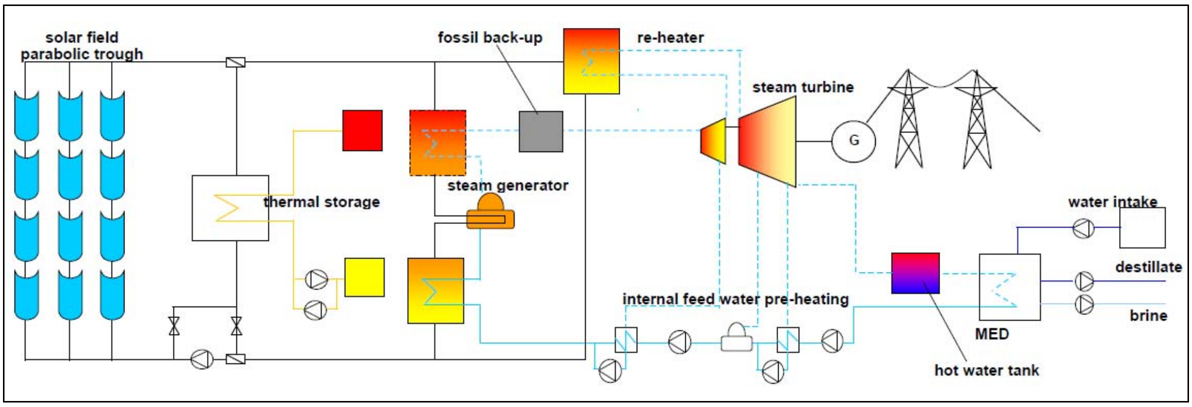


Figure 5: PT-MED configuration

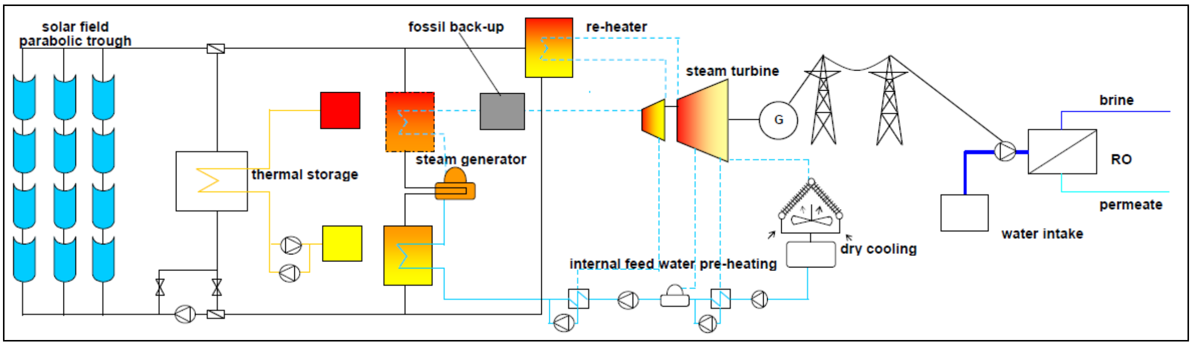


Figure 6: PT-RO configuration

The site selection is based on either suggestion of local partners or on search for representative locations in the selected countries (demand, solar resources, seawater salinity). The size of the plants (8,000 m^3/day, 16 MW) base on concrete needs for water and electricity. Figure 7 gives a rough overview about the selected locations and their DNI resources. At a first glance it can be seen that very high DNI values are in Morocco (but not near the shore) and in South Egypt.

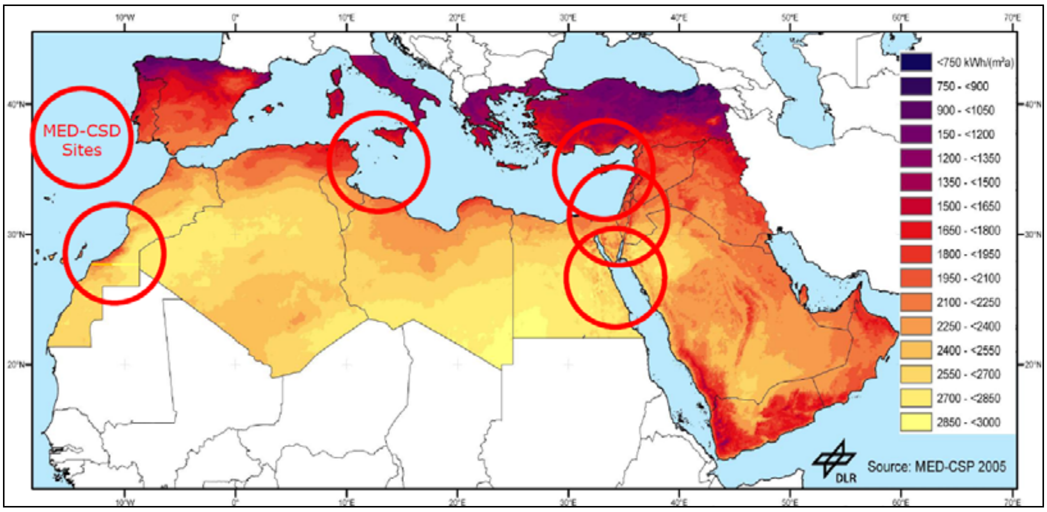


Figure 7: Direct Normal Irradiation (DNI) of the MENA-Region and selected MED-CSD sites

4. Technical and financial methodology

The plenty of selected locations and configurations (ca. 80 cases) made necessary the choice of similar electricity and water demand profiles (and as consequence similar plant design) for all simulated plants. In this way it is possible to maintain certain comparability among the different cases. The input data for the technical model are mainly ambient data (DNI, ambient temperature, wind velocity) and demand profiles for electricity and water (figure 8). Input data are given with hourly steps. Two different DNI models were adopted, which are based on different assumptions about the aerosol type and concentration in the atmosphere. It is interesting to note that the differences between the 2 DNI models for a single location account up to ca. 550 kWh/m^2/year. The two models present also differences in the typical maximal hourly DNI values. This fact would also influence the detailed engineering of the plant. Once all input data were ready, the technical feasibility study was carried out in INSEL [2], a graphical programming language which is characterized by a modular structure. In other words the simulation is split into units/blocks with a fixed number of inputs, block parameters and outputs. This feature is essential to guarantee a high degree of flexibility and to compare different plant configurations. During the project several CSP components like concentrating solar collectors (parabolic trough, linear Fresnel reflector), thermal energy storage (molten salt), steam turbines, cooling systems (wet and dry cooling) and desalination technologies (multi effect desalination, reverse osmosis) were implemented. The most interesting results of the yearly simulation are hourly values of electricity and water production, heat collected by the solar field, stored heat in the molten salt tanks (diagram in figure 8), internal electricity consumption and hybridisation ratio.

After the technical analysis has been performed, next step is to evaluate the economic feasibility of the simulated configurations. EDF has implemented a tailor-made tool to perform an accurate financial analysis. The model methodology is shown in figure 9. The required inputs are results from the technical model (electricity and water production, hybrid rate, plant size), cost inputs like capital expenditures and information about construction and operation time of the plant. The costing has been performed by INVEN with a more detailed model than the annual performance model. Other essential inputs are macro-economic data like general inflation rate, revenues and expenses escalation rate, investment cost (development cost, start-up costs, initial cash reserve) and financial inputs like equity rate of return, interest debt rate, adopted financing model and price of sale for electricity and water. In some considered country a feed-in tariff already exists (Italy and Cyprus), while for the other cases realistic assumptions on revenues have been discussed with experts and local partners.

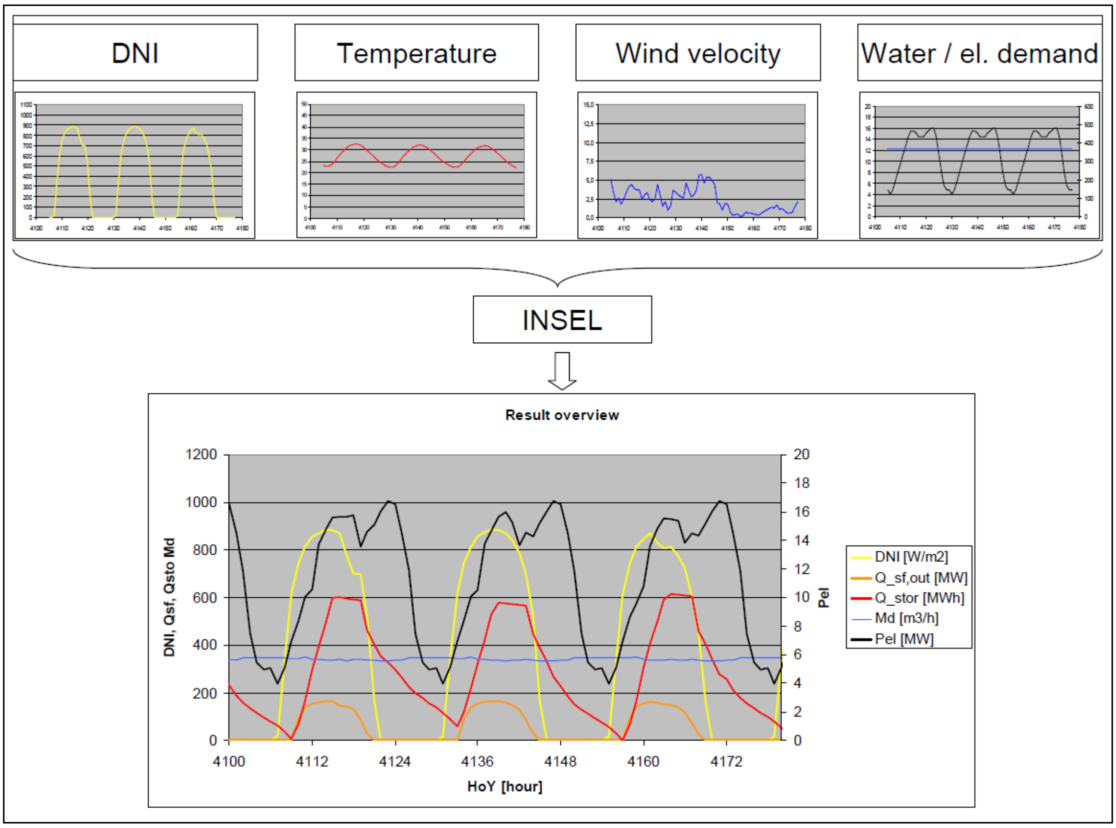


Figure 8: Methodology of the technical model

The choice of the financing model was also discussed, because the profitability of a project can be seen from different points of view. The main difference in the financing models is the different discount rate on equity. First option is the corporate finance model. In this case the project is considered as a whole, taking into account all funds (loan and equity) and all cash flows during operation life. The cash flows are discounted with the Weighted Average Cost of Capital after tax (WACC), which represents the weighted cost of both debt and equity. This point of view does not satisfy investors, which want higher return on equity. In this approach the profitability is defined by the net present value (NPV). The NPV is the sum of future cash flows, which are discounted with the minimum equity rate of return requested by investors. In the end, the economic analysis was performed assuming the investor's point of view.

Among the most relevant results of the economic analysis are the lines shown in the diagram in figure 9. In the diagram the x-axis represents the levelized electricity cost (LEC, [€/MWh]) and the y-axis the levelized water cost (LWC, [€/m^3]). The inclined lines represent sets of points with the same NPV. A particular line is the one with NPV=0, i.e. the break-even line. It is obvious that an attractive project has a NPV=0 line with lower intercepts on the x and y axes. In particular, a certain project is economically feasible if the NPV=0 line has one or more points below both blue and orange lines, which are the prices that a utility would pay for produced water and electricity, respectively. If a configuration doesn't have any point below these prices, a grant or a higher tariff is necessary to reach the minimum feasibility point, which is the interception of blue and orange lines (green line). Red and dark blue lines in figure 9 represent investor and corporate finance models, respectively.

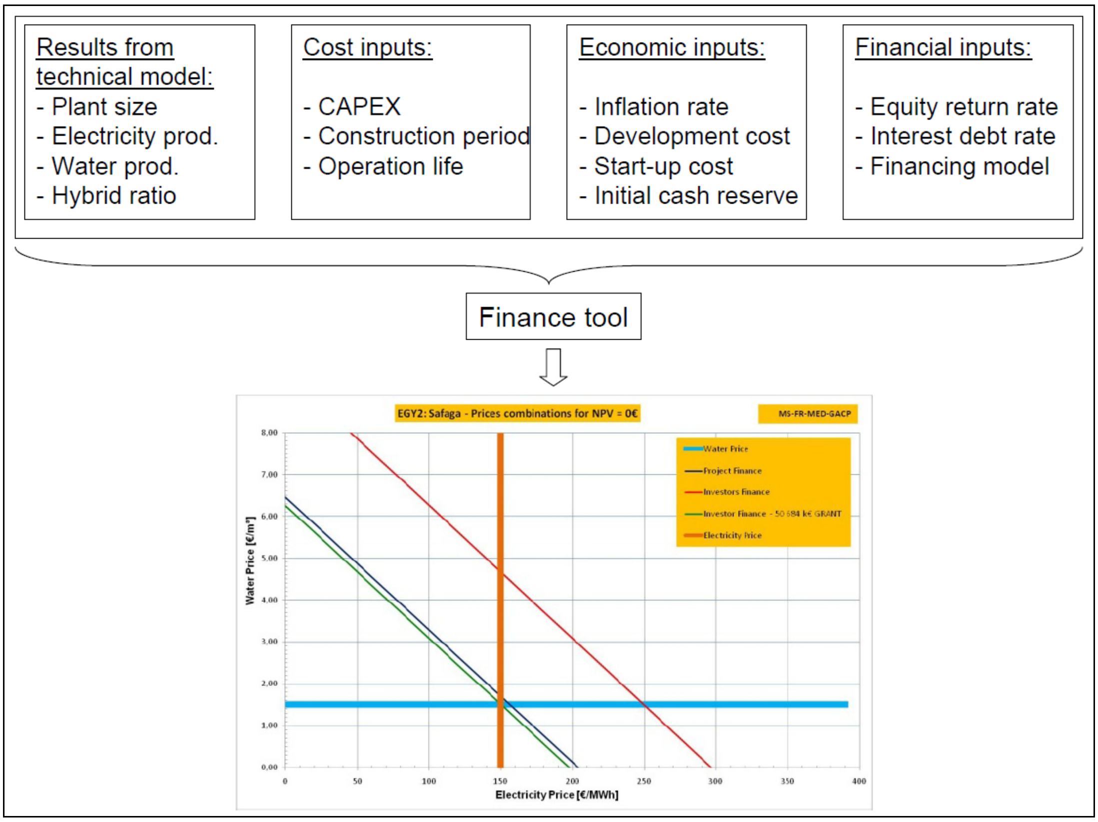


Figure 9: Methodology of the economical model

5. Results overview

In this section are summarized the most relevant results from the technical and economic models. All the plants are designed to produce the same amount of electricity and water. This means that the size of turbines, solar fields and molten salt storages are similar, but not exactly the same. In particular, the size of the solar field depends on the heat required by the turbine in design conditions, which in turn is function of net electricity production, steam condensation temperature in the turbine, total internal electricity consumption and distance between CSP and desalination plant. The net design electricity production is the same in all considered plants, but this is not the case for the steam condensation temperature. Indeed, this temperature is a function of the cooling type. CSP-MED configurations have definite steam condensation temperature, because the heat quality required by the MED is fixed at 80 °C during the charge of the hot water tank and at 65 °C in discharge-modus, but CSP-RO have a dry cooling and the turbine efficiency is mainly a function of the design ambient temperature (typical maximal summer temperature). So, if in a CSP-RO plant a turbine works with lower efficiency due to high condensation temperature, more heat is required to produce the required amount of electricity. In the end, such a configuration will have larger solar field and higher investment cost. This situation is typical for inland sites like M'sied (MOR2), West Bank (PAL2) and Safaga (EGY2). On the contrary, CSP-MED plants present all the same solar field area.

The total internal electricity consumption (so-called parasitic) is made up of the sum of sun tracking losses and several pumping losses, e.g. in solar field, storage turbine and desalination. The electricity consumption of MED is almost constant, while the one of RO depends on seawater salinity. High saline water requires high pressure and therefore more electricity in the pumps of RO vessels in order to overcome higher osmotic pressure. Locations with lower salinity like Tan-Tan (MOR1) and West Bank (PAL2) will be characterised by lower desalination investment cost in comparison to sites where the salinity is much higher like in Safaga (EGY2). The MED -as it is a distillation process- is not prone to this effect. However, high seawater salinity reduces the performance of the thermal desalination (higher boiling point elevation). In the end, the solar field for the RO is typically slightly larger than for the MED. The reason is that the higher electrical consumption of the RO over-compensates the lower thermal efficiency of the turbine in the MED-case.

Last important design parameter is the distance between power plant and desalination. For example, it has been estimated that due to losses along the electric connection only 95 % of the electricity produced in M'sied (MOR2) will reach the shore site where the desalination plant is located. So, the plant has to be over-dimensioned in order to cover these losses. In the end, the effects of high ambient temperature and electricity losses result in a 10 % higher solar field area.

Looking at the plant performances, the solar full load hours depends almost linearly on the yearly DNI sum (the solar multiple was kept constant). Locations with relative bad solar resources (< 1,700 kWh/m^2/year) like Tan-Tan (MOR1) or Pantelleria (ITA2) reach barely 2,100 solar full load hours, while in Safaga (EGY2) and M'sied (MOR2), which have a DNI higher than 2,600 kWh/m^2/year, the solar full load hours arrive at 4,000. The hybrid ratio, which strongly affects the OPEX, is inversely proportional to the DNI yearly sum and varies between 25 % and 60 % under the given boundary conditions (electricity demand curve). Concerning the solar field technologies, from a technical point of view the linear Fresnel reflector has a lower optical efficiency (higher cosines losses) than the parabolic trough. This means that in order to collect the same amount of heat a larger mirror area is necessary. However, this disadvantage is compensated by higher land use factor and lower specific investment cost. In the end, on the 72 different studied configurations, the average price of installed capacity is about 5.83 €/W for FR, while the average price for PT is 5.95 €/W. On the other hand, it has to be kept in mind that FR is not as a mature technology as PT. Currently, the total installed capacity of FR is 2 MW (30 MW under construction), while the installed capacity of PT amount to 480 MW (ca. 500 MW under construction). Moving to desalination, RO presents least investment cost. However, MED saves the condenser cost and typically has lower OPEX. On the contrary, replacement cost for RO membranes (due also to not optimal water pre-treatment) can considerably affect the operational cost.

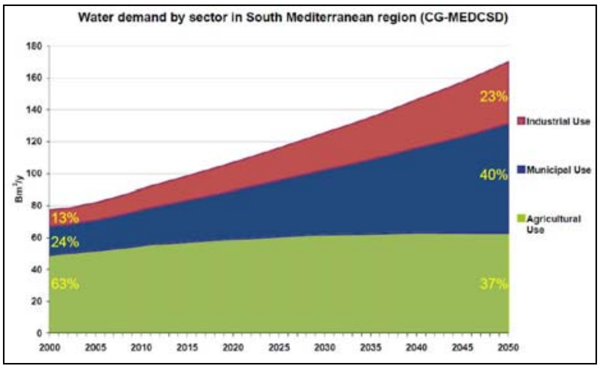
Finally, considering the economic feasibility of the projects, the calculations assuming a corporate finance model shows that most of the projects are feasible, i.e. they have a positive NPV. On the contrary, assuming the private investor point of view (the "realistic" point of view), none of the analysed configuration is economically feasible (NPV<0) without a feed-in tariff or a grant. However in Italy, where feed-in tariffs for both electricity and water are already present, a very small grant is still required. The results show also the high influence of the expected rate of return on equity. Private investors require high revenues in risky countries like Palestine and Egypt (up to 20 %), and this is an obstacle for the project profitability also in locations with an excellent solar irradiation like Safaga (EGY2).

In conclusion, assuming the private investor point of view, at the state of the art the profitability of the projects can be reached only using feed-in tariffs or grants. Another option to reach a NPV=0 is to increase the share of debt in order to reduce the weight of the higher return of rate required by investors (leverage effect). Beyond that, the further market introduction of CSP should start from periods with high electricity prices (peak load) in order to maximise the revenues.

6. Techno-economic potential of CSP Desalination

Based on the results from the techno-economic feasibility study, the aim of the MED-CSD study was also to develop long term scenarios (up to 2050) for water and electricity demand, with particular focus on critical issues like water deficit and possible short and mid term strategies and countermeasures to reduce this problem. Finally, the role of renewable energies and in particular CSP for large scale sustainable water and electricity production were highlighted [1, deliverable 3.1]. In order to carry out this analysis, simple empirical models were used [3,4]. The water demand model is mainly function of population growth rate, distribution efficiency and efficiency enhancement in time. The electricity demand model is an exponential curve which depends on per capita GDP and empirical parameters extrapolated from statistical analysis of historical data. The used model takes into account electricity losses in the grid and internal electricity consumption in the energy sector. The models are applied on national basis and then diagrammed in 3 macro-regions (North Mediterranean countries (NMC), South-West Mediterranean countries (SWMC), i.e. North-African Countries from Morocco to Egypt, South-East Mediterranean countries (SEMC), i.e. Israel, PNA, Jordan, Syria, Lebanon and Turkey). Beyond that, it is important to note that the results are scenarios and not forecasts, and that an analysis carried out on country level is not able to identify local problems (i.e. Italy considered as a whole is not a water-poor country; however there are locally severe water shortages). Different assumptions about economic growth served to show the range of uncertainty of the possible scenarios. The Business as Usual Scenario (BaU) bases on FUGI and IMF GDP forecasts, while the Closing the Gap Scenario (CG) assumes that the distance between the 2006 average of per capita GDP in NMC and MENA countries will be reduced by 50 % in 2050. Different efficiency enhancements (Low, Middle and High) are also taken into account.

Nowadays, in MENA countries the agricultural sector is the most important consumer of water (around 63 %) (figure 10). Further development of this share is related to the population growth. Water demand for industrial and municipal water accounts for around 37 % and its growth is dependent on the GDP increase. According to the Closing the Gap scenario, it is expected that by 2050 the water demand will approximately double, with dramatic demand and deficit increases in Egypt (ca. 60 Bm^3/y) and Syria (10 Bm^3/y). This means that the water deficit in Egypt will be as large as the Nile River (55 Bm^3/y). The municipal and industrial water demand will strongly increase, while the growth the agricultural water demand will only be moderate, decreasing its relative share down to 37 %. Efficiency enhancement in water distribution and use will be requested in order to minimize the water deficit. Adequate countermeasures like better water management and re-use of water should be taken as soon as possible, but they alone will not be sufficient to avoid the collapse of water supply in the long-term if no additional new freshwater sources are activated in time. The best possible management is useless if there is not enough available water. Concerning the electricity demand, growth of population and economic growth will lead to high increase of energy demand in the Mediterranean region. Figure 11 shows that the growth will be driven by the SWMC (and in minor measure by the SEMC). On country level, the major consumers of the region will be Egypt, Turkey, Algeria, Morocco and Syria. On the contrary, starting from 2040 European countries will face a slight decrease of the electricity demand, due to energy efficiency enhancements.



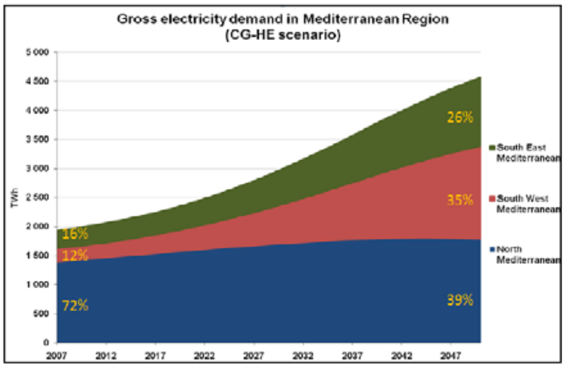


Figure 10: Water demand in South Mediterranean Countries (Closing the Gap – middle efficiency)
Figure 11: Gross electricity demand in Mediterranean Region (Closing the Gap – High efficiency)

Nowadays the electricity consumption of the SMC barely represents 30 % of the whole region with 536 TWh/y, while NMC represent 70 % (1,400 TWh/y) of the region. According to MED-CSD scenarios, it is expected that South Mediterranean region electric consumption will represent between 55 % and 60 % of the whole region. In countries with high income like NMC and Israel, the development of the electricity demand will depend mainly on the efficiency of the energy efficiency policies. As nowadays inefficiencies are not high, the decrease in energy intensity in these countries is expected to be moderate in the next years. On the contrary, low income countries will all face high population increase and high economic growth. Therefore strong expansion of the electric infrastructures to satisfy the growing demand and to provide the conditions for a further economic development is needed.

7. Outlook

In conclusion, it should be underlined again the importance to start now a paradigm change in water and electricity supply system, in order to meet the requirements for low cost water and electricity in the MENA region and avoiding tensions related to water scarcity. This structural change must be done adopting new and sustainable solutions. Renewable energies like CSP will be a key factor in this development, due also to the possibility to couple it with desalination units. CSP-DES plants are an attractive option to produce secure and cost stable water and electricity. Other positive aspects are high use of local resources and reduction of greenhouse gases emissions. Beyond that, such plants could become the nucleus of a totally new social paradigm: the conservation and recuperation of land endangered by desertification. Concentrating solar multipurpose plants in the margins of the desert could generate solar electricity for domestic use and export, freshwater from seawater desalination and provide shade for agriculture and other human activities. CSP and heat storage are proven, state of the art technologies. The present drawback of relative high investment cost can be solved by definition of adequate financial boundary conditions and by individuation of market niches. Scale effects will drive the cost down and the realisation of demonstration plants will show more and more the attractiveness of this solution.

References

[1] MED-CSD deliverables, http://www.med-csd-ec.eu/eng/deliverables.php

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

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

[4] Trieb and Klann, [Online] 2006, [Cited: 12.08.2010], http://www.dlr.de/tt/Portaldata/41/Resources/dokumente/institut/system/projects/csp/Demand-Model_20061128.pdf