3. Freshwater Demand and Deficits in MENA

In this chapter we will quantify the growing demand for freshwater in MENA on the basis of a simple empirical model and show how water consumption will be driven by growing population and by economic development of the region.

It is well known that the renewable freshwater resources of MENA are rather limited, and that increasing shortages and deficits of freshwater are threatening economic development and social peace in some parts of MENA (Blue Plan 2005/, /IEA 2005/, /Gleick 2004/, /FAO 2003/. Comparing the existing sustainable freshwater resources with the present and future demand, we have quantified the present and also the threatening future freshwater deficits of each country of the region. Part of the presently used freshwater that is stemming from overuse of groundwater or from fossil-fuel-powered desalination must be considered unsustainable, as it is based on fading resources which are related to exploding costs and considerable environmental damage.

Efficiency of extraction, distribution and end-use of water is rather low, leaving a considerable potential for future efficiency gains, if adequate water policies are successfully implemented to foster such goal. Also the re-use of water is an important measure to reduce future water deficits in MENA. In fact, efficiency gains can be considered an additional future source of freshwater, because the water is there, but up to now, unused.

Taking into account those partially counteracting effects, we have formulated a simple empirical model for the prediction of freshwater demand which was applied to every country in MENA.

3.1 Population Prospects

Population and population growth are the major driving forces for freshwater demand. The population growth scenario used here is based on the intermediate World Population Prospect of the United Nations that was revised in the year 2004 /UN 2006/. According to that estimate, the population in the total MENA region will steadily grow from about 300 million today to over 600 million in 2050. The population in North Africa will grow from today’s 140 million to 245 million in 2050. With 125 million in 2050, Egypt will be accounting for more than 50 % of the population of the North African region. The population in the Western Asian countries will grow from 125 to almost 240 million by 2050, Iran being the country with the largest population in this region. The population on the Arabian Peninsula will increase from today’s 50 million to 130 million in 2050. The dominating countries in terms of population are Saudi Arabia and Yemen. The Saudi Arabian population will stabilize by the middle of the century around 50 million, but Yemen’s population will still be growing quickly by that time, with almost 60 million becoming the most populated country in this region (Figure 3-1).

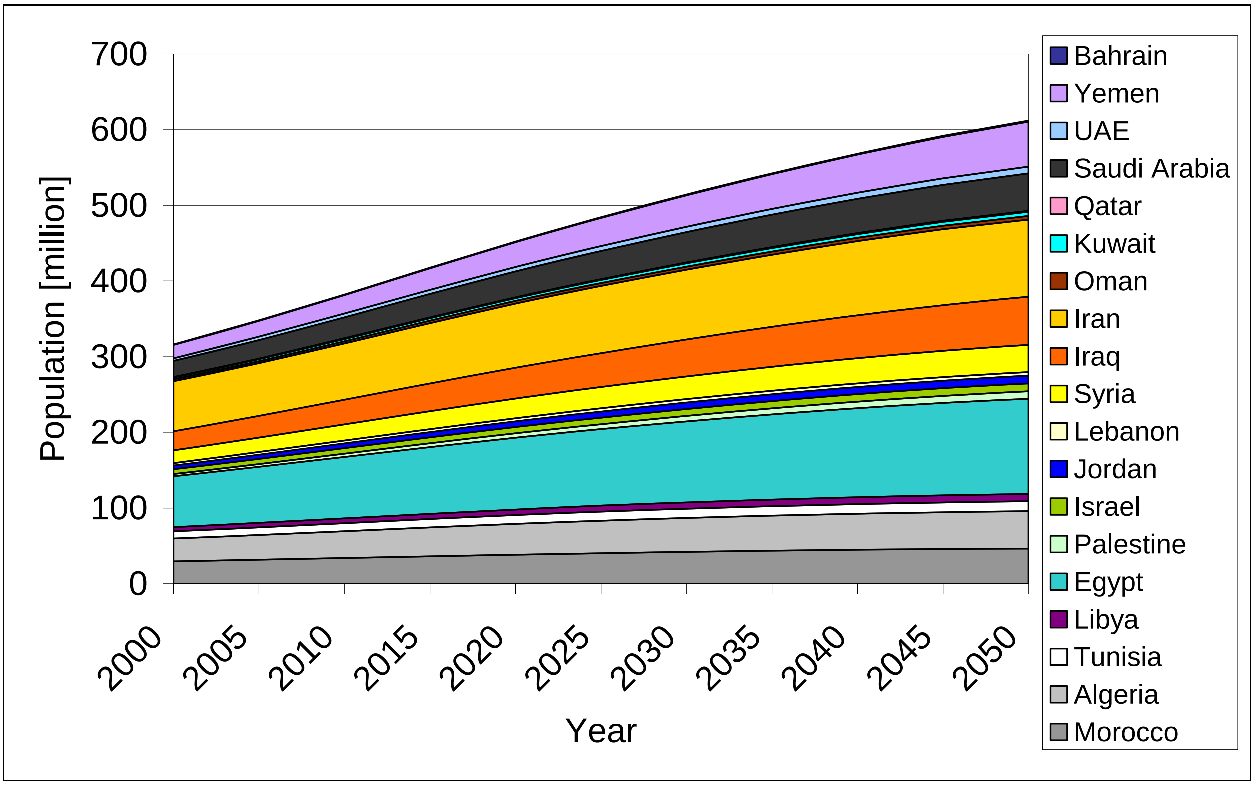

Figure 3-1: Population of the analysed countries in MENA according to the United Nations medium growth scenario revised in 2004 /UN 2006/.

Population [Million]	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Yemen	17.9	21.0	24.5	28.5	32.7	37.1	41.5	46.0	50.5	55.0	59.5
Bahrain	0.7	0.7	0.8	0.9	0.9	1.0	1.0	1.1	1.1	1.1	1.2
UAE	3.2	4.5	5.0	5.6	6.1	6.7	7.2	7.7	8.2	8.7	9.1
Kuwait	2.2	2.7	3.0	3.4	3.7	4.0	4.3	4.6	4.8	5.1	5.3
Oman	2.4	2.6	2.9	3.2	3.5	3.8	4.1	4.3	4.6	4.8	5.0
Qatar	0.6	0.8	0.9	1.0	1.0	1.1	1.2	1.2	1.3	1.3	1.3
Saudi Arabia	21.5	24.6	27.7	30.8	34.0	37.2	40.1	42.9	45.3	47.5	49.5
Arabian Peninsula	**48.6**	**56.8**	**64.8**	**73.3**	**82.0**	**90.8**	**99.4**	**107.7**	**115.8**	**123.5**	**130.7**
GCC	**30.7**	**35.9**	**40.3**	**44.8**	**49.3**	**53.7**	**57.9**	**61.8**	**65.3**	**68.4**	**71.2**
Iran	66.4	69.5	74.3	79.9	85.0	89.0	92.3	95.2	98.0	100.4	101.9
Iraq	25.1	28.8	32.5	36.5	40.5	44.7	48.8	52.8	56.7	60.3	63.7
Israel	6.1	6.7	7.3	7.8	8.3	8.7	9.2	9.5	9.9	10.2	10.4
Jordan	5.0	5.7	6.3	7.0	7.6	8.1	8.7	9.1	9.6	9.9	10.2
Lebanon	3.4	3.6	3.8	4.0	4.1	4.3	4.4	4.5	4.6	4.7	4.7
Palestine	3.2	3.7	4.3	5.0	5.7	6.4	7.2	7.9	8.7	9.4	10.1
Syria	16.8	19.0	21.4	23.8	26.0	28.1	30.0	31.7	33.3	34.7	35.9
Western Asia	**125.9**	**137.1**	**150.0**	**163.9**	**177.3**	**189.4**	**200.5**	**210.9**	**220.7**	**229.6**	**237.0**
Morocco	29.2	31.5	33.8	36.2	38.3	40.3	42.0	43.5	44.8	45.7	46.4
Algeria	30.5	32.9	35.4	38.1	40.6	42.9	44.7	46.2	47.5	48.6	49.5
Libya	5.3	5.9	6.4	7.0	7.5	8.0	8.3	8.7	9.0	9.3	9.6
Tunisia	9.6	10.1	10.6	11.1	11.6	12.0	12.4	12.6	12.8	12.9	12.9
Egypt	67.3	74.0	81.1	88.2	94.8	101.1	107.1	112.7	117.8	122.2	125.9
North Africa	**141.8**	**154.3**	**167.5**	**180.6**	**192.9**	**204.2**	**214.5**	**223.8**	**231.9**	**238.8**	**244.3**
Total MENA	**316.3**	**348.2**	**382.3**	**417.8**	**452.2**	**484.4**	**514.3**	**542.4**	**568.5**	**591.9**	**611.9**

Table 3-1: Population of the analysed countries in MENA in million persons between the years 2000 and 2050 according to the United Nations medium growth scenario revised in 2004 /UN 2006/.

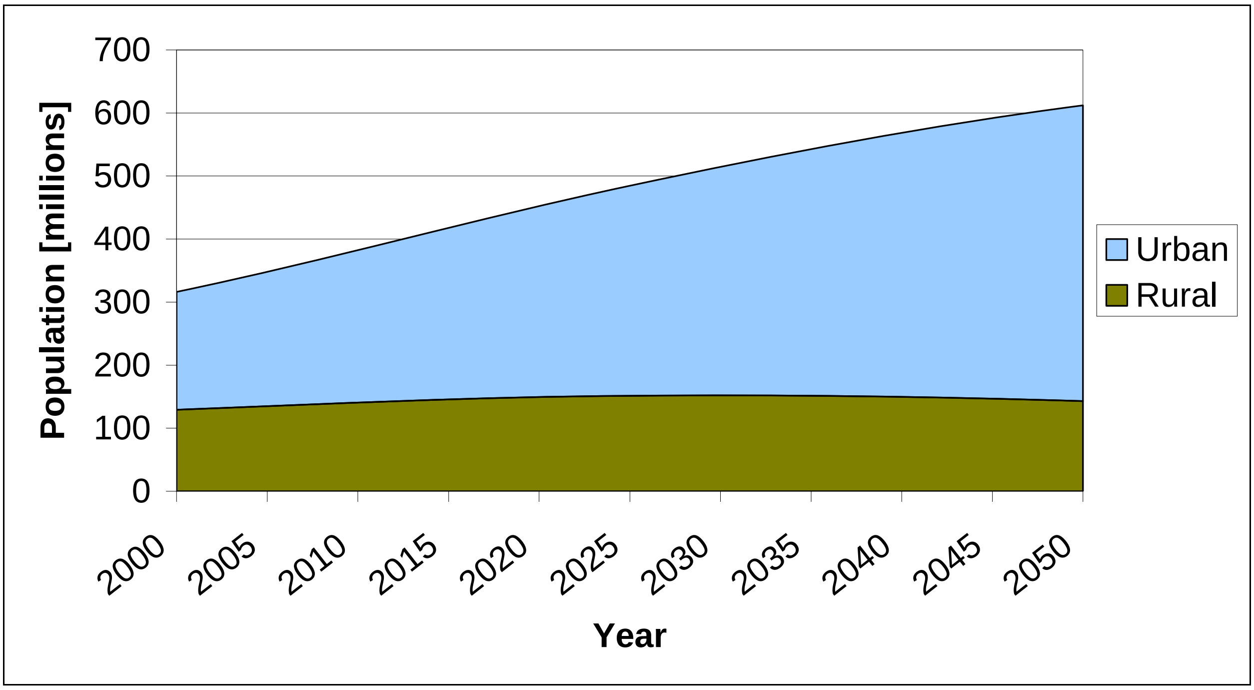

Figure 3-2: Urban and rural population prospects in MENA according to the United Nations medium growth scenario revised in 2004 /UN 2006/ (extrapolated after 2030)

Rural Share [%]	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Yemen	76.0%	73.5%	71.0%	68.3%	65.4%	62.5%	59.5%	56.3%	53.2%	50.0%	46.8%
Bahrain	7.1%	6.5%	5.9%	5.3%	4.8%	4.4%	4.0%	3.6%	3.3%	2.9%	2.7%
UAE	12.4%	11.1%	10.0%	8.9%	7.9%	7.1%	6.3%	5.6%	5.0%	4.4%	3.9%
Kuwait	3.9%	3.6%	3.4%	3.1%	2.9%	2.7%	2.5%	2.3%	2.2%	2.0%	1.9%
Oman	23.3%	21.4%	19.6%	17.9%	16.4%	15.0%	13.6%	12.4%	11.3%	10.2%	9.3%
Qatar	7.0%	6.3%	5.7%	5.2%	4.7%	4.2%	3.8%	3.5%	3.1%	2.8%	2.5%
Saudi Arabia	12.8%	11.6%	10.5%	9.5%	8.6%	7.8%	7.0%	6.3%	5.7%	5.1%	4.6%
Arabian Peninsula	**36.1%**	**34.4%**	**33.3%**	**32.3%**	**31.2%**	**30.1%**	**28.9%**	**27.6%**	**26.4%**	**25.1%**	**23.8%**
GCC	**12.7%**	**11.4%**	**10.4%**	**9.4%**	**8.5%**	**7.7%**	**6.9%**	**6.3%**	**5.7%**	**5.1%**	**4.6%**
Iran	35.2%	32.5%	29.8%	27.3%	24.9%	22.7%	20.6%	18.7%	16.9%	15.2%	13.7%
Iraq	33.7%	32.6%	31.4%	30.3%	29.2%	28.1%	27.1%	26.0%	25.0%	24.1%	23.1%
Israel	8.2%	7.6%	7.1%	6.6%	6.1%	5.7%	5.3%	4.9%	4.6%	4.2%	3.9%
Jordan	21.7%	20.6%	19.6%	18.6%	17.7%	16.7%	15.9%	15.0%	14.2%	13.4%	12.7%
Lebanon	3.9%	3.6%	3.4%	3.1%	2.9%	2.7%	2.5%	2.3%	2.2%	2.0%	1.9%
Palestine	1.0%	1.4%	1.8%	2.1%	2.5%	2.6%	2.6%	2.7%	2.7%	2.8%	2.8%
Syria	9.7%	8.9%	8.2%	7.6%	7.0%	6.5%	5.9%	5.5%	5.0%	4.6%	4.3%
Western Asia	**33.6%**	**31.5%**	**29.5%**	**27.6%**	**25.8%**	**24.2%**	**22.6%**	**21.1%**	**19.7%**	**18.4%**	**17.2%**
Morocco	44.0%	41.3%	38.6%	36.0%	33.5%	31.0%	28.7%	26.4%	24.3%	22.3%	20.4%
Algeria	42.5%	40.1%	37.5%	34.9%	32.3%	30.0%	27.9%	25.7%	23.7%	21.8%	20.0%
Libya	12.0%	11.2%	10.5%	9.8%	9.1%	8.5%	7.9%	7.3%	6.8%	6.4%	5.9%
Tunisia	33.8%	31.4%	29.2%	27.0%	25.0%	23.0%	21.2%	19.5%	17.9%	16.4%	14.9%
Egypt	58.9%	57.0%	55.0%	53.0%	51.0%	48.9%	46.9%	44.9%	42.9%	41.0%	39.0%
North Africa	**48.9%**	**46.8%**	**44.6%**	**42.5%**	**40.4%**	**38.3%**	**36.4%**	**34.5%**	**32.6%**	**30.8%**	**29.1%**
Total MENA	**40.8%**	**38.7%**	**36.8%**	**34.9%**	**33.0%**	**31.2%**	**29.5%**	**27.9%**	**26.3%**	**24.8%**	**23.3%**

Table 3-2: Rural population share of the analysed countries in MENA according to the United Nations medium growth scenario revised in 2004 /UN 2006/.

The share of rural population of the total MENA region is today about 41 %. Rural population will most probably be stagnating over the coming decades. Therefore, the share of rural population will be reduced by 2050 to about 23 % (Table 3-2 and Figure 3-2).

This trend – although at different shares of total population – can be seen in all countries and sub-regions. Countries like Yemen, Egypt, Morocco, Algeria and Iran have a rather large portion of rural population, while the rural population share of e.g. the GCC countries is rather low. The distribution of rural and urban population will be significant when analysing the markets for decentralised small-scale and centralised large-scale seawater desalination systems.

3.2 Economic Growth

After population, the second driving force for water demand is economic growth, represented by the change of the gross domestic product (GDP) over time. The GDP is expressed in US$ 2001 purchasing power parity (PPP), defined by the basket of commodities of the Penn World Tables /Heston et al. 2002/.

Long-term average per capita growth rates of the GDP for the different countries are selected in a range of reasonable values, most countries closing the gap of GDP per capita to a certain reference country with very high GDP per capita – we have selected United States as reference for this purpose – by 50 % in the year 2050 (Table 3-3). As the USA is a large country with very high GDP per capita, it represents something like an upper margin of productivity. Thus, the growth rate for the USA can be seen as reference case for a highly developed technical and organisational progress.

The countries analyzed here reach higher GDP per capita growth rates as they are able to accelerate productivity growth by imitation, subsequently reducing their gap to the U.S. and approximately reaching present central European economic standards in 2050. For example, Germany and the United Kingdom had in 2006 a per capita GDP of 31,800 $/cap/year /CIA 2007/, an order of magnitude that according to our model is achieved by most MENA countries by 2050 (Figure 3-3).

North Africa		**Western Asia**		**Arabian Peninsula**	
Morocco	4.6	Jordan	4.4	Oman	3.2
Algeria	4.0	Lebanon	4.2	Kuwait	2.1
Tunesia	3.6	Syria	4.7	Qatar	1.9
Libya	3.8	Iraq	5.6	Saudi-Arabia	2.7
Egypt	4.1	Iran	3.8	UAE	1.8
		Israel	1.9	Yemen	4.5
Reference U.S.	1.2	Palestine	4.6	Bahrain	2.3

Table 3-3: Average long-term per capita GDP growth rates in %/year selected for the scenario calculation.

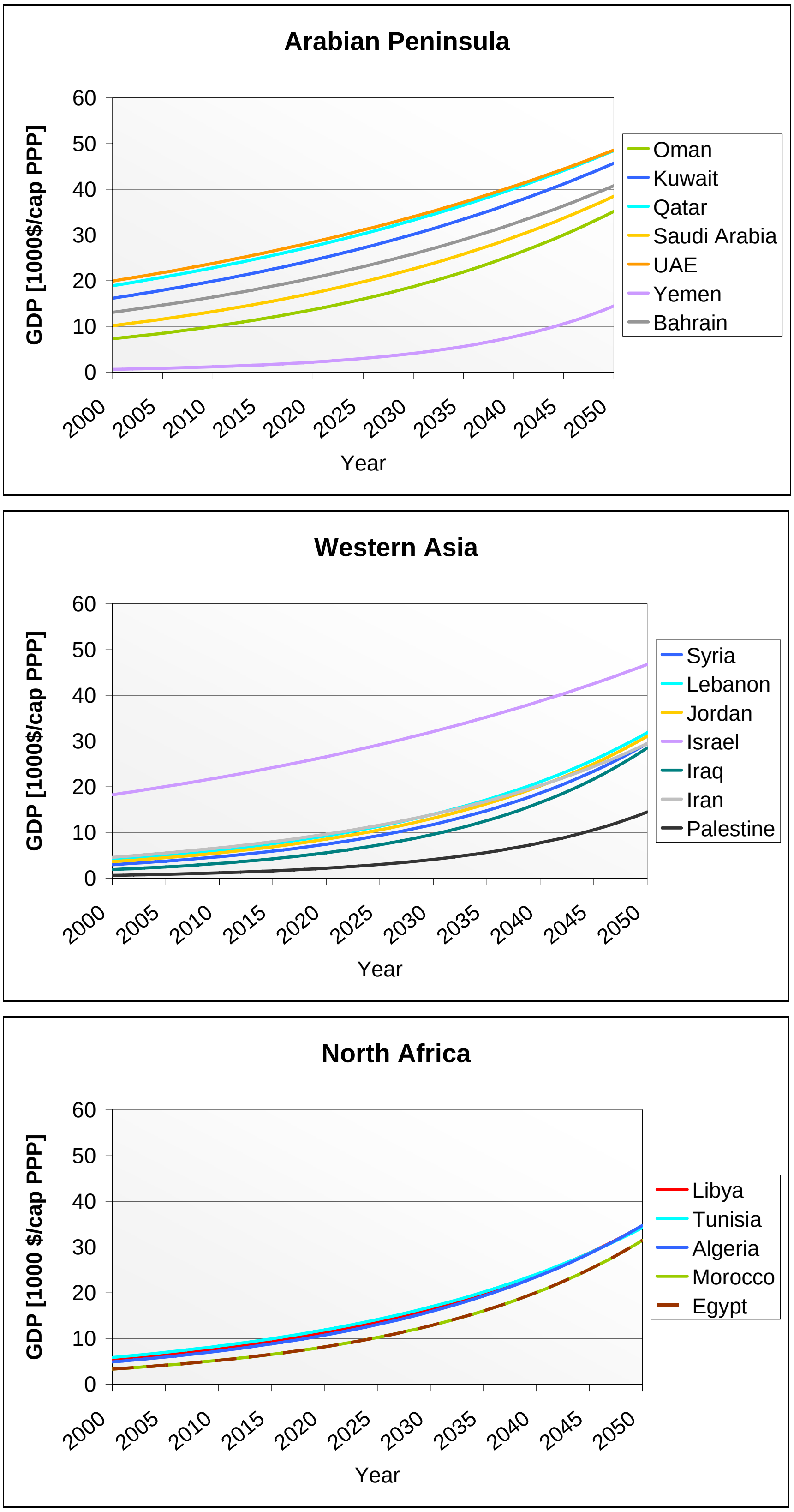

Figure 3-3: Development of the per capita GDP for the MENA countries according to the economic growth model applied in the AQUA-CSP study.

3.3 Water Demand Prospects

In the following we introduce a simple method for estimating the freshwater demand on country level /Trieb and Müller-Steinhagen 2007/. It shows how the demand for freshwater may develop under certain key assumptions for population, economic growth and increasing efficiency in the water sector. The water demand ω for irrigation (ω_{irr}), municipal use (ω_{mun}) and industrial consumption (ω_{ind}) is a function of time t:

$$\omega(t) = \omega(t-1) \cdot (1+\gamma(t)) \cdot \frac{\eta(t-1)}{\eta(t)} \cdot (1-\mu) \qquad \text{Equation (1)}$$

with the relevant driving force, the growth rate γ of the population γ_{pop} or of the gross domestic product γ_{GDP}, respectively, the efficiency of distribution η and the end use efficiency enhancement μ. The distribution efficiency departs from the present values achieved in each country $\eta(t_S)$ in the starting year of the scenario t_S = 2001, and develops with a linear function of the calendar year according to

$$\eta(t) = \eta(t_E) \cdot \varepsilon(t) + \eta(t_S) \cdot (1-\varepsilon(t)) \qquad \text{Equation (2)}$$

until reaching the efficiency $\eta(t_E)$ in the final year of the scenario t_E = 2050, which is calculated from

$$\eta(t_E) = \eta(t_S) + \alpha \cdot (\beta - \eta(t_S)) \qquad \text{Equation (3)}$$

with the best practice efficiency β and the progress factor α, that describes how much of the efficiency gap between present practice and state of the art is closed until 2050. The transition from present practice to state of the art best practice follows a linear function of time using the weighing factor ε,

$$\varepsilon = \frac{t - t_S}{t_E - t_S} \qquad \text{Equation (4)}$$

with the starting year t_S = 2001, the final year t_E = 2050 and the time variable t = 2001, 2002, ... 2050.

Sector	Irrigation	Municipal	Industrial
Driving Force	γ_{pop}	γ_{GDP}	γ_{GDP}
Best Practice	β_{irr} = 70 %	β_{mun} = 85 %	β_{ind} = 85 %
Progress Factor	α_{irr} = 50 %	α_{mun} = 65 %	α_{ind} = 65 %
General End Use Eff. Enhancement	μ_{irr} = 0	μ_{mun} = 1.8 %/y	μ_{ind} = 1.8 %/y

Table 3-4: Parameters used for demand side calculation

For the different demand sectors (irrigation, municipal use and industrial use) different sets of parameters according to Table 3-4 are used to calculate the future water demand.

For the calculation of the water demand for irrigation, the population growth rate of each country γ_{pop} that can be derived from Table 3-4 was used as driving force indicator. This implies that the present per capita water consumption for irrigation is in principle maintained also in the future, maintaining also today's level of per capita availability of water for food production in each country. The parameters α and β for irrigation imply that half of the gap between the present irrigation efficiency and best practice which is assumed to be 70 % is closed by 2050. The end use efficiency enhancement of irrigation is already considered with that, so μ is neglected. Starting values of irrigation efficiency and municipal/industrial distribution efficiency for the year 2000 for each country were taken from /FAO 2007/ and /World Bank 2007/.

For the municipal and industrial water demand we have used the GDP growth rate as driving force indicator, which is the sum of the per capita GDP growth rate γ_{GDP} from Table 3-3 and the population growth rate γ_{pop}. The model assumes that about two thirds of the gap of present water distribution efficiency and best practice distribution efficiency (85 %) is closed until 2050. The general end use efficiency is assumed to increase by relative μ = 1.8 % per year, leading to a general reduction of water consumption for constant water services of 60 % until 2050. A similar development has e.g. been experienced in Australia in the past 40 years, where the water demand doubled with a growth rate of 1.6 %/y while the GDP grew by a factor of 5 with a rate of 4.2 %/y. In this case, the general end use enhancement was 2.6 %/y including the irrigation sector. Australia as a mostly arid country, that has experienced a transition to a strong industrial country in the past 40 years, may serve as a good example for the MENA economies in terms of water management and efficiency /ABS 2006/.

Starting values for the water withdrawal in the year 2000 were taken from /FAO 2007/. If there was more in-depth information available from the MENA region itself on the freshwater demand of the starting year 2000, it was used instead of the FAO data, like e.g. in the case of Saudi Arabia, UAE and Palestine /ESCWA 2001-2/, /Shaheen 2006/.

The resulting model of the development of freshwater demand in each country is shown in Figure 3-4 and Table 3-6. All in all, the MENA freshwater demand will grow more or less proportional to the population, which could be interpreted as if a significant part of the additional growth of per capita GDP and the related additional water services can be compensated by efficiency enhancement. This demonstrates the crucial importance of water management and efficiency of distribution and end use. However, it also shows that these measures alone will not suffice to cover the future demand of the MENA region, especially if present demand is already today over-using the available natural freshwater resources.

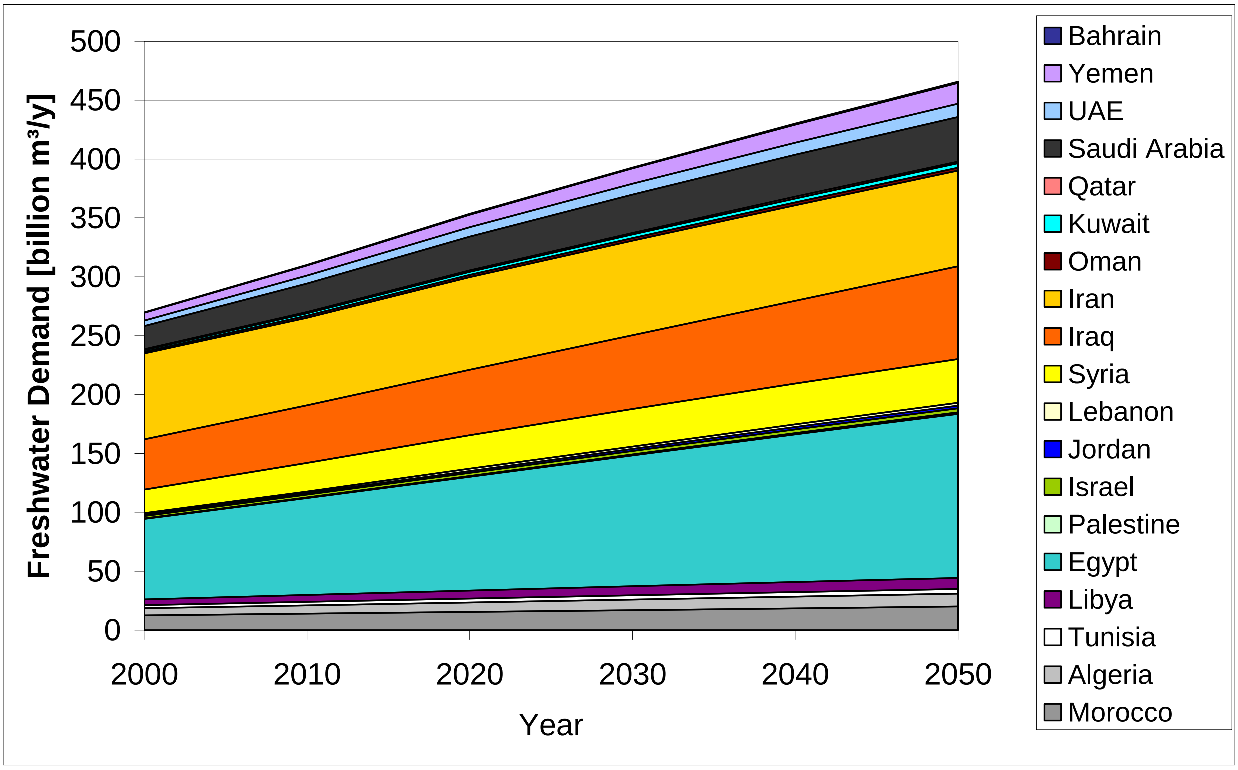

Figure 3-4: Freshwater demand derived from growth of population and economy considering increasing use of wastewater and efficiency as described in the text.

The future demand is calculated individually for every country and aggregated to the regions of North Africa, Western Asia and Arabian Peninsula as a function of population and economic growth (Table 3-6).

The future water demand of the agricultural sector was calculated as function of population. The idea behind the model is that the per capita water supply for food production purposes is maintained at least constant in every country to avoid an increasing dependency on food imports /FAO 2002/, /PRB 2002/ (Figure 3-6). In our scenario, the efficiency of irrigation technologies is enhanced with time, through change of irrigation systems and technical advance.

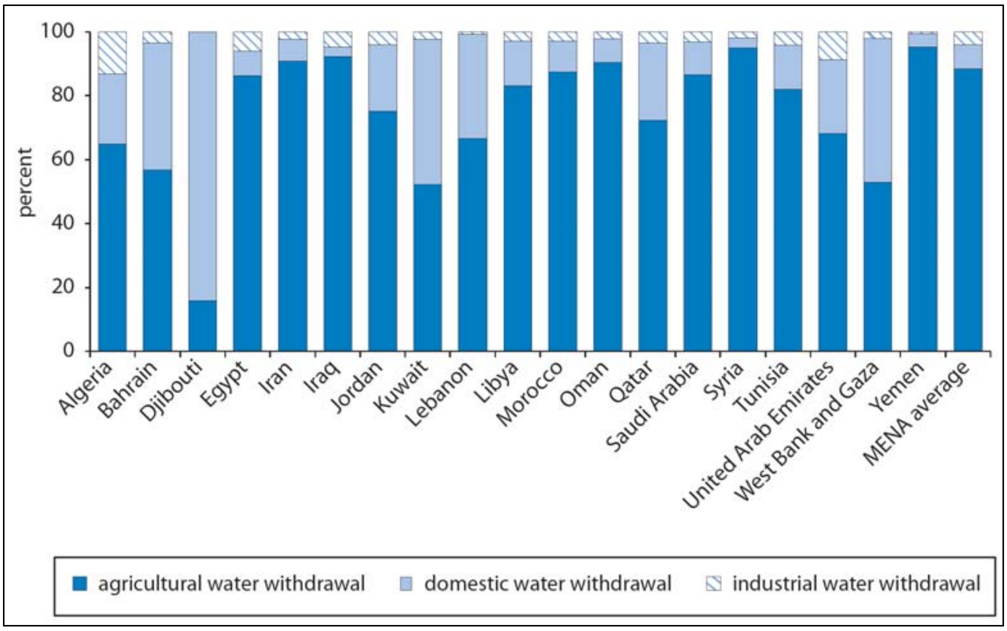

Figure 3-5: Annual water withdrawal by sector in 1998-2002 /World Bank 2007/, /FAO 2007/

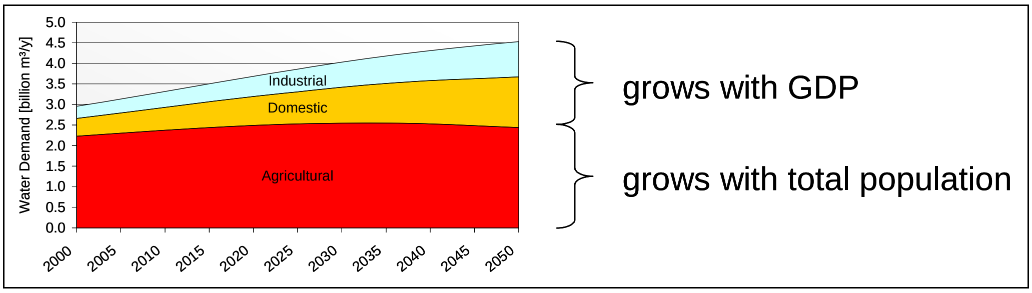

Figure 3-6: Example of the AQUA-CSP scenario showing the relation of water demand to the input parameters population and economic growth for Tunisia

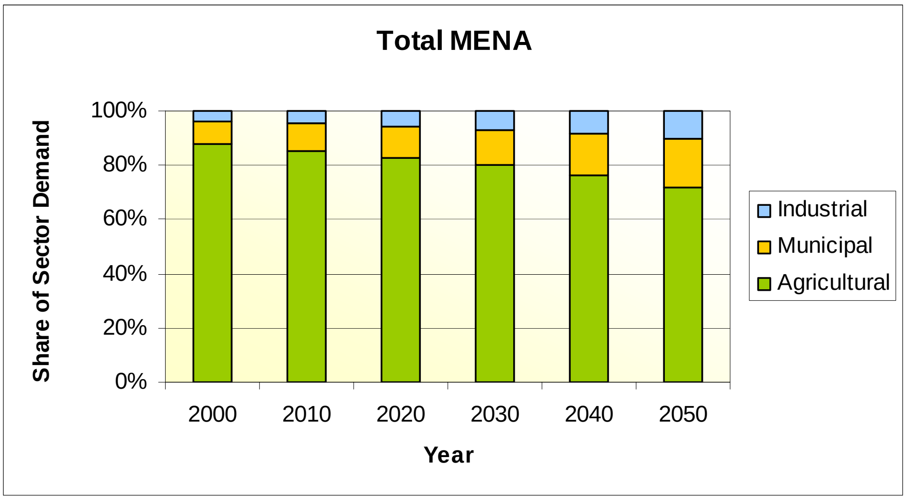

Figure 3-7: Share of water demand by sectors in the AQUA-CSP scenario

In our model the water demand of the industrial and domestic sectors grows in proportion to the national economy represented by the GDP. Efficiency enhancements of the municipal water supply system are considered. Efficiency starts with actual values in each country taken from /FAO 2007/ and reaches close to best practice values by 2050.

The water demand in the MENA region in the year 2000 consists of 88 % agricultural use, 8 % municipal use and 4 % industrial use (Figure 3-5). While the water demand of the agricultural sector will be stagnating in countries like Morocco, Algeria and the GCC with retrogressive rural population, it will still increase significantly e.g. in Yemen and Egypt. This pattern is likely to change over the years, as shown in Figure 3-7 with the municipal and industrial sectors becoming more important.

The by far strongest growth of total freshwater demand will take place in Egypt, which will make up for about 32 % of the total MENA freshwater demand in the year 2050 (Figure 3-4). Water demand will also grow significantly in Iraq, Saudi Arabia, Syria and Yemen. Taking into account the growth of population and economy and the different measures of increasing the extraction, distribution and end-use efficiency of the water sector as shown in this chapter, the freshwater demand in MENA will almost double until 2050. This will exert significant pressure on the scarce water reserves of this mainly arid region.

Nevertheless, our scenario is rather optimistic compared to other scenarios that predict a doubling of demand already for the year 2025 or a stagnation of freshwater supply after 2000, as will be shown in Chapter 3.5. In contrast to such extremes, we believe that a well balanced approach of increasing the efficiencies of water extraction, distribution and end-use, better water management and increased seawater desalination powered by renewable, mainly solar energy will lead to a satisfying result for the MENA region (Chapter 4).

3.4 Freshwater Sources and Deficits

Our analysis shows the renewable freshwater resources and compares them to the growing freshwater demand of each country. Within a specific country, there may be regions with deficits that cannot be identified on the basis of statistical country-wide data. An analysis of Spain or Italy at that level would not identify any deficits, however, we know that in Andalusia and Sicily, there is a severe water shortage, and plans are underway to build desalination plants. Most of the actual data on renewable water resources and exploitable shares has been obtained from the AQUASTAT Database of the Food and Agriculture Organisation of the United Nations /FAO 2007/. The following definitions have been used for our water balances:

- Renewable Water = Renewable Surface Water + Renewable Groundwater – Overlap
- Exploitable Water = Renewable Water · Exploitable Share

- Sustainable Water = De Facto Used Share of Exploitable Water + Reused Waste Water
- Water Demand = Agricultural + Municipal + Industrial Demand
- Deficit = Water Demand – Sustainable Water
- Non-sustainable water = Overuse of Groundwater + Desalination based on Fossil Fuels

In its recent report "Making the Most of Scarcity " the World Bank has analysed the available freshwater resources in the Middle East and North Africa /World Bank 2007/. Figure 3-8 shows the per capita available renewable freshwater sources in each country. Different to our analysis in Chapter 2, this data includes non-conventional sources of water used at present, like desalination and "virtual" water obtained from food imports. Considering the generally accepted threshold of 1000 m³/cap/year for water poverty, only five countries have sufficient water resources: Iraq, Iran, Syria, Lebanon and Morocco. Egypt is exactly at the rim, and all other MENA countries can be considered as poor in natural water resources.

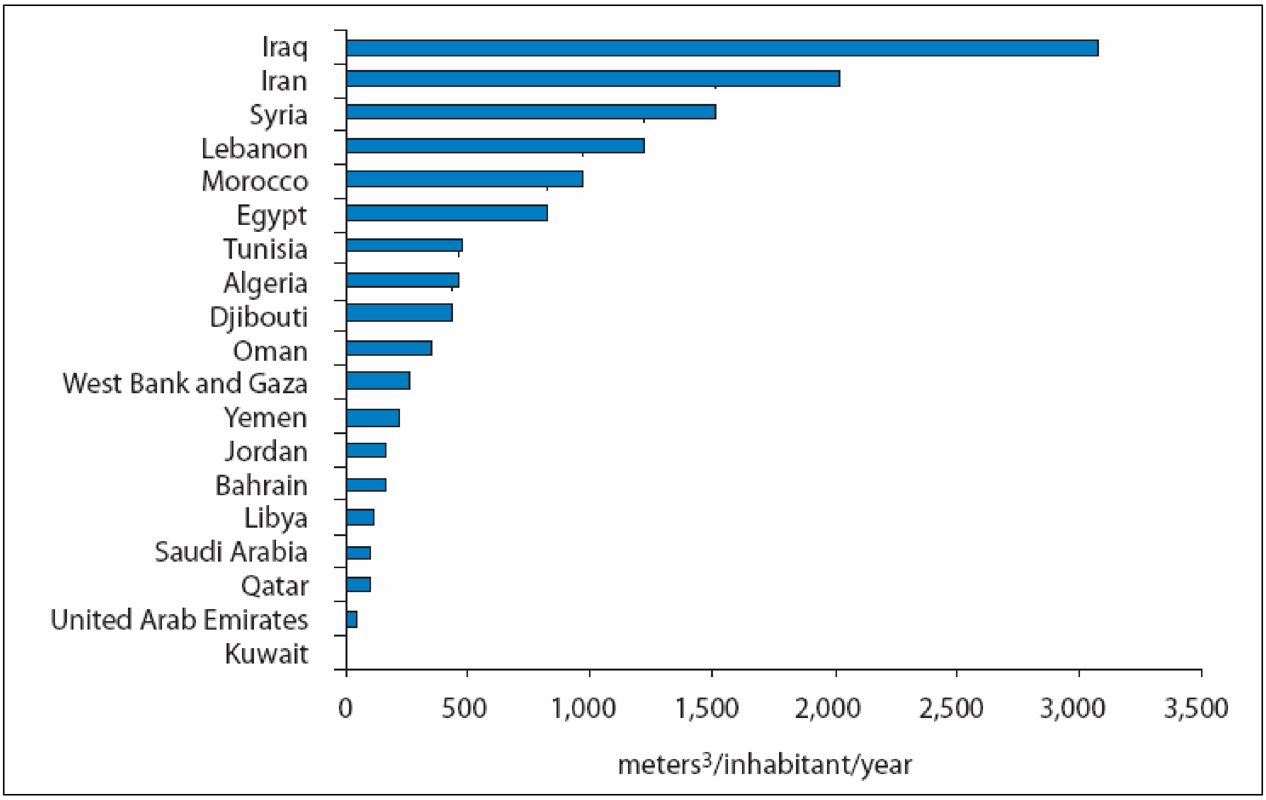

Figure 3-8: Per capita available renewable water in MENA /World Bank 2007/. Data includes non-conventional sources like desalination and "virtual water" through food imports.

	Water available by source (10^9 m^3/yr)			
Country	Internal renewable water resources	External renewable water resources	Nonrenewable groundwater	Virtual water
Algeria	13.9	0.4	1.7	10.9
Bahrain	0.1	0.1	0.1	0.5
Djibouti	0.3	0.0	0.0	0.1
Egypt	4.9	56.5	0.8	18.9
Iran	128.5	9.0	0.0	6.8
Iraq	35.2	40.2	0.0	1.4
Jordan	0.7	0.2	0.2	5.0
Kuwait	0.3	0.0	0.3	1.4
Lebanon	4.8	0.0	0.0	2.0
Libya	0.7	0.0	3.7	1.4
Morocco	29.0	0.0	0.0	5.8
Oman	1.0	0.0	0.2	1.4
Qatar	0.2	0.0	0.2	0.3
Saudi Arabia	3.2	0.0	17.8	13.1
Syria	7.6	19.3	0.0	−4.1[a]
Tunisia	4.2	0.4	0.7	4.1
United Arab Emirates	0.7	0.0	1.6	4.2
West Bank and Gaza	0.8	0.0	0.0	2.2
Yemen	2.7	0.0	1.3	1.6

Table 3-5: Water available or used by source in MENA /World Bank 2007/, /FAO 2007/

Internal renewable resources account for the average annual flow of rivers and recharge of groundwater generated from endogenous precipitation. Double counting of surface water and groundwater is avoided as far as possible. Renewable resources are a measure of flow rather than stock or actual withdrawal. They are, therefore, typically greater than the volume of exploitable water resources, for which consistent data are unavailable. In our study, the exploitable share was estimated from data from /World Bank 2007/, /FAO 2007/.

External renewable water resources refer to surface and renewable groundwater that come from other countries plus part of shared lakes and border rivers as applicable, net of the consumption of the country in question.

Non-renewable groundwater resources are naturally replenished only over a very long timeframe. Generally, they have a negligible rate of recharge on the human scale (<1 percent) and thus can be considered non-renewable. In practice, non-renewable groundwater refers to aquifers with large stocking capacity in relation to the average annual volume discharged.

Virtual water is water used to produce food products that are traded across international borders. It is the quantity of water that would have been necessary for producing the same amount of food that a country may be exporting or importing. These figures reflect both crop and livestock net imports.

In our model the amount of **reused waste water** is increased continuously from the statistical values of each country in the year 2000 until reaching a best practice rate of 50 % within the municipal and industrial sector in the year 2050. The sustainable water is shown in Figure 3-9 in comparison to the agricultural, municipal and industrial freshwater demand of the MENA region.

Sustainable water increases with time due to presently untapped resources in some countries that will be exploited in the future and due to an increased reuse of wastewater of the municipal and industrial sector. **Unsustainable water supply** from fossil fuelled desalination and from excessive groundwater withdrawal is considered as potential future deficit.

The difference of sustainable sources and water demand leads to the **water deficit** displayed in Figure 3-10 as a function of time. There is already a significant deficit today, which is covered by sea water desalination based on fossil fuels and by the over-exploitation of groundwater resources, with the consequence of subsequently dropping groundwater levels, intrusion of salt water into the groundwater reservoirs and desertification in many regions in MENA (Figure 3-11). According to our analysis, this deficit tends to increase from 50 billion m³ per year in the year 2000, which is almost the annual flow of the Nile River allocated to Egypt, to 150 billion m³ in the year 2050. Egypt, Saudi Arabia, Yemen, and Syria are the countries with the largest future deficits. The Egyptian deficit in 2050 will amount to 65 billion m³/y which is almost equivalent to the annual flow of the Nile River, the total deficit in MENA will be equivalent to three times the Nile.

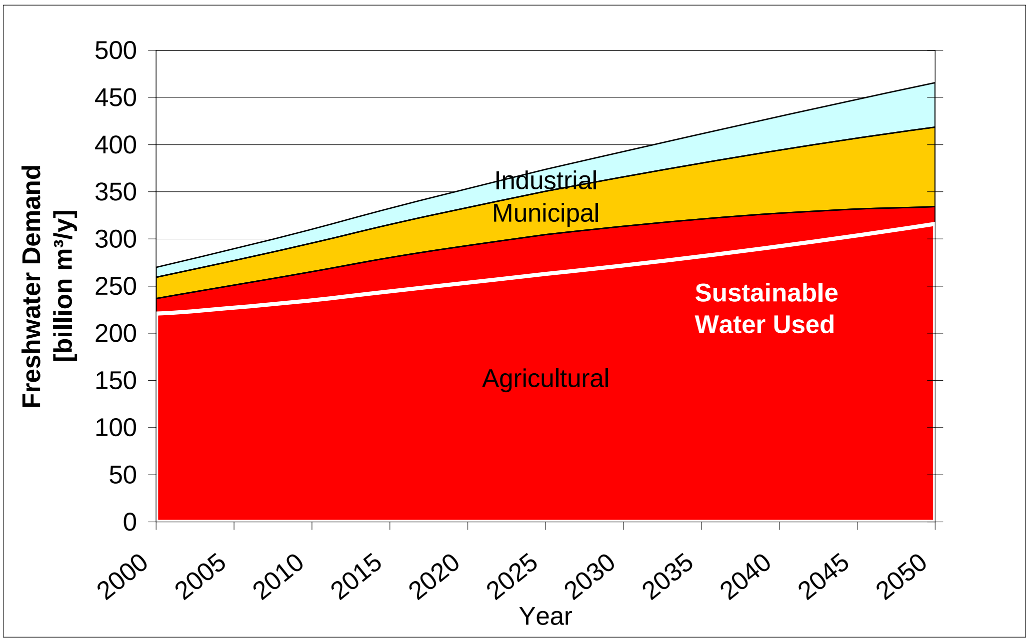

Figure 3-9: Industrial, municipal and agricultural freshwater demand in MENA in comparison to sustainable used freshwater resources of the region (white line). The increase of de-facto used sustainable water is due to enhanced re-use of water and to resources in some countries remaining untapped up to now.

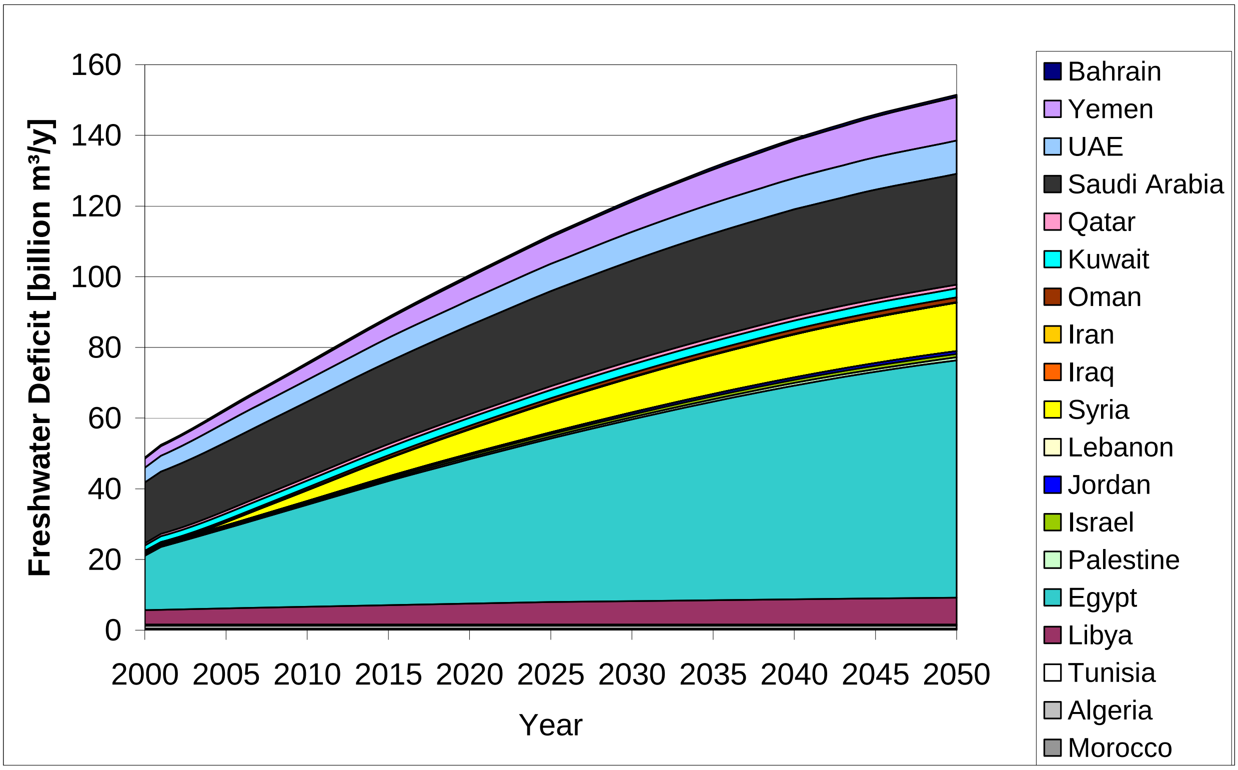

Figure 3-10: Freshwater deficit defined as the difference between water demand and sustainable freshwater for each of the MENA countries according to the AQUA-CSP scenario. Today, part of the water demand is covered by desalination powered by fossil fuels and by the exploitation of non-renewable groundwater. These are not considered as sustainable sources and thus are included as potential future deficits

Enhancement of efficiency of water distribution, water use and water management in order to achieve best practice standards by 2050 is already included in the underlying assumptions of this scenario. It is obvious that the MENA countries will be confronted with a very serious problem in the medium term future, if those and adequate additional measures are not initiated in time.

The total annual water deficits in MENA will increase from today 50 billion m³/y that are at present supplied by excessive groundwater withdrawals and fossil fuelled desalination, to about 150 billion m³/y by the year 2050 (Table 3-6). There is no sustainable source in sight to supply such deficits except seawater desalted by renewable energy. The cost of fossil fuels is already today too high for intensive seawater desalination and its volatility and the fact that fossil fuels are limited in time eliminates fossil fuels as a resource for sustainable water security in MENA. Nuclear power is as well a very limited and costly resource, and in addition to that faces unsolved problems like nuclear waste disposal, proliferation and other serious security issues.

It is particularly interesting to see that Syria, which – at least statistically – is not suffering from water scarcity at present, seems to enter a phase of scarcity and deficits in the coming decades, in spite of the large number of rivers entering the country. Many smaller countries in MENA do not contribute much to the total deficit, but may have serious water scarcity within their borders.

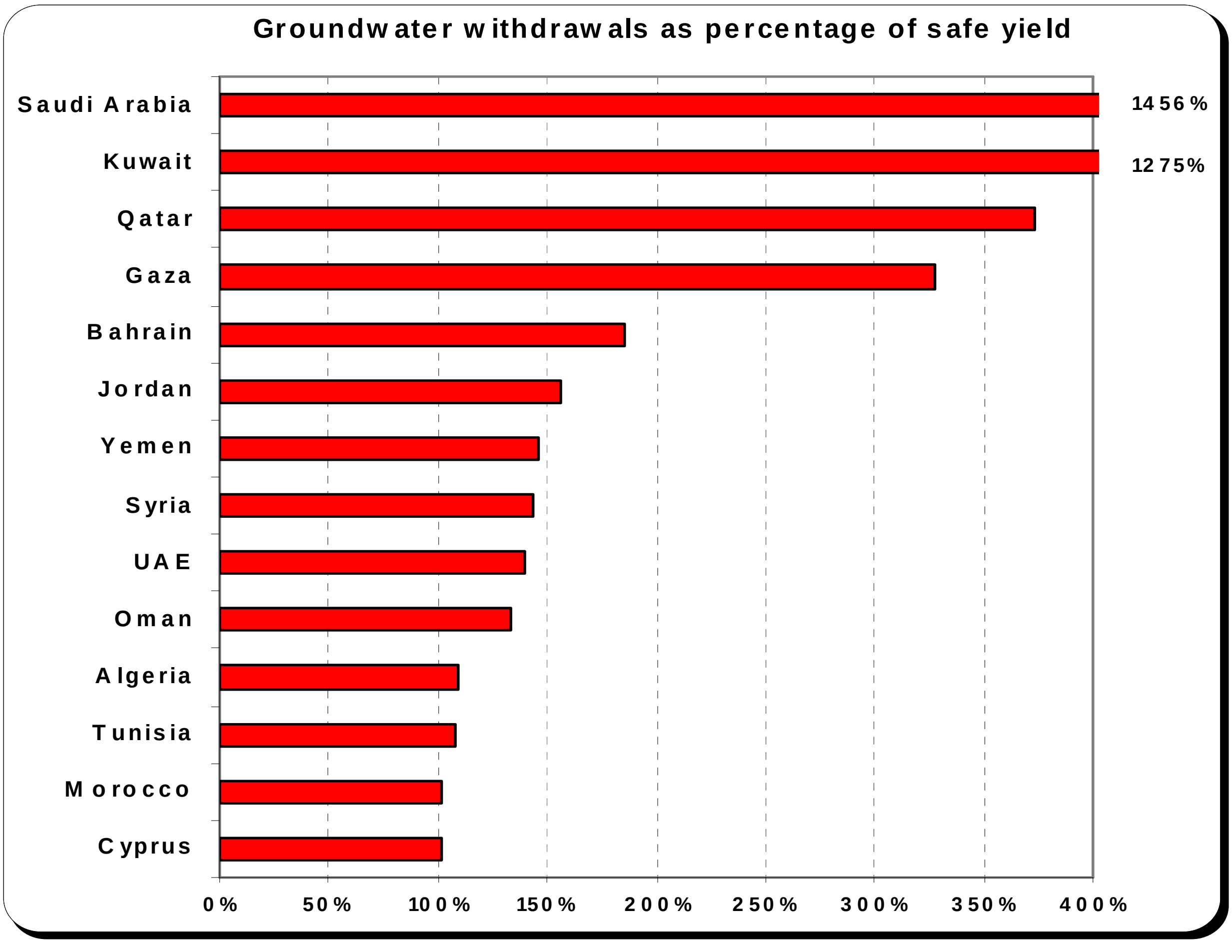

Figure 3-11: Groundwater withdrawals as percentage of save yield for selected countries /Saghir 2003/

North Africa

The sustainable sweet water resources of Northern Africa are today almost used to their limits and no considerable increase of their exploitation can be expected for the future. Unsustainable use from fossil desalination and from excessive ground water withdrawal is already taking place to a considerable extent, with a dramatic increase of this situation ahead (Table 3-6).

In spite of that, the per capita water withdrawal in North Africa will grow from 670 to about 750 m^3/cap/y which is due to a relative moderate growth of the population and an increasing importance of the municipal and industrial sector, mainly in Egypt. The scenario assumptions lead to a linear growth of the water demand in North Africa from today 95 billion m^3/y to 183 billion m^3/y in 2050. A reduction in the agricultural sector is compensated by the growth of the domestic and industrial sectors. Sustainable sources in North Africa cannot be exploited to a greater extent than today. All countries will experience growing deficits, with Egypt being by far the dominating case, due to a strong agricultural sector and large population, followed by Libya and the Maghreb countries. The deficit of Egypt expected for 2050 might arise to the present water capacity of the Nile river of about 65 billion m³/y. An official expectation of a deficit of 35 billion m³/y until 2025 was recently published.

All countries in North Africa will experience a reduction of their water demand growth rates until 2050. The per capita consumption is presently highest in Egypt and Libya (about 1000 m³/cap/y), and lowest in Algeria (200 m³/cap/y), with a slightly increasing trend in all countries. The strong economic growth of the North African countries reveals the challenge of sustainable development, as the water demand of the industrial and domestic sector will growth very quickly and overcompensate possible reductions in the agricultural sector.

Arabian Peninsula

The Arabian Peninsula is characterised by a strongly growing population and a dominating water demand of the agricultural sector, especially in Yemen. The demand will increase from 34 to 72 billion m³/y. The region's water demand is dominated by Saudi Arabia and Yemen, both relying to a great extent on non-sustainable sources, like fossil-fuelled desalination and excessive groundwater withdrawal. Due to the combination of high population and high dependency on agriculture, both countries will be facing considerable deficits, if their water supply would be persistently based on the limited resources of fossil fuels and non-renewable groundwater, as is the case today because the sustainable natural resources of this region are very limited. On the Arabian Peninsula, the relation of sustainable and unsustainable use of water is rather dramatic. The specific consumption on the Arabian Peninsula will fall from today over 700 to about 545 m³/capita and year, due to a strong growth of the population and a persisting importance of the agricultural sector, coupled with very limited natural water resources.

Western Asia

Western Asia still has large sustainable water resources that will be increasingly exploited in the future. However, even in this region, non-sustainable use as from fossil fuelled desalination and from unsustainable groundwater withdrawal is already experienced on a local level and shows an increasing trend in the future.

Western Asia will reduce its per capita demand from 1110 to about 870 m³/cap/y. The water demand in Western Asia will increase from today 140 billion m³/y to about 210 billion m³/y in 2050, showing a trend for stabilisation by that time.

There are vast sustainable water resources in that region which will be increasingly exploited in the future. However, local deficits will occur in Syria, Jordan, Israel and later also in Iraq.

Total MENA

The per capita water demand and its future trend is different in the three regions. The MENA average per capita consumption will be slightly reduced from about 850 to 750 m³/capita/year. The MENA water demand situation is characterised by several facts that at a first glance seem to be rather paradox. On one hand, there is a severe water shortage, with the total region on average living beyond the commonly accepted water poverty level of 1000 m³/cap/y, while on the other hand there is a dominating agricultural production sector that due to the arid climate of the region consumes more than 85 % of the available natural renewable water resources. This situation is sharpened by a strongly growing population, which will double in the 50 years between the beginning and the middle of the 21st century.

Up to now, the proposed answers to this situation were dominated by a call for better water management, measures to increase efficiency, higher and unsubsidised water tariffs, increased accountability, re-use of wastewater, better management of groundwater, reduction of agriculture and increase of food imports. Some of the countries that had the energetic and financial means to do so, mostly the GCC countries, also took into consideration seawater desalination, using for this purpose their abundant fossil energy resources /World Bank 2007/.

However, groundwater resources are already over-used, fuel for desalination is becoming very expensive, and there is simply not enough water available, no matter if well managed or not. Of course, the above mentioned measures make a lot of sense and should be implemented as soon as possible. They will effectively stretch existing resources and delay a possible collapse. But they will not be able to avoid a collapse of water supply in the long-term, if no additional, new sources for freshwater are found and activated in time. As a consequence of scarcity, some places in MENA are already abandoned, and migration induced by water scarcity is increasing, solving nothing but creating similar problems in other regions (Chapter 4 and Chapter 5).

North Africa		2000	2010	2020	2030	2040	2050
Demand Growth Rate	%/y	1.78	1.66	1.37	1.18	1.03	1.00
Population	Million	141.9	167.3	192.8	214.5	231.9	244.3
Exploitable Water	Bm³/y	81.8	81.8	81.8	81.8	81.8	81.8
Sustainable Water Used	Bm³/y	72.8	77.5	83.5	90.5	98.7	108.6
Agricultural Demand	Bm³/y	80.4	92.1	103.0	111.4	117.6	120.9
Municipal Demand	Bm³/y	8.6	12.1	16.8	22.6	29.7	38.4
Industrial Demand	Bm³/y	5.4	7.6	10.6	14.3	18.8	24.3
Total Demand North Africa	Bm³/y	94.4	111.9	130.3	148.3	166.1	183.6
per capita Consumption	m³/cap/y	666	669	676	691	716	752
Wastewater Re-used	Bm³/y	3.2	5.6	9.2	14.5	21.7	31.3
North Africa Deficit	Bm³/y	21.6	34.7	47.6	58.9	69.0	76.9

Western Asia		2000	2010	2020	2030	2040	2050
Demand Growth Rate	%/y	0.80	1.10	0.80	0.63	0.60	0.60
Population MP	Mp	126.0	149.9	177.2	200.6	220.8	236.9
Exploitable Water	Bm³/y	238.3	238.3	238.3	238.3	238.3	238.3
Sustainable Water Used	Bm³/y	139.3	148.8	160.6	170.3	180.0	190.2
Agricultural Demand	Bm³/y	127.7	136.7	147.1	153.1	155.9	155.8
Municipal Demand	Bm³/y	8.5	10.9	14.4	18.6	23.9	30.5
Industrial Demand	Bm³/y	4.2	5.7	7.8	10.7	14.8	20.2
Total Demand Western Asia	Bm³/y	140.4	153.4	169.4	182.4	194.6	206.5
per capita Consumption	m³/cap/y	1114	1023	956	909	881	872
Wastewater Re-Used	Bm³/y	0.9	2.5	5.3	9.5	15.9	25.3
Western Asia Deficit	Bm³/y	1.1	4.6	9.0	12.4	15.0	16.8

Arabian Peninsula		2000	2010	2020	2030	2040	2050
Demand Growth Rate	%/y	2.85	1.99	1.60	1.19	0.89	0.76
Population	Million	48.5	64.8	82.0	99.4	115.8	131.0
Exploitable Water	Bm³/y	7.8	7.8	7.8	7.8	7.8	7.8
Sustainable Water Used	Bm³/y	8.2	8.8	9.8	11.1	12.8	15.0
Agricultural Demand	Bm³/y	29.5	36.7	43.4	49.3	53.9	57.3
Municipal Demand	Bm³/y	4.1	5.7	7.2	8.8	10.5	12.4
Industrial Demand	Bm³/y	0.6	0.9	1.1	1.3	1.6	1.8
Total Demand Arabian Peninsula	Bm³/y	34.3	43.3	51.6	59.4	66.0	71.6
per capita Consumption	m³/cap/y	707	667	630	597	570	547
Wastewater Re-Used	Bm³/y	0.4	1.0	2.0	3.3	5.0	7.1
Arabian Peninsula Deficit	Bm³/y	26.1	34.4	41.8	48.3	53.2	56.6

Total MENA		2000	2010	2020	2030	2040	2050
Demand Growth Rate	%/y	1.41	1.43	1.13	0.92	0.81	0.78
Population	Million	316.4	382.0	452.0	514.5	568.5	612.2
Exploitable Water	Bm³/y	327.9	327.9	327.9	327.9	327.9	327.9
Sustainable Water Used	Bm³/y	220.2	235.2	253.9	271.9	291.5	313.8
Agricultural Demand	Bm³/y	237.6	265.6	293.5	313.8	327.4	334.1
Municipal Demand	Bm³/y	21.2	28.7	38.4	50.0	64.1	81.2
Industrial Demand	Bm³/y	10.3	14.2	19.5	26.3	35.2	46.4
Total Demand MENA	Bm³/y	269.1	308.5	351.4	390.1	426.7	461.7
per capita Consumption	m³/cap/y	851	808	777	758	751	754
Wastewater Re-Used	Bm³/y	4.4	9.1	16.5	27.3	42.6	63.8
Total MENA Deficit	Bm³/y	48.9	73.8	98.4	119.7	137.2	150.4

Table 3-6: Numerical data of the AQUA-CSP water demand scenario by region. For single country data please refer to the Annex.

3.5 Comparison to Other Scenarios

The results of the AQUA-CSP water demand scenario can be compared to other scenarios from the literature. The data includes the total freshwater demand for agriculture and for municipal and industrial use. We have taken into account the total withdrawal of water including transport losses. Unfortunately, we could not find a comprehensive analysis of future freshwater demand prospects for all countries of the MENA region, except for one that only gives estimates of municipal and industrial demand, and so we had to compare our results to different sources regarding different countries. Also, there was no scenario available that looks further than 2030.

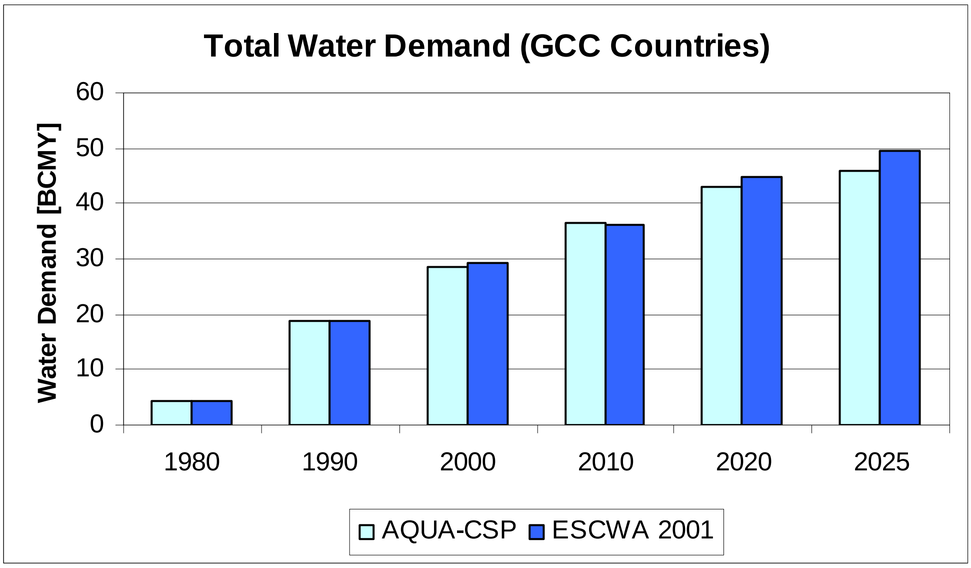

Figure 3-12: Total water demand in the GCC countries analysed by /ESCWA 2001/ compared to AQUA-CSP results. GCC = Gulf Cooperation Council = Saudi Arabia, UAE, Kuwait, Qatar, Oman, Bahrain

The results of the AQUA-CSP study compare fairly well to a forecast of the total water demand of the Economic and Social Commission for Western Asia (ESCWA) from an analysis that was done for the countries of the Gulf Cooperation Council (GCC) shown in Figure 3-12 /ESCWA 2001/. A similar good coincidence for the total Arabian Peninsula from /Al-Zubari 2002/ is shown in Figure 3-13.

For the Northern African countries, we could compare our results to data of the Blue Plan for the Mediterranean Region shown in Figure 3-14 that gives slightly lower prognostics of water demand in its reference scenario /Blue Plan 2005/.

Several other predictions for the total water demand for the year 2025 were available from different sources that differ considerably, as shown in Figure 3-15. The results of AQUA-CSP are close to the average value of those sources.

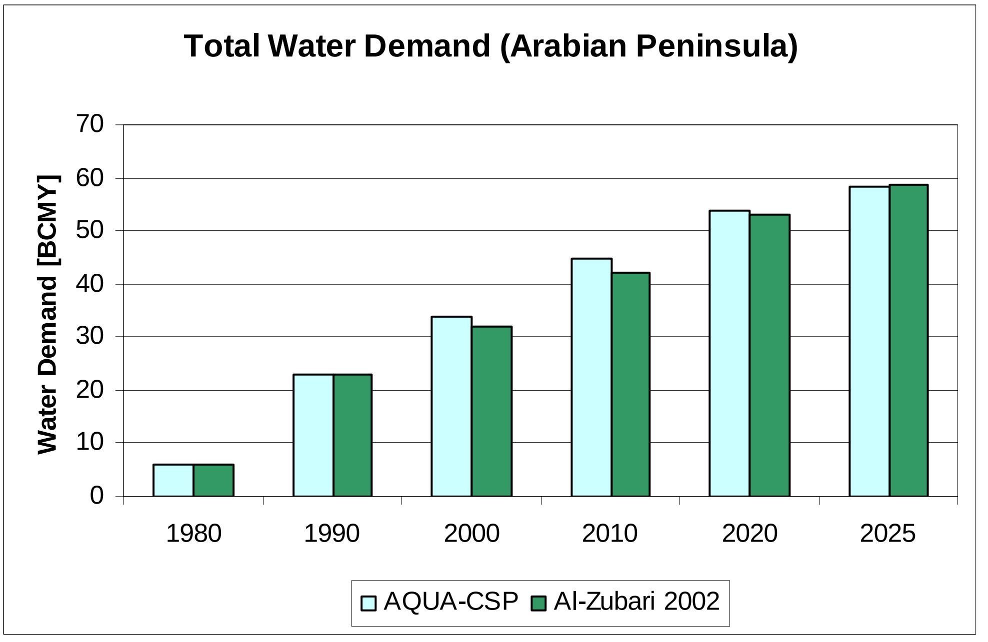

Figure 3-13: Projected water demand of the Arabian Peninsula from /Al-Zubari 2002/ compared to the results of AQUA-CSP (includes GCC and Yemen)

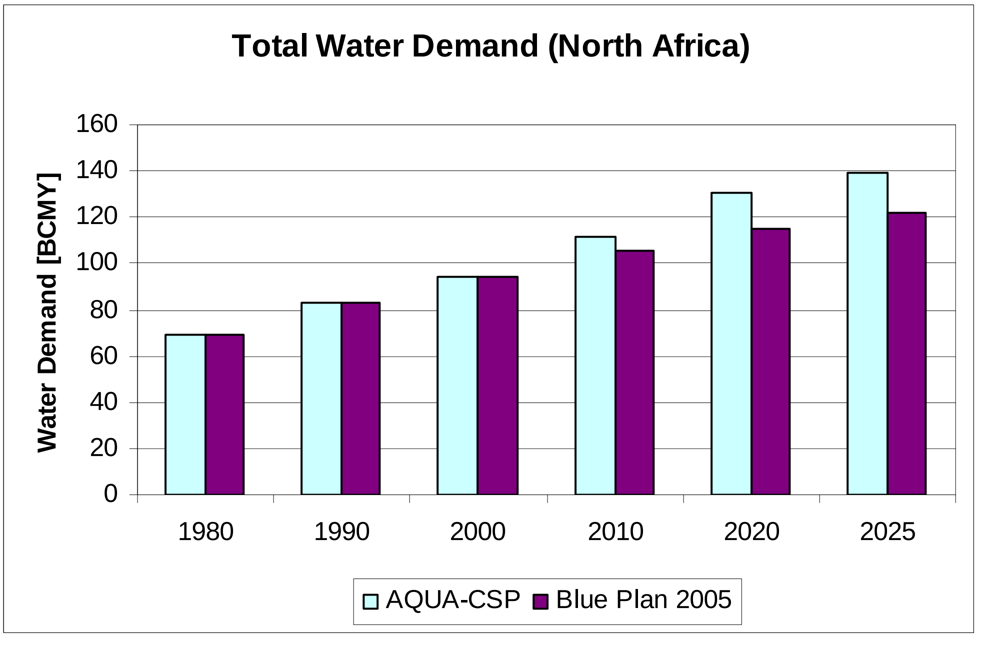

Figure 3-14: Total water demand in the North African countries /Blue Plan 2005/ compared to AQUA-CSP. Countries included: Morocco, Algeria, Tunisia, Libya, Egypt

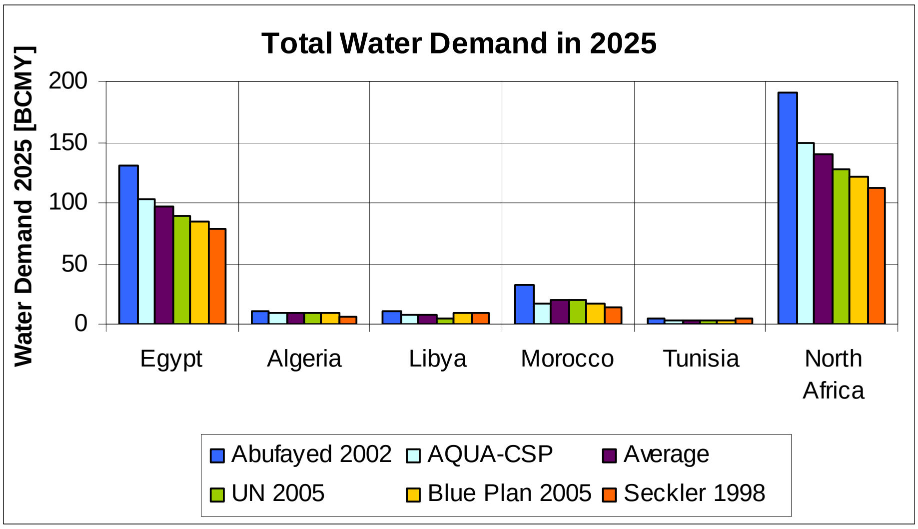

Figure 3-15: Total water demand estimates for the year 2025 from different sources compared to the results of AQUA-CSP. The average value of all sources is also given.

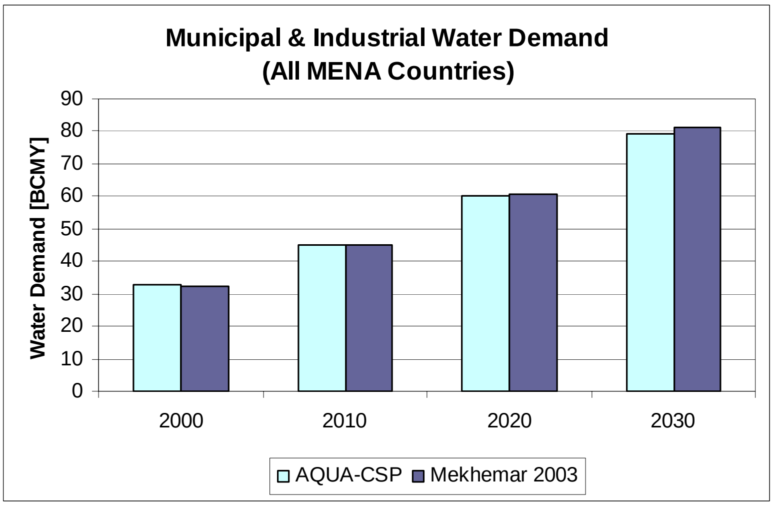

Figure 3-16: Scenario of the municipal and industrial withdrawal of freshwater for all MENA countries compared to the corresponding results of AQUA-CSP.

Furthermore we could compare our data to a scenario of the municipal and industrial water demand of all MENA countries until 2030, which is displayed in Figure 3-16. Again here, we have a fairly good accordance of both data sets (after eliminating an obvious error in the compared data from /Mekhemar 2003/ for the demand estimate of Algeria, that erroneously included agricultural demand).

Water demand prospects for some Western Asian countries were compared with forecasts from /El-Fadel 2001/ and /Al-Zubari 2002/ as shown in Figure 3-17 and Figure 3-18, also coinciding fairly well.

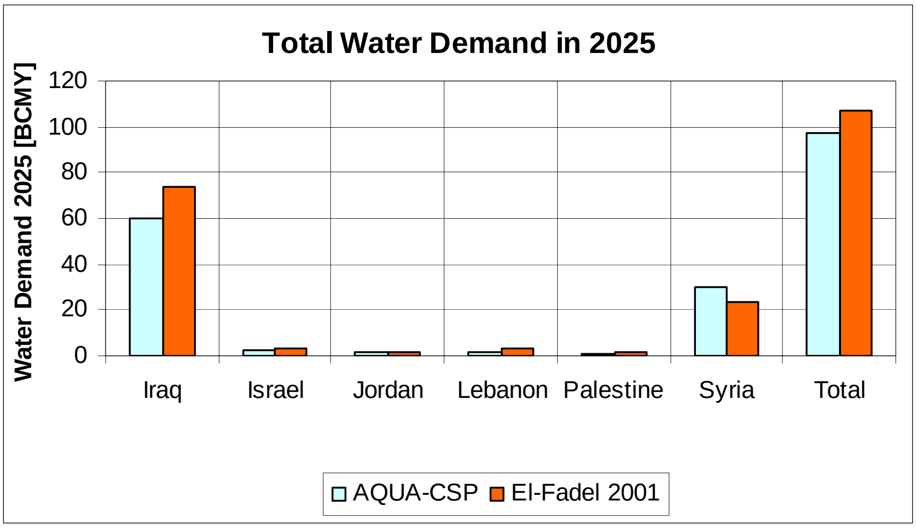

Figure 3-17: Total water demand in 2025 for some Western Asian countries predicted by /El-Fadel 2001/ compared to the results of AQUA-CSP.

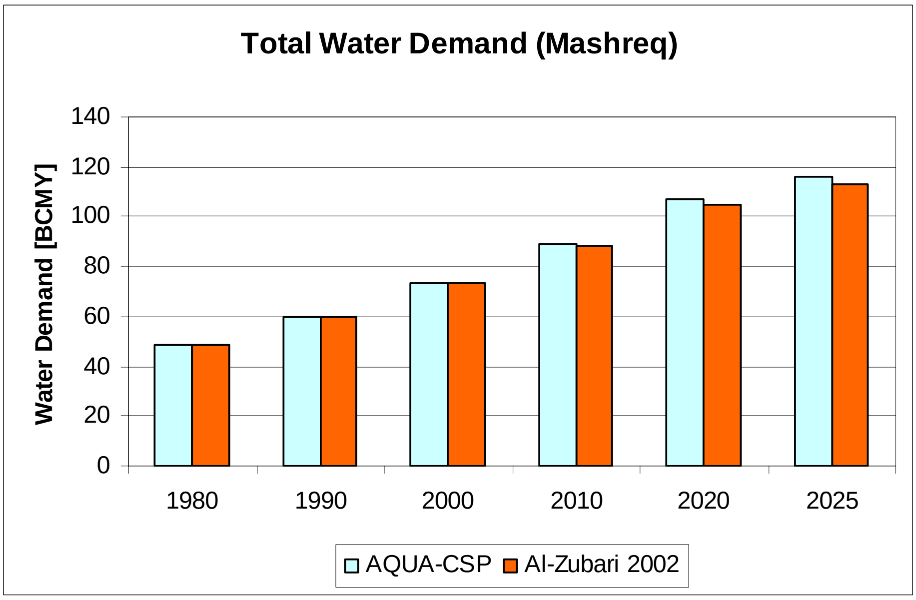

Figure 3-18: Water demand prospects of the Mashreq region by /Al-Zubari 2002/ compared with the results of AQUA-CSP (Countries included are: Egypt, Lebanon, Israel, Palestine, Jordan)

We must also mention a scenario from IEA World Energy Outlook that takes into consideration a selection of countries from the Arabian Peninsula and from North Africa /IEA 2005/. This scenario gives a rather pessimistic view, as it displays a sharp stagnation of water withdrawal from the year 2000 onwards (Figure 3-19). This would in fact lead to a severe reduction of per capita availability of freshwater in the affected countries, with the corresponding consequences for economic growth and social stability (Chapter 4).

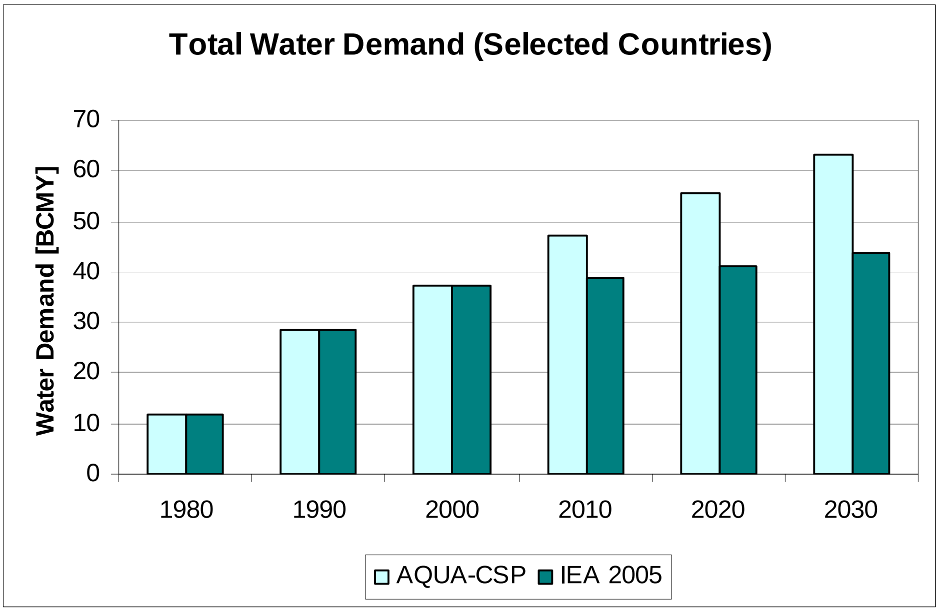

Figure 3-19: Total water demand in countries selected by /IEA 2005/ compared to AQUA-CSP and to historical data from /UNU 1997/ and /FAO 2007/. Aggregated countries selected by /IEA 2005/: Algeria, Libya, Saudi Arabia, Kuwait, Qatar, UAE

Some of the evaluated scenarios accept a significant future reduction of the per capita availability of water, taking as a given threshold the limited available sources of natural renewable water sources. Therefore, their results rather represent a more or less plausible amount of withdrawal of freshwater from those limited sources than a demand driven by the needs of population, which would rather grow proportional to population. Other predictions are based on a given per capita water demand that is extrapolated to the future considering the growth of population and economy and the increase of water transport and end-use efficiency.

There are two fundamentally different approaches for the prediction of the future water demand: on one hand scenarios of water extraction limited by the availability of natural resources, on the other hand scenarios considering only the future needs of population, which are assumed to be satisfied in any way, either by natural sources, better efficiency of water supply or seawater desalination. While in the first case, a considerable reduction of per-capita water takes place that is forced by the scarcity of freshwater, in the second, a reduction of per-capita consumption is not forced, but may be enabled by better efficiency of water distribution and end-use.

Most scenarios are based on a mixture of those assumptions, and predictions up to 2025 can differ considerably. It can be stated that the prediction of the water demand of AQUA-CSP is slightly higher than the average of other forecasts for the North African countries and very similar for the Western Asian and GCC countries when compared to the scenarios that were evaluated within this study. All in all, the AQUA-CSP freshwater demand scenario compares rather well to the medium term expectations of the Arab world until 2025.

3.6 Variations of the AQUA-CSP Scenario

In order to assess the importance of possible measures to increase the efficiency of municipal and industrial water distribution and of irrigation we have calculated two variations of the AQUA-CSP scenario, one assuming extreme efficiency gains and another basically following a business as usual strategy, with only moderate efficiency gains. The parameters of our model were set accordingly as shown in Table 3-7.

The scenario "Business as Usual" assumes that the difference between present efficiencies and best practice values of irrigation efficiency (70 %) and municipal distribution efficiency (85 %) is only reduced by 20 %, and that only 30 % of waste water is re-used by 2050. By contrast, the scenario "Extreme Efficiency" assumes a full acquaintance of best practice values by 2050 and also a 75 % re-use of waste water for all MENA countries by that time.

The model shows that the deficit of 2050 can be reduced from 150 billion m^3/y to 100 billion m^3/y under the "Extreme Efficiency" scenario. This is a considerable reduction of the water deficit of about 35 % with respect to the AQUA-CSP reference scenario, but it can be seen clearly that a considerable deficit will remain even under these very optimistic assumptions.

The scenario "Business As Usual" shows that a strategy following current paths would lead to a catastrophic situation for the MENA region, as the water deficit would grow to about 230 billion m^3/year which would lead to severe environmental and socio-economical impacts. However, please note that even this scenario achieves efficiency gains compared to today's situation.

The AQUA-CSP reference scenario reflects a compromise between those two extremes, with efficiency gains that are achievable within a reasonable time span. However, the challenge remains to cover a freshwater deficit of about 150 billion m^3/year by 2050, and to eliminate as soon as possible the already existing unsustainable use of water of 50 billion m^3/year, before irreversible environmental and socio-economic impacts take place in the most affected countries.

Type of Scenario	Business As Usual	AQUA-CSP	Extreme Efficiency
Progress Factor α_{irr} for Irrigation Efficiency	20 %	50 %	100 %
Progress Factors $\alpha_{mun, ind}$ for Distribution Efficiency	20 %	65 %	100 %
Waste Water Re-Use	30 %	50 %	75 %

Table 3-7: Input parameters for progress achievements and waste water re-use for the different scenario variations

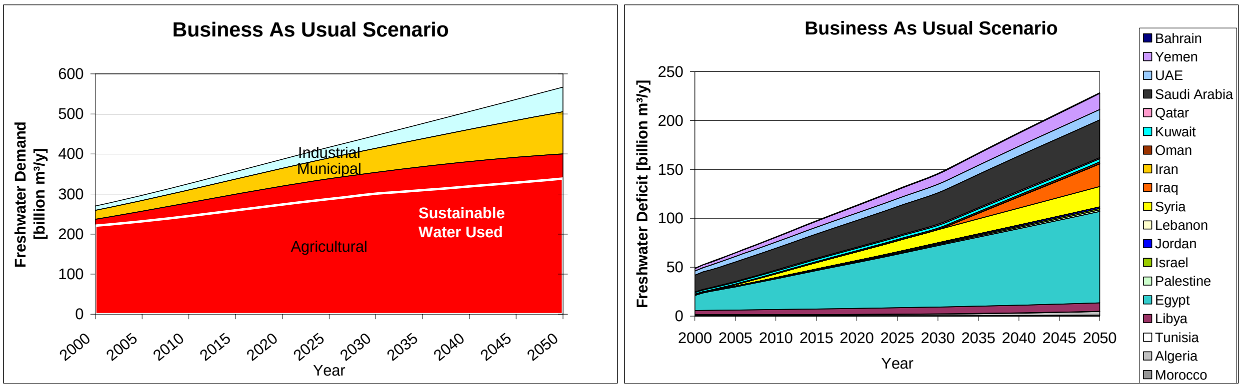

Figure 3-20: Results of the model calculation with minimum measures for increasing water distribution and irrigation efficiency and waste water re-use for all MENA countries

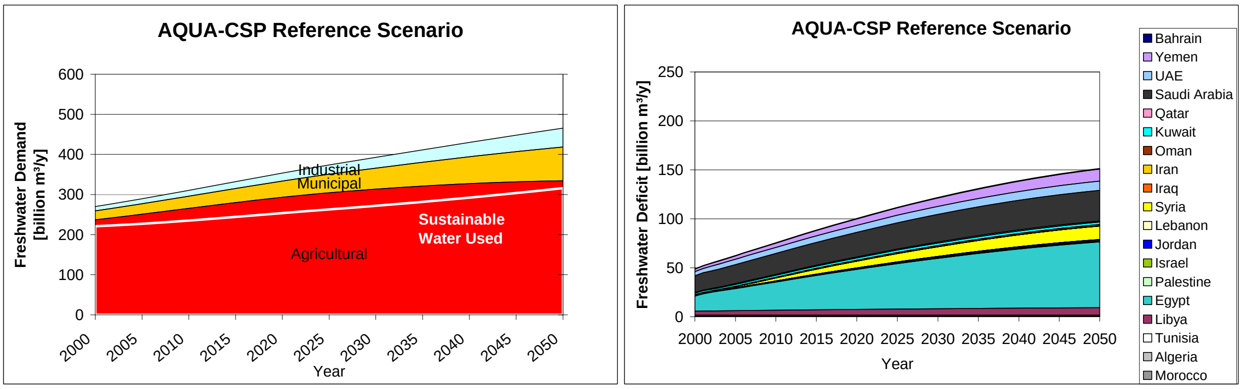

Figure 3-21: Results of the model calculation with AQUA-CSP reference parameters concerning measures for water distribution, irrigation efficiency and waste water re-use for all MENA countries

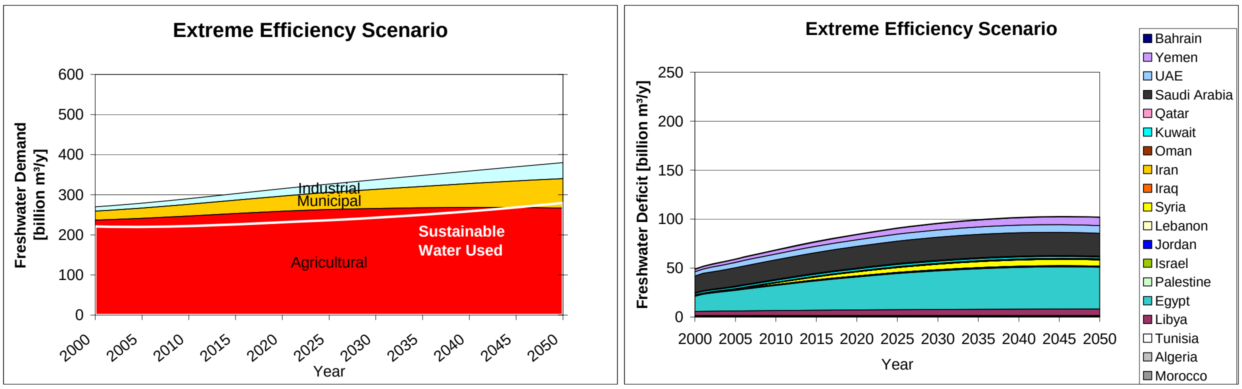

Figure 3-22: Results of the model calculation with maximum measures for increasing water distribution and irrigation efficiency and waste water re-use for all MENA countries