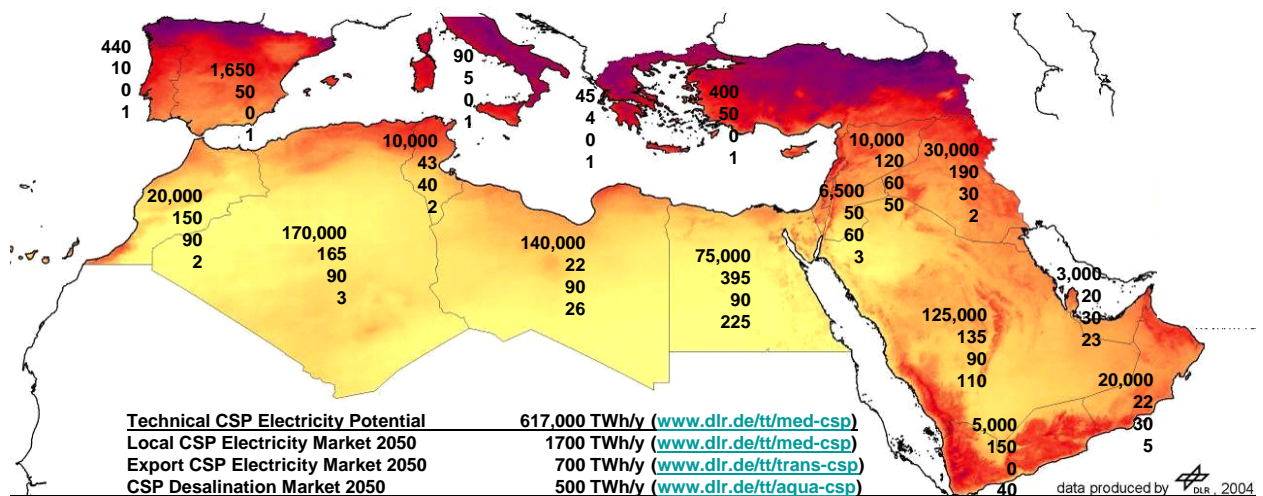


## 4. Seawater Desalination Markets in MENA

The analysis of water deficits in Chapter 3 shows that there is a pressing need for new, non-conventional, sustainable water sources in many countries of the MENA 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 future deficits. Although the demand of the agricultural sector, which in MENA makes up to 85 % of the total water demand, will not grow as fast as in the past decades, all countries will see a quickly growing demand of the urban centres and industry /Al-Zubari 2002/.

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 rate of renewal, making this solution not more sustainable than a dependency on fossil fuels for seawater desalination. A renewable, sustainable freshwater source with low and stable cost will be required.



**Figure 4-1: Concentrating Solar Power Potentials until 2050 in TWh/y. Techno-economic supply-side potential (top), potential for local electricity (second from top), potential for electricity export from MENA to Europe (third from top) and potential for seawater desalination (bottom). For better comparison, desalination potentials have been converted to electricity required by reverse osmosis. Background: Fig. 1-13.**

Within the study at hand, we have assessed the potential of desalination powered by CSP as a possible sustainable solution for water scarcity in MENA. The goal of our analysis was to find out whether future deficits could be covered by solar thermal power plants in co-generation with thermal multi-effect desalination and by using solar electricity for reverse osmosis. Other renewable sources of heat and electricity can also be used for these purposes. However, we have concentrated our focus on direct solar energy as it is by far the most abundant renewable energy

source in the MENA region. Within each country, the total technical potential of CSP for power generation and for RO and the specific coastal potential for combined generation of power and desalted water via MED has been assessed in /MED-CSP 2005/. Desalination must be seen only as one market segment of CSP, which has large market potentials for power generation, on one hand for local demand in MENA and Southern Europe, and on the other hand for solar electricity export from MENA to Europe. These potentials were assessed within the preceding studies /MED-CSP 2005/, /TRANS-CSP 2006/. The study at hand adds the potentials for seawater desalination. The results for each country and for the region as a whole are shown in Figure 4-1. For better comparison, desalination potentials have been converted to electricity as if supplied exclusively by reverse osmosis.

The general role of desalination in our developing world can be illustrated by quoting a study from the World Bank: “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<sup>3</sup>.

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. Although desalination is still more expensive than most existing conventional water sources, its cost is generally lower than 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” /World Bank 2004/.

The opinion of the World Bank quoted here is based on the paradigm of fossil fuel powered desalination, and in this context, it is quite reasonable: the cost of fossil fuels is increasing steadily, and environmental concerns are becoming imperative. However, it neglects the option of solar powered desalination at large scale, which is characterised by subsequently decreasing cost of solar energy and by reduced environmental impacts. Under this new premise, desalination can adopt a totally different position within a global strategy for sustainable water.

Nevertheless, before enough capacities of CSP-desalination can be realised in the medium-term, increasing water deficits will have to be bridged by fossil fuelled desalination and by groundwater withdrawals, hoping that those limited resources will remain available and affordable. A considerable increase of non-sustainable use of water will thus occur in the coming decades. This calls for an intensive additional use of renewable energy sources for non-conventional water production by desalination, and also calls for intensive freshwater management and efficiency enhancement in urban and rural applications. Only the resolute

employment and efficient combination of all possible measures will lead to a satisfactory and sustainable water supply in MENA. Seawater desalination with renewable energies must not be considered an alternative, but a complement to other measures to increase water efficiency as recommended by the United Nations and other organisations. Important factors for water sustainability are among others /FAO 2003/:

- increase irrigation efficiency (from presently less than 40 % to over 70 %)
- increase municipal water distribution efficiency (from presently less than 50 % to 85 %)
- increase general efficiency of all end uses of water by at least 1.5 % per year
- avoid upstream soil erosion by excessive logging and other activities
- concentrate agriculture on high value crops with low water demand
- avoid overexploitation of groundwater resources because this will cause the groundwater level to sink and favours the intrusion of salt water
- clean and reuse at least 50 % of municipal and industrial wastewater
- harvest rain water by small scale distributed basins and dams.

A sustainable supply can only be achieved in time if those measures are realised with high priority. Neglecting those measures would lead to an unacceptable future situation that would be worse than the one shown in our business-as-usual scenario in Chapter 3.6, which considers a moderate increase of efficiency. On the other hand, Chapter 3.6 also shows that enhanced efficiency and re-use of wastewater will be able to reduce, but not to remove the growing freshwater deficit of a population doubling until 2050. Extended seawater desalination will therefore become an imperative component of future freshwater supply in almost all MENA countries.

The future markets for seawater desalination were assessed in two ways. Firstly, a short term analysis by Global Water Intelligence /GWI 2004/ was taken as reference for an estimate of the “conventional” desalination potentials in the Middle East and the Mediterranean countries until the year 2015. For the long-term assessment, we used our own demand side assessment until 2050 shown before in Chapter 3, to estimate the future potential for CSP desalination.

## **4.1 Short-Term Desalination Markets until 2015**

The short term desalination capacities expected in the Middle East and Mediterranean countries until 2015 are shown in Figure 4-2 for both membrane and thermal desalination technologies. In 2002, a capacity of roughly 11 million m<sup>3</sup>/d of thermal desalination plants was installed in the total region, with most of it – almost 10 million m<sup>3</sup>/d – in the Arabian Gulf area. Membrane desalination summed up to a capacity of roughly 7 million m<sup>3</sup>/d, with 4.5 million m<sup>3</sup>/d installed in the Gulf region.

In the Gulf region, both technologies are expected to double their installed capacity until 2015, to 9 million m<sup>3</sup>/d for membrane and 19 million m<sup>3</sup>/d for thermal desalination. Thus, the Gulf region will remain the dominant desalination market world wide, with a visible preference for thermal desalination technology (Figure 4-3).

In the Mediterranean region, there is a visible preference for membrane technology, 2.5 million m<sup>3</sup>/d installed in 2002 growing to 8 million m<sup>3</sup>/d by 2015. Thermal desalination is used to a lesser extend but also growing considerably, with 1 million m<sup>3</sup>/d in 2003 growing to 4 million m<sup>3</sup>/d in 2015 (Figure 4-4). The figures show that the Mediterranean desalination market is smaller, but growing much faster than the Gulf market, and that there is a visible preference for membrane technology. Therefore, looking at both regions together, membrane desalination is slowly catching up with thermal desalination, with around 17 million m<sup>3</sup>/d of membrane technology and 22 million m<sup>3</sup>/d of thermal desalination capacity expected to be installed by 2015 (Figure 4-2).

There is no evidence of RO taking over considerable market shares from thermal desalination systems within the world’s largest agglomeration of desalination plants, the Gulf Region. Thus, thermal desalination will remain an important technology, with a subsequent substitution of older MSF plants by more efficient alternatives, mainly MED. To increase efficiency, most thermal desalination plants will in the future be coupled to power generation.

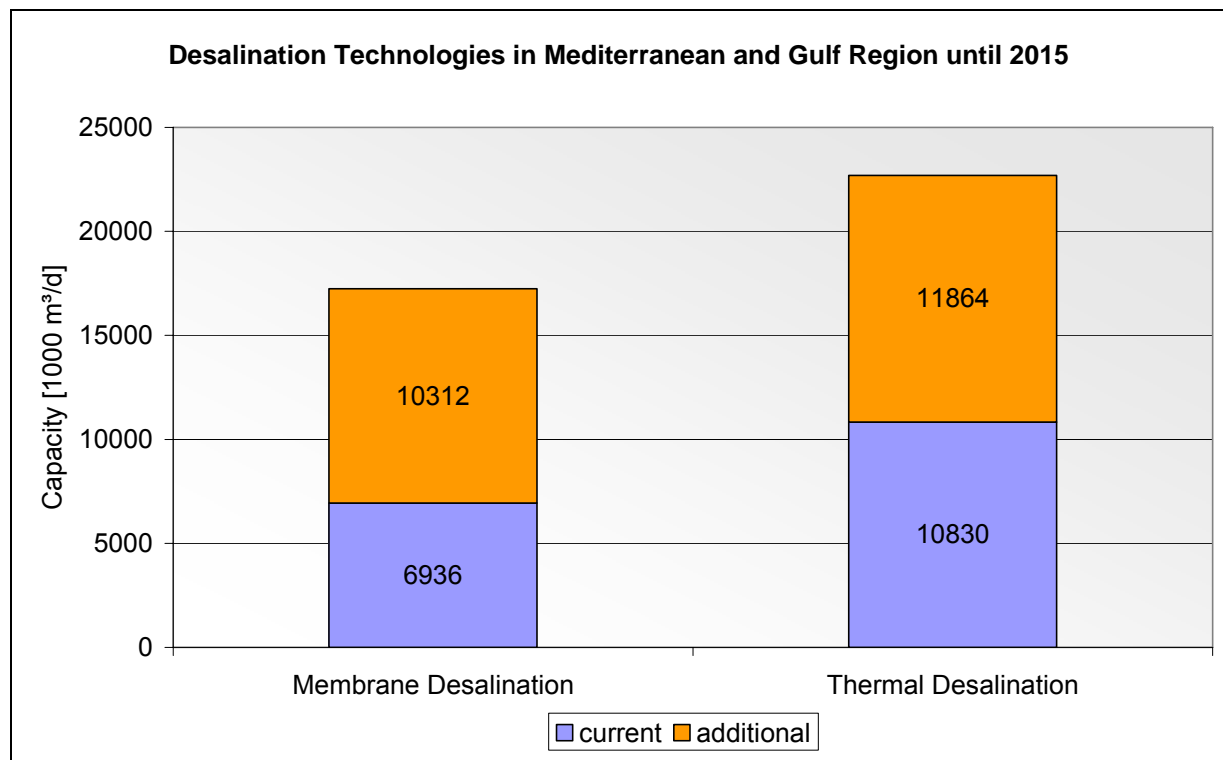


Figure 4-2: Potential of desalination capacity in MENA in 2002 (current) and 2015 /GWI 2004/

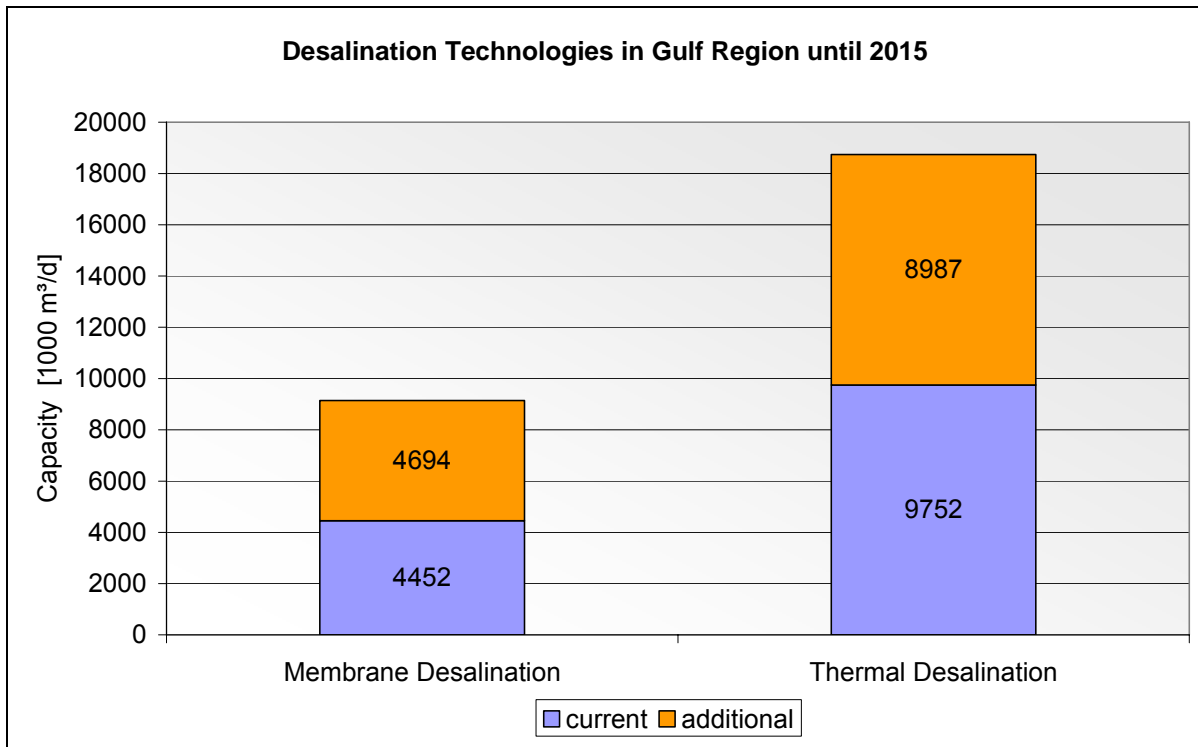


Figure 4-3: Potential of desalination capacity in the Gulf region in 2002 (current) and 2015 /GWI 2004/

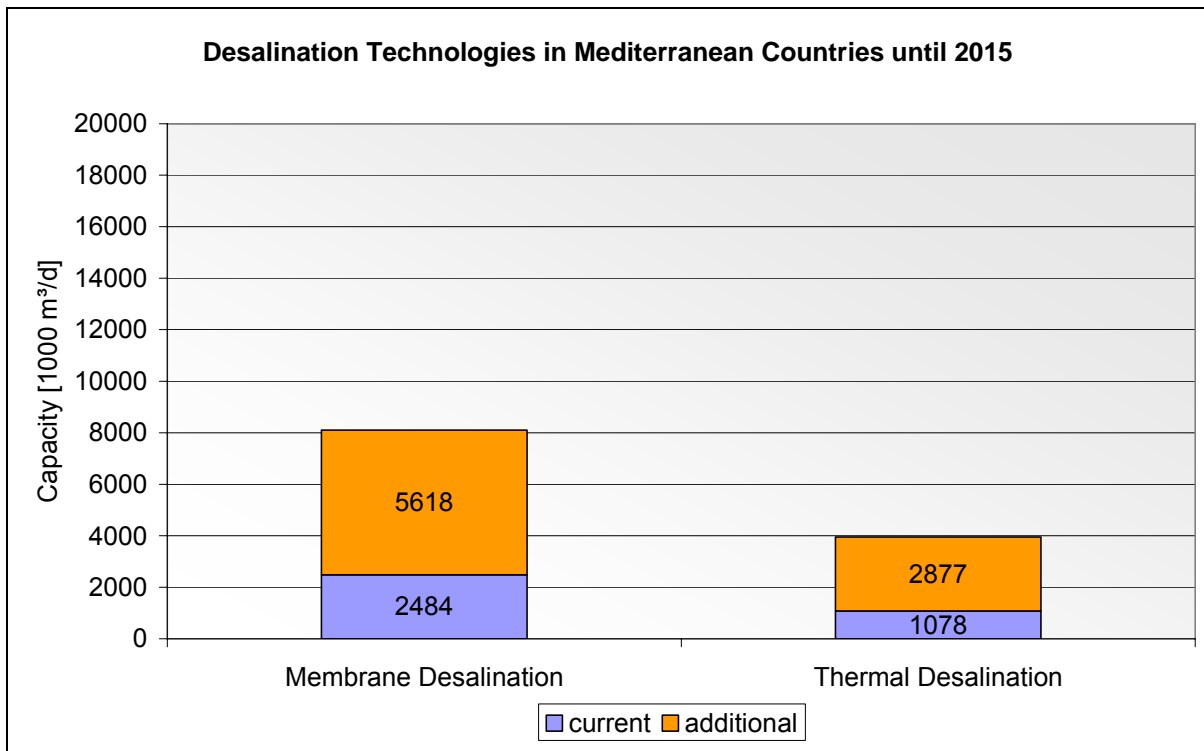


Figure 4-4: Potential of desalination capacity in the Mediterranean region in 2002 (current) and 2015 /GWI 2004/

Country	Current Capacity			2015 Capacity			Cost of Water	Water tariffs	Capital Expenditure	Operating Expenditure	Remarks
	MED, TVC, MSF	RO, ED, MVC	Total	MED, TVC, MSF	RO, ED, MVC	Total					
	thermal	other		thermal	other				2005-2015		
	m³/d	m³/d	m³/d	m³/d	m³/d	m³/d	\$/m³	\$/m³	M\$	M\$/y	
Algeria	95,375	79,625	175,000	870,000	1,305,000	2,175,000	-	60% of costs	1800	350	
Bahrain	445,000	55,000	500,000	630,000	270,000	900,000	-	subsidies	440	102	75% of cap.: 70% MSF, 30% RO
Cyprus	1,448	95,053	96,500	10,575	200,925	211,500	-	0.8 from the Lamaca plant	104	20	
Egypt	45,000	255,000	300,000	248,500	461,500	710,000	-	0.25 - 0.35	369	72	current cap.: Process: 79% RO; 6% VC; 12% MSF; 6% ED; 1% MED Σ 104%
Iraq	0	384,500	384,500	0	984,500	984,500	-	20% of costs	570	120	
Israel	0	439,878	439,878	89,494	1,700,384	1,789,878	-	0.25 to 1.1 (homes and industry: 1.1, but municipality pays the supplier 0.45; farmers pay 0.25 for fresh water and 0.14/0.18 for second-treatment/high quality recycled water)	1215	237	
Jordan			220,000	72,000	648,000	720,000		min. 0.42 for up to 20m³ per month, higher prices for more than 20m³, farmers: 0.11 to 0.5	350	69	
Kuwait	318,000	1,182,000	1,500,000			3,250,000	1.75	0.65	1925	447	
Libya	405,000		415,000	1,537,250	827,750	2,365,000	-	0.15 for the first 25 to 30m³ of water consumed, apply in the bigger cities	2145	463	current cap.: Wangnick: 808564 m³/d => many of old plants no longer operational, in 2000 available for use only 142500 m³/d
Morocco	3,885	11,115	15,000	107,500	107,500	215,000	-	-	180	35	
Oman	316,127	6,452	322,579	463,547	309,031	772,579	1.56	1.17	495	115	
Palestine			10,400	12,060	68,340	80,400	-	0.87 - 1.45	63	11	
Qatar	841,500	8,500	850,000	872,200	373,800	1,246,000	1.15	0.43	436	101	
Saudi Arabia	4,030,000	2,470,000	6,500,000	8,925	2,975,000	11,900,000	-	0.025 - 1.6	5,940	1,380	
Tunisia	660	54,340	55,000	51,250	153,750	205,000	-	-	135	22	
UAE	3,542,000	308,000	3,850,000	5,187,000	2,793,000	7,980,000	Abu Dhabi: 0.6	subidies are payed in the other emirates	4543	1055	
Yemen	0	76,000	76,000	0	131,000	131,000	-	if tariffs are charged at all don't cover costs	41	9	

Table 4-1: Desalination Plant Inventory in 2002 and Outlook to 2015 /GWI 2004/

## **4.2 Long-Term Markets for Seawater Desalination until 2050**

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. However, presently there are considerable freshwater deficits in MENA that are poorly covered by groundwater depletion and by fossil fuelled desalination. In the future, those deficits could be covered by solar thermal power plants, partially in co-generation with thermal multi-effect desalination, and also by using solar electricity for reverse osmosis. Other renewable sources of heat and electricity will also be used for these purposes. Numeric data for single countries is given in the Annex.

### **4.2.1 General Results for the MENA Region**

Figure 4-5 shows that considerable amounts of water desalted by renewable energy cannot be achieved in the short term, because renewable production capacities have still to be build and related investments must be achieved. Until 2020, increasing deficits will have to be bridged by fossil fuelled desalination and by excessive groundwater withdrawals, hoping that those limited resources will remain available and affordable until then. This may seem optimistic, but there are no sustainable and affordable alternatives. On the other hand, it is a reassuring fact that the potential of CSP is neither limited by the solar energy resource nor by its cost, but only by the possible speed of CSP capacity expansion (starting with zero in the year 2006) and that there is a viable and affordable long-term solution for the freshwater deficits in MENA.

Once the industrial CSP production capacities will have grown to a mature level, in the time span from 2020 to 2030 the growing freshwater deficits will be increasingly 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. Finally, with a strong effort, freshwater deficits could be fully removed by the middle of the century.

In the medium term until 2020, the re-use of waste-water and fossil fuelled desalination will have equal importance to reduce the increasing over-use of non-renewable groundwater resources. However, this does not imply a preference for fossil fuelled desalination for coming projects. On the contrary, the scenario assumes a rather quick expansion of CSP for desalination. However, it also shows that it will easily take 15-20 years from now until the CSP shares will attain a noticeable weight within the mix of water resources of the MENA region (Figure 4-6).

This enforces the urgency of a change of thinking and acting of the MENA governments and decision makers: only an immediate change to sustainable solutions will yield acceptable results in good time. Efficiency gains are already considered in our scenario, as explained in Chapter 3, reducing considerably the water demand with respect to business as usual. In spite of that, unsustainable over-use of ground water will still increase, reaching a maximum of almost 70 billion m<sup>3</sup>/y around 2020, which is equivalent to the annual flow of the Nile river.

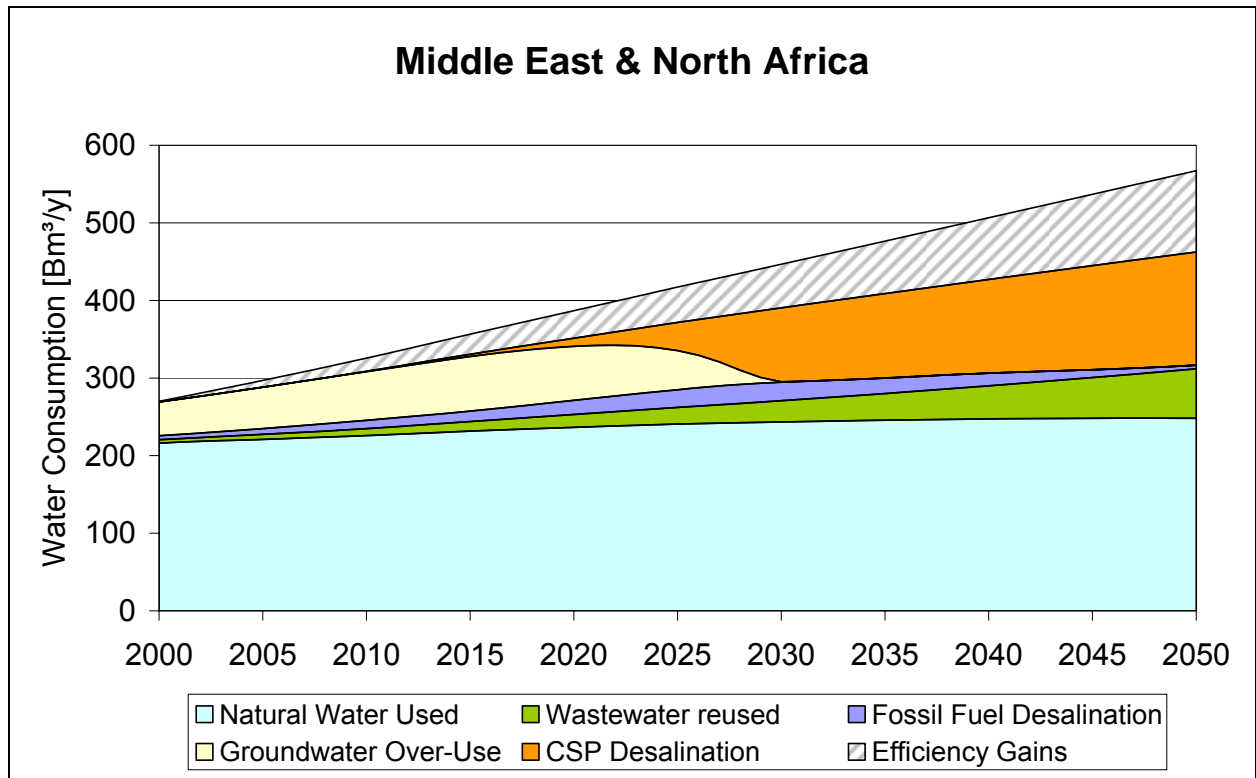


Figure 4-5: Water demand scenario for MENA until 2050 and coverage of demand by sustainable sources, by unsustainable sources and by solar desalination. (shaded: efficiency gains with respect to business as usual)

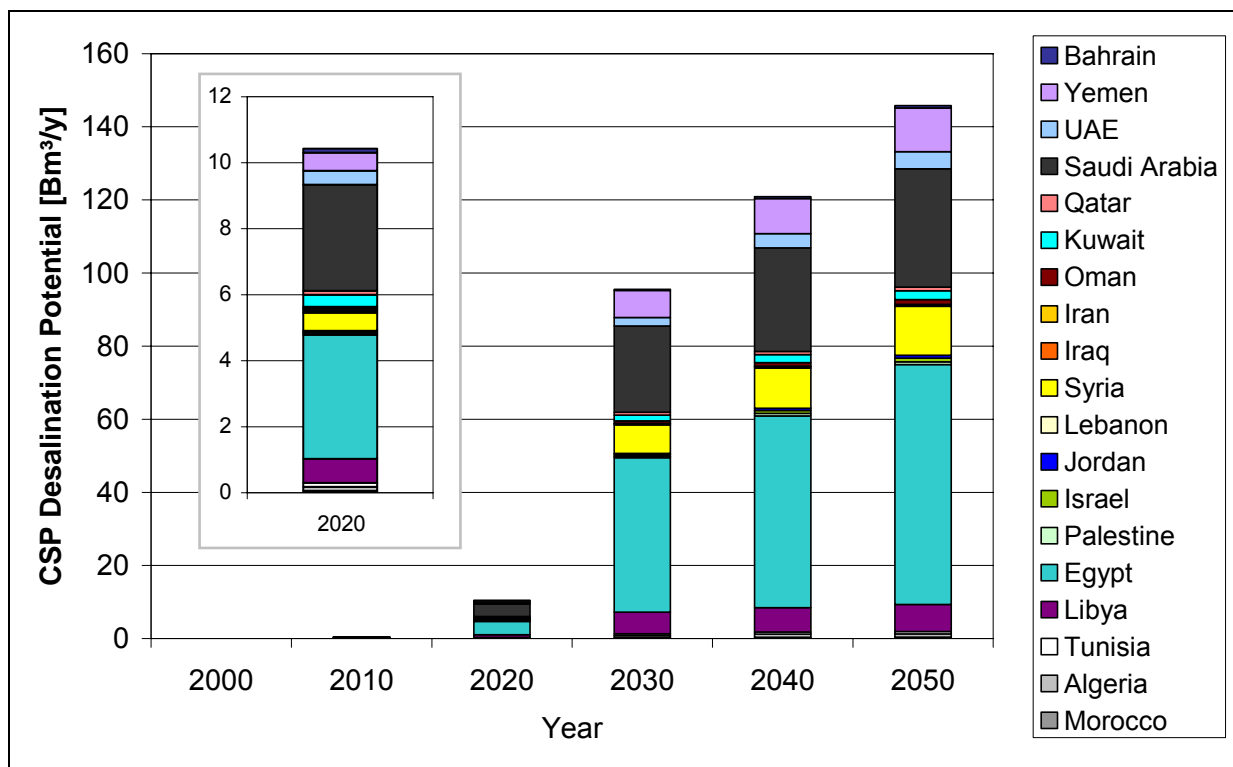


Figure 4-6: CSP potential for seawater desalination in all MENA countries until 2050.

The use of fossil fuelled desalination will increase five-fold to almost 24 billion m<sup>3</sup>/y in the same time span. Re-use of waste-water is an effective means to combat water scarcity, but limited by the available amounts of water that can be re-used. Until 2050, re-use of wastewater will provide an amount of water equivalent to the over-use of groundwater in 2010 – 62.5 Bm<sup>3</sup>/y – but in the meantime other gaps will have opened. Therefore, combining all measures including seawater desalination will be the only viable solution to get rid of the growing water deficits in MENA. On the other hand, large scale desalination only has the perspective to become environmentally and economically sustainable if powered by solar energy (Chapters 1, 5 and 6). After a phase of market introduction and demonstration that will last about 10-15 years, the most dynamic expansion of CSP for desalination will take place between 2020 and 2030, when CSP will gradually take over large shares of freshwater supply from depleting groundwater resources. In 2050 demand will be mainly covered by natural water (248 Bm<sup>3</sup>/y) and by solar powered desalination (145 Bm<sup>3</sup>/y). If provided by RO with an average consumption of 3.5 kWh/m<sup>3</sup>, the desalted water would lead to an additional electricity demand of around 500 TWh/y in 2050.

<b>Total MENA</b>		<b>2000</b>	<b>2010</b>	<b>2020</b>	<b>2030</b>	<b>2040</b>	<b>2050</b>
Population	Million	316.4	382.0	452.0	514.5	568.5	612.2
Exploitable Water	Bm <sup>3</sup> /y	327.9	327.9	327.9	327.9	327.9	327.9
Sustainable Water Used	Bm <sup>3</sup> /y	220.2	235.2	253.9	271.9	291.5	313.8
Agricultural Demand	Bm <sup>3</sup> /y	237.6	265.6	293.5	313.8	327.4	334.1
Municipal Demand	Bm <sup>3</sup> /y	21.2	28.7	38.4	50.0	64.1	81.2
Industrial Demand	Bm <sup>3</sup> /y	10.3	14.2	19.5	26.3	35.2	46.4
Total Demand MENA	Bm <sup>3</sup> /y	269.1	308.5	351.4	390.1	426.7	461.7
per capita Consumption	m <sup>3</sup> /cap/y	851	808	777	758	751	754
Wastewater Re-Used	Bm <sup>3</sup> /y	4.4	9.1	16.5	27.3	42.6	63.8
CSP Desalination	Bm <sup>3</sup> /y	0.0	0.5	10.4	95.5	120.9	145.8
Minimum CSP Capacity	GW	0.0	0.2	4.5	40.9	51.7	62.4
Fossil Fuel Desalination	Bm <sup>3</sup> /a	5.2	10.8	18.3	23.9	16.3	4.6
Groundwater Over-Use	Bm <sup>3</sup> /y	43.7	62.5	69.6	0.3	0.0	0.0
Natural Water Used	Bm <sup>3</sup> /y	215.9	225.7	236.6	243.5	247.4	248.0

**Table 4-2: Aggregated data of all MENA countries of the AQUA-CSP scenario until 2050**

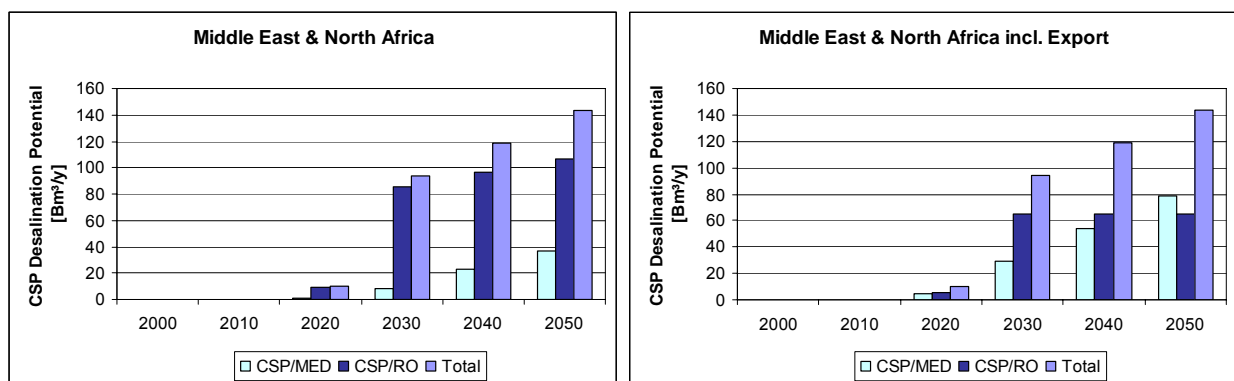
Thus, desalination powered by CSP has the potential to relieve the MENA region from one of its most pressing problems – water scarcity – with a realistic medium-term perspective until 2030. Although water scarcity can be more pronounced in other countries, in terms of quantity, five countries will dominate the CSP desalination market: Egypt, Saudi Arabia, Libya, Yemen and – astoundingly – Syria, as shown in Figure 4-6 (see Annex for country data). There will be basically three types of CSP plants, serving domestic electricity supply, electricity export or sea water desalination in different combinations:

- CSP plants for co-generation with coupled seawater desalination must be located 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 co-generation will be limited to appropriate industrial sites or hotel resorts with sufficiently large demand of heat and power. While their heat will be used on-site for desalination and district cooling, their electricity might be used on-site too or be sold to the grid for municipal use, export or RO-desalination.

The mix of these three plant types will vary according to the regional demand of each country and the local supply side conditions. The scenario gives a rough estimate of the overall potentials of the region. 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.



**Figure 4-7: Shares of CSP plants using Multi-Effect desalination (CSP/MED) and Reverse Osmosis (CSP/RO) assuming that MED will exclusively be used in co-generation with domestic electricity demand (left) and including an additional combination of MED with solar export electricity (right).**

A certain limitation for plants using Multi-Effect Desalination is given assuming that MED will only be used in co-generation with electricity. Thus, the potential for CSP electricity generation would also limit the potential for CSP/MED. If we assume a power to water ratio of typically 1 kW/m³/d and a capacity factor of 7500 full load hours per year for such plants, the share of CSP/MED (25 %) and CSP/RO (75 %) would result as given in Figure 4-7 (left). However, this neglects the direct use of concentrating solar fields for the operation of thermal desalination plants and also neglects the possibility of interconnecting MED desalination plants to power

stations producing electricity for export to Europe. Allowing for a combination with electricity exports would yield a much higher share of 55 % for CSP/MED (Figure 4-7 (right)). A final estimate of concrete numbers depends very much on future decisions of national policies and is in fact of secondary importance. It is therefore not given here.

To solve the immediate problem of groundwater depletion until 2030, a minimum capacity of 40 GW of CSP must be installed for seawater desalination in order to cover the freshwater deficits by that time. After that, the installation of another 20 GW until 2050 would also cover the further growing demand in a sustainable way. All plants would operate in base-load mode with 7500 full load operating hours per year and exclusively produce electricity and heat for RO and MED seawater desalination. In this configuration, about 1/5 of the water deficit would be covered by reject steam of CSP power stations combined with thermal MED, while 4/5 of the water would be covered by electricity from CSP powering RO membrane desalination.

#### **4.2.2 North African Markets**

The demand for freshwater in North Africa will almost double in 50 years from 95 Bm<sup>3</sup>/y in 2000 to 184 Bm<sup>3</sup>/y in 2050 (Figure 4-8), while only 82 Bm<sup>3</sup>/y of exploitable natural water resources are available in the region. Although the agricultural sector will decrease its share of consumption with time, it will still make up for 65 % of the total water demand in 2050 (Table 4-3). Efficiency gains in irrigation and municipal water distribution, re-use of waste water and solar powered seawater desalination will allow to slightly increase the per capita water consumption, from 660 to 750 m<sup>3</sup>/cap/y, in spite of a strongly growing population that will increase from 140 to 240 million people.

Unsustainable over-use of groundwater will continue and even increase from about 22 Bm<sup>3</sup>/y in 2000 to a maximum of 38 Bm<sup>3</sup>/y around 2020 until it can be alleviated earliest by 2030. Fossil fuel powered desalination will be developed in the first years in parallel to solar powered desalination using CSP and other renewable sources, but – due to its elevated cost – will lose importance in the medium and long term. CSP desalination will become visible to a larger extent by 2020 producing 5 Bm<sup>3</sup>/y of freshwater, and will achieve an annual production of 75 Bm<sup>3</sup>/y in 2050. To this end, a minimum CSP capacity of 2 GW must be installed in MENA for desalination by 2020, and 32 GW in 2050. This will add to the peak electricity demand of about 200 GW expected for this region in 2050 and to 100 GW of capacity installed for solar electricity exports in the total MENA region as scheduled by the prior studies /MED-CSP 2005/ and /TRANS-CSP 2006/.

Re-used waste water will cover about 9 Bm<sup>3</sup>/y in 2020 and over 30 Bm<sup>3</sup>/y by 2050, making up by then for about 17 % of the water supply, while 75 Bm<sup>3</sup>/y will come from CSP desalination as

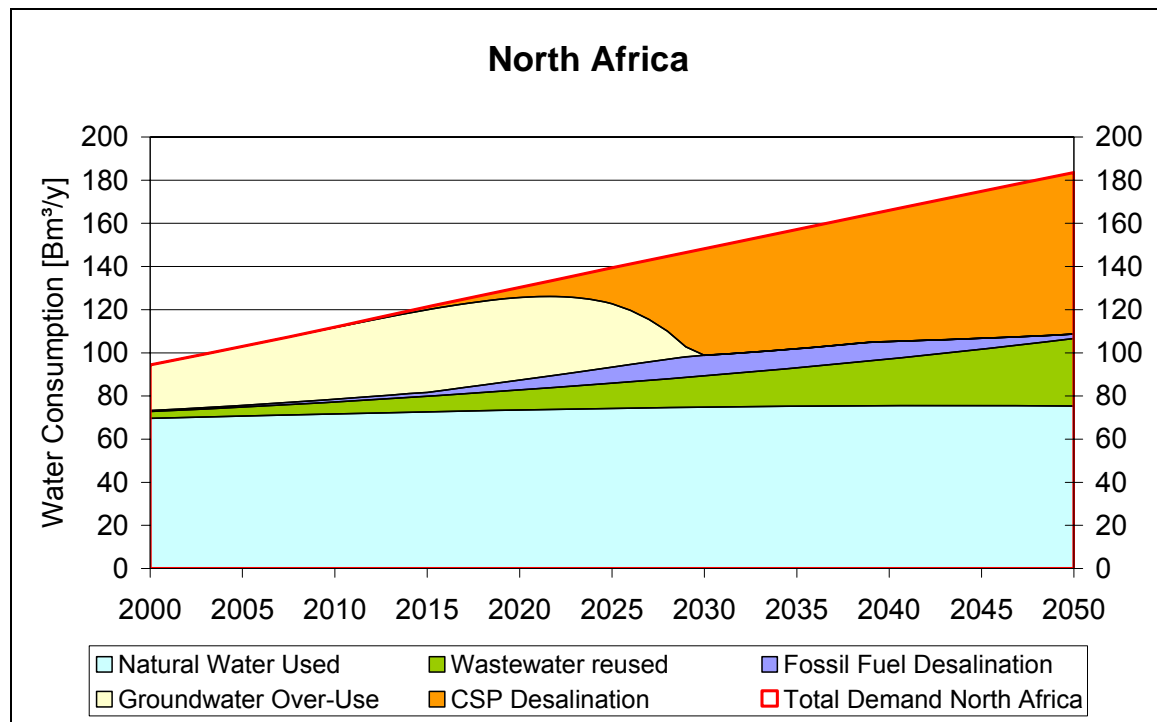
well as from natural resources, making up for 41 % of the water supply, each. By 2050, only a minor share will still be provided by fossil fuelled desalination.

The most dynamical development of the CSP desalination market will take place between 2020 and 2030, with a new desalting capacity of 45 Bm<sup>3</sup>/y built within that time-span of only 10 years. This is in fact a challenge, and the required industrial production capacities for the components of CSP desalination plants can only be achieved in time if market expansion according to our scenario starts immediately in the MENA region. Otherwise, market introduction may be delayed, and the use of unsustainable sources of water will continue and increase. However, it is not clear for how long this unsustainable use can continue in any case, as the groundwater sources may be totally depleted in many areas of MENA, with severe negative impacts on environment and society.

North Africa will be the largest future market for CSP desalination, with Egypt and Libya being the main candidates for installing large plant capacities, even surpassing the demand for desalination on the Arabian Peninsula. For this region, there is no alternative for CSP desalination in view, and gladly, there is no alternative required. The immense solar radiation potential, easily available seawater and land and the option of combining solar electricity exports to Europe with seawater desalination for local use, makes CSP the most logical, economical and environmental friendly solution for the threat of freshwater scarcity. The end of groundwater overuse scheduled in our scenario by 2030 may look optimistic and will require a tremendous effort from policy, investors and technology providers, but may result as imperative for survival of the whole region, because the exploitable groundwater resources may already be depleted by that time (Chapter 5).

<b>North Africa</b>		<b>2000</b>	<b>2010</b>	<b>2020</b>	<b>2030</b>	<b>2040</b>	<b>2050</b>
Population	Million	141.9	167.3	192.8	214.5	231.9	244.3
Exploitable Water	Bm <sup>3</sup> /y	81.8	81.8	81.8	81.8	81.8	81.8
Sustainable Water Used	Bm <sup>3</sup> /y	72.8	77.5	83.5	90.5	98.7	108.6
Agricultural Demand	Bm <sup>3</sup> /y	80.4	92.1	103.0	111.4	117.6	120.9
Municipal Demand	Bm <sup>3</sup> /y	8.6	12.1	16.8	22.6	29.7	38.4
Industrial Demand	Bm <sup>3</sup> /y	5.4	7.6	10.6	14.3	18.8	24.3
Total Demand North Africa	Bm <sup>3</sup> /y	94.4	111.9	130.3	148.3	166.1	183.6
per capita Consumption	m <sup>3</sup> /cap/y	666	669	676	691	716	752
Wastewater Re-used	Bm <sup>3</sup> /y	3.2	5.6	9.2	14.5	21.7	31.3
CSP Desalination	Bm <sup>3</sup> /y	0.0	0.2	4.7	49.5	60.9	74.9
Minimum CSP Capacity	GW	0.0	0.1	2.0	21.2	26.1	32.1
Desalination by Fossil Fuel	Bm <sup>3</sup> /a	0.4	1.3	4.6	9.5	8.1	2.0
Groundwater Over-Use	Bm <sup>3</sup> /y	21.2	33.2	38.3	0.0	0.0	0.0
Natural Water Used	Bm <sup>3</sup> /y	69.6	71.6	73.5	74.9	75.5	75.3

**Table 4-3: Aggregated data of the AQUA-CSP scenario for North Africa until 2050**



**Figure 4-8: Water demand scenario for North Africa until 2050 and coverage of demand by sustainable sources, by unsustainable sources and by solar desalination, including efficiency gains.**

### 4.2.3 Western Asian Markets

Western Asia has the highest exploitable natural water resources of the MENA region, which today make up for 99 % of water supply (Table 4-4 and Figure 4-9). Up to now, there are only few regions that suffer from an over-exploitation of groundwater, and seawater desalination is hardly an issue. However, this pattern has been changing recently in Jordan, Israel and Palestine, and in a few years, deficits will also increasingly become visible in Syria and Iraq.

Efficiency gains in agriculture, industry and municipal distribution and the re-use of waste water are the most important measures to prevent the region from water scarcity. Desalination, no matter if based on fossil or solar energy, will only be used as last resource, and only in the regions where deficits are highest, like Syria and Iraq.

However, even in this relatively water-abundant region, CSP desalination will become an important contribution to freshwater sustainability, avoiding an increasing over-exploitation of groundwater and the use of fossil fuels for desalination. Nevertheless, the over-use of groundwater will reach a maximum of 5 Bm<sup>3</sup>/y in 2020 and fossil fuelled desalination will increase to about 3 Bm<sup>3</sup>/y by 2030. After that, desalination using CSP and other renewable energy sources will alleviate the region from unsustainable use of water, which will take a time span of about 10-15 years. A completely sustainable supply can be achieved by 2050, if the necessary measures are taken in time.

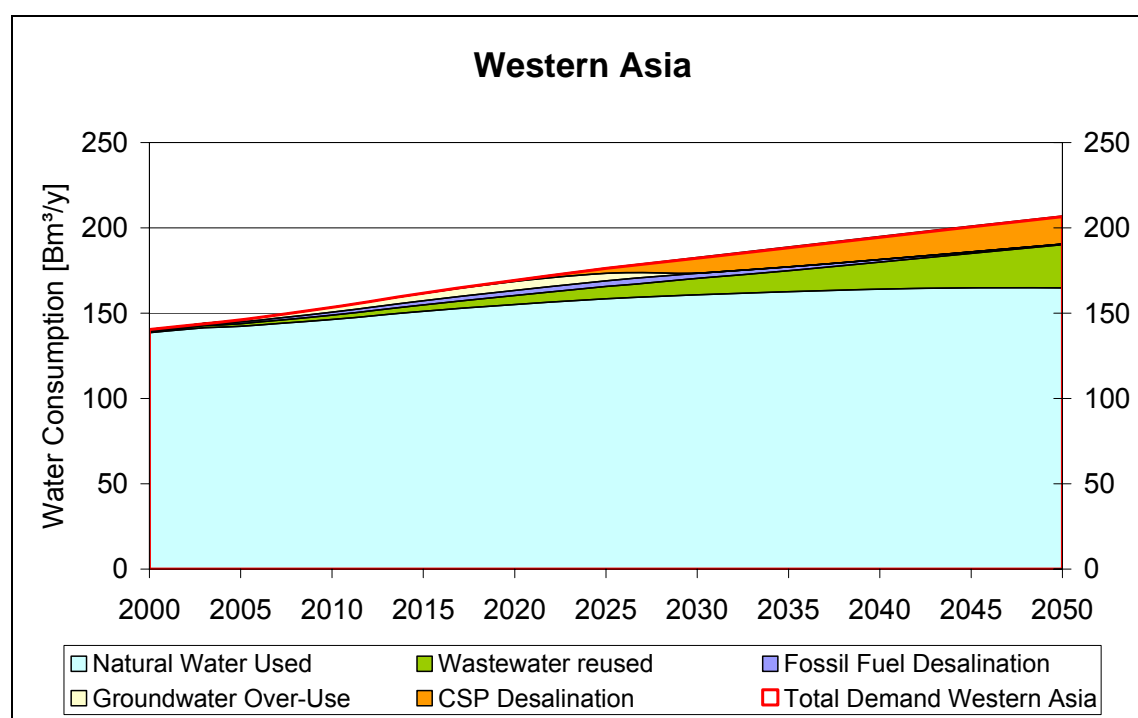


Figure 4-9: Water demand scenario for Western Asia until 2050 and coverage of demand by sustainable sources, by unsustainable sources and by solar desalination, including efficiency gains.

Western Asia		2000	2010	2020	2030	2040	2050
Population MP	Mp	126.0	149.9	177.2	200.6	220.8	236.9
Exploitable Water	Bm <sup>3</sup> /y	238.3	238.3	238.3	238.3	238.3	238.3
Sustainable Water Used	Bm <sup>3</sup> /y	139.3	148.8	160.6	170.3	180.0	190.2
Agricultural Demand	Bm <sup>3</sup> /y	127.7	136.7	147.1	153.1	155.9	155.8
Municipal Demand	Bm <sup>3</sup> /y	8.5	10.9	14.4	18.6	23.9	30.5
Industrial Demand	Bm <sup>3</sup> /y	4.2	5.7	7.8	10.7	14.8	20.2
Total Demand Western Asia	Bm <sup>3</sup> /y	140.4	153.4	169.4	182.4	194.6	206.5
per capita Consumption	m <sup>3</sup> /cap/y	1114	1023	956	909	881	872
Wastewater Re-Used	Bm <sup>3</sup> /y	0.9	2.5	5.3	9.5	15.9	25.3
CSP Desalination	Bm <sup>3</sup> /y	0.0	0.0	0.8	9.4	13.6	16.5
Minimum CSP Capacity	GW	0.0	0.0	0.3	4.0	5.8	7.1
Fossil Fuel Desalination	Bm <sup>3</sup> /a	0.7	1.8	3.0	3.1	1.4	0.4
Groundwater Over-Use	Bm <sup>3</sup> /y	0.4	2.8	5.2	0.0	0.0	0.0
Natural Water Used	Bm <sup>3</sup> /y	138.5	146.3	155.2	160.8	164.1	164.8

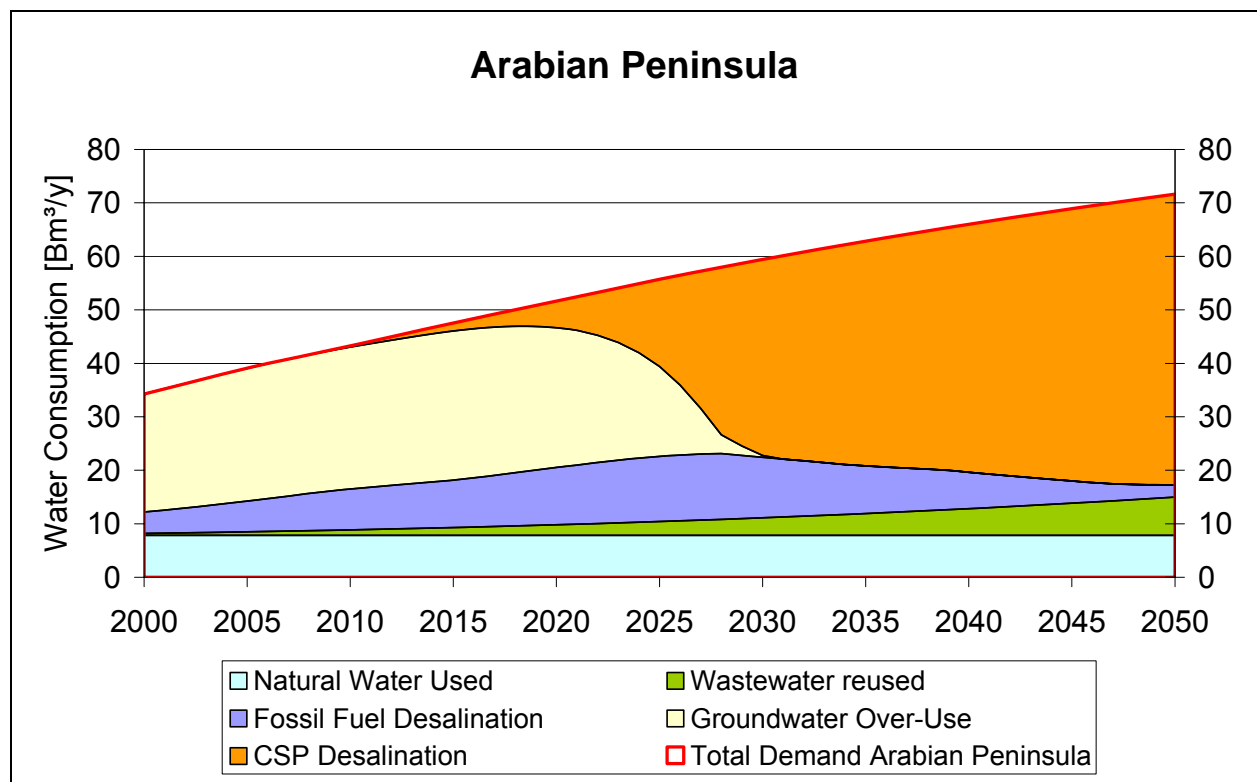
Table 4-4: Numerical data of the AQUA-CSP scenario for Western Asia until 2050

#### 4.2.4 Markets on the Arabian Peninsula

On the Arabian Peninsula, the non-sustainable over-use of groundwater makes up for the largest portion of freshwater supply, with a maximum of 25 Bm<sup>3</sup>/y (Figure 4-10 and Table 4-5). Today's total demand of about 35 Bm<sup>3</sup>/y will at least double until 2050, which must be compared to a natural exploitable water resource of only 7.8 Bm<sup>3</sup>/y. Until 2020, fossil-fuel-powered desalination will become the second most important source of freshwater, which is also a source

that is not considered sustainable in economical and environmental terms. This makes the Arabian Peninsula the most critical region in MENA, not because of its absolute deficits (which are smaller than those of North Africa), but in terms of dependency on non-sustainable water, that makes up for 75 % of the total supply.

With the Masdar initiative, the United Arab Emirates have recently started to build up a sustainable solution for energy and water based on renewable energy sources including concentrating solar power /Masdar 2007/. However, it will take at least 15 years until visible shares of CSP desalination can be build up in the energy and water sectors of the region, today starting with zero. Until 2020, the expansion of CSP desalination will still be over-compensated by the annual growth of demand for freshwater. By 2025 global industrial CSP production capacities will finally have become large enough to cope with the growing demand, and the freshwater deficits can and must then be alleviated within a time span of 10-15 years. Fossil fuelled desalination will remain until 2050, as new plants built until 2025 will most probably be operated until the end of their economic life time which is about 20-25 years.



**Figure 4-10: Water demand scenario for the Arabian Peninsula until 2050 and coverage of demand by sustainable sources, by unsustainable sources and by solar desalination, including efficiency gains.**

In order to achieve a fast elimination of un-sustainable supply of water, a minimum capacity of 2 GW of CSP desalination systems must be installed until 2020, and 22 GW until 2050. The share of agricultural water on the Arabian Peninsula is relatively high, with 83 % today and 77 % in 12.11.2007

2050. Due to an only moderate share and growth of industrial and municipal water demand and a presently low efficiency of those sectors, the option of re-using waste water is rather limited. However, in the long term it will be an important factor of security and sustainability and will approximately supply the same amount of freshwater as the natural exploitable water resources.

In absolute numbers, Saudi Arabia and Yemen are the countries with the largest deficits on the Arabian Peninsula. However, all countries of the region suffer from severe water scarcity and a high dependency on non-sustainable sources. Therefore, the Arabian Peninsula has the highest priority, and absolutely no alternative to immediately start market introduction and market expansion of CSP desalination systems.

Having an important potential domestic market for CSP desalination, the necessary financial means due to its oil and gas exports, and with the Masdar initiative already started in the United Arab Emirates, the Arabian Peninsula has a very good chance to become a technology- and market leader for CSP desalination in the medium term future. In 2050, CSP desalination on the Arabian Peninsula can make up for over 50 Bm<sup>3</sup>/y of freshwater, which is almost the annual volume of the Nile river allocated to Egypt. There will be a considerable environmental impact on the coasts around the Peninsula from such large amounts of seawater desalination. The necessary measures of environmental impact prevention will have highest priority, but can be solved satisfyingly, as will be described in Chapter 6.

In spite of this optimistic perspective and in spite of considerable future efficiency gains that were postulated in our scenario as described before, the per capita supply of water on the Arabian Peninsula will have to be reduced from today about 680 m<sup>3</sup>/cap/y to less than 550 m<sup>3</sup>/cap/y in 2050. This is due to a rapidly growing population from about 50 million in 2000 to over 130 million in 2050, with the highest growth rates in Yemen and Saudi Arabia.

<b>Arabian Peninsula</b>		<b>2000</b>	<b>2010</b>	<b>2020</b>	<b>2030</b>	<b>2040</b>	<b>2050</b>
Population	Million	48.5	64.8	82.0	99.4	115.8	131.0
Exploitable Water	Bm <sup>3</sup> /y	7.8	7.8	7.8	7.8	7.8	7.8
Sustainable Water Used	Bm <sup>3</sup> /y	8.2	8.8	9.8	11.1	12.8	15.0
Agricultural Demand	Bm <sup>3</sup> /y	29.5	36.7	43.4	49.3	53.9	57.3
Municipal Demand	Bm <sup>3</sup> /y	4.1	5.7	7.2	8.8	10.5	12.4
Industrial Demand	Bm <sup>3</sup> /y	0.6	0.9	1.1	1.3	1.6	1.8
Total Demand Arabian Peninsula	Bm <sup>3</sup> /y	34.3	43.3	51.6	59.4	66.0	71.6
per capita Consumption	m <sup>3</sup> /cap/y	707	667	630	597	570	547
Wastewater Re-Used	Bm <sup>3</sup> /y	0.4	1.0	2.0	3.3	5.0	7.1
CSP Desalination	Bm <sup>3</sup> /y		0.2	5.0	36.6	46.4	54.4
Minimum CSP Capacity	GW	0.0	0.1	2.1	15.7	19.8	23.3
Fossil Fuel Desalination	Bm <sup>3</sup> /a	4.0	7.7	10.7	11.3	6.8	2.3
Groundwater Over-Use	Bm <sup>3</sup> /y	22.1	26.5	26.1	0.3	0.0	0.0
Natural Water Used	Bm <sup>3</sup> /y	7.8	7.8	7.8	7.8	7.8	7.8

**Table 4-5: Numerical data of the AQUA-CSP scenario for the Arabian Peninsula until 2050**

### 4.3 Method Applied for Market Assessment

The aim of this work package was to find a consistent scenario for the expansion of concentrating solar power for seawater desalination in the analysed countries until 2050. The emphasis of the study lies on CSP technology in the context of other renewable and non-renewable energy technologies and other available sources of freshwater. As shown in Chapter 3.5, a number of water supply scenarios on regional level can be found in the literature /Seckler 1998/, /ESCWA 2001/, /Al-Zubari 2002/, /Abufayed 2002/, /Mekhemar 2003/, /UN 2005/, /Blue Plan 2005/, /IEA 2005/. No consistent long-term scenarios for the total MENA region and for all water sectors are available. However, a long-term approach is necessary, as sustainability cannot be achieved with short-term measures. If limited to short-term measures and perspectives, most efforts would fail to achieve the sustainability goal, and short-sighted analysis of the situation would lead to misleading recommendations.

Therefore, we have tried to build a consistent, long-term scenario of the water demand of all MENA countries until 2050, and compared this “prediction” to the available, exploitable freshwater resources of the region. Our analysis was based on statistical data 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 shall 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, like e.g. the market introduction of renewable energy.

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

- affordable cost of water from seawater desalination based on low energy cost from concentrating solar power as shown in Chapter 1 and Chapter 5,
- low environmental impact of power generation and seawater desalination, due to the use of renewable energy for desalination and due to the substitution of chemicals by renewable energy, as explained in Chapter 6,
- low conflict potential due to water scarcity, and fair access to water for everybody due to the exploitation of a new, domestic source of water (seawater) and using a domestic energy source (solar energy) for desalination, as will be shown in Chapter 5,

- economic stability due to low and stable cost of water for the economic development of arid regions, as will be explained in Chapter 5,
- energy and water security, as shown in Chapter 4.

There are technical, economical, social and environmental barriers that limit the expansion of any energy technology. As drafted in Figure 4-11, an overlay of such “guard rails” can be defined as a function of time, limiting market expansion by subsequently changing factors. As an example, market expansion of most renewable energy or desalination 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

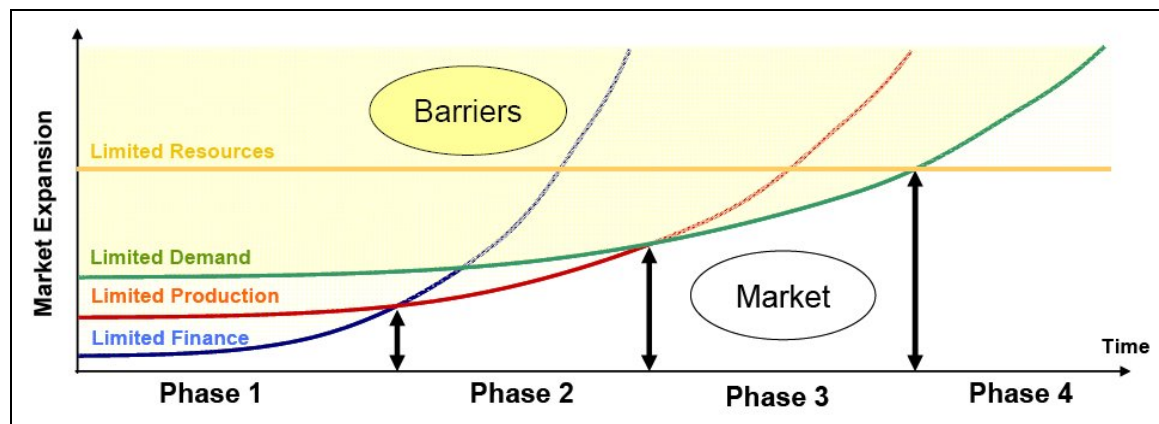
**Phase 1** is characterised by a situation where research and development has led to innovative technologies ready for commercial application, but still with a high investment cost due to their limited number of projects and lack of mass production. A rather high risk perception by potential investors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

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 sustainable supply, and willing to introduce this new option into the existing technology portfolio.

Good 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 that initially cover the relatively high initial cost of renewables, creating a niche market for those technologies. Another example is the Aqaba Solar water Project described in Chapter 1, where the self-generation of power, cooling and water of a hotel resort by a combined generation plant

using solar energy is cheaper and more cost-stable than conventionally buying those services from the public grid.



**Figure 4-11: Finding a market scenario with the Guard-Rail-Principle.** Subsequently, different factors limit technology expansion. The potential market volume is represented by the white area while the different overlapping guard-rails 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 becomes the limiting factor for market expansion. In competition to other technologies and solutions, the demand for a certain source of water is also coupled to its cost.

The water 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 water like those induced by pollution, climate change, or groundwater depletion, e.g. accepting higher tariffs for clean, environmentally friendly sources of water than for those that pollute the ambient.

**Phase 4** finally describes a situation where the resource itself becomes the limiting factor for market development. Fortunately in our case neither seawater nor solar energy are scarce resources in the MENA region.

The following potential barriers and frame conditions have been taken into account to narrow down the course of the CSP desalination market in the MENA region:

- maximum growth rates of CSP desalination capacities
- annual water demand
- replacement of old desalination plants
- cost of water in comparison to competing technologies

Those parameters were not treated as static constants, but are analysed in their dynamic transition towards a sustainable supply scheme.

In the first place we have assessed the available natural **renewable water resources** of each of the analysed countries as described in Chapter 2. These are well documented by international institutions like the United Nations or the World Bank, and consist of surface and groundwater that is renewed either by rainfall or by rivers or underground flows coming from outside the country /FAO 2007/, /World Bank 2007/, /BGR 2006/. Only a part of the available natural water resources is renewable, while some of the existing groundwater aquifers consist of fossil water that is not renewed in a sufficiently short time span to be considered renewable. Of the renewable water, only a part is exploitable. This is due to different reasons, e.g. the economic feasibility of their exploitation, the fact that sources may be very dispersed or remote, or to environmental or other restrictions. The **exploitable share** of natural water sources in each country has been taken from literature if available or assumed to be equal to renewable water /FAO 2007/.

In a second place, we have analysed the **demand of water** for agricultural, municipal and industrial use and formulated a consistent method to predict its future development as function of population and economic growth as described in Chapter 3. In this model we have taken into account **efficiency gains**, based on a possible transition from the present average efficiency of irrigation and municipal distribution to a long-term best practice value. In addition to the AQUA-CSP reference scenario that may be considered as “desirable and realistic”, we have assessed two further scenarios, one oriented at a business-as-usual strategy with relatively low future efficiency gains, and another with extreme efficiency gains. Finally, we made a balance of exploitable water and water demand as function of time, resulting in the potential future **freshwater deficits** for each country up to the year 2050.

In a third place, in Chapter 4 we have developed a **long-term scenario** showing how the growing freshwater demand in each MENA country can be covered in a sustainable way, by

using the different available water resources that consist of exploitable natural surface and groundwater, limited use of non-renewable groundwater, fossil fuel powered desalination, solar powered desalination and re-use of municipal and industrial waste-water. The scenario shows the present and future deficits of freshwater and the pressing need to change to a sustainable form of supply before groundwater resources are totally depleted. Fossil fuelled desalination markets in several countries have been assessed up to 2015 by /GWI 2004/ and up to 2030 by /IEA 2005/. These values have been taken as given. Once the over-use of fossil groundwater will be eliminated by solar and fossil fuelled desalination between 2020 and 2030, a further growth of desalination capacity is only allowed within our model on the basis of solar desalination. However, the average life-time of the existing fossil desalination plants is taken into account to derive their remaining share of water supply after that time. The share of re-used waste water in each country starts with the historical value of the year 2000 and is linearly extended to a maximum value of 50 % of the municipal and industrial water demand by 2050. In the “Extreme Efficiency” scenario this value has been augmented to 75 %, in the “Business-As-Usual” scenario it was set to only 30 %.