Europe - Middle East - North Africa Cooperation for Sustainable Electricity and Water

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Abstract

This report summarizes the results of two studies of electricity supply for Europe (EU), the Middle East (ME) and North Africa (NA) up to the year 2050. It shows that a transition to competitive, secure and sustainable supply of electricity and water is possible using renewable energy sources, efficiency gains and fossil fuel backup for balancing power. A strong cooperation between the EU and MENA for the market introduction of renewable energy and the interconnection of the electricity grids by high-voltage direct-current transmission are keys to the success and survival of the whole region. However, the necessary measures will take at least two decades to become effective. Therefore, adequate policy and economic frameworks for their realization must be introduced immediately. The importance of sustainable energy for the security of freshwater supplies in MENA is also described.

Keywords: concentrating solar power, renewable energy, solar electricity, long term scenario, Europe, Middle East, North Africa

Introduction

In order to find a viable transition to an electricity supply that is inexpensive, compatible with the environment and based on secure resources, rigorous criteria must be applied to ensure that the results are compatible with a comprehensive definition of sustainability (Table 1). A central criterion for power generation is its availability at any moment on demand. Today, this is achieved by consuming easily stored, fossil or nuclear energy sources that can provide electricity whenever and wherever required. This is the easiest way to provide power on demand. However, consuming the stored energy reserves of the globe has a high price: they are quickly depleted and their residues contaminate the planet.

With the exception of hydropower, natural flows of energy are not widely used for power generation today, because they are not as easily stored and exploited as fossil or nuclear fuels. Some of them can be stored with a reasonable technical effort for a limited time-span, but others must be taken as provided by nature (Table 1). The challenge of future electricity supply is to find a well balanced mix of available technologies and resources that is capable of satisfying not only the criterion of "power on demand", but all the other criteria for sustainability, too (MED-CSP 2005, TRANS-CSP 2006).

The paper describes a scenario of electricity demand and supply in EUMENA up to the middle of the century, and confirms the importance of renewable energy sources and international cooperation to achieve economic and environmental sustainability.

Criteria for Energy Sustainability:	Technology Portfolio:	
✓ **Inexpensive** low electricity cost no long term subsidies	✓ **Coal, Lignite** ✓ **Oil, Gas** ✓ **Nuclear Fission, Fusion**	**ideally stored energy**
✓ **Secure** diversified and redundant supply power on demand based on undepletable resources available or at least visible technology	✓ **Concentrating Solar Power (CSP)** ✓ **Geothermal Power (Hot Dry Rock)** ✓ **Biomass** ✓ **Hydropower**	**storable energy**
✓ **Compatible** low pollution climate protection low risks for health and environment fair access	✓ **Wind Power** ✓ **Photovoltaic** ✓ **Wave / Tidal**	**fluctuating energy**

Table 1: Criteria for sustainability and portfolio of technologies and resources for power generation

Increasing Pressure on Electricity and Water

As a first step, our analysis quantifies electricity demand in Europe and MENA up to the middle of the century. Growing freshwater deficits in MENA are also part of the energy problem, as there will be an increasing demand for seawater desalination. For simplicity we assume that in the long term, the necessary energy for desalination will also be supplied by electricity.

Population growth is a major driving force for electricity and water consumption. According to the World Population Prospect of the United Nations the population of the European region will stabilize at around 600 million while MENA will grow from 300 million in the year 2000 to a similar 600 million by the middle of the century (UN 2004).

The second driving force is economic growth, which usually has two opposing effects on energy and water demand: on the one hand, the demand increases because new services are provided within a developing economy. On the other hand, efficiency of production, distribution and end-use is enhanced, thus allowing the provision of more services for a given amount of energy. In past decades, all industrial nations observed a typical decoupling of economic growth and energy demand. In order to be able to afford efficiency measures, a certain economic level beyond sheer subsistence must have been attained, something that is now true of most countries in EUMENA.

Our analysis shows that by 2050 electricity consumption in the Middle East and North Africa is likely to be around 3000 TWh/year (Figure 1), which is comparable with what is consumed in Europe today. Meanwhile, European consumption is likely to increase to and stabilize at a value of about 4000 TWh/year (Figure 2). Due to the dynamics of efficiency gains, our model yields lower levels of predicted demand than most other scenarios (IEA 2005, IEA 2006, CEC 2006, Mantzos and Capros 2005). However, there are also scenarios indicating lower demand (Benoit and Comeau 2005, Teske et al., 2007). The reduction of demand in Europe after 2040 (as shown in Figure 2) is however uncertain. Stagnant or slowly growing demand is also a possibility, since efficiency gains may be transformed into new energy services not considered here, such as, for example, electric vehicles or hydrogen for the transport sector.

A similar analysis has been done for the water sector in MENA. The difference between the available sources of fresh water that are renewable and growing demands for water leads to the water deficit displayed in Figure 3. There is already a significant deficit today, which is poorly met by sea-water desalination via fossil fuels and by the over-exploitation of ground-water resources, something that, in many regions in MENA, leads to falling levels of ground-water, intrusion of salt water into groundwater reservoirs and the growth of deserts.

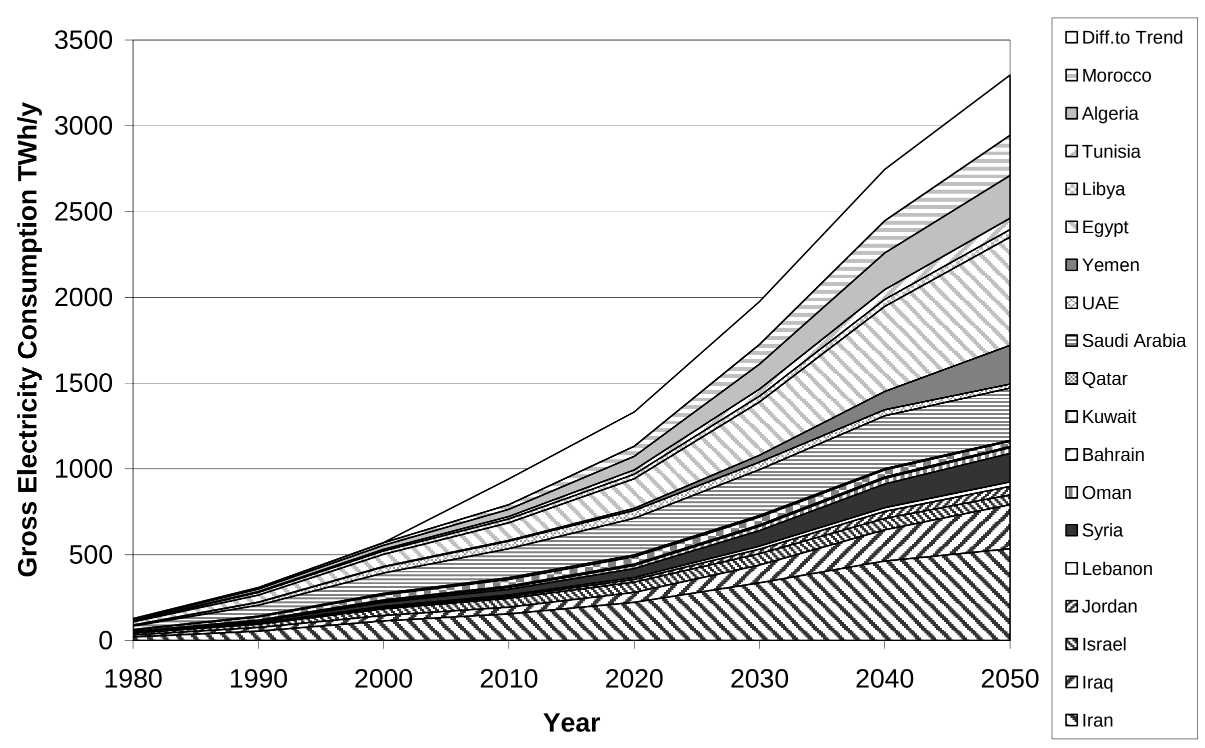

Figure 1: Electricity demand scenario for the MENA countries considered in the study (MED-CSP 2005)

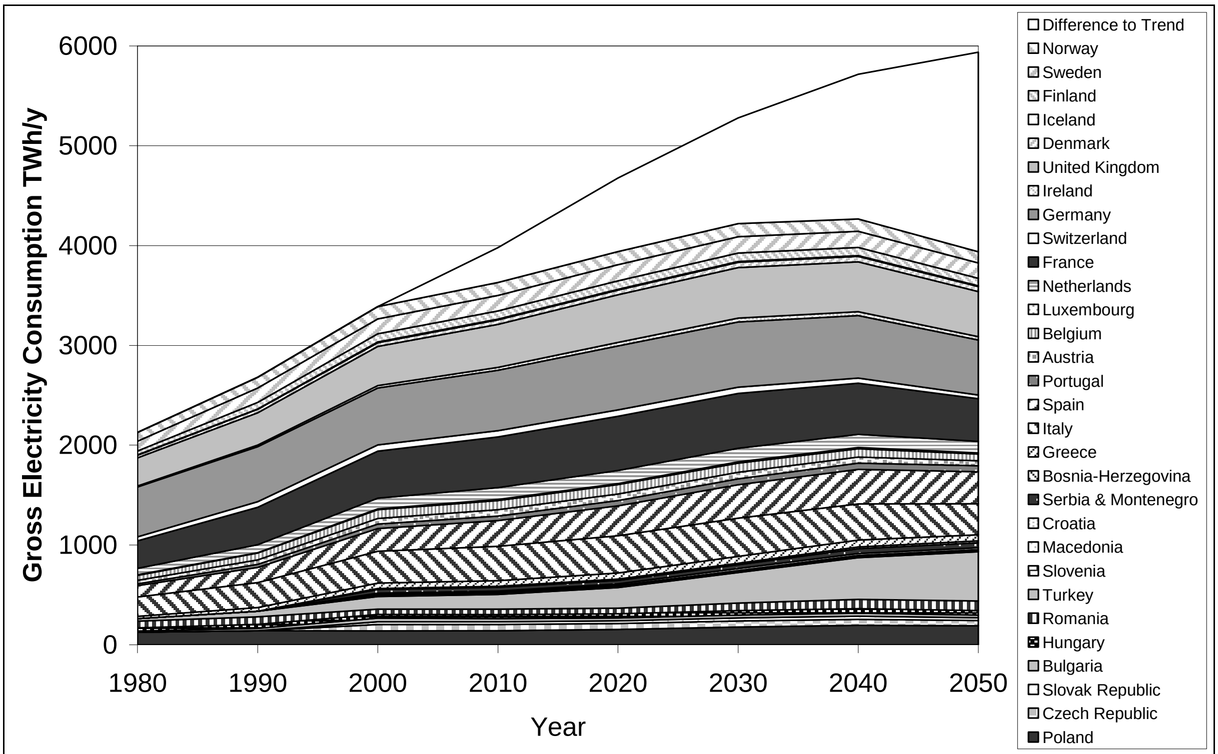

Figure 2: Electricity demand for the European countries considered in the study (TRANS-CSP 2006)

According to our projection, this deficit tends to increase from the current 60 billion m³ per year, which is almost the annual flow of the Nile River, to 150 billion m³ in the year 2050. Egypt, Saudi Arabia, Yemen, and Syria are the countries with the largest deficits. Enhancement of efficiency of water distribution, water use and water management to achieve best-practice standards is already included in the underlying assumptions of this scenario. It is obvious that the MENA countries will be confronted with a very serious problem in the not too distant future, if those measures and the necessary additional measures are not initiated in good time. Seawater desalination is one of those additional options. Assuming that, on average, 3.5 kWh of electricity is needed to desalinate one cubic meter of seawater, this would mean an additional requirement of almost 550 TWh/y by 2050 in order to produce the quantities of freshwater that will be needed. This would be equivalent to the current electricity demand of a country like Germany (MED-CSP 2005).

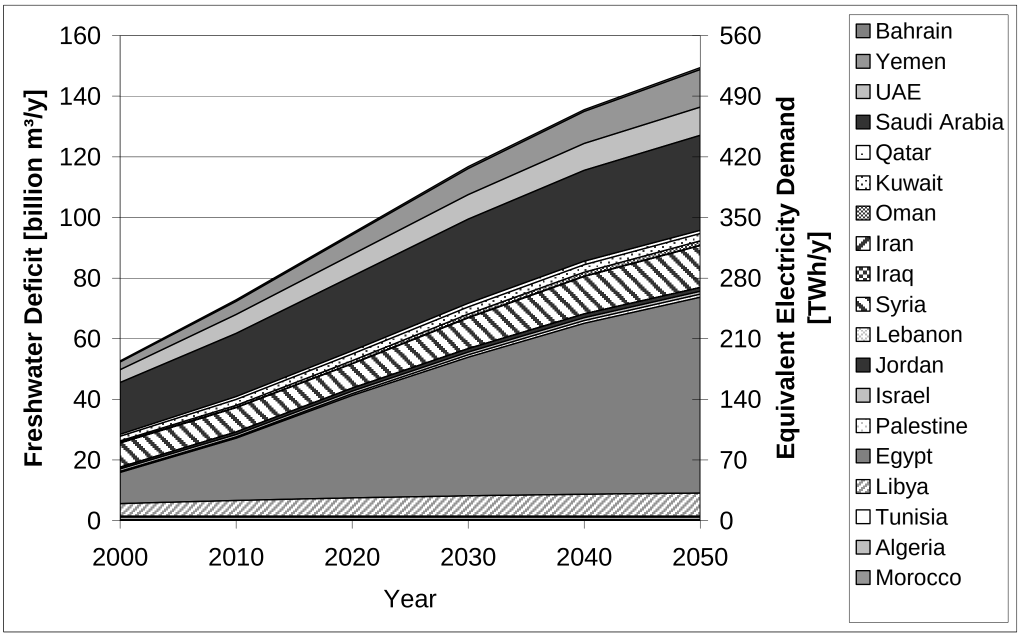

Figure 3: Freshwater deficit defined as the difference between water demand and renewable freshwater resources for each of the MENA countries, and equivalent electricity demand for seawater desalination (Trieb and Müller-Steinhagen 2007).

Portfolio of Resources and Technologies

In the financial and insurance business there is a clear answer to the question of security and risk management: the diversification of the assets portfolio (Awerbuch and Berger 2003). This simple truth has been completely ignored in the energy sector. Here, decisions were based on "least cost and proven technology" and the portfolio was usually limited to fossil fuel, hydropower and nuclear plants. This short-sighted policy has been harmful both for consumers and for the environment: prices of all kinds of fossil fuels and of uranium have multiplied several times since the year 2000 and the burning of these fuels is seriously contaminating the global atmosphere. Today, consumers and taxpayers have no choice but to pay the higher cost of fossil fuels, as the energy policies of the past failed to build up alternatives in good time and to establish them as part of the energy market. To add insult to injury, fossil and nuclear energy technologies still receive 75 % of current energy subsidies (EEA 2004), a number that increases to over 90 % if the failure to impose external costs is also considered.

Nevertheless, an impressive portfolio of renewable energy technologies is available today (Dürrschmidt et al. 2006). Some of these have fluctuating output, like wind and photovoltaic power (PV), but some of them (such as biomass, hydropower and concentrating solar thermal power (CSP)) can meet both peak- and base-load demands for electricity (Table 2). The long-term economic potential of renewable energy in EUMENA is much larger than present demand, and the potential of solar energy dwarfs them all. From each km² of desert land, up to 250 GWh of electricity can be harvested each year using the technology of concentrating solar thermal power. This is 250 times more than can be produced per square kilometre by biomass or 5 times more than can be generated by the best available wind and hydropower sites. Each year, each square kilometre of land in MENA receives an amount of solar energy that is equivalent to 1.5 million barrels of crude oil[1]. A concentrating solar thermal power plant of the size of Lake Nasser in Egypt (Aswan) could harvest energy equivalent to the present Middle East oil production[2].

In addition, there are other large sources of renewable energy in EUMENA: there is potential of almost 2000 TWh of wind power and 4000 TWh/y of power from geothermal, hydro and biomass sources including agricultural and municipal waste. Also PV, wave and tidal power have considerable potentials in the region. By contrast with fossil and nuclear fuels, renewable energy sources in the region are over-abundant. However, each renewable energy resource has a specific geographic distribution (Figure 4). Each country will therefore have its specific mix of resources, with hydropower, biomass and wind energy being the preferred sources in the North, and solar and wind energy being the most powerful sources in the South of EUMENA.

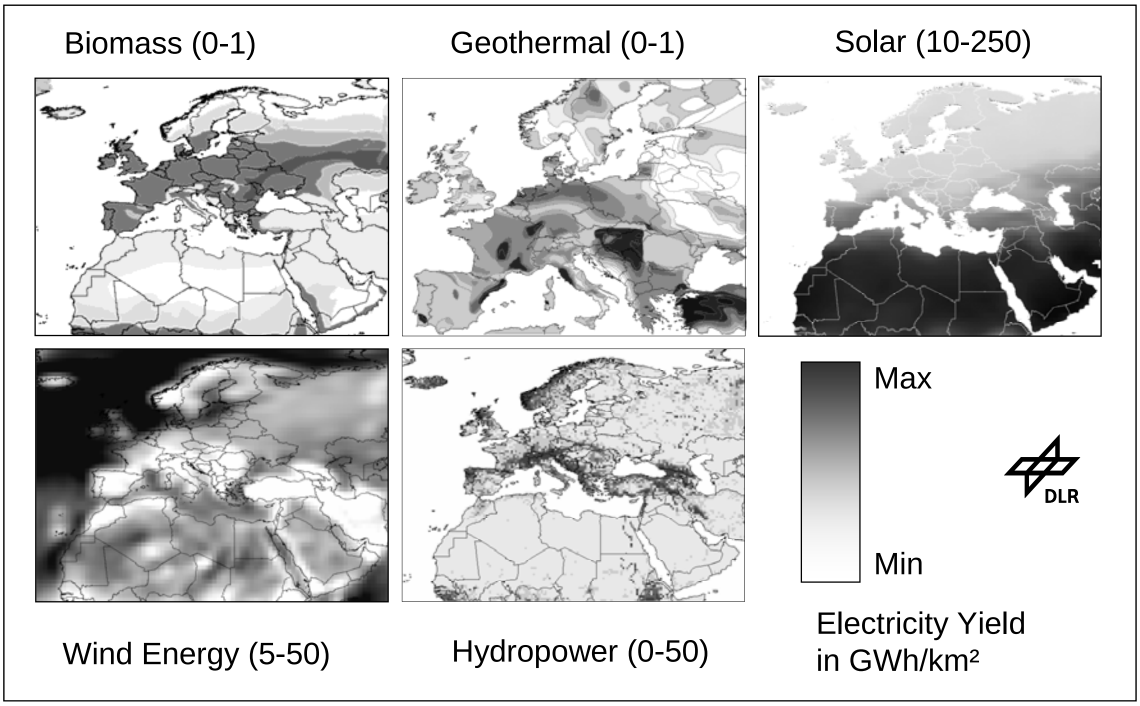

Figure 4: Renewable energy resource maps for EUMENA, showing the minimum and maximum annual electricity yield (as specified in brackets) that can be harvested by each technology from 1 km² of land area. Solar includes both photovoltaic and concentrating solar thermal power technologies. The overall potential and the different characteristics of each resource are given in Table 2 (MED-CSP 2005).

[1] reference solar irradiance 2400 kWh/m²/year, 1600 kWh heating value per barrel

[2] Lake Nasser has a surface of 6000 km², Middle East oil production is currently $9 \cdot 10^9$ barrels/year

	Unit Capacity	Capacity Credit *	Capacity Factor **	Potential*** (TWh/y)	Type of Resource	Applications	Comment
Wind Power	1 kW – 5 MW	0 – 30 %	15 – 50 %	1950	kinetic energy of the wind	electricity	fluctuating, supply defined by resource
Photovoltaic	1 W – 5 MW	0 %	5 – 25 %	325	direct and diffuse irradiance on a surface tilted with latitude	electricity	fluctuating, supply defined by resource
Biomass	1 kW – 25 MW	50 - 90 %	40 – 90 %	1350	municipal and agricultural organic waste and wood	electricity and heat	seasonal fluctuations but good storability, power on demand
Geothermal (Hot Dry Rock)	25 – 50 MW	90 %	40 – 90 %	1100	heat from hot dry rocks of several 1000 meters depth	electricity and heat	no fluctuations, power on demand
Hydropower	1 kW – 1000 MW	50 - 90 %	10 – 90 %	1350	kinetic and potential energy from water flows	electricity	seasonal fluctuation, good storability in dams, also used as pump storage for other sources
Solar Updraft Tower	100 – 200 MW	10 to 70 % depending on storage	20 to 70 %	part of CSP potential	direct and diffuse irradiance on a horizontal surface	electricity	seasonal fluctuations, good storability, base-load power
Concentrating Solar Thermal Power (CSP)	10 kW – 200 MW	0 to 90 % depending on storage and hybridisation	20 to 90 %	630,000	direct irradiance on a surface tracking the sun	electricity and heat	fluctuations are compensated by thermal storage and (bio)fuel, power on demand
Gas Turbine	0.5 – 100 MW	90 %	10 – 90 %	n. a.	natural gas, fuel oil	electricity and heat	power on demand
Steam Cycle	5 – 500 MW	90 %	40 – 90 %	n. a.	coal, lignite, fuel oil, natural gas	electricity and heat	power on demand
Nuclear	> 500 MW	90 %	90 %	n. a.	uranium	electricity and heat	base-load power

Table 2: Some characteristics of contemporary power technologies. * Contribution to firm power and reserve capacity. ** Average annual utilisation. * Technical electricity potential in EUMENA that can be exploited in the long-term at competitive cost considering each technology's learning curve. In the case of PV only the demand-side potential used until 2050 was assessed; the technical potential is comparable to that of CSP.**

Fossil energy sources like coal, oil and gas can be a useful complement to the renewable energy mix, being easily stored forms of energy that can be used for balancing power and for grid stabilization. If their consumption is reduced to the point where they are used exclusively for this purpose, their cost escalation will be only a minor burden to economic development and their environmental impact can be minimized. Moreover, their availability will be extended for decades or even centuries.

By contrast, nuclear fission plants are not easily combined with renewables because their output cannot, economically, be varied to meet fluctuating demands. Moreover, decommissioning costs of nuclear plants exceed their initial investment (NDA 2002) and, half a century after market introduction, there are still unsolved problems like plutonium proliferation and nuclear waste disposal. The other nuclear option, fusion, is not expected to be commercially available before 2050 and is therefore not relevant for our proposals (HGF 2001).

Several renewable power technologies can also provide base-load and balancing power. These include: geothermal (hot dry rock) systems that are today in a phase of research and development; hydropower plants with large storage dams in Norway, Iceland and the Alps; most biomass plants; and concentrating solar thermal power plants (CSP) in MENA. CSP plants use the high annual solar irradiance of that region, the possibility of solar thermal energy storage for overnight operation and the option of backup firing with fuels or biomass. CSP in Europe is subject to significant seasonal fluctuations. Constant output for base-load power can only be provided with a considerable fossil fuel share. Due to the higher solar irradiance in MENA, the cost of concentrating solar power there is usually lower and its availability is better than in Europe. Therefore, there will be a significant market for solar electricity imports to complement the European sources and provide firm renewable power capacity at competitive cost.

A Sustainable Energy Outlook for EUMENA

Following the criteria for sustainability in Table 1 and additional technical, social and economic frame conditions described in other reports (MED-CSP 2005, TRANS-CSP 2006), we have developed a scenario for electricity generation for 50 countries in EUMENA up to the year 2050. Except for wind power that is already booming today, and hydropower that has been established for some time, renewable energy will hardly become visible in the electricity mix before 2020 (Figure 5 and Figure 6). At the same time, phasing out of nuclear power in many European countries and the stagnating use of coal and lignite due to climate protection will generate increasing pressure on natural gas resources, increasing their consumption as well as their installed capacity for power generation. Until 2020, renewables like wind and PV power will mainly have the effect of reducing fuel consumption, but will do little to replace existing sources of balancing power. Owing to growing demands and the replacement of nuclear power, consumption of fossil fuels cannot be reduced before 2020. Fuel oil for electricity will largely disappear by 2030 and nuclear power will follow after 2040. The consumption of gas and coal will increase until 2030 and thereafter be reduced to a compatible and affordable level by 2050. In the long term, new services such as electric vehicles may increase the electricity demand further and thus require a higher exploitation of renewables.

The electricity mix in the year 2000 depends mainly on five resources, most of them limited and imported, while the mix in 2050 will be based on ten energy sources, most of them domestic and renewable. Thus, our scenario responds positively to the European Strategy for Sustainable, Competitive and Secure Energy declared by the European Commission in the corresponding Green Paper and Background Document, aiming at higher diversification and security of the European energy supply (Commission of the European Communities 2006).

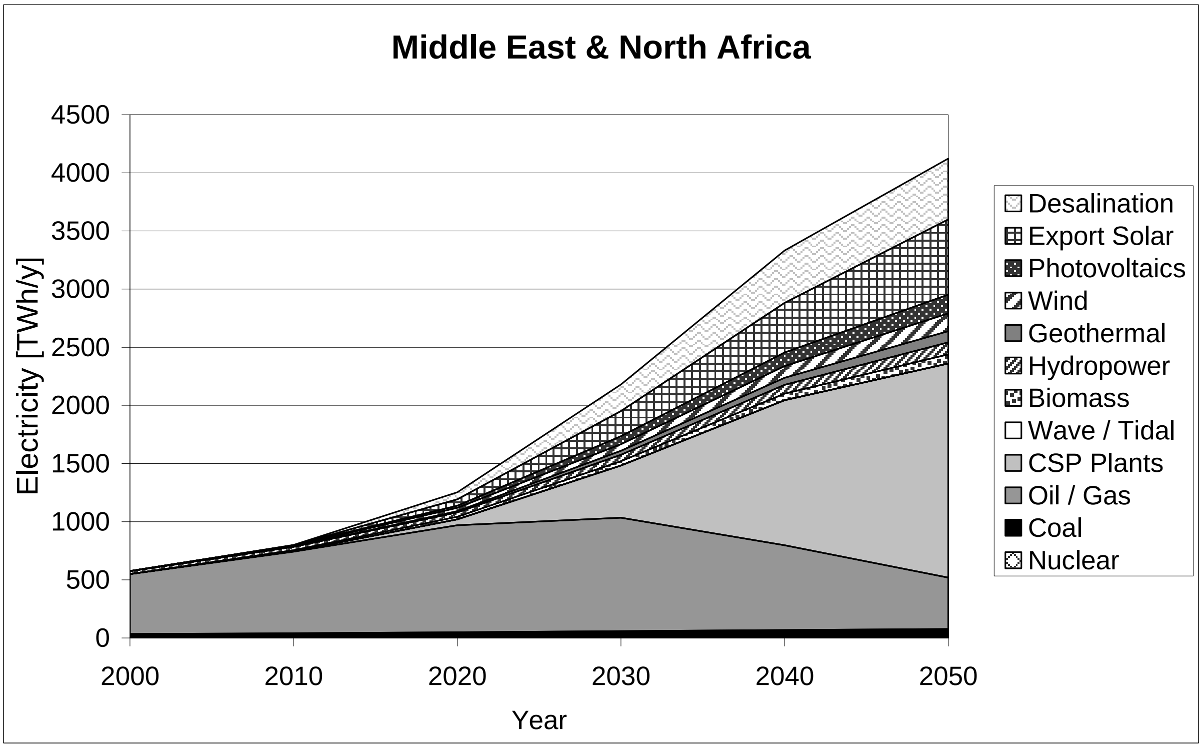

Figure 5: Electricity generated for regional demand according to Figure 1 and in addition for seawater desalination and for export to Europe using the different forms of primary energy available in MENA

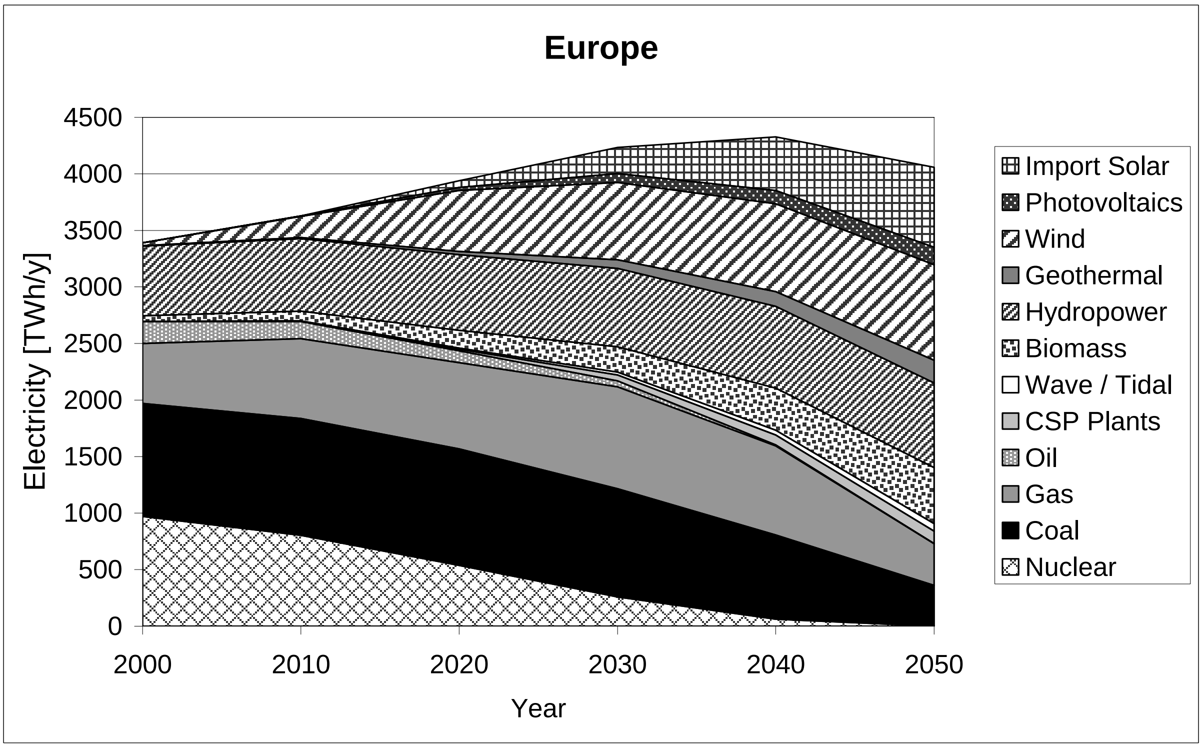

Figure 6: Electricity generated from the different forms of primary energy in Europe including the import of solar electricity from MENA

A prerequisite of the electricity mix is to provide firm capacity with a reserve of about 25 % in addition to the expected peaking load (Figure 7). Before significant CSP imports start in the year 2020, this can only be provided by extending the capacity and fuel consumption of gas fired peaking plants based on natural gas and later eventually on coal gasification. In Europe, the consumption of natural gas doubles with respect to the starting year 2000; but it is then brought back to the initial level, after the introduction in 2020 of increasing shares of CSP imports from MENA as well as geothermal and hydropower imports from Scandinavia, via High-Voltage Direct-Current (HVDC) interconnections. European renewable energy sources that could provide firm capacity are rather limited from the point of view of their potential. Therefore, CSP imports from MENA to Europe will be essential to reduce both the installed capacity and the fuel consumption of gas fired peaking plants and to provide firm renewable power capacity. In MENA, concentrating solar power is the only source that can really cope with rapidly growing electricity consumption, providing both base-load- and balancing power. By 2050, fossil energy sources will be used solely for backup purposes. This will reduce their consumption to a sustainable level and bring down the otherwise rapidly escalating cost of power generation. Fossil fuels will be used to guarantee firm balancing power capacity, while renewables will serve to reduce their consumption for everyday use and base-load supply.

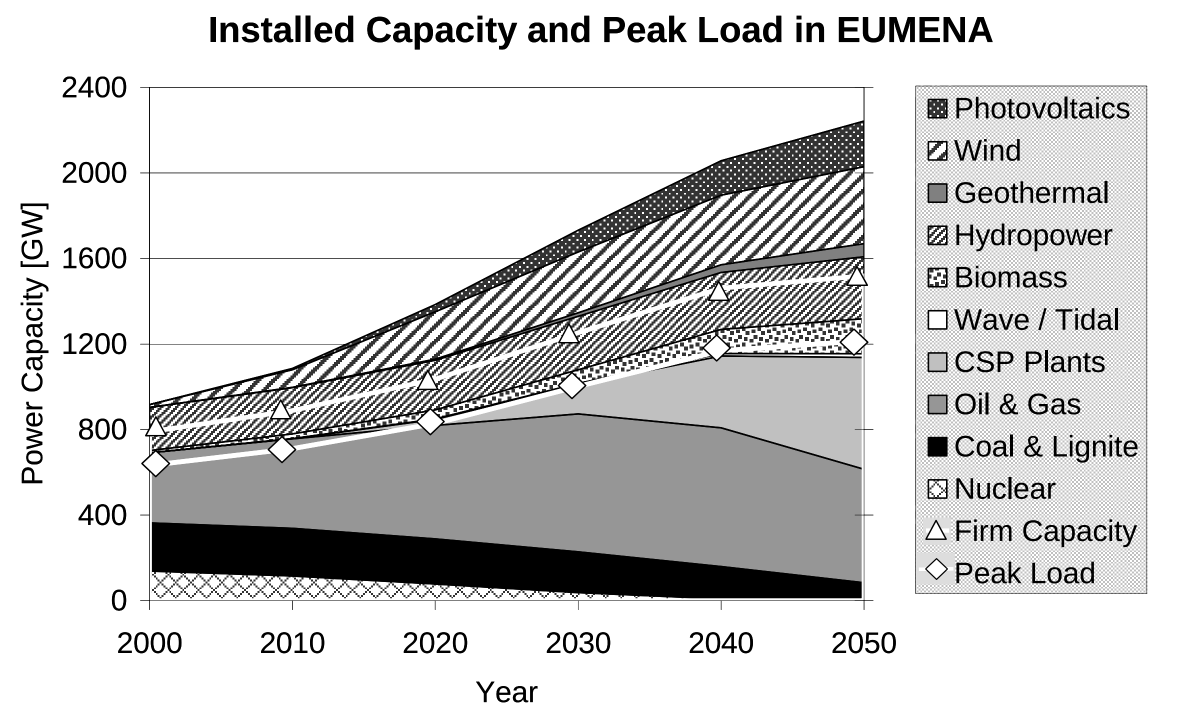

Figure 7: Scenario of the installed power capacity in comparison to the cumulated peak load of all countries in the EUMENA region. Firm power capacity is calculated on the basis of capacity credits for each technology according to Table 2. By the year 2050, 68 % of the installed CSP capacity is used for domestic power, 19 % for export and 13 % for desalination.

An efficient backup infrastructure will be necessary to complement the renewable electricity mix: on one hand to provide firm capacity on demand by quickly-reacting, natural-gas-fired peaking plants, and on the other hand as an efficient grid infrastructure that allows the distribution of renewable electricity from the best centres of production to the main centres of demand. The best solution is a combination of High-Voltage Direct-Current (HVDC) transmission lines and the conventional Alternating Current (AC) grid. At lower voltage levels, decentralised structures will also gain importance, combining, for example, PV, wind and microturbines operating together just like a single virtual power plant. Such a grid infrastructure will not be motivated by the use of renewables alone. In fact, its construction will probably take place anyway, in order to stabilize the growing European grid, to provide greater security of supply, and to foster competition (Asplund 2004, Eurelectric 2003). By 2050, transmission lines with a capacity of 5 GW each will transport about 700 TWh/y of solar electricity from 20 different locations in the Middle East and North Africa to the main centres of demand in Europe (Figure 8 and Table 3). HVDC technology has been a mature technology for several decades and is becoming increasingly important for the stabilisation of large-scale electricity grids, especially if more fluctuating resources are incorporated. HVDC transmission over long distances contributes considerably to increase the compensational effects between distant and local energy sources. And it allows failures of large power stations to be accommodated via distant backup capacity. It can be expected that a HVDC backbone will be established in the long term to support the conventional electricity grid and to increase the stability of the future power-supply system.

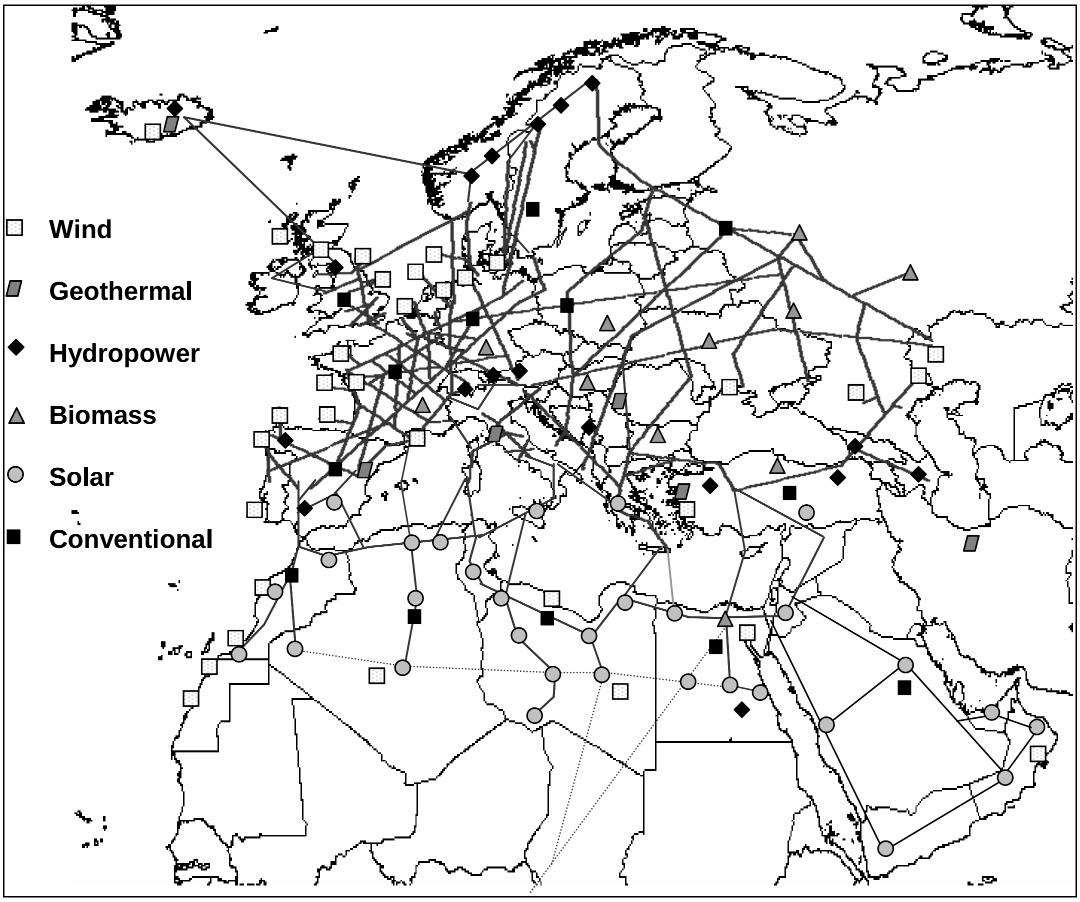

Figure 8: Concept of a EUMENA interconnected electricity grid based on HVDC power transmission as "Electricity Highways" to complement the conventional AC electricity grid. Asplund 2004 (modified).

As a spin-off effect of this development, the import of solar electricity from MENA will become an attractive means of diversifying the European power-generation portfolio. Solar and wind energy, hydropower, geothermal power and biomass will be generated in places where they work best and where they are most abundant. This power will be distributed all over

Europe and MENA through a highly efficient HVDC grid at high-voltage levels, and delivered to consumers by the conventional interconnected AC grid at low-voltage levels. By analogy with the network of interstate highways, a future HVDC grid will have a low number of inlets to and outlets from the conventional AC system because its primary purpose will be to serve long-distance power transmission, while the AC grid will function in a manner that is analogous to the operation of country roads and city streets. About 10 % of the generated solar electricity will be lost by HVDC transmission from MENA to Europe over 3000 km distance. In 2050, twenty power lines with 5000 MW capacity each could provide about 15 % of the European electricity demand in the form of solar imports, motivated by their low cost of around 5 €-cent/kWh (not accounting for further cost reduction via carbon credits) and their high flexibility for base-, intermediate- and peak-load operation.

Year		2020	2030	2040	2050
Transfer Capacity GW		2 x 5	8 x 5	14 x 5	20 x 5
Electricity Transfer TWh/y		60	230	470	700
Capacity Factor		0.60	0.67	0.75	0.80
Turnover Billion €/y		3.8	12.5	24	35
Land Area	CSP	15 x 15	30 x 30	40 x 40	50 x 50
km x km	HVDC	3100 x 0.1	3600 x 0.4	3600 x 0.7	3600 x 1.0
Investment	CSP	42	143	245	350
Billion €	HVDC	5	20	31	45
Elec. Cost	CSP	0.050	0.045	0.040	0.040
€/kWh	HVDC	0.014	0.010	0.010	0.010

Concentrating Solar Thermal Power (CSP) plants use mirrors to concentrate sunlight for steam and power generation. Solar heat can be stored in tanks of molten salt and used for nighttime operation of the turbines, which can also be powered by oil, natural gas or biomass fuels.

High Voltage Direct Current (HVDC) transmission lines are used in some 100 projects world wide transmitting today about 80 GW of electricity from remote, mostly renewable sources like large hydropower dams and geothermal plants to large centres of demand.

Table 3: Main indicators of a EUMENA High Voltage Direct Current (HVDC) interconnection for Concentrating Solar Thermal Power (CSP) from 2020 – 2050 according to the TRANS-CSP scenario. In 2050, lines with a capacity of 5 GW each will transmit about 700 TWh/y of electricity from 20 different locations in the Middle East and North Africa to the main centres of demand in Europe.

There is a common belief that for every wind farm or PV plant a fossil fuel fired backup power plant must be installed. However, hourly time series modelling of the power supply system of selected countries according to our scenario showed that even without additional storage capacities for electricity, the need for fossil fuel fired peaking plants remains relatively constant even when the share of fluctuating sources (PV and wind) is increased. In any case, the necessary balancing capacity is already there, provided for the purpose of covering fluctuations in demand. No extra capacity is needed as long as the fluctuating renewable energy share is smaller than the existing peaking capacity, which is the case in our scenario.

In fact, as a consequence of the increasing share of renewable electricity generation, the need for conventional base load plants with constant output will step by step disappear (Figure 9). Base load will be covered by plants for combined generation of heat and power (CHP) using fossil and biomass fuels, river run-off hydropower, wind power and photovoltaics. Intermediate power capacity will be provided by better storable sources like hydropower from dams, biomass and geothermal power. This combination of power sources will not totally cover, but fairly approximate the daily load curve. The remaining balancing capacity will be supplied by pump storage, hydropower dams, concentrating solar power imports and fossil fuel fired peaking plants. In addition to that, enhanced demand side management will increasingly be used to minimise the need of pump storage capacity and fossil fuel consumption for peaking power, which both will remain in the same order of magnitude as today (Brischke 2005).

The fossil fuel fired power capacities remaining in 2050 will exclusively serve balancing duties and combined generation of heat and power. This is in line with the strategy of using those valuable, easily stored primary energy sources exclusively for what they are best suited for and not wasting them for quotidian use. Base load plants with constant output fuelled by nuclear fission, fusion or lignite will not be able to function within such a system, as they are not capable of providing quickly changing output to fill the gap between the partially fluctuating supply from cogeneration and renewables and the otherwise fluctuating demand. In fact, gas driven plants will be the preferred choice for this purpose.

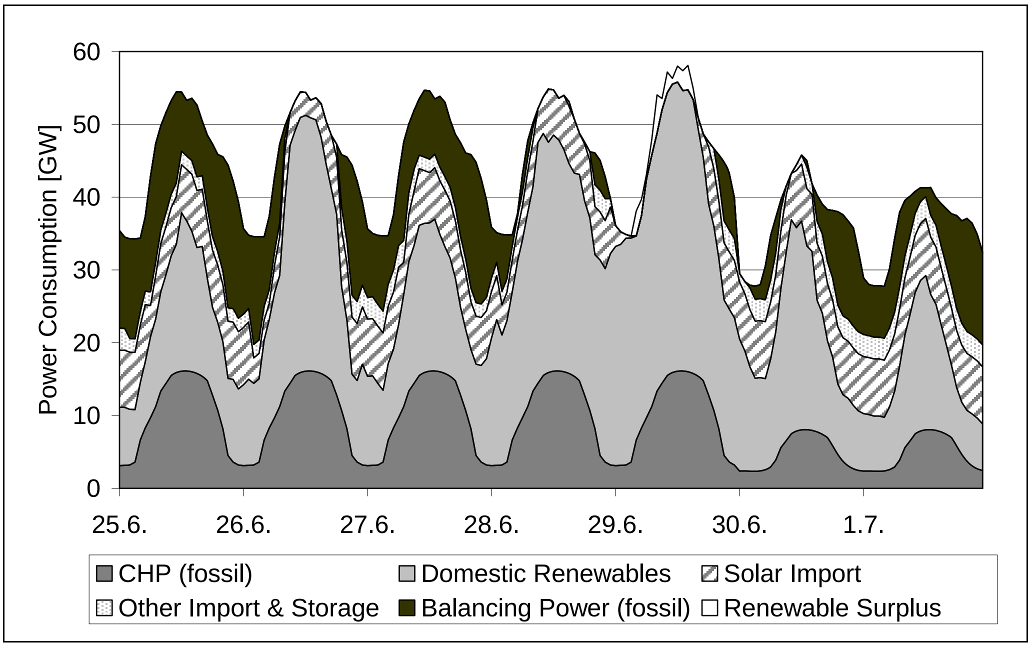

Figure 9: Model of the hourly electricity balance of Germany in 2050 (Brischke 2005)

Commitment to Least Cost Supply

New CSP plants in Spain with up to 50 MW capacity receive a feed-in tariff of about 0.22 €/kWh today. Installing CSP plants world wide, a reduction of the solar electricity cost due to economies of scale can be achieved with a progress ratio of about 90 %[3] (Pitz-Paal et al. 2005). As an example, a first 10 MW plant in Jordan could produce electricity at about 0.18 $/kWh. In the period up to 2010, the cost of solar electricity in newly installed plants will drop to less than 0.10 $/kWh, in 2020 to 0.06 $/kWh and in 2030 to 0.05 $/kWh (Figure 10, thick line). We have assumed solar only operation, an average solar irradiance of 2400 kWh/m²/y, an economic lifetime of 25 years and a project rate of return of 6.5 %/y which is normally expected within the German feed-in tariff system for renewable energy (BMU 2004). Similar reductions would be achieved with a radiation level of 2700 kWh/m²/y and a return of 8 %/y, or a radiation level of 2000 kWh/m²/y and an interest rate of 5 %/y. Thus, investors can optimize their site and financing conditions according to their specific needs.

[3] A progress ratio of 90 % means that the specific investment is reduced by 10 % every time the total installed capacity of the solar collectors is doubled (Neij et al. 2003)

The cost of new gas-fired combined-cycle plants is about 0.058 $/kWh in Jordan (World Bank 2006) and 0.040 - 0.064 $/kWh in the OECD (IEA 2005-2). In our model the current cost of new conventional power plants is represented by 0.056 $/kWh and the cost of the national electricity mix by 0.043 $/kWh, both increasing with a rate of 1.8 %/y[4] (Figure 10, dash-dotted line and thin line). CSP becomes cheaper than new gas fired power plants in 2015 and cheaper than the electricity mix in 2020. Shortly after 2020, the cost of the national electricity mix in a case where CSP is introduced in Jordan (dashed line) will become lower than in case of conventional production (thin line). Up to 2020, the cost of the mix including CSP will be only 0.05 cent/kWh higher than conventional production, which is almost negligible if it is compared to the cost-escalation of 1 cent/kWh caused by increases in the price of fossil fuel in the same time-span. After 2020, the cost of conventional production will increase considerably, but the further expansion of CSP capacities will avoid a substantial increase of the cost of the national electricity mix.

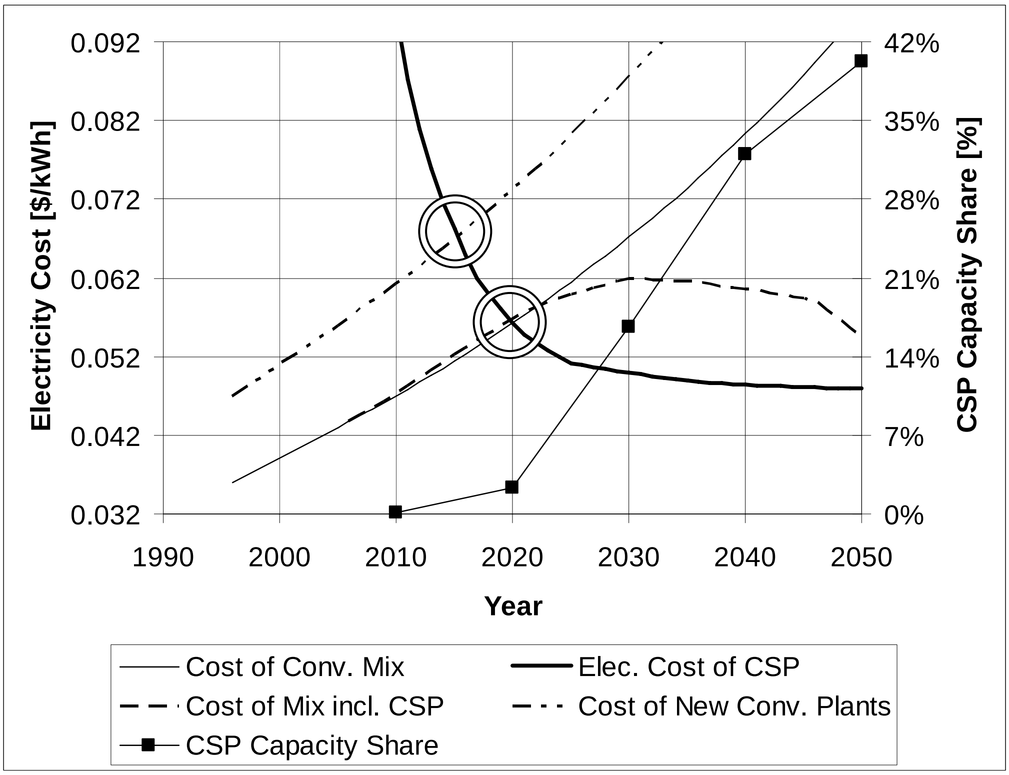

Figure 10: Thick line: electricity cost of new CSP plants. Dash-dotted line: cost of new gas-fired combined cycles. Thin line: cost of conventional electricity mix in Jordan. Dashed line: cost of the national electricity mix including CSP. Black squares: installed solar capacity share in the Jordanian electricity mix according to MED-CSP 2005. The circles indicate the cross-over of the cost of CSP versus new conventional power plants (upper) and versus the national electricity mix (lower). Long-term exchange rate $ / € = 1.

The strategy to achieve this is simple: the CSP share shall be increased to 3 % in the period up to 2020, providing the necessary revenues to CSP operating companies in the form of long-term power-purchase agreements with a national power company, preferably backed by an international guarantee. This will effectively contribute to the international effort to achieve reductions in the cost of CSP. Once cost break-even with conventional power is achieved, the

[4] Electricity price escalation from 1996 to 2005 in Jordan, http://www.nepco.com.jo/english_etariff.html

CSP capacities are extended faster to 15 % by 2030, thus avoiding further increases in the nationwide cost of electricity. After 2030, the cost of the electricity mix is brought back to present levels, by increasing the CSP share to 40 %. This concept can be realized in all MENA countries, and is also valid for other renewables like e. g. electricity from wind or biomass, taking into account their specific characteristics and potential in each country.

In view of the electricity cost escalation we have seen in recent years, the idea of introducing CSP and other renewables on a large scale is the only viable solution for avoiding further long-term cost elevation in the power sector and to return to a relatively low cost level for electricity in the medium-term future. This is in line with the utilities' commitment to deliver least cost electricity to their clients.

An affordable and sustainable source of energy is also required for an even more vital commodity: freshwater from seawater desalination. CSP and other renewables can be the solution for this, too (Bennouna and Nokraschy 2006). The ongoing AQUA-CSP study analyses the potential of CSP for seawater desalination in the MENA region and describes the technical options available, ranging from solar-powered membrane desalination to the combined generation of solar electricity and heat for thermal multi-effect desalination (AQUA-CSP 2007).

An Alternative to Climate Change and Nuclear Proliferation

By implementing our scenario, carbon emissions can be reduced to values that are considered compatible with the goal of stabilising the CO_2 content of the atmosphere at 450 parts per million as proposed by the International Panel on Climate Change (UBA 2005). Starting with 1790 million tons of carbon dioxide per year in the year 2000, emissions can be reduced to 690 Mt/y in 2050, instead of growing to 3700 Mt/y in a business as usual case. The final per capita emission of 0.58 tons/cap/y in the electricity sector is acceptable in terms of a maximum total emission of 1-1.5 tons/cap/y that has been recommended by the German Scientific Council on Global Environmental Change (Graßl 2003). Further reductions can be achieved after 2050. Other pollutants are reduced in a similar way, without any need to expand the use of nuclear energy and its associated risks. Carbon capture and sequestration (CCS) has been considered in our study as a complement, but not as an alternative to renewable energy, as it will reduce power plant efficiency and thus accelerate the consumption of fossil fuels. The fact that the cost of carbon capturing always adds to the cost of fossil fuels will accelerate cost break-even with renewables and increase the speed of their market introduction.

The land required for the total renewable energy infrastructure including the proposed HVDC transmission lines for the period up to 2050 amounts to roughly 1 % of the total land area of EUMENA. This is comparable to the land required at present for the transport and mobility infrastructure in Europe. Using a geographic information system (GIS) three examples of HVDC lines connecting very good sites for CSP generation in MENA with three major European centres of demand were analyzed on the basis of a life cycle eco-balance (May 2005). The GIS was programmed to minimize cost, environmental impacts and visibility of the power lines, and we found that the resulting impacts are in an acceptable range. In general, the environmental impacts of HVDC lines are much lower than those of comparable AC overhead lines using conventional technology. Altogether, our scenario shows a way to reduce significantly the negative environmental impacts of power generation, and could also serve as a model for global application.

If desalination of sea water is powered by solar energy, its environmental impacts can also be reduced. However, seawater desalination itself is always a considerable burden to the environment, due to the resulting salty brine and the necessary chemical water treatment. Therefore, activating the existing potential for enhanced efficiency of water use, water management and infrastructure is also a very high priority, in order to minimize the need for desalination. The AQUA-CSP study analyses the environmental impact of a broad application of solar-powered seawater desalination to cover the expected freshwater deficits in MENA (AQUA-CSP 2007). The results will be published by the end of 2007.

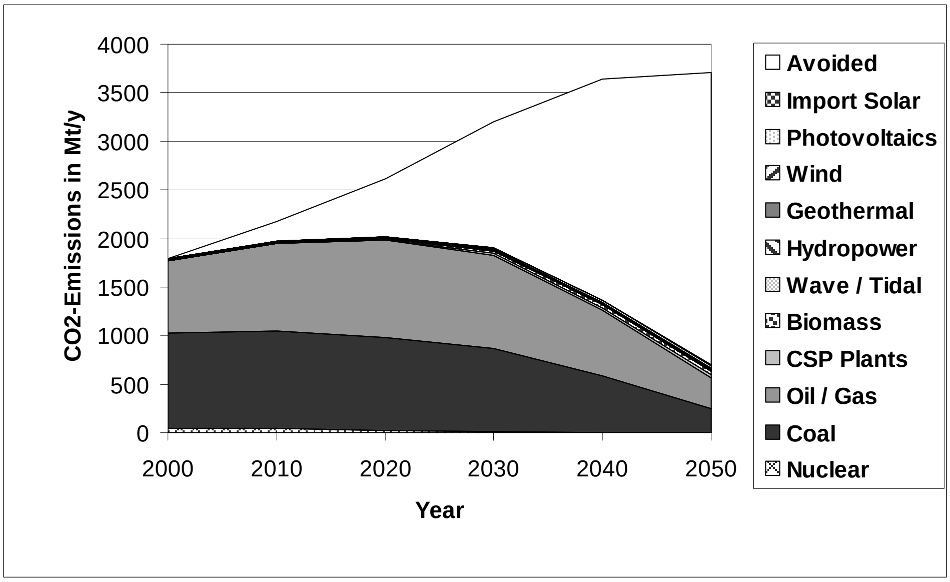

Figure 11: CO_2-emissions from electricity generation in million tons per year for all EUMENA countries and emissions avoided by implementing the proposed scenario with respect to an electricity mix equivalent to that of the year 2000.

Interaction of Electricity with other Energy Sectors

A sustainable solution must not only be found for electricity, but also for the heating, cooling and transport sectors. Energy efficiency and increasing renewable shares are also useful guidelines for these sectors. In the long term, there is the option of a partial shift from traditional heat and fuel to electricity. Examples for such a possible shift are electric heat pumps or direct electricity for space and water heating and electric or hybrid vehicles. In terms of sustainability, the higher demand for electricity arising from that shift will not constitute a problem if electricity is mainly produced by renewable energy as proposed in our scenario. In the power sector, each kWh of electricity produced by solar and wind energy will substitute approximately three kWh of primary energy from coal, oil, gas or uranium[5]. This relation depends on the actual efficiency of conventional primary-energy conversion, which ranges from about 20 % in the transport sector to about 80 % in space heating. Thus, the use of renewable electricity will add to the efficiency gains of primary energy in all energy sectors. A partial long-term shift of other sectors to (clean) electricity is possible, as the renewable electricity potential in EUMENA is large enough to cope with that additional demand. In addition to electricity, direct renewable solutions also exist for those sectors, such as the use of bio-fuels for transport and heating, energy-efficient buildings, absorption cooling and solar water heaters, to give only a few examples (Dürrschmidt et al. 2006).

[5] assuming a typical conventional power plant efficiency of 33%

Combined heat and power is an important measure for increasing the energy efficiency of fossil fuels. Some renewable technologies, such as biomass, geothermal and concentrating solar thermal power plants, can also use this option for the combined generation of electricity and heat – usually via steam – for industrial processes, cooling and desalination, and will gain an increasing share in a future energy supply system.

Five Focal Points for Sustainable Energy Policy

The timely realization of a scenario that meets all criteria of sustainability will require determined political support and action. Five focal points for national and international policy for all countries in Europe, the Middle East and North Africa (EUMENA) result from our studies:

1. **Increase support for research and development and for the market introduction of measures for efficient supply, distribution and use of energy (*efficiency focus*).**
2. **Increase support for research and development and provide a reliable framework for the market introduction of renewable energy technologies based on best practice experience (*renewable energy focus*).**
3. **Initiate a EUMENA-wide partnership for sustainable energy. Provide European support to accelerate renewable energy use in MENA (*interregional cooperation focus*).**
4. **Initiate planning and evaluation of a EUMENA High Voltage Direct Current super-grid to combine the best renewable energy sources in this region and to increase diversity and redundancy of supply (*interconnection focus*).**
5. **Support research and development for shifting the use of fossil fuels from bulk electricity supply to a source of balancing power for volatile renewable sources, including necessary structural changes (*balancing power focus*).**

Conclusions

The report quantifies the renewable electricity potentials in Europe and MENA and confirms their ability to provide firm power capacity on demand. Our study includes an interconnection between the electricity grids of Europe, the Middle East and North Africa (EUMENA) and evaluates the potential and benefits of solar power imports from the South. The conventional electricity grid is not capable of transferring large amounts of electricity over long distances. Therefore, a combination of the conventional Alternating Current (AC) grid for local distribution and High-Voltage Direct-Current (HVDC) transmission technology for long-distance transfer will be used in a Trans-Mediterranean electricity scheme based mainly on renewable energy sources with fossil fuel backup. Sustainable energy will also be vital for sustainable freshwater supply by desalination. The results can be summarized in the following statements:

1. A mix of various renewable energy sources backed by fossil fuels can provide sustainable, competitive and secure electricity. Our scenario for EUMENA starts with the 16 % share of renewable electricity that existed in the year 2000 and reaches 80 % in 2050. An efficient backup infrastructure will be necessary to complement the renewable electricity mix, providing firm capacity on demand by quickly-reacting gas-fired peaking plants, and by an efficient grid infrastructure to distribute renewable electricity from the best centres of production to the main centres of demand.

2. Market introduction of renewable electricity requires initial support in the form of long term power purchase agreements that cover the costs of operation together with a reasonable return on investment. This will mean only a small increase in national electricity prices, but will avoid their long-term escalation thanks to an increasing proportion of relatively inexpensive renewables and corresponding reductions in cost.
3. If initiated now, the change to a sustainable energy mix will, within a time-span of about 15 years, lead to power generation that is less expensive than it would be in a business-as-usual strategy. Fossil fuels with steadily rising costs will be replaced progressively by renewable forms of energy, most of which will be home-grown. The negative socio-economic impacts of increases in fossil-fuel prices can be reversed by 2020 if an adequate political and legal framework for the introduction of renewables into the market is established in time. Long-term power-purchase agreements like those provided by the German or Spanish Renewable Energy Acts are very effective instruments for the market introduction of renewables. If initial tariff additions are subsequently reduced to zero, they can be considered as a very efficient public investment rather than a subsidy.
4. Solar electricity generated by concentrating solar thermal power plants in MENA and transferred to Europe via high-voltage direct-current transmission can provide firm capacity for base-load and peaking power, effectively complementing European electricity sources. Starting between 2020 and 2025 with a transfer of 60 TWh/y, solar electricity imports could subsequently be extended to 700 TWh/y by 2050. High solar irradiance in MENA and low transmission losses of around 10 % will yield a competitive price of about 0.05 €/kWh in Europe for import of solar electricity.
5. Instead of a doubling of carbon dioxide emissions in the period up to 2050, which is likely to happen in a business-as-usual scenario, the CO_2 emissions from power generation in EUMENA can be reduced to 38 % of emissions of the year 2000. Only 1 % of the land area will be required for the renewable electricity mix, which is equivalent to the land used at present for transport and mobility in Europe.
6. Growing freshwater deficits in MENA will increasingly require seawater desalination, but this must be done using sustainable sources of energy. Solar electricity for membrane desalination and combined solar heat and power for thermal seawater desalination are major candidates for such a sustainable solution.
7. European support for MENA for the introduction of renewables into the market can ameliorate the increasing pressure on fossil fuel resources that would otherwise result from the economic growth of this region, thus helping indirectly to secure fossil fuel supply also in Europe. The necessary political process could be initiated by a renewable energy partnership and a common free trade area for renewable forms of energy in EUMENA and culminate in a Community for Energy, Water and Climate Security.

In order to achieve those benefits, the governments of EUMENA must now take the initiative and establish an adequate legal and financial framework for new investment into this least-cost option for clean and sustainable energy. As energy is also a prerequisite for a sustainable supply of water, a timely decision by the EUMENA governments to initiate that path is of vital importance for the total region.

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Acknowledgements

The authors thank the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety for the financial support of the studies described here and for its leading role in renewable energy dissemination world-wide. Special thanks to TREC and Dr. Gerhard Knies and to the study team Dr. Christoph Schillings, Stefan Kronshage, Dr. Peter Viebahn, Nadine May and Christian Paul from DLR, Stuttgart, Germany, Dr. Uwe Klann, Stuttgart, Germany, Eng. Malek Kabariti and Ammar Taher from National Energy Research Center, Amman, Jordan, Prof. Dr. Abdelaziz Bennouna from Centre National Pour la Recherche Scientifique et Technique, Rabbat, Morocco, Dr. Hani Nokraschy from Nokraschy Engineering, Holm, Germany, Eng. Samir Hassan and Laila Georgy Yussef from New and Renewable Energy Authority, Cairo, Egypt, Tewfik Hasni from New Energy Algeria, Algiers, Dr. Nasir El-Bassam from Internationales Forschungszentrum für Erneuerbare Energien, Sievershausen, Germany, and Honorat Satoguina, Hamburger Weltwirtschaftsarchiv, Hamburg, Germany.