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A Renewable Energy and Development Partnership EU-ME-NA for Large Scale Solar Thermal Power & Desalination in the Middle East and in North Africa

Proposal by the Trans-Mediterranean Renewable Energy Cooperation TREC
(www.trec-eumena.org)

for a World Sustainability Project

A Strategy for

- Sustainable Water and Energy Security
- Climate Stability and Development
- EU-ME-NA as Co-operative for Sustainability

15-April-2004

***Summary**: Fresh water, the primary resource of life, is limited in most MENA countries. If the MENA countries would build, with available technology and in co-operation with Europe, solar thermal electricity and desalination facilities to supply around 1 billion m³ water per year, the installation of such a capacity would be sufficient to mature concentrating solar thermal technology to a point where it would begin to provide solar heat at costs lower than from fossil fuels. Such a project will induce significant economic development in the MENA region and generate a powerful instrument to fight global climate change. If it would be started now, this aim could be achieved until 2015. By 2025, solar electricity could be produced at 2 - 5 ct/kWh, and could be exported to Europe for additional 2 ct/kWh, while desalinated water could be co-generated at a cost of 10 – 90 ct/m³. An additional public funding in the range of 0.2 to 2 billions US$, distributed over the first 6-10 years, is required as start up support, with the exact amount depending on solar radiation of the sites chosen and on the conditions for soft loans.*

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* by TREC (www.trec-eumena.org). **TREC** is a collaboration of experts on renewable energies and on development from Europe, the Middle East and from North Africa, supported by the Club of Rome and the Hamburg Climate Protection Foundation prepared by Gerhard Knies (gerhard.knies@trec-eumena.org)

** by DLR (www.dlr.de/system). The German Aerospace Center (DLR) is preparing a scenario and a comprehensive data base for the market introduction of concentrating solar thermal power plants in the Mediterranean Region within the study **MED-CSP** sponsored by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) prepared by Franz Trieb (franz.trieb@dlr.de)

The Vision of a Trans-Mediterranean Renewable Energy and Development Co-Operation *

1. Confrontation or Co-operation around the Mediterranean?

The regions of Europe, the Middle East and North Africa (EU-ME-NA) can produce from their inexhaustible resources of solar radiation, wind and sea water, any amount of desalinated water for MENA and any amount of clean electricity for Europe, by their economic co-operation and with the technology of co-generation, for all future times and without polluting or burdening the environment, if they combine their supplementary resources and join their forces.

This co-operation for sustainability can become an alternative to approaches with high potential for confrontation between and within these regions over limited resources of water, oil and natural gas. It can create developmental opportunities, a transition from exploiting mineral resources to a knowledge and skill based economy, and it can put an end to the threatening global warming process. It can initiate the transition from clash between civilisations to EUMENA as a co-operative for development, sustainability and peace.

In separation, Europe will be much slower in reducing green house gas emissions, and MENA countries will be slower in economic development. Their co-operation on renewable energies can become the express train to development, climate stabilisation and good neighbourhood.

At the International conference on security in Munich at February 7th 2004 the German *Foreign Minister Fischer* made the following statements:

…

Whether the Mediterranean becomes an area of cooperation or confrontation in the 21st century will be of strategic importance to our common security.

…

The cooperation should focus on four main priorities: security and politics; the economy; law and culture; civil society.

The first priority would be to develop close political cooperation and a security partnership. It would be aimed at creating transparency and at confidence-building among all the states involved. Furthermore, the reform processes of the countries in the region should be supported, indeed in all areas of policy, institutions, democracy and law.

…

A new economic partnership for the Mediterranean countries could be the second focus. This, too, is of crucial relevance to security. Above all, developing and integrating hitherto separate national economic areas could play a decisive role in supporting the process of political and social change.

So why should we not vigorously pursue the ambitious goal of creating a free trade area together by 2010 to embrace the entire Mediterranean area?

…

2. EUMENA – a region for sustainability, development and peace

An important step towards more political and ecological stability could be made by a Trans-Mediterranean Renewable Energy Cooperation (TREC). Fig.1 shows the basic concept. The

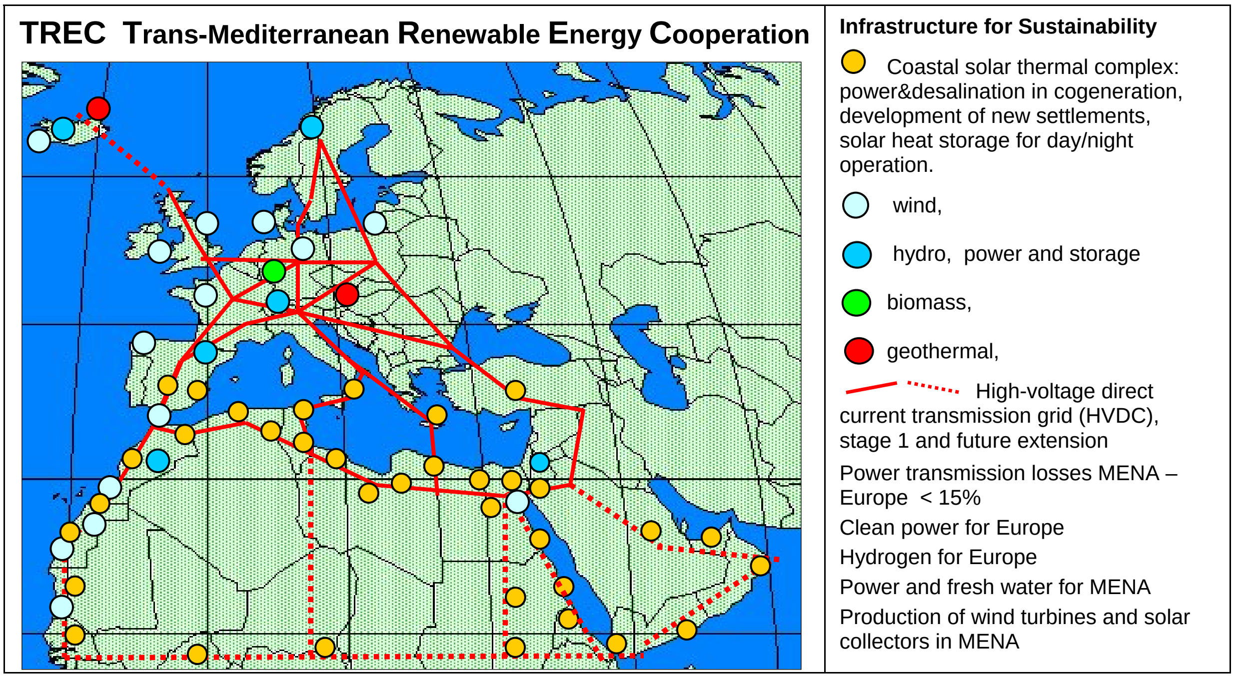


Figure 1: Renewable energy optimisation by long-distance power interconnections and synergy exploitation of resources in Europe and Middle East / North Africa (hereafter: EUMENA).

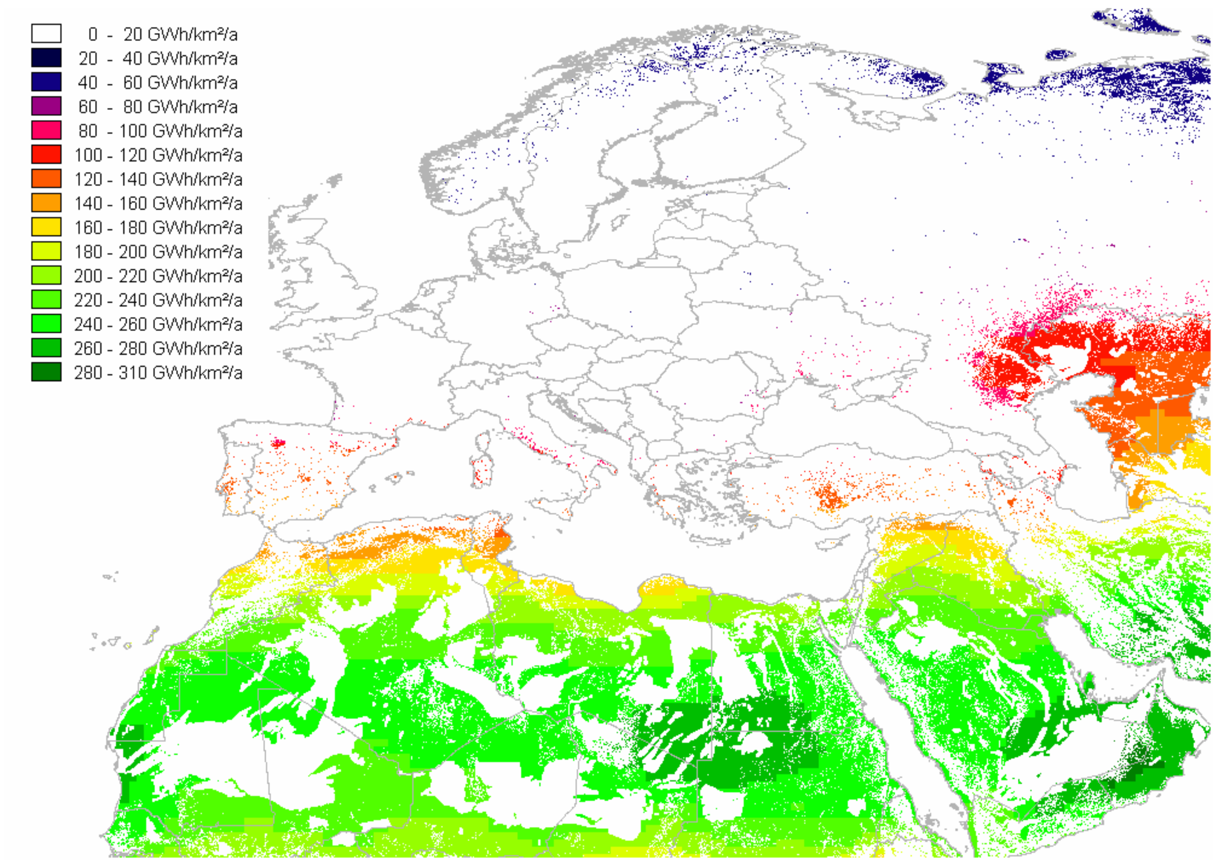


Figure 2: Solar electricity generating potential by concentrating solar power in GWh/km²/a around the Mediterranean Sea. On average locations in MENA (green areas), the solar thermal energy potential is equivalent to 1 – 2 barrels of fuel oil per year on every square meter of land. White areas are unsuitable for CSP.

TREC project could initiate a free trade zone and a transmission infrastructure for renewable energies among the countries surrounding the Mediterranean Sea. The technologically highly developed European countries in the North presently are using mainly fossil fuels for their energy demands, thereby excessively burdening the global atmosphere with greenhouse gas (GHG) emissions. The countries to the South and the East of the Mediterranean have growing demand for fresh water, which can be produced by waste heat from solar thermal electricity generation. Further they have vast but unused sites with excellent solar and wind energy resources. High-voltage direct current (HVDC) interconnections enable low-loss transmission to be made over great distances at low cost.

- Connecting the best wind and solar sites of large regions like EUMENA can significantly reduce fluctuations and costs of clean power.
- Connecting the high power demand region Europe with the excellent solar and wind regions in MENA will benefit the water and power supplies for both regions.
- Combining solar thermal power generation with seawater desalination improves solar energy economy more than for the fossil alternatives.

How can this get started?

- If Europe decides to buy a substantial fraction of its energy as solar and wind electricity from countries in MENA, and
- if the MENA countries get started to develop, with technical support from Europe, the capability of building and operating solar collectors for co-generating desalinated water and electricity from solar energy, and of building components for wind turbines,

then the proposed Trans-Mediterranean Renewable Energy Cooperation could

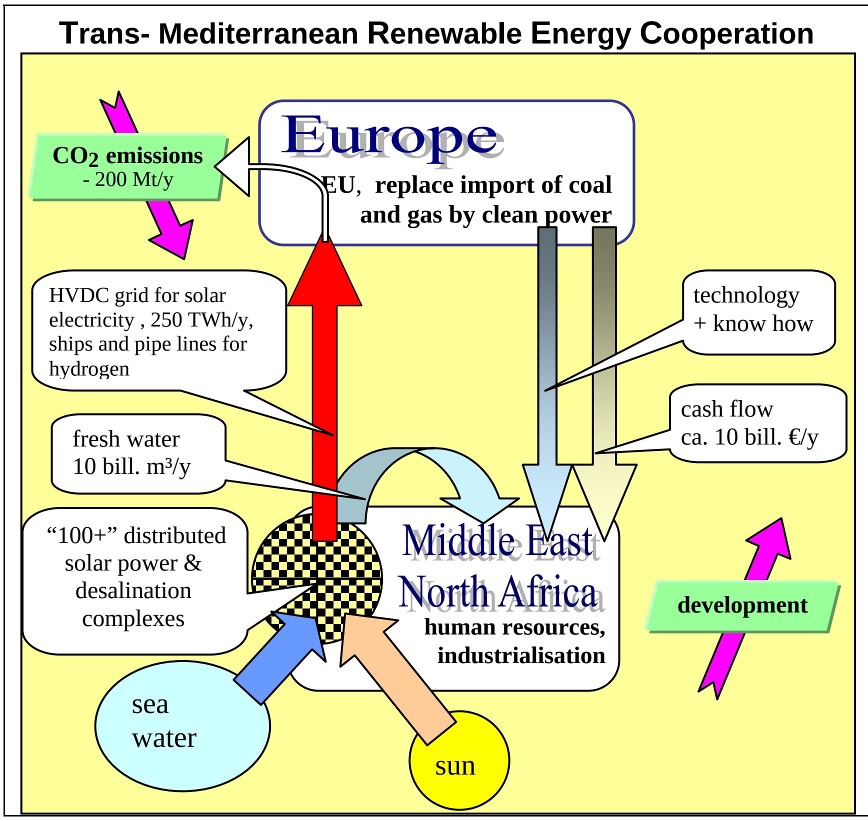
- turn the formerly contradictory goals of *climate protection* and *economic development* into mutual reinforcing objectives by making clean energy production in MENA for both local and European markets a motor of industrial and socio-economic development in MENA countries
- help to transform the Mediterranean from a region of various divisions and conflicts into a region of harmonised socio-economic development, cooperation and good neighbourhood
- create qualified job opportunities in and reduce emigration and brain drain from the MENA countries.

3. Economic development and fresh water for MENA in co-production with clean power for Europe

Within this EU-ME-NA co-operation, MENA countries could take advantage of their superior solar and wind potentials and generate clean electricity as a competitive industrial product for export to the European market. In cogeneration with solar power, huge amounts of sea water could be desalinated to overcome the expected shortages of fresh water in the MENA countries. Additional fresh water for drinking, industry and eventually for irrigation purposes constitutes an indispensable precondition for further development in many areas. Thus, the proposed TREC project would expand the perspectives for human and socio-economic development in the MENA countries.

Wind and solar energy potentials in MENA are superior to the European sites in terms of quality (intensity by factors up to 3) and of quantity (size and availability of sites). The required technologies are already available. Wind energy converters and concentrating solar thermal power stations have been developed in Europe and in other parts of the world. Their functionality and reliability have been proven in many years of practical application, and their production costs have continuously decreased. Information on wind and on solar radiation is available from satellite remote sensing and from ground measurements for most regions of the world. At the most productive sites in the MENA region, wind and solar power can become cost competitive with energies from fossil fuels if financial conditions were adapted to their specific long-term investment needs. Large wind power capacities and also a few solar thermal power plants are already installed all over world.

The specific strength of the MENA region is its excellent solar radiation conditions which qualifies this region for the market introduction of concentrating solar power technology (Figure 2). After future anticipated cost reductions due to economies of scale and continuing technological refinements, solar energy can become, within 10 years, economically superior to fossil fuels and competitive at more and more sites in Africa and other regions in the world. This is why concentrating solar collector technology can become an important branch of industry and economy in MENA countries.



Features of TREC

- hundreds of distributed solar power & desalination plants, with 10–400 MW_{el}.
- Wind & solar power, and hydrogen for export from MENA to Europe, and for local demand
- interconnecting HVDC grid
- water desalination for MENA in cogeneration
- component production in MENA
- industrial & socioeconomic development in MENA
- faster climate stabilisation
- create jobs in MENA instead of CO_2 in Europe

Power of 250 TWh/y is about 10% of EU annual electricity consumption, and also about the power generated from imported coal in the EU. Such a capacity could be installed within 20 years.

Figure 3: Circuit of climate protection and development. CO_2 reduction in Europe fosters development for the Middle East and North Africa.

The developmental circuit with a flow of clean power - and later also hydrogen - from MENA to Europe and with flow of technology, know-how and capital from EU to MENA countries is sketched in Fig. 3. The production of electricity from solar radiation and wind energy requires greater manufacturing efforts and equipment installations than extracting crude oil or natural gas. The widespread industrial activities and technological developments involved will create many jobs at different levels of skills and qualification.

The initial phase of technology market introduction in MENA will need some financial and a great deal of political support. In particular solar thermal power and desalination plants need preferential financing during the start-up phase; however the total required support would be significantly lower than the 7-10 billion Euro continuously spent every year for coal and nuclear power subsidies in the OECD. It is rather in the order of a one-time 2 billion dollar start-up investment. After break-even with fossil fuel costs solar and wind energy costs will continue to fall while those for fossil fuels will continue to rise, leading to growing savings for national economies in the future. The proposed Trans-Mediterranean Renewable Energy Cooperation would establish an inexhaustible and practically unlimited expandable source of power and water with continuously declining costs.

4. Worldwide impact of the TREC project

The impact of TREC would extent far beyond the regions adjacent to the Mediterranean. Firstly, any contribution to climate protection and to political stabilisation is clearly of worldwide benefit. Secondly, the greatest energy resource worldwide is solar radiation. The technology of solar steam production is suitable for all arid and desert regions of the world, which also provide abundant free space for their deployment. After cost reductions to the level of fossil fuels and below will have been achieved by the TREC project, solar collectors could also operate in North and South America, North and South Africa, India, China and Australia, i.e. for more than 90% of the world’s population. Thus the TREC project could make solar power an essential element of timely climate stabilisation.

5. Relation to global developmental goals

The proposed project directly corresponds with three out of the eight development goals proclaimed for the new century in the UN Millennium Declaration by the world leaders:

- Goal 1, eradicate extreme hunger and poverty
- Goal 7, ensure environmental stability (which includes timely climate stabilisation)
- Goal 8, develop a global partnership for development

The global community has largely accepted that ensuring climate security requires action. The Kyoto process is an indispensable means of giving climate protection the quality of international law. The goal of TREC is to bring renewable energies into the position that enables us to comply with the requirements of the Intergovernmental Panel on Climate Change (IPCC) for climate security, and to render the dangerous fossil and nuclear energy technologies obsolete.

These objectives could be achieved within a few decades, if regarded as a goal for humanity, and not left as a matter of investment decisions aiming at the highest short term returns. The integrated sustainability region EUMENA can show leadership for a global sustainable energy future by embracing this world sustainability project.

Scenario for Implementation of Solar Power **

The Strategy in Brief

1. Solar thermal energy for the generation of superheated steam is still slightly more expensive than heat from oil or gas. But technology improvement and economies of scale for large amounts of concentrating solar collectors can make also solar energy cheaper than oil or gas within less than 10 years from now if a capacity of ca. 500 million m³/year of desalted water is installed and if electricity is produced in co-generation with desalted water. Cost reduction of concentrating solar power (CSP) technology is the main objective of the strategy presented.

2. The cost of solar energy depends mainly on the amount of solar irradiation, the cost of concentrating solar collectors and on the conditions of finance. At an average radiation site with 2500 kWh/m²/y and under the financial conditions of a public infrastructure investment, i.e. at 9% effective interest rate we estimate that an additional public funding of 700 million US$ over a period of 10 years is needed in comparison to using fossil fuels, under these reference conditions. Under private financing conditions, this initial cost barrier may reach 2 billion US$, but with favourable soft loans it may come down to as low as 200 million. The choice of favourable solar locations may further reduce the needed initiating support.

3. In many MENA countries the need for fresh water is even more pressing than for electricity. With the expected development of population and economy, the total water deficit in 20 years is estimated to be of the order of 65 billion m³/a equivalent to the capacity of the Nile river. This amount of water could be generated for 10 – 90 ct/m³, depending on capital cost and on solar radiation, from the inexhaustible resources of sea water and solar radiation, which are readily available in the MENA region.

4. Solar electricity co-generated with such a volume of water will be cheap (of 2 – 5 ct/kWh) and abundant enough to serve any MENA demand and allow for substantial exports to Europe, which is in high demand for clean power. Also the growing electricity demand in MENA can be satisfied to a great extent.

5. If Europe would buy clean power from MENA, the water shortage of MENA and the CO_2 emission problem of Europe could be tackled ”in co-generation”. By a EUMENA cooperation on development and deployment of technology, global climate change could be limited. This calls for a concerted action within an *Integrated Sustainability Region EU-MENA.* The initial funding of this infrastructure project brings tremendous public benefits to the EU-MENA region: economic development, and low cost and sustainable supply of clean power and water.

6. A strategic EU-MENA project to bring down the cost of solar energy below fossil fuels would not only solve the water problem of the involved MENA countries and ease the European CO_2-reduction, but would also make solar energy accessible to the whole world. Therefore, this would constitute an outstanding, unique “World Sustainability Project”.

7. Preferential financing of this “World Sustainability Project” during the initial 8 years can be achieved by applying the following measures:

+ Soft loans, grants and guaranties by national and international donors.
+ Priority feed-in tariffs and long-term power purchase agreements for solar thermal electricity in the MENA and EU electricity grids.

Period	Comment	Capacity installed for Power, Water	Invest-ment US$	Support Required	Cost Level Achieved for Power & Water *
2004 – 2006	MENA Demand Side Strategy Development and Assessment Phase, Optionally first POSEIDON Plant	0 – 5 MW, 0 -1.7 Mm³/y	0.5 - 20 million	Public Private Partnership, Technology & Resource Assessment Study, Strategy Development, Political Support	5.1 – 7.8 ct/kWh 75 – 90 ct/m³
2006 – 2010	Technology Transfer Phase	355 MW, 118 Mm³/y	1.3 billion	Public Private Partnership, Soft Loans, Grants, Long-Term Power & Water Purchase Agreements, Guaranteed Feed-in Tariffs, Insurance & Guaranties	3.8 – 6.8 ct/kWh 75 – 90 ct/m³
2010 – 2015	Technology Establishment Phase	2100 MW, 700 Mm³/y	7.4 billion	Public Private Partnership, Soft Loans, Grants, Long-Term Power & Water Purchase Agreements, Guaranteed Feed-in Tariffs, Insurance & Guaranties	3 – 6 ct/kWh 60 – 90 ct/m³
2015 – 2020	Market Settlement Phase	6600 MW, 2200 Mm³/y	21.9 billion	Public Private Partnership, Long-Term Power & Water Purchase Agreements, Insurance & Guaranties	3 – 5.2 ct/kWh 29 – 90 ct/m³
2020 – 2025	Market Expansion Phase	21 GW, 7 billion m³/y	80 billion	Public Private Partnership, Long-Term Power & Water Purchase Agreements	3 – 5 ct/kWh 15 – 75 ct/m³
2025 - 2050	Commercial Phase	450 GW, 150 billion m³/y	2000 billion	Non	3 – 5 ct/kWh 5 – 65 ct/m³

* Variation between Reference Scenario (9 % Interest Rate, 20 Years Capital Return Period) and Optimized Conditions Scenario (4 % Interest Rate, 40 Years Project Life)

Table 1: A Scenario for CSP Market Introduction

The Fresh Water Situation in the MENA Region

Fresh water, the primary resource of life, is limited in most MENA countries. Water scarcity often imposes the main restriction on development and may even threaten the substance of existence itself. The size of coming water deficits for NA countries is estimated in Table 2.

	Year	Population	Water Resources (billion m³/year)			Water Demand (billion m³/year)			Balance
		million	Surface	Ground	Desalination	Municipal	Industrial	Agricultural	billion m³/year
Algeria	2000	33	13,5	3,7	0,2	2,6	0,5	3	11,3
	2025	52	13,5	3,7	0,3	4,7	1,1	5,2	6,5
Egypt	2000	62	65,5	7,4	0,1	4,5	6,1	59,9	2,5
	2025	86	65,5	7,4	0,2	7,8	9,9	112,6	-57,2
Libya	2000	6	0,3	3,4	0,8	0,7	0,1	4,5	-0,8
	2025	14	0,3	3,4	1,5	1,3	0,3	9,1	-5,5
Morocco	2000	32	19,5	5	0,1	1,7	0,4	11	11,5
	2025	47	19,5	5	0,2	4,3	0,9	28,1	-8,6
Tunisia	2000	10	2,7	1,8	0,3	0,4	0,3	1,8	2,3
	2025	14	2,7	1,8	0,6	1,3	0,7	3,2	-0,1
North Africa	***2000***	***143***	***101,5***	***21,3***	***1,5***	***9,9***	***7,4***	***80,2***	***26,8***
	2025	***213***	***101,5***	***21,3***	***2,8***	***19,4***	***12,9***	***158,2***	***-64,9***

Table 2: Water resources and expected demand for the NA states for the year 2000 and 2025 (business as usual desalination build out). Source: Abufayed et al., Desalination 152(2002), pp. 75-80

The water shortage will mainly hit the population centres. For instance, the historic city of Sana'a with its unique cultural legacy is burdened by the dilemma of growth: Sana'a continues to undermine its balance with natural renewable aquatic resources by extracting ground water pumped from the Sana'a basin. Municipal water dependency is depleting the water table, which is currently declining at a rate of six meters per year.[1] For the sake of its current growth, Sana'a thus continues to sacrifice its future.

This situation will prevail until fresh water can be supplied in a sustainable manner. Many cities and countries in the MENA region face similar prospects. A large number of settlements and cities already have extended their fresh water demands far beyond the continuous capacities of their renewable supplies. Furthermore, the progress of climate change caused by global CO_2 emissions arising from burning oil and gas, will be reducing rainfall especially in the MENA region.

The Green-House-Gas Emissions of Europe

The European OECD countries are emitting 3800 Mt CO_2, which is 15.2 % of the global 25000 Mt. To achieve climate stability, Europe has to cut back to 20 % of its present emissions. In the European power sector, about 2000 TWh/a have to be replaced by clean power. 1500 TWh of electricity can be co-generated with 60 billion m³ desalinated water for the MENA needs. In other words, a "clean power + fresh water" co-operation between EU and MENA would help to reduce those GHG emissions substantially.

Solutions by Solar Thermal Power & Desalination Facilities

The Trans-Mediterranean Renewable Energy Cooperation TREC proposes to install Solar Thermal Power & Desalination Facilities (STPD) as a world sustainability project. In a STPD, fresh water and electricity can be produced from sea water and solar radiation. This can become beneficial for many places in the MENA region. Even an area such as Sana'a, located 200 km away from the coast and at an altitude of 2200 meters, could get water and the power for pumping from such a facility located at the Red Sea. The required solar technologies are available (Annex 1).

Desalination and transportation of water for tens of millions of people – a number expected to grow in the coming decades - require a great deal of energy with unlimited availability, at stable costs over centuries, and without contributing to climate change. These requirements can be met by solar energy, which is abundant in all MENA countries. It is inexhaustible, expandable and clean, while its cost predictably declines with increasing demand. This resource may be exploited using the technology of concentrating solar thermal power (CSP), which has already been developed and employed at appropriate locations in Europe and elsewhere. An STPD world sustainability project could establish water and energy security in the MENA region. It would have the following distinguishing features.

[1] Yemen Times, Issue 39, 1997: Consultative Council Tackles Yemen's Water Crisis!
The Consultative Council (CC) is addressing Yemen's water crisis head-on. "We want the general public to be aware that there is a problem, and that we need to address it," said Mr. Abdulaziz Abdulghani, Chairman of the CC. The Council has invited various government bodies and professional specialists to present their summary assessment of the problem, and proposals of solutions, in daily hearings to be held during 4-7/10/1997.
In a synopsis report already prepared by the CC, it is clear that many Yemeni cities, notably Sana'a and Taiz, already face a nightmare. The Sana'a basin is being depleted at an alarming rate. "The water level falls by 1.5 centimeters every day," the report reads.

Water and Power for domestic demand:

The scenario starts with a 5 MW plant with a desalination capacity of 1.7 million m³/a. By 2015, a desalination volume of shortly 700 million m³/a could be achieved, and 17 TWh/a of clean electricity would be co-generated (Figure 4). This power would be sufficient for pump-

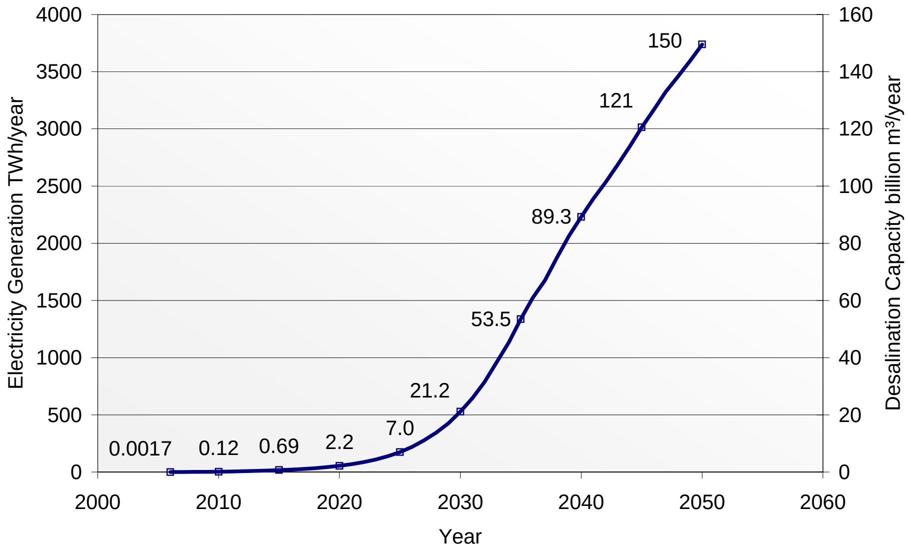


Figure 4: Expansion scenario of solar thermal electricity and water generation in MENA. The numbers within the graph indicate the accumulated desalination volume in billion cubic meters per year.

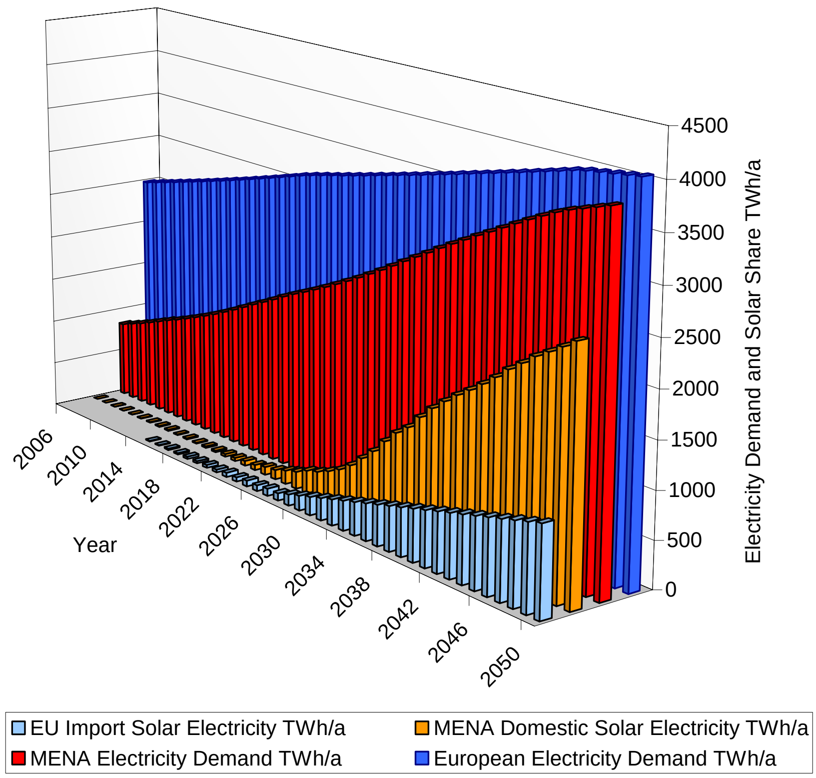


Figure 5: Scenario of the electricity demand in EU and MENA and the share of solar thermal electricity for domestic supply and for export to Europe in the scenario considered here. EU includes the Western and Eastern European electricity grids UCT1 and UCT2. MENA includes the South Western Mediterranean Block (SWMB), the South Eastern Mediterranean Block (SEMB), Turkey and the Arabian Peninsula.

ing fresh water from the plant to locations several hundred kilometres distant and at high elevations. The "market introduction phase" yielding competitive prices for both products can be finalised before 2015, with a desalination capacity of up to 700 million m³/a, and an electricity generation of 17 TWh/a.

In the above mentioned case of Sana'a, pumping from sea level would take about 30 % of the co-generated electricity. The solar energy resource in MENA is practically unlimited. The existing potential would suffice to cover the total world energy demand several hundred times. In our scenario the expected deficit of freshwater in MENA could be covered by the year 2040, together with 50 % of the regional domestic power demand, which by then could have grown almost to the level of the European demand (Figure 5).

Export of Electricity:

Solar electricity could also be exported to Europe, creating a strong economic exchange and a free trade area EUMENA for clean power. In the long-term, something like 20 % of the European demand could be covered (Figure 5). Export could start as soon as the first interconnecting line between Europe and MENA would be available. Prior to that, green power markets from Europe could be virtually extended to MENA in order to contribute to the finance of this infrastructure, e.g. in the frame of the Clean Development Mechanism (CDM) and green electricity trading. CO_2-emission certificate trading will also be helpful. The physical export of solar power may start as soon as competitive costs are achieved and the necessary infrastructure would be available.

Land Use:

The solar collector array required for desalinating 1 billion m³ would cover a total land area of approximately 10 km x 10 km, corresponding to about 10 m³ desalinated water per m² of collector area. In case of linear Fresnel or multi-tower technology (Annex 1), the collectors would act like blinds, blocking the intense direct solar radiation and creating a cool space underneath with sufficient light for horticulture or other purposes. About 10 % of the desalted water would be sufficient for irrigating the desert land beneath the collectors with a water column of 1 m/a. In the year 2050, the scenario arrives at 3600 TWh/a of electricity and 150 billion m³/a of desalted water. For this a collector field of 120 x 120 km² will be necessary, which is equivalent to not more than 0.15 % (0.0015) of the Sahara desert.

Economy of Solar Energy vs. Fossil Fuels

For comparing costs of solar energy with fuels we convert both resources to the same energy unit. Here we choose US-gallon of fuel #2 for which the costs are well documented in US-cent, as reference unit (www.oilnergy.com). We compare the costs of solar steam with the cost of fuel oil that would be necessary to produce the same amount of steam, in units of cent/gallon fuel. This equivalent solar fuel cost is directly comparable to the market price of fuel oil #2. A conversion factor of 25 gallons of fuel oil per MWh of steam was used. The equivalent solar fuel cost includes all investments, interest rates, operation, maintenance, personnel and insurance costs as well as the thermal energy losses in the collector. The future cost trends have been related to the scenario of expansion of STPD plants in MENA described before (Figure 1), considering technology learning and economies of scale (Annex 2). An initial average fuel price of 75 ct/gal escalating with 1.2 %/a was assumed for an equivalent conventional fuel-fired system with the same energy and water output.

The expected costs are shown in Figure 3a for an average solar irradiation level in MENA and for varying interest rates, and in Figure 3b for a constant interest rate and varying irradiation. A 20 year period for the return of capital (investment plus interest) and a 40 year operation life time of the plants was assumed for the calculations. Interest rates may vary between 12 % for private projects and 6 % for subsidised public-private partnerships (Figure 3a), and the irradiation intensity may vary from 2000 kWh/m²/year in Northern Morocco to about 3000 kWh/m²/a in some regions along the Red Sea (Figure 3b). An interest rate of 9 %/a (equivalent to 7 % debt interest and 15 % equity interest) and an annual solar irradiation of 2500 kWh/m²/a is considered as reference case (Details in Annex 3).

The cost difference between the solar and the fossil cost curves can be integrated up to the break-even point, yielding the required start-up subsidies. They are totalling up to 700 million US$ for the reference case. For the private investment case (12 % interest, red curve in Fig. 3a) they amount to 2000 million US$, and for the soft loan case (6 % interest, blue curve in Fig 3a) to about 200 million. Similar variations go along with modest and excellent radiation conditions shown in Fig. 3b. This means, that low interest rates as well as the choice of high radiation locations could dramatically reduce the cost of market introduction. The resulting required initial support of 2000, 700 or 200 million US$ is to be compared to the overall investment of 23.7, 8.7 or 2.5 billion US$ for the respective period until break-even (6, 10 or 13 years). In all cases the required support is roughly 8 % of the investment.

In the Figures 6a and 6b the cost reductions are exhibited as depending on the time of plant construction. Underlying to this timely evolution is the capacity expansion assumed in the

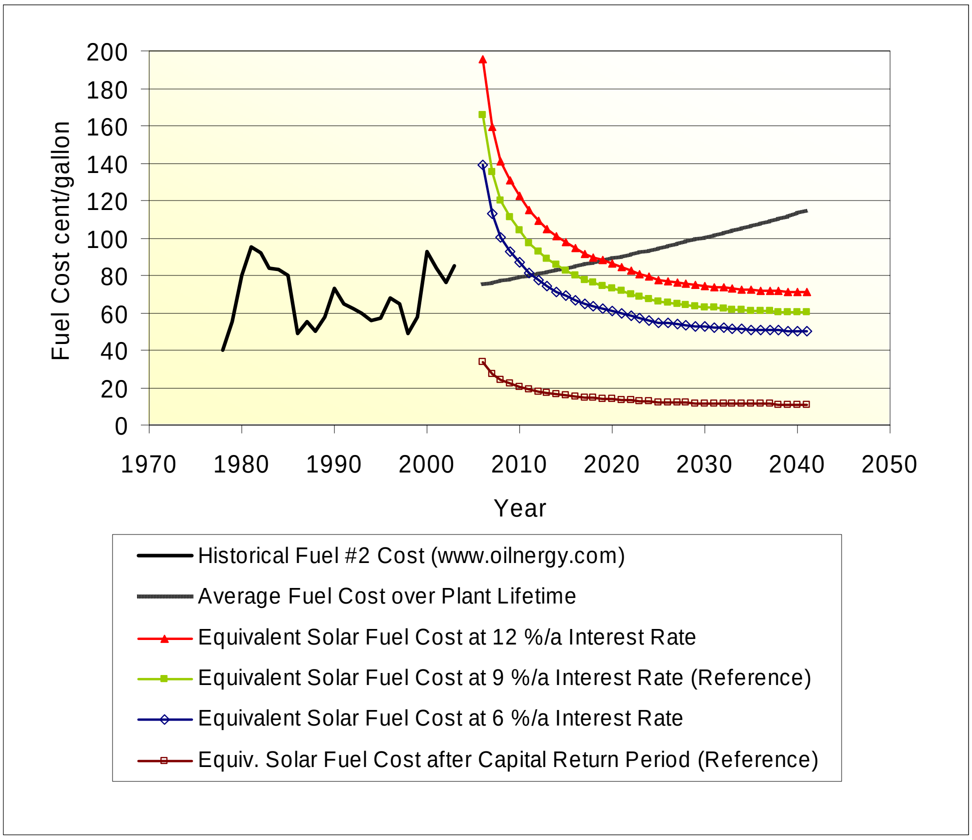


Figure 6a: The equivalent solar fuel cost as a function of commercial interest rates; Constant parameters: irradiation 2500 kWh/m²/a, capital return 20 a, plant life 40 a

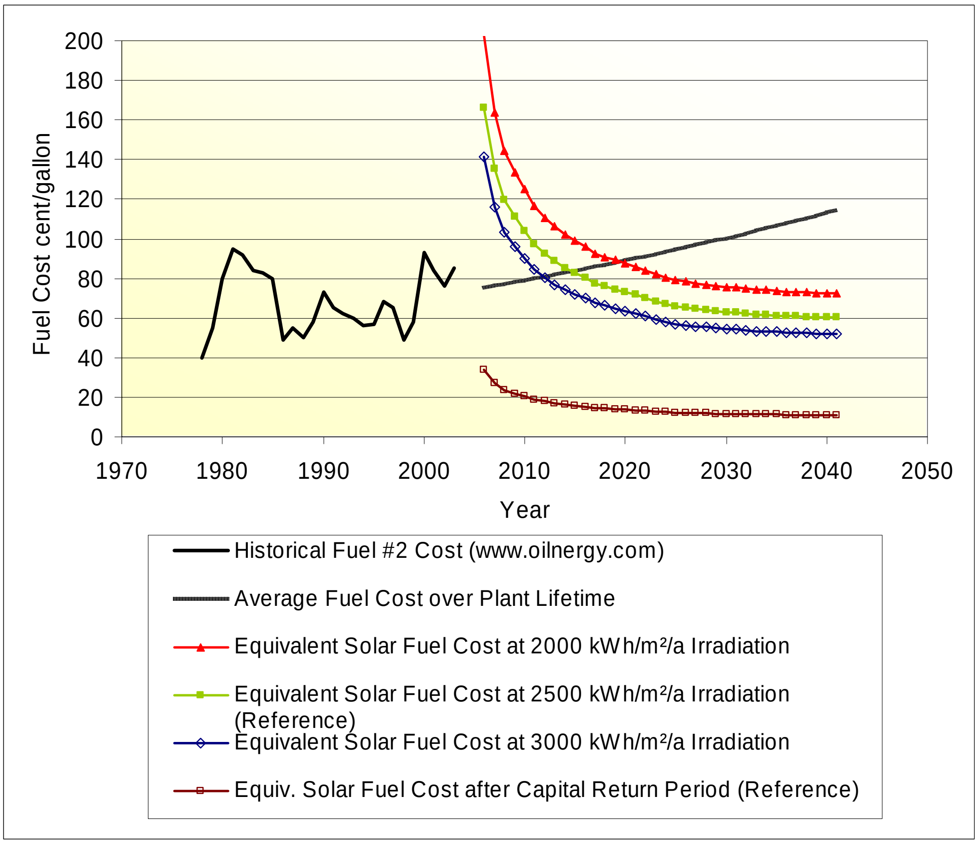


Figure 6b: The equivalent solar fuel cost as a function of solar irradiation; Constant parameters: interest rate 9 %/a, capital return 20 a, plant life 40 a

scenario. The cost reduction can also be shown as a function of capacity expansion. This is displayed in Figure 7 for the same radiation and financial configurations as in Figure 6a.

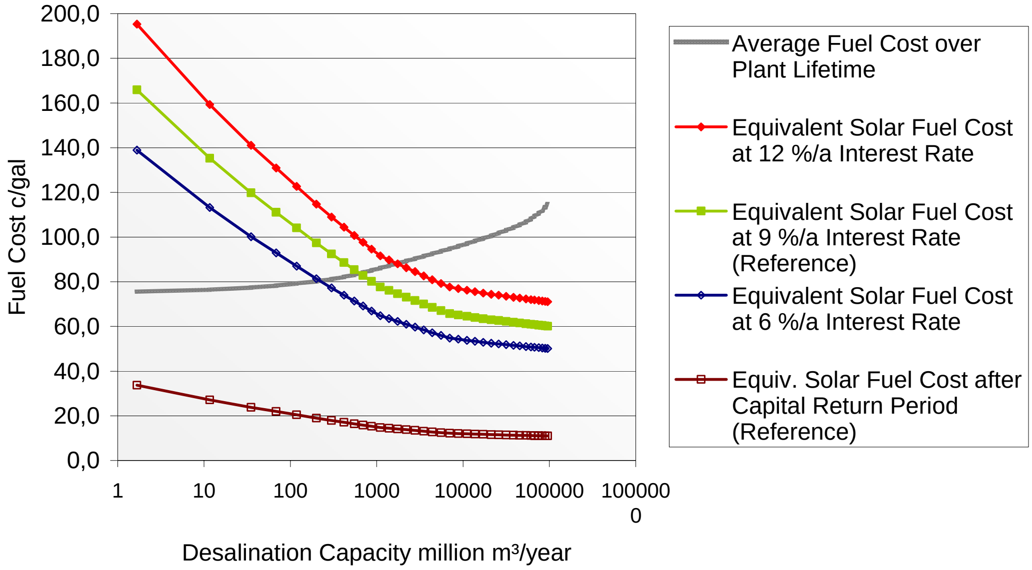


Figure 7: Equivalent solar fuel cost as a function of the installed desalination capacity in MENA compared to the expected fossil fuel costs within the same time span, irradiation 2500 kWh/m²/a

Figure 7 shows that, depending on the conditions of finance, a STPD capacity of the order of 200, 700 or 1700 million m³ per year is the volume needed for bringing the cost of solar thermal energy to below that of fossil fuels. These water volume values correspond to power capacities of 600, 2000 or 5000 MW, respectively.

Amortization of Initial Support

Even if an initial support of 2000 million US$ for the start-up phase would pay off by the following benefits:

1. Fossil fuel costs are expected to rise with growing scarcity, posing a potential future danger to the national economies. However, by the transition to solar energy, energy costs will begin to fall after the break-even point. Within a maximum of 5 years after break-even, the initial additional public funding would already be gained back as savings from avoided fuel expenses. After that, billions of US$ would be saved every year. Even countries with own oil or gas reserves would be much better off saving their fossil fuel treasures or at least selling them on the world market rather than burning them for nothing.

2. After the capital pay back period of 20 years, each STPD plant will have another 20 years of “golden end” operation time, where the solar energy cost comes down to about 10 % of the fuel cost. Power and water from STPD plants during this period will be even cheaper than today’s subsidized electricity and water costs in most MENA countries. That means that future costs can be kept as low as today, without any subsidies.

This analysis shows that within one decade, concentrating solar thermal energy can be made cheaper than fuel, if the initial cost barrier is overcome by public or international funding. The sooner the MENA countries embark on the trail of cost reductions, the more they will take advantage from solar energy. However, if they wait until private investors do the first step when fossil fuel prices begin to exceed the initial solar energy cost, they will pay a high price via rising fuel costs. They loose many years of economic and developmental advantages from their solar energy potentials.

Market introduction with optimized conditions

To unlock the solar potential for the benefit of MENA countries a strategy of combining favourable conditions is required. There are many ways that could help to overcome the initial cost barrier and to lower the costs for solar energy. An optimized conditions scenario is displayed in Figure 8, where an excellent solar location with 2750 kWh/m²/a direct normal irradiation is combined with a low investment interest rate. Here 75% of the investment is covered by a soft loan with 0 % interest rate and 25% by private capital with 16% interest.

In the comparison of solar and fossil fuel costs in Figs. 8 and 9, these favourable financial conditions apply to both, to solar and to fossil fuel plants. Already after 1 year the solar energy will be cheaper than fossil fuel.

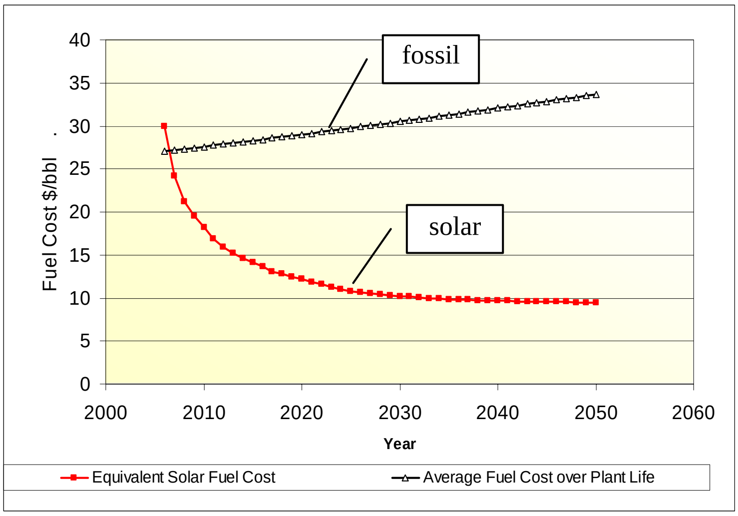


*Figure 8: Average fuel cost of fossil and of concentrating solar power plants in the **optimized conditions scenario** with the specifications: Interest rate 4 %/y, lifetime 40 years, initial fuel cost 25 $/bbl, fuel cost escalation 0.5 %/y, insurance rate 0.5 %/y, O&M cost 2.5 % of investment per year, initial steam cycle investment of solar plants 1050 $/kW, conventional steam cycle plant investment 800 $/kW, initial multi-effect desalination plant investment 1150 $/m³/day, carbon emission credits 10 $/ton, average solar irra-diation 2750 kWh/m²/y.*

Such a **program of accelerated cost reduction as a means for water and energy security** could bring the MENA countries into a very favourable position: solar electricity and desalinated water would become substantially cheaper than from fossil production, as shown in Fig. 9. The solar path would become increasingly beneficial for national economies. The solar technology could be applied anywhere in MENA, and also world wide. It could guarantee long term and large scale production of low cost power and water in a sustainable and environmentally friendly way. After about 15 years desalinated water could cost <0.20$/m³, and after about 25 years <0.10$/m³, making it also interesting for irrigation. Co-generated power would not have to exceed 3.5 cent/kWh. Such a project could help to limit global warming and create a good position for clean energy export to Europe and other regions with Kyoto obligations. It would qualify as a world sustainability project.

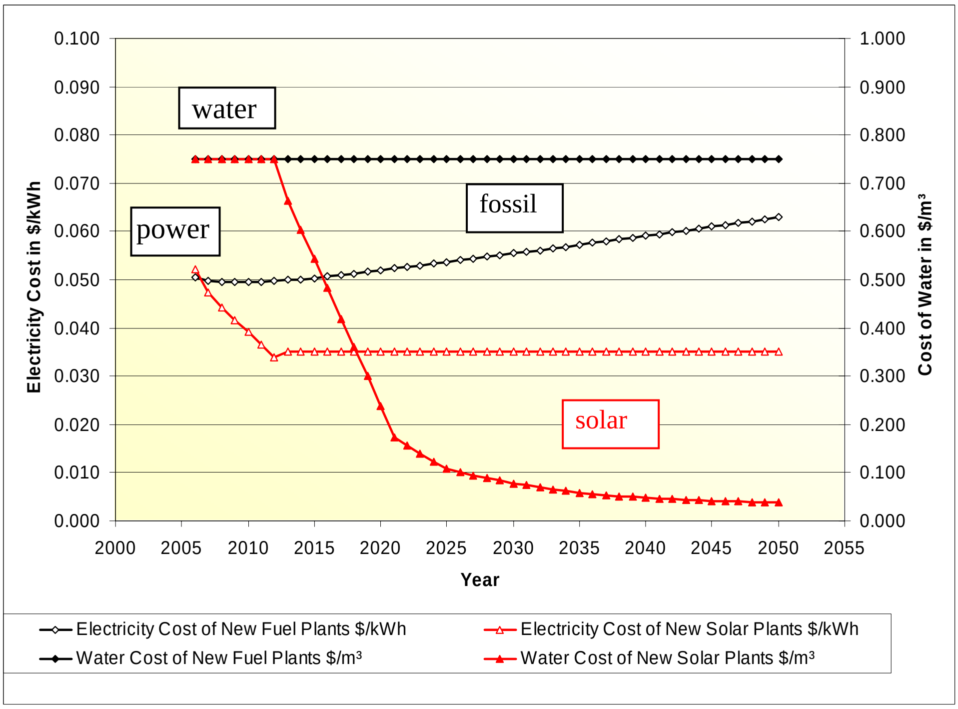


*Figure 9: **Optimized conditions scenario**, showing a cost profile for power and water from fossil fired (black) and from concentrating solar co-genera-tion plants (red) for combined power and water production in MENA. Calcula-tion parameters as in Figure 8.*

The initial support for STPD is very unlike the long-term subsidies often given to oil, gas and coal: it is an investment into continued cost reduction.

Besides returning a considerable profit within the lifespan of each plant, the proposed MENA project triggers a number of benefits for the whole EU-MENA region and beyond.

General Benefits of the Project

1. The freshwater source from seawater and solar radiation will work "for ever". Many cities and regions in MENA will be provided with adequate water supplies without temporal restrictions.
2. Solar thermal energy will become less expensive than fossil fuels, offering to the MENA countries a source of wealth and development. They can begin saving money using their greatest, inexhaustible natural energy resource.
3. An accelerated development under optimized financial and solar conditions can bring the MENA countries in a very favourable position: After about 10 years desalinated water cost can reach 0.35$/m³, and after about 20 years 0.15$/m³, and co-generated power would not exceed 3.5cent/kWh.
4. Once solar thermal technologies provide energy cheaper than fossil fuels at good locations, they can produce clean power for most of the world's population, mitigating global climate change while resolving the problem of fading resources at even lower energy costs than today! This qualifies the proposed project as a *world sustainability project*.
5. MENA countries may start to co-generate with their water low cost clean power for export to Europe, within a period of 10 years.
6. The semi-shadowed ground under the collectors may host irrigated horticulture in coastal desert regions, providing a valuable source of food and jobs in the MENA countries.
7. The spearheading countries would develop solar sciences, research, and industry, thereby building an economy based on technical skills and cumulative knowledge.
8. The joint implementation of this world sustainability project could draw Europe, the Middle East, and North Africa together into close co-operation, thus laying ground for an Integrated Sustainability Region EUMENA.

Start of Implementation **

1. Technology Transfer Projects

As already pointed out, the solar technologies in question are not yet in operation in the MENA region. To bring concentrating solar collector systems for steam production into the region we propose to build prior to large systems a few technology transfer projects. They are described in the following.

The POSEIDON[2] Project: Technology Transfer and Adaptation

The POSEIDON concept aims at planning, optimizing, designing and building a first plant for solar electricity generation and seawater desalination based on concentrating solar thermal power (CSP) technology in a MENA coastal area with arid or semi-arid climate, and to prepare for the replication of this concept in the MENA region and world wide.

POSEIDON includes the first concrete steps to be taken in the frame of the MENA Solar Thermal Power & Desalination (STPD) strategy developed in the previous paper. Any of the available concentrating solar technologies (parabolic trough, linear Fresnel or central receiver) may be chosen by the participating MENA countries that want to join this strategy (Annex 1).

Phase 1: Within Phase 1 of the POSEIDON project, a co-generation steam cycle power block (PB) with a rated electric capacity of 5 MW combined with a multi-effect-desalination plant (MED) with a desalination capacity of 5000 m³/day shall be erected. The main product is desalted water, electricity a side-product, and the main purpose of this first project is the demonstration of the integrated plant concept (Fig. 10). The power & desalination plant will deliver a total of 40 GWh of net electricity and 1.7 million m³ of desalted water per year.

The plant consists of three subsystems:

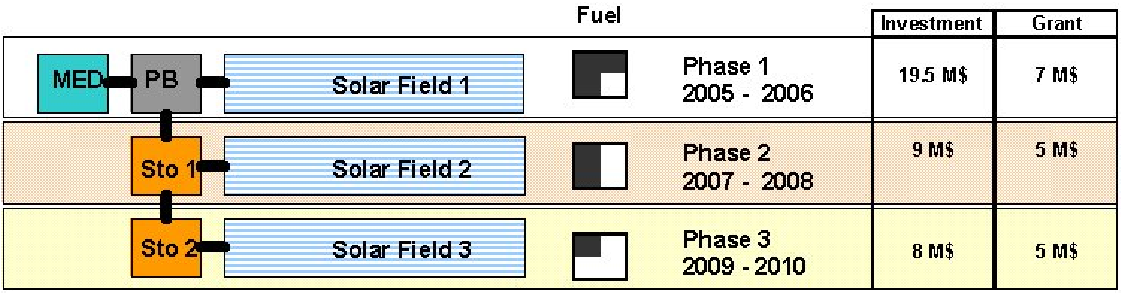
1. Concentrating solar thermal collector field and steam generation system
2. Steam cycle co-generation power block
3. Multi-effect-desalination plant

A concentrating solar collector field (SF) with an aperture reflector area of 25000 to 35000 m² (depending on site and technology) will deliver the necessary steam to drive the steam turbine co-generation cycle. A fossil fuel fired boiler is installed in series to the solar field to guarantee the necessary operating steam parameters at any time. A second boiler is installed in parallel to the solar field as backup and for night-time operation (Fig. 11). With 8000 annual full load operating hours (base load), the plant will have a solar share of about 25 %, while backup thermal energy will be provided by fossil or renewable fuels available on site. For Phase 1, the investment amounts to 19.5 M$ within the years 2005 to 2006.

[2] **PO**wer from concentrated **S**olar **E**nergy with **I**ntegrated sea water **D**esalinati**ON**

Although all components of the system are state of the art technology, their integration into one system must be optimised in technical and economical terms. Therefore, market introduction in MENA should start with a small STPD-unit of 5 MW of power capacity and, following a careful learning approach, steadily develop plants with larger capacities in order to benefit from the related economies of scale. System integration can thus be achieved without greater risks, since this small demo-plant can be operating and creating full revenues from the beginning. Phase 1 could be completed by the end of 2006. By that time, the concentrating solar thermal collector system would have fully demonstrated its qualification for providing steam to the subsequent co-generation process for electricity and desalted water under MENA site conditions. From that moment, plants can be designed with the same configuration but much larger capacity, taking advantage of the economies of scale of larger collector fields and power systems and inducing further learning.

Phase 2 will be realised between 2007 and 2008, when the demo-plant will be extended with a larger solar field and a thermal energy storage system (Sto 1 in Fig.10), which will allow for night time solar operation and increase the solar share to about 50 %. The estimated investment for that phase amounts to 9 M$. When this extension is demonstrated, design and implementation of larger plants can be based on this configuration, again taking advantage of the related economies of scale.



In

Figure 10: Sketch of the POSEIDON demo-plant in its three phases of implementation. Fuel consumption is initially 75 % of that of a conventional plant and 25 % at the end of phase 3.

Phase 3, the solar field of the pilot plant will be extended further and a second storage system will be implemented. Thus, the solar share of the pilot plant will increase to 75 % by the year of 2010. The investment will amount to 8 M$. After this final step, large scale solar collectors with storage can become a standard energy source for combined power and desalination in MENA. Introducing large concentrating solar thermal power and desalination plants with increasing storage capacity to the market as described in the previous strategy paper, will finally lead to costs of concentrated solar thermal energy to be lower than that of fuels.

Economy of the POSEIDON Project

The three phases of the demo-project require a total investment of 36.5 M$. Assuming a world market price of fuel of 75 ct/gal, the electricity cost of a fossil fuel fired plant with the same output and financing conditions (interest 9 %, debt period 20 years) would be in the order of 5.9 ct/kWh, and the cost of desalted water 0.9 \$/m³ (Table.3). In order to achieve the same price as a fuel-fired plant, an investment subsidy (grant) of 17 M$ would be needed for the three phases together. Alternatively, electricity revenues of 10.5 ct/kWh and water revenues of 0.9 $/m³ would also cover the full costs of this first 5 MW plant.

After 20 years of operation, the debt capital will be returned together with the interest payments. Due to the much longer technical lifetime of such a plant, a second 20 years period without annuity service (which is the main cost item) will start then, yielding cost reduction of around 90% for power and water. This “golden end” period will lead to unbeatable low prices for power and water in MENA, because once the capital is returned, only operation and maintenance costs remain.

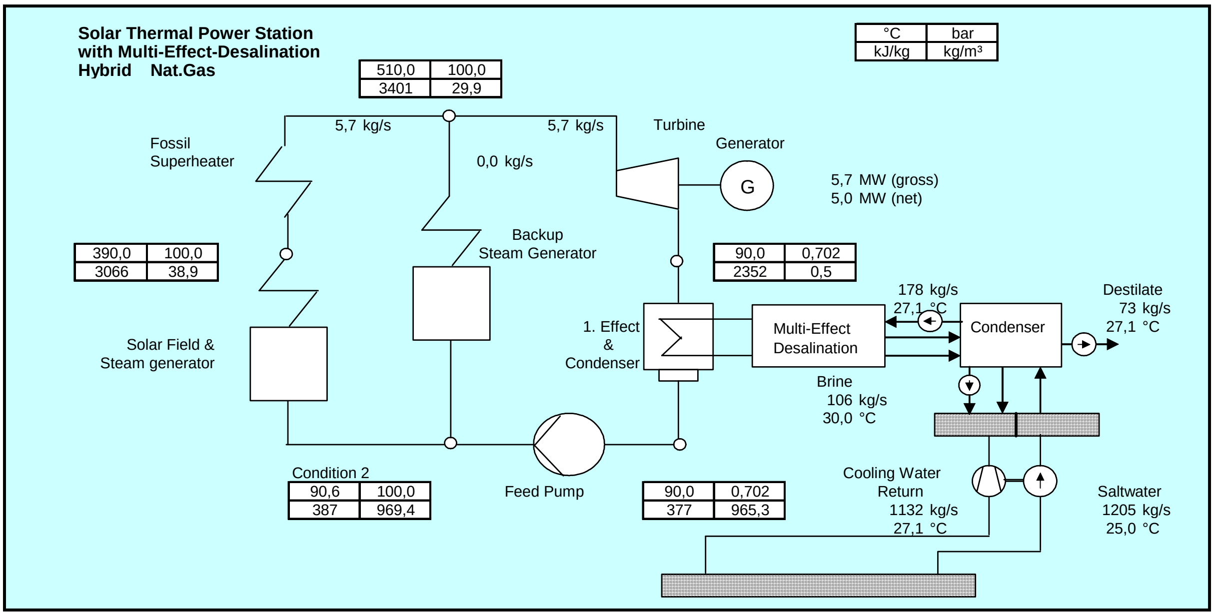


Figure 11: Simplified sketch of a POSEIDON concentrating solar power station with combined multi-effect desalination plant under design operating conditions

In parallel to the step-by-step expansion of the demo-plant and with the experience gained, a scale-up to larger plants can take place once the first prototype (Phase 1) is running, building larger plants based on a demonstrated concept. Specific costs of the larger plants will be much lower than for the demo-plant, as learning effects and economies of scale will reduce costs. Thus, the initial investment and the initial technical and financial risks are greatly reduced for the larger plants which will always be based on demonstrated technology, while innovations will take place primarily within the smaller demo-plant. The POSEIDON project will include the planning, engineering, procurement and construction of a demo-plant and preparations for its replication in the MENA region.

The co-generation of desalted water will create a second income source, allowing for a relatively low electricity cost in spite of the small size of the pilot plant. Of course, the price can be shifted from power to water according to the economic circumstances. 47 % of the total investment is required as grant, the rest is covered by revenues.
Larger plants will have capacities of 50 up to several 100 MW.

Investment		
MED-Plant	5,8	M$
Solar Field	20,0	M$
Storage	5,5	M$
Power Block	5,3	M$
Total	**36,5**	**M$**
Required Support	17,0	M$
Eff. Investment	***19,5***	***M$***
Spec. Inv. MED	1150	$/m³/d
Spec. Inv. SF	238	$/m²
Spec. Inv. PB	1050	$/kW
Spec. Inv. Sto.	73	$/kWhe
Fuel escalation	1,20%	
Plant Life	40	y

Cost		
Capital	2,14	M$/y
O&M	0,91	M$/y
Insurance	0,18	M$/y
Fuel	0,64	M$/y
Total Cost	**3,87**	**M$/y**
Revenue Water	-1,50	M$/y
Effective Cost	***2,37***	***M$/y***
Effective LEC	***0,059***	***$/kWh***
Debt Period	20	y
Interest	9,0%	
O&M Rate	2,5	%/y
Insurance Rate	0,5	%/y
Fuel Price	17,5	$/MWh
Water Price	0,9	$/m³

Technology		
Power	5	MW
Water	5000	m³/d
Solar Share	0,75	
Fuel Share	0,25	
Gross Efficiency	0,33	
Full Load Hours	8000	h/y
Net Electricity	40,0	GWh/y
Water	1,7	Mm³/y
Solar Field Size	84000	m²
Available Heat	91,3	GWht/y
Spec. Heat MED	54,8	kWh/m³
Spec Elec. MED	2	kWh/m³
Total Elec. MED	3,3	GWh/y
Storage Capacity	15	h
Storage Capacity	75	MWh

Table 3: Technical and economic parameters of the three phases of the Poseidon Project

The POSEIDON project will also demonstrate that CSP is well suited for a smooth transition from today's fossil energy schemes to a future solar energy economy, without any constraints in power availability or grid stability. Under very good meteorological conditions, even around the clock and around the year full solar operation is feasible for future plants with 24 hour thermal energy storage, eventually yielding electricity costs as low as 2 ct/kWh.

The project may be co-financed by green electricity trading in Europe, because both solar generation and co-generation of electricity (even if based on fossil fuels) are treated as green power. The combination of solar energy with co-generation is green power par excellence. Green power certificates could create an additional financial return of the initial investment.

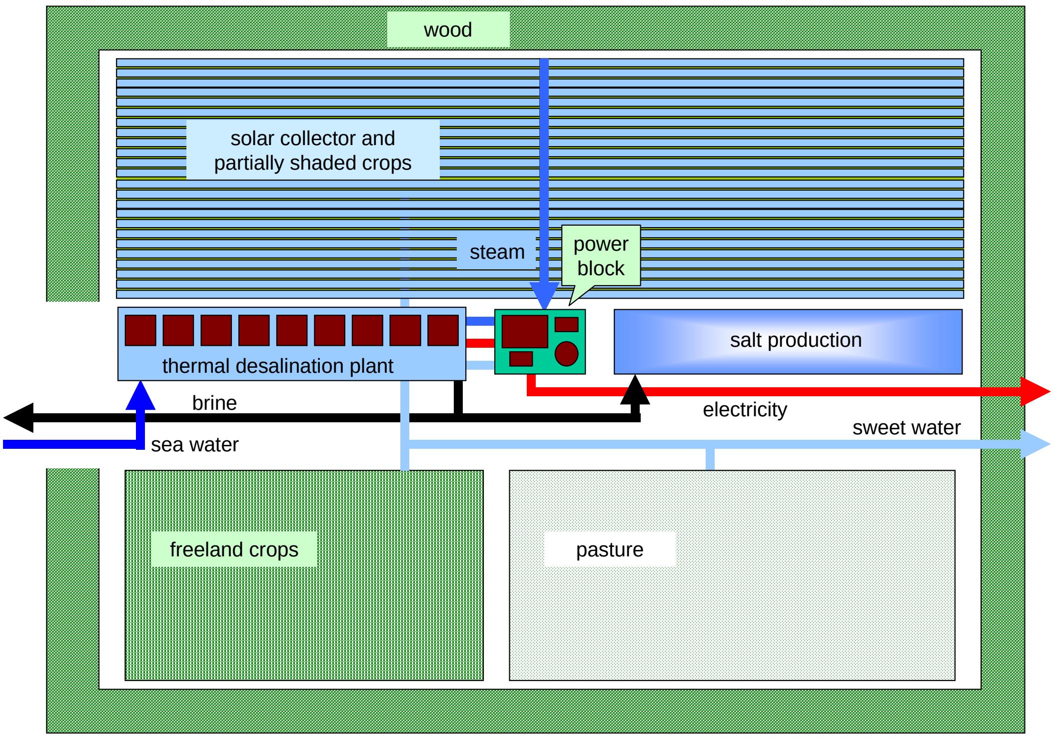


Figure 12: Impression of a multi-purpose concentrating solar power plant generating electricity and water for the industrial and agricultural development of desert or semi-desert zones

The project could also be designed as a multi-purpose plant, providing shade and shelter for agriculture, parking, salt production, forestry etc., with many possibilities to additionally combat desertification and to trigger the economic development of arid regions (Fig. 12).

2. Education, Research and Technology Development by the POSEIDON Project

Technological improvements are one of the keys to cost reduction, and potential benefits by cost reduction are the driving force for technological improvements. The highest interest in technological improvements is naturally in the countries using the power and water from the STPD plants. This requires qualified people. Hence there should be research and technology development opportunities in these countries. Also, potential use of shaded and irrigated land under the collectors can only be developed under real climatic conditions. Further, the R&D options at the demo-plants will attract scientists from all over the world and bring brain ("brain gain") and knowledge into the MENA countries. These demo-plants can thus become the core for educational institutions in the field of solar science and technology, and for technology development. The more the demo-plants will be accessible for experimentation, the more beneficial they will become for the development of MENA countries.

Actions*

Europe and MENA - a Renewable Energy and Development Partnership

The TREC initiative proposes that the regions of EUMENA, Europe, the Middle East and North Africa, join their forces and their energy demand to exploit renewable energies. Europe could provide technological know how for MENA to get started quickly, and MENA countries could become a substantial and economical source of clean power for Europe[3], and a unique opportunity for MENA countries to develop industrialization and to generate an industrial product for export.

The prospect of these benefits calls for practical steps to get started. We plan four such steps:

1. Sustainable Water and Energy Security Initiative (SWESI)

To unlock the solar potential for the benefit of MENA countries could work as follows:

- Some countries agree to form a **Sustainable Water and Energy Security Initiative (SWESI), to organize their co-operation.**.
- They identify a desalination demand in the range of ½ - 1 Billion m³ per year,
- They will support construction of solar thermal power and desalination plants as **infrastructure project for their own water and energy security** by low interest loans.
- They establish a strategy team with the task of organizing a fast beginning of installing demonstration and technology transfer projects
- The strategy team will be a mixture of experts and of governmental representatives. It will be constituting at the Sana'a conference and by the end of 2004 deliver a plan for quick start up strategy.

2. Strategy workshop

The Club of Rome and TREC call for 2 workshop on

How Solar Thermal Power can be made beneficial for MENA Countries

in conjunction with the Arab International Conference on Solar Energy Applications in Tripoli, Libya, and with the annual meeting 2004 of CoR, in October 2004.
This strategy workshop should address and organize the following topics:

- Solar thermal potential maps
- Power and desalination in cogeneration
- Water demand inventory, mainly for cities
- Industrial capacity development
- Finance
- Solar science, research and development
- Market introduction strategy
- Structures of Co-operation

[3] two recent studies, one by the EU commission and one by the International Energy Agency IEA, demonstrate that attempts to achieve climate stability and secure energy supply with the renewable energy potentials in strictly separated world regions like EU, the Middle East, Africa and the like, as in a pre-globalization world, will fail to cope with climate change

3. Information visits to interested countries

The knowledge on advanced solar technology and its beneficial potential for many MENA countries is not broadly disseminated at present. For this reasons, many MENA countries are missing opportunities of their technological and economic development. TREC can help to overcome this deficit. Information events could be organized by interested countries with TREC experts giving information on these matters to competent scientific institutions and to relevant political/governmental bodies or interested business circles.

4. STPD users organisation

TREC is a network for information, consultation, and problem resolution and invites European and MENA countries to join this partnership to efficiently exploit renewable energies to their benefits. For instance, by amalgamating the wide-spread need for STPD (solar thermal power and desalination) facilities in the MENA region all participants will benefit from forming a demand-side lobby group. Coordinated demands will ease the way and lower the costs for system solutions through:

1. Common conceptual and technological approaches
2. Cost reductions resulting from mutual problem analyses and feasibility assessments with appropriate studies
3. Benefits derived from sharing technology improvements
4. Mutual advantages arising from collective contributions to the economies of scale.

The conference MENAREC at Sana'a and the international conference renewables2004 at Bonn present excellent occasions of forming a future **STPD users organisation** (see Annex 4). Governmental representatives may indicate their country's interest in membership. As a result, the STPD user organisation can arrange for substantial discounts for a first assessment of feasibility and cost of a STPD facility when there are several optional locations within a country, and also for the follow-up feasibility study.

The more we identify common demands, the more we will benefit from joint solutions.

Annex

Annex 1: Concentrating Solar Thermal Power Technology Options **

Concentrating solar thermal power technologies (CSP) are based on the concept of concentrating solar radiation to be used for electricity generation within conventional power cycles using steam turbines, gas turbines or Stirling engines (Figures A1 and A2). For concentration, most systems use glass mirrors that continuously track the position of the sun. The concentrated sunlight is absorbed on a receiver that is specially designed to reduce heat losses. A fluid flowing through the receiver takes the heat away towards the power cycle, where e.g. high pressure, high temperature steam is generated to drive a turbine. Air, water, oil and molten salt are used as heat transfer fluids.

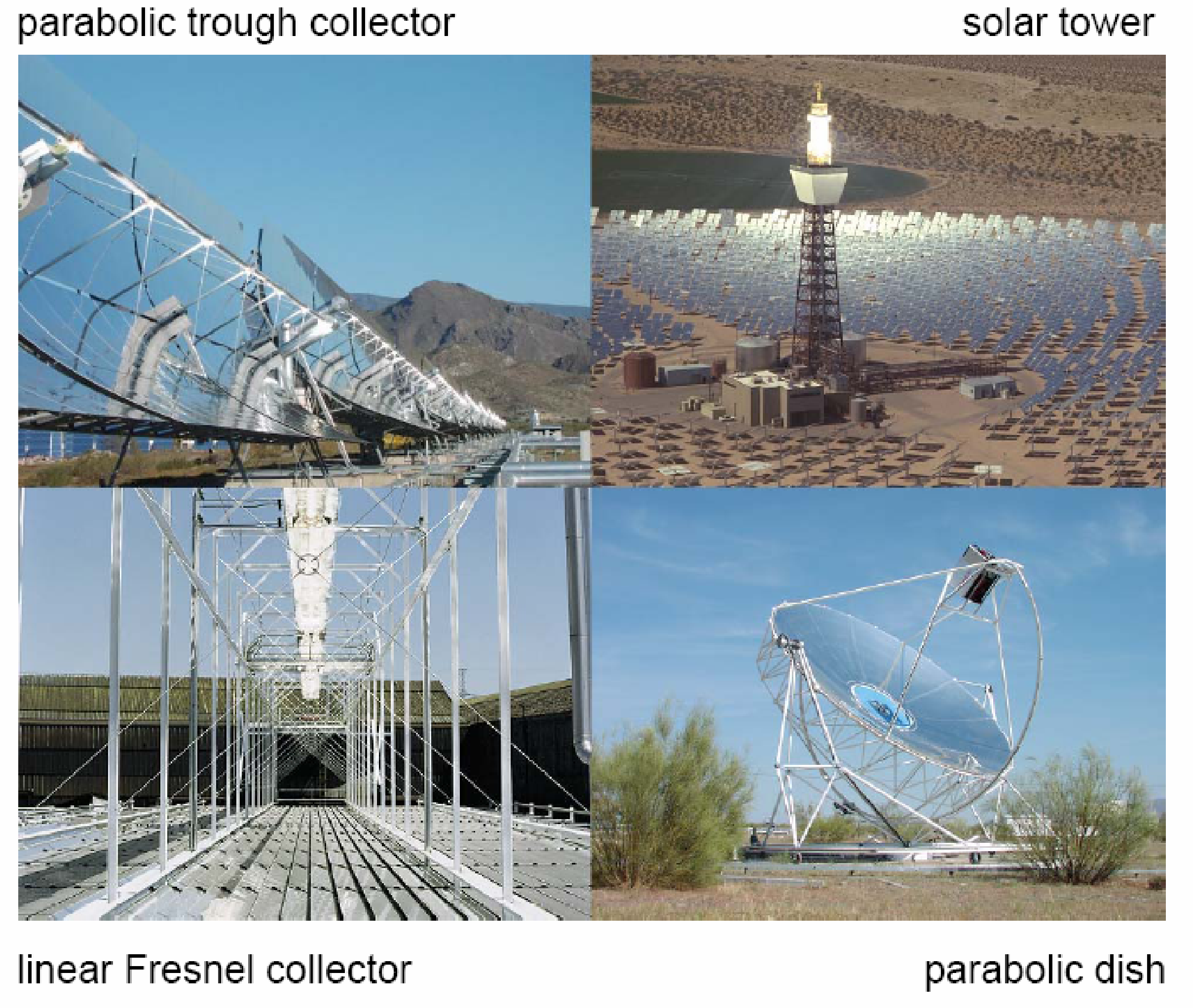


Figure A1: The four CSP collector technology main streams realised up to date (Sources: DLR, SNL, Solarmundo, SBP)

Parabolic troughs, linear Fresnel systems and power towers can be coupled to steam cycles of 5 to 200 MW of electric capacity, with thermal cycle efficiencies of 30 – 40 %. Dish-Stirling engines are used for decentralised generation in the 10 kW range. The values for parabolic troughs have been demonstrated in the field. Today, these systems achieve annual solar-to-electricity-efficiencies of about 10 – 15 %, with the perspective to reach about 18 % in the medium term (Table A1). The values for the other systems are based on component and prototype system test data and the assumption of mature development of current technology. The overall solar-electric efficiencies include the conversion of solar energy to heat within the collector and the conversion of the heat to electricity in the power block. The conversion efficiency of the power block remains basically the same as in fuel fired power plants.

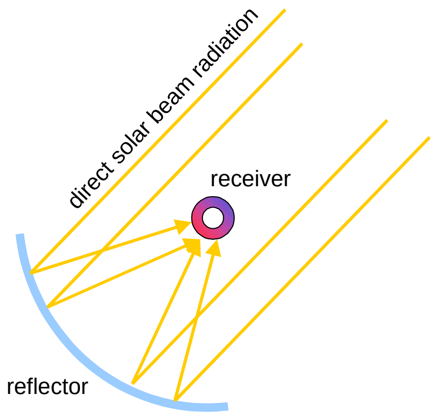


Figure A2: Principle of concentrating solar beam radiation

Each of these technologies can be operated with fossil fuel as well as solar energy. This hybrid operation has the potential to increase the value of CSP technology by increasing its power availability and decreasing its cost by making more effective use of the power block. Solar heat collected during the daytime can be stored in concrete, molten salt, ceramics or phase-change media. At night, it can be extracted from the storage to run the power block. Fossil and renewable fuels like oil, gas, coal and biomass can be used for co-firing the plant, thus providing power capacity whenever required (Figure A3).

	Capacity Unit MW	Concen-tration	Peak Solar Efficiency	Annual Solar Efficiency	Thermal Cycle Efficiency	Capacity Factor (solar)	Land Use m²/MWh/y
Trough	10 – 200	70 - 80	21% (d)	10 – 15% (d)	30 – 40 % ST	24% (d)	6 - 8
				17 – 18% (p)		25 – 70% (p)	
Fresnel	10 - 200	25 - 100	20% (p)	9 - 11% (p)	30 - 40 % ST	25 - 70% (p)	4 - 6
Power Tower	10 – 150	300 – 1000	20% (d)	8 – 10 % (d)	30 – 40 % ST	25 – 70% (p)	8 - 12
			35 % (p)	15 – 25% (p)	45 – 55 % CC		
Dish-Stirling	0.01 – 0.4	1000 – 3000	29% (d)	16 – 18 % (d)	30 – 40 % Stirl.	25% (p)	8 - 12
				18 – 23% (p)	20 – 30 % GT		

Table A1 Performance data of various concentrating solar power (CSP) technologies
(d) = demonstrated, (p) = projected, ST steam turbine, GT Gas Turbine, CC Combined Cycle. Solar efficiency = net power generation / incident beam radiation
Capacity factor = solar operating hours per year / 8760 hours per year

Moreover, solar energy can be used for co-generation of electricity and process heat. In this case, the primary energy input is used with efficiencies of up to 85 %. Possible applications cover the combined production industrial heat, district cooling and sea water desalination.

All concepts have the perspective to expand their time of solar operation to base load using thermal energy storage and larger collector fields. To generate one Megawatt-hour of solar electricity per year, a land area of only 4 to 12 m² is required. This means, that one km² of arid land can continuously and indefinitely generate as much electricity as any conventional 50 MW coal- or gas fired power station.

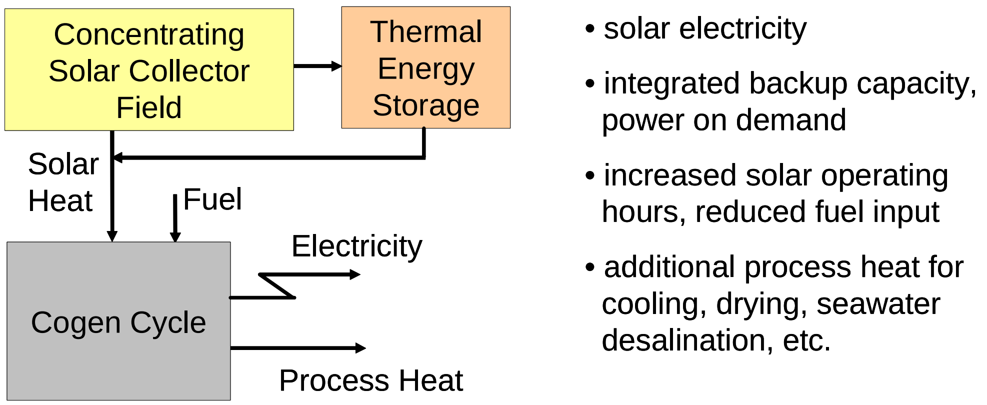


Figure A3: Principle of a solar thermal co-generation of power and desalinated water

Prospects of Research and Development

While present parabolic trough plants use synthetic oil as heat transfer fluid within the collectors, and a heat exchanger for steam generation, efforts to achieve direct steam generation within the absorber tubes are underway in the DISS and INDITEP projects sponsored by the European Commission, with the aim to reduce costs and to enhance efficiency by 15-20%. Direct solar steam generation has recently been demonstrated by CIEMAT and DLR on the Plataforma Solar in Almeria/ Spain, in a 500 m long test loop, providing superheated steam at 400 °C and 100 bar. All those R&D efforts aim at increasing efficiency and reducing costs.

A European industrial consortium has developed the new parabolic trough collector SKAL-ET, which aims to achieve better performance and cost by improving the mechanical structure and the optical and thermal properties of the parabolic troughs. Another European consortium has developed a simplified trough collector prototype with segmented flat mirrors following the principle of Fresnel.

The high temperatures available in solar towers can not only be used to drive steam cycles, but also for gas turbines and combined cycle systems. Such system promises up to 35 % peak and 25 % annual solar-electric efficiency when coupled to a combined cycle power plant. A solar receiver was developed within the European SOLGATE project for heating pressurised air by placing the volumetric absorber into a pressure vessel with a parabolic quartz window for solar radiation incidence. Multi-tower solar arrays may be arranged in the future so that the heliostat reflectors can alternatively point to various tower receivers. Like in other Fresnel systems, the horizontally arranged heliostats almost completely cover the land area and create a bright, semi-shaded space below for agricultural or other purposes.

Cost Perspectives of Concentrating Solar Thermal Power in EUMENA

With costs of 200 – 250 US$ per square meter for the turnkey installed collector field, electricity from CSP is today slightly more expensive than that from conventional power plants.

The technology must still run through a learning curve to become competitive within the next decade, with a realistic perspective to achieve collector costs of about 100 Euro/m². Preferential financing such as established by the German, Spanish and Algerian Renewable Energy Acts, emission trading and support from the Global Environmental Facility (GEF) can help to activate start-up funding.

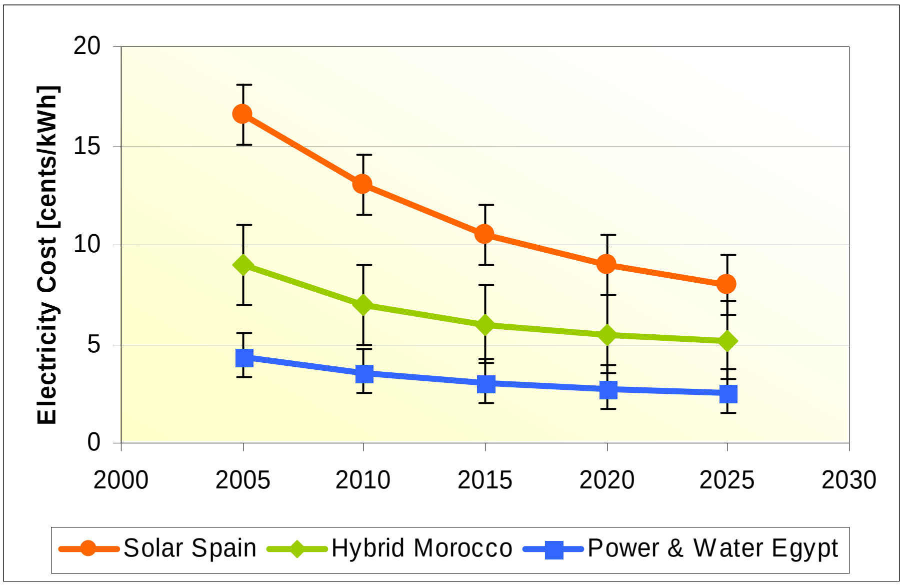


Figure A4: Electricity Cost of CSP-Plants for different environments and applications. Costs are reduced by R&D, economies of scale and by increasing operating hours through thermal energy storage. Solar Spain: Solar electricity generation in Spain, Solar Share = 100%, Direct Normal Irradiation DNI = 1900 – 2200 kWh/m²y, Capacity Factor CF = 20 % - 50 %, Hybrid Morocco: Hybrid electricity generation in Morocco (solar share = 25 % - 75 %, DNI = 2200 – 2500 kWh/m²y, CF = 40 % - 75%), Power & Water Egypt: Hybrid co-generation of power and desalinated water in Egypt (solar share = 25 % - 75 %, DNI = 2500 - 2850 kWh/m²y, CF = 85 %, revenue for desalted water = 0.5 - 1 $/m³). General economic assumptions: discount rate 8 %, plant life 25 years, fuel cost 2 - 4 $/GJ, escalation 0.5 %/y (Source: DLR)

The cost of solar thermal electricity depends on solar irradiation intensity and on the operation mode. For solar only operation in Spain it is about 0.16 – 0.18 Euro/kWh. Under those conditions, in the medium term, solar electricity costs of 6 - 8 ct/kWh can be achieved. Better radiation conditions are available in Morocco. Costs of hybrid (solar/fossil fired) plants would be in the range of 8 - 10 c/kWh today, with medium term perspectives to reach 4 - 6 ct/kWh. Under very good radiation conditions like in Egypt and in hybrid base-load operation using combined power and desalination plants, costs as low as 3-4 ct/kWh can be expected for the present technological concepts.

Clean Electricity for Europe by High Voltage Direct Current Transmission

An interconnection of the electricity grids of Europe and MENA would allow to transmit renewable electricity to Europe and to stabilise the MENA power grid. Such EU-MENA interconnection would not only reduce the cost of clean electricity in Europe, but would also create considerable financial benefits for the MENA countries.

The technology needed for such a south-north-interconnection is already state-of-the-art: at present, more than 60000 MW of electric capacity is transmitted by over 55 high voltage direct current transmission lines (HVDC) that are in operation world wide, mainly with the purpose to transfer electricity from remote hydro- or geothermal power sources to the urban centres of demand. The length of such lines reaches 2000 km and more, their transmission capacity up to 12000 MW each.

The additional cost on electricity for a transmission over 3500 to 4500 km distance would be in the order of 1 – 1.5 ct/kWh, including the infrastructure for the transmission line and the necessary converter stations as well as the 10 – 15 % electricity lost during transmission. The investment for a line with a capacity of 5000 MW would be in the order of 2 – 2.5 billion $. This means that electricity generated e.g. in combined solar power and desalination plants in MENA and exported to Europe would there be available at a cost of 4-6 ct/kWh.

European CSP Technology Overview *

Technology	Experience	Next Step	Current Providers/Developers of the Solar Components
Parabolic trough reflector with oil-cooled vacuum-isolated absorber tube in hybrid steam cycle power plant	SEGS I – IX , 354 MW installed between 1985 and 1991 in California, since then operating, steam generated in oil/steam heat exchangers at 370°C, 100 bar	50^{+} MW projects under development in Israel and USA	Solel, Israel (design, absorber), Flagsol (Germany (reflectors)
Re-designed and up-scaled structure of oil-cooled parabolic trough for steam cycle operation	100 & 150 m units of SKAL-ET (up-scaled EuroTrough) collector integrated to SEGS VI in California since April 2003	2 x 50 MW project under development in Southern Spain	EuroTrough Consortium, Solarmillennium AG, Flagsol, Schlaich, Bergermann & Partner, Schott, Germany (reflectors, structure, absorber tube)
Direct steam generating parabolic trough	700 m DISS test-loop in Plataforma Solar de Almeria, Spain, direct steam generation demonstrated at 400 °C, 100 bar	Concept for a 5 MW demo plant under development (INDITEP project)	Iberinco, Initec, Ciemat, (Spain) Flagsol, DLR, ZSW (Germany)
Solar tower system with pressurised hot-air central receiver for solar gas turbine and combined cycle operation	240 kW gas turbine operated first time December 2002 at Plataforma Solar de Almeria, gas turbine operated at 800 °C, 8 bar, (SOLGATE project)	2 x 80 kW gas turbine co-generation system for electricity and cooling under construction in Italy	DLR (Germany), Esco Solar (Italy)
Solar tower system with un-pressurised volumetric hot-air receiver	3 $MW_{thermal}$ TSA project in 1996-1998, steam generated at 550 °C, 100 bar; new modular ceramic hot-air-receiver presently tested in the European. Solair Project	Receiver endurance test and concept development for a 2 MW prototype plant within the German Cosmosol project	Solucar, Ciemat (Spain), Heliotech (Denmark), DLR, Kraftanlagen München, (Germany)
Linear Fresnel collector with secondary concentrator and direct steam generating absorber tube	100 m prototype tested in Liege, Belgium, direct saturated steam generated at 290 °C (Solarmundo project)	200 m test loop for superheated steam generation at Plataforma Solar de Almeria	FhG-ISE, PSE, DLR (Germany)

* only selected European main-stream activities are listed, RD&D of CSP technology is also taking place in other parts of the world, mainly USA and Australia

Annex 2: Details of the MENA Solar Power & Desalination Scenario **

The scenario displayed in the attached table is calculated for the reference case with 9 % project interest rate, 20 year capital return period and 2500 kWh/m²/a annual solar irradiation. It can be scaled and be applied to any region in the MENA region. It is based on the following principles:

1. The scenario is not a prognosis. It is a possible, self-consistent way of proceeding. It will not occur spontaneously, but instead must be pursued with deliberate effort.
2. Within the scenario described here, technological assumptions are based on concentrating solar collector fields generating steam for electricity plants combined with multi-effect-desalination units employing co-generated heat. The parameters for efficiency, collector performance and specific investment costs have been selected according to the current state-of-the-art of trough technology. Scenarios based on other concentrating solar thermal power technologies (CSP) can also be derived.
3. The project begins in 2006 with a 5 MW demo-plant and ultimately expands to units of 200 MW and more.
4. Initial subsidiary fossil-fuel firing is gradually supplanted by increased solar operation, culminating in a solar share of close to 100 % in 2021.
5. The annual operating hours are constant for all plants of the project (base load at 8000 h/a).
6. Thermal storage capacity and energy efficiency are continuously increased, and the costs of components reduced. These developments are accompanied by an intensive research and development programme in the host country.
7. For each component, a specific progress ratio is applied, with appropriate learning (cost reduction) rates for solar collectors and storage and for the adaptation of conventional power equipment to the solar field (power block and balance of plant). Positive effects from expanding solar thermal power into other world regions and respective additional learning are neglected in this calculation. Technology learning rates are usually higher than those assumed here. Growth rates have been assumed to be relatively moderate. Growth could go faster if desired.
8. The initial costs are conservative estimates according to the present state of the art.
9. Electricity costs are calculated for each year in US$ (real value 2004) using the annuity method, assuming a project interest rate of 9 % and a capital return period of 20 years, while the operation time is 40 years (Reference Case).
10. The annual costs of solar and fossil fired plants are compared for each generation of plants over their total lifetime, and the net present value (NPV) of the cost difference over the total lifetime of the plants is calculated in order to obtain the initial investment support needed in the respective year of construction. The total investment for the first STPD plants with 700 billion m³ water capacity is of a total of 9 billion $, over a time period of 10 years. From that investment, only 700 million US$ are required as transient external support, with the rest covered by revenues from power, water and CO_2 certificates. After 2015, no further support is required (Reference Case).
11. The indicated costs and revenues include the generation of power and water at a coastal site. They do not include the distribution of power or water.
12. With the assumptions made in this scenario, full competitiveness with today's natural gas fired systems would be achieved by 2015, if natural gas or fuel oil prices start at 75 $/gal, equivalent to 25 $/barrel crude oil, and reach 30 $/barrel in 2025.
13. Export of solar electricity starts 2015 with a capacity of 1 GW. The capacity is successively expanded at increasing rates to 120 GW in 2050, while 330 GW are reserved for domestic supply of the intensively growing MENA power market.
14. The cost of High Voltage Direct Current Transmission (HVDC) was calculated for a distance of 3500 km from MENA to Central Europe. For 120 GW capacity in 2050, the total investment cost is 53 billion $, the cost of imported electricity in Europe amounts to 5.3 ct/kWh (Reference Case).

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Year	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Overall Capacity Extension SEGS																					
Installed Capacity MW	5	35	105	205	355	600	900	1250	1650	2079	2620	3301	4159	5240	6602	20968	63470	160476	267757	361700	448567
Solar Share	0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9	0.95	1	1	1	1	1	1
Total Electricity Generation GWh/a	40	280	840	1640	2840	4800	7200	10000	13200	16632	20956	26405	33270	41921	52820	167745	507757	1283807	2142060	2893602	3588537
Solar Elec. GWh/a	10	82	278	598	1138	2118	3438	5118	7198	9600	12844	17203	23038	30823	41178	156103	496115	1272164	2130418	2881960	3576895
Desalination Capacity million m³/a	1.7	12	35	68	118	200	300	417	550	693	873	1100	1386	1747	2201	6989	21157	53492	89252	120567	149522
Collector Field 1000 m²	28	231	783	1684	3205	5964	9681	14412	20270	27035	36168	48442	64875	86798	115956	439586	1397060	3582415	5999256	8115599	10072536
Storage h	0	1.6	3.2	4.8	6.4	8	9.6	11.2	12.8	14.4	16	17.6	19.2	20.8	22.4	24	24	24	24	24	24
Total Storage Cap. MWh	0	48	272	752	1712	3672	6552	10472	15592	21769.6	30418.2	42405.3	58881.95	81372.64	111890.8	456666.6	1476702.8	3804850.8	6379610.5	8634237.7	10719042
Investment Cost Learning																					
Collector Field $/m²	320	248	215	196	181	168	159	151	145	140	135	131	128	126	124	115	111	108	106	105	105
PB & BOP & Adaptation $/kW	1050	992	961	942	927	913	903	894	887	881	875	869	863	857	852	823	800	800	800	800	800
Storage $/kWh		90	73	65	59	53	50	47	45	43	41	40	38	37	35	30	29	28	28	27	27
MED Cost $/m³/d	1150	1025	961	924	895	867	847	831	817	806	800	800	800	800	800	800	800	800	800	800	800
New Capacities per Year																					
New Power Capacity MW	5	30	70	100	150	245	300	350	400	429	541	681	858	1081	1362	4327	12284	24479	19834	20474	17253
New Storage Capacity MWh	0	48	224	480	960	1960	2880	3920	5120	6178	8649	11987	16477	22491	30518	103842	294827	587505	476013	491366	414062
New Collector Field 1000 m²	28	203	552	901	1521	2760	3717	4731	5857	6765	9133	12275	16433	21923	29158	97473	276744	551471	446818	461229	388666
New MED Capacity m³/d	4566	27397	63926.9	91324.2	136986	223744	273973	319635	365297	391781	493644	621991	783709	987473.3	1244216	3951378	11218674	22355582	18113138	18697352	15755783
New Annual Electricity GWh/a	40	240	560	800	1200	1960	2400	2800	3200	3432	4324	5449	6865	8650	10899	34614	98276	195835	158671	163789	138021
New Annual Solar electr. GWh/a	10	72	196	320	540	980	1320	1680	2080	2402	3243	4359	5835	7785	10354	34614	98276	195835	158671	163789	138021
New Annual Water million m³/a	2	10	23	33	50	82	100	117	133	143	180	227	286	360	454	1442	4095	8160	6611	6825	5751
Investment of New Plants																					
Investment Power Block M$	5.3	29.8	67	94	139	224	271	313	355	378	473	592	741	927	1160	3563	9828	19583	15867	16379	13802
Investment Solar Field M$	9.0	50.4	118	176	275	464	589	715	849	948	1235	1603	2109	2766	3617	11179	30687	59495	47486	48588	40687
Investment MED M$	5.3	28.1	61	84	123	194	232	266	299	316	395	498	627	790	995	3161	8975	17884	14491	14958	12605
Investment Storage M$	0.0	4.3	16	31	56	105	143	185	230	266	358	477	630	828	1081	3105	8519	16514	13180	13485	11292
Total Annual Investment M$	***19.5***	***112.6***	***263***	***386***	***593***	***986***	***1235***	***1478***	***1733***	***1908***	***2461***	***3169***	***4107***	***5311***	***6853***	***21008***	***58009***	***113477***	***91023***	***93410***	***78386***
Cumulated Investment M$	***19.5***	***132.1***	***396***	***781***	***1375***	***2361***	***3596***	***5074***	***6807***	***8714***	***11176***	***14345***	***18453***	***23764***	***30617***	***101912***	***304309***	***756719***	***1250839***	***1680395***	***2075699***
Annual Cost of New Plants for their lifetime																					
Annual Capital Cost M$/a	2.1	12.3	28.9	42.3	65.0	108.0	135.3	161.9	189.8	209.0	269.6	347.2	450.0	581.8	750.8	2301.3	6354.6	12431.0	9971.3	10232.7	8586.9
Annual Fuel Cost M$/a	1.9	10.9	23.9	32.0	44.5	66.8	74.5	78.2	79.2	73.6	78.2	79.8	76.3	64.9	41.4	0.0	0.0	0.0	0.0	0.0	0.0
Annual O&M Cost M$/a	0.5	2.8	6.6	9.6	14.8	24.7	30.9	36.9	43.3	47.7	61.5	79.2	102.7	132.8	171.3	525.2	1450.2	2836.9	2275.6	2335.2	1959.6
Annual Insurance Cost M$/a	0.1	0.6	1.3	1.9	3.0	4.9	6.2	7.4	8.7	9.5	12.3	15.8	20.5	26.6	34.3	105.0	290.0	567.4	455.1	467.0	391.9
Total Annual Cost M$/a	***4.7***	***26.6***	***60.7***	***85.8***	***127.2***	***204.4***	***246.9***	***284.4***	***320.9***	***339.9***	***421.7***	***522.1***	***649.5***	***806.0***	***997.7***	***2931.5***	***8094.9***	***15835.3***	***12702.0***	***13035.0***	***10938.5***
Electricity Cost of New Solar Plants $/kWh **	***0.078***	***0.073***	***0.070***	***0.069***	***0.068***	***0.066***	***0.064***	***0.063***	***0.061***	***0.060***	***0.058***	***0.057***	***0.055***	***0.054***	***0.052***	***0.045***	***0.043***	***0.041***	***0.040***	***0.040***	***0.040***
Cost of Water of New Solar Plants $/m³	***0.900***	***0.900***	***0.900***	***0.900***	***0.900***	***0.900***	***0.900***	***0.900***	***0.900***	***0.900***	***0.900***	***0.900***	***0.900***	***0.900***	***0.900***	***0.900***	***0.900***	***0.900***	***0.900***	***0.900***	***0.892***
Annual Revenues of new plants for their lifetime																					
Annual Revenue Power M$/a	2.4	13.9	32.2	46.2	69.7	114.6	141.5	166.7	192.5	208.7	266.3	340.3	434.8	555.5	709.7	2415.4	7344.5	15665.0	13577.6	14985.6	5520.8
Annual Revenue Water M$/a	1.5	9.0	21.0	30.0	45.0	73.5	90.0	105.0	120.0	128.7	162.2	204.3	257.4	324.4	408.7	1298.0	3685.3	7343.8	5950.2	6142.1	5127.8
Revenue from CO2 Trading M$/a	0.0	0.2	0.4	0.7	1.1	2.1	2.8	3.5	4.4	5.0	6.8	9.2	12.3	16.3	21.7	72.7	206.4	411.3	333.2	344.0	289.8
Total Annual Revenue M$/a	***3.9***	***23.0***	***53.6***	***76.9***	***115.8***	***190.1***	***234.3***	***275.2***	***316.8***	***342.5***	***435.3***	***553.7***	***704.5***	***896.2***	***1140.2***	***3786.1***	***11236.2***	***23420.1***	***19861.0***	***21471.6***	***10938.5***
Required Additional Funding																					
Annual Difference M$/a	-0.8	-3.6	-7.1	-8.9	-11.4	-14.3	-12.7	-9.2	-4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Additional Funding M$ *	**7**	**33**	**65**	**82**	**104**	**131**	**116**	**84**	**37**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Cumulated Additional Funding M$	**7**	**40**	**104**	**186**	**290**	**421**	**536**	**621**	**658**	**658**	**658**	**658**	**658**	**658**	**658**	**658**	**658**	**658**	**658**	**658**	**658**
Additional Annual R&D Funding M$	**5**	**10**	**15**	**15**	**15**	**15**	**15**	**15**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**10**	**10**	**10**	**10**	**10**	**10**
Year	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Alternative Fuel Fired Plants:																					
Fuel Cost $/barrel (equivalent)	***25.0***	***25.0***	***25.0***	***25.0***	***25.0***	***25.3***	***25.6***	***25.9***	***26.2***	***26.5***	***26.9***	***27.2***	***27.5***	***27.8***	***28.2***	***29.9***	***31.7***	***33.7***	***35.8***	***38.0***	***40.3***
Investment of Fuel Plants																					
Investment Power Block M$	4.0	24.0	56.0	80.0	120.0	196.0	240	280	320	343	432	545	687	865	1090	3461	9828	19583	15867	16379	13802
Investment MED M$	5.3	28.1	61	84	123	194	232	266	299	316	395	498	627	790	995	3161	8975	17884	14491	14958	12605
Total Annual Investment M$	***9.3***	***52.1***	***117***	***164***	***243***	***390***	***472***	***546***	***619***	***659***	***827***	***1042***	***1313***	***1655***	***2085***	***6623***	***18802***	***37468***	***30358***	***31337***	***26407***
Annual Cost of Fuel Plants over their lifetime																					
Annual Capital Cost M$/a	1.0	5.7	12.9	18.0	26.6	42.7	51.7	59.8	67.8	72.2	90.6	114.2	143.9	181.3	228.4	725.5	2059.7	4104.5	3325.6	3432.8	2892.8
Annual Fuel Cost M$/a	2.6	15.6	36.8	53.3	80.9	133.7	165.6	195.5	226.2	245.5	313.0	399.1	508.9	648.9	827.4	2789.3	8406.0	17780.3	15291.5	16754.8	14986.5
Annual O&M Cost M$/a	0.2	1.3	2.9	4.1	6.1	9.8	11.8	13.6	15.5	16.5	20.7	26.1	32.8	41.4	52.1	165.6	470.1	936.7	758.9	783.4	660.2
Annual Insurance Cost M$/a	0.0	0.3	0.6	0.8	1.2	2.0	2.4	2.7	3.1	3.3	4.1	5.2	6.6	8.3	10.4	33.1	94.0	187.3	151.8	156.7	132.0
Total Annual Fuel Plant Cost M$/a	***3.9***	***22.9***	***53.2***	***76.2***	***114.7***	***188.1***	***231.5***	***271.7***	***312.5***	***337.4***	***428.4***	***544.6***	***692.2***	***879.9***	***1118.4***	***3713.5***	***11029.9***	***23008.8***	***19527.8***	***21127.7***	***18671.5***
Electricity Cost of New Fuel Plants $/kWh **	***0.059***	***0.058***	***0.058***	***0.058***	***0.058***	***0.058***	***0.059***	***0.060***	***0.060***	***0.061***	***0.062***	***0.062***	***0.063***	***0.064***	***0.065***	***0.070***	***0.075***	***0.080***	***0.086***	***0.091***	***0.098***
New CO2 avoided 1000 t/year	7	50	137	224	378	686	924	1176	1456	1682	2270	3051	4085	5450	7248	24230	68793	137084	111070	114652	96614
New CO2 avoidance cost $/t	50.1	32.6	23.5	18.2	13.8	9.5	6.3	3.6	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total CO2 avoided 1000 t/year	7	57	195	419	797	1483	2407	3583	5039	6720	8991	12042	16127	21576	28824	109272	347280	890515	1491292	2017372	2503826

Year	2001	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2025	2030	2035	2040	2045	2050
Electricity Demand UCTE1 TWh/a	2130	2283	2315	2348	2381	2414	2448	2482	2517	2552	2588	2624	2661	2698	2736	2774	2944	3095	3252	3418	3593	3693
Peak Load UCTE1 GW	354	379	385	390	396	401	407	412	418	424	430	436	442	448	455	461	489	514	541	568	597	614
Growth Rate UCTE1	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1	1	1	1	1	0.5
Electricity Demand UCTE2 TWh/a	195	209	212	215	218	221	224	227	230	234	237	240	244	247	250	254	272	292	313	332	349	359
Peak Load UCTE2 GW	31	33	34	34	35	35	36	36	37	37	38	38	39	39	40	40	43	46	50	53	55	57
Growth Rate UCTE2	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1	1	0.5
Electricity Demand Turkey TWh/a	126	180	193	208	223	240	255	269	285	300	317	335	354	374	395	412	490	582	691	791	832	855
Peak Load Turkey GW	20	22	24	25	27	29	31	33	35	37	39	41	43	46	48	50	60	71	84	97	102	104
Growth Rate Turkey	7.4	7.4	7.4	7.4	7.4	7.4	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	3.5	3.5	3.5	3.5	2	2	1
Electricity Demand SEMB TWh/a	128	183	196	211	227	243	259	274	289	305	322	340	359	380	401	423	539	641	761	904	1073	1211
Peak Load SEMB GW	19.5	28	30	32	35	37	39	42	44	46	49	52	55	58	61	64	82	98	116	138	163	184
Growth Rate SEMB	7.4	7.4	7.4	7.4	7.4	7.4	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	3.5	3.5	3.5	3.5	3.5	2
Electricity Demand SWMB TWh/a	49	70	75	81	87	93	99	105	111	117	123	130	138	145	153	162	206	245	291	346	411	464
Peak Load SWMB GW	9	13	14	15	16	17	18	19	20	21	23	24	25	27	28	30	38	45	53	64	75	85
Growth Rate SWMB	7.4	7.4	7.4	7.4	7.4	7.4	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	3.5	3.5	3.5	3.5	3.5	2
Electricity Demand Gulf TWh/a	346	411	425	440	456	472	488	505	523	541	560	580	600	621	643	665	773	896	1034	1141	1242	1305
Peak Load Gulf GW	48	57	59	61	63	65	68	70	73	75	78	80	83	86	89	92	107	124	143	158	172	181
Growth Rate Gulf	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3	3	2	2	1	1
Solar Power Generation TWh/a		0.040	0.28	0.84	1.64	2.84	4.8	7.2	10.0	13.2	16.6	21.0	26.4	33.3	42	53	168	508	1284	2142	2894	3589
CSP Installed Capacity GW		0.005	0.04	0.11	0.21	0.36	0.6	0.9	1.3	1.7	2.1	2.6	3.3	4.2	5	7	21	63	160	268	362	449
EU Import Solar Electricity TWh/a											8	8	16	16	24	24	64	160	360	560	760	960
Export CSP Capacity GW											1	1	2	2	3	3	8	20	45	70	95	120
MENA Domestic Solar Electricity TWh/a	0	0	0	1	2	3	5	7	10	13	9	13	10	17	18	29	104	348	924	1582	2134	2629
MENA Domestic Solar Capacity GW	0	0	0	0	0	0	1	1	1	2	1	2	1	2	2	4	13	43	115	198	267	329
Solar Share on EU Electricity Demand	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	0.3%	0.6%	0.5%	0.8%	0.8%	2.0%	4.7%	10.1%	14.9%	19.3%	23.7%
Solar Share on EU Peak Load Capacity	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.2%	0.4%	0.4%	0.6%	0.6%	1.5%	3.6%	7.6%	11.3%	14.6%	17.9%
Solar Share on MENA Electricity Demand	0.0%	0.0%	0.0%	0.1%	0.2%	0.3%	0.4%	0.6%	0.8%	1.0%	0.7%	0.9%	0.7%	1.1%	1.1%	1.7%	5.2%	14.7%	33.3%	49.7%	60.0%	68.5%
Solar Share on MENA Peak Load Capacity	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%	0.4%	0.5%	0.7%	0.9%	0.6%	0.8%	0.6%	1.0%	1.0%	1.5%	4.5%	12.9%	29.1%	43.3%	52.0%	59.2%
HVDC Cost Calculation																						
New HVDC Capacity GW	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	2	5	5	5	5	5
New Export Electricity TWh/a	0	0	0	0	0	0	0	0	0	0	8	0	8	0	8	0	16	40	40	40	40	40
Length of HVDC over Land km					1500	1500	1500	1500	1500	1500	2700	2700	2700	2700	2700	3000	3500	3500	3500	3500	3500	3500
Length of HVDC over Sea km					50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
HVDC Investment M$	0				0	0	0	0	0	0	600	0	600	0	600	0	1132	2150	2150	2150	2150	2150
Transfer Efficiency %	98.8%	98.8%	98.8%	98.8%	92.7%	92.7%	92.7%	92.7%	92.7%	92.7%	88.3%	88.3%	88.3%	88.3%	88.3%	87.2%	85.5%	85.5%	85.5%	85.5%	85.5%	85.5%
Capital Cost M$/a					0.0	0.0	0.0	0.0	0.0	0.0	54.0	0.0	54.0	0.0	54.0	0.0	102.0	193.7	193.7	193.7	193.7	193.7
O&M Cost M$/a					0.0	0.0	0.0	0.0	0.0	0.0	6.0	0.0	6.0	0.0	6.0	0.0	11.3	21.5	21.5	21.5	21.5	21.5
Total Annual HVDC Cost M$/a					0.0	0.0	0.0	0.0	0.0	0.0	60.0	0.0	60.0	0.0	60.0	0.0	113.3	215.2	215.2	215.2	215.2	215.2
Additional LEC for HVDC System $/kWh					0.000	0.000	0.000	0.000	0.000	0.000	0.008	0.000	0.008	0.000	0.008	0.000	0.007	0.005	0.005	0.005	0.005	0.005
Additional LEC by Transmission Losses $/kWh					0.000	0.000	0.000	0.000	0.000	0.000	0.009	0.000	0.008	0.000	0.008	0.000	0.009	0.008	0.008	0.008	0.008	0.008
Total Additional HVDC Cost $/kWh					**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.016**	**0.000**	**0.016**	**0.000**	**0.016**	**0.000**	**0.016**	**0.014**	**0.013**	**0.013**	**0.013**	**0.013**
Total Cost of imported Electricity in EU $/kWh					**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.077**	**0.000**	**0.073**	**0.000**	**0.069**	**0.000**	**0.061**	**0.056**	**0.055**	**0.054**	**0.053**	**0.053**

European Electricity Demand TWh/a	2325	2492	2527	2563	2599	2635	2672	2709	2747	2786	2825	2864	2904	2945	2986	3028	3217	3386	3565	3750	3942	4051
MENA Electricity Demand TWh/a	649	844	890	940	992	1048	1102	1153	1207	1264	1323	1385	1451	1519	1591	1663	2009	2364	2777	3182	3557	3835

Spread Sheet Parameters for the Calculation of the Reference Scenario:

Minimum Electricity Cost $/kWh	***0.04***
CO2 Certificate Value $/t	***3***
Initial Price of Desalted Water $/m³	***0.9***
Prog. Ratio Collector & Storage	0.92
Progress Ratio MED	0.96
Progress Ratio BOP	0.98
Project Internal Rate of Return (IRR)	9.0%
Plant Lifetime a	20
O&M Rate of Inv./a	0.025
Insurance Rate of Inv./a	0.005
Initial Fuel Cost $/barrel	25.0
Electric Cycle Eff.	0.3
spec. PB Invest. fossil Plant $/kW	800
Fuel Cost Escalation Rate /a	1.2%
spec. MED cost full devel. plant $/m³/d	800
Avoided CO2 kg/kWh	0.7
Direct Normal Irradiation kWh/m²/year	2500
Annual Full Load Hours h/a	8000

Total Investment until 2025 M$	**101912**
Cum. Add. Funding M$	**658**
NPV of Cum. Add. Funding M$	**447**
NPV of Cum. Gains M$	**68249**
Year of Amortisation	**2019**
Export Electricity Cost $/kWh	**0.053**

HVDC Data	
Number of Converter Stations	2
spec. Cost of Conv. Stations $/kW	65
spec. Cost of Land Cable $/kW/1000km	75
spec. Cost of Sea Cable $/kW/1000km	750
Efficiency (Base Load) %/1000 km	96,0%
Efficiency of Converters	98,8%
O&M Rate % of Inv./a	1,0%
Economic Lifetime a	80

HVDC Infrastructure Investment Period 2006 - 2050:	
Final Cost of EU Imported Clean Electricity $/kWh	**0,053**
Total Investment in HVDC Infrastructure in billion $	**53,1**

Annex 3: Financing the MENA Solar Thermal Power & Desalination Plants **

Concentrating solar power has the potential of becoming considerably cheaper that fossil fuels in the near future. To achieve this goal an initial support is required. One way of providing this support could be via a grant subsidy on the investment of the individual power projects. The necessary grants depend on the conditions of finance of the projects and on the site conditions, mainly on solar irradiation. In the following, we will analyse how the initial subsidies needed to reach cost crossing point with fuels could be reduced by public-private collaboration and by enhanced knowledge of the solar radiation resource.

Case 1: Fully privately financed individual projects
The highest amount of grant funding of 2600 million US$ would be required if all projects were financed exclusively on private basis, leaving all the related risks deriving from fluctuating sales prices, currency instability, power purchase security, etc. to the private investors. As a consequence, those investors will request high interest rates, represented here by 24 % equity interest and 8 % debt interest. Assuming 25 % equity share and 75 % debt share on investment, the overall project interest rate would equal 12 %.The top curve in Fig. A5 shows this case assuming that the plants will be installed on sites with an average solar irradiation level of 2500 kWh/m²/a.

Case 2: Privately financed projects with CO_2 emission trading
Assuming that revenues from carbon trading will be in the order of 3 $/t of avoided CO_2, the total grant funding may be reduced to about 2100 million US$. However, the example shows that the initially required funding is not reduced significantly. This means, emission trading will not trigger market introduction, although it may accelerate it to a certain extend.

Case 3: Privately financed projects with guaranteed power purchase agreements
Our Reference case assumes a decided political will to introduce STPD plants in MENA. In this case, the involved countries would guarantee the purchase of power and water from STDP plants at fair (but not necessarily subsidised) prices for the duration of the debt period. This would be an alternative to paying grant subsidies that would cover the extra risk of investors without sales guaranties. We assume that providing long-term power and water purchase agreements would reduce project interest rates to 9 %, which is equivalent to debt interest rates of 7 % and equity interest rates of 15 %. Carbon trading at 3 $/t is included as in the case before. Purchase guaranties would reduce the required grants to 658 million US$.

As alternative to the grant, a priority feed-in law covering the full cost of solar power could be used to distribute the additional cost among all the power consumers of the region. Allocating the required start-up funding to let's say 75 million households in MENA would mean a extra annual charge of 0.88 US$ (of 2004) per household for the 10 year market introduction period until 2015. After that, no extra payment would be required, and the cost of solar power and water will even fall with later plants.

Case 4: Enhanced knowledge of the solar irradiation resource
In addition to the described enhanced financing conditions, grants can be substantially reduced by a better knowledge of the solar irradiation conditions and enhanced site selection. Modern assessment methods based on satellite remote sensing of the atmosphere can provide solar irradiation maps for large regions or countries in very high spatial and temporal resolution and quality. Systematically selecting sites for STPD projects with irradiation better than 2800 kWh/m²/a, grant funding could be reduced from 658 to 307 million US$. The cost of

finding the best sites by such an analysis would certainly be much lower than the expected savings.

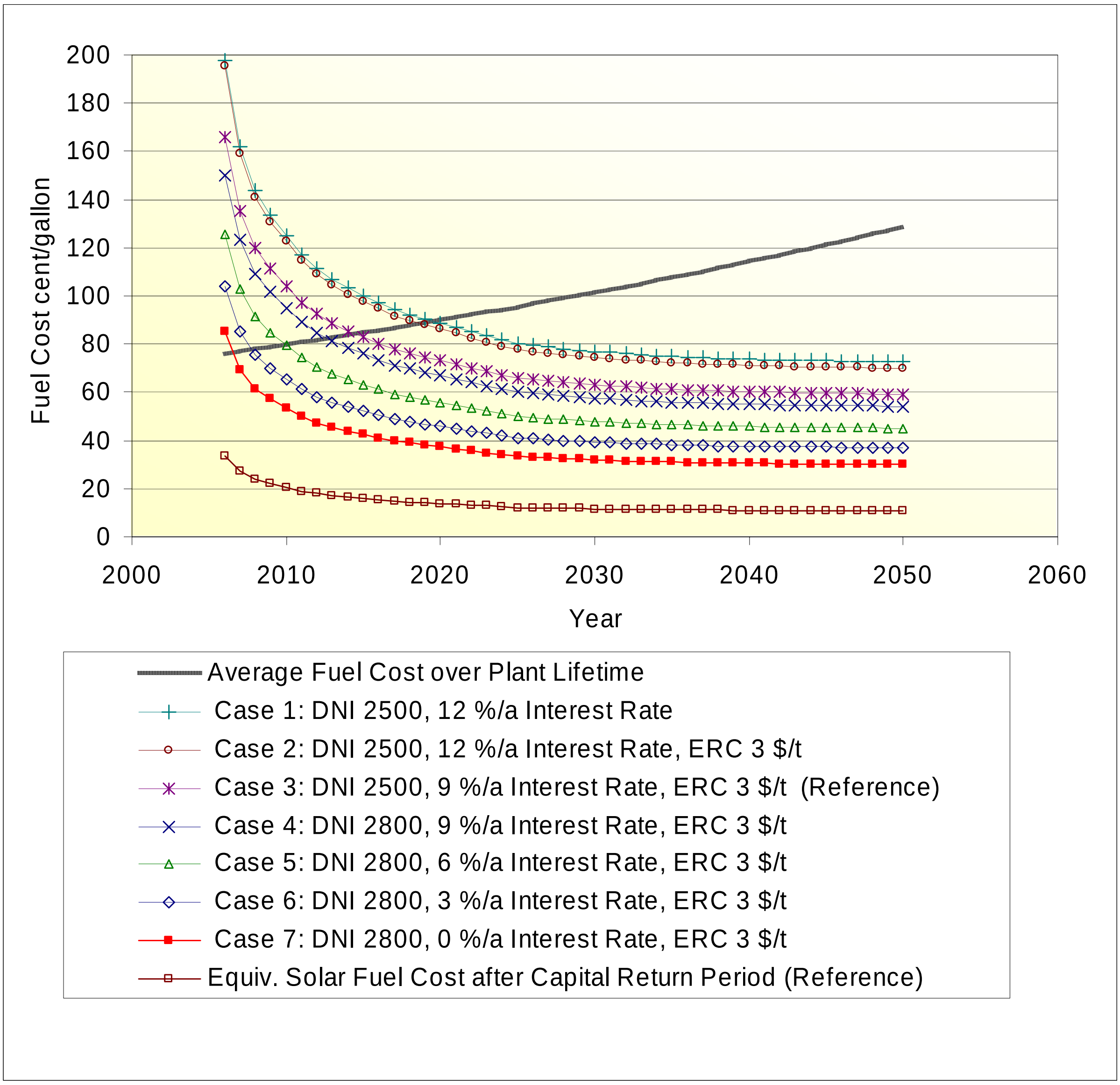

Figure A5: Learning curves of solar thermal power & desalination plants: The equivalent solar fuel cost as a function of time for different conditions of finance and solar irradiation. For comparison to fuel costs, all values are displayed in units of US-cent/gallon of fuel oil #2.

Conditions of Irradiation and Finance	***Grant M$***
Case 1: DNI 2500, 12 %/a Interest Rate	2596
Case 2: DNI 2500, 12 %/a Interest Rate, ERC 3 $/t	2094
Case 3: DNI 2500, 9 %/a Interest Rate, ERC 3 $/t (Reference)	658
Case 4: DNI 2800, 9 %/a Interest Rate, ERC 3 $/t	307
Case 5: DNI 2800, 6 %/a Interest Rate, ERC 3 $/t	66
Case 6: DNI 2800, 3 %/a Interest Rate, ERC 3 $/t	10
Case 7: DNI 2800, 0 %/a Interest Rate, ERC 3 $/t	1

Table A2: Total grant required for the start-up phase for different conditions of irradiation and finance according to Figure A5. DNI: Direct Normal Irradiation in kWh/m²/a, Interest Rate means average Project Rate of Return, ERC Emission Reduction Credit in $/t

Case 5: Public-private partnership with subsidised loans
An overall project interest rate of 6 % would be equivalent to an equity interest rate of 15 % and a subsidised soft loan at 3 % interest rate. Such conditions can be achieved in the case of strong political interest and large expected public benefits, as will be the case here. However, it will depend on the policy of the MENA countries and international funding institutions, if such soft loans would be made available for that purpose. In that case, grant funding could be partially substituted by soft loan funding and thus be reduced to 66 million US$.

Case 6 and 7: Full soft loan finance
Financing the total project volume by subsidised soft loans at 3 % interest rate would reduce grant funding requirement further to 10 million US$. At 0 % interest rate, the necessary grant funding would be almost zero. This would be an alternative form of providing the necessary start-up funding. Such kind of finance should be limited to the introduction phase. After reaching cost cross-over with fuels, subsidies should be subsequently reduced until reaching normal financing conditions like e.g. in the Reference Case.

Strategic Options of Finance

The study shows how the need for start-up subsidiary funding can be reduced considerably by providing an attractive, low risk environment to private investors and by providing a reliable basis for economic assessment of the projects. The main tools to achieve this are on one side guaranteed long-term purchase agreements for power and water and on the other side the provision of reliable solar resource data. These measures can reduce the necessary subsidies from 2000 million US$ (Case 2) to about 300 million US$ (Case 4), and considerably reduce the investment risks of private investors. It is common in the financial world, that projects with lower risks have a higher rating and can usually be financed with lower interest rates than risky projects. Risky projects are always expected to provide higher interest returns.

Governments supporting the STPD strategy have the choice to ether provide the necessary grants in addition to private funding or to establish appropriate economic frame conditions in their region – like in the Reference Case - in order to achieve the same goals at a considerably lower cost. Thorough solar resource assessment will additionally reduce costs and risks of the projects. Governments and international funding institutions can provide soft loan funding as alternative to investment grants. Like the grants, such funding would be only transitional until cost cross-over with fossil fuels would be achieved.

Another alternative is a priority feed-in law for renewable electricity like already introduced in Germany, Spain or Algeria, providing electricity tariffs equivalent to the full cost of generation and guaranteeing those payments over the capital return period by national laws. In this case, the initial additional cost of solar power generation would be distributed among all power consumers of the country or region.

As can be appreciated by comparing Case 1 and Case 2, carbon trading and green electricity trading will only have a limited impact on the market introduction of STPD. The former is limited by the present low emission certificate prices (although they might increase in the future), the later is limited by the green power market itself, which is rather small and still limited to the European domestic market.

It is particularly important to install fair financing conditions for STPD plants during the introduction phase. Equal market conditions of solar and fossil fuel is a minimum requisite for success. If fossil fuel consumption is directly subsidised or indirectly by not applying world market prices in power cost calculations such false cost allocations would hinder the market introduction of solar energy and burden the national economy with increasing subsidies. Therefore, equal conditions ought to be applied to taxation and subsidisation of fossil and solar "fuel". If there are subsidies on fossil fuel prices, the same should be granted to solar energy. Those subsidies could immediately be financed by selling the amount of fuel saved in the solar plant on the world market. Equalising the financial conditions of fuel and solar energy will not raise the cost of electricity, but rather keep it low in the long term, alleviating the national economies in many countries from the continued subsidisation of fossil fuels.

The Reference Scenario

The total cumulated investment needed to install 2000 MW of power and 700 million m³/a of desalination capacity to reach the cross-over point in the Reference Case 3 will be 8.7 billion US$ by the year 2015. Of that amount, 660 million US$ will be required as grant or other equivalent subsidy. Under the conditions of finance and irradiation of the reference case, after 2015, no further subsidies will be required, and the generating cost will fall further. After 20 years of operation, having paid back the investment capital and interests, the first plants will enter their "golden end" period, with costs reduced to about 10 % of those of fuel fired systems. Therefore, the equipment and the operation and maintenance of the plants should be of the highest possible quality in order to profit from a long as possible lifetime and golden end period. The required amount of annual investments and grants is shown in Figure A6.

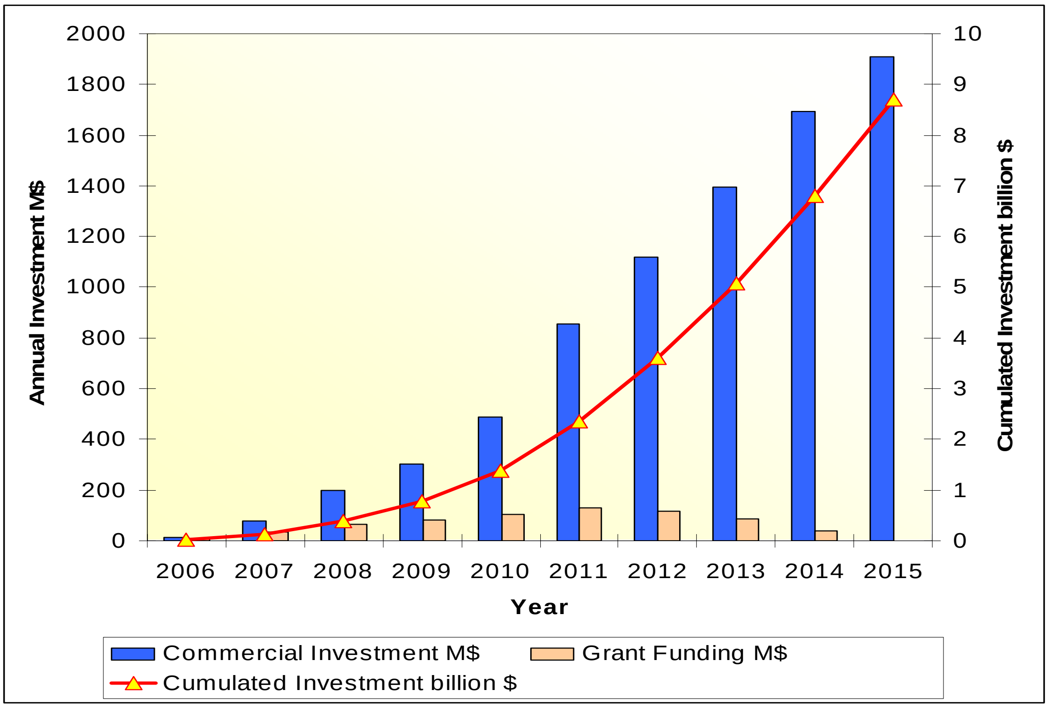

Figure A6: Annual investment in new STPD plants and grants required until cost break-even for the Reference Case 3 (long-term guaranteed power purchase agreements, 9 % interest rate, irradiation 2500 kWh/m²/a, carbon credits 3 $/t).

Demand Side Strategy Development until 2006

In the initial phase until 2006, a demand side strategy for the MENA countries must be developed. The CSP technology portfolio must be clearly described with respect to status, cost, resources and most promising applications, and a demand-side driven strategy for implementation must be established. The MED-CSP study sponsored by the German Ministry for the Environment may be the ideal basis for this assessment phase, as the MENA countries may on one side provide the relevant demand side information and on the other side define key questions to be solved by that study. The study will show the perspectives of CSP export to Europe in combination with water desalination for MENA and clarify the necessary steps for implementation. In addition to that study, an in-depth solar energy resource assessment for MENA is recommended to optimise the site selection of CSP projects (Table A3).

Technology Transfer until 2010

Within the technology transfer phase, first non-commercial projects shall be developed and implemented in different MENA countries. The spectrum of projects may include the demonstration of parabolic trough, Fresnel and solar tower plants, starting with small capacities of 5 - 15 MW per plant and slowly increasing the size for further plants. Depending on the individual national strategies, the scope of those projects may range from “proven technology application” to “participation in technology development”. The application of combined seawater desalination may be introduced as well as the use of thermal energy storage. Taking as an example the successful development of the CSP plants in California, an installed capacity of 355 MW will be achieved within a 5 years period until 2010. In case of combined power and desalination plants, the investment required would amount to 1.375 billion US$. To achieve a project return of 9 %/y for those first projects according to the reference case scenario, a grant of 290 million US$ (or equivalent financial support) would be required during this phase. At the end of this phase, the cost of solar energy will be equivalent to 38 $/bbl, providing electricity at 6.8 ct/kWh and water at 90 ct/m³. The grant will reduce costs to 5.8 ct/kWh and 90 ct/m³ as for equivalent fossil fuelled plants (with fuel at 25 $/bbl). By 2010, an amount of 118 million m³ of desalted water will be produced per year.

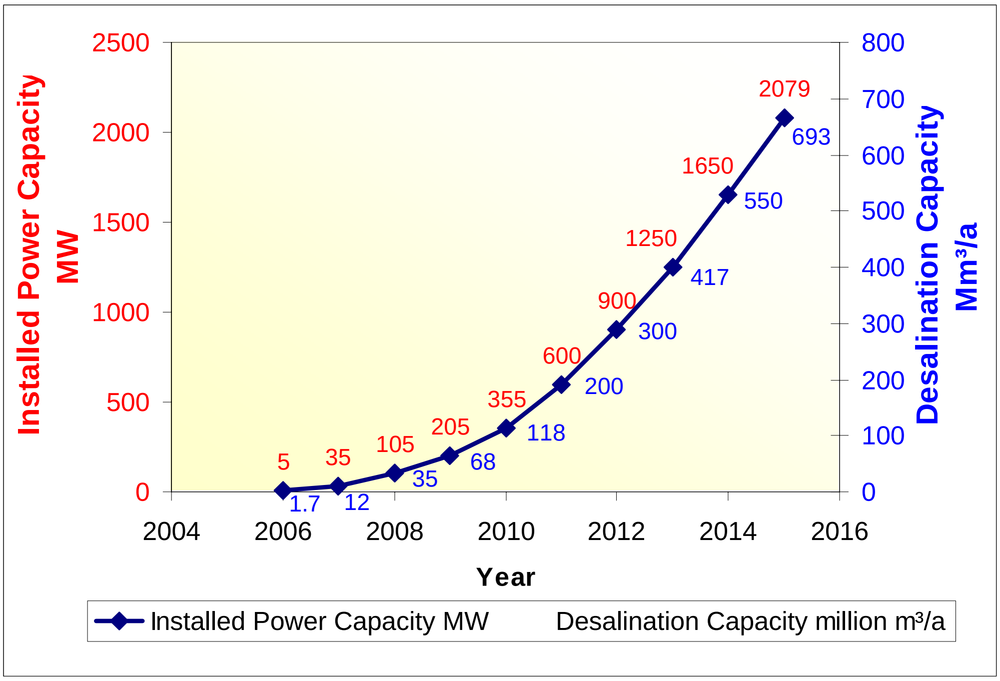

Figure A7: The first 10 years of CSP market introduction in MENA

Technology Establishment until 2015

The technology lines initiated in the preceding phase must now be brought to financial maturity, expanding the capacity of new projects to 100 to 200 MW each and increasing storage capacity and collector areas. An interruption of the market introduction like the one that occurred in California in 1991 must be strictly avoided. Then, a continuous expansion will lead to considerable effects of the economies of scale and technology learning, presumably achieving cost equity of concentrating solar collectors and fossil fuel by the year 2015. The total investment within this phase amounts to 7.34 billion US$, of which 370 million US$ will be required as grant or equivalent support. By 2015, solar energy cost will be equal to fuel oil at 30 $/bbl. Because of progressive fuel cost escalation, fossil plants installed by that time will have the same life cycle average fuel cost. By that time, electricity from CSP will be produced at 6 ct/kWh and water at 90 ct/m³ which will be comparable to power and water from equivalent fuel plants under the same financial reference conditions (9 % project interest rate, 20 years capital return period, fuel initially at 26.5 $/bbl). The total CSP capacity installed in MENA by 2015 would amount to 2.1 GW, with 693 million m³ per year of desalted water. Due to the initially relatively high cost, desalted water would be directed primarily to domestic and industrial use.

Market Settlement until 2020

At the end of this phase by 2020, the cost of concentrating solar collectors will be reduced to a point where even projects financed within a completely private scheme at 12 % project interest rate and without long-term guaranteed power purchase agreements would be fully competitive to fuels. This marks the start of the commercial deployment of CSP for power and water. Solar “fuel” costs would be reduced to 26.6 $/bbl, being considerably lower than the 28.2 $/bbl expected for fossil fuels by that time, specially when considering that fuel costs will increase even more over the lifetime of new plants, while the costs of collectors will be constant for the capital return period, and after that become zero. CSP plants will deliver power at 5.2 ct/kWh and water at 90 ct/m³. A power capacity of 6.6 GW will be installed by 2020, together with a desalination capacity of 2.2 billion m³/y. The investment within this phase will be 21.9 billion US$. No financial support would be required in this phase. For the first time, solar energy will be cheaper than fuel, and the savings with respect to an equivalent fuel driven scheme would amount to a total of 3 billion US$, compensating the initial necessary grants of a total of 660 million US$ by almost 5 times. In the first year of this period (2016), export of CSP to Europe may start with a first limited amount, making use of existing transfer schemes and interconnections. Also, the building of special HVDC transfer lines with a unit capacity of 2 GW each would be started. By 2020, a transfer capacity of 3 GW providing 24 TWh/y of export solar electricity would be installed, creating an annual revenue of 1.25 billion US$/y to the CSP projects in MENA.

Least Cost Option after 2025

Concentrating solar power will be the least cost option for power and desalted water in MENA after 2025. The first plants installed in 2006 will have finished their capital return period and will produce power and water at extremely low cost equivalent to a fuel cost of less than 4 $/bbl. This will allow for electricity costs as low as 3 ct/kWh and desalted water below 10 ct/m³, respectively, for this portion of the power park. New plants installed after 2025 will have an equivalent fuel cost well below 24 $/bbl, providing power for 5 ct/kWh and water at costs decreasing to 65 ct/m³ and less, if the reference case assumptions are applied (9

% interest rate, 20 years capital return). Until 2025, the supply of desalted water from CSP of 7 billion m³/y would still fall short of the expected additional demand, which is 15 billion m³/y for the North African countries and their domestic and industrial sector alone (Table A3).

However, the agricultural sector, which makes up over 85 % of the water demand in MENA, could also be started to be tackled by that time. If solar electricity and seawater desalination for the MENA countries would be considered as a public infrastructure project with a moderate capital interest rate of e.g. 4 %/y rather than a private investment project with 9 % interest rate, power and water could in the long term be supplied at 4 ct/kWh and 40 ct/m³, respectively, with falling trend and no fuel-related cost traps for the national economies ahead. On the contrary, the trading of carbon emission certificates can be expected to increase, providing additional revenues of up to 10 or 15 $/ton of avoided carbon dioxide. This would reduce costs further to 3 ct/kWh and 10 ct/m³, respectively. Making use of advanced irrigation technologies and crops with a water demand of 0.5 to1 m³/m², and planting e.g. row-crops with high revenues of 50 ct/m² within the semi-shade under the collectors, water co-generated from CSP at 10 to 40 ct/m³ would equal an area-specific water cost of 5 to 40 ct/m² and thus become interesting for application even in the agricultural sector, solving a tremendous problem of the MENA countries of the coming decades.

Scenarios with Optimized Conditions

One can compare two scenarios to solve the water (and power) shortage of MENA until the middle of this century: one using fossil fuels, and the other one using concentrated solar energy. Both scenarios assume that steam cycle power plants are used for co-generation of electricity and desalted water, which in fact would be the most efficient way to tackle both problems. The total capacity expansion is assumed to be financed as public-private infrastructure projects with a 4 % interest rate. The average project life is 40 years. Fuel costs start with 25 US$/barrel in 2006 and increase by only 0.5 %/year. Emission trading yields 10 US$ per ton of avoided carbon dioxide for the solar part. Optimised solar energy resource assessment yields sites with an average of 2750 kWh/m²/y of solar irradiation. The results of both scenarios are shown in Figure A8, where the cost of power and water for both options is displayed.

The fuel-driven scenario starts in 2006 with an electricity cost of 5 ct/kWh and slowly rises to 6.3 ct/kWh in the year 2050 due to the moderate fuel cost escalation rate of 0.5 %/y. For the fuel powered scenario, the cost of water remains constant at 75 ct/kWh over the whole time span. This clearly indicates that the cost of power and water from fossil plants would be relatively high and increasing with time and that the supply of the agricultural sector in MENA would probably not be feasible by such an option, as this would require water at a cost considerably lower than 75 ct/m³.

The equivalent CSP scenario starts at the same cost of power and water, which can be achieved right from the beginning under the assumed conditions of finance and emission trading. That means that in principle, no additional start-up support (grant) would be required for CSP under those optimized conditions. With each new plant, the cost of power steeply falls until reaching 3.5 ct/kWh in 2012. After that, the price of power is maintained constant and instead, the cost of water starts falling, reaching a level below 10 ct/m³ after 2025. This clearly shows that very low prices of electricity could be reached and maintained by CSP, relieving the national economies of MENA from an increased subsidisation of power and fuels. At the same time, costs of desalted water as low as 10 ct/m³ can be achieved in the long-term, thus solving the increasing problem of severe water shortage in the domestic, industrial and later even in the agricultural sector of the MENA countries. After 2030, the solar energy cost of new plants will be below an equivalent 10 $/bbl of fuel oil (Figure A9).

The amounts of power and water generated within the scenario do not touch nor the limits of the solar resources in MENA, nor the limits of demand for power and water in the EUMENA region in the time span under consideration. The solar energy scenario shown here has no intrinsic contradictions and is in itself consistent. However, it will not happen spontaneously, it must be pursued with an appropriate political and financial effort in order to become reality.

The conditions of finance during the first 10 - 15 years of market introduction are crucial for success. They must be discussed and defined by the stakeholders from the public and private financing sector and guaranteed by governments and international funding organisations. The need for grants is defined by the question if such projects would be financed on a private basis (commercial case or reference case with 12 % or 9 % interest rate over 20 years capital return period), or rather as a public infrastructure project with 4 % interest rate over the total lifetime of 40 years as shown in the example below, where no additional grants would be needed. A net real interest rate of 4 % would be equivalent to the average profitability of the German industrial engineering sector. This seems quite acceptable for the purpose in view, as the scope of such a programme would not be the quick multiplication of private investment money, but to provide a solution for a public need. Nevertheless, if appropriate governmental and international guarantees are given within a public-private-partnership, private investors would also find attractive investment opportunities within this scope.

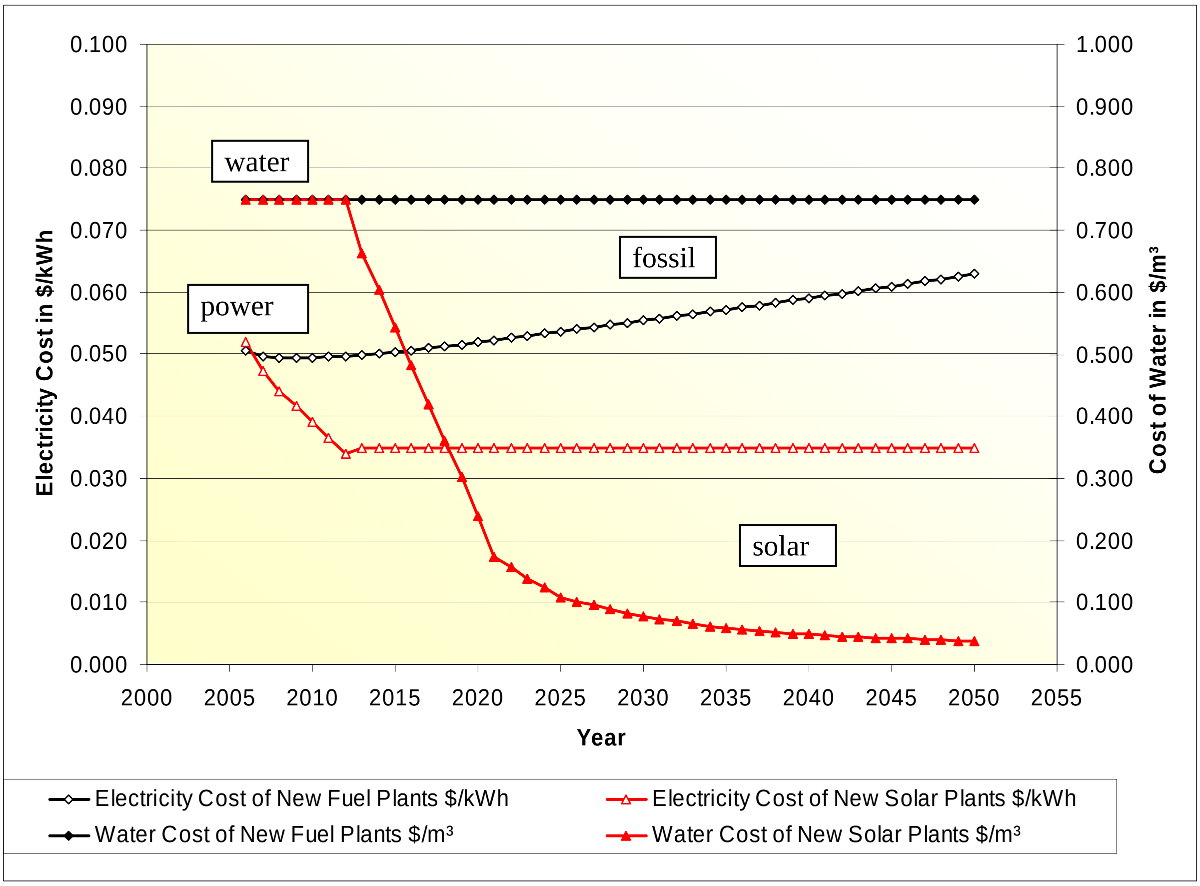

Figure A8: Optimized conditions scenario showing the cost of power and water from fossil fired and from concentrating solar co-generation plants for combined power and water in MENA. Interest rate

4 %/y, lifetime 40 years, initial fuel cost 25 \$/bbl, fuel cost escalation 0.5 %/y, insurance rate 0.5 %/y, O&M cost 2.5 % of investment per year, initial steam cycle investment of solar plants 1050 \$/kW, conventional steam cycle plant investment 800 \$/kW, initial multi-effect desalination plant investment 1150 \$/m³/day, carbon emission credits 10 \$/ton, average solar irradiation 2750 kWh/m²/y.

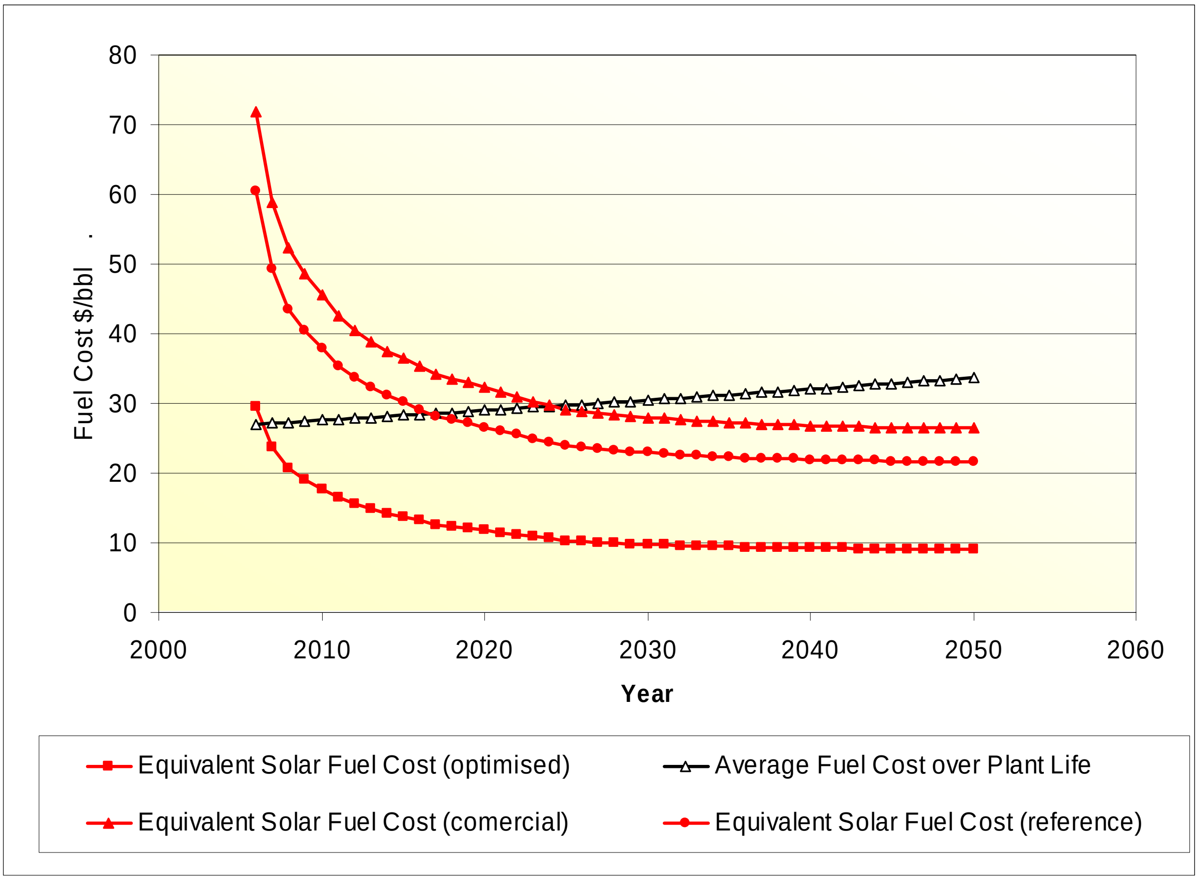

Figure A9: Average fuel cost of fossil and concentrating solar power plants in different scenarios:
Optimised Scenario: 4 % project interest rate, 40 years project lifetime, emission credits 10 \$/ton CO2, irradiation 2750 kWh/m²/y, public-private partnership .In the optimised scenario, the equivalent solar fuel cost reaches a sustainable level below 10 \$/bbl in the year 2030.Parameters are the same as those used in Figure A8.
Reference Scenario: 9 % project interest rate, 20 year capital return period, emission credits 3 \$/ton CO2, radiation 2500 kWh/m²/y, long term power & water purchase agreements
Commercial Scenario: 12 % project interest rate, 20 year capital return period, irradiation 2500 kWh/m²/y, no emission trading, commercial financing.
A break-even of fossil and solar energy costs is achieved in all scenarios in spite of the low fossil fuel cost escalation rate of 0.5 %/a assumed here.

Table A3: Scenario for CSP Market Introduction

Period	**Comment**	**Total Installed Capacity for Power & Water**	**Investment**	**Support Required**	**Cost Level Achieved for Power & Water ***
2004 – 2006	MENA Demand Side Strategy Development and Assessment Phase, Optionally first POSEIDON Plant	0 – 5 MW, 0 – 1.7 Mm³/y	0.5 - 20 million US$	Public Private Partnership, Technology & Resource Assessment Study, Strategy Development, Political Support	5.1 – 7.8 ct/kWh 75 – 90 ct/m³
2006 – 2010	Technology Transfer Phase	355 MW, 118 Mm³/y	1.3 billion US$	Public Private Partnership, Soft Loans, Grants, Long-Term Power & Water Purchase Agreements, Guaranteed Feed-in Tariffs, Insurance & Guaranties	3.8 – 6.8 ct/kWh 75 – 90 ct/m³
2010 – 2015	Technology Establishment Phase	2079 MW, 693 Mm³/y	7.4 billion US$	Public Private Partnership, Soft Loans, Grants, Long-Term Power & Water Purchase Agreements, Guaranteed Feed-in Tariffs, Insurance & Guaranties	3 – 6 ct/kWh 60 – 90 ct/m³
2015 – 2020	Market Settlement Phase	6600 MW, 2200 Mm³/y	21.9 billion US$	Public Private Partnership, Long-Term Power & Water Purchase Agreements, Insurance & Guaranties	3 – 5.2 ct/kWh 29 – 90 ct/m³
2020 – 2025	Market Expansion Phase	21 GW, 7 billion m³/y	80 billion US$	Public Private Partnership, Long-Term Power & Water Purchase Agreements	3 – 5 ct/kWh 15 – 75 ct/m³
2025 – 2050	Commercial Phase	450 GW, 150 billion m³/y	2000 billion US$	non	3 – 5 ct/kWh 5 – 65 ct/m³

* Variation between Reference Scenario (9 % Interest Rate, 20 Years Capital Return Period) and Optimised Conditions (4 % Interest Rate, 40 Years Project Life)

Annex 4:

TREC Solar Thermal Power & Desalination User Association *

1. TREC provides the framework for a MENA wide user network of Solar Thermal Power & Desalination (STPD). Countries or communities considering the installation of 1 or more STPD facilities can this way organize their common interests.

2. The installation of STPD facilities will offer to the MENA countries inexhaustible and expandable sources of fresh water, technological and economic development, and with clean power a product for export to Europe. The participating MENA countries can acquire advantages if they coordinate their efforts

a) to reduce initial costs occurring before a decision for a contract can be made

b) to reduce implementation costs for the STPD

c) to enhance performance and to reduce costs by sharing operation & maintenance (O&M) efforts

d) to organize the necessary work on research and development of relevant technologies

e) to integrate and to economize the production of components in MENA countries

f) to reduce capital and insurance cost for STPD facilities

g) to consult governments and investors in MENA in a producer independent way when choosing between different technological options.

h) to lobby for clean power import by the EU from MENA region.

3. Initial costs occurring to SPTD clients before a decision for a contract can be made originate from

- first assessment and consulting services in the frame of the MED-CSP study (AS)
- country wide solar yield map (SYM)
- feasibility study (FE)

4. A country wide solar yield map with a grid of 1x1km² and with 1 hourly time segments can be produced, for all potential users in the country. Cost 50,000 -100,000 € depending on country size.

5. If AS and SYM yield promising results, a FE can be decided upon. Here again, several customers can share the study and reduce costs, since feasibility studies for different STPDs at different locations have a number of tasks in common which don't have to repeated from scratch. Since FE costs amount to several 100,000 € substantial saving can be achieved.

6. As to the implementation stage several customers can thru the user association for STPD, strengthen their bargaining position against producers by pooling their demands, since due to the high modularity discounts for large numbers of parts are possible.

7. During operation, methods and control software can be optimized, costs for stockpiling spare parts can be reduced, experience of technical service can be shared, remote performance monitoring and early warnings can be organized by the STPD winner club net work.

8. R&D. The technology of solar steam generators has been proven to work. We have available a first generation of this technology. The total investment volume into STPD facilities may well reach several 10 billion Euros within a few decades. Hence technology optimization thru R&D is of great interest. Since many independent countries are involved, R&D efforts can be optimized MENA-wide, as well as education and training of competent manpower. The STPD user association can assist by networking for this task with a MENA-wide scope.

9. Industrial integration. Different from steam turbines and generators, for the solar components there is no leading producer yet established. About ¾ of the investments for STPD facilities will go into the solar steam generator and heat storage. Here is the chance for an emerging industry in MENA countries. The STPD user association can organize to consult national governments and industry in MENA countries on how to create an industrial basis for the production of solar components.

10. Instead of fuel costs the STPD have capital and insurance costs as main expense. Both costs depend on the risk attached to each plant. The risk for a larger number of plants is relatively smaller than for a single plant. The STPD user association can therefore exploit the better bargaining position resulting for a larger set of plants.

11. The STPD user association may have its own technology experts that consult the clients independent of producer interests, when it comes to choose between alternatives. This is very important as the collector technology is new and technical competence is normally available only from production companies.

12. In the long term, may be 10 years from now, clean power export to EU will become a salient feature. This is a highly interesting option for MENA countries for economic co-operation with the EU. This requires infrastructure like enforced power lines in the European grid and trans-Mediterranean cables, fair trade conditions plus unrestricted access to the EU power market, and an integration of wind and solar power imports into the EU power policy. Here the STPD user association may engage in the political lobby work.

With these supports available the potential clients for STPD facilities can safely do the first step and gather first information on possible STPD projects and on the benefits that they offer to its participants.

To get going along these lines TREC announces the

First MENA Strategy Workshop on
How Solar Thermal Power can be made beneficial for MENA Countries

Date: October 2004
Place: Tripoli
Organized by TREC, CoR, Center for Solar Energy Studies Libya
In conjunction with: The Arab International Conference on Solar Energy Applications

Topics:
- Solar thermal potential maps
- Power and desalination in cogeneration

- Water demand inventory
- Industrial capacity development
- Finance
- Solar science, research and development
- Market introduction strategy
- Structures of Co-operation