4 Demand Side Assessment for Electricity and Water

The MED-CSP scenario focuses on the demand of **electricity and water**. It considers the individual situation of each country concerning population growth, economic growth and energy requirements. It assumes economic growth rates sufficiently high to close the gap with the USA per capita national income by 50 % until 2050. That means that most MENA countries will achieve a per capita income equivalent to the present central EU states by 2050. This good economic development goes together with efficiency gains in the electricity sector, leading to a slightly slower growth of demand in the coming decade. After 2040, a saturation of electricity demand will be visible in most countries. This scenario is called “Closing the Gap, High Efficiency Gains”, CG/HE.

Most Maghreb and Western Asia countries are already well on this track. Egypt would have to accelerate economic growth a little bit. Yemen would require economic growth of 11 %/year for 40 years to achieve this goal, which is rather unrealistic. Therefore, the economic growth rate has been limited to a maximum of 7 %.

A scenario with lower economic growth was also assessed, maintaining the present per capita income gap to the USA. However, the electricity requirements would be even higher in this case after 2030, because efficiency gains could not be performed due to the restricted economic situation.

Figure 4-1 shows the gross electricity consumption of all countries analysed within the study since 1980. The scenario CG/HE fits particularly well to the historical data. While the European countries and the OPEC countries of the Arabian Peninsula show a clear saturation of electricity demand after 2030, most other MENA countries will have a strongly growing electricity demand, with Egypt, Turkey and Iran becoming the biggest centres of demand by the middle of the century.

The total gross electricity demand of the analysed countries has grown by 3 times in the past 20 years, from 500 TWh/year in 1980 to 1500 TWh/year in 2000, with an average annual growth of 50 TWh/year. The scenario calculation yields a growth of again shortly 3 times in the coming 50 years, to 4100 TWh/year in 2050. This results in an average annual growth of 52 TWh/year.

The scenario predicts a slight slowdown of electricity demand in the coming decade. This could be interpreted as result of the coming liberalisation of the power market in most countries, efficiency gains and reduced losses due to uncontrolled extraction of electricity from the grid. The electricity demand scenario was calculated on a year-by-year basis.

A second and more pronounced slowdown of electricity demand is predicted by the middle of the century, when most countries will have achieved a well balanced level of demand and will enter a phase of stabilisation.

For the scenario CG/HE the water demand of the MENA countries was assessed as well. The results are shown in Figure 4-2. Starting with a demand of 300 billion cubic meters per year in 2000, water demand reaches a level of shortly 550 Bm^3/y in 2050, growing by 50 % in this time span. The water demand scenario was calculated in time-steps of 10 years.

The scenarios for the electricity demand and for water demand were calculated using GDP per capita and population as **driving forces**. The methodology will be described in the following.

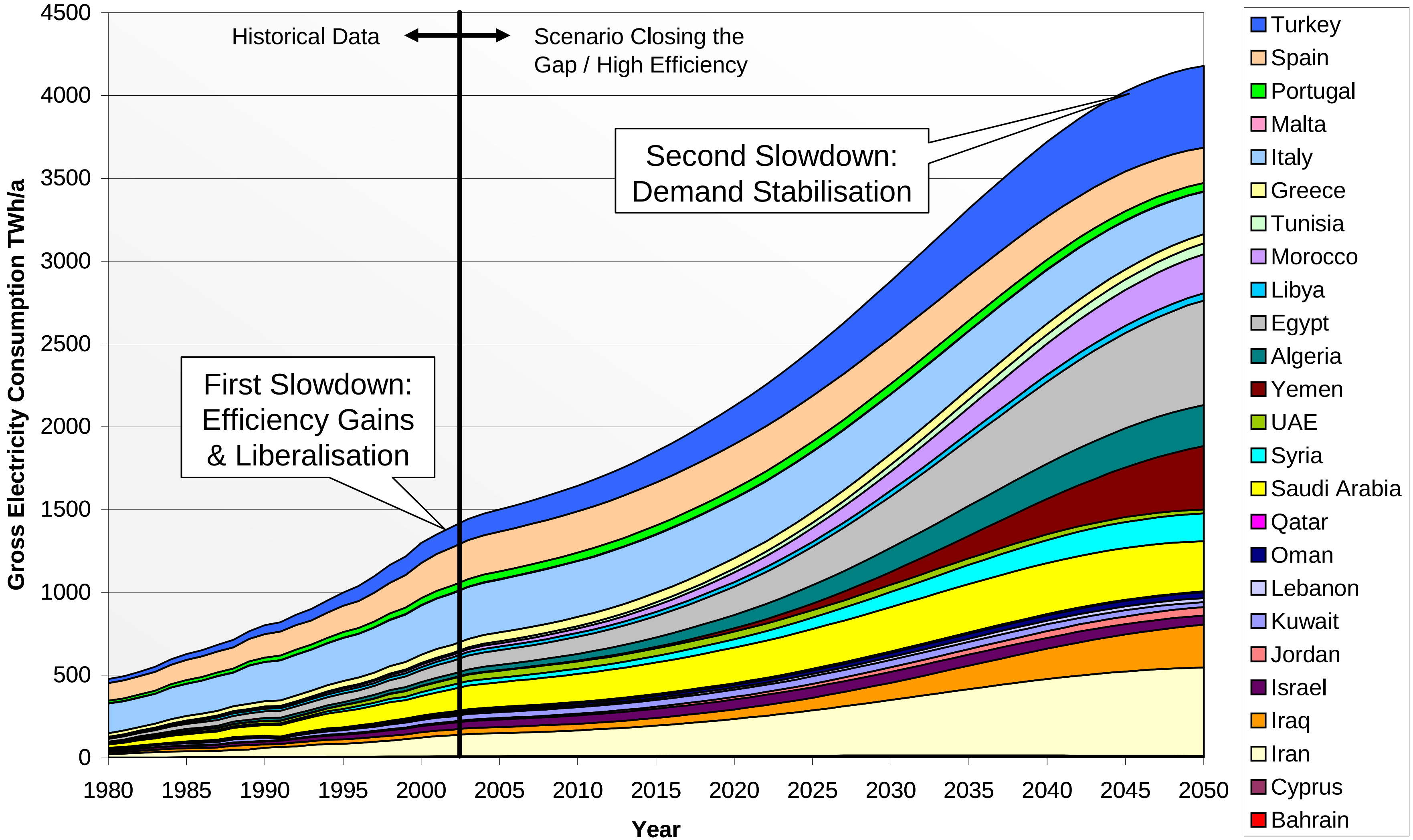


Figure 4-1: Gross Electricity Consumption of the Countries analysed within MED-CSP in the Scenario CG/HE. Historical data based on /EIA 2004/

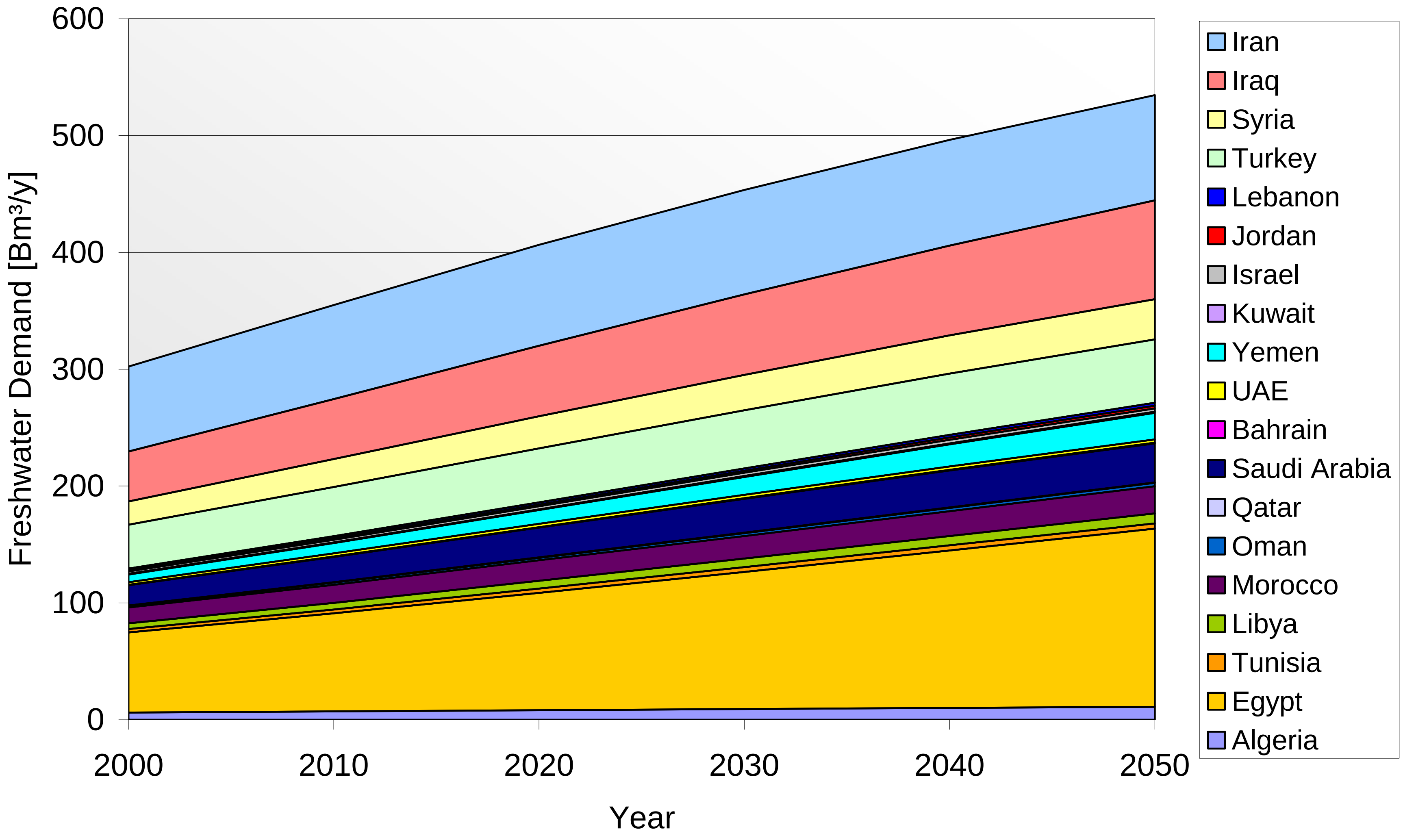


Figure 4-2: Water demand projection in the MENA countries in the scenario CG/HE. Historical data of the year 2000 based on /FAO 2004/

4.1 Growth of Population

All scenarios are calculated with the World Population Prospect of the United Nations for intermediate growth that was revised in the year 2002. The data was taken from /Statistisches Bundesamt 2003/ and /FAO 2004/. According to that analysis, the population in the analysed region as a total will steadily growth from today 500 million people to over 800 million people by 2050 (Figure 4-4). The growth of the rural population will come to stagnation, while the urban population will steadily expand (Figure 4-5 and Figure 4-6). The rural / urban population ratio will be reduced from today 0.6 to 0.3 in the year 2050. The development of the rural, urban and total population in all individual countries analysed within the study can be seen in Annex 2.

North Africa

The population in North Africa will grow from today 150 million to 250 million in 2050. In terms of population, Egypt is the dominating country, accounting for 50 % of the population of the total region (Figure 4-7). Among the North African countries, Egypt has the largest share of rural population which is well above the MENA average, while Libya and Malta show a very low rural / urban population ratio. The other countries are close to the MENA average. Among the North African countries, only Egypt has a growing rural population. The dominating population of Egypt leads to an average rural population share of North Africa that is clearly above the MENA average.

Western Asia

The population in the Western Asian countries will grow from 200 to well over 300 million people by 2050, being Iran and Turkey the dominating countries in this region (Figure 4-10). Only Syria displays a rural population share that is well over the MENA average, however the total Western Asian rural population share is clearly below the MENA average. Israel and Lebanon are the countries with less rural population (Figure 4-11 and Figure 4-12).

Arabian Peninsula

The population on the Arabian Peninsula will increase from today 50 million to 160 million people in 2050. The dominating countries are Saudi Arabia and Yemen (Figure 4-13). While the Saudi Arabian population will be stabilising by the middle of the century, the population in Yemen will still be growing quickly by that time, becoming the most populated country in this region. All countries in the region have a rural population share well below the MENA average, except Yemen, which has an outstanding high rural population share (Figure 4-14 and Figure 4-15). Due to the strong influence of Yemen, the rural / urban population ratio of the Peninsula will become higher than the MENA average, although it is below its average today.

Southern Europe

The population of the Southern Mediterranean countries will decrease from 120 million in 2000 to roughly 100 million in 2050. In contrast to the MENA countries, the Southern European countries show a clearly stagnating and retrogressive population (Figure 4-16), with the strongest reduction taking place in the most populated countries Italy and Spain. The rural/urban population ratio varies from 0.1 in Malta to 0.7 in Greece and decreases steadily with time (Figure 4-17 and Figure 4-18).

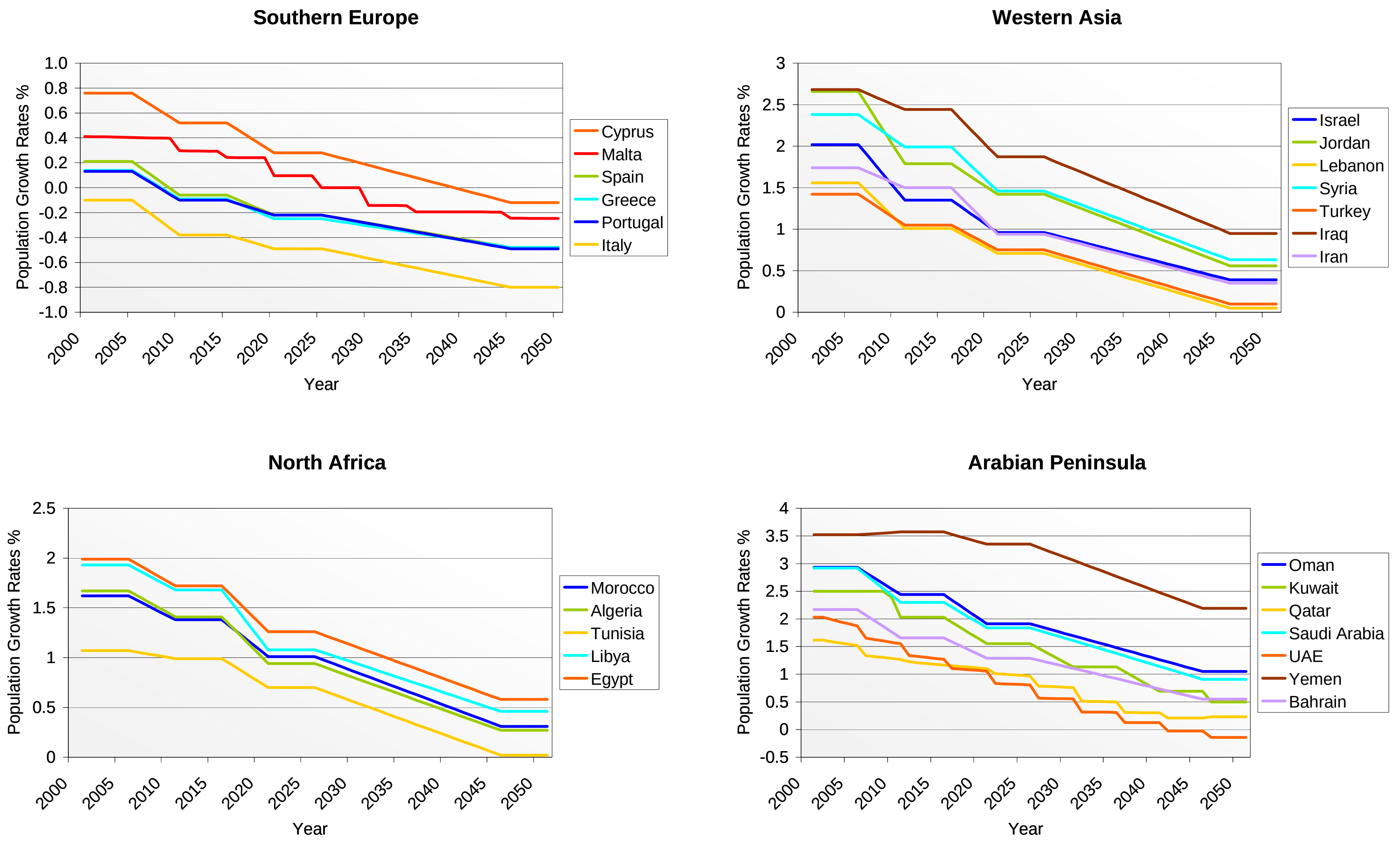


Figure 4-3: Population growth rates used in the MED-CSP scenario derived from /FAO 2004/

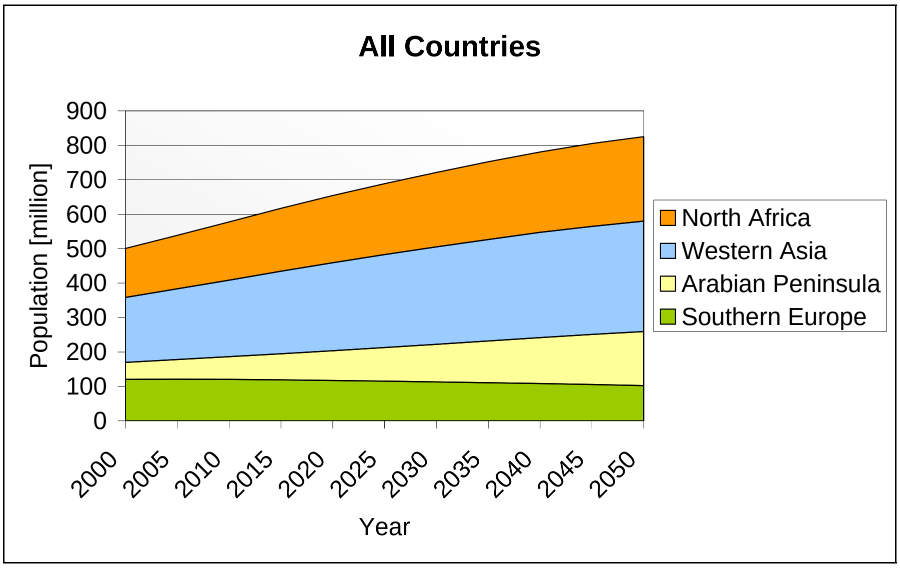


Figure 4-4: Population growth in all analysed countries until 2050

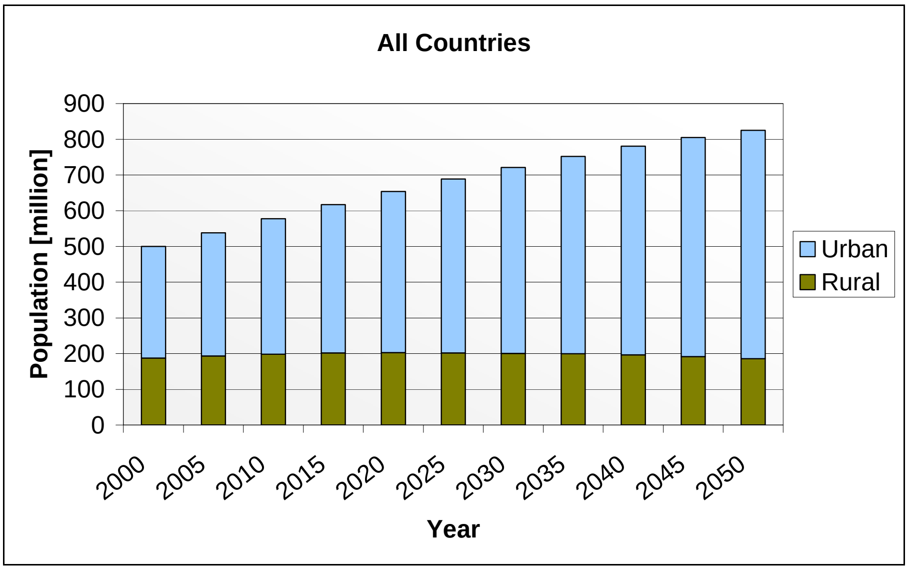


Figure 4-5: Growth of rural vs. urban population in all countries until 2050

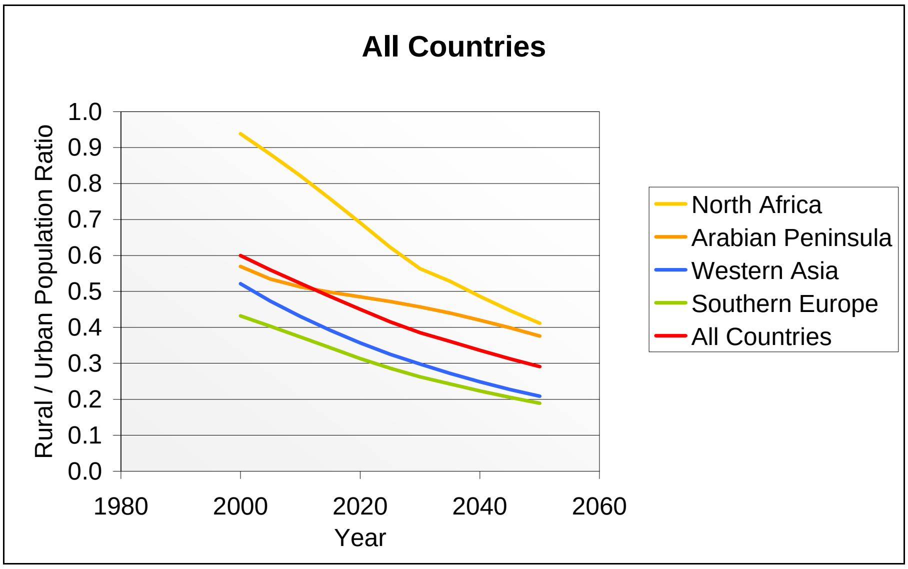


Figure 4-6: Rural to urban population ratio for all countries as function of time

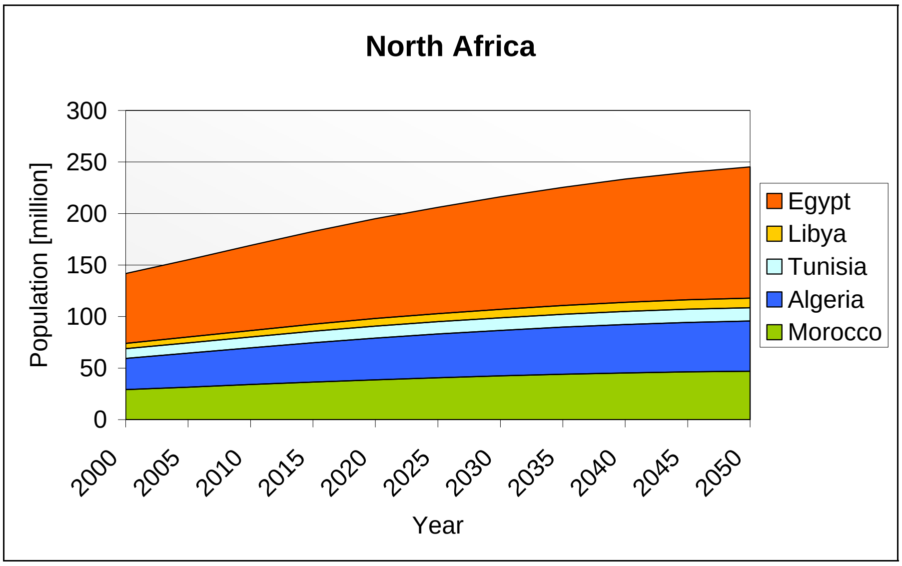


Figure 4-7: Population growth in North Africa by countries

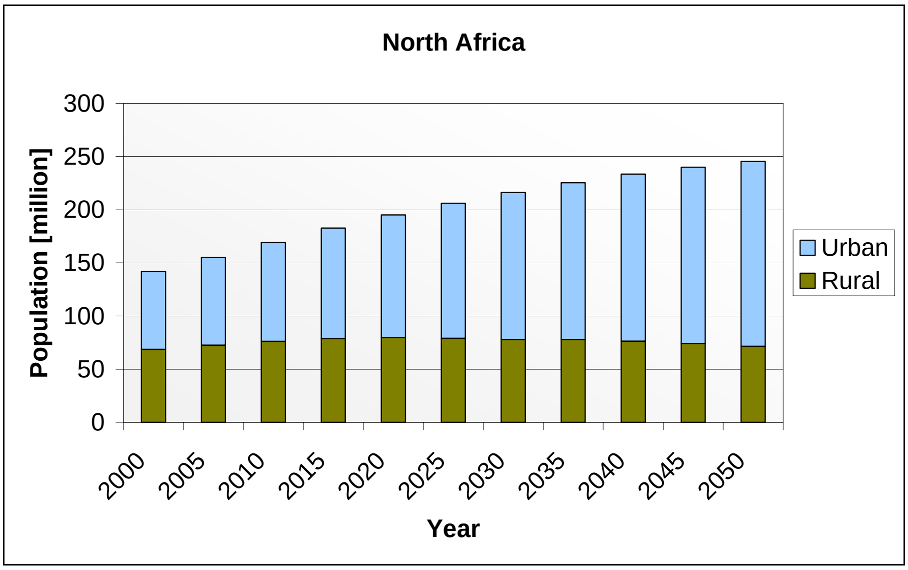


Figure 4-8: Development of rural vs. urban population in North Africa

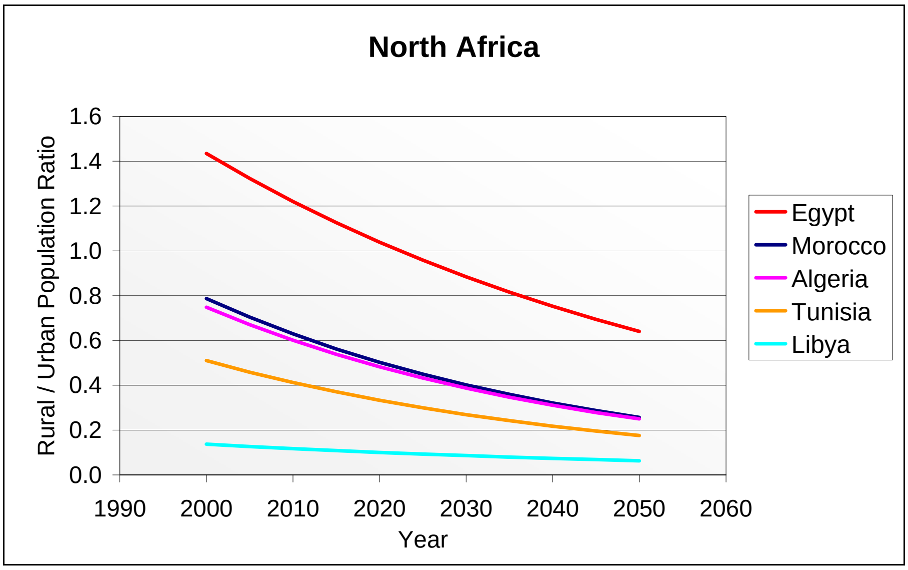


Figure 4-9: Rural / urban population ratio of the Northern African countries

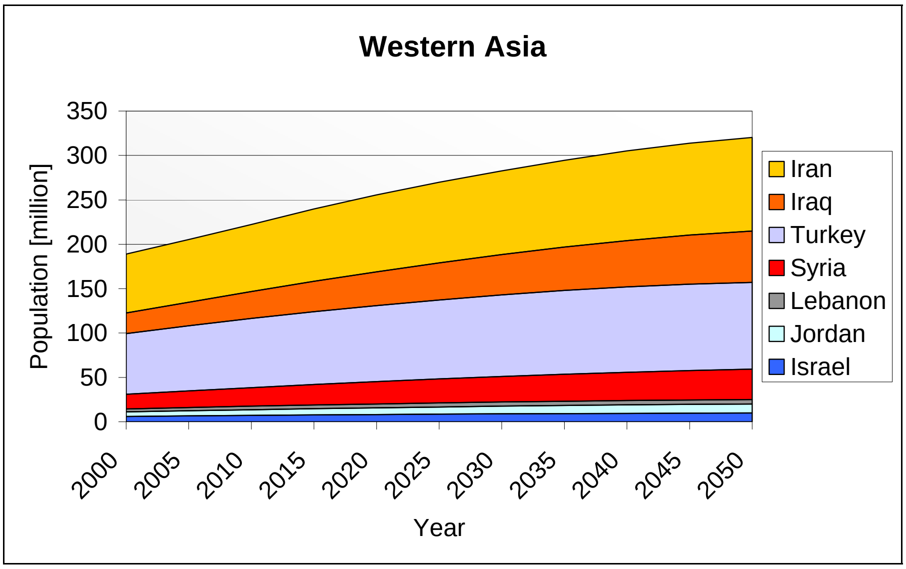


Figure 4-10: Population growth in the Western Asian countries

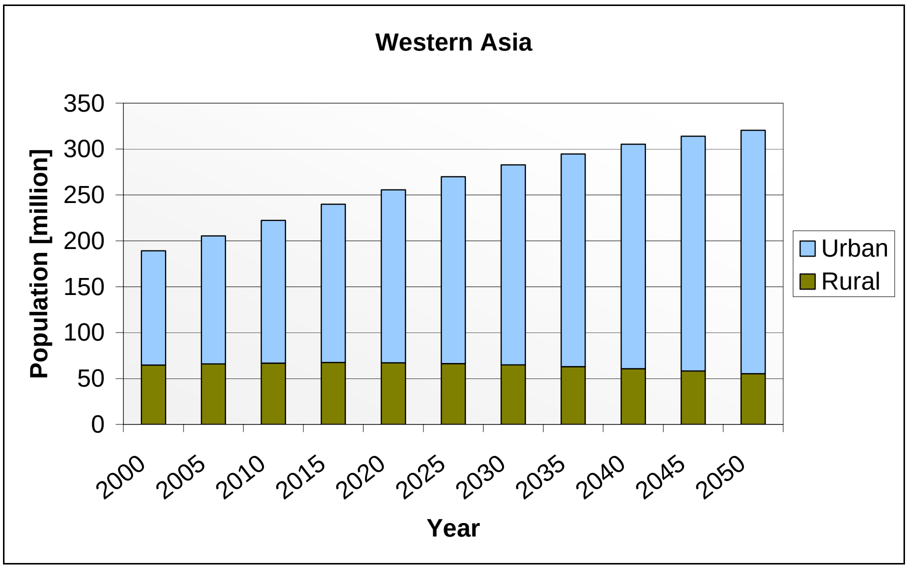


Figure 4-11: Rural vs. Urban population in the Western Asian countries as function of time.

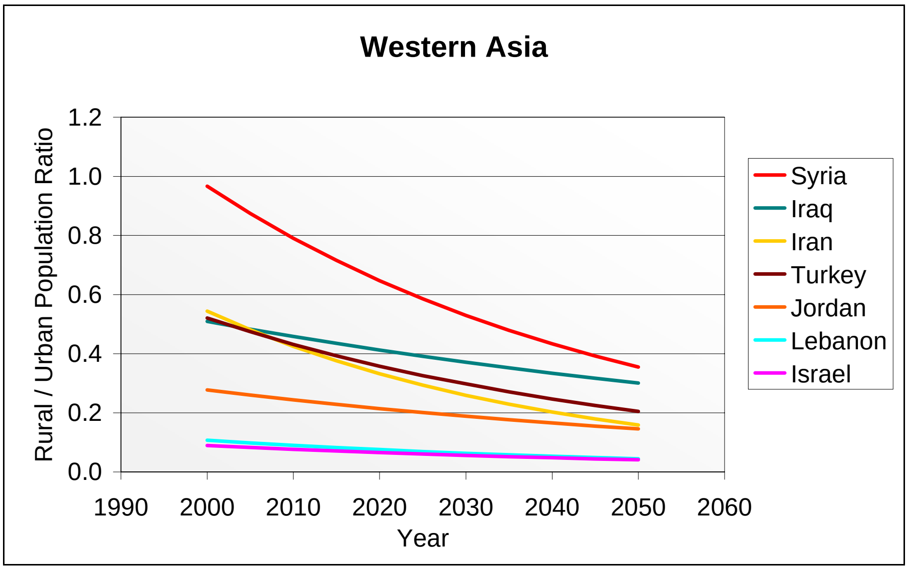


Figure 4-12: Rural to urban population ratio in the Western Asian countries until 2050.

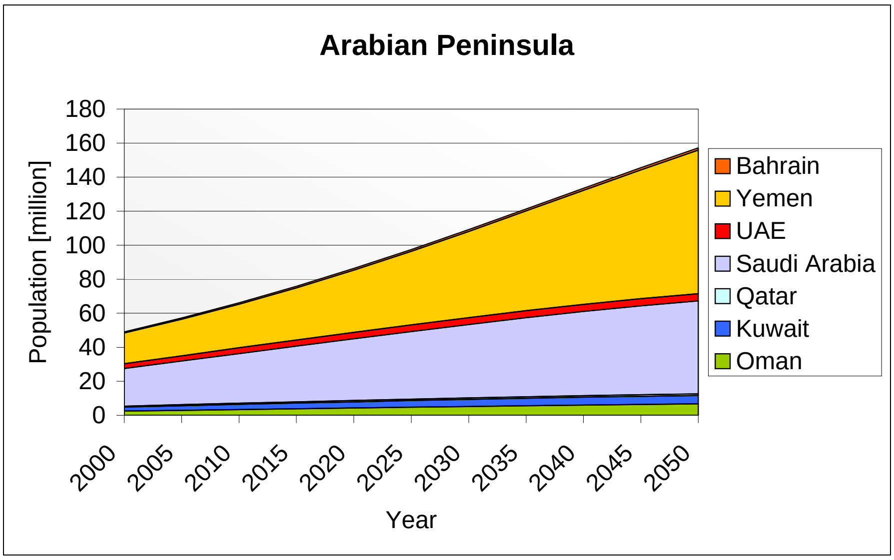


Figure 4-13: Population growth on the Arabian Peninsula until 2050

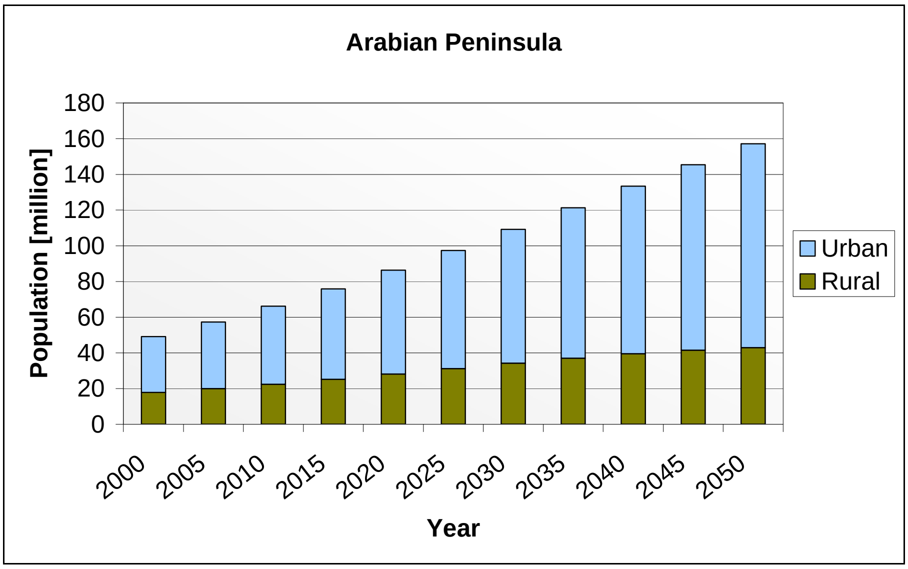


Figure 4-14: Rural and urban population on the Arabian Peninsula until 2050

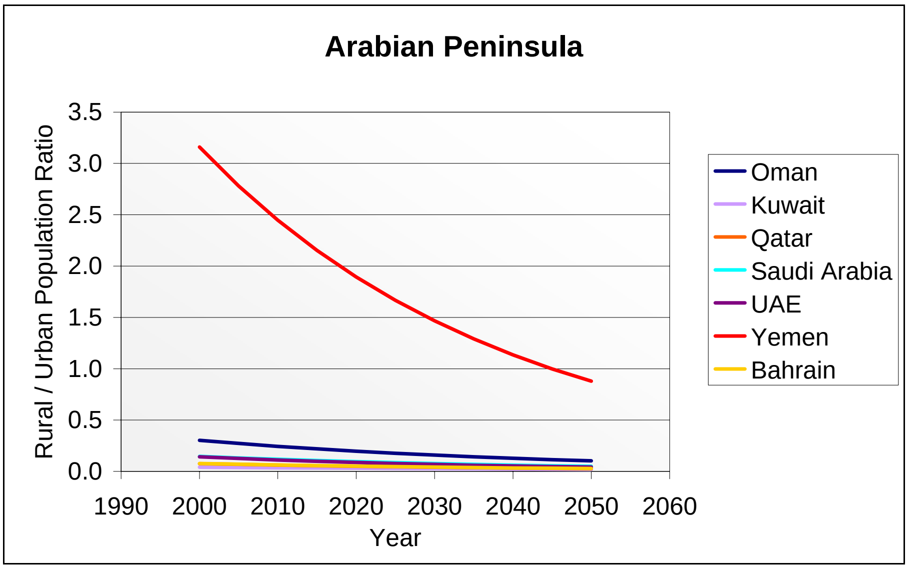


Figure 4-15: Rural / urban population ratio on the Arabian Peninsula until 2050.

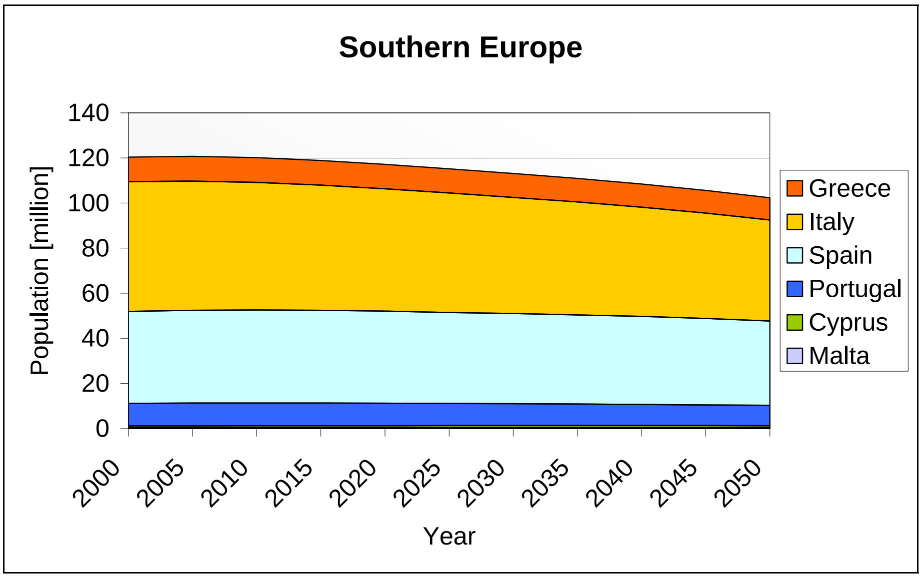


Figure 4-16: Population growth in the Southern European countries until 2050

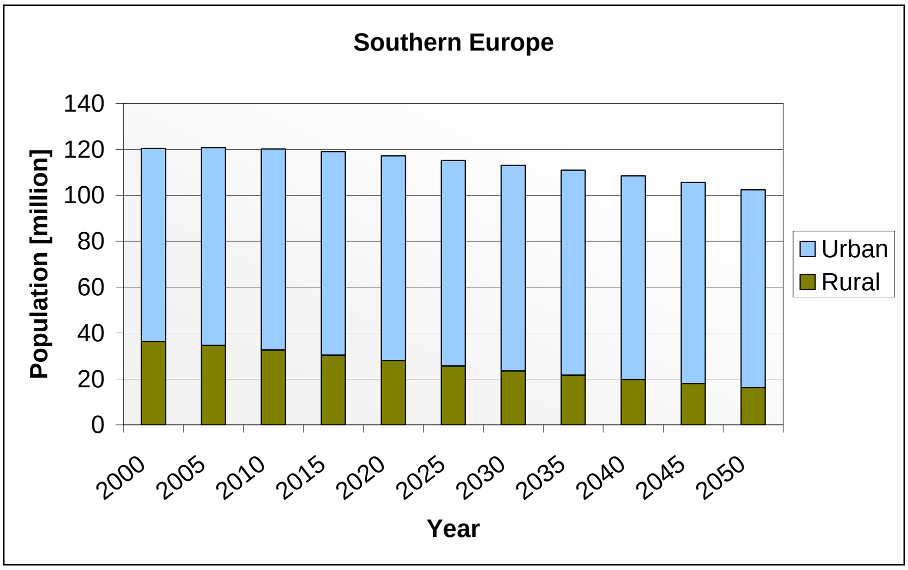


Figure 4-17: Rural and urban population in Southern European countries until 2050

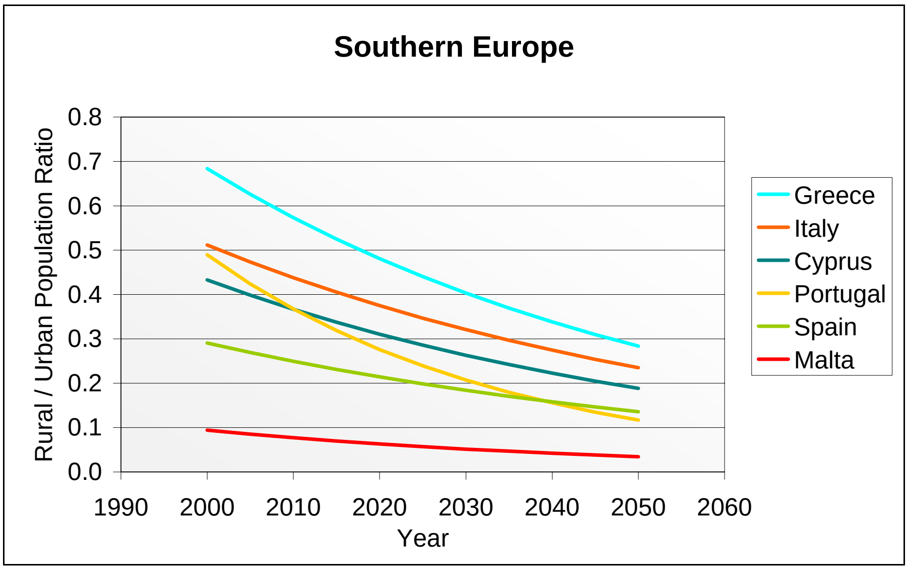


Figure 4-18: Rural / urban population ratio for the Southern European countries until 2050.

4.2 Growth of Economy

In the following the Gross National Income (GNI) in Purchasing Power Parity (PPP) US$-2001 per capita will be employed as indicator for economic growth. While the Gross Domestic Product is a better measure for economic activities within a country the GNI is a better indicator of the population's income. Both indicators are closely linked. This would not be true if for example capital belonged in great part to foreigners without balancing wealth of the population abroad. A gross concept is used to take the capital endowment into account and because of better data availability and reliability. The PPP used is calculated on the basis of an US-basket of goods and services. Figure 4-19 compares the respective GNI per capita in PPP with the World Bank's Atlas-method, which essentially smoothes exchange rate fluctuations. Measured in PPP-US$ the relative difference in GNI per capita is smaller than in Atlas-$, which results from cancelling pure price differences. The relation of GNI in PPP to GNI in Atlas-$ decreases with increasing income. A regression suggests that a 1.45%-increase in GNI in Atlas-$ is necessary to reach a 1%-increase in GNI (PPP). Different functions suggest that at the lower end of the income scale a lower increase in GNI in Atlas-$ is necessary while at the upper end a higher increase is required.

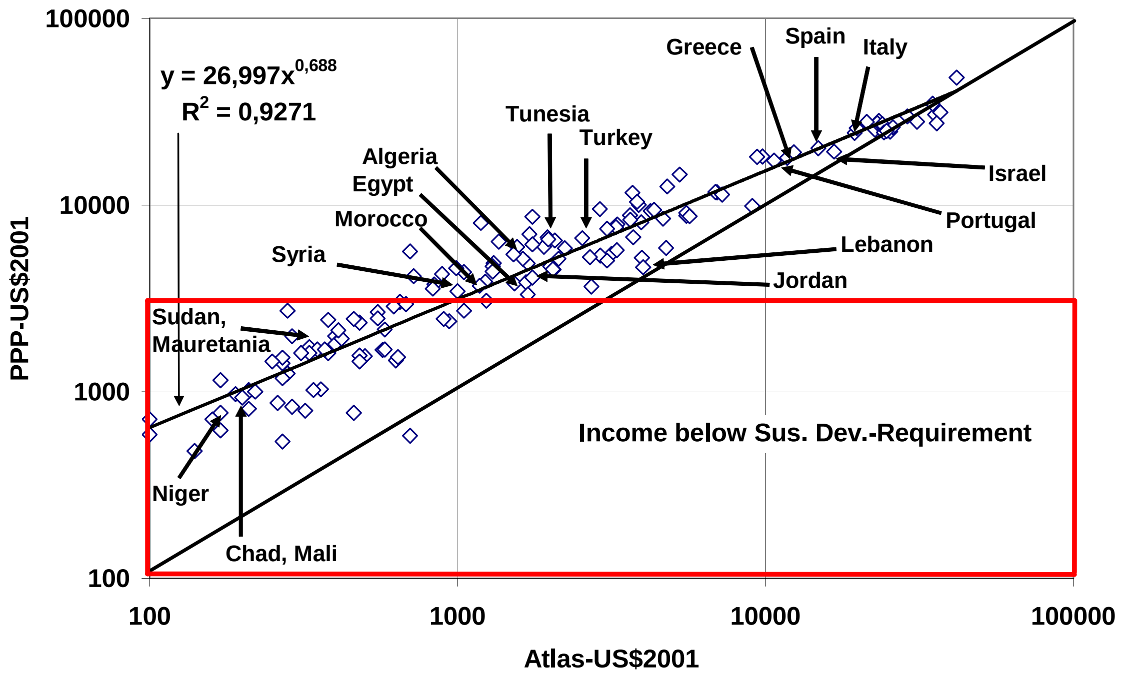


Figure 4-19: Comparing Gross National Income (GNI) per capita in 2001 in US-$2001 (PPP) vs. Atlas US-$2001. Source: World Bank, cited according to /Statistisches Bundesamt 2003/; sample size: 154

To give an impression of the current economic state some MENA states together with other Mediterranean countries and the southern Saharan states are identified in Figure 4-1. Recently, the /WBGU 2003/ suggested a minimum GNI per capita (in PPP) below which it seams impossible to provide certain fundamental health and educational services to all people as a Sustainable Development criterion (red square in Figure 4-19). It is interesting to notice that all MENA states, except Iraq and Yemen, have a higher income. This suggests that from a point of view of sustainable development increasing the GNI per capita is not a top priority in itself but may of course be a way to fulfil other sustainable development criteria or be a worthwhile goal in itself.

To calculate scenarios – not forecasts – the average annual growth rate of 1.2 % of the GDP per capita (in 1995 US$ (PPP)) for the United States and Canada (2000-2030) in the reference scenario of the /IEA 2002/, p. 137ff. is used as benchmark until 2050. For each country two possible convergence paths with reference to the 2050-GDP per capita of the United States are defined: Same growth rate of the GNI per capita as the United States, i.e. 1.2 %/y ("following up" (FU)) and halving the relative difference of GNI per capita from 2003 until 2050 ("closing the gap" (CG)). For the MENA-States the implied annual growth rates of GNI per capita and the past growth rates are shown in Table 4-1.

Some remarks might be appropriate to explain this approach:

- Although the USA serves as benchmark for economic growth, this does not imply that the current general consumption or energy consumption patterns in the USA are especially important. They are not and will not be used as benchmarks.
- The USA were used as benchmark as they have one of the highest GDP per capita and are big enough to give confidence that it is feasible generally to achieve that GDP. So their GDP per capita can serve as an indicator for the state-of-the-art production frontier which might be reachable for all states. The state-of-the-art is the appropriate reference as potential growth rates depend on the possible contribution of imitation – and adaptation - or innovation to socio-technological development.
- Halving the relative difference in 50 years refers to the literature on economic growth. Such a speed of convergence – if convergence exists at all - is within the range of the estimations in the literature albeit on the lower speed side. The estimated speed convergence based on theoretical model spreads approximately from 25-50 years (s. /Barro and Sala-i-Martin 1995/).

In the scenario "closing the gap" the annual growth rates of the GDP were restricted to a maximum 7 %/a, as there seams to be an upper boundary on long-term-growth stemming possibly from the speed of change a society might master. 7 %/a is in this respect somewhat cautious. However, only the growth of four countries is affected by this limitation: Jordan's and Syria's, albeit negligible, and Iraq's and Yemen's in a substantial way. Given the past performance of Yemen, the very high growth rate of population and additional data on education, an average growth rate of GDP per capita of almost 4 %/a can be considered as very optimistic, while the 7.8 %/a over 50 years – which would result without the 7 %-restriction – seams to be hardly reachable. For Iraq, a fast economic development might be possible, which might boost economic growth for a decade or so. However, in the long run the resulting 5.1%/a growth rate of the per capita GDP would be a very respectable achievement. Note that Lebanon realized an 8.4 %/a growth rate of GDP/capita during the nineties while recovering from the civil war damages. It is assumed that this growth rates will not be sustainable over a longer period and will slow down to 4.2 %/a.

Four different groups of countries can be distinguished in EU and MENA. For each group the economic scenarios must be interpreted differently:

1. Very poor countries: Yemen;
2. Middle-income countries: Morocco, Tunesia, Egypt, Iran, Jordan, Syria, Lebanon, Turkey;

3. Countries that depend to a great extend on export of energy resources: Algeria, Lybia, Iraq, Oman, Kuwait, Qatar, Saudi-Arabia, UAE and Bahrain.
4. High income countries without considerable fossil energy resources: Malta, Cyprus, Israel and the EU countries

Group 1 (Yemen): With a per capita GDP of 770 US-$2001(PPP) Yemen belongs to the poorest countries of the world. For comparison: Ethiopia: 710, Zambia: 790, Sudan: 1610, Morocco 3700, poorest country: Sierra Leone: 480. In the past ten years the economic development didn't even match the population growth. From that perspective clearly the first aim is to prevent a further decline of per capita GDP. In the following-up scenario this turn around will be achieved, but with a growth rate of 1.2 %/y the GDP per capita would be fairly low even in 2050 (1300 US$-1996(PPP)). With the scenario "closing the gap" a 4600 US$-1996(PPP) means that Yemen will have reached today's middle-income-country level in 2050. For Yemen the difference between the two economic scenarios is considerable. Even to reach the "following up" scenario within the near future will be hard to achieve, and quite likely will demand broad and successful economic and societal measures. While a forecast for the next decade may use even lower growth rates, the aim of this study suggests that there is no sense to investigate an energy strategy for a development path that stays below any sensible policy target. Here, it becomes especially obvious that the goal of this part is not to forecast the future development but to design sensible scenarios for energy demand taking into account the study's own goals.

Group 2: For this middle-income-countries CG is within reach and somewhat optimistic, while the FU-scenario is relatively pessimistic. So from the current perspective a path between both scenarios seams likely, while a little higher growth rates are possible, too. In CG this states will reach a GDP per capita in 2050 which lies between the current level of France and the USA, while in FU the GDP per capita will be in the range of today's Turkish and Hungarian level.

Group 3: Today, the economic development of these countries depends on the energy markets. Their income is relatively high. The scenarios assume that the countries succeed to diversify their economy activities. As their income is relatively high the two scenarios do not differ very much. In CG their GDP/capita will be well above the current GDP/capita of the USA in 2050, while in FU the range of today's Portugal and USA may serve as reverence.

Group 4: The growth rates do not differ between the two scenarios by much. The production is close to the state-of-the-art boundary. Therefore the expansion of the state-of-the-art is of major concern here. As discussed above the growth rates might be judged as a little cautious. The 2050-level of GDP per capita will be nearly USA's today in FU and will approach 50,000 US-$1996(PPP) in CG.

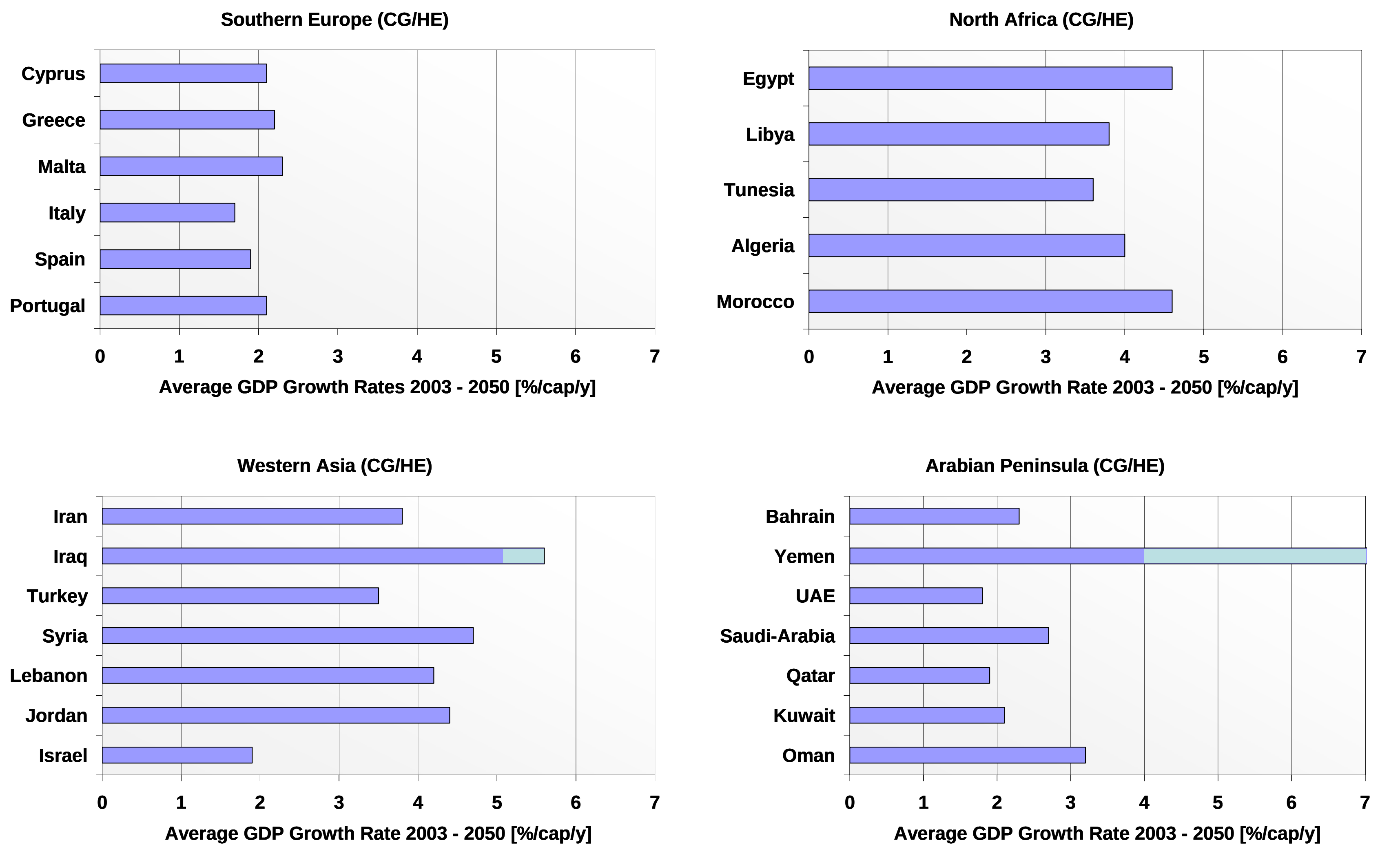


Figure 4-20: Average per Capita GDP Growth Rates 2003 – 2050 within the Scenario CG/HE. Per capita growth rates in Iraq and Yemen are reduced due to the restriction of the 50 year average GDP growth rate to a maximum of 7 %/y.

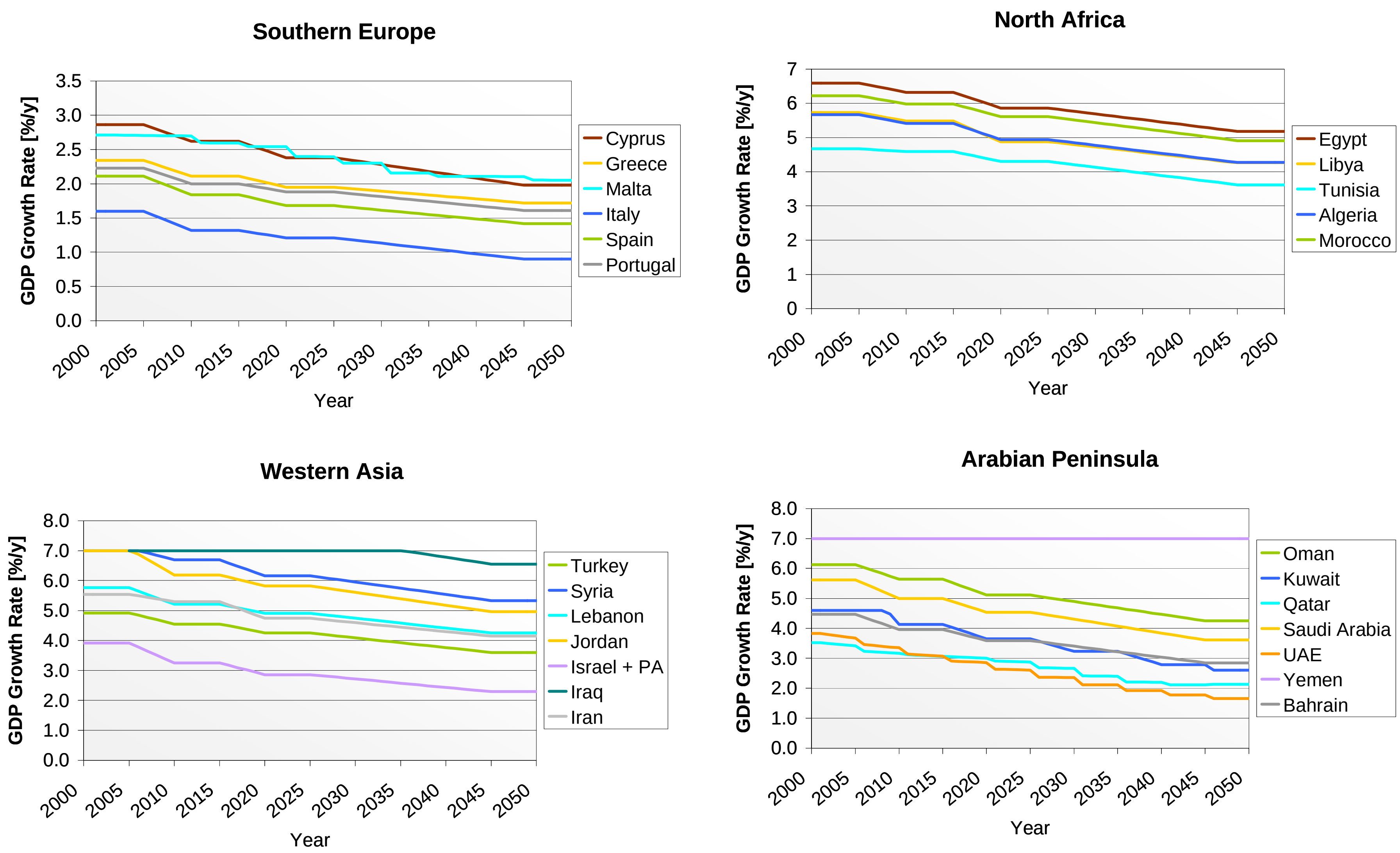


Figure 4-21: GDP Growth Rates until 2050 within the Scenario CG/HE

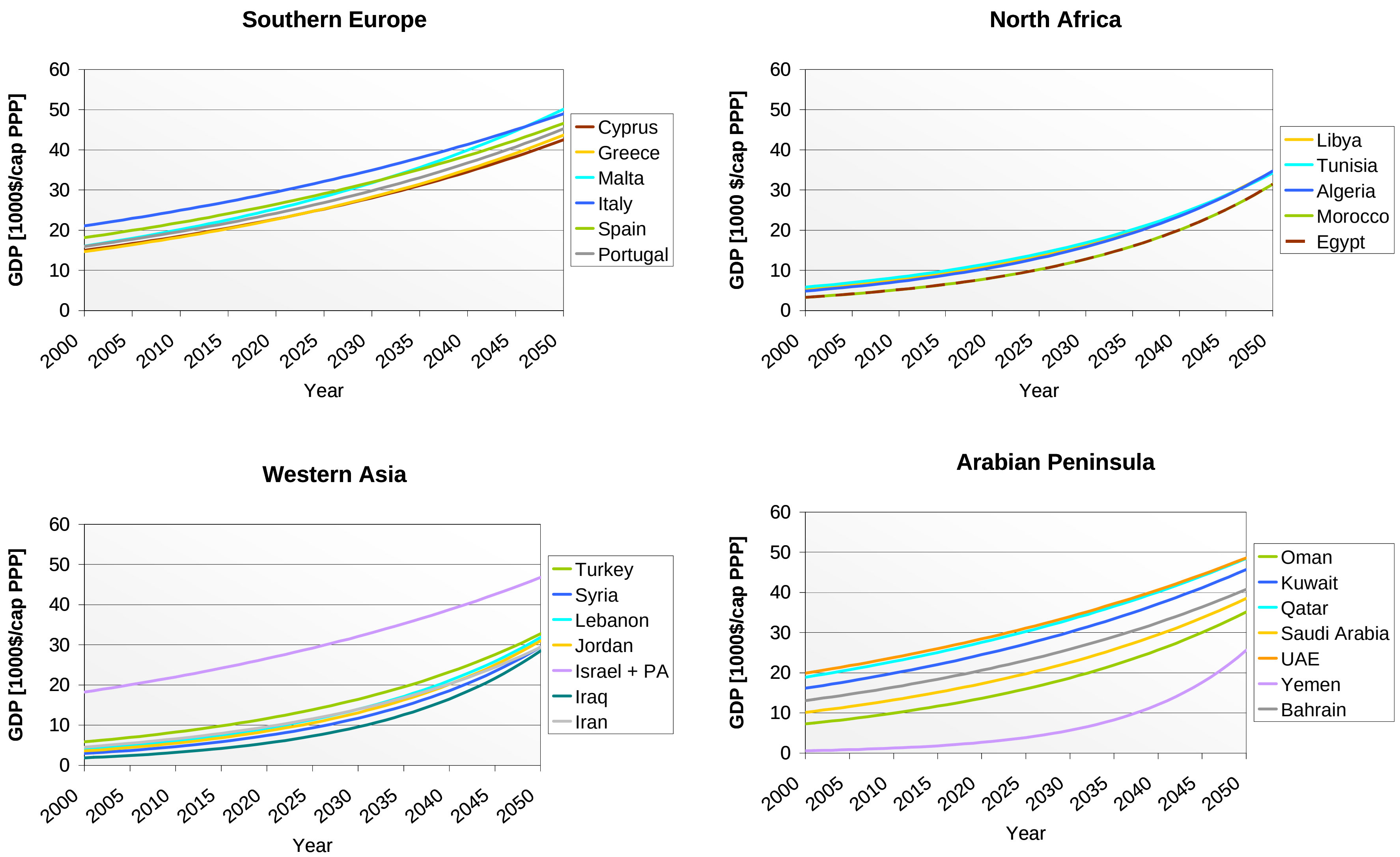


Figure 4-22: Development of per Capita GDP until 2050 within the Scenario CG/HE

	Growth rate GDP/capita following up (FU)	**Growth rate GDP, following up (FU)**	**Growth rate GDP/capita closing the gap (CG)**	**Growth rate GDP, closing the gap (CG)**	**GDP/capita Growth Rates 1990-2000**	**GDP Growth rates, 1990-2000**
Malta	1.2	1.2	2.3	2.3	6.5 (1994-1998)	6.5 (1994-1998)
Morocco	1.2	2.1	4.6	5.6	1.5	3.3
Algeria	1.2	2.1	4.0	4.9	1.3	3.2
Tunesia	1.2	1.8	3.6	4.2	3.1	4.7
Libya	1.2	2.3	3.8	4.9	n.a.	n.a.
Egypt	1.2	2.4	4.6	5.8	2.8	4.8
Cyprus	1.2	1.4	2.1	2.3	3.6 (1990-1996)	4.9 (1990-1996)
Israel	1.2	2.2	1.9	2.9	2.9	5.8
Jordan	1.2	2.5	4.4	5.8	1.4	5.8
Lebanon	1.2	1.8	4.2	4.9	8.4	10.2
Syria	1.2	2.6	4.7	6.1	0.5	3.5
Turkey	1.2	1.9	3.5	4.2	1.8	3.5
Iraq	1.2	3.0	5.1	7.0	n.a.	n.a.
Iran	1.2	2.1	3.8	4.8	4.4	5.9
Oman	1.2	3.0	3.2	5.1	n.a.	n.a.
Kuwait	1.2	2.7	2.1	3.6	n.a.	n.a.
Quatar	1.2	2.0	1.9	2.7	n.a.	n.a.
Saudi-Arabia	1.2	2.9	2.7	4.5	n.a.	n.a.
UAE	1.2	1.9	1.8	2.5	n.a.	n.a.
Yemen	1.2	4.3	4.0	7.0	-1.2	2.8
Bahrain	1.2	2.4	2.3	3.5	n.a.	n.a.
USA	1.2	2.2	1.2	2.2	2.4	3.4

Table 4-1: Average annual Growth rates of GDP and GDP/capita in both scenarios and between 1990 and 2000 (in %). Source for historical past growth: /PWT 2002/.

4.3 Electricity Demand

4.3.1 Relation of GDP per capita and electricity consumption per capita

The essential part for deriving the electricity demand is a link between GDP per capita and electricity consumption per capita. With the population growth the overall electricity demand can then be calculated. Electricity use for desalination is investigated separately and will not be taken into account here.

The approach is based on regressions, i.e. on past experiences. Past experiences may be misleading as technological, economic, political or social developments may change development patterns. Additionally, sudden breaks may occur, like the change in the energy consumption patterns in industrial countries after the first oil crisis. However, an open minded investigation of possibilities allows including this kind of changes in an analysis. Furthermore, it is well known that past experience might be quite good to forecast developments in the near future because stocks of capital and societal conventions or rules and life style are changing slowly. In the long run this is not true. At last, the forms of regression function might not be determined a priori or might not be isolated by statistical performance. Extrapolating different functions might however yield very different results in the long run. Figure 4-23 shows a self-explaining example for this problem.

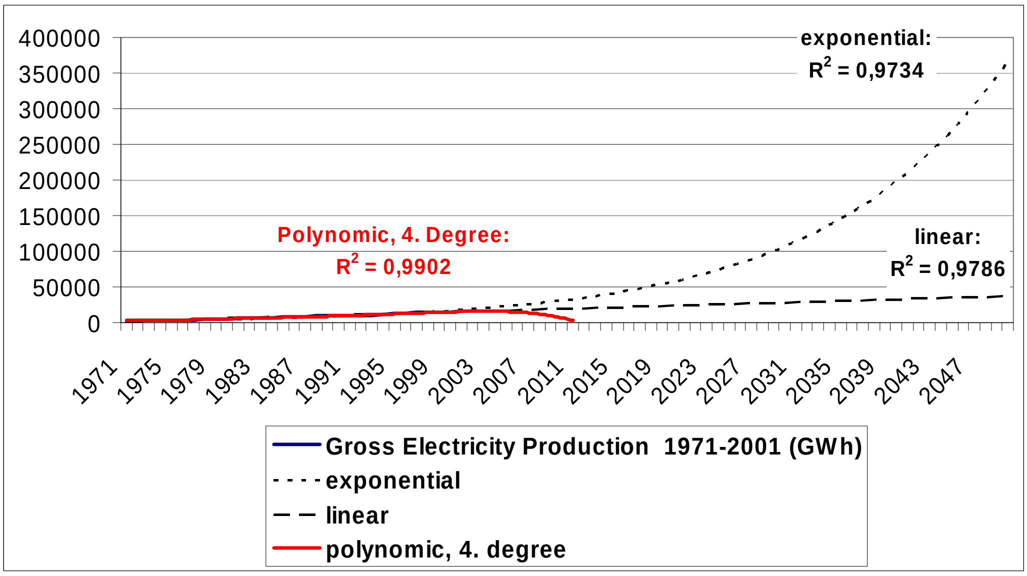


Figure 4-23: Example for problems with trend extrapolations - the Moroccan trend for gross electricity production in GWh/y. Data Source: /IEA 2003-4/

To deal with that problem, the development of population and GDP per capita are used as driving forces and the methodology links scenarios for population and GDP per capita with the energy demand. As the population scenario is well introduced further attention was given to the economic scenario. As discussed above the two scenarios cover a considerable range of possible future developments. Furthermore, two alternative functional links between GDP per capita and electricity demand per capita will be discussed and used. With two alternative economic developments and two alternative links to energy demand and an additional comparison with technological oriented scenarios for industrial countries it is possible to cover a wide range of possible future trends that are free of contradictions.

It should be remembered in the due course that this are scenarios and not forecasts. Generally, the smaller the unit under investigation the higher the uncertainties, which particularly should be taken into account in interpreting the results for small single countries.

In short, the method used to calculate electricity demand can be described as follows:

1. For every year in the period 1960-2001, regressions between the GDP per capita and total final consumption (TFC) of electricity per capita were calculated using power functions for a number of countries. /IEA 2003/, /PWT 2002/. GDP data from the World Bank GDP was used for comparison.
2. For the two parameters of the regression equations time trends were estimated using power functions and alternatively linear functions. Power functions gave a significantly better fit for the first term (a). For the second term (b) it was hard to distinguish a linear trend from a power trend. So both were used, resulting in two alternative links between GDP per capita and electricity consumption per capita. The linear trend gives a scenario with high efficiency gains (HE) while the power trend results in increasing electricity intensities and low efficiency gains (LE).
3. From the TFC for electricity the gross electricity demand was derived by using data from /IEA 2001/ on distribution losses, consumption in the energy sector and so called “own use”. These consumptions were split in a proportional and a fixed term. The fixed term is meant to accommodate the use for oil production. The proportional term was linearly reduced to a level which is now common in industrial countries (i.e. 8 %). It should be noted that the data on these terms are not of a high quality and are sometimes missing. Luckily, the impact of these terms is generally small.
4. The resulting general functions were calibrated to individual countries assuming a linear mix of the current values and the estimated value. The weight of the estimated value is assumed to increase linearly from a current 0 to 1 in 2050.
5. The two scenarios are obtained by combining high economic growth with high efficiency growth and low economic growth with low efficiency growth, as the increase of efficiency is coupled to investment and the higher growth rates result in higher investment rates and a higher share of new machineries.

The single points will now be discussed in more detail.

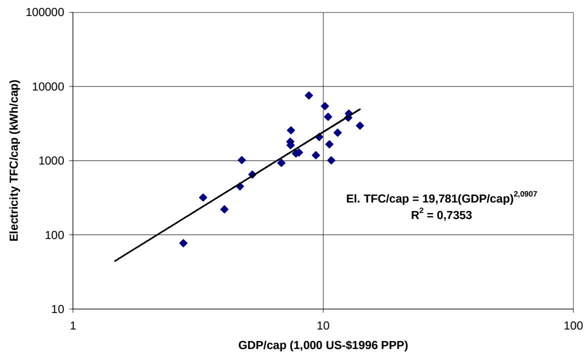
Step 1: Using data from /PWT 2002/ and /IEA 2003-2, 3/ regressions for GDP per capita and total final energy consumption per capita were calculated for different years using power functions. Overall power functions delivered the best fits, although polynomials of a certain order might do as well1. As no functional form is a priori adequate the decision to use power functions is partly based on convenience and the ease of use.

Figure 4-24 shows six examples of results.

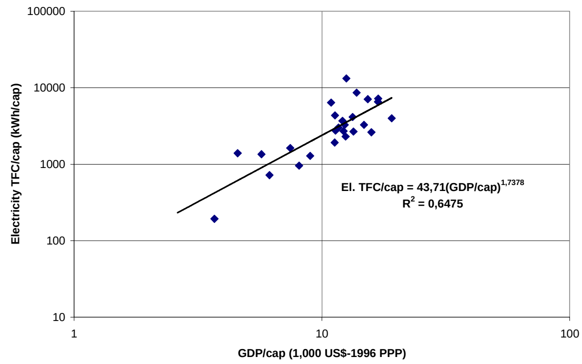
The correlation is generally quite high but is sinking along the time trend. With a sample which contains a broad set of countries, i.e. low income, middle income and high income countries, the correlation is stronger than with only one country group, e.g. compare R^2 in 1d) and 1e). Using only one country group there might be no strong correlation between the two

[1] Trivially, a polynomial of the order of the sample size gives generally a perfect fit. Without any degrees of freedom it is statistically worthless. Only polynomials with a maximal degree of four were used.

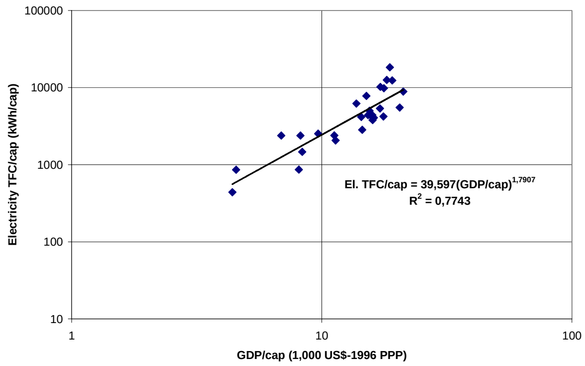
variables. Additionally, certain country groups show exceptional behaviour; in 1e) two of these groups are marked: Transition economies and northern countries. In these cases regressions were calculated with and without each or all of these country groups. Overall the statistics leads to the conclusion that the general approach seams to be fine for a long term analysis covering middle income countries, which will reach levels of today's industrial countries. Please note that even in high income countries there is no evidence of a falling electricity demand, although the energy intensity of GDP might be reduced.



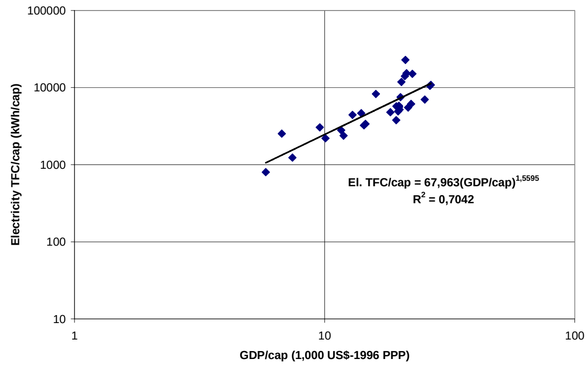
a) In the year 1960



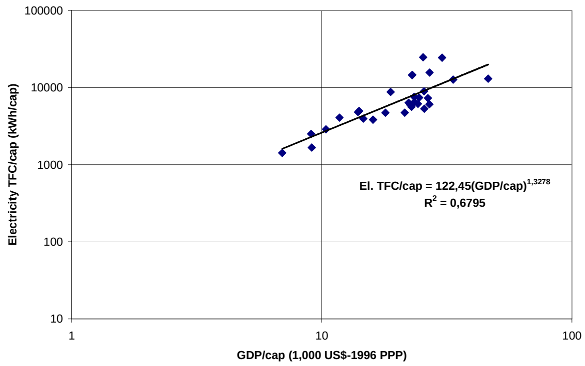
b) In the year 1970



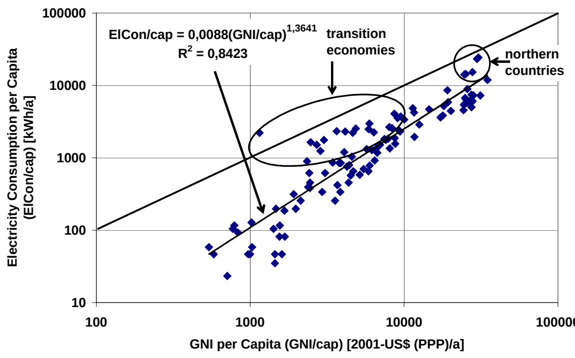
c) In the year 1980



d) In the year 1990



d) In the year 2000



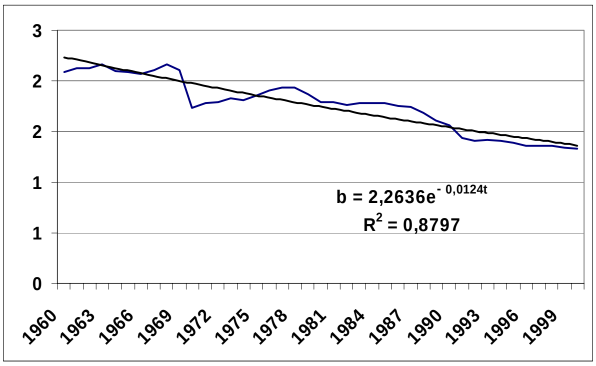
e) Different sample and data source. Year 2001.

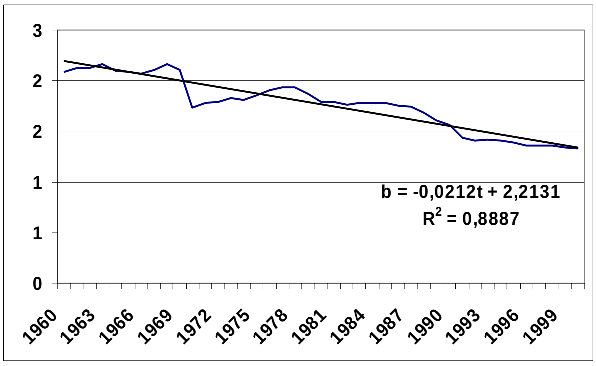
Figure 4-24: Examples for correlation between Total Final electricity Consumption per capita and GDP or GNI per capita Notes: TFC: Total final consumption. Data sources: /PWT 2002/, /IEA 2003-2,3/, e): /Statistisches Bundesamt 2003/

A power function would result in proportional growth rates of GDP per capita and of total final consumption of electricity per capita. The factor is given by the exponent. For example, the 1.3641 in Figure 4-24e) implies that a 1% higher GDP per capita is combined by a 1.3641 % higher total final consumption of electricity per capita. Note that all regressions suggest that the electricity consumption per capita increases proportionally with higher GDP per capita. However, it becomes apparent that the exponent is decreasing over time while the absolute term is increasing. Therefore it seems not to be appropriate to use a power function with constant parameters.

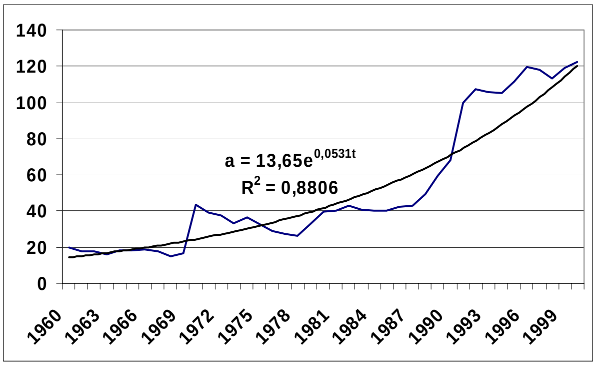
Step 2: Figure 4-25 a)-d) shows the development of the exponents and the absolute term from the sample including every year from 1960 to 2000. For both parameters an exponential as well as a linear time trend can be seen. Other functional forms delivered worse, while polynomials of higher order did not increase the fit by significant margins. The two functions of the regressions of the exponent's time trend are hard to distinguish. So both equations are used.

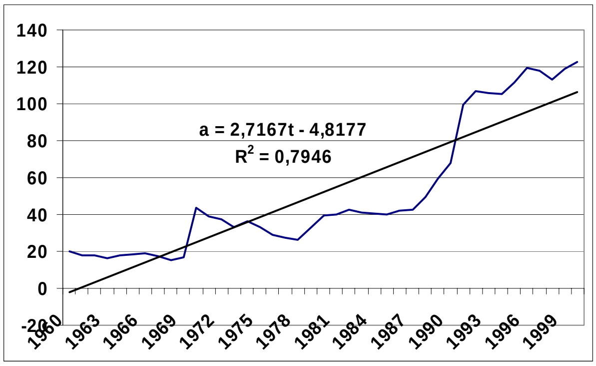
For the absolute term this is not true. The exponential function shows a significantly better fit. These conclusions were confirmed by tests using historical simulations, although until now it was not possible to systematically conduct and evaluate these simulations.





a) Exponential regression for exponent **b) Linear Regression for exponent**





c) Exponential regression for absolute term **d) Linear Regression for absolute term (not used)**

Figure 4-25: Regressions for the time dependency of the parameters

In the scenarios until 2050 the link between the economic growth and the electricity demand will be provided by a power function whose absolute term follows the exponential time trend according to Figure 4-25c) and whose exponent follows either an exponential time trend according to Figure 4-25a) or a linear time trend according to Figure 4-25d). As the linear regression function of the exponent results in comparison with the exponential regression function in a lower electricity demand the respective scenarios will be called "high efficiency gains (HE)" while the scenarios using the exponential function will be called "low efficiency gains (LE)". Using the two economic scenarios, the two functions linking economics and electricity and the population scenario four scenarios of the TFC of electricity can be calculated assuming a typical (an average) country.

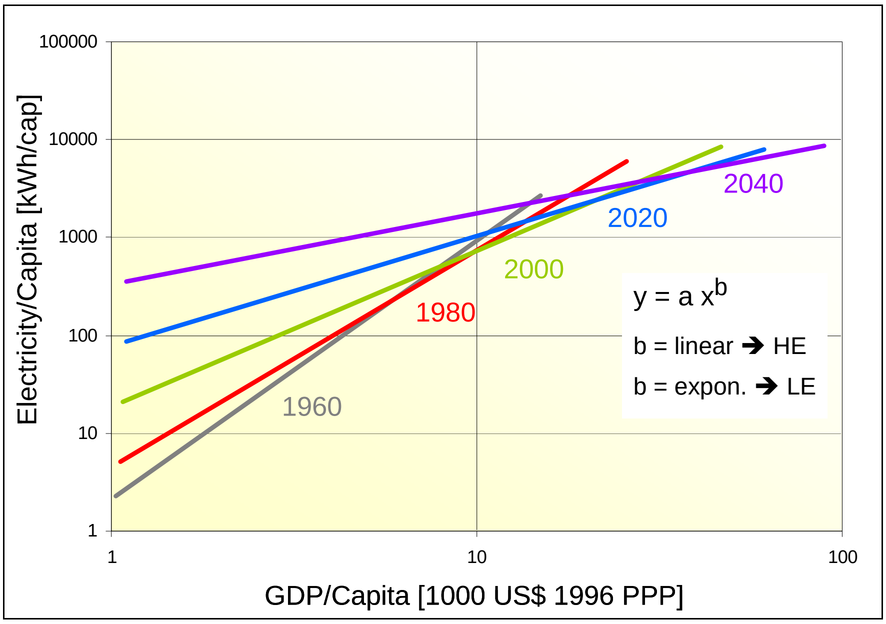


Figure 4-26: Fit functions for the years 1960 to 2040 for a sample of 25 (150) countries showing the correlation and extrapolation of total final electricity consumption per capita as function of GDP per capita for the high efficiency trend HE

With the time dependency of the exponent and the absolute terms the growth rates of GDP per capita and TFC of electricity are no longer proportional. Only for all countries with a certain GDP per capita in a certain year an equal TFC of electricity will result. The link is now time dependent. Also with the change of the parameters the TFC of electricity per capita will develop in different ways for countries with different GDP per capita at the start but equal growth rates of GDP per capita.

Step 3: Until now the approach is not country specific in the sense that for two countries starting with the same GDP per capita and experiencing the same growth rate of GDP per capita the resulting path for TFC of electricity per capita will be identical. This step will introduce a first country specific component and the concept of TFC will be left to reach a concept which is more appropriate for the further work.

/IEA 2003-4/ delivers the distribution losses, consumption in the energy sector and the so called own use for each country. It was assumed that distribution losses and "own use" are indicators of inefficiencies and that the relative values of these positions compared to the total final demand of electricity will be reduced linearly to 8 % by 2050. For countries which show currently a high value this linear reduction of losses will of course decrease the growth rate of energy demand over the whole period but will in terms of growth rates of electricity reduce this growth rates especially near 2050.

A second term – consumption in the energy sector – was assumed to reflect oil and gas production and was held constant. It should be noted that the data do not show all these categories for all countries. For Libya, for example, there's no difference at all between electricity production and total final consumption of electricity. These means that the de facto concepts used in the date differs by country and that it is not possible to handle all countries strictly comparable. So, if data on an issue discussed here were available they are used in the described way. Else no adjustment was made.

Additionally, it has to be noted that the distribution losses might contain use of electricity without payments and the content of the other categories might not be well defined either. Then the interpretation given above might not be well founded. However, as the method delivers the electricity demand for a typical country it can be argued that the scenarios assume that the final demand for electricity will gradually show up as final demand - for example: in 2050 all people will pay for their consumed electricity - and that the efficiency of the distribution sector will increase to the state-of-the art. This seems to be a reasonable assumption.

Step 4: The method described until now will generally not predict exactly the present electricity demand per capita of any particular country. The real values, however, are distributed statistically around this estimate. Therefore it is necessary to calibrate the starting point of the function for every country. For the calibration it was assumed that the deviation from the estimated value is contingent and that each country will realize the estimated value in 2050. The difference between the present real electricity demand per capita and the fit functions of the scenarios will decrease over time. This is done by weighting the actual (2001) value of a country with 49 and the estimate with 0 and then changing the weight linearly on a year by year base to reach 0 and 49 respectively, in 2050.

An electricity consumption per capita which is higher than the estimated value for a certain GDP per capita is judged as some kind of inefficiency or special economic structure which will vanish over time. An electricity demand per capita that is smaller than the estimate is interpreted as a lack of a stock of machineries etc., which are to be expected with such an income, or again a specific structure of the economy. Again, it is assumed that these deviations from the estimated and extrapolated function will be reduced to zero until 2050. An electricity demand path for a country, which currently has a relative high per capita demand, will therefore be expected to experience a decrease (or limited increase) in energy intensity.

Step 5: The steps so far result in four scenarios for electricity demand for each country: closing the gap & low efficiency gains (CG/LE), closing the gap & high efficiency gains (CG/HE), following up & low efficiency gains (FU(LE) and following up & high efficiency gains (FU/HE). To reduce the number of possibilities it is assumed that the economic scenarios (closing the gap, following up) will occur in every country simultaneously. Therefore the huge amount of possibilities stemming from mixing following up and closing the gap on a country base is avoided.

Secondly the four scenarios were reduced to two by comparing the results with technology oriented studies and thereby testing their plausibility. The two scenarios selected are "closing the gap & high efficiency gains" (CG/HE) and "following up & low efficiency gains" (FU/LE). The combination "following up-high efficiency gains" results in a decrease of energy intensity which is too high to be in line with technological discussions and is thought to be implausible therefore, especially as the economic growth rates in following-up are typically not high enough to expect a fast spread of new technologies and to give strong incentives for the development of this technologies. On the other hand, if the introduction of strong measures to combat climate change would reduce the growth of GDP per capita this scenario might be possible. The other excluded scenario “closing the gap & low efficiency gains” shows accelerating energy intensities of GDP after 2020-2030. To our knowledge there are currently no arguments for such a development. Until 2020-2030 this might be a sensible scenario, in that period the difference between this scenario and the two other scenarios investigated seems not to be large enough to require an additional investigation, because it was felt that no new strategic insights would result.

In addition, it can be argued that a fast economic development will increase the spread and development of new machinery which is likely to be associated with high efficiency gains. However, from the discussion of similar scenarios for different countries it is not very probable that this kind of efficiency gains will be achieved without determined policy measures. Again it must be noted that these are scenarios and no predictions. There realisation requires technical, financial, social and political effort. They will not happen spontaneously.

The results for the two chosen scenarios will now be discussed in detail. The other two scenarios might be easily calculated using the excel sheet and combining high and low efficiency gains.

Selection of the MED-CSP Base Scenario:

4 Scenario Variations for Economic Growth:	
CG/HE	**Closing 50 % of the per Capita GDP Gap with USA by 2050 High Efficiency of the Power Sector**
CG/LE	Closing 50 % of the per Capita GDP Gap with USA by 2050 Low Efficiency of the Power Sector
FU/HE	Following Up with the per Capita GDP Gap with USA until 2050 High Efficiency of the Power Sector
FU/LE	Following Up with the per Capita GDP Gap with USA until 2050 Low Efficiency of the Power Sector

Table 4-2: The four main scenario variants for economic growth. CG/HE is used further in the study and its results will be described in detail. The USA per capita GDP has been used as reference indicator because it shows the achievable maximum values. This does not imply any preference or model function of the American way of life. It simply defines the per capita GDP values of each country shown in Table 4-1.

4.3.2 Scenarios of Electricity Demand

Before discussing the results of both scenarios it is appropriate to recall their meaning and aim. First, these are scenarios and not forecasts. The aim of the CG/HE scenario is to investigate, whether a high economic growth can be accommodated by the energy system without compromising sustainable development goals especially on green house gas emissions. In such a scenario it is natural to assume that the efficiency gains on the demand side are high as under these conditions some measures to increase efficiency are likely to be imposed and a high economic growth rate is more likely to be associated with a fast diffusion of new technologies.

For the FU/LE scenario an economic growth rate is assumed that might be somewhat disappointing for MENA. With its low efficiency gains or to be more precise: its rising energy intensities this scenario might be seen as somewhat cautious on economic and technological development. However, for the next two decades it is not too far from the other scenario. Alternatively, the technological side of this scenario might be interpreted as a continuing trend to substitute other energy carriers by electricity and the increase of electricity consuming machines and consumer goods.

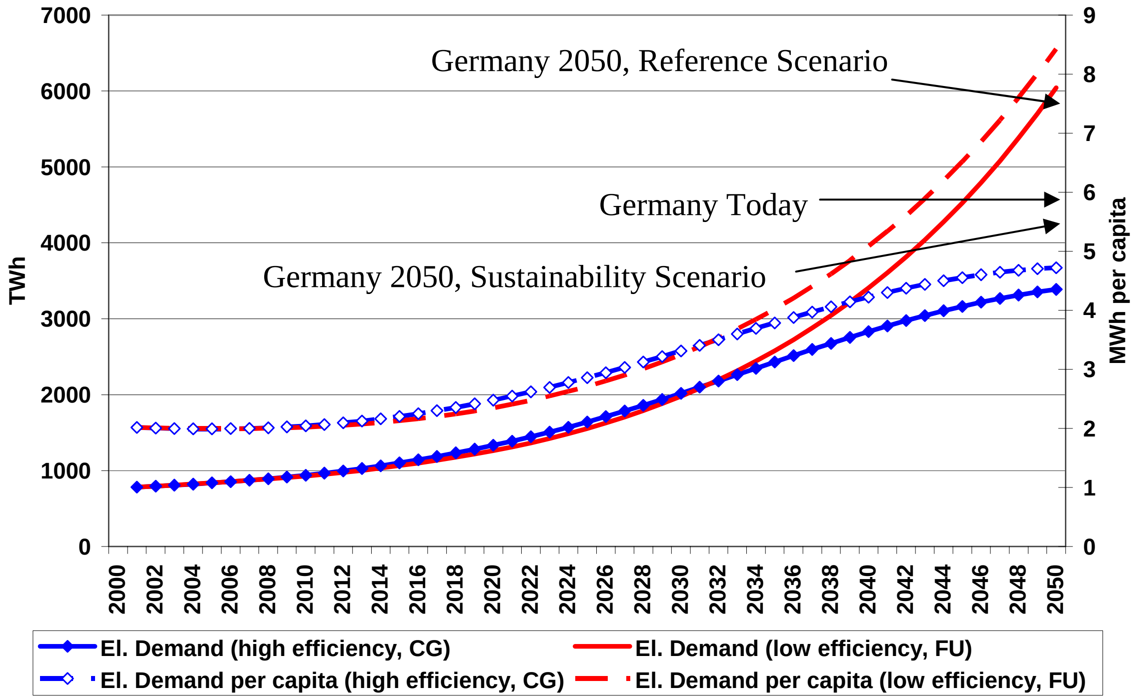


Figure 4-27: Electricity demand and electricity demand per capita in MENA according to the scenarios CG/HE and FU/LE (results obtained from aggregation of single country scenarios).

The scenario results for energy demand and energy demand per capita are shown in Figure 4-27. For comparison some values for Germany are provided. Please note that the energy intensity will not decrease – or increase – uniformly over time as the reduction of current inefficiencies is time dependent and the general development depends on income levels.

According to the scenarios the electricity demand of the MENA region will increase from some 700 TWh to 2000 TWh in 2030 and to between 3500 TWh and 6000 TWh in 2050. The per capita consumption of electricity will rise to almost 5 or 8.5 MWh/capita. For comparison the current figures and two scenario results for Germany are included /DLR, ifeu, WI 2004/.

The results for the individual countries are shown in Annex 3. For the **high income countries** which don't depend on energy exports – Israel, Malta, Cyprus and Southern European countries – the development of the electricity demand depends mainly on the development of energy efficiency. As the current inefficiencies are not too high the decrease in energy intensity is moderate. It seems possible to maintain the current electricity per capita until 2050 although in the next decades a temporary increase might occur. The electricity consumption per capita after 2040 in scenario FU is very high. Substantial higher growth rates of GDP are not likely as these countries operate with state-of-the-art technologies.

For the **energy export countries** (Arabian Peninsula without Yemen) the data generally indicate quite huge potentials to reduce the electricity intensity. This explains the suggestion that the electricity demand per capita might decrease in the next decades and substantially so until 2050. Comparable to the discussion of other high income countries the other suggestion is that the increase in energy intensity will only be temporarily compensated by increasing efficiency and rises substantially in the long run. This will have a huge effect in the long run. The hugest country in this group – Saudi Arabia – will determine the electricity demand of the overall country group. Here the possible economic development is of great importance. Anyway, a doubling of the capacities within the next 25 years seems to be a quite robust strategy for Saudi-Arabia. Most other countries of this group will also face an increasing energy demand. Only in the long run some countries may reduce their absolute electricity demand.

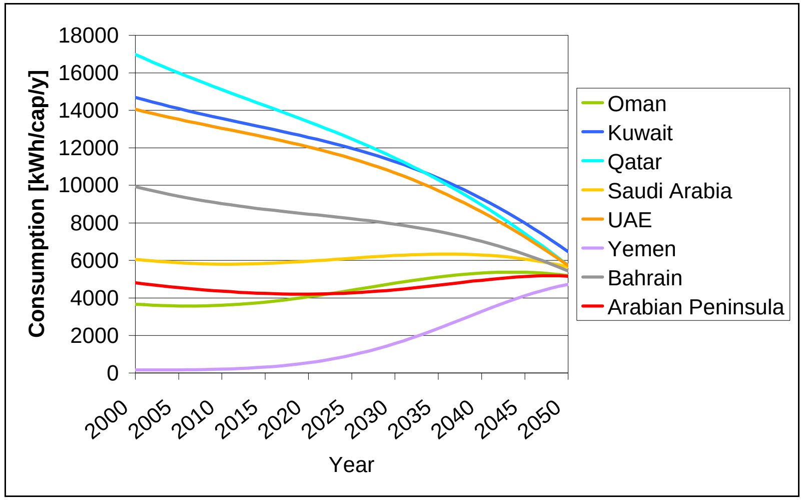
Yemen will need a fast and continuing extension of energy supply just to allow a modest improvement of economic conditions over the next half century. Otherwise the population growth might result in significant social tensions and massive emigration. Therefore an increasing power supply should be seen as mandatory. The success will depend on whether Yemen has the possibility to finance these investments by itself or to find foreign investors. Concerning public investments the current GDP per capita raises doubts. Efficiency gains will not significantly reduce the need of supply expansion.

The remaining **middle income countries** all face a significant increase in population and labour force growth and the countries are well positioned to reap a demographic dividend in form of an accelerating economic growth as the share of labour force of the whole population is likely to rise strongly because of the reduced birth rate which in the future will decrease further. All these countries need strong expansions in electricity production to accommodate the population growth and to provide the conditions for a further economic development. For the next 20 to 30 years both scenarios suggest a similar expansion. Turkey, Egypt, Iran, Algeria and Morocco are the most important. For comparison, Egypt will need additional capacities until 2050 which are in the range of the overall electricity production in Germany. These countries have a fast growing demand for electricity and/or electricity technologies. The satisfaction of their demand in a sustainable way will be the main challenge for the future electricity system of MENA.

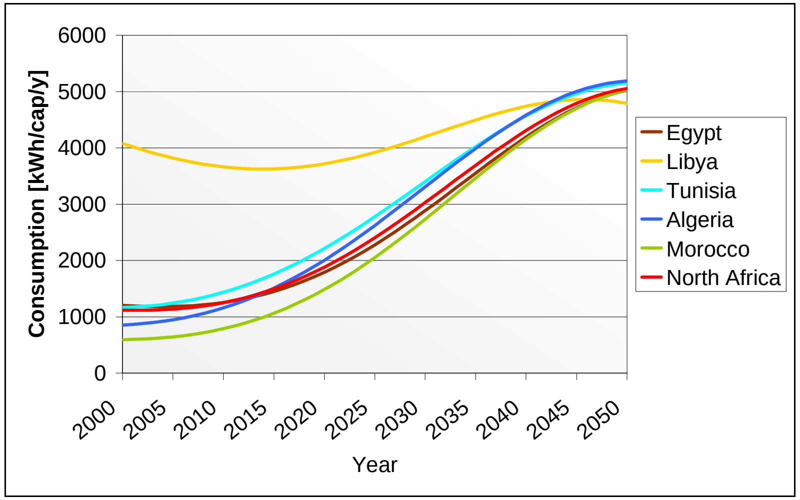
Figure 4-28 shows the per capita power consumption in the analysed countries and its development until 2050. The scenario assumptions lead to a certain equalization of the per capita electricity demand at about 5000 kWh/cap/y in most countries which is in line with the sustainability criteria of fair access to energy sources described in Chapter 1 and proposed also by /WBGU 2003/. The European countries – which show a relatively homogeneous consumption – the island states, Saudi Arabia and Israel are already on this path and will probably maintain that demand in the future.

In terms of per capita electricity consumption, the Arabian Peninsula is the most heterogeneous region, with values ranging from a few 100 kWh/cap/y in Yemen to almost 18000 kWh/cap/y in Qatar. Most oil exporting countries have today a much higher per capita consumption than average and will probably have to adapt to lower values as energy becomes more expensive and scarce. The other MENA countries - especially Yemen - have today a much lower per capita demand and will subsequently come to higher consumption in line with their expected economic progress.

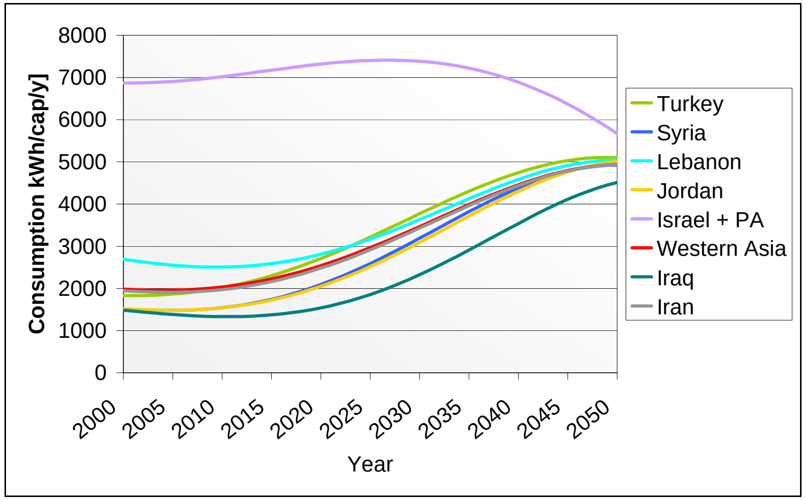
Arabian Peninsula



North Africa



Western Asia



Southern Europe

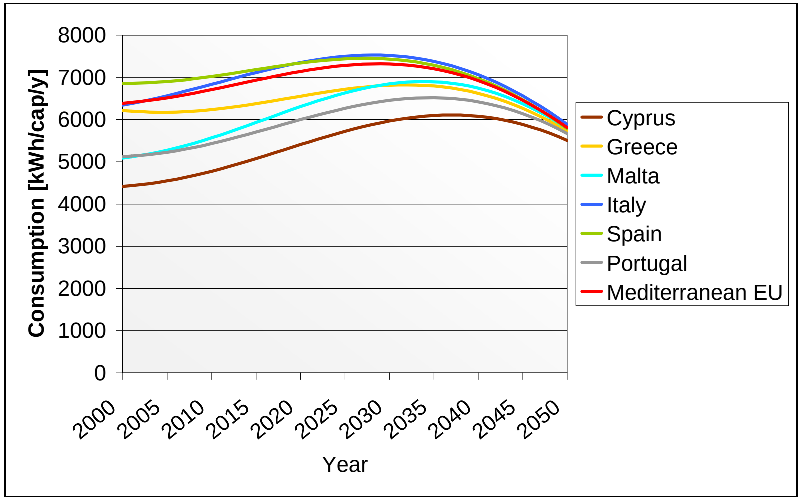


Figure 4-28: Per capita power consumption in the scenario CG/HE

	Elec-tricity per capita, (FU)	**Elec-tricity per GDP** (FU)	**Elec-tricity** (FU)	**Elec-tric-ity/cap ita** (CG)	**Elec-tricity per GDP** (CG)	**Elec-tricity** (CG)	**Elec-tricity per capita,** 1990-2000	**Elec-tricity per GDP** 1990-2000	**Elec-tricity,** 1990-2000
Portugal	3.1	1.9	2.9	0.2	-1.9	0.0	4.5	1.5	4.6
Spain	2.7	1.5	2.5	-0.4	-2.2	-0.6	3.9	1.7	4.2
Italy	3.0	1.8	2.5	-0.2	-1.9	-0.7	2.3	1.2	2.5
Greece	2.6	1.4	2.4	-0.2	-2.4	-0.4	3.8	1.5	4.2
Malta	3.1	1.9	3.1	0.3	-2.0	0.3	4.6	-1.9 (1994-1998)	5.7
Morocco	5.3	4.1	6.2	4.5	-0.1	5.5	3.6	2.1	5.4
Algeria	5.1	3.9	6.0	3.8	-0.2	4.7	2.7	1.4	4.7
Tunisia	4.7	3.5	5.3	3.1	-0.5	3.7	4.6	1.5	6.2
Libya	1.8	0.6	2.9	0.4	-3.4	1.5	0.1	n.a.	2.1
Egypt	3.9	2.7	5.1	3.1	-1.5	4.3	3.6	0.9	5.6
Cyprus	3.2	2.0	3.5	0.4	-1.7	0.6	4.1	0.5 (1990-1996)	5.5
Israel	2.6	1.4	3.6	-0.4	-2.3	0.6	4.5	1.7	7.5
Jordan	3.5	2.3	4.8	2.6	-1.7	3.9	3.0	1.5	7.4
Lebanon	2.5	1.3	3.1	1.4	-2.8	2.0	18.2	9.7	19.9
Syria	3.2	2.0	4.6	2.5	-2.1	3.9	4.6	4.0	7.5
Turkey	3.8	2.6	4.5	2.2	-1.3	2.9	6.6	4.8	8.5
Iraq	2.4	1.2	4.2	2.3	-2.7	4.1	0.5	n.a.	3.5
Iran	3.3	2.1	4.2	2.0	-1.7	3.0	5.9	1.5	7.5
Oman	2.6	1.4	4.4	0.8	-2.4	2.6	3.4	n.a.	7.3
Kuwait	0.9	-0.3	2.4	-1.7	-3.8	-0.2	n.a.	n.a.	5.8
Qatar	0.8	-0.4	1.6	-2.1	-4.0	-1.3	n.a.	n.a.	6.9
Saudi-Arabia	2.1	0.9	3.8	-0.1	-2.8	1.6	3.9	n.a.	7.6
UAE	1.3	0.1	2.0	-1.8	-3.6	-1.2	n.a.	n.a.	8.5
Yemen	5.6	4.4	8.6	6.2	2.2	9.2	2.0	3.2	5.9
Bahrain	1.4	0.2	2.6	-1.2	-3.5	0.0	2.8	n.a.	6.1
USA and Canada*	0.6	-0.6	1.4				1.5	-0.9	2.5
Germany**	0.5	-1.3	0.1	-0.2	-1.9	-0.6	0.1	-1.5	0.4

Source for past growth of GDP and Population: /PWT 2002/. Additional population data: /Stat. BA 2003/. Electricity data: /IEA 2003a,b,c/.
* Scenario for USA and Canada: /IEA 2002/, period covered: 2000-2030. Period 1990-2000: USA.
**Scenarios for Germany. Source: /DLR, ifeu, Wuppertal Institut 2004/, Reference scenario (in column “FU”), RES extension scenario (in column “CG”).

Table 4-3: Average annual Growth rates of electricity demand, electricity demand per capita and electricity per GDP in both scenarios and between 1990 and 2000 (in %)

4.4 Freshwater Demand

The analysis shows scenario predictions for the demand and the resources of sweet water on country level. Inside a country, there might be regions with deficits that cannot be identified on the basis of statistical country wide data. The analysis of Spain or Italy at that level would not yield any deficits, however, we know that in Andalusia and Sicily, there is a severe water shortage, and plans are underway to build desalination plants or even to withdraw water from the Ebro river and transfer it to Southern Spain in order to solve that problem. Excessive withdrawal of groundwater is also a common problem in many regions. The study concentrates on those cases that can be identified as problematic on the basis of national statistics. Sub-national demand for non-conventional freshwater resources is neglected.

The following definitions have been used for the water balances in this study:

- Renewable Water = Renewable Surface Water + Renewable Groundwater - Overlap
- ExploiTable 4-Water = Renewable Water * ExploiTable 4-Share
- Sustainable Water = ExploiTable 4-Water + Reused Waste Water
- Water Demand = Agricultural + Domestic + Industrial Demand
- Unsustainable Water = Water Demand - Sustainable Water

  = Fossil Fuelled Desalination + Excessive Groundwater Withdrawal

  = Potential Future Deficit (to be covered by wind and solar powered desalination)

Most of the actual data on water resources and use has been obtained from the AQUASTAT Database of the Food and Agriculture Organisation of the United Nations (FAO) /AQUASTAT 2004/. Extrapolations to the future have been made on the basis of population and GDP growth rate expectations as described in this report.

The extrapolation of future water demand on country level is based on the assumptions that:

- agricultural production and its water demand per capita will be maintained as today. This means that the demand of the agricultural sector will be growing proportionally to population,
- the demand of the domestic and industrial sector will grow proportionally to the Gross Domestic Product GDP, which is calculated for every country adding the population growth rate to the per capita GDP growth rate,
- the efficiency of water use in the agricultural and municipal sector will be increased from today's country specific values to a maximum value which depends on the selected scenario, the water demand growth rate thus becoming lower than the population or GDP growth rates. Enhanced technologies will additionally de-couple water demand from economic growth as experienced e.g. in Australia in the past decades /Gleick 1998/ and /PWT 2004/.

As in the analysis of the power sector, two different economic scenarios have been used as baseline for water demand predictions (refer to Table 4-1):

The scenario **"Following Up"** assumes an average per capita GDP growth rate of only 1.2 % for every country from today until 2050. This implies that the relative distance between the actual GDP/capita (US$-PPP) of the respective country and the USA will remain constant because the GDP of USA at the same time will also be growing by 1.2 %. Efficiencies of the agricultural and the municipal water supply system and the reuse of wastewater increase gradually from the present national performance values to a future better value of an enhanced system. However, the efficiency enhancements are limited by the slow economic development. Population growth and the agricultural sector dominate the water demand growth rates in this case. De-coupling of the water demand from the economic growth by using enhanced water supply technologies is also limited in this scenario (Table 4-1) /Gleick 1998/ and /PWT 2004/.

The scenario **"Closing the Gap"** assumes that the relative distance between the actual GDP/capita (US$-PPP) in USA and the respective country is reduced to 50 % until 2050 while the GDP of USA at the same time is growing by 1.2 %. This scenario assumes that the MENA countries will by 2050 achieve GDP per capita values close to that of the European countries. In this case, the industrial and domestic sectors will dominate the water demand growth. However, efficiencies will also be increased and a significant de-coupling of water demand and economic growth as experienced in Australia in the past decades will take place.

The 50 year average of GDP growth is limited to a maximum of 7 % for both scenarios. This limits the per capita GDP growth rate for those countries that have a very high population growth rate, like e.g. Yemen.

The water demand in the MENA region consists today of 85 % agricultural use, 9 % domestic use and 6 % industrial use. 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. Starting data from the year 2000 was obtained from /Aquastat 2004/.

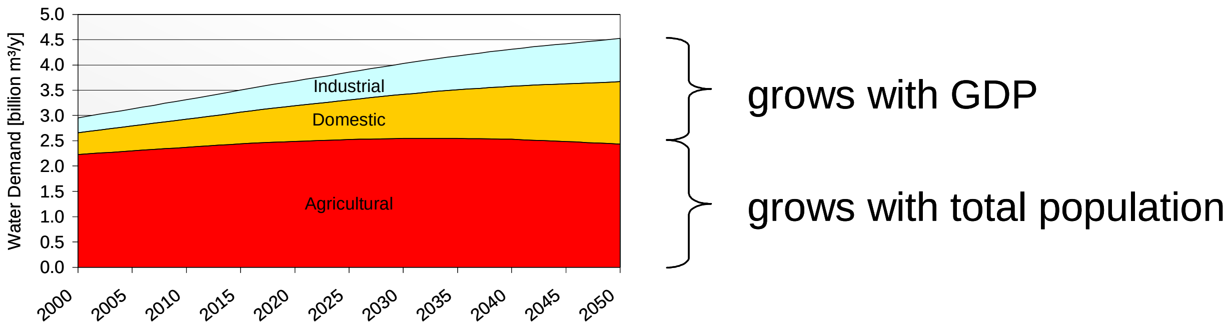


Figure 4-29: Water demand of the industrial, domestic and agricultural sectors as function of population and GDP. Note: GDP is a function of population and per capita GDP growth rates.

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/. Although renewable water resources are scarce in many MENA countries, salt water, energy for desalination and land are plenty. A stagnation of water supply would lead to a considerable reduction of agricultural activities, as the urban water demand will grow steadily in MENA. In our scenario, the efficiency of irrigation technologies is enhanced with time, through change of irrigation systems and technical advance. Irrigation efficiency values start with actual levels in each country and achieve best practice (60 – 70 %) by 2050.

The water demand of the **industrial and domestic sectors** growths in proportion to the national economy represented by the GDP according to the scenario CG/HE. Efficiency enhancements of the municipal water supply system are considered. Efficiency starts with actual values in each country and reaches best practice values (> 80 %) by 2050.

Under the assumptions of the scenario ***"Following Up"***, the share of agricultural water use will fall to about 80 %, and the domestic and industrial share will increase to 12 % and 8 %, respectively. The total water demand will increase from today 300 billion m³/y to about 510 billion m³/y in the year 2050 (Figure 4-30). The scenario reflects the influence of enhanced water management, policies and efficiencies that are of highest priority for a sustainable water future in MENA, but that are limited by the slow economic growth within this scenario.

Under the assumptions of the scenario ***"Closing the Gap"***, the share of agricultural water use will fall to about 66 %, and the domestic and industrial share will increase to 18 % and 16 % respectively, more and more dominating the water demand. The total water demand will increase from today 300 billion m³/y to about 540 billion m³/y in the year 2050 (Figure 4-31). The scenario also reflects the pronounced influence of enhanced water management, policies and efficiencies, giving them highest priority for a sustainable water future in MENA, especially in this scenario oriented to a high economic growth.

In terms of water demand, both scenarios are rather optimistic compared to other scenarios that predict a doubling of demand already for the year 2025, by extrapolating the water demand growth rates as experienced in the last decades /Al-Zubari 2002/, /Saghir 2003/. However, we believe that a reduction of the agricultural sector demand and the successive decoupling of economic growth and industrial and domestic water demand are realistic approaches. On a first glance, it is surprising that both scenarios culminate in a rather similar water demand of 510 / 540 billion m³/y by 2050 which obviously will be achieved with or without economic growth. It reflects the positive impact of economic stability and development on water supply. In the scenario "following up", consumption is limited by availability, while in the scenario "closing the gap", it is rather limited by the enhanced efficiency of the supply system.

As the future deficits and the additional demand for non-conventional resources will not change considerably assuming one scenario or the other, the scenario ***"Closing the Gap"*** - which is more desirable from the point of view of the MENA countries - will be used hereafter as reference in the further analysis.

An overview of the Total Renewable Water Resources (TRWR) in the countries of the EU-MENA region is given in the maps in Figure 4-47, Figure 4-45 and Figure 4-46. The term "dependency ratio" describes the share of renewable water coming into the country from outside. The most prominent example is Egypt with a dependency ratio of 97 % due to its almost exclusive supply by the Nile River.

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. Unsustainable water supply from fossil fuelled desalination and from excessive groundwater withdrawal is considered as potential future deficit (Figure 4-32).

The sustainable sweet water resources of Northern Africa are today almost used to their limits, and therefore, 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. On the Arabian Peninsula, the relation of sustainable and unsustainable use of water is even more dramatic.

The total annual water deficits in MENA will increase from today 35 billion m³/y that are at present supplied by excessive groundwater withdrawals and fossil fuelled desalination, to about 155 billion m³/y by the year 2050. There is no sustainable resource in sight to supply such deficits except renewable energies. 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.

The water demand growth rates will decline in all three MENA regions from about 1.5 %/y to less than 1 %/y. The per capita water demand and its future trend is different in the three regions (Figure 4-34). The MENA average per capita demand is expected to stay almost constant at about 800 m³/capita/year. Western Asia will reduce its per capita demand from 1000 to about 900 m³/cap/y, while the demand in North Africa will grow from 700 to about 800 m³/cap/y which is due to a relative moderate growth of the population and an increasing importance of the domestic and industrial sector, mainly in Egypt. The specific consumption on the Arabian Peninsula will fall from today 600 to about 400 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.

The development of the consumption pattern of every MENA country for the scenario “Closing the Gap” can be seen in Annex 4. The relation of rural and urban population in each country described in Chapter 4.1, Figure 4-6, is an indicator for the possibilities of reducing the water demand of the agricultural sector which is presently dominating the water demand in most MENA countries. While the water demand of the agricultural sector will be stagnating in countries like Malta, Morocco, Algeria with retrogressive rural population, it will still increase significantly in Yemen or Egypt.

North Africa

The scenario assumptions lead to a linear growth of the water demand in North Africa from today 100 billion m³/y to 200 billion m³/y in 2050 (Figure 4-35). The 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 a very strong agricultural sector and large population, followed by Libya and the Maghreb countries (Figure 4-36). The deficit of Egypt expected for 2050 might arise to the present water capacity of the Nile river of about 70 billion m³/y. An official expectation of a deficit of 35 billion m³/y until 2025 was recently published.

Figure 4-37 shows the demand growth rates and the per capita demand for the single countries in North Africa. All countries will experience a reduction of their water demand growth rates of about 0.5 % until 2050. The per capita consumption is highest in Egypt and Libya (about 1000 m³/cap/y), and lowest in Algeria and Malta (200 m³/cap/y), with a slightly increasing trend in all countries.

The strong economic growth of the scenario “Closing the Gap” reveals the challenge of this path, as the water demand of the industrial and domestic sector will growth very quickly and overcompensate possible reductions in the agricultural sector.

Western Asia

The water demand in Western Asia will increase from today 175 billion m³/y to about 275 billion m³/y in 2050, showing a slight stabilisation trend by that time (Figure 4-38).

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 (Figure 4-39).

The demand growth rates are high in Jordan but at a very low level of per capita demand, as can be appreciated from Figure 4-40. Strong consumers are Iraq, Turkey and Syria, with only Syria facing a short-term deficit. The average per capita demand of the Western Asian region will be slightly reduced from 950 to 850 m³/cap/y, while in all countries the consumption growth rates will be reduced.

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 30 to 65 billion m³/y (Figure 4-41). 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 (Figure 4-44). 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 (Figure 4-42).

The per capita consumption on the Arabian Peninsula will be reduced from 600 to 450 m³/cap/y. Saudi Arabia and UAE will have the highest consumption per capita of about 800 – 700 m³/cap/y. The strongest decrease of per capita consumption will be experienced in Yemen.

In terms of population growth and share of the agricultural sector, Yemen is a very specific case among the MENA countries. The per capita consumption will decrease from 400 to 250 m³/cap/year, but the consumption growth rates will not decrease until after 2030. The scenario “Closing the Gap” would require a continuous GDP growth rate of Yemen of 11 % until 2050 (a necessary 7.8 % per capita growth rate to close the GDP per capita gap with USA plus a 3.2 % population growth rate), which is unrealistic and therefore limited to a maximum of 7 %.

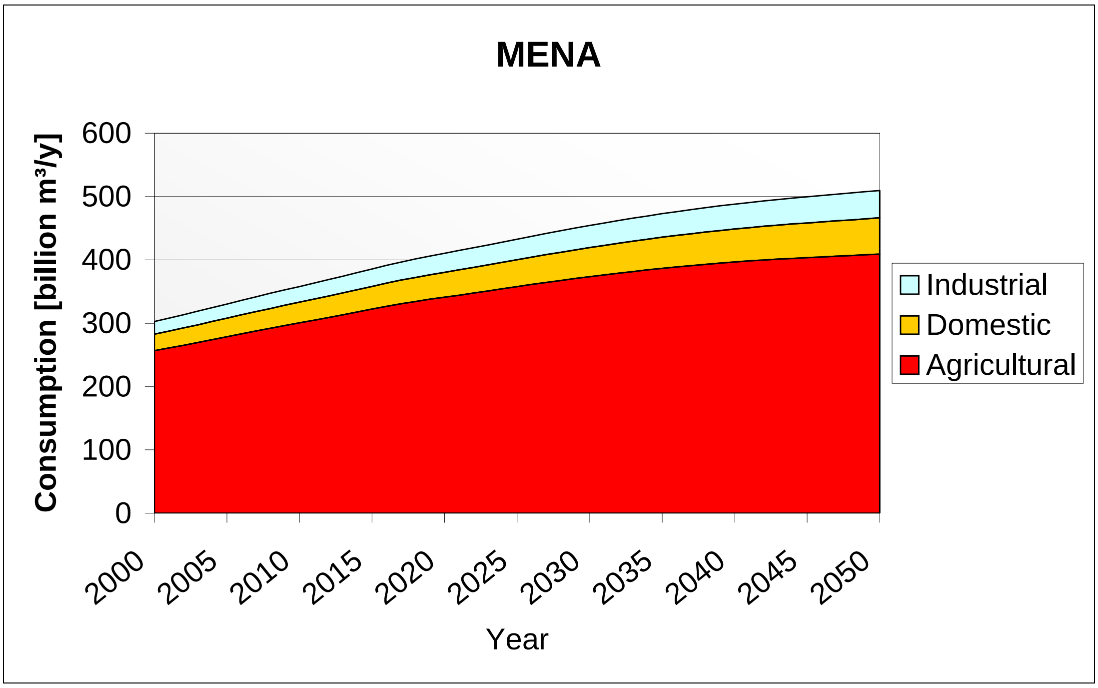


Figure 4-30: Water demand structure in MENA and its evolution until 2050. Scenario "Following Up"

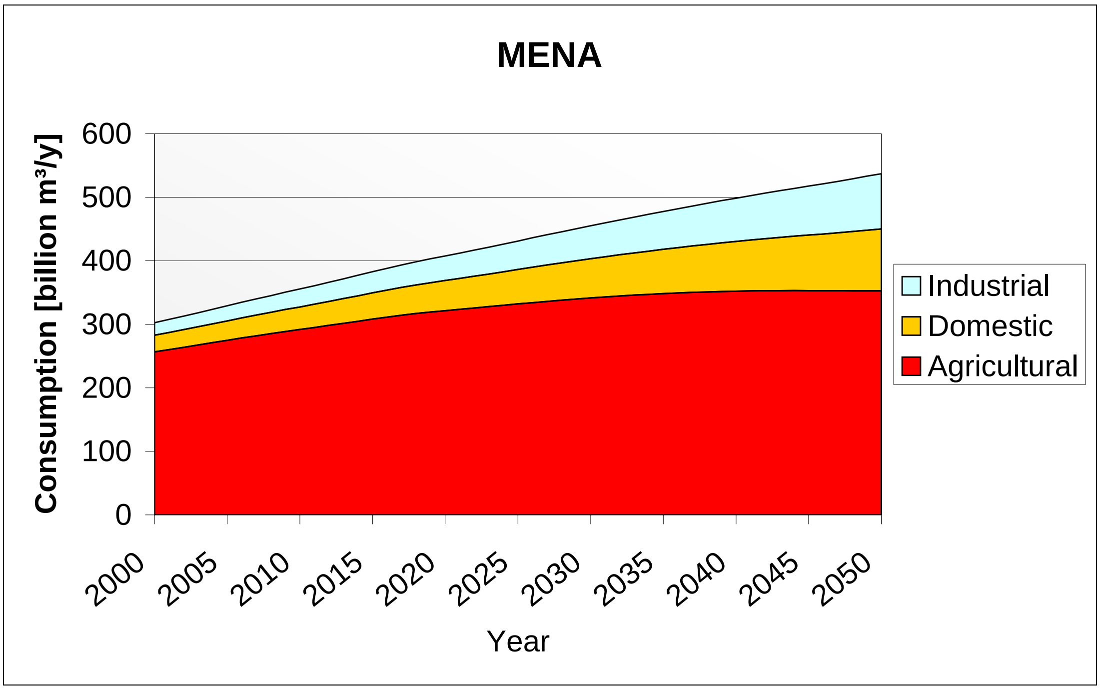


Figure 4-31: Water demand structure in MENA and its evolution until 2050. Scenario "Closing the Gap"

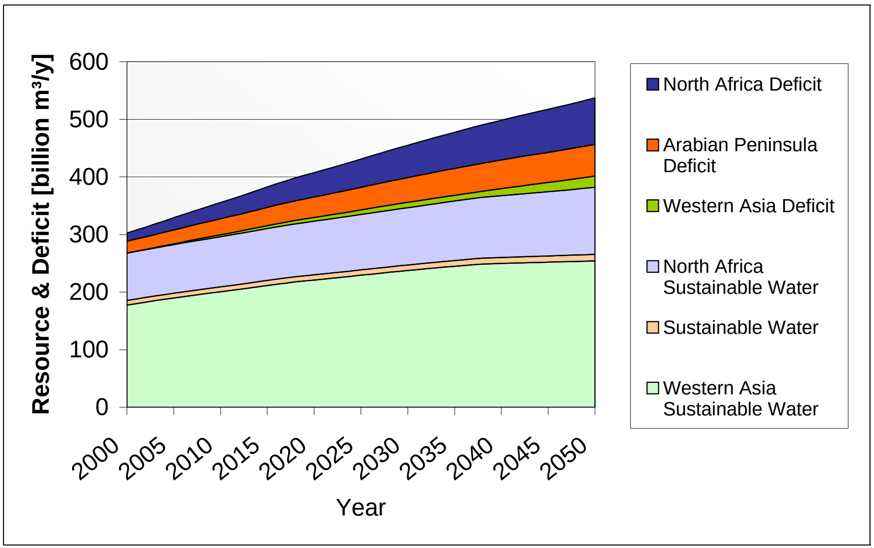


Figure 4-32: Water supply from sustainable sources and deficits in MENA (Closing the Gap).

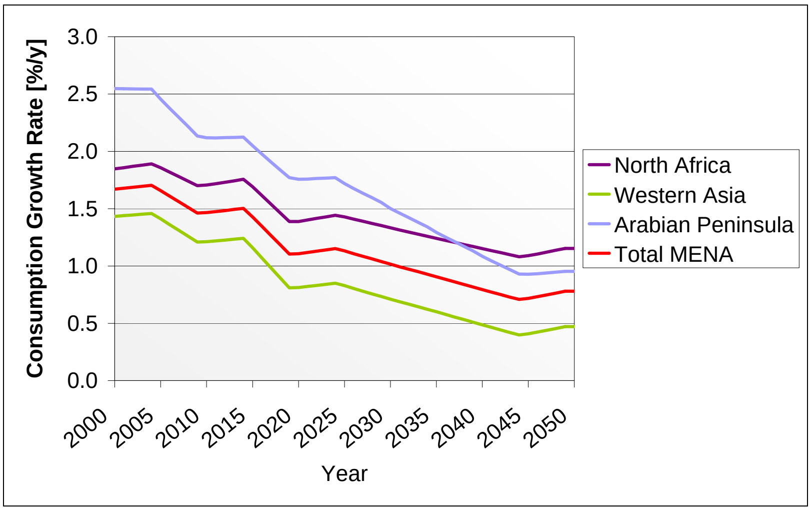


Figure 4-33: Water consumption growth rates in MENA (Closing the Gap).

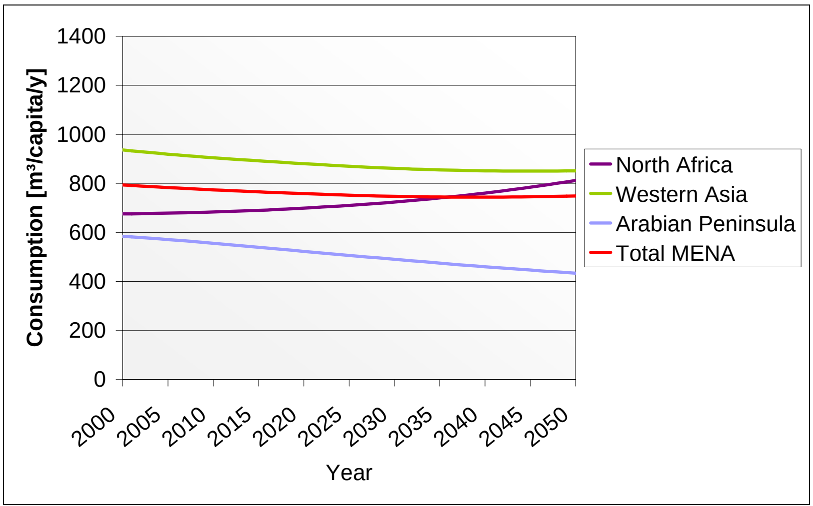


Figure 4-34: Water consumption per capita in MENA (Closing the Gap).

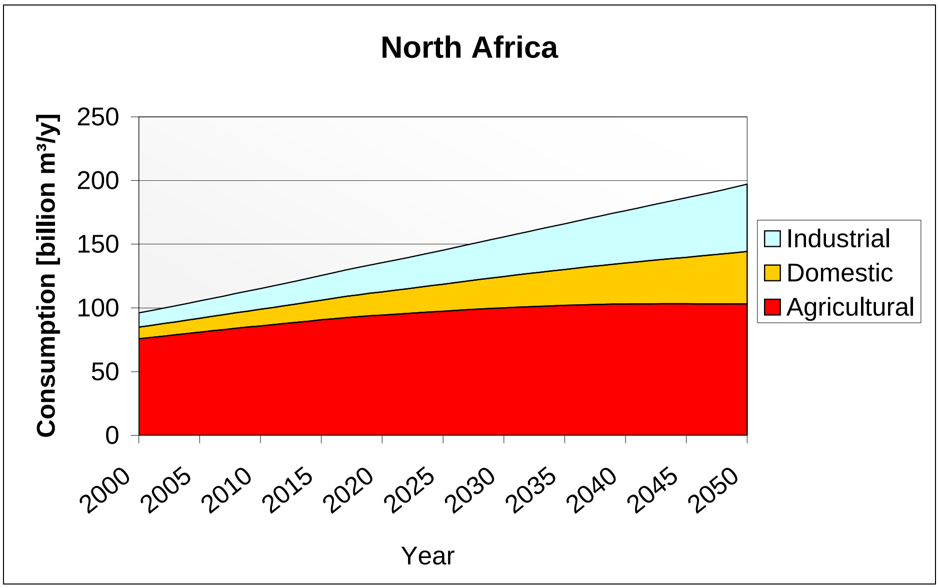


Figure 4-35: Water demand structure in North Africa and its evolution until 2050

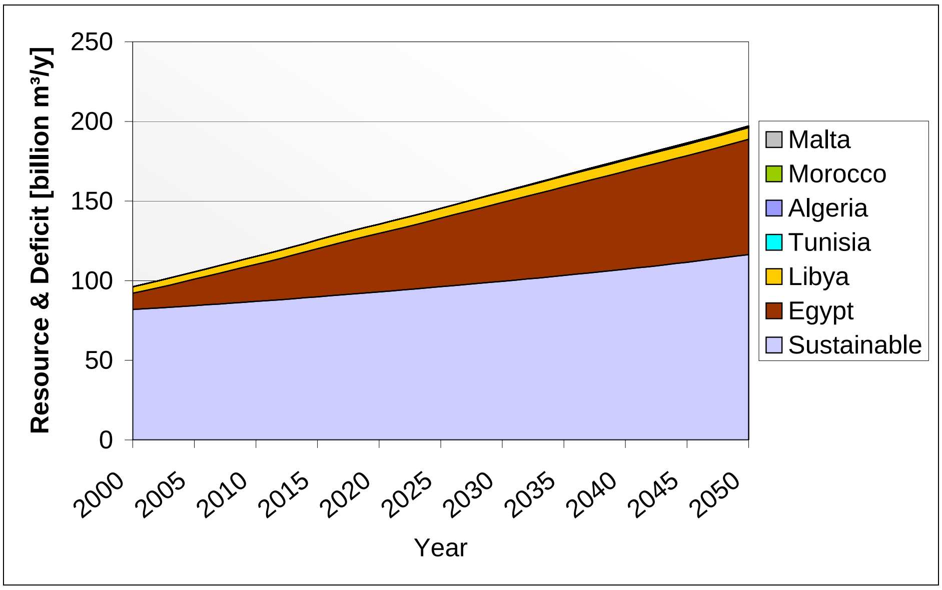


Figure 4-36: Regional sustainable water resource and national deficits in North Africa until 2050.

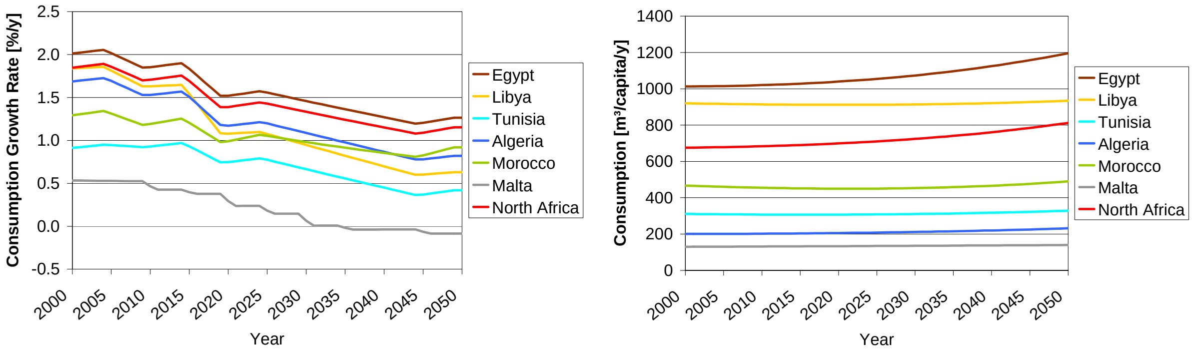


Figure 4-37: Water consumption growth rates and consumption per capita in North Africa until 2050.

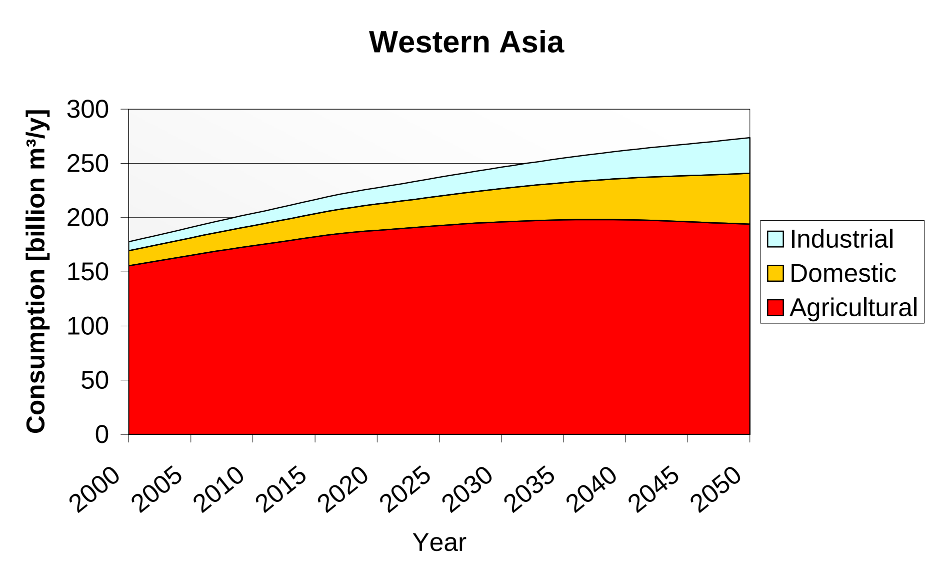


Figure 4-38: Water demand structure in Western Asia and its evolution until 2050

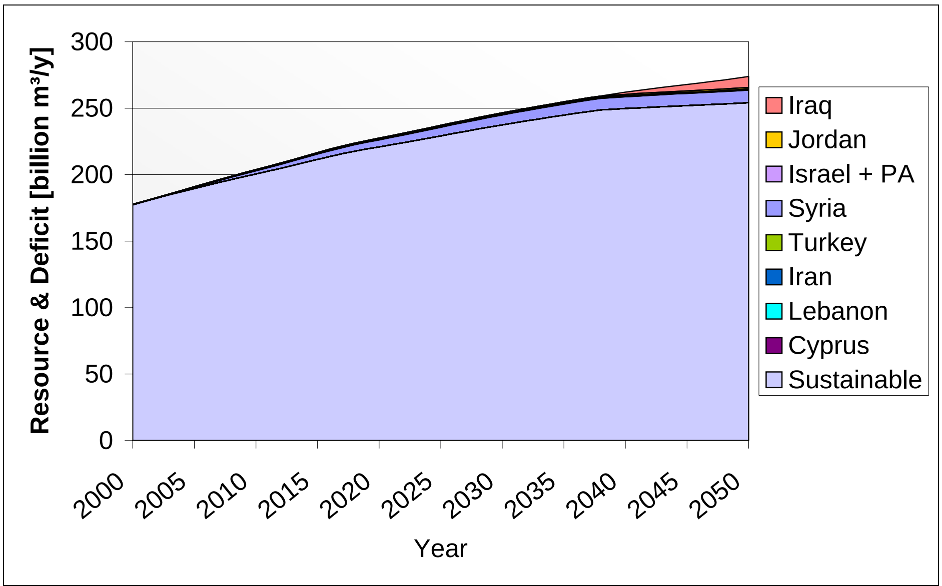


Figure 4-39: Regional sustainable water resource and national deficits in Western Asia until 2050.

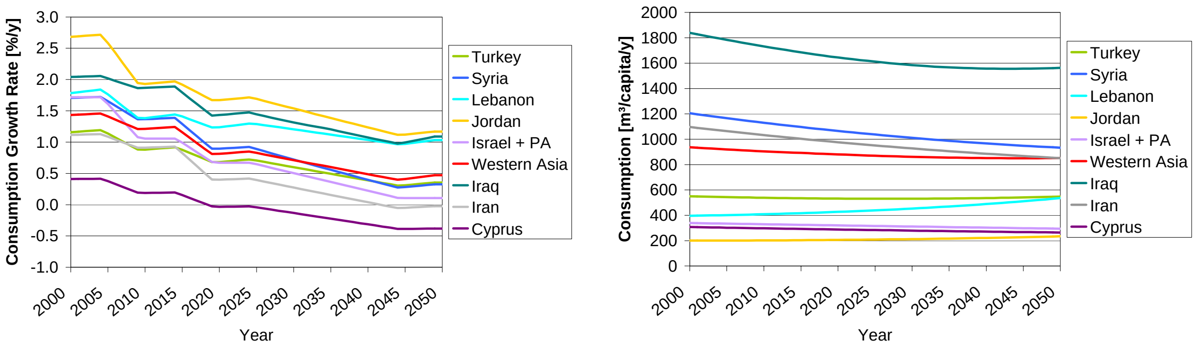


Figure 4-40: Water demand growth rates and demand per capita in Western Asia until 2050.

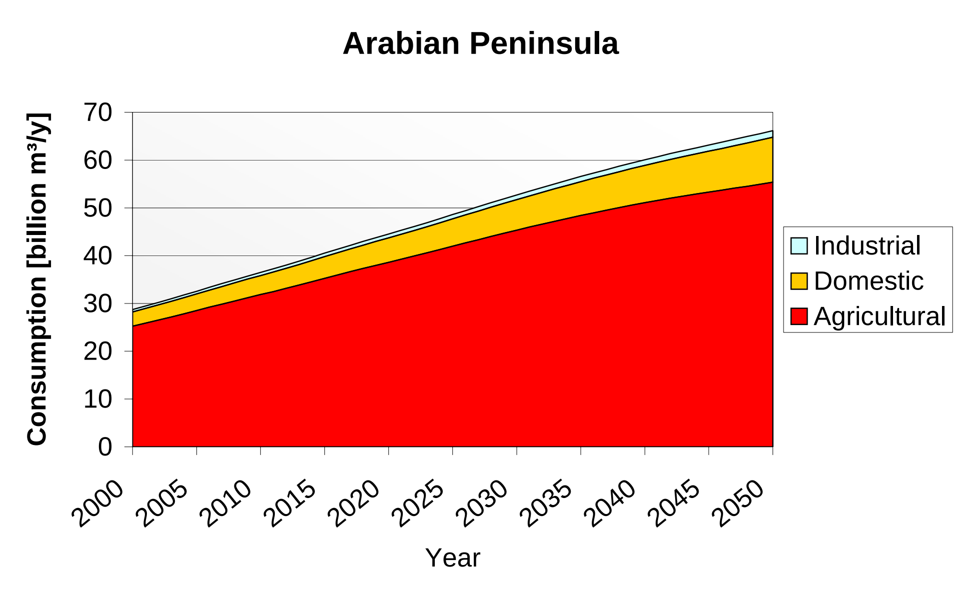


Figure 4-41: Water demand structure for Arabian Peninsula and its evolution until 2050

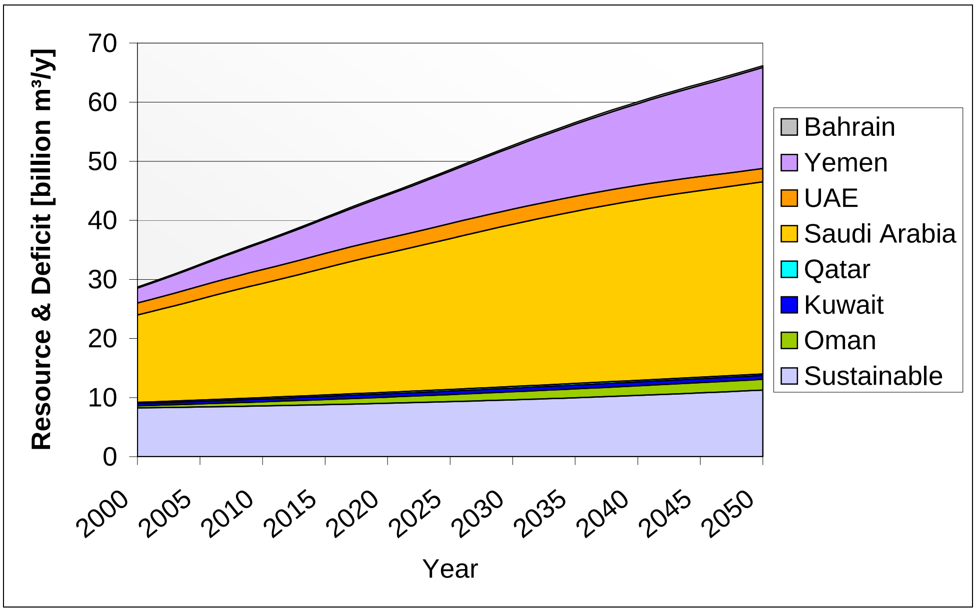


Figure 4-42: Regional sustainable water resource and national deficits for Arabian Peninsula until 2050.

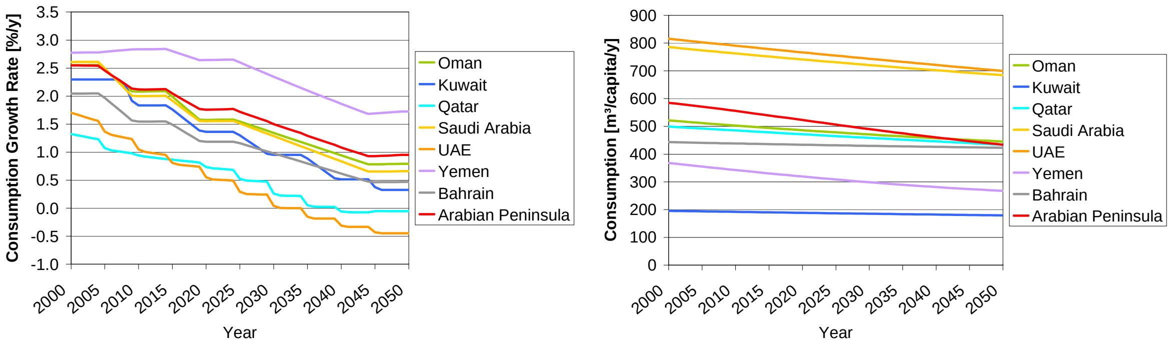


Figure 4-43: Water demand growth rates and demand per capita for the countries of the Arabian Peninsula until 2050.

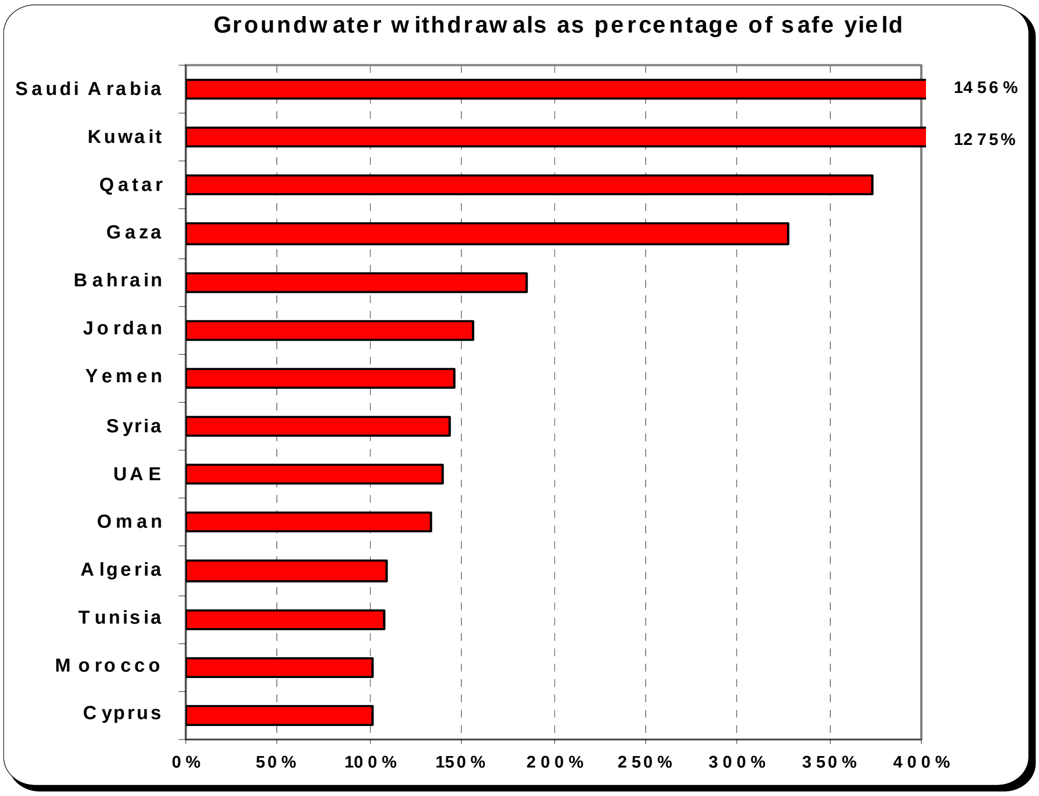


Figure 4-44: Groundwater withdrawels as percentage of save yield for selected countries /Saghir 2003/

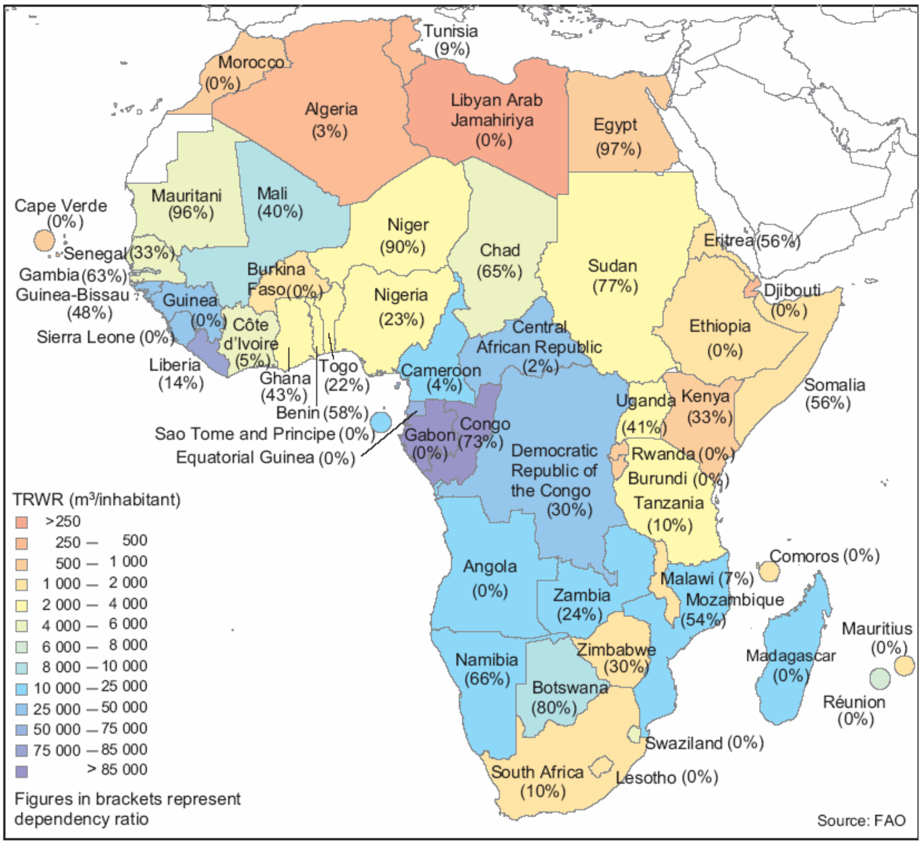


Figure 4-45: Water resources in the Africa region, total renewable water resources (TRWR) and dependency ratio /FAO 2003/

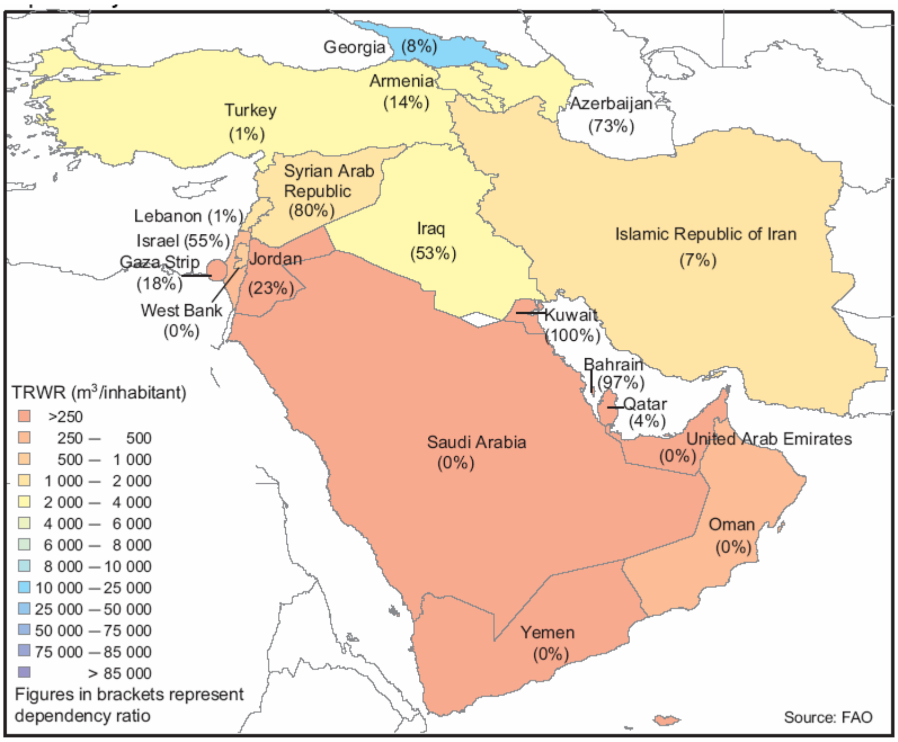


Figure 4-46: Water resources in the Near East region, total renewable water resources (TRWR) and dependency ratio /FAO 2003/

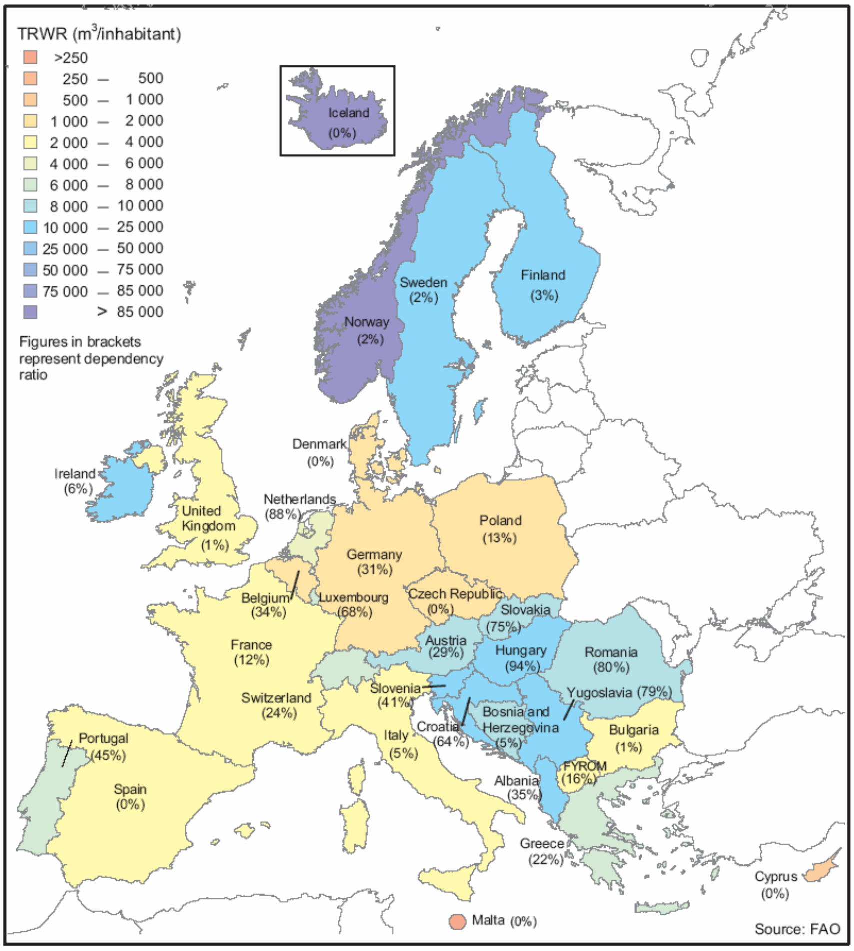


Figure 4-47: Water resources in the Western and Central Europe region, total renewable water resources (TRWR) and dependency ratio /FAO 2003/