# 5 A Scenario for Energy and Water Security

The aim of this work package was to find a consistent scenario for the expansion of renewable energies in the analysed countries until 2050. Again, the emphasis of the study lies on CSP technology for electricity and water in the context of other renewable and non-renewable energy technologies. A number of energy scenarios on regional or global level can be found in the literature /EU 2000/, /EU 2003/, /WETO 2003/, /Shell 2001/. However there are no consistent scenarios for the EU-MENA region available on country level.

A scenario is not a prediction. A scenario is one of many possible ways to reach a certain future situation. It will require a social and political effort to reach that goal, it will not happen spontaneously. A scenario should be free of inconsistencies or it will be disregarded. With a scenario, one can examine if a preset goal is desirable or not, if a consistent way to that goal exists and what kind of measures could or must be taken to reach or to avoid it. One can vary the input parameters of a scenario to see if there are different, maybe better ways to reach the goal. A scenario represents a span of possible futures of which one may become reality if the preconditions are fulfilled. No economic or otherwise optimisation of the scenario was performed. Optimisations over a time span of 50 years would be rather questionable, as the input parameters for any optimisation would be a function of time and thus would have a wide range of insecurity. Moreover, most optimisation methods neglect singularities that may change the course of history in an unforeseeable way.

With respect to sustainability our scenario leads to a desirable goal, which is characterised by

- low cost of energy,
- low environmental impact of power generation,
- low conflict potential,
- fair access to energy,
- economic stability for development,
- energy and water security.

There are technical, economical, social and environmental barriers that limit the expansion of any energy technology. As drafted in Figure 5-1, an overlay of such “crash-barriers” can be defined as a function of time, limiting market expansion by subsequently changing factors.

As an example, market expansion of most renewable energy technologies can be characterised in a simplified way by four main phases of market expansion:

Phase 1: Technology cost is high and expansion requires preferential investment

Phase 2: Prices become competitive but production capacities are still limited

Phase 3: Production catches up and the market is defined by demand

Phase 4: As demand grows the availability of resources may become limiting

**Phase 1** is characterised by a situation where research and development has lead to innovative technologies ready for commercial application, but still with a high investment cost due to their limited number of projects and lack of mass production. A rather high risk perception by potential investors is usually associated with new technologies, further elevating their cost.

Technological progress and economies of scale will certainly lead to subsequent cost reductions, but this can only be achieved if market expansion takes place at least at a certain minimum rate in niche markets.

First pilot plants will usually not be competitive with existing technologies. The 10th or 20th plant probably would, but it would never come to this because nobody would start. The only possibility to overcome this situation is setting economic frame parameters that guarantee a preferential investment into the new technology. This can only be done by governments or international organisations like the European Commission or the World Bank capable of recognising the chance of a future low cost energy supply, and willing to introduce this new option into the technology portfolio /Capros et al. 2000/, /IRESMED 2000/.

Examples for such measures are the German, Spanish and lately also the Algerian renewable energy acts that by law guarantee feed-in tariffs for renewable electricity in those countries that initially cover the relatively high cost of renewables. In Germany, the feed-in tariffs are reduced by 5 % every year in order to give a strong incentive to technology progress that must cope with that reduction.

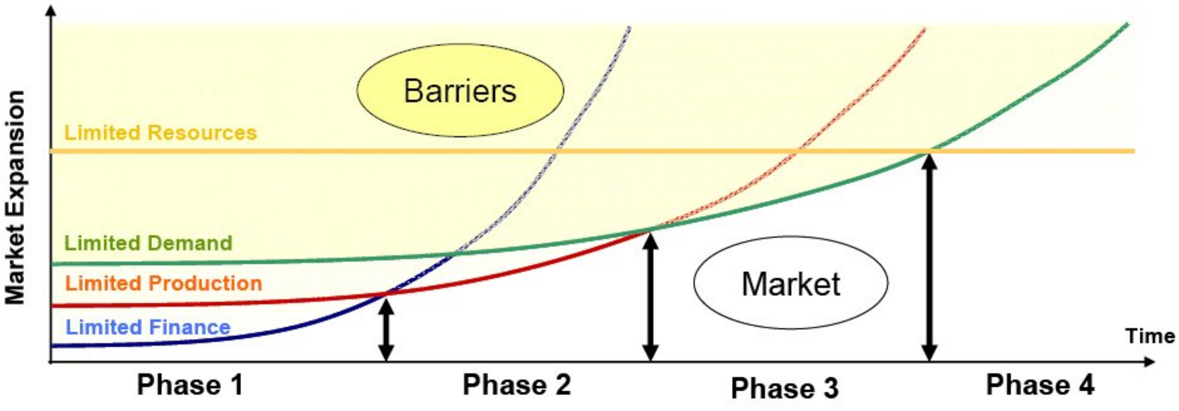


**Figure 5-1: Finding Renewable Energy Scenarios with the Crash-Barrier Principle. Subsequently, different factors limit technology expansion. The potential market volume is represented by the white area while the different overlapping crash-barriers are represented by the coloured lines.**

**Phase 2** is initiated once the cost of a new technology becomes competitive under conventional economic market conditions. Then, it can expand beyond the initial niche markets. In that phase the production capacities must be extended considerably in order to cope with the increased market volume. For industry this is a very attractive phase, as it is only limited by the industrial production growth rates that can be achieved.

Initially, production growth rates can exceed 100 %/year, because the volumes are still small in absolute terms. However, as the production volumes increase, growth rates are limited. Over a long term of e.g. ten years, a maximum growth rate not exceeding 30 % can be used as a thumb rule for a first estimate. In the renewable energy sector, growth rates of this order of magnitude have been experienced by wind power and photovoltaic systems in the past years.

**Phase 3** starts once the industrial production capacities reach eye-to-eye level with demand. In this phase, the demand for electricity becomes the limiting factor for market expansion. The demand is not only defined by the quantity of electricity required, but also by its temporal structure (base-, intermediate or peaking load), environmental and social compatibility, security of supply etc. Renewable electricity must fit to the specific requirements of the power sector. In competition to other technologies, the demand for a certain source of electricity is also coupled to its cost. Covering peaking demand usually yields high revenues, while base load electricity only delivers low revenues per generated kilowatt-hour.

The demand structure of a country will certainly change with time and with economic development, as described in the previous chapter. It will also change with a country's – and its politician's – awareness of the external (societal) costs of electricity generation like those induced by pollution and climate change, e.g. accepting higher tariffs for clean energy sources than for those that pollute the ambient.

**Phase 4** finally describes a situation where the renewable energy resources become the limiting factor for market development.

The following potential barriers and frame conditions have been taken into account to narrow down the course of electricity market development of renewable energies in the MED-CSP scenario:

- existing grid infrastructure and cost of interconnection
- maximum growth rates of renewable energy technology production capacities
- annual electricity demand
- peaking power demand and secured power reserve capacity
- replacement of old plants
- cost of electricity in comparison to competing technologies
- opportunities of finance
- policies and energy economic frame conditions

All those parameters are not treated as static constants, but are analysed in their dynamic transition towards a sustainable energy scheme. They will be described in more detail in the following (policy issues are described in detail in Chapter 1 and Chapter 8).

## 5.1 Technical and Infrastructural Frame Conditions

### 5.1.1 Interconnection to the Existing Grid Infrastructure

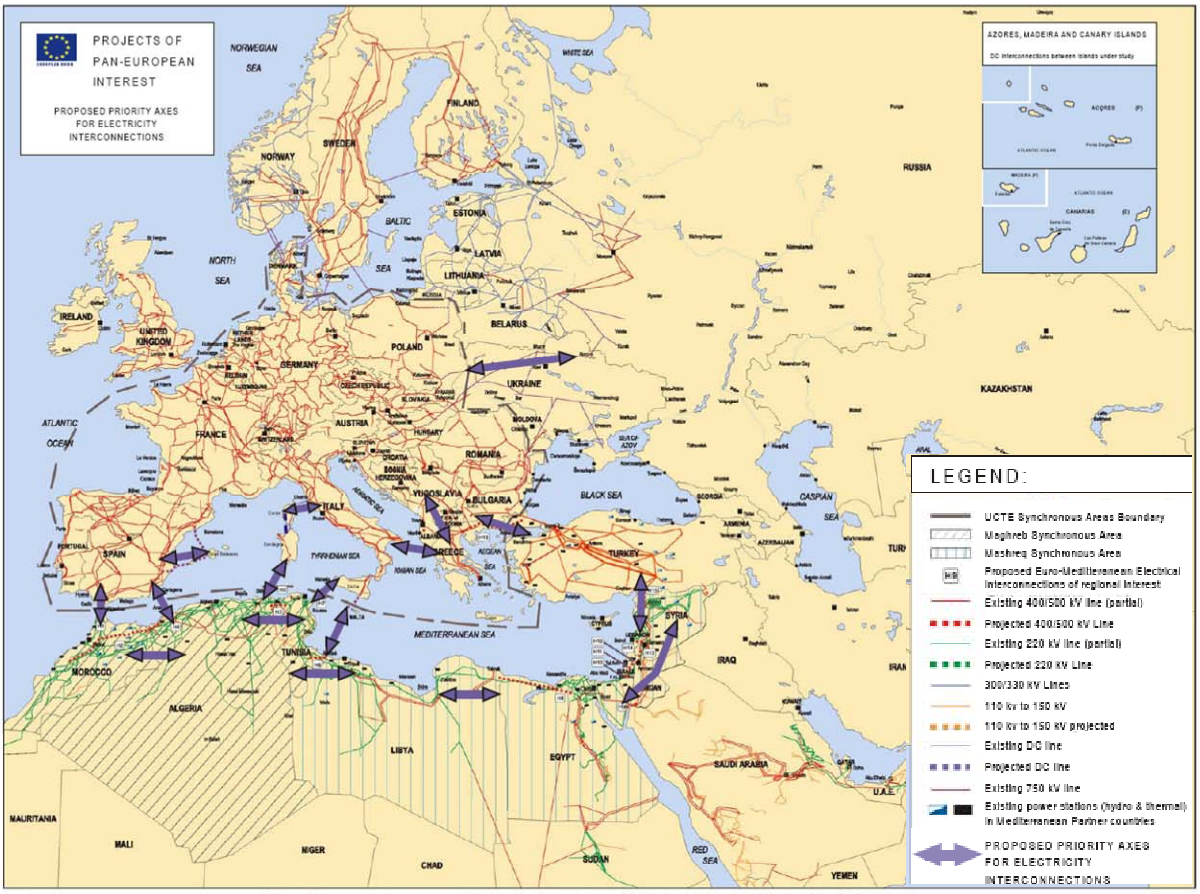
The technical limitations analysed within the study include the distance that must be overcome to interconnect new power plants to the existing infrastructure, mainly represented by the cost for extending the electricity and road grid. For small initial renewable energy projects with investment volumes of several million to ten million Euros the cost of interconnection to the electricity grid will be very significant, and they will therefore be realised in close vicinity to the existing grid (Figure 5-2). The figure suggests that mainly the coastal rim of MENA, the Nile valley and central Saudi Arabia would be developed for renewable electricity generation in the medium future. All over Europe, the distances to the electricity grid are relatively small. However, additional grid infrastructure will be necessary to couple decentralised renewable electricity generators like wind parks, photovoltaic and biomass plants to the grid.

With the increasing size of renewable power projects the cost of interconnection will become less important in comparison to the total project investment, and longer distances will be overcome, especially if areas with better renewable energy resources are made accessible. A good example for this are the large existing hydropower schemes in Egypt, that have justified the construction of several alternate current (AC) lines with over 500 kV operative voltage over hundreds of kilometres from the dams in Southern Egypt to the population centres in the North. Such structures are typical for regions with highly concentrated population centres and low population density in the rest of the area as is the case in Egypt. In contrast to that, a typical central European country like Germany has a strongly diversified electricity grid with many nodes and interconnections, but with up to a maximum voltage of 400 kV only.

In the long term, renewable electricity may be exported from MENA to Europe at the scale of several billion kWh/year. The SYSTMED report by /EURELECTRIC 2003/ shows that the electricity transfer capacity of the Mediterranean Ring Interconnection is expected to be less than 500 MW in 2010, and that there will be still some interconnections missing by that time. The Mediterranean ring interconnection might be closed by 2015. However, it is clear that this interconnection will allow for the temporary exchange of capacities between the Mediterranean countries, but it will not be appropriate for a continuous, long distance transfer of solar electricity from MENA to Europe at a large scale. Transfer of large quantities of solar electricity will require a totally new grid infrastructure of High Voltage Direct Current (HVDC) interconnections between MENA and Europe. Such a scenario will be analysed in more detail in the study TRANS-CSP to be elaborated in the year 2005.

As has been shown in chapter 4, the electricity demand in the analysed EU-MENA countries will steadily grow to about three times of today’s demand until 2050. This will require an extension of the electricity grid in terms of generation and transfer capacity.

The economies of scale of electricity grids are better for increased transfer capacities. Grid accessibility is only a temporary limitation for the renewable energy potentials in MENA. The larger the renewable energy installations, the lower will be the specific share of infrastructure and interconnection costs on the total project cost. Thus, the range of economically feasible grid interconnections will grow together with the size of renewable energy projects in the region, subsequently providing access to more remote areas with potentially better renewable electricity yield. Expansion will start with smaller plants in the vicinity of the existing grid and in the medium term interconnecting sites with high renewable energy yield to the largest centres of demand. At a later stage, even intercontinental HVDC interconnections between Europe and MENA may become operative (ref. Chapter 6).



Graphic design in collaboration with EIR Development Partners (CATSTA 21/05/2003)

This map is for communication purposes only in view of its presentation to the Euro-Mediterranean Ministerial Meeting of May 2003.
The information contained in this map does not necessarily reflect the policy of the European Union.

**Figure 5-2: Electricity grid and proposed areas for electricity interconnections in the EU-MENA region Source: SAVE Programme of the European Commission**

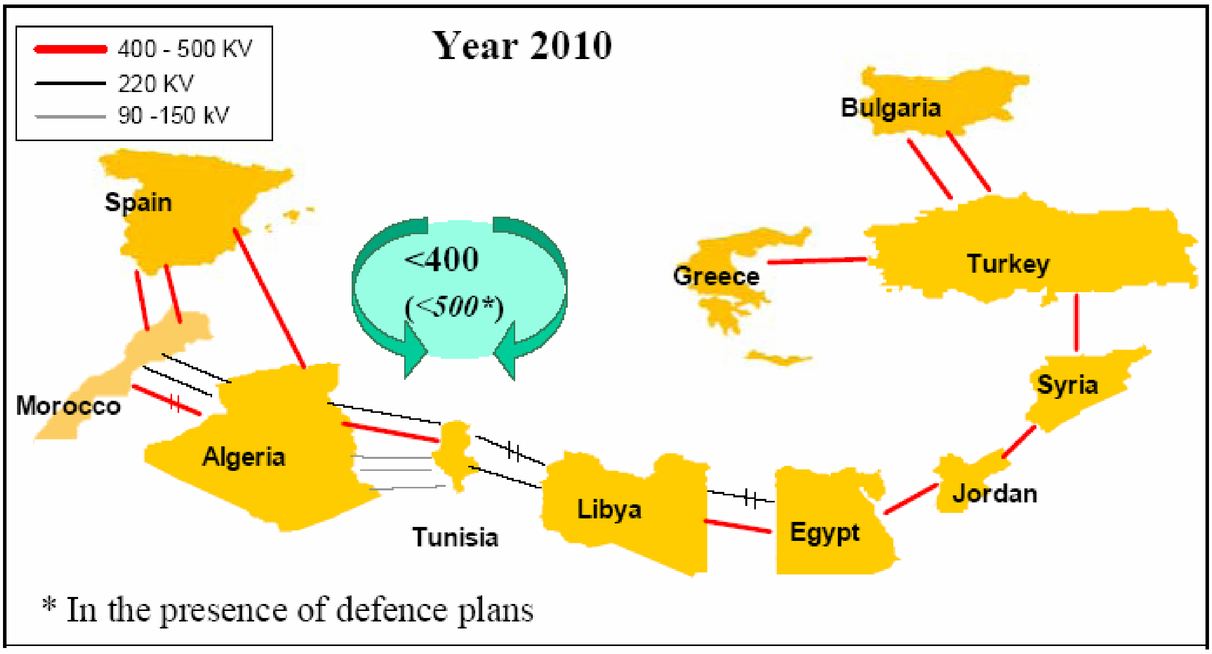


**Figure 5-3: Synthesis of limits of power exchanges (MW) for year 2010 through the AC grid and example of improvements that can be achieved through defence plans /EURELECTRIC 2003/**

### 5.1.2 Growth Rates of Renewable Electricity Generation Technologies

In 1990, wind capacity in Germany amounted to only 68 MW, but in the year 2003 Germany was the greatest wind energy producer world wide, with a total installed wind power capacity of 14600 MW. A similar development at a lower level was experienced by photovoltaic systems with 1.6 MW installed in 1990 and 390 MW in 2003 /Quaschning 2000/, /BMU 2004/. The German Feed-In Law for Renewable Energies and the Renewable Energy Act are the main pillars of this explosive development, which was only possible under the favourable conditions granted by those instruments. Like in the beginning of any market deployment, capacity levels were usually low, and the installed capacity was easily doubled from one year to the other, with growth rates often exceeding 100 %/y. Between 1990 and 2003, both wind and PV capacities have increased in Germany by a factor of over 200 times.

However, as the total installed capacity expands, doubling becomes more difficult. The experience in Germany shows that a long-term growth rate of 20-40 % is a reasonable estimate for technologies that have achieved a level of 10 GW of installed capacity and higher. In absolute terms, this growth rate means installing a new capacity of 2-4 GW per year. Due to the continuous increase of the installed capacity, growth rates of around 30 %/y can usually be maintained only for a few years up to a maximum of one decade.

Market growth rates depend not only on the existing policy framework, but also on other constraints like e.g. acceptance, availability of suitable sites, overall economic situation, investment cycles, and the existing production capacities for the necessary plant components.

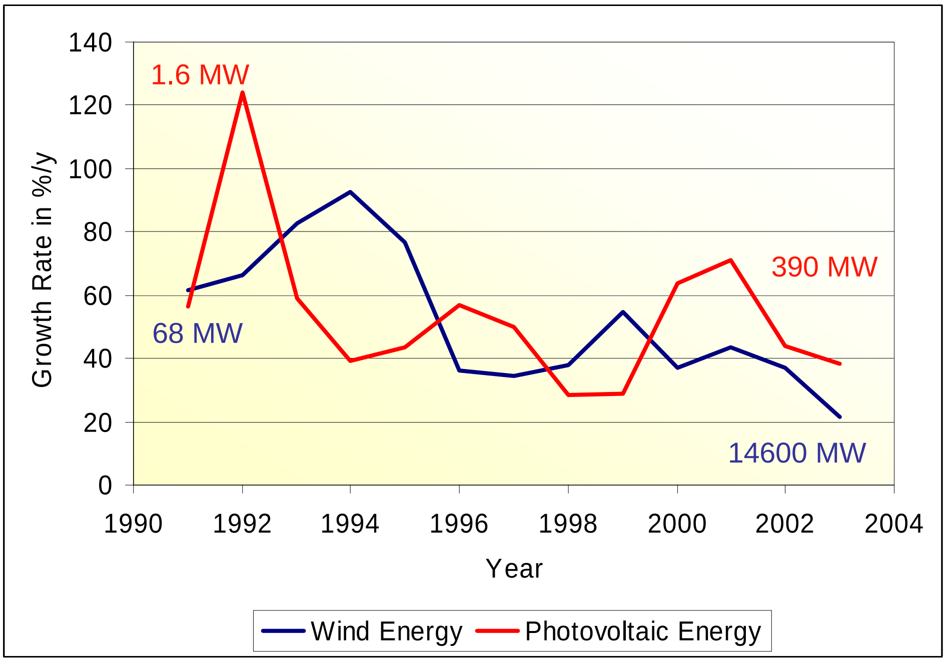


Figure 5-4: Growth rates of PV and wind energy in Germany /Quaschning 2000/, /BMU 2004-1/

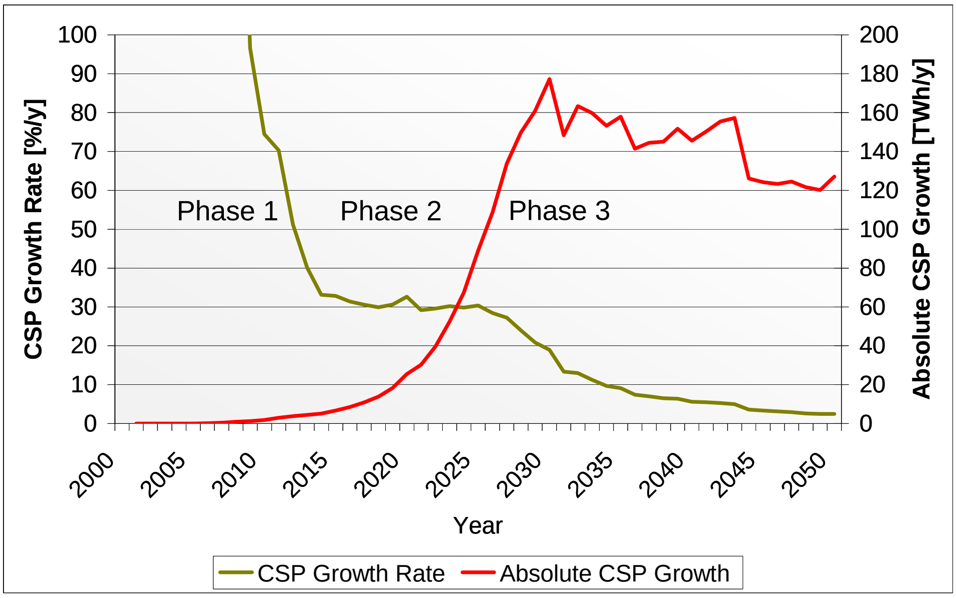


**Figure 5-5: Growth rate of CSP production capacities during the three phases of market introduction, in relative and absolute terms of annual solar electricity generation, calculated for 2500 kWh/m²/y irradiance. The values summarize all countries analysed in the study.**

Figure 5-5 shows the annual growth rates and the absolute new capacity installed per year for concentrating solar power in the MED-CSP scenario. The first three phases described in the beginning of this chapter can be clearly identified:

Starting in 2006 with Phase 1, doubling of CSP capacities at a low level is still easy, while the acquisition of finance is the limiting factor. After 2015 within Phase 2 the financing barriers are subsequently removed, but with total installed power capacities of well over 10 GW, the technology growth rates now become the limiting factor. This phase continues with a growth rate of roughly 30 %/y over a maximum of 10 years. Then, after 2025 within Phase 3, the demand for CSP electricity becomes the limiting factor and the growth rates are subsequently reduced, while the absolute capacity installed every year is maintained at a high level. As can be seen in the figure, stagnating growth rates do not necessarily mean stagnating market volumes, on the contrary. The largest increase in market shares is achieved within Phase 2.

In the case of CSP in MENA, Phase 4 is never achieved, because the solar energy resource is so vast that it never becomes the limiting factor for this region of the world. However, there are limitations of the CSP resources is some individual countries, mainly on the islands and in Southern Europe as described in chapter 3. The trend of growth rates shown in Figure 5-5 has been used as one of the limiting barriers for CSP market development. In the scenarios of all MENA countries, the growth rates of the other renewable energies were lower than those experienced in Germany.

### 5.1.3 Time Pattern of Electricity Demand

Using the demand as a parameter of the crash-barrier principle requires a more precise definition of the demand structure. There is a demand for electricity in terms of energy (GWh/y), a demand for peak power in terms of GW of installed capacity including reserves, and a certain time structure that defines how much power capacity is required at what time, defined by the load curve in terms of GW that varies for every hour of the year.

Annual electricity generation and peak power capacity are related according to the equation:

Generated Energy (GWh/y) = Peak Power Capacity (GW) · Capacity Factor · 8760 h/y

The higher the capacity factor of a power plant, the longer is its time of operation during the year, and the better is its economic performance, especially, if the investment cost is high. Utilities try to distribute power generation to plants that operate at full load most of the time (base load plants), to plants that are shut down once or twice a day (intermediate load) and peaking plants that compensate the short term fluctuations of the load.

Coal, nuclear and river runoff hydropower plants are typically used for base load, as they are rather expensive and cannot be quickly adapted to changing load patterns. Coal, oil and gas fired plants are used for intermediate load. Peaking load is covered by gas or oil fired plants and by hydropower storage plants.

As an example, the load curve of the day of the annual peaking load in the year 2001 in Egypt is displayed in Figure 5-7. The curve shows a peaking demand of 12.4 GW in the evening and a typical time structure with a smaller peak around noon.

The evolution of the maximum load with time is calculated in proportion to the growing electricity demand according to the scenario CG/HE described in Chapter 4. We have assumed that there are no inter-annual changes of the temporal structure of the load curve. Electricity demand and peak power will increase with every year, but the load curve will have the same time pattern (Figure 5-6).

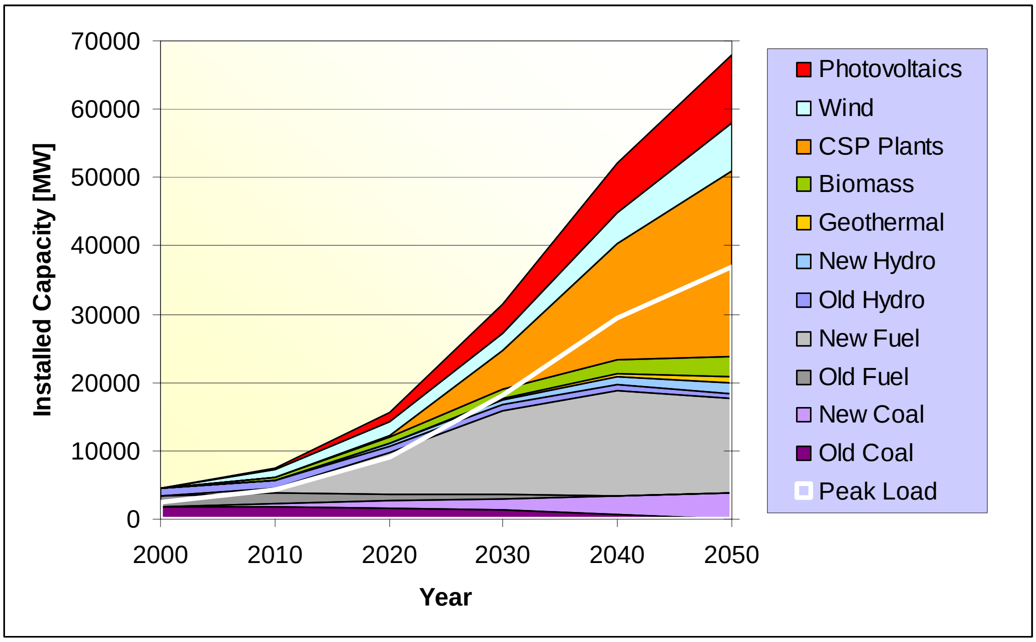


**Figure 5-6: Example of the composition of the installed power capacity in Morocco within the MED-CSP scenario. The Figure 5-shows the growing peak load demand and the capacity overhead that increases with growing renewable energy share. A minimum 25 % reserve of secured capacity is granted any time. The contribution of each technology to secured capacity is defined in chapter 2.**

Modelling the power park of the future, we have tried to find a “well balanced mix” of renewable and fossil energy sources, taking the best of each technology to deliver a reliable and economic power supply compatible with environment and socio-economic development. One of the pre-conditions of this electricity mix is that it must cover the power demand at any time, with a security margin of 25 % of minimum remaining reserve capacity.

The different technologies of our portfolio contribute differently to secured power: fluctuating sources like wind and PV contribute very little, while fossil fuel plants contribute at least 90 % of their capacity to secure power on demand. Hourly time series of resource data for wind and solar radiation have been used to estimate those limitations. Besides of the total demand of electricity of each country, also the secured coverage of peaking demand has been used as frame condition for the MED-CSP scenario. The individual country scenarios have been designed such that they satisfy this condition at any time of the year.

Figure 5-7 shows the evolution of the electricity mix with increasing renewable energy shares for the peak load day in Egypt. Fossil fuel fired plants are subsequently substituted by renewable energy, but fossil peaking power capacity remains active all the time. CSP and also geothermal energy will partially take over peaking duties in the later phase of the scenario.

One of the consequences of renewable energy scenarios is that the ratio of the total installed power plant capacity to peak load increases, or in other words, the average capacity factor of the power park decreases. The increasing capacity overhead is due to the fluctuating supply from wind and PV plants that have a rather low capacity factor and that do not contribute to secured power. However, this does not necessarily lead to an augmentation of fossil fuel based peaking duties, as there are a number of effects that compensate such fluctuations:

- temporal fluctuations of a large number of distributed wind or PV plants will partially compensate each other, delivering a much smoother capacity curve than single plants,
- temporal fluctuations of different, uncorrelated renewable energy resources will partially compensate each other, together delivering a much smoother capacity curve than one single resource
- fluctuations can be compensated by distribution through the electricity grid,
- biomass, hydro-, geothermal and solar thermal plants can deliver power on demand and be applied as renewable backup capacity for fluctuating inputs,
- load management can enhance the correlation of demand and renewable supply,
- finally, fossil fuel fired peaking plants can be used for further adaptation to the load.

In effect, controlling many distributed, fluctuating and unpredictable elements within a power system is nothing new. Exactly the same occurs with the load induced by millions of consumers connected to the grid. All together deliver a relatively stable and predictable load curve. As can be appreciated in the example of Figure 5-7, a large number of distributed renewable energy sources in a well balanced mix can even show a better adaptation to the time pattern of the load than nuclear or coal fired base load plants with a flat capacity curve.

In the special case of Egypt, the typical daily time pattern of wind energy fits nicely to the increase of electricity demand in the afternoon and evening, while photovoltaic systems cover a great part of the smaller peak load at noon, thus easing the workload of the scarce hydropower resources. In the course of time, CSP takes over increasing parts of the intermediate and peaking load sector. In 2050, the valuable fossil fuel resources are only used for the purpose they are best suited for: peaking power.

The principle characteristics of the power mix of our scenario are described in the following:

### Wind Power

Wind is a strongly fluctuating energy source that cannot be controlled by demand. However, distributed wind parks partially compensate each others fluctuations and show a relatively smooth transition of their total output. Depending on the different situation in each country, up to 15 % of the installed wind capacity can be considered as secured (refer to chapter 2). Hourly wind data was taken for selected sites from the World Wind Atlas /WWA 2004/.

### Photovoltaic

PV power is strongly fluctuating and only available during daytime. There is no contribution to secured power, but a good correlation with the usual daytime power demand peak of most countries. PV is specially suited for distributed power supply. Hourly global irradiance on a fixed surface oriented south and tilted according to its latitude was taken from the Meteonorm database /METEONORM 2004/ to calculate the output of PV generators as a function of time.

### Geothermal Hot Dry Rock

Geothermal power can be delivered on demand as base, intermediate or peaking power using the earth as natural storage system. Plant sizes are limited to about 50 to 100 MW maximum. It can be used to compensate the fluctuations from wind and pv-power.

### Biomass Power Generation

Biomass can deliver power on demand as it is easily storable. However, biomass is scarce in MENA and subject to seasonal fluctuations. As a strategic guideline, biomass can be supplied in times when wind and pv power is low in order to compensate those sources, and shut down when wind and pv power is available to save the scarce biomass resources.

### Hydropower

The situation is similar for hydropower from dams, which can be delivered on demand but is scarce in MENA and subject to strong seasonal fluctuations. If used only in times when pv and wind power are low, it acts like a natural complement and as a storage system for those resources. Hydropower is saved when wind and pv energy is available and preferably used during peaking periods, while its annual capacity factor remains more or less constant. The interaction of pv, wind, biomass and hydropower can be appreciated in Figure 5-7.

### Solar Thermal Electricity

Concentrating solar thermal power stations can deliver power on demand, making use of their thermal storage capability and hybrid operation with fuels. They are the natural link between the fossil system and the other renewables. Being the biggest natural resource, they will provide the core of electricity in MENA. In the later stage of the scenario, they will subsequently take over peaking load duties from fossil fired plants.

### Oil and Gas fired Power Plants

Oil and gas fired power plants are today the most applied technology in MENA. They will subsequently take over the part of closing the gap between the load and renewable power during peaking times. Therefore, their average fossil fuel consumption and their $CO_2$ emissions will be reduced faster than their installed capacity.

### Coal Steam Plants

Only a few countries in MENA use coal fired power plants today. Coal constitutes a feasible, however problematic supplement to power generation in MENA, as it would be exclusively based on imports and is considered a heavy burden for climate stability. Therefore, domestic sources like renewables, oil and gas will be the preferred choice in most MENA countries.

Power technologies based on hydrocarbons will increasingly be charged with extra costs of CO2 sequestration, as their effect on climate change is very dangerous. If they decide for a power supply based mainly on fossil fuels, most MENA countries will soon face a situation where they must decide ether to overload their economy by subsidies to afford CO2 sequestration or to overload the global environment and thus accelerating desertification.

### Nuclear Fission and Fusion

Nuclear plants are a fading technology with unsolved problems of nuclear waste disposal and very high environmental risks. With present consumption – only 7 % of the world energy demand is covered by nuclear energy today – the global uranium resources will not last longer than 50 years and are becoming more and more expensive. Breeder technology could expand those resources but would lead to a dangerous proliferation of plutonium. In spite of massive subsidies of several billion Dollars per year, nuclear power has presently a share on the power plant market place of less than 1 %, which is a clear indicator of its obsolescence. In spite of R&D expenditures of more than a billion Dollars per year spent by the OECD for several decades and scheduled to be spent also in the future, electricity from fusion is not expected to be available before 2050, and the outcome of this costly effort is completely unknown. Obviously, nether of those nuclear power technologies can therefore contribute to the reduction of greenhouse gas emissions or to sustainable development.

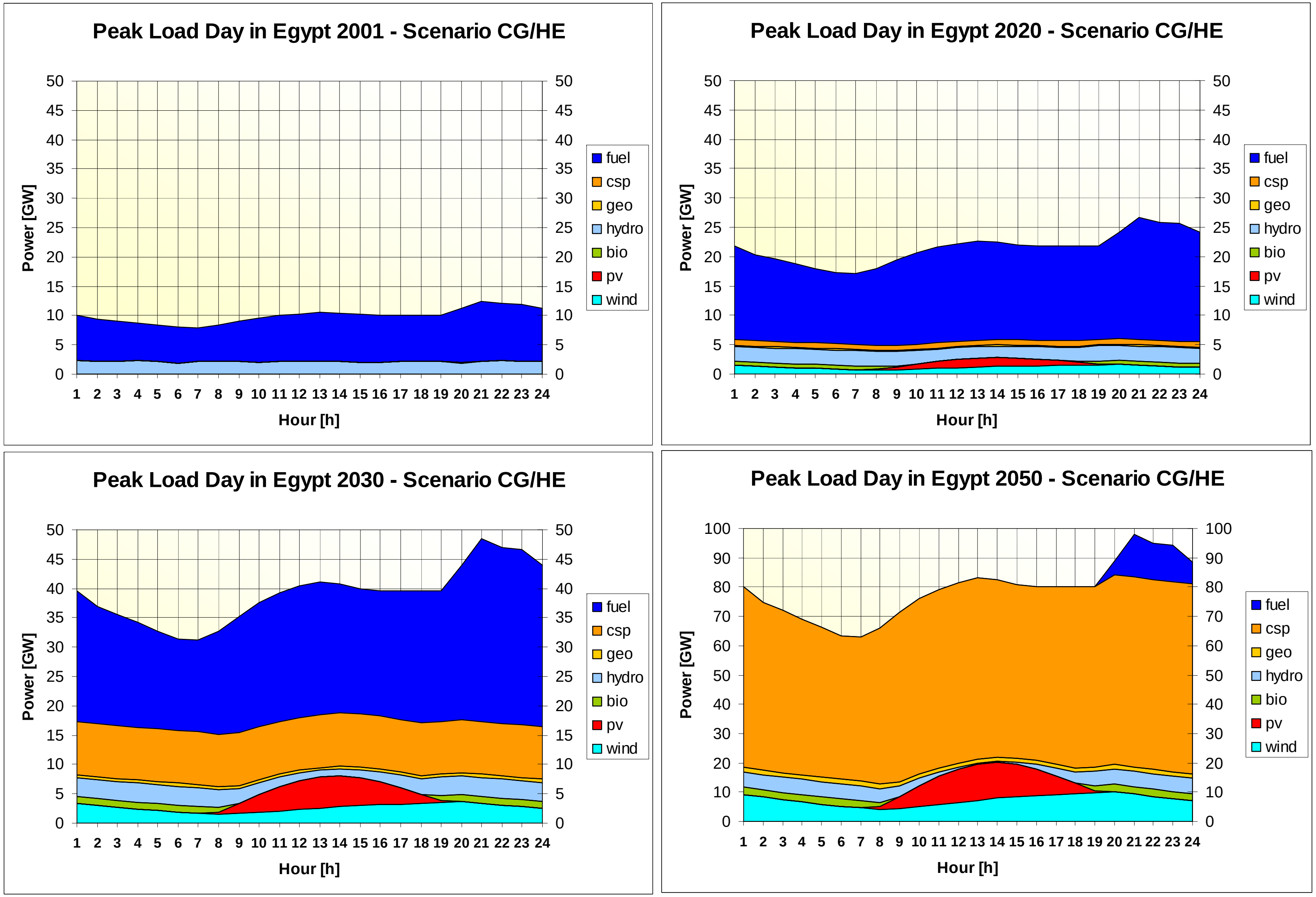


**Figure 5-7: Power Generation on the Peak Load Day in Egypt in the Years 2001, 2020, 2030 and 2050 according to the MED-CSP scenario. Note that the scaling of the power axis of the lower right figure (2050) changes to 100 GW.**

### 5.1.4 Technology Investment Cycles

Investment cycles are very important for energy planning. Once a power plant is installed, it will occupy the corresponding capacity for a lifetime of several decades. Figure 5-8 shows the life curves of the existing Moroccan power park as an example. Especially in the context of carbon reduction one must take into account that a coal or oil-fired steam cycle power plant build today will still exist in the year 2040 or even in 2050, polluting the environment in a way that will clearly contradict global climate policy. However, once built, it would be very expensive to replace such plants before the finalization of their economic lifetime. The result of faulty planning would not only be devastating for the environment, but also for economic development.

Therefore, it is particularly important to consider the complete technology portfolio including renewable energies in all present power investment schedules. For MENA, the situation today is different than for Europe: while MENA will still need growing conventional power capacities to cover its rapidly increasing demand in the near future, Europe – with a medium term stagnating electricity demand ahead – must immediately start to substitute as much fossil fuels as possible by renewable energies in order to achieve a sustainable mix of power technologies and resources by the middle of this century.

Market expansion of CSP and other renewable energies is limited by the capacities occupied by the conventional existing power park in each country, and by the lifetime associated to each type of plant. In other words, the market is defined by the demand for new plants and by the demand for the replacement of old plants. Part of the newly installed capacities will be covered by conventional power technologies, and these capacities will be inaccessible for renewable energy expansion during their lifetime. Figure 5-8 shows these issues for the example of Morocco. The inventories for all countries are given in Annex 5.

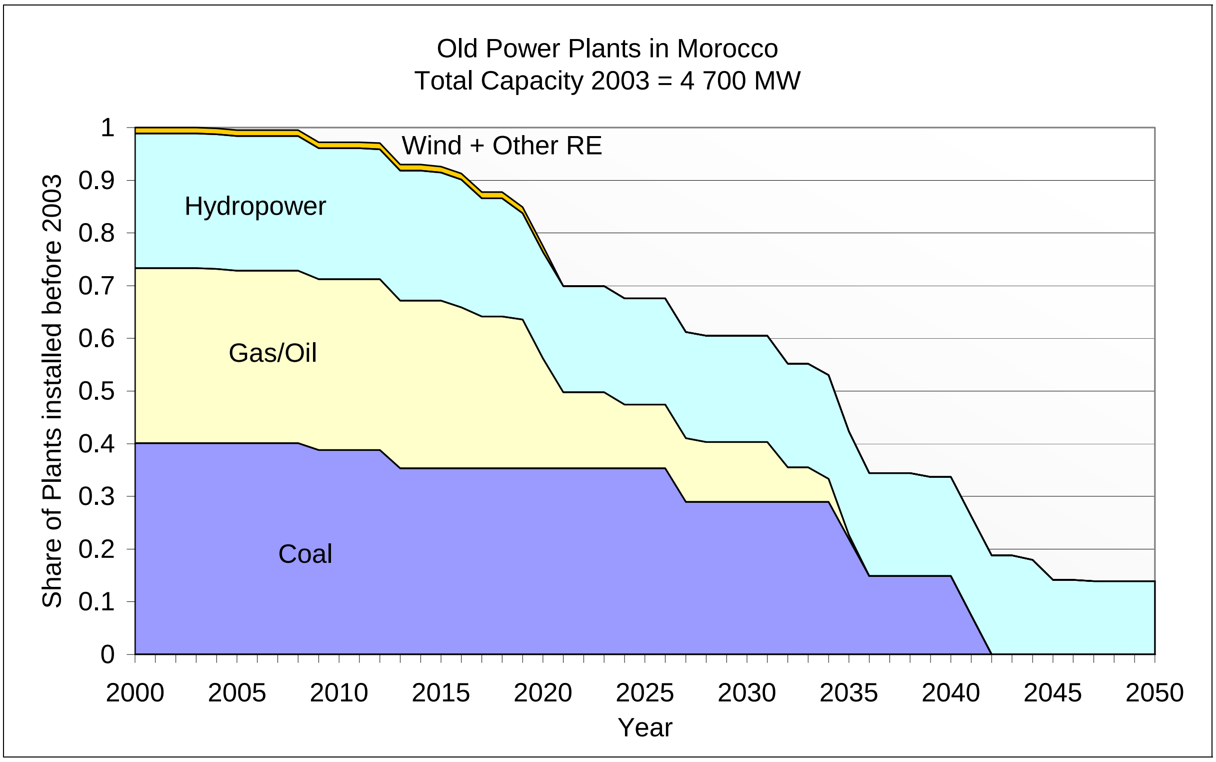


**Figure 5-8: Life curve of the power plant inventory installed before 2003 in Morocco as function of time. Lifetime of gas and steam turbines 40 years, wind power 20 years, hydropower 65 years /Platts 2004/.**

## 5.2 Energy Economic Frame Conditions

### 5.2.1 General Economic Frame Conditions

The scenario departs from a crude oil price of 25 $/bbl and equivalent prices for fuel oil (184 $/ton) and natural gas (6 $/GJ) in the year 2000. These prices equal 15 $/MWh of thermal energy. The starting coal price in 2000 is 49 $/ton, equal to 6 $/MWh thermal energy. Escalation rates for all fuels were assumed to be 1 %/year. Considering today's cost level of fossil fuels, this is a very conservative estimate. Higher fuel prices may be more realistic for the future, which would favour a faster growth of renewable energies in the world market.

World fuel market prices are in principle applicable for all countries, even for those exporting fuels. This is due to the fact that in view of the strong growth of demand in the MENA countries, export of fuels will increasingly compete with domestic consumption. Fuel can be burned or sold, not both at the same time. Oil exporting economies must calculate with world market prices if they burn fuel because this reduces their potential national income. It is an illusion to believe that domestic fuel is for free. Burning fuel for free is equivalent to burning a national treasure. Even fuel potentials that would not justify the construction of an international marketing infrastructure (pipelines) due to their limited amount cannot be considered as for free, as they are obviously not sustainable and must be replaced soon, as domestic consumption growths. However, future generations will not receive an equivalent to the value of the burned fuel – and thus will have no means to replace it – if fuels are consumed today without any cost.

Our scenario assumes that the European countries will introduce CO2-sequestration after 2020, and will reach a sequestration share of 50 % of their conventional power generation by 2050 (Figure 5-9). This will increase the cost of conventional power generation of newly installed plants or of old plants with added sequestration by about 3 cents/kWh after 2020, which will be reduced to 2 cent/kWh in 2030 and 1.5 cent/kWh in 2040 and later /NREL 2003/. MENA countries will probably not apply CO2 sequestration within the analysed time span, because this would considerably burden their economic development.

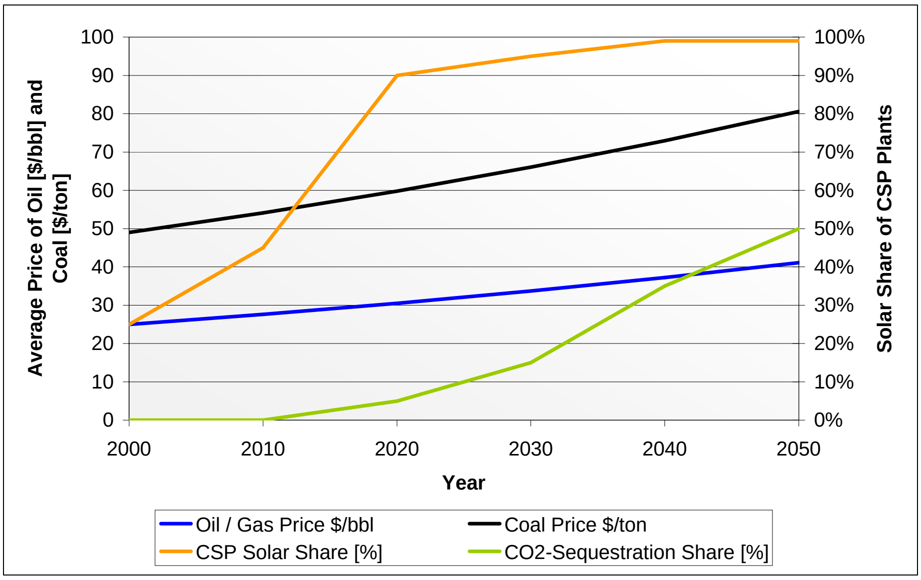


**Figure 5-9: Some energy economical limiters: development of Fuel Prices ($-2000), Solar Share of CSP Plants and CO2-Sequestration Share of Fossil Power Generation in Europe within the MED-CSP Scenario**

### 5.2.2 The Cost of Power Technologies

All technologies analyzed within this study are subject to technology development and economies of scale. While renewables have still a rather elevated investment cost, they are in a phase of fast technological progress with market growth rates of over 25 % per year, which will lead to a significant cost reduction in a relatively short time (Figure 5-10). This has been observed in the past and will continue in the future – although slowing down with increasing market presence /EXTOOL 2003/, /WETO 2003/.

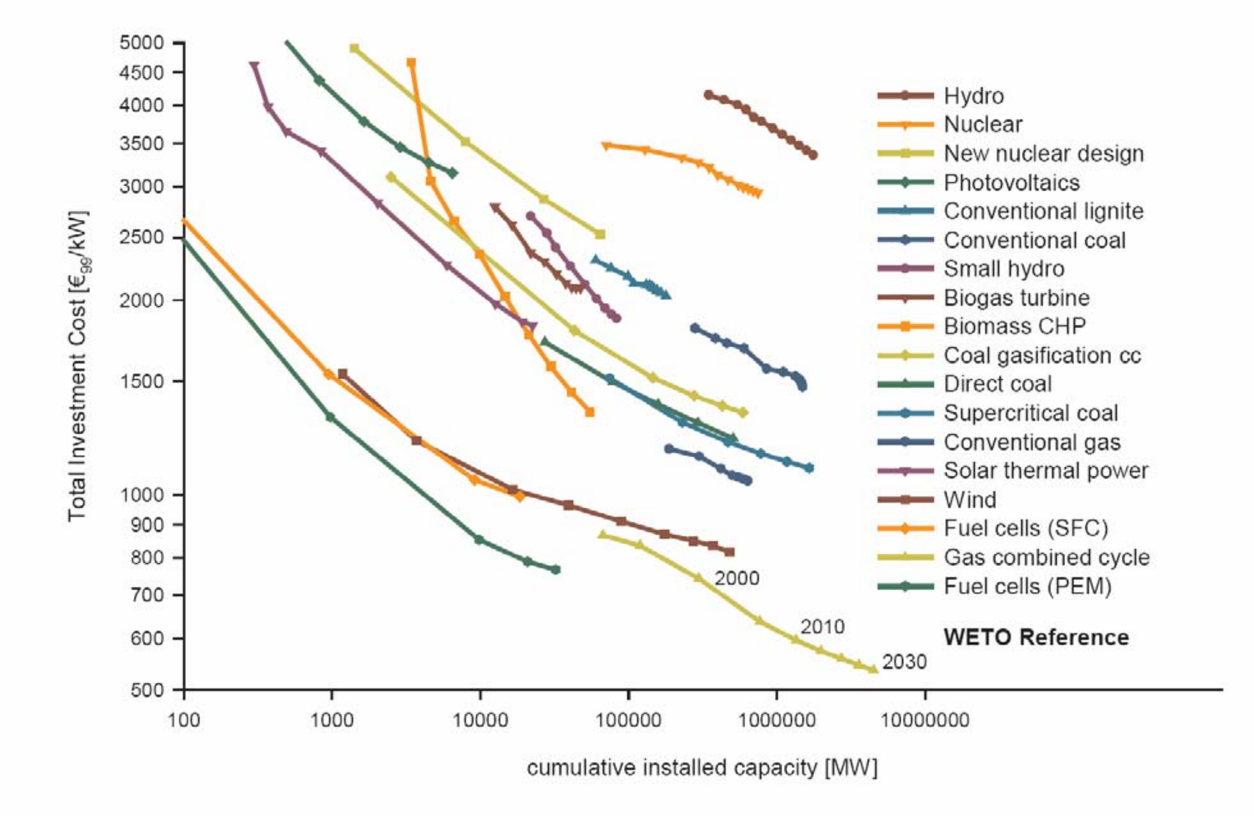


**Figure 5-10: Technology Learning Curves according to the WETO reference data base /WETO 2003/**

On the contrary, fossil and nuclear power technologies are mature since many years and are massively applied world wide. Investment cost reductions are hardly noticeable at present, although existent. However, many cost reductions have been compensated by the necessity of adding measures for the protection of the environment, like e.g. filters and chemical flue gas treatment. Moreover, the primary energy sources used by those technologies are not for free and everlasting like solar or wind energy, but increasingly becoming scarce, expensive and burdened by severe environmental constraints like e.g. global climate change.

As shown in the example in Figure 5-12, the investment cost of most renewable energy technologies for power generation is actually reduced during the ongoing market introduction phase. Concentrating solar thermal power plants are the only exception, as their specific investment cost is rather going to increase with time, because the solar field and thermal storage capacities per power unit will be expanded to augment the solar share in base load operation. Nevertheless, their cost of electricity will fall just like that of all other renewable power technologies (Figure 5-13), while collectors and storage technologies become less expensive as shown in Figure 5-11.

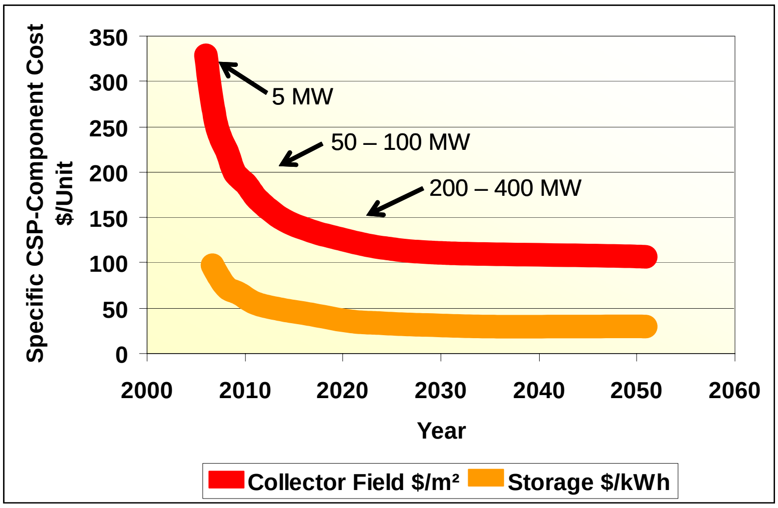


**Figure 5-11: Expected learning curve of concentrating solar collector fields and storage technologies. Also refer to /NREL 2003/.**

The cost of renewable energies will also depend on the meteorological conditions in each country, which may widely differ, as shown in chapter 3.

The electricity cost scenario was calculated with an average real discount rate of 5 %/year. All numbers are given in real values of $-2000. The electricity cost of renewable energies is calculated as function of the performance indicators described in Chapter 3 and taking into consideration realistic learning effects by economies of scale and technical progress as shown in Figure 5-12. Those learning curves refer to the specific investment per installed kW and are shown as a function of time.

CSP, geothermal power and biomass plants will subsequently take over peak load duties of the power park. As they enter the intermediate and peak load segment, their annual full load hours will be reduced and their specific electricity cost and revenues will slightly increase after 2040. The electricity cost is calculated by the following equation:

$$C_{el} = \frac{Inv \cdot FCR + O\,\&\,M + F}{E_{year}}$$

| | |
|---|---|
| $C_{el}$ | cost of electricity in $-2000/kWh |
| $Inv$ | investment cost in $-2000 |
| $FCR$ | fixed charge rate as function of interest rate and economic lifetime (annuity) |
| $O\&M$ | annual cost of operation and maintenance, personnel, insurance, etc. |
| $F$ | annual fuel expenses |
| $E_{year}$ | electricity generated per year = installed capacity (MW) · full load hours (h/y) |

The parameters used for the calculation of the electricity cost as a function of time are given in the examples in Table 5-1 and Table 5-2, showing some parameters that vary for each country and site and others that are assumed to be equal within one scenario calculation.

| | Economic Life years | Efficiency % * | Fuel Price Escalation % | Operation & Maintenance % of Inv./y | Annual Full Load Hours hours/year* |
|---|---|---|---|---|---|
| **Steam Coal Plants** | 40 | 40% | 1.0% | 3.5% | 5000 |
| **Steam Oil Plants** | 30 | 40% | 1.0% | 2.5% | 5000 |
| **Combined Cycle Natural Gas** | 30 | 48% | 1.0% | 2.5% | 5000 |
| **Wind Power** | 15 | | | 1.5% | 2000 |
| **Solar Thermal Power** | 40 | 37% | 1.0% | 3.0% | 8000 |
| **Hydropower** | 50 | 75% | | 3.0% | 2600 |
| **Photovoltaics** | 20 | 10% | | 1.5% | 1800 |
| **Geothermal Power** | 30 | 13.5% | | 4.0% | 7500 |
| **Biomass Power** | 30 | 35% | | 3.5% | 3700 |

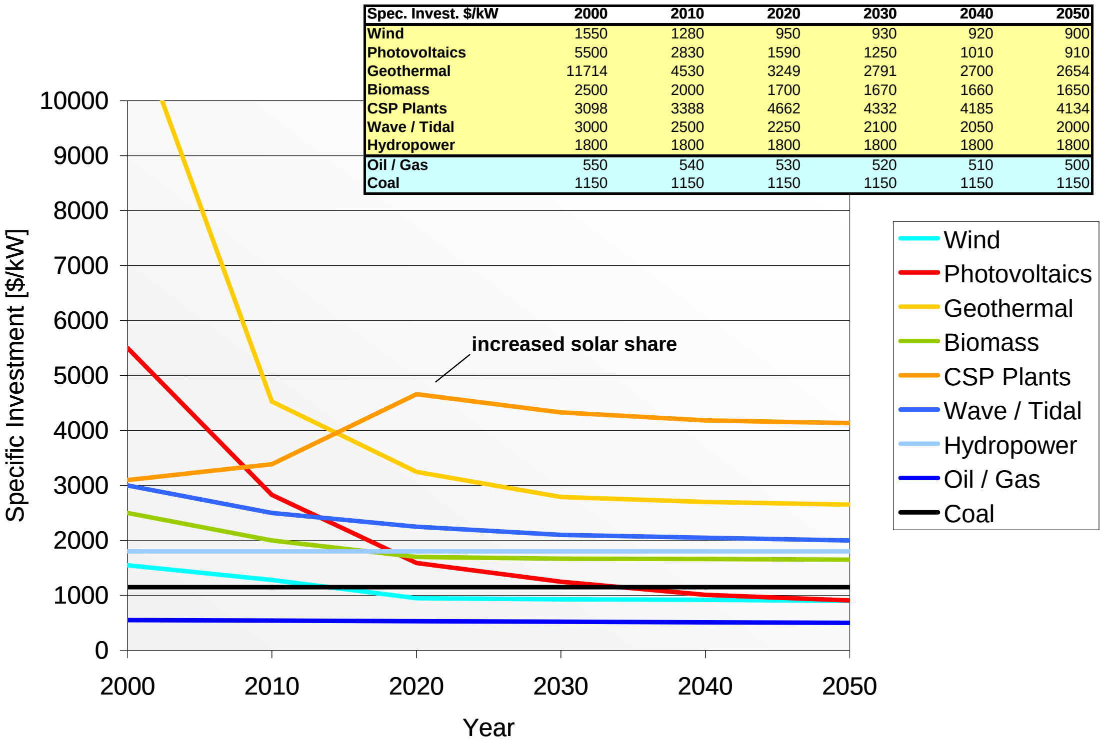
* vary for different countries and sites

**Table 5-1: Example of parameters used for the calculation of the electricity cost.**

| Year | Unit | 2000 | 2010 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|
| Solar Share | % | 25% | 45% | 90% | 95% | 99% | 99% |
| Total Full Load Hours per Year | h/y | 8000 | 8000 | 8000 | 7500 | 6500 | 5500 |
| Solar Full Load Hours per Year | h/y | 2000 | 3600 | 7200 | 7125 | 6435 | 5445 |
| Fuel Cost | $/bbl | 25.0 | 27.6 | 30.5 | 33.7 | 37.2 | 41.1 |
| Investment | $/kW | 2659 | 2941 | 4015 | 3724 | 3602 | 3560 |
| Electricity Cost | cent/kWh | 7.9 | 7.1 | 5.2 | 4.8 | 5.0 | 5.8 |

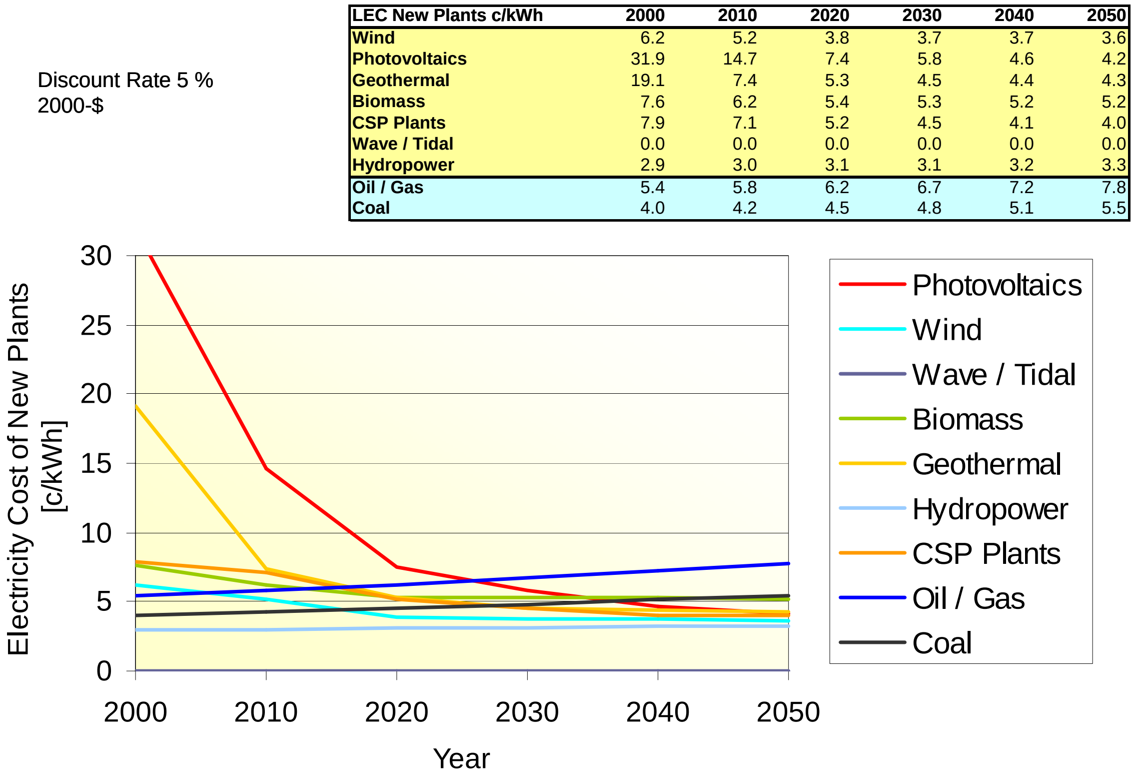
| | | |
|---|---|---|
| Country | Egypt | |
| Performance Indicator DNI | 2800 | kWh/m²/y |
| Discount Rate | 5 | %/y |

**Table 5-2: Example of the electricity cost calculation for CSP for Egypt in the MED-CSP scenario and the corresponding frame parameters used for calculation. The initial solar share of 25 % is subsequently increasing to almost full solar operation. The increased use of thermal storage and larger collector fields leads to increasing specific investment, while the overall electricity cost is reduced. Note that the total full load hours decrease in the later stage due to increased peaking duties taken over by CSP plants. This leads to a slight increase of CSP electricity costs in 2040 and later. If CSP plants would maintain base load operation with 8000 h/y, their electricity cost would continuously fall as shown in the example in Figure 5-13.**



| Spec. Invest. $/kW | 2000 | 2010 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| **Wind** | 1550 | 1280 | 950 | 930 | 920 | 900 |
| **Photovoltaics** | 5500 | 2830 | 1590 | 1250 | 1010 | 910 |
| **Geothermal** | 11714 | 4530 | 3249 | 2791 | 2700 | 2654 |
| **Biomass** | 2500 | 2000 | 1700 | 1670 | 1660 | 1650 |
| **CSP Plants** | 3098 | 3388 | 4662 | 4332 | 4185 | 4134 |
| **Wave / Tidal** | 3000 | 2500 | 2250 | 2100 | 2050 | 2000 |
| **Hydropower** | 1800 | 1800 | 1800 | 1800 | 1800 | 1800 |
| **Oil / Gas** | 550 | 540 | 530 | 520 | 510 | 500 |
| **Coal** | 1150 | 1150 | 1150 | 1150 | 1150 | 1150 |

**Figure 5-12: Example of specific investment of power technologies in the MED-CSP scenario in $/kW of installed capacity. The cost is reduced by technology learning and by economies of scale. The specific investment of CSP increases due to increasing solar shares (increased collector fields and storage) and increasing annual solar operating hours, although collectors and storage – and the produced electricity – become cheaper with time.**



| LEC New Plants c/kWh | 2000 | 2010 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| **Wind** | 6.2 | 5.2 | 3.8 | 3.7 | 3.7 | 3.6 |
| **Photovoltaics** | 31.9 | 14.7 | 7.4 | 5.8 | 4.6 | 4.2 |
| **Geothermal** | 19.1 | 7.4 | 5.3 | 4.5 | 4.4 | 4.3 |
| **Biomass** | 7.6 | 6.2 | 5.4 | 5.3 | 5.2 | 5.2 |
| **CSP Plants** | 7.9 | 7.1 | 5.2 | 4.5 | 4.1 | 4.0 |
| **Wave / Tidal** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Hydropower** | 2.9 | 3.0 | 3.1 | 3.1 | 3.2 | 3.3 |
| **Oil / Gas** | 5.4 | 5.8 | 6.2 | 6.7 | 7.2 | 7.8 |
| **Coal** | 4.0 | 4.2 | 4.5 | 4.8 | 5.1 | 5.5 |

**Figure 5-13: Example of electricity costs (US-cent/kWh) and learning in the MED-CSP scenario, discount rate 5 %/y. Renewables are calculated according to their performance indicators described in Chapter 3. Fuel plants are calculated according to the total power demand with 6500 full load hours per year.**

## 5.3 A Scenario for Energy Security in the Mediterranean Region

Based on the described “crash-barriers” and the “well balanced mix” a scenario was developed for each of the countries analyzed in the MED-CSP study. The results are presented in the following for the total region. The figures for all individual countries are given in the Annex 6.

### 5.3.1 Energy Security

According to the study results for the total region for the year 2050, wind, hydropower, biomass, geothermal energy and photovoltaic systems could generate a volume of 200 – 300 TWh/y each and thus contribute considerably to the increasing electricity demand (Figure 5-16 to Figure 5-21). With the resource potentials of over 400 TWh/y for each of these technologies derived in chapter 3, this leaves still space for future growth (Table 5-4). Wave and tidal power will also have some minor contributions. However, the biggest renewable energy contribution will come from concentrating solar thermal power with over 2200 TWh/y. This amount still represents less than 1 % of the resource potential of this region, but over 50 % of the region’s electricity demand in 2050 (Figure 5-14).

The European countries show rather large potentials of hydropower, wind power and biomass and less potential for solar power generation. This is due to the fact that solar collector production capacities are still small today, and once they become visible after 2020, the electricity demand is already stagnating or retrogressive in those countries. Also, in comparison to the large power demand of the northern Mediterranean region, solar power potentials are relatively limited there (Annex 6).

The island states Malta and Cyprus have relatively limited renewable potentials for power generation which is mainly due to their areal restrictions and topography. Due to our relatively coarse analysis, their wind potentials may be underestimated. Nevertheless, about 20 – 30 % of their electricity could be generated by renewable sources by 2050, making them increasingly independent from fossil fuels.

The Arab oil producing countries will probably maintain a rather high share of oil and gas for power generation and slowly change to solar schemes, while biomass, wind and hydropower are rather limited in this region.

All other MENA countries in North Africa, Western Asia and the Arabian Peninsula will increasingly make use of concentrating solar power as an ideal technology for a transition from an oil/gas fired power generation to a renewable energy driven scheme. The other renewable energy sources will also have a considerable, though smaller share. Geothermal power is very promising in Turkey, Saudi Arabia and Yemen. Wind power potentials are strongest in Morocco, Egypt and Oman.

For each country, the installed capacity of the power park was calculated in a way that the national peak load is always covered with an additional minimum reserve of 25 % of secured capacity. While PV and wind power are resource driven, the other renewable energy technologies can be applied in a demand driven manner, providing peak load, intermediate load and base load capacity on demand and serving as backup capacity for the fluctuating resources. Due to the fact that wind and PV electricity shares only participate with a minor share in the provision of secured capacity, the total installed capacity tends to increase subsequently in relation to the peak load. Typical capacity/peak load relations are today about 1.2

to 1.8, increasing to 1.7 to 2.5, respectively. For the total region this relation changes from 1.4 in the year 2000 to 1.8 in the year 2050, as can be derived from Table 5-3 and Figure 5-15.

| Electricity in TWh/a | 2000 | 2010 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| **Load** | 1290.3 | 1643.4 | 2123.5 | 2880.5 | 3720.6 | 4178.5 |
| **Wind** | 7.2 | 50.2 | 108.4 | 168.5 | 223.2 | 285.2 |
| **Photovoltaics** | 0.0 | 4.6 | 27.7 | 96.8 | 161.5 | 218.5 |
| **Geothermal** | 4.7 | 7.8 | 28.7 | 76.8 | 132.8 | 204.9 |
| **Biomass** | 6.4 | 36.8 | 71.2 | 109.4 | 150.8 | 194.6 |
| **CSP Plants** | 0.0 | 4.6 | 68.1 | 551.0 | 1449.6 | 2122.1 |
| **Wave / Tidal** | 0.0 | 0.5 | 2.2 | 4.9 | 8.7 | 13.7 |
| **Hydropower** | 154.3 | 160.9 | 177.9 | 205.3 | 241.7 | 288.5 |
| **Oil / Gas** | 798.6 | 1051.7 | 1314.6 | 1392.5 | 1109.9 | 654.6 |
| **Coal** | **256.9** | **263.9** | **267.4** | **275.4** | **242.4** | **198.4** |

| Installed Power in GW | 2000 | 2010 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| **Peak Load** | 233.8 | 298.6 | 384.9 | 520.0 | 669.2 | 749.3 |
| **Wind** | 3.3 | 22.9 | 50.0 | 78.8 | 103.8 | 131.3 |
| **Photovoltaics** | 0.0 | 3.0 | 16.0 | 55.4 | 91.7 | 123.0 |
| **Geothermal** | 0.6 | 1.0 | 4.1 | 11.4 | 24.2 | 43.3 |
| **Biomass** | 1.8 | 10.5 | 20.3 | 31.3 | 49.9 | 73.0 |
| **CSP Plants** | 0.0 | 0.6 | 8.5 | 74.2 | 228.4 | 391.5 |
| **Wave / Tidal** | 0.0 | 0.1 | 0.5 | 1.2 | 2.2 | 3.4 |
| **Hydropower** | 68.5 | 73.1 | 82.6 | 97.2 | 116.4 | 141.3 |
| **Oil / Gas** | 210.3 | 269.5 | 352.6 | 441.7 | 457.0 | 370.4 |
| **Coal** | **45.4** | **46.9** | **47.7** | **49.2** | **43.9** | **36.6** |

**Table 5-3: Electricity Generation & Installed Power Capacity of All Countries analysed within MED-CSP**

| | Hydro | Geo | Bio | CSP | Wind | PV | Wa/Ti |
|---|---|---|---|---|---|---|---|
| **Bahrain** | n.a. | n.a. | 80.0% | 10.6% | 50.0% | n.a. | n.a. |
| **Cyprus** | 20.0% | n.a. | 63.0% | 4.5% | 50.0% | n.a. | 50.0% |
| **Iran** | 56.3% | 50.0% | 67.7% | 1.7% | 50.0% | n.a. | n.a. |
| **Iraq** | 50.4% | n.a. | 76.3% | 0.7% | 50.0% | n.a. | n.a. |
| **Israel** | 50.1% | n.a. | 70.1% | 9.1% | 50.0% | n.a. | n.a. |
| **Jordan** | 70.0% | n.a. | 78.8% | 0.6% | 50.0% | n.a. | n.a. |
| **Kuwait** | n.a. | n.a. | 80.0% | 0.9% | n.a. | n.a. | n.a. |
| **Lebanon** | 70.0% | n.a. | 80.0% | 85.7% | 50.0% | n.a. | n.a. |
| **Oman** | n.a. | n.a. | 80.0% | 0.1% | 75.0% | n.a. | n.a. |
| **Qatar** | n.a. | n.a. | 80.0% | 0.4% | n.a. | n.a. | n.a. |
| **Saudi Arabia** | n.a. | 50.0% | 77.0% | 0.1% | 50.0% | n.a. | n.a. |
| **Syria** | 81.3% | n.a. | 77.9% | 1.1% | 50.0% | n.a. | n.a. |
| **UAE** | n.a. | n.a. | 80.0% | 0.5% | n.a. | n.a. | n.a. |
| **Yemen** | n.a. | 60.0% | 74.7% | 5.0% | 50.0% | n.a. | n.a. |
| **Algeria** | 78.0% | 50.0% | 62.6% | 0.1% | 50.0% | n.a. | n.a. |
| **Egypt** | 63.7% | 50.3% | 79.6% | 0.5% | 75.0% | n.a. | n.a. |
| **Libya** | n.a. | n.a. | 75.4% | 0.0% | 50.0% | n.a. | n.a. |
| **Morocco** | 68.0% | 50.0% | 59.0% | 0.7% | 75.0% | n.a. | n.a. |
| **Tunisia** | 82.4% | 50.0% | 64.2% | 0.5% | 93.8% | n.a. | n.a. |
| **Greece** | 50.7% | 50.0% | 49.6% | 87.5% | 71.1% | n.a. | 50.0% |
| **Italy** | 97.1% | 72.4% | 39.5% | 71.4% | 63.3% | n.a. | 50.0% |
| **Malta** | n.a. | n.a. | 72.4% | 21.1% | 50.0% | n.a. | 50.0% |
| **Portugal** | 68.5% | 50.7% | 38.3% | 7.0% | 42.5% | n.a. | 50.0% |
| **Spain** | 87.7% | 50.0% | 34.6% | 2.0% | 75.0% | n.a. | 50.0% |
| **Turkey** | 62.7% | 40.0% | 50.3% | 95.4% | 54.5% | n.a. | n.a. |
| **Total** | 66.8% | 49.5% | 48.5% | 0.3% | 63.7% | n.a. | n.a. |

**Table 5-4: Rate of exploitation of renewable energy sources in 2050 in percent of the total economic potential.**

### 5.3.2 Energy Price Stability

Renewable energies will compete with fossil fuels. The cost of electricity from fossil fuel fired plants was calculated on the basis of the average annual full load hours of each country's power park and according to the relation of oil/gas and coal plants installed. The electricity cost of new natural gas fired combined cycle power plants is displayed in those figures as well as the cost of steam-coal plants under the economic frame conditions explained in chapter 5.2. The cost of fuel oil steam cycles is usually higher than the cost of gas fired combined cycles or coal plants and is not displayed here. For individual countries see Annex 6.

In Europe, the ***electricity cost of most renewable energies will cross below the cost of fuel driven plants between 2010 and 2020***. Most renewable power plants will then produce electricity at a lower cost than new, fuel driven plants, especially after $CO_2$-sequestration is introduced in 2020.

But even in the MENA countries, where $CO_2$ sequestration is not expected to become applicable within the analyzed time span, most renewable power plants will produce cheaper electricity than new fuel fired plants after 2020.

The level of electricity costs between 3 and 6 cents/kWh achieved in the long term by renewable energy sources is quite low and will become a motor for economic development in the second quarter of this century. Therefore, the relatively high initial cost of renewable energies is only a temporary initial barrier, which can be overcome by technology development and by the policies and financing schemes explained in Chapter 8. Besides of environmental concerns, the main reason to change to renewable energies is the high cost level expected for electricity generated by fossil fuels, which in the medium term will achieve a range between 5 and 10 cent/kWh. This and the additional high volatility of fuel prices will be strong driving forces for renewable energy market expansion.

Although climate change and environmental concerns are very good reasons for a change to renewable energy sources, the main issue is the security of supply and the cost of energy in the future. Most economies in MENA will not be able to develop properly in view of the increasing cost of fossil fuels. Those countries will also be seriously affected by climate change and desertification. Therefore, economical and ecological considerations lead both to a solar energy economy in the EU-MENA region. The often quoted conflict between economy and the environment is only a – temporary – illusion caused by short sighted energy policies.

### 5.3.3 Climate Stability

The specific carbon dioxide emissions of the national power park of each country were calculated on the basis of average specific values that have been obtained from life cycle analysis of each technology. For the future fuel-based power generation in Europe, an increasing share of $CO_2$ sequestration was considered as discussed in chapter 5.2. At present, the total carbon emissions of electricity generation of all countries analyzed in the study amount to approximately 770 million tons per year. Instead of growing to 2000 million tons of $CO_2$ emissions per year that would be expected for the year 2050 in a business as usual case our scenario achieves a reduction of emissions of 40 % to 475 million tons within that time span (ref. Chapter 7, Figure 7-4). For individual country results see Annex 6.

### 5.3.4 Social Stability

In contrary to a general believe, the mitigation of greenhouse gases in the power sector based on renewable energies does not necessarily have to be financed by subsidies. On the contrary, renewables constitute the most economic solution for future energy security. However, they require initial investments to start and to continue the technology learning curves of the renewable energy technologies and to achieve cost break-even with fossil fuels as soon as possible. The sooner this development starts, the sooner they will be able to relieve national economies from the subsidization of their power sector. The fastest way to achieve this is shifting the present subsidies from the fossil and nuclear power sector to renewables.

This would finish the present distortion of electricity costs and bring renewables to an eye-to-eye level with fossil fuels on the market. Renewables will quickly achieve independency from public support and make most subsidies obsolete. Even in the worst – and unrealistic – case of no further technical development of renewables, the need for subsidies would at least not increase like in the case of fossil and nuclear fuels.

The MED-CSP scenario shows a possible pathway to a sustainable energy supply system in the EU-MENA region. This pathway is affordable, technically feasible and desirable for the protection of the global environment. We have not found any serious argument against such a development, except a wide-spread underestimation of the potentials of renewable energy sources and the understandable interest of certain lobby groups to maintain their comfortable portfolio of subsidies also in the future. However, the global environment and the global social system has come to a point where it cannot further be burdened by the obsolete, dangerous and in the meantime also costly energy supply schemes of the past century. Fossil and nuclear power technologies were useful for some time giving a strong push to technological and economical development in the north-western hemisphere, but they – and the environment – would be completely overloaded if they were expected to do the same for the rest of the world. Their increasing scarcity and cost will rather become an economic burden and a reason for global conflicts, if no alternatives are built up in time.

The study has shown that those alternatives are at hand and that they must be activated now by an appropriate political, technological and financial effort. Waiting for the pressure to grow would probably deprive most national economies from their economical and political means to react appropriately to the global challenges that this century is going to face.

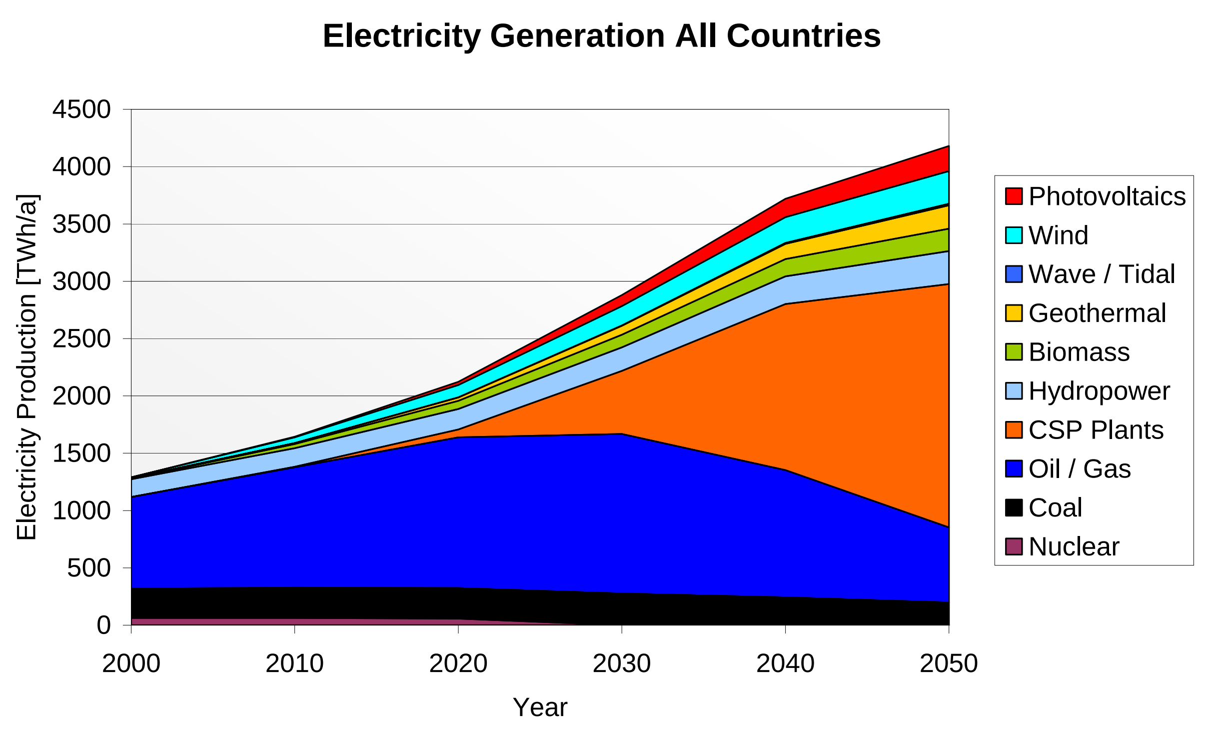


**Figure 5-14: Annual electricity generation within the analysed countries in the scenario CG/HE**

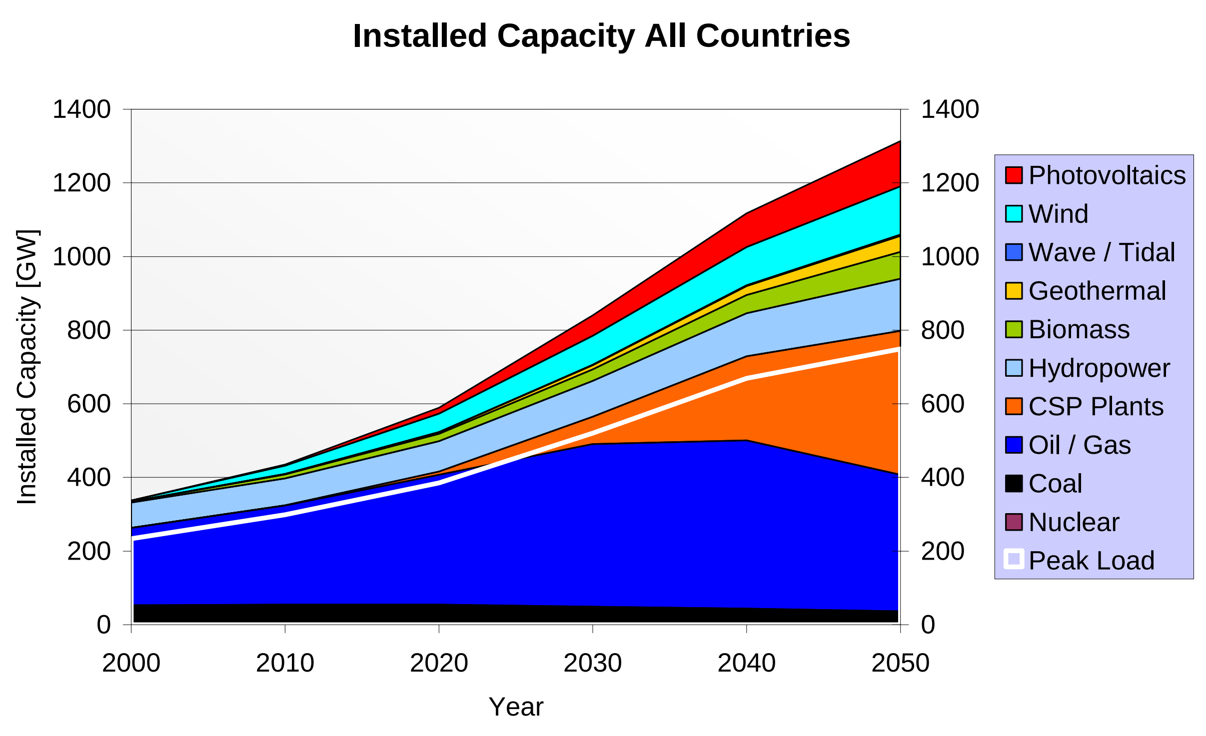


**Figure 5-15: Installed power capacity and peak load within the analysed countries in the scenario CG/HE**

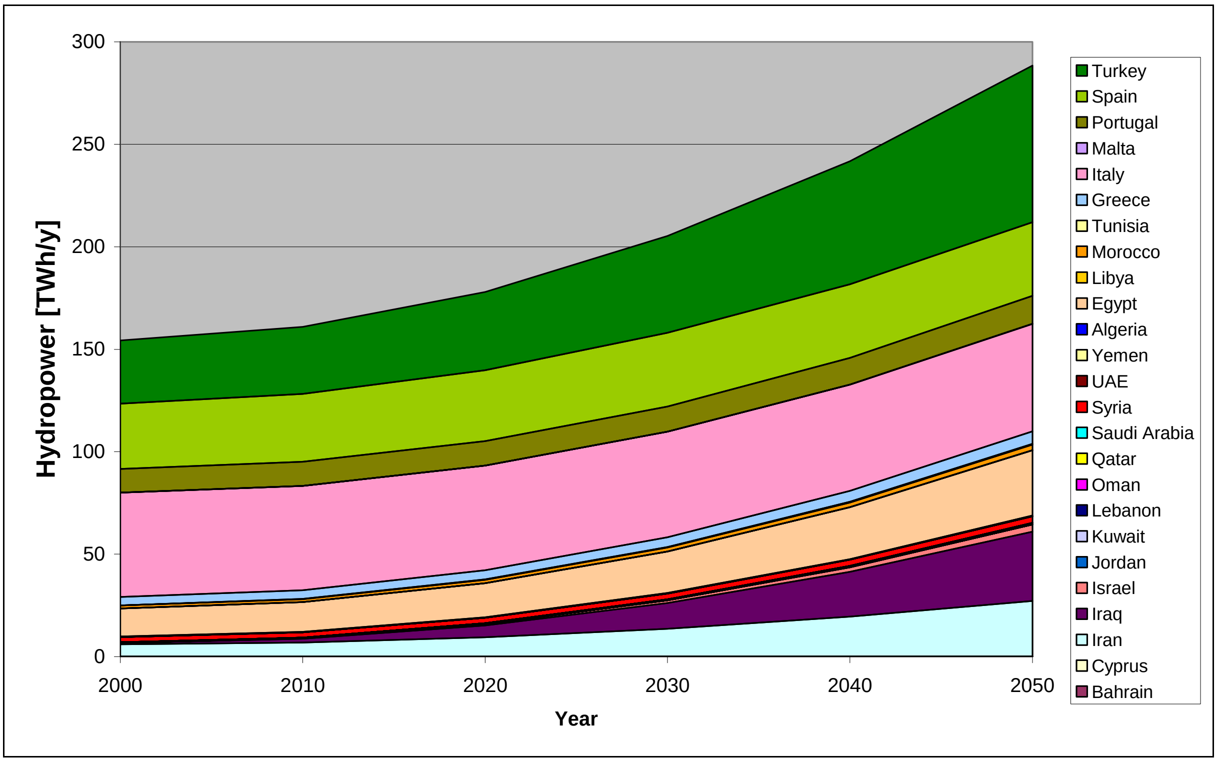


**Figure 5-16: Hydropower generation in the MED-CSP scenario. Possible negative effects of climate change on hydropower resources were not considered.**

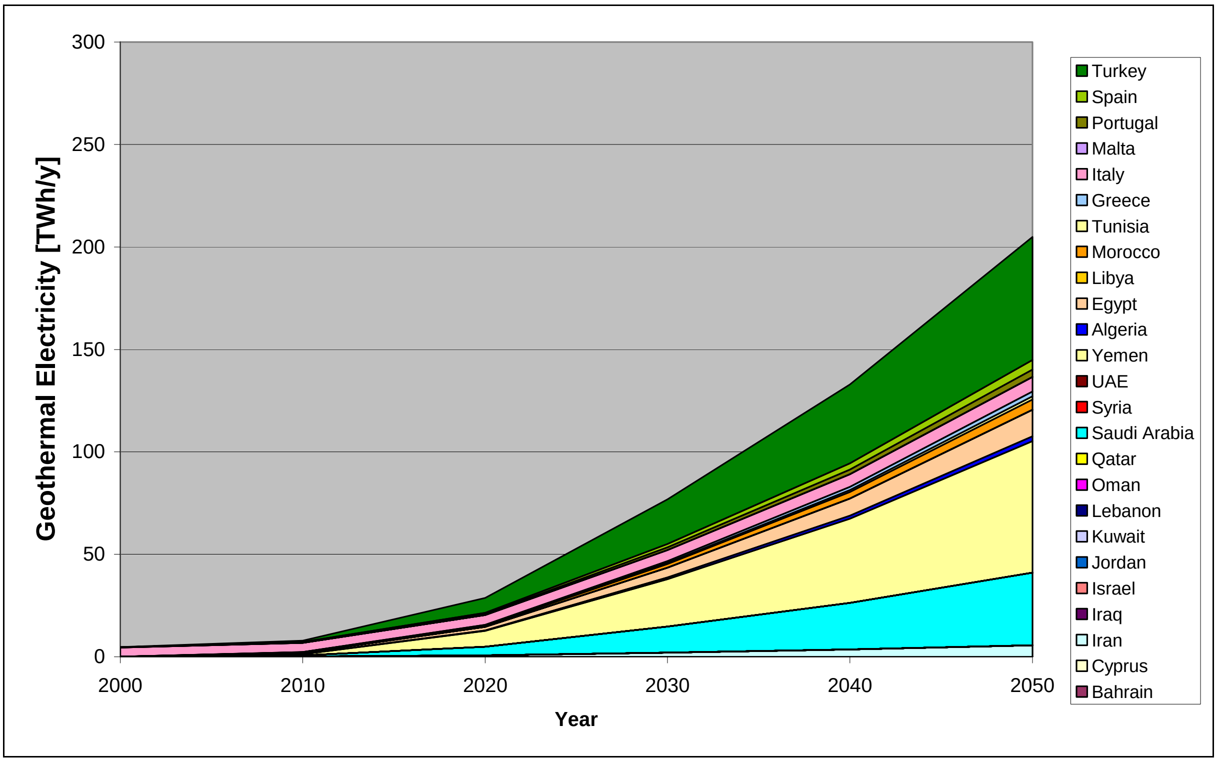


**Figure 5-17: Geothermal electricity generation from Hot Dry Rocks in the MED-CSP scenario (minor shares of conventional geothermal electricity included)**

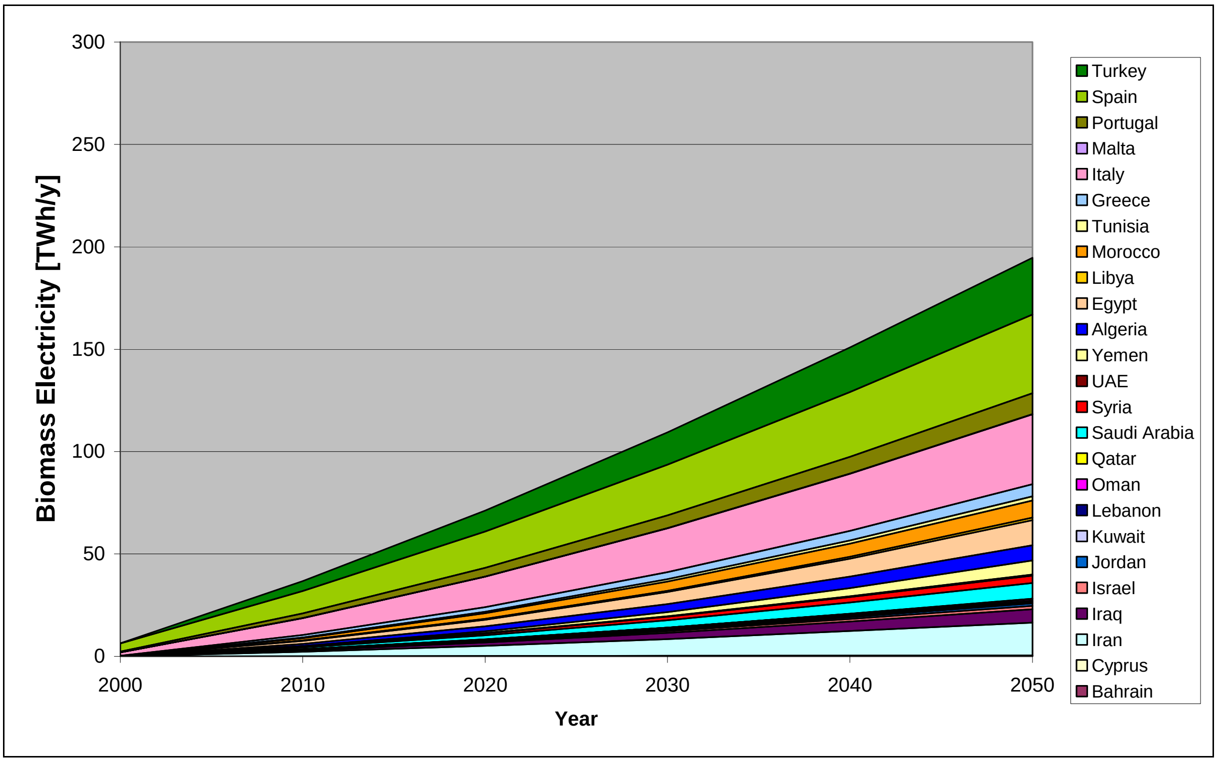


**Figure 5-18: Electricity generation from biomass in the MED-CSP scenario. Only agricultural and municipal organic waste and wood resources were considered for power generation. No energy crops.**

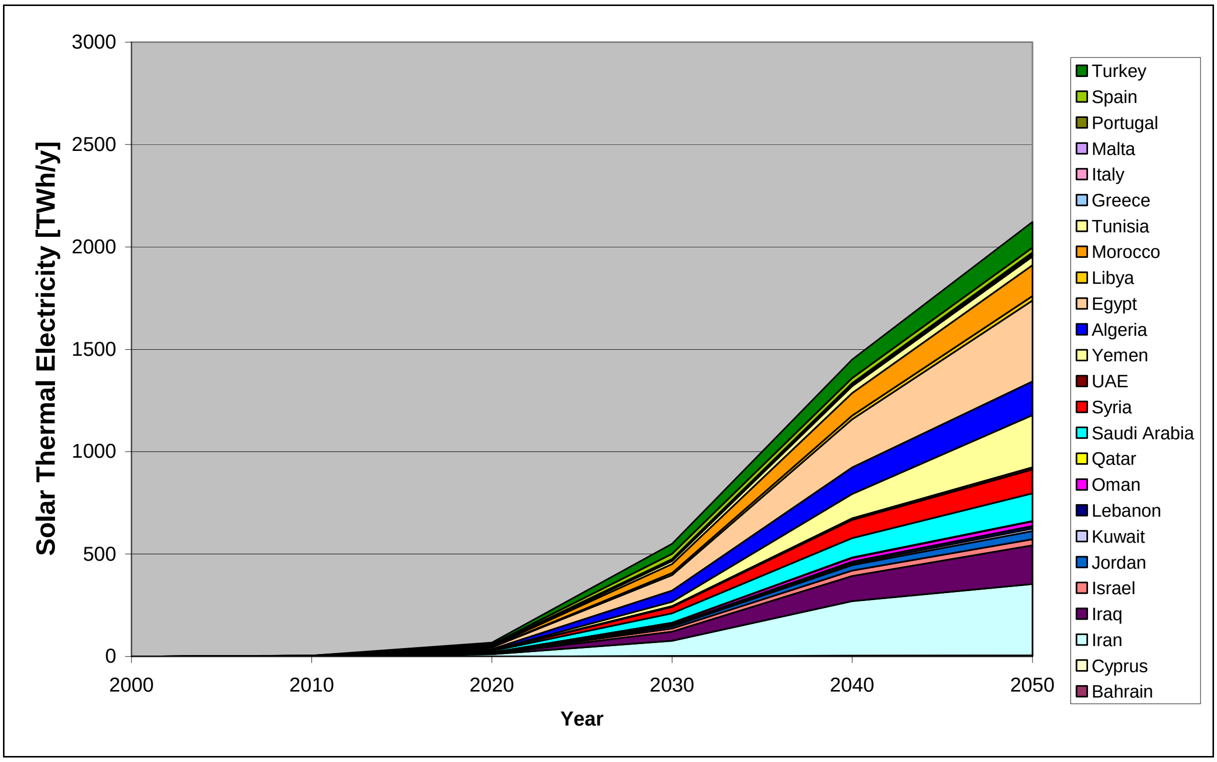


**Figure 5-19: Solar thermal electricity generation in the MED-CSP scenario (note the higher scaling of the electricity axis). CSP is initially applied to base load (8000 h/y) and subsequently takes over also peaking duties in the later stage of the scenario.**

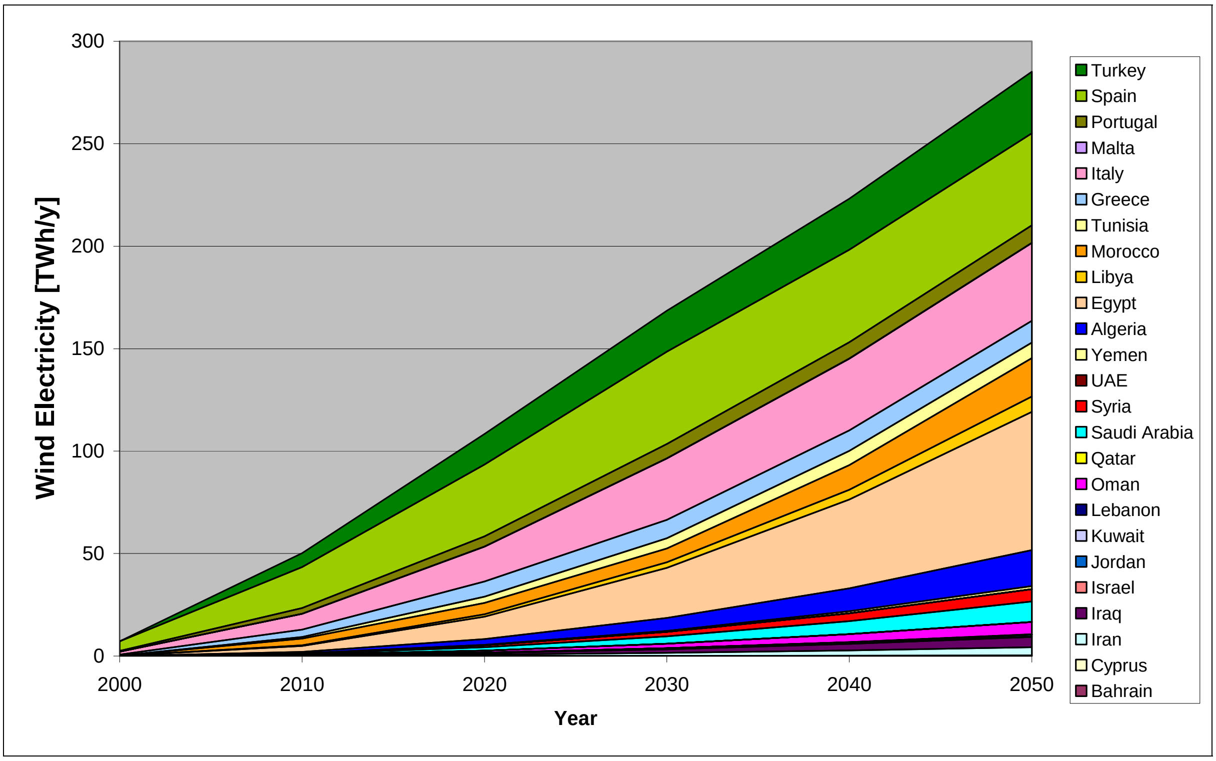


**Figure 5-20: Wind electricity generation in the MED-CSP scenario**

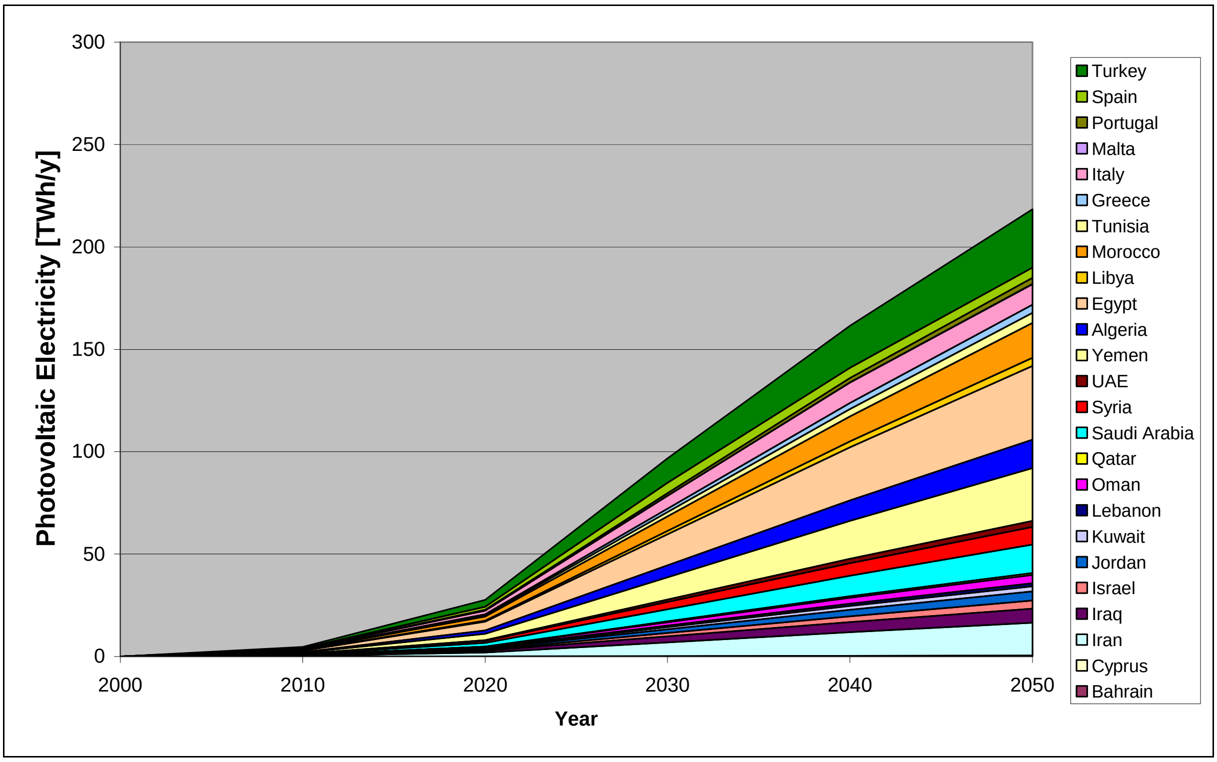


**Figure 5-21: Photovoltaic electricity generation in the MED-CSP scenario**

## 5.4 A Scenario for Water Security in the Mediterranean Region

### 5.4.1 A Pressing Need for Action

The analysis of water deficits in MENA in chapter 4 shows that there is a pressing need for new, non-conventional, sustainable water sources in many countries of this region. The hot spots can be found in North Africa (mainly Egypt and Libya) and the Arabian Peninsula (mainly Yemen and Saudi Arabia), while the situation is by far less critical in most countries of Western Asia. However, Syria, Jordan and Israel also face considerable deficits. Although the demand of the agricultural sector, which in MENA makes up 85 % of the total water demand, will not grow as fast as in the past decades, this will be compensated by a quickly growing demand of the urban centres and industry /Al-Zubari 2002/.

The use of water is today heavily subsidised in many MENA countries /Saghir 2003/. This reflects the fact that the cost of supplying water is already too high today considering the per capita income level, especially in the agricultural sector. Today, the cost of desalting water ranges between 0.5 and 1 $\$/m^3$, which is usually higher than the prices paid for water in most MENA countries. Economies building their water supply to a great extent on desalination with fossil fuels would suffer from additional subsidy loads, from the volatility of fossil fuel costs and from the gradual depletion and cost escalation of fossil energy resources. A severe stagnation of investments in the water sector is a consequence of this situation, the total water sector becoming more and more dependent on national and international subsidisation.

Today, many countries try to avoid an increasing dependency on desalination and fossil fuels by exploiting their groundwater resources. However, in many countries the exploitation rate is much higher than the renewable groundwater resources, making this solution not more sustainable than the dependency on fossil fuels. A renewable, sustainable freshwater source with low and stable cost is required.

Neither water nor energy is scarce in MENA. Both are available in abundance and forever, in form of sea water, solar radiation and other renewable energy sources. Instead of spending money in military conflicts on those matters, it would be wiser to spend efforts to activate the vast resources that are there, but unused. In the following we will describe the potential of those resources.

In the present study, we have assumed that unsustainable water supplied by groundwater depletion and by fossil fuelled desalination represents a potential future deficit together with the increasing demand. This deficit could be covered by solar thermal power plants in co-generation with thermal multi-effect desalination, and additionally using the remaining electricity for desalination by reverse osmosis. Other renewable sources of heat and electricity will also be used for these purposes. However, we have not distinguished the individual potentials of the different renewable power technologies for desalination, but only their potential as a whole.

The general role of desalination in our developing world can be illustrated by quoting a recent study from the World Bank /World Bank 2004/. “Desalination alone cannot deliver the promise of improved water supply. The ability to make the best use of desalination is subject to a series of wider water sector related conditions. In some countries weak water utilities, politically determined low water tariffs, high water losses and poor sector policies mean that desalinated water, just like any other new source of bulk water, may not be used wisely or that desalination plants are at risk of falling into disrepair. Under these conditions, there is a risk that substantial amounts of money are used inefficiently, and that desalination cannot alleviate water scarcity nor contribute to the achievement of the Millennium Development Goals. It may be preferable not to engage in desalination on a large scale unless the underlying weaknesses of the water sector are seriously addressed. A program to address these weaknesses should include a reduction of non-revenue water; appropriate cost recovery; limited use of targeted subsidies; sound investment planning; integrated water resources management; proper environmental impact assessments; and capacity building in desalination as well as in water resources management and utility management. In any case, desalination should remain the last resort, and should only be applied after cheaper alternatives in terms of supply and demand management have carefully been considered.

The private sector can play a useful and important role in funding and operating desalination plants, but only if the above conditions are met. If these conditions are absent, there is a risk that excessive investments in desalination become a drain to the national budget, either directly under public financing or indirectly through implicit or explicit guarantees under private financing.

Desalination technology itself has evolved substantially, making it significantly cheaper, more reliable, less energy-intensive and more environmentally friendly than it was a few decades ago. This trend is likely to continue. It is especially true for reverse osmosis, which is gaining a large share of the market outside the Gulf countries where mainly distillation technologies continue to be used. World desalination capacity is around 30 MCM/day and growing. Desalinated water costs in recent projects with Private Sector Participation verges around USD 0.70 per $m^3$.

Desalination has the potential to contribute to the alleviation of global water scarcity. In the past century, global water consumption levels increased almost tenfold, reaching or exceeding the limits of renewable water resources in some areas, such as in the Middle East and North Africa. This bodes well for the Southern Mediterranean countries, and indeed many other coastal countries, many of which face water shortages and have so far had limited experience with desalination. In particular, desalination can help to alleviate the pressure on coastal aquifers suffering from seawater intrusion. It can also provide an alternative to inter-basin transfers of surface water or the reallocation of water from agriculture to municipal uses whose economic and social costs have to be assessed on a case-by-case basis.

In some water scarce and poor countries, desalination may remain unaffordable in the foreseeable future. But for hundreds of millions of people living in the water-scarce coastal areas of middle income countries, desalination offers the prospect of a reliable, good quality drinking water supply, thus making a contribution to achieve the Millennium Development Goals.

Affordability for the poor is a key issue for sound water sector policies. The poor pay currently high prices to water vendors and they generally have a high willingness to pay for improved supply. No matter what kind of technologies is used to supply drinking water, targeted subsidies are needed to ensure a basic amount of water supply for the poor. In particular, subsidies and cross subsidies are necessary to increase access to water supply by the poor.

Desalination is likely to provide only a portion of the total water needs alongside with existing conventional sources /Mandil et al. 2000/. Although desalination is still more expensive than most existing conventional water sources, its cost is generally lower then the incremental cost of extra bulk supply from conventional water sources, such as dams and inter-basin transfers. Also, upward pressure on tariffs due to the incremental costs of desalination is gradual and often within the ability and willingness to pay of water users.”

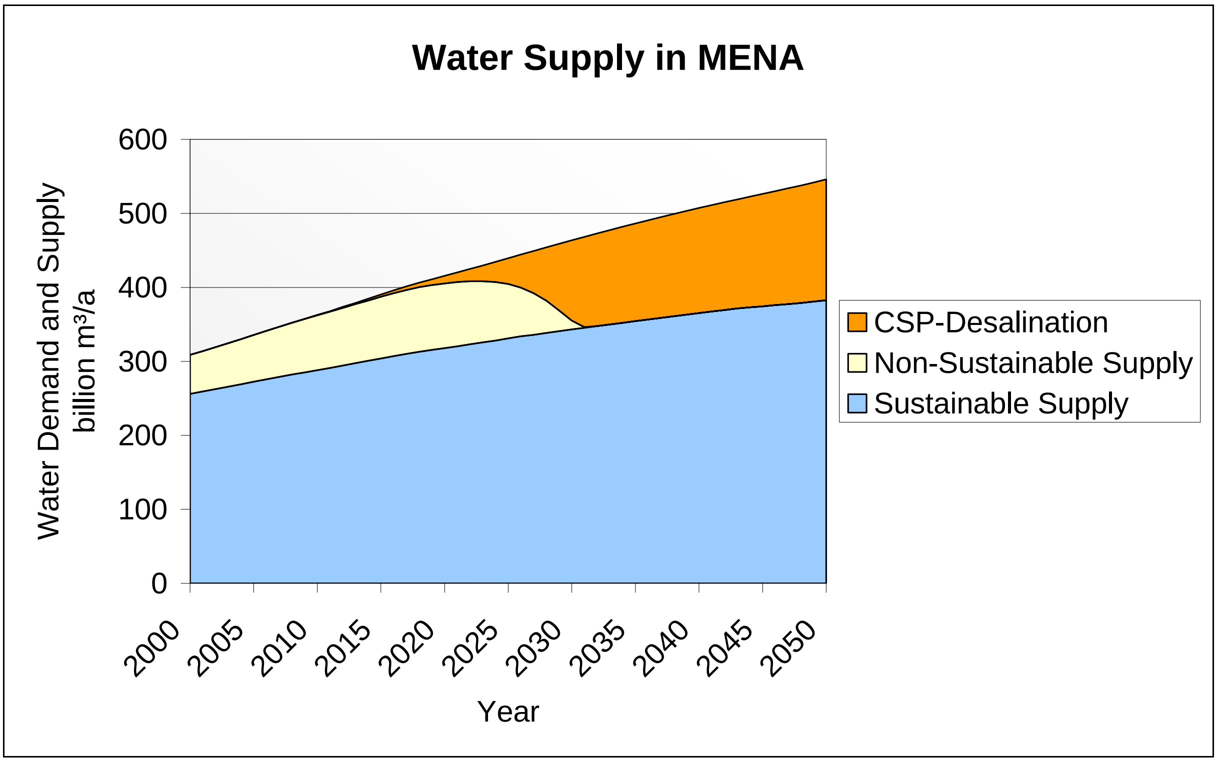


**Figure 5-22: Water demand and supply structure in MENA according to the MED-CSP scenario. Non-Sustainable Water includes overexploitation of groundwater resources and desalination with fossil fuels. Sustainable Water includes all natural surface and groundwater resources that are renewable and exploitable, plus efficiency gains by increasingly re-used wastewater. A possible reduction of renewable water due to climate change is not considered. CSP-Desalination includes seawater desalination on the basis of renewable energy, mainly CSP, in each country within the scenario CG/HE.**

## 5.4.2 The Potential for Renewable Sea Water Desalination in MENA

Today, 35 billion m³/y of the water consumption in MENA are covered by non-sustainable water sources. According to the scenario “Closing the Gap” described in chapter 4, this deficit will increase to about 155 billion m³/y by 2050.

In the time span from 2020 to 2030 these deficits could be subsequently covered by desalination plants powered with renewable energies, mainly CSP, reducing the non-sustainable water supply and providing most of the non-conventional water by the year 2030 and afterwards. Increasing deficits will have to be bridged by fossil fuelled desalination and groundwater withdrawals, hoping that those resources will remain available and affordable until then. This may seem optimistic, but there are no sustainable and affordable alternatives. On the other side, it is a reassuring fact that the potential of CSP is nether limited by the solar energy resource nor by its cost, but only by the possible speed of CSP capacity expansion, and that there is a solution for the freshwater deficits in MENA that can be realized until 2030.

However, a considerable increase of non-sustainable use of water will occur in the meantime, with a maximum of 90 billion cubic meters per year between 2015 and 2020. This calls for the intensive additional use of other renewable sources like geothermal and wind power for non-conventional water production, and also calls for an intensive freshwater management and efficiency enhancements in urban and rural applications. Only a decided employment and efficient combination of all possible measures will lead to a satisfactory and sustainable water supply security in MENA. Seawater desalination with renewable energies is not an alternative, but only a complement to the other measures to increase water efficiency as recommended by the United Nations and other organisations. The main factors for water sustainability are among others /FAO 2002/:

- avoid upstream soil erosion by excessive logging and other activities
- increase irrigation efficiency (from presently average 40 % to over 50 %)
- increase municipal water distribution efficiency (from presently average 50 % to over 70 %)
- concentrate agriculture on high value crops with low water demand
- avoid overexploitation of groundwater resources because this will cause the groundwater level to sink
- clean and reuse municipal wastewater
- harvest rain water by small scale distributed basins and dams

Desalination of seawater only makes sense if those measures are also realised. To quantify the CSP potential of the water sector, we have assumed that all plants would be coupled to multi-effect desalination plants, while the electricity generated is completely used for reverse osmosis in order to produce larger amounts of desalted water. In view of the quick increase of water deficits in MENA, this will be necessary to avoid a severe overexploitation of unsustainable water sources. This approach leads to a minimum installed (electric) capacity of CSP necessary to cover the future water deficits in MENA (Figure 5-23).

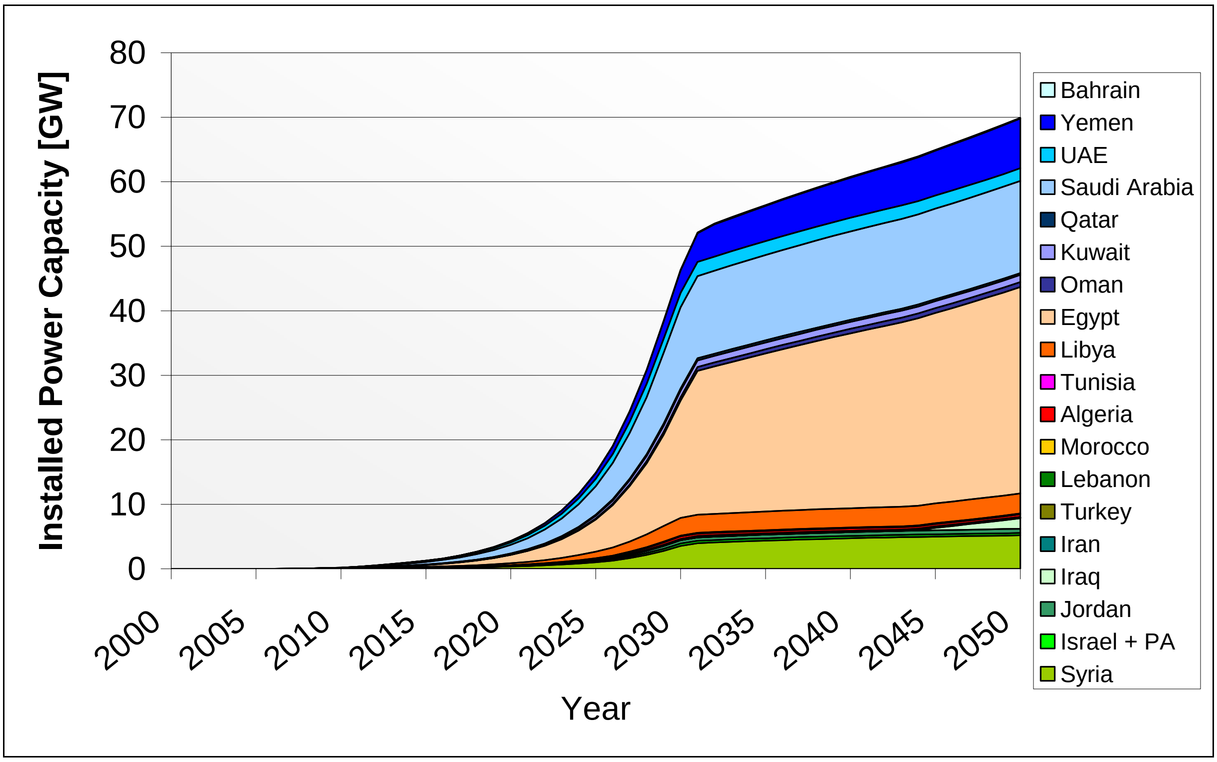


**Figure 5-23: Power capacity for desalination plants with MED and RO in MENA**

In MENA, the capacity of CSP plants until 2050 – if installed exclusively for seawater desalination – could amount to a total of 67 GW. North Africa (35 GW) has the largest potential for CSP desalination plants, followed by the Arabian Peninsula (26 GW) and Western Asia (8 GW) as shown in Figure 5-23. The balance for the individual countries in the three MENA regions is shown in Annex 7.

A CSP production of 115 TWh/y in 2025 and 550 TWh/y in 2050 would be used for desalination purposes. After 2030, the CSP desalination capacities would be large enough to cope with the freshwater demand and desalination will grow much slower. While in 2025 about 29 % of the total CSP production would be used for desalination, in 2050 only 16 % would be used for that purpose.

The scenario is a rough estimate of the CSP potential in MENA. There will be three types of plants for domestic electricity supply, electricity export and sea water desalination used in different combinations:

- CSP Plants for co-generation with coupled seawater desalination must be at the coast, as the co-generated heat cannot be transferred over long distances. Their electricity can be used for additional reverse osmosis desalination (RO), for domestic electricity consumption or for export. As the coastal regions in MENA are strongly used by other human activities, this plant type will be limited to regions with appropriate site conditions and available land area.
- CSP Plants used exclusively for power generation can be anywhere on the grid. Their electricity can be transmitted to any other place and used for domestic supply, export or RO-desalination. This type of plants will be placed where good irradiation coincides with good infrastructure conditions.
- CSP Plants for industrial co-generation will be limited to appropriate industrial sites. While their heat will be used on-site, their electricity might be used on-site too or be sold to the grid for domestic use, export or RO-desalination. Co-generation plants are considered as part of the domestic CSP production potential.

In the real world, there will be a mix of these three plant types, which will vary according to the regional demand of each country and the local supply side conditions. The scenario can only give a rough estimate of the overall potentials of the region, showing the amounts of energy potentially used for domestic supply, export or desalination. However, it cannot distinguish and quantify the different plant types that will be erected in each country, which will be subject of the national strategic power expansion planning.

The capacity potential for CSP would in reality be higher, as part of the plants would be only used for co-generation of city power and MED desalination, but without RO desalination. The installation of such plants would be limited to the sea shore. Another part would only be used for power generation for RO, but without making use of co-generation with MED plants. Those CSP plants could be anywhere on the grid, while only the RO desalination plant must be located at the sea shore.

**North Africa**

The deficit in North Africa will grow from 16 billion m³/y in 2000 to 84 billion m³/y in 2050 with a major share of Egypt (Figure 5-24). The CSP capacity potential for desalination amounts to 32 GW for Egypt and 3 GW for Libya, while the other countries have minor shares. On the basis of country statistics, no potential can be detected for Morocco, Malta and Tunisia, although there may be deficits on the local level (Annex 7).

### Western Asia

Western Asia has relatively large renewable water resources with considerable potential remaining for further exploitation. However, there are numerous deficits on the regional level. The deficit in Western Asia will grow from 10 billion m³/y today to 20 billion m³/y in 2050 with a major share of Syria, and after 2040, also Iraq (Figure 5-25). The CSP capacity potential for solar desalination amounts to 5 GW for Syria and 1 GW for Israel and Jordan, each. The other countries have minor shares. On the basis of country statistics, no potential can be detected for Cyprus, Lebanon, Turkey and Iran, although there may be deficits on the local level (Annex 7).

### Arabian Peninsula

The renewable water resources on the Arabian Peninsula are below 10 billion m³/y. They may increase with time due to re-use efficiency gains, but will still remain small compared to the growing demand. The deficit on the Arabian Peninsula will therefore increase from 27 billion m³/y in the year 2000 to 61 billion m³/y in 2050 with a major deficit in Saudi Arabia and Yemen. The CSP capacity potential for seawater desalination amounts to 14 GW for Saudi Arabia and 8 GW for Yemen, while the other countries have minor shares (Annex 7).

### Southern Europe

There are increasing deficits on regional level in the Southern European countries that cannot be derived from overall country statistics. In principle, there is enough water available, but its geographical distribution leads to shortages on a local level. We have tried to quantify desalination potentials extrapolating present capacities and growth rates. However, those potentials amount to only 1 % of the total potential of the MENA countries (Table 5-5).

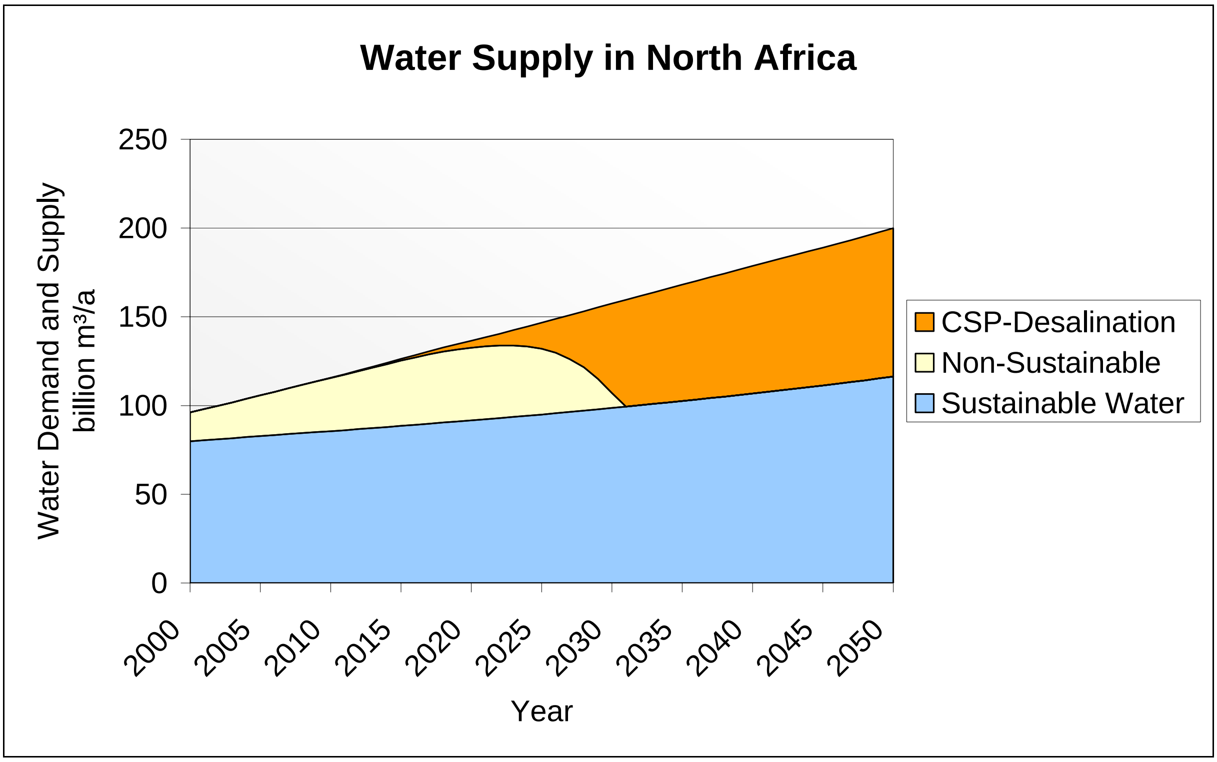


**Figure 5-24: Water demand and water supply structure in North Africa. Definitions in Figure 5-22.**

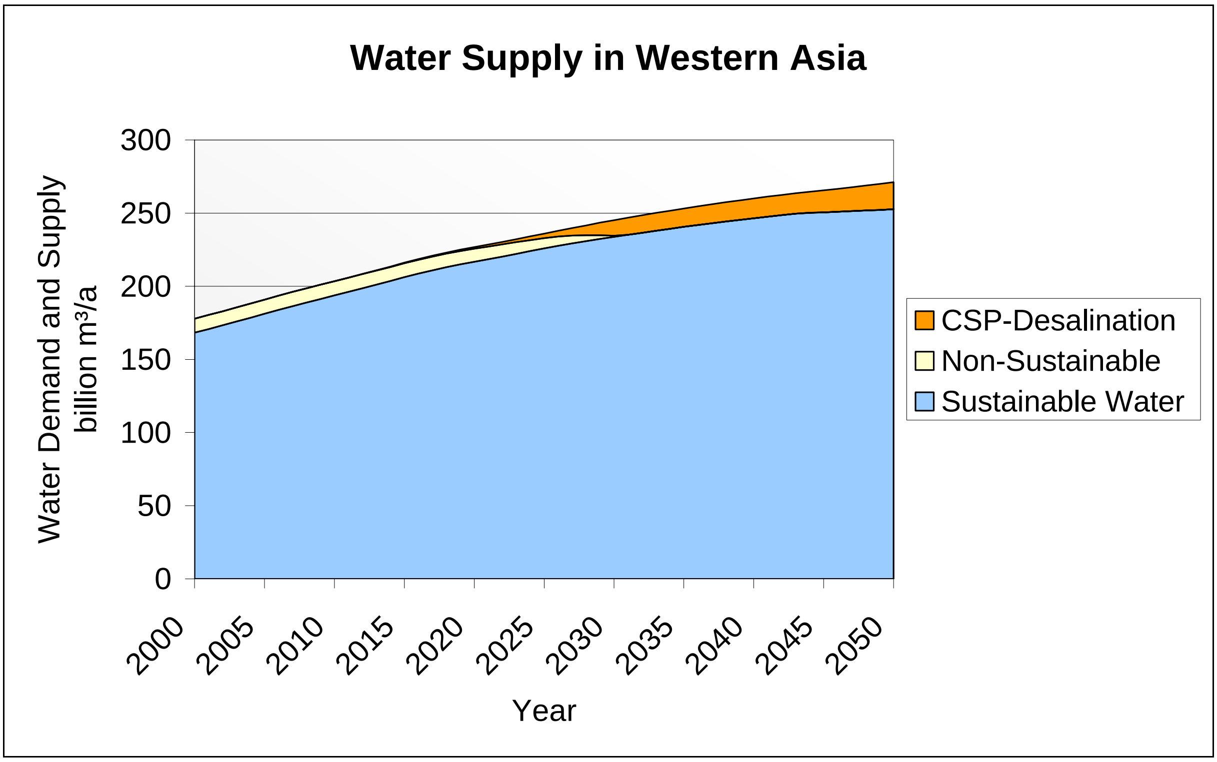


**Figure 5-25: Water demand and water supply structure in Western Asia. Definitions in Figure 5-22.**

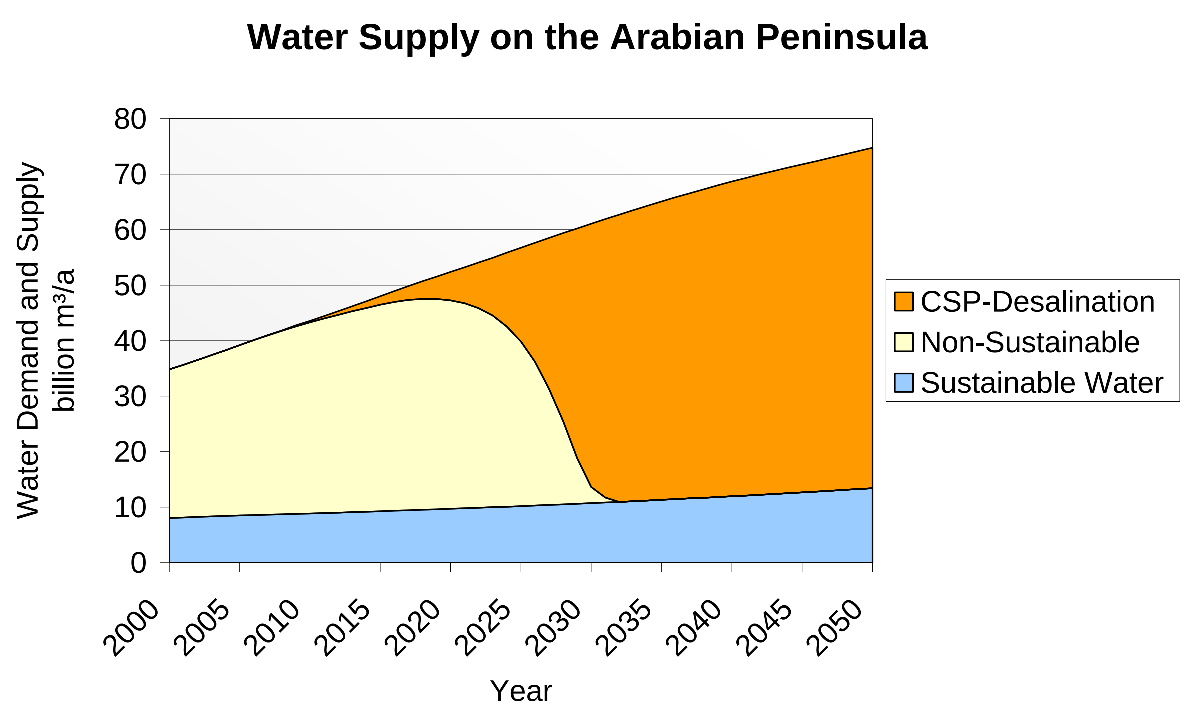


**Figure 5-26: Water demand and water supply structure on the Arabian Peninsula. Definitions in Figure 5-22.**

| | Multi-Stage-Flash 2004 | MED+VC 2004 | Reverse Osmosis 2004 | Total Desalination 2004 | Non-Sust. Water 2004 | Desalination Scenario 2050 | Energy for Desalination 2050 |
|---|---|---|---|---|---|---|---|
| | Mm$^3$/y | Mm$^3$/y | Mm$^3$/y | Mm$^3$/y | Mm$^3$/y | Mm$^3$/y | TWh/y |
| **Cyprus** | 2.8 | 0.9 | 49.2 | 52.8 | 5 | 90 | 0.31 |
| **Greece** | 2.5 | 5.0 | 7.6 | 15.1 | | 24 | 0.08 |
| **Italy** | 93.4 | 43.3 | 58.2 | 194.9 | | 305 | 1.04 |
| **Malta** | 8.6 | 1.5 | 41.2 | 51.3 | | 80 | 0.28 |
| **Portugal** | 0.0 | 0.2 | 1.0 | 1.2 | | 2 | 0.01 |
| **Spain** | 32.5 | 33.7 | 563.5 | 629.7 | | 985 | 3.37 |
| **Turkey** | 0.0 | 3.2 | 0.3 | 3.5 | | 6 | 0.02 |
| **Iran** | 116.7 | 39.8 | 4.5 | 161.1 | | 252 | 0.86 |
| **Iraq** | 0.0 | 0.2 | 0.5 | 0.7 | | 3840 | 13.15 |
| **Israel** | 2.6 | 11.0 | 419.6 | 433.2 | 340 | 1018 | 3.49 |
| **Jordan** | 0.0 | 0.4 | 1.6 | 2.0 | 560 | 1030 | 3.53 |
| **Lebanon** | 0.2 | 5.4 | 0.1 | 5.6 | | 9 | 0.03 |
| **Syria** | 0.0 | 0.0 | 2.2 | 2.2 | 8000 | 12170 | 41.67 |
| **Bahrain** | 207.8 | 18.1 | 28.2 | 254.2 | 170 | 488 | 1.67 |
| **Kuwait** | 908.8 | 3.9 | 142.6 | 1055.2 | 370 | 1691 | 5.79 |
| **Oman** | 103.9 | 25.3 | 21.0 | 150.2 | 340 | 1820 | 6.23 |
| **Qatar** | 363.4 | 92.4 | 2.4 | 458.2 | 210 | 783 | 2.68 |
| **Saudi Arabia** | 1765.3 | 1119.1 | 288.9 | 3173.3 | 14800 | 29722 | 101.77 |
| **UAE** | 2122.0 | 835.4 | 237.5 | 3195.0 | 2000 | 4550 | 15.58 |
| **Yemen** | 0.9 | 22.5 | 0.3 | 23.8 | 2500 | 18040 | 61.77 |
| **Algeria** | 92.0 | 13.3 | 168.8 | 274.1 | 600 | 975 | 3.34 |
| **Egypt** | 53.8 | 7.0 | 53.0 | 113.8 | 10200 | 75000 | 256.80 |
| **Libya** | 320.6 | 156.5 | 24.7 | 501.8 | 4100 | 7330 | 25.10 |
| **Morocco** | 2.6 | 25.0 | 11.2 | 38.7 | 270 | 340 | 1.16 |
| **Tunisia** | 0.1 | 2.0 | 0.7 | 2.8 | 290 | 294 | 1.01 |
| **Total** | **6201** | **2465** | **2129** | **10794** | **44755** | **160844** | **551** |

**Table 5-5: Present seawater desalination capacities and non-sustainable use of water in 2004 and in 2050 as well as energy equivalent required for desalination in the MENA region /Wangnick 2004/**