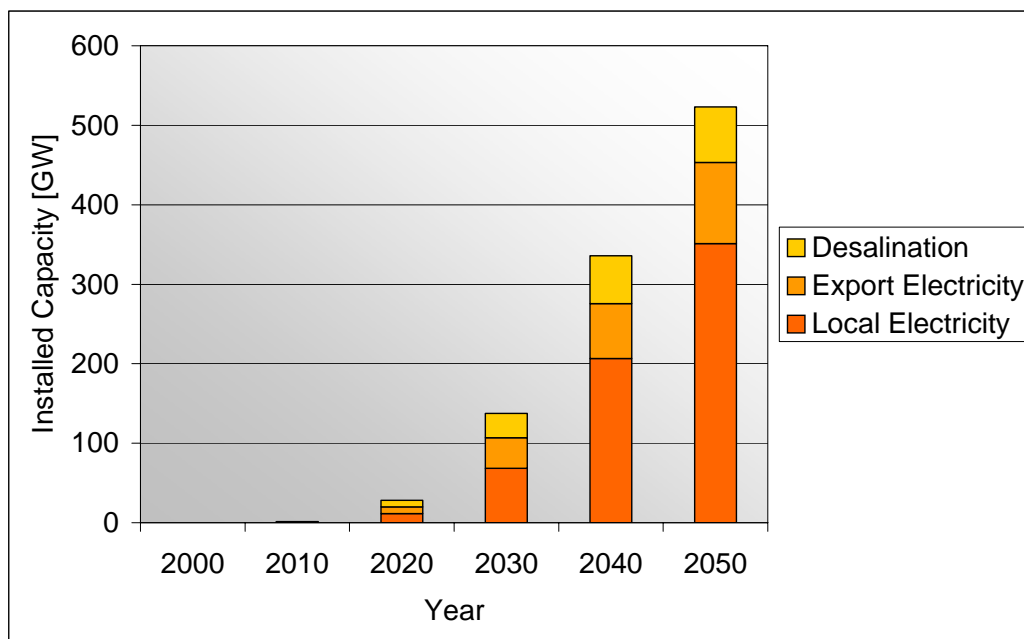


## 5. Socio-Economic Impacts of CSP Desalination

Figure 5-1 shows the market perspectives of CSP in terms of total installed capacity resulting from the scenarios developed in the MED-CSP study for the coverage of the domestic electricity demand in the EU-MENA countries, from the TRANS-CSP study that quantifies the potential of solar electricity exports from MENA to Europe, and finally, found within the prior chapters of this report, the potential for seawater desalination. The addition of capacities of those three sectors leads to a total installed CSP capacity of about 28 GW by 2020, 140 GW by 2030 and 520 GW by 2050 in the total EUMENA region. Over 90 % of this capacity will be installed in MENA (please compare to Figure 4-1).



**Figure 5-1: Market perspectives of concentrating solar power for local electricity supply, export electricity from MENA to Europe and seawater desalination /MED-CSP 2005/, /TRANS-CSP 2006/**

The expansion of CSP in the electricity sector of Europe and MENA will have considerable socio-economic and environmental impacts, most of them positive, that have already been described in the previous studies /MED-CSP 2005/ and /TRANS-CSP 2006/. Within this chapter, we will describe the socio-economic impacts of a broad dissemination of CSP desalination plants in the MENA region. First of all, we will try to quantify the cost of water that can be expected in the medium and long-term from such systems, and compare it to the present and expected cost of water in the MENA region. The main question is, will the MENA countries enter a never ending spiral of subsidies for water and energy or can water scarcity be solved in a sustainable way?

Certainly, a low production cost is only one part of the challenge, as its benefits are often lost if the efficiency of distribution and use of water is well below state of the art. In that case, a lot of the extracted water may be lost and useless on one side, or a cheap source of water may be rapidly depleted on the other side. Many MENA countries are already on such a track, and the cost of not-acting is becoming visible in many areas, affecting economic development and often even social peace. A phenomenon appearing recently is the growing competition of urban and rural population for water, in most cases being the rural population the losers, moving as a consequence to the rapidly growing Mega-Cities of the region and sharpening the problem there. This context will be described here.

Finally, after analysing the problem of water scarcity and summarising the presently discussed portfolio of solutions, we will add the AQUA-CSP concept of cultivating the desert for a growing population in MENA, using the natural resources that have always been there but are still totally untapped: desert land, salty water and solar energy.

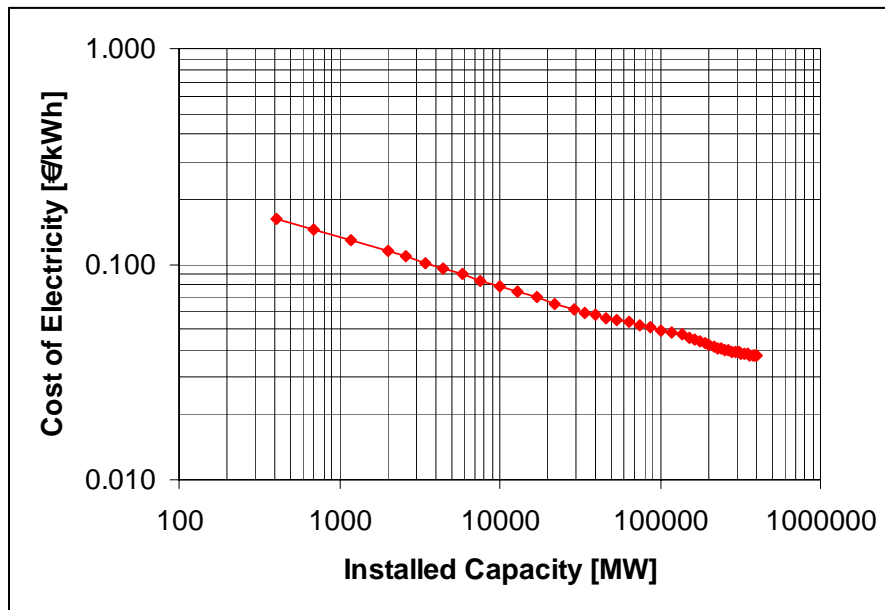
## 5.1 Cost Perspectives of CSP Desalination

Within this chapter, we will analyse the future cost perspectives of freshwater produced by CSP-powered desalination taking into account the expected capacity expansion of CSP as a total and the related cost learning curves resulting from research and development, from mass production, from economies of scale of larger plant units and from the integration of solar thermal storage capacities into the power plants. The different effects that lead to a cost reduction of electricity from CSP as function of the total installed capacity have been described in numerous publications /NEEDS 2007/, /TRANS-CSP 2006/, /MED-CSP 2005/, /Ecostar 2004/, /Sargent & Lundy 2003/, /Sokrates 2003/.

Learning curves describe the cost reduction of a product as function of the total amount of that product sold on the world market, in our case the total installed capacity of CSP plants /Neij 2003/. A cost learning curve is described by the following equation as function of the progress ratio (PR):

$$c = c_0 \cdot \left(\frac{P}{P_0}\right)^{\frac{\log(PR)}{\log(2)}} \quad \text{Equation 5-1}$$

As an example, a progress ratio of PR = 90 % means that the specific cost ( $c$ ) is reduced with respect to the initial value ( $c_0$ ) by 10 % every time the total installed capacity ( $P$ ) is doubled with respect to the initial value ( $P_0$ ). Several analysis predict a progress ratio of 86 % for concentrating solar power technology /Sokrates 2003/, /Ecostar 2004/, /Needs 2007/. The cost learning curve for solar electricity resulting from an analysis in the frame of the European NEEDS project is shown in Figure 5-2.

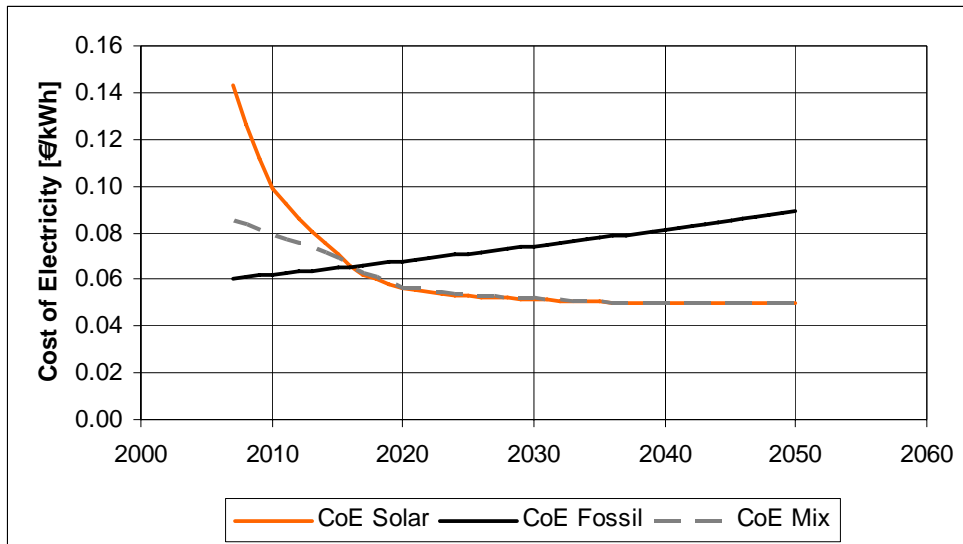


**Figure 5-2: Cost of electricity from CSP as function of installed capacity according to the optimistic-realistic scenario variant of /NEEDS 2007/ for sites with an annual irradiance of 2500 kWh/m<sup>2</sup>/y, 8000 full load hours per year. The learning curve corresponds to a progress ratio of 0.862 for solar electricity, which is equal to the progress ratio found in /Sokrates 2003/.**

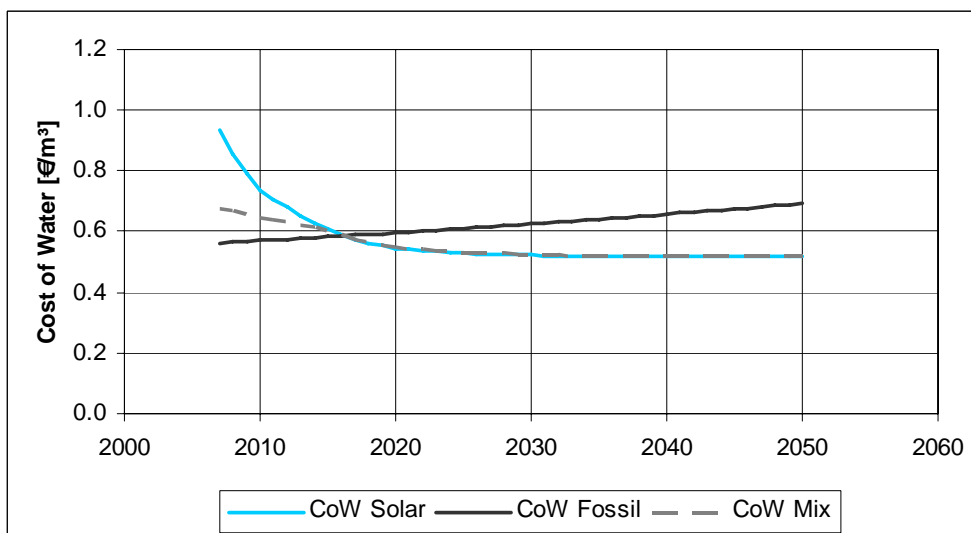
The curve starts with a solar electricity cost of 0.163 €/kWh in 2007 with presently installed 410 MW and ends with 0.037 €/kWh in 2050 with over 400 GW installed capacity. In spite of a higher total installed capacity in our predictions as shown in Figure 5-1, we will use a more conservative cost scenario, as shown in Figure 5-3, calculated on the basis of a lower annual solar irradiance of 2400 kWh/m<sup>2</sup>/y and less operating hours. This represents an average value, as direct normal irradiance in MENA may vary from 2000 to 2800 kWh/m<sup>2</sup>/y (Figure 1-13). Figure 5-3 shows the learning curve for the AQUA-CSP reference scenario as function of time instead of installed capacity. We have also calculated the cost of electricity generated by conventional, gas-fired power stations, and the mixed cost taking into consideration the solar share of our scenario, which increases from initially roughly 20 % today to over 95 % after 2025, which can be achieved by the increased use of solar thermal energy storage for night-time operation (Figure 5-5). At the same time, the cost of fossil fuel increases from 25 €/MWh in 2007 to 40 €/MWh in 2050, equivalent to about 60 \$/bbl of fuel oil. This cost represents the average fuel cost over the total lifetime of the plants installed in the respective year. It stands for the present and expected cost of natural gas.

As has been described in Chapter 1, CSP plants can produce both electricity and water, and the resulting cost of one product has a strong influence on the cost of the other. Therefore, in order to get a reliable definition of the cost of water from CSP desalination, we have opted in a first step for separating the plant into two parts, one that produces exclusively solar electricity and another one that uses this solar electricity for seawater desalination.

In fact, this is exactly the definition of a CSP/RO configuration. As we have seen in Chapter 1, the cost of CSP/MED is expected to be only slightly below the values resulting for CSP/RO, and therefore it would theoretically suffice to calculate the long-term learning curve of CSP/RO systems as representative cost learning curve for both options.



**Figure 5-3: Projected cost of electricity (CoE) from CSP, from gas fired power stations and from hybrid systems in the AQUA-CSP reference scenario (prices in real €2007, 5 %/y interest rate, 25 years economic life, solar irradiance 2400 kWh/m<sup>2</sup>/y, initial fuel cost 25 €/MWh, fuel cost escalation 1 %/y, gas power plant efficiency 47%, power plant investment 500 €/kW, O&M rate 2%/y, 7500 full load hours per year, long-term exchange rate €\$ = 1.0). Cost break-even can occur much earlier if fossil fuel costs escalate faster.**



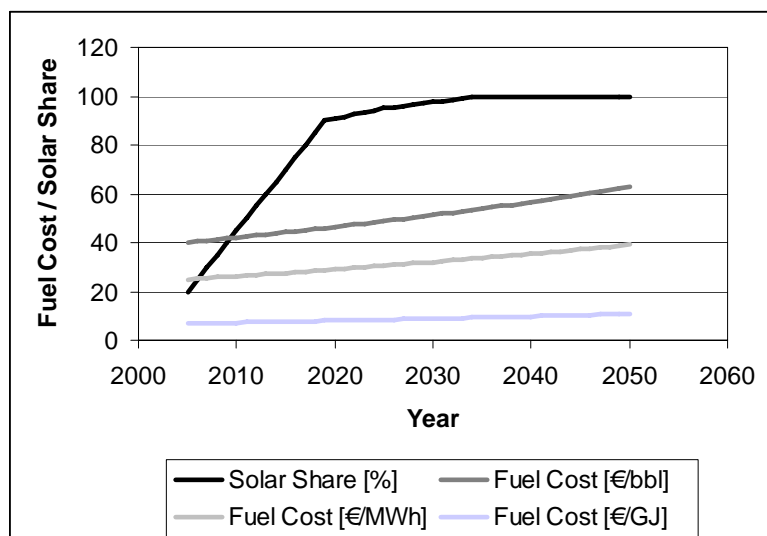
**Figure 5-4: Projected cost of water (CoW) from RO using conventionally generated power or solar electricity in the AQUA-CSP reference scenario (RO investment 900 €/m<sup>3</sup>/d, RO power demand 4.5 kWh/m<sup>3</sup>, electricity cost and other economic frame parameters as given in Figure 5-3 and Figure 5-5).**

The resulting learning curve is shown in Figure 5-4 for CSP/RO, for an interest rate of 5 %/y and 25 years of economic lifetime. The learning curve starts around 0.9 €/m<sup>3</sup> today and quickly falls down to 0.55 €/m<sup>3</sup> by 2020. In the long-term, a value below 0.5 €/m<sup>3</sup> is achieved. At the same time, the cost of conventional seawater desalination rises from initially 0.55 €/m<sup>3</sup> today to 0.6 €/m<sup>3</sup> in 2020 and up to 0.7 €/m<sup>3</sup> in 2050. That means that before 2020, solar desalination will become considerably cheaper than conventional desalination driven by fossil fuel fired power plants, provided that the expansion of CSP takes place as scheduled.

Figure 5-3 and Figure 5-4 show another very important fact: the future cost difference of fossil and solar production of electricity and water leaves a considerable margin for the pricing of both commodities. As CSP plants can produce both power and water, the sales-price for one commodity can be adjusted closer to the – competing – price of fossil generation. This results in a lower cost of the other commodity, that now can be sold at lower price. The cost reduction acquainted by CSP in time can either be fully accounted to both commodities as shown in Figure 5-3 and Figure 5-4, or it can be allocated preferentially to one commodity, while the other one is priced as high as the market allows. As an example, if the revenue achieved for solar electricity in 2020 would be 0.070 €/kWh as for fossil generation instead of 0.057 €/kWh which would be its cost according to Figure 5-3, the water produced by such plants could be sold at 0.26 €/m<sup>3</sup> as shown in Table 1.9, Chapter 1, instead of 0.55 €/m<sup>3</sup> as shown in Figure 5-4.

The combination of solar power and water would allow to produce water at prices that would be competitive even in the irrigation sector. This is only possible because the primary energy source, solar power, becomes cheaper with time, while its competitors, conventional fuels, become more expensive, thus elevating the achievable market prices for energy and water. The visibility of this unique opportunity may be distorted by existing energy subsidies, and MENA governments must individually analyse their situation very carefully in order to see the real chance of acting behind the curtain of illusion created by subsidised prices for energy and water.

The economic frame parameters used for this calculation can also be varied. As an example, the real interest rate of 5 %/y used here as reference represents the average internal rate of return of the modelled power and desalination projects. It is in the same order of magnitude as a typical average discount rate of a national economy. It is also in the same order of magnitude of what can be expected as project return e.g. investing in the frame of the German Feed-In Law for renewable energies. Therefore, this value may be a useful indicator for the economical feasibility of such projects, but other values are possible. For example, many water utilities in the MENA region do not have a positive return on investment at all, but either zero or even a negative return, which means they are heavily subsidizing water by public funding from taxes and from other sources of income, or by increasing their national debt. Energy sources used for desalination are also often subsidised, and the resulting water prices do not necessarily represent the real market value.



**Figure 5-5: Solar share and average lifetime fuel cost of CSP and conventional plants built in the respective year assumed for the AQUA-CSP cost scenario as function of time**

In addition to the calculations for CSP/RO we have made a scenario calculation for CSP/MED type plants, fixing the revenues for electricity at 0.05 €/kWh and calculating the resulting cost of water, as shown in Figure 5-6. Furthermore, we have calculated the cost of electricity for a fixed revenue for water of 0.5 €/m<sup>3</sup>, as shown in Figure 5-7. The plants are operated at full load for 7500 hours per year and have a solar share and fuel cost according to Figure 5-5.

In the case of the CSP/MED plants we have also varied the project interest rate in order to show its potential significance for irrigation and agriculture. After 2020, a cost of desalted water from CSP of less than 0.10 €/m<sup>3</sup> is possible if the respective interest rate would be zero. This would be comparable to present prices of water for irrigation, that often lead to negative rates of return. Such a low cost of water can be obtained if governments decide to build and operate such plants without interest rates, custom duties, taxes or other duties that would elevate their cost, only expecting such projects to pay back for investment and operation cost in order to facilitate new investments. Governments would not necessarily have to subsidise the produced water or the construction of those plants, because revenues as low 0.10 €/m<sup>3</sup> for water and 0.05 €/kWh for the generated electricity would just suffice to pay back for the cost of construction and operation (but would not yield additional gains – interest rates – in that case).

A possibility of achieving low costs of water for agriculture and at the same time attractive interest rates for investors would be to elevate the sales price of electricity as it would be defined by the generation of electricity from competing fossil fuel fired plants. This will be possible in the medium term future, as electricity prices from fossil fuel fired plants will quickly escalate and create a rather high level of energy costs world wide. Following electricity cost development of conventional gas-fired power plants, the revenue for electricity would slowly escalate from 0.060 €/kWh today to 0.068 €/kWh in 2020 and 0.088 €/kWh in 2050 (Figure 5-8).

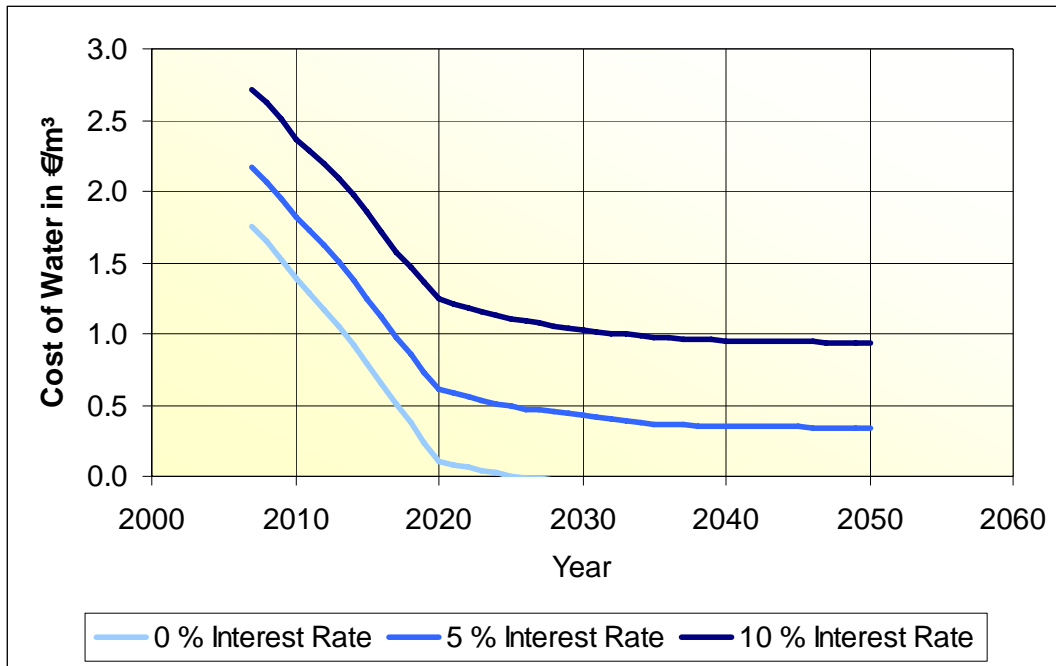


Figure 5-6: Cost of water from CSP/MED plants for different interest rates assuming that electricity produced by the plants will achieve a fixed revenue of 0.05 €/kWh. In the long-term, a cost of water of 0.34 €/m<sup>3</sup> and 0.05 €/kWh for electricity can be achieved in the AQUA-CSP reference case with 5 % interest rate (annual real project rate of return).

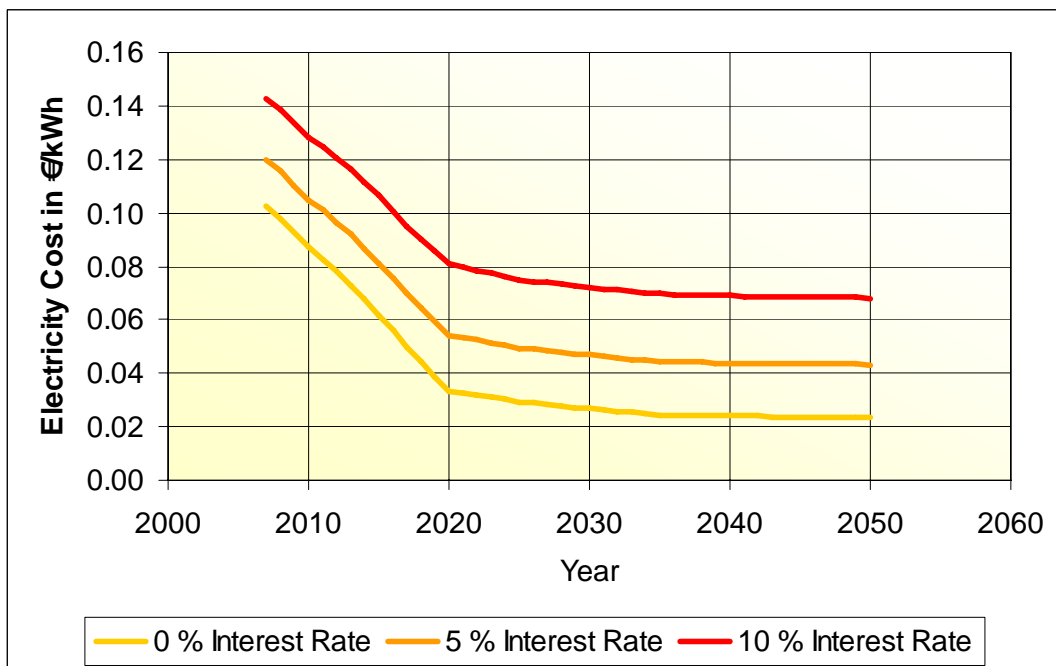


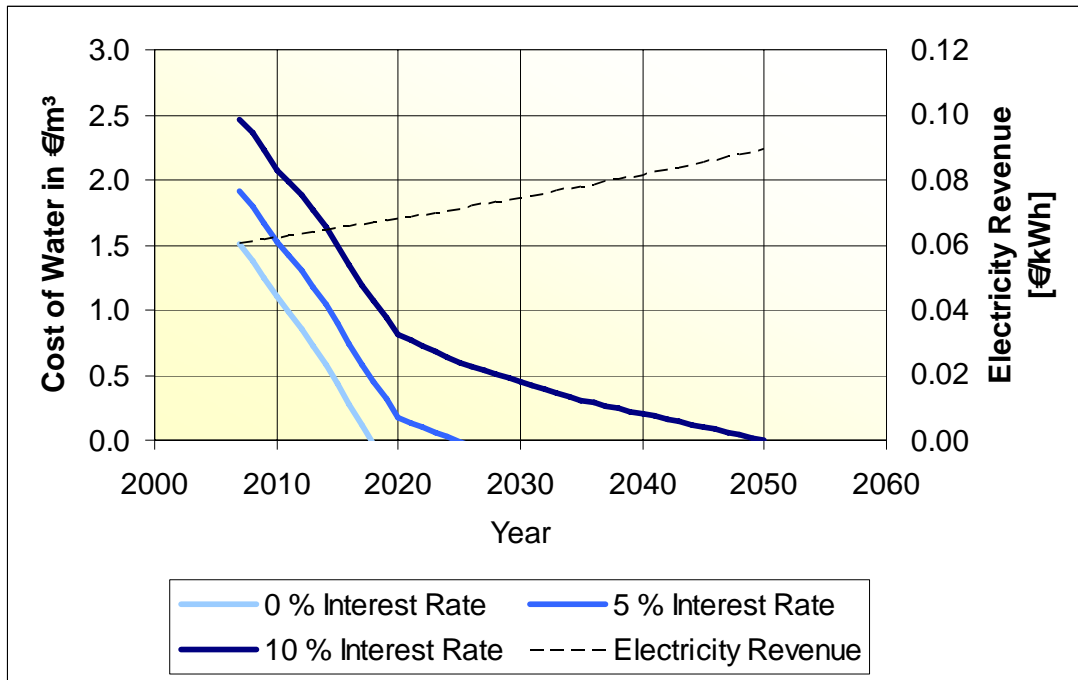
Figure 5-7: Cost of electricity from CSP/MED plants for different interest rates assuming that water produced by the plants will achieve a fixed revenue of 0.5 €/m<sup>3</sup>. In the long-term, a cost of electricity of 0.04 €/kWh and 0.5 €/m<sup>3</sup> of water can be achieved in the AQUA-CSP reference case with 5 % interest rate (annual real project rate of return).

In 2020, this would lead to a higher revenue for power and thus to a much lower cost of water of only 0.28 €/m<sup>3</sup> in spite of 5 % rate of return, without having to rely on any subsidies (see also Chapter 1, Table 1-9). This model is rather attractive, as – mostly urban – electricity consumers will be more readily able to pay for the real costs of electricity, thus allowing for a rather low, however unsubsidised cost of water for irrigation in rural areas. Another option for combining water and electricity prices will be the export of solar electricity from MENA to Europe, which may allow for a relatively high revenue for clean solar electricity and at the same time be a very attractive means of inter-regional cooperation /TRANS-CSP 2006/.

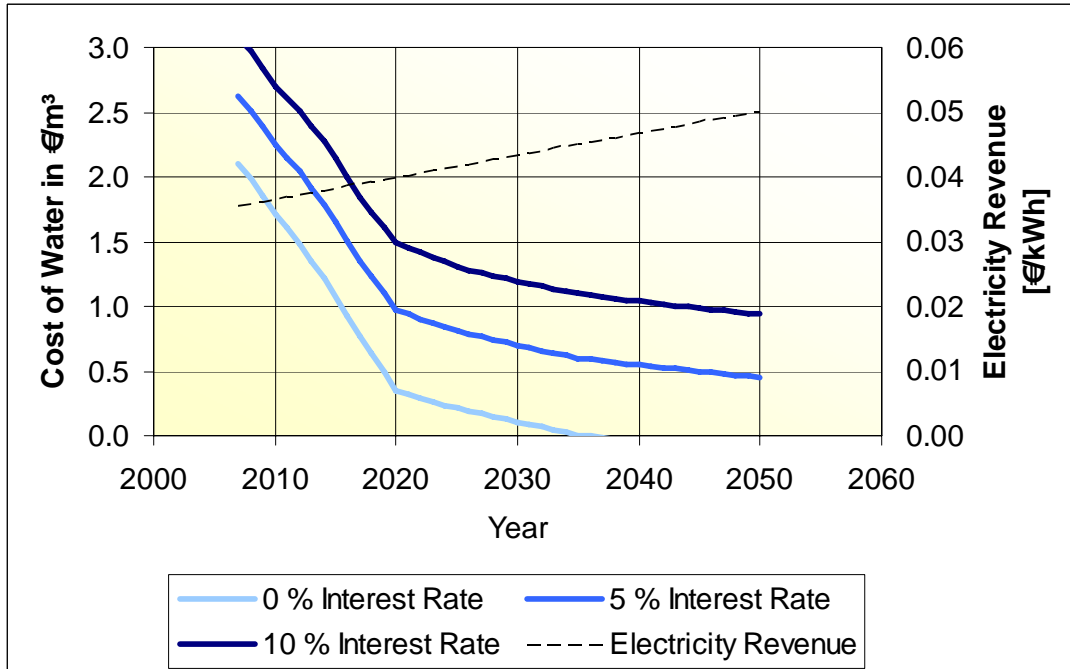
On the other hand, if CSP plants would have to compete with subsidised electricity without being subsidised themselves, a situation as shown in Figure 5-9 will occur, with revenues from electricity being too low to achieve an acceptable cost of water for irrigation. However, even assuming revenues for electricity as low as 0.035 €/kWh today growing very slowly to 0.05 €/kWh in 2050, the equivalent cost of water from combined CSP desalination would be in the order of 1.00 €/m<sup>3</sup> in 2020 and 0.5 €/m<sup>3</sup> in 2050, that would be acceptable even today in the municipal supply sector. In this case, to achieve costs that would be low enough for irrigation, subsidies or reduced interest rates would be required for desalting water with CSP.

Figure 5-10 and Table 5-1 show contemporary prices for water in the MENA countries and compare them to the real cost of extracting water in some selected countries. The data was obtained in the year 2000, so we can assume a considerably higher cost today. For simplicity and lack of better data, we may assume a similar situation for water costs as in those examples in the total MENA region. At least in those countries that are using water beyond the renewable rate, desalination would define the marginal cost of producing water. Looking at the water production cost of some selected countries in the year 2000 in Figure 5-10, and comparing this figure to the cost of CSP in Figure 5-10, it can be seen that water from CSP desalination will in the medium-term become very attractive when compared to other water sources with costs of 0.5-0.75 \$/m<sup>3</sup> in the municipal sector and 0.10-0.40 \$/m<sup>3</sup> for irrigation.

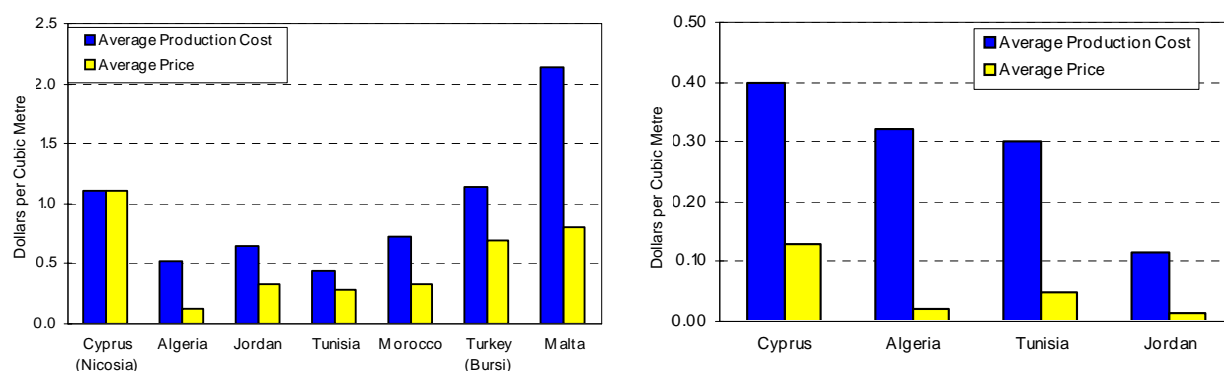
Due to increasing water shortage and escalating energy prices, water prices are steadily climbing upwards, and investment into alternatives must start right now. However, Figure 5-10 shows that cost and pricing of water in MENA is rather unbalanced. Pricing of power and water in MENA is and will remain a political issue, and will probably remain relying on subsidies for some time. In any case, our analysis shows clearly that trying to solve the water scarcity problem with conventional desalination based on fossil fuels would lead to a subsequently higher cost of water that will be unaffordable in the short and medium term, while a timely investment into CSP will certainly lead to steadily falling, attractive costs of generating electricity and desalted water. Compared to today's situation, it may even become possible to achieve a long-term reduction and elimination of subsidies in both the energy and water sector, a target that will certainly be impossible to achieve relying further on fossil fuels.



**Figure 5-8: Cost of water from CSP/MED plants for different interest rates assuming that electricity produced by the plants will achieve a revenue equivalent to the unsubsidised cost of gas power stations. Please note that with 0 %/y interest rate (but covering construction and operation cost) and a revenue for water of 0.067 €/kWh, before 2020 water could already be produced as bye-product without cost.**



**Figure 5-9: Cost of water from CSP/MED plants for different interest rates assuming that electricity produced by the plants will achieve only low revenues competing with subsidised electricity prices.**



**Figure 5-10: Water pricing in US\$ per cubic metre versus real costs in the municipal (left) and irrigation sector (right) in selected MENA countries /Saghir 2000/**

Country / City	Sector	Water Tariff in \$/m³	Year	Source	Comment
Saudi Arabia	Average	0.03	2003	IEA 2005	
Saudi Arabia	Range	0.025 – 1.6	2003	GWI 2004	
Kuwait	Average	0.65	2003	IEA 2005	
Qatar	Average	0.43	2003	GWI 2004	
Qatar	Average	1.20	2003	IEA 2005	
Egypt	Average	0.03 – 0.05	2000	Saghir 2000	
Egypt	Average	0.25 – 0.35	2003	GWI 2004	
Israel	Municipal	0.25 – 1.1	2003	GWI 2004	+0.45\$/m³ sub.
Israel	Irrigation	0.14 – 0.25	2003	GWI 2004	
Jordan	Municipal	0.42 +	2003	GWI 2004	
Jordan	Irrigation	0.11 – 0.5	2003	GWI 2004	
Amman	Municipal	0.62	2000	Saghir 2000	
Libya	Municipal	0.15 +	2003	GWI 2004	
Oman	Average	1.17	2003	GWI 2004	
Palestine	Range	0.87 – 1.45	2003	GWI 2004	
Ramallah	Municipal	1.10	2000	Saghir 2000	
Khan Younis, Gaza	Irrigation	0.46	2000	Saghir 2000	
Gaza City	Municipal	0.29	2000	Saghir 2000	
Kuwait	Average	0.65	2003	GWI 2004	
Sana'a, Yemen	Municipal	0.28	2000	Saghir 2000	
Tunisia	Irrigation	0.022-0.077	2000	Bahri 2001	
Tunisia	Re-use	0.015	2000	Bahri 2001	
Tunisia	Average	0.22	2000	Saghir 2000	
Morocco	Municipal	0.20 – 0.55	2000	Saghir 2000	
Lebanon	Average	0.32	2000	Saghir 2000	
Algiers	Municipal	0.18	2000	Saghir 2000	
Syria	Average	0.08	2000	Saghir 2000	
United States	Average	1.30	2003	IEA 2005	
Germany	Average	2.00	2006	Lexikon.Wasser.de	
France	Average	3.15	2003	IEA 2005	

**Table 5-1: Average water tariffs in selected countries in MENA from different sources. Please note the substantially higher water tariffs in water-rich countries like Germany and France (bottom). Exchange rate €\$ = 1.**

In the MENA region there is a – slightly reluctant – trend to achieve a better **accountability** for energy and water and to reduce subsidies in both sectors. In terms of sustainability it is very important that prices reflect the real cost of any product, including externalities like environmental or socio-economic damages that may be caused by the use of those commodities. If prices and costs are unbalanced, there will be on one hand a careless, inefficient use, and on the other hand there will be no money available on the provider's side to invest in efficiency of supply and distribution. This leads to a vicious circle of increasing losses and at the same time increasing societal costs and subsidies. Because of subsidies, these costs will not be paid by consumers, but by all tax payers and eventually by the whole society, in form of deceases, conflicts and economic constraints.

Therefore, a better accountability for water and energy is of high priority in the MENA region to increase the quality of water management and supply /World Bank 2007/. However, a change to more realistic prices of water and energy must occur gently and socially compatible, and it will take time.

The question is, how should a reduction of subsidies and a more realistic tariff system be achieved in view of energy prices that have been multiplying within a time-span of only a few years? In the year 2000, crude oil was still at 20 \$/barrel, but its price jumped to 60 \$/barrel in 2006, which is three times higher. Natural gas was around 2 \$/GJ in 2000 and at 6 \$/GJ in 2006, also three times higher. Coal prices doubled in the same time-span, starting with 30 \$/ton in 2000 and ending up with an average cost of 60 \$/ton in 2006. Since 2000 the price of uranium has even become fourfold /oilnergy 2007/, /Thomson 2006/, /Cameco 2006/.

Even if energy costs would escalate much slower in the future as assumed conservatively in the AQUA-CSP reference scenario – at only 1 %/y – the economic performance of CSP will be much better than that of conventional power generation and seawater desalination, as has been shown before in this chapter.

Triple costs within 6 years is equivalent to a **cost escalation** rate of 20 %/y. Such an escalation of water and electricity prices would not be acceptable for most energy and water consumers in MENA, because their per capita income is growing much slower. Thus, any possibility for reducing energy or water subsidies is eliminated by rising energy costs. In reality, the subsidised gap between costs and prices is even becoming larger.

Money for investments that would be necessary to change the situation will increasingly be consumed by exploding running-costs, with no way out of that dilemma, except the change to a source of energy and water that instead of escalating in cost becomes cheaper with time and use. This source is already there and available, and it must now be activated: solar energy from concentrating solar power, using the desert sun for energy and seawater for desalination. In terms of technology, the necessary production capacities must be build in order to satisfy a significant share of demand as shown in Chapter 4, and in terms of economy, the production capacities must

become large enough to achieve the necessary economies of scale and mass production to reduce production costs to really low levels as shown within this chapter. This still remains a challenge, as it will require significant investment, political will, international cooperation and clever and efficient implementation, but is the only way out of the dilemma of energy and water scarcity.

**Subsidies** for power and water should slowly be reduced. As long as CSP plants will have to compete with subsidised fuel, electricity or water, they should obtain an equivalent subsidy in order to be able to be introduced to the market. In the short term, they will require less subsidies than conventional production, and in the long-term, subsidies for power and water may even be reduced to zero.

To achieve this goal, there is absolutely no alternative in sight. We therefore strongly recommend an immediate start of investment in CSP technology for power and seawater desalination in MENA, without any delay. The resource is waiting to be tapped, the technology is ready for the market, and MENA has now the chance to make the best use of this option. Any waiting will increase the problem – in the worst case causing irreversible damage – and subsequently deprive the MENA governments from the economical means to react properly to this critical situation. Even in the case of strong efforts and decided action, the achievement of considerable, visible shares of sustainable water from CSP will at least take 10-15 years.

Each country in MENA can develop its individual strategy for market introduction according to the technical and economic frame conditions available. Some countries have sites with a solar irradiance well over 2800 kWh/m<sup>2</sup>/y and very steady conditions all around the year, and of course, due to that climatic situation, those are the countries with the sharpest water scarcity. Governments can decide either to subsidise electricity or water or just provide investment at low interest rates, taxes and custom duties for CSP projects. **Niche markets** like feed-in tariffs for solar electricity as in Spain or Germany or auto-generation of power and water for hotel resorts as in the Aqaba case described in Chapter 1.2.3 should be strongly supported and implemented by the MENA governments, because those are the most efficient forms of market introduction.

Last but not least, we should mention the phenomenon of **marginal costs**. The marginal cost is the cost of producing a commodity without considering the investment and capital cost for building new plants. In case of any conventional power or desalination plant, this cost includes the cost of operation and maintenance and a large amount of fuel. In case of a solar plant, only operation and maintenance must be considered, as solar energy is used as “fuel”. That means that after having paid back for the initial investment of such plants, power and water from CSP plants will see a cost reduction of 90 % with respect to their initial cost, while power and water from conventional plants relying on fossil fuel will only see a cost reduction of about 10-20 %, if any. Operators of CSP plants will be awarded in case of careful maintenance of their system that will lead to a longer economic lifetime, while conventional plant operators will be punished by escalating fuel prices, no matter if they carefully maintain their system or not.

## 5.2 Exploitation of Fossil Groundwater

Exploitation of groundwater is taking place world wide and is one of the most important sources of freshwater. However, in the arid regions of the world, groundwater is only renewed to a marginal extent. In the MENA region, there are very large bodies of groundwater that are made up of fossil water, that means water that was deposited there tens of thousands of years ago, when there still was significant rainfall in the region. As an example, the Nubian Sandstone Aquifer System (NSAS) is one of the largest freshwater deposits of the world, but is hardly renewed and thus considered mostly fossil water. The extraction of that water must be considered as mining of a fossil resource, just like oil, coal or natural gas.

COUNTRY	AQUIFER SYSTEM	EXTENSION (km <sup>2</sup> )	ACCESSIBLE RESERVES (Mm <sup>3</sup> )	CURRENT EXTRACTION (Mm <sup>3</sup> /y)	STATIC DURATION (y)
Egypt, Libya	Nubian Sandstone	2,200,000	10,220,000	4,500	2271
Algeria, Libya, Tunisia	North Western Sahara	1,000,000	1,280,000	2,560	500
Saudi Arabia, Bahrain, Qatar, UAE	Various	250,000	2,185,000	18,200	120
Jordan	Qa Disi Aquifer	3,000	6,250	170	37

**Table 5-2: Main aquifer systems containing fossil water in the MENA region. Accessible reserves are compared to the present extraction rate, yielding as indicator the “static duration” of the resource under theoretical constant rates of withdrawal. /UNESCO 2006/**

COUNTRY	AQUIFER SYSTEM	Extraction 2050 BAU (Mm <sup>3</sup> )	Extraction as Percentage of Reserve	Extraction AQUA-CSP (Mm <sup>3</sup> )	Extraction as Percentage of Reserve
Egypt, Libya	Nubian Sandstone	2,500,000	24.5%	675,000	6.6%
Algeria, Libya, Tunisia	North Western Sahara	350,000	27.3%	87,000	6.8%
Saudi Arabia, Bahrain, Qatar, UAE	Various	2,800,000	128.1%	860,000	39.4%
Jordan	Qa Disi Aquifer	31,000	496.0%	3,200	51.2%

**Table 5-3: Main aquifer systems in the MENA region. Accessible reserves are compared to the cumulated future extraction scheduled in the Business As Usual (BAU) Scenario (Chapter 4) and the AQUA-CSP Reference Scenario until 2050.**

The **Nubian Sandstone Aquifer System** in Egypt, Libya, Chad and Sudan has a thickness of up to 3500 m, an extension of 2.2 million km<sup>2</sup> (Figure 5-11), and a total stored water volume of

373,000 Bm<sup>3</sup> of which 14,500 Bm<sup>3</sup> are considered to be accessible<sup>1</sup> /UNESCO 2006/. The accessible share in Egypt and Libya is reported to be 10,220 Bm<sup>3</sup>. Present extraction is reported to be from around 2.2 Bm<sup>3</sup>/y /UNESCO 2006/ to 4.5 Bm<sup>3</sup>/y /AQUASTAT 2005/, which is equivalent to an extraction rate of only 0.02-0.05 % per year. Theoretically, the accessible reserve would still last about 2270 years if used at current rates of extraction. Until the year 2000 about 40 Bm<sup>3</sup> had been extracted from the aquifer, which is less than 0.4 % of the total. Nevertheless, by that time the groundwater level had already fallen by 60 meters since 1960, with 97 % of the existing natural shallow wells in the region falling dry /UNESCO 2006/.

If the extraction would come to 24.5 % of the accessible reserve as scheduled in the business as usual scenario for Egypt and Libya developed in Chapter 4 (Table 5-3), freshwater would probably have to be pumped from a depth of around 1000 meters. This however would require about 4-6 kWh/m<sup>3</sup> of electricity which would be more than required by equivalent seawater desalination.

Even in the case of the AQUA-CSP reference scenario, 6.6 % of the accessible reserve of the aquifer equivalent to 675 Bm<sup>3</sup> would be used until 2050 (Table 5-3). This would still have serious consequences for the groundwater level, but not nearly as sharp as for the business as usual case.

The **North Western Sahara Aquifer** will suffer similar consequences if following a business-as-usual strategy (Table 5-3 and Figure 5-12). Libya has already initiated a significant withdrawal of fossil groundwater with the Great Man-Made River Project. According to /UNESCO 2006/, current extraction from the aquifer amounts to about 2.6 Bm<sup>3</sup>/y, which theoretically would allow a continuous extraction for about 500 years. However, taking into consideration growth of demand and following a business-as-usual scenario, about 27 % of the reserve would have been withdrawn by 2050, while the AQUA-CSP reference scenario leads to an extraction of only 6.8 % by that time.

The **Aquifers on the Arabian Peninsula** are facing an even more serious situation: at present rate of withdrawal, the theoretical duration of the aquifers would only be 120 years (Table 5-2 and Figure 5-13), with some sources even predicting a total depletion within a time span of only 35 years /EoEarth 2007/. Even in the case of the AQUA-CSP reference scenario, 40 % of the reserves would be extracted until 2050. This will have dramatic consequences for the groundwater level and for the environment, probably affecting most existing wells and oasis in the region. There may also be a serious intrusion of salt water into the coastal groundwater reserves, in the worst case making them useless. The good news is that there is a source of freshwater available as a bridge from current unsustainable supply to a future sustainable water production based on solar energy. However, it is unclear if this source of groundwater is

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1 In the original literature, the terms “exploitable” or “recoverable” are used instead of „accessible“. However, those terms are misleading as they suggest that the reserves are renewable, which is not the case.

sufficiently large and stable in order to last long enough to achieve sustainability without major negative consequences for the natural environment and for the society of the Arabian Peninsula. The countries of the Arabian Peninsula would therefore be wise to immediately initiate a transition to a sustainable supply based on CSP seawater desalination, re-use of waste water, water management, efficient distribution and efficient use of water in all sectors of demand.

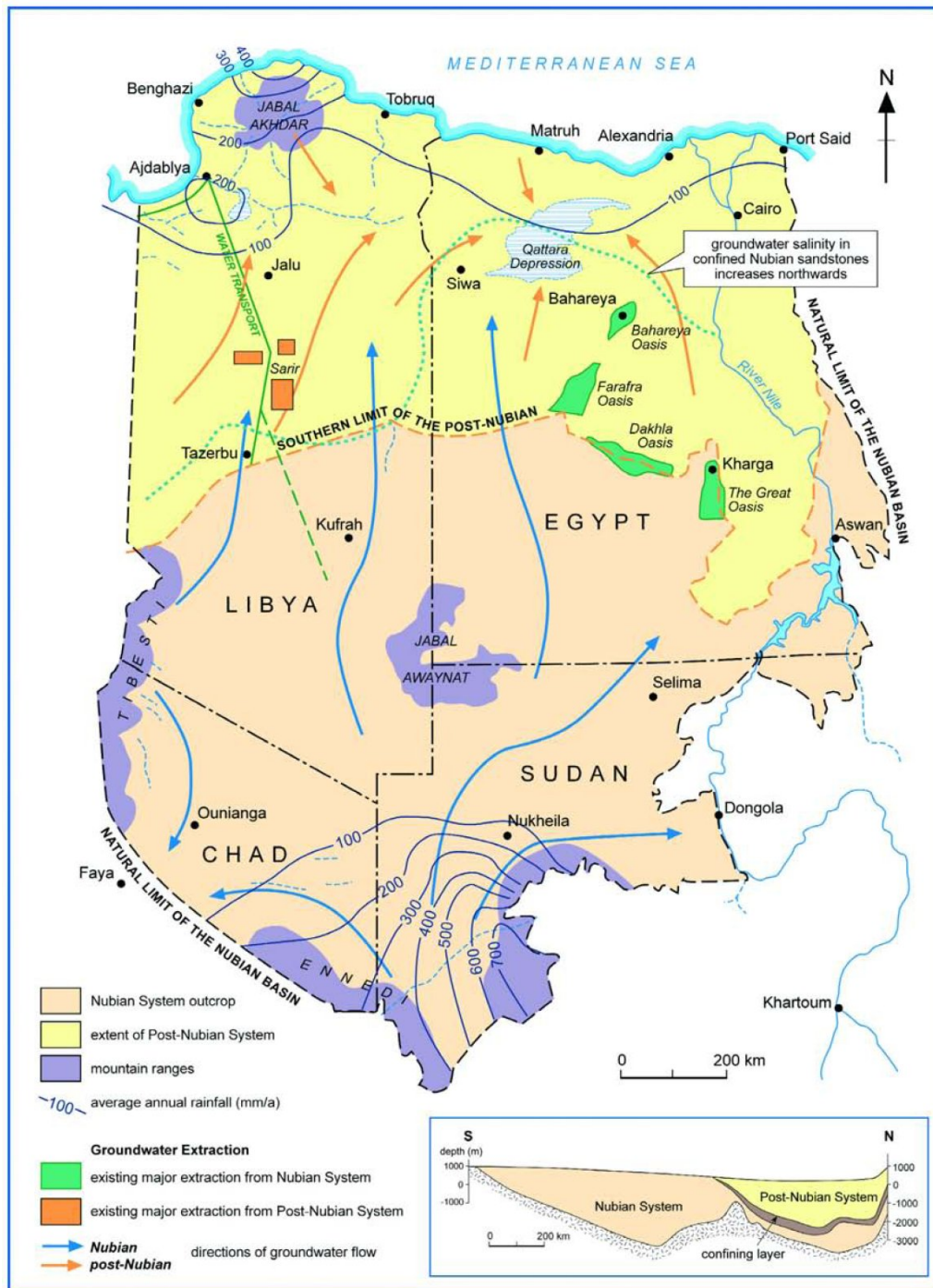


Figure 5-11: Extension of the Nubian Sandstone Aquifer System /UNESCO 2006/

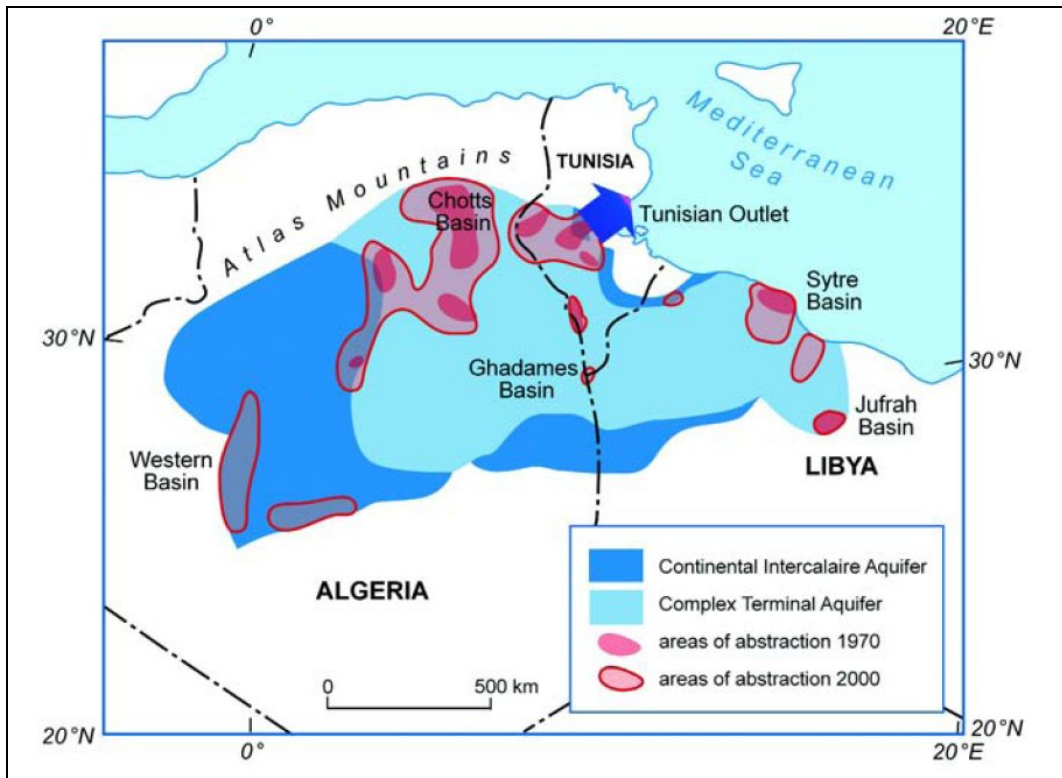


Figure 5-12: North-Western Sahara Aquifer System /UNESCO 2006/

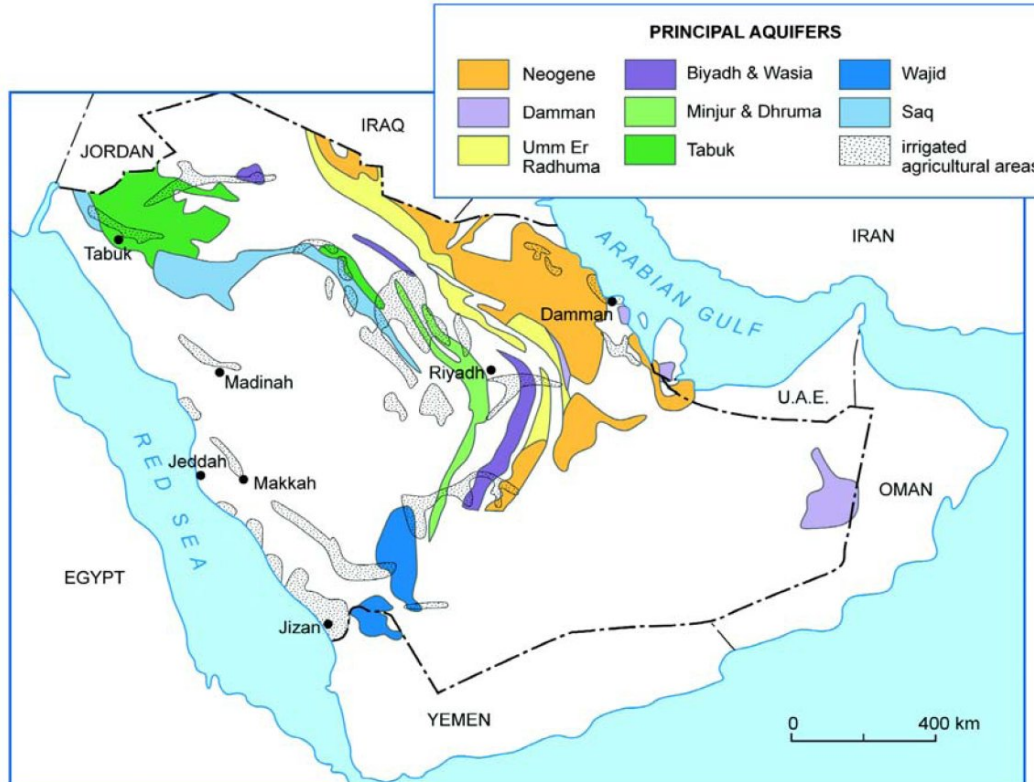


Figure 5-13: Saudi Arabian Aquifer Systems /UNESCO 2006/

The **Sustainable Groundwater Potential**, as used in /IWRM 2007/, refers to the total rates that can be abstracted on a sustainable base; for future uses the term reserves is utilized. Sustainability, on the other hand, can be given several definitions. However, in all cases, the quality of the resource base should be maintained suitable to the originally allocated sector (i.e. no deterioration) and the environment enhanced. Three distinct examples are given below.

- In the case of *renewable groundwater from external sources* (e.g. coastal aquifers and shallow wadi aquifers), the permissible development should be equal to the rate of recharge. This may not imply that the time span be restricted to a season or a year.
- In the case of *renewable groundwater from internal sources* (e.g. the Nile alluvium), the permissible development should be equal to the recharge without affecting flow in surface water channels and the river. Again, this does not imply specific time spans.
- In the case of *non-renewable groundwater* (e.g. the Nubian sandstone, Moghra), the permissible development is made to satisfy the economy of developmental activities and to ensure that groundwater will serve several generations (up to e.g. 500 years).

Based on the previous criteria, the Egyptian groundwater potential, uses and reserves have been assessed, as summarized in Table 5-4. The total sustainable potential is reported to be in the order of 12.5 Bm<sup>3</sup>/y, of which 7 Bm<sup>3</sup>/y were already used in the year 2000. With respect to that year, groundwater resources in Egypt offer an additional sustainable potential of only 5.5 Bm<sup>3</sup>/y. In our reference scenario, the sustainable groundwater potential is already fully exploited by 2010. In the business-as-usual case, exploitation would exceed in the long-term 50 Bm<sup>3</sup>/y. In the AQUA-CSP reference scenario, exploitation reaches a maximum of 17.5 Bm<sup>3</sup>/y by 2020 and is later reduced to zero. This means that in Egypt – like in most MENA countries – the threshold of sustainable groundwater exploitation is likely to be overshoot significantly in the coming decades, even in the case of the AQUA-CSP reference scenario, but worse in a business-as-usual case. Figure 3-11 in Chapter 3 shows the most critical groundwater withdrawals as percentage of save yield for the countries in MENA (see Annex for scenario data for all MENA countries).

Region	Potential (million m <sup>3</sup> /year)	Usage in 2000 (million m <sup>3</sup> /year)	Reserves (million m <sup>3</sup> /year)
Delta	5,220	4,195	1,025
Valley	3,170	1,932	1,238
Western Desert	3,748	817	2,931
Eastern Desert	90	8	82
Sinai	210	89	121
North-West Coast	80	2	78
<b>Total Egypt</b>	<b>12,518</b>	<b>7,043</b>	<b>5,475</b>

**Table 5-4: Sustainable Groundwater Potentials in Egypt /IWRM 2007/**

### 5.3 Performance of Water Utilities and Irrigation

Table 5-5 shows current indicators of the water sector in the analysed countries in MENA:

**Water Scarcity** is the ratio of total water use to water availability. Water scarcity will generally range between zero and hundred percent, but can in exceptional cases (e.g. groundwater mining) be above a hundred percent.

**Water Dependency Ratio** measures the share of total renewable water resources originating from outside the country. It is the ratio of the amount of water flowing in from neighbouring countries to the sum of total internal renewable water resources plus the amount of water flowing in from neighbouring countries expressed as percentage.

**Access to Save Water** gives the percentage of the total population of a country with reasonable access to an adequate amount of water from an improved source such as household connection, public standpipe, borehole, protected well or spring or rainwater collection.

**Public Utility Performance** is water sold as percentage of water supplied by utilities. The difference is caused by leaks or uncontrolled withdrawal from the distribution systems.

**Agricultural Water Requirement Ratio** is the ratio of the irrigation water requirement to the total agricultural water withdrawals of a country. It measures the efficiency of irrigation.

Country	Water Scarcity (%)	Dependency Ratio (%)	Access to Save Water (%)	Public Utility Performance (%)	Agricultural Water Requirement Ratio (%)
<b>North Africa</b>					
Algeria	40	3	76	49	37
Morocco	42	0	80	75	37
Egypt	106	97	72	50	53
Tunisia	57	9	87	82	54
Libya	720	0	68	(70)	60
<b>Western Asia</b>					
Lebanon	34	1	99	60	40
Jordan	115	23	95	55	38
Palestine	--	18	45	47	(20)
Syria	75	80	69	55	45
Iran	53	7	92	68	32
Iraq	55	53	--	(40)	32
Israel	110	55	100	(69)	(60)
<b>Arabian Peninsula</b>					
Bahrain	236	97	100	77	(60)
Yemen	157	0	30	36	40
UAE	1488	0	100	70	(60)
Oman	132	0	92	65	(50)
Qatar	538	4	100	65	(60)
Saudi Arabia	714	0	82	72	43
Kuwait	2070	100	100	62	(60)
<b>Goal</b>	--	--	<b>100</b>	<b>85</b>	<b>70</b>

Table 5-5: Water indicators for the analysed MENA countries: ( ) own estimate, -- no data.  
Sources: /FAO 2003/, /AQUASTAT 2007/, /World Bank 2007/, /Blue Plan 2005/.

A study by the Center for Environment and Development for the Arab Region and Europe (CEDARE) has thoroughly analysed the potential water savings until the year 2025 for most of the countries analysed in AQUA-CSP except for Iran, Israel and Palestine (Table 5-6). The results show an astounding conformity with the results of the AQUA-CSP model scenario for the year 2025, although both results were obtained by very different approaches (compare Chapter 3 with /Abu-Zeid et al. 2004/).

Country	Potential Total Irrigation Savings M m3/year	Potential Total Domestic Savings M m3/year	Potential Total Indust./Com. Savings M m3/year	Potential Treated Wastewater For Reuse M m3/year	Total Potential Water Savings M m3/year
ALGERIA	422	567	13.2	1785	2,787
BAHRAIN	20	44	0.2	80	144
EGYPT	6,733	1510	78.3	7298	15,620
IRAQ	7,139	743	48.5	4332	12,263
JORDAN	179	167	0.9	292	638
KUWAIT	49	96	0.2	126	271
LEBANON	111	146	0.8	299	557
LIBYA	975	391	2.8	751	2119
MOROCCO	1,358	246	5.5	744	2,353
OMAN	296	51	0.8	109	457
QATAR	32	31	0.2	39	102
SAUDI ARABIA	3,189	1014	4.4	1803	6,010
SYRIA	2,201	302	5.9	507	3,016
TUNISIA	387	129	1.7	298	815
U.A.E.	179	203	3.0	431	816
YEMEN	582	148	0.8	286	1017
<b>Total</b>	<b>23852</b>	<b>5787</b>	<b>167</b>	<b>19180</b>	<b>48985</b>
<b>AQUA-CSP</b>	<b>22902</b>	<b>4389</b>	<b>3144</b>	<b>18467</b>	<b>48902</b>

**Table 5-6: Potential for water savings in the MENA countries except Iran, Israel and Palestine until 2025 from /Abu-Zeid et al. 2004/ and savings resulting from the AQUA-CSP Reference Scenario compared to the Business-As-Usual Scenario as described in Chapter 3. The difference in “Industrial Savings” is probably due to a different aggregation of measures (municipal distribution is included in both “domestic” and “industrial” in case of AQUA-CSP, while in /Abu-Zeid et al. 2004/ it is allocated to the domestic sector.**

**Irrigation efficiency** can be increased by adopting proper irrigation scheduling, precision land levelling, use of modern on-farm irrigation systems (sprinkler & drip irrigation), cleaning and maintaining furrows, canal lining, use of dikes to prevent undesirable surface drainage, improved crop management and use of low water consumption crop varieties /FAO 2002/.

**Domestic/Municipal water efficiency** can be increased by reducing leakages from the municipal distribution grid in- and outside buildings, by improving the maintenance of supply networks, by introducing reliable metering devices to increase accountability, by introducing water saving devices like low flow shower heads, washing machines, dish-washers and low-volume toilets, and by landscape water conservation like planting plants native to the region, rainwater harvesting from rooftops in cisterns and gray-water reuse for the irrigation of parks and other public areas. Delivering water for urban uses and expanding delivery networks to surrounding

sub-urban and rural neighbourhoods can benefit greatly from improved regional delivery technologies /Sandia 2005/.

**Industrial and commercial water efficiency** can be improved by avoiding leakages in the industrial distribution systems for water and steam, self closing faucets, low flow toilets, and a multitude of potential water savings within the specific production processes, including the multiple use of water for different cascaded processes and the recycling of waste water. Infrastructure improvements include the addition of grey water plumbing to facilitate reuse on a grand scale within individual buildings and process chains /Sandia 2005/, /Tropp 2006/.

**Reuse of wastewater** is a possibility of water saving common to all water sectors. Sewage treatment facilities in MENA tend to lag behind water provision. There are human health risks of discharges of untreated sewage to surface and groundwater. There is also a threat of discharges of untreated sewage to the oceans, seas and on marine ecosystems and wetlands. Wastewater treatment provides opportunities to increase the use of waste water in agriculture. The percentage of population served with water supply and sanitation varies from one country to another. As more water supply and sanitation coverage is provided, the potential for reuse of treated wastewater increases. It has to be noted that domestic wastewater can reach up to 80 % of domestic use if efficiently collected and if countries are fully equipped with sewage treatment facilities /Sandia 2005/, /Tropp 2006/.

**Unaccounted for Water (UFW)** is a major loss term in municipal water distribution systems. UFW is the difference between the amount of water sold and the amount of water supplied, expressed as a percentage of the amount of water supplied. Well managed systems achieve values of 10-15 percent. In developing nations UFW values can range from 39 to 52 percent /Sandia 2005/. UFW is a function of leakage from old transmission systems, poor metering and/or poor management. Reducing UFW in developing nations generally calls for modernization of pumping and distribution systems – which could be considered more of a governance and economic problem than a technical problem /World Bank 2007/. New technologies designed to monitor and detect system weaknesses (breaks, leakages) could help eliminate some water loss. These monitoring technologies would be linked to distribution management centres located at key nodes around the distribution system, and could allow for the quick identification and repair of system weaknesses. Improvements to all these technologies would lead to greater volumes of conserved municipal water, but in these cases the real bottleneck is not at the technological level but at the policy level. Development of various kinds of fiscal incentives to drive the conversion to low-volume appliances, water harvesting and reuse are likely to have much larger impacts on water conservation than will marginal improvements to domestic water conservation technologies. Reducing water subsidies to farmers and factories would create further economic incentives to adopt water-efficient agricultural practices. In turn, public education and marketing campaigns to sway the public's perception on the necessity of

such measures will also be necessary. The political will necessary to enact such changes has proven to be the most formidable barrier in their implementation /Sandia 2006/, /World Bank 2007/.

*Investment for achieving water savings* is estimated to be around 2.6 €/m<sup>3</sup> for irrigation, 4.9 €/m<sup>3</sup> for domestic use, 2.8 €/m<sup>3</sup> for industrial and commercial use and 1.75 €/m<sup>3</sup> for recycled and treated wastewater reuse /Abu-Zeid et al. 2004/. Using a capital recovery factor of 7.1 %/y (5 %/y discount rate, 25 years life), this translates to a cost per cubic metre of saved water of 0.19 €/m<sup>3</sup> for irrigation, 0.35 €/m<sup>3</sup> for domestic water, 0.20 €/m<sup>3</sup> for industrial water and 0.12 €/m<sup>3</sup> for wastewater reuse. These figures compare favourably with a desalination cost of around 0.50-0.70 €/m<sup>3</sup> and even with the cost of overexploiting groundwater, as will be shown in Chapter 5.4, and demonstrate the natural priority of efficiency measures in the water sector.

However, comparing the saving potentials to the growing gap opening between sustainable natural sources and freshwater demand as shown in Chapters 3 and 4, it becomes clear that increasing efficiency alone will not solve the problem. New sources of freshwater must be found, and they must be secure, sustainable and affordable for municipal use as well as for agriculture.

#### **5.4 The Cost of Doing Nothing**

The arid basin of Sana'a possesses a Quaternary alluvial aquifer locally overlying a deeper Cretaceous Sandstone aquifer for which there is no evidence of significant recharge and which presently contains mainly fossil groundwater (Figure 5-14). In the absence of regulation some 13,000 water wells have been constructed for urban and rural water supply and to irrigate some 23,000 ha. These wells extract groundwater in part from the deep aquifer. As a consequence groundwater levels are falling by 3-5 metres per year as a result of the imbalance between groundwater extraction and recharge /UNESCO 2006/.

Options for resolving the imminent Sana'a water crisis have been investigated by members of the Trans-Mediterranean Renewable Energy Cooperation (refer to the Annex). According to a preliminary analysis, lasting solutions can be achieved by seawater desalination at the Red Sea coast using solar energy from concentrating solar power. There are 2 fundamentally different solutions for Sana'a:

- Seawater is desalinated and pumped to Sana'a using CSP plants located near Al-Hudaydah at the Red Sea coast ("Saving Sana'a" solution)
- The large majority of Sana'a population is relocated to coastal regions like Al-Hudaydah and others ("Sana'a Relocation" solution)

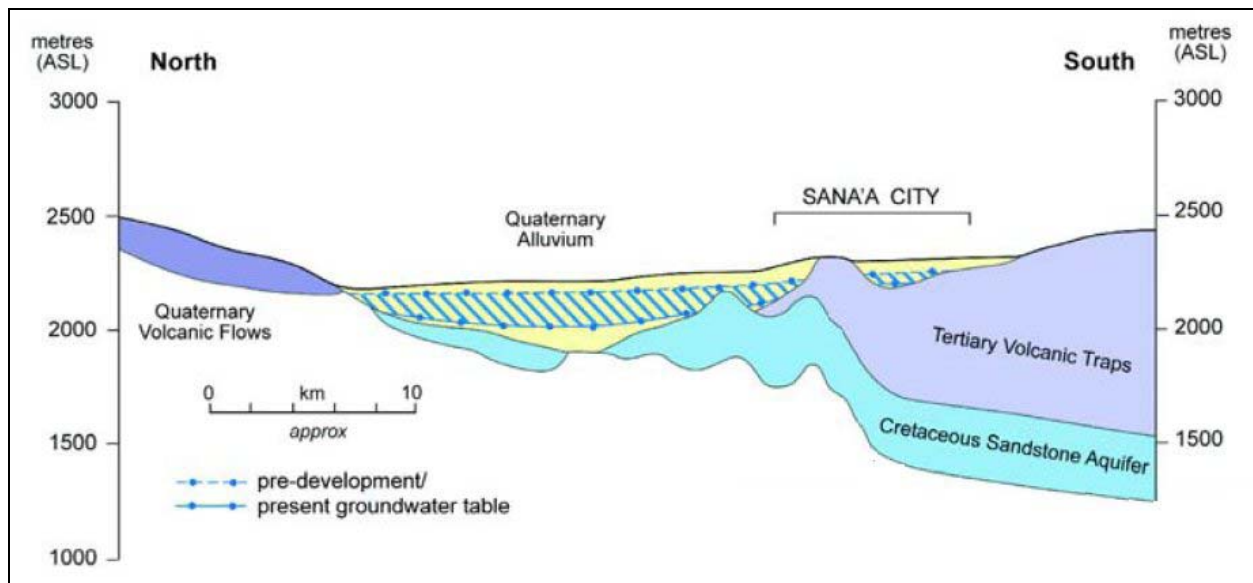


Figure 5-14: Sana'a Basin Aquifer System /UNESCO 2006/

In both cases, desalination plants with a cost of 4 Billion US\$ would have to be installed at the sea shore to supply additional water for 2 million people. Building new settlements for 2 Million relocated people will cost over 35 Billion US\$, while the costs for a pipeline and a concentrating solar power plant for desalting and pumping 1 Billion m<sup>3</sup> water per year to Sana'a will require about 6 Billion US\$ /TREC 2006/. The amount needed for "Saving Sana'a" is equivalent to the world market value of 2 % of the proven Yemeni oil reserves. Operating costs will be around 1US\$/m<sup>3</sup>. Construction of the pipeline can be well controlled, while relocation of 2 Million people can lead to conflicts and surprises and can induce uncontrollable developments including armed hostilities (see the following box from /World Bank 2007/). Socially, logistically, financially, politically and internationally a continuation of Sana'a by supplying freshwater through a pipeline from the Red Sea is preferable to relocating its population. In spite of that, the Yemeni government has not reacted up to now to that proposal.

The UNESCO World Heritage of the old city of Sana'a may be a rather spectacular case of water crisis in the Middle East and North Africa, but unfortunately it is no exception. Many cities in MENA suffer from water shortage and there is an increasing competition of rural and urban areas for water, as will be discussed later in Chapter 5.5. Water scarcity is becoming a major barrier for economic development.

Table 5-7 (left) shows an estimate of the impact of groundwater depletion originating from **overuse of groundwater** on the gross domestic product (GDP) of several MENA countries /World Bank 2007/. If these numbers are used to calculate the cost of those excessive water withdrawals (Table 5-7, right), the resulting cost of water including the cost of production and the loss of GDP ranges between 0.58 \$/m<sup>3</sup> and 1.86 \$/m<sup>3</sup>, which is already today higher than the cost of seawater desalination, and much higher than the cost of efficiency measures.

### Water and Land Disputes Leave Many Dead, According to the Yemeni Press

“Six people were fatally shot and seven injured in tribal clashes in Hajja which broke out two weeks ago and continued till Tuesday between the tribes of al Hamareen and Bani Dawood. Security stopped the fighting and a cease fire settlement for a year was forged by key shaykhs and politicians. The fighting was triggered by controversy over agricultural lands and water of which both sides claim possession. Meanwhile...there is speculation of retribution attacks on government forces which used heavy artillery and tanks to shell several villages in al-Jawf...” (*Al Thawra* 1999).

“Sixteen people have been killed and tens injured since the outbreak of armed clashes between the villagers of Qurada and state troops, who used heavy artillery and rockets to shell the village. Scores of villagers were arrested and hundreds fled their homes. The incident began when Qurada refused to share well water with neighboring villagers” (*Al Shoura* 1999).

	Cost of Groundwater Depletion % GDP	GDP 2005 B\$/y	GDP Lost M\$/y	Overuse Bm <sup>3</sup> /y	Cost of Groundwater Depletion \$/m <sup>3</sup>	Cost of Production \$/m <sup>3</sup>	Total Cost \$/m <sup>3</sup>
Algeria	1.2	90	1080	0.7	1.54	0.32	1.86
Egypt	1.3	85	1105	4.0	0.28	0.30	0.58
Jordan	2.1	12.5	263	0.2	1.31	0.25	1.56
Tunisia	1.2	33	396	0.6	0.66	0.30	0.96
Yemen	1.4	15	210	2.5	0.08	0.50	0.58
<b>Total</b>		<b>532</b>	<b>3054</b>	<b>8.0</b>	<b>0.38</b>	<b>0.36</b>	<b>0.74</b>

Table 5-7: Cost of groundwater depletion in some MENA countries from /World Bank 2007/ and own calculations of the resulting cost of water (blue section)

To this adds a loss of water and GDP due to **environmental degradation** in the same order of magnitude (Table 5-8). The countries analysed in those two tables alone suffer a loss of GDP of over 11 billion US\$/year due to groundwater overuse and environmental degradation. It is obvious that almost any measure, ranging from efficiency enhancement to reuse of wastewater and seawater desalination would be more cost effective than the presently ongoing depletion. Unfortunately, this simple truth is often hidden by subsidies, either of energy for groundwater pumping or directly by subsidizing the water supplied.

However, these numbers also show the trap in which many MENA countries find themselves at present: the loss of GDP creates a scarcity of funds that avoids investment into new, more sustainable sources. It becomes more and more difficult to find a budget for investment in

innovations, because increasing production cost and increasing budget losses due to depletion bind public funding that would be required for a change. This trap is quickly closing, and some countries may already be beyond the point of being able to free themselves, even if they realised the situation. On the other hand, there are also countries that would in principle be capable of changing, but are structurally unable or unwilling to do so or uninformed about alternatives /World Bank 2007/.

	<b>Cost of Environmental Degradation</b> % GDP	<b>GDP 2005</b> B\$/y	<b>GDP Lost</b> M\$/y
Algeria	0.8	90	720
Egypt	1	85	850
Iran	2.7	193	5211
Jordan	1.2	12.5	150
Lebanon	1	20	200
Morocco	1.3	58	754
Syria	0.9	25	225
Tunisia	0.6	33	198
Yemen	0.6	15	90
<b>Total</b>		<b>532</b>	<b>8398</b>

**Table 5-8: Cost of environmental degradation of water sources in MENA /World Bank 2007/ and own calculations**

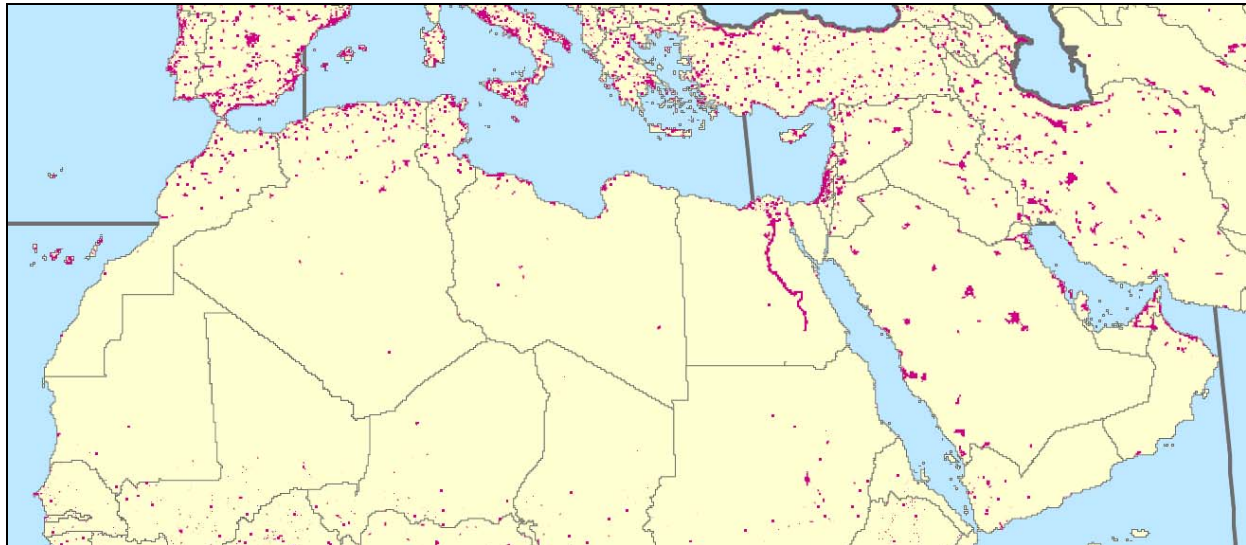
## 5.5 Urbanisation versus Rural Development

The Middle East and North Africa has one of the fastest growing populations in the world with an average annual growth rate of 2.1 percent in the past decade. The population is growing from around 100 million in 1960, through a present 311 million to a projected 430 million in 2025, bringing the available amount of water per capita in many countries to far below the scarcity level. Most of population growth has occurred in urban areas, where the population share is expected to exceed 70 percent by 2015. The urban growth rate has been around 4 percent per year during the last twenty years /World Bank 2005/.

The region's 25 largest cities are expected to grow with 2.7 percent per year between 2000 and 2010 /UN-Habitat 2004/. Whereas Bahrain, Kuwait and Qatar were already 80 percent urban in the 1970s, the region's lesser urbanized nations all have experienced sharp urban population increases – a trend expected to continue (see also Figure 3-2).

Statistically Egypt, Sudan and Yemen will be the only MENA nations less than 50 percent urbanized in 2015. However, the Nile Valley could already today be considered a large single urban structure (Figure 5-15) and it is likely that single settlements will slowly grow together, if they have not done so already. Around 2030 nine MENA countries will likely be more than 90

percent urban: Bahrain (95.8 percent), Israel (94.5 percent), Kuwait (98.4 percent), Lebanon (93.9 percent), Libya (92.0 percent), Oman (95.2 percent), Qatar (95.9 percent), Saudi Arabia (92.6 percent) and the United Arab Emirates (93.3 percent) /Tropp 2006/.

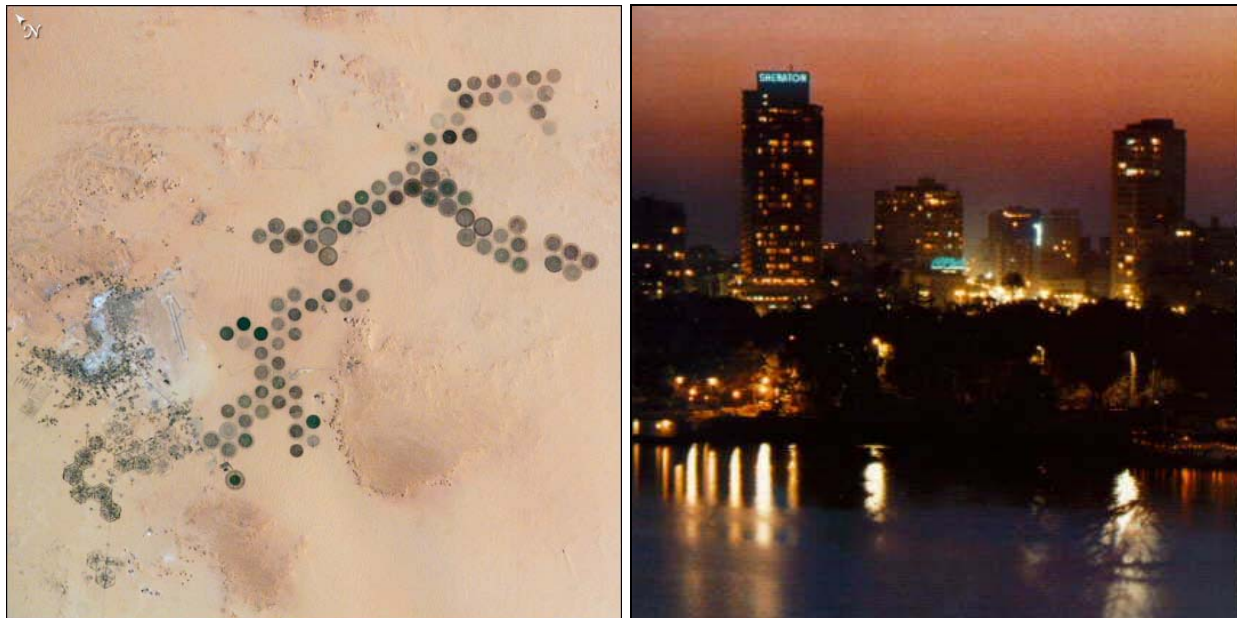


**Figure 5-15: Urban settlements with more than 5000 inhabitants in MENA (red areas) /CIESIN 2005/**

According to /Tropp 2006/ “a common feature of urban transition in most developing countries is that the relative urban growth is higher in small- and medium-sized urban areas as compared to mega cities. The MENA region is no exception. In 2000, the MENA region had 16 cities of over 1 million inhabitants, with only Cairo, Istanbul and Tehran exceeding 5 million. By 2010, there will probably be 24 cities of over 1 million within the region. It is forecast that by 2015, six cities will be larger than 5 million, with Cairo and Istanbul both exceeding 11 million. Tehran and Baghdad will remain the third and fourth largest cities, with 6.9 and 4.8 million /UN-Habitat 2004/. Small- and medium sized cities tend to have lower levels of services compared to bigger cities. It is thus essential that more focus is put on those cities that currently are below or around 1 million inhabitants. Such a focus presents opportunities to apply innovative water technologies and practices more widely and to avoid past mistakes of unplanned development in mega cities.”

As a conclusion of his analysis of the water situation in MENA, Tropp states that “there is evidently no blueprint solution to the challenges related to water and irrigated agriculture in the region. Most countries in the region face acute problems related to water scarcity that are amalgamated by the highly complex political map of the region and difficulties to re-think agricultural policies. Many countries in the region are at a crossroads over their future use of water for irrigated agriculture. A critical question for many countries in the region is: *Is agriculture an economically viable option?* Despite that some countries have managed to shift into more high-value crops, such as fruits and flowers, it is not realistic to perceive that all

countries will be able to follow such a path. It is also required to resolve the insufficient provision of drinking water supply and sanitation. Some countries in the region, for example Egypt, seem to be on track to meet the Millennium Development Goals (MDGs) on water supply and sanitation, while Yemen is far off the MDG mark.



**Figure 5-16: Astronaut view of agricultural fields using centre pivot irrigation at Al Khufrah Oasis in South-Eastern Libya (left) and a view of Cairo from the Nile River at night (right)**

The most water-scarce countries in the region will thus have to pose some very serious questions related to irrigated agriculture. ***Can current levels of irrigated agriculture be maintained in the long run?*** What are the environmental, social and political costs of maintaining current levels of water allocation? There is increasing evidence that unless countries apply economic policies that shift away from increased water use, water will continue to fuel political tensions between and within countries. It is somewhat hopeful that the much-hyped “water wars” are increasingly being replaced by a new type of thinking: Water for long-term stability in the region. However, much remains to be done before such a way of perceiving shared waters impacts political levels and the practice of politics in the region.

In developing local and national financing and adaptive strategies to water scarcity and climate variability, the ***role of virtual water*** (water virtually provided with food imports) should also be considered. Alternatively, or as a supplementary measure, countries can diversify economies and shift away from water intensive agriculture and industries to reduce water scarcity as well as drastically reduce investment needs. Structural shifts away from water-intensive irrigated agriculture and industries could decrease economic vulnerability to droughts and land degradation. Equally and sometimes even more important is the shift towards sectors where the

country or a community has a comparative advantage in terms of water use efficiency. Relying on trade in virtual water to meet a country's power supply and food needs could drastically reduce unsustainable water use. Furthermore, it could also mitigate the need for diverting national resources as well as foreign direct investment and aid towards costly water supply projects to support water intensive activity in areas that do not have the necessary water resources" (end of quotation of /Tropp 2006/).

The message is clear: stop consuming a lot of water by growing plants in the deserts and rather import virtual water by directly importing food from places that have better resources available.

However, problems arising from international marketing of agricultural products are well known: countries importing virtual water in form of food will also import virtual and actual subsidies from rich countries against which their own farmers will have to compete in local markets. Virtual water markets suffer from the same distortions as the markets for the products that facilitate water exchange /World Bank 2007/. This and the reduction of domestic market volumes would directly impact rural economy and livelihood, and consequently aggravate urbanisation. A shift of farmers to high income - low water crops could alleviate some of those impacts, but markets for "fruits and flowers" are usually risky and limited and could collapse if everybody jumped into.

Another major concern is the interaction of food imports and food security, as imports will have to be financed by other sources of income. Therefore, food imports may be an attractive option e.g. for oil-producing countries with huge foreign income, but may be a considerable challenge for countries that depend on food imports and energy imports as well.

## 5.6 Cultivating the Desert

In general, seawater desalination is not considered a viable option for resolving water scarcity in arid regions like the Middle East and North Africa. The Human Development Report 2006 /HDR 2006/ states that "A major constraint on commercial desalinization is the cost of energy. Due to innovation and development, production costs have fallen and output increased. However, the sensitivity of production costs to **energy prices**, allied to the high costs of pumping water over long distances (to cities lying further inland<sup>1</sup>), creates restrictive conditions. For oil-rich countries and relatively wealthy cities close to the sea, desalinization holds out promise as a source of water for domestic consumption, but the potential for addressing the problems of poor cities in low-income countries is more limited, and desalinization is unlikely to resolve the fundamental mismatch between supply and demand in water. It currently contributes only 0.2 % to global water withdrawals and holds limited potential for agriculture or industry (Figure 5-17).

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<sup>1</sup> note from the author

“If we could ever competitively, at a cheap rate, get fresh water from saltwater, this would be in the long-range interests of humanity and really dwarf any other scientific accomplishment”, observed US President John F. Kennedy. Practiced since biblical times, the creation of fresh water by extracting salt from sea water is not recent human endeavour. But does it offer a solution to problems of water stress and scarcity?” (end of quotation).

The answer is clearly “no”, if water supply by desalination would depend on fossil fuels, because fuel prices could escalate further to an unaffordable level and finally fuels could be depleted on a world wide scale. Loosing those primary fossil resources for energy supply would be bad enough, but loosing the related freshwater resources as well would be catastrophic.

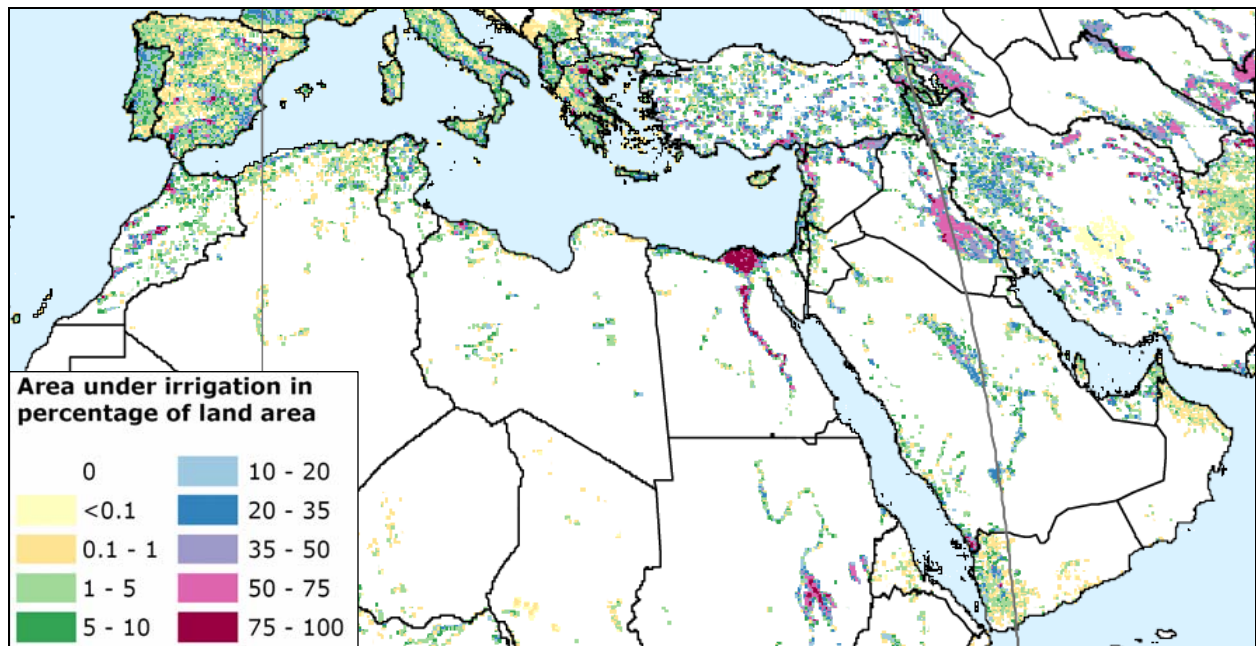
However, the answer is clearly “yes”, if desalination is based on a renewable and secure resource of energy that is compatible with the environment and becomes cheaper with time. This is reflected in our reference scenario in Chapter 4, where fossil-fuel-based desalination disappears in the long-run after reaching a maximum share of 6 % by 2030, while CSP-desalination achieves major shares of freshwater supply after being introduced to the market. Unfortunately, present decision makers within the water sector are not yet familiar with this option, and consequently exclude seawater desalination from their portfolio of possible solutions to the MENA water crisis or only consider it as a marginal element of supply.

<p>Desalination is a technical option for creating fresh water from sea water. Distilling sea water by boiling it and collecting the vapour is an age-old activity—an activity transformed over the past 20 years through new technologies. But there are limits to its scope.</p> <p>In 2002 the global market for desalination stood at \$35 billion. There are now more than 12,500 plants operating in 120 countries. Traditionally, desalination has taken place through thermal heating, using oil and energy as the source. The most modern plants have replaced this technology with reverse osmosis—forcing water through a membrane and capturing salt molecules. The costs of producing water from this source have fallen sharply, from more than \$1 per cubic metre a decade ago to less than half that today. The energy to drive the conversion is a significant part of the cost.</p> <p>Israel provides the gold standard in water desalination. Following implementation of a planning strategy launched in 2000—the Desalination Master Plan—the country now generates about a quarter of its domestic fresh water through desalination. The \$250 million Ashkelon Plant, which began operation in 2005, is the world’s largest and most advanced reverse osmosis facility, producing fresh water at a cost of \$0.52 per cubic metre. It supplies about 15% of Israel’s fresh water used for domestic consumption. Current plans envisage an increase in production from desalination plants from 400 million cubic metres today to 750 million cubic metres by 2020.</p> <p>Current desalination capacity is heavily concentrated. The Gulf states account for the bulk of capacity, with Saudi Arabia</p>	<p>accounting for one-tenth of total output. Elsewhere, Tampa Bay in Florida and Santa Cruz in California have adopted reverse osmosis plants, and China has announced plans for a plant in Tianjin, its third largest city. In Spain the new government abandoned plans to pump water across the country from the wet north to the arid south in favour of 20 reverse osmosis plants (enough to meet 1% of needs), though the costs of desalinated water may not entice farmers from their current groundwater irrigation sources. In the United Kingdom the water utility serving London has a reverse osmosis plant that will come into operation in 2007.</p> <p>This pattern of distribution highlights both the potential and the limits of desalination. While costs are falling, the capital costs of new plants are considerable and operating costs are highly sensitive to energy prices. Recent projects in Israel and other countries demonstrate this, with tenders for water supply rising to \$0.80–\$1.00 per cubic metre. The cost of pumping water rises sharply with distance as well, so that inland cities would face higher cost structures. These factors help to explain why oil-rich states and coastal cities in water-stressed areas will probably remain the main users.</p> <p>Overall use patterns are likely to change slowly. In some countries desalination can be expected to account for an increased share of domestic and industrial water use. Municipalities currently account for two-thirds of use and industry for a quarter. The potential in agriculture is limited by cost. That is especially so for producers of low value-added staple crops that require large volumes of water.</p>
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**Source:** Rosegrant and Cline 2003; Schenkeveld and others 2004; Rijsberman 2004a; BESA 2000; Water-Technology.net 2006.

**Figure 5-17: Desalination – And its Limits. Source: Human Development Report 2006 /HDR 2006/**

Cultivating the desert is an old dream of humanity. Vast areas are there, soils are rather fertile, but cannot be used due to the lack of water. Today, considerable areas in the MENA deserts are already cultivated, most of them using (fossil) groundwater or water from rivers coming from outside into the country, like the Nile (Figure 5-18). In the previous chapters we have seen that in terms of water consumption, the region is now reaching or surpassing its natural limits.



**Figure 5-18: Irrigated areas in the MENA region.** The map depicts the area equipped for irrigation in percentage of cell area. For the majority of countries the base year of statistics is in the period 1995-2000 /FAO 2005/. Al-Khufra Oasis from Figure 5-16 (left) is the point located in the lower right corner of Libya.

But what if the vision of John F. Kennedy became true and we could cheaply obtain freshwater from saltwater? The consequences for MENA would be striking: MENA could become self-sufficient in food production in spite of its growing population and without having to deplete its fossil energy and water resources. Using solar energy for seawater desalination would effectively fight the problem of water scarcity by making use of the main cause of this problem itself: the intensive solar irradiance in the MENA region.

Concentrating solar power can already today compete with unsubsidised world market prices of fuel oil and is heading for competitiveness with natural gas by 2010. Ten years later, around 2020, it will be even cheaper than coal. After that, costs will further decline, due to technological learning, competition and economies of scale, and as we have seen in Chapter 5.1, the combination of seawater desalination with power generation could allow for water prices that would even become competitive for irrigation.

What if seawater could be desalted on a large scale for municipal use and for irrigation, and if at the same time the best use of water would be achieved by increasing the efficiencies of distribution, waste-water recycling and end-use of water? On a large-scale, this could have the effect of re-filling existing or already depleted groundwater resources by seepage and thus increasing the – in that case renewable – groundwater resources in the MENA region, that could be further used in the traditional way by groundwater pumping. This would be something like a natural recycling of part of the desalted seawater.

What if the only reason why seawater desalination is today not considered sustainable by most decision makers – its high energy consumption – is removed by a sustainable form of energy from the MENA region itself? What if imports of food, virtual water and energy could be replaced by a resource that is domestic to MENA: by solar energy? The AQUA-CSP study shows that such a source is available and the necessary technology is ready for the market in form of concentrating solar power for seawater desalination.

Concentrating solar power (CSP) is a unique source of energy in the MENA region. It is available everywhere in very large amounts. It is a very concentrated, easily controllable and storable form of energy. It is already affordable today and becoming cheaper with time. It is compatible to the environment and can be used for multiple purposes like power generation, seawater desalination, cooling and even for shading, if linear Fresnel technology is applied (Figure 5-19).

As proposed by the Trans-Mediterranean Renewable Energy Cooperation /TREC 2006/, concentrating solar thermal power stations in MENA could be used for export electricity to Europe and for providing regional freshwater from combined thermal desalination of sea water. In the TRANS-CSP study /TRANS-CSP 2006/, we have analysed the potential of combining CSP exports to Europe with local sea water desalination for the MENA region.

The combination of export solar electricity with sea water desalination will have only a moderate contribution to the coverage of the water deficit, because CSP exports will start relatively late, compared to the extremely pressing situation in the water sector. CSP plants exclusively producing water with reverse osmosis and thermal multi-effect desalination and MED plants coupled to domestic solar power generation will provide the core of the desalination capacity in MENA. In the year 2050, a maximum 30 billion m<sup>3</sup>/y could be desalted by about 40 % of the installed CSP export plants, covering roughly 20 % of the freshwater deficit. 25 billion m<sup>3</sup>/y would be desalted by domestic CSP plants, while 110 billion m<sup>3</sup>/y must be desalted by exclusive CSP desalination plants with RO and MED.

Electricity produced in CSP plants can be used for domestic needs and export, as well as for additional desalination of sea water through reverse osmosis (RO), if required. The design of such combined solar power and desalination plants can be flexibly adapted to any required size and need. The advantages of this concept lay at hand:

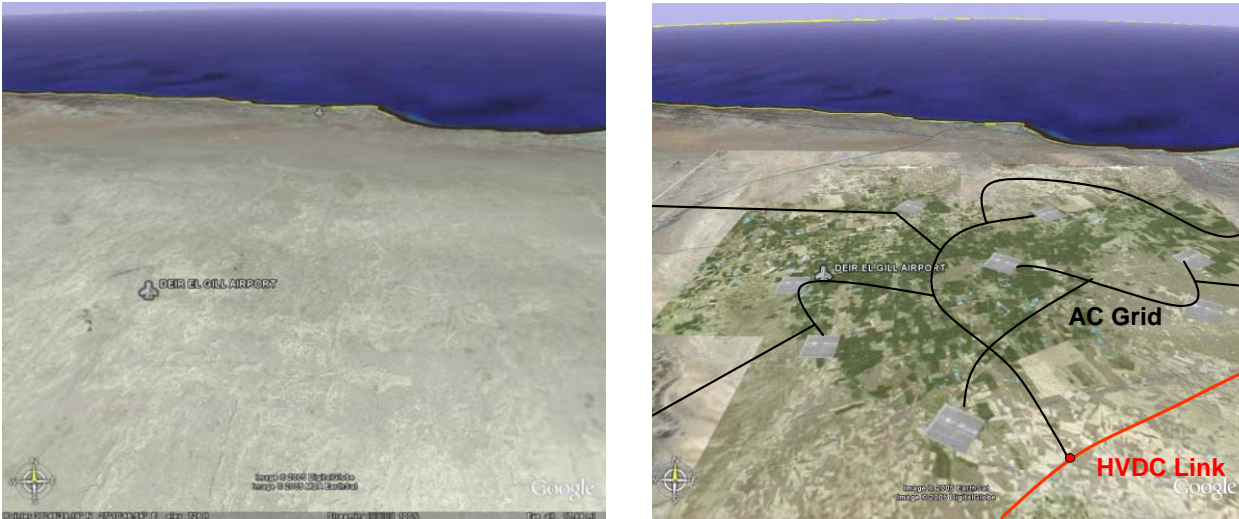


**Figure 5-19: Photo of the top of a Linear Fresnel Concentrating Solar Collector and artist view of a greenhouse installed underneath to protect the plants from excessive irradiance and evaporation. This could be a concept for multi-purpose plants for power, water and horticulture. Other local uses include shade for parking and the production of steam for cooling and process heat. (Source: Solarmundo, DLR)**

- outstanding overall conversion efficiency of over 80 % for both solar heat and fuel,
- outstanding economic efficiency through the second valuable product freshwater,
- energy, water and income for the sustainable development of arid regions.

Concentrating solar multipurpose plants in the margins of the desert could generate solar electricity for domestic use and export, freshwater from seawater desalination, and in addition provide shade for agriculture and other human activities. Such plants could turn waste land into arable land and create labour opportunities in the agriculture and food sector. Tourism and other industries could follow. Desertification could be stopped (Figure 5-20).

A brief introduction to the possibilities of integrated multi-purpose plants using CSP for energy, water and agriculture in the MENA region is given in the Annex. The brief study shows options for combination, suitable crops and the conditions required to achieve sustainable agriculture based on renewable sources in desert environments. The concept is being developed by members of the Trans-Mediterranean Renewable Energy Cooperation (TREC) and the German Section of the Club of Rome (CoR) and proposed in combination with an export strategy for solar electricity from the Middle East and North Africa to Europe ([www.trec-eumena.net](http://www.trec-eumena.net)).



**Figure 5-20: Left: typical region at the Mediterranean coast in Northern Egypt from Google Earth (left). Right: artist impression of the same region with large CSP plants for power and desalination connected to the national utility grid and to a trans-continental HVDC link that could be a key for the economic development of desert regions along the coasts of the Mediterranean Sea, the Red Sea and the Persian Gulf.**