MED-CSP

Concentrating Solar Power for the Mediterranean Region

Final Report

by

German Aerospace Center (DLR)
Institute of Technical Thermodynamics
Section Systems Analysis and Technology Assessment

Study commissioned by

Federal Ministry for the Environment,
Nature Conservation and Nuclear Safety
Germany

The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

DLR

The full **MED-CSP Study Report** can be found in the corresponding files with the individual reports of all work packages at the website: http://www.dlr.de/tt/med-csp

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Project Responsible:

Dr. Franz Trieb
Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR)
Institute of Technical Thermodynamics
Systems Analysis and Technology Assessment
Pfaffenwaldring 38-40
D-70569 Stuttgart
Germany
Tel.: ++49-711 / 6862-423
Fax: ++49-711 / 6862-783
Email: franz.trieb@dlr.de
http://www.dlr.de/tt/med-csp

Stuttgart, 16th of April 2005

MED-CSP Team

German Aerospace Center (DLR)
Dr. Franz Trieb, Dr. Christoph Schillings, Stefan Kronshage, Dr. Uwe Klann, Dr. Peter Viebahn, Nadine May, Regina Wilde, Christian Paul, Stuttgart, Germany

National Energy Research Center (NERC)
Eng. Malek Kabariti (Director), Amman, Jordan

Centre National pour la Recherche Scientifique et Technique (CNRST)
Prof. Dr. Abdelaziz Bennouna, Rabat, Morocco

Nokraschy Engineering GmbH (NE)
Dr. Ing. Hani El Nokraschy, Holm, Germany

New and Renewable Energy Authority (NREA)
Samir Hassan (Director), Laila Georgy Yussef, Cairo, Egypt

New Energy Algeria (NEAL)
Tewfik Hasni (Director), Alger, Algeria

Internationales Forschungszentrum für Erneuerbare Energien e.V. (IFEED)
Dr. Nasir El Bassam (Director), Braunschweig, Germany

Hamburg Institute of International Economics (HWWA)
Honorat Satoguina, Hamburg, Germany

Acknowledgements:

The MED-CSP team thanks the German Ministry for the Environment, Nature Conservation and Nuclear Safety for sponsoring this project, specially to Ralf Christmann from BMU and Ludger Lorych from VDI/VDE/IT for their efficient project management, Bernhard Lehner from WWF-US and Lukas Menzel from USF Kassel for the data for the hydropower resource maps based on the model WaterGap 2.1, to BESTEC GmbH for providing a geothermal resource map, Gregor Czisch from ISET for providing data for the wind and global radiation maps, Manfred Hafner from OME for providing information on the Mediterranean Ring, Mousa Abu-Arabi from MEDRC, Oman, for valuable contributions to the discussion on desalination, Waheeb Al-Naser from Bahrain for helping with the demand side analysis, the Trans-Mediterranean Renewable Energy Cooperation (TREC) and especially Gerhard Knies for providing a very useful discussion forum, our secretary Ursula Steffen for the organisation of the project meetings, our colleagues at DLR and especially Joachim Nitsch for help and guidance in the scenario building, to the administrative people who had to deal with the project budget, and to everybody else who helped in making this project a success.

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One must never stop to imagine the world
as it would be in the soundest way

Friedrich Dürrenmatt

Introduction

To keep global warming in a tolerable frame, the Scientific Council of the German Government for Global Environmental Change (WBGU) recommends in its latest study based on a scenario of the IPCC (Intergovernmental Panel for Climate Change) to reduce CO_2-emissions on a global level by 30 % until 2050. According to this, developing countries and countries in transition may increase their transmissions by about 30 % considering their still growing infrastructure, while industrial countries will have to reduce their emissions by 80 %. Because a fair access to energy for everybody is also a sustainability criteria, by 2050, global per capita emissions of 1-1.5 tons of CO_2 should be achieved. However, environmental sustainability must go hand in hand with economic wealth, business opportunities and development. A special interest lies on the electricity sector which is responsible for a considerable share of greenhouse gas emissions. A further field of interest is the increasing demand for technically desalted water, which will require increasing energy input to the water supply sector.

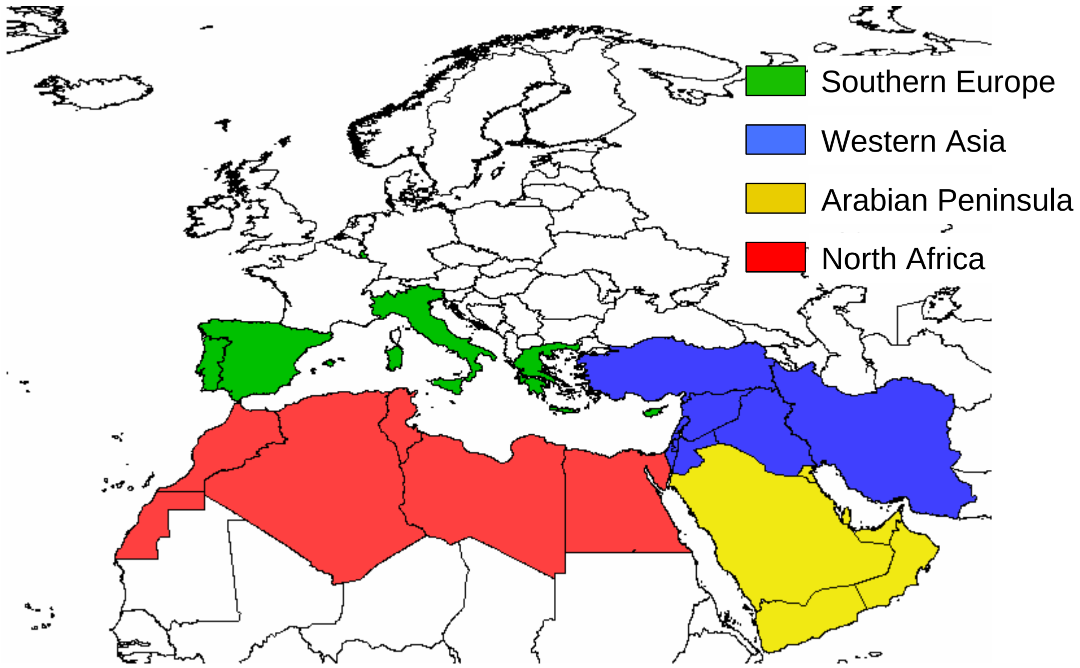


Figure 0-1: Countries of the EU-MENA region analysed within the MED-CSP Study

In front of this background, the WBGU recommends to establish model projects to introduce renewable energies on a large scale as a strategic lever for a global change in energy policies. A strategic partnership between the European Union (**EU**), the Middle East (**ME**) and North Africa (**NA**) is a key element of such a policy for the benefit of both sides: MENA has vast resources of solar energy for its economic growth and as a valuable export product, while the EU can provide technologies and finance to activate those potentials and to cope with its national and international responsibility for climate protection – as documented in the Johannesburg agreement to considerably increase the global renewable energy share as a priority goal.

International and national policies must establish appropriate frame conditions for the expansion of renewable energies. Only then industry and investors will support such projects and provide the necessary large investments, as demonstrated by the success of the German and Spanish renewable energy acts.

In order to establish appropriate instruments and strategies for the market introduction of renewables in the European and MENA countries, well founded information on demand and resources, technologies and applications is essential. It must further be investigated if the expansion of renewables energies would imply unbearable economic constraints on the national economies of the MENA region.

The present study provides such information as data basis for strategic development in the EU-MENA region in order to achieve sustainable long-term energy and water security.

Main Results of the MED-CSP Study

The MED-CSP study focuses on the electricity and water supply of the regions and countries illustrated in Figure 0-1 including Southern Europe (Portugal, Spain, Italy, Greece, Cyprus, Malta), North Africa (Morocco, Algeria, Tunisia, Libya, Egypt), Western Asia (Turkey, Iran, Iraq, Jordan, Israel, Lebanon, Syria) and the Arabian Peninsula (Saudi Arabia, Yemen, Oman, United Arab Emirates, Kuwait, Qatar, Bahrain).

The results of the MED-CSP study can be summarized in the following statements:

- Environmental, economic and social **sustainability in the energy sector can only be achieved with renewable energies**. Present measures are insufficient to achieve that goal.
- **A well balanced mix** of renewable energy technologies can displace conventional peak-, intermediate and base load electricity and thus **prolongs the global availability of fossil fuels for future generations** in an environmentally compatible way.
- Renewable energy **resources are plentiful** and can cope with the growing demand of the EU-MENA region. The available resources are so vast that an additional supply of renewable energy to Central and Northern Europe is feasible.
- **Renewable energies are the least cost option** for energy and water security in EU-MENA.
- Renewable energies are the **key for socio-economic development and for sustainable wealth** in MENA, as they address both environmental and economical needs in a compatible way.
- Renewable energies and energy efficiency are the main pillars of **environmental compatibility**. They need initial public start-up investments but no long-term subsidies like fossil or nuclear energies.
- An adequate set of **policy instruments must be established** immediately to accelerate renewable energy deployment in the EU and MENA.

Chapter 1 (Sustainability Goals) gives an overview of the present efforts and achievements in EU and MENA to reach sustainability in the energy sector. It shows that the measures taken up to now do not suffice to avoid increased climate gas emissions by the power sector (Figure 0-2).

Although climate change is a serious concern, sustainability must also be achieved in terms of economy, affordability, technology, health and social compatibility. A strategy for power and water security must match the time horizon of all sustainability considerations, which is at least 50 - 100 years and more. Strategies optimising a pathway within a smaller time horizon may lead to the wrong direction, because measures necessary to achieve the long-term goal may be ignored or delayed.

The sustainability goal proposed by WBGU of emitting not more than 1 ton of carbon dioxide per capita by 2050 to avoid drastic climate change is a challenge, because all EU countries are still far above this level today, and most MENA countries already show this level of emissions too, but their demand will still grow. Affordable access to energy and water for a growing population is as well a requisite for economic sustainability. The fair and affordable access to energy and water for a fast growing population is another important sustainability goal in MENA.

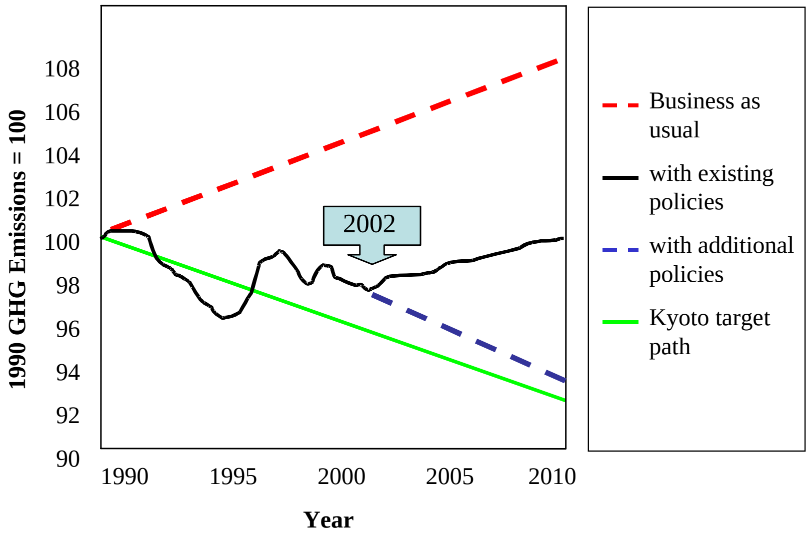


Figure 0-2: UE-15 greenhouse gas emissions until 2002 and projections until 2010 /Lefevere 2004/

The instruments for the market expansion of renewable energies applied today – mainly in the EU – range from the Kyoto instruments to quota models and feed-in tariffs like those applied in Germany and Spain. At the same time, there is a general trend for the liberalisation of the electricity market. In spite of the global leading role of the EU in terms of climate protection, those measures do not yet suffice to achieve the long-term goals (Figure 0-2).

Climate protection has only an ancillary role in the MENA region, and only a few countries have ratified the Kyoto protocol. In this region, economic and social development is the first priority. At a first glance, the higher initial cost of renewable energies suggests that there is a contradiction between environmental and economic sustainability goals. However, renewable energies can cope with both challenges, if adequate policy instruments are implemented to immediately initiate their broad application.

Intensive international collaboration is a main requisite for success. The global tasks usually overstrain the capabilities of national governments, although they are the one who must initiate international collaboration without delay.

Chapter 2 (Renewable Energy Technologies) provides an overview on the renewable energy technology portfolio and presents renewable energy applications in the electricity sector including co-generation and sea water desalination.

Although the focus of the study is on concentrating solar thermal power, other renewable energies like wind energy, hydropower, biomass, wave and tidal power, photovoltaic and geothermal energy are also represented, which in principal are also concentrated solar energy, with the exception of geothermal energy, of which 50 % stems from nuclear decomposition in the interior of our planet. Biomass can be obtained from municipal and agricultural waste and from solid biomass, mainly wood. Due to the competition of energy crops with food and water for the region, this option has been neglected. Renewable energy technologies can only be seen in the context of all other technology options. Even fossil fuels are solar energy concentrated over millions of years in an ideal, storable form. A main task of the study was to find a well balanced mix of technologies that leads to a sustainable and secure supply.

Electricity must be delivered on demand. Fluctuations of wind and photovoltaic electricity must be compensated by sources that can deliver power on demand, like biomass, hydropower, geothermal power and solar thermal power plants that can operate on base-, intermediate- and peak load demand. Each technology is characterised by a specific capacity credit that is their contribution to secured power capacity (Table 0-1). By 2050, fossil fired plants will only be used for what they are best suited for: peaking demand. Because of this reduction to their key function, their use will become environmentally compatible, and their availability will be prolonged for centuries. The expensive and energy consuming sequestration of carbon dioxide from flue gases becomes obsolete.

The core base and intermediate load electricity will come from renewables, which altogether can provide this function without constraints, sometimes even showing a better adaptation to the time pattern of the load than conventional base load plants with their typical flat capacity curve. Solar thermal power plants with their capability of thermal energy storage and of solar/fossil hybrid operation can provide firm capacity and thus are a key element for grid stabilisation and power security in such a well balanced electricity mix (Figure 0-5 to Figure 0-8).

Large nuclear plants cannot be easily applied to peak load due to their economical and technical constraints and will not have a considerable role in such an energy supply system.

Chapter 3 (Renewable Energy Resources) analyses the renewable energy potentials available in the EU-MENA region for each technology and for each country (Figure 0-3 and Figure 0-4). The results are a detailed mapping of resources and a quantification of the technical and economic potentials by country in terms of renewable electricity. The quality of the different resources of each country is represented by special performance indicators.

The renewable energy sources in the countries analysed in the MED-CSP study can cope with the growing demand of the developing economies. Wind, geothermal power from hot dry rocks, hydropower and biomass power potentials are each in the order of about 400 TWh/y. Those resources are more or less locally concentrated and not available everywhere, but can be distributed through the electricity grid. The by far biggest resource in MENA is solar irradiance, with a potential that is by several orders of magnitude larger than the total world electricity demand.

This resource can be used both in distributed photovoltaic systems and in large central solar thermal power stations. Thus, both distributed rural and centralised urban demand can be covered by renewable energy technologies.

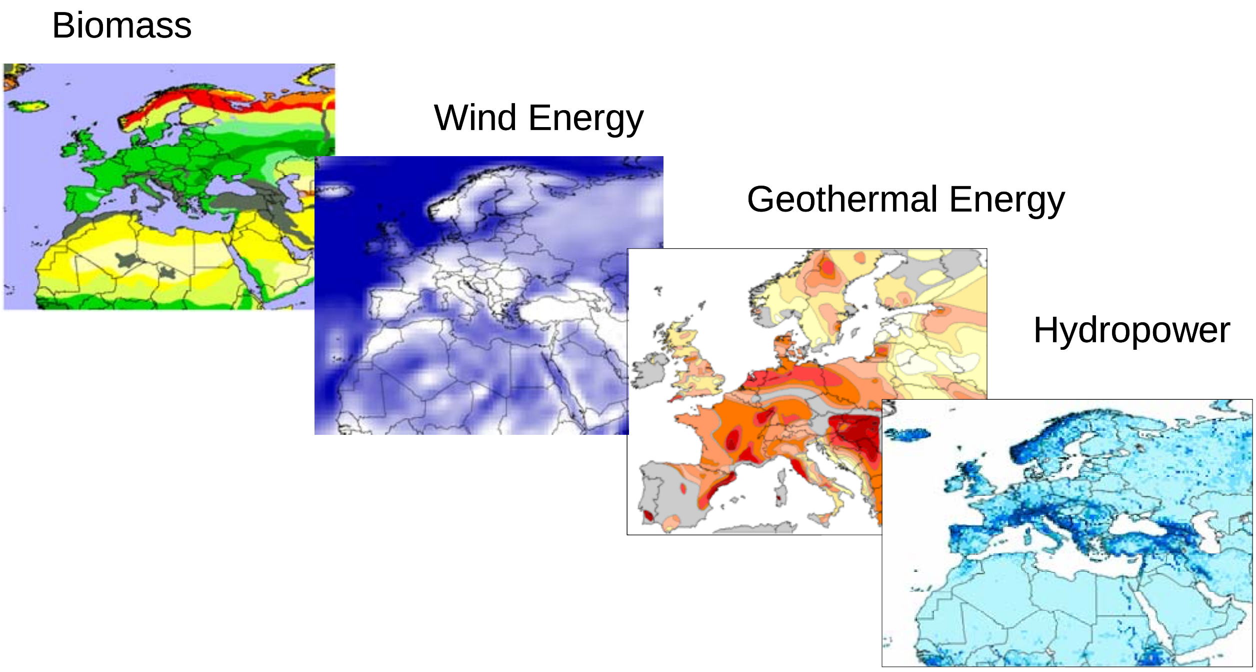


Figure 0-3: Maps of the renewable energy yield of the different resources in EU-MENA (darker colours indicate higher potentials per unit area, the colour code is described in the main report).

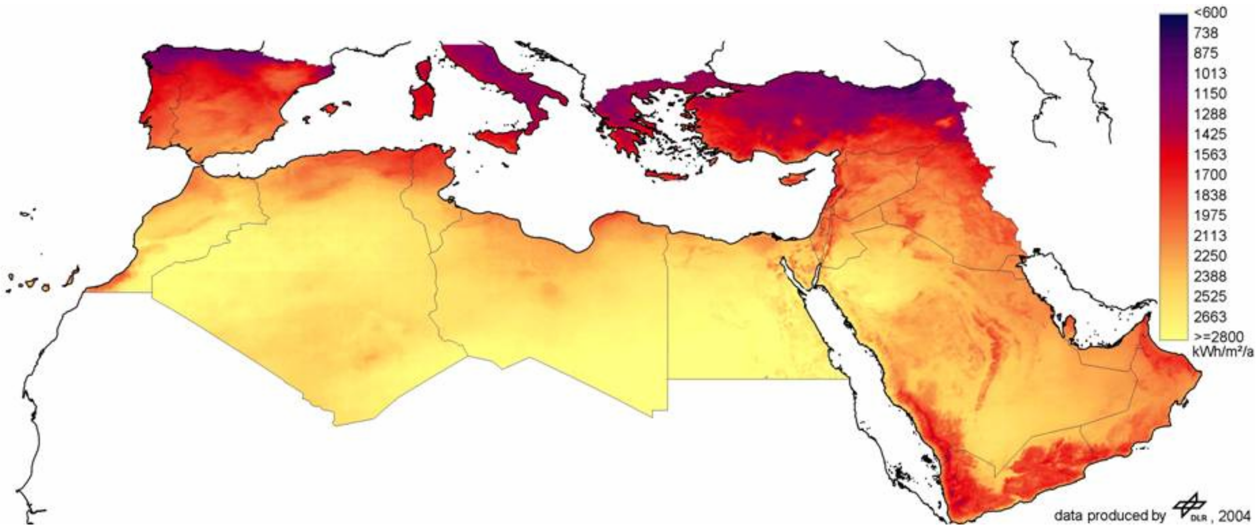


Figure 0-4: Annual Direct Solar Irradiance in the southern EU-MENA Region. The primary energy received by each square meter of land equals 1 – 2 barrels of oil per year.

	Unit Capacity	Capacity Credit	Capacity Factor	Resource	Applications	Comment
Wind Power	1 kW – 5 MW	0 – 30 %	15 – 50 %	kinetic energy of the wind	electricity	fluctuating, supply defined by resource
Photovoltaic	1 W – 5 MW	0 %	15 – 25 %	direct and diffuse irradiance on a fixed surface tilted with latitude angle	electricity	fluctuating, supply defined by resource
Biomass	1 kW – 25 MW	50 - 90 %	40 – 60 %	biogas from the decomposition of organic residues, solid residues and wood	electricity and heat	seasonal fluctuations but good storability, power on demand
Geothermal (Hot Dry Rock)	25 – 50 MW	90 %	40 – 90 %	heat of hot dry rocks in several 1000 meters depth	electricity and heat	no fluctuations, power on demand
Hydropower	1 kW – 1000 MW	50 - 90 %	10 – 90 %	kinetic energy and pressure of water streams	electricity	seasonal fluctuation, good storability in dams, used also as pump storage for other sources
Solar Chimney	100 – 200 MW	10 to 70 % depending on storage	20 to 70 %	Direct and diffuse irradiance on a horizontal plane	electricity	seasonal fluctuations, good storability, base load power
Concentrating Solar Thermal Power	10 kW – 200 MW	0 to 90 % depending on storage and hybridisation	20 to 90 %	Direct irradiance on a surface tracking the sun	electricity and heat	fluctuations are compensated by thermal storage and fuel, power on demand
Gas Turbine	0.5 – 100 MW	90 %	10 – 90 %	natural gas, fuel oil	electricity and heat	power on demand
Steam Cycle	5 – 500 MW	90 %	40 – 90 %	coal, lignite, fuel oil, natural gas	electricity and heat	power on demand
Nuclear	1000 MW	90 %	90 %	uranium	electricity and heat	base load power

Table 0-1: Some characteristics of contemporary power technologies

Chapter 4 (Demand Side Analysis) quantifies the demand side potential for electricity and water for each country of the region. The growth of population and economy will lead to a considerable growth of energy demand in the MENA countries. By 2050, the MENA countries will achieve an electricity demand in the same order of magnitude as Europe (3500 TWh/y). Although our scenario considers efficiency gains and moderate population growth or even retrogressive population figures in some of the analysed countries, electricity demand will almost triple from shortly 1500 TWh/y today to 4100 TWh/y in 2050 (Figure 0-5). This is moderate considering that electricity demand has also tripled in the past 20 years.

The water demand of the MENA countries will increase from today 300 billion cubic meters per year to over 500 billion m³/y in 2050. Most countries show stagnating or even retrogressive figures in the agricultural sector and strong growth in the domestic and industrial sector. In many MENA countries and also in some Southern European regions, natural water resources are already now exploited beyond their sustainable yield.

The excessive use of freshwater resources is only possible for a transient time. In spite of a growing demand for water, overexploitation must be reduced in the mid term future and avoided afterwards. This will require efficient and environmentally compatible desalination technologies and a plentiful, sustainable and affordable energy source.

Fossil or nuclear fuels cannot cope with any of these criteria. On the contrary, already today they are subsidised due to their high cost, they are causing serious national and international conflicts and climate change, and oil, gas and uranium are expected to become increasingly scarce and expensive within the next 50 years. Even in the oil exporting countries there is an increasing conflict between oil exports and internal consumption. A strategy for energy and water security can therefore not be built on fossil fuel resources, but they can be a component of a strategy for sustainability.

Chapter 5 (Scenario for Energy & Water Security) quantifies the possible step-by-step expansion of renewable energies in the Mediterranean region until 2050 (Figure 0-5). Each country shows a different balanced mix of renewable and fossil energies to obtain a sustainable supply system (Figure 0-8). Every country in EU-MENA has its own specific natural sources of energy and water and very different patterns of demand. The MED-CSP scenario shows a way to match resources and demand in the frame of the technical, economic, ecologic and social constraints of each country in a sustainable way. The following potential barriers and frame conditions have been taken into account to narrow down the course of market development of renewable energies in the MED-CSP scenario (**scenario guard rails**):

- renewable energy resource potentials
- maximum growth rates of renewable energy technology production capacities
- annual electricity demand and water demand based on the growth of population and economy
- peaking power demand and firm capacity requirements
- replacement of old plant capacities (investment cycles)
- cost of electricity in comparison to competing technologies
- opportunities of finance

- policies and energy economic frame conditions
- existing grid infrastructure and cost of interconnection

All those parameters were not treated as static constants, but were analysed in their dynamic transition towards a sustainable energy scheme. Renewable energies will initially need public support but will steadily grow within niche markets and become cheaper due to learning and economies of scale. After 2025, electricity from most renewable energies will be cheaper than electricity from fossil fuels (Figure 0-9), even not accounting for the societal external costs of fossil fuel consumption. Renewable energies are the only way to stabilise energy costs in the long term on a low price level.

Most MENA countries show a strong economic growth that will lead to an approximation to the European economies by the middle of the century. However, business-as-usual strategies for energy and water would lead to a depletion of fossil fuel and natural water resources within a few years, to unaffordable costs of energy and water and to social conflicts. Economic development would be increasingly burdened by subsidisation and conflicts. To this add possible impacts from climate change like desertification, losses of arable land and floods. Due to the increasing lack of water, food imports would increase, but it is unclear how this should be financed.

Only a change to renewable energies can lead to affordable and secure energy and water. This will not require long term subsidies like in the case of fossil or nuclear power, but only an initial investment in the frame of a concerted action of all EU-MENA countries to put the new renewable energy technologies in place. Comparing Figure 0-7 and Figure 0-8 it becomes obvious that the satisfaction of the growing electricity demand in MENA can only be satisfied in a sustainable way by renewable energies. In the year 2050, the electricity consumption of many MENA countries like Egypt and Turkey will by far exceed the consumption of present EU countries like e.g. Italy. Also many oil exporting countries like Iran, Iraq and Saudi Arabia will follow that trend, with an increasing conflict between internal consumption and export of that precious commodity.

In a later stage of the MED-CSP scenario, a considerable reduction of fuel consumption for electricity takes place in the European countries. However, in most MENA countries, the consumption of fuels will grow or at best stagnate, in spite of an intensive use of renewable energies. In Europe biomass, hydropower, wind energy and to a lesser extent other renewables will become the most important suppliers of power. The by far biggest energy resource in MENA is solar power from concentrating solar thermal power plants, which in most countries will provide the core of electricity. This is due to the fact that they will be able to provide not only the required large amounts of electricity, but also firm power capacity on demand.

In addition to that wind energy is a major resource in Morocco, Egypt and Oman, while geothermal power is available in Turkey, Iran, Saudi Arabia and Yemen. Major hydropower and biomass resources are limited to Egypt, Iran, Iraq and Turkey. Initially, photovoltaic electricity will be mainly used in decentralised, remote applications. Further cost reductions will lead to increasing shares of PV in the electricity grid. In a later stage, also very large PV systems in desert regions will become feasible. However, their contribution to firm capacity is very limited, while concentrating solar power plants can deliver firm capacity on demand.

Comparing Figure 0-5 (Electricity Generation) with Figure 0-6 (Installed Capacity) reveals that the installed concentrating solar power capacity by 2050 is as large as that of wind, PV,

biomass and geothermal plants together, but due to their built-in solar thermal storage capability, CSP plants deliver twice as much electricity per year as those resources.

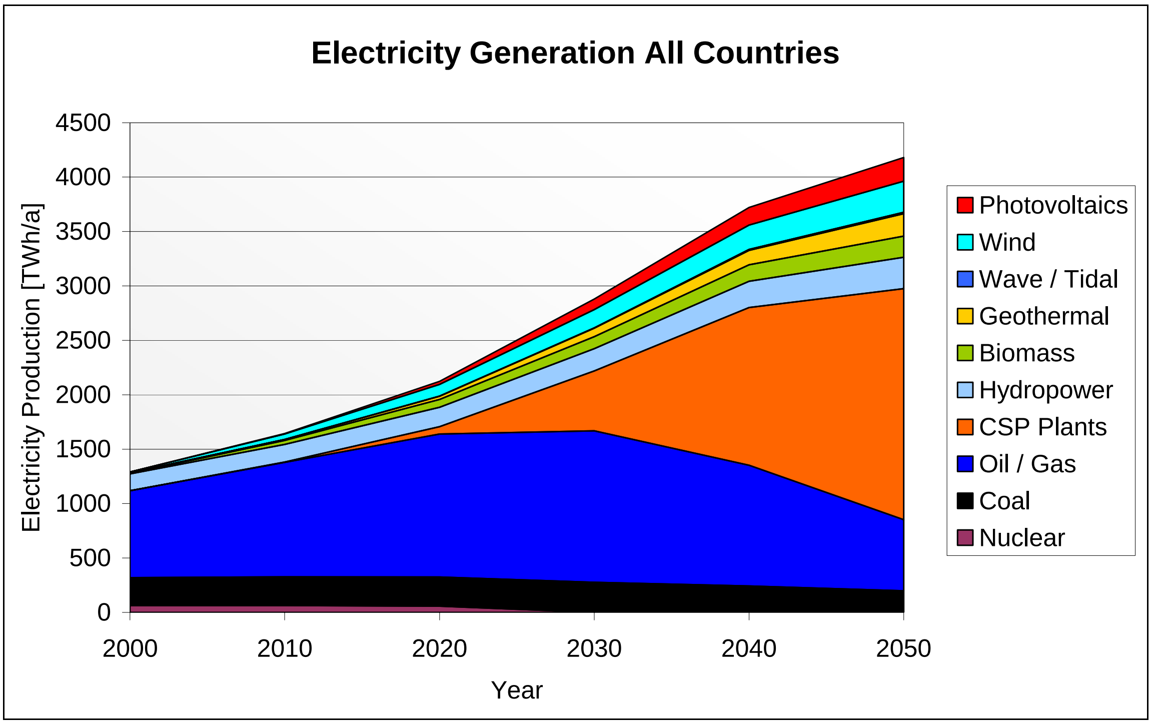


Figure 0-5: Annual electricity demand and generation within the countries in the MED-CSP scenario

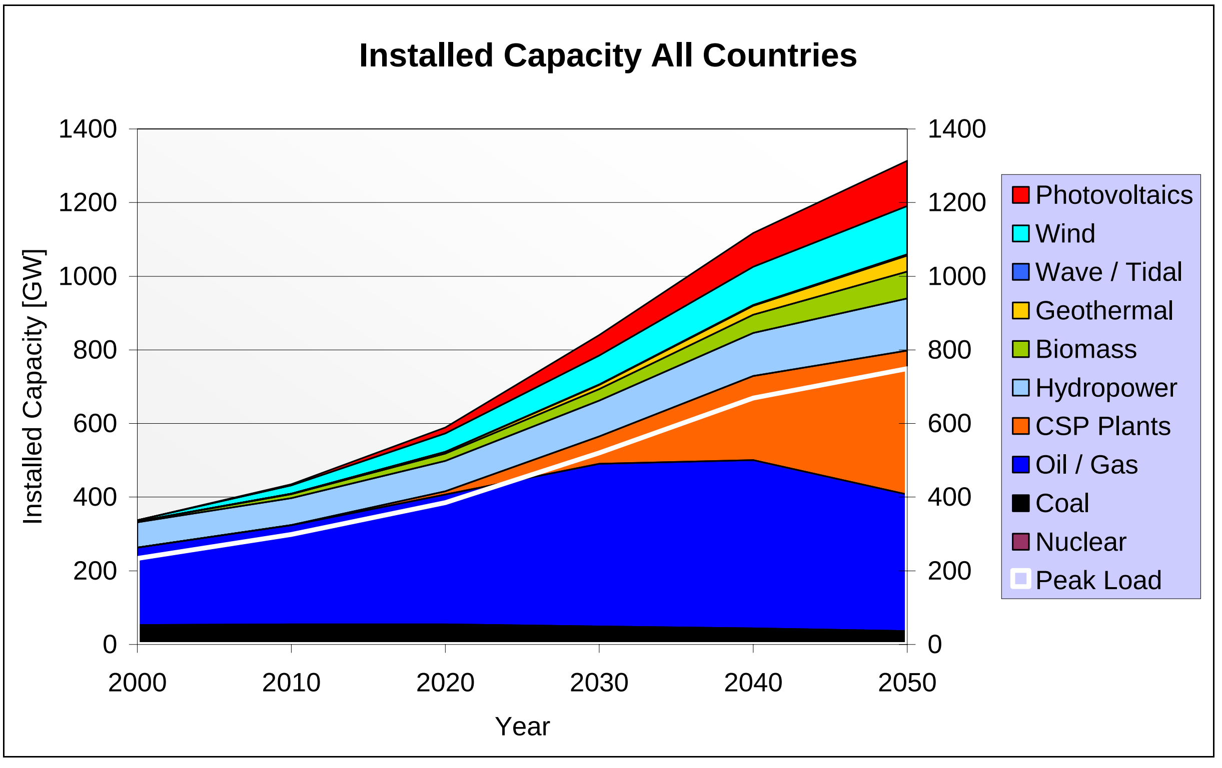


Figure 0-6: Installed power capacity and peak load within the analysed countries in the scenario CG/HE

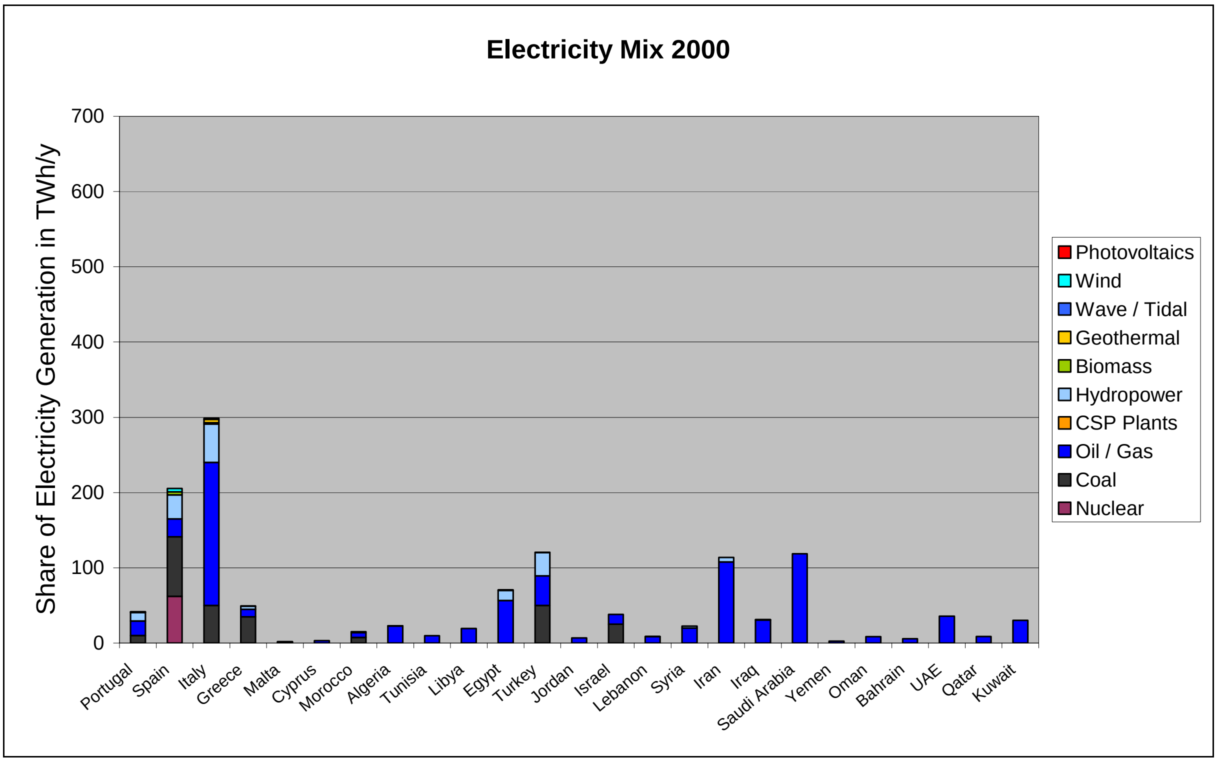


Figure 0-7: Share of different technologies for electricity generation in the year 2000.

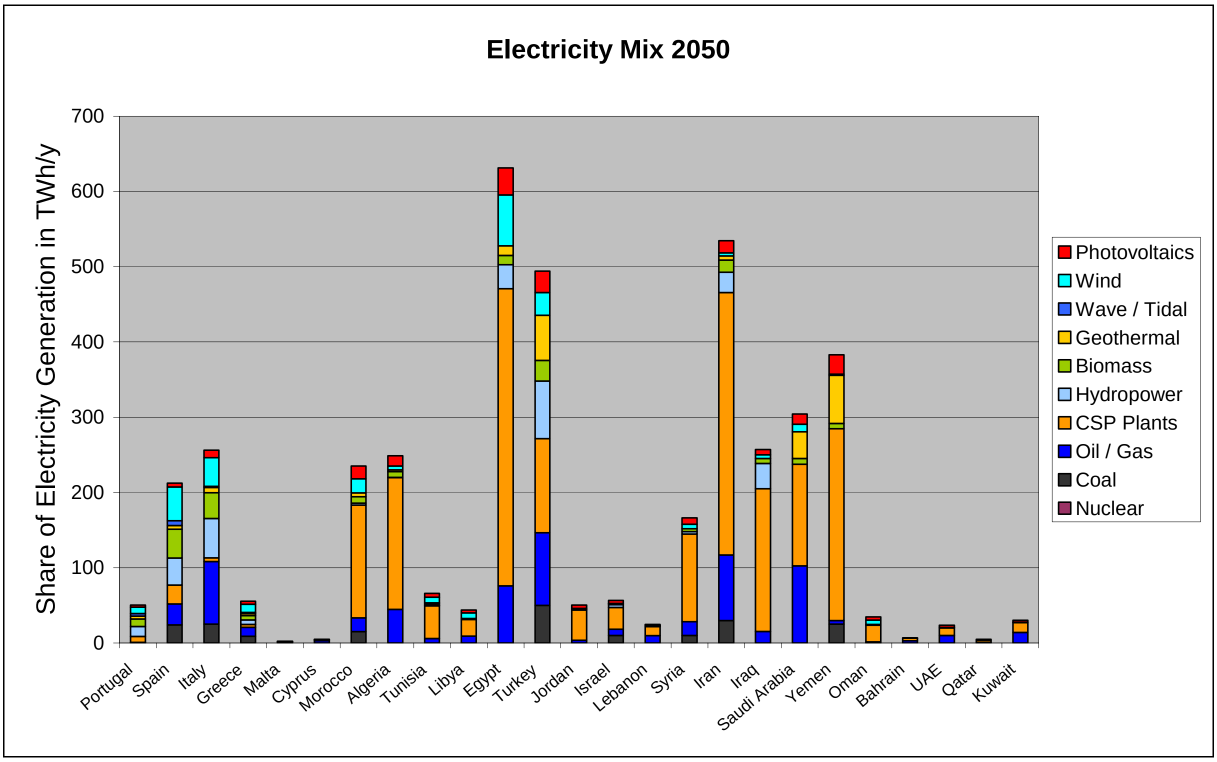


Figure 0-8: Total electricity consumption and share of different technologies for electricity generation in the analysed countries in the year 2050 according to the MED-CSP scenario.

Chapter 6 (Socio-Economic Impacts) describes the socio-economic impacts of the scenario developed in the study. The most important benefit is a stabilisation of electricity costs at a low price level and the reduction of subsidy requirements in the energy sector. In most countries, the dependency on energy imports is reduced, opening new business opportunities for industrial development. In the total EU-MENA region there may be 2 million direct and indirect jobs in the renewable energy sector by the year 2050.

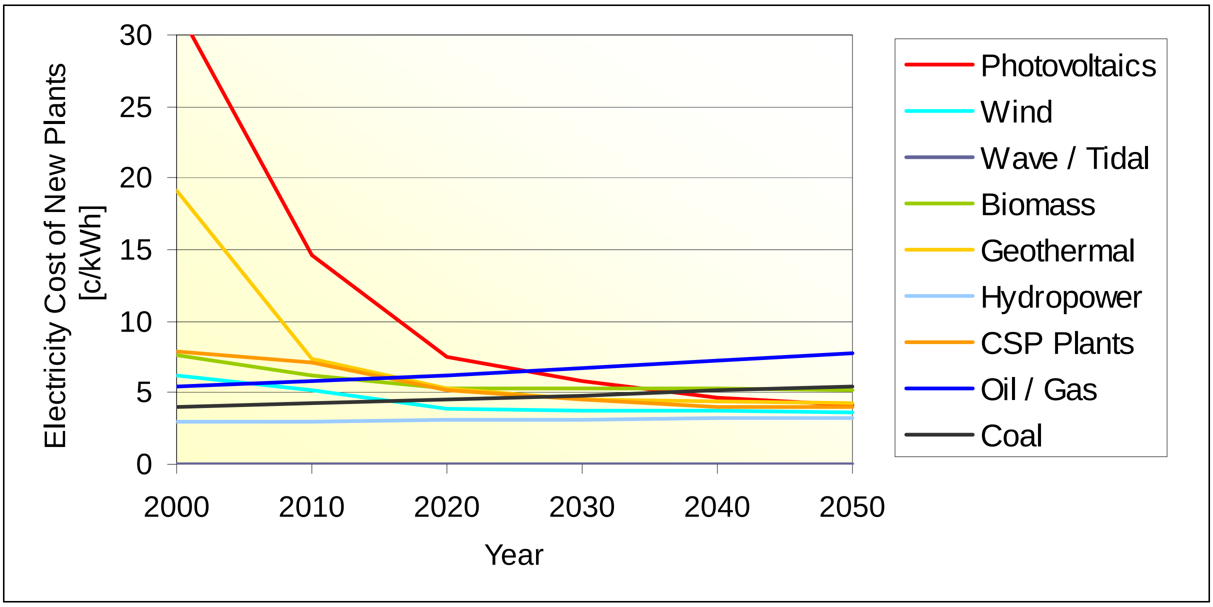


Figure 0-9: Example of electricity costs and learning in the MED-CSP scenario

There is often an insinuation of a conflict between economy and the environment, assuming that renewable energies will require large amounts of public subsidies. This is true for measures like CO_2-sequestration, which add a certain cost to power generation. However, this is not the case for renewables. Renewable energies will only require a transient initial support in order to be established in the power market, but in short term will become the less expensive option for electricity generation (Figure 0-9 and Figure 0-10), even not accounting for the external costs of fossil fuels, which were accepted by the European Commission to be in the order of 5 cent/kWh. The transient support for renewables must be considered as a public investment into a better – and cheaper – supply system, in contrast to the long-term, steadily increasing subsidies actually required by and readily applied to fossil and nuclear power in the present.

The calculation of the cumulated initial cost leads to a total amount of 75 billion $ needed to bring the renewable energy mix to cost break-even with fossil fuels before the year 2020 (Figure 0-10). From that point until 2050, the analysed region will save 250 billion $ with respect to a business as usual policy scenario. It must be noted that the reference case of a fossil fuel based policy scenario departs from the assumption that fuel prices start at 25 $/bbl for oil and 49 $/ton for coal and escalate by only 1 %/y, which from today's point of view seems to be rather conservative (present fuel prices are at a level of 55 $/bbl and 65 $/ton, respectively, and escalation rates amounted to 40 %/y since 2003).

In a business as usual scenario, the growth of economy and the resulting electricity demand in MENA would lead to greenhouse gas emissions equivalent to those of Europe, causing significant external costs to the national economies. Rising fuel prices and additional costs for CO_2-sequestration would seriously burden economic development. In contrary to fossil fuels, all renewable energy technologies show degressive costs (Figure 0-9) that only depend on the actual state of the art and knowledge, but not on scarce resources. High economic growth will lead in this case to a better applicability of efficiency measures and to a faster reduction of energy demand and energy costs than a stagnating economy. Renewable energies will thus foster economic growth instead of burdening it.

MENA countries will benefit from renewable energies by reducing their energy subsidies, especially those who have to buy fuels on the world market, like Jordan and Morocco. They will be able to foster their national economies through low cost, secure energy supply. Oil and gas exporting countries will be relieved from burning their export product number one, and in the long term may additionally come to export solar electricity. A strong renewable energy industry in MENA will lead to highly qualified labour options and alleviate MENA from the brain drain occurring today.

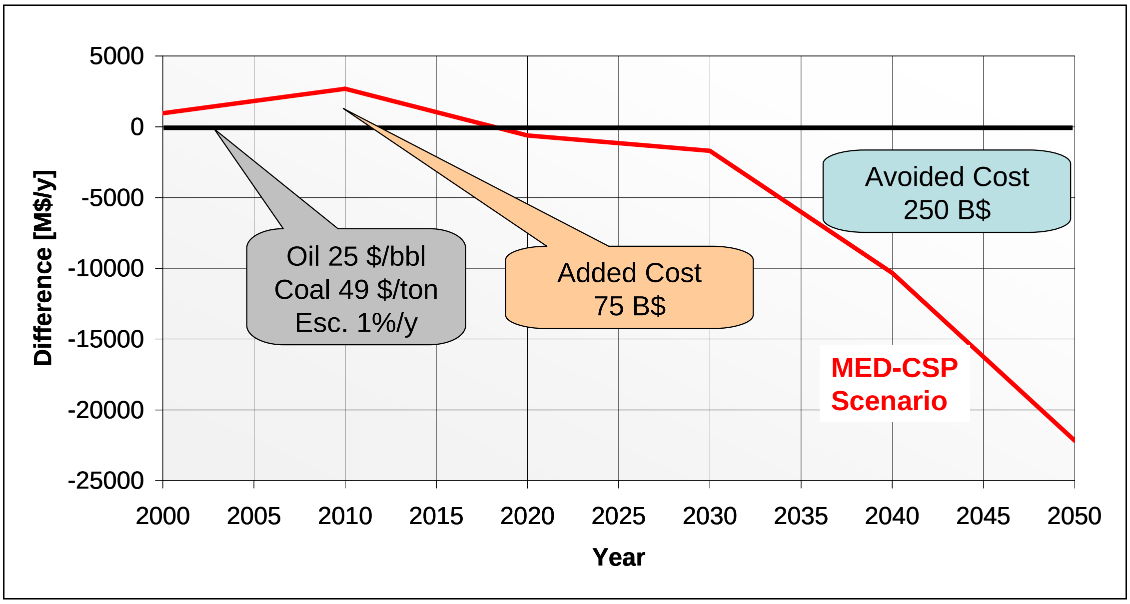


Figure 0-10: Total annual difference of electricity expenses between the MED-CSP scenario and a business as usual policy scenario based primarily on fossil fuels, summarised for all countries analysed in the study. Positive values = initial additional cost, negative values = avoided cost with respect to a business as usual policy. The cumulated initial cost amounts to 75 billion $, while 250 billion $ are avoided until 2050. The added and avoided costs vary with different assumptions made for fuel prices, escalation rates, CO_2-policy, etc. which are described in the main report. However, the break-even of renewable energies and fuels is achieved sooner or later under all variants.

The water supply situation in MENA is very critical. At some places the groundwater level falls 6 meters per year. Large cities like the capital of Yemen Sana'a may come to a point where their water supply runs dry and their groundwater resources may be exhausted within a 10 years period. A solution can only be seen in using large amounts of energy for seawater desalination. However, a strategy based on fossil or nuclear energy would not lead to an affordable and secure water supply system. Again, renewables and in a first place solar thermal power are the key to reduce the conflict potential of energy and water scarcity in MENA.

Chapter 7 (Environmental Impacts) highlights the main environmental impacts of the scenario. Carbon emissions from electricity generation are reduced by about 40 % in spite of the growing demand (Figure 0-11). It is a common misbelieve that renewable energies require large land resources. Among all electricity generating technologies including all nuclear and fossil systems, solar power technologies are those with the smallest land requirements. This is due to the fact that nuclear and fossil power plants not only require the land where they are placed, but additional infrastructure for mining, transport and disposal, which must be considered in an overall lifecycle balance, and which is much smaller for solar systems.

Moreover, wind parks can still be used for other purposes like agriculture and pasture, photovoltaic systems are often integrated to roofs and facades, and concentrating solar collector fields - acting similar to a blind - offer a partially shaded space below, that might be used for agriculture, as chicken farm, as greenhouse or for other purposes. Instead of consuming land, such plants would gain additional useful land from the desert.

Most renewable energy technologies have no emissions during operation. On a life cycle basis, emissions occur only during the production of the plants. However, if renewable shares increase in the power sector, also the emissions during construction will be subsequently reduced, as they origin from fossil energy consumption.

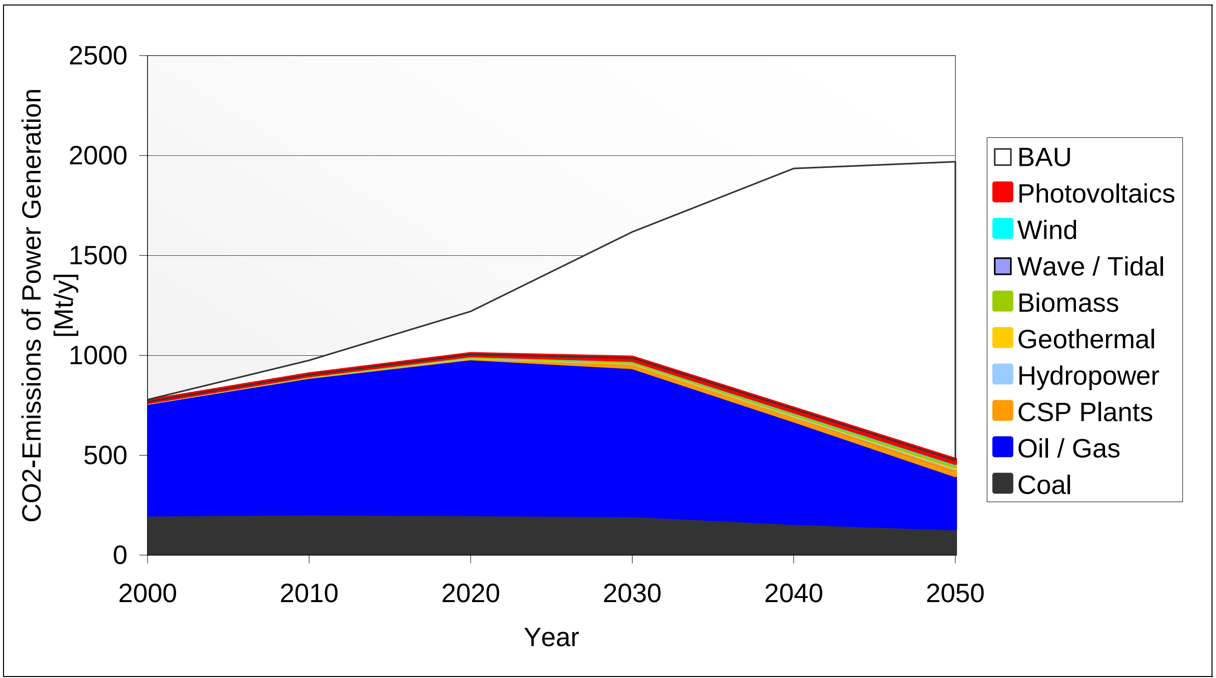


Figure 0-11: CO_2-emissions of electricity generation in million tons per year for all countries for the MED-CSP scenario and emissions that would occur in a business as usual case (BAU)

Fossil power systems show emissions that are one or two orders of magnitude higher than those of renewables. CO_2 sequestration will require extra energy and thus will lead to higher emissions, which must additionally be disposed off, entering a kind of vicious circle. However, it can be a component of a strategy for sustainability.

In a business-as-usual scenario, the growth of population and economy would lead to an increase of carbon dioxide emissions in the analysed countries from 770 million ton per year

today to 2000 million tons per year in 2050, with devastating effects on the global and regional climate. The strategy outlined by our study leads to emissions of only 475 million tons per year in 2050 in line with the goal established by WBGU (Figure 0-11), achieving per capita emissions of 0.58 tons/cap/y in the power sector. Thus, 28 billion tons of carbon dioxide are avoided until 2050, which is equal to the present total annual emissions world wide.

Chapter 8 (Policy Instruments) describes policy instruments and possibilities of finance from Kyoto-instruments to tax reductions, feed-in-laws and international grants. In the MENA region a RES deployment strategy is mandatory. It should be based on an international agreement which offers the single countries incentives to act and reduces the perceived risk of investors with respect to fundamental policy changes. Due to the different regulations of the electricity sector it is appropriate to use different instruments adapted to the different countries. The instruments used within a country should be specifically related to technologies or technology-bundles. A concerted grid expansion and a fair grid access are mandatory. Support by financial institutions shall be complementary to other instruments and shall be project-dependent. As an international agreement is required to introduce RES-technologies there seems to be a case to found a special financial institution or to change the duty of an existing financial institution to handle financial flows between states or to offer special credits.

In project planning true opportunity costs for fossil fuels – typically derived from world market prices – have to be used, also in countries where fossil fuels are subsidized.

It is a legitimate question to ask who should afford the initial investments of 75 billon $ required to bring renewables into the market within the 15 years time span needed to reach cost break-even with fuels. In principle, the electricity consumers are those who benefit directly from this strategy. If the initial investment would be equally distributed among all electricity consumers in the region, each of them would have to afford additionally 10 $/y for electricity payments for a period of 15 years in order to finance the total market introduction of renewables. After those 15 years, all consumers will benefit from stable and low electricity costs, avoiding to be exposed to volatile and rather high electricity costs in the case of a business as usual policy.

The required amount of 75 billion $ is comparable to the amount of investments needed (and actually spent) from now on to develop and build the first commercial nuclear fusion reactor expected for the year 2050. If a first commercial fusion plant is realised by 2050, it will not have avoided any CO_2 by that time, while the renewable energy mix will have avoided 28 billion tons of CO_2 and in addition to that, will have relieved the EU-MENA economies by expenses of about 250 billion $ otherwise required for fossil energies (without accounting for external costs). According to the developers of fusion, the electricity cost of a first commercial reactor would be in the range of 10-12 cent/kWh. This will probably be competitive with fossil fuel plants by 2050, but it is about twice as much as required for the average cost of the renewable energy mix by that time (Figure 0-9). Therefore, a wise and responsible energy policy must support renewable energies as well.

It is the responsibility of national governments and international policy to organise a fair financing scheme for renewable energies in the EU-MENA region in order to avoid the obvious risks of present energy policies and change to a sustainable path for wealth, development, and energy and water security.

1 Sustainability Goals in Europe and MENA

The Brundtland Commission defined sustainable development as – “development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs” /Brundtland 1987/. This definition is the starting point of almost all sustainability definition attempt in the different sectors of the economy. Nowadays countries and groups of countries attempt to define sustainable development criteria and make effort to implemente them. Energy plays a crucial role in sustainable development - its availability influences all fields of social, economical and political activities; it affects the state of the environment and the climate.

Sustainable development in the energy sector can be operationalised by the following guidelines (Table 1-1), which were derived using the Sustainable Development (SusDev) concept from /Kopfmüller et al. 2001/, /Coenen, Grunwald 2003/, and /Kopfmüller 2004/ and formulated for energy systems in /HGF 2001/.

(1) Equality of access: Equal opportunities in accessing energy resources and energy services shall be assured for all.

(2) Conservation of resources: The different energy resources shall be maintained for the generations to follow, or there shall be comparable options created at time to provide sufficient energy services for future generations.

(3) Compatibility with environment, climate and health: The adaptability and the ability for regeneration of natural systems (the “environment”) may not be exceeded by energy-related emissions and waste. Risks for human health – by e.g. the accumulation of problematical pollutants and harmful substances – shall be avoided.

(4) Social compatibility: It shall be assured when designing the energy supply systems that all people affected by the system are able to participate in the particular decision-making processes. The scope of economic players and communities in acting and designing may not be restricted by these systems, but shall be expanded wherever possible.

(5) Low risk and high error tolerance: The unavoidable risks and hazards that arise from the generation and use of energy shall be minimised and limited in their propagation in space and time. Human errors, improper handling, wilful damage and incorrect use shall also be taken into consideration in the assessment.

(6) Comprehensive economic efficiency: Energy services shall - in relation to other costs in the economy and of consumption – be made available at costs which are acceptable. The criterion of “acceptability” on the one hand refers to the individual economic costs arising in conjunction with the generation and use of the energy and, on the other hand, refers to the overall economic costs while taking also into consideration the external ecological and social costs.

(7) Meet the need of supply at any time: The energy required to satisfy the human needs must be available in line with demand at all times and in sufficient quantities in terms of time and space. This calls for an adequately diversified energy supply so as to be able to react to crises and to have sufficient scope for the future and room for expansion as required. Efficient and flexible supply systems that shall harmonise efficiently with existing settlement structures shall be created and maintained.

(8) International co-operation: Developing the energy systems shall reduce or eliminate conflict potentials between states from a shortage of resources and also promote the peaceful co-existence of states by a joint use of capabilities and potentials.

Table 1-1: Guidelines for Sustainability in the Energy Sector. Source: /Kopfmüller et al. 2001/, /Coenen, Grunwald 2003/, /BMU 2004/ and /Kopfmüller 2004/.

From Table 1-1, it is clear that a deeper understanding of the fundamentals is required if the path towards sustainability shall be successful. Despite the certainly progressive status in environmental policies in certain areas such as pollution abatement in electricity generation, the the world is today still far away from a sustainable path.

1.1 Deficits of the Energy Sector

If today's energy supply is measured on the basis of these guidelines, then major deficits can be seen, that are:

- Excessive consumption of limited energy resources
- Induced global climate change
- Extremely large differences in energy consumption between the industrialised countries and developing countries
- Risks associated with using nuclear power

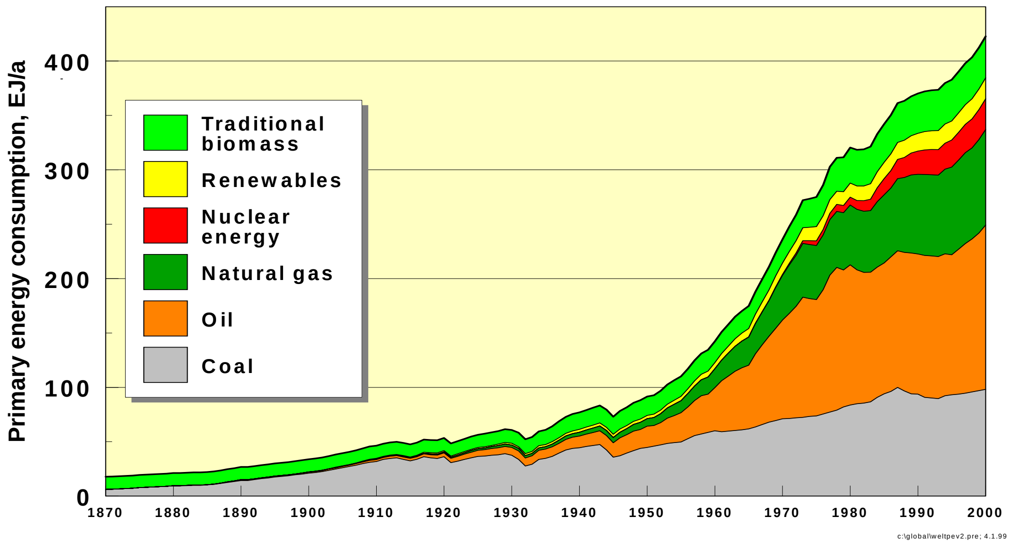
Limitation of Fossil Fuels

Since the beginning of industrialisation, the energy consumption has increased considerably more rapidly than has the number of people on the planet. Whereas the world population has quadrupled since 1870 to 6 billion at present, the world-wide energy consumption, and by this the consumption of fossil resources in the form of coal, oil and natural gas, has increased by a factor of sixty to the present level of 423 EJ/a (2000; EJ = Exajoule). Thus, the average person today consumes fifteen times more energy than a person 130 years ago. The actual rapid increase in the consumption of energy started about 1950 and the world-wide consumption of energy has doubled between 1970 and 2000. Moreover, left on its own no fundamental change of this growth trend can be foreseen in the future.

At the present time, the traditional use of biomass in the form of non-commercial applications of firewood constitutes 9% of the world-wide consumption of primary energy in many of the less-developed countries. The other renewables, first and foremost hydropower, have together a share of 4.5%. Nuclear power contributes 6.7% to the primary energy supply. Thus, some 80% of the world's energy supply is based on oil, gas, and coal. In commercial applications this Figure 1-is as high as 88%. This means that the world-wide energy supply is based primarily on finite fossil energy carriers. Thus it is clear that even in the event of a very rapid change in the energy supply structure, fossil-based energy will still be needed for the decades to come, and this possibly even to a greater extent than today. Therefore, how many resources are still available and how long these resources will last is an issue of central importance. The reserves of fossil sources of energy still remaining amount to some 34,000 EJ (status 2001). This is equivalent to approximately eighty times the present consumption of energy in the world today but only 2.4-times the total quantity of fossil energy that has already been consumed.

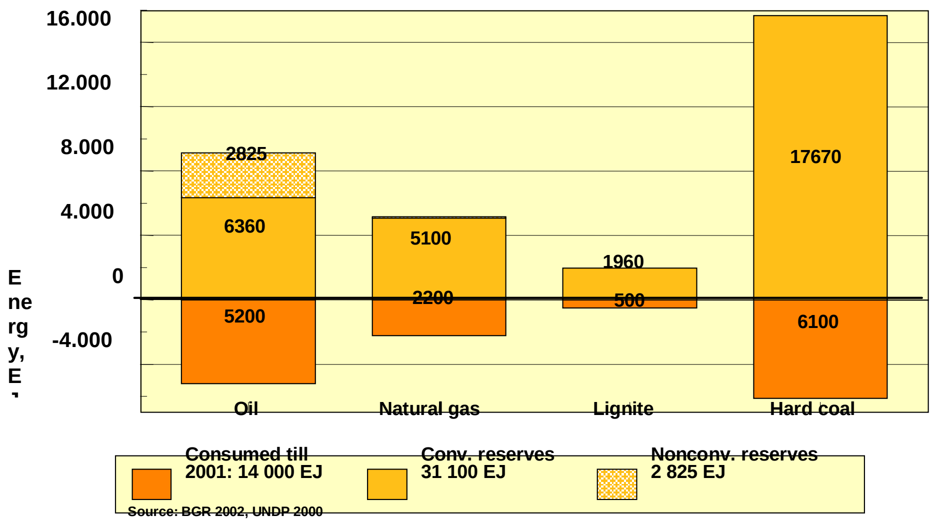
Coal constitutes more than 60% of these reserves. Conventional mineral oil is, with 20% of the reserves still left, the energy carrier which has been exploited the most in comparison with the other fossil energy sources. Comparing this with the major significance assigned to mineral oil of a 35%-share of the global energy supply, then it becomes clear that the supply will have to fall back here - in the foreseeable future - to the non-conventional oil reserves (heavy oil, oil shale,

oil sands) and to the resources as well, in order to meet the (still increasing) demand in the future. Including natural gas - without taking into account the very uncertain data about aquifers and gas hydrates - the resources of hydrocarbons with some 28,200 EJ make up the present reserves from all fossil-type energy carriers. Large resources to the extent of 116,000 EJ are being presumed for coal.



Source: /IEA 2003/

Figure 1-1: Development of the world-wide primary energy consumption and coverage of the demand by the various sources of energy including the non-commercial usage of bio-masses (firewood)



Sources: BGR 2003

Figure 1-2: Reserves per 2001 of fossil sources of energy in comparison with the quantities of energy already consumed in Exa-Joule (EJ)

These trends, indicating shortages in the reserves of oil and natural gas, are also reflected in the "static lifetime" of these energy sources. This term describes the time left until these reserves will be completely exhausted at the present rate of consumption. The shortest static lifetime - 43 years (2001) - is that of conventional mineral oil. Adding unconventional mineral oil – that is to say heavy oils, oil sands and oil shale –will increase the static lifetime to 62 years. For an unchanged rate of consumption, natural gas will last for approximately another 64 years, whereas the reserves of coal will be available for about another 200 years. Uranium, another finite source of energy, will only last for another 40 years, using light-water reactors without conditioning the nuclear fuel. It would appear that there are considerable amounts of resources still available which in principal can also be used. Such considerations however do not include the following aspects:

Very unequal distribution of oil and gas: On the one hand, the world-wide maximum in producing mineral oil – the so-called "mid-depletion point" - is expected within the next 10 to 20 years. Considerable increases in the price of crude oil are then likely as of this point in time at the latest. Natural gas alone cannot compensate for the expected shortage, and the usage of reserves of unconventional oil is expensive. Assured access to cost-favourable energy resources is already of such major significance today for the industrial countries.

The just distribution of resources amongst present and future generations – a major principle of sustainability – is not ensured. Even if today's generation were to come to the conclusion that an appropriate basis for acting shall be left for future generations despite the exploitation of the reserves of fossil and nuclear energy carriers, then in the light of the long time needed to develop and introduce new energy technologies, the minimum requirement has to be to begin now to introduce forcefully these new technologies not dependent on using fossil or nuclear fuels and not to lay down any structures today which might make future changes impossible or impede changes significantly in this context.

The Global Climate

Presumably not the depletion of the fossil energy resources will be the reason, which will force a change in the use of energy. In fact it will be the limited capacity of the environment to absorb the waste-products of energy consumption, which demands resolute actions towards a more sustainable energy economy. This applies mainly for the products which are released into the atmosphere. During the combustion of fossil energy carriers pollutants like sulphur dioxide and nitrogen oxide are formed, which contribute to the formation of acid rain. An incomplete combustion causes the emission of carbon monoxide, unburned hydrocarbons and sooty particles; moreover the combustion of solid fuel will produce considerable amounts of dust. These emissions along with a number of others do not only affect the environment, but they also are directly injurious to human health. Indeed, an improved combustion and the use of catalysts and filters can reduce those emissions considerably. Large progress has been made in this respect in numerous industrialised countries within the last three decades, driven by an effective environmental policy and by significant financial resources. As a consequence, the air has become cleaner, particularly in congested urban areas. One severe problem has remained – the formation of nitrogen oxide by the growing individual transport, which shall be reduced by tightened exhaust regulations for new vehicles. But in less developed countries the burdens from these emissions are quickly growing.

Besides these “classical” air pollutants, carbon dioxide (CO_2) is always emitted from the combustion of fossil fuels. This gas is not toxic, but it boosts the greenhouse effect, thus rising the mean global temperature in the lower atmosphere. Since the beginning of industrialisation, the concentration of CO_2 in the atmosphere has risen by one fourth and has thus caused an increase of the mean temperature near ground by 0.6 ± 0.2 °C. If no counter measures are undertaken to reduce these emissions and those of other greenhouse gases, a further increase of the mean temperature is expected from scenarios of the IPCC (2001)[1] in the range of 1.4°C to 5.8 °C until the year 2100. Besides the increase of temperature, changes in the distribution of rainfall, an increase in the frequency of extreme weather conditions such as storms, displacement of climate and vegetation zones and degradation of soils with fatal results for the strained global nutritional situation are expected. Changes of the climate are natural phenomena and have often happened in the geological history of the earth. However, the present changes are extraordinarily fast and abrupt. Human civilisations and the environment may not have enough time to adapt to the quickly changing conditions.

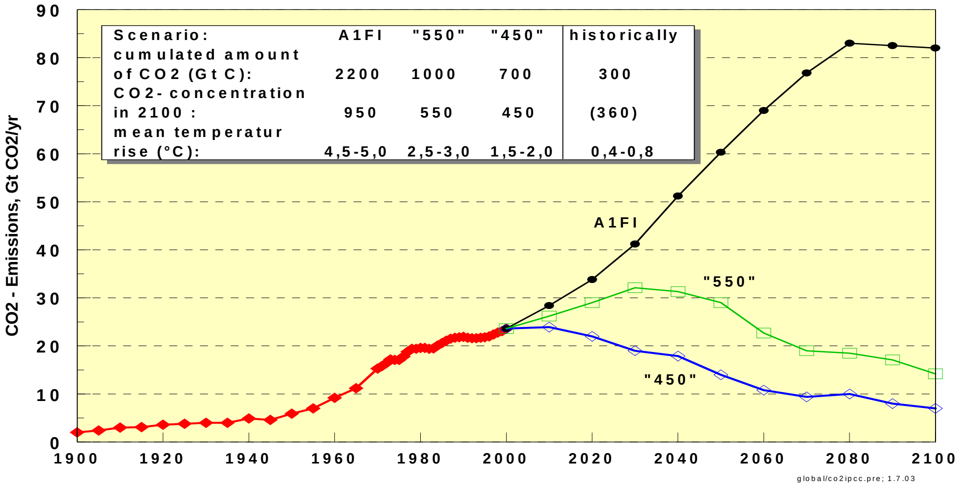
Energy related CO_2-emissions contribute about half to the man-made greenhouse effect. Therefore, efforts to reduce them are in the centre of climate protection activities. The increase of these emissions with currently 24.7 billion tons of CO_2/yr (2002), resulting from steadily growing global energy consumption, has led to a total of additional 1000 billion tons of CO_2 which have been emitted into the atmosphere since the beginning of industrialisation. 80% of that has been emitted in the last 50 years. Because the growth took place mainly in the industrialised countries, they are responsible for about 90 % of the CO_2-emissions generated from energy consumption. Actually they generate two third of the global CO_2-emissions.

Global climate change due to the combustion of fossil energy carriers, to the exhaustive use of forests and to an industrialised agriculture (emissions of the greenhouse gas N_2O) is a predominantly assured fact. To keep the temperature rise within low limits (<2°C), the concentration of CO_2 in the atmosphere, which is actually 360 ppm, must not rise beyond 450 ppm until the end of this century. To reach this value, a world-wide reduction of the energy related CO_2-emissions of more than half of the present amount before 2100 is indispensable. Bearing in mind the further growing population, each of the prospective 9-10 billion humans must not emit more than one ton of CO_2 per year. If a rather unlimited coverage of the growing energy consumption predominantly by fossil energies is assumed, the CO_2-emissions will rise considerably and the resulting temperature changes very likely will cause huge, irreversible, and uncontrollable damages. The scenario A1FI of the IPCC with a far reaching consumption of all fossil resources is such a non-sustainable example. Therefore, within only few decades, an effective combination of technologies for a more efficient energy use in all sectors and CO_2-free or CO_2-poor energy conversion technologies are required to keep the already existing climate change within tolerable limits.

In contrast to the “classical” air pollutants the negative impacts of the CO_2-emissions solely have a global character. A reduction of emissions does not lead directly to local advantages for the energy consumer. Only if actions are taken world-wide, the CO_2-emissions can be reduced to the necessary size. Single states or groups of states can only lead the way to a certain extent. The

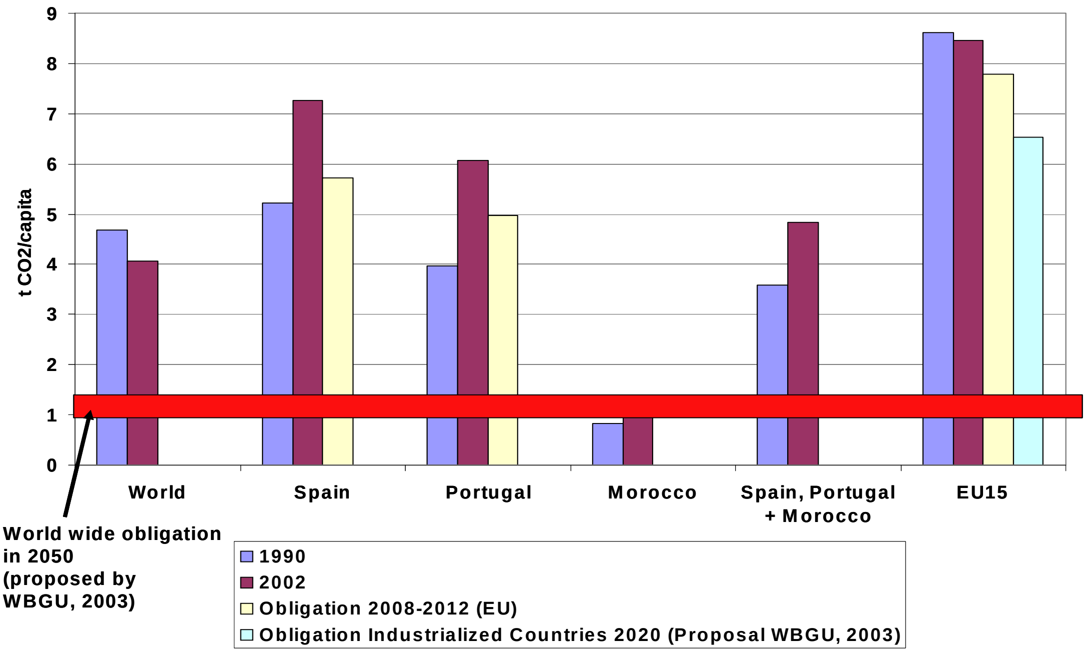
1 IPCC (ed.), Climate Change 2001: The Scientific Basis. IPCC Third Assessment Report. Summary for Policy Makers. Cambridge, New York: Cambridge University Press.

global dimension of the greenhouse effect, therefore, demands a broader way of political actions as it is the case with national problems. In view of the far reaching dangers of the greenhouse effect climate protection is one of the essential rationales for introducing a sustainable energy economy /WBGU 2003/.



Source: /IPCC 2002/

Figure 1-3: Development of the energy related CO_2–emissions in different IPCC-scenarios compared to the historical process and their impacts on CO_2-concentration and temperature in the atmosphere (A1FI = Meeting growing energy demand mainly by fossil energies; „450“ and „550“ = average values of scenarios which result in a stable concentration of CO_2 in the atmosphere)



Source : Adapted from /WBGU 2003/, /Statistisches Bundesamt 2003/, p.187f

Figure 1-4: CO2 emissions per capita in the World, EU15, Morocco, Portugal, and Spain and proposals for future obligations

The 2050-threshold of per capita emissions was calculated using the population data for 2050 from middle variant of UN's World Population Prospect, Revision 2002 (/Stat. BA 2003/ p.188f.). The worldwide CO_2 emission boundary stem from the judgement that a stabilisation of CO_2 concentration at 450 ppm is necessary to restrict the temperature increase to 2°C until 2100 and taken into account that a path which underestimates the temperature sensitivity to an increase of CO_2 concentration will be very difficult to correct. Whether the maximal increase of 0.2°C per decade will be observed depends on the exact path of reduction, however[1]. The resulting CO_2 emissions in 2050 are 9,300-12,500 Mt/a and 1.0-1.4 t/(capita*a), which equals 37-51% respective 25-34% of the current values. To reach this ambitious goal without risking serious negative secondary effects a world wide emission trading system is mandatory. An equal allocation of emission rights per capita in 2050 is proposed, to meet SusDev criteria on intragenerational justice. Additionally, a better renewable energy cooperation between regions and sub-regions and massive support to renewable energy sources, combined with a world wide emission trading system, should be of great contribution.

The world wide per capital goal as measuring criteria (Figure 1-4), which implies a reduction of the current emission per capita to a third or a fourth, approximately equals the current per capita emissions in Morocco. This implies that the Moroccan emissions must maximally increase with the rate of population growth. Allowing trade in CO_2 certificates and assuming equal allocation of emissions rights, the emission-goal of 2050, and the current emissions per capita, Morocco's net trading position in CO_2 certificates would be zero. Because an increase in energy use per capita seems mandatory to reach the social SusDev goals and ineviTable 1-if the world wide income distribution should become more equal, Morocco should increase its CO_2 intensity of energy use approximately simultaneously to the growth rate of energy use. If this is not reached it seems unlikely that selling CO_2-certificates will contribute to the Moroccan income in the long run and Morocco might end up demanding certificates.

Turning to Portugal and Spain, both countries currently show CO_2 emissions per capita well above the world but below the EU15 average. Without determined measures both countries will hardly reach the binding CO_2 goals in 2008-2012, which requires a turn around of the emission trend although the goal already had allowed a significant increase in emissions[2]. Spain's emissions have already passed a proposed intermediate goal for industrialized countries in 2020. So both countries have to reduce their per capita emissions significantly within the next half century.

Large Differences in Energy Consumption

A severe sustainable development problem is the disparity of energy consumption between industrialised and developing countries, which has increased rather than decreased over the recent years. Actually, 15% of the world population in high income countries consume 74% of conventional energy carriers and 63% of electricity. In contrast, 41% of the world population living in the low income countries have access to only 12% of economic wealth and 6% of energy. They are responsible only for 11% of the global CO_2 emissions. Moreover, as many developing countries consider the structure and level of energy supply in the industrialised countries as a means for achieving economic prosperity, they follow the resource-consuming

1 For a full discussion including uncertainties see WBGU (2003, 2003a).

2 Looking at the basket of all GHG-Emissions does not change the description (s. DIW, 2003, p.579)

development path of these countries, and thus further increase the already existing sustainability problems. Only if a fundamental restructuring of the energy supply system is achieved, there is a chance to limit the expected global increase in energy consumption and then a chance for a stabilisation of CO_2 concentration in the atmosphere. To this ends, in the developing countries a combination of decentralised and central energy supply technologies as good as possible should be created right from the start. From the point of view of sustainability, i.e. also under the precondition that in the long run a share of renewables as high as possible has to be mobilised, the alternative is not “centralised” or “decentralised” but rather getting the most efficient and most practical connection of plants of different sizes and performances.

Nuclear Power and the Environmental Risks

Since electricity generation from nuclear fission is close to CO_2-free, many people considered nuclear power as indispensable for achieving our CO_2 abatement targets. But taking into consideration, the fact that climate protection requires the abatement of large quantities of CO_2 over a long time period, the increase in risk stemming from each new nuclear power plant (especially, the social and managerial requirements and their time horizon for save nuclear material flows should be considered), the limited availability of resources prevents nuclear energy from fulfilling these requirements. Even at today's level of nuclear energy use, the availability of cheap uranium for light water reactors is expected to last for only 40 years. The long term supply of a large amount of electricity requires the use of reprocessing and breeding technologies, which are not only more costly, but also more risky than today's reactors.

Furthermore, the different risks liked to nuclear energy are in conflict with the basic requirements of a sustainable energy supply. Thus, the exclusion of nuclear energy could be based on the following reasons:

- Accidents in nuclear reactors, leading to unacceptable human health risks, cannot be ruled out. The regions affected by such an accident would suffer from extreme consequential damages.
- All processes of the nuclear fuel cycle, including fuel preparation, processing and waste disposal generate radioactive material, which is partly emitted. Up to now, the technical feasibility of a safe and long term separation of radioactive material from the ecosphere has not been proven in spite of considerable expenditures in research and development.
- Total protection against proliferation of plutonium as a side product of nuclear fission seems to be impossible, in particular if plutonium has to be handled within an international breeding economy. A misuse of weapon-grade plutonium is a continuous threat for humanity.
- A full scope protection of nuclear facilities against external forces and sabotage is impossible or at least would lead to extremely high costs and a limitation of civic liberties.
- A limitation of the use of nuclear power to the industrialised countries only in order to reduce the risks described above would hinder a peaceful global co-operation and thus, is not viable for policy reasons.

Therefore, the benefits of electricity supply from nuclear power, although it's CO_2 free, seem to be small compared to the risks which are inherently related to the continuous use or even further expansion of nuclear power.

1.2 Efforts for Energy Sustainability

Today, a bundle of policies deals with the promotion of renewable energy sources and the transformation of the energy mix in the European Union.

One of the most relevant legislations for renewable energies is the **European Directive on renewable electricity (2001/77/EG):** By the year 2010, the EU is willing to cover 22% of the grid mix by renewable energies. The energy sector needs to be sufficiently liberalized and not be characterized by market distortions. The Transmission Operators and the Distribution Network Operators are required to guarantee an undiscriminatory access to the grid to the power producers. This includes giving priority access to renewable energy whenever possible, i.e. without compromising the maintenance and reliability of the system. However, not all Member States are likely to achieve their target. The Newly Associated States (NAS) face the challenge to quickly comply with the growth targets for renewable energies in the generation mix.

Apart from this, the **European Directive on the energy performance of buildings** provides incentives for the use of renewable energies in the building sector: 4 January 2006 is the deadline for compliance, regulation in force, updating their energy performance regulations in order to improve energy efficiency of their buildings, requirements on the integral energy performance of new and renovated buildings, on energy certification for all buildings when sold or rented out, inspection schemes for heating and cooling installations, minimum standard for each country, production of energy performance certificates when buildings are constructed, sold or rented, regular inspection of boilers and air-conditioning systems.

Currently, biofuels are still more expensive than the alternatives, i.e. petrol or diesel. The **European Directive on biofuels (2003/30/EG)** stands for a progressive introduction of biofuels derived from agricultural, forestry and organic waste products. The targets are a 2% market share by December 2005 and a 5.75% market share by December 2010. Lower shares have to be justified. Until 31st December 2004, the directive must be transposed into national law by the Member States.

And finally, the **European Directive on Cogeneration** postulates a share of at least 18% of the whole electricity production as a target of the EU by 2012.

Sustainable development is not limited to country boundaries. It is a global challenge and the EU wants to play a key role in attaining worldwide sustainable development.

On the World Summit on Sustainable Development (WSSD) during September 2002 in Johannesburg, the EU committed itself together with other signatories of the UNFCCC to elaborate strategies for a sustainable development worldwide.

As a key objective, the linking of globalization to sustainable development was pointed out. To fulfill this vision, developing countries need to equitably take part in the world economy in order to be able to benefit from the liberalization of the markets and the global competition. Structural changes are required regarding the financial markets which have to become more transparent and less volatile with the aim to provide incentives for environmentally and socially sustainable

production and trade. But first of all, sources of financing have to be provided for developing countries. In this context especially the private sector has to be involved which may for instance be achieved through CDM project activities. In spite of its focus on climate change prevention, the CDM shows opportunities to achieve sustainable development in the host country through projects meanwhile reducing GHG emissions. For instance, the provision of the population with energy is the key to wealth and influences most of the economic and social areas of a country.

During the WSSD, the EU presented its strategy “Sustainable development in Europe for a better world” also known as the “Strategy for Sustainable Development” which had passed the European Counsel in Gothenburg in 2001. The strategy deals both with EU-internal and EU-external aspects of the subject.

The comprehensive objective of the EU Strategy for Sustainable Development is to improve the life quality for current and future generations. Economic growth, protection of environment and social integration are no more considered as conflicting objectives, on the contrary, it is envisaged to achieve them simultaneously.

The Strategy for Sustainable Development completes the Lisbon Strategy, which consists of measures to be taken to achieve economical, social and ecological renewal within the EU, by an environmental dimension. Environmental protection is a precondition for sustainable development contributing to the achievement of the other objectives of the Lisbon Strategy such as competitiveness and innovation.

As a first step, the Strategy for Sustainable Development deals with four subject areas which are significant for a sustainable development:

The first is the mitigation of the climate change. This may be achieved through energy efficiency measures, capture of fugitive emissions as well as by increasing the use of renewable energy. The second area relates to the transport system and land use. Under aspects of emission reductions, transportation systems and the construction of cities may be optimized e.g. by shortening the routes in order to produce fewer emissions. Third, sustainable development is intended to protect public health. And finally, natural resources shall be managed more responsibly.

However, these concepts are still very general and need to be further elaborated to internalize external effects, i.e. the ecological and social costs; clear environmental standards are indispensable.

Between August and October 2004, the European Commission has conducted a broadly designed public consultation. On the outcome of this process the European Commission will elaborate an evaluation report for the EU Strategy for Sustainable Development, which will be the basis for the planned examination/ reconsideration of the strategy by the European Council.

As a result, the EU has now created three different policies related to the Sixth Environmental Action Programme (6th EAP) without clarifying how these relate to each other:

- The Strategy for Sustainable Development (EU SDS), which rests on the basis defined at the European Council in Gothenburg (June 2001);
- The “Cardiff Process” describing the sectoral strategies for the integration of the environmental dimension into other policies;

- The “Lisbon Strategy” for employment, economic reform and social cohesion, to which the environmental dimension was added at the Stockholm European Summit (Spring 2001).

Although these strategy papers illustrate which overall path to take, so far no consensus could be achieved on how to harmonize and exactly put them into practice through sectoral policies. In addition, it has been criticized that this approach narrows sustainable development down to environmental concerns. The review of the European Commission is expected for January 2005 /Hinterberger et al. 2003/.

Some sustainability criteria for developing countries were developed within the Clean Development Mechanism (CDM). Apart form generating additional emission reductions, the CDM is intended to contribute to the sustainable development in the Non-Annex I countries. Each project activity is examined by the DNA against the set of sustainability criteria of the host country. In addition to the very general sustainability goals outlined by the Millennium Decision, the host countries are required to formulate their own specific sustainability goals, because priorities may considerably change from country to country. It lies in the responsibility of the host country to decide whether a proposed project complies with the country’s criteria, because it disposes of the most detailed knowledge on the country-specific needs. Project participants have to specify the influence of the project on the sustainable development of the country in their PDD. If the host country has published a framework, it gives the project participants a guidance, which aspects need to be dealt with. Further, national development strategies, energy and environmental strategies as well as social and economic plans have to be consulted in order to put the criteria into concrete terms. Without defined national criteria for sustainable development, project participants face difficulties in providing the required information to demonstrate project worthiness.

DNAs have already been set up in Egypt, Israel, Jordan, Lebanon, Morocco, the Syrian Arab Republic and Yemen, but only Morocco has published its national criteria for sustainable development which are available at the DNA’s website www.mdpmaroc.com. Morocco has been the leading African country regarding CDM especially in capacity building. This is partly due to the UNDP capacity building project initiated in 1994 and later supplemented by a CDM component. The country disposes of negligible domestic fossil energy sources, but at the same time of a large potential of renewable energy. The national sustainability criteria require a CDM project activity to comply with the following issues:

- The project shall integrate into the principal orientations of development of the country and has to be part of the defined priorities of the national strategy for sustainable development.
- The project shall be conforming to different laws in place in the country particularly those regarding the environment and its preservation. It is particularly indispensable that an environmental impact analysis of the project is realized conforming to the national law on environmental impact analysis.
- The project shall serve the reinforcement of national the energy potential and / or its diversification and its extension concerning renewable energies and / or the optimization of its different uses.

- The project shall permit the use of effective and clean technologies and prevent any import of outmoded technologies.
- The project shall have a tangible positive impact on the local population: Job creation, wealth creation, improvement of live quality, strengthening of sustainable development and clean development capacities.
- The project shall create competitive incentives for private enterprises involved in the activity.
- The project might improve the capacity of the country to combat the fatal effects of the climate change and to adapt to them.

If a DNA has not set up its own catalogue of sustainability criteria, it may fall back on the criteria developed by Sutter /Sutter 2003/

	Criterion
Social Criteria	Stakeholder Participation
	Improved Service Availability
	Capacity Development
	Equal Distribution of Project Return
Environmental Criteria	Fossil Energy Resources
	Air Quality
	Water Quality
	Land Resources
Economic Criteria	Microeconomic Efficiency
	Technology Transfer
	Regional Economy
	Employment Generation

Source: Adapted from /Sutter 2003/.

Table 1-2: Suggested criteria for sustainable development design

1.3 The Kyoto Mechanisms

The Kyoto Protocol is the first internationally agreed policy measure that deals with the stabilisation and the reduction of the greenhouse gases in the atmosphere. With its flexible mechanisms, the Kyoto Protocol adopted in Kyoto at the COP3 in 1997 should contribute to the greenhouse gas emissions reduction though projects activities based as well in industrialised countries as in the developing countries.

It sets differentiated, legally binding emission targets for the industrialised countries and countries in transition (Annex B countries). Each Annex B country disposes of the right to generate an assigned amount of emissions based on varying proportions of 1990 levels. Basically, Annex B countries are required to reduce their emissions to approximately 95% of

1990 levels. The emission targets can be reached via domestic action, by investment in emission reduction projects abroad or the acquisition of emission rights from another country. The latter two options are feasible due to the three “Kyoto Mechanisms” set up, witch allow transboundary co-operation in mitigation activities.

Since the Kyoto Protocol had only given a general framework on the emission reduction options, it has to be waited untill 2001 for clarification and agreements on the mechanisms rules contained in the Marrakech Accords. The ratification of the Kyoto Protocol and the fulfilment of certain reporting requirements are a prerequisite for countries participating in the mechanisms.

As for the three mechanisms, there exist the Clean Development Mechanism (CDM), the Joint Implementation (JI), and the International Emission Trading (IET) with the possibility to build bubbles. The latter mechanism concerns the transfer of parts of the national emission budgets whereas the CDM and the JI are project-based mechanisms.

As far as the IET is concerned, it could only take place between Annex B countries and consists just of a transfer from one country to another, after 2008. Countries forming a bubble can distribute their target internally ex-ante as long as the total of the targets is not exceeded. In effect, the EU is the only country group forming a bubble; it has redistributed its target of –8% in a way that Portugal is allowed to increase its emissions by 25%, while Luxembourg has to reduce its ones by 28%, to mention the extremes /Michaelowa et al. 2004/.

In addition, the Joint Implementation concerns Annex B countries that are countries with binding targets. Emission credits (“Emission Reduction Units”, ERUs) can only accrue from 2008. The ERUs have to be certified by “independent entities” and the JI will probably use the rules developed by the CDM Executive Board /Michaelowa et al 2004/. Important here to notice is that the ERUs are deduced from the budget of the host country. Hence, JI does not increase the overall emission budget at a global level.

As for the Clean Development Mechanism (CDM), it accounts for emission reductions which take place in Non-Annex I countries. Thereby, the CDM is the only market mechanism in the Kyoto Protocol that is open to the participation of developing countries. By enhancing cooperation between developed and developing countries, Annex I countries shall assist Non-Annex I countries in achieving sustainable development providing technology transfer. It is the objective of the CDM to help developing countries to contribute to the stabilization of the GHG concentration in the atmosphere, the ultimate goal of the UNFCCC while opening a way of sustainable growth to them. Meanwhile, the CDM assists industrialized countries in achieving compliance with their emissions reductions commitments under the Kyoto Protocol.

One important characteristic of the CDM is that the emission credits are added to the overall emissions budget of Annex B countries. For this reason the quality of the credits has to be guaranteed. Thereby, emission credits only accrue after independent verification through the “Operational Entities” (OEs), which basically are commercial certification companies. Then, these emissions are called Certified Emission Reductions (CERs). An elaborated “project cycle” was defined in the Marrakech Accords which leads to high transaction costs. Of course, it was a concern that transaction costs can prevent small projects from taking place (Michaelowa et al. 2003). For these reasons, some clement rules have been settled for renewable energy projects below 15 MW capacity, energy efficiency projects that save less than 15 GWh per year and other

projects that annually emit less than 15,000 t CO_2[1]. For this specific project size, the so-called "standardised baselines" can be used in order to reduce transaction costs. However, even with these clement rules it is unpredicTable 1-whether small projects will be competitive (Michaelowa et al. 2004).

An important feature of the CDM is that since CERs are generated in countries without emission targets, adding the issued CERs to the investor budget increase the overall emission budget at the global level. But these increasing global budget will stop when each country of the globe disposes of its emission reduction target. At this time of course no morew CERs will be issued.

In order to smoothly carry out the CDM, the necessary institutions have to be built in the developed as well as in the developing countries. Due to very restricted financial resources and organizational deficiencies, the institutional network in many Non-Annex I countries is still uncompleted or entirely missing. A lot of capacity building is needed to enable developing countries to seize/take the opportunities the CDM offers. The Marrakech Accords (2001) require each country which wants to take part in the CDM to set up a Designated National Authority (DNA). The mandatory role of the DNA is the approval of CDM project activities. Therefore, the DNA has to define criteria for sustainable development in order to specify for instance the additionality requirements, the foreign currency requirements and the criteria for job loss prevention. Further, the DNA has to clarify the sectoral and technological priorities and has to organize the sharing of CERs.

Further, the DNA is encouraged to engage in capacity building. The aim is to promote competitiveness of national CDM project proponents and to market the national CDM program to investors. In detail the DNA can improve the informational situation by creating an information database, engaging in the dissemination of information and by organizing trainings for technicians. At the same time, the DNA can support the policy development of the host country government, as well as provide support to (potential) CDM project activities and to the Designated Operational Entities (DOEs) which carry out validations and certifications of projects. In addition, the DNA is responsible of carrying out marketing activities for the CDM. Due to this central position, the DNA has a big influence on the working of the CDM in the host country.

The costs linked to the CDM institutions building and running consist in the start-up funding of about US$ 150,000 for donor seed funding (Indonesia case (Michaelowa, et all, 2004)), fixed costs of about US$ 115,000 per year, and variable costs of US$ 70,000 per year (assumed 10 projects submitted per year). This leads to a total sum of US$ 185,000 per year. The variable costs differ from country to country on the basis of the salaries for officials or experts.

In view of avoiding danger of the greenhouse effect climate protection is one of the essential rationales for introducing a sustainable energy economy. Hence a paradigm changing towards an accelerated utilisation of renewables and a steady decrease in the use of fossil energy carriers is an ultimate task. Of course, it is highly likely that renewable energy projects will play a lead role in the CDM and the JI in terms of number of projects carried through. But taking into consideration the total emission reductions, the average size of renewable energy projects was much smaller than the size of other project categories. Moreover, at the moment no study has

1 These three project categories are the so-called small scale projects (UNFCCC).

been carried out which exactly defines the amount of GHG to be reduced with the Kyoto Mechanisms /Michaelowa et al. 2004/. Nevertheless, their proper use will contribute to the emissions reduction. With the ratification of Russia, the Kyoto Protocol will enter into force and the first climate friendly projects that are linked to it will subsequently be implemented.

Status and Prospects of the Kyoto Instruments in Europe

The Kyoto Mechanisms are already quite developed in Europe and play an important role in its climate policy. Above all the Southern Member States of the EU are strongly interested in the CDM in MENA (Italy, Portugal, Monaco, Spain). The sub-region offers a huge potential in renewable energies, although not yet exploited due to many reasons. One reason is the lack of knowledge on region specific parameters which have to be taken into account when implementing renewable energies in the sub-region. Researchers are actively taking these parameters into account by designing renewable energy projects for the MENA. This is the case of the Trans-Mediterranean Renewable Energy Cooperation, whitch links water supply and poverty alleviation issues to energy production. Therefore, the EU is willing to support research in this area. Potential CDM project activities are as appealing for the EU, as they form an alternative solution for the EU Member States to meet their emission reduction targets. Moreover, the geographic situation of the sub-region (proximity to Europe) offers a cost efficient renewable energy import to Europe. This of course should contribute to the achievement of the European Directive on renewable electricity (2001/77/EG), witch states that by the year 2010, the EU should cover 22% of the grid mix by renewable energies.

The EU wants to dedicate a budget of about 19 million Euro for CDM awareness-building worldwide, with MENA countries having a share of about 26%, that are 5 million Euro /Michaelowa et al., 2004/.

The EU is widely considered as a leader in the development of the CDM. In April 2004, the European Parliament agreed on the “Linking directive”, which allows CERs to be used in the EU trading scheme starting from January 2005. In the approaches of this vote, it had been discussed to limit the CER import to the EU market for emission trading. However, the European Parliament decided not to fix a common CER import limit, as this implementation would have come under the member state competence and thus would have been unlikely to be put into practice. Even if the Kyoto Protocol would not enter into force in early 2005, the survival of the Kyoto Mechanisms would be guaranteed.

The market impact the CDM will exercise is difficult to predict. The private demand for CERs depends on the design of the national allocation plans. As most published plans are weak, the EU Commission is very likely to refuse some. A tendency to shift the demand from companies to governments is noticeable. The impact further depends on CER or ERU import regulations and fees of the governments of the Member States.

Status and Prospects of the Kyoto Instruments in MENA

The following figures provide an overview on the current status of the Kyoto institution building in MENA. The national CDM projects of selected MENA countries are shown in Annex 8.

In Egypt, all CDM institutions have been set up and the country has 21 projects in the pipeline. The donors and investors mainly consist of UNEP, Japan, Italy, Switzerland, the World Bank and the GEF. Regarding the Kyoto Protocol, the Egyptian government is willing to ratify. The CDM will be used as a vehicle to gain additional investment and to reduce energy insecurity.

The Kyoto Mechanism thus plays also an important role in Egypt's national climate change mitigation strategy. Egypt is the second most advanced in the sub-region after Morocco regarding the Kyoto Protocol issues.

In Morocco, too, all CDM institutions have been set up with Morocco offering a suitable environment for CDM projects. The official CDM web site of the country provides all information about the CDM (www.mdpmaroc.com). Further, Morocco benefits from a PNUD-GEF capacity building programme in the Maghreb countries to develop his project portfolio. The main investors in Morocco are the World Bank, UNEP, Germany, France, Italy, and the Netherlands.

Although the country disposes of a huge potential in solar and wind energy, 97% of the energy imported in 2000, this equals about 17.8 MUS$. To change this unfavourable situation, Morocco places the renewable energy sources and the CDM in the central point of his national energy supply strategy and it turns out to be the most developed country in the region as far as CDM institutions are concerned. Morocco has 34 projects in its pipeline. The overall GHG emission reduction potential reaches about 3.5 million t/annum. Already in January 2003, the project pipeline contained ten projects out of which three Project Design Documents (PDD) developed by Ecosecurities were approved by the DNA in November of the same year. A fourth project got the DNA approval in 2004.

The first project is a wind power plant in Essaouira, which would generate an average of 162,000 CERs over 10 years. The second project is an energy efficiency project in the chemical industry, with an average potential of 100,000 CERs over 10 years. The third project deals with the collection and flaring of landfill gas on Rabat landfill, with an average 72,000 CERs over 21 years /ONE 2003/.

Even though Morocco is very advanced in the CDM process, so far no project has been submitted to the Executive Board for several reasons. For instance, in the case of a wind power project proposal near Tangiers and Tarfaya with a capacity of 200 MW and a potential generation of 450,000 CERs per year, it was the Moroccan electricity utility ONE which prevented the project to go further.

Apart from the DNA-approved projects, there have been submitted three Project Idea Notes (PIN) to the DNA in June 2004 for examination. For convenience the other projects in pipeline which are at different levels of development will not be discussed[1].

In Tunisia, the CDM is considered as an important source of additional investment and as an opportunity to enhance sustainable development. For local policy, the CDM plays an important role and is included into the national GHG emissions reduction strategy. The Tunisian government, too, is preparing to ratify the Kyoto Protocol. There are factors which are favorable for the successful adoption of the CDM: as Morocco, Tunisia benefits from the PNUD-GEF capacity building program in the Maghreb countries to develop a project portfolio. To finally implement the activities of this portfolio, i.e. a 16 million tons reduction in CO_2-eq, Tunisia needs a total of 248 MUS$ from which 49 – 81 MUS$ could be obtained from the CDM

1 The full project pipeline is about 34 CDM projects in forestry, waste management, renewable energy, energy efficiency, industrial process field (For more details see Secretary of State for the Environment. Climate Change Unit. CDM permanent Secretariat, CDM projects. Moroccan preliminary portfolio. June 2004).

investors and 167- 199 MUS$ have to be procured from other sources of investment during the period 2002- 2010.

So far, the OPEC countries have not ratified the Kyoto Protocol, because it would be detriment to their primary market interest. Nevertheless, they are very active in the international climate negotiations due to the strategic role of oil and gas in their economic activities. Several OPEC countries even have completed their internal ratification procedures. After Russia's ratification, rapid notification of the ratification is expected from them.

With exception of Indonesia and Algeria, no CDM institution building has been undertaken so far in the OPEC countries. Nevertheless, renewable energy is increasingly seen as a building block of the future OPEC economy due to the continuous diminishment of the reserves.

The present energy demand is expected to rise considerably in future due to the expected economic growth of the MENA. Therefore, the main objective has to be to further uncouple growth from energy consumption. The solution is to promote energy efficiency measures in combination with increased use of renewable energies.

Enhanced energy efficiency and a shift to renewable energy sources is the key for sustainable development of the energy sector in the MENA. However, the adoption of new technology takes its time and the MENA are lacking of skilled manpower and financial means. Therefore, they are dependent on technology transfer from industrial countries. Here, the CDM may bring some contributions.

Taking into consideration the discussion on sustainability illustrated earlier, and a ton per capita emission, it is obvious that Morocco with its actual economic growth will get in a near future an emission reduction target. These coupled with the high energy import dependence may justify the efforts of the country to make use of the CDM.

Generally, MENA countries are in favour of the idea of exporting renewable to Europe under a Trans-Mediterranean Renewable Energy Cooperation /TREC 2004/. Hence technology transfer and development through CDM could be one step towards this constellation.

	National focal point	**1st National Communi-cation**	**Kyoto Protocol ratification**	**DNA**	**CDM projects in pipeline**	**Donors / Investors**
Algeria	Ministry of Foreign Affairs	30/04/01	No	No	**Yes**	World bank, UNDP, GEF
Cyprus	Ministry of Agriculture, Natural Resources and Environment	No	16/07/99	No	-	-
Egypt	Egyptian Environmental Affairs Agency	19/07/99	No	**Yes** **Environmental Affairs Agency (EEAA)**	**Yes**	UNEP, Japan, Italy, Switzerland WB/GEF, EEAA
Israel	Ministry of the Environment	18/11/00	15/03/04	**Yes** **Ministry of the Environment**	-	-
Jordan	Ministry of the Environment	06/03/97	17/01/03	**Yes** **Ministry of the Environment**	AIJ E7	UNEP, Netherlands
Lebanon	Organisation of Arab Petroleum Exporting Countries (OAPEC)	02/11/99	No	**Yes** **Ministry of the Environment**		
Libyan Arab Jamahiriya	National Committee for Climate Change		No	No	-	
Morocco	Ministry of Local Administration and Environment	01/11/01	25/01/02	**Yes** **Ministry of the Environment**	**Yes**	WB,UNEP Germany, France, Italy, Netherlands,
Oman	Ministry of Regional Municipalities, Environment and Water Resources	No	No	No	-	
Saudi Arabia	Ministry of Petroleum and Mineral Resources	No	No	No	-	
Sudan	Ministry of the Environment	07/06/03	02/11/04	No	-	
Syrian Arab Republic	Ministry of Local Administration and Environment	No	No	**Yes** **Ministry of the Environment**	-	
Tunisia	Ministry of Environment and Water Resources	27/10/01	22/01/03	No	**Yes**	
United Arab Emirates	No	No	No	No	-	UNEP, Japan
Yemen	Environment Protection Authority (EPA)	29/10/0	No	**Yes** **Environment Protection Authority (EPA)**	-	

Source: Kyoto Protocol Status ratification, (UNFCCC, 25/11/2004).

Table 1-3: The development of the Kyoto institutions in the MENA region

1.4 Limits of Existing Instruments to Achieve Sustainability Goals

Society is forced to move towards a sustainable energy system not only because the fossil energy carriers are limited but specially due to the fact that our environment has limited capacity to absorb the waste-products of energy consumption. Thereby, efforts to reduce them are the focus of the climate policies. In effect, society is still far away from the sustainability goals and strong policy supporting the development of renewable energy technologies is needed in order to achieve an important contribution of renewable energy sources to the world energy consumption mix that at the end lead to a low-greenhouse gas energy system.

As for policy measures, the Kyoto Protocol is supposed to foster the introduction of more renewable energies into the worldwide energy system. The Emission Trading (ET) which enables countries to trade carbon credits at an international market for emissions allows Annex I countries to buy or sell AAUs (Assigned Amount Units) at a market price. Due to the fact that emissions will be reduced where there reduction is the cheapest, the ET will lead to a big cost reduction in achieving the Kyoto targets. The second mechanism, JI, and the third, CDM, should generate emission reductions as was already explained in the last section.

Those emission reductions will be used to supply the ET system so that the Kyoto instruments are well combined. Moreover, a reasonable use of the instruments should lead to a contribution of Annex I and Non-Annex I countries to the global emission reductions and the achievement of the ultimate objective of the Protocol.

Although the Kyoto Protocol offers an emission reduction possibility, it is clear that it is not a panacea for large-scale renewable promotion at the current market price of the greenhouse gas reduction credits. Therefore,supplementary policy measures are required. The tendency is that, at regional and sub-regional level, specific policies are adopted.

Since the European Union is the pioneer in climate policy regarding the greenhouse gas emission reductions, the analysis will be limited to the supplementary climate policy at the European Union level.

Generally, the challenge in the support of the renewable energies are the price gap between their price and those of the fossil energy carriers, as well as the dependency from financing for research and development.

An overview of promotional systems for RES in EU-15 is given in Figure 1-5. A more detailed description is given in Chapter 8. It is apparent that most countries are using either the feed-in tariff model (respectively minimum price standards) or the certificate trading model (respectively the quota model). Bidding schemes, originally introduced in UK, are used in Ireland only. The feed-in model turned out to be the most successful instrument in terms of installed RES-capacity, but an increasing number of countries are considering the certificate trading model as the future winner. Possibly a mixture of both will be used in the future because “green” certificates also can be combined with feed-in models.

Graphically, a tendency of the EU-15 greenhouse gas emissions until 2002 and a projection up to 2010 can be seen in Figure 1-6 under the actual policy measures.

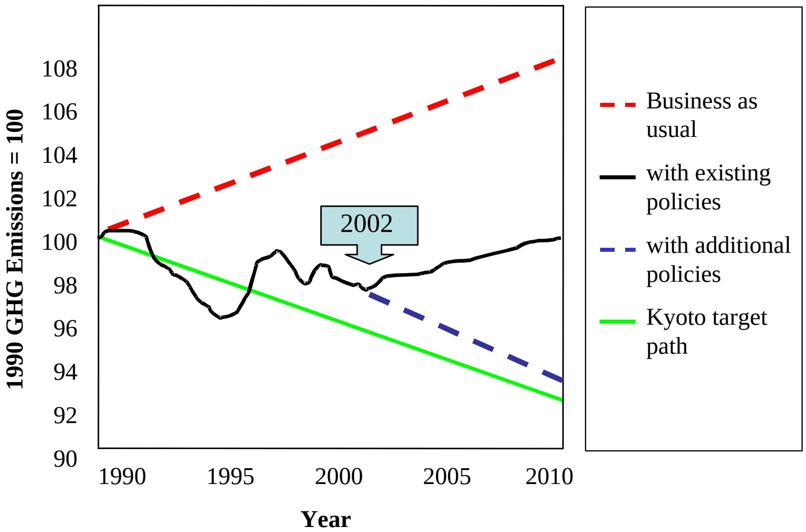
It is noteworthy that with existing policies in the community, the emission path is bellow the ones of the of the business as usual. Still, these policies are not enough to bring the emission curb in the direction of the reductions suggested under the Kyoto Protocol. With the help of

supplementary policies the emission path of the community is hoped to change considerably and follow the Kyoto target path. These means that only with deliberate policy assistance to the renewable energy sources, one can still hope to cut down the emissions and finally find the path traced by the Kyoto Protocol. For that, let’s examine the weakness of the actual policies.

	AU	**BE**	**DK**	**FI**	**FR**	**GE**	**GR**	**IR**	**IT**	**LU**	**NL**	**PO**	**SP**	**SW**	**UK**
FIT	X		(X)		X	X	X			X		X	X		
BID								X							
SUB			(X)	X		(X)	(X)	(X)		(X)	X			(X)	
CTM	(X)	X	Xp						X		(X)			Xp	X

FIT = Feed-in tariffs; BID = Bidding System; SUB = Subsidies, Tax relief; CTM = Certificate trading model; X = Main instrument; (X) = Additional instrument or combination with main instrument; p = proposed.

Figure 1-5: Overview of promotional systems for RES in the countries of EU-15 by 2002



Source: Adapted from J. Lefevere, 2004, European Commission: DG Environment Directorate.

Figure 1-6: UE-15 greenhouse gas emissions until 2002 and projections until 2010 /Lefevere 2004/

The European community has done a lot in environmental policy to tackle the major challenges for a massive introduction of renewable energy sources. Albeit the contribution of renewable energies to the total energy consumption is growing in the community, society is still far away from reaching the goals. This situation could to some extend be explained by the weaknesses in the policy measures. In effect, as was shown in chapter 3, the desired targets will not be reached with the present policy instruments and measures.

The CDM and the JI which have the potential to foster renewable energies are market mechanisms that are not designed to finance the projects as a whole but only their carbon component. Moreover, the change in the internal rate of return due to incorporation of the carbon

revenues with current CO_2 prices is not that much high to give incentive to the CDM project developers. Therefore, one could not expect a large contribution of the CDM regarding the market share of renewable energies. In reality, CDM activities are driven by the profits on the carbon component of the projects. For that reason, a lot of environmental friendly projects will not be implemented. Moreover, the sustainable development definition, which in the frame of the CDM is let to the hosts countries, could lead to a competition between different host countries and finally decrease the projects quality because the project developers are not willing to finance sustainable development that they considere to be public goods. As the Kyoto Protocol will enter into force in the coming month it will turn out how far these speculations stand to the reality.

Furthermore, as the experiences in the different Member States of the EU has shown, a specific support instrument for the renewable energies is crucial. In effect, the levels of RES electricity premium tariffs are generally insufficient. Moreover, a wide range of policies to promote renewable energy technologies fails in supporting the most cost effective ones. The different design of the national renewable portfolio standards hinder rather than enable the free trade of renewable certificates between different countries. It is evident that renewable energies characterised by decentralised and dispersed application are disadvantaged by the present political framework that supports only the fossil energy carriers. A successful RES policy needs to address also non-economic barriers for RES. This includes a fair access to the electricity grid, adapted building permission procedures for wind power plants or consideration of solar thermal collectors in building codes. Policy measures addressing these issues are not clear enough at the EU level.

A comprehensive education program does not exist at the EU level. In fact, workmen, tradesmen and engineers need to be educated comprehensively about RES technologies and their applications. Moreover, in schools and universities RES subjects are not incorporated enough in their curricula. Last but not least, there is an ongoing demand for R&D to exploit the cost reduction potential through technical progress.

In addition to what has been discussed so far, the weaknesses of the support instruments to the RES at the financial level are obvious. There is not enough funding to foster the R&D likewise to support market introduction to the renewable energy. For example the EU had a program of spreading and financing research on RES in 1998. The program was not successful because the EU’s own financial means allocated to the campaign were rather limited with 74 million US-$ over 5 years compared to the total required investment of 20 billion US-$.

It was the objective of this chapter to show whether the existing mechanisms and measures are sufficient to direct the society towards a sustainable development path in good time. The analysis has demonstrated that with the current policies and measures the sustainability development goals of the EU will not be achievable, and even to a lesser extent those of MENA.

Additional effort is indispensable to increase investment in renewable energy technologies so that a significant share of RES in the energy system may be reached in time. Although the Kyoto Protocol and its flexibility mechanisms form an adequate framework and could become a very successful means to promote RES in the long run, the putting into practice takes time, transaction costs are still high and prices for certificates are low. Therefore, it will probably not lead to the desired increase in RES in the recent future. Also the EU and their Member States have been very active to promote RES by setting themselves ambitious emission reduction targets and

implementing a wide set of policies and measures. Nevertheless, even they are very likely to fail their targets by 2010 and 2050.

In order to expect some fundamental changes in the energy mix until 2050, early actions promoting renewable energy technologies are required such as special policy measures and the creation of a renewable energy funds. Moreover to make use of the huge renewable energy potential in MENA, demonstration renewable energy projects are needed to show the reliability of the exiting technologies. In addition, R&D are indispensable to improve and spread existing technologies.

To make use of the Kyoto mechanisms the MENA countries which have not yet ratified the Kyoto Protocol have to ratify und set up their national authorities.

Finally, realistic energy scenarios are needed to give an indication of a realistic sustainable energy path our societies should follow. This will be the attempt of the following work packages.

2 Renewable Energy Technologies and Applications

The study focuses on concentrating solar thermal power generation because this is by far the greatest renewable energy resource in the EU-MENA region, but other renewable energy sources are represented as well, in order to obtain a well balanced mix of energies that can not only cope with the growing energy demand, but also with the needs of power security and grid stability. The renewable energy technology portfolio that was considered within the study is described in the following. An overview and comparison of all technologies is given in Table 2-3 and in the literature /BMU 2004-2/, /ECOSTAR 2004/, /NREL 2003/.

2.1 Concentrating Solar Thermal Power Technologies

Concentrating solar thermal power technologies (CSP) are based on the concept of concentrating solar radiation to be used for electricity generation within conventional power cycles using steam turbines, gas turbines or Stirling engines. For concentration, most systems use glass mirrors that continuously track the position of the sun. The concentrated sunlight is absorbed on a receiver that is specially designed to reduce heat losses. A fluid flowing through the receiver takes the heat away towards the power cycle, where e.g. high pressure, high temperature steam is generated to drive a turbine. Air, water, oil and molten salt are used as heat transfer fluids.

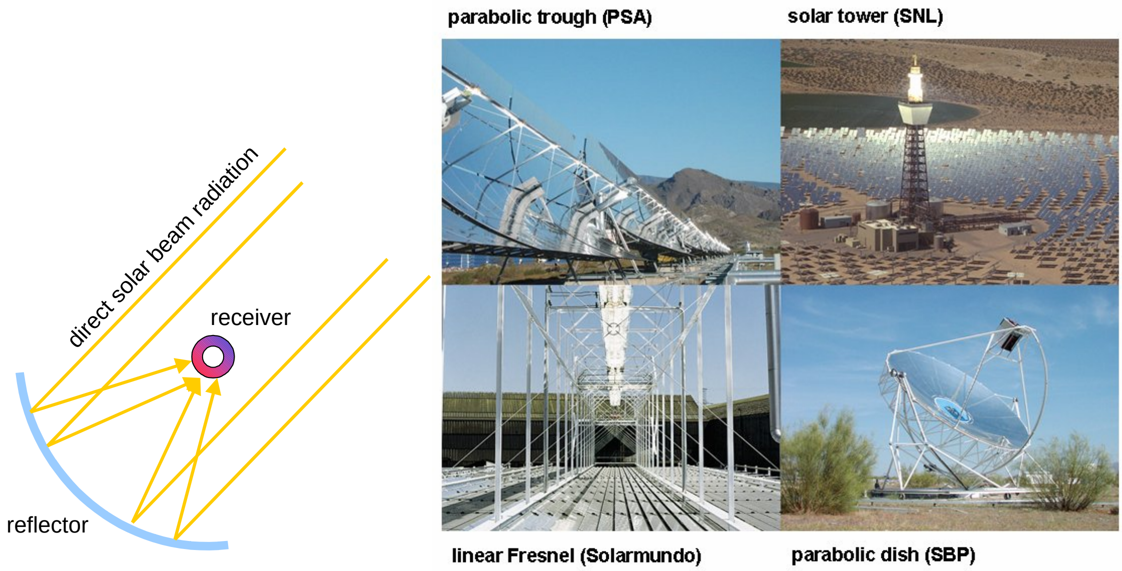


Figure 2-1: Principle of concentrating solar beam radiation and the four CSP collector technology main streams realised up to date (Sources: DLR, SNL, Solarmundo, SBP)

Parabolic troughs, linear Fresnel systems and power towers can be coupled to steam cycles of 5 to 200 MW of electric capacity, with thermal cycle efficiencies of 30 – 40 %. Dish-Stirling engines are used for decentralised generation in the 10 kW range. The values for parabolic troughs have been demonstrated in the field. Today, these systems achieve annual solar-to-electricity-efficiencies of about 10 – 15 %, with the perspective to reach about 18 % in the medium term (Table 2-1). The values for the other systems are based on component and prototype system test data and the assumption of mature development of current technology. The overall solar-electric efficiencies include the conversion of solar energy to heat within the

collector and the conversion of the heat to electricity in the power block. The conversion efficiency of the power block remains basically the same as in fuel fired power plants.

Power towers can achieve very high operating temperatures of over 1000 °C, enabling them to produce hot air for gas turbine operation. Gas turbines can be used in combined cycles, yielding very high conversion efficiencies of the thermal cycle of more than 50 %.

Each of these technologies can be operated with fossil fuel as well as solar energy. This hybrid operation has the potential to increase the value of CSP technology by increasing its power availability and decreasing its cost by making more effective use of the power block. Solar heat collected during the daytime can be stored in concrete, molten salt, ceramics or phase-change media. At night, it can be extracted from the storage to run the power block. Fossil and renewable fuels like oil, gas, coal and biomass can be used for co-firing the plant, thus providing power capacity whenever required (Figure 2-2).

	Capacity Unit MW	Concen-tration	Peak Solar Efficiency	Annual Solar Efficiency	Thermal Cycle Efficiency	Capacity Factor (solar)	Land Use m²/MWh/y
Trough	10 – 200	70 - 80	21% (d)	10 – 15% (d)	30 – 40 % ST	24% (d)	6 - 8
				17 – 18% (p)		25 – 90% (p)	
Fresnel	10 - 200	25 - 100	20% (p)	9 - 11% (p)	30 - 40 % ST	25 - 90% (p)	4 - 6
Power Tower	10 – 150	300 – 1000	20% (d)	8 – 10 % (d)	30 – 40 % ST	25 – 90% (p)	8 - 12
			35 % (p)	15 – 25% (p)	45 – 55 % CC		
Dish-Stirling	0.01 – 0.4	1000 – 3000	29% (d)	16 – 18 % (d)	30 – 40 % Stirl.	25% (p)	8 - 12
				18 – 23% (p)	20 – 30 % GT		

Table 2-1: Performance data of various concentrating solar power (CSP) technologies
(d) = demonstrated, (p) = projected, ST steam turbine, GT Gas Turbine, CC Combined Cycle. Solar efficiency = net power generation / incident beam radiation
Capacity factor = solar operating hours per year / 8760 hours per year

Moreover, solar energy can be used for co-generation of electricity and process heat. In this case, the primary energy input is used with efficiencies of up to 85 %. Possible applications cover the combined production of industrial heat, district cooling and sea water desalination.

All concepts have the perspective to expand their time of solar operation to base load using thermal energy storage and larger collector fields. To generate one Megawatt-hour of solar electricity per year, a land area of only 4 to 12 m² is required. This means, that one km^2 of arid land can continuously and indefinitely generate as much electricity as any conventional 50 MW coal - or gas fired power station.

Thus, two main characteristics make concentrating solar power a key technology in a future renewable energy supply mix in MENA:

- it can deliver secured power as requested by demand
- its natural resource is very abundant and practically unlimited

Their thermal storage capability and hybrid operation with fuels allows CSP plants to provide power on demand. Their availability and capacity credit is considered to be 90 %. CSP plants can be build from several kW to several 100 MW capacity.

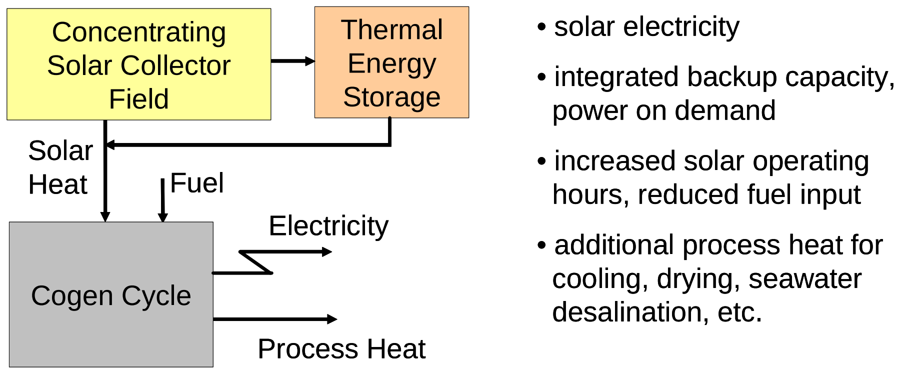


Figure 2-2: Principle of solar thermal co-generation of heat and power

Prospects of CSP Research and Development and Projects Ahead

While present parabolic trough plants use synthetic oil as heat transfer fluid within the collectors, and a heat exchanger for steam generation, efforts to achieve direct steam generation within the absorber tubes are underway in the DISS and INDITEP projects sponsored by the European Commission, with the aim to reduce costs and to enhance efficiency by 15-20% (Table 2-2). Direct solar steam generation has recently been demonstrated by CIEMAT and DLR on the Plataforma Solar in Almeria/ Spain, in a 500 m long test loop, providing superheated steam at 400 °C and 100 bar. All those R&D efforts aim at increasing efficiency and reducing costs.

A European industrial consortium has developed the new parabolic trough collector SKAL-ET, which aims to achieve better performance and cost by improving the mechanical structure and the optical and thermal properties of the parabolic troughs. Another European consortium has developed a simplified trough collector prototype with segmented flat mirrors following the principle of Fresnel.

The high temperatures available in solar towers can not only be used to drive steam cycles, but also for gas turbines and combined cycle systems. Such system promises up to 35 % peak and 25 % annual solar-electric efficiency when coupled to a combined cycle power plant. A solar receiver was developed within the European SOLGATE project for heating pressurised air by placing the volumetric absorber into a pressure vessel with a parabolic quartz window for solar radiation incidence. Multi-tower solar arrays may be arranged in the future so that the heliostat reflectors can alternatively point to various tower receivers. Like in other Fresnel systems, the horizontally arranged heliostats almost completely cover the land area and create a bright, semi-shaded space below for agricultural or other purposes.

A review of presently existing or developed CSP projects is given in Annex 9.

Table 2-2: **Selected CSP Technology Overview ***

Technology	**Experience**	**Next Step**	**Current Providers/Developers of the Solar Components**
Parabolic trough reflector with oil-cooled vacuum-isolated absorber tube in hybrid steam cycle power plant	SEGS I – IX , 354 MW installed between 1985 and 1991 in California, since then operating, steam generated in oil/steam heat exchangers at 370°C, 100 bar	50^+ MW projects under development in Israel and USA	Solel, Israel (design, absorber), Flagsol (Germany (reflectors)
Re-designed and up-scaled structure of oil-cooled parabolic trough for steam cycle operation	100 & 150 m units of SKAL-ET (up-scaled EuroTrough) collector integrated to SEGS VI in California since April 2003	2 x 50 MW project under development in Southern Spain	EuroTrough Consortium, Solarmillennium AG, Flagsol, Schlaich, Bergermann & Partner, Schott, Germany (reflectors, structure, absorber tube)
Direct steam generating parabolic trough	700 m DISS test-loop in Plataforma Solar de Almeria, Spain, direct steam generation demonstrated at 400 °C, 100 bar	Concept for a 5 MW demo plant under development (INDITEP project)	Iberinco, Initec, Ciemat, (Spain) Flagsol, DLR, ZSW (Germany)
Solar tower system with pressurised hot-air central receiver for solar gas turbine and combined cycle operation	240 kW gas turbine operated first time December 2002 at Plataforma Solar de Almeria, gas turbine operated at 800 °C, 8 bar, (SOLGATE project)	2 x 80 kW gas turbine co-generation system for electricity and cooling under construction in Italy	DLR (Germany), Esco Solar (Italy)
Solar tower system with un-pressurised volumetric hot-air receiver	3 $MW_{thermal}$ TSA project in 1996-1998, steam generated at 550 °C, 100 bar; new modular ceramic hot-air-receiver presently tested in the European. Solair Project	Receiver endurance test and concept development for a 2 MW prototype plant within the German Cosmosol project	Solucar, Ciemat (Spain), Heliotech (Denmark), DLR, Kraftanlagen München, (Germany)
Linear Fresnel collector with secondary concentrator and direct steam generating absorber tube	100 m prototype tested in Liege, Belgium, direct saturated steam generated at 275 °C Compact Linear Fresnel Reflector 1 MWth prototype installed in a steam cycle plant in Liddell in New South Wales, Australia	200 m test loop for superheated steam generation at Plataforma Solar, Spain Design and construction of a first 1 MWe pilot plant	FhG-ISE, PSE, DLR (Germany) Solar Heat & Power (Germany)

* only the existing plants in California and selected European main-stream activities are listed, RD&D of CSP technology is also taking place in other parts of the world, mainly USA and Australia (the famous solar tower test facility Solar 2 has been deactivated in the meantime). There is also parabolic trough development going on in Italy, however, the author had no reliable information on that.

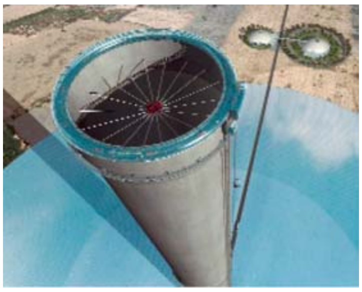
2.2 Renewable Energy Technology Options for Europe and MENA

The market potential of CSP plants must be seen in the context of other renewable energy technologies for power generation. In the following we show those options and how they are modelled within the study (Figure 2-3). A description of each technology can be found in /BMU 2004-3/.

Wind Power (Enercon)

Hydropower (Tauernkraft)

Solar Chimney (SBP)



Photovoltaic (NREL)

Hot Dry Rock (Stadtwerke Urach)

Biomass Power (NREL)

Figure 2-3: Renewable energy technologies considered in the MED-CSP study in addition to concentrating solar thermal power plants

Wind Power

Wind power can be generated in distributed wind power plants of up to 5 MW capacity each, or in large wind parks interconnecting tens or even hundreds of such plants. There are onshore and offshore wind parks, build into the sea where it is not deeper than 40 m. Wind power is typically fluctuating and cannot be delivered on demand. Wind power is stored for some seconds in the rotating mass of the wind turbines or as chemical or mechanical energy in batteries or large pump storage systems. There are also investigations on storing wind power in form of pressurized air. Fluctuations of the wind velocity are only correlated within a few kilometres of distance. Therefore, the fluctuations of a number of wind mills spread over a large area will usually compensate each other to some extend, leading to power supply transients that are quite manageable by the rest of the power park. However, their share on secured power capacity (capacity credit) is only between 0 and maximum 30 % of their installed capacity in very good areas with continuous trade winds /EWEA 2002/.

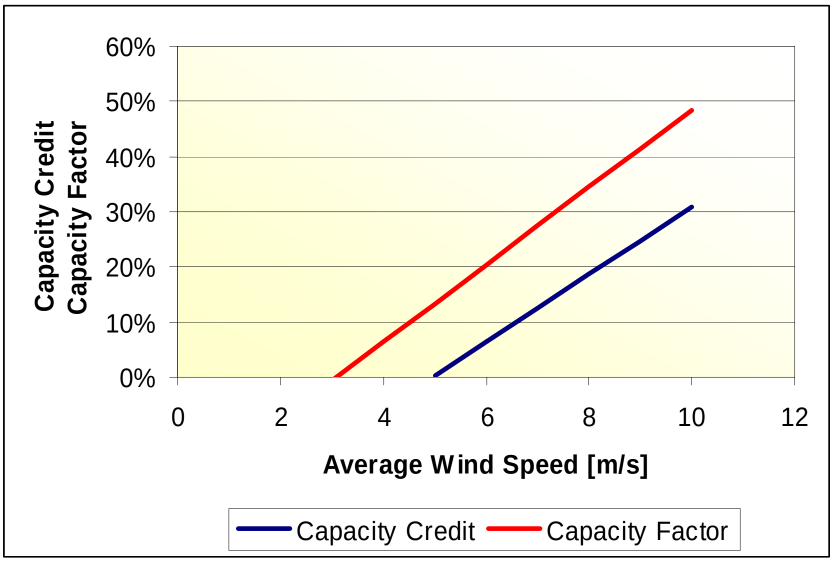


Figure 2-4: Capacity factor and capacity credit of wind power as function of the average wind speed derived from /EWEA 2002/ pp. 47 and from own calculations based on time series analysis

The technical performance of large wind power parks is modelled by the functions shown in Figure 2-4 that define their overall annual full load hours and their annual electricity yield. Even under optimum conditions with an average wind speed of 10 m/s, a large wind park will deliver only 50 % of its capacity over the year, and only 30 % as secured continuous contribution.

The electricity yield E_{wind} from wind power plants is calculated with the following equation, taking into consideration the capacity factor of the wind power park that is approximately a function of the average annual wind speed as shown in Figure 2-4:

$$E_{wind} = P_{wind} \cdot CF_{wind} \cdot 8760 \text{ h/y}$$

E_{wind}	Annual electricity yield from wind power [MWh/y]
CF_{wind}	Capacity factor as function of the average annual wind speed
P_{wind}	Installed wind power capacity [MW]
8760	represents the total hours per year

Photovoltaic Power

PV systems are typically used for distributed or remote power systems with or without connection to the utility grid. Their capacity ranges from a few Watt to several MW. Batteries are usually applied in smaller decentralized supply systems to store the solar energy over the night. There are also scenarios for very large PV systems up to 1.5 GW each to be built in desert areas until 2050 /IEA 2003-1/. Both small and large scale options have been included in the MED-CSP scenario, but only grid connected PV has been quantified in the renewable electricity mix. The electricity yield of PV systems is modelled as function of the global irradiance on a surface tilted at the respective latitude angle. PV cannot offer any secured capacity. Backup capacity must be provided by other technologies within the grid. Energy from

very large PV could be stored in pump storage systems. The annual capacity factor and the annual full load hours are defined by the annual solar irradiance and the relation of the annual mean system efficiency to the layout efficiency (q-factor). The q-factor is today typically 0.67 and expected to become 0.85 in the year 2050. This results in the performance functions shown for different annual irradiances in Figure 2-5.

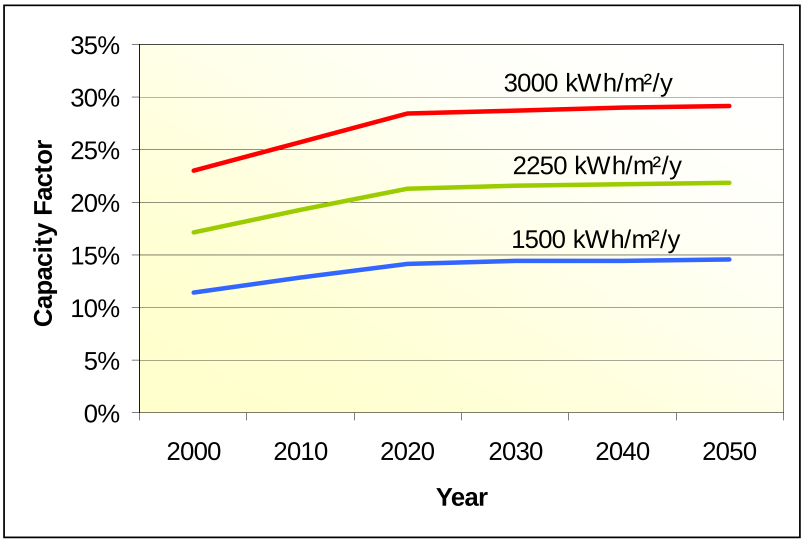


Figure 2-5: Capacity factor of grid-connected PV systems as function of global irradiance on a surface tilted at latitude angle and year of commissioning. There is no capacity credit for PV-power.

The electricity yield E_{PV} from photovoltaic systems is calculated with the following equation, taking into consideration the capacity factor of the PV power plants that is a function of the average annual irradiance on a tilted surface as shown in Figure 2-5:

$$E_{PV} = P_{PV} \cdot CF_{PV} \cdot 8760\ h/y$$

$$CF_{PV} = q_{PV} \cdot GTI \cdot \eta_{PV} \cdot A_{PV} / 8760\ h/y$$

E_{PV}	Annual electricity yield from photovoltaics [kWh/y]
CF_{PV}	Capacity factor as function of the annual global irradiance
P_{PV}	Installed photovoltaic power capacity [kW]
q_{PV}	annual system efficiency / standard design efficiency
GTI	Global irradiance on a tilted surface [kWh/m²/y]
η_{PV}	Annual PV system efficiency in first year (assumed as $\eta_{PV} = 0.1$)
A_{PV}	Design collector area for standard efficiency [m²/kW] ($A_{PV} = 10$ m²/kW)
8760	represents the total hours per year

Geothermal Power (Hot Dry Rocks)

Geothermal heat of over 200 °C can be delivered from up to 5000 m deep holes to operate organic Rankine cycles or Kalina cycle power machines. Unit sizes are about 1 MW today and limited to about 100 MW maximum in the future. Geothermal energy is often used for the co-generation of heat and power. Geothermal power plants are used all over the world where surface near geothermal hot water or steam sources are available, like in USA, Italy and the

Philippines. In the MED-CSP study region those conventional geothermal potentials are significant in Island, Italy, Turkey, Yemen and Iran. Those potentials are small in comparison to the HDR potentials and are not quantified separately in the study. The Hot Dry Rock technology aims to make geothermal potentials available everywhere, drilling deep holes into the ground to inject cold water and receive hot water from cooling down the hot rocks in the depth /IGA 2004/. However, this is a very new though promising approach and technical feasibility must still be proven. Geothermal power plants provide power on demand using the ideal storage of the earth's hot interior as reservoir. They can provide peak load, intermediate load or base load electricity. Therefore, the capacity factor of geothermal plants is defined by the load and their operation mode. Assuming a plant availability of 90 %, their capacity credit would have that same value.

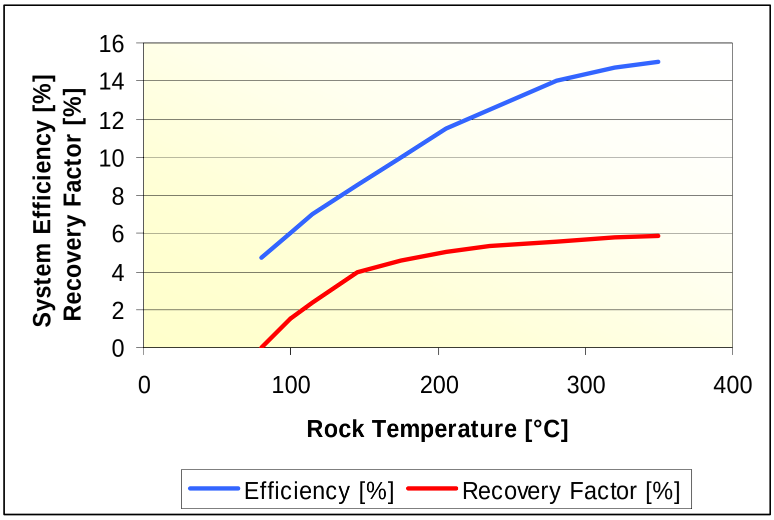


Figure 2-6: Efficiency (η) and recovery factor (R) of geothermal power schemes as function of temperature adapted from /TAB 2003/.

The available heat in place E_{th} is calculated as a function of the volume of rocks that will be affected by the cooling process /TAB 2003/. From that, the extracTable 2-geothermal electricity per year E_{geo} can be calculated as a function of the power cycle efficiency, the recovery factor and the total time of extraction. The recovery factor takes into account that only a small part of the affected rock volume is cooled down, and that the lower cycle temperature is higher than the surface temperature.

$$E_{th} = c_G \cdot \rho_G \cdot V \cdot (T_{5000} - T_{surface})$$

$$E_{geo} = E_{th} \cdot R \cdot \eta / t_{extract}$$

E_{th} Heat in place [J]

E_{el} ExtracTable 2-electricity [J/y]

c_G Spezific heat of the rocks [J/kg K]

ρ_G Density of the rocks [kg/m^3]

V Volume of rock affected [m^3]

T_{5000} Temperature of the rocks at 5000 m depth [°C]

$T_{surface}$ Surface Temperature [°C]
R Recovery Factor
η System Efficiency
$t_{extract}$ Extraction time [y]

For the study we have made the following assumptions:
$c_G = 840$ [J/kg·K], $\rho_G = 2600$ kg/m^3, $T_S = 10°C$, V = 1 km³, $t_{extract} = 1000$ years

Biomass Power (Waste and Wood)

There are a number of potential sources to generate energy from biomass: biogas can be produced by the decomposition of organic materials like municipal liquid waste, manure or agricultural residues. Biogas reactors usually require large quantities of water. The calorific value of biogas is about 6 kWh/m³. Biogas can be used in combustion engines or turbines for electricity generation and for co-generation of heat and power. Landfill gas can be used in a similar way.

Solid biomass from agricultural or municipal residues like straw or bagasse and from wood can be used to generate heat and power. From every ton of solid biomass about 1.5 MWh of heat or 0.5 MWh of electricity can be generated in steam cycle power plants.

There is also the possibility to raise energy crops. However, this option has been neglected in the MENA region due to their competition with food crops and the severe water supply situation.

The size of biomass plants ranges from some kW (combustion engines) to about 25 MW. Biomass can be stored and consumed on demand for power generation. However, there are often seasonal restrictions to the availability of biomass. Typical plants have capacity factors between 0.4 and 0.6 that are equivalent to 3500 – 5500 full load hours per year. They are usually operated to provide intermediate or peaking power but seldom for base load. The availability of biomass plants is high at 90 % and so is their capacity credit. This credit can be lower if the plants are used for co-generation of heat and power and if heat is the primary product. Electricity generation from biomass is calculated with the following equations:

$$E_{bio} = E_{mun} + E_{agr} + E_{wood}$$
$$E_{mun} = N \cdot w_{mun} \cdot e_{bio}$$
$$E_{agr} = w_{agr} \cdot e_{bio}$$
$$E_{wood} = p_{wood} \cdot A_{forest} \cdot e_{bio}$$

E_{bio} Electricity from biomass [MWh/y]
E_{mun} Electricity from municipal waste [MWh/y]
E_{agr} Electricity from agricultural residues [MWh/y]
E_{wood} Electricity from wood [MWh/y]
e_{bio} Specific electricity yield from biomass [MWh/ton]

w_{mun} Specific municipal waste production per capita [tons/capita/year]

w_{agr} Agricultural waste production [tons/year]

p_{wood} Biomass productivity [tons/ha/year]

A_{forest} Forest area of a country [ha]

N Urban population [persons]

For the study we have made the following assumptions: e_{bio} = 0.5 MWh/ton, w_{mun} = 0.35 ton/capita/year.

Hydropower

Hydropower is already used in many MENA countries. Plants range from large multi-Megawatt dams like Aswan to micro-hydropower schemes of several kW capacity. Hydropower is often submitted to seasonal fluctuations and especially in MENA, dry years often lead to hydropower shortages. There a run-of-river plants that provide power according to the available water flow. Dam storage power plants can provide power on demand and can be used to compensate the fluctuations of other renewable energies. In MENA hydropower is used mainly for peaking and intermediate load with 1000 to 4000 full load hours per year. Capacity factors are defined by the individual regional power demand and water resources. The Nile river is the most plentiful hydropower resource of the region. However, there are some indications that the hydropower potentials in the Southern Mediterranean region may be submitted to a reduction of up to 25 % in the course of this century due to climate change /Lehner et al. 2005/. Capacity credit and availability of hydropower plants are considered to be 90 %. Electricity generation from hydropower is well documented and thus taken from literature /WEC 2004/, /Horlacher 2003/.

$$E_{hydro} = P_{hydro} \cdot CF_{hydro} \cdot 8760\ h/y$$

E_{hydro} Annual electricity yield from hydropower plants [MWh/y]

CF_{hydro} Capacity factor (from existing hydropower plants of a country)

P_{hydro} Installed hydropower capacity [MW]

8760 represents the total hours per year

Concentrating Solar Thermal Power and Solar Chimneys

Concentrating solar thermal power plants with thermal energy storage and fuel co-firing can provide power on demand, with a capacity credit and availability of 90 % like conventional power plants. Electricity generation is a function of their capacity factor which is defined by the demand. The plants are operated in accordance with the rest of the renewable energy mix in order to minimize the gap between the load and the renewable electricity supply.

The electricity yield E_{CSP} from solar thermal power plants is calculated with the following equation, taking into consideration the capacity factor that is defined by the load. The solar

share is steadily increased and the fossil share reduced, by increasing the solar collector field and storage capacities.

$$E_{CSP} = P_{CSP} \cdot CF_{CSP} \cdot 8760 = E_{solar} + E_{fossil}$$

E_{CSP} Annual electricity yield [MWh/y]
E_{solar} Annual solar electricity yield [MWh/y]
E_{fossil} Annual fossil electricity yield [MWh/y]
CF_{CSP} Capacity factor as function of load
P_{CSP} Installed capacity [MW]
8760 represents the total hours per year

Solar chimneys are also considered as solar thermal power plants, though not concentrating. They consist of a very large glass or plastic roof with a chimney in its centre. The air underneath the glass roof is heat and by its lower weight forced into the chimney, where it activates a wind turbine for power generation. They can be built in the range of 100 - 200 MW capacity. Heat can be stored in the soil and in water storage below the collector for night-time operation. They cannot be used for co-generation of electricity and heat. Hybrid operation with fuels is not possible. There availability and capacity credit is considered 90 %. They are suited for base load and intermediate power. Solar chimney potentials are considered part of the solar thermal power potential and are not quantified separately.

Conventional Power

The MED-CSP study also looks at conventional power technologies as possible alternative or complement to a sustainable energy supply. The availability and capacity credit of all conventional systems is assumed to be 90 %. They provide power on demand with different capacity factors. All thermal plants can be used for co-generation of electricity and heat.

- **Oil and Gas fired Power Plants**

  Oil and gas can be used in steam cycle, gas turbine or combined cycle power plants. They are built in all capacity classes from several kW to several 100 MW. The can provide peak, intermediate and base load.

- **Coal Steam Plants**

  Only a few countries in MENA use coal fired steam cycles. Coal must be imported. Capacities range from some 10 to several 100 MW. Due to the long start-up time and the relatively high investment cost, they are only applied in the intermediate and base load segment.

- **Nuclear Fission and Fusion**

  Nuclear plants use nuclear fission processes to generate steam for steam turbines. There is intensive research on nuclear fusion aiming at providing first results in terms of a first

power plant in the year 2050 or beyond. Projected units sizes are in the GW capacity range. Due to their high investment cost, they are only applied in the base load segment.

2.3 Renewable Energy Applications

Electricity Generation

All the technologies investigated within this study can be used for electricity generation. Only biomass, hydropower, geothermal power, solar thermal and conventional power plants can deliver electricity on demand. Photovoltaic systems, micro-hydropower, wind power, biogas motor generators and dish-Stirling engines are specially suited for decentralized and remote electricity generation. In the quantification of market potentials in our scenario we do not distinguish between centralised, grid-connected power and remote systems. Both centralized and decentralized systems have considerable market potentials and will complement each other rather than compete.

Combined Generation of Electricity and Heat

All thermo-electric systems like biomass, geothermal, solar thermal and conventional plants can be used for co-generation of electricity and heat (see Annex 10 for examples).

- **Seawater Desalination**

Electricity can be used for seawater desalination by reverse osmosis, while co-generated heat can be applied to multi-effect, vapour compression and multi-stage flash thermal desalination plants. Also combinations are possible. Thermal seawater desalination uses input steam with a temperature range between 70 – 110 °C.

- **Cooling**

Electricity can be used directly in conventional mechanical compression chillers for air conditioning, cooling and refrigeration. Co-generated heat can be applied to drive vapour absorption chillers. Vapour absorption chillers use input steam with a temperature between 120 – 180 °C. Concentrating solar power has also been directly applied to provide cooling and air conditioning for a Hotel in Turkey.

- **Industrial Process Heat**

Industrial process heat in form of steam or hot air in the temperature range of 50 - 300 °C can be delivered by all thermal systems that are capable of co-generation. It is particularly efficient to cascade the use of heat at different temperature levels.

- **Integrated Systems and Multipurpose Plants**

The collectors of some CSP systems provide shaded areas that could be used for purposes like greenhouse, chicken farm, parking etc. Integrated systems that use power, desalted water and shade for generating a new environment for farming in desert regions could become feasible in the future as countermeasure to desertification and loss of arable land. This requires more investigation on the possibilities and restrictions of such systems (Annex 10).

	Unit Capacity	Capacity Credit	Capacity Factor	Resource	Applications	Comment
Wind Power	1 kW – 5 MW	0 – 30 %	15 – 50 %	kinetic energy of the wind	electricity	fluctuating, supply defined by resource
Photovoltaic	1 W – 5 MW	0 %	15 – 25 %	direct and diffuse irradiance on a fixed surface tilted with latitude angle	electricity	fluctuating, supply defined by resource
Biomass	1 kW – 25 MW	50 - 90 %	40 – 60 %	biogas from the decomposition of organic residues, solid residues and wood	electricity and heat	seasonal fluctuations but good storability, power on demand
Geothermal (Hot Dry Rock)	25 – 50 MW	90 %	40 – 90 %	heat of hot dry rocks in several 1000 me-ters depth	electricity and heat	no fluctuations, power on demand
Hydropower	1 kW – 1000 MW	50 - 90 %	10 – 90 %	kinetic energy and pressure of water streams	electricity	seasonal fluctuation, good storability in dams, used also as pump storage for other sources
Solar Chimney	100 – 200 MW	10 to 70 % depend-ing on storage	20 to 70 %	Direct and diffuse irradiance on a hori-zontal plane	electricity	seasonal fluctua-tions, good storabil-ity, base load power
Concentrating So-lar Thermal Power	10 kW – 200 MW	0 to 90 % depending on storage and hy-bridisation	20 to 90 %	Direct irradiance on a surface tracking the sun	electricity and heat	fluctuations are compensated by thermal storage and fuel, power on de-mand
Gas Turbine	0.5 – 100 MW	90 %	10 – 90 %	natural gas, fuel oil	electricity and heat	power on demand
Steam Cycle	5 – 500 MW	90 %	40 – 90 %	coal, lignite, fuel oil, natural gas	electricity and heat	power on demand
Nuclear	1000 MW	90 %	90 %	uranium	electricity and heat	base load power

Table 2-3: Some characteristics of contemporary power technologies

3 Renewable Energy Resources in EU-MENA

The renewable energy resources in the Euro-Mediterranean region were assessed on the basis of spatial information available from different sources described later in this chapter. The direct normal irradiance (DNI) used by concentrating solar power systems was assessed by DLR's high resolution satellite remote sensing system /SOLEMI 2004/, while the data for the other renewable energies was taken from materials kindly provided by the renewable energy scientific community. We have taken into consideration the following renewable energy resources for power generation:

- Direct Solar Irradiance on Surfaces Tracking the Sun (Concentrating Solar Thermal Power Plants)
- Direct and Diffuse (Global) Solar Irradiance on a Fixed Surface tilted South according to the Latitude Angle (Photovoltaic Power)
- Wind Speed (Onshore and Offshore Wind Power Plants)
- Hydropower Potentials from Dams and River-Run-Off Plants
- Heat from Deep Hot Dry Rocks (Geothermal Power)
- Biomass from Municipal and Agricultural Waste and Wood
- Wave and Tidal Power

Both the technical and economic potentials were defined for each renewable energy resource and for each country. The **technical potentials** are those which in principle could be accessed for power generation by the present state of the art technology (Table 3-1). For each resource and for each country, a **performance indicator** was defined that represents the average renewable energy yield with which the national potential could be exploited (Table 3-2). The **economic potentials** are those with a sufficiently high performance indicator that will allow new plants in the medium and long term to become competitive with other renewable and conventional power sources, considering their potential technical development and economies of scale as described in Chapter 2.

The renewable energy potentials for power generation differ widely in the countries analysed within this study. Altogether they can cope with the growing demand of the developing economies in MENA. The economic wind, biomass, geothermal and hydropower resources amount each to about 400 TWh/y. Those resources are more or less locally concentrated and not available everywhere, but can be distributed through the electricity grid, which will be enforced in the future in line with the growing electricity demand of this region. The by far biggest resource in MENA is solar irradiance, with a potential that is by several orders of magnitude larger than the total world electricity demand. The solar energy irradiated on the ground equals 1 – 2 barrels of fuel oil per square meter and year. This magnificent resource can be used both in distributed photovoltaic systems and in large central solar thermal power stations. Thus, both distributed rural and centralised urban demand can be covered by renewable energy technologies.

The **accuracy** of a global resource assessment of this kind cannot be better than ± 30 % for individual sites as it depends on many assumptions and simplifications. However it gives a first estimate of the order of magnitude of the renewable energy treasures available in Europe and MENA.

Table 3-1: Technical and Economic Renewable Electricity Supply Side Potentials in TWh/year

	Hydro		Geo		Bio		CSP		Wind		PV		Wa/Ti	
	Tech.	Econ.	Tech.	Econ.	Tech.	Econ.	Tech.	Econ.	Tech.	Econ.	Tech.	Econ.	Tech.	Econ.
Bahrain	5.0	n.a.	n.a.	n.a.	n.a.	0.2	36	33	n.a.	0.1	n.a.	0.3	n.a.	n.a.
Cyprus	24.0	1.0	n.a.	n.a.	n.a.	0.5	23	20	10.0	0.5	n.a.	0.2	n.a.	0.2
Iran	88.0	48.0	n.a.	11.3	n.a.	23.7	>	20000	n.a.	8.0	n.a.	16.0	n.a.	n.a.
Iraq	90.0	67.0	n.a.	n.a.	n.a.	8.6	30806	28647	300.0	10.0	n.a.	6.8	n.a.	n.a.
Israel	44.0	7.0	n.a.	n.a.	n.a.	2.2	318	318	22.0	0.5	n.a.	4.0	n.a.	n.a.
Jordan	n.a.	0.1	n.a.	n.a.	n.a.	1.6	6434	6429	109.0	2.0	n.a.	4.5	n.a.	n.a.
Kuwait	n.a.	n.a.	n.a.	n.a.	n.a.	0.8	1525	1525	n.a.	n.a.	n.a.	2.5	n.a.	n.a.
Lebanon	2.0	1.0	n.a.	n.a.	n.a.	0.8	19	14	9.0	0.2	n.a.	1.5	n.a.	n.a.
Oman	n.a.	n.a.	n.a.	n.a.	n.a.	1.1	20611	19404	44.0	8.0	n.a.	4.1	n.a.	n.a.
Qatar	n.a.	n.a.	n.a.	n.a.	n.a.	0.1	823	792	n.a.	n.a.	n.a.	1.0	n.a.	n.a.
Saudi Arabia	n.a.	n.a.	n.a.	70.9	n.a.	9.9	125260	124560	300.0	20.0	n.a.	13.9	n.a.	n.a.
Syria	7.0	4.0	n.a.	n.a.	n.a.	4.7	10777	10210	98.0	12.0	n.a.	8.5	n.a.	n.a.
UAE	n.a.	n.a.	n.a.	n.a.	n.a.	0.7	2078	1988	n.a.	n.a.	n.a.	3.0	n.a.	n.a.
Yemen	n.a.	n.a.	n.a.	107.0	n.a.	9.1	5143	5100	8.0	3.0	n.a.	25.8	n.a.	n.a.
Algeria	5.0	0.5	n.a.	4.7	n.a.	12.1	169440	168972	7278	35.0	n.a.	13.9	n.a.	n.a.
Egypt	80.0	50.0	n.a.	25.7	n.a.	15.3	73656	73656	7650	90.0	n.a.	36.0	n.a.	n.a.
Libya	n.a.	n.a.	n.a.	n.a.	n.a.	1.7	139600	139477	5363	15.0	n.a.	3.9	n.a.	n.a.
Morocco	5.0	4.0	n.a.	10.0	n.a.	14.3	20151	20146	1188	25.0	n.a.	17.0	n.a.	n.a.
Tunisia	1.0	0.5	n.a.	3.2	n.a.	3.2	9815	9244	50.0	8.0	n.a.	5.0	n.a.	n.a.
Greece	25.0	12.0	n.a.	4.7	n.a.	11.8	44	4	136.0	15.0	n.a.	4.0	n.a.	4.0
Italy	105.0	54.0	n.a.	9.8	n.a.	86.4	88	7	223.0	60.0	n.a.	10.0	n.a.	3.0
Malta	n.a.	n.a.	n.a.	n.a.	n.a.	0.2	2	2	n.a.	0.2	n.a.	0.1	n.a.	0.1
Portugal	33.0	20.0	n.a.	7.0	n.a.	26.6	436	142	63.0	20.0	n.a.	3.0	n.a.	7.0
Spain	70.0	41.0	n.a.	9.4	n.a.	111.1	1646	1278	226.0	60.0	n.a.	5.0	n.a.	13.0
Turkey	216.0	122.0	n.a.	150.0	n.a.	55.0	405	131	200.0	55.0	n.a.	28.6	n.a.	n.a.
Total		**432**		**414**		**402**		**632099**		**447**		**218**		**27**

Remarks:	Hydro	Geo	Bio	CSP	Wind	PV	Wa/Ti
	well documented resource taken from literature	from 5000 m temperature map considering areas with T>180°C as economic	from agricultural (bagasse) and municipal waste and renewable solid biomass potentials	from DNI and CSP site mapping taking sites with DNI > 2000 kWh/m²/y as economic	from wind speed and site mapping taking sites with a yield > 14 GWh/y and from literature (EU)	No information except for EU. General PV growth rates used for calculation	No information except for EU mid term economic potentials

Table 3-2: Renewable Electricity Performance Indicators. They define the representative average renewable electricity yield of a typical facility in each country.

	Hydro	Geo	Bio	CSP	Wind	PV	Wa/Ti
	Full Load Hours per Year	Temperature at 5000 m Depth	Full Load Hours per Year	Direct Normal Irradiance	Full Load Hours per Year	Global Horizontal Irradiance	Full Load Hours per Year
	h/y	°C	h/y	kWh/m²/y	h/y	kWh/m²/y	h/y
Bahrain	1000	100	3500	2050	1360	2160	4000
Cyprus	1000	100	3500	2200	1666	2100	4000
Iran	1351	295	3500	2200	1176	2010	4000
Iraq	2500	100	3500	2000	1789	2050	4000
Israel	1429	100	3500	2400	1176	2320	4000
Jordan	1667	100	3500	2700	1483	2310	4000
Kuwait	0	100	3500	2100	1605	1900	4000
Lebanon	1681	100	3500	2000	1176	1920	4000
Oman	0	100	3500	2200	2463	2050	4000
Qatar	0	100	3500	2000	1421	2140	4000
Saudi Arabia	0	275	3500	2500	1789	2130	4000
Syria	1606	100	3500	2200	1789	2360	4000
UAE	0	100	3500	2200	1176	2120	4000
Yemen	0	295	3500	2200	1483	2250	4000
Algeria	1000	213	3500	2700	1789	1970	4000
Egypt	4875	180	3500	2800	3015	2450	4000
Libya	100	100	3500	2700	1912	1940	4000
Morocco	1232	281	3500	2600	2708	2000	4000
Tunisia	1017	188	3500	2400	1789	1980	4000
Greece	1334	213	3500	2000	2218	1730	4000
Italy	2502	200	3500	2000	1605	1800	4000
Malta	0	100	3500	2000	1666	2150	4000
Portugal	2589	213	3500	2200	2095	1910	4000
Spain	1705	213	3500	2250	2463	2000	4000
Turkey	2762	281	3500	2000	2218	1900	4000

3.1 Resources for Concentrating Solar Power

In the initial proposal we planned to use data from the ECMWF and NCAR/NCEP based on the space missions of the NOAA satellite of NASA to derive solar energy potentials. This data has a time resolution of 3 hours and a geographic resolution of approximately 1 degree (Longitude and Latitude) and are available on a global level. However, taking into account the great importance of concentrating solar power systems derived from the study results, the accuracy and resolution of this data set was not satisfactory. Therefore, we decided to apply a high resolution, highly accurate method developed at DLR as in-kind contribution to the study (ref. Annex 11 for abbreviations).

This method models in detail the optical transparency of the atmosphere to calculate the **Direct Normal Irradiance (DNI)** on the ground, by quantifying those atmospheric components that absorb or reflect the sunlight, like clouds, aerosols, water vapour, ozone, gases and other. Most of this information is derived from satellite remote sensing /SOLEMI 2004/.

Weather satellites like Meteosat-7 from the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) are geo-stationary satellites at a distance of 36,000 km at a fix point over the globe that send half-hourly images for weather forecasting and other purposes. From those images, the optical thickness of clouds can be derived obtaining half-hourly cloud values for every site. Of all atmospheric components, clouds have the strongest impact on the direct irradiation intensity on the ground. Therefore, the very high spatial (5 x 5 km) and temporal (0.5 hour) resolution provided by METEOSAT is required for this atmospheric component.

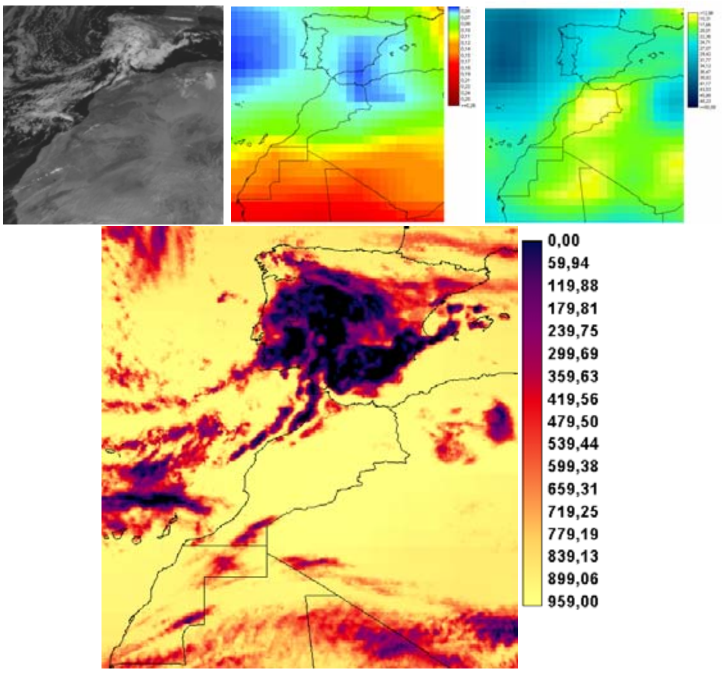


Figure 3-1: Original image from METEOSAT 7 (top left), aerosol content from GACP (top centre), water vapour content from NCAR-NCEP (top right) and resulting map of the hourly Direct Normal Irradiance (bottom) in W/m² for the Iberian Peninsula and the Maghreb Region on February 7, 2003, 12:00 /SOLEMI 2004/.

Aerosols, water vapour, ozone etc. have less impact on solar irradiation. Their atmospheric content can be derived from several orbiting satellite missions like NOAA and from re-

analysis projects like GACP or NCEP/NCAR and transformed into corresponding maps/layers of their optical thickness. The spatial and temporal resolution of these data sets can be lower than that of clouds. The elevation above sea level also plays an important role as it defines the thickness of the atmosphere. It is considered by a digital elevation model with 1 x 1 km spatial resolution. All layers are combined to yield the overall optical transparency of the atmosphere for every hour of the year. Knowing the extraterrestrial solar radiation intensity and the varying angle of incidence, the direct normal irradiation can be calculated for every site and for every hour of the year. Electronic maps and GIS data of the annual sum of direct normal irradiation can now be generated as well as hourly time series for every single site. The mean bias error of the annual sum of direct normal irradiation - which is decisive for economic assessment - is usually in the order of ± 5 %. More information can be found at the web sites www.dlr.de/steps , www.solemi.com and http://swera.unep.net .

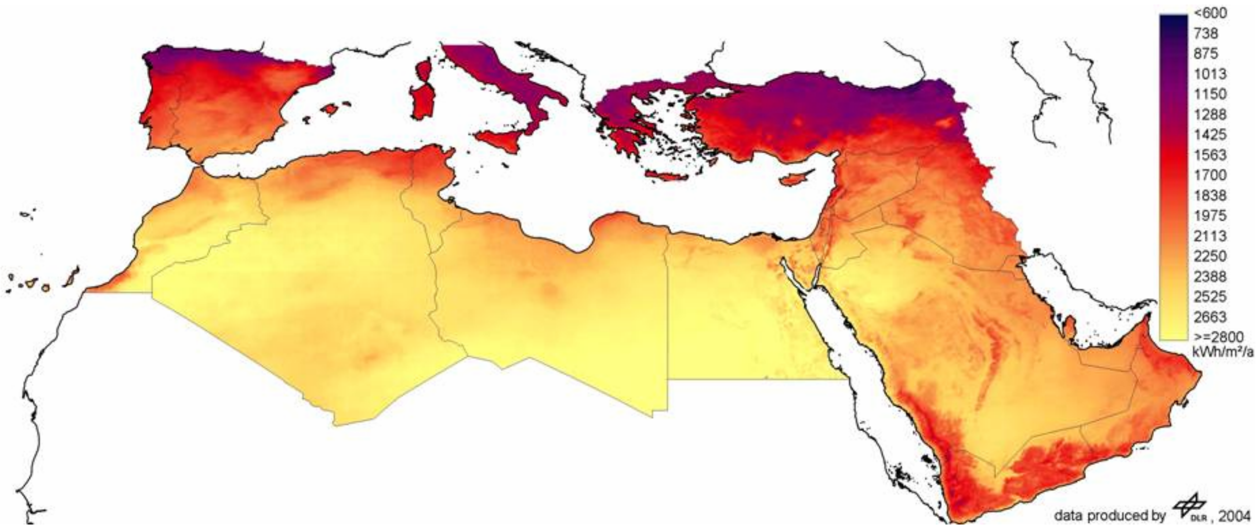


Figure 3-2: Annual Direct Normal Irradiance of the year 2002

The analysis was performed for the countries shown in Figure 3-2 for the year 2002. A one-year basis is not sufficient for the development of large CSP projects, as the annual climatic fluctuations can be in the range of ± 15 %. For project development purposes, at least 5-15 years of data should be processed. However, for the assessment of national solar electricity potentials and their geographic distribution, this basis is good enough, especially because in most MENA countries, the total solar energy potential is some orders of magnitude higher than the demand.

The next step is the detection of land resources which allow for the placement of the concentrating solar collector fields. This is achieved by excluding all land areas that are unsuitable for the erection of solar fields due to ground structure, water bodies, slope, dunes, protected or restricted areas, forests, agriculture etc. Geographic features are derived from remote sensing data and stored in a geographic information system (GIS). Finally, those data sets are combined to yield a mask of exclusion criteria for a complete region or country (Figure 3-3). The remaining sites are in principle potential CSP project sites with respect to the exclusion criteria applied (Table 3-3).

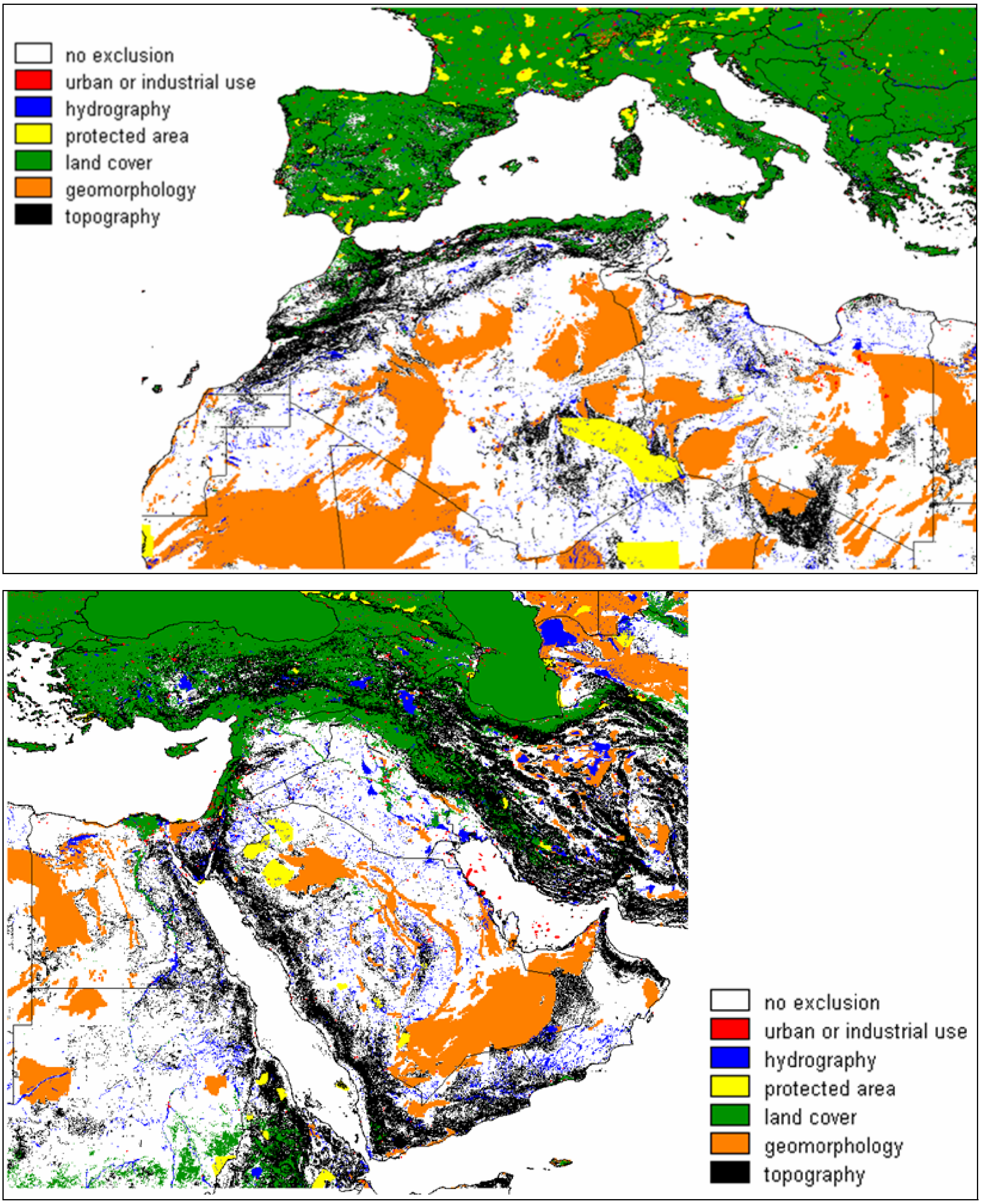


Figure 3-3: Exclusion Areas for Concentrating Solar Thermal Power Plants

The data was used to generate maps of DNI at the remaining sites for each country. Those maps were statistically analysed yielding the number of sites available in each country with a certain direct normal irradiance (Figure 3-4). From this information, the potential solar electricity yield for every class of solar irradiance was calculated, defining the **technical potential** of CSP of each country (Figure 3-5). Solar electricity potentials were calculated from the annual DNI with a conversion factor of 0.045, which takes into account an average annual efficiency of 15 % and a land use factor of 30 % for CSP technology (ref. Chapter 2). This is state of the art for parabolic troughs and thus a very conservative assumption.

Exclusion Criteria for CSP Plants	**compulsive**	**optional**
Slope of Terrain		
> 2,1 %	x	
Land Cover		
Sea	x	
Inland Water	x	
Forest		x
Swamp	x	
Agriculture		x
Rice Culture		x
Hydrology		
Permanent Inland Water	x	
Non-Permanent Inland Water		x
Regularly Flooded Area		x
Geomorphology		
Shifting Sand, Dunes	x	
Security Zone for Shifting Sands 10 km		x
Salt Pans		x
Glaciers	x	
Security Zone for Glaciers		x
Land Use		
Settlement		x
Airport		x
Oil or Gas Fields		x
Mine, Quarry		x
Desalination Plant		x
Protected Area, Restricted Area		x

Table 3-3: Compulsive and optional criteria for the exclusion of terrain for CSP plants. Within the MED-CSP study, all criteria were applied for the site exclusion of CSP.

Although CSP generation is possible at lower values a threshold of 1800 kWh/m²/y of annual direct normal irradiance was assumed to define the overall technical potential of CSP. The results of a detailed analysis for all countries within the MED-CSP study are given in the Annex of this chapter. The **economic potential** was considered to be limited by a DNI of 2000 kWh/m²/y. This is an adequate threshold to achieve in the medium term solar electricity costs competitive with conventional and other renewable energy sources for power generation (ref. Chapter 5).

The **coastal potential** of CSP was investigated separately excluding additionally all sites located higher than 20 meters above sea level and far away from the seashore. This potential was used to estimate the potential areas for combined electricity generation and seawater desalination with concentrating solar power plants.

The results of all countries are given in Annex 1.

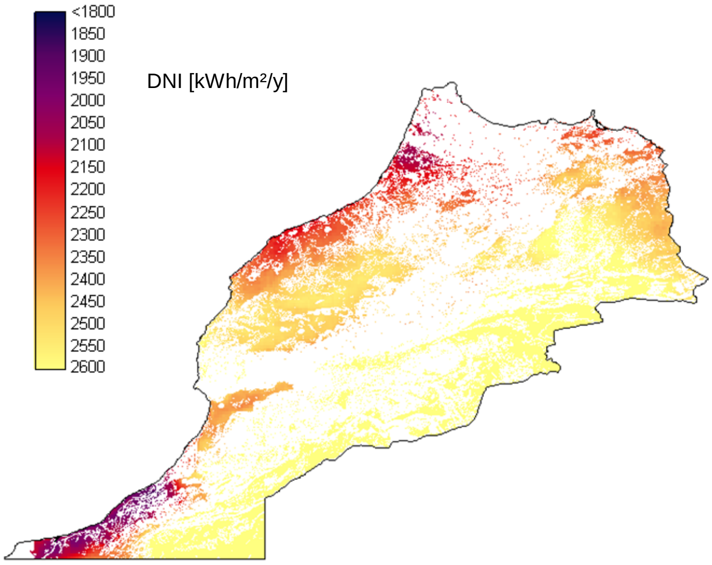


Figure 3-4: Annual Direct Normal Irradiance of the year 2002 on non-excluded areas in Morocco

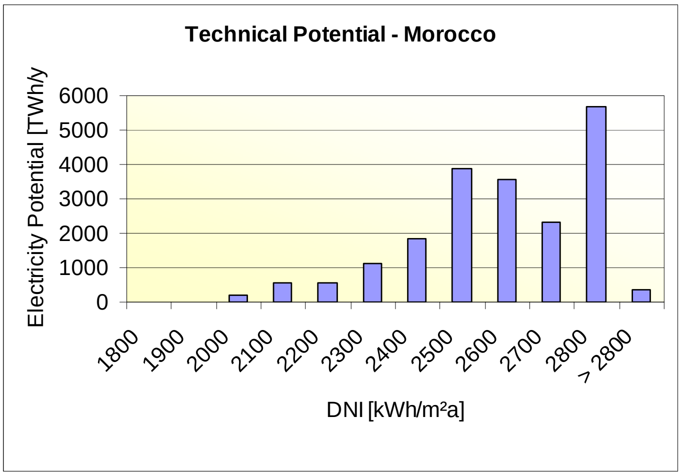


Figure 3-5: Technical solar thermal power potentials in Morocco distributed to different classes of Direct Normal Irradiance.

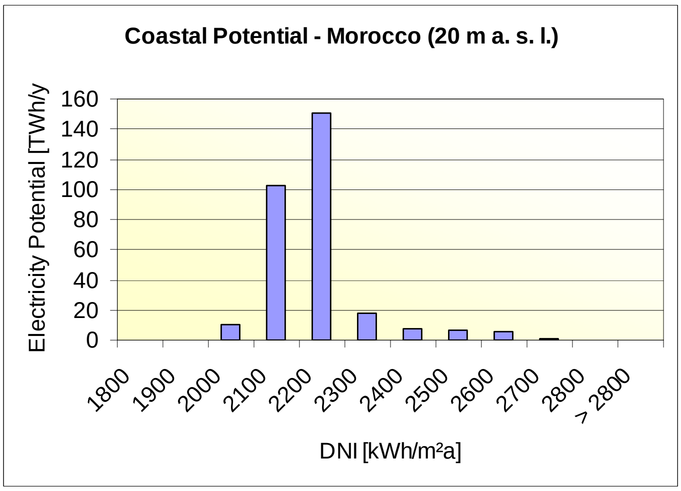


Figure 3-6: Coastal solar thermal electricity potentials in Morocco by classes of Direct Normal Irradiance for sites at the seashore with an elevation of less than 20 meters above sea level.

3.2 Other Renewable Energy Resources

Hydropower

The national technical and economic hydropower potentials were taken from the literature /WEC 2004/, /Horlacher 2003/. The annual full load hours are used as performance indicator. They were calculated from the installed capacity and the annual electricity generation of the plants installed at present in each country /Enerdata 2004/. The map of gross hydropower potentials illustrates the geographic distribution of the hydropower potentials (Figure 3-7).

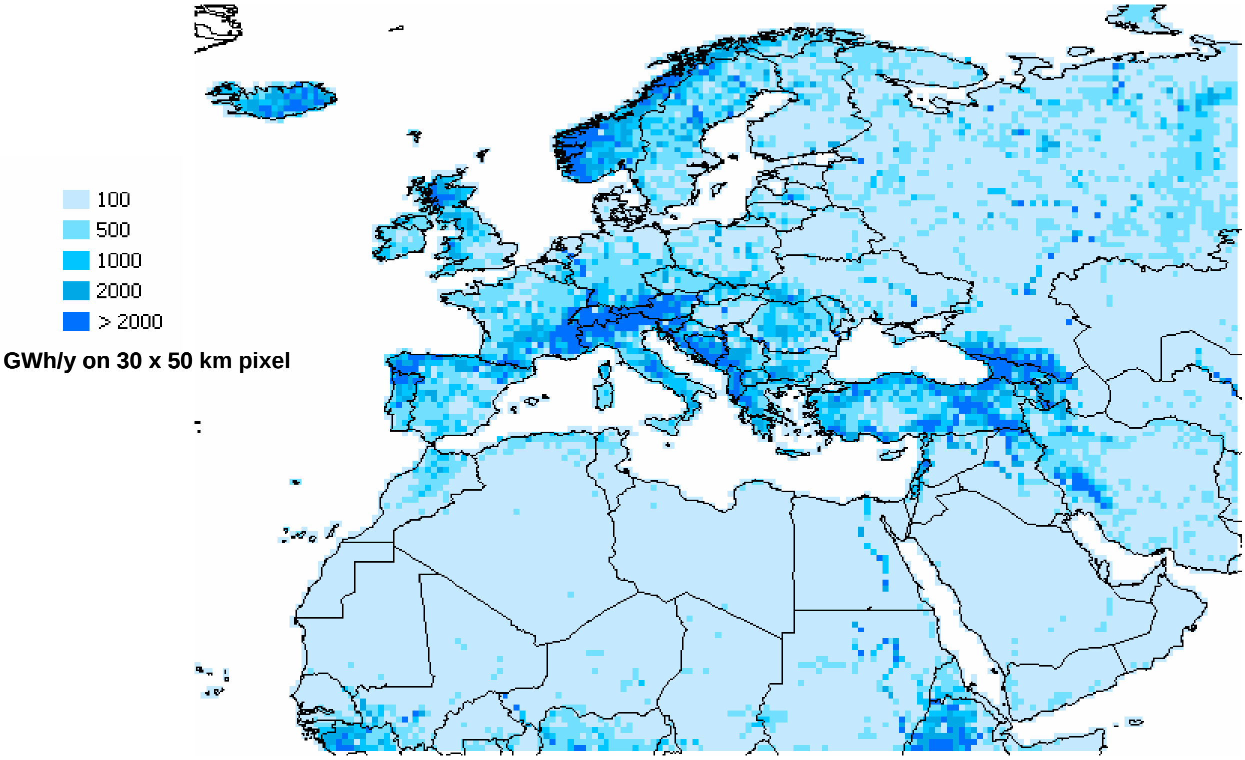


Figure 3-7: Gross Hydropower Potentials in EU-MENA adapted from /Lehner et al. 2005/

The total economic hydropower potential of all countries analysed within the study is 432 TWh/y. In the year 2000, about 70 GW of hydropower were installed, producing 155 TWh/y of electricity.

There is certain evidence that climate change is possibly having an increasing impact on hydropower generation with the possibility of reductions of up to 25 % in the long term in the Southern Mediterranean countries /Bennouna 2004/, /Lehner et al. 2005/. Although we have not quantified such impacts in the study we believe that this is a serious concern that should be taken into account in energy planning. Efficiency of hydropower use should be enhanced systematically in order to counteract at least partially such effects.

Geothermal Power

Considerable conventional geothermal resources are available in Italy (already used to a great extent), Turkey and Yemen. Conventional geothermal resources were taken from literature /GEA 2004/. For Europe, medium term geothermal power potentials from literature were taken for cross-checking /EU 2004/.

A map of subsoil temperatures at 5000 m depth was taken to assess the total areas with temperatures higher than 180°C as economic potential for Hot Dry Rock technology. It was assumed that a layer with 1 km thickness in 5000 m depth was used as heat reservoir /BMU 2003-2/, /GGA 2000/. The total heat in place was then calculated from the volume with a certain temperature range available in a country according to the equation given in chapter 1. The technical HDR potential for temperatures below 180 °C was not assessed.

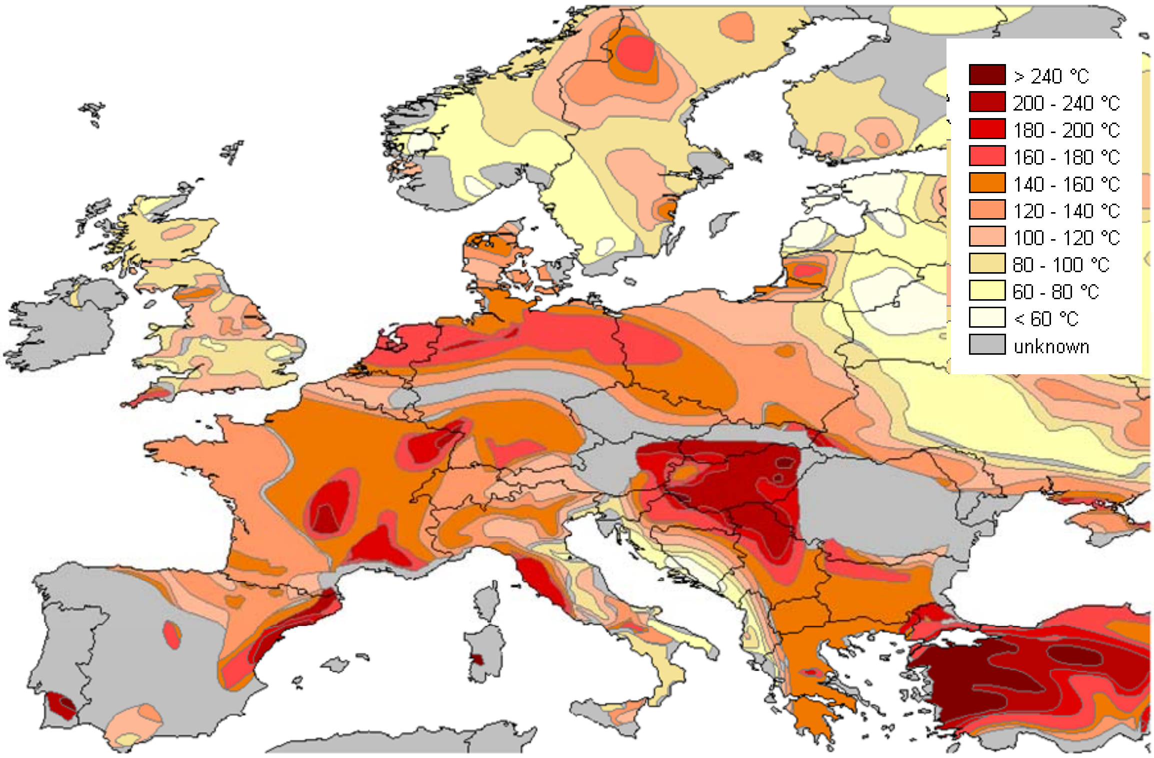


Figure 3-8: Temperature at 5000 m Depth for Hot Dry Rock Geothermal Power Technology /BESTEC 2004/

The temperature at 5000 m depth was used as performance indicator. With that information, the efficiency and the specific investment cost (Inv) of a HDR plant was compared with that of a reference plant and calculated according to the following equation, using a scaling exponent of 0.7:

$$Inv = Inv_{Reference} \cdot (\eta_{Reference}/\eta)^{0.7}$$

The efficiency of the power cycle η was taken as a function of the borehole temperature from Figure 3-8 in chapter 2. The data of the reference plant was taken from /ANU 2003/.

The annual electricity that can be generated from Hot Dry Rocks depends on the heat in place and the time of extraction. That time was assumed to be 1000 years in order to ensure that the geothermal potentials can be renewed within this time span. At such a slow pace, the geothermal power potentials can be considered as renewable energies that could be used continuously without limitations in time like the other renewable energy sources.

In the year 2000 about 600 MW of conventional geothermal power capacity was installed in the analysed countries producing 4.6 TWh/y of electricity. The total economic potential was estimated to be around 400 TWh/y, which is however a quite rough and conservative estimate.

Electricity from Biomass

The electricity potential of municipal waste, solid biomass (wood) and agricultural residues was calculated according to the equations given in Chapter 2

From the literature, **agricultural residues** like e.g. bagasse, which at present are mainly unused for power purposes were taken as reference /WEC 2004/. An electricity conversion factor of 0.5 MWh/ton of biomass was assumed for the calculation of the potential electricity yield from agricultural waste biomass. It was assumed that 80 % of this potential will be used in 2050. A possible increase or reduction in agricultural biomass production was neglected. The results are summarized in Table 3-4.

The amount of potentially available **municipal waste** was calculated in proportion to the growing urban population in each country. The growth of population was taken from the UN medium growth model scenario that will be described in more detail in Chapter 4. Due to growing urban population, the biomass potential from municipal waste grows steadily with the years. We have assumed a constant municipal waste productivity of 0.35 ton/cap/year and a waste-to-electricity conversion factor of 0.5 MWh/ton. 80 % of this potential was estimated to be used until 2050.

Solid biomass (mainly wood) potentials were assessed from a global map of biomass productivity in tons/ha/year and from the existing forest areas of each country (Figure 3-9 and Figure 3-10). A possible change of the productivity or forest areas in the future has been neglected. Results were cross-checked for plausibility with historical data from European countries /WEC 2004/. There will be a competition with traditional fuel wood use in most MENA countries which must be taken into consideration. Therefore, the rate of use of the fuel wood potential was assumed to be 40 % only until 2050. Annual full load hours are used as performance indicator.

The total installed capacity of biomass power plants in the analysed countries in the year 2000 amounted to 1.8 GW that were generating a total of 6.4 TWh/year of electricity. For the total region a biomass electricity potential of 400 TWh/y was identified, of which about 50 % might be used until 2050. Potential from residues dominate in MENA, while power from solid and other biomass sources is also very important in Europe.

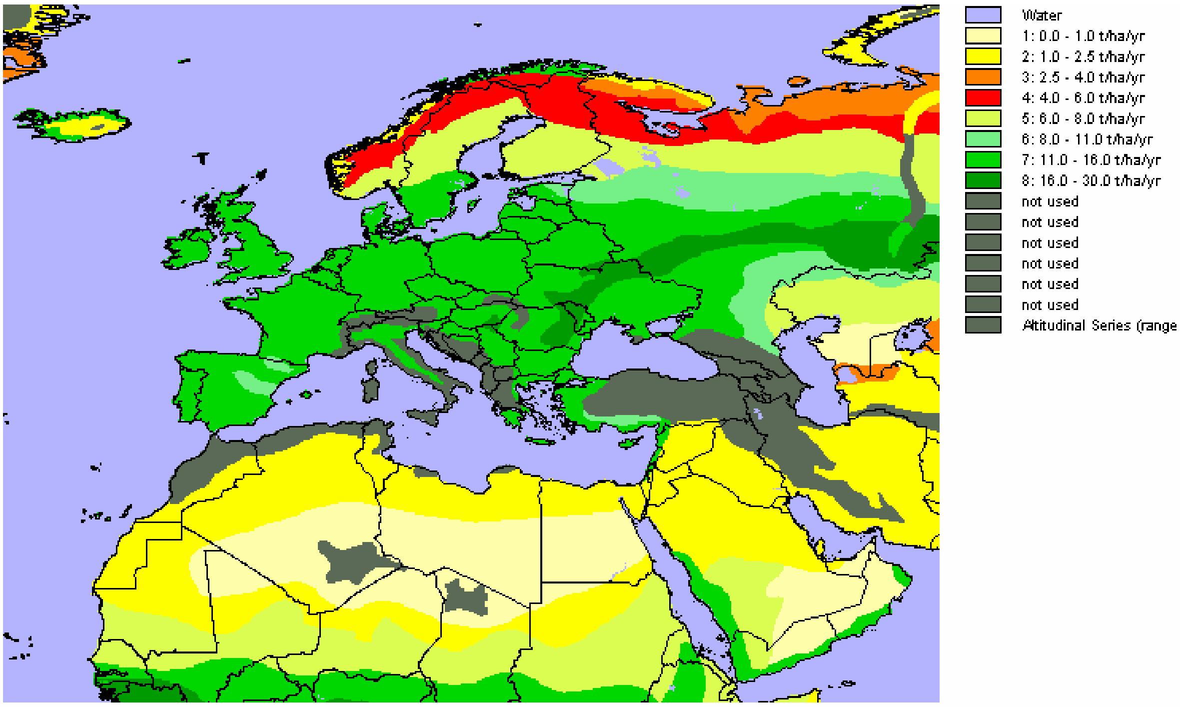


Figure 3-9: Map of biomass productivity /Bazilevich 1994/.

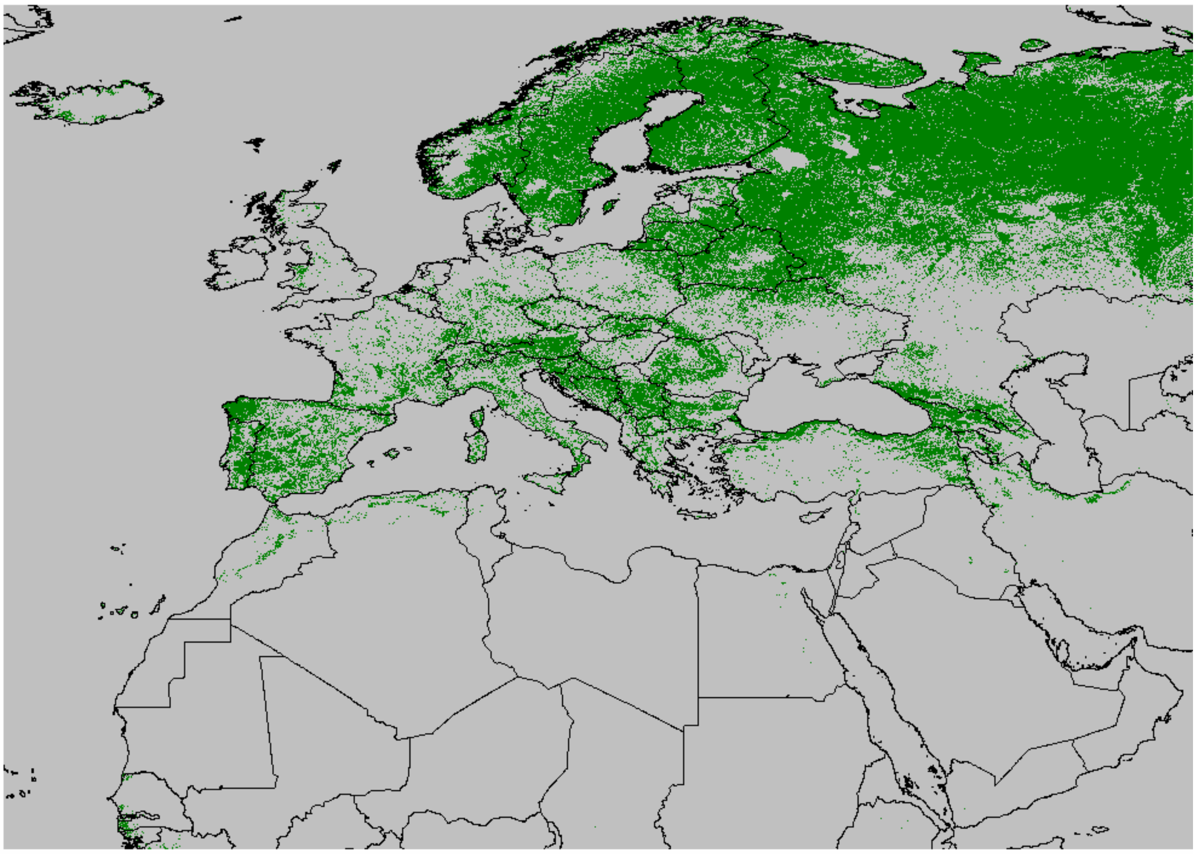


Figure 3-10: Map of forest areas (green) in the EU-MENA region /USGS 2002/

Table 3-4: Summary of the biomass electricity potential from agricultural waste (mainly bagasse), wood and municipal waste

	MaxUse	MaxUse	MaxUse	2050						2000	2010	2020	2030	2040	2050
	Agr. Res.	Wood	Mun.Res.	Max	Agr.Res.	Agr.Res.	Forest	Prod.	Wood	Mun.Waste	Mun.Waste	Mun.Waste	Mun.Waste	Mun.Waste	Mun.Waste
				TWh/y	1000 t/y	TWh/y	1000 km²	t/ha/y	TWh/y	TWh/y	TWh/y	TWh/y	TWh/y	TWh/y	TWh/y
Bahrain	80%	40%	80%	0.22		0.00		1	0.00	0.11	0.14	0.16	0.18	0.20	0.22
Cyprus	80%	40%	80%	0.47		0.14	1	4	0.20	0.10	0.11	0.12	0.12	0.13	0.13
Iran	80%	40%	80%	23.69	914	0.46	73	2	7.30	7.44	9.33	11.46	13.03	14.69	15.94
Iraq	80%	40%	80%	8.60		0.00	8	2	0.80	2.74	3.59	4.66	5.87	6.85	7.80
Israel	80%	40%	80%	2.23		0.00	1	11	0.55	0.97	1.18	1.35	1.49	1.60	1.68
Jordan	80%	40%	80%	1.60		0.00	1	1	0.05	0.69	0.90	1.09	1.28	1.43	1.55
Kuwait	80%	40%	80%	0.85		0.00		1	0.00	0.38	0.51	0.62	0.72	0.79	0.85
Lebanon	80%	40%	80%	0.83		0.00		11	0.00	0.55	0.64	0.72	0.77	0.81	0.83
Oman	80%	40%	80%	1.08		0.00		11	0.00	0.35	0.49	0.64	0.79	0.94	1.08
Qatar	80%	40%	80%	0.15		0.00		1	0.00	0.09	0.11	0.13	0.14	0.14	0.15
Saudi Arabia	80%	40%	80%	9.89		0.00	15	1	0.75	3.34	4.60	5.81	7.00	8.18	9.14
Syria	80%	40%	80%	4.66		0.00	5	1	0.25	1.49	2.02	2.66	3.30	3.89	4.41
UAE	80%	40%	80%	0.69		0.00	3	0	0.00	0.43	0.53	0.61	0.66	0.69	0.69
Yemen	80%	40%	80%	9.06		0.00	4	6	1.20	0.78	1.28	2.20	3.63	5.49	7.86
Algeria	80%	40%	80%	12.07		0.00	21	5	5.25	3.02	3.90	4.79	5.54	6.27	6.82
Egypt	80%	40%	80%	15.27	3 060	1.53	1	3	0.15	5.06	6.36	8.17	10.38	11.95	13.59
Libya	80%	40%	80%	1.72		0.00	4	1	0.20	0.80	0.99	1.17	1.31	1.43	1.52
Morocco	80%	40%	80%	14.26	408	0.20	30	5	7.50	2.83	3.68	4.52	5.28	6.01	6.55
Tunisia	80%	40%	80%	3.17		0.00	5	5	1.25	1.09	1.32	1.53	1.69	1.84	1.92
Greece	80%	40%	80%	11.84		1.50	36	5	9.00	1.15	1.21	1.28	1.32	1.34	1.34
Italy	80%	30%	80%	86.36		10.00	100	14	70.00	6.74	6.83	6.89	6.86	6.65	6.36
Malta	80%	40%	80%	0.16		0.06		1	0.03	0.06	0.07	0.07	0.07	0.07	0.07
Portugal	80%	30%	80%	26.61		3.00	37	12	22.20	1.13	1.32	1.37	1.39	1.43	1.41
Spain	80%	30%	80%	111.05	9000	4.50	144	14	100.80	5.53	5.78	5.88	5.91	5.89	5.75
Turkey	80%	40%	80%	55.00		0.00	102	8	40.80	7.86	9.53	11.05	12.39	13.50	14.20
Total				**402**		**21**			**268**	**55**	**66**	**79**	**91**	**102**	**112**

Wind Energy

Wind power resources are given in the literature for European countries including Malta and Cyprus and for Morocco, Tunisia, Egypt and Turkey /EWEA 2002/, /EU 2004/, /OME 2002/. There is additional information on wind power potentials for Morocco, Jordan, Egypt and Turkey in /GTZ 2002/ and /GTZ 2004/.

For the other countries, electricity potentials were estimated taking into account wind speed and areal restrictions from the wind map in Figure 3-11 and site exclusion similar to that used for CSP but adapted to wind power. The original wind speed was taken from /ECMWF 2002/ for 33 and 144 meters height and was interpolated by ISET to 80 meters height. This map gives a very rough estimate of the distribution of wind speed as an average for an area of 50 x 50 km. The original data has a geographic resolution of 1.12 degrees.

Wind electricity potentials were calculated as function of the average wind speed according to the equations given in chapter 2. We have assumed a maximum installed capacity of 10 MW per square kilometre of land area. Areas with annual full load hours over 1400 h/y equivalent to a capacity factor of 16 % were considered as long-term economic potential. Results were cross-checked and eventually corrected for those countries that have made a national resource assessment /OME 2002/, /REA/WED 1996/, /REA/WED 2003/, /GTZ 2004/, /GTZ 2002/, /WEC 2004/. Annual full load hours (capacity factor) define the performance indicator. They have been derived from literature, the World Wind Atlas /WWA 2004/ for a selection of sites in each country, and from the wind speed map. Potentials include onshore and offshore.

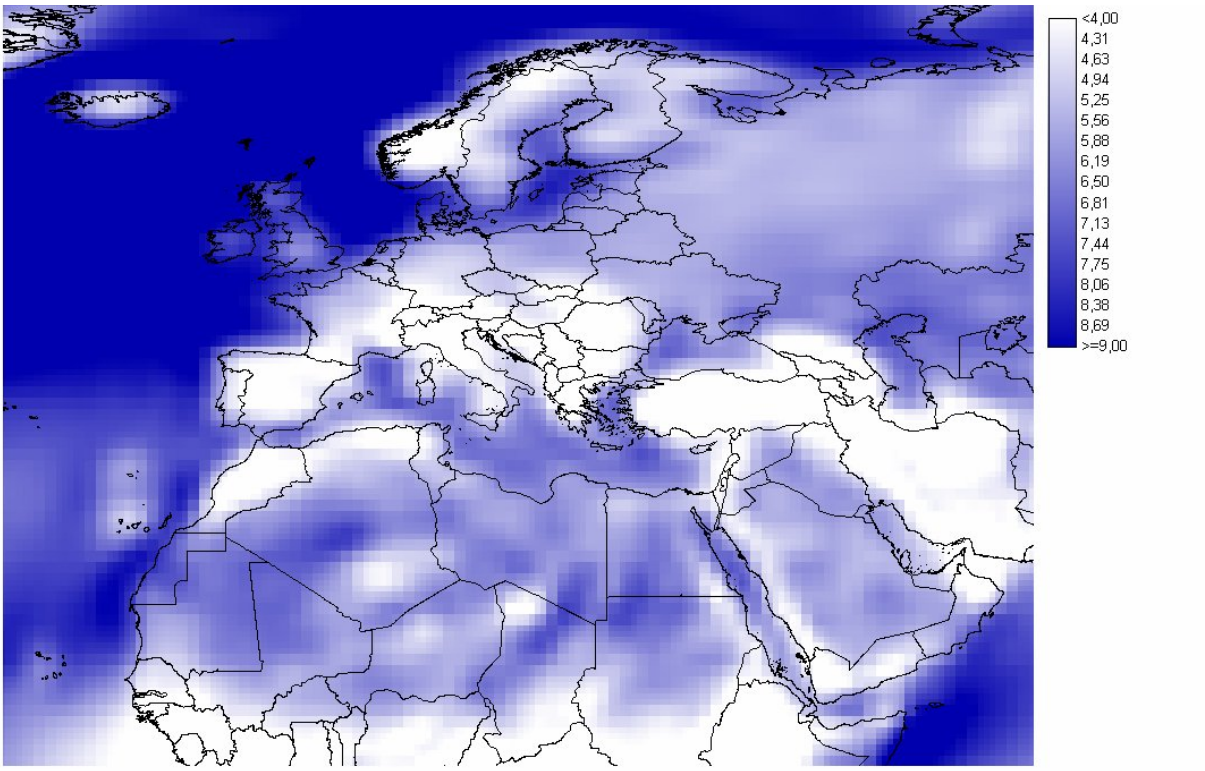


Figure 3-11: Annual average wind speed at 80 m above ground level in m/s. Source: Prepared by DLR with data from ECMWF, ISET for /WBGU 2003/

In the year 2000 a total of 3.3 GW of wind capacity was installed in the analysed region producing 7.2 TWh/y of wind electricity /Enerdata 2004/. The total economic wind power potential in the region amounts to 440 TWh/y, of which 285 TWh/y could be exploited until 2050.

Photovoltaic

Photovoltaic applications are in principal unlimited. There are no criteria for site exclusion for PV systems, as they can be installed almost everywhere. However, their expansion is still limited by their high investment cost. Using present growth rates and scenarios for very large PV systems and distributed applications, PV potentials were assessed in a relatively intuitive way. For EU states, literature gives mid term potentials for PV /EU 2004/. The global irradiance on a surface tilted according to the latitude was used as performance indicator (Figure 3-12 and /Meteonorm 2004/). Although we have not introduced any economic threshold, the learning curves of PV suggest that this technology will become competitive by the middle of this century under the irradiance conditions of the MENA region.

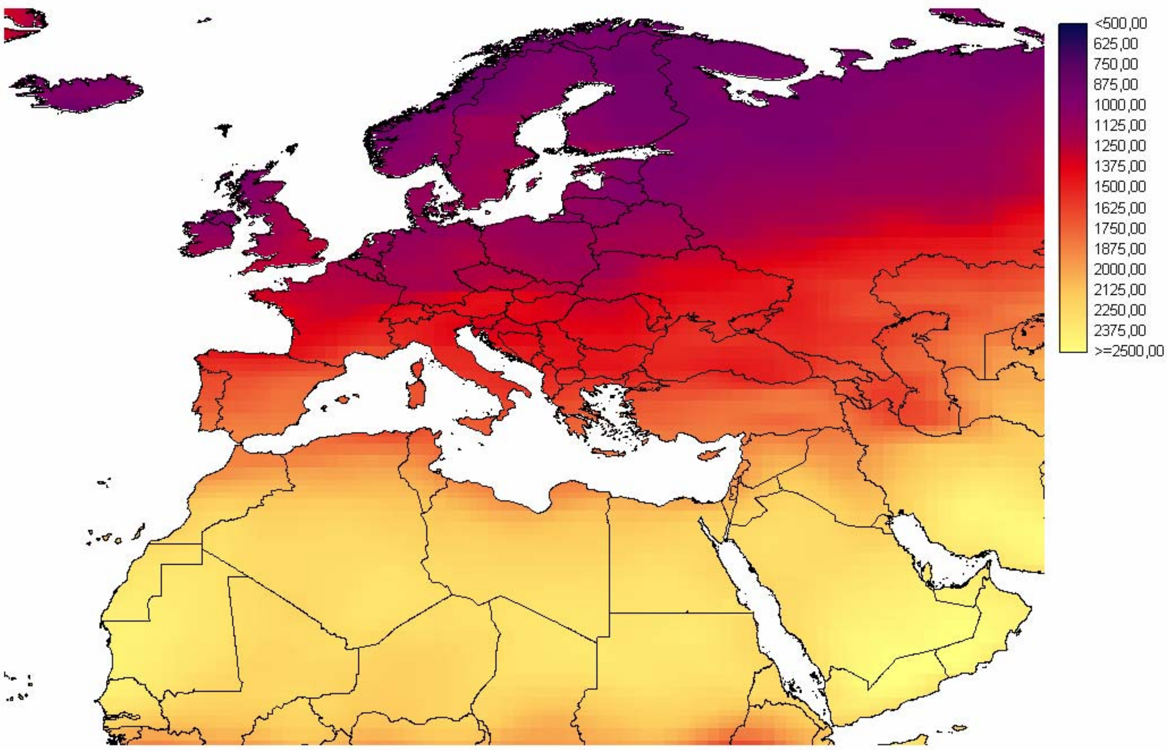


Figure 3-12: Annual Global Irradiation on Surfaces Tilted South with Latitude Angle in kWh/m²/year
Source: Prepared by DLR with data from /ECMWF 2002/ for /WBGU 2003/

PV systems are especially suited for decentralized small scale applications in remote regions, where they often are already competitive to conventional Diesel motor-generator power supply schemes. This special market segment has been assessed by several studies /OME 2002/, /GTZ 2002/, /GTZ 2003/. In our study we have only included global PV potentials without quantifying grid-connected and remote systems separately. In the year 2000 about 0.02 TWh/y of solar electricity was produced by PV mainly in Italy and Spain. Including Very Large PV Systems (VLS-PV) of up to 1.5 GW of capacity in the desert regions until 2050 as suggested by /IEA 2003/, we estimate the PV potential in the analysed region to about 218 TWh/y with a total installed capacity of 125 GW.

Wave and Tidal power potentials were taken from the literature /EU 2004/. Performance Indicators are the annual full load hours which have been set for all locations to 4000 h/y.

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.

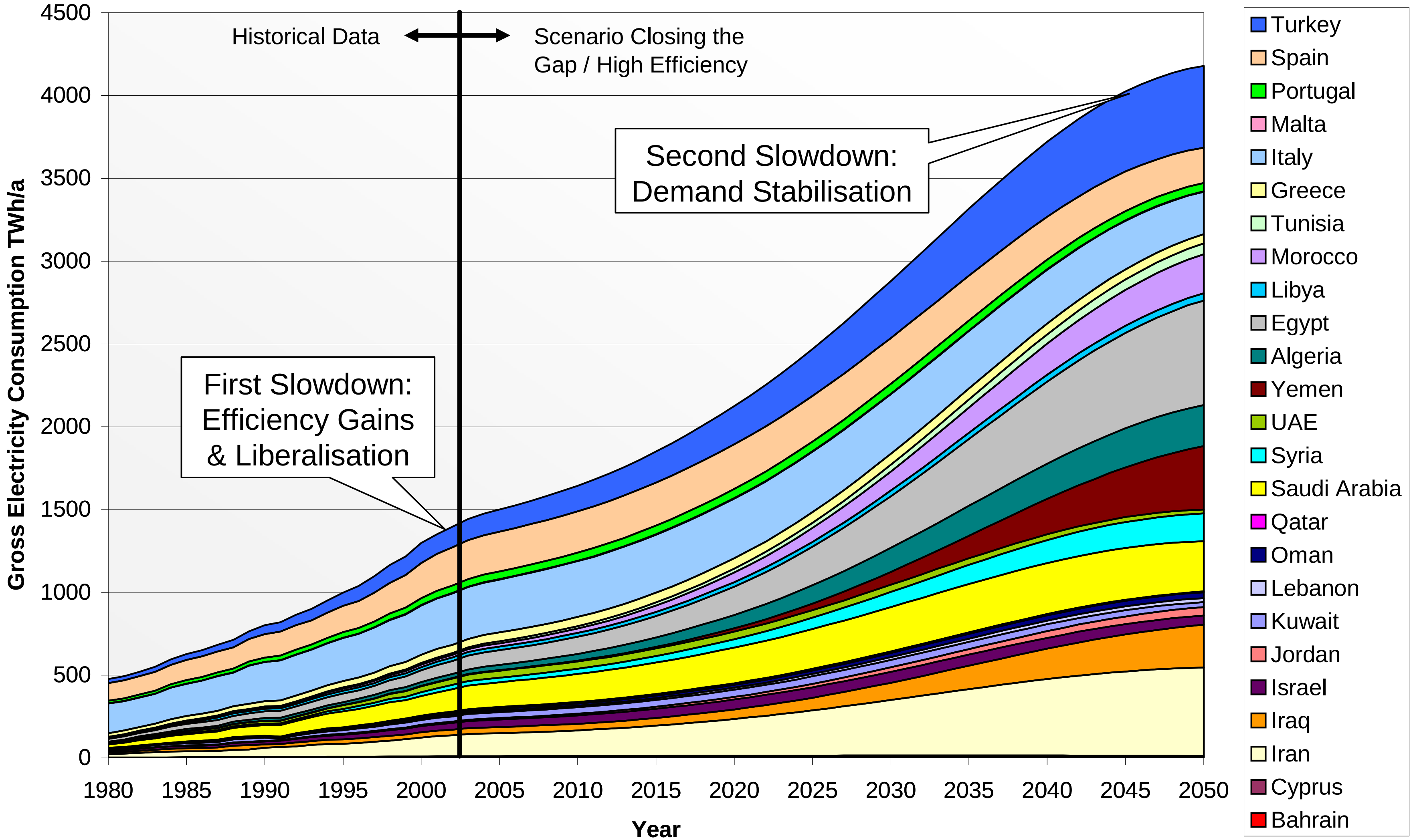


Figure 4-1: Gross Electricity Consumption of the Countries analysed within MED-CSP in the Scenario CG/HE. Historical data based on /EIA 2004/

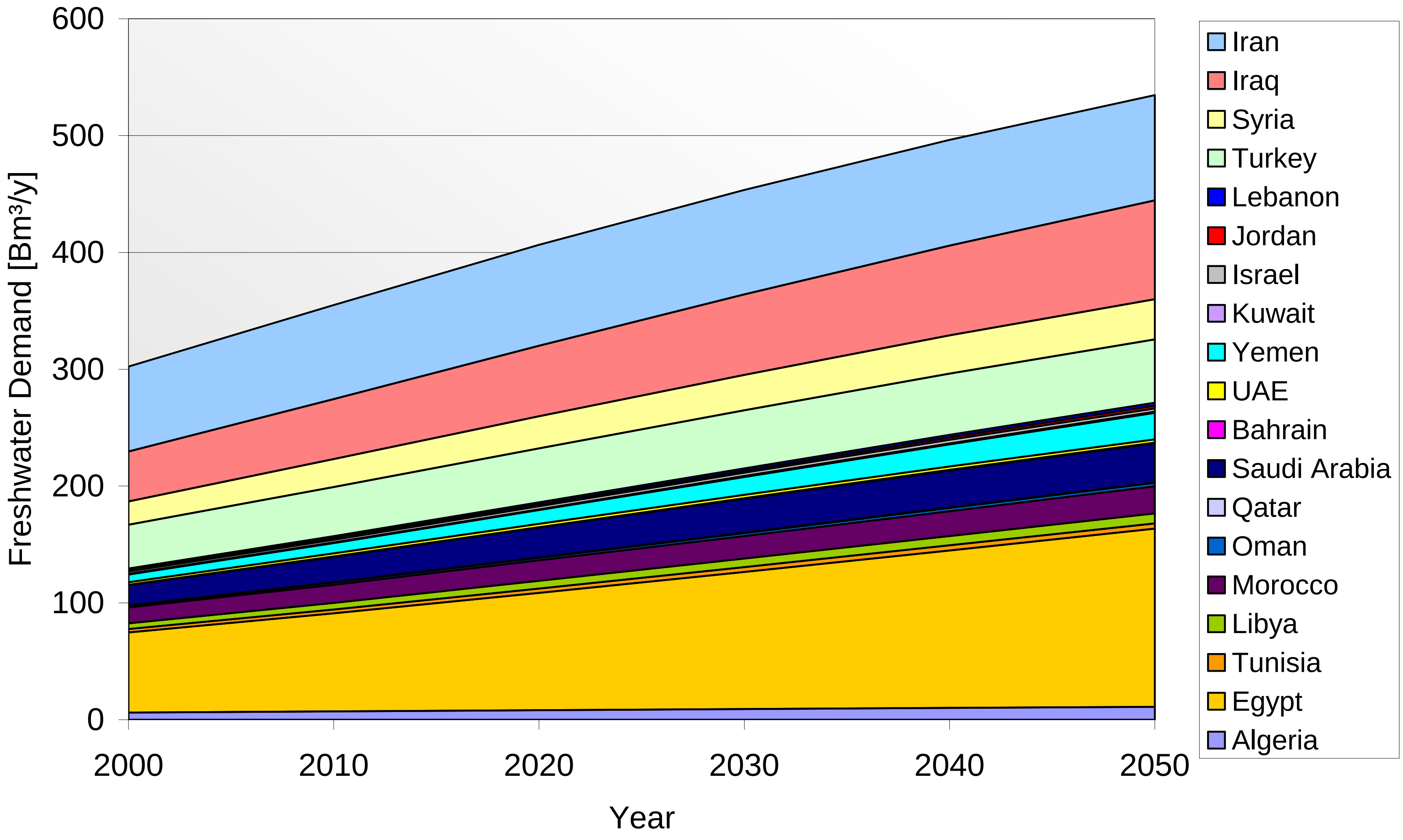


Figure 4-2: Water demand projection in the MENA countries in the scenario CG/HE. Historical data of the year 2000 based on /FAO 2004/

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).

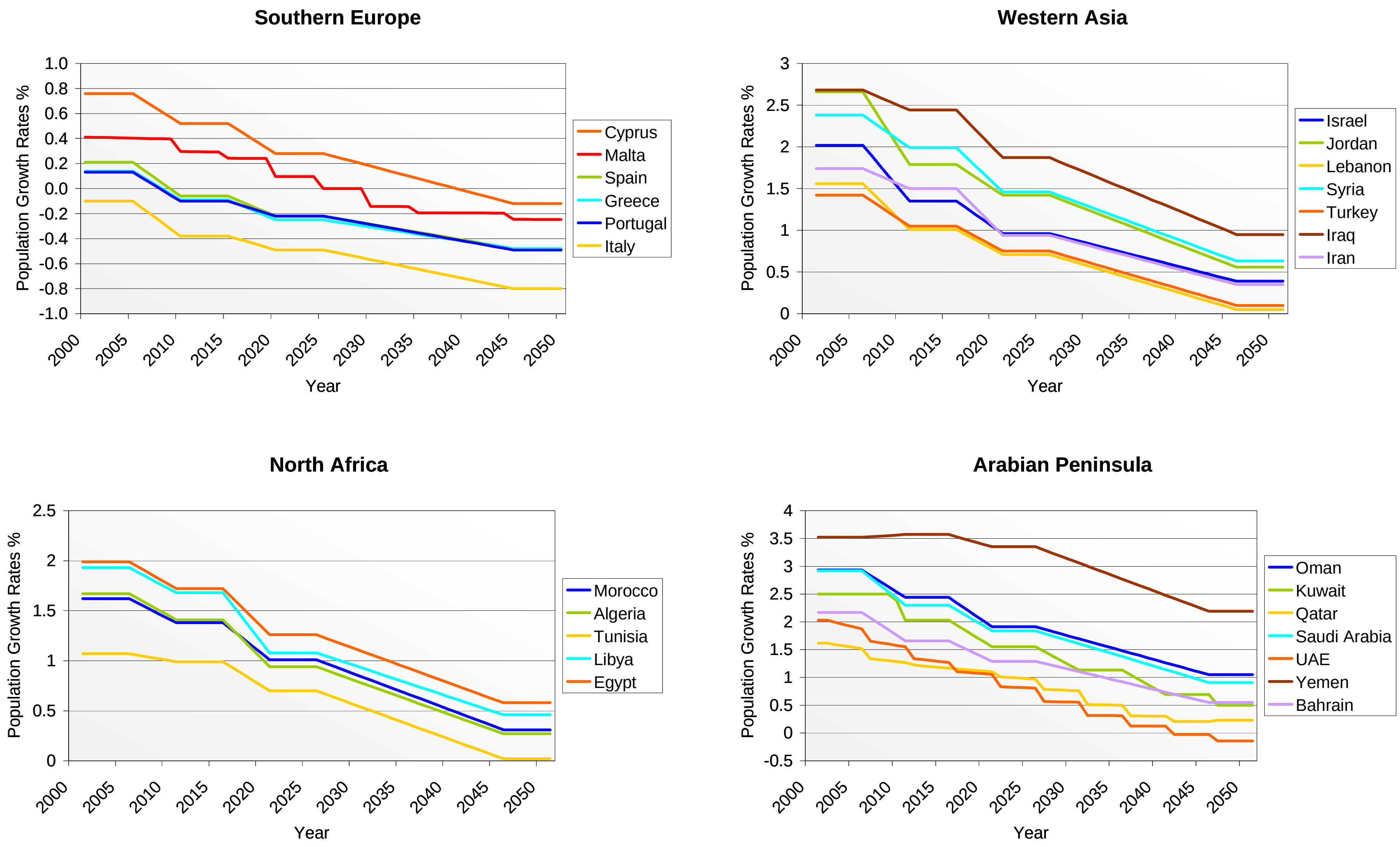


Figure 4-3: Population growth rates used in the MED-CSP scenario derived from /FAO 2004/

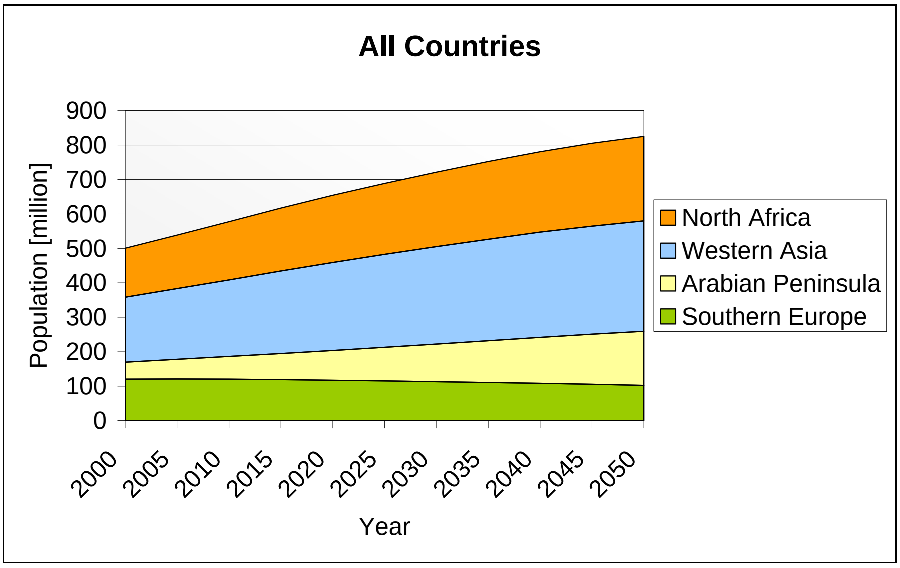


Figure 4-4: Population growth in all analysed countries until 2050

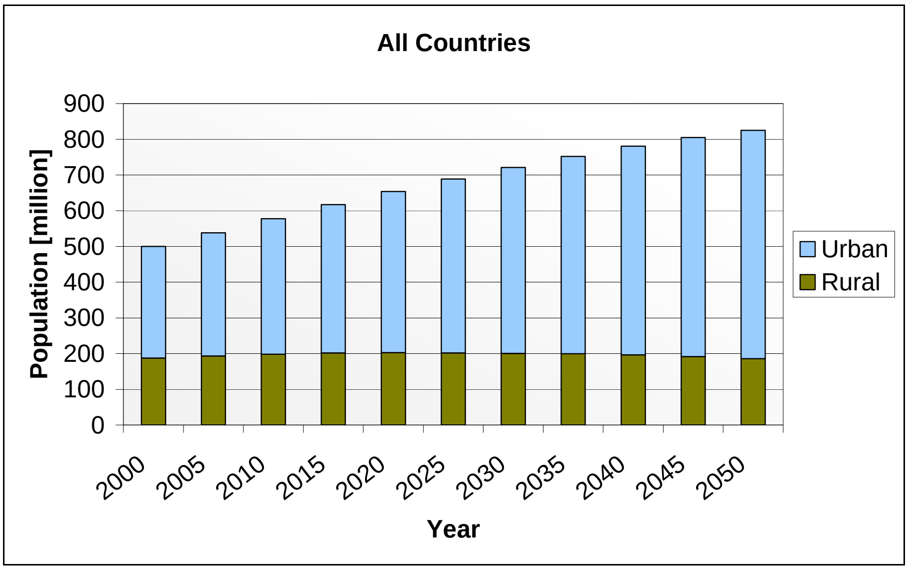


Figure 4-5: Growth of rural vs. urban population in all countries until 2050

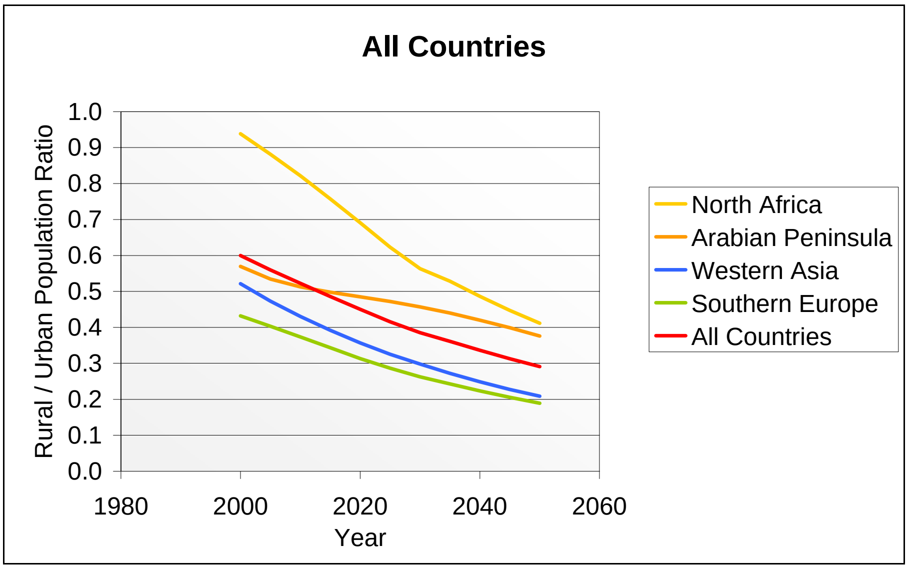


Figure 4-6: Rural to urban population ratio for all countries as function of time

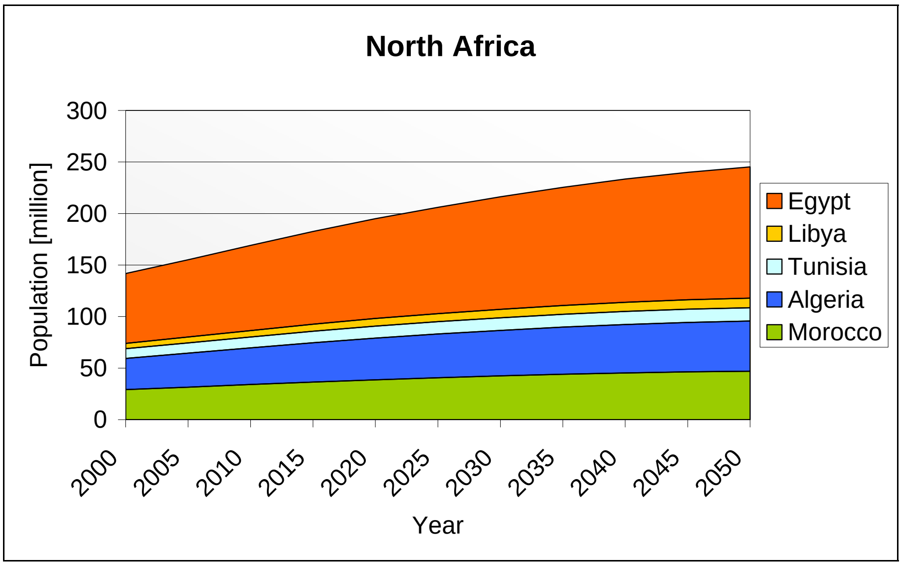


Figure 4-7: Population growth in North Africa by countries

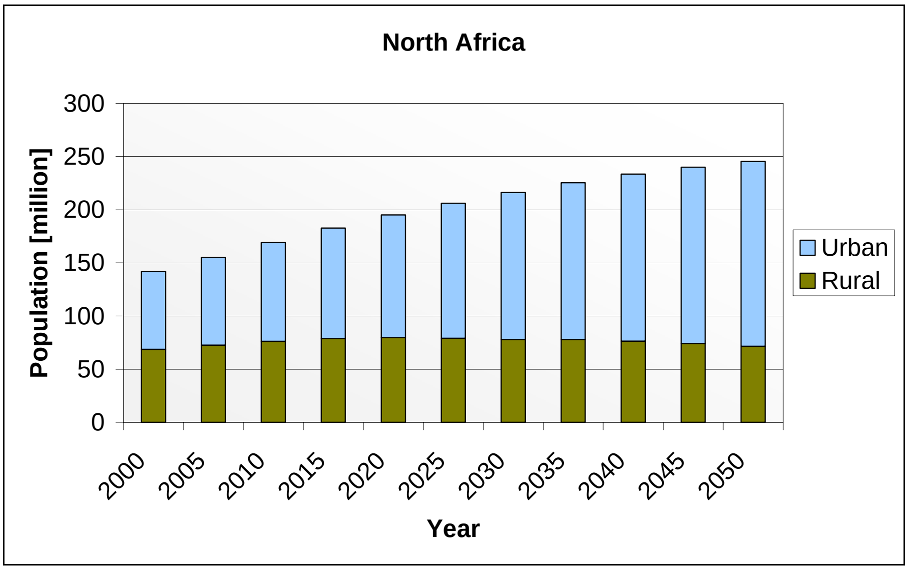


Figure 4-8: Development of rural vs. urban population in North Africa

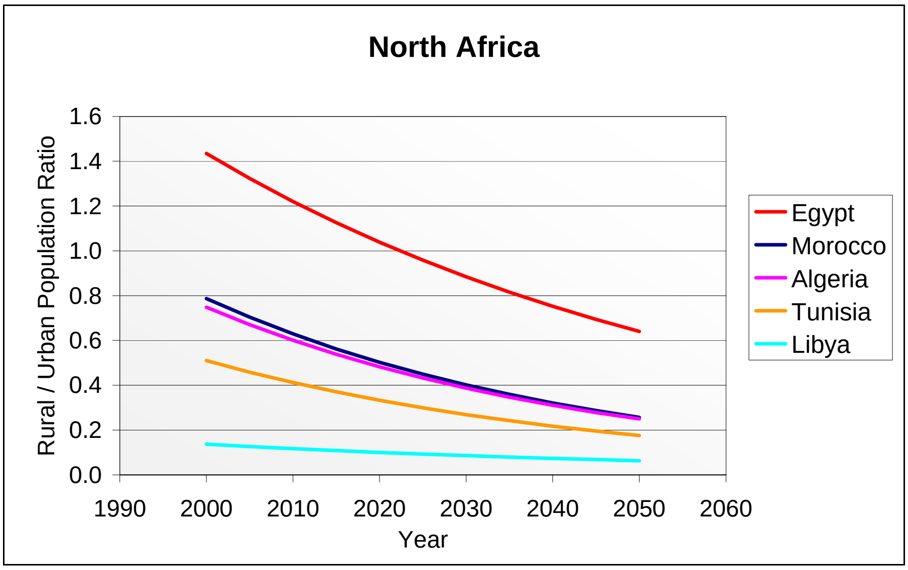


Figure 4-9: Rural / urban population ratio of the Northern African countries

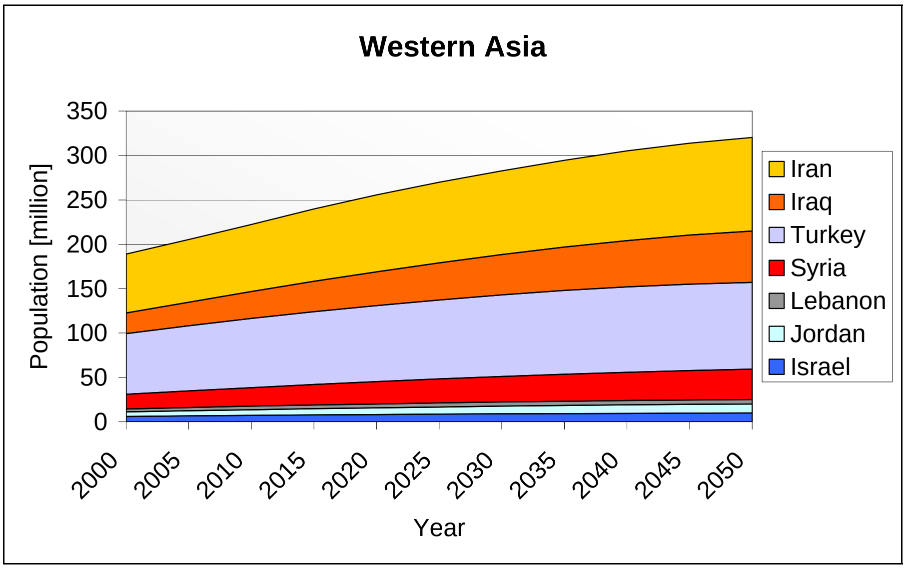


Figure 4-10: Population growth in the Western Asian countries

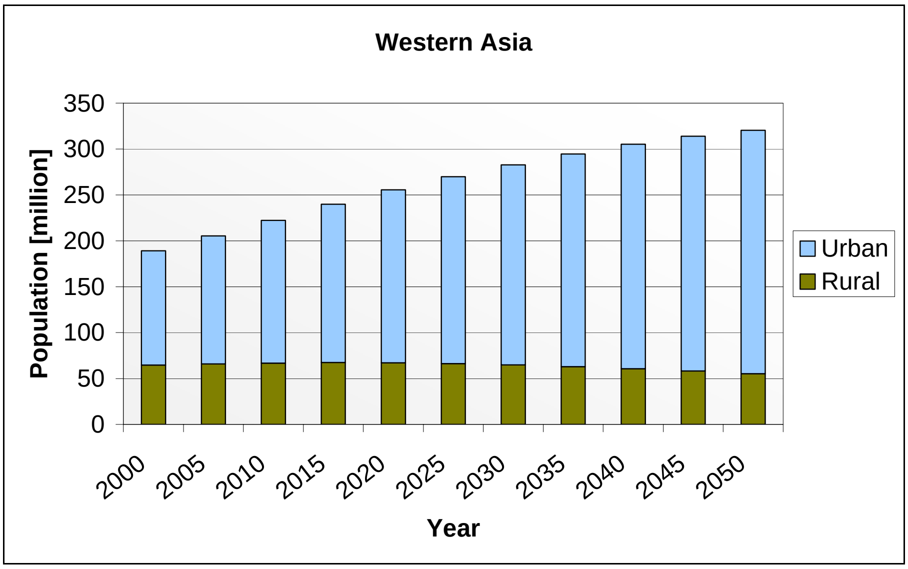


Figure 4-11: Rural vs. Urban population in the Western Asian countries as function of time.

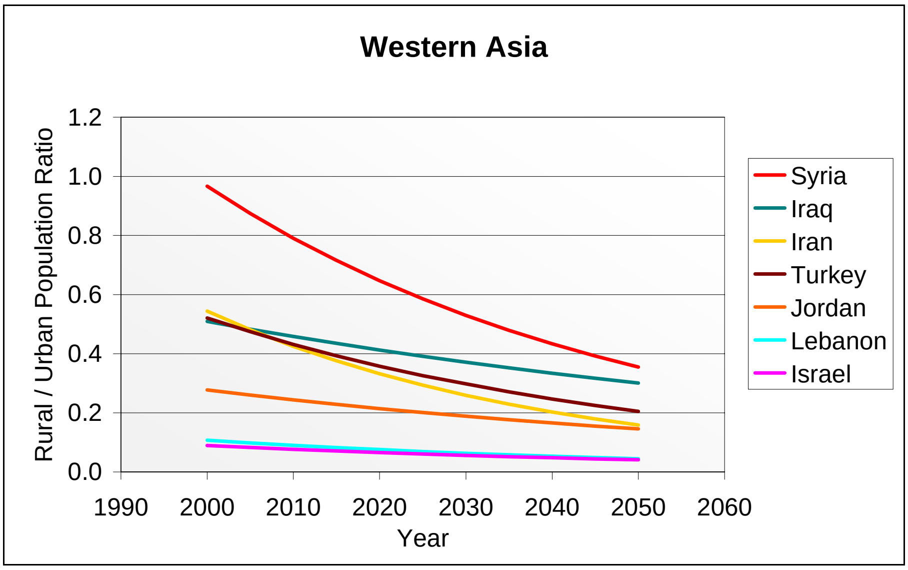


Figure 4-12: Rural to urban population ratio in the Western Asian countries until 2050.

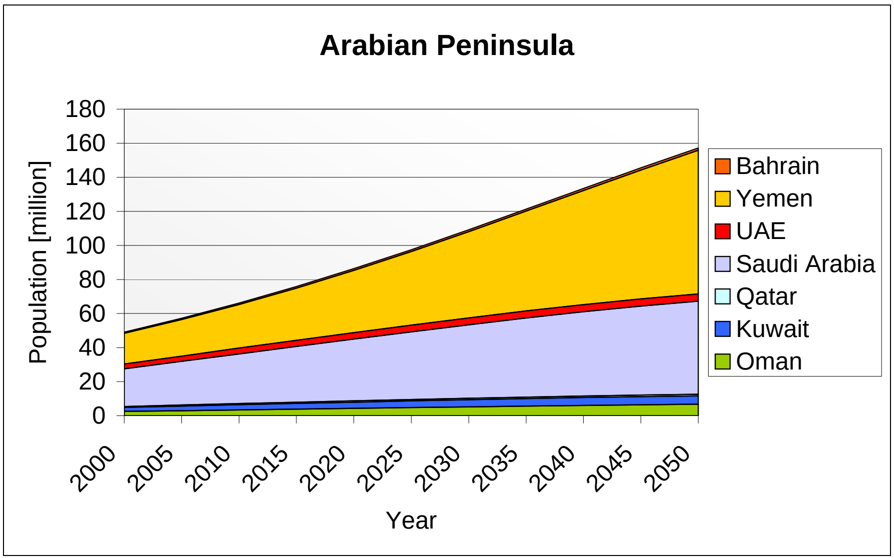


Figure 4-13: Population growth on the Arabian Peninsula until 2050

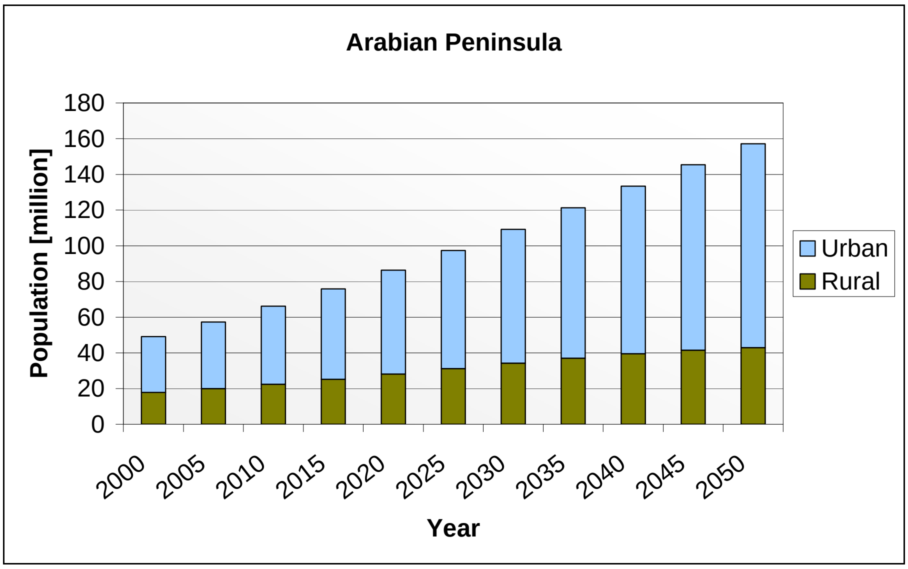


Figure 4-14: Rural and urban population on the Arabian Peninsula until 2050

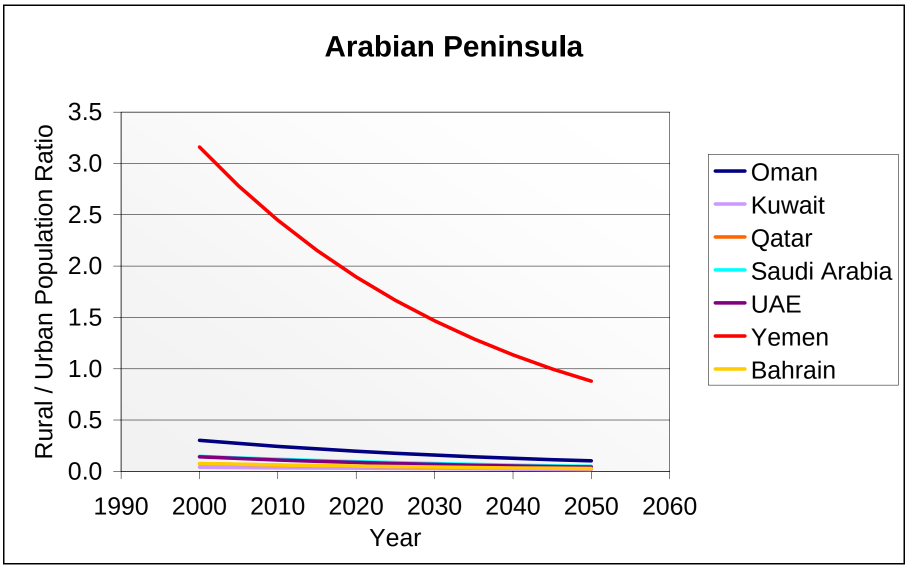


Figure 4-15: Rural / urban population ratio on the Arabian Peninsula until 2050.

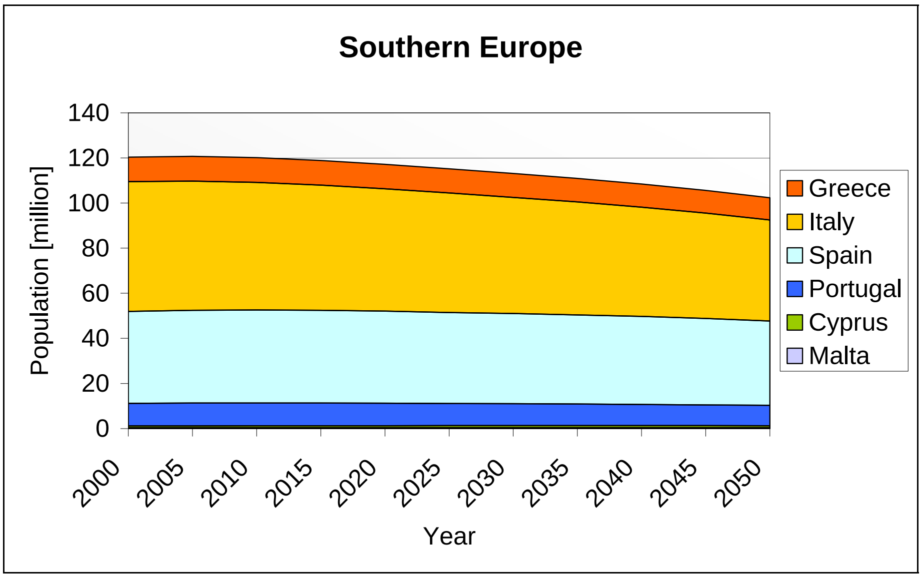


Figure 4-16: Population growth in the Southern European countries until 2050

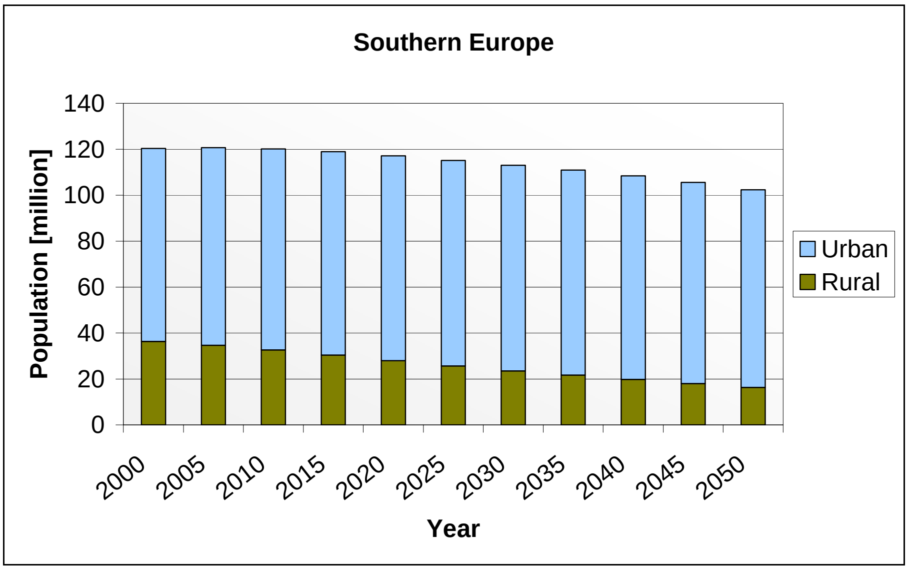


Figure 4-17: Rural and urban population in Southern European countries until 2050

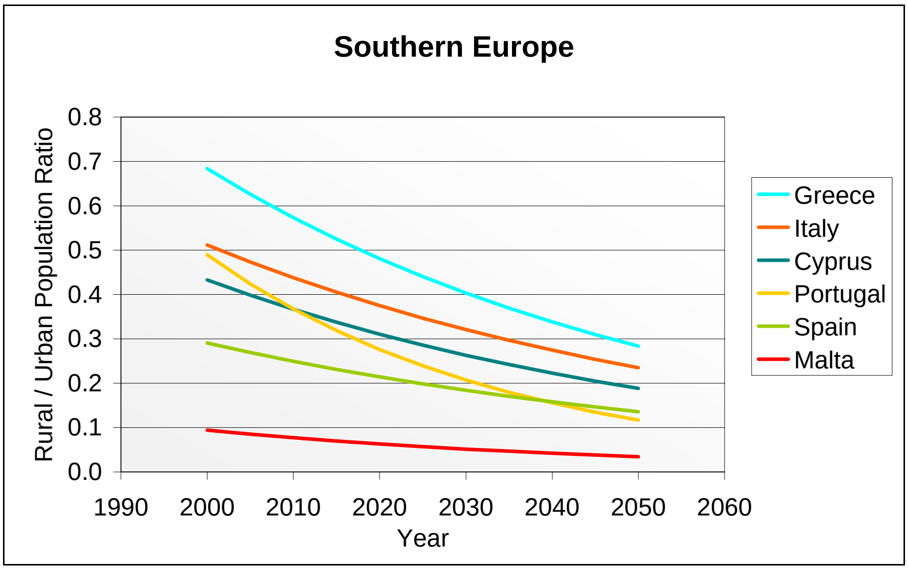


Figure 4-18: Rural / urban population ratio for the Southern European countries until 2050.

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.

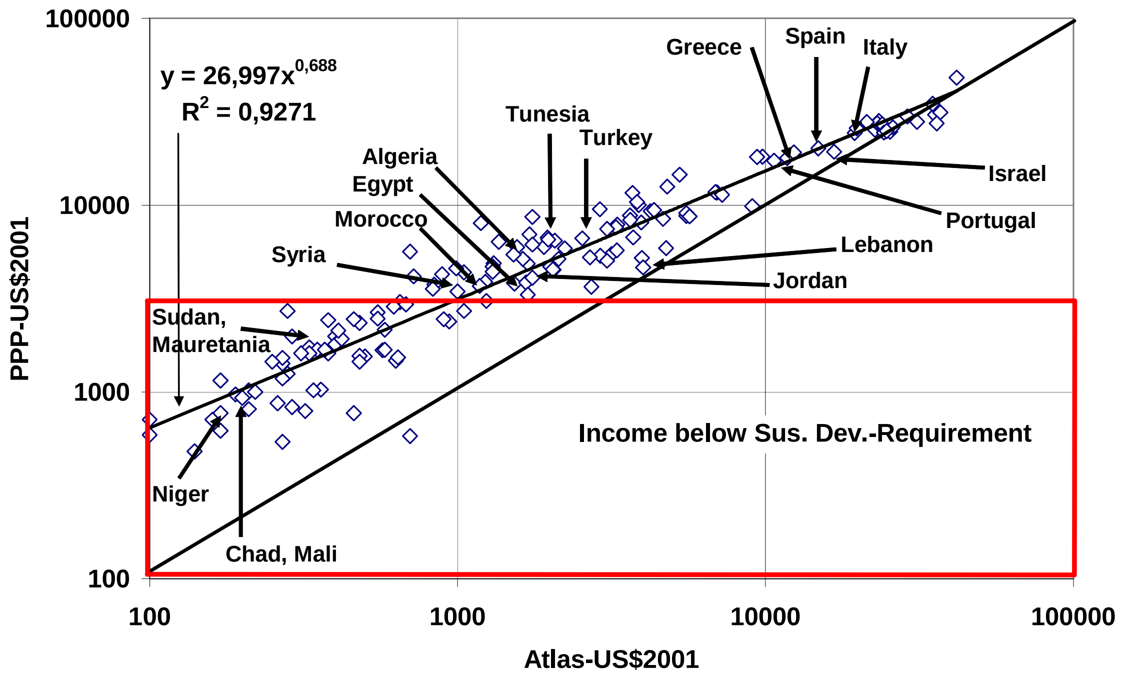


Figure 4-19: Comparing Gross National Income (GNI) per capita in 2001 in US-$2001 (PPP) vs. Atlas US-$2001. Source: World Bank, cited according to /Statistisches Bundesamt 2003/; sample size: 154

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.

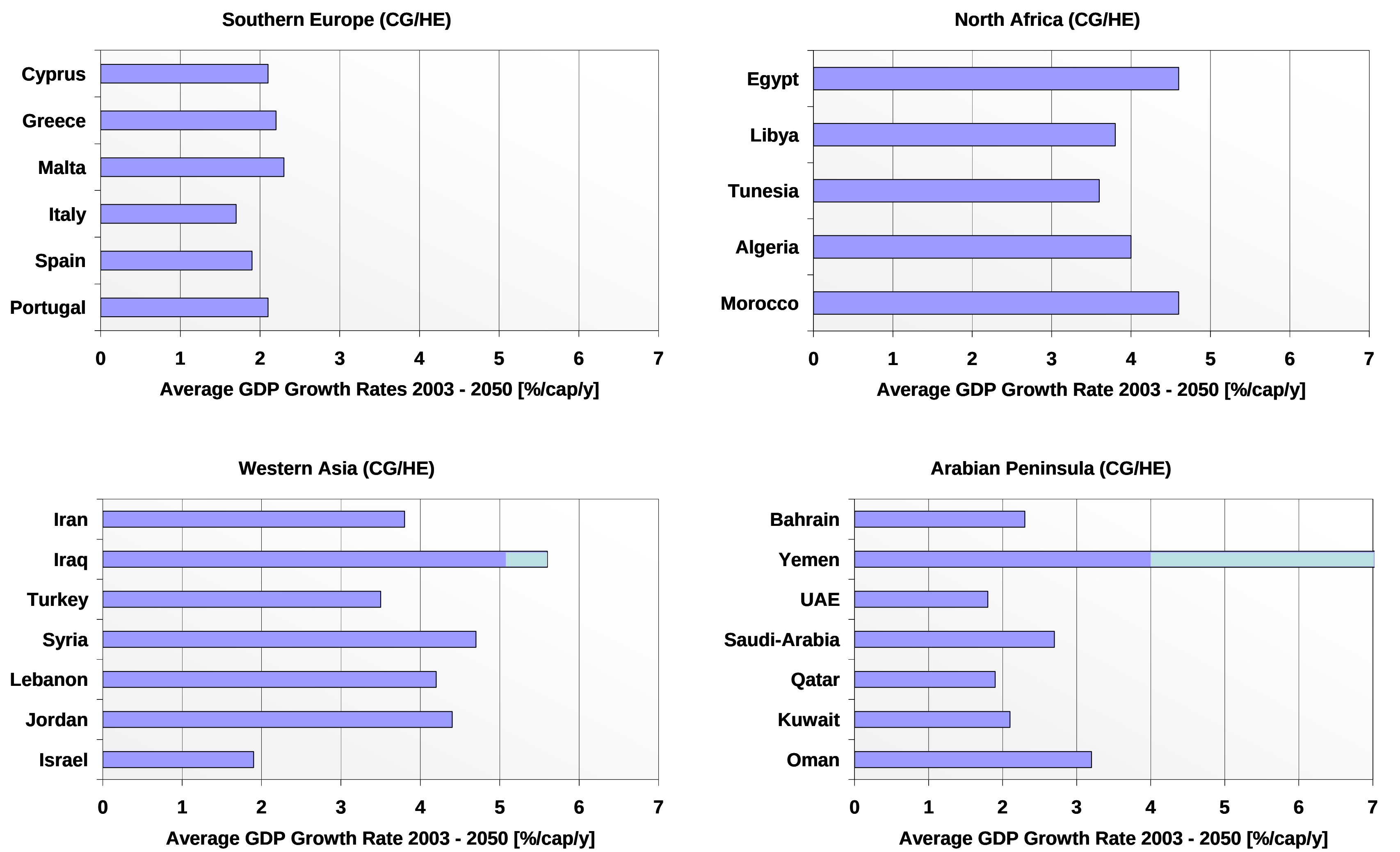


Figure 4-20: Average per Capita GDP Growth Rates 2003 – 2050 within the Scenario CG/HE. Per capita growth rates in Iraq and Yemen are reduced due to the restriction of the 50 year average GDP growth rate to a maximum of 7 %/y.

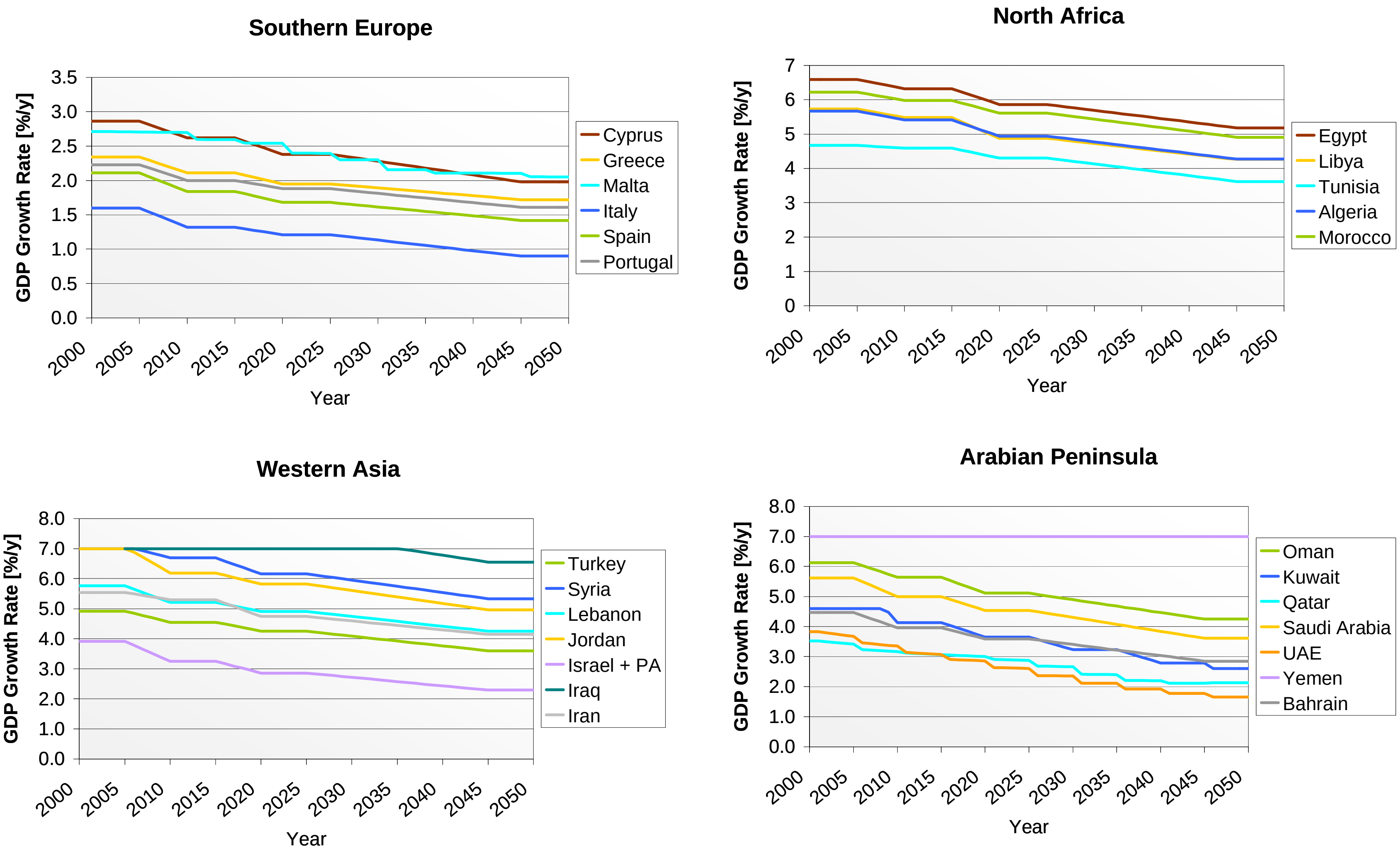


Figure 4-21: GDP Growth Rates until 2050 within the Scenario CG/HE

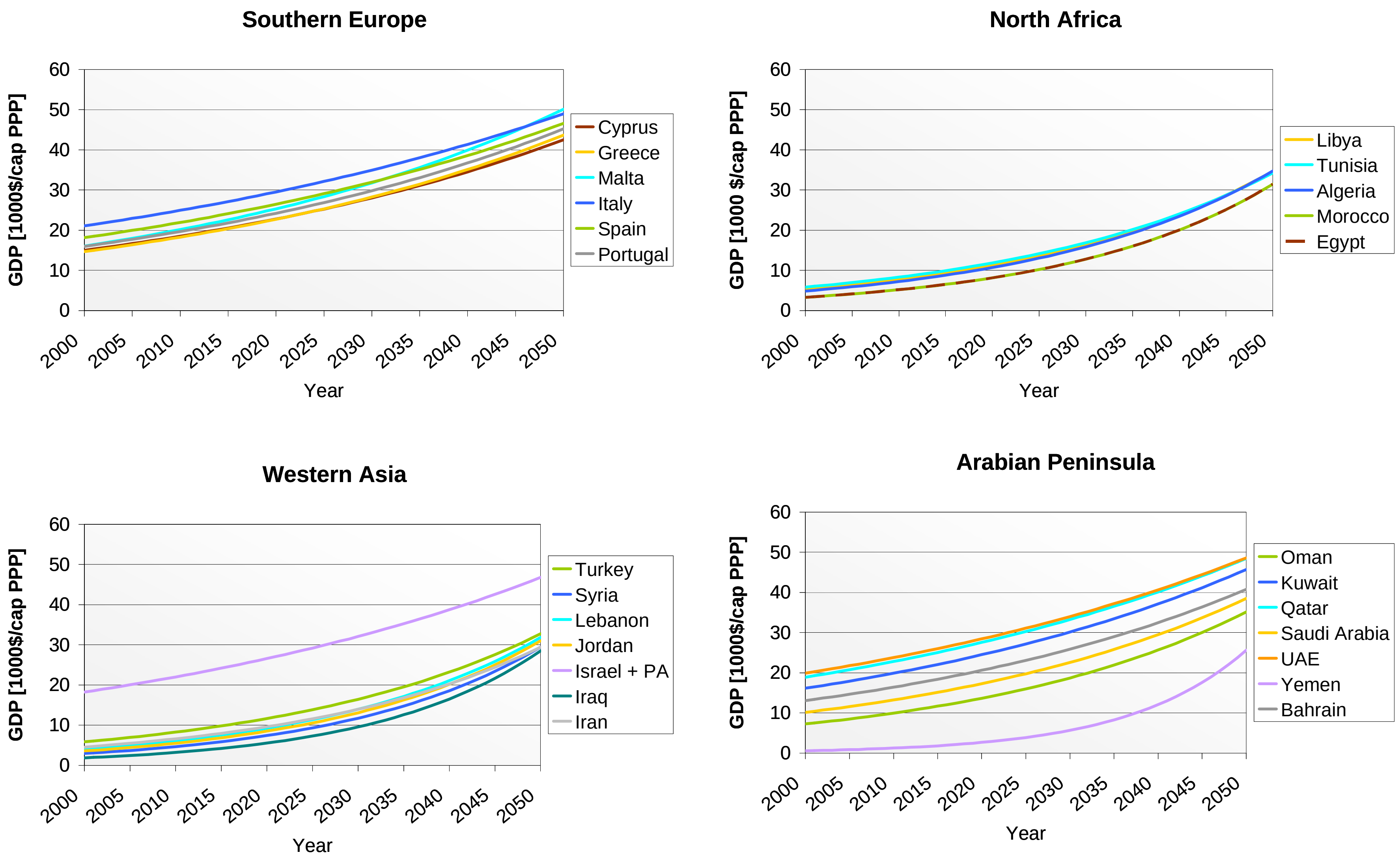


Figure 4-22: Development of per Capita GDP until 2050 within the Scenario CG/HE

	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.

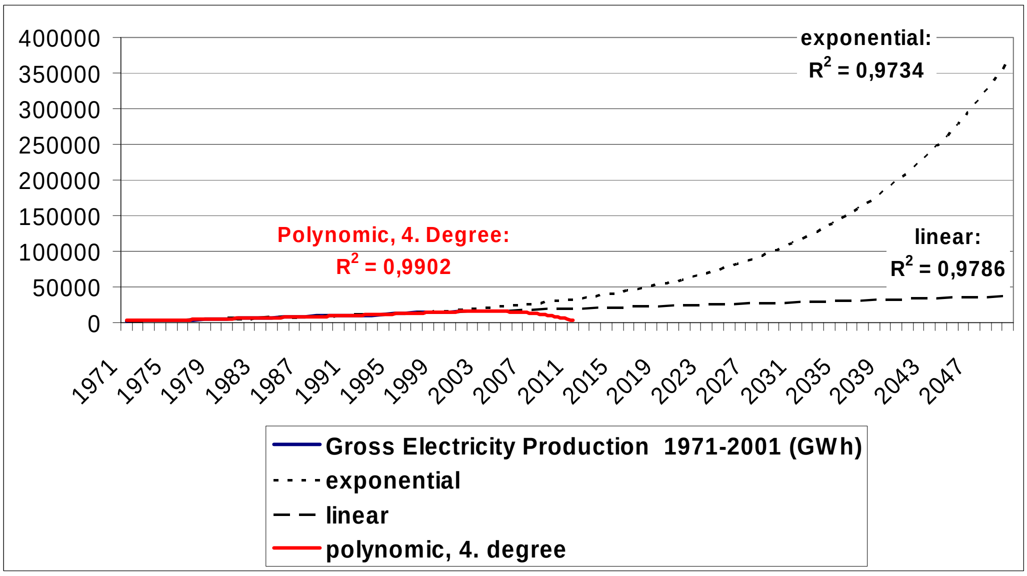


Figure 4-23: Example for problems with trend extrapolations - the Moroccan trend for gross electricity production in GWh/y. Data Source: /IEA 2003-4/

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.

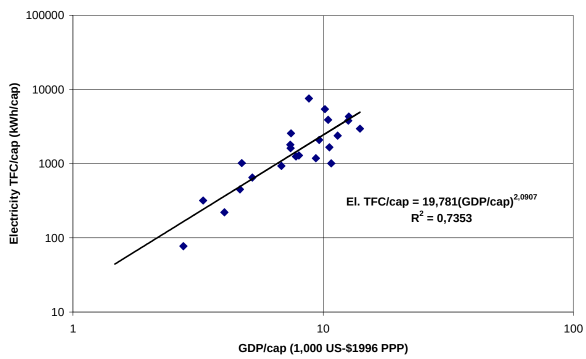
Step 1: Using data from /PWT 2002/ and /IEA 2003-2, 3/ regressions for GDP per capita and total final energy consumption per capita were calculated for different years using power functions. Overall power functions delivered the best fits, although polynomials of a certain order might do as well1. As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

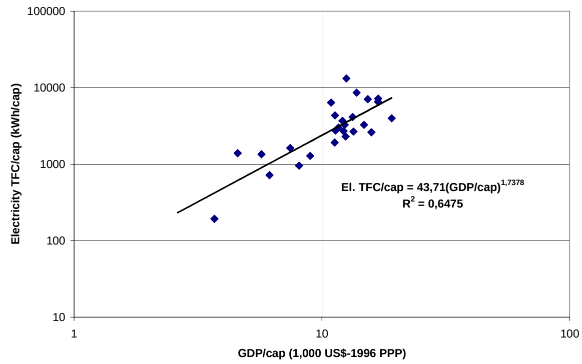
Figure 4-24 shows six examples of results.

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.

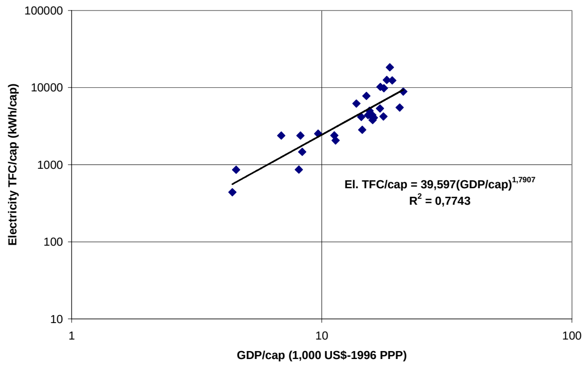
variables. Additionally, certain country groups show exceptional behaviour; in 1e) two of these groups are marked: Transition economies and northern countries. In these cases regressions were calculated with and without each or all of these country groups. Overall the statistics leads to the conclusion 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.

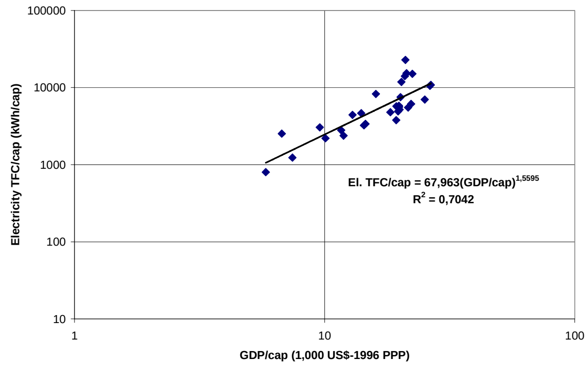




a) In the year 1960

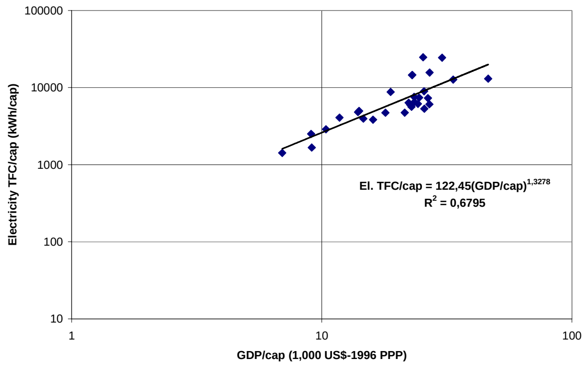
b) In the year 1970

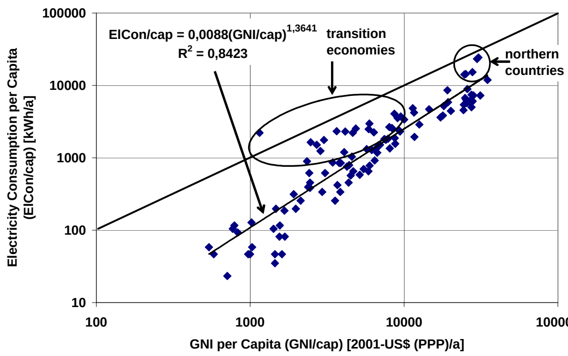




c) In the year 1980

d) In the year 1990





d) In the year 2000

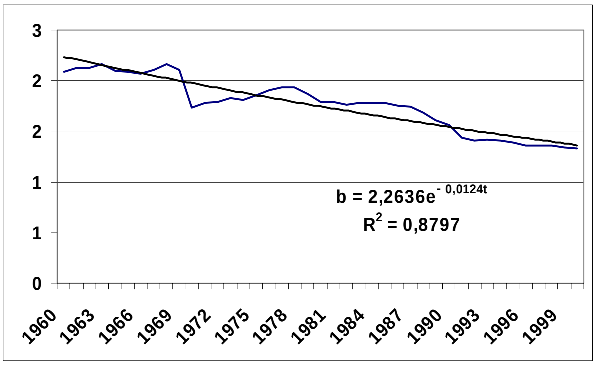
e) Different sample and data source. Year 2001.

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/

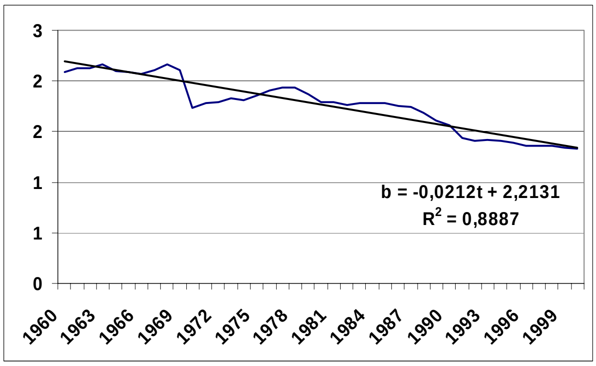
A power function would result in proportional growth rates of GDP per capita and of total final consumption of electricity per capita. The factor is given by the exponent. For example, the 1.3641 in Figure 4-24e) implies that a 1% higher GDP per capita is combined by a 1.3641 % higher total final consumption 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.

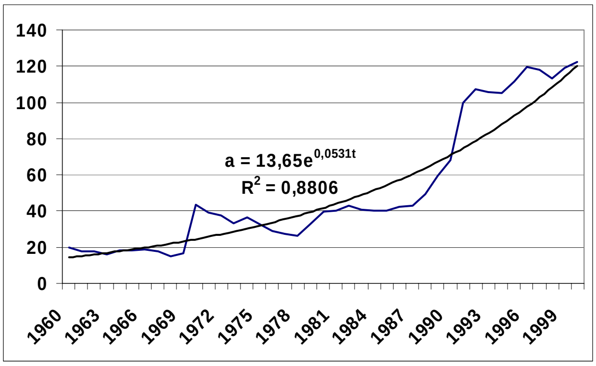
For the absolute term this is not true. The exponential function shows a significantly better fit. These conclusions were confirmed by tests using historical simulations, although until now it was not possible to systematically conduct and evaluate these simulations.



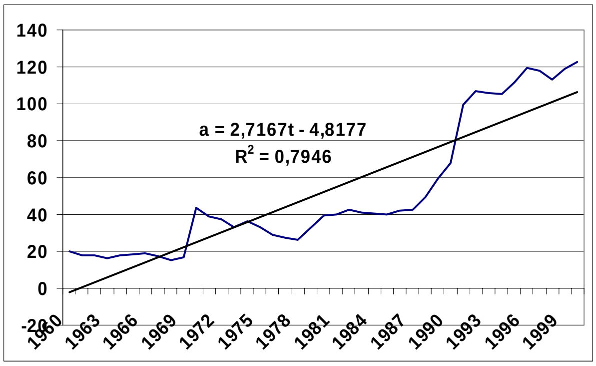
a) Exponential regression for exponent



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 re-

gression 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.

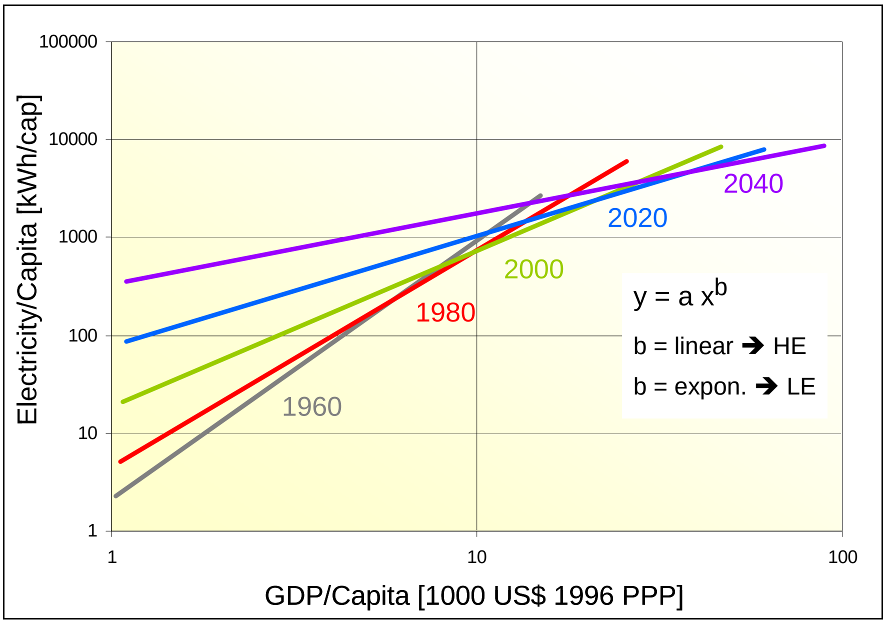


Figure 4-26: Fit functions for the years 1960 to 2040 for a sample of 25 (150) countries showing the correlation and extrapolation of total final electricity consumption per capita as function of GDP per capita for the high efficiency trend HE

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 incen-

tives 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.

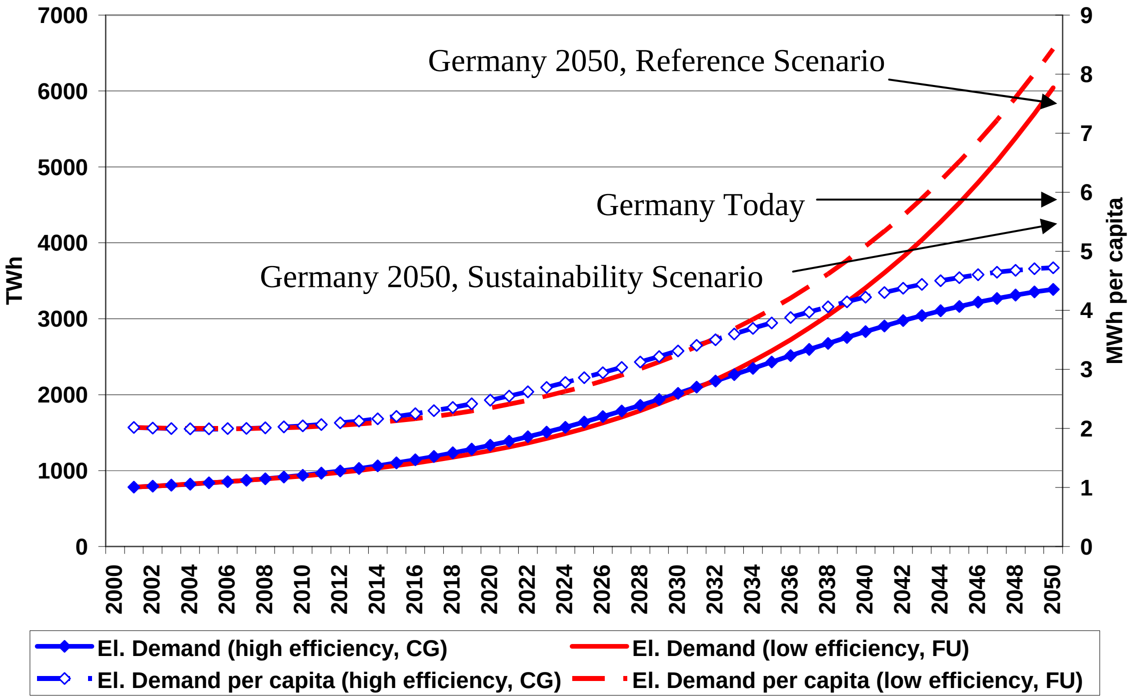


Figure 4-27: Electricity demand and electricity demand per capita in MENA according to the scenarios CG/HE and FU/LE (results obtained from aggregation of single country scenarios).

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.

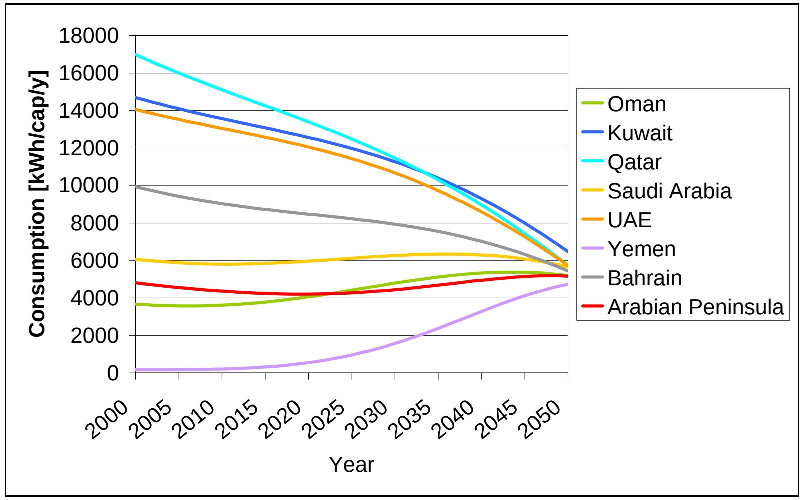
Yemen will need a fast and continuing extension of energy supply just to allow a modest improvement of economic conditions over the next half century. Otherwise the population growth might result in significant social tensions and massive emigration. Therefore an increasing power supply should be seen 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.

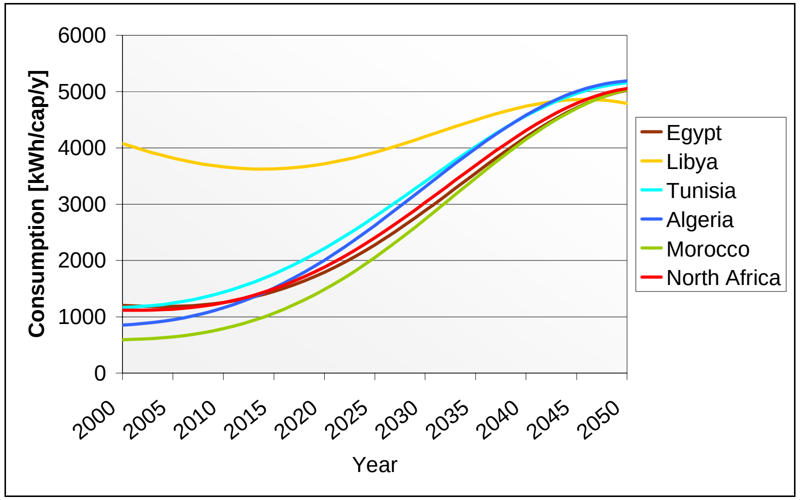
Figure 4-28 shows the per capita power consumption in the analysed countries and its development until 2050. The scenario assumptions lead to a certain equalization of the per capita electricity demand at about 5000 kWh/cap/y in most countries which is in line with the sustainability criteria of fair 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.

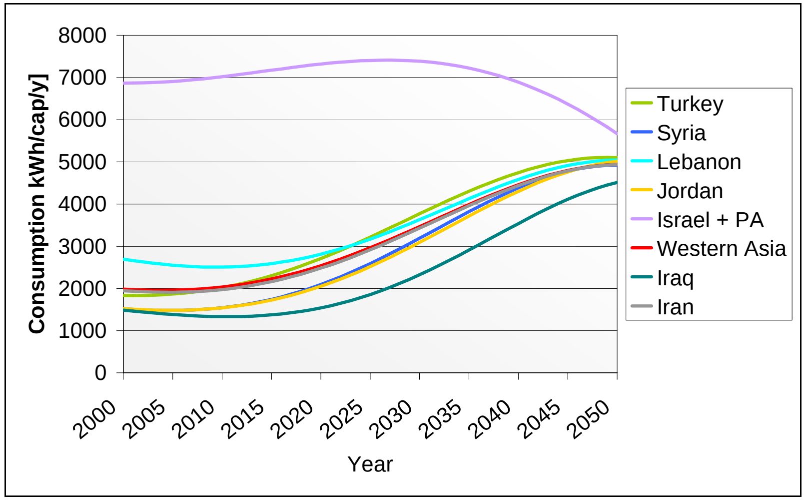
Arabian Peninsula



North Africa



Western Asia



Southern Europe

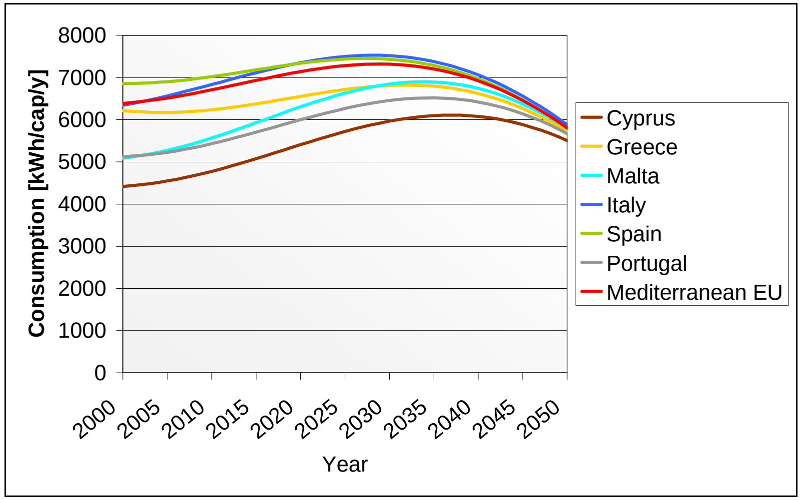


Figure 4-28: Per capita power consumption in the scenario CG/HE

	Elec-tricity per capita, (FU)	**Elec-tricity per GDP** (FU)	**Elec-tricity** (FU)	**Elec-tric-ity/capita** (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/.

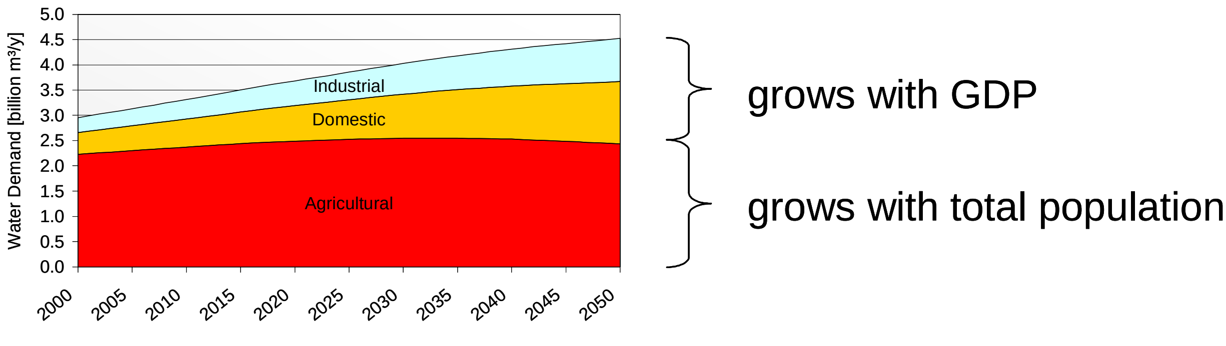


Figure 4-29: Water demand of the industrial, domestic and agricultural sectors as function of population and GDP. Note: GDP is a function of population and per capita GDP growth rates.

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 %.

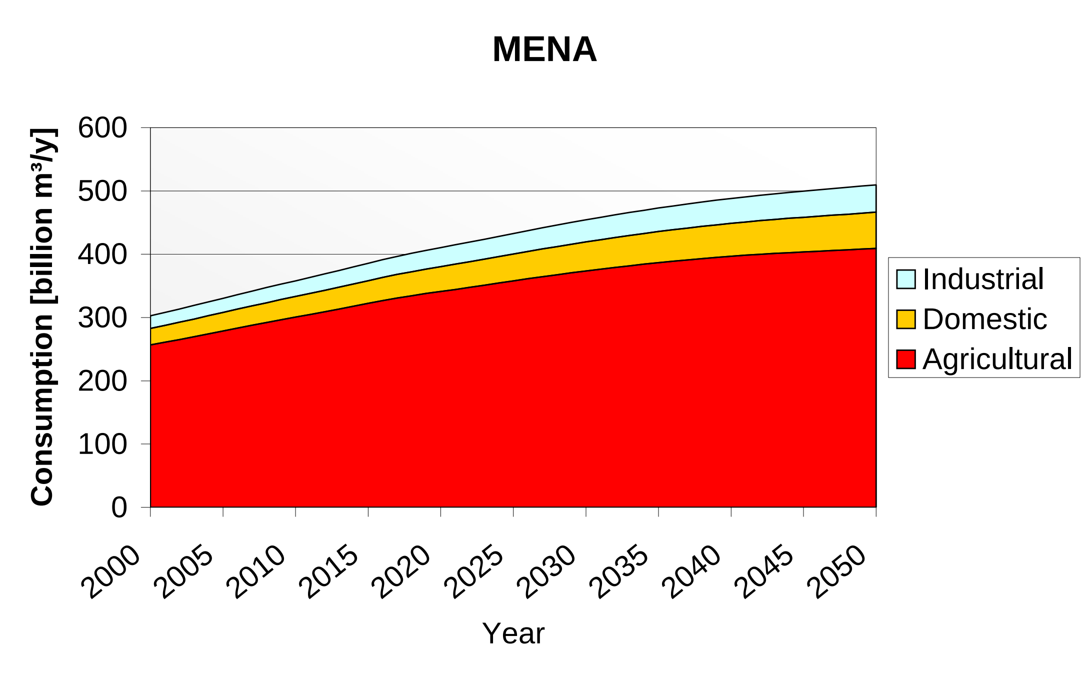


Figure 4-30: Water demand structure in MENA and its evolution until 2050. Scenario "Following Up"

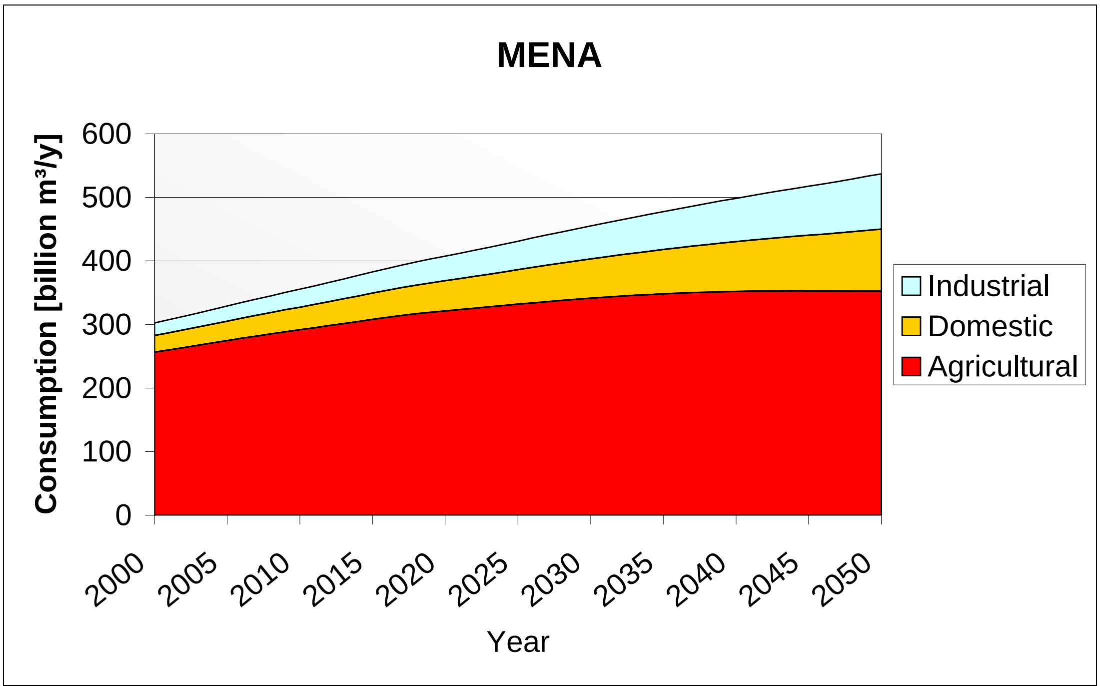


Figure 4-31: Water demand structure in MENA and its evolution until 2050. Scenario "Closing the Gap"

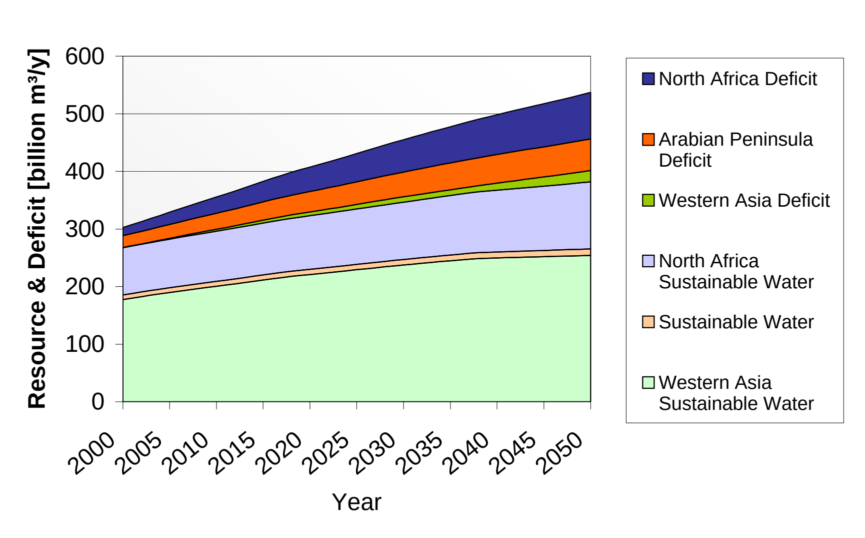


Figure 4-32: Water supply from sustainable sources and deficits in MENA (Closing the Gap).

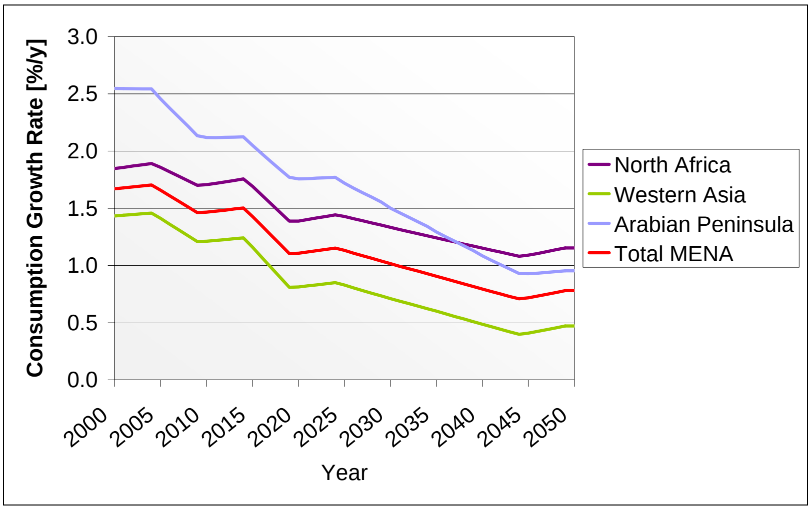


Figure 4-33: Water consumption growth rates in MENA (Closing the Gap).

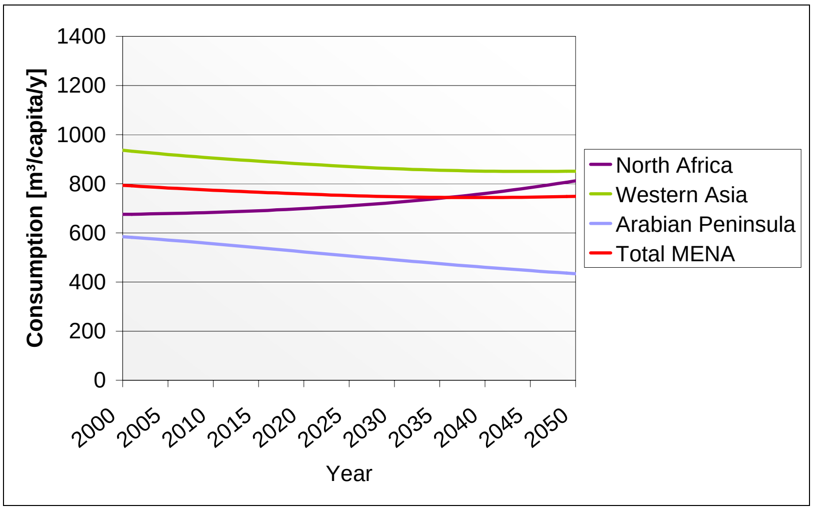


Figure 4-34: Water consumption per capita in MENA (Closing the Gap).

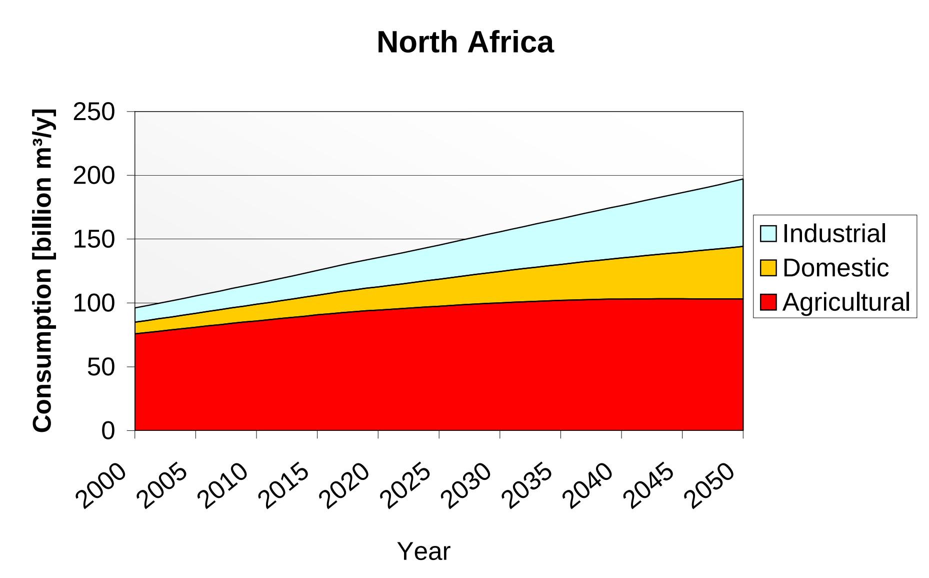


Figure 4-35: Water demand structure in North Africa and its evolution until 2050

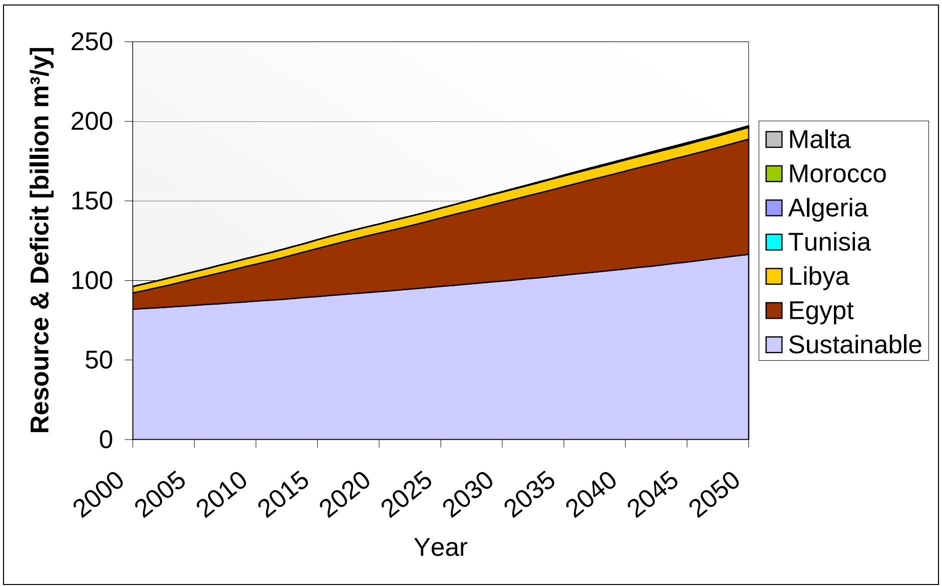


Figure 4-36: Regional sustainable water resource and national deficits in North Africa until 2050.

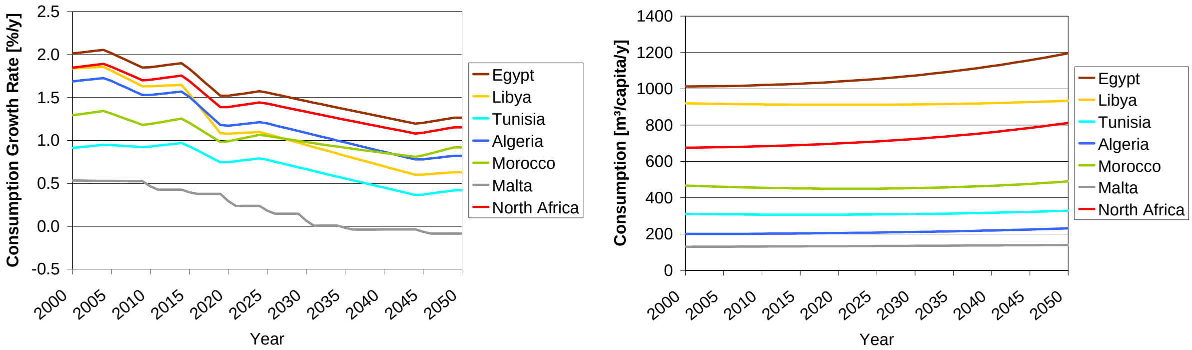


Figure 4-37: Water consumption growth rates and consumption per capita in North Africa until 2050.

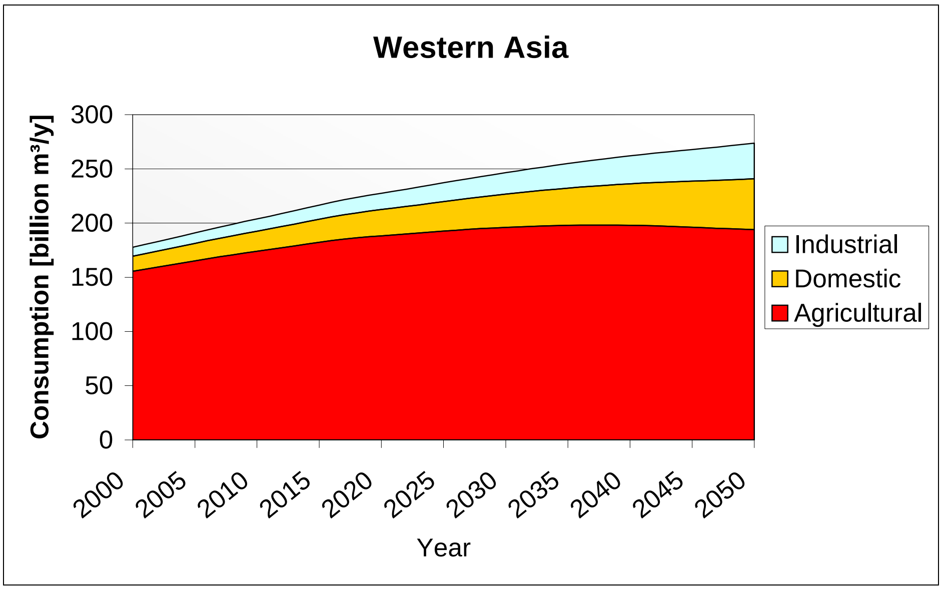


Figure 4-38: Water demand structure in Western Asia and its evolution until 2050

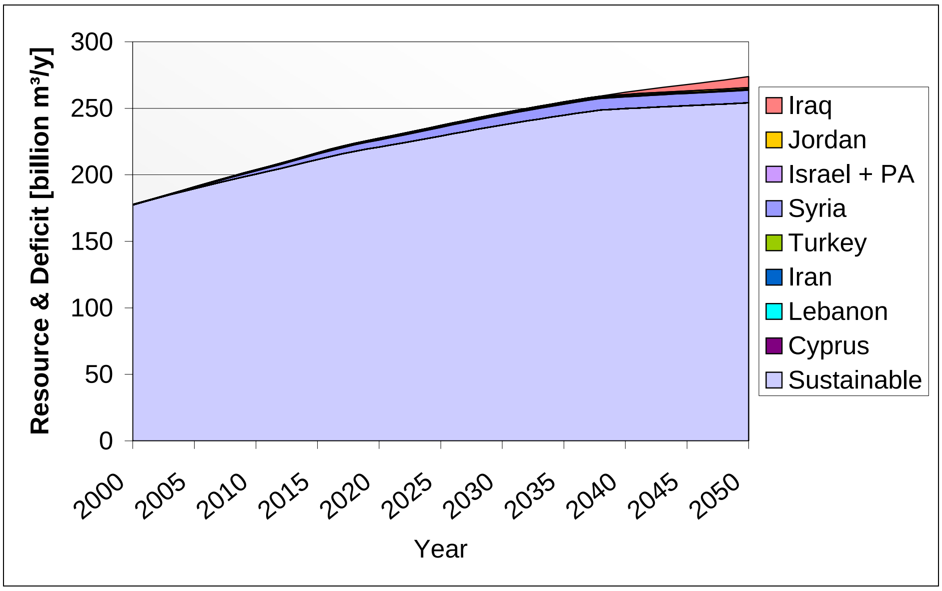


Figure 4-39: Regional sustainable water resource and national deficits in Western Asia until 2050.

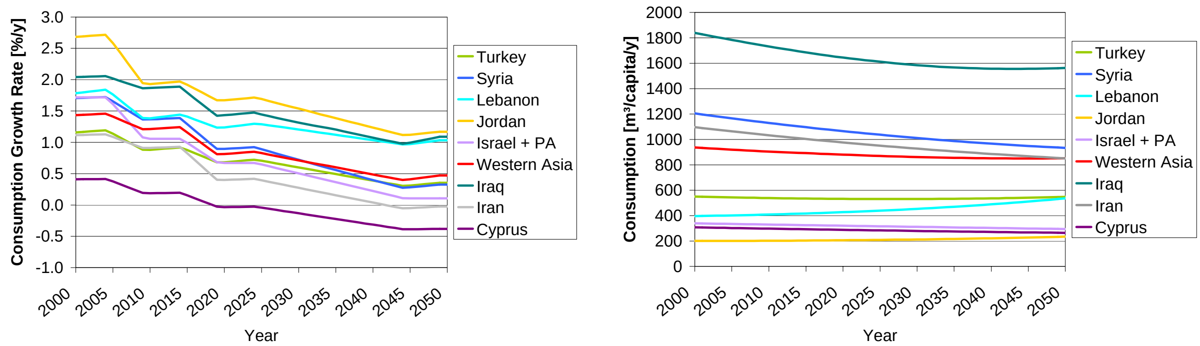


Figure 4-40: Water demand growth rates and demand per capita in Western Asia until 2050.

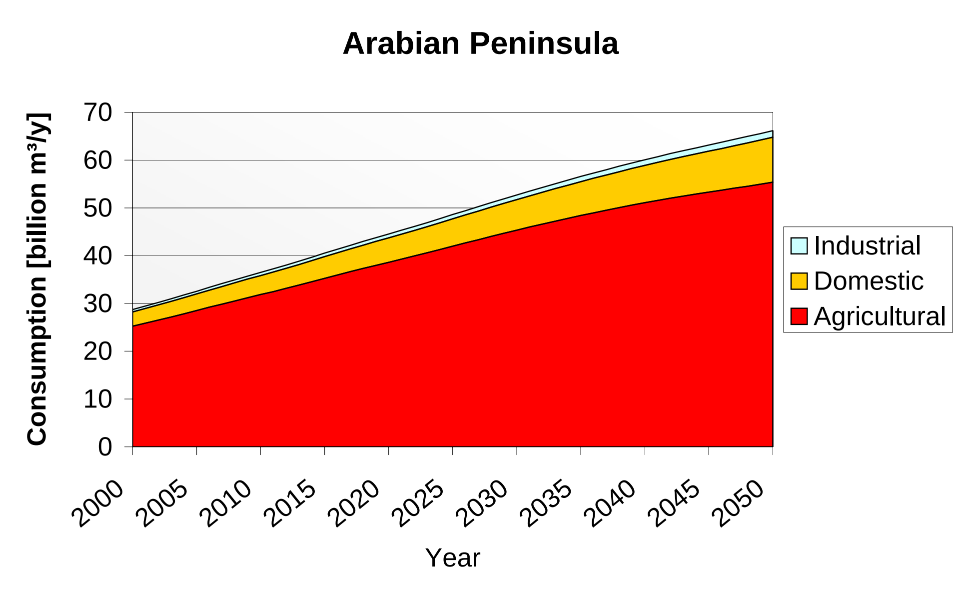


Figure 4-41: Water demand structure for Arabian Peninsula and its evolution until 2050

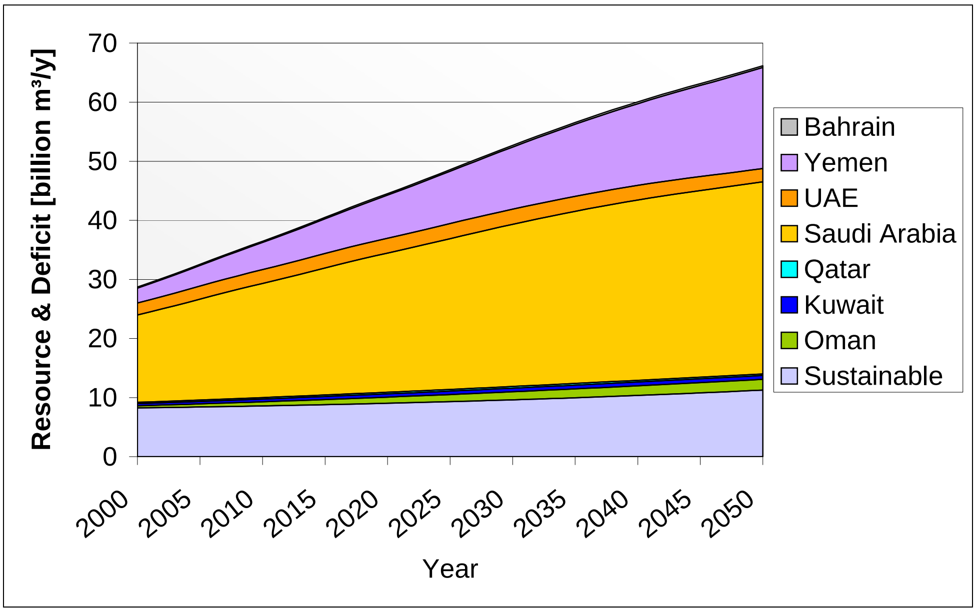


Figure 4-42: Regional sustainable water resource and national deficits for Arabian Peninsula until 2050.

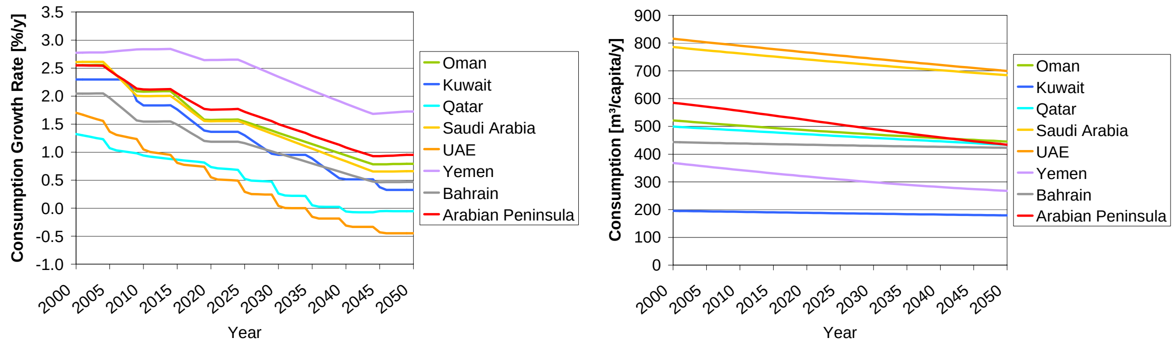


Figure 4-43: Water demand growth rates and demand per capita for the countries of the Arabian Peninsula until 2050.

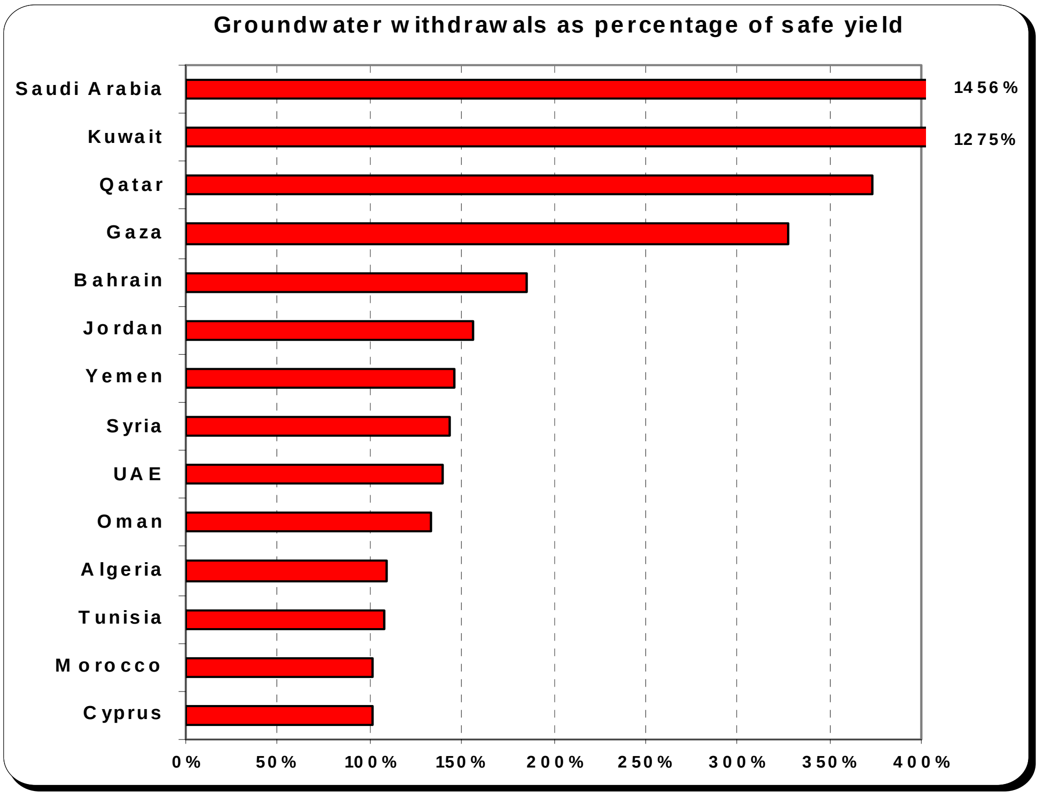


Figure 4-44: Groundwater withdrawels as percentage of save yield for selected countries /Saghir 2003/

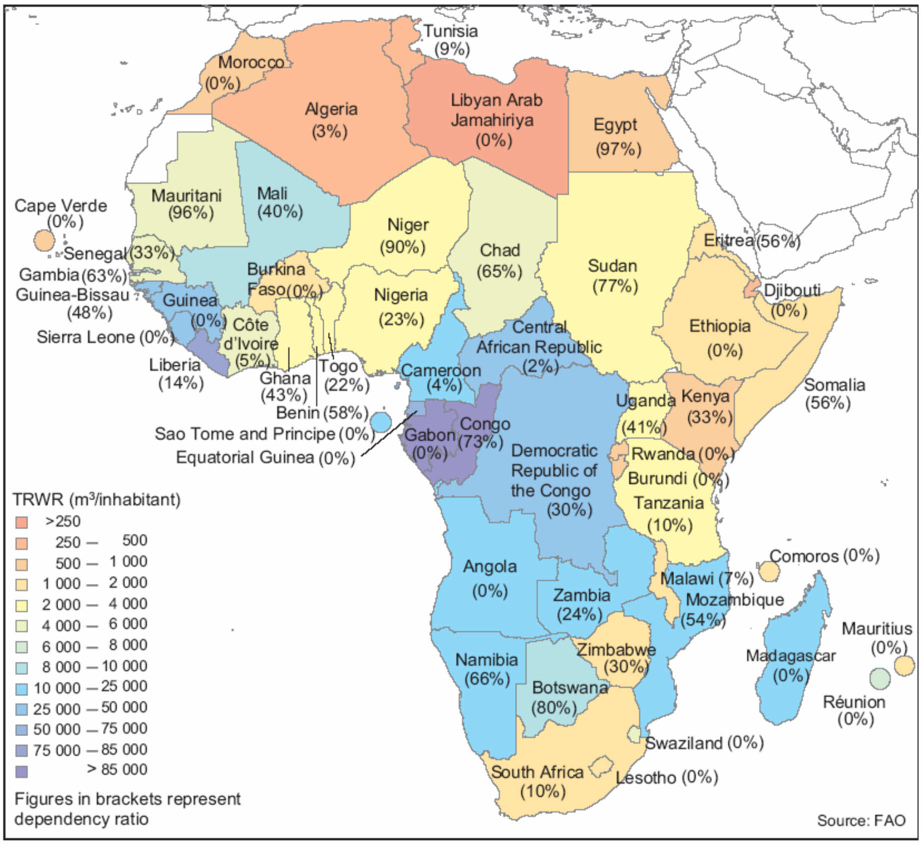


Figure 4-45: Water resources in the Africa region, total renewable water resources (TRWR) and dependency ratio /FAO 2003/

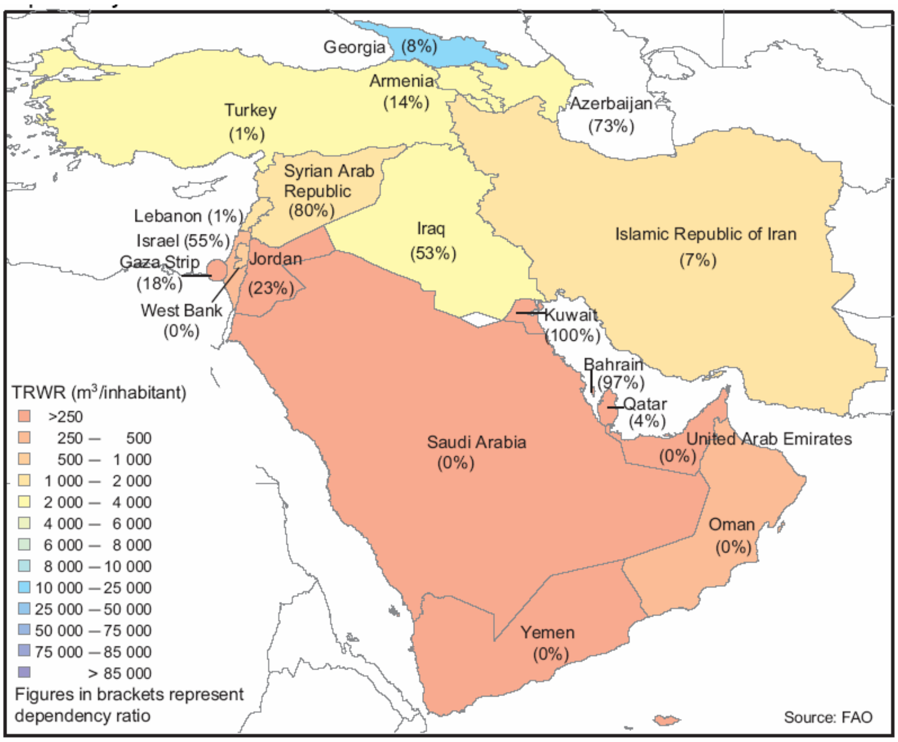


Figure 4-46: Water resources in the Near East region, total renewable water resources (TRWR) and dependency ratio /FAO 2003/

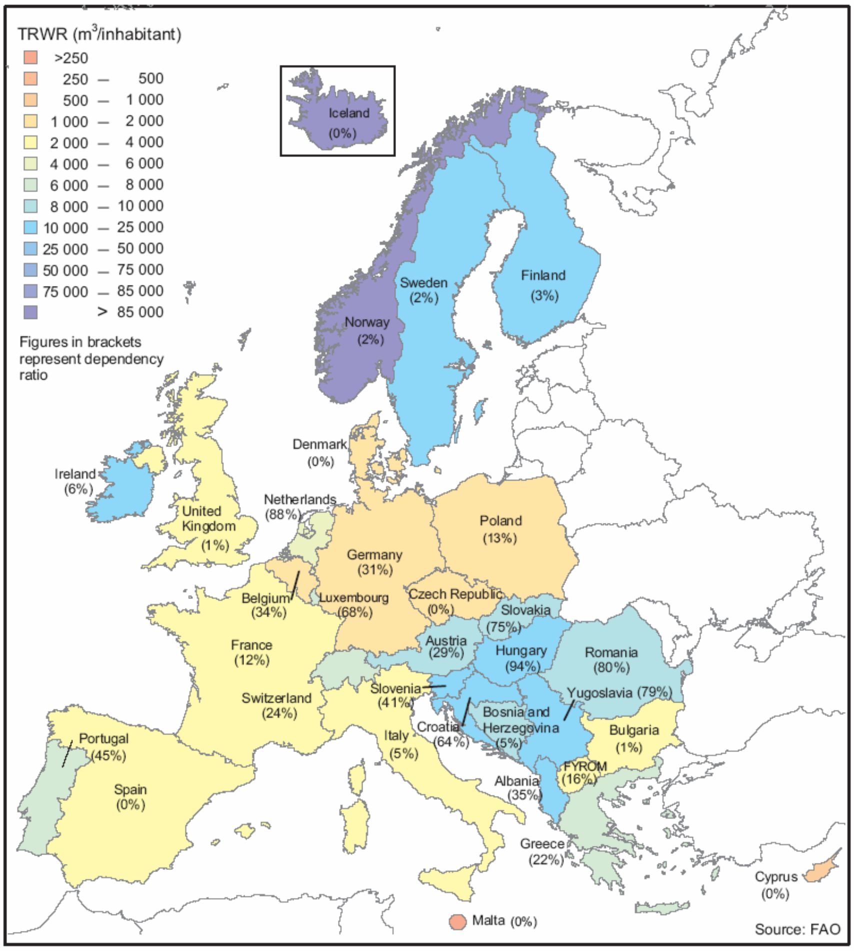


Figure 4-47: Water resources in the Western and Central Europe region, total renewable water resources (TRWR) and dependency ratio /FAO 2003/

5 A Scenario for Energy and Water Security

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

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

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

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

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

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

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

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

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

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

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

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

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

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

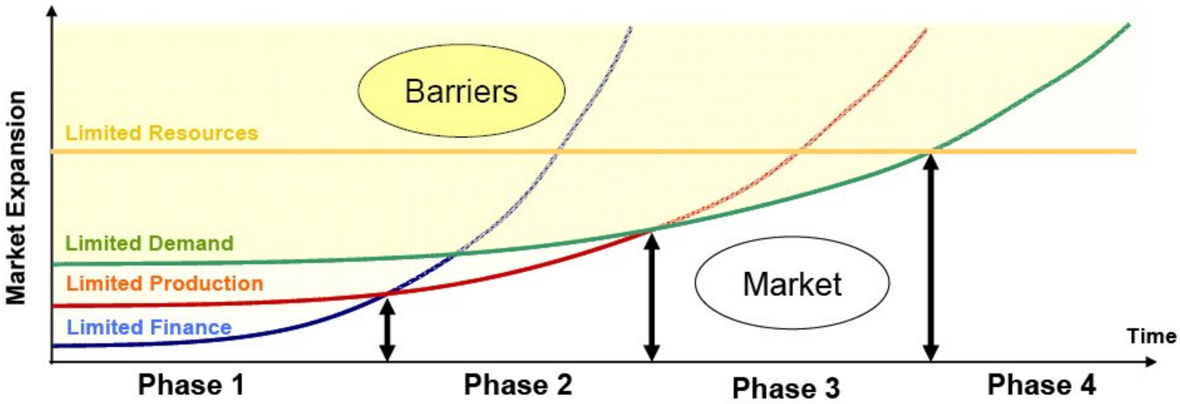


Figure 5-1: Finding Renewable Energy Scenarios with the Crash-Barrier Principle. Subsequently, different factors limit technology expansion. The potential market volume is represented by the white area while the different overlapping crash-barriers are represented by the coloured lines.

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

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

Phase 3 starts once the industrial production capacities reach eye-to-eye level with demand. In this phase, the demand for electricity becomes the limiting factor for market expansion. The demand is not only defined by the quantity of electricity required, but also by its temporal structure (base-, intermediate or peaking load), environmental and social compatibility, security of supply etc. Renewable electricity must fit to the specific requirements of the power

sector. In competition to other technologies, the demand for a certain source of electricity is also coupled to its cost. Covering peaking demand usually yields high revenues, while base load electricity only delivers low revenues per generated kilowatt-hour.

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

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

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

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

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

5.1 Technical and Infrastructural Frame Conditions

5.1.1 Interconnection to the Existing Grid Infrastructure

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

With the increasing size of renewable power projects the cost of interconnection will become less important in comparison to the total project investment, and longer distances will be overcome, especially if areas with better renewable energy resources are made accessible. A

good example for this are the large existing hydropower schemes in Egypt, that have justified the construction of several alternate current (AC) lines with over 500 kV operative voltage over hundreds of kilometres from the dams in Southern Egypt to the population centres in the North. Such structures are typical for regions with highly concentrated population centres and low population density in the rest of the area as is the case in Egypt. In contrast to that, a typical central European country like Germany has a strongly diversified electricity grid with many nodes and interconnections, but with up to a maximum voltage of 400 kV only.

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

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

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

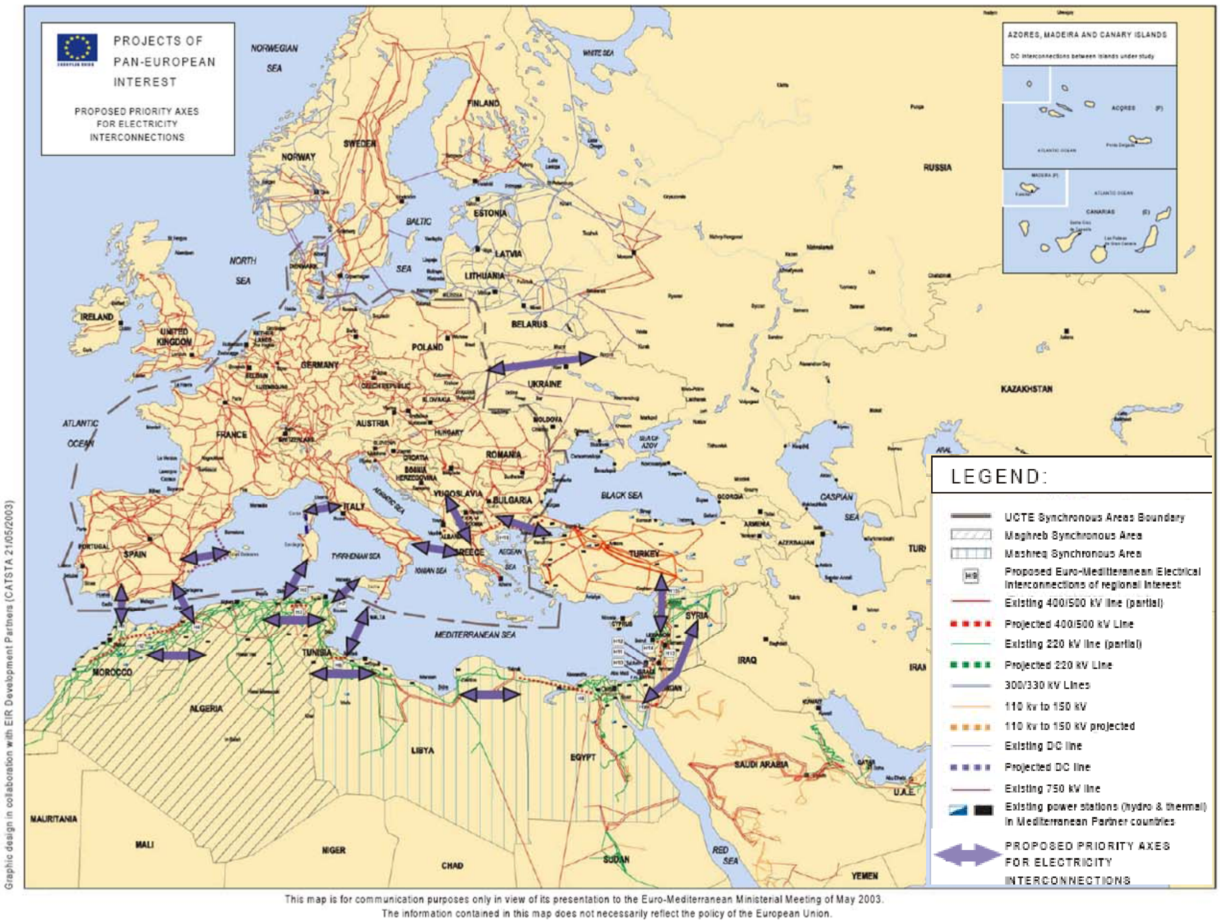


Figure 5-2: Electricity grid and proposed areas for electricity interconnections in the EU-MENA region
Source: SAVE Programme of the European Commission

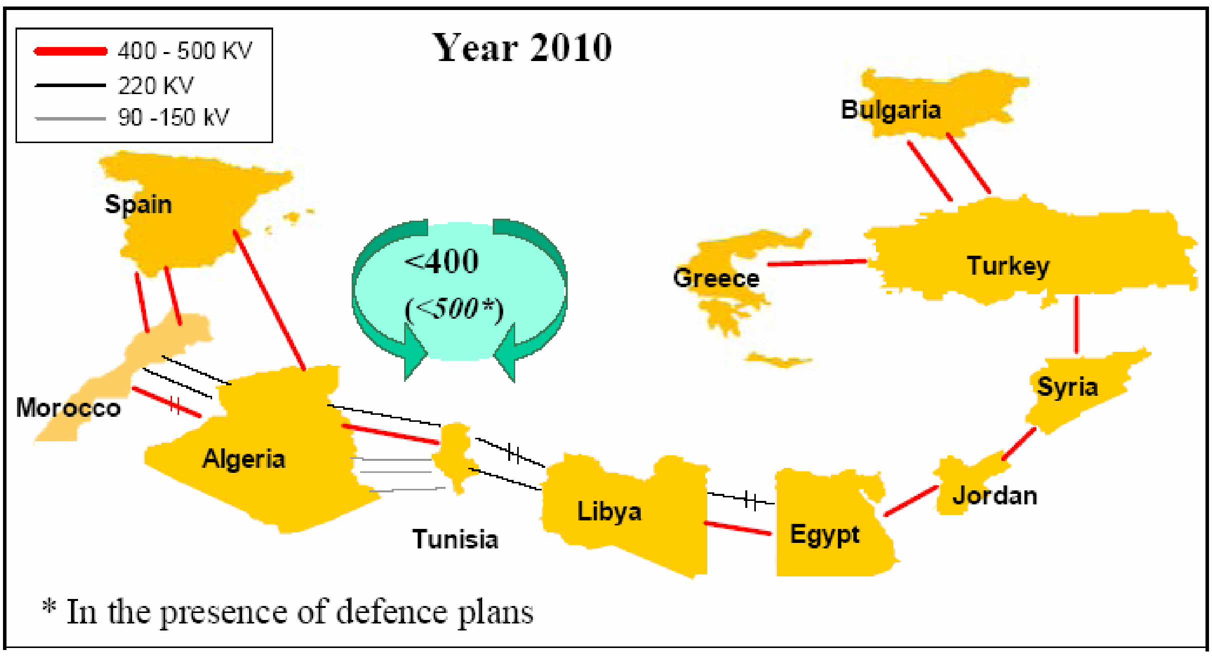


Figure 5-3: Synthesis of limits of power exchanges (MW) for year 2010 through the AC grid and example of improvements that can be achieved through defence plans /EURELECTRIC 2003/

5.1.2 Growth Rates of Renewable Electricity Generation Technologies

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

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

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

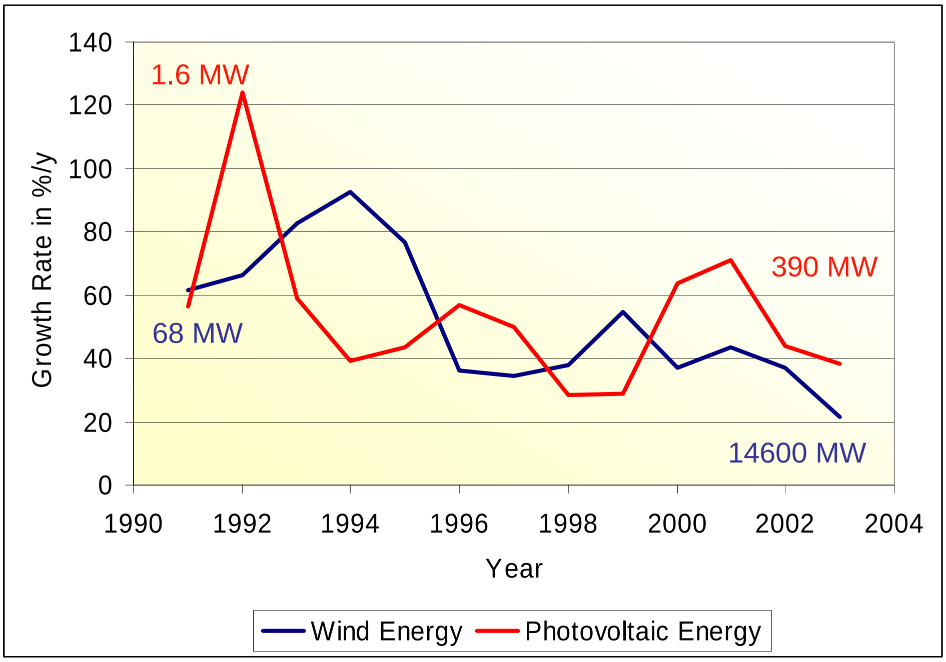


Figure 5-4: Growth rates of PV and wind energy in Germany /Quaschning 2000/, /BMU 2004-1/

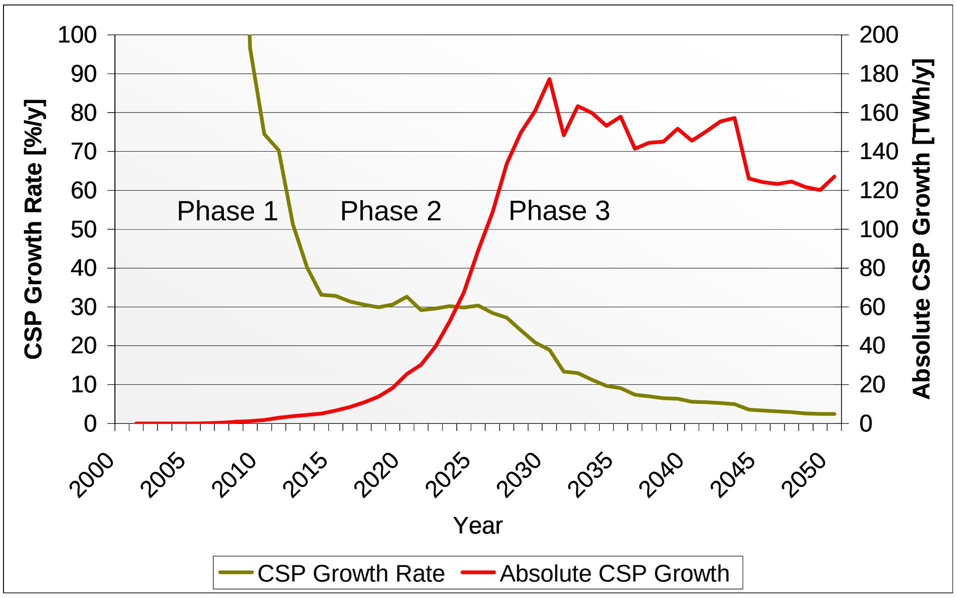


Figure 5-5: Growth rate of CSP production capacities during the three phases of market introduction, in relative and absolute terms of annual solar electricity generation, calculated for 2500 kWh/m²/y irradiance. The values summarize all countries analysed in the study.

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

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

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

5.1.3 Time Pattern of Electricity Demand

Using the demand as a parameter of the crash-barrier principle requires a more precise definition of the demand structure. There is a demand for electricity in terms of energy (GWh/y), a demand for peak power in terms of GW of installed capacity including reserves, and a certain

time structure that defines how much power capacity is required at what time, defined by the load curve in terms of GW that varies for every hour of the year.

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

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

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

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

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

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

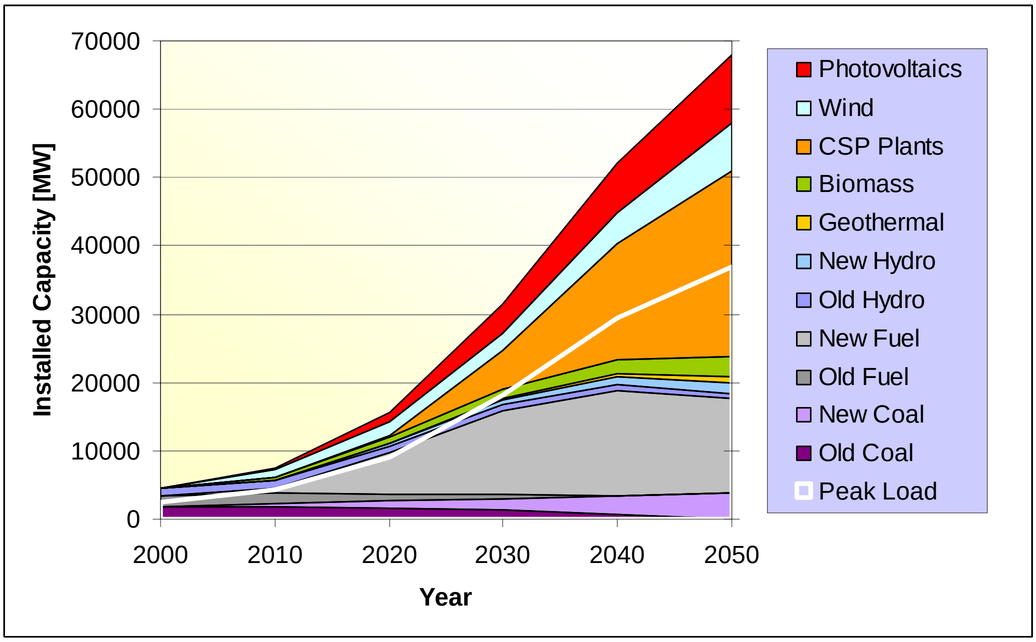


Figure 5-6: Example of the composition of the installed power capacity in Morocco within the MED-CSP scenario. The Figure 5-shows the growing peak load demand and the capacity overhead that increases with growing renewable energy share. A minimum 25 % reserve of secured capacity is granted any time.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

Modelling the power park of the future, we have tried to find a “well balanced mix” of renewable and fossil energy sources, taking the best of each technology to deliver a reliable and

economic power supply compatible with environment and socio-economic development. One of the pre-conditions of this electricity mix is that it must cover the power demand at any time, with a security margin of 25 % of minimum remaining reserve capacity.

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

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

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

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

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

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

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

Wind Power

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

Photovoltaic

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

Geothermal Hot Dry Rock

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

Biomass Power Generation

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

Hydropower

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

Solar Thermal Electricity

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

Oil and Gas fired Power Plants

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

Coal Steam Plants

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

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

Nuclear Fission and Fusion

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

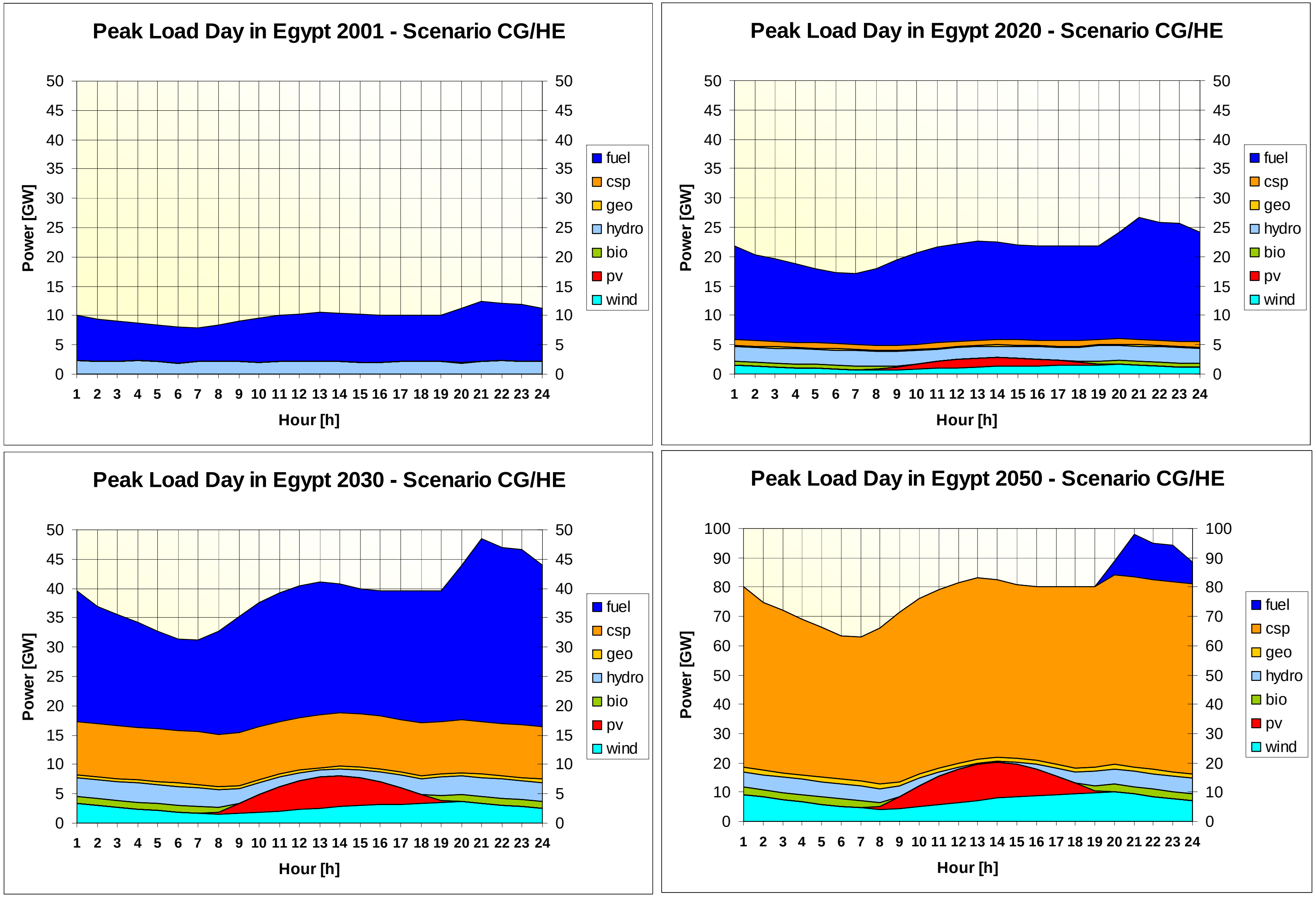


Figure 5-7: Power Generation on the Peak Load Day in Egypt in the Years 2001, 2020, 2030 and 2050 according to the MED-CSP scenario. Note that the scaling of the power axis of the lower right figure (2050) changes to 100 GW.

5.1.4 Technology Investment Cycles

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

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

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

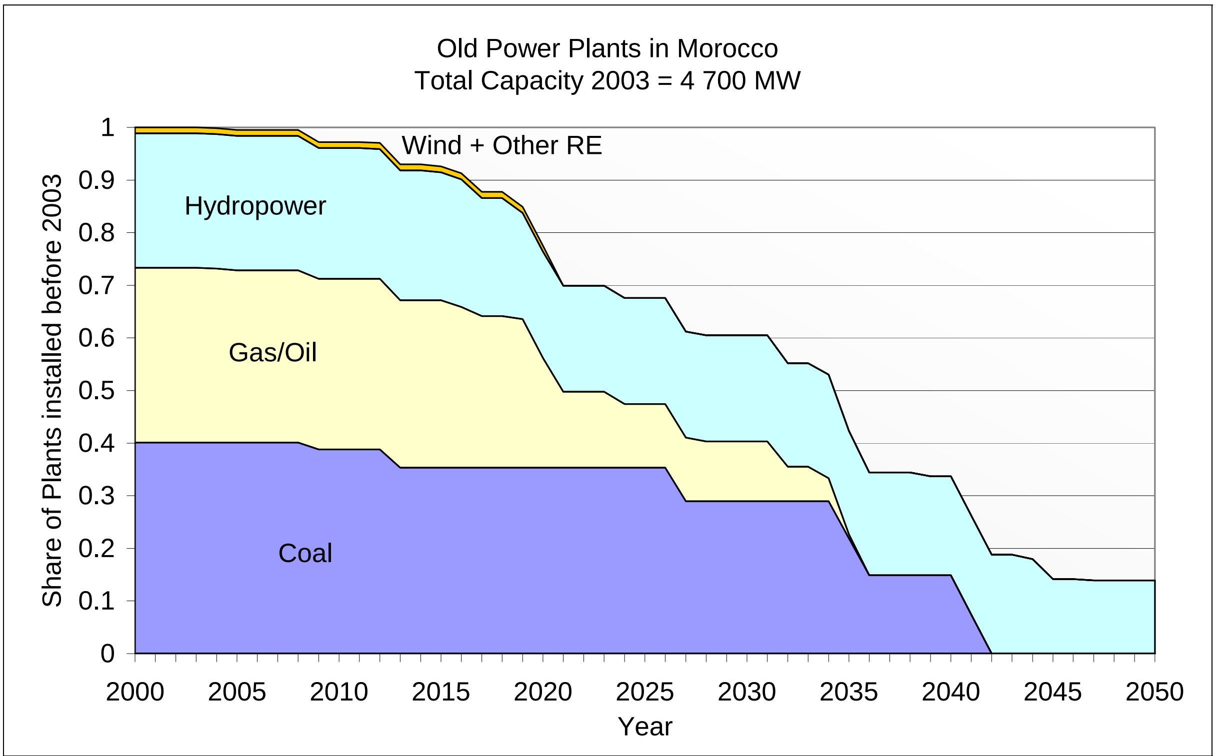


Figure 5-8: Life curve of the power plant inventory installed before 2003 in Morocco as function of time. Lifetime of gas and steam turbines 40 years, wind power 20 years, hydropower 65 years /Platts 2004/.

5.2 Energy Economic Frame Conditions

5.2.1 General Economic Frame Conditions

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

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

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

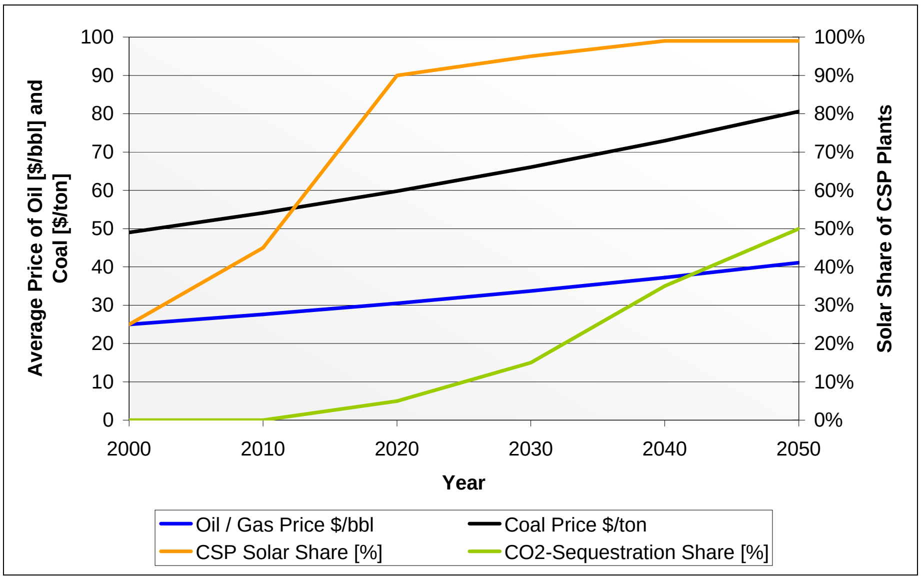


Figure 5-9: Some energy economical limiters: development of Fuel Prices (\$-2000), Solar Share of CSP Plants and CO2-Sequestration Share of Fossil Power Generation in Europe within the MED-CSP Scenario

5.2.2 The Cost of Power Technologies

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

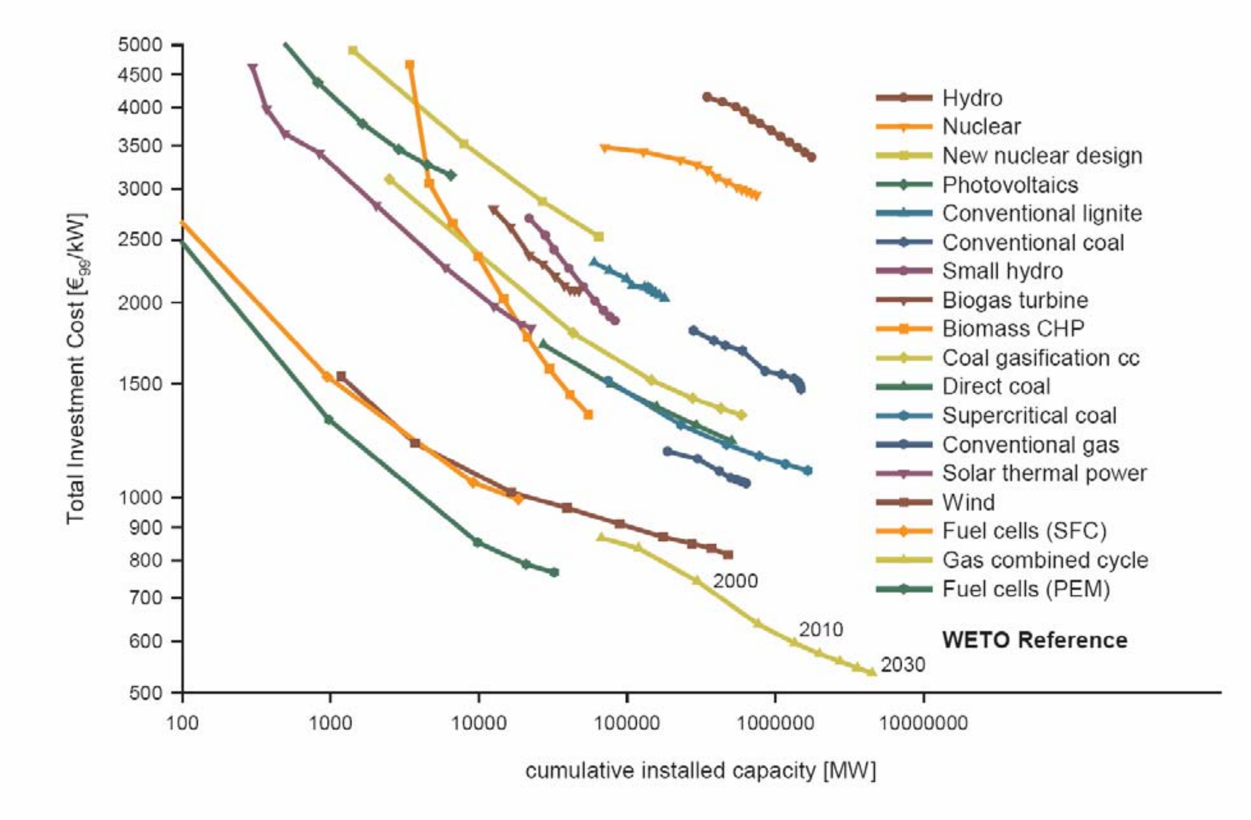


Figure 5-10: Technology Learning Curves according to the WETO reference data base /WETO 2003/

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

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

nologies (Figure 5-13), while collectors and storage technologies become less expensive as shown in Figure 5-11.

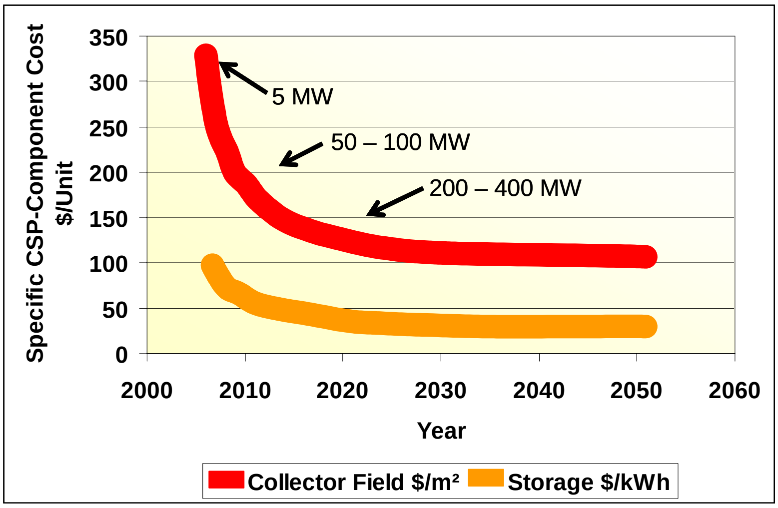


Figure 5-11: Expected learning curve of concentrating solar collector fields and storage technologies. Also refer to /NREL 2003/.

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

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

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

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

C_{el} cost of electricity in $-2000/kWh

Inv investment cost in $-2000

FCR fixed charge rate as function of interest rate and economic lifetime (annuity)

O&M annual cost of operation and maintenance, personnel, insurance, etc.

F annual fuel expenses

E_{year} electricity generated per year = installed capacity (MW) · full load hours (h/y)

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

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

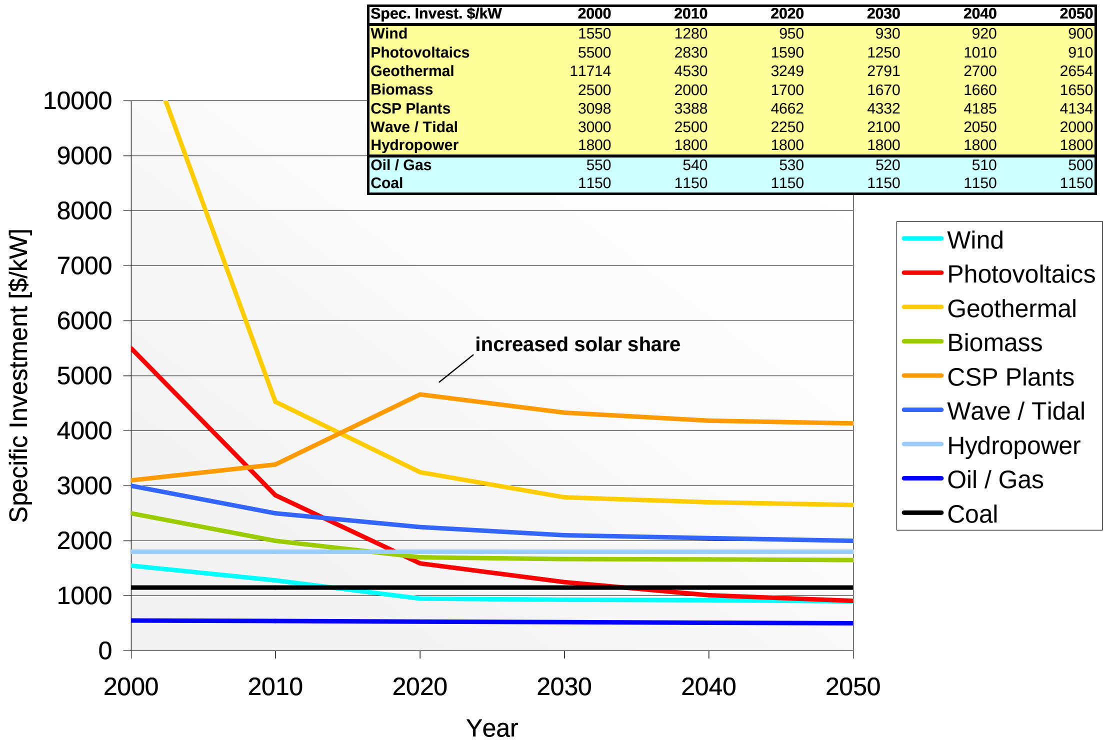
* vary for different countries and sites

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

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

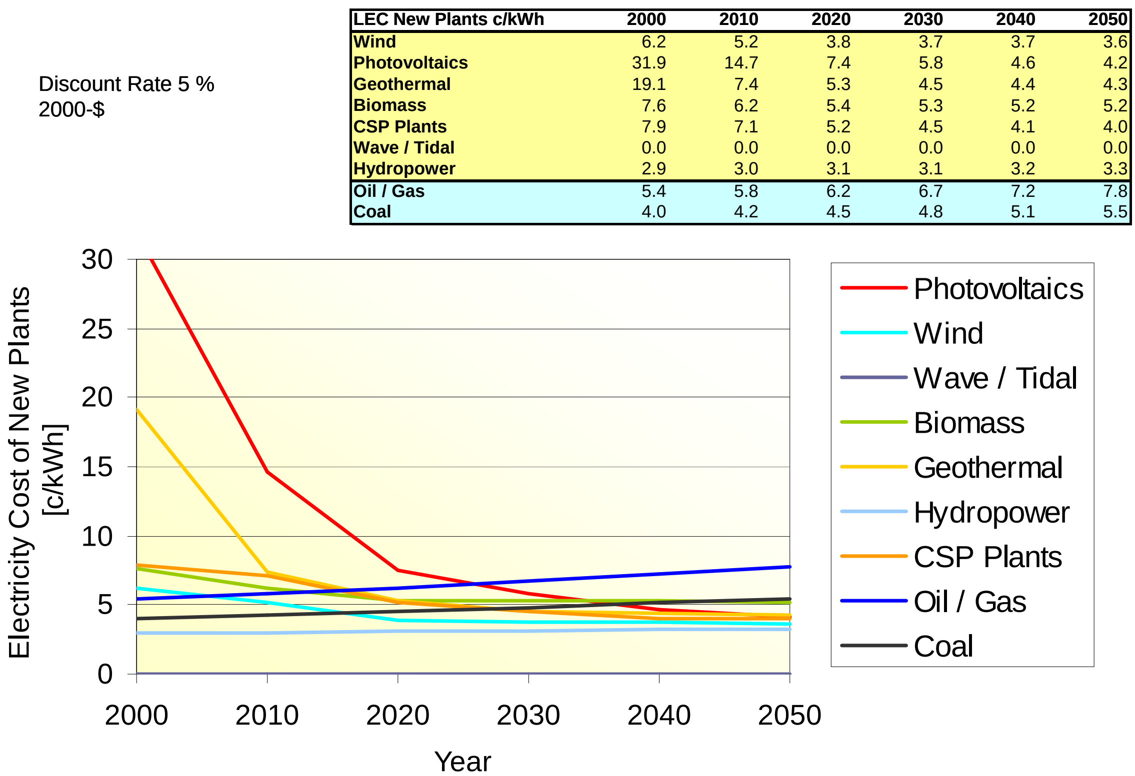
Country	Egypt	
Performance Indicator DNI	2800	kWh/m²/y
Discount Rate	5	%/y

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



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

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



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

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

5.3 A Scenario for Energy Security in the Mediterranean Region

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

5.3.1 Energy Security

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

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

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

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

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

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

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

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

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

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

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

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

5.3.2 Energy Price Stability

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

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

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

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

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

5.3.3 Climate Stability

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

5.3.4 Social Stability

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

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

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

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

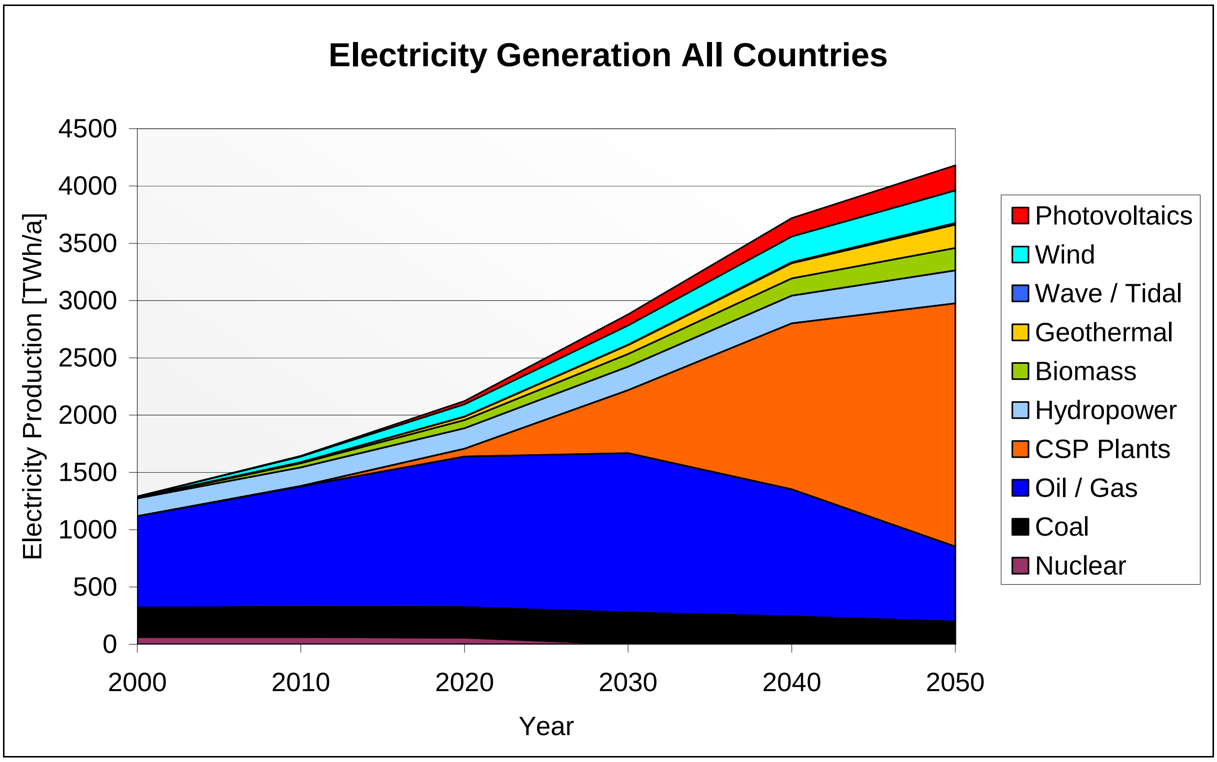


Figure 5-14: Annual electricity generation within the analysed countries in the scenario CG/HE

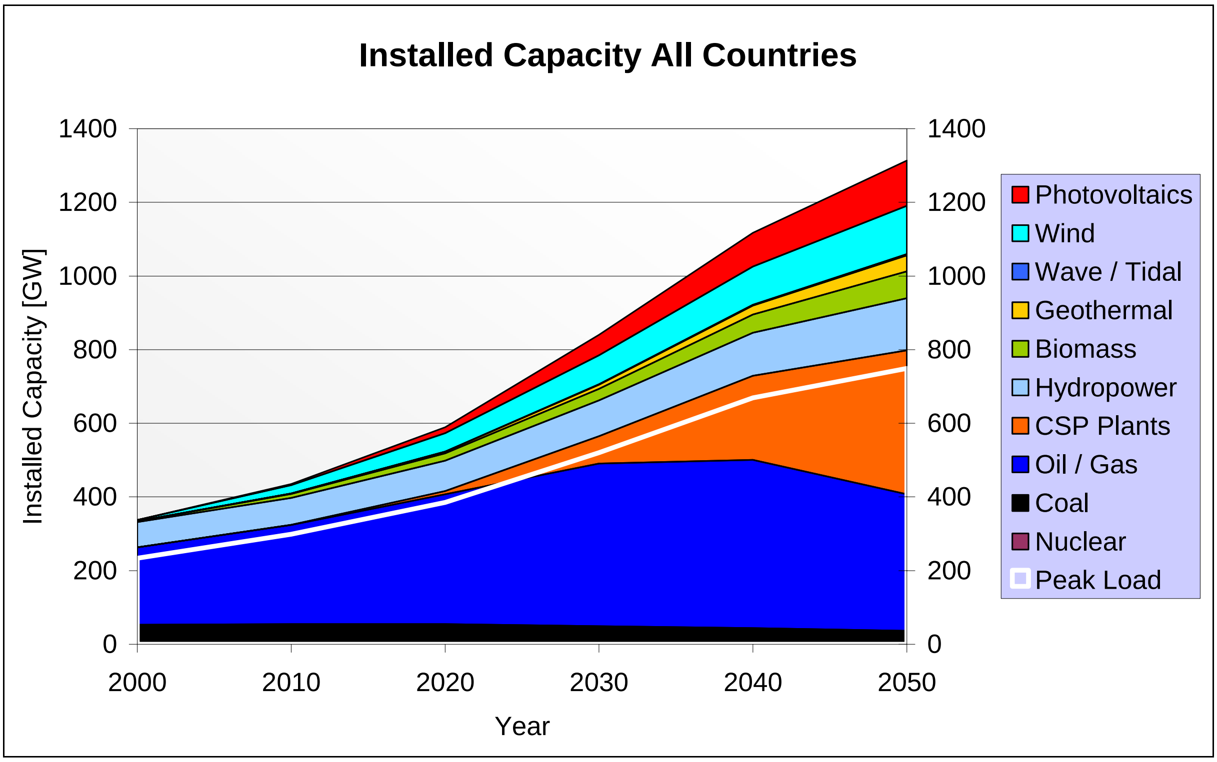


Figure 5-15: Installed power capacity and peak load within the analysed countries in the scenario CG/HE

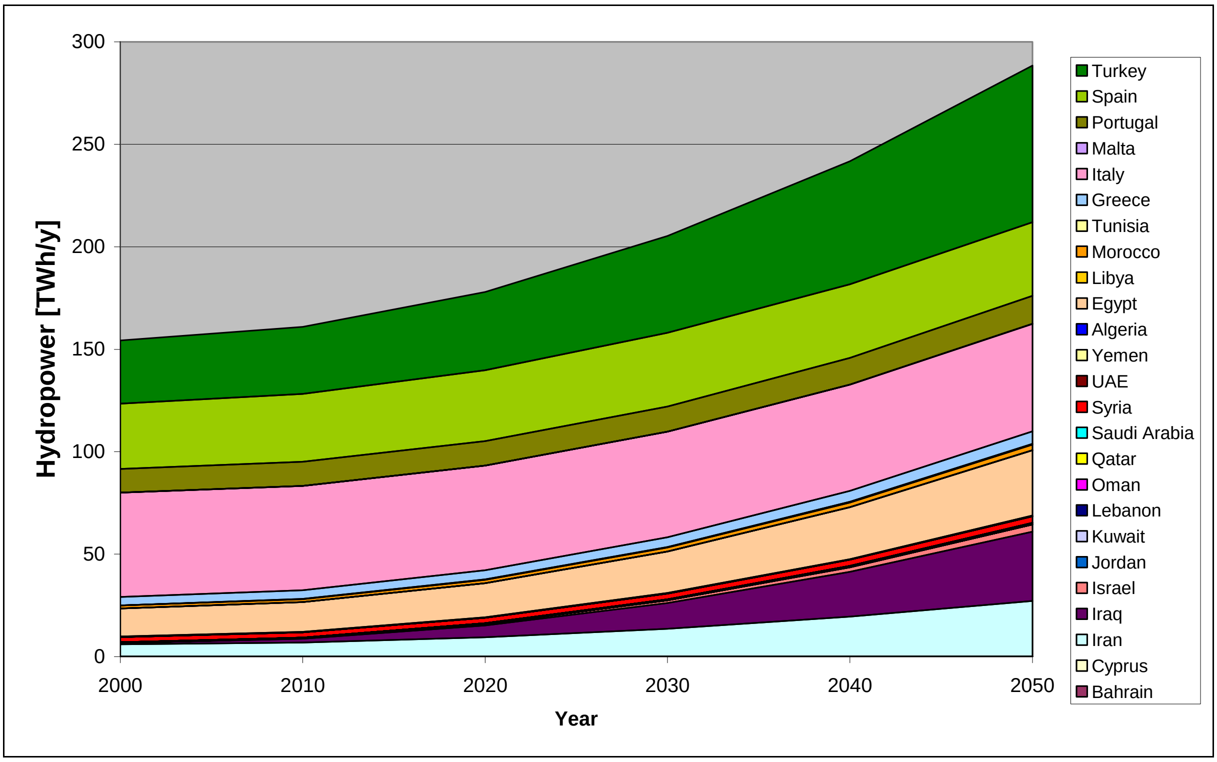


Figure 5-16: Hydropower generation in the MED-CSP scenario. Possible negative effects of climate change on hydropower resources were not considered.

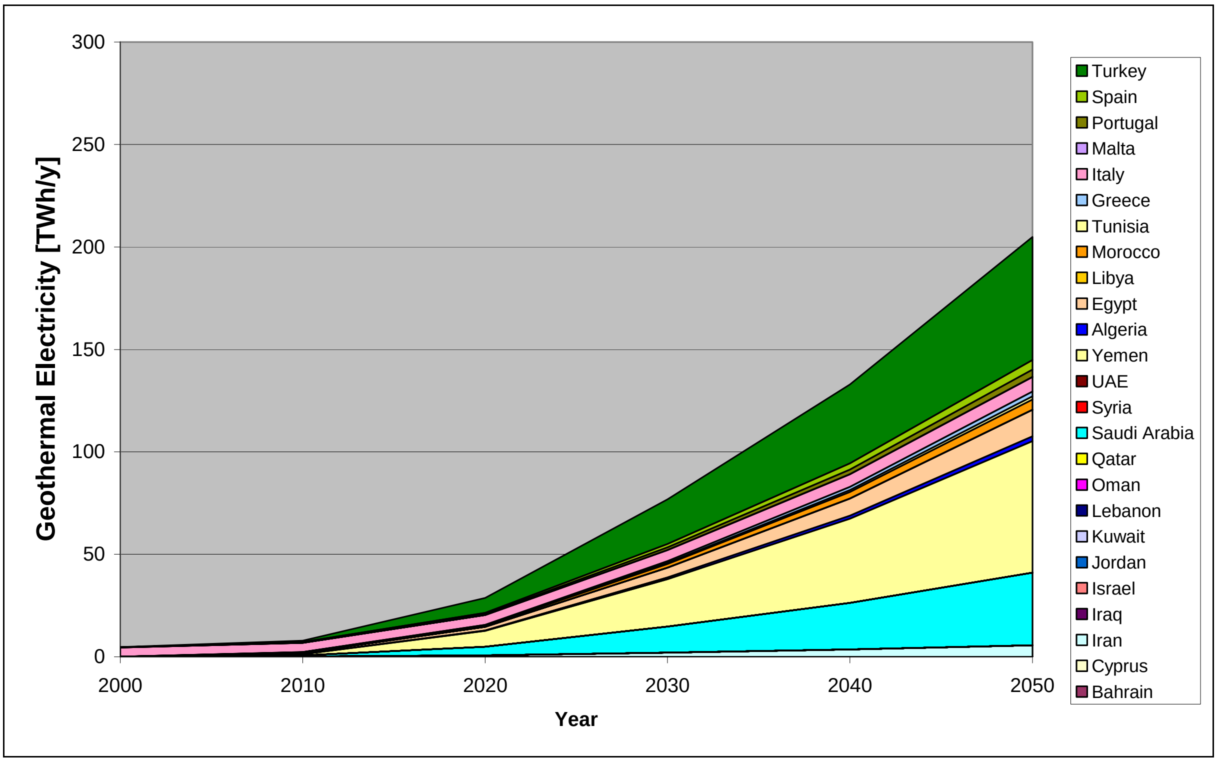


Figure 5-17: Geothermal electricity generation from Hot Dry Rocks in the MED-CSP scenario (minor shares of conventional geothermal electricity included)

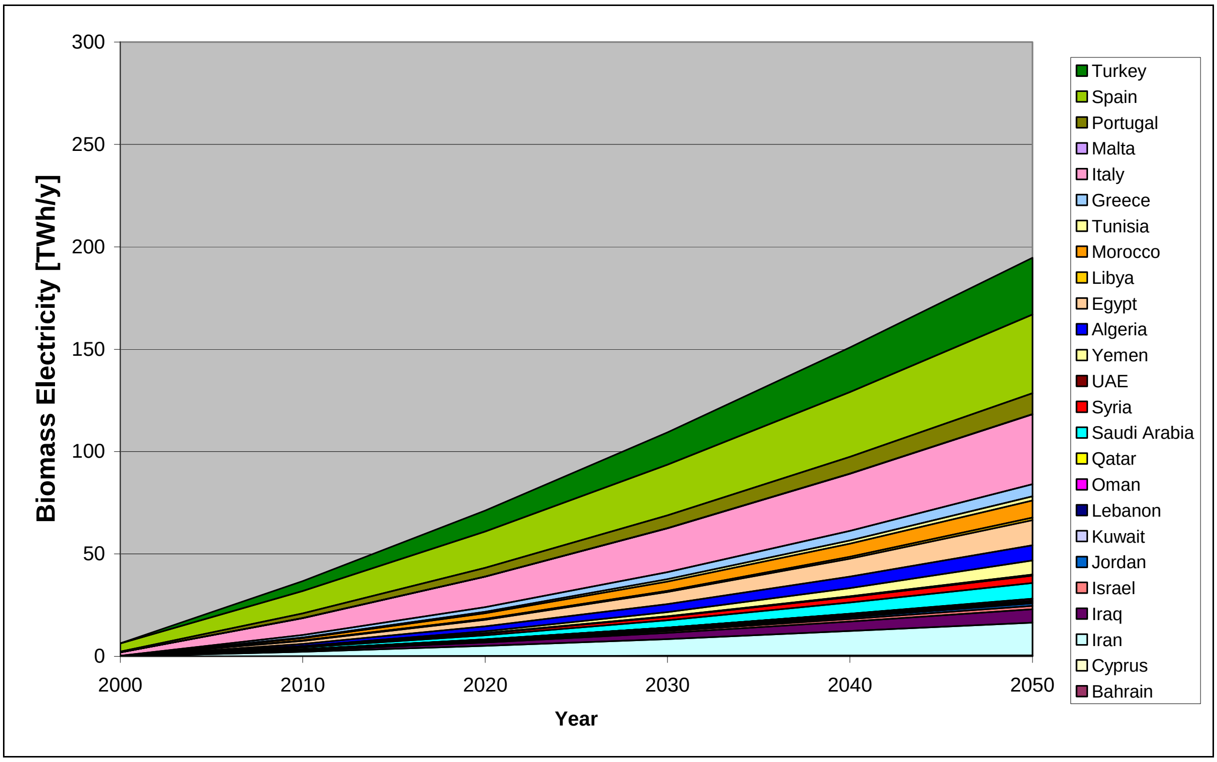


Figure 5-18: Electricity generation from biomass in the MED-CSP scenario. Only agricultural and municipal organic waste and wood resources were considered for power generation. No energy crops.

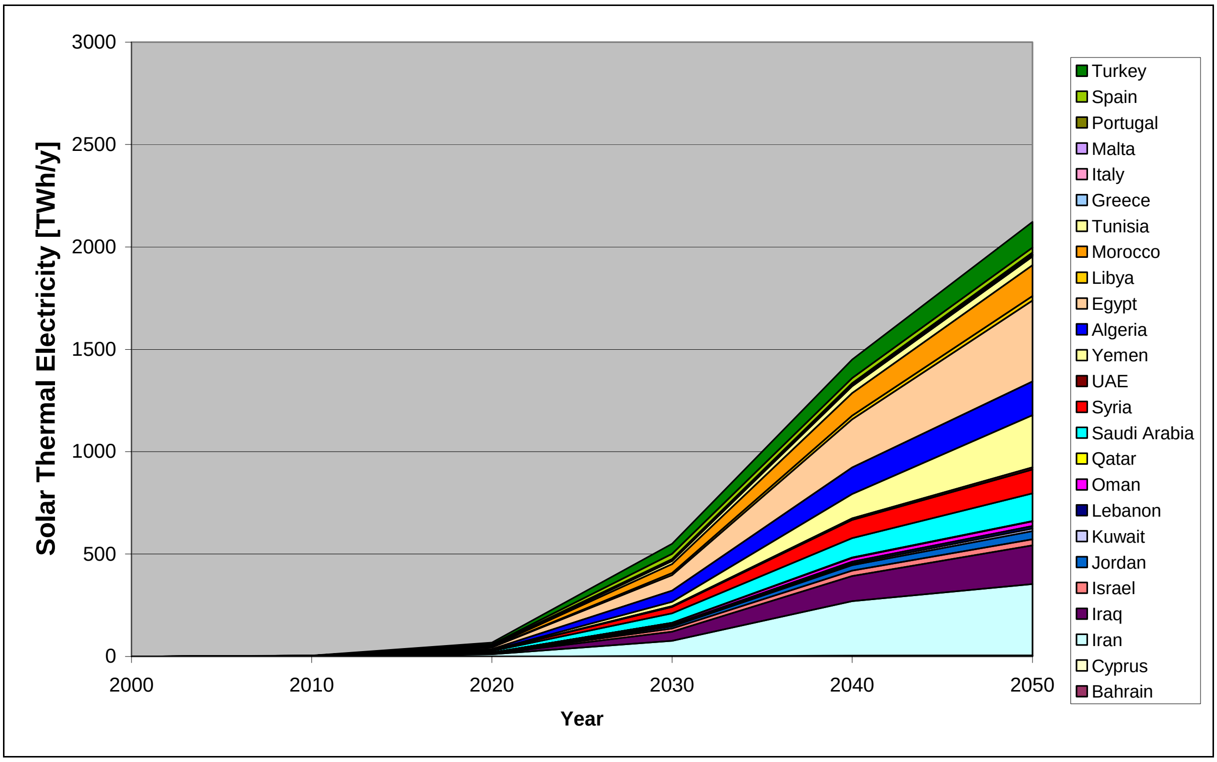


Figure 5-19: Solar thermal electricity generation in the MED-CSP scenario (note the higher scaling of the electricity axis). CSP is initially applied to base load (8000 h/y) and subsequently takes over also peaking duties in the later stage of the scenario.

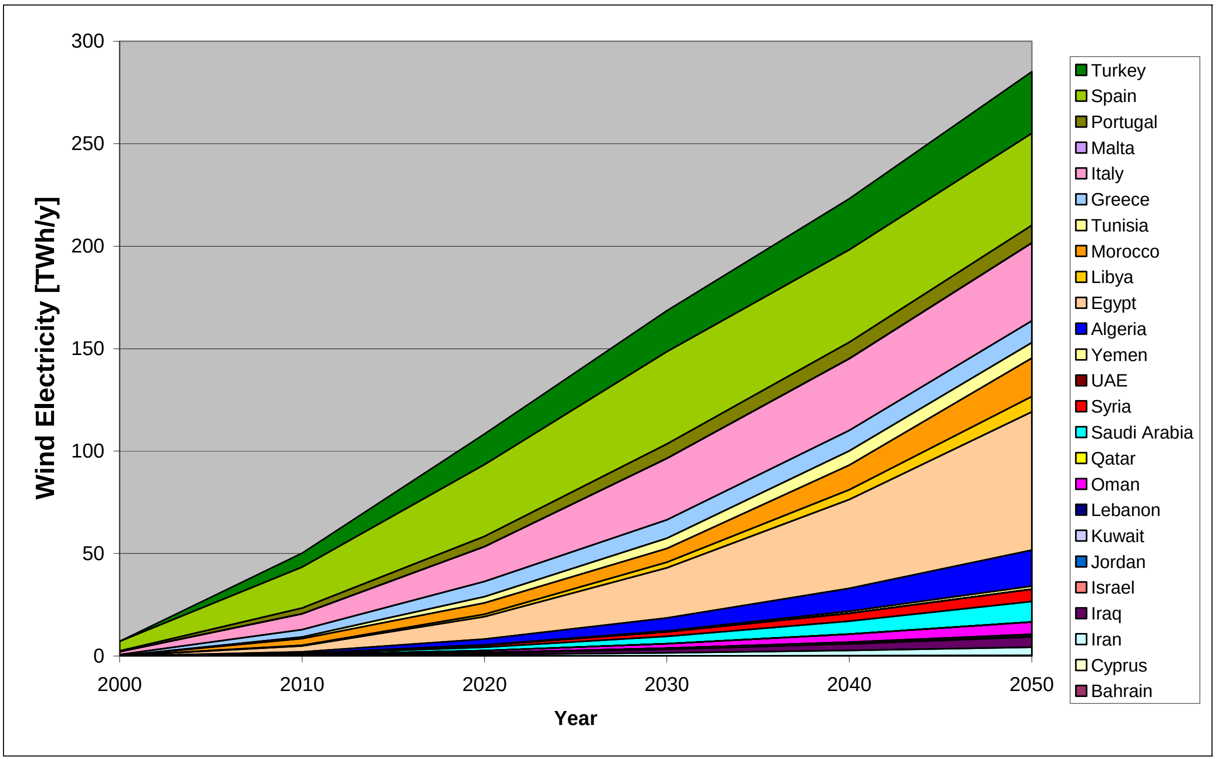


Figure 5-20: Wind electricity generation in the MED-CSP scenario

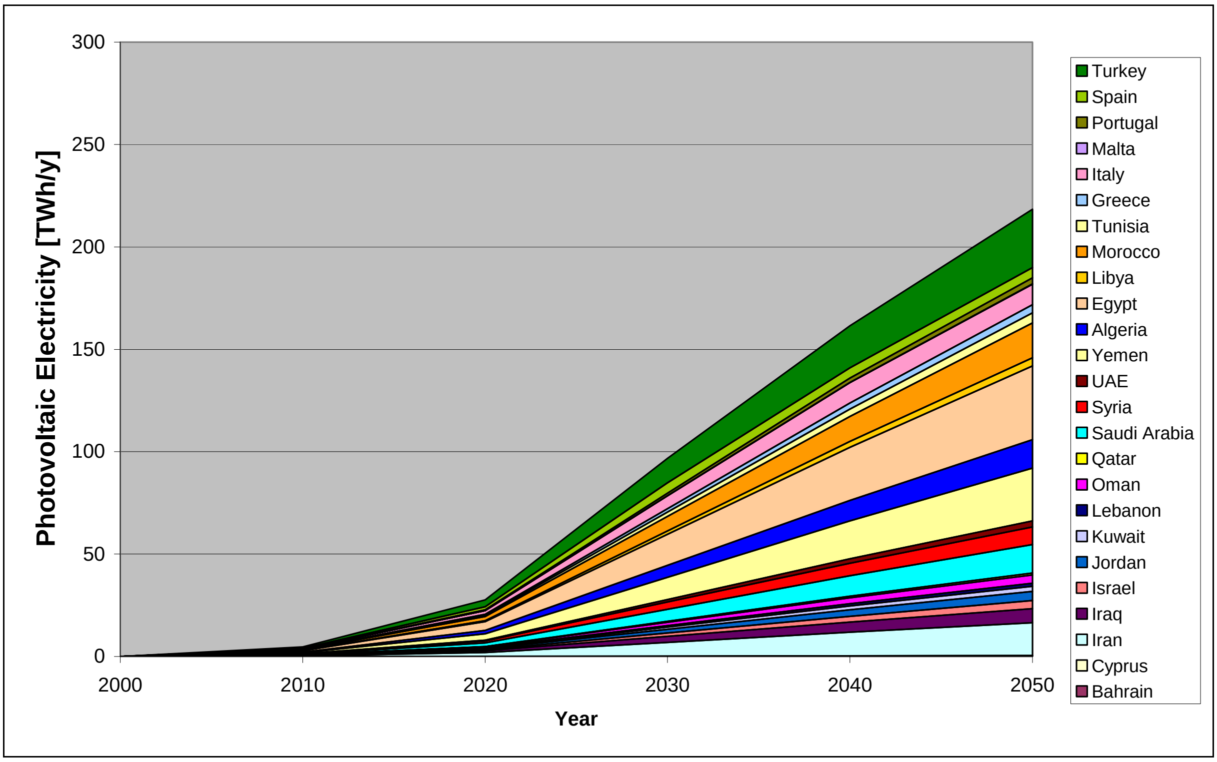


Figure 5-21: Photovoltaic electricity generation in the MED-CSP scenario

5.4 A Scenario for Water Security in the Mediterranean Region

5.4.1 A Pressing Need for Action

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

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

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

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

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

The general role of desalination in our developing world can be illustrated by quoting a recent study from the World Bank /World Bank 2004/. “Desalination alone cannot deliver the promise of improved water supply. The ability to make the best use of desalination is subject to a series of wider water sector related conditions. In some countries weak water utilities, politically determined low water tariffs, high water losses and poor sector policies mean that desalinated water, just like any other new source of bulk water, may not be used wisely or that

desalination plants are at risk of falling into disrepair. Under these conditions, there is a risk that substantial amounts of money are used inefficiently, and that desalination cannot alleviate water scarcity nor contribute to the achievement of the Millennium Development Goals. It may be preferable not to engage in desalination on a large scale unless the underlying weaknesses of the water sector are seriously addressed. A program to address these weaknesses should include a reduction of non-revenue water; appropriate cost recovery; limited use of targeted subsidies; sound investment planning; integrated water resources management; proper environmental impact assessments; and capacity building in desalination as well as in water resources management and utility management. In any case, desalination should remain the last resort, and should only be applied after cheaper alternatives in terms of supply and demand management have carefully been considered.

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

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

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

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

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

Desalination is likely to provide only a portion of the total water needs alongside with existing conventional sources /Mandil et al. 2000/. Although desalination is still more expensive than most existing conventional water sources, its cost is generally lower then the incremental cost

of extra bulk supply from conventional water sources, such as dams and inter-basin transfers. Also, upward pressure on tariffs due to the incremental costs of desalination is gradual and often within the ability and willingness to pay of water users."

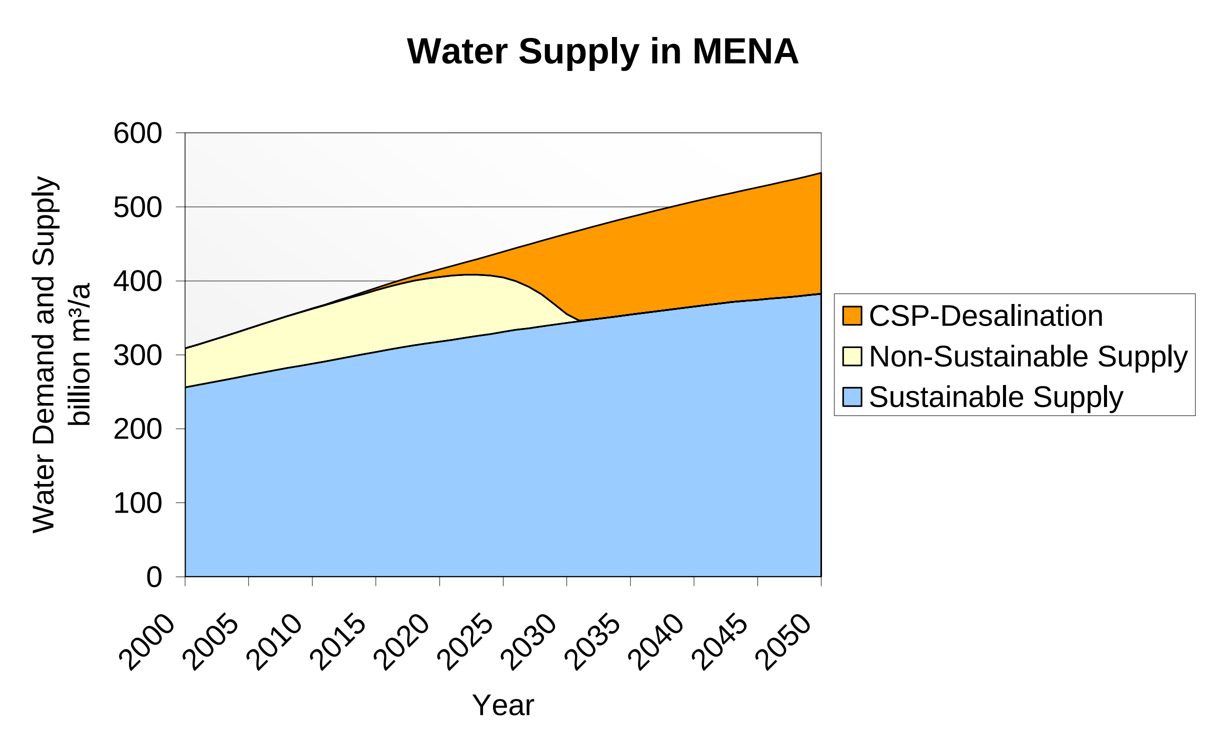


Figure 5-22: Water demand and supply structure in MENA according to the MED-CSP scenario. Non-Sustainable Water includes overexploitation of groundwater resources and desalination with fossil fuels. Sustainable Water includes all natural surface and groundwater resources that are renewable and exploitable,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

5.4.2 The Potential for Renewable Sea Water Desalination in MENA

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

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

However, a considerable increase of non-sustainable use of water will occur in the meantime, with a maximum of 90 billion cubic meters per year between 2015 and 2020. This calls for the intensive additional use of other renewable sources like geothermal and wind power for non-conventional water production, and also calls for an intensive freshwater management

and efficiency enhancements in urban and rural applications. Only a decided employment and efficient combination of all possible measures will lead to a satisfactory and sustainable water supply security in MENA. Seawater desalination with renewable energies is not an alternative, but only a complement to the other measures to increase water efficiency as recommended by the United Nations and other organisations. The main factors for water sustainability are among others /FAO 2002/:

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

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

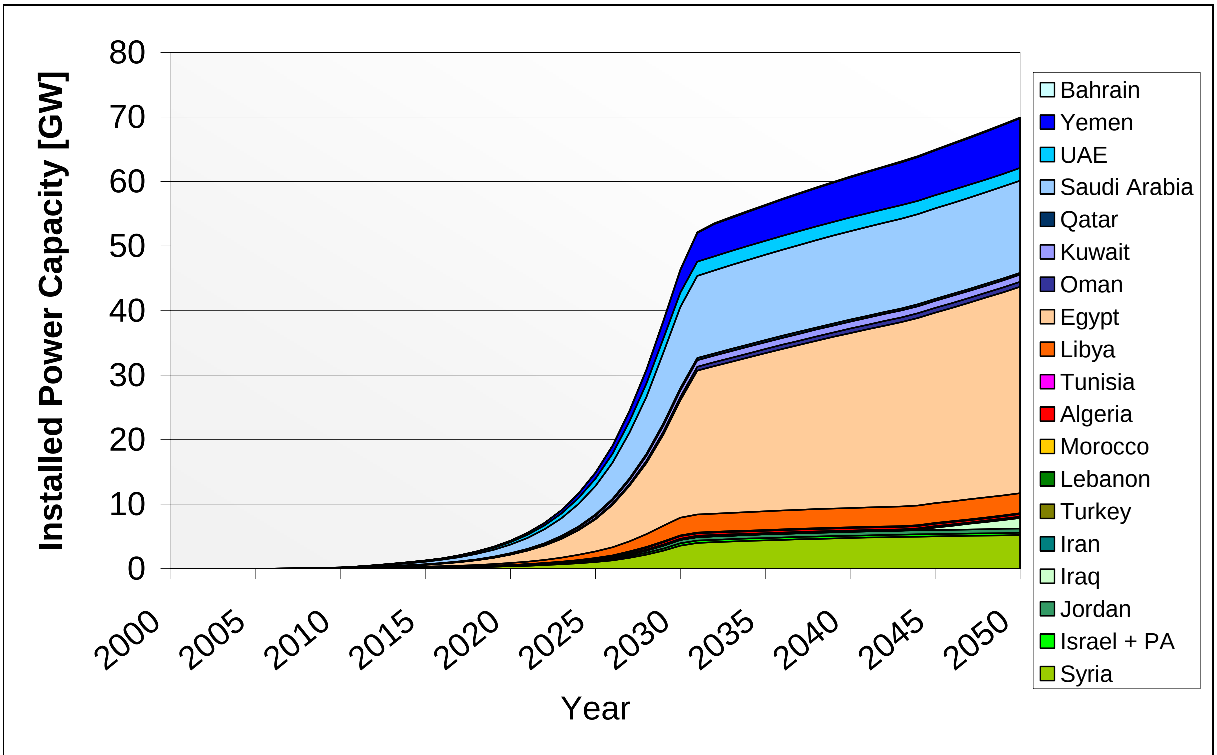


Figure 5-23: Power capacity for desalination plants with MED and RO in MENA

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

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

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

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

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

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

North Africa

The deficit in North Africa will grow from 16 billion m³/y in 2000 to 84 billion m³/y in 2050 with a major share of Egypt (Figure 5-24). The CSP capacity potential for desalination amounts to 32 GW for Egypt and 3 GW for Libya, while the other countries have minor

shares. On the basis of country statistics, no potential can be detected for Morocco, Malta and Tunisia, although there may be deficits on the local level (Annex 7).

Western Asia

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

Arabian Peninsula

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

Southern Europe

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

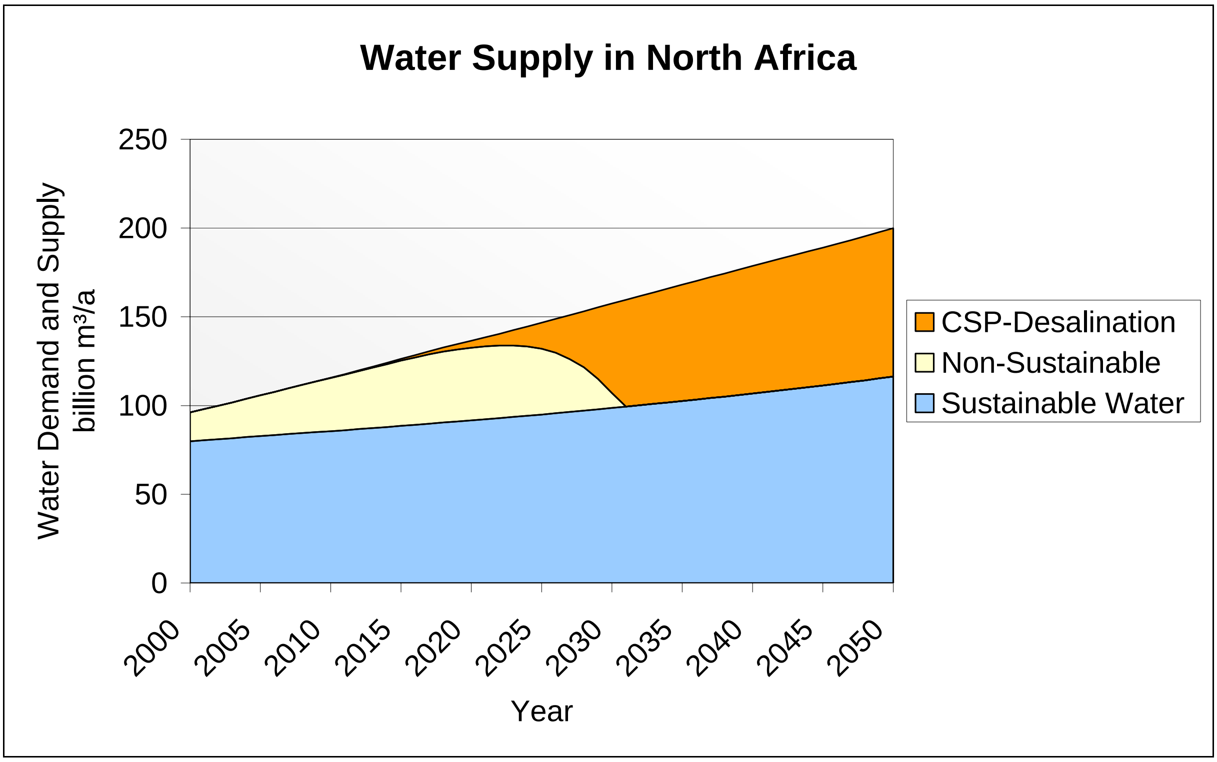


Figure 5-24: Water demand and water supply structure in North Africa. Definitions in Figure 5-22.

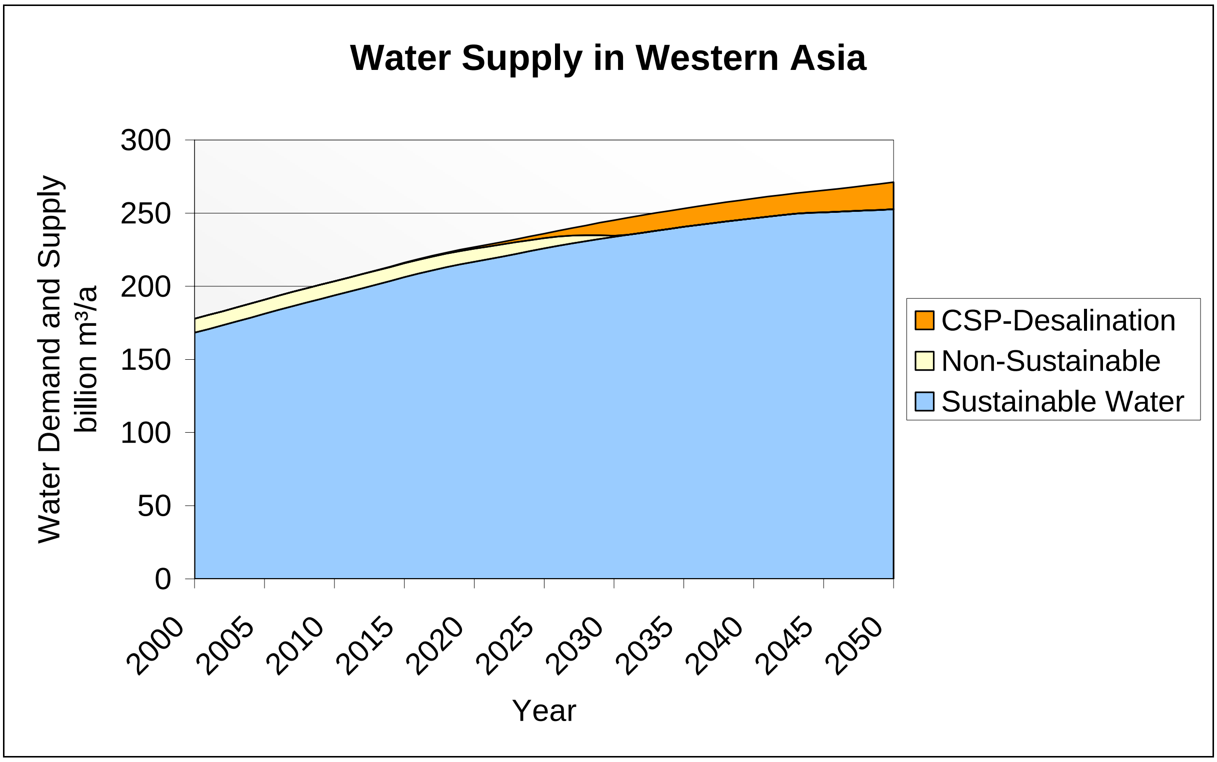


Figure 5-25: Water demand and water supply structure in Western Asia. Definitions in Figure 5-22.

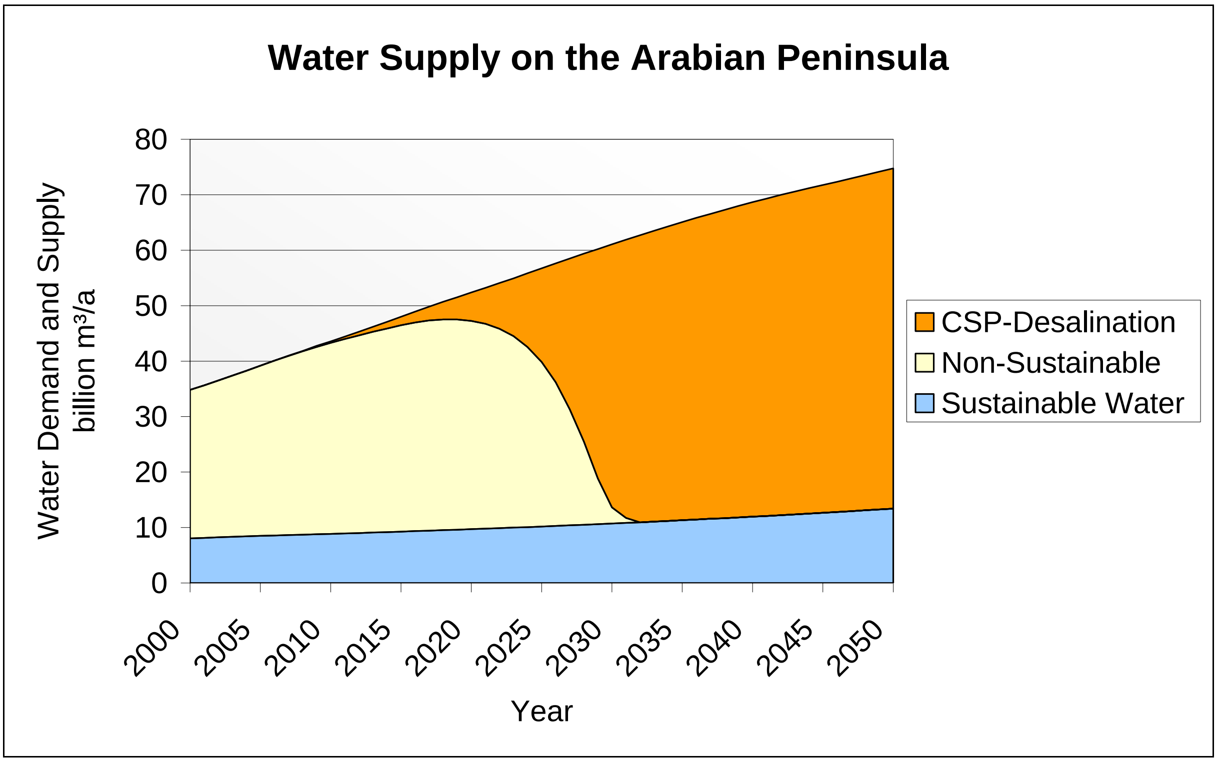


Figure 5-26: Water demand and water supply structure on the Arabian Peninsula. Definitions in Figure 5-22.

	Multi-Stage-Flash 2004	MED+VC 2004	Reverse Osmosis 2004	Total Desalination 2004	Non-Sust. Water 2004	Desalination Scenario 2050	Energy for Desalination 2050
	Mm³/y	Mm³/y	Mm³/y	Mm³/y	Mm³/y	Mm³/y	TWh/y
Cyprus	2.8	0.9	49.2	52.8	5	90	0.31
Greece	2.5	5.0	7.6	15.1		24	0.08
Italy	93.4	43.3	58.2	194.9		305	1.04
Malta	8.6	1.5	41.2	51.3		80	0.28
Portugal	0.0	0.2	1.0	1.2		2	0.01
Spain	32.5	33.7	563.5	629.7		985	3.37
Turkey	0.0	3.2	0.3	3.5		6	0.02
Iran	116.7	39.8	4.5	161.1		252	0.86
Iraq	0.0	0.2	0.5	0.7		3840	13.15
Israel	2.6	11.0	419.6	433.2	340	1018	3.49
Jordan	0.0	0.4	1.6	2.0	560	1030	3.53
Lebanon	0.2	5.4	0.1	5.6		9	0.03
Syria	0.0	0.0	2.2	2.2	8000	12170	41.67
Bahrain	207.8	18.1	28.2	254.2	170	488	1.67
Kuwait	908.8	3.9	142.6	1055.2	370	1691	5.79
Oman	103.9	25.3	21.0	150.2	340	1820	6.23
Qatar	363.4	92.4	2.4	458.2	210	783	2.68
Saudi Arabia	1765.3	1119.1	288.9	3173.3	14800	29722	101.77
UAE	2122.0	835.4	237.5	3195.0	2000	4550	15.58
Yemen	0.9	22.5	0.3	23.8	2500	18040	61.77
Algeria	92.0	13.3	168.8	274.1	600	975	3.34
Egypt	53.8	7.0	53.0	113.8	10200	75000	256.80
Libya	320.6	156.5	24.7	501.8	4100	7330	25.10
Morocco	2.6	25.0	11.2	38.7	270	340	1.16
Tunisia	0.1	2.0	0.7	2.8	290	294	1.01
Total	**6201**	**2465**	**2129**	**10794**	**44755**	**160844**	**551**

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

6 Socio-Economic Impacts of the MED-CSP Scenario

There is a common believe that renewable energies are expensive. However, they are continuously becoming cheaper by technology learning and by economies of scale in contrary to fuel-based power technologies that are submitted to highly fluctuating and slowly increasing fuel prices /IÖW/ISET 2002/, /IEA/NEA 1998/, /BMWT 2002/, /WETO 2003/. Therefore, it is only a question of time that renewables will take over power generation due to economic reasons.

However, learning curves do not happen spontaneously. Society must invest to achieve continuous learning and lower cost of renewable energy technologies. This is often called subsidization, but it is not, it's an investment into a better – and in the long term cheaper – technology. Real subsidies are only necessary where technologies have become too expensive after having past their economic summit years ago, like e.g. nuclear power plants, steam plants fired with German coal or oil fired plants in many MENA countries. Real subsidies are usually increasing and everlasting if they are not stopped. On the contrary, investments into renewables are limited in time with the goal to achieve benefits in the future.

Most subsidies are hidden /RIVM 2001/. E.g. the cost of damages to health, buildings and the environment caused by fossil fuel based technologies is never charged to the fuel price, but society as a total has to cope with that burden. Most oil producing countries are burning fuel at marginal cost rather than at the world market price, forgetting that once fuel is burned it cannot be sold anymore by them or by later generations. It's just like burning a national treasure.

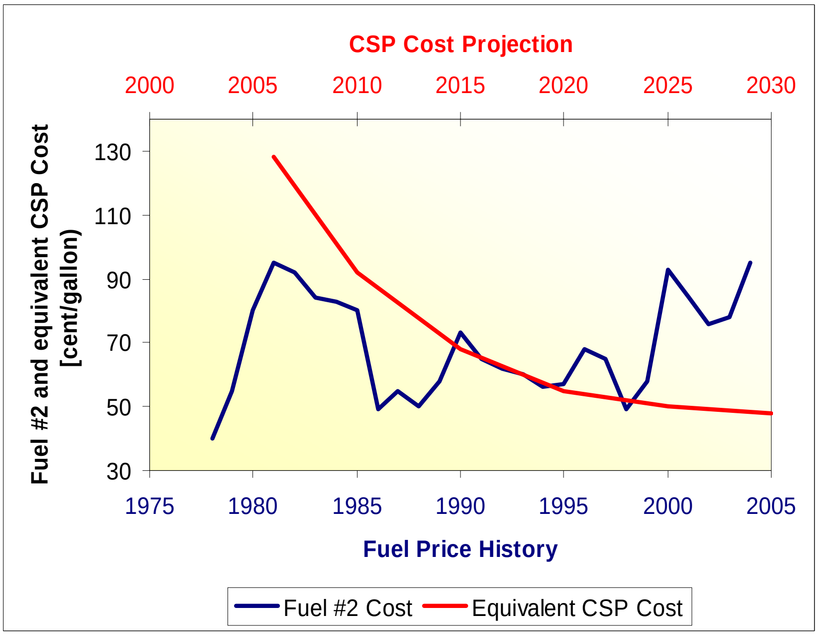


Figure 6-1: The merry-go-round of fossil fuel prices calls for CSP and other renewables to stabilise energy costs. Heating oil prices between 1978 and 2002 and projected equivalent solar energy cost in the time span from 2005 to 2025 (Source: oilnergy.com, historic data from Energy Information Agency and projection by DLR)

The investment cost of almost every technology becomes lower with mass production and technical development. Renewable energy technologies are no exception. The investment of fossil or nuclear plants still becomes lower, too, but at a much slower pace, as they already exist in a very large scale. Secondly, the electricity cost of fossil plants depends mainly on the fuel cost and not so much on investments /EIA 2003/. Renewables are still young technologies. Their cost depends mainly on investments. Therefore, they show strong learning and scale effects. Their operation cost does not depend on volatile fuel prices, but on natural energy sources that are for free.

Figure 6-1 shows the historical course of the heating oil spot prices since 1975 as overlay to the equivalent cost of concentrated solar energy from solar thermal power plants as projected in the scenario until 2030. Figure 6-2 shows the cost projections of heating oil (fuel #2) according to IEA and the learning curve of concentrating solar power as function of the total installed capacity from the MED-CSP scenario. Both comparisons show that after approximately a ten years investment phase, the initially higher solar energy cost would become competitive with fossil fuels. If the development of CSP that started in the mid 80's in California would have been continued, today CSP would already be considerably cheaper than heating oil.

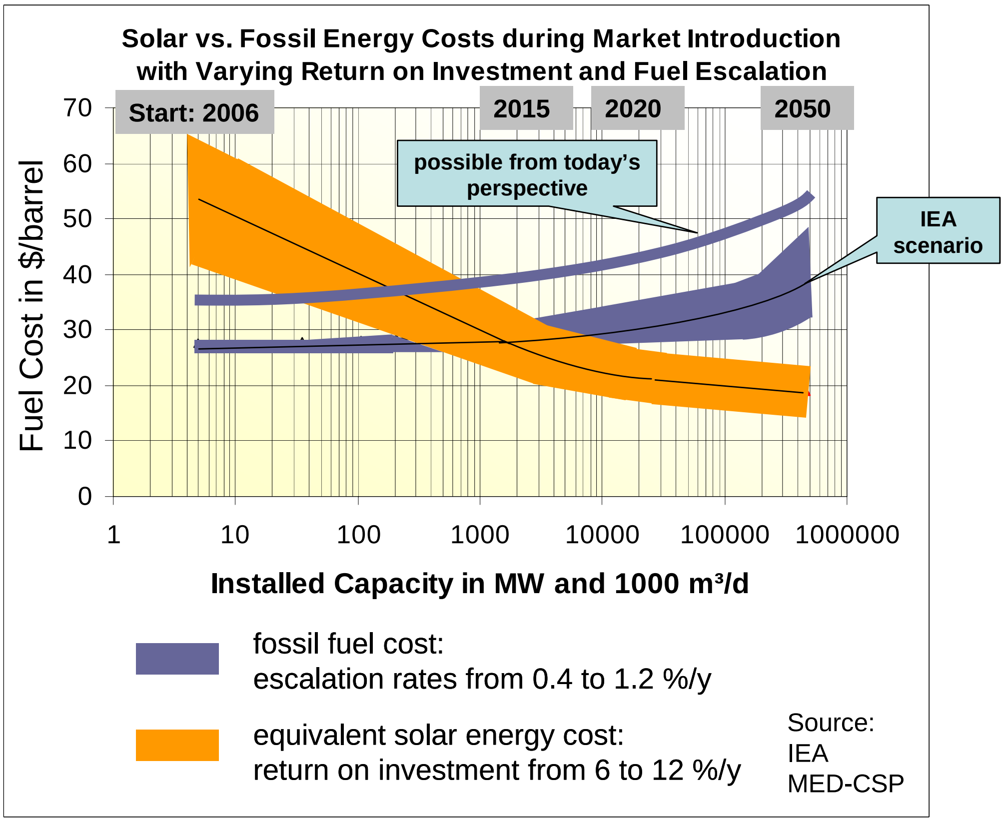


Figure 6-2: Cost of fuel according to IEA expectations and equivalent cost of solar energy from CSP in the MED-CSP scenario as function of installed capacities and time. Under the assumptions of the scenario, the break even of costs may occur between 2010 and 2015 with an installed capacity of around 2000 MW. However, with present fuel costs of well over 30 $/barrel (Figure 6-3), a break even may occur much sooner.

An important reason for introducing CSP and other renewable energies as an alternative to fossil energy resources is to **avoid future cost traps** related to fluctuating and increasing fuel

prices. Fuel price fluctuations have become sharper in the past years, and a continuous trend to increase is becoming evident. Today, fuel resources are continuously diminishing and subsequently reduced to a few regions, while their global mid depletion point - this is the point when their extraction rate comes to its summit - is expected to be reached before the 2020's. USA and Europe have already passed beyond their respective regional mid depletion points, and as a consequence, their domestic fuel supply share is reduced year by year, speeding up their dependency on the remaining global resources - which are mainly concentrated in the Middle East /LBST 2000/. Renewables are the only way to considerably reduce the growing public expenses and subsidies into the power sector.

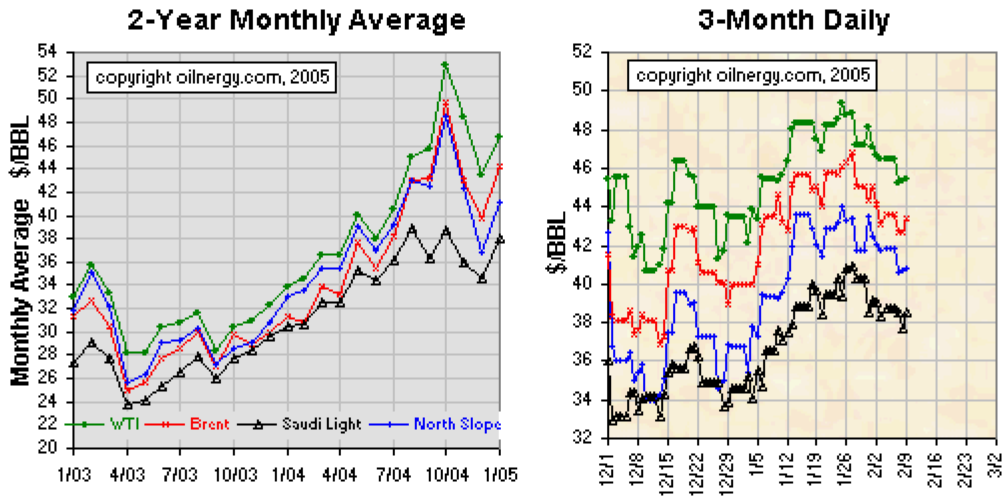


Figure 6-3: Spot prices of various key crude oils from www.oilnergy.com at 10th of February 2005.

One major socio-economic advantage of renewable energies is that they will **relieve the national economies from energy subsidies** /EREF 2004/. The stronger the investments in the renewable energy sector, the sooner this will happen. It makes absolutely no sense to wait, as every year conventional power generation becomes more expensive, increasingly burdening national economies through directly escalating costs and through the damages to health, environment and the global climate caused by those technologies. The initially higher cost of renewable energies will come down to a fully competitive level with fuel based power generation within one decade even not accounting for external environmental or societal costs. After that, renewables will slowly take over the power market due to their better economic performance and stability (Figure 6-4).

At present, we experience increasing pressure on fossil fuel resources on a global scale, and a painful elevation of fuel prices. Renewable energies and in a first place concentrated solar thermal power offers a solution. Renewable energies can relieve the national economies from energy subsidies through:

- lower cost of primary energy
- lower external costs of energy
- income from export of solar electricity
- income from export of saved fuels

➢ income from emission trading

In the coming decades, the MENA countries are facing an era of strong economic growth. In the long term, this process would place the MENA economies on equal eye level with Europe. However, the increasing scarcity of water and the elevated cost of fossil fuels will burden their economic development just in the critical phase of this period, possibly depriving them from their right to follow this path of economic equalization.

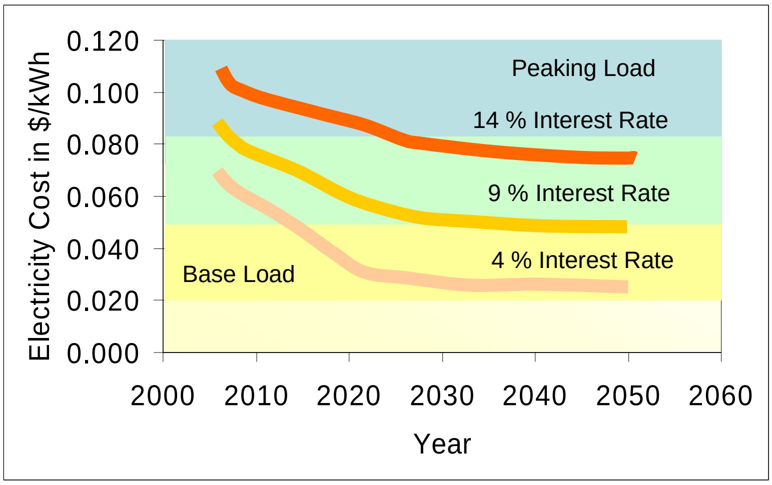


Figure 6-4: Cost of electricity by CSP in cogeneration with Multi-Effect-Desalination for 4, 9 and 14% rate of return, water cost 0.50 $/m³. 8000 full load hours per year, annual irradiance 2500 kWh/m²/y.

At the end of the oil-age, the MENA countries must now shift to their more plentiful and long-lasting **domestic energy sources**: renewable energies. This process requires not more than adequate initial investment by the governments of the EU-MENA region. The benefits are numerous: The direct costs of energy production and the external (social) costs of the damages induced by power generation can be reduced. Additional national income can be generated by exporting not only saved fuels, but also renewable electricity to Europe. The availability of fossil fuels will be stretched over centuries and its consumption reduced to a level compatible with the environment. Oil wars will become obsolete. Future generations will still be able to use the valuable oil and gas resources while the MENA region will develop economically. The fact that renewable energies are much more evenly distributed than oil or gas reserves will lead to an eye-level approximation of the national economies of the EU-MENA region. The economic gap between countries like Yemen and Spain will slowly disappear to the benefit of both.

Another benefit is the **diversification of supply** by local renewable energy resources (Figure 6-5, Figure 6-6). Today, many countries like e.g. Morocco have to import large quantities of primary energy carriers like oil, coal and natural gas that represent a major burden for their foreign exchange balance and for their national economy. In view of the quickly growing demand, this **dependency on energy imports** would become unaffordable for many countries in the medium term future. Using a domestic, renewable source will alleviate this burden, and a future export of solar electricity to Europe could even turn the wheel into the opposite direction and create additional income. Diversification also means higher security of supply

and redundancy and has a clearly stabilising effect on national energy costs. A primary function of conventional power plants is the stabilisation of the electricity grids. Hybrid CSP plants with solar energy storage can also provide this important function without any constraints.

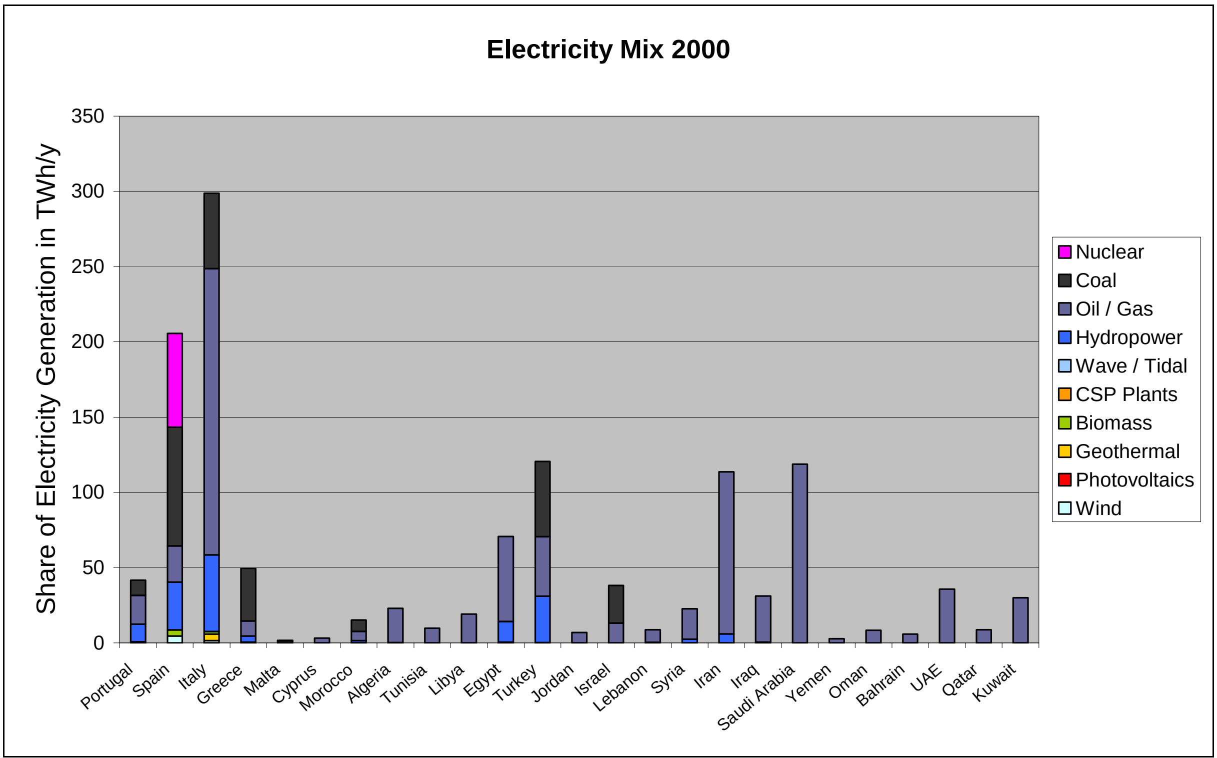


Figure 6-5: Share of different technologies for electricity generation in the year 2000.

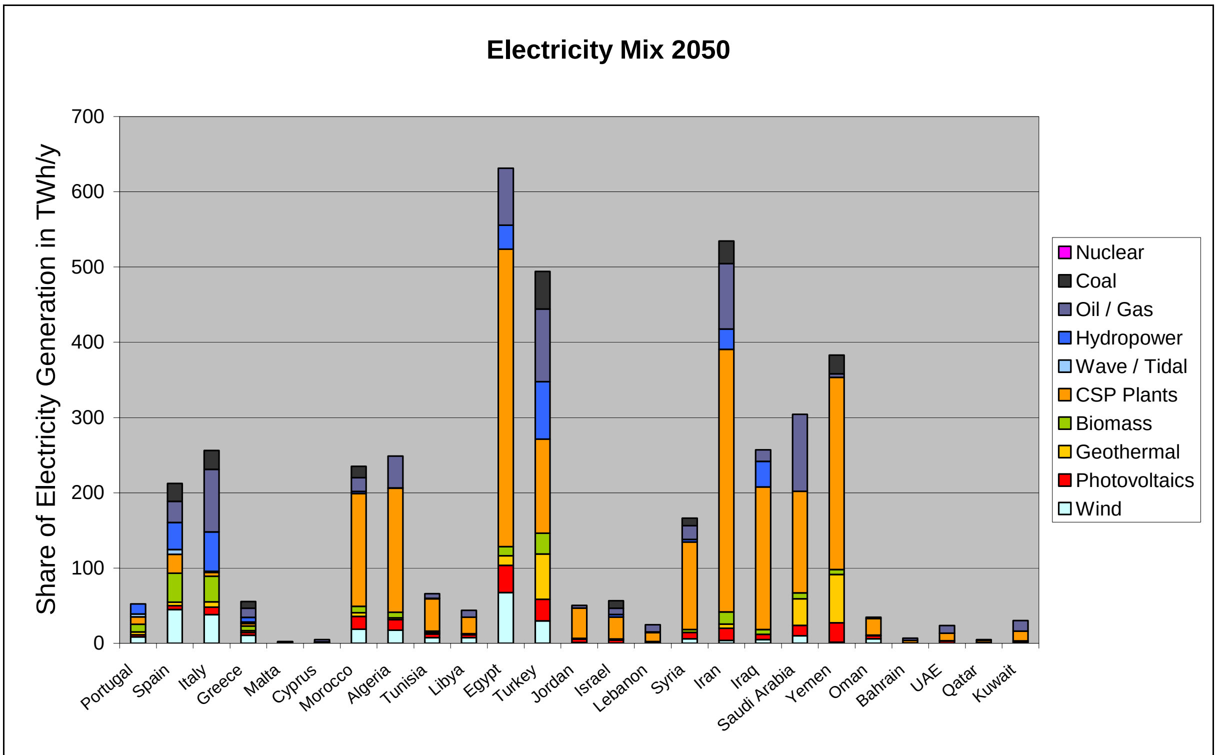


Figure 6-6: Share of different technologies for electricity generation in the analysed countries in the year 2050 according to the MED-CSP scenario.

Renewable energies are characterized by their diversity of resources and technologies and their enormous capacity range from a few Watt to hundreds of Megawatt. They can be adapted to any kind of energy service and closely interlocked with conventional modern energy technologies in order to provide full power availability and security of supply at any time and place. Renewable energy technologies fit very well into modern supply systems that are increasingly relying on **distributed generation** and network integration, like e.g. in "virtual power plants". On the other hand, **intercontinental grid** connections can effectively combine the different regional resources to yield the necessary redundancy of supply and address the sustainability goal of international cooperation (Figure 6-7). Large centres of supply will evolve at sites with very abundant and thus, cost effective renewable energy resources, providing electricity and renewable hydrogen to the regions of demand, i.e. large urban areas in industrialised and developing countries, by means of high voltage direct current (HVDC) transmission and by pipelines, respectively /ABB 2004/. At the same time, such centres will become a regional nucleus of economic development and wealth and will help to stabilise the socio-economic structures. Many of those centres will be established in developing countries, contributing considerably to the positive progress of our developing world /TREC 2004/.

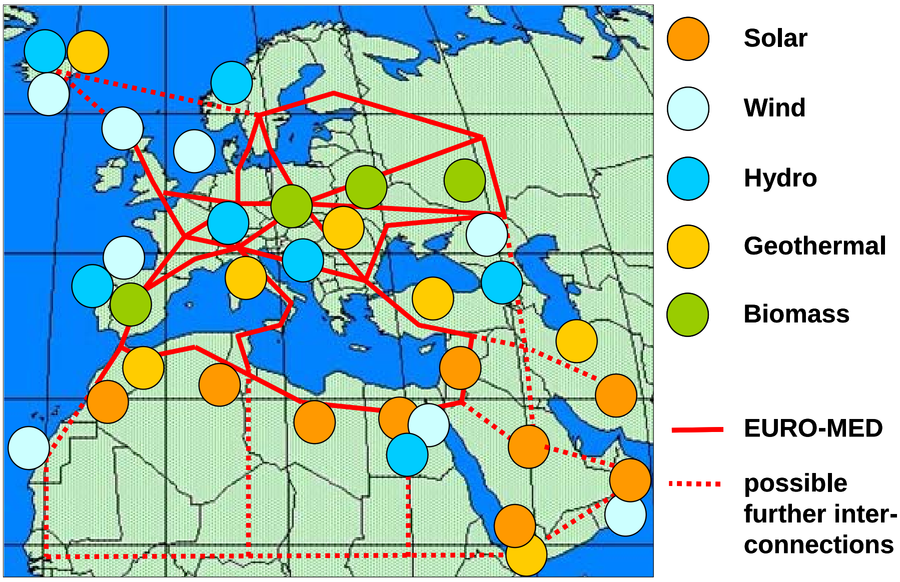


Figure 6-7: Projection of a future Trans-Mediterranean grid interconnecting the best sites for renewable energy use in EU-MENA

Using solar energy means manufacturing machines that use renewable energies. It means replacing minerals from the subsoil by capital goods. Renewable energies require a lot of labour on all industrial levels from base materials like steel, glass and concrete to civil engineering and high tech-applications. Increased industrial activities will create **job opportunities** and reduce the brain-drain from MENA to the industrial countries. Considerable shares of the equipment and construction materials of the solar field and the power block can be produced domestically in many countries with potential CSP deployment. For parabolic trough systems, an evaluation of the supply capability of selected countries like Morocco, Spain and Brazil indicates domestic shares ranging between 40 and 60 % for the

first plants. Local supply shares can be increased for subsequent projects if **domestic industries** adopt an increased production of the solar field and power block components.

Technology	**Employment during Construction [Person-Years]**	**Employment during Operation in 20 Years [Person-Years]**
Wind Power	14	11
Photovoltaic	19	26
Biomass	9	27
Micro-Hydropower	32	16
Large Hydropower	9	8
Geothermal	8	4
Solar Thermal Power	20	20

Table 6-1: Specific Employment Effects of different renewable energy technologies normalised to an annual production of 2 GWh /BEI 2003/

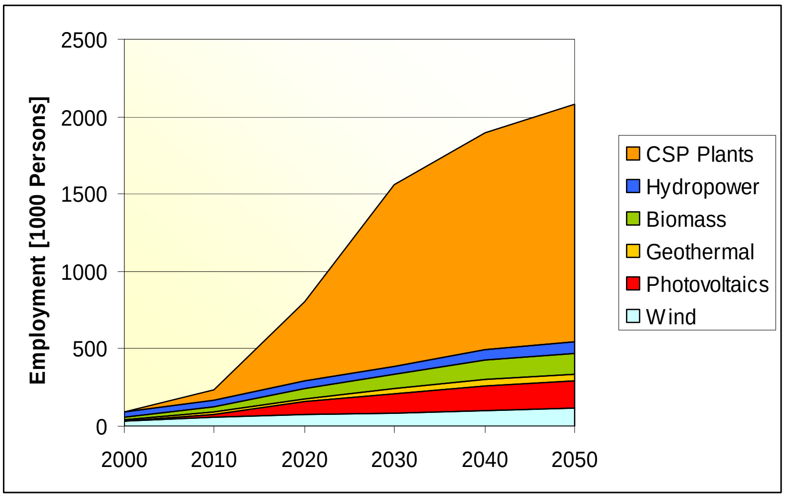


Figure 6-8: First guess of gross employment in the renewable electricity sector in the analysed countries for the MED-CSP scenario based on the specific employment in Germany from Table 6-1 /BEI 2003/

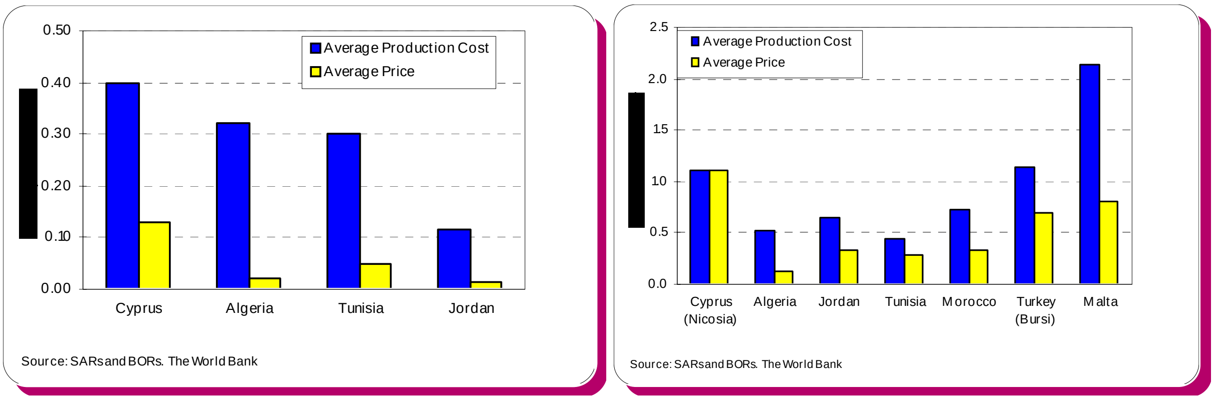
Table 6-1 gives a rough estimate of the **gross employment effects** of renewable energies. Thereby the whole upstream chain is taken into account including direct and indirect gross-employment. The numbers are from /BEI 2003/ who investigated the effects in Germany and use German shares of import, labour productivity and working hours per person. Certainly, these parameters are not the same for any MENA-country and are likely to differ widely. Using this rough estimate for the MED-CSP scenario, a tentative gross employment of 2 million persons in the renewable electricity sector can be expected (Figure 6-8).

Those numbers show gross employment effects. Negative employment-effects of the substituted power generation systems were not subtracted. Cost-differences were not taken into account ether. During the time in which RES-electricity is more expensive it will

generally reduce economic activities elsewhere and reduce employment. If RES-electricity is cheaper than alternative technologies, then this effect will become positive. These effects are very hard to estimate. Current studies on employment effects of Germany's Feed-in-tariff show that in the beginning even a negative effect may result. However, as the methods of these studies are under discussion and the quality and quantity of data is not good, the results can't be judged as reliable. Unanimously, the overall employment effect of renewables is estimated to be small as long as no potential exports of RES-technologies are taken into account. This is not surprising as neither the electricity sector nor the increase of the price for electricity is very large in comparison to other sectors.

The **scarcity of freshwater resources** is challenging food independency and social stability of a growing population in MENA. Efficient production and use of freshwater is a vital issue in this region. The pressing need for sea water desalination leads to higher energy demand and to an unavoidable additional burden for the national economies. There is no sustainable solution for water security based on fossil or nuclear energy, and moreover, there is a growing conflict between domestic consumption and export of fossil fuels.

Cost traps in the energy sector originating from fluctuating fuel prices are serious enough, but the traps originating from a future freshwater deficit will be even worse, because water is indispensable even at the lowest economic level of development. With a water deficit equivalent to the Nile expected in 2025, the North African states face a challenge never experienced before in their history. To solve this severe societal problem, they will require large amounts of low cost energy for desalination and, of course, an enhanced water infrastructure and optimal water management (Figure 6-10).



a) Irrigation Sector *b) Municipal Sector*

Figure 6-9: The present status of water pricing in the MENA Region in $/m³ /Saghir 2003/

Combined solar power and desalination plants will not only tackle the problems related to a sustainable energy supply at a low cost, but also those related to clean water and to the conservation of productive soils. In the world's arid regions, such plants could become the nucleus of a totally new social paradigm: the conservation and recuperation of land endangered by desertification, comparable to the conservation and recuperation of flooded land in the Netherlands. Providing power, water, shadow and foreign exchange from the export of green power and revived agriculture, such plants can provide all what is needed to

effectively combat desertification and to regain land for human settlement and agriculture that otherwise would be lost to the desert.

Arable **land resources** in MENA and world wide are disappearing at a speed of several hectares per minute. Concentrating solar multipurpose plants in the margins of the desert could generate solar electricity for domestic use and export, freshwater from seawater desalination and provide shade for agriculture and other human activities. Such plants could turn waste land into arable land and create labour opportunities in the agriculture and food sector. Tourism and other industries could follow. Desertification could be stopped.

Solar energy and saltwater are unlimited resources if used in a way compatible with environmental and socio-economical constraints. The economic figures of most renewable energies indicate clearly that within a manageable time span they will become much more cost effective than fossil fuels. Renewable energies are the **least cost option for energy and water security** in MENA. With increasing electricity intensity in a developing world, their importance will steadily grow, being only limited by demand, not by resources.

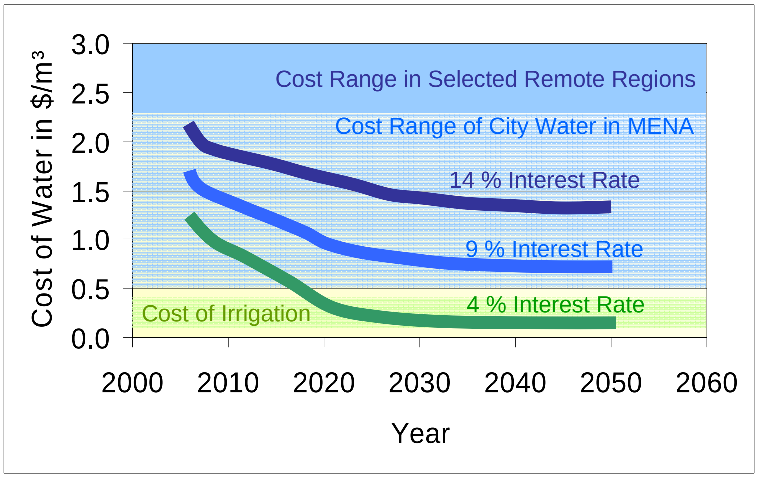


Figure 6-10: Cost of Water desalted by CSP in Cogeneration with MED for 4, 9 and 14% Rate of Return, Electricity Cost 4 ct/kWh. 8000 full load hours per year, annual irradiance 2500 kWh/m²/y.

In a future sustainable energy scheme, renewable fuels like hydrogen may be generated by solar electricity, **expanding renewable electricity markets** beyond the traditional electricity sector into the industrial and mobility sectors. The growth rates of renewable energies are today in the order of 20 – 40 %/y and may be kept at this high level for a decade or more. All in all, the study shows that there are many good reasons to accelerate market expansion of renewable energies in the EU-MENA region:

Energy sustainability can only be achieved with renewable energies

Although climate change is a serious concern, sustainability must also be achieved in terms of economy, affordability, technology, health and social compatibility. A strategy must match the time horizon of sustainability considerations, which is at least 50 - 100 years and more. Strategies optimising a pathway within a smaller time horizon may lead to the wrong direction, because measures necessary to achieve the long-term goal may be ignored or delayed. The sustainability goal proposed by WBGU of emitting 1 ton of carbon dioxide per

capita by 2050 to avoid drastic climate change is a challenge, because most MENA countries already show this level of emissions today, but their demand will still grow. Affordable access to energy and water for a growing population is as well a challenge. Both goals together can only be achieved by renewable energies in combination with increased energy efficiency.

A well balanced mix of renewable energies can replace electricity from fossil fuels

Electricity must be delivered on demand. Fluctuations of wind and photovoltaic electricity must be compensated by sources that can deliver power on demand, like biomass, hydropower, geothermal power and solar thermal power plants that can operate on base-, intermediate- and peak load demand. By 2050, fossil fired plants will only be used for peaking demand, while the core electricity will come from renewables. Solar thermal power plants with their capability of thermal energy storage and of solar/fossil hybrid operation are a key element for grid stabilisation and power security in such a mix. Renewable energies will initially need public support but will steadily continue their growth within niche markets. After 2025, electricity from most renewable energies will be cheaper than electricity from fossil fuels.

Renewable energy resources are plentiful in the EU-MENA region

The renewable energy sources in the countries analysed in the MED-CSP study can cope with the growing demand of the developing economies. The wind, geothermal, hydropower and biomass potentials are each about 400 TWh/y. Those resources are more or less locally concentrated and not available everywhere, but can be distributed through the electricity grid if its capacity is expanded in line with the growing demand. The by far biggest resource in MENA is solar irradiance, with a potential that is by several orders of magnitude larger than the total world electricity demand. This resource can be used both in distributed photovoltaic systems and in large central solar thermal power stations. Thus, both distributed rural and centralised urban demand can be covered by renewable energy technologies.

The demand for energy and water will grow by three times until 2050

The growth of population and economy will lead to a considerable growth of energy demand in the MENA countries. By 2050, the MENA countries will achieve an electricity demand in the same order of magnitude as today Europe (3500 TWh/y). Although our scenario considers efficiency gains and moderate population growth or even retrogressive population figures in some of the analysed countries, electricity demand will almost triple from 1500 TWh/y today to 4100 TWh/y in 2050. This is moderate considering that electricity demand has also tripled in the past 20 years.

In many MENA countries and also in some Southern European regions, natural water resources are already now exploited beyond their sustainable yield. In the future, overexploitation of natural water resources must be avoided and growing demand must be additionally covered by seawater desalination. This will require efficient and environmentally compatible desalination technologies and a plentiful, sustainable and affordable energy source. Fossil or nuclear fuels cannot cope with any of these criteria. On the contrary, already today they are subsidised due to their high cost, they are causing serious national and

international conflicts and climate change, and oil, gas and uranium are expected to become increasingly scarce and expensive within the next 50 years. A strategy for energy and water security can therefore not be built on fossil fuel resources, but they can be a component of such a strategy.

Energy and water security can be achieved in every country of the EU-MENA region

Every country in EU-MENA has its own specific natural sources of energy and water and very different patterns of demand. The MED-CSP scenario shows one possible way to match resources and demand in the frame of the technical, economic, ecologic and social constraints of each country in a sustainable way. Most MENA countries show a strong economic growth that will lead to an approximation to the European economies by the middle of the century. However, conventional strategies for energy and water would lead to a depletion of fossil fuel and natural water resources within a few years, to unaffordable costs of energy and water and to social conflicts. Economic development would be increasingly burdened by subsidisation and regional conflicts. To this add possible impacts from climate change like desertification, losses of arable land and floods. Due to the increasing lack of water, food imports would increase, but it is unclear how this should be financed. Only a change to renewable energies can lead to affordable and secure energy and water. This will not require long term subsidies like in the case of fossil or nuclear power, but only an initial investment of all EU-MENA countries to put the new renewable energy technologies in place.

Renewable energies are the key to socio-economic development in MENA

The growth of energy demand in MENA would lead to greenhouse gas emissions equivalent to those of Europe. Rising fuel prices and an additional cost for CO2-sequestration would seriously burden economic development. In contrary to fossil fuels, all renewable energy technologies show degressive costs. This will obviously lead to a replacement of fossil fuels in the power sector. MENA countries will benefit by reducing their energy subsidies. Oil and gas exporting countries will be relieved from burning their export product number one, and in the long term may additionally come to export solar electricity. A strong renewable energy industry in MENA will lead to high qualified labour options and relief MENA from the brain drain occurring today.

Water supply in MENA is critical, as a solution can only be seen in using large amounts of energy for seawater desalination. A strategy based on fossil or nuclear energy would not lead to an affordable and secure water supply system. Again, renewables and in a first place solar thermal power are the key to reduce the conflict potential of energy and water scarcity in MENA.

Renewable energies and energy efficiency are the pillars of environmental compatibility

It is a common misbelieve that renewable energies require large land resources. Among all electricity generating technologies including all nuclear and fossil systems, solar power technologies are those with the smallest land requirements. This is due to the fact that nuclear and fossil power plants not only require the land where they are placed, but additional infrastructure for mining, transport and disposal, which must be considered in an overall

lifecycle balance (very long time for nuclear waste), and which is much smaller for solar systems.

Most renewable energy technologies have no emissions at all during operation. On a life cycle basis, emissions occur only during the production of the plants. However, if renewable shares increase in the power sector, also the emissions during construction will be subsequently reduced, as they origin from fossil energy consumption. Fossil power systems show emissions one or two orders of magnitude higher than those of renewables. CO2 sequestration will require extra energy and thus will lead to higher emissions, which must additionally be disposed off, entering a kind of vicious circle.

Goals	**Security of Human Subsistence**	**Conservation of the Social Productivity Potential**	**Preservation of Options for Development**
Rules	Protection of Human Health	Sustainable Use of Renewable Resources	Equal Opportunities of Education, Labour and Information
	Guaranteed Supply of Basic Needs	Sustainable Use of Non-Renewable Resources	Participation in Social Decision Processes
	Security of Self-Dependent Subsistence	Sustainable Use of the Environment as Sink	Conservation of the Cultural Heritage and Diversity
	Fair Access to Environmental Resources	Avoidance of Unacceptable Technical Risks	Conservation of the Cultural Function of Nature
	Compensation of Extreme Differences of Income and Wealth	Sustainable Development of Human, Scientific and Material Resources	Conservation of Social Resources

Directly addressed by the MED-CSP scenario
Indirectly addressed by the MED-CSP scenario
Requires additional political and social measures

Table 6-2: Goals and minimum requirements (rules) of sustainability according to /HGF 2001/.

Table 6-2 shows that the sustainability goals “Security of Human Subsistence” and “Conservation of the Social Productivity Potential” and the corresponding minimum requirements are directly addressed by the MED-CSP scenario /HGF 2001/. The achievement of those goals requires political decisions that aim into the right direction and additional political and social measures to keep the window open for new “Options for Development”.

The Middle East & North Africa Renewable Energy Conference MENAREC 1 in Sana’a, Yemen in April 2004 and the International Conference for Renewable Energies in Bonn, Germany in June 2004 are creating a considerable momentum in this direction, documented by the International Action Programme presented at the conference “renewables 2004” in Bonn.

This must now culminate in concrete actions to be taken in the EU-MENA countries to start renewable energy projects and to include renewable energies in infrastructure planning and expansion.

The Cost of Introducing Renewable Energies

The calculation of the cumulated initial cost leads to a total amount of 75 billion $ needed to bring the renewable energy mix to cost break-even with fossil fuels before the year 2020 (Figure 6-11). From that point until 2050, the analysed region will save 250 billion $ with respect to a business as usual policy scenario. It must be noted that the reference case of a fossil fuel based policy scenario departs from the assumption that fuel prices start at 25 $/bbl for oil and 49 $/ton for coal and escalate by only 1 %/y, which from today's point of view seems to be rather conservative (present fuel prices are at a level of 55 $/bbl and 65 $/ton, respectively, and escalation rates amounted to 40 %/y since 2003).

It is a legitimate question to ask who should afford the initial investments of 75 billon $ required to bring renewables into the market within the 15 years time span needed to reach cost break-even with fuels. In principle, the electricity consumers are those who benefit directly from this strategy. If the initial investment would be equally distributed among all electricity consumers in the region, each of them would have to afford additionally 10 $/y for electricity payments for a period of 15 years in order to finance the total market introduction of renewables. After those 15 years, all consumers will benefit from stable and low electricity costs, avoiding to be exposed to volatile and rather high electricity costs in the case of a business as usual policy. Alternative strategies for finance are given in Chapter 8.

The cost and savings of introducing renewable energies in EU-MENA varies with the parameters assumed in the scenario (Figure 6-12). However, any set of parameters leads sooner or later to a break-even of the renewable energy mix and the fossil fuel system. Even if carbon dioxide would not be an important environmental issue, renewable will result as the cheaper alternative in the medium term future. Energy (and water) cost stability can therefore only be achieved through the massive introduction of renewable energies in the power sector.

The required amount of 75 billion $ during the introduction phase is comparable to the amount of investments needed (and actually spent by the OECD) to develop and build the first commercial nuclear fusion reactor expected for the year 2050. If a first commercial fusion plant is realised by 2050, it will not have avoided any CO_2 by that time, while the renewable energy mix will have avoided 28 billion tons of CO_2 and in addition to that, will have relieved the EU-MENA economies by expenses of about 250 billion $ otherwise required for fossil energies (without accounting for external costs). According to the developers of fusion, the electricity cost of a first commercial reactor would be in the range of 10-12 cent/kWh. This will probably be competitive with fossil fuel plants by 2050, but it is about twice as much as required for the average cost of the renewable energy mix by that time. Therefore, a wise and responsible energy policy must support renewable energies as well.

It is the responsibility of national governments and international policy to organise a fair financing scheme for renewable energies in the EU-MENA region in order to avoid the obvious risks of present energy policies and change to a sustainable path for wealth, development, and energy and water security.

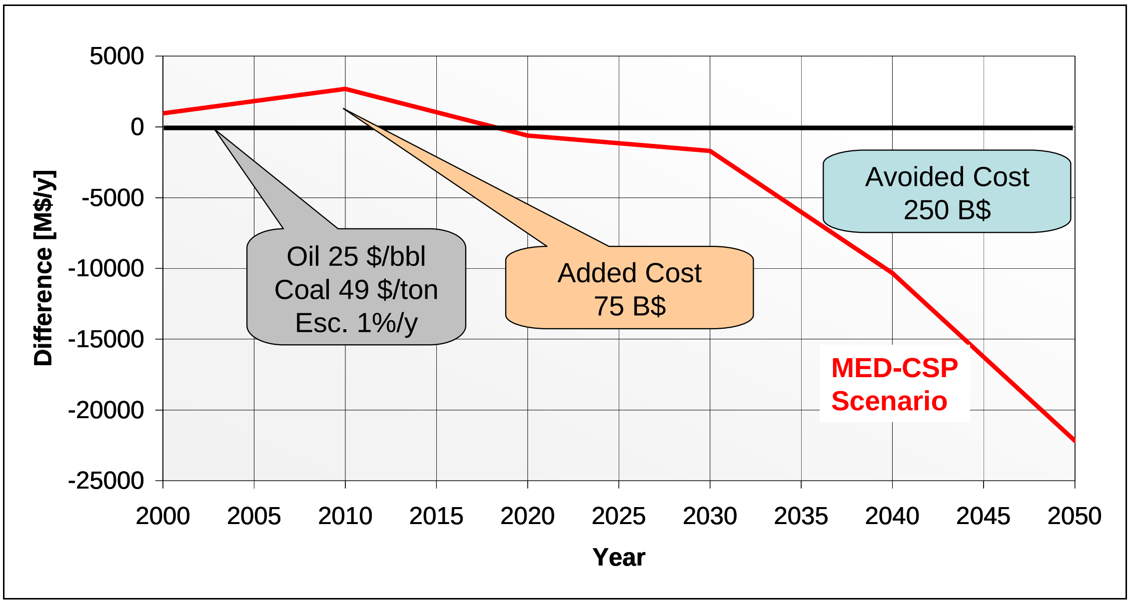


Figure 6-11: Total annual difference of electricity expenses between the MED-CSP scenario and a business as usual policy scenario based primarily on fossil fuels, summarised for all countries analysed in the study. Positive values = initial additional cost, negative values = avoided cost with respect to a business as usual policy. The cumulated initial cost amounts to 75 billion $, while 250 billion $ are avoided until 2050. The added and avoided costs vary with different assumptions made for fuel prices, escalation rates, CO_2-policy, etc. which are described in the main report. However, the break-even of renewable energies and fuels is achieved sooner or later under all variants.

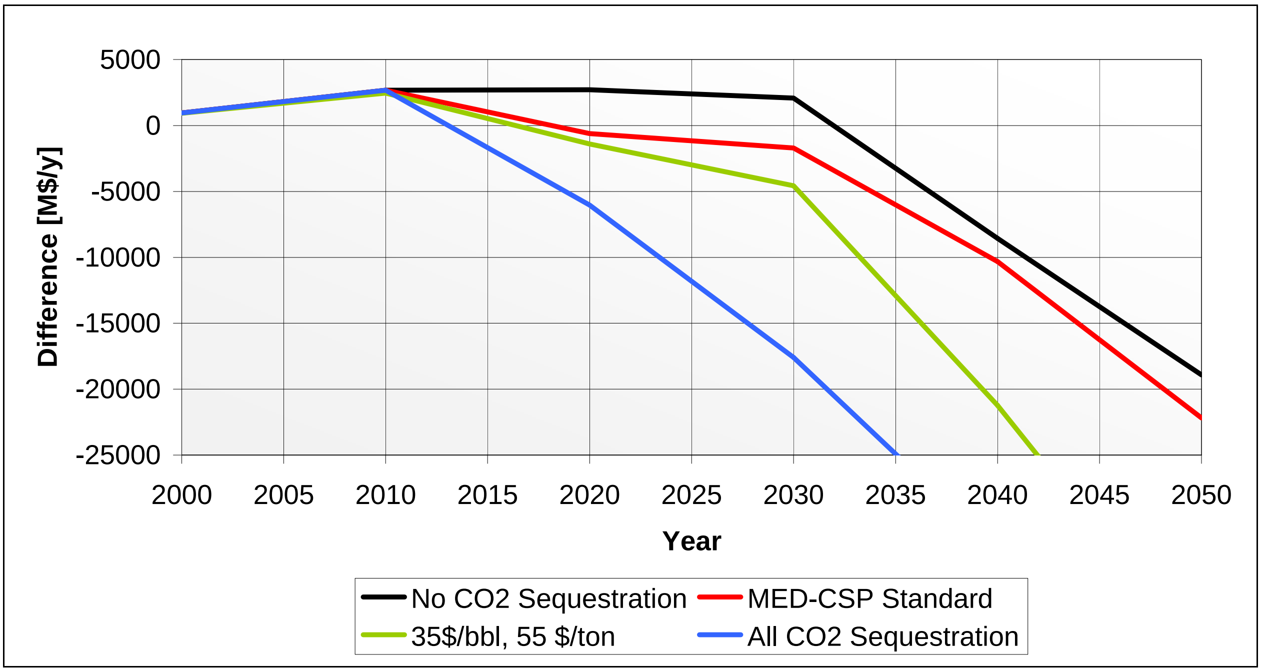


Figure 6-12: Calculation like in Figure 6-11, but varying the parameters of the scenario. "No CO2 Sequestration" is calculated as if CO_2 would not lead to any external costs in no country. "MED-CSP Standard" is calculated with CO_2 sequestration in Europe, initial oil price of 25 $/bbl and initial coal price of 49 $/ton, escalating with 1 %/y. The scenario "35 $/bbl, 55 $/ton" is calculated with those prices, sequestration only in EU and the scenario "All Sequestration" assumes that all countries have to introduce CO2 sequestration, while prices remain like in the standard scenario.

7 Environmental Impacts of the MED-CSP Scenario

The environmental problems linked to the use of fossil and nuclear energy sources are well acknowledged today: global climate change, acidification of ecosystems, risks from nuclear accidents, long term accumulation of radioactive waste, and effects on the public health from air pollution /ExternE 1999/. Our energy system is based on digging materials out of the subsoil and dissolving them after their use in the atmosphere and in the surface environment, where they tend to accumulate, creating serious environmental impacts. As renewable energy technologies rely on natural energy and material flow cycles, they can reduce the environmental impact of energy supply. Although for most of them the energy conversion process is emission free, environmental impacts result from the provision of raw materials and the manufacturing and disposal of components. The following environmental characterisation is based on a life cycle perspective, taking into account emissions from all the up- and downstream processes related to energy conversion **(**Figure 7-1).

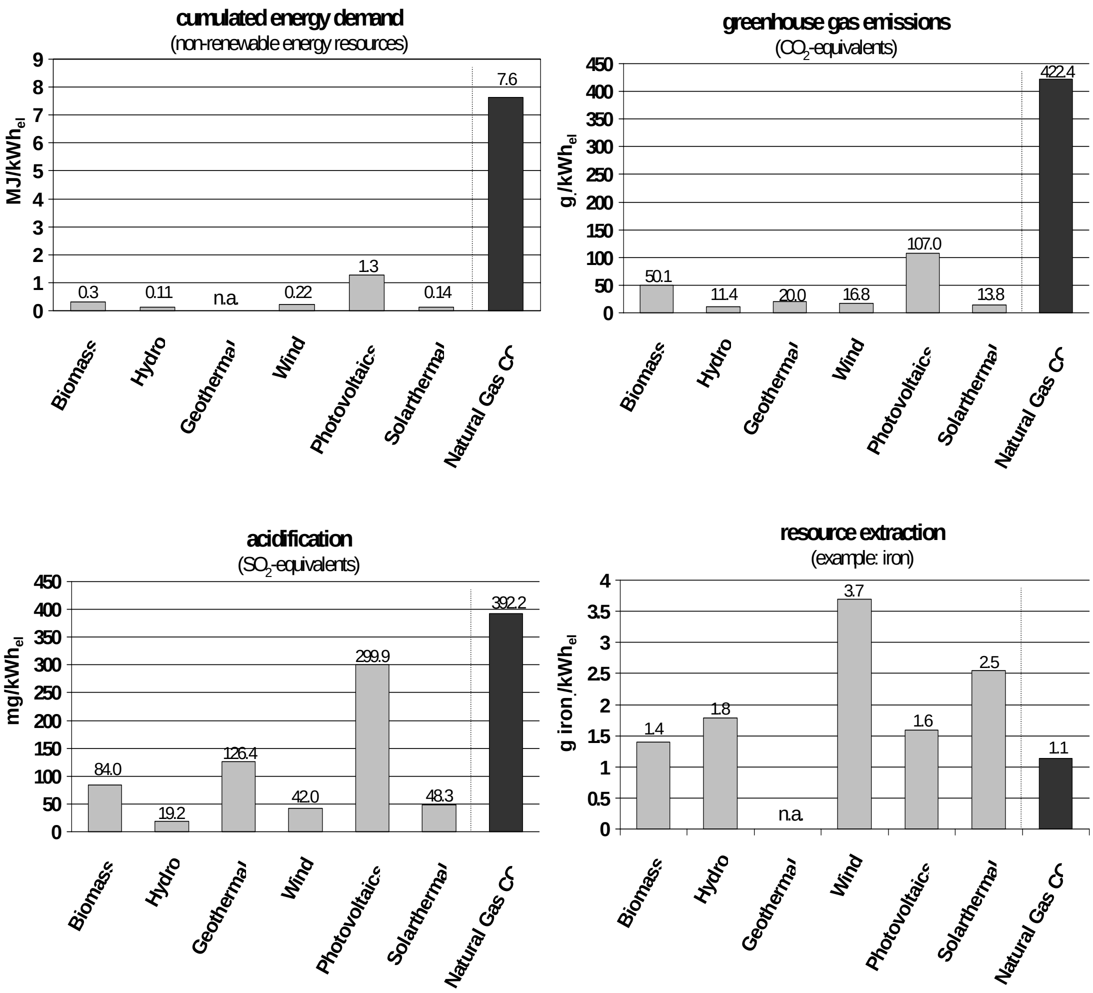


Figure 7-1: Environmental characteristics (cumulated energy demand, greenhouse gas emissions, acidification, resource extraction) of RES-technologies for electricity generation (Biomass: forest residuals, 20 MW steam turbine; Hydro: 3 MW run-of-river plant; Geothermal: 900 kW organic rankine cycle (ORC) cogeneration plant; Wind: 1.5 MW on-shore; PV: 3 kW p-Si roof application, Central Europe; Solar thermal: parabolic trough 80 MW (Southern Europe); Natural Gas CC: natural gas combined cycle, 58 % efficiency)

It is obvious that both the consumption of non-renewable energy resources and the emissions of greenhouse gases is more than an order of magnitude higher than that of renewables even for a highly efficient gas fired combined cycle power plant – and the difference is even larger compared to less efficient coal fired steam cycle power plants. This fact underlines the important role of renewable energies for climate protection. Electricity generation from hydropower, wind and solar thermal power plants ranks particularly high on these two categories. For geothermal energy, the combined production of heat and electricity is required to achieve similar values. Harvesting, transport and processing of biomass requires substantial combustion of fossil fuels, so that biomass ranks slightly worse than the non-combustion processes. Despite significant improvements in recent years, the manufacturing of photovoltaic cells still requires a quite high material and energy input, leading to relatively high life cycle emissions, which in the case of SO_2 are even in the same order of magnitude as those from the gas fired power plants.

Basically, the environmental impacts of renewable energy technologies are dominated by emissions from energy conversion in upstream processes such as component manufacturing or transportation. The data thus primarily characterise the resource efficiency of the underlying economy rather than the performance of a specific energy conversion technology. Changes in the national energy mix will therefore have a direct impact on the life cycle emissions. The evaluation of emerging technologies should thus be based on conditions that are representative for the time of their market entry, rather than associating them with the environmental load from technologies that they are expected to replace. Figure 7-2 illustrates the large potential for the reduction of life cycle CO_2-emissions from a PV-roof application due to key technological developments (use of solar-grade silicon, increase in recycling rates, electricity generation with a high share of renewable energies).

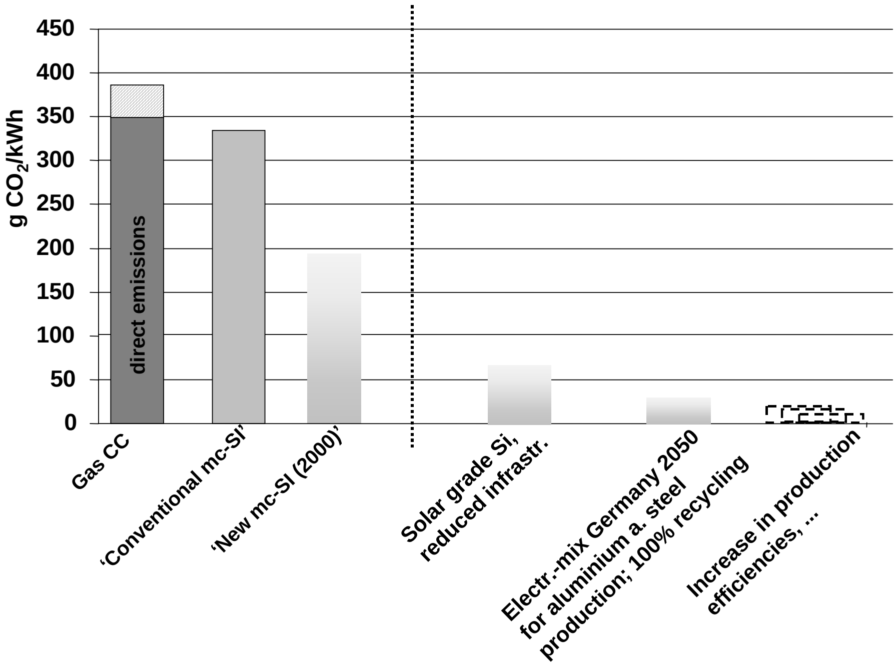


Figure 7-2: Life cycle emissions of CO_2 from a 3 kW p-Si roof application as a function of technological development and change in the energy mix of an economy

Certainly, environmental impacts from energy generating processes leading to public health effects, losses of crops and material damage pose a significant economic burden on society

which is not reflected in current energy prices. Hence, the claim for adjusting those external costs asks for a supplement to the energy price that accounts for environmental damage costs from power plant emissions. Although the quantification of environmental impacts and the subsequent monetary valuation is extremely complex and a matter of great uncertainties, the European Commission, based on a thorough research effort, decided to allow Member States to grant operating aid of up to 5 cent/kWh to new plants producing renewable energy on the basis of external costs avoided. This measure for internalising environmental damage costs underlines the environmental advantages of renewable energy technologies and helps to increase their competitiveness /EWEA 2002/.

Our present energy system is still revealing numerous sustainability deficits, in particular with respect to its impacts on ecosystems. It is based on energy carriers with limited availability. It burdens our atmosphere, our soil, and water with pollutants and greenhouse gases, and moreover, leaks in oil pipelines, oil-tanker accidents, area-devastating coalmining, an unresolved question of how to dispose of nuclear waste, and the possibilities of reactor accidents. The list of environmental problems in the field of energy is long.

A more intensive use of renewable energy promises to be the remedy. The fuels for the corresponding energy conversion technologies are the natural flows of energy surrounding us in the form of radiated solar energy and the wind, the energy from flowing waters and the energy from waves, the energy contained in biomass and geothermal energy. By using these flows of energy abundant in nature, the consumption of fossil and nuclear energy on our planet can be avoided.

Renewable energy is largely compatible with our climate and resources. However, the installations needed to convert these flows of energy must first be constructed, operated, and finally be dismantled at the end of their useful service life. Raw materials and energy are necessary for these purposes. What are the effects on the environment compared to using conventional energy? Two key parameters can clarify this question: the energy payback time, i.e. the time needed by an energy system to generate the same amount of energy required for its construction, operation, and disposal; and the cumulated greenhouse gas emissions.

For fossil fired or nuclear plants, the energy payback time for the construction of the plant is around 2 to 3 months. Yet in terms of their overall operation, these plants never amortise because more energy always is consumed in the form of fuel than is produced in the form of useful energy. Water, wind, and solar-thermal power plants need between 3 and 13 months for amortisation of their construction energy, i.e. considerably less than their useful service life. Once this amortisation time has elapsed, each hour of operation then provides valuable energy which is “ecologically gratis”!

The production of solar cells is energy intensive. Today’s systems based on crystalline silicon have energy amortisation times of several years in Germany and shortly one year in the Southern Mediterranean region, however, their useful service life is a multiple of this time period. Further progress in the production and technology of solar cells should reduce this value to between one and two years within the next decade. Therefore, a multiple of the energy originally expended in constructing these systems using renewable energy is produced within their operational lifetime – quite the opposite to both fossil-fired plants and nuclear power stations. This low consumption of resources is also reflected in the associated emissions of green-house gases. These emissions from constructing the plants, whereby the present- day energy supply structure was taken as the baseline, for most renewable energy

technologies is between 10 and 25 g/kWh of useful energy. In the case of photovoltaic systems, reductions are possible in the medium term to about 50 g/kWh.

If the future energy supply were to include higher proportions of renewable energy, then the emissions of greenhouse gases resulting from constructing the plants would fall even more, since more low-emission energy would then be used and technical progress would optimise the efficient and ecological production. Thus, on the ecology balance sheet, renewable energy can be designated as being an environmentally very compatible energy technique, even when considering the plant construction.

For an ecologically optimised expansion of renewable energy, it is furthermore necessary to consider other environmental aspects as well. Besides the environmental effects associated with the construction, operation, and disposal of the installation, there are other problem areas characteristic for each individual technology which can lead to conflicts with the goal of nature conservation.

All detrimental effects to the environment resulting from the use of renewable energy must be analysed with great care so that new problems do not arise while attempting to establish a long-term sustainable energy system. Exactness in planning, embedding in the local conditions, compatibility of the utilised technologies, consideration for ecology-based criteria, and a sound mix of different kinds of renewable energy carriers, must assure a maximum of environmental compatibility when providing energy. The German Federal Ministry for the Environment is thus funding several socio-economic studies which analyse in detail the ecological benefits as well as potential weaknesses of renewable energy technologies. Based on the results of these studies, strategies for an ecologically optimised expansion of renewable energies in Germany are derived.

The measures of environmental compatibility specified for renewable energy must of course also be applied for the types of energy still being used today. Otherwise the danger exists of a one-sided and therefore biased assessment, which can lead to a situation in which small local impacts from using renewable energy are classified as alarming, while considerably more serious effects on our entire habitat from using fossil and nuclear energy are overlooked.

7.1 Environmental Impacts of Renewable Energy Technologies

The environmental impact of renewable energy technologies are summarized in Table 7-1 and described in more detail in the following.

Wind Energy

Wind power plants are usually installed at windy and exposed sites. Planning the installation must therefore, as a matter of fact, consider all the needs of nature protection as well as compatibility with bird flight routes and similar aspects. Compliance is assured by legislative requirements and the designation of high-priority and suitable areas. Furthermore, in the case of offshore wind parks, the compatibility with the marine fauna must be assured. Even the disputed spoiling of the appearance of the country-side, in particular in the highly structured central mountain regions, can be subjected in part to objective observations if, for instance, areas of particularly high visual sensitivity are represented by appropriate GIS-supported methods. A balance between climate protection and the appearance of a local wind power plant can therefore be found.

Wind turbines occupy only a small fraction of the land area required for their erection, the rest can be used for other purposes or left in its natural state. For this reason, wind power development is ideally suited to farming areas. In other settings, however, wind power development can create serious land-use conflicts. In forested areas it may mean clearing trees and cutting roads, a prospect that is sure to generate controversy, and near populated areas, wind projects often run into stiff opposition from people who regard them as unsightly and noisy, or who fear their presence may reduce property values.

In California, bird deaths from electrocution or collisions with spinning rotors have emerged as a problem at the Altamont Pass wind "farm," where more than 30 threatened golden eagles and 75 other raptors such as red-tailed hawks died or were injured during a three-year period. Studies under way to determine the cause of these deaths and find preventive measures may have an important impact on the public image and rate of growth of the wind industry. In appropriate areas, and with imagination, careful planning, and early contacts between the wind industry, environmental groups, and affected communities, siting and environmental problems should not be insurmountable /EWEA 2002/, /BMU 2004-1/, /BMU 2004-2/, /Brower 1992/.

Solar Energy

Since solar power systems generate no air pollution during operation, the primary environmental, health, and safety issues involve how they are manufactured, installed, and ultimately disposed of. Energy is required to manufacture and install solar components, and any fossil fuels used for this purpose will generate emissions. Thus, an important question is how much fossil energy input is required for solar systems compared to the fossil energy consumed by comparable conventional energy systems. Although this varies depending upon the technology and climate, the energy balance is generally favourable to solar systems in applications where they are cost effective, and it is improving with each successive generation of technology.

Materials used in some solar systems can create health and safety hazards for workers and anyone else coming into contact with them. In particular, the manufacturing of photovoltaic cells often requires hazardous materials such as arsenic and cadmium. Even relatively inert silicon, a major material used in solar cells, can be hazardous to workers if it is breathed in as dust. Workers involved in manufacturing photovoltaic modules and components must consequently be protected from exposure to these materials. Photovoltaic systems can take advantage of unused space on the roofs of homes and buildings and in urban and industrial lots. And, in solar building designs, the structure itself acts as the collector, so there is no need for any additional space at all.

The large amount of land required for utility-scale solar power plants-approximately one square kilometre for every 20-60 megawatts (MW) is often considered an additional problem. However, looking at the life cycle use of land including raw material exploitation, operation, infrastructure and disposal, solar technologies come out as the most area efficient electricity generating technologies (Figure 7-3). Generating electricity from coal actually requires as much or more land per unit of energy delivered if the land used in strip mining is taken into account. The collectors of large scale photovoltaic systems as well as the mirrors from concentrating solar thermal power systems can be used as shading device as described in Chapter 2. Thus they would gain waste desert land for human activities rather than “consuming” land for energy use.

Table 7-1: Potential Environmental Impacts of Power Technologies

Fossil Fuel Technologies

- Effects of atmospheric pollution on human health
- Accidents affecting workers and/or the public
- Effects of atmospheric pollution on:
  - materials and buildings
  - crops and forests
  - freshwater and fisheries
  - unmanaged ecosystems
- Impacts of global warming
- Impacts of noise
- Impacts of coal and lignite mining on ground and surface waters
- Impacts of coal mining on building and construction
- Resettlement necessary through lignite extraction
- Accidental oil spills effect marine life
- Emissions from exploration and extraction from oil and gas wells

Nuclear Technologies

- Radiological health impacts by routine and accidental releases to the environment
- Radiological health impacts on workers due to routine work and accidental exposure
- Increased natural background radiation due to major accident releases

Wind Power

- Accidents affecting workers and/or the public
- Effects on visual amenity
- Impact on marine life and shipping routes in case of offshore plants
- Danger of collisions in case of offshore parks
- Effects of noise emissions on amenity
- Atmospheric emissions during manufacturing, construction and servicing

Hydropower

- Occupational health effects
- Employment benefits and local economic effects
- Impacts of transmission lines on bird populations
- Damage to private goods (forestry, agriculture, water supply, ferry traffic)
- Damages to environmental goods and cultural objects

Solar Photovoltaic Power

- Accidents affecting workers and/or the public
- Effects on visual amenity
- Atmospheric emissions during manufacturing, construction and servicing
- Hazardous materials from production and disposal of equipment

Solar Thermal Power

- Atmospheric pollution from combustion (in hybrid operation) and during production and construction of equipment
- Visual impact on amenity, noise of cooling towers
- Smell from synthetic oil heat transfer fluid
- Synthetic oil heat transfer fluid considered hazardous material
- Pollution of soil and water from spilling HTF oil
- Impact of concentrated beam radiation on persons, birds and insects
- Impact of large plants on regional albedo
- Land use

Geothermal Power

- Thermal and chemical atmospheric, water and soil pollution by well blow-outs and leakage and during drilling
- Noise from drilling and from cooling towers
- Solid waste disposal
- Visual impact on amenity from pipelines and cooling towers
- Sinking of land surface

Biomass Power

- Atmospheric pollution by combustion and collection of biomass
- Smell and visual impact on amenity
- Land use of energy crops
- Impact of fertilizers on soil and water
- Water demand
- Potential overuse of fuel wood and land resources

Solar-thermal power plants (like most conventional power plants) also require cooling water, which may be costly or scarce in desert areas. However, again like in conventional plants, alternatively dry cooling towers with air fan can be applied for cooling. Another solution is to use a co-generation system for thermal sea water desalination as cooling device. In this case the plant would even generate poTable 7-water instead of consuming water, provided that salty water is available. Of course on the coasts, direct cooling with sea water is also feasible.

Solar thermal parabolic trough plants in California report some leakages of the synthetic heat transfer fluid oil contained in the collector field to transport the heat from the collectors to the steam cycle plant. There is also a smell of the HTF reported to prevail in the installations. However, those problems were obviously manageable in the 20 years of operation experienced up to now. Leakages have been controlled by new interconnection elements (ball joints) and contaminated soil can be recovered by bacteriological decontamination. Research and development of the past years has lead to various new systems that don't need the synthetic oil any more, but directly use water and steam as heat transfer fluid.

Geothermal Energy

Geothermal energy is heat contained below the earth's surface. The only type of geothermal energy that has been widely developed is hydrothermal energy, which consists of trapped hot water or steam. However, new technologies are being developed to exploit hot dry rock (accessed by drilling deep into rock), geo-pressured resources (pressurized brine mixed with methane), and magma.

The various geothermal resource types differ in many respects, but they raise a common set of environmental issues. Air and water pollution are two leading concerns, along with the safe disposal of hazardous waste and land subsidence. Since these resources would be exploited in a highly centralized fashion, reducing their environmental impacts to an accepTable 7-level should be relatively easy. But it will always be difficult to site plants in scenic or otherwise environmentally sensitive areas.

The method used to convert geothermal steam or hot water to electricity directly affects the amount of waste generated. Closed-loop systems are almost totally benign, since gases or fluids removed from the well are not exposed to the atmosphere and are usually injected back into the ground after giving up their heat. Although this technology is more expensive than conventional open-loop systems, in some cases it may reduce scrubber and solid waste disposal costs enough to provide a significant economic advantage.

Open-loop systems, on the other hand, can generate large amounts of solid wastes as well as noxious fumes. Metals, minerals, and gases leach out into the geothermal steam or hot water as it passes through the rocks. The large amounts of chemicals released when geothermal fields are tapped for commercial production can be hazardous or objectionable to people living and working nearby.

At The Geysers, the largest geothermal development, steam vented at the surface contains hydrogen sulphide (H2S)-accounting for the area's "rotten egg" smell-as well as ammonia, methane, and carbon dioxide. At hydrothermal plants carbon dioxide is expected to make up about 10 percent of the gases trapped in geo-pressured brines. For each kilowatt-hour of

electricity generated, however, the amount of carbon dioxide emitted is still only about 5 percent of the amount emitted by a coal- or oil-fired power plant.

Scrubbers reduce air emissions but produce a watery sludge high in sulphur and vanadium, a heavy metal that can be toxic in high concentrations. Additional sludge is generated when hydrothermal steam is condensed, causing the dissolved solids to precipitate out. This sludge is generally high in silica compounds, chlorides, arsenic, mercury, nickel, and other toxic heavy metals. One costly method of waste disposal involves drying it as thoroughly as possible and shipping it to licensed hazardous waste sites.

Usually the best disposal method is to inject liquid wastes or re-dissolved solids back into a porous stratum of a geothermal well. This technique is especially important at geo-pressured power plants because of the sheer volume of wastes they produce each day. Wastes must be injected well below fresh water aquifers to make certain that there is no communication between the usable water and waste-water strata. Leaks in the well casing at shallow depths must also be prevented.

In addition to providing safe waste disposal, injection may also help prevent land subsidence. At Wairakei, New Zealand, where wastes and condensates were not injected for many years, one area has sunk 7.5 meters since 1958. Land subsidence has not been detected at other hydrothermal plants in long-term operation.

Most geothermal power plants will require a large amount of water for cooling or other purposes. In places where water is in short supply, this need could raise conflicts with other users for water resources.

The development of hydrothermal energy faces a special problem. Many hydrothermal reservoirs are located in or near wilderness areas of great natural beauty. Proposed developments in such areas have aroused intense opposition.

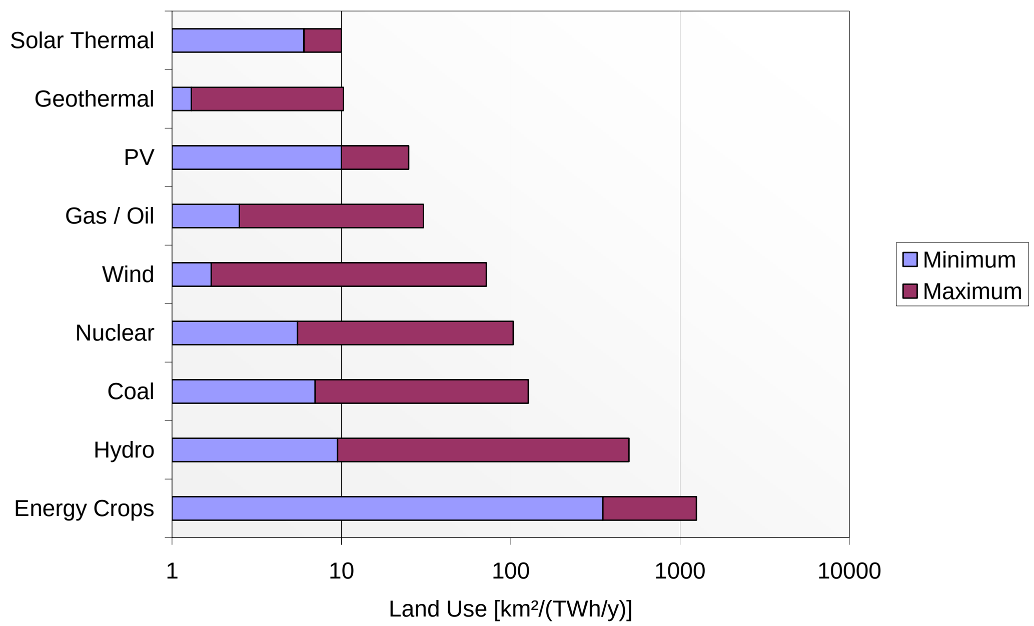


Figure 7-3: Maximum and minimum values found in the literature for life cycle land requirements of different power technologies per TWh/y /WEC 2004/, /HGF 2001/, /SECO 2003/, Ecoinvent 2000/. Due to different sources and methodologies, the results shown in the graph are not necessarily comparable to each other.

Biomass

The use of biomass must be carefully analysed with particular regard to the required surface areas. Today and in the near future primarily residuals and waste material are used as bio-energy carriers. In the long-term, the cultivation of biomass for energy purposes will compete with the ecologically desirable reduced intensification of agriculture.

Emissions from conventional biomass-fuelled power plants are generally similar to emissions from coal-fired power plants, with the noTable 7-difference that biomass facilities produce very little sulphur dioxide or toxic metals (cadmium, mercury, and others). The most serious problem is their particulate emissions, which must be controlled with special devices. More advanced technologies, such as the whole-tree burner (which has three successive combustion stages) and the gasifier/combustion turbine combination, should generate much lower emissions, perhaps comparable to those of power plants fuelled by natural gas.

Facilities that burn raw municipal waste present a unique pollution-control problem. This waste often contains toxic metals, chlorinated compounds, and plastics, which generate harmful emissions. Since this problem is much less severe in facilities burning refuse-derived fuel pelletized or shredded paper and other waste with most inorganic material removed-most waste-to-energy plants built in the future are likely to use this fuel. Co-firing refuse derived fuel in coal-fired power plants may provide an inexpensive way to reduce coal emissions without having to build new power plants /NREL 2004/.

A major benefit of substituting biomass for fossil fuels is that, if done in a sustainable fashion, it would greatly reduce emissions of greenhouses gases. The amount of carbon dioxide released when biomass is burned is very nearly the same as the amount required to replenish the plants grown to produce the biomass. Thus, in a sustainable fuel cycle, there would be no net emissions of carbon dioxide, although some fossil-fuel inputs may be required for planting, harvesting, transporting, and processing biomass. Yet, if efficient cultivation and conversion processes are used, the resulting emissions should be small (around 20 percent of the emissions created by fossil fuels alone). And if the energy needed to produce and process biomass came from renewable sources in the first place, the net contribution to global warming would be zero.

Similarly, if biomass wastes such as crop residues or municipal solid wastes are used for energy, there should be few or no net greenhouse gas emissions. There would even be a slight greenhouse benefit in some cases, since, when landfill wastes are not burned, the potent greenhouse gas methane may be released by anaerobic decay.

One surprising side effect of growing trees and other plants for energy is that it could benefit soil quality and farm economies. Energy crops could provide a steady supplemental income for farmers in off-seasons or allow them to work unused land without requiring much additional equipment. Moreover, energy crops could be used to stabilize cropland or rangeland prone to erosion and flooding. Trees would be grown for several years before being harvested, and their roots and leaf litter could help stabilize the soil. The planting of coppicing, or self-regenerating, varieties would minimize the need for disruptive tilling and planting. Perennial grasses harvested like hay could play a similar role; soil losses with a crop such as switchgrass, for example, would be negligible compared to annual crops such as corn.

If improperly managed, however, energy farming could have harmful environmental impacts. Although energy crops could be grown with less pesticide and fertilizer than conventional

food crops, large-scale energy farming could nevertheless lead to increases in chemical use simply because more land would be under cultivation. It could also affect biodiversity through the destruction of species habitats, especially if forests are more intensively managed. If agricultural or forestry wastes and residues were used for fuel, then soils could be depleted of organic content and nutrients unless care was taken to leave enough wastes behind. These concerns point up the need for regulation and monitoring of energy crop development and waste use.

Energy farms may present a perfect opportunity to promote low-impact sustainable agriculture, or, as it is sometimes called, organic farming. A relatively new federal effort for food crops emphasizes crop rotation, integrated pest management, and sound soil husbandry to increase profits and improve long-term productivity. These methods could be adapted to energy farming. Nitrogen-fixing crops could be used to provide natural fertilizer, while crop diversity and use of pest parasites and predators could reduce pesticide use. Though such practices may not produce as high a yield as more intensive methods, this penalty could be offset by reduced energy and chemical costs. This would fit quite well into the concept of integrated multi-purpose solar plants as described in Chapter 2 and in the special report on this topic by /Bassam 2004/.

Increasing the amount of forest wood harvested for energy could have both positive and negative effects. On one hand, it could provide an incentive for the forest-products industry to manage its resources more efficiently, and thus improve forest health. But it could also provide an excuse, under the "green" mantle, to exploit forests in an unsustainable fashion. Unfortunately, commercial forests have not always been soundly managed, and many people view with alarm the prospect of increased wood cutting. Their concerns can be met by tighter government controls on forestry practices and by following the principles of "excellent" forestry. If such principles are applied, it should be possible to extract energy from forests indefinitely.

Hydropower

The use of hydroelectric power can create severe ecological problems. In the case of run-of-river power stations, the migration of the fish can be impeded by an interruption in the natural flow of the water. The construction of weirs, discharge channels, and dammed-up waters, together with reduced flow rates, turbulence, and dragging power of the waters, can cause changes in the water structure, transportation of sediments, and the ecological balance of the waters and the surroundings.

Furthermore, dam-type hydroelectric power stations can lead to conflicts of use with farming and to flooding of large open spaces. At the same time, however, these are also protect against high water and provide drinking water.

The conflicts in goals between protecting the climate and protecting the waters can be reduced by construction measures. For example, upstream migration routes for fish, re-routing, and sluice flows can improve the passage through the rivers.

For example, minimum amounts of water being discharged from power stations can prevent the build-up of sludge and damage to the mother bed. Environmental impact assessment required for authorization place high requirements on the ecological quality of the plant. At untouched stretches it is a matter of consequence to deny the construction of hydroelectric power stations for the conservation of the environmental treasures usually found there.

The impact of very large dams can very serious. The reservoirs created by such projects frequently inundate large areas of forest, farmland, wildlife habitats, scenic areas, and even towns. In addition, the dams can cause radical changes in river ecosystems both upstream and downstream.

Small hydropower plants using reservoirs can cause similar types of damage, though obviously on a smaller scale. Some of the impacts on fish can be mitigated by installing "ladders" or other devices to allow fish to migrate over dams, and by maintaining minimum river-flow rates; screens can also be installed to keep fish away from turbine blades.

7.2 Environmental Impacts resulting from the MED-CSP Scenario

The MED-CSP scenario was developed according to the following principles:

- Environmental and economic sustainability.
- Balanced mix of renewable and conventional energy technologies to cope with technical, economical and environmental requisites defined by “crash barriers”.
- Cooperation and learning from best practice in Northern and Southern countries.

The goal was to quantify a power supply system in the analysed EU-MENA countries with considerably reduced greenhouse gas emissions and other pollutants without creating other serious environmental, societal or economic problems. The key concerns resulting from the scenario CG/HE were land use, emissions of greenhouse gases and other pollutants, and direct environmental impacts. They are summarised in the following.

Land Use

The specific land requirement of hydropower ranges between 10 km²/(TWh/y) for micro-hydropower and over 400 km²/(TWh/y) for very large schemes like the Aswan dam (Table 7-2). The average value resulted in 165 km²/(TWh/y) for the total analysed region. Geothermal power requires little land (1 to 10 km²/(TWh/y)), and the areas affected are in the subsoil at thousands of meters depth. In our scenario, biomass is produced mainly by agricultural and municipal residues (no extra land use) and from wood, resulting in an average land use of only 2 km²/(TWh/y). Energy crops – with a very high land use – were not considered in the MENA countries, as they would compete with food and water supply. For wind power, the average land use was 46 km²/(TWh/y). The specific values differ considerably according to the different performance indicators in each country.

Concentrating solar thermal power schemes have a specific land use of 6-10 km²/TWh. However, land could be gained from waste land, if multi-purpose CSP plants are applied. This would mean winning additional land rather than land “consumption”. Photovoltaic energy has no additional land use if installed on roofs, and a slightly higher land use than CSP if installed in large installations. An average land use of 7 km²/(TWh/y) was assumed. It may seem paradox that solar and geothermal power generation has the best land use efficiency among all power technologies, even when not considering the potential land gain effect.

The total mix of renewable energies in 2050 within the scenario CG/HE has an average land use of 22.5 km²/(TWh/y), which is in the same order as the average value of natural gas fired combined cycle power stations, which represent the best available fossil fuelled power technology. Disposal of sequestrated CO2 is not considered within this figure. The land use of

oil or coal fired steam cycles is between 50 and 100 km²/TWh. Considering the long time during which areas are affected by nuclear waste disposal and uranium mining, nuclear plants also have a high land consumption in the order of 100 km²/(TWh/y). This figure does not account for nuclear accidents like the one in Tschernobyl. The change to renewable energies will therefore lead to a more efficient land use for power generation.

Solar thermal power plants will also be used for sea water desalination. A concentrating solar thermal collector array required for desalinating 1 billion m³/y would cover a total land area of approximately 10 km x 10 km, corresponding to about 10 m³ desalinated water per m² of collector area. In case of linear Fresnel or multi-tower technology, the collectors could act like blinds, blocking the intense direct solar radiation and creating a cool space underneath with sufficient light for horticulture or other purposes. About 10 % of the desalted water would be sufficient for irrigating the desert land beneath the collectors with a water column of 1 m/a. In the year 2050, our scenario arrives at 2900 TWh/y of electricity (including solar power generation and desalination) and 160 billion m³/y of desalted water. For this a collector field of 120 x 120 km² would be necessary, which is equivalent to not more than 0.15 % (0.0015) of the Sahara desert.

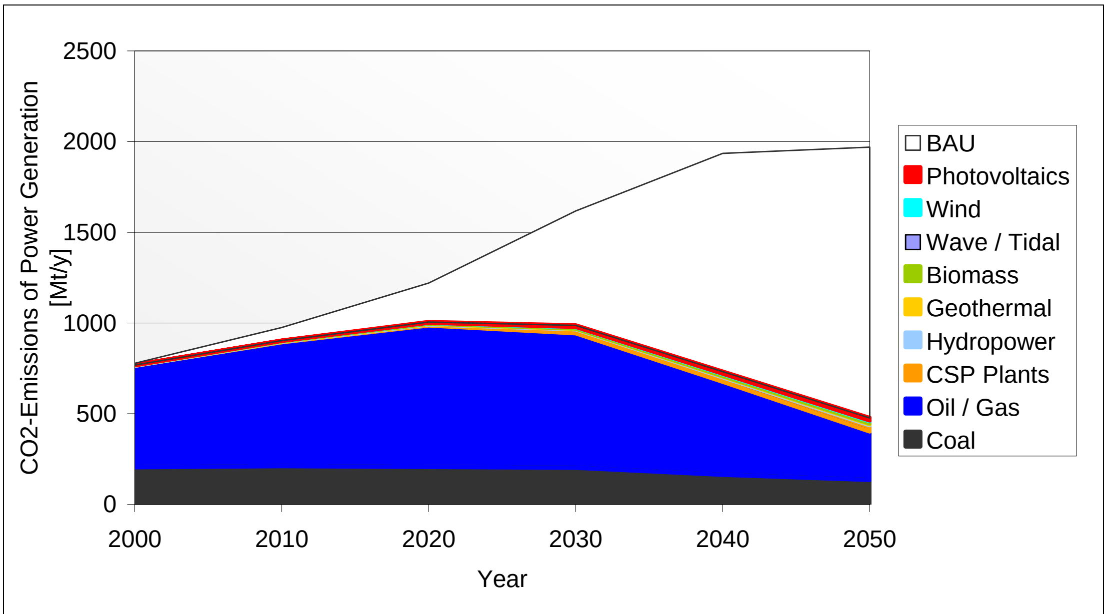


Figure 7-4: CO2-emissions of electricity generation in million tons per year for all countries for the scenario CG/HE and emissions that would occur in a business as usual case (BAU)

Emission of Greenhouse Gases and other Pollutants

The emissions of renewable energy technologies are mainly occurring during the production of the plant's components, because most plants are produced within today's industrial production schemes that use mostly fossil energies. Thus, the emission occurs from fossil power plants that are at present used to provide energy for the production of plant components. The life cycle emissions are valid for a power park with average CO2 emissions of 700 g/kWh. During operation, only biomass and geothermal plants produce emissions. The emission of greenhouse gases (CO2 equivalent) of renewable energy technologies are by orders of magnitude lower than those of fossil fuelled technologies. Coal plants usually have emissions of 900 – 1100 kgCO2/MWh, oil plants around 600 - 700 kgCO2/MWh. Even coal

plants with CO2 sequestration would still emit more CO2 than solar or wind power plants, as about 20 % of their emissions would still reach the atmosphere. Moreover, it is not yet clear for how long CO2 reservoirs of sequestration would remain isolated from the atmosphere. Other emissions that mainly occur during combustion like nitrates NOx and sulphates SOx as well as phosphoric acids are also avoided. They can lead to acidification and over-nutrition (eutrophication) of soils and water bodies. Emissions of CSP plants in hybrid operation will gradually be reduced with time applying increased solar thermal storage capacities.

For the future fuel-based power generation in Europe, an increasing share of CO2 sequestration was considered as discussed in chapter 5.2.

At present, the total carbon emissions of electricity generation of all countries analyzed in the study amount to approximately 770 million tons per year. Instead of growing to 2000 million tons per year that would be expected for the year 2050 in a business as usual case our scenario achieves a reduction of emissions to 475 million tons within that same time span (Figure 7-4). The scenario avoids a total of 28 billion tons of carbon dioxide until 2050, which is equivalent to the present total annual CO_2-emissions world wide.

The scenario reaches a per capita emission of 0.58 tons/cap/y in the power sector in 2050 (Figure 7-5). This is acceptable in terms of the recommended total emission of 1-1.5 tons/cap (ref. WP 1).

Other Environmental Impacts

Any power technology has an impact on the environment, which must be evaluated very carefully in order to avoid harmful results. Wind plants may have a negative impact on bird habitats and, through visual effects and noise, on recreational and municipal areas. Offshore wind parks may additionally affect marine habitats in their vicinity. Geothermal hot dry rock technology will establish a water cycle from the depths, which will contain a lot of minerals harmful to the surface environment. Therefore, it must be secured that the water cycle used for extracting the heat from the ground is always returned and not infiltrated into surface or groundwater bodies. The disposal of biomass residues is in fact a positive contribution to the environment. Using wood for energy purposes is more critical considering the present over-exploitation of fuel wood in most arid regions. Plants must be carefully designed and distributed to not overexploit the natural resources. It must also be considered that traditional fuel wood would compete with fuel wood for electricity. All in all the environmental impacts of most renewable energy technologies is manageable if there is a careful prior analysis and design.

The environmental impact of hydropower is well known and documented world wide. Especially in arid regions, large dams may affect severely the natural habitat of many species, as they usually dwell in the narrow and shaded canyons of the river beds which are set underwater by the dam. Therefore in most cases large hydro dams must be considered as questionable in terms of environmental compatibility.

The effects of large scale sea water desalination plants must also thoroughly be evaluated in order to avoid damages by the salty brine and by chemical additives used against scaling and fouling. Due to the large demand of desalination that can be foreseen, intensive research and development for environmentally compatible desalination technologies is of high priority in order to avoid the overload of the local environment of those plants.

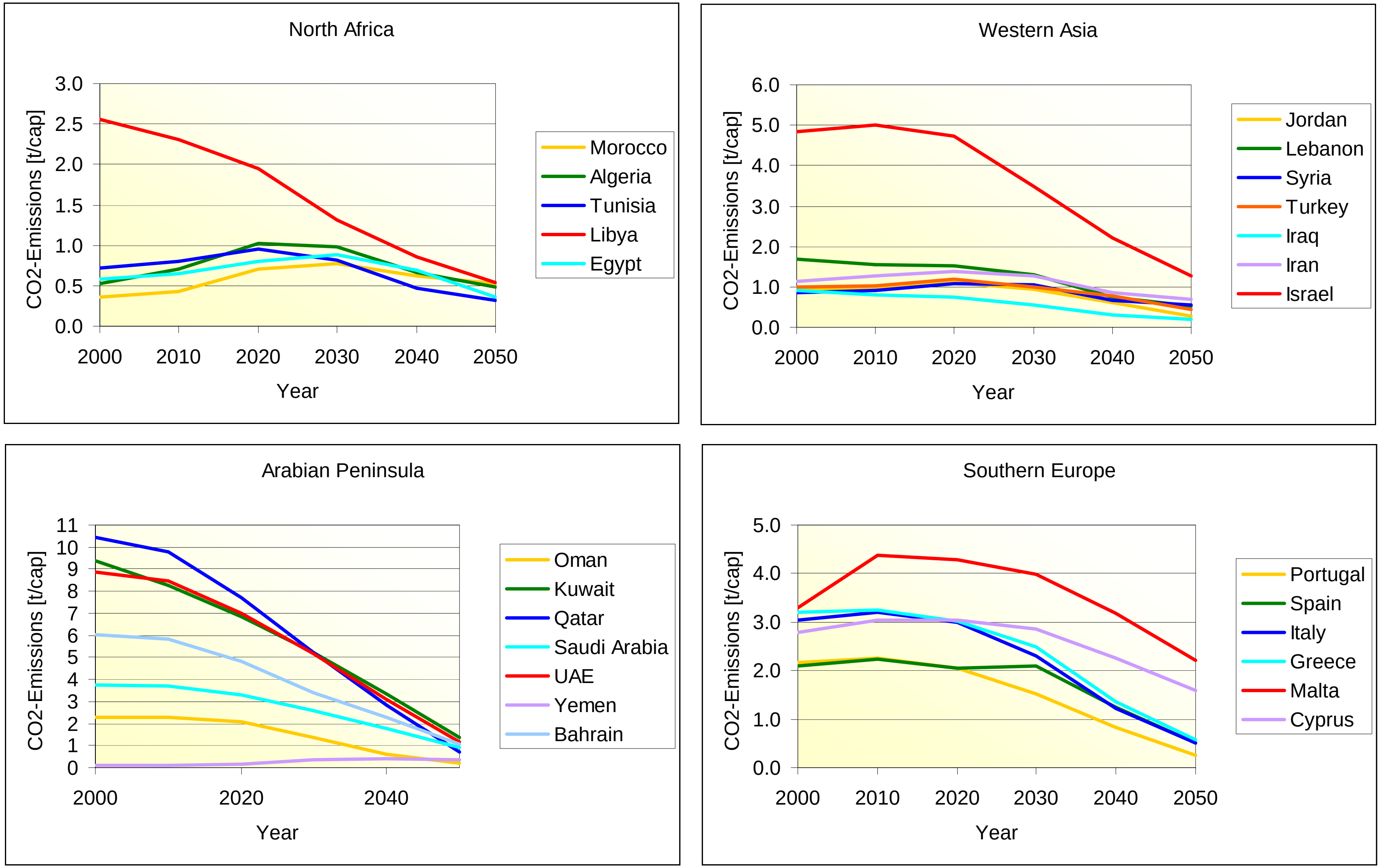


Figure 7-5: Annual per Capita CO2 Emissions of Power Generation (Scenario CG/HE)

	Hydro	Geo	CSP	Bio	Wind	PV	Total	Country	Area Used
	km²	km²	km²	km²	km²	km²	km²	km²	%
Bahrain	0	0	21	0	2	2	25	707	3.5%
Cyprus	20	0	5	0	15	1	42	9251	0.5%
Iran	1890	11	2093	29	340	112	4476	1648000	0.3%
Iraq	11828	0	1137	3	279	48	13295	438317	3.0%
Israel	351	0	174	0	21	28	574	21946	2.6%
Jordan	4	0	240	0	67	31	343	97740	0.4%
Kuwait	0	0	78	0	0	18	96	17818	0.5%
Lebanon	140	0	72	0	9	11	231	10452	2.2%
Oman	0	0	133	0	244	29	405	212457	0.2%
Qatar	0	0	17	0	0	7	24	11437	0.2%
Saudi Arabia	0	71	810	6	559	97	1543	2240000	0.1%
Syria	650	0	699	2	335	60	1747	185180	0.9%
UAE	0	0	60	1	0	21	82	77700	0.1%
Yemen	0	128	1530	2	101	180	1941	536869	0.4%
Algeria	78	5	989	8	978	97	2155	2381741	0.1%
Egypt	13696	26	2370	0	2240	252	18584	1002000	1.9%
Libya	0	0	131	2	392	27	553	1775500	0.0%
Morocco	544	10	900	12	692	119	2277	458730	0.5%
Tunisia	82	3	260	2	419	35	801	163610	0.5%
Greece	608	5	21	14	481	28	1157	131957	0.9%
Italy	5245	14	30	30	2367	70	7757	301302	2.6%
Malta	0	0	2	0	5	1	8	316	2.4%
Portugal	1370	7	60	11	406	21	1875	92389	2.0%
Spain	3594	9	150	43	1827	35	5658	504782	1.1%
Turkey	6880	120	750	41	1353	200	9343	779452	1.2%
Total km²	46978	410	12733	208	13133	1529	74991	13099653	0.6%
Electricity TWh/y	288	205	2122	195	285	218	3314		
Relative km²/(TWh/y)	162.9	2.0	6.0	1.9	46.1	7.0	22.5		

Table 7-2: Areas required for renewable electricity generation in 2050 for the scenario CG/HE. The two columns at right show the total area of each country and the percentage of this area used for power generation by renewable energy sources in 2050. Hydropower surface demand varies strongly between countries. Photovoltaic surface demand considers only 50 % of the total because many plants will be installed on roofs. Wind power and CSP surface demand is calculated as if exclusively used for power generation. Biomass surface demand is only considered for fuel wood energy

8 Deployment Policies for Renewable Energy Technologies

The regulatory frameworks of the MENA-countries are described to provide the background for the following discussion of instruments. At first, an overview over the whole set of instruments under discussion is given.

8.1. The Regulation of the Electricity Sector

Table 8-1 provides an overview of the general economic characteristics of different parts of the electricity sector and shows four blue prints for regulatory regimes following /IEA 2001/. The electricity system can be separated into five different services: generation of electricity, transmission of power over an interconnected network at very high voltage levels, system operation by co-ordination of services to ensure that the system is constantly in the state of static electrical equilibrium, intermediary trade of electricity, distribution of power at low voltage, and end user supply including procurement of energy, transportation services, and the metering and billing of consumption. Whether competition might generally work efficiently in a certain service depends primarily on the significance of economies of scale, network externalities and the amount of sunk costs. Column 5 summarizes these features following /IEA 2001/, p.18. It can be concluded that for system operation, distribution, and transportation there are arguments why competition might not work properly. These arguments are strongest for system operation and weakest for transmission. The three activities need a special regulation, which considers that the system operation will only be functional as a monopoly. In the other areas competition is possible. The major challenge is to provide a fair access to the grid.

This might be compromised by the integration of regulated services with competitive services in one company, which will have the incentive and ability to discriminate. For example a transmitting company that generates electricity as well, might charge an excessive fee for transmission, put excessive technical constraints on the connection of a power plant of a competitor, or invest strategically in grid augmentation, all of which might be hard to detect by a regulator or by competition authorities. Therefore it is important which of the different services is integrated in one company and how they are integrated. Vertical separation tries to limit or remove the ability and/or the incentive to discriminate /IEA 2001/, pp. 69. Vertical separation following short of ownership (or divestiture) separation which requires distinct legal identities with different management and no significant common ownership will reduce the ability to discriminate in different degrees but will preserve the incentive. Accounting Separation, which just require separate accounts, will reduce the ability to discriminate the least. Separating employees and assuring that in the competitive part no other information are available than for other actors (Functional Separation) reduces the ability further. If operation and decision are separated the strongest form of a reduction of the ability to discriminate with common ownership is reached.

Whether the regulated services or the competitive services are integrated is of secondary importance. Separation should be considered mainly for generation and transmission/system operation, generation and distribution, and distribution and end supply. The last one will probably yield little benefits as only a small share of total costs occurs there. In addition the separation might be difficult /IEA 2001/, p78.

	Mono-poly	**"Portfolio manager"**	**Manda-tory pool model**	**Retail Compe-tition**	**General characteristics**
Genera-tion	Mono-poly	Compe-tition	Compe-tition	Compe-tition	Limited scale economies at plant level; Co-ordination economies at system level; complementarity with transmission => potentially competitive
Trans-mission	Mono-poly	Mono-poly	Mono-poly	Mono-poly	Network externalities; in general no natural monopoly; large sunk costs => Investment incentives need special attention; one grid but possibly several owners
System Opera-tion	Mono-poly	Mono-poly	Mono-poly	Mono-poly	Monopoly (due to technical constraints) => no competition
Inter-mediaries	Non-existent	Mono-poly	Mono-poly	Compe-tition	No special features => potentially competitive
Distribu-tion	Mono-poly	Mono-poly	(Mono-poly)	(Mono-poly)	Often a natural monopoly; large sunk costs => (in general) no competition
End User Supply	Mono-poly	Mono-poly	Compe-tition	Compe-tition	Limited scale economies; no special features => potentially competitive
Integra-tion	Vertically integrated	Un-bundled*	Un-bundled**	Un-bundled**	For competition ideal: Ownership separation

* Intermediaries, distribution and supply integrated. Transmission and system operation integrated.

** Transmission and System Operation integrated.

Table 8-1: Characterisation of regulatory regimes in the electricity market (source: /IEA 2001/; p. 18 and 56 ff.; revised)

Table 8-2 gives a rough picture of the concerned countries' regulatory systems. For EU-member countries the EU-framework applies, which leaves some space for different national laws. A liberalized system with competition in power generation will be established in all EU-countries. The regulation in the EU-countries typically aims to implement Retail Competition. The type of unbundling and the concentration of power differ widely, however. Without any further regulation a fair net access in Greece might be a problem, according to the market share and weak type of separation. Generally, the Commission of the European Communities (EU 2004/, p.44) thinks, that in Greece the "big danger is that the construction and upgrading of the grid lines will be delayed, postponing as a consequence the development of

renewables". As additional objections grid connection difficulties are explicitly mentioned. From the European experience a fair or preferential grid connection for renewable energy systems is essential.

In many of the other countries the regulation of the electricity market is presently a subject to change. There is a trend to privatization and the introduction of competitive elements. The scheduled and actual degree of deregulation is however very heterogeneous. In some countries, foreign or in general private operators of power plants are not allowed, or regulations are unclear. State monopolies are usual practice. Instruments for the support of renewables that require a competitive structure are not suiTable 8-in such environments. However the regulation of the electricity market is presently restructured in most countries. Therefore, such instruments can also become feasible in countries that at the moment do not have competition in the power sector. However, it is important to note that the European Commission offers Economic and Financial Aid for market oriented reforms of the electricity sector in Mediterranean countries. The experience within the EU and the instruments for RES-deployment in the EU are therefore especially interesting for some of the MENA-countries.

Operation of plants by foreign power companies is only possible in the European Union, Morocco, Jordan, Yemen and Oman. The precise future regulation is yet unclear in many countries. No possibilities for foreign companies exist in Syria and Libya.

The possibility of independent power producers (IPP) is a requisite for some of the instruments of RES deployment that require free market access for power generation. It is not feasible to apply such instruments where a state monopoly without regulations for IPP exists, and where no changes are scheduled. This is the case in most oil exporting countries.

Artificially low electricity prices induced by some kind of state subsidies increase the initial need of renewables for support in addition to the real cost difference. But this requires two conditions: First, the success to reach sustainability depends on an efficient use of energy. The goal may be missed even if a RES-deployment path like in the scenario is realized, if no measures for energy efficiency are taken as well. Second, if a broad subvention of electricity prices seams to be necessary, it might not be feasible to use instruments which finance the cost difference through an increase of electricity prices. A justification for the reduced prices is the importance of electricity for poor households. While this argument is well established, it might be better to focus the subvention on poor households and sell at market or at least cost-covering prices to other customers.

	Type of current regulation	**Goal: Type of regulatory**	**Private/ Foreign ownership**	**Concentration of Generation /Type of unbundling**	**Electricity prices**
Portugal		Retail competition	Liberalised access		
Spain		Retail competition	Liberalised access	Ownership separation	
Italy		Retail competition	Liberalised access	Some vertical integration will remain	

	Type of current regulation	**Goal: Type of regulatory**	**Private/ Foreign ownership**	**Concentration of Generation /Type of unbundling**	**Electricity prices**
Greece	Ongoing liberalisation	Retail competition	Liberalised access (2006-2007)	One company 97 % market share / Functional and accounting separation	
Morocco	Ongoing restructuring from Monopoly	Retail com-petition; one regulated and one free system in parallel	IPPs and foreign investment	A company (ONE) will be responsible for system operation, transmission and distribution	
Algeria	Recent restructuring from Monopoly; privatisation stalled at the moment	Goal system not clear, perhaps retail competition	IPPs	Some vertical integration will remain	
Tunisia	Portfolio manager	No general changes	IPPs (BOT)	One company 90% market share	
Libya	State owned Monopoly	No general changes			strongly subsidized
Egypt	State owned Monopoly	Future direction is unclear	BOT (no new BOT projects likely in the near future		partially subsidized
Israel	Monopoly	No company shall control more than 50% of production or transmission, gradual liberali-sation, privati-sation prepared	IPPs	No company shall control more than 50% of production or transmission by 2010	
Jordan	Portfolio Manager	Retail competition	Above 5 MW bid invitation	Generation, Transmission and supply unbundled	partially subsidized
Lebanon	Monopoly	Privatisation stopped			
Syria	Monopoly	No general changes	No consideration		n.a.
Turkey	Ongoing restructuring	Retail competition	Due to restructuring unclear, probably IPPs in the near term	One company 91 % of power generation / vertical divestiture	

	Type of current regulation	Goal: Type of regulatory	Private/ Foreign ownership	Concentration of Generation /Type of unbundling	Electricity prices
Iraq			BOT, BOO		n.a.
Iran	Monopoly		BOT, BOO (not available)		strongly subsidized
Saudi-Arabia	Monopoly	Restructuring on the way; partial privatisation; Framework for private sector involvement		One power generation company/ unbundling power generation, transmission & distribution	Artificially low prices
Kuwait	Monopoly	IPP's future uncertain		One power generation company	Artificially low prices
Bahrain	Monopoly	Privatisationund er consideration		One power generation company	Artificially low prices
Qatar	Monopoly	No general changes		One power generation company	Artificially low prices
UAE	Monopoly	Perhaps gradually privatisation	Actual projects partially with foreign ownership		Artificially low prices
Oman	Monopoly	Privatisation, unbundling announced		IPP	Artificially low prices
Yemen	Monopoly		Private power generation possible and welcomed		Artificially low prices

Sources: EIA: Country Analysis Brief

Note: No data for Malta and Cyprus. For both countries EU-Regulations will apply. The characterisation of the regulation should only be used to give a brief impression. IPP: Independent Power Producers, BOT: Build-operate-transfer; BOO: build-operate-own, BOOT: Build-Operate-Own-Transfer; for a discussion see [OME, 2003].

Table 8-2: Overview of broad characteristics of regulatory regimes in MENA

8.2. General discussion of instruments

In addition to the CSP-issue and the general case for the deployment of RES-technologies for each EU-15 member-state an EU directive sets mandatory targets for the share of electricity from renewable energy sources in 2010. Table 8-3 shows the actual shares as well as the mandatory targets. Taking into account that the electricity demand is rising quite fast in

Portugal and Spain, a substantial additional RES-capacity is needed to meet these targets. To reach these targets the governments have implemented various instruments for the market deployment of renewable energies.

Year	**1997**	**2002**	**Target 2010**
Portugal	39	22*	39
Spain	20	16.2*	29.4
Italy	16	16.8	25
Greece	5.5	7.3	20.1

* The reduction is partly due to fluctuations of hydropower production.

Table 8-3: State of renewables and targets according to EU Directive for Electricity Produced from Renewable Energy Sources (percent of total electricity generation)

To reach these targets and more general to achieve economic competitiveness quickly without unnecessary financial burdens the learning curve of renewable energy technologies has to be exploited as best as possible. As with new RES-technologies most or all of the learning takes place in the production of the equipment and not during the operation, a continuity of the investment in the RES-technologies is necessary. Such continuity is expected by all participators especially by the investors in RES production industries. Existing instruments should decrease their risk in building up industries and shall allow them to develop long term strategies for a market introduction, which should reduce costs, for example by making full use of scale economics. This requires a long term commitment of governments.

On the other hand, a long term commitment by governments buries the risk that they are not able to react to new knowledge or changing environments. In addition, the instruments in combination with the commitment may create no or too little incentives for the producers to reduce costs. Therefore it is essential to combine a long term commitment of governments with a well designed instrument with short term flexibility. There should be confidence that the government will not use the short term flexibility to exploit specific investment which was undertaken in confidence of the government’s decision to accelerate the deployment of RES-technologies. This is especially important if a country’s actual or potential market share of the world wide investment in a certain RES-technology is rather high. If a country has the aim to build up an industry for a certain RES-technology, then a reliable long term strategy and a binding commitment will become especially important. A binding commitment may be reached by introducing sanctions, e.g. in international treaties, or – more often in regard of government actions – building up a reputation through action that the goal is indeed important.

What does this imply for CSP-technologies? First, the potential of the EU-member countries is not big enough to allow a market introduction of CSP on their own. The demand in these countries is important to assist the market introduction and to reach environmental targets of these countries. So a commitment of at least some of the other MENA-countries is needed. Second, the pure amount of the CSP-capacity to be installed in the scenario, suggests that a cooperation of some of the MENA-countries is necessary to achieve a fast cost reduction. Even countries with a large demand, demand increase, and a huge potential may not be able to

assure an expansion path which allows a fast cost reduction. Third, if this is true and a commitment of governments is necessary, an international agreement or treaty is necessary, too. This agreement should contain targets for the CSP-capacities. Whether or not sanctions shall be implemented or how a distribution of benefits, e.g. from the formation of production facilities connected to CSP-production, can be reached that gives every involved party an incentive to act according to the agreement, can not be discussed here[1]. But some kind of incentive for the governments to reach the targets will be necessary to convince potential investors in CSP-production facilities. Of course, especially in the context of CO2-emission reduction targets agreements or contracts with EU-countries may be of importance, too.

As the different RES-technologies are in different phases of technological development different instruments and different amounts of specific support are necessary. While in an early phase the technological development and experience is the most important, organisational issues and incentives to accommodate the load curve will increase in importance with the market share and technological development of a technology. Thus, in a competitive environment the second phase might require instruments which leave it to the power producer to sell the electricity produced. In countries in which the size of a CSP-plant is relatively large in comparison to the home market, additional grid capacities for the international trade of electricity accommodating the load curve might become important quite early.

As different RES-technologies are in different stages of development and most are necessary to reach long term environmental and social targets not all technologies should compete with each other on the basis of actual costs. This strategic aspect should be considered in designing an instrument. While it could be argued that in general poorer countries shouldn't invest much in the early development of new RES-technologies, this is not the case for CSP-technologies and the middle income MENA-countries. As the potentials in industrialized countries are very restricted, they can't push through a complete CSP market deployment strategy on their own. More importantly, the CSP-technologies offer the opportunity of long term economic gains from cheaper electricity and water and from export of zero emission electricity for the non-European-MENA-countries. So, it is in the interest of these countries to invest in the development of these technologies and to obtain a share in profits and business opportunities. Of course, this does not deny that foreign finance and assistance is important too, among others, to overcome financial constraints and transfer technological knowledge.

8.2.1 European Policies for RES Deployment

To give an overview over the specific instruments and to give an example of an international framework, it is helpful to look at the EU-policy in more detail. Energy policy takes place on different levels within the European Community (EU): Policy on the level of the European Union with its institutions European Parliament, European Commission and European Council is gaining more and more importance for the promotion of RES. On the one hand, the general framework conditions for European energy markets are very much targeted on creating a common market for energy with equal conditions for all market players across the EU. As an example, the EU directive: "Common Rules for the Internal Market in Electricity"

[1] An example for such an agreement, which is probably worth studying in detail, is the launch of Airbus by EU-member-states.

has created a fairer access to the electricity grid for independent power producers with RES and green electricity suppliers.

The European Community Guidelines on State Aid for Environmental protection allow Member States to grant operating support to new RES power plants of up to 5 cent/kWh referring thereby to the amount of external costs of conventional fuelled power plants. At the same time, the European Union is also an active player to promote RES directly. In 1997 the White Paper on “Energy for the future - renewable sources of energy” was issued setting a target of doubling the share of RES on primary energy supply by 2010 and describing scenarios and policy strategies to reach this goal. As a follow-up a “Campaign to Take Off” has been launched in 1998. The EU’s own financial means allocated to this campaign are rather limited with 74 million US-$ over 5 years compared to the total required investment of 20 billion US-$. However, the campaign aimed to levy a multiple of this amount by national support means. The European Directive ‘On the Promotion of Electricity produced from RES in the Internal Electricity Market’ sets indicative targets to the EU Member States regarding the share of RES for electricity production by 2010. Albeit the directive failed to establish a common European instrument to foster RES for electricity generation, it has created some momentum to establish support policies on the national level like recently in the UK and in Sweden.

The political status at the European Union could be summarized as follow:

- In December 1997, the European Commission adopted the White Paper for a “Community Strategy and Action Plan, Energy for the Future: Renewable Sources of Energy”. The objective is to increase RES to an amount equal to 12% of the EU gross inland energy consumption by 2010. In 2001 this action plan was supplemented by a directive of the European Parliament on the promotion of electricity from RES. The target is to increase the share of RES electricity generation to 22% of total consumption in 2010. The directive holds specific targets for the individual share of RES electricity per EU member state.
- In 1999 the European Commission started a campaign for Take-Off (CTO) with the intention to start the implementation strategy set out in the White Paper with indicative targets for the period 1999 – 2003. In 2001 an additional draft directive on biofuels was proposed. The aim is to increase the consumption of biofuels to 2% of the consumption of diesel and gasoline in 2005.
- A directive establishing a scheme of greenhouse gas emissions (GHG) trading within the community was adopted (2003).
- A decision for monitoring community GHG emission and implementing the Kyoto Protocol was adopted (February 2004).
- A directive concerning the establishment of a scheme for greenhouse gas emission allowance trading (Emission Trading Directive) within the community (Directive 2003/87/EC) was agreed and the project-based mechanisms were linked to the European GHG emission trading (linking Directive) (September-October 2004) /Lefevere 2004/.
- The directive on energy performance of building (January 2003), a directive on taxation of energy products (October 2003), was adopted.

- The directive on the promotion of co-generation (CHP) (February 2004) was adopted.
- Promotion of bio-fuels for transport is undertaken. (http://europa.eu.int/comm/environment/climate).

A political review of all national RES policies is scheduled for the end of 2005 creating a basis for a common European support instrument for electricity from RES.

As for national support mechanisms, they remain the most important means to foster the deployment of RES. To name only a few: National minimum price standards also referred to as fixed feed-in tariffs have in particular brought forward wind power in Denmark, Germany and Spain[2]. Favourable conditions have been created for biomass fuelled district heating in Sweden by high taxes on conventional energy carriers and a CO_2 tax refund. Soft loans and direct investment grants determine the demand for solar collectors in Germany. Examples for regional and municipal RES policies are the solar ordinance in Barcelona requiring real estate developers to install solar water heaters and the green power purchase of some Dutch municipalities.

Generally, RES policies have been focused on the electricity sector rather than on transport or heating purposes mainly because state intervention in the electricity sector is necessary (see above). Minimum price standards, bidding schemes and renewable portfolio standards, also referred to as RES quotas or green certificates, have been the major way to support electricity generation from RES on the national level. Minimum price standards require the grid operator or the default electricity supplier to purchase electricity form RES generators at fixed premium prices. It should be noted that a minimum price standard does not only regulate the price but also grid access and power purchase. Within bidding schemes RES capacity is publicly tendered periodically and power purchase contracts are awarded to the winning bids. With renewable portfolio standards, electricity suppliers are obliged to cover a certain share of their electricity supply with RES. The engaged parties comply with the obligation by presenting tradable 'green certificates' certifying the generation of a certain amount of electricity. Thus, these certificates have an economic value generating an extra income to RES-electricity producers.

Countries with minimum price standards (e.g. Germany since 1991, France since 2001, Spain since 2000, Denmark until 2000) have seen the largest growth of RES electricity. This particularly applies to wind power. At the same time, a viable RES manufacturing industry has been established in these countries. To organise political support and create local acceptance, it has been proven successful to spread ownership among many, preferably local people. Even though it is not appropriate to attribute the success in RES deployment solely to a single policy instrument, it becomes clear that a well-designed minimum price standard together with supplementing policies like simplified building permission procedures seems to be the most effective way to support the introduction of RES electricity. Nevertheless, a proper design of a specific support instrument is even more crucial than the type of instrument as indicated by experiences in different countries, in which RES electricity has grown only insignificantly due to insufficient levels of premium tariffs.

[2] In Spain, the investors can select between a feed-in-tariff and a bonus. With a bonus the producer has to sell the electricity by himself and receives a fixed amount for every kWh – the bonus - in addition. Thus, with a bonus the producer needs a distribution unit and the price he receives depends on the time of production.

England and Wales introduced a bidding scheme called Non-Fossil-Fuel obligation in 1990. In five rounds between 1990 and 1998, developers of RES plants could bid in different technology slots (e.g. wind power, waste to power, hydro power). The winners with the lowest offered generation costs were awarded with a 15 year power purchase agreement. The bid prices sank between 45% (hydro power) and 70% (wind power) between the first and the last round. Yet, due to different conditions in the bidding procedure and the awarded power purchase agreements as well, the bids are not directly comparable to each other. More over, up to October 2002 no large wind project of the last bid round in 1998 had been commissioned at the low average bid price of 4.5 cent/kWh. Presumably, these prices are economically not feasible.

Renewable portfolio standards have recently been discussed widely and have been introduced in Austria, Belgium, Italy, Sweden and the United Kingdom. While such mechanisms are promising, practical experience has been limited and rather mixed in Europe. Larger providers are more ready to take the risk of selling electricity and certificates under uncertain conditions than small generators. Instead of a wide range of different RES technologies only the most cost effective technology will be supported at a given time. Long-term contracts rather than spot markets will govern transactions between RES providers and the obliged parties, thus undermining competition. The different design of the national renewable portfolio standards hinder rather than enable the free trade of certificates between different countries.

Increasing prices for conventional fuels have been an effective method to deploy biomass and other RES in the heating sector in Northern Europe. The widespread district heating grids support the application of RES in these countries. Solar collectors have been successfully promoted in household applications by tax benefits and direct investment grants. Building regulations allowing only a certain maximum fossil based heat demand for new buildings are another effective way. Austria has been extremely successful in deploying solar collectors via grass-rooted do-it-yourself construction groups. In some countries, the RES use in the transportation sector is fostered by exempting car fuels based on biomass from tax. For instance this has led to a sudden growth of demand in Germany since 2001.

	AU	**BE**	**DK**	**FI**	**FR**	**GE**	**GR**	**IR**	**IT**	**LU**	**NL**	**PO**	**SP**	**SW**	**UK**
FIT	X		(X)		X	X	X			X		X	X		
BID								X							
SUB			(X)	X		(X)	(X)	(X)		(X)	X			(X)	
CTM	(X)	X	Xp						X		(X)			Xp	X

FIT = Feed-in tariffs; BID = Bidding System; SUB = Subsidies, Tax relief; CTM = Certificate trading model; X = Main instrument; (X) = Additional instrument or combination with main instrument; p = proposed.

Table 8-4: **Overview of promotional systems for RES in the countries of EU-15 by 2002**

An overview of promotional systems for RES in EU-15 is given in Table 8-4. It is apparent that most countries are using either the feed-in tariff model (respectively minimum price standards) or the certificate trading model (respectively the quota model). Bidding schemes, originally introduced in UK, are used in Ireland only. The feed-in model turned out to be the

most successful instrument in terms of installed RES-capacity, but an increasing number of countries are considering the certificate trading model as the future winner. Possibly a mixture of both will be used in the future because “green” certificates also can be combined with feed-in models.

8.2.2 Other Instruments for RES Deployment

With each of these types of instruments a certain expansion of RES-production can be reached. It is a question of the intensity. What kind of instruments are the most suiTable 8-depends among others on the stage of a technology, the actors involved, regulation of the electricity market, and the general economic policy issues. From the dependence on the stage of a technology and, additionally, the requirements of the grid it is necessary to incorporate technological differentiation in the bundle of instruments. Due to the sort of instrument and the transparency required for regulators and other actors it might be appropriate to bundle some technologies. For example, a Certificate trading model might not work if too many differentiations are introduced as too many separate markets are created which might be too small to work properly.

Many variants of the mentioned instruments are possible. For example: The difference between a bonus and a feed-in-tariff was already mentioned; a bidding system might also use the investment costs; a subsidy might be a special tariff reduction for RES-Technologies, e.g. everything which increases the relative costs of other energy technologies by discrimination of taxes or tariffs or handouts to the advantage of RES-Technologies without a justification in the general tax system[3]; a quota system might not use certificate trading and it is possible to introduce technology-specific quotas. The last two differences are especially important as a quota allows targeting certain technologies and as a quota system with certificate trade demands competition in the power production sector, which doesn’t exist in many MENA-countries. Thus, instruments have to be adapted. Additionally, under the category “subsidies” support from development banks should be subsumed, although the activities of these institutions may not be focused on RES technologies. These instruments may be important for certain countries or projects, but in a RES deployment strategy they are only additional instruments as they will only apply to certain countries or projects and they will cover only parts of the additional costs or reduce them. The last applies also for the CDM-mechanism under Kyoto Protocol (see chapter 4). The International financial institutions, which may grant support, are[4]:

- Export credit agencies,
- The European Investment Bank (EIB) and Facility for Euro-Mediterranean Investment and Partnership (and the European Commission),
- The World Bank Group,
- Regional institutions (Arab regional financial institutions, and African Development Bank).

[3] It should be noted that tax or especially tariff reductions or exemptions can hardly be managed to accommodate a certain deployment path. First, there is a boundary for the maximal relief given by the amount of the tax, which might fall short of the amount required in the first phase of market introduction. Second, the gain from a certain tax relief is hard to calculate and may depend on an intransparent amount of juristical attributes of companies involved. The same is not true for subsidies.

[4] For a general discussion of financing see [OME, 2003]. The following description of the international financial institutions is based on this source.

Export credit agencies combine a role of agent extending State guarantees and services on commercial risk and may also be lenders. Their impact is de facto equivalent to an export subvention for industrial countries. It will decrease the price of equipment – the most relevant area for RES-technologies[5] - from industrial countries and as every payment on investment will tend to increase artificially the capital intensity. The distortion however is thought not to be of importance as the amount is relatively small and the substitutability within a certain RES-technology and between different RES-technologies is likely to be limited at least if a demanding deployment path will be realized. As a second impact the development of a competing industry in the importing country is hampered. Again, this is judged to be in general not very grief as the industry most likely does not exists and, again, the amount is not very large for example compared to the impact of specially tariff reductions for (certain) energy technologies, which some MENA countries use. In general, the export credit agencies are helpful for the financial and risk side of a RES-business. However, due to their limited impact, they are not judged to play a pivotal role in the design of instruments for any RES-deployment strategy.

For countries of the Euro-Mediterranean Partnership the EIB provides support. The EIB aims among others at supporting projects with a regional dimension resulting from cooperation between the countries concerned and create basic infrastructure, especially in the environmental protection field. So, especially, if an international agreement is the base for a CSP-strategy in the region helpful assistance may be offered. The same is true for related grid-extension-projects, which under some circumstance might receive grants from the **MEDA-programme of the European Commission**. The EIB, for example, is involved in the power interconnection between Morocco and Algeria and participates in the financing of power lines in Egypt, Morocco, Syria, and Tunisia. Apart from assistance the main financial help may be long-term loans in which the EIB does not ask for political risk coverage. Under the **Facility for Euro-Mediterranean Investment and Partnership (FEMIP)** it plans to invest between 8-10 billion Euro (2003-2006) in the region.

The current involvement of the World Bank Group in the MENA-Region is not very important. Some activities of the World Bank Group might be of interest in this context, however. Apart from **zero-interest-credits from the International Development Association**, which might be available for certain countries, the political risk insurance to private investors by the **Multilateral Investment Guarantee Agency** might be useful. It applies to actions of firms which have an effective impact on collective welfare (employment, taxes, know-how transfer etc.). In a country where foreign private investments in the energy sector are welcomed the Agency might offer an attractive alternative to care for political risk thereby reducing the interest rate of a project. In addition, the **Global Environmental Facility (GEF)** of the World Bank, UNDP and UNEP, promotes the adoption of renewable energies by reducing implementation costs. This source might be especially interesting for certain projects or may finance parts of the overall project.

Some of the Arab regional financial institutions, like the **Inter-Arab Investment Guarantee Corporation**, facilitate project finance but generally they are quite small and may only act complementary to other support. Some of the funds or banks, which also cover the electricity sector, seem to focus on fossil fuel power plants. It should be investigated whether a focus on

[5] As in general capital costs have a higher share of total costs for RES-Technology compared to competing technologies every measure that reduces the capital costs works to the advantage of RES-Technologies.

RES-technologies might be introduced. This may be part of a regional agreement about a CSD-deployment strategy. As far as the **African Development Bank** is concerned it currently mainly supports public entities, is not deeply involved in RES-technologies and there might be only some single projects in a RES-deployment path which might receive grants.

The conclusion from this overview is:

- In the region an international RES deployment strategy is mandatory. It should be based on an agreement which offers the single countries incentives to act according to the treaty and reduces the perceived risk of fundamental policy changes for investors in the production of RES-technologies.
- Due to the different regulations of the electricity sector it is appropriate to use different instruments in different countries (e.g. a specific instrument should not be mandatory in the agreement).
- The instruments within a country should be defined specific to technologies or technology-bundles.
- The experience of EU-countries will be of importance only to those countries which have a competitive power generation market or are starting to create one.
- In addition to all instruments a concerted grid expansion and to some instruments a fair grid access is mandatory.
- The financial institutions' support will be complementary to other instruments and will be project-dependent and not cover the whole deployment strategy (the same is true for development assistance grants);
- As an international agreement is required to introduce RES-technologies there seems to be a case to found a special financial institution or to change the duty of an existing financial institution to handle financial flows between states or to offer special credits.

8.3. Characteristics of Market Instruments

So as general criteria for the discussion of the instruments efficiency, ease of implementation and of handling, compatibility with regulation and general economic policy will be used. Even efficiency has to be investigated before the background of a given regulation as it is unlikely that most of the implemented regulation will reach efficiency. The best instrument under this condition is usually not the instrument which might be considered efficient in a general discussion.

Now consider the essential instruments in Table 8-5. You find the instruments in the rows, and some characteristics in the columns. With “hierarchic” there's an addition. It stands for organisational forms where the state can decide directly on investment in the power sector and implement it by order. This means that no other incentives are necessary; of course the issue of financing the initial cost difference remains, which has to come from the state budget, i.e. from taxes or borrowing. The other instruments may be financed via the state, too. In Europe the financing especially of FITs and the quota systems is organised via a mark up on the electricity prices. This will not be a likely policy option in countries that subsidize electricity on a broad base (Saudi-Arabia, Kuwait, Bahrain, Qatar, UAE, Oman, Yemen). Principally, all those instruments may be implemented with state financing.

		Organisation of power generation	Appropriate for small/big IPPs or autoproducers (in case of monopoly irrelevant)	Handling	Error-proneness/ required precision and knowledge	Possible Static efficiency	Possible Dynamic efficiency
SUB	**Production**	Monopoly/IPPs/Competition	Not for very small	Difficult	High/high	High/Low*	Low/High*
	Investment	Monopoly/IPPs/Competition	Especially for very small	Easy	Low/low	Low	Low
FIT	**FIT properly**	IPPs/ Competition	For all (see 2 columns ahead, however)	Easy/difficult and complex (depending on implementa-tion)	Low/high	high/low*	Low/high*
	Bonus	Competition	Not for small		High/high	Very high/low*	Low/very high*
Quota	**CTM (tradeable)**	Competition	Not for small	Very difficult	Very high/very high	Very high/low*	Low/very high*
	Non-tradeable	Monopoly (IPPs, Competition)	For small	Easy/difficult	Very low/high	Generally very low	Generally very low
BID	**Electricity-price**	IPPs/ Competition	Not for small (see 2 columns ahead, however)	Difficult	high/high	Very high/low*	Low/very high*
	Investment	IPPs/ Competition	Not for small	Very easy	Low/high	Low	Low
Hierarchic (by order)		(State-) Monopoly	No IPPs	Very easy	Very low/high	Generally very low	Generally very low

Table 8-5a: Characteristics of instruments

		Stage of Development of Technology	Bearing of risk of electricity price variations during lifetime	Incentive to accommodate to load curve	Quantitative Target precision	Suitable for CSP in an early stage in MENA countries	Suitable for CSP in a later stage
SUB	**Production**	Early	RES-Power generator	Yes	Very high		
	Investment	Very early	RES-Power generator	Yes	Low	First steps	
FIT	**FIT properly**	Early	Customers	No	Low	Early	
	Bonus	Late	RES-Power generator	Yes	Very low		X
Quota	**CTM (tradable)**	Very late	RES-Power generator	Yes	High (if cost estimation is reliable)		X
	Non-tradable	Early	RES-Power generator	Yes		If required by regulation	
BID	**Electricity-price**	Early	Customers	No (price tender)	Price tender like FIT; Quantity tender like Quota	Early	
	Investment	(Very) early	RES-Power generator	Yes	Low	Very early	
Hierarchic (by order)		Every stage	State	Not automatically	Very high	If the only possibility according to regulation (state owned monopoly)	

Notes: * without/with differentiation between different technologies, respectively; under differentiation for each of some technologies different tariffs, quotas etc. are introduced; FIT = Feed-in tariffs; BID = Bidding System; SUB = Subsidies, Tax relief; CTM = Certificate trading model; IPP=Independent Power Producer.

Table 8-5b: Characteristics of instruments

Beginning with the **organisation of power generation** it becomes obvious that most of the instruments will not work in a monopoly. This calls for a competitive environment because it's not only the competition between profit-maximizing power producers (and potential new producers) which drive the instrument. In addition a workable power market for the electricity is necessary. As most of the MENA-countries have just recently started to liberalise the electricity market, there are few countries where Bonus, CTM, and BID (for electricity) could be recommended at present. Apart from the European countries Morocco, Tunisia, Jordan, and perhaps Turkey and Israel have or can be expected to have soon such a regulation. Additionally for these countries as well as for all other countries with the exception of Libya, Egypt, Lebanon, Syria, Saudi-Arabia, Kuwait, Bahrain, and Qatar subsidies (SUB), properly adjusted feed-in tariffs (Fit properly), and bidding (BID) may be a consideration. For the last countries only the categories "non-tradable Quota" and "Hierarchic" apply. However, it must be noted that the categorization of the Arabian states regarding their regulatory goals is very uncertain.

The **appropriate size of independent power projects** influences the efficiency of all instruments through the specific transaction costs. For a balanced mix of RES-technology additional instruments might be necessary, as the transaction costs might be too high for some options to allow an economic sound deployment. Large CSP projects have an advantage in this context.

Concerning the necessary organisations and their effectiveness the column **handling** gives an assessment of the ease in four discrete steps. "Very difficult" indicates that a sophisticated and very reliable bureaucracy is necessary, which might not exist in some countries. For most MENA-countries an instrument which is easy to handle may be of advantage. It should be mentioned that some of the instruments described as difficult did not work properly in some EU-countries. As can be seen the **error-proneness/required precision and knowledge** is typically highly correlated with the ease of **handling**, some instruments which are quite easy to handle might require a high precision and knowledge as current, economic decisions affect payments over a long time.

The advantage of the more complicated instruments can be seen in the row **possible static efficiency**. It indicates that given a fitting regulation the cheapest available RES-technology at each moment is selected by the instruments. With the appropriate overall economic policy this is static efficiency. Transaction costs are not considered here. "Possible" refers to the fact that it can be formed to reach a static efficiency but an indication "high" does not mean that independently from the details an instrument will reach a high static efficiency. It becomes apparent that those instruments which reach a high possible static efficiency are relatively hard to handle and require very high precision. So there seams to be a trade off between transaction costs (e.g. ease of handling, information costs) and the pure economic costs. This is indeed the case: those instruments that allow for competition to work out a balanced technology-mix have the possibility to reach a given target efficiently. But to make competition work so that the actors don't find weaknesses in the regulation and to plan the right dynamic behaviour might be very difficult and requires much knowledge and skills from the state.

On the other hand, it's easier to order and control that a certain sum should be invested in a RES-technology, but in this case it's very unlikely that the cheapest technology mix will be chosen and run efficiently. The state will not have the required information, and it's hard to

implement incentives – if not economic pressure – to run a power station efficiently. The second thought entering this column is that the aim is the production of electricity and not the capacity by itself. It can be presumed that an instrument which subsidizes investment is inferior to an instrument targeting production. That explains the differences between the two variants in the rows SUB and BID. Instruments that promise high static efficiency should target electricity production and preferably involve competition. The later, however, are only available in the few countries, where the regulation of the electricity market is compatible with these instruments as discussed above. In the other countries some of the instruments, although judged to have low efficiency, have to be used. Furthermore, the judgement on efficiency has to be refined by taking dynamic efficiency into consideration.

Unlike the static efficiency the **dynamic efficiency** takes into account inter-temporal aspects. Especially, the learning curve of new RES-technologies like CSP is considered, where a new investment reduces the prices of all future investments. The reduction of the future prices in connection to the future quantities has to be taken into account to decide economically on the efficient investment today. This means that a whole path of investment should be considered which leads to a defined aim in the future, e.g. a certain amount of electricity generation or CO2-Emissions say in 2050. If this is considered the static efficiency may be violated. If learning curves are considered, the higher current price of a technology may be offset by the reduction of future costs. In this case, currently high costs are equivalent to an investment. As the learning-curves differ for different technologies and some technologies may already be mature, different rules for different technologies should apply.

"Dynamic Efficiency" shows whether an instrument is appropriate to accommodate this difference of technologies. For 'Hierarchic', BID investment, and SUB investment the same reasoning as under 'Static efficiency' applies. For the other instruments a reversion of the efficiency compared to static efficiency occurs: if there's technical differentiation to accommodate different learning rates, static efficiency will be violated because the current least-cost-option is not chosen. Therefore a trade-off between static and dynamic efficiency exists. To solve this trade-off two restrictions have to be recognized: First, to realize dynamic efficiency financial constraints may be more severe, because during the first period additional investment in learning increases financing deficit. Second, the current investment prejudges the future development as the machines live quite long. This is accounted for in the scenarios. So to realise developments like in the scenarios it's important to select instruments and design them in a way that a higher dynamic efficiency is possible, i.e. differentiated by technology.

Not only is a differentiation between technologies necessary within an instrument. Additionally, the instrument has to be adapted to **state of the art, the stage of technology**. High initial learning rates and technological uncertainties require other instruments than in a later stage where an almost mature technology has to be primarily introduced organisationally to be integrated in the overall energy system. From the instruments some fit particularly well to a technology in an early stage, others are more suited for a technology which is almost matured. To the first class belong subvention, especially on investment, FIT properly, non-tradable quotas, and BIDs. As the technological risk is high it is important that other risks are relatively low. In addition, in an early development there are typically constraints on credit financing or very high interest rates. To tackle these constraints it is best to reduce investment costs (BID and SUB investment) and secondly to provide a calculable income stream from the electricity sold, e.g. by a long-term power purchase agreement. While the uncertainty of

production remains, the price risk is eliminated or reduced by e.g. a FIT properly and a Subvention (SUB) of production, respectively. For a later stage, where the organisational and system-level integration are the most important, the power producers should sell the electricity the usual way and receive additional payments proportional to the production. This is achieved by a bonus and a CTM. With a CTM an additional market has to be established.

The next two columns – **Bearing of risk...** and **Incentive to accommodate …** - refer explicitly to the two just mentioned issues of risk and system-level integration. With the usual financing – as mentioned above – the risk is taken over by the producer. This is desired in a later stage but might put financial constraints in an early stage of a technology, and work as a significant barrier to entry. As the production from a technology becomes important relatively to the overall production, it is necessary that an adjustment to (or of) the load curve takes place. FIT and BID take the risk from power producers in an early stage, but give no incentive to adjust in a later stage, except if tariffs are subsequently reduced.

As the last characteristic of instruments **Quantitative target precision** has to be discussed. The target is the amount of RES-electricity assumed. Thereby, it will be assumed that the state can enforce each measure freely, i.e. that the implementation and enforcement of an instrument will not create insurmounTable 8-resistance by political powerful groups. However, e.g. /Timpe et al. 2001/ argue that a target precise quota-system with an ambitious target will probably not be implemented if uncertainty about future RES-electricity costs prevails, because very high future costs will possibly be realised and that provokes strong resistance against such a system. For the instruments under consideration only those that target the quantity of production of electricity directly are precise, those that target investment or prices are less precise. Especially low is the target precision of "Bonus" as the payments are bound to production and don't depend on overall development of RES-deployment. Additionally, the development of electricity prices is important. Thus, it is very hard to plan a bonus which results in a certain production of RES-electricity.

The **conclusions for a CSP-deployment policy** can be found in the last two columns, which distinguish between the different stages of technological development. Apart from countries in which regulation allows only "hierarchic" or "non-tradable Quotas" as instrument, as a first step Subvention on Investment seems especially appropriate as they reduce the financing of the capital, while the disadvantages are not so important if relatively small capacities are built in the beginning of deployment. The same is true for BID on investment. However, it requires competition between potential power suppliers who might not exist at a very early stage. With a somewhat smoother learning-curve and larger volumes bids on electricity prices or a feed-in-tariff might work best. The frequency of bids has to be high enough to allow for a steady production of power plants. In the latest stage, when organisational and system-level integration are becoming important a transition to a "Bonus" and "CTM" (maybe with Bonus as intermediate step) might be a good solution. The instruments under "early" might be also appropriate at the very beginning. Whether the costs of a CTM and the obstacles from transmission to a CTM can be justified has to be thoroughly analysed. The potential of CTM for CSP seems to be high, however, because CSP are relatively big and an international CTM-system may result in efficiency gains. It has to be remembered however, that the MENA countries' regulations of the electricity market may not allow for a CTM. Indeed the set of appropriate instruments may be quite small if a specific country is considered.

8.4. Overview of Instruments by Country

The results of the discussion by MENA-countries are shown in Table 8-6. This table considers the current state of regulation, the planed regulation and the stage of the technological development of CSP ("later stage" refers to 5-10 years after initiating a deployment path as in the scenario). Some estimation and rough categorization which can't be accurate by nature is involved to provide a quick overview. If the regulation changes the discussion of instruments in the last section applies. Five country groups can be distinguished:

1. EU-Member countries (Portugal, Spain, Italy Greece, Malta, Cyprus),
2. Countries with some and probably increasing competition (Morocco, Algeria, Tunisia, Israel, Jordan, Turkey, Iraq, Iran, UAE, Oman),
3. Countries, currently without but probably in the future with competition (Egypt, Lebanon, Saudi-Arabia, Kuwait, Bahrain, Qatar),
4. Countries, currently and probably in the future without competition (Syria, Lybia),
5. Yemen.

Group 1: The EU-members have implemented measures for the RES-deployment (see discussion above). In the near future there will be an evaluation of these measures and a harmonisation is likely to follow. Also, liberalisation and deregulation of the power market is mandatory. Today, it seems that a CTM might occur. Alternatively, it is likely that at least for big RES-power plants a bonus system will be implemented (for the reasons see the discussion of instruments).

Group 2: These countries are in the process of liberalizing their power market. Therefore, market oriented instruments can be applied. Taking into account the stage of development of CSP-technologies, a pattern starting with subsidies and followed by a Bidding System or a proper Feed-in-Tariff seems appropriate. The Feed-in-Tariff may be carried on for longer, but at last a Bonus or CTM - maybe at international level – should be the instrument of choice. Not too many changes between instruments should be tried, however, as a smooth change – e.g. from Feed-in-tariff to CTM – may be rather difficult. The very high regulatory skills required for a CTM raise some doubts about its appropriateness. Additionally, Feed-in-tariffs which are financed through higher electricity prices are not likely to appeal to countries with highly subsidized electricity prices. In the long run subventions of electricity consumption are expected to vanish allowing Feed-in-tariff, a Bonus system or CTM to occur.

Group 3: If no competition on the electricity market exists market oriented instrument are not possible. Only non-tradable quota and hierarchic decisions remain. Besides a liberalisation as soon as possible other instruments should be used. They offer the potential of efficiency gains. Depending on the degree of liberalisation and deregulation Bidding systems, Feed-in-tariffs or a Bonus system may be used.

Group 4: If there's a monopoly and no IPP are allowed and this is not expected to change, only quotas or hierarchic decisions remain as feasible instruments.

Group 5: Due to the very low income and the relatively low electrification rate, Yemen has to be considered separately. From the standpoint of the regulatory regime Yemen belongs to the group in "Point 2". Therefore the same instruments are recommended. However, due to the low income external financing may be necessary. Additionally the low rate of grid connection

has to be accounted for, which would place the burden of financing only on a few grid connected costumers and may give incentive to delay grid connection. Altogether, this may make especially BID-Systems with external financing an attractive instrument.

	Early stage	**Later stage**
Portugal	FIT properly (existent)	CTM, Bonus (among other things depended on EU decisions)
Spain	FIT properly (or Bonus) (existent)	CTM, Bonus (among other things depending on EU decisions)
Italy	CTM (existent)	CTM, Bonus (among other things depending on EU decisions)
Greece	FIT properly (existent)	CTM, Bonus (among other things depending on EU decisions)
Morocco	BID, Sub, FIT properly	FIT properly, Bonus (CTM)
Algeria	BID, Sub, FIT properly	FIT properly, Bonus (CTM)
Tunisia	BID, Sub, FIT properly	FIT properly, Bonus (CTM)
Libya	Non-tradable quota, hierarchic	Non-tradable quota, hierarchic (introducing market competition is the current general economic policy, however)
Egypt*	Non-tradable quota, hierarchic	BID (electricity prices), FIT properly
Israel	BID, Sub, FIT properly	FIT properly, Bonus (CTM)
Jordan	BID, Sub, FIT properly	FIT properly, Bonus (CTM)
Lebanon	Non-tradable quota, hierarchic	BID (electricity prices), FIT properly
Syria	Non-tradable quota, hierarchic	Non-tradable quota, hierarchic
Turkey	BID, Sub, FIT properly	FIT properly, Bonus (CTM)
Iraq*	BID, Sub, FIT properly	FIT properly, Bonus (CTM)
Iran	BID, Sub, FIT properly	FIT properly, Bonus (CTM)
Saudi-Arabia*	Non-tradable quota, hierarchic	BID (electricity prices), FIT properly, Bonus
Kuwait*	Non-tradable quota, hierarchic	BID (electricity prices), FIT properly, Bonus
Bahrain*	Non-tradable quota, hierarchic	BID (electricity prices), FIT properly, Bonus
Qatar*	Non-tradable quota, hierarchic	BID (electricity prices), FIT properly, Bonus
UAE	BID, Sub	FIT properly, Bonus (CTM)
Oman	BID, Sub	FIT properly, Bonus (CTM)
Yemen	BID, Sub**	BID, FIT properly, Bonus**

Notes: FIT = Feed-in-tariffs; BID = Bidding System; SUB = Subsidies, Tax relief; CTM = Certificate trading model (further details s. Table 8-5).

* Considerable doubts about planned electricity-regulation.

** Substantial external financing may be necessary.

Table 8-6: Possible main-instrument for the deployment of CSD by country (taking into account (expected) technological development and (expected) regulatory framework)

8.5. Conclusions concerning Policy and Market Instruments

- In the MENA region an international RES deployment strategy is mandatory. It should be based on an international agreement which offers the single countries incentives to act according to the treaty and reduces the perceived risk of investors with respect to fundamental policy changes. In order to profit from the experience and technology of the European Union, a EU-MENA renewable energy partnership should be developed in the near term.
- Due to the different regulations of the electricity sector it is appropriate to use different instruments adapted to the different countries (e.g. a specific instrument should not be mandatory in the agreement; s. Table 8-6).
- The instruments within a country should be specifically related to technologies or technology-bundles.
- In addition to all instruments a concerted grid expansion and a fair grid access is mandatory.
- Support by financial institutions will be complementary to other instruments and will be project-dependent. It will not cover the whole deployment strategy (the same is true for development assistance grants);
- As an international agreement is required to introduce RES-technologies there seems to be a case to found a special financial institution or to change the duty of an existing financial institution to handle financial flows between states or to offer special credits.
- In project planning true opportunity costs for fossil fuels – typically derived from world market prices – have to be used, also in countries where fossil fuels are subsidized.

9. Bibliography

/ABB 2004/ HVDC References – ABB HVDC Classic and Light Projects, ABB Power Transmission 2004, http://www.abb.com/global/abbzh/abbzh251.nsf!OpenDatabase&db=/global/gad/gad02181.nsf&v=17EA&e=us&c=C1256D71001E0037C1256C330030750D

/Al-Zubari 2002/ Waleed k. Al-Zubari, Alternative Water Resource Management Policies in West Asia, Industry and Environmental Journal, Issue Theme: Regional Challenges for Sustainability, Volume 25, No. 1, pp. 43-47, UNEP 2002

/ANU 2003/ Dr. Prame Chopra, The Econimics (Hot Rock Energy power plant), Australian National University, Canberra, 30 July 2003, http://hotrock.anu.edu.au/economics.htm

/AQUASTAT 2004/ Aquastat, FAO's Information System on Water and Agriculture, online database: http://www.fao.org/ag/agl/aglw/aquastat/dbase/index.stm

/Barro and Sala-i-Martin 1995/ Barro, R. J. / X. Sala-i-Martin (1995): Economic Growth, McGraw-Hill, New York.

/Bassam 2004/ N. El Bassam and T. Otto, Farming Systems under and around Solar Thermal Power and Desalination (STPD) Plants " Eco-Solar Oasis", Krähenfeld 2004

/Bazilevich 1994/ Bazilevich, N., Global Primary Productivity Database. Unpublished., Clark University, Worcester, MA 1994, http://www.ngdc.noaa.gov/seg/cdroms/ged_iib/datasets/b02/baz.htm#top

/BEI 2003/ Pfaffenberger et al., Ermittlung der Arbeitsplätze und Beschäftigungswirkungen im Bereich Erneuerbarer Energien, Bremer Energie Institut, Bremen 2003

/BESTEC 2004/ G. Wittig, Bestec GmbH, Stand des europäischen Hot-Dry-Rock Forschungsprojektes in Soultz-sous-forets, EWIV Wärmebergbau, Strasbourg 2003

/Bennouna 2004/ A. Bennouna, Perspektiven der Netzgebundenen Umwandlung Regenerativer Energien in Marokko, Rabat 2004

/BGR 2003/ Reserven, Ressourcen und Verfügbarkeit von Energierohstoffen. Rohstoffwirtschaftliche Länderstudien, Heft XXVIII, Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Hannover

/BGR 1998/ Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Reserven, Ressourcen und Verfügbarkeit von Energierohstoffen 1998, Hannover/Berlin 1998, ISBN 3-510-95842-X

/BMU 2003-1/ J. Nitsch et. al., Ecologically Optimized Extension of Renewable energy Utilization in Germany, German Federal Ministry for the Environment, Stuttgart April 2004

/BMU 2003-2/ U. Bruchmann, Umweltpolitik - Geothermie - Energie der Zukunft, Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, Berlin Sept. 2004

/BMU 2004-1/ J. Nitsch, S. Gärtner, K. Barthel et.al., Umweltpolitik - ökologisch optimierter Ausbau der Nutzung erneuerbarer Energien in Deutschland, Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, Berlin April 2004

/BMU 2004-2/ F. Trieb et. al., Concentrating Solar Power, German Federal Ministry for the Environment, Stuttgart 2003

/BMU 2004-3/ W. Dürrschmidt, G. Zimmermann, Eds., Renewable Energies - Innovation for the future, German Federal Ministry for the Environment, Berlin 2004, http://www.bmu.de

/BMWT2002/ B. Hirschl, M. Hoppe-Kilpper, Markt- und Kostenentwicklung erneuerbarer Energien, Bundesministerium für Wirtschaft und Technologie, Berlin, Kassel, April 2002

/Brower 1992/ Michael Brower, Cool Energy: Renewable Solutions to Environmental Problems, UNION OF CONCERNED SCIENTISTS, MIT Press, 1992, http://www.portaec.net/library/energy/environmental_impacts_of_renewab.html

/Brundtland 1987/ Brundtland, G.H., Our Common Future, World Commission on Environment and Development, Report 1987

/Capros, P. et al. 2000/ Scenarios related to the Security of Supply of the European Union, National Technical University of Athens, Greece, Report for EU15

/Coenen, R.; Grunwald, A. (ed.) 2003/ Nachhaltigkeitsprobleme in Deutschland, Analyse und Lösungstrategien, edition sigma, Berlin, 2003

/CIA 2004/ CIA World Factbook: http://www.cia.gov/cia/publications/factbook/print/tc.html

/DLR 2004/ W. Krewitt, Brennstoffzellen in der Kraft - Wärme – Kopplung, Deutches Zenterum für Luft- und Raumfahrt, Berlin 2004

/DLR, ifeu, Wuppertal Institut 2004/ Nitsch, J. et al. (2004): Ökologisch optimierter Ausbau der Nutzung erneuerbarer Energien in Deutschland, Forschungsvorhaben im Auftrag des Bundesministeriums für Umwelt, Naturschutz und Reaktorsicherheit.

/EcoInvent 2000/ EcoInvent Database for Life-Cycle Analysis of Emissions and Materials, Vers. 2000

/ECMWF 2002/ ECMWF Re-analysis generated for 15 years (ERA-15) from December 1987 to February 1994, European Centre for Medium-Range Weather Forecasts, London 2002, http://wms.ecmwf.int/research/era/Era-15.html

/ECOSTAR 2004/ R. Pitz-Paal, Project Presentation: Integrating and strengthening the ERA, European Concentrated Solar Thermal Road-Mapping, Cologne 2004

/EEAC 2004/ Towards European targets for Greenhouse Gas Reduction 2050 and 2020, Network of European Environment and Sutainable Development Advisory Council, Postbus 2004, www.EEAC-network.org

/EIA 2003/ Electricity Prices for Industry, National Energy Information Center, Aug. 2003, http://www.eia.doe.gov/emeu/international/elecprii.html

/EIA 2004/ Country Analysis briefs, all countries except Cyprus and Malta, http:www.eia.doe.gov/emeu/cabs

/El-Nashar 2000/ Ali M. El-Nashar, Cogeneration for power and desalination - state of the art review, Abu Dhabi Water and Electricity Authority, Abu Dhabi Sept. 2000, www.elsevier.com/locate/desal

/ENERDATA 2004/ GasElecStat 2004 databases, ENERDATA S.A.

/EREF 2004/ EU Investigation Requested into illegal aid to Finnish nuclear plant, European Renewable Energies Federation, Brussels 2004, http://www.eref-europe.org/docs/pressreleases.htm

/EU 2000/ E. Nogaret, Integration of Renewable Energies in the Southern Mediteranean Countries, The European Commission, 2000

/EU 2003/ L. Mantzos et. al., European Energy and Transport trends ton 2030, The European Commission, Brussels 2003

/EU 2004/ The share of renewable energy in the EU, Commission of the European Communities, Brüssel Mai 2004

/EURELECTRIC 2003/ Systmed Report, Manzoni et. al., Mediterranean Interconnection: State of the Art 2003, Union of the Electricity Industry: State of the Art, December 2003

/ExternE 1999/ Externalities of Energy, Vol. 7: Methodology 1998 update. EU-DG XII: Science, Research and development, EUR 19083, Brussels, Belgium

/EWEA 2002/ P. Gardner, et. al., Wind Energy - The Facts, European Wind Energy Association, Berlin 2002, http://www.ewea.org/06projects_events/proj_WEfacts.htm

/EXTOOL 2003/ Lena Neijj et al., Experience Cirves: A Tool for Energy Policy Assessment, Lund University, European Commission, Lund 2003

/FAO 1997/ K. Frenken, Irrigation in the Near East Region in Figures, Food and Agriculture Organization of the United Nations, Rome 1997

/FAO 2002/ Crops and Drops - making the best use of water for agriculture, Food and Agriculture Organization of the United Nations, Rome 2002, http://www.fao.org/landandwater

/FAO 2003/ Review of World Water Resources by Country, Food and Agriculture Organization of the United Nations, Rome 2003

/FAO 2004/ FAO Database Collections FAOSTAT 2004, last updated February 2004

http://faostat.fao.org/faostat/collections?version=ext&hasbulk=0

/GEA 2004/ Gawell, K., Reed, M., Wright, M., Geothermal Energy: The Potential for Clean Power from the Earth, Geothermal Energy Association, Washington 2004, http://www.geo-energy.org/PotentialReport.htm

/Georgy 2004/ L. Georgy Yussef, North African, European, Middle East Electricity Cooperation & African Interconnection, Cairo 2004

/GGA 2000/ S. Hurter et. al., Atlas of Geothermal Resources in Europe: Planning Exploration and Investments, Geowissenschaftliche Gemeinschaftsaufgaben, Hannover 2000

/Gleick 1998/ Peter H. Gleick, Water Futures: A Review of Global Water Resources Projections, World Water Vision of the 21st Century,(www.watervision.org)

/GTZ 2002/ Stromproduktion aus erneuerbaren Energien: Energiewirtschaftliche Rahmenbedingungen in 15 Entwicklungs- und Schwellenländern, Deutsche Gesellschaft für Technische Zusammenarbeit, Eschborn 2002

/GTZ 2004/ Energiepolitische Rahmenbedingungen für Strommärkte und erneuerbare Energien - 21 Länderanalysen, Deutsche Gesellschaft für Technische Zusammenarbeit, Eschborn 2004

/HGF 2001/ J. Nitsch, et. al., Schlüsseltechnologie Regenerative Energien, Deutches Zenterum für Luft- und Raumfahrt, Stuttgart, Karlsruhe, Nov. 2001

/Horlacher 2003/ Prof. Dr.-Ing. habil. H. Horlacher, Globale Potenziale der Wasserkraft, Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen, Berlin, Heidelberg 2003

/IEA 2001/: Competition in electricity markets, Paris.

/IEA 2002/ IEA (2002): World Energy Outlook 2002, Paris.

/IEA 2003/ Renewables – Information 2003, International Energy Agency

/IEA 2003-1/ K. Kurokowa, Energy from the Desert - Feasibility of Very Large Scale Photovoltaik Power Generation (VLS-PV) Systems, Photovoltaik Power Systems Executive Committee of the International Energy Agency, London 2003

/IEA 2003-2/ Electricity Information 2003, International Energy Agency

/IEA 2003-3/ Energy Statistics of OECD Countries 1960 – 2001, International Energy Agency

2003 Edition

/IEA 2003-4/ Energy Statistics of Non- OECD Countries 1971 – 2001, International Energy Agency

2003 Edition

/IEA/NEA 1998/ E. Bertel et. al., Projected Costs of Generating Electricity Update 1998, International Energy Agency/Nuclear Energy Agency, Paris 1998

/IGA 2004/ Mary H. Dickson, Mario Fanelli, What is geothermal energy?, International Geothermal Association, Pisa 2004

/IÖW/ISET 2002/ B. Hirschl et. al., Markt- und Kostenentwicklung erneuerbarer Energien, Institut für ökologische Wirtschaftsforschung gGmbH/Institut für Solare Energieversorgungstechnik, Berlin, Kassel, April 2002

/IPCC (ed.) 2001/ Climate Change 2001: The Scientific Basis. IPCC Third Assessment Report. Summary for Policy Makers, Cambridge, New York, Cambridge University Press

/IPCC 2002/ Climate Change 2001; Report 2; T. Morita, J. Robinson (Lead authors): Greenhouse gas emissions mitigation scenarios and implications. Intergovernmental Panel of Climate Change 2002 (also: Special Report on Emission Scenarios. Working Group III: Mitigation of Climate Change, April 1999)

/IRESMED 2000/, E. Nogaret, Integration of renewable energies in the Southern Mediterranean Countries, OME 2000

/Kopfmüller, J.; Brandl, V.; Jörissen, J. et al. 2001/ Nachhaltige Entwicklung integrativ betrachtet. Konstitutive Elemente, Regeln, Indikatoren, edition sigma, Berlin

/Kopfmüller 2004/ Kopfmüller, J., An integrative sustainable development approach and its application

for Germany, International Sustainable Development Research Conference. Manchester, 2004

/LBST 2000/ J. Schindler, W. Zittel, Fossile Energiereserven (nur Erdöl und Erdgas) und mögliche Versorgungsengpässe aus Europäischer Perspektive, ludwig bölkow systemtechnik, Ottobrunn Juli 2000

/Lefevere 2004/ J. Lefevere, Regulatory Development & Linkages, The European Union, Climate, Ozone and Energy Unit, DG Environment, European Commission 2004, www.ieta.org/ieta/www/pages/getfile.php?docID=566

/Lehner et al. 2005/ Lehner, B., Czisch, G., Vassolo, S, The impact of global change on the hydropower potential of Europe: a model-based analysis. Energy Policy, Vol. 33/7: 839-855 based on Alcamo et al. (2003), Döll et al. (2003), Umweltsystemforschungszentrum an der Gesamthochschule Kassel, Kassel 2005

/Mandil et. al. 2000/ M. A. Mandil, A.A. Bushnak, Future needs for desalination in South Mediterranean countries, Water and Environmental Services Co. Ltd., Alexandria May 2002

/Meteonorm 2004/ Global Meteorological database for Applied Climatology Meteornorm Version 5.0, Meteotest, Bern 2004, http://www.meteotest.com

/MLMWE 2004/ Ministry of Land-Use Management, Water and the Environment, Project Identification Note: (www.mdpmaroc.com), 2004

/Hinterberger 2003/ Projects: Ways towards Sustainability in the EU beyond the Spring European Summit 2003, Authors: Friedrich Hinterberger and Renata Zacherl, http://www.seri.at/spring2003/

/MLMWE 2002a/ Portfolio of projects for Reducing Greenhouse Gas Emission in Algeria Report 2002, MLMWE, Algeria 2002

/MLMWE 2002b/ Portfolio of projects for Reducing Greenhouse Gas Emission in Morocco Report 2002, MLMWE, Morocco 2002

/MLMWE 2002c/ Portfolio of projects for Reducing Greenhouse Gas Emission in Tunisia Report 2002, MLMWE, Tunisia 2001

/ONE 2003/ National Office of Electricity Morocco 2003/ Project document Design developed by Ecosecurities, ONE Morocco 2003

/Nokrashy 2004/ H. El Nokrashy, Renewable Energy Mix for Egypt, Nokraschy Engineering GmbH, Hamburg, http://www.nokraschy.net/RenwableEnergyMixforEgypt.pdf

/NREL 2003/ H. Price, Assessment of Parabolic Trough and Power Tower Solar Technology Cost and Performance Forecasts, National Renewable Energy Laboratory, Chicago Oct. 2003

/NREL 2004/ Pamela L. Spath, Margaret K. Mann, Biomass Power and Conventional Fossil Systems with and without CO2 Sequestration - Comparing the Energy Balance, Greenhouse Gas Emissions and Economics, National Renewable Energy Laboratory, NREL/TP-510-32575, January 2004, http://www.osti.gov/bridge

/OME 2001/ Les perspectives énergétiques & électriques des pays Méditerranéens Horizon 2010, Organization Mediterranee de l'Energie, Novembre 2001

/OME 2002/ Large Scale Integration of Solar and Wind Power in Mediterranean Countries, MED2010, Observatoire Méditerranéen de lÉnergie, , Paris 2002, http://www.ome.org

/OME 2003/ Possible Innovative Schemes to Facilitate Energy Investment in Southern and Eastern Mediterranean Countries, Observatoire Méditerranéen de lÉnergie, Rome Dec. 2003, http://www.ome.org

/Platts 2004/ UDI World Electric power Plants Data Base, Platts, a divison of The McGraw-Hill Companies, Inc., Washington 2004

/PRB 2002/ F. Roudi-Fahimi et. al., Finding the Balance: Population and Water Scarity in the Middle East and North Africa, Population Reference Bureau, Washington July 2002

/PWT 2002/ Heston, A.; R. Summers, B. Aten (October 2002). Penn World Tables Version 6.1, Center of International Comparisons at the University of Pennsylvania (CICUP).

/Quaschning 2000/, Systemtechnik einer klimaverträglichen Elektrizitätsversorgung in Deutschland für das 21. Jahrhundert, Verband Deutscher Ingenieure, Düsseldorf 2000

/REA/WED 1996/ N. G. Mortensen et. al., Wind Atlas for the Gulf of Suez 1991-95, New and Renewable Energy Authority, Meteorology and Wind Energy Department, Cairo/Roskilde 1996

/REA/WED 2003/ N. G. Mortensen et. al., Wind Atlas for the Gulf of Suez, New and Renewable Energy Authority,Wind Energy Department, Cairo/Roskilde 2003

/Michaelowa et. al. 2004/, A,. Michaelowa, Clean Development Mechanism and Joint Implemenation - New instruments for Financing renewable Energy Technologies, International Conference for Renewable Energies, Bonn 2004

/RIVM 2001/ A. de Moor, Towards a Grand Deal on subsides and climate change, RIVM Netherlands Institut of Public Health and the Environment, May 2001

/Sachs and Larrain 1993/ Sachs, J. /P. Larrain (1993): Macroeconomics in the Global Economy, Harvester Wheatsheaf, New York et al.

/Saghir 2003/ Jamal Saghir, URBAN WATER AND SANITATION IN THE MIDDLE EAST AND NORTH AFRICA: THE WAY FORWARD, Building Knowledge and Expertise in Infrastructure Finance, 24 January- 4 February 2000, World Bank, Amman, Jordan

/SANDIA 2003/ James E. Miller, Review of water Resources and Desalination Technologies, Sandia National Laboratories, Albuquerque 2003

/SECO 2003/ State Energy Conversion Office, Fact Sheet No. 8, Albuquerque 2003

/Shell 2001/ Energy Needs, Choices and Possibillities – Scenarios to 2050. Global Business Environment Shell International 2001

/SOLEMI 2004/ Solar Energy Mining, http://www.solemi.de

/SOLGAS 1995/ M. Blanco, SOLGAS Project: Hybrid Combined Cycle Cogeneration Plant based on Central Receiver Technology, European Commission, 1995

/SOLITEM 2004/ SOLITEM Solar Energy Technologies Ltd., http://www.solitem.com.tr/tur_inx_2.htm

/Statistisches Bundesamt 2003/ Statistisches Jahrbuch für das Ausland 2003, Wiesbaden

/UN 2003/ Human Development Report 2003, UNDP, New York 2001.

/Sutter 2003/ C. Sutter, Sustainability Check for CDM Projects, Swiss Federal Institute of Technology (ETH), Zürich 2003

/TAB 2003/ Herbert Paschen, Dagmar Oertel, Reinhard Grünwald, Möglichkeiten geothermischer Stromerzeugung in Deutschland, Büro für Technikfolgenabschätzung des Deutschen Bundestages, Berlin 2003

/Timpe et al. 2001/ Timpe, C., H. Bergmann, M. Cames, U. Klann, O. Langniß. J. Nitsch, J.-P. Voß, Umsetzungsaspekte eines Quotenmodells für Strom aus erneuerbaren Energien, Abschlußbericht im Auftrag des Ministeriums für Umwelt und Verkehr Baden-Württemberg, Stuttgart 2001.

/TREC 2004/ G. Knies, Solar energy&Water for Sustainable Prosperity in MENA, Trans-Mediteranean Renewable energy Collaboration TREC, Tripoli 2004

/USGS 2002/ Global Land Cover Characteristics Database, Version 2.0, USGS EROS Data Center Reston, VA 2002, http://edcdaac.usgs.gov/glcc/tabgeo_globe.asp

/Wangnick 2004/ Wangnick Consulting, World Inventory of Desalination Plants 2004

/WBGU 2003a/, H. Graßl et. al., Über Kioto hinaus denken - Klimaschutzstrategien für das 21. Jahrhundert, Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen, Berlin 2003

/WBGU 2003/ H. Graßl et. al., Welt im Wandel - Energiewende zur Nachaltigkeit, Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen, Berlin März 2003

/WEC 1998/ Energie für Deutschland - Fakten, Perspektiven und Positionen im globalen Kontext, Dt. Nat. Komitee DNK des Weltenergierates, Düsseldorf

/WETO 2003/ EC DG Research, World Energy, Technology and Climate Policy Outlook, European Comission, Luxembourg 2003

/White Paper 1997/ Energy for the Future: Renewable Sources of Energy, EU-Commission COM (97) 599 final

/World Bank 2004/ Schenkeveld et al., Seawater and Brackish Water Desalination in the Middle East, North Africa and Central Asia – A Review of Key Issues and Experience in Six Countries, World Bank, December 2004 , http://www.worldbank.org/watsan/bnwp

/WWA 2004/ World Wind Atlas 2004, Meteotest, Bern 2004, http://www.meteotest.com

10. Annex: Individual Country Data

Annex 1: Concentrating Solar Thermal Power Potentials

The following section shows the CSP potentials for most countries analysed in the MED-CSP study. The map shows Direct Normal Irradiance in kWh/m²/y on all areas that are not excluded from the land resource assessment.

One histogram shows how much electricity (TWh/y) can be generated in each class of Direct Normal Irradiance (kWh/m²/y). This defines the Technical Potential and the CSP performance indicator of each country.

The second histogram shows the same but only for coastal areas not higher than 20 meters above sea level (a. s. l.). This defines the technical potential for CSP plants with combined seawater desalination near the coast.

There is also a list of indicators that compares the existing CSP potentials with the demand figures of each country for the scenario described in WP 5. They are displayed for each country on the following pages with the following colour key:

Technical Potential:	**defined by all non-excluded areas with a Direct Normal Irradiance higher than 1800 kWh/m²/y**
Economic Potential:	**defined by all non-excluded areas with a Direct Normal Irradiance higher than 2000 kWh/m²/y**
Power Demand 2000:	**according to the scenario described in WP 5**
Power Demand 2050:	**according to the scenario described in WP 5**
Tentative CSP 2050:	**according to the scenario described in WP 5**
Coastal Potential:	**economic potential defined by all non-excluded areas with a DNI higher than 2000 kWh/m²/y and 20 m a. s. l.**
Water Demand 2050:	**power demand for desalination in TWh/y according to the scenario described in WP 5**

All analysed countries except Turkey, Italy, Greece, Malta and Lebanon have CSP potentials that are by several orders of magnitude higher than the present and expected demand.

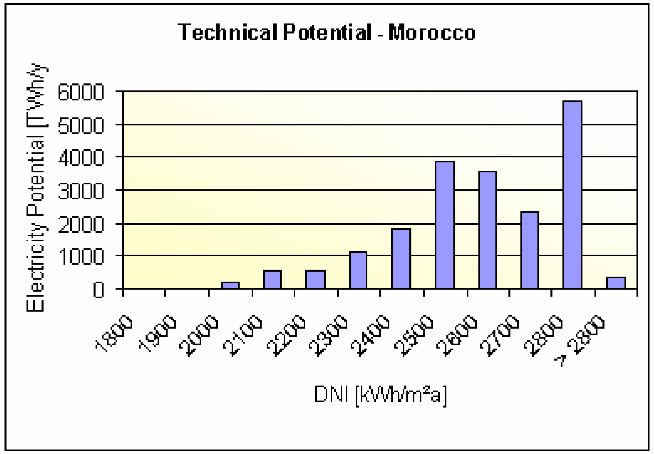
The coastal potentials for CSP plants in Syria, Jordan and Israel seem to be smaller than the expected demand for sea water desalination in those countries. However, the exclusion criteria used for our regional analysis were very rigorous (e.g. altitude < 20 m. a. s. l., full priority for agricultural land etc.). Therefore it is possible, that a more in-depth country analysis allowing e.g. for multi-purpose plants that use agricultural areas and higher altitudes would yield sufficient potentials for that purpose, too.

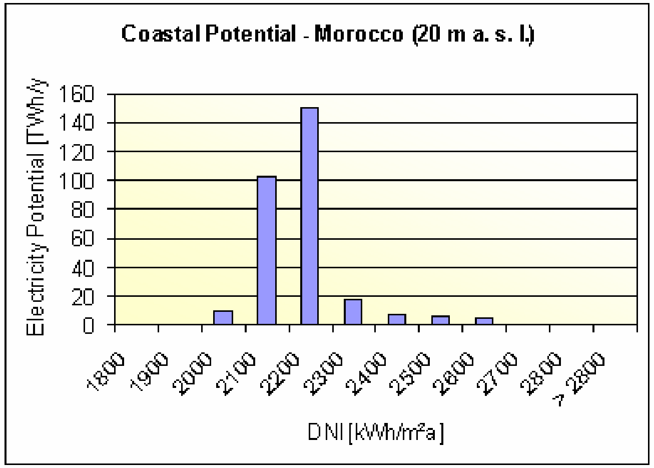
The geographic locations of the potential areas for CSP implementation are displayed in the following pages for each individual country of the analysed EU-MENA region.

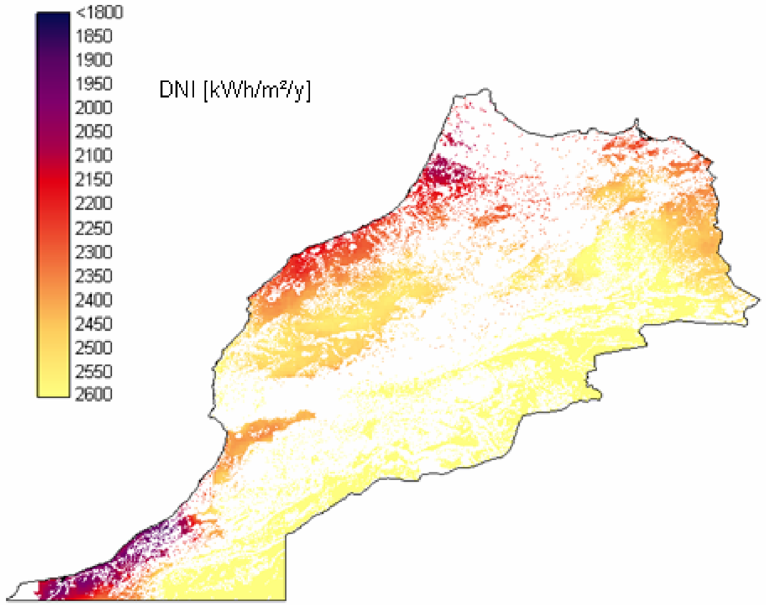
MED-CSP

Solar Thermal Electricity Generating Potentials in Morocco

DLR





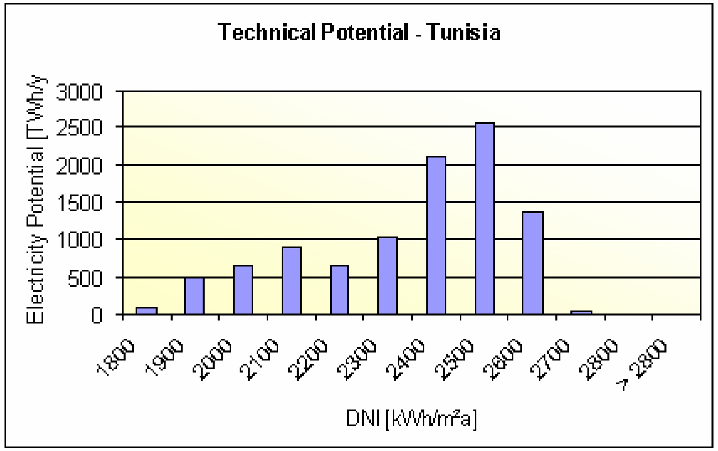


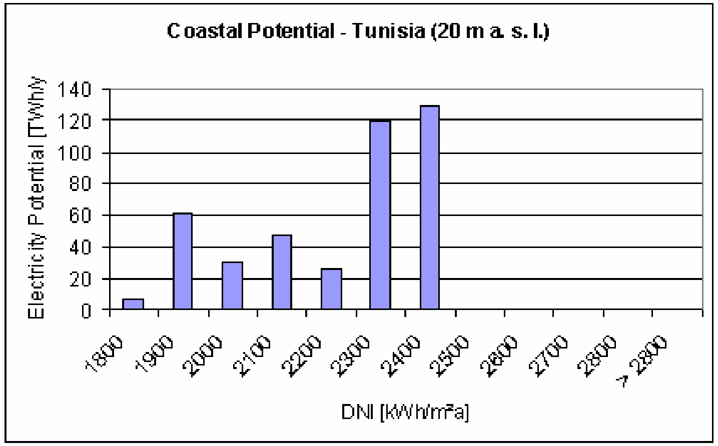
Technical Potential:	20151 TWh/y (DNI > 1800 kWh/m²/y)
Economic Potential:	20146 TWh/y (DNI > 2000 kWh/m²/y)
Power Demand 2000:	15 TWh/y
Power Demand 2050:	235 TWh/y (Scenario CG/HE)
Tentative CSP 2050:	150 TWh/y (Scenario CG/HE)
Coastal Potential:	300 TWh/y (< 20 m a. s. l.)
Water Demand 2050:	1.2 TWh/y (Power for Desalination)

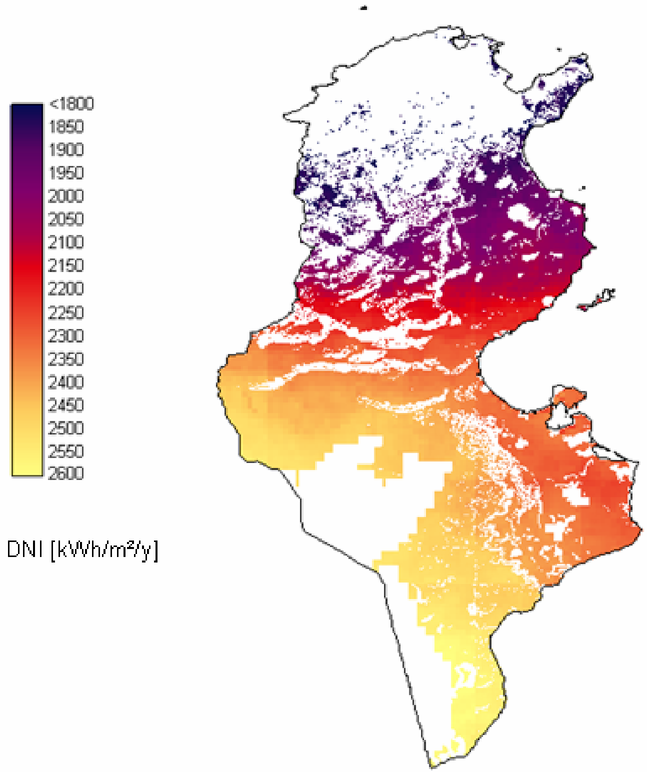
MED-CSP

Solar Thermal Electricity Generating Potentials in Tunisia

DLR



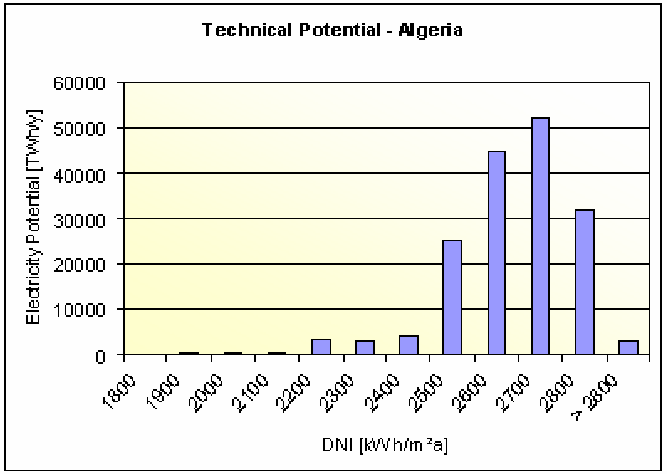


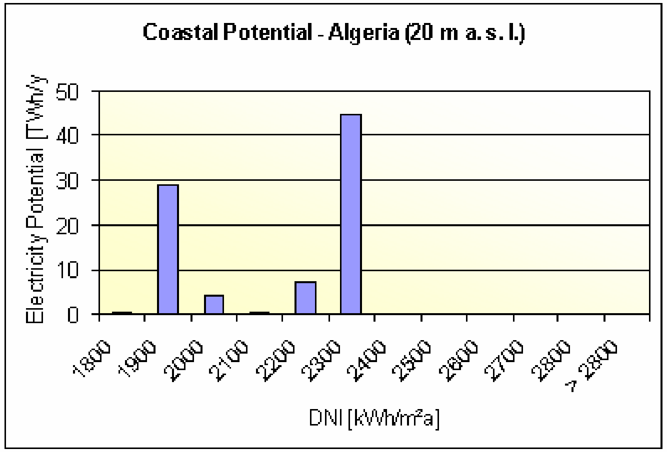


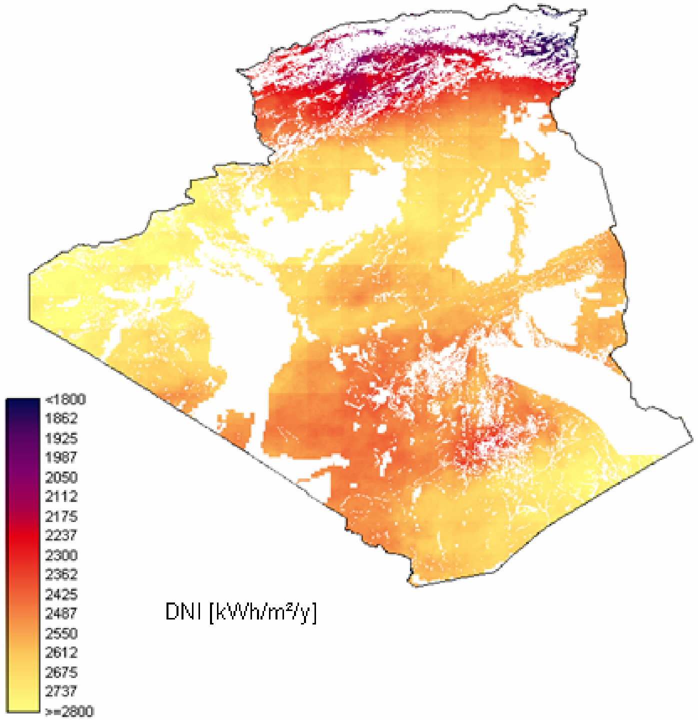
Technical Potential:	9815 TWh/y (DNI > 1800 kWh/m²/y)
Economic Potential:	9244 TWh/y (DNI > 2000 kWh/m²/y)
Power Demand 2000:	10 TWh/y
Power Demand 2050:	66 TWh/y (Scenario CG/HE)
Tentative CSP 2050:	43 TWh/y (Scenario CG/HE)
Coastal Potential:	352 TWh/y (< 20 m a. s. l.)
Water Demand 2050:	1 TWh/y (Power for Desalination)

MED-CSP

Solar Thermal Electricity Generating Potentials in Algeria

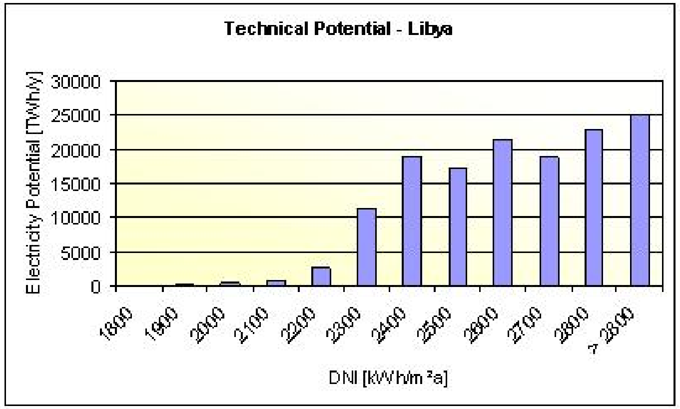


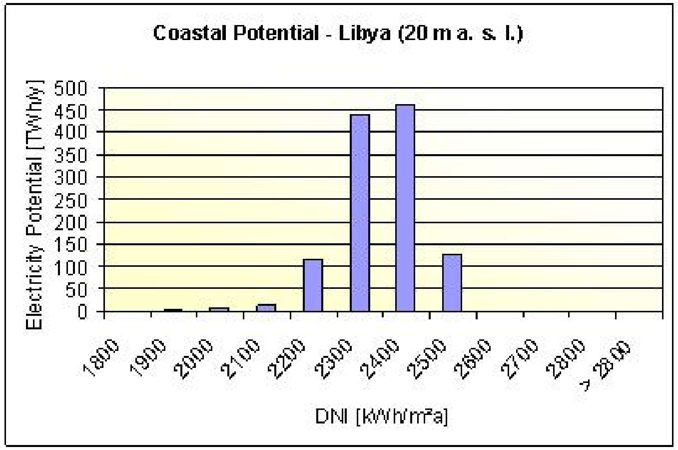


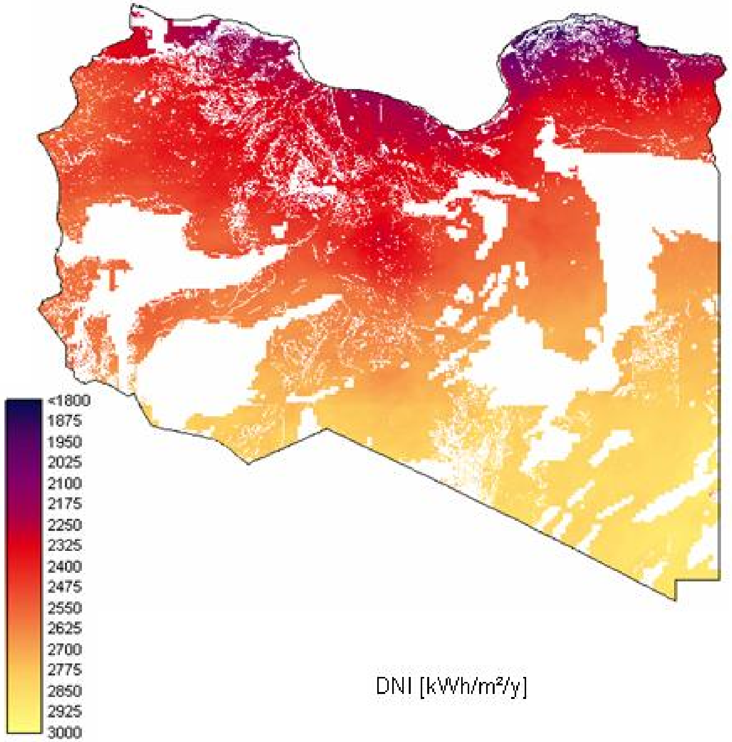


Technical Potential: 169440 TWh/y (DNI > 1800 kWh/m²/y)
Economic Potential: 168971 TWh/y (DNI > 2000 kWh/m²/y)
Power Demand 2000: 23 TWh/y
Power Demand 2050: 249 TWh/y (Scenario CG/HE)
Tentative CSP 2050: 165 TWh/y (Scenario CG/HE)
Coastal Potential: 57 TWh/y (< 20 m a. s. l.)
Water Demand 2050: 2.8 TWh/y (Power for Desalination)

Solar Thermal Electricity Generating Potentials in Libya

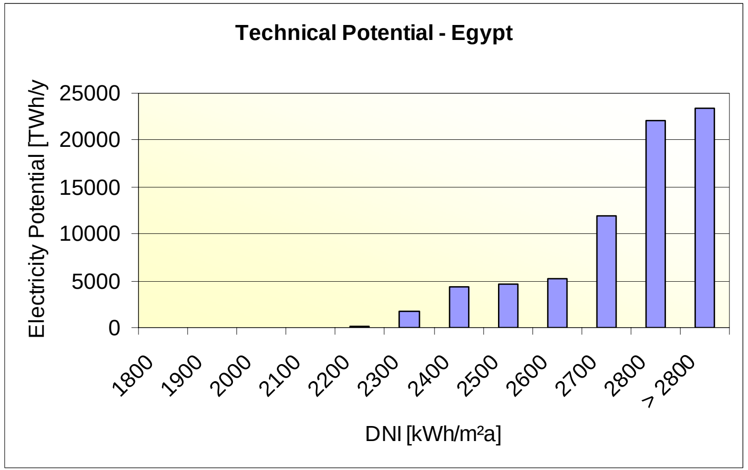


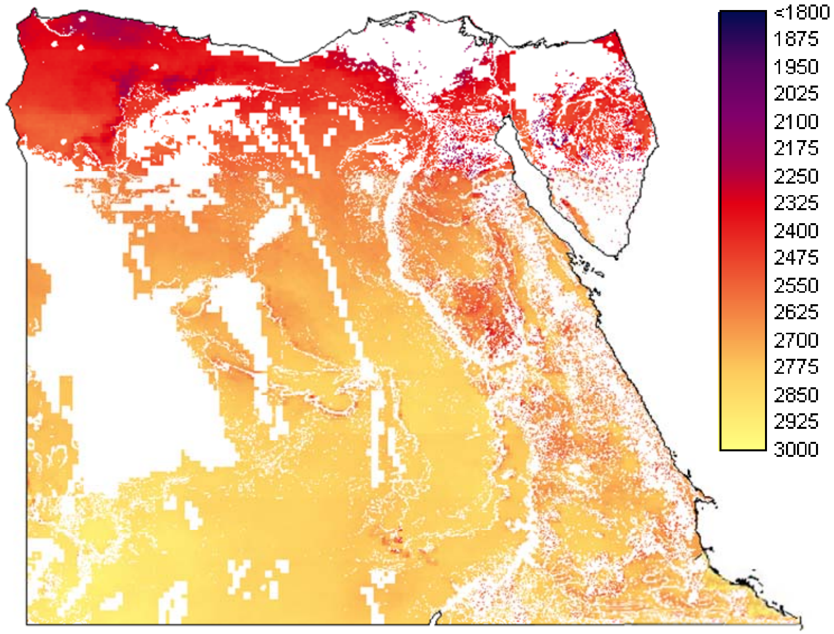


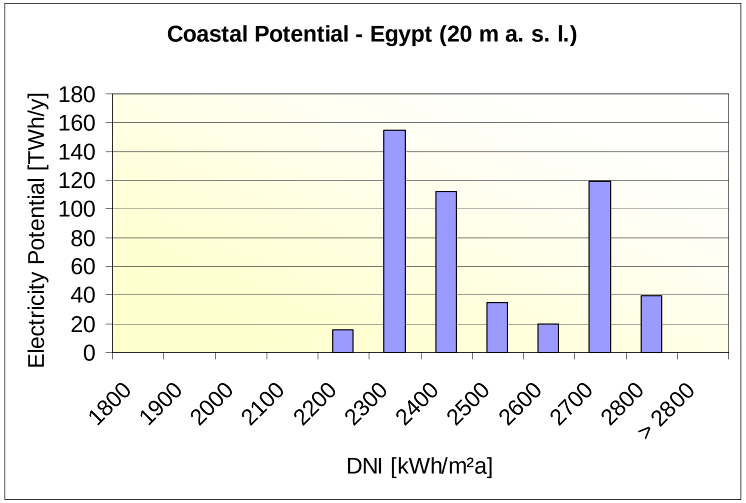


Technical Potential: 139600 TWh/y (DNI > 1800 kWh/m²/y)
Economic Potential: 139470 TWh/y (DNI > 2000 kWh/m²/y)
Power Demand 2000: 19 TWh/y
Power Demand 2050: 44 TWh/y (Scenario CG/HE)
Tentative CSP 2050: 22 TWh/y (Scenario CG/HE)
Coastal Potential: 498 TWh/y (< 20 m a. s. l.)
Water Demand 2050: 25 TWh/y (Power for Desalination)

Solar Thermal Electricity Generating Potentials in Egypt





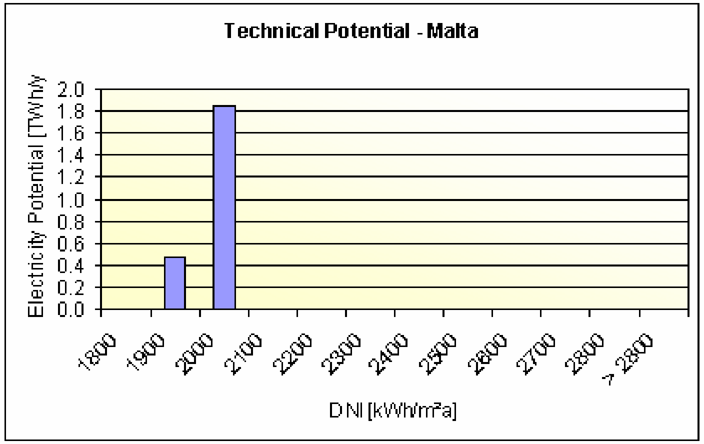


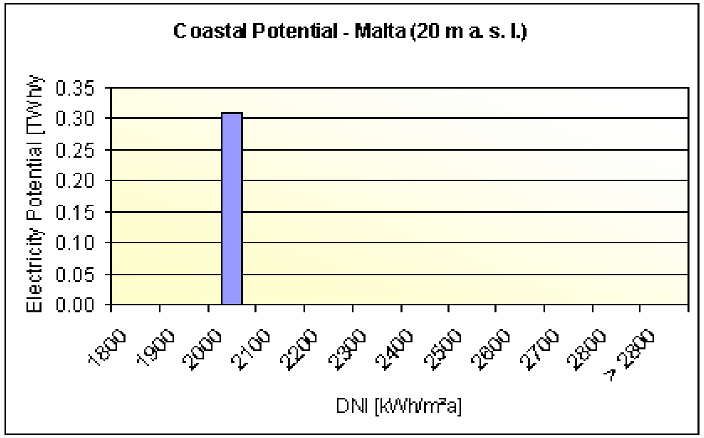
Technical Potential:	**73656 TWh/y (DNI > 1800 kWh/m²/y)**
Economic Potential:	**73655 TWh/y (DNI > 2000 kWh/m²/y)**
Power Demand 2000:	**71 TWh/y**
Power Demand 2050:	**631 TWh/y (Scenario CG/HE)**
Tentative CSP 2050:	**395 TWh/y (Scenario CG/HE)**
Coastal Potential:	**496 TWh/y (< 20 m a. s. l.)**
Water Demand 2050:	**256 TWh/y (Power for Desalination)**

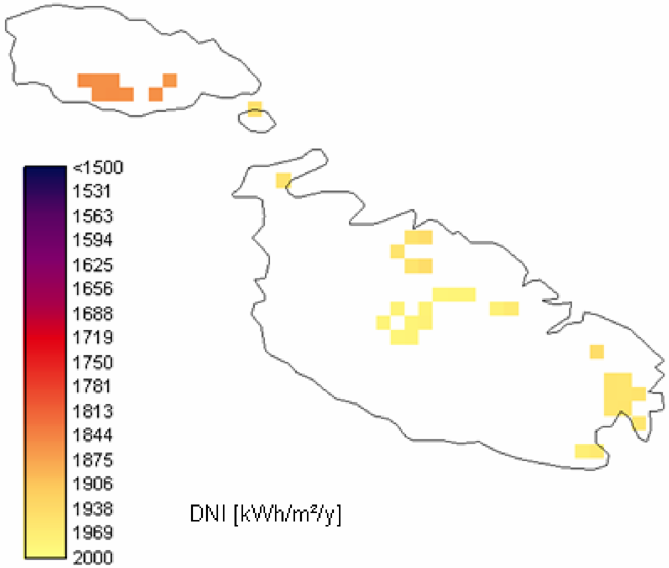
MED-CSP

DLR

Solar Thermal Electricity Generating Potentials in Malta

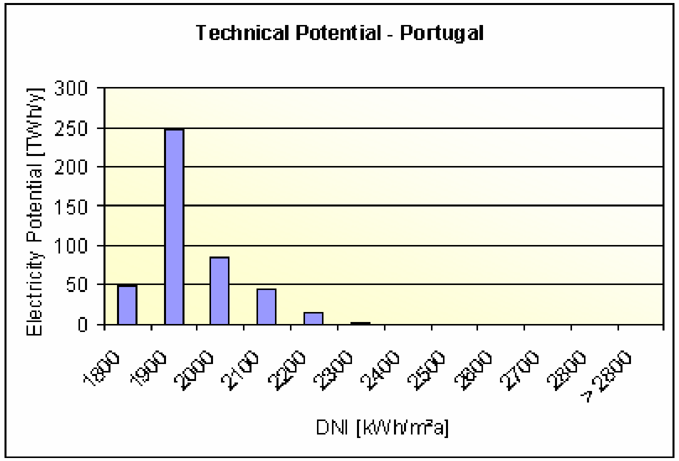


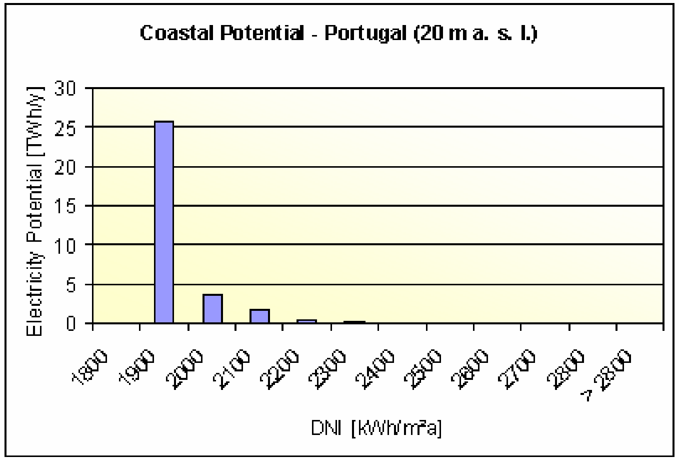


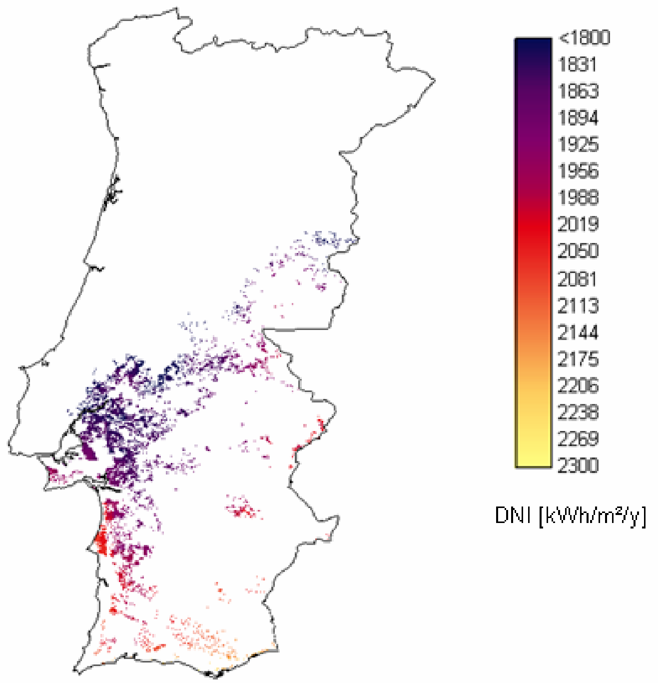


Technical Potential:	2.3 TWh/y (DNI > 1800 kWh/m²/y)
Economic Potential:	1.9 TWh/y (DNI > 2000 kWh/m²/y)
Power Demand 2000:	1.8 TWh/y
Power Demand 2050:	2.3 TWh/y (Scenario CG/HE)
Tentative CSP 2050:	0.4 TWh/y (Scenario CG/HE)
Coastal Potential:	0.3 TWh/y (< 20 m a. s. l.)
Water Demand 2050:	< 1 TWh/y (Power for Desalination)

Solar Thermal Electricity Generating Potentials in Portugal

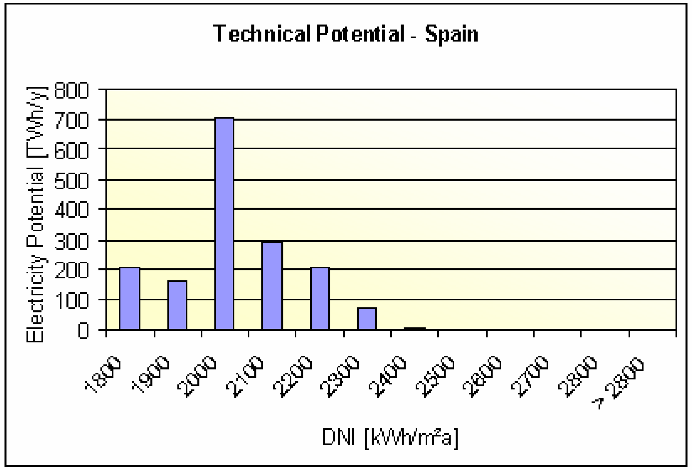


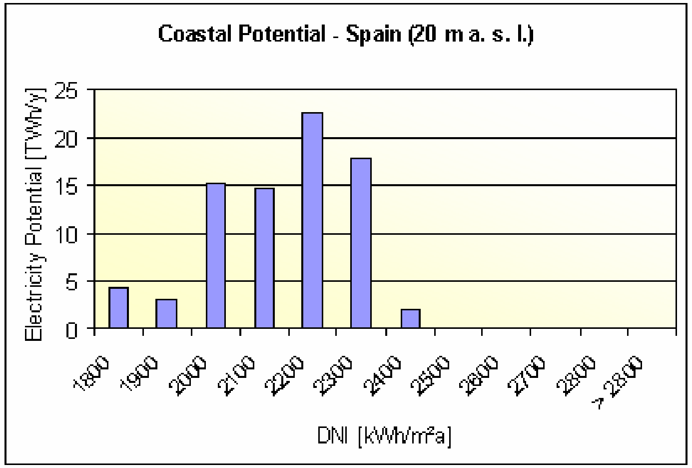


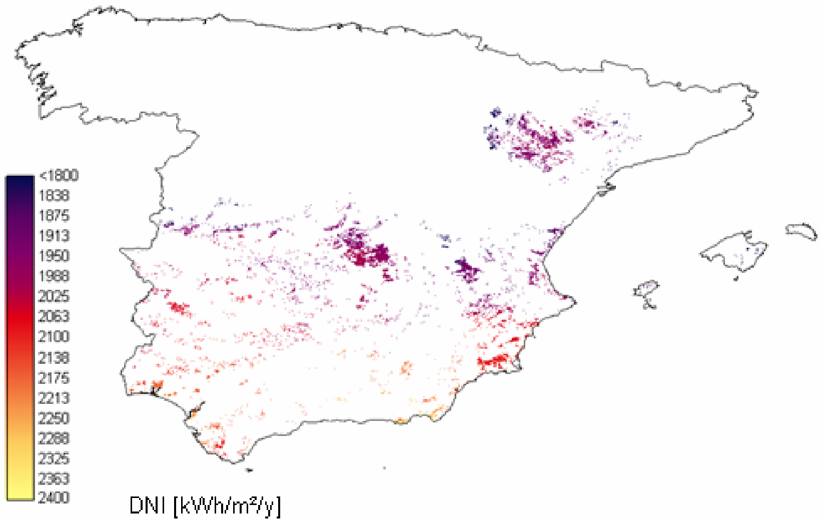


Technical Potential: 436 TWh/y (DNI > 1800 kWh/m²/y)
Economic Potential: 142 TWh/y (DNI > 2000 kWh/m²/y)
Power Demand 2000: 42 TWh/y
Power Demand 2050: 51 TWh/y (Scenario CG/HE)
Tentative CSP 2050: 10 TWh/y (Scenario CG/HE)
Coastal Potential: 7 TWh/y (< 20 m a. s. l.)
Water Demand 2050: < 1 TWh/y (Power for Desalination)

Solar Thermal Electricity Generating Potentials in Spain





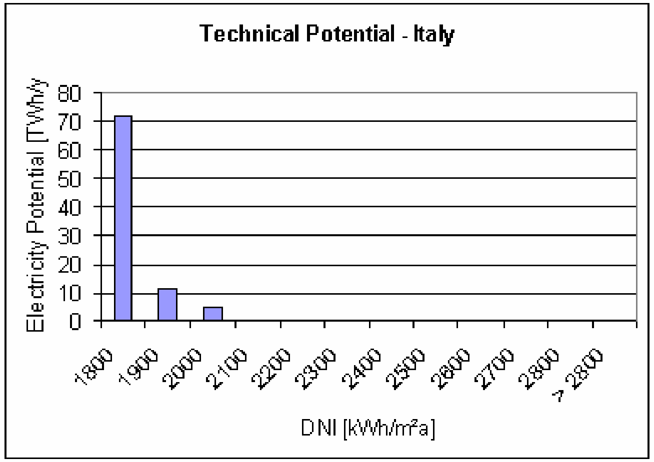


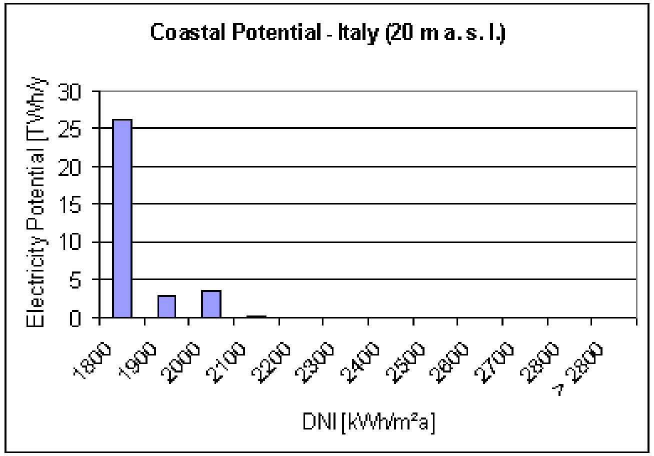
Technical Potential:	1646 TWh/y (DNI > 1800 kWh/m²/y)
Economic Potential:	1278 TWh/y (DNI > 2000 kWh/m²/y)
Power Demand 2000:	213 TWh/y
Power Demand 2050:	213 TWh/y (Scenario CG/HE)
Tentative CSP 2050:	25 TWh/y (Scenario CG/HE)
Coastal Potential:	73 TWh/y (< 20 m a. s. l.)
Water Demand 2050:	3.4 TWh/y (Power for Desalination)

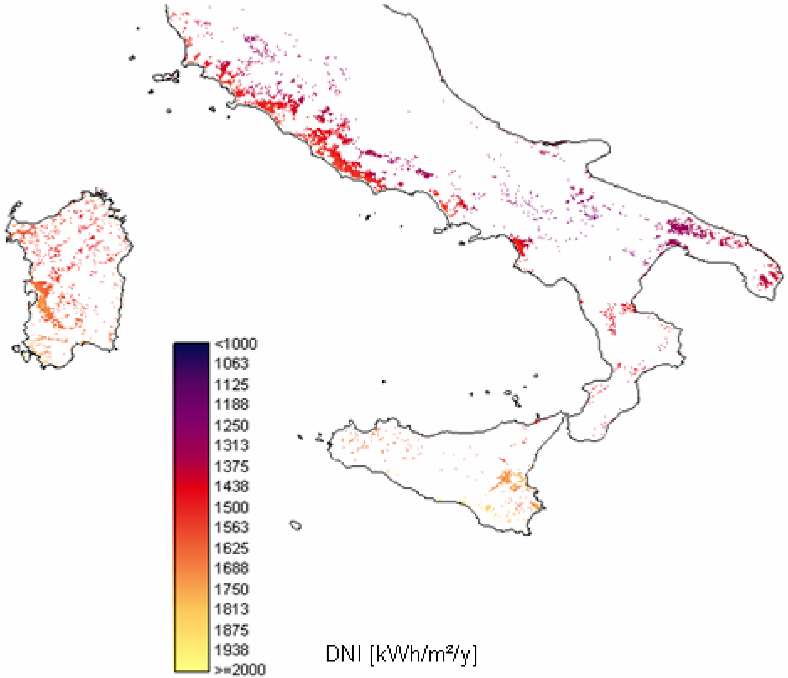
MED-CSP

Solar Thermal Electricity Generating Potentials in Italy

DLR

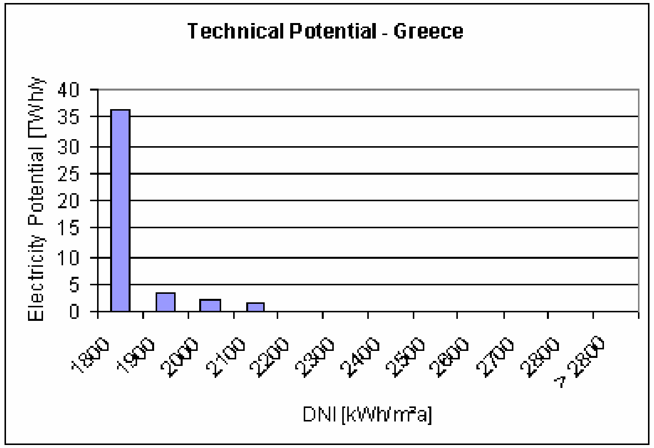


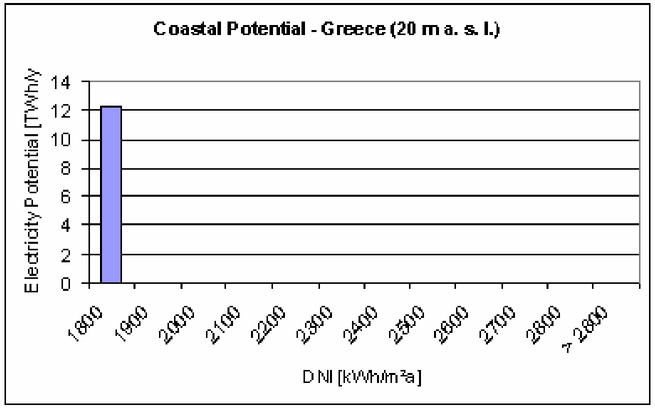


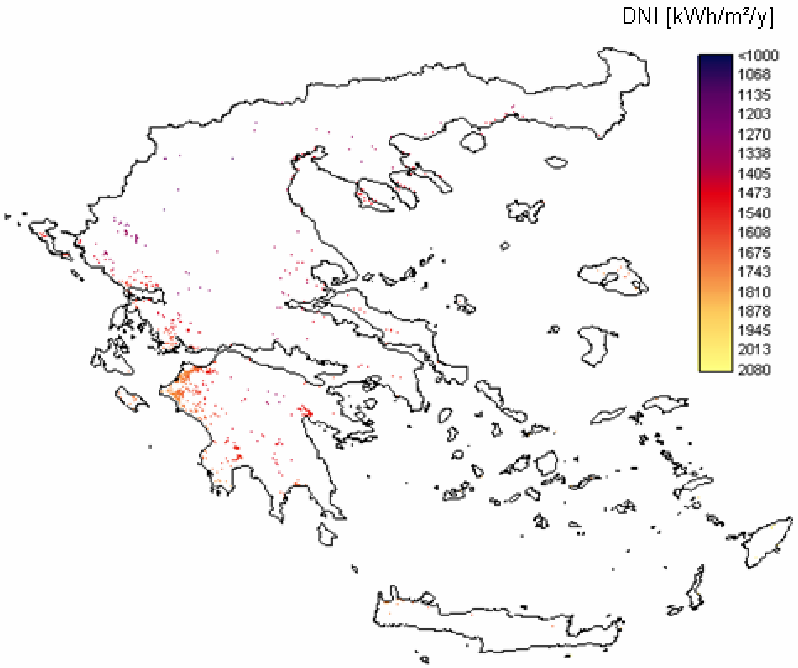


Technical Potential:	88 TWh/y (DNI > 1800 kWh/m²/y)
Economic Potential:	5 TWh/y (DNI > 2000 kWh/m²/y)
Power Demand 2000:	299 TWh/y
Power Demand 2050:	256 TWh/y (Scenario CG/HE)
Tentative CSP 2050:	5 TWh/y (Scenario CG/HE)
Coastal Potential:	3 TWh/y (< 20 m a. s. l.)
Water Demand 2050:	1TWh/y (Power for Desalination)

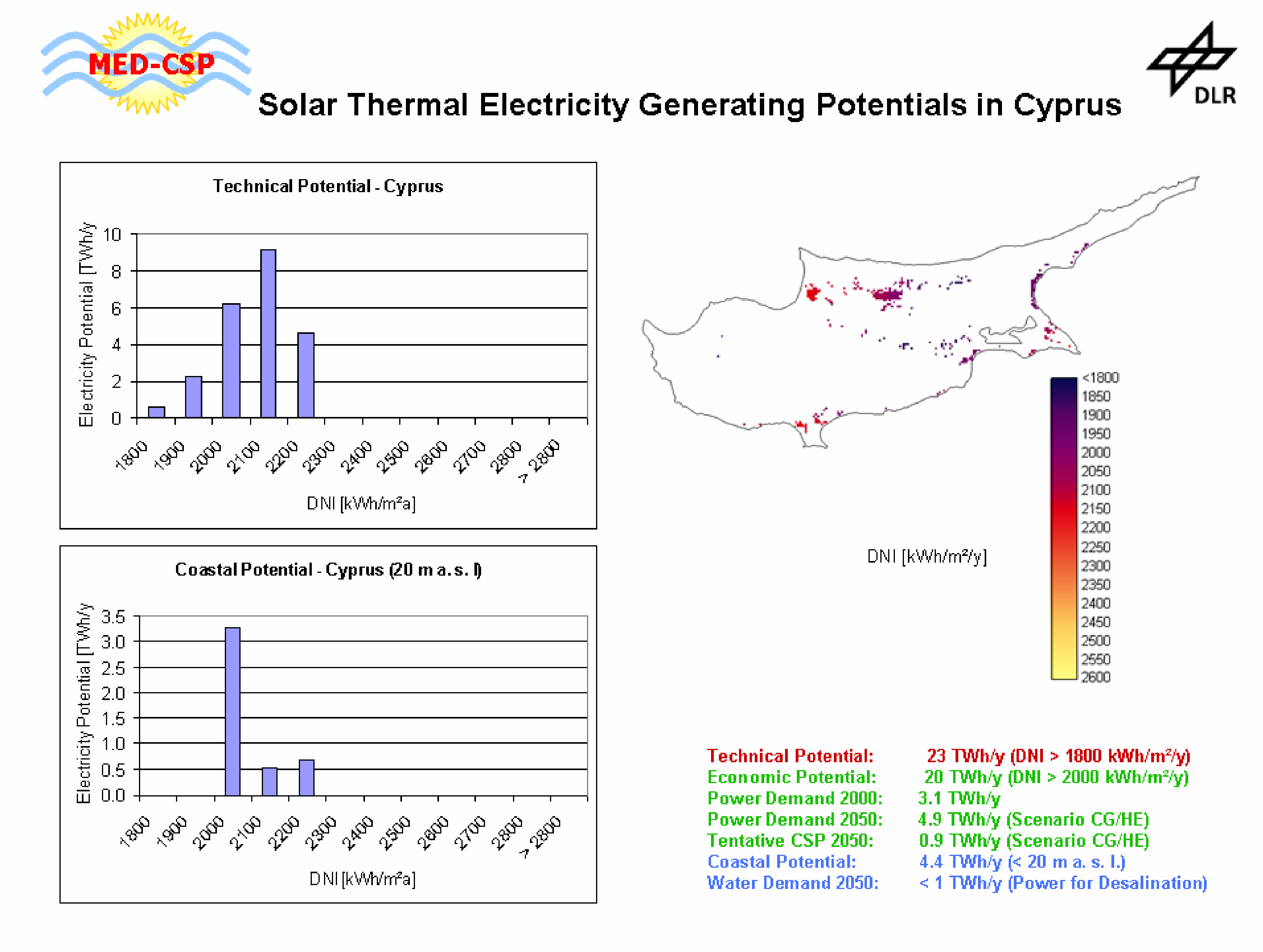
Solar Thermal Electricity Generating Potentials in Greece



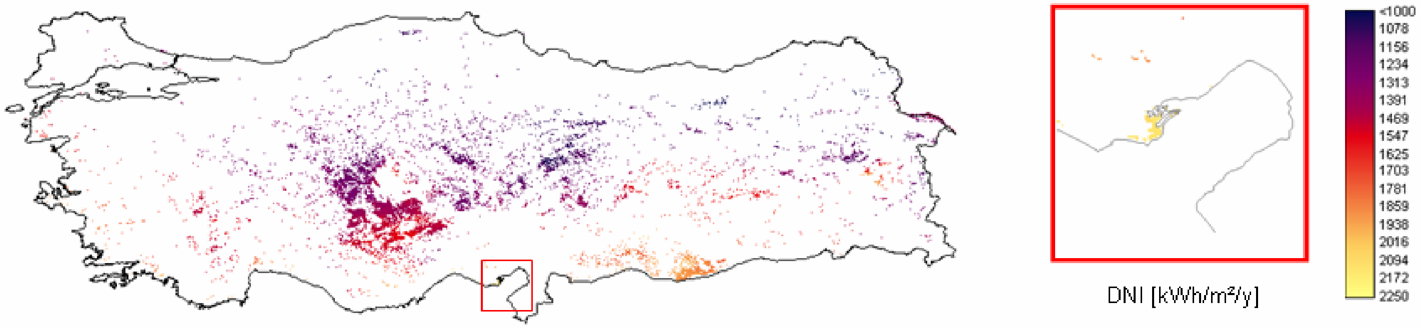


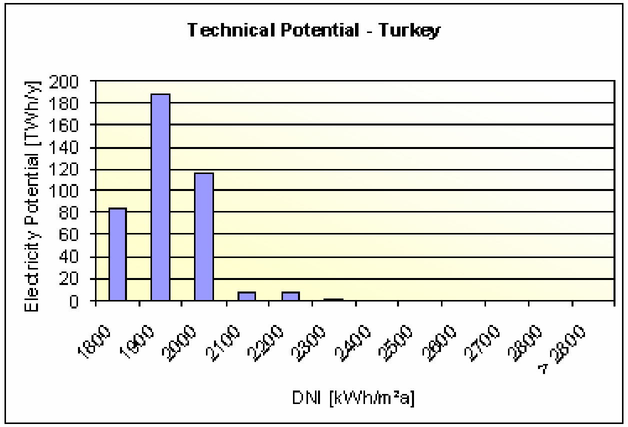


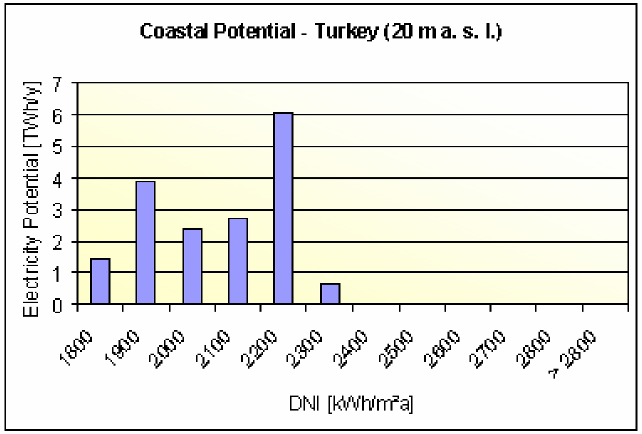
Technical Potential:	44 TWh/y (DNI > 1800 kWh/m²/y)
Economic Potential:	4 TWh/y (DNI > 2000 kWh/m²/y)
Power Demand 2000:	50 TWh/y
Power Demand 2050:	56 TWh/y (Scenario CG/HE)
Tentative CSP 2050:	3.5 TWh/y (Scenario CG/HE)
Coastal Potential:	0 TWh/y (< 20 m a. s. l.)
Water Demand 2050:	< 1TWh/y (Power for Desalination)


MED-CSP
Solar Thermal Electricity Generating Potentials in Cyprus
DLR
Technical Potential - Cyprus
Electricity Potential [TWh/y]
0
2
4
6
8
10
1800
1900
2000
2100
2200
2300
2400
2500
2600
2700
2800
> 2800
DNI [kWh/m²a]
Coastal Potential - Cyprus (20 m a. s. l)
Electricity Potential [TWh/y]
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
1800
1900
2000
2100
2200
2300
2400
2500
2600
2700
2800
> 2800
DNI [kWh/m²a]
DNI [kWh/m²/y]
<1800
1850
1900
1950
2000
2050
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
2600
Technical Potential: 23 TWh/y (DNI > 1800 kWh/m²/y)
Economic Potential: 20 TWh/y (DNI > 2000 kWh/m²/y)
Power Demand 2000: 3.1 TWh/y
Power Demand 2050: 4.9 TWh/y (Scenario CG/HE)
Tentative CSP 2050: 0.9 TWh/y (Scenario CG/HE)
Coastal Potential: 4.4 TWh/y (< 20 m a. s. l.)
Water Demand 2050: < 1 TWh/y (Power for Desalination)

Solar Thermal Electricity Generating Potentials in Turkey





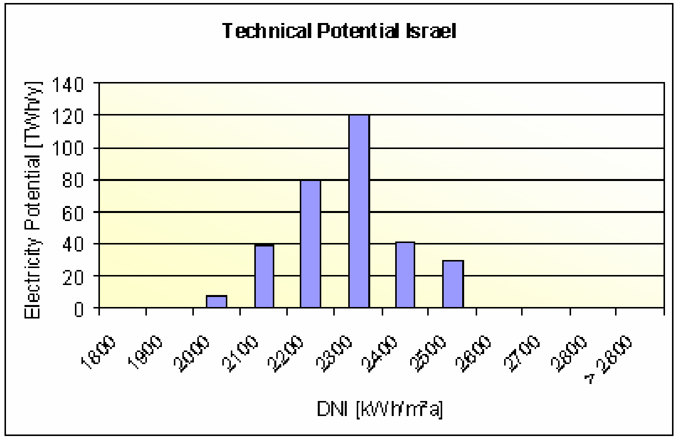


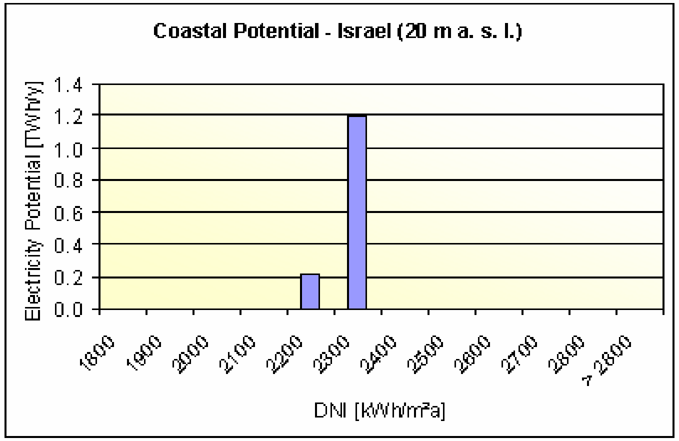
Technical Potential:	405 TWh/y (DNI > 1800 kWh/m²/y)
Economic Potential:	131 TWh/y (DNI > 2000 kWh/m²/y)
Power Demand 2000:	121 TWh/y
Power Demand 2050:	425 TWh/y (Scenario CG/HE)
Tentative CSP 2050:	125 TWh/y (Scenario CG/HE)
Coastal Potential:	12 TWh/y (< 20 m a. s. l.)
Water Demand 2050:	< 1TWh/y (Power for Desalination)

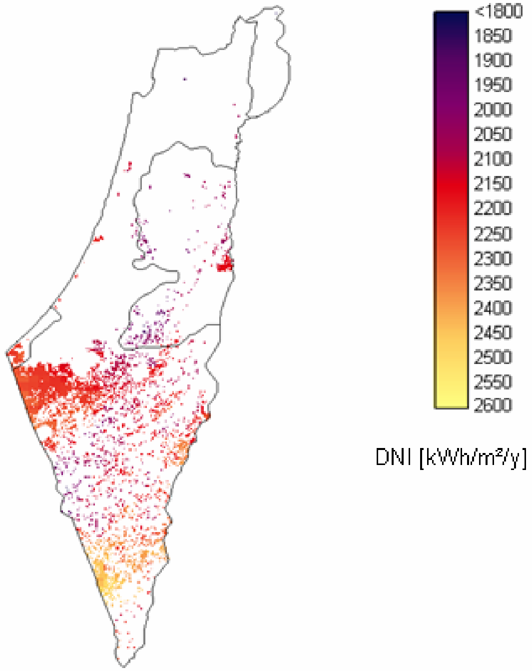
MED-CSP

Solar Thermal Electricity Generating Potentials in Israel

DLR

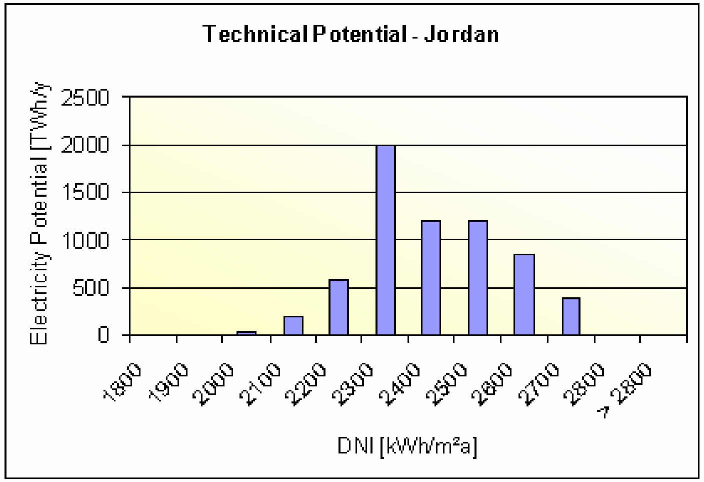


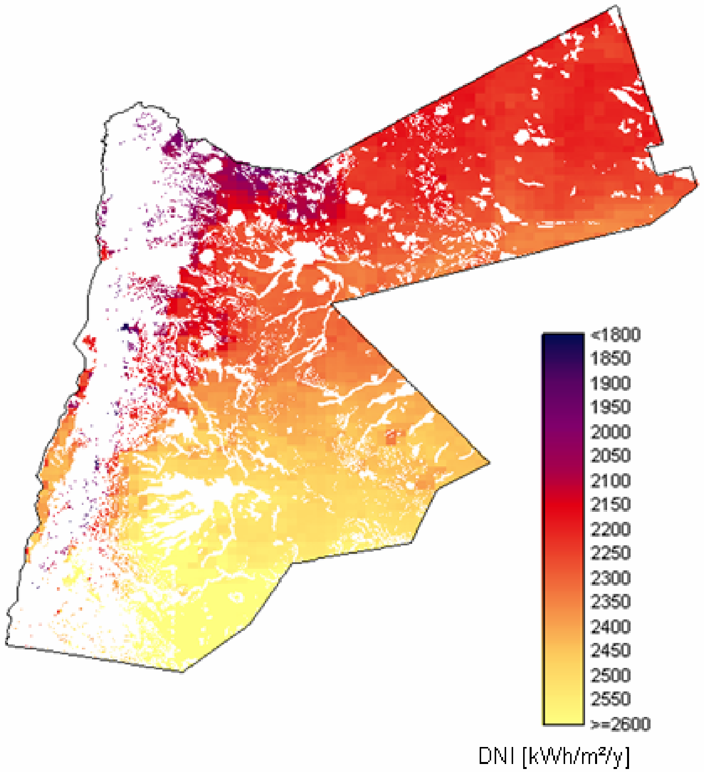




Technical Potential: 3118 TWh/y (DNI > 1800 kWh/m²/y)
Economic Potential: 3112 TWh/y (DNI > 2000 kWh/m²/y)
Power Demand 2000: 42 TWh/y
Power Demand 2050: 57 TWh/y (Scenario CG/HE)
Tentative CSP 2050: 22 TWh/y (Scenario CG/HE)
Coastal Potential: 1.5 TWh/y (< 20 m a. s. l.)
Water Demand 2050: 2.7 TWh/y (Power for Desalination)

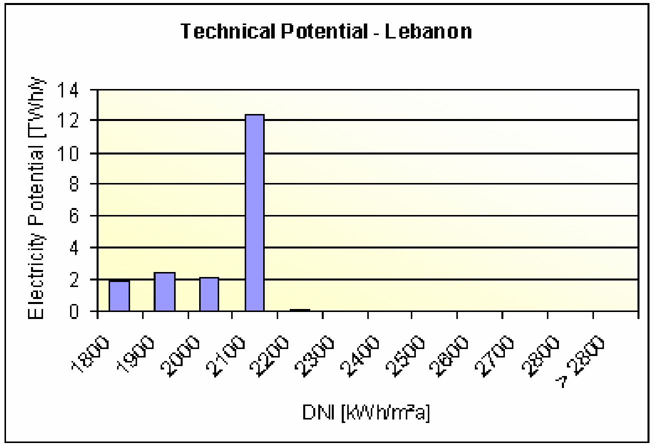
Solar Thermal Electricity Generating Potentials in Jordan

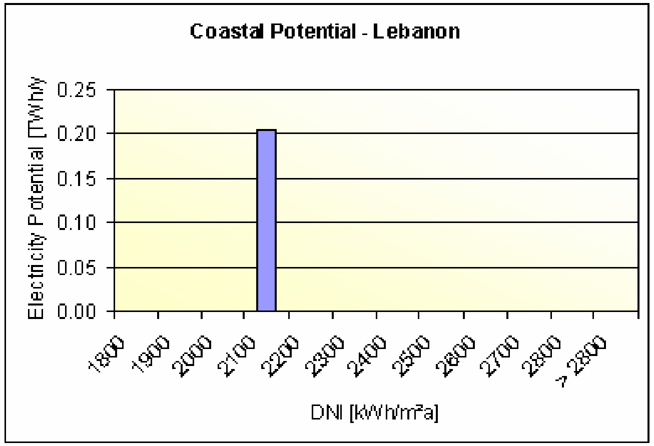


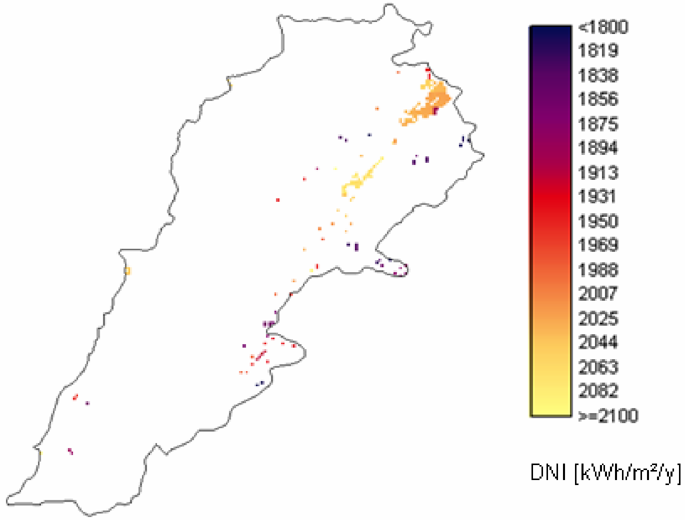


Technical Potential:	6434 TWh/y (DNI > 1800 kWh/m²/y)
Economic Potential:	6429 TWh/y (DNI > 2000 kWh/m²/y)
Power Demand 2000:	7 TWh/y
Power Demand 2050:	50 TWh/y (Scenario CG/HE)
Tentative CSP 2050:	40 TWh/y (Scenario CG/HE)
Coastal Potential:	0 TWh/y (< 20 m a. s. l.)
Water Demand 2050:	3.5 TWh/y (Power for Desalination)

Solar Thermal Electricity Generating Potentials in Lebanon

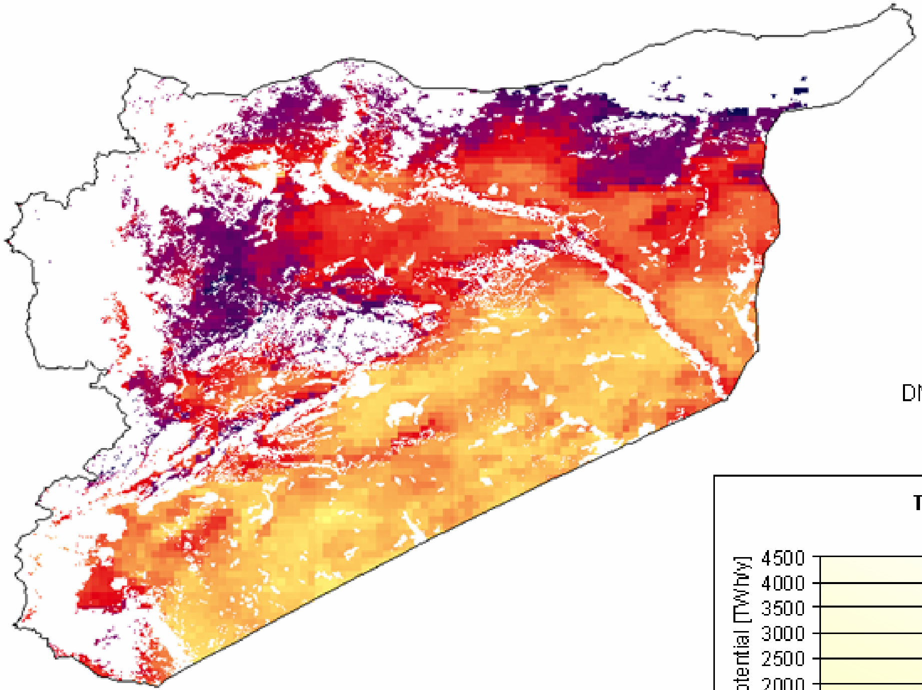


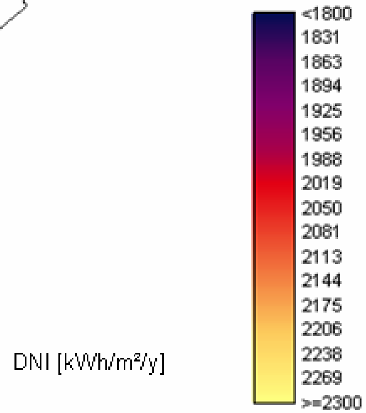


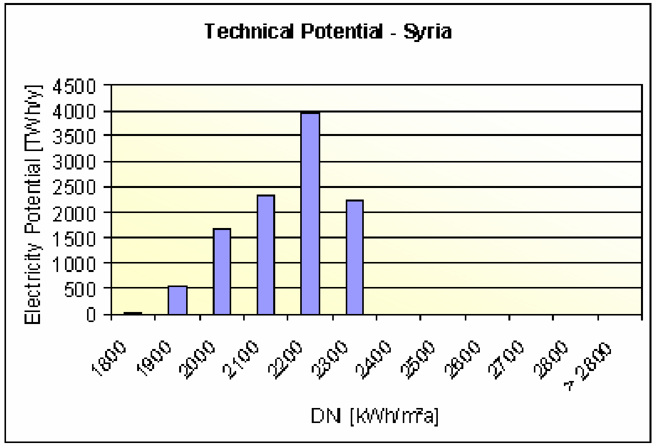


Technical Potential:	19 TWh/y (DNI > 1800 kWh/m²/y)
Economic Potential:	14 TWh/y (DNI > 2000 kWh/m²/y)
Power Demand 2000:	9 TWh/y
Power Demand 2050:	25 TWh/y (Scenario CG/HE)
Tentative CSP 2050:	12 TWh/y (Scenario CG/HE)
Coastal Potential:	0.2 TWh/y (< 20 m a. s. l.)
Water Demand 2050:	< 1 TWh/y (Power for Desalination)

Solar Thermal Electricity Generating Potentials in Syria

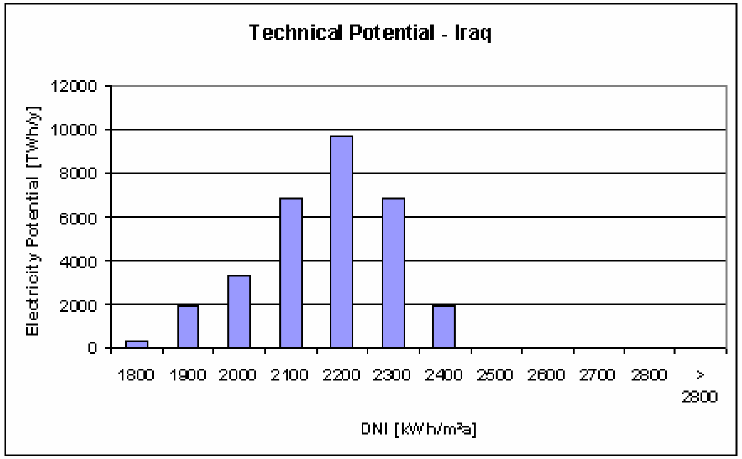


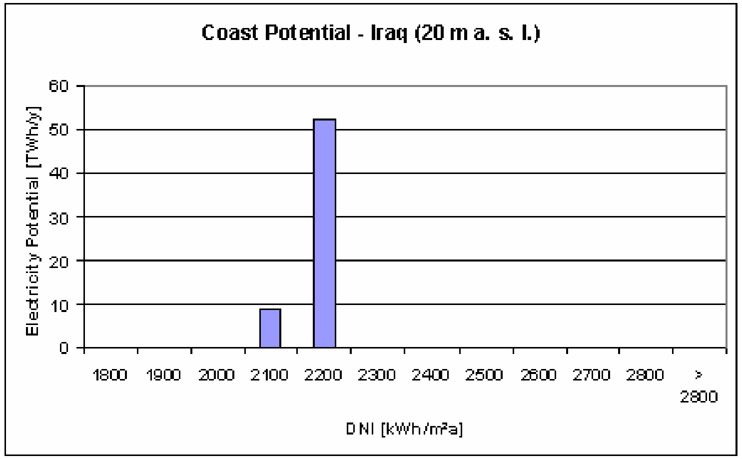


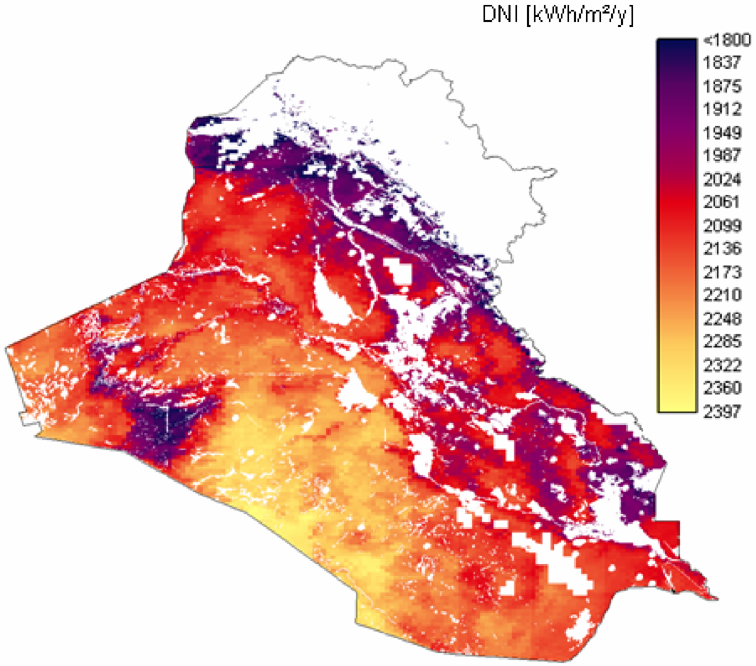


Technical Potential: 10777 TWh/y (DNI > 1800 kWh/m²/y)
Economic Potential: 10210 TWh/y (DNI > 2000 kWh/m²/y)
Power Demand 2000: 23 TWh/y
Power Demand 2050: 166 TWh/y (Scenario CG/HE)
Tentative CSP 2050: 117 TWh/y (Scenario CG/HE)
Coastal Potential: 0 TWh/y (< 20 m a. s. l.)
Water Demand 2050: 42 TWh/y (Power for Desalination)

Solar Thermal Electricity Generating Potentials in Iraq





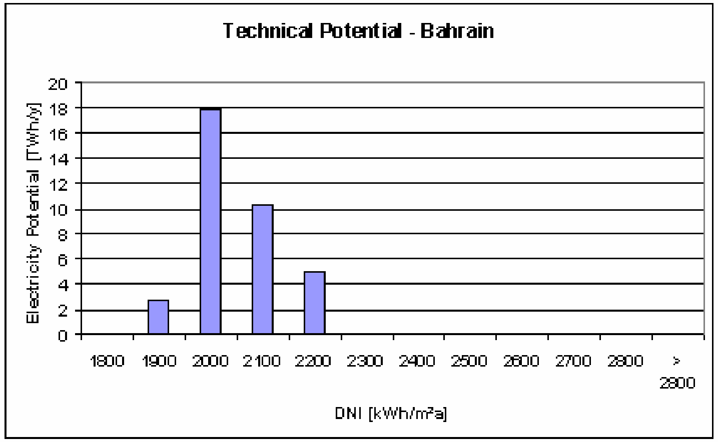


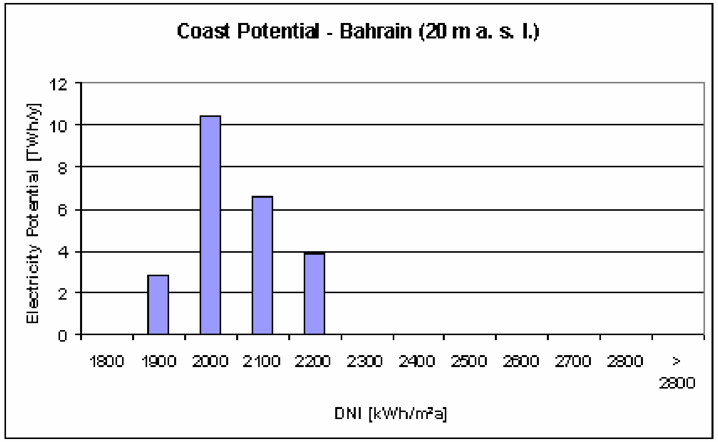
Technical Potential:	30806 TWh/y (DNI > 1800 kWh/m²/y)
Economic Potential:	28647 TWh/y (DNI > 2000 kWh/m²/y)
Power Demand 2000:	31 TWh/y
Power Demand 2050:	257 TWh/y (Scenario CG/HE)
Tentative CSP 2050:	190 TWh/y (Scenario CG/HE)
Coastal Potential:	61 TWh/y (< 20 m a. s. l.)
Water Demand 2050:	13 TWh/y (Power for Desalination)

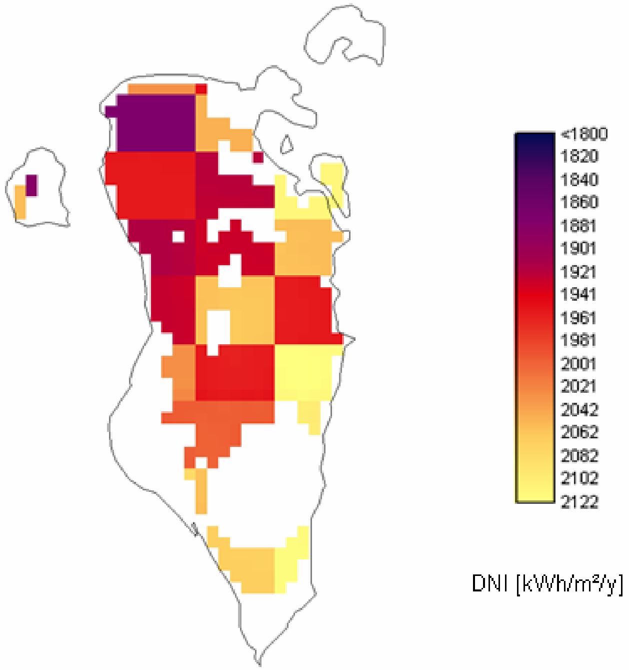
MED-CSP

Solar Thermal Electricity Generating Potentials in Bahrain

DLR





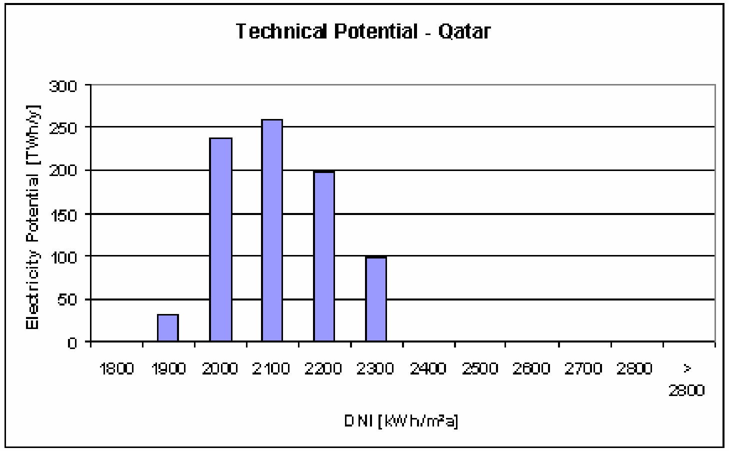


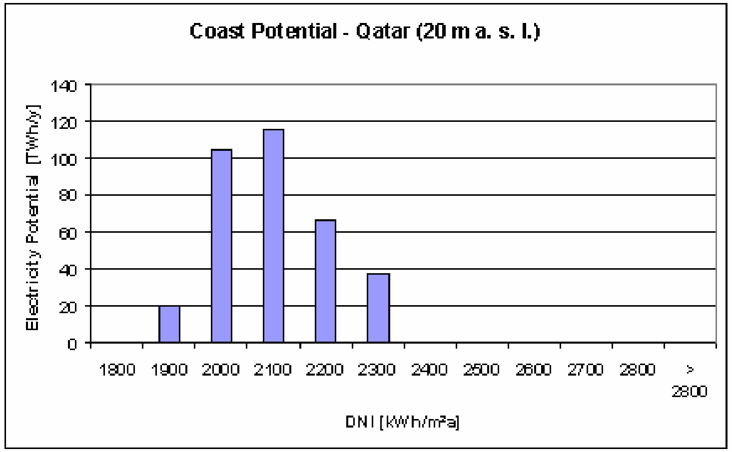
Technical Potential:	36 TWh/y (DNI > 1800 kWh/m²/y)
Economic Potential:	33 TWh/y (DNI > 2000 kWh/m²/y)
Power Demand 2000:	5.8 TWh/y
Power Demand 2050:	6.9 TWh/y (Scenario CG/HE)
Tentative CSP 2050:	3.5 TWh/y (Scenario CG/HE)
Coastal Potential:	21 TWh/y (< 20 m a. s. l.)
Water Demand 2050:	1 TWh/y (Power for Desalination)

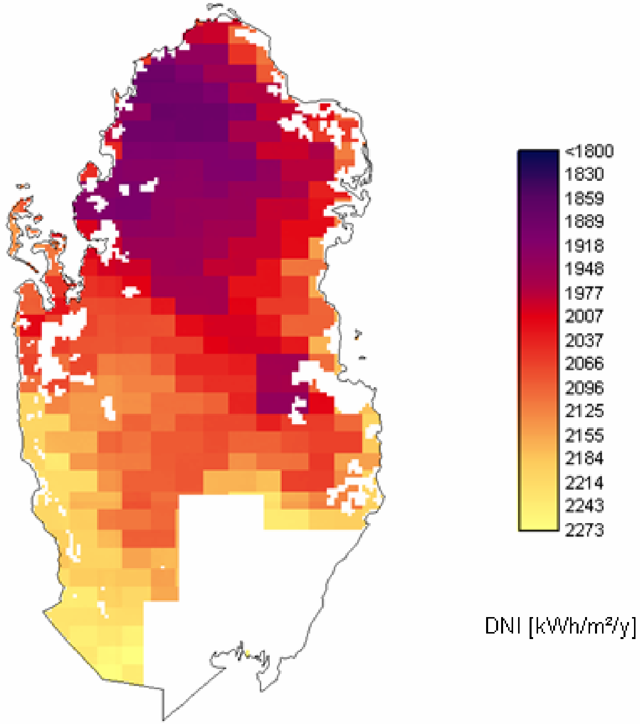
MED-CSP

Solar Thermal Electricity Generating Potentials in Qatar

DLR

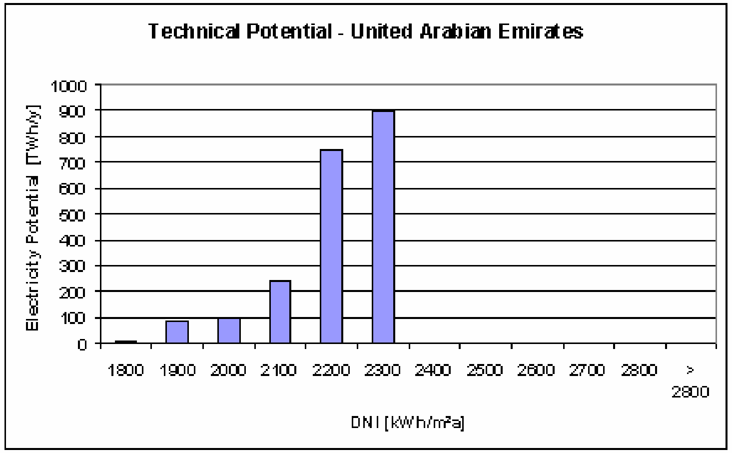


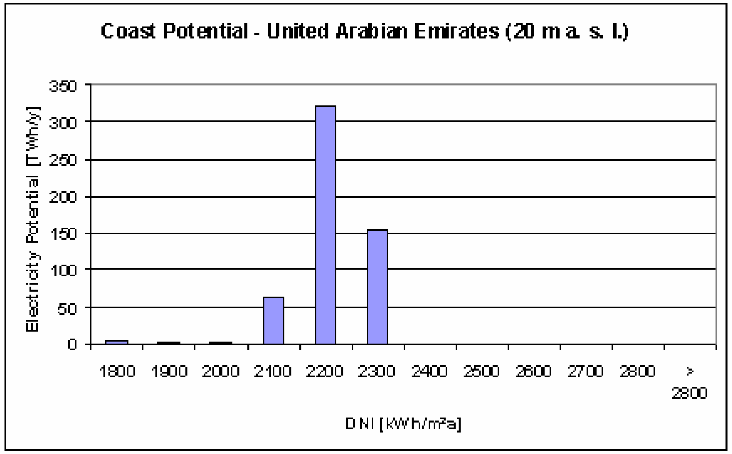


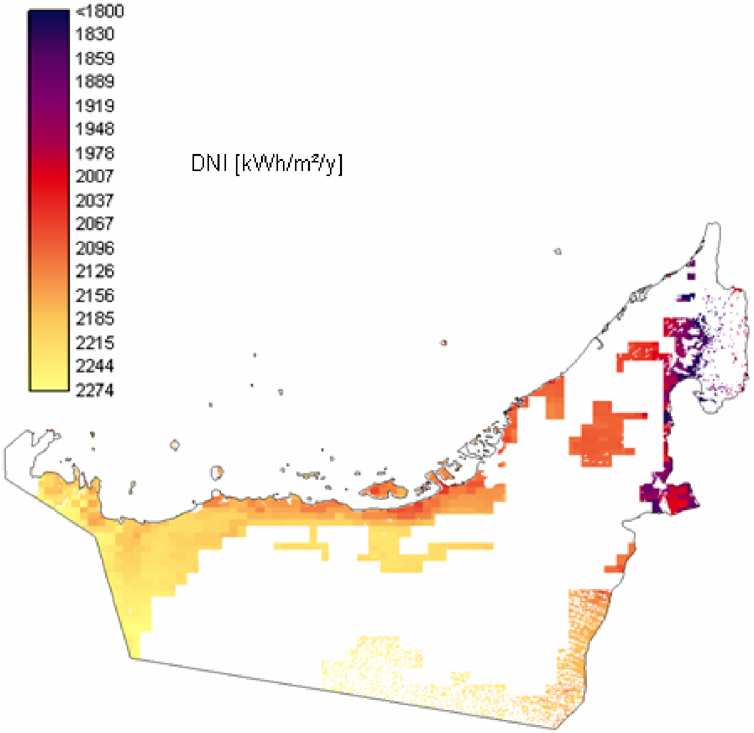


Technical Potential:	823 TWh/y (DNI > 1800 kWh/m²/y)
Economic Potential:	792 TWh/y (DNI > 2000 kWh/m²/y)
Power Demand 2000:	9 TWh/y
Power Demand 2050:	5 TWh/y (Scenario CG/HE)
Tentative CSP 2050:	2.8 TWh/y (Scenario CG/HE)
Coastal Potential:	324 TWh/y (< 20 m a. s. l.)
Water Demand 2050:	1 TWh/y (Power for Desalination)

Solar Thermal Electricity Generating Potentials in UAE

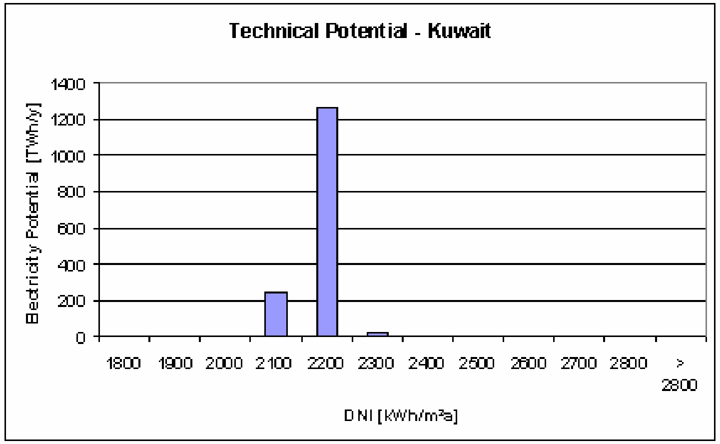


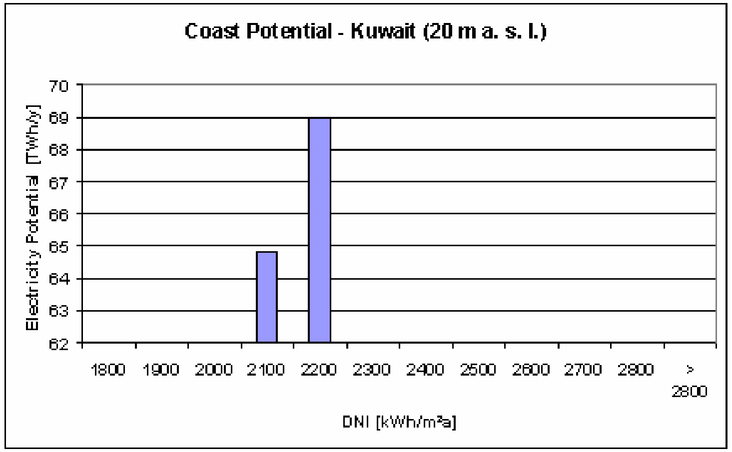


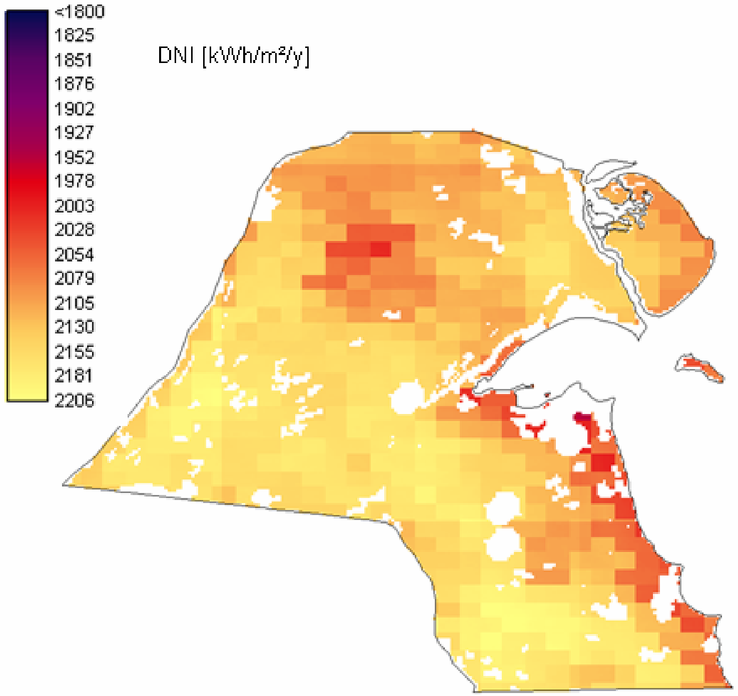


Technical Potential:	2078 TWh/y (DNI > 1800 kWh/m²/y)
Economic Potential:	1988 TWh/y (DNI > 2000 kWh/m²/y)
Power Demand 2000:	36 TWh/y
Power Demand 2050:	24 TWh/y (Scenario CG/HE)
Tentative CSP 2050:	10 TWh/y (Scenario CG/HE)
Coastal Potential:	538 TWh/y (< 20 m a. s. l.)
Water Demand 2050:	8 TWh/y (Power for Desalination)

Solar Thermal Electricity Generating Potentials in Kuwait





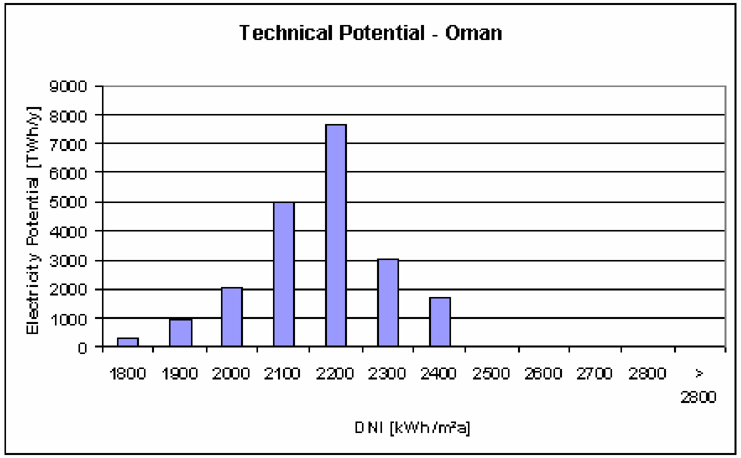


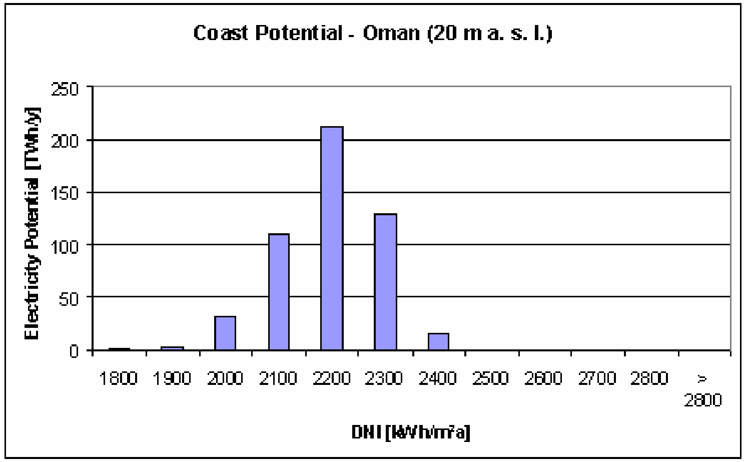
Technical Potential:	1525 TWh/y (DNI > 1800 kWh/m²/y)
Economic Potential:	1525 TWh/y (DNI > 2000 kWh/m²/y)
Power Demand 2000:	30 TWh/y
Power Demand 2050:	30 TWh/y (Scenario CG/HE)
Tentative CSP 2050:	13 TWh/y (Scenario CG/HE)
Coastal Potential:	134 TWh/y (< 20 m a. s. l.)
Water Demand 2050:	2.2 TWh/y (Power for Desalination)

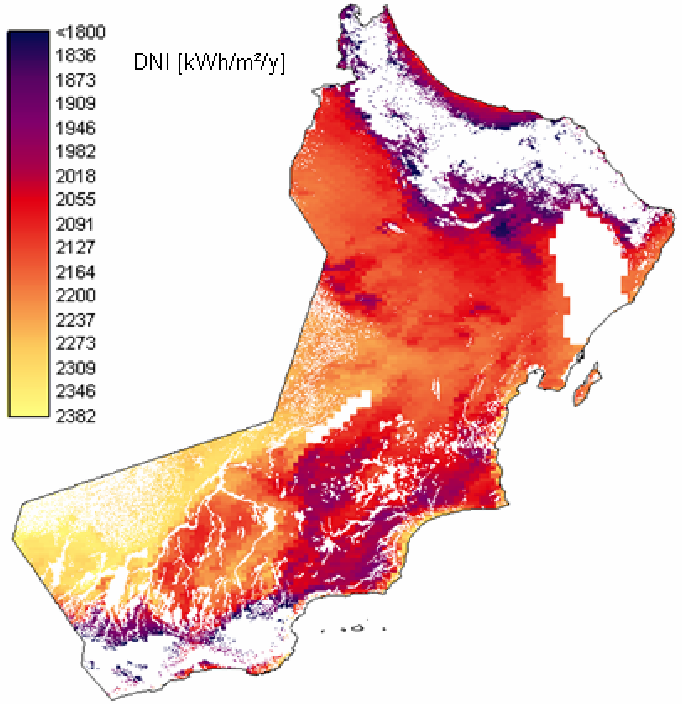
MED-CSP

Solar Thermal Electricity Generating Potentials in Oman

DLR

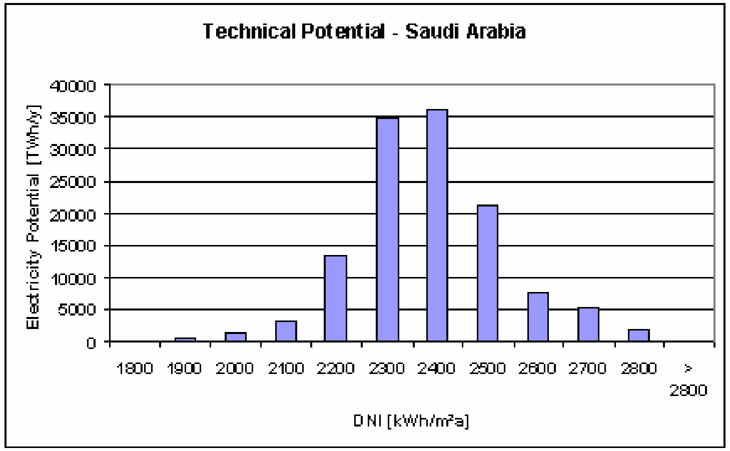


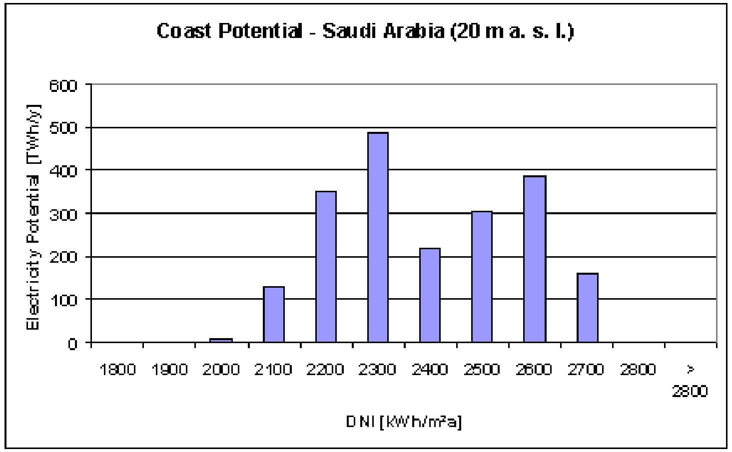


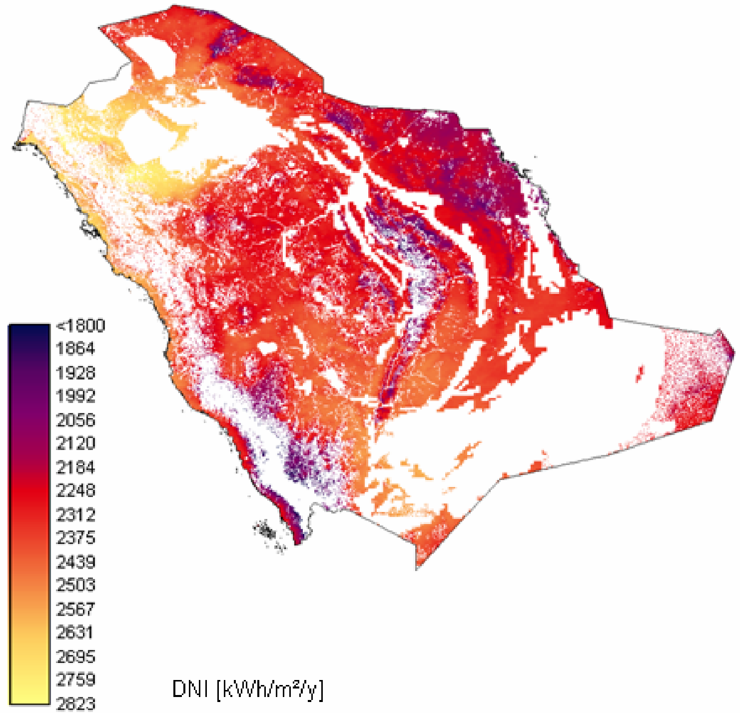


Technical Potential:	20611 TWh/y (DNI > 1800 kWh/m²/y)
Economic Potential:	19404 TWh/y (DNI > 2000 kWh/m²/y)
Power Demand 2000:	8.5 TWh/y
Power Demand 2050:	35 TWh/y (Scenario CG/HE)
Tentative CSP 2050:	22 TWh/y (Scenario CG/HE)
Coastal Potential:	497 TWh/y (< 20 m a. s. l.)
Water Demand 2050:	6 TWh/y (Power for Desalination)

Solar Thermal Electricity Potentials in Saudi Arabia





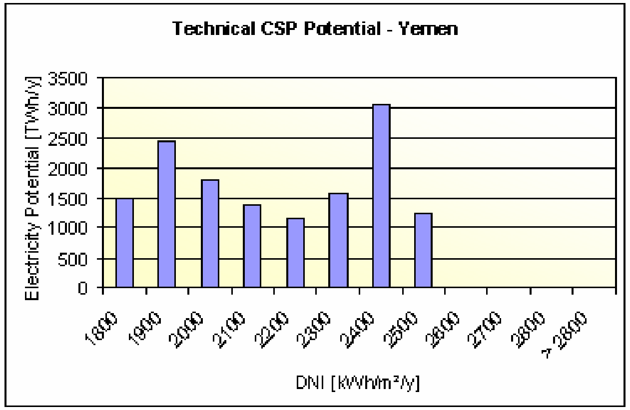


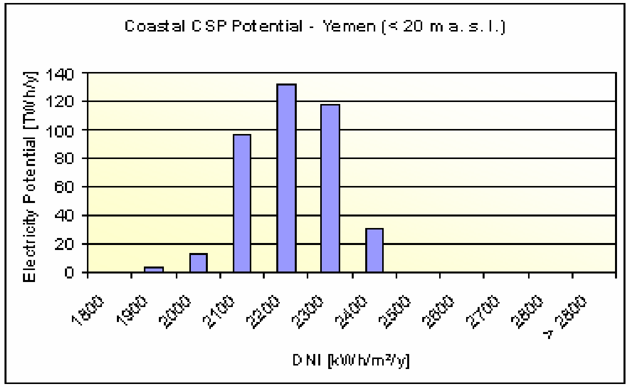
Technical Potential:	125260 TWh/y (DNI > 1800 kWh/m²/y)
Economic Potential:	124560 TWh/y (DNI > 2000 kWh/m²/y)
Power Demand 2000:	119 TWh/y
Power Demand 2050:	305 TWh/y (Scenario CG/HE)
Tentative CSP 2050:	135 TWh/y (Scenario CG/HE)
Coastal Potential:	2055 TWh/y (< 20 m a. s. l.)
Water Demand 2050:	99 TWh/y (Power for Desalination)

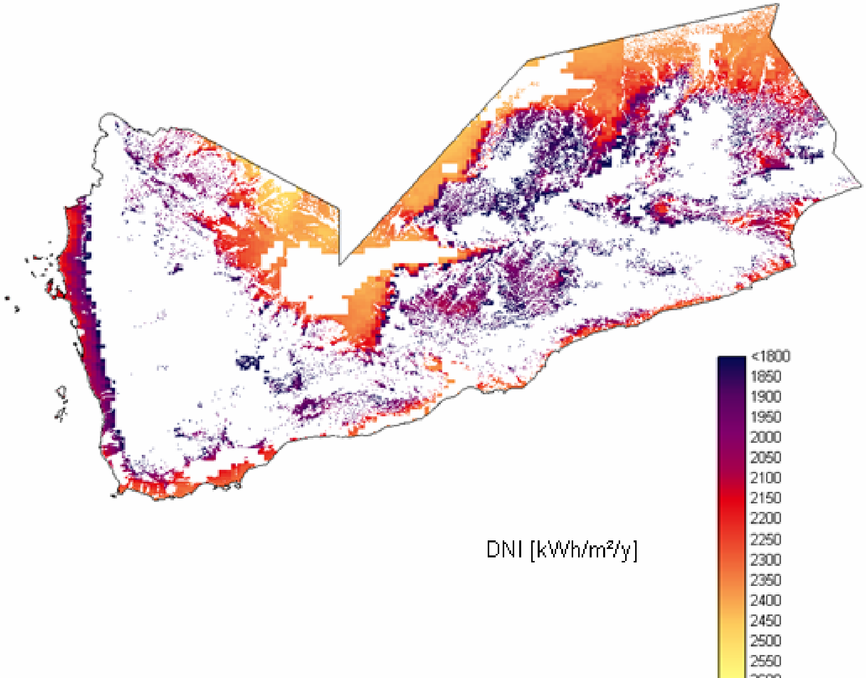
MED-CSP

Solar Thermal Electricity Generating Potentials in Yemen

DLR







Technical Potential:	5143 TWh/y (DNI > 1800 kWh/m²/y)
Economic Potential:	5100 TWh/y (DNI > 2000 kWh/m²/y)
Power Demand 2000:	3 TWh/y
Power Demand 2050:	383 TWh/y (Scenario CG/HE)
Tentative CSP 2050:	300 TWh/y (Scenario CG/HE)
Coastal Potential:	390 TWh/y (< 20 m a. s. l.)
Water Demand 2050:	62 TWh/y (Power for Desalination)
Sana'a Project:	10 TWh/y (Desalination & Pumping)

Annex 2: Population Structure and Outlook to 2050

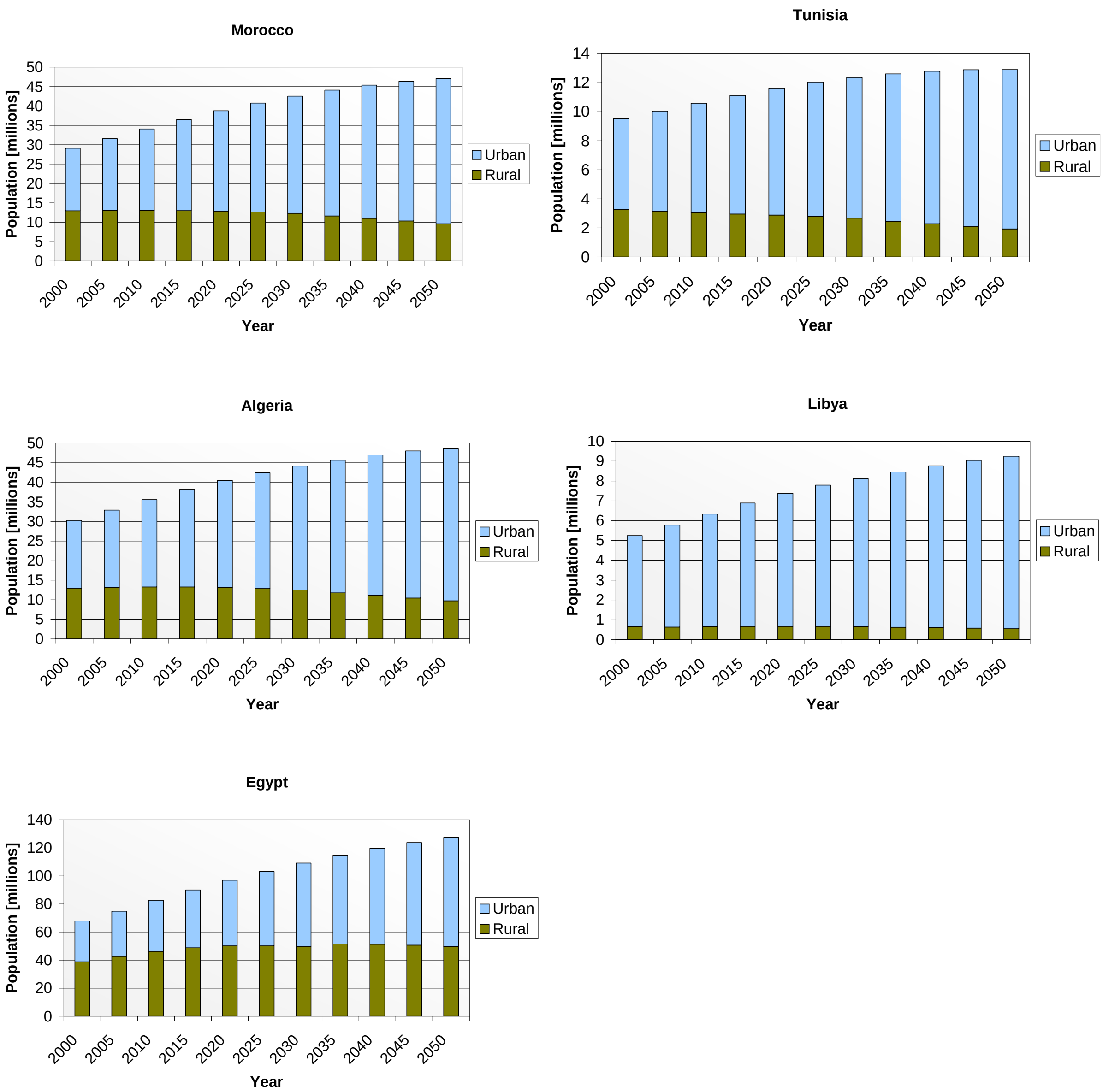


Figure A-1: Development of rural and urban population of the Northern African countries until 2050.

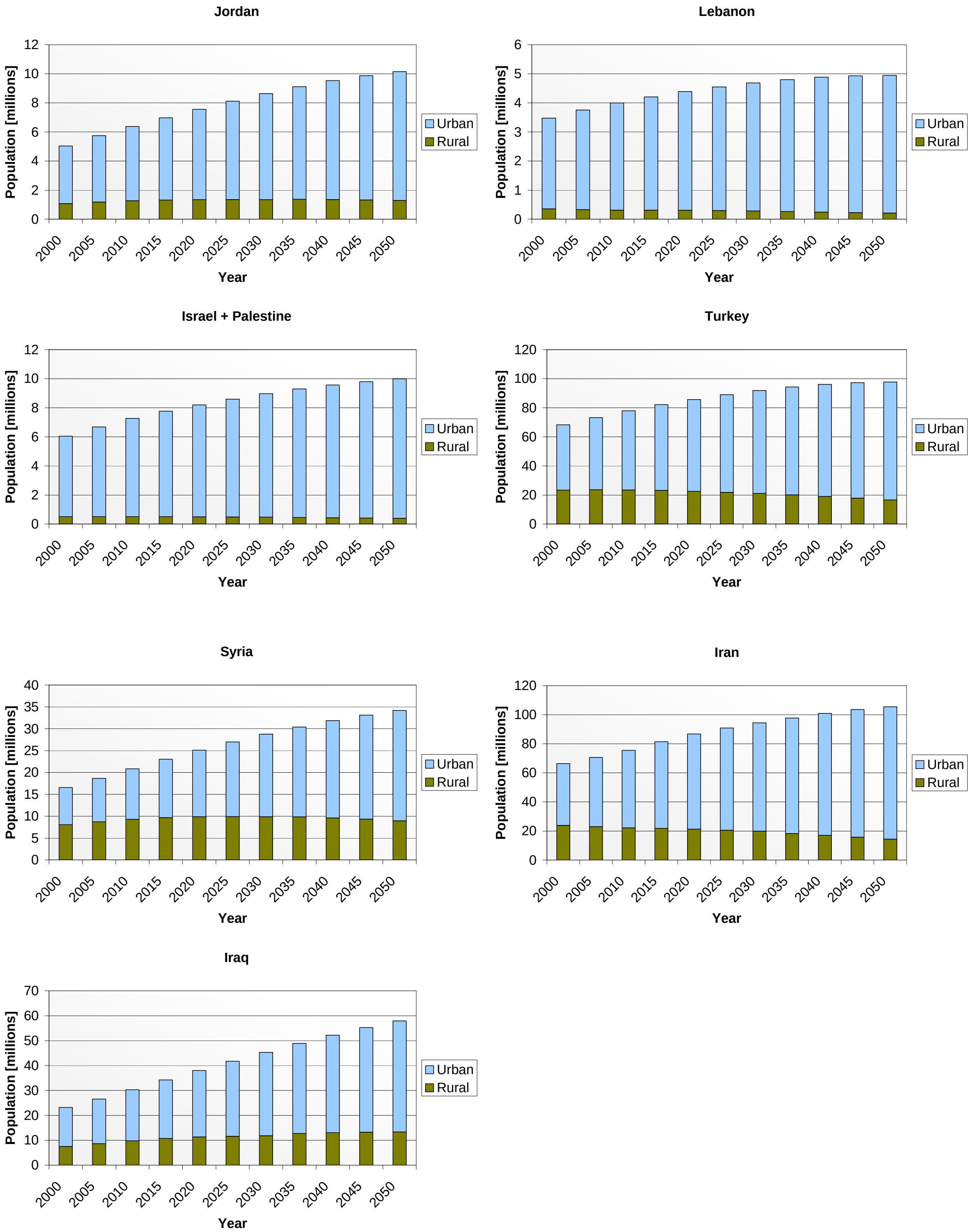


Figure A-2: Development of rural and urban population of the Western Asian countries until 2050

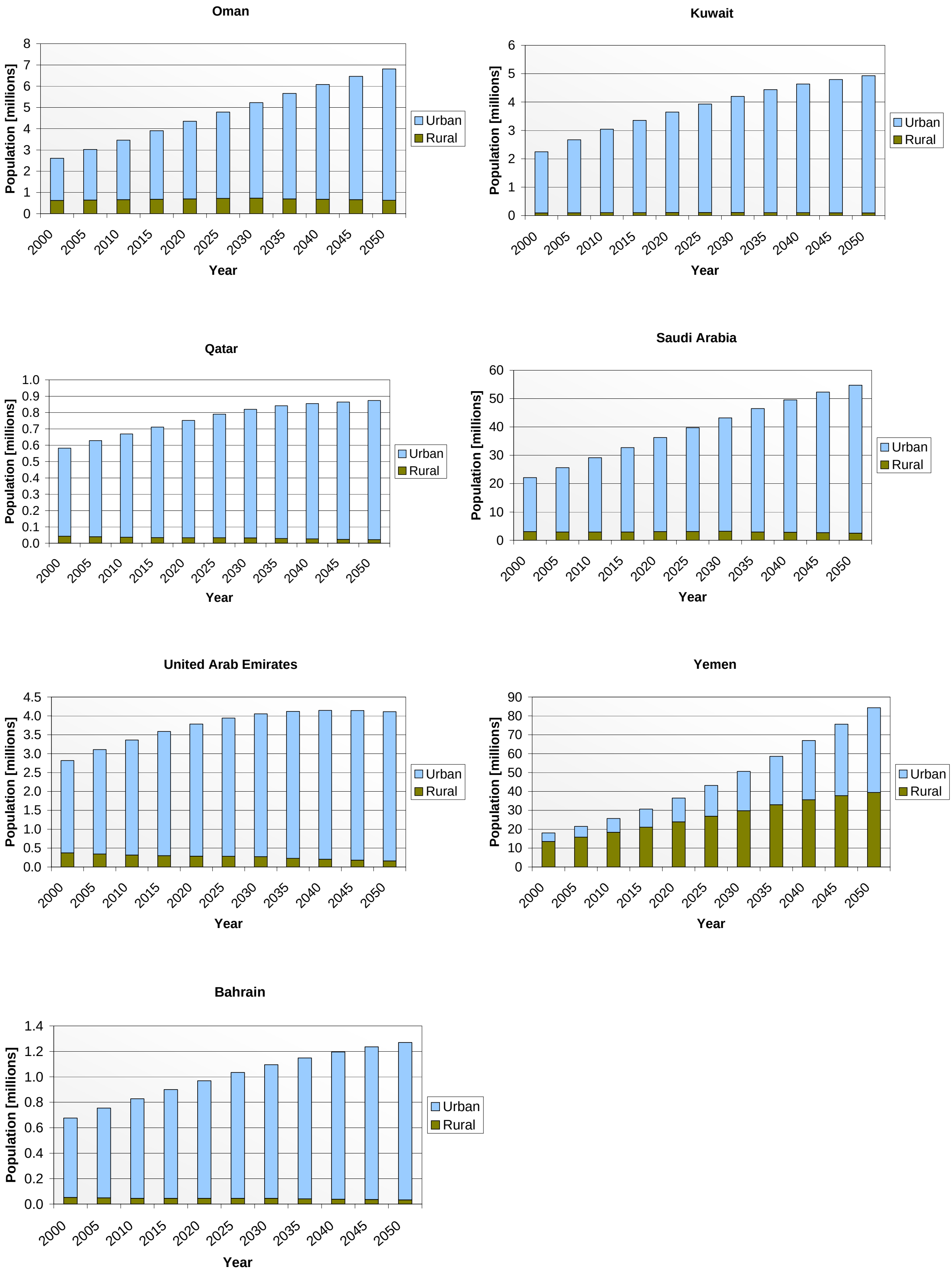


Figure A-3: Development of rural and urban population on the Arabian Peninsula until 2050 by country

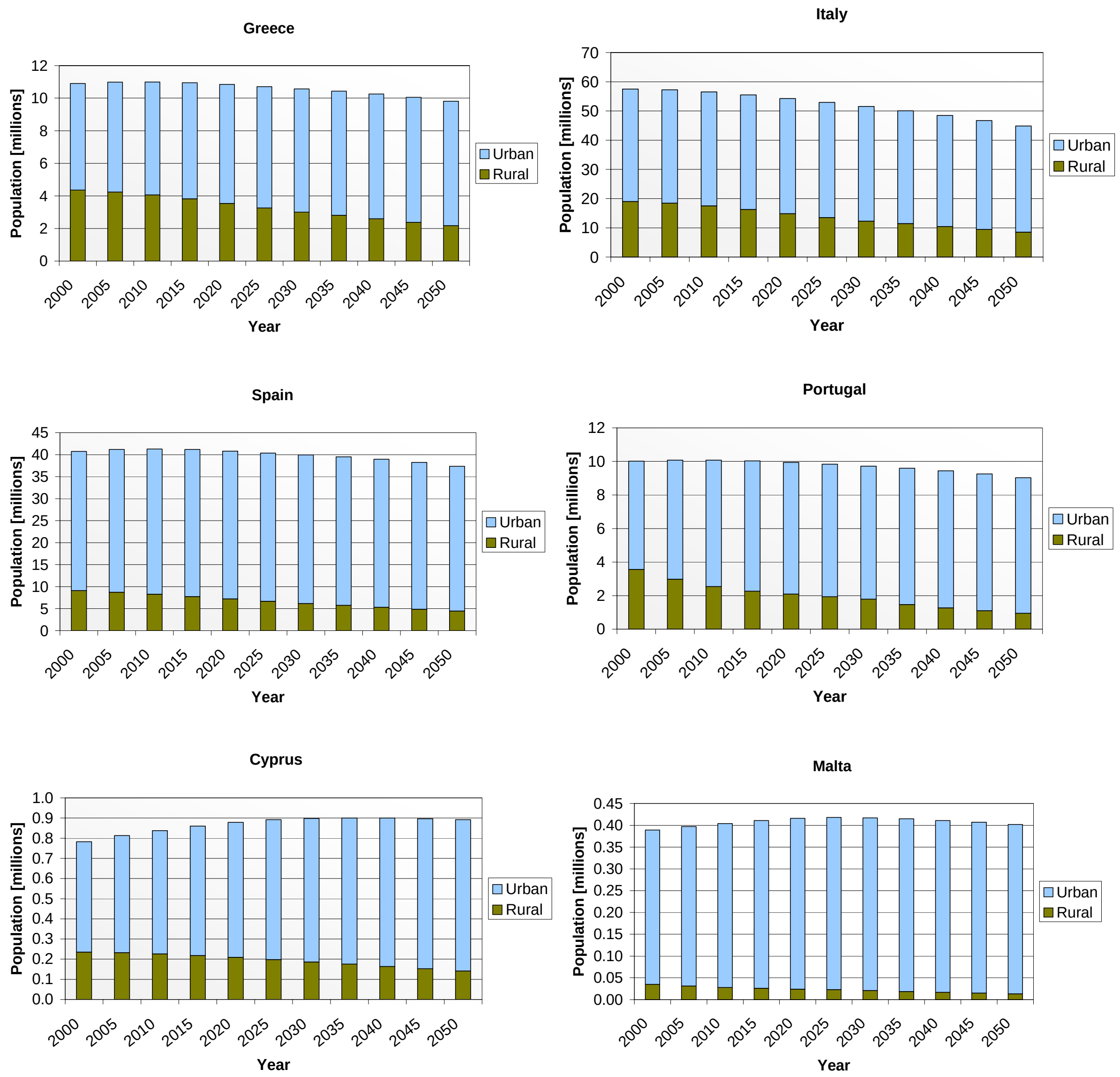


Figure A-4: Development of rural and urban population in the Southern European countries analysed in the study until 2050 by country

Annex 3: Electricity Demand Projections in the Scenarios CG/HE and FU/LE

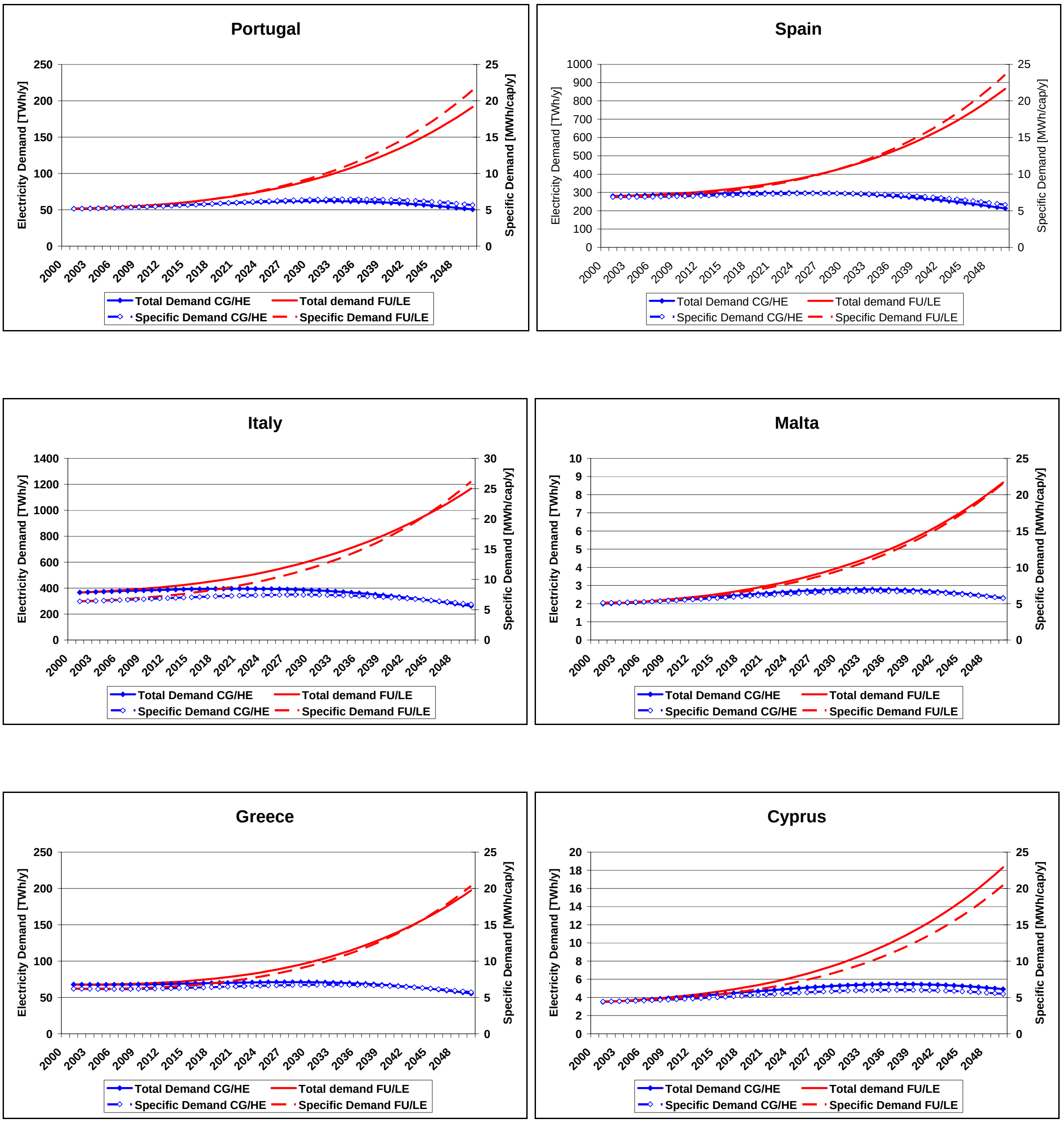


Figure A-5: Electricity demand and electricity demand per capita in the Southern European countries according to the scenarios CG/HE and FU/LE.

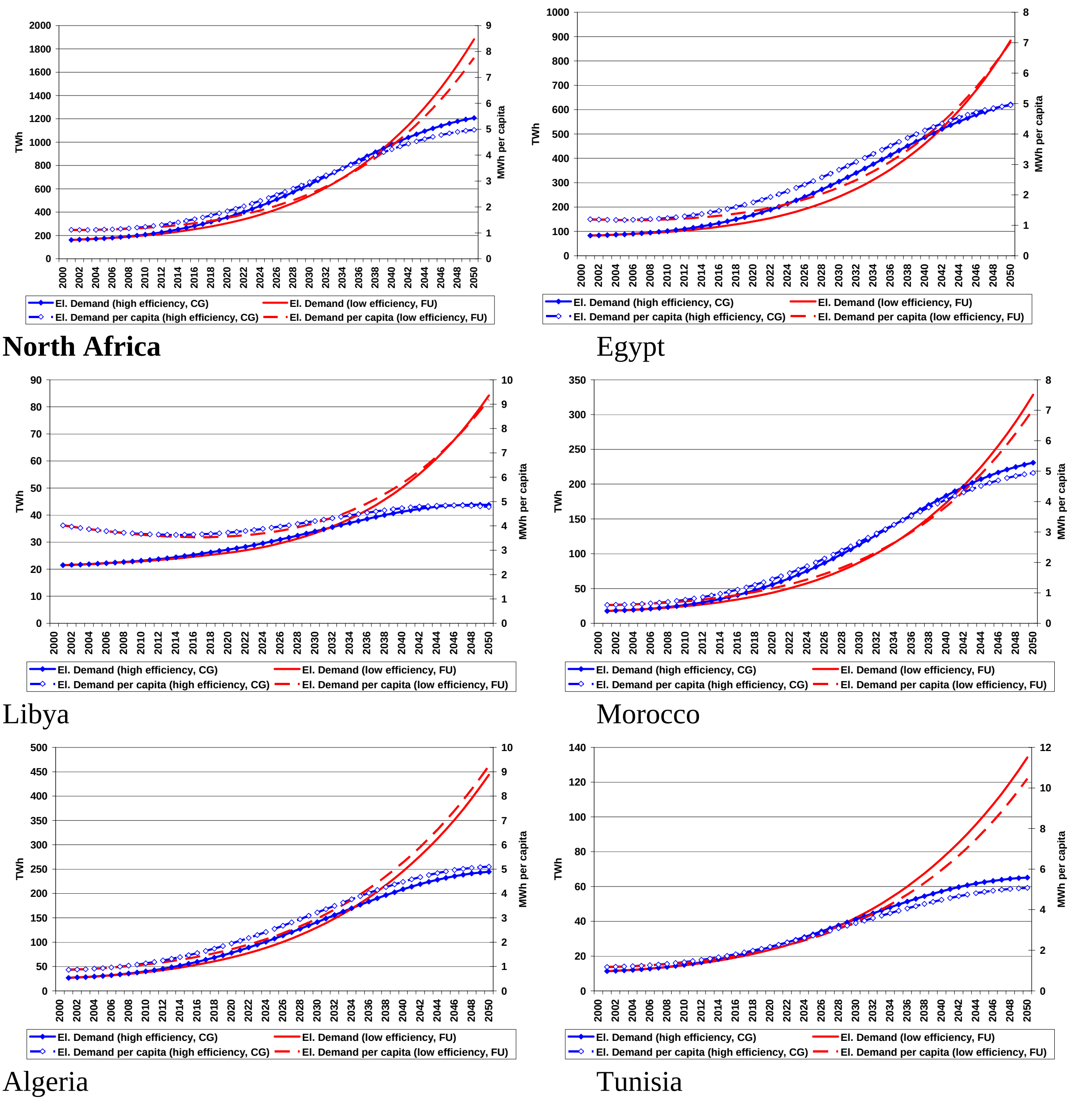
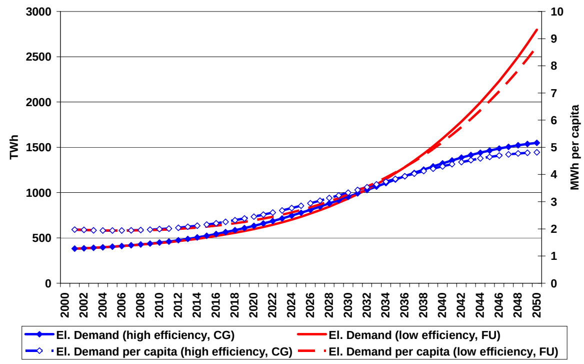
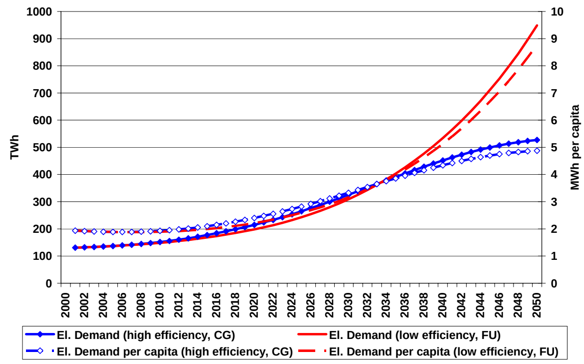


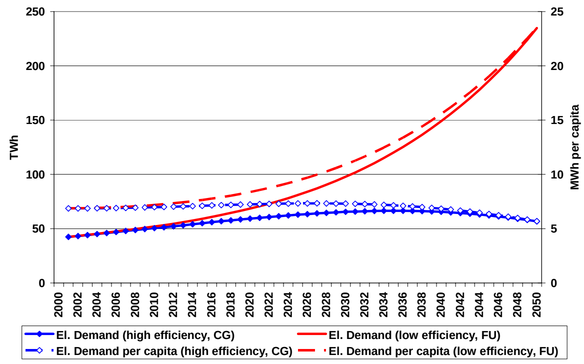
Figure A-6: Electricity demand and electricity demand per capita in North Africa and the North African countries according to the scenarios CG/HE and FU/LE.



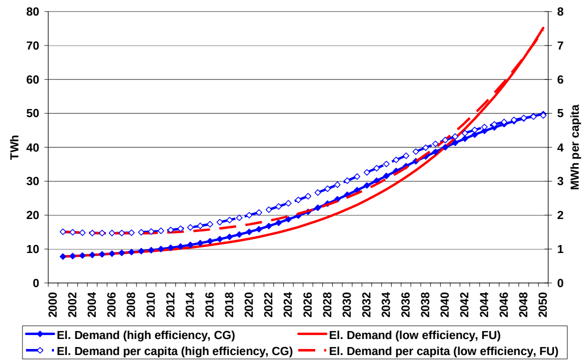
Western Asia



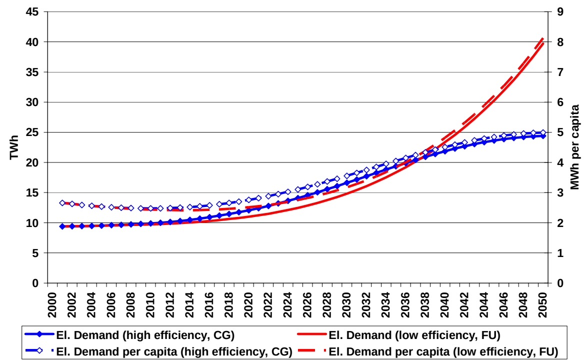
Iran



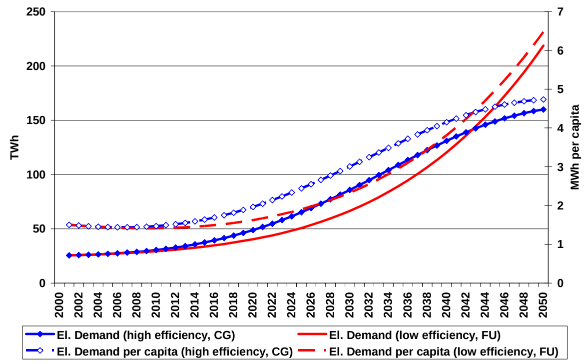
Israel



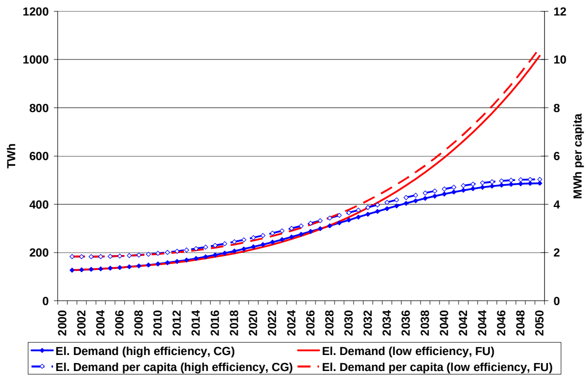
Jordan



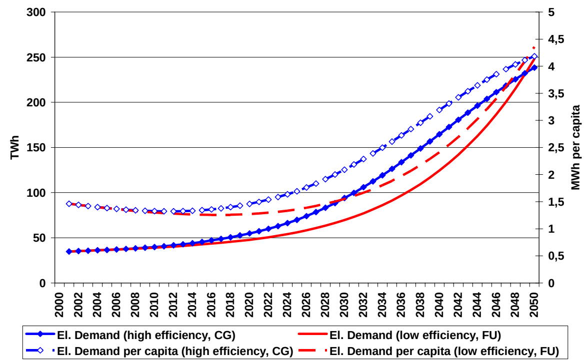
Lebanon



Syria

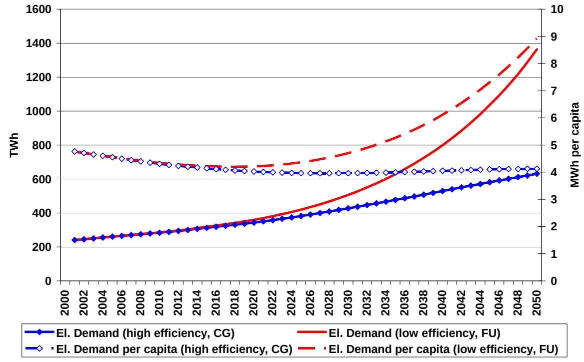


Turkey

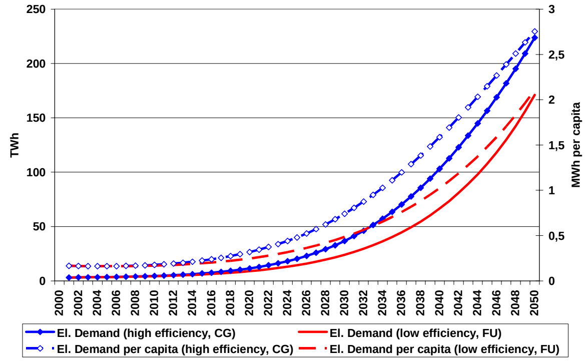


Iraq

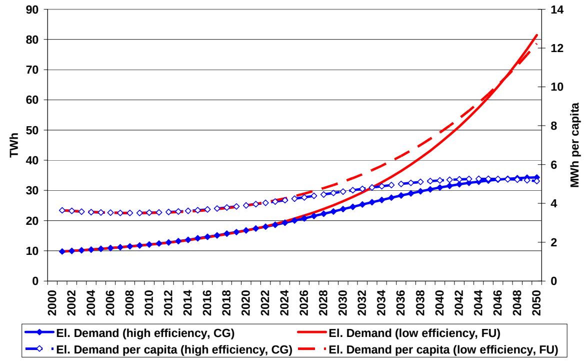
Figure A-7: Electricity demand and electricity demand per capita in Western Asia and the Western Asian countries according to the scenarios CG/HE and FU/LE.



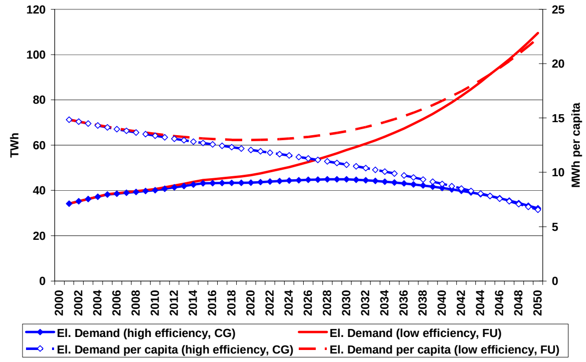
Arabian Peninsula



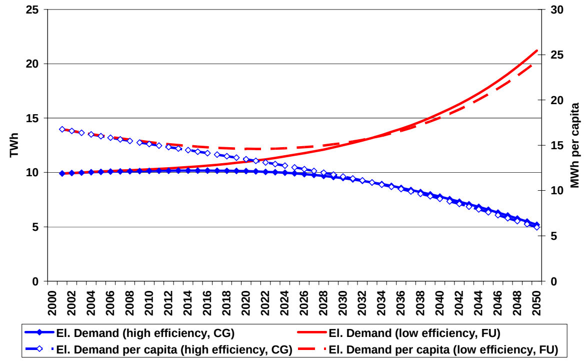
Yemen



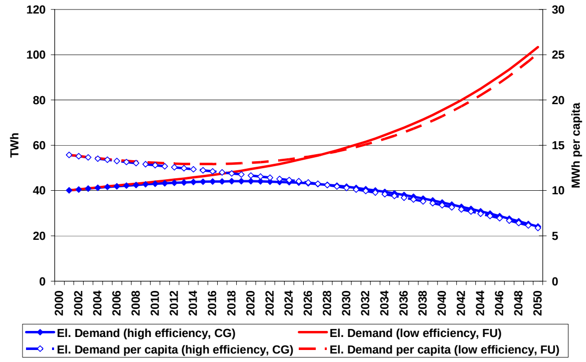
Oman



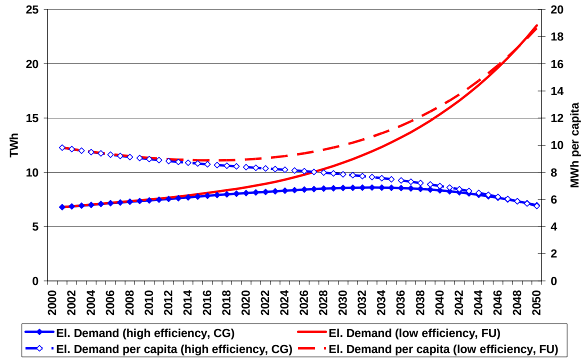
Kuwait



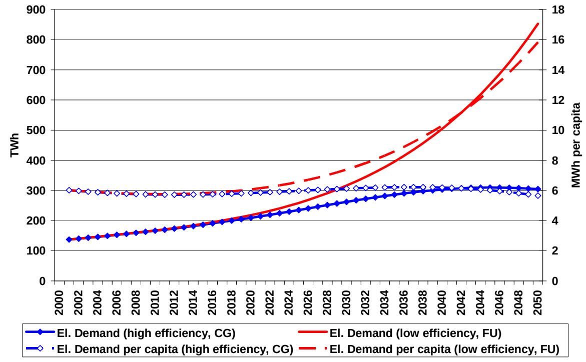
Qatar



UAE



Bahrain



Saudi Arabia

Figure A-8**:** Electricity demand and electricity demand per capita on the Arabian Peninsula according to the scenarios CG/HE and FU/LE.

Annex 4: Water Demand Structure and Projections until 2050

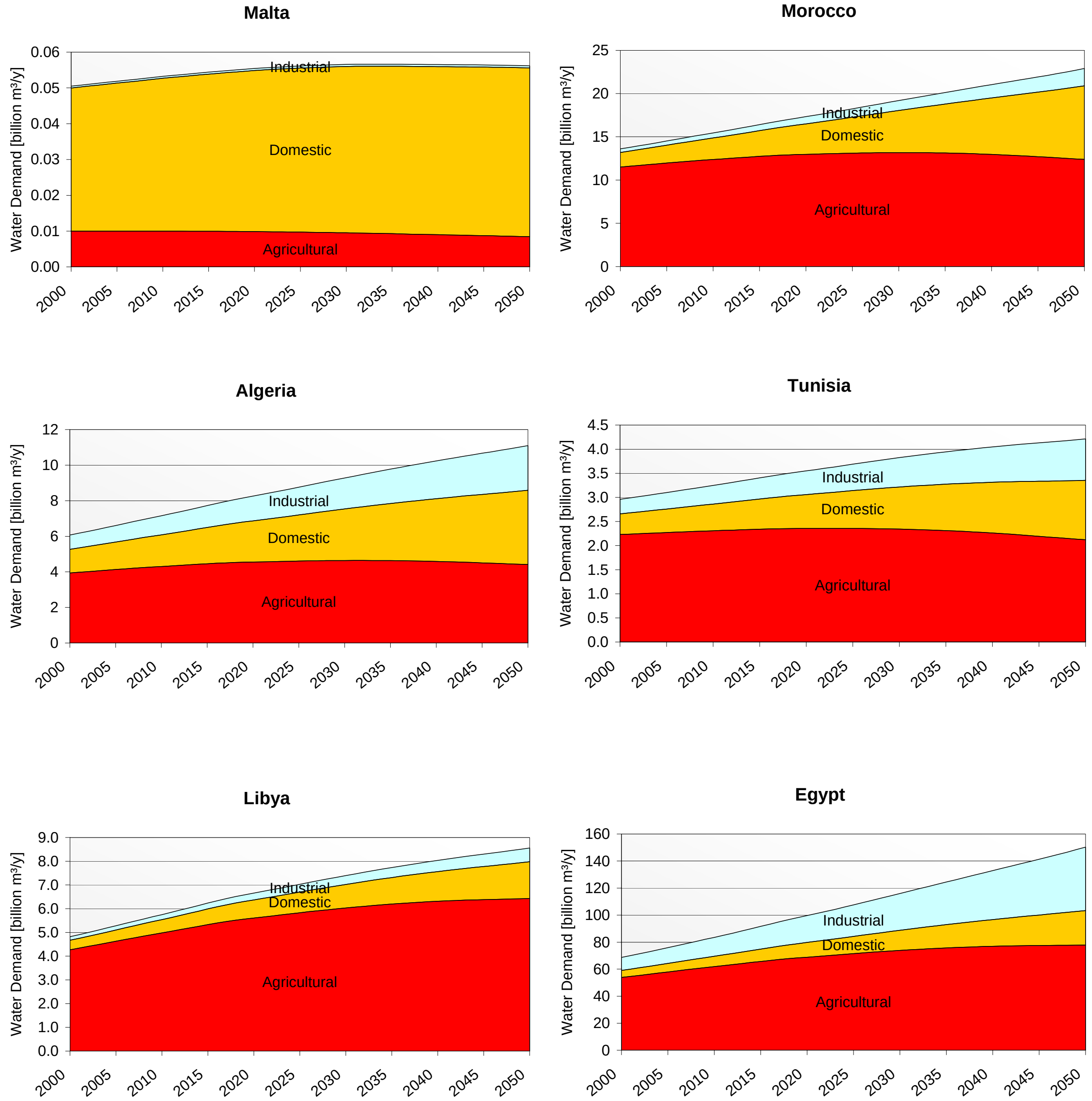


Figure A-9: Development of the water demand structure for the North African countries until 2050

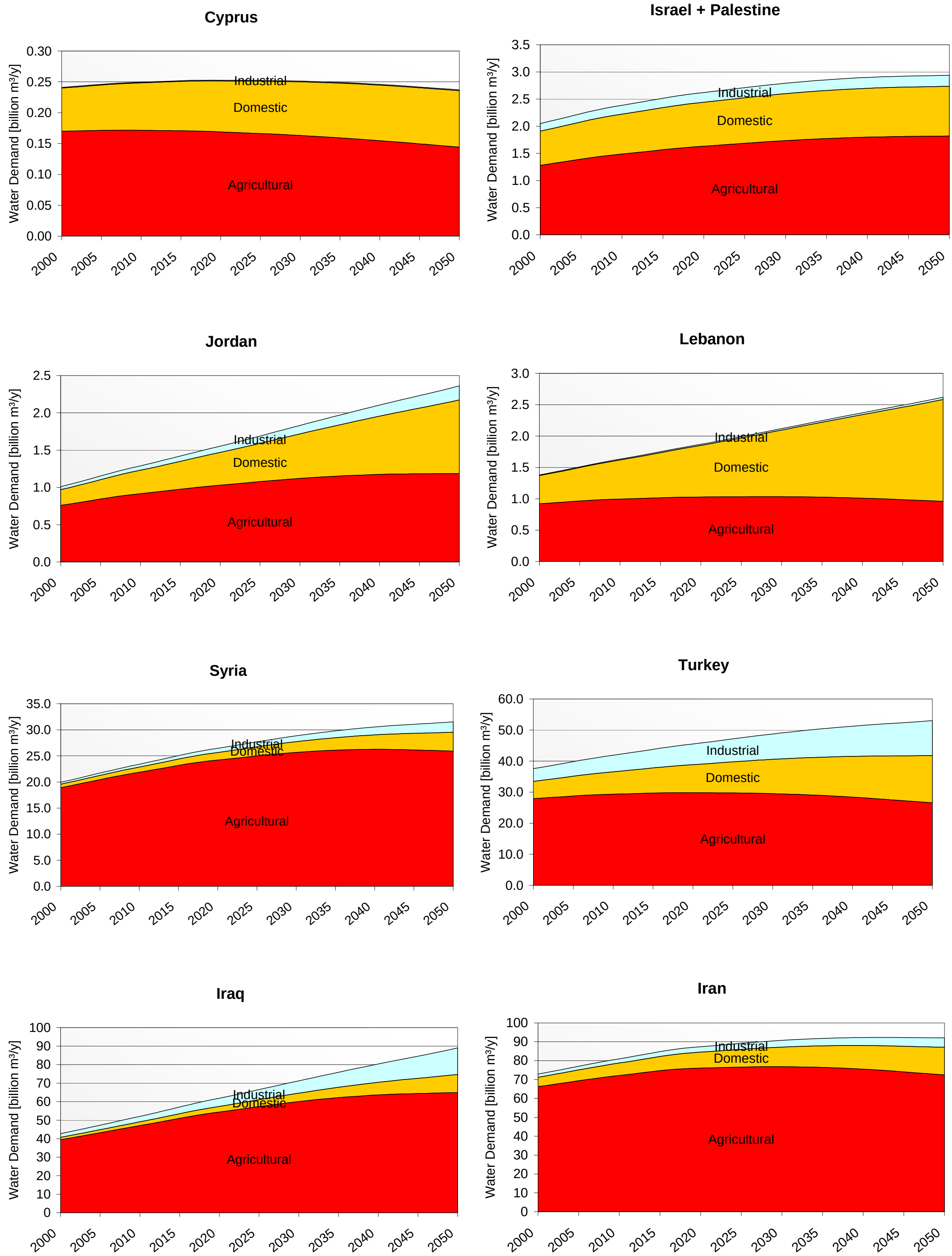


Figure A-10: Development of the water demand structure for the Western Asian countries until 2050

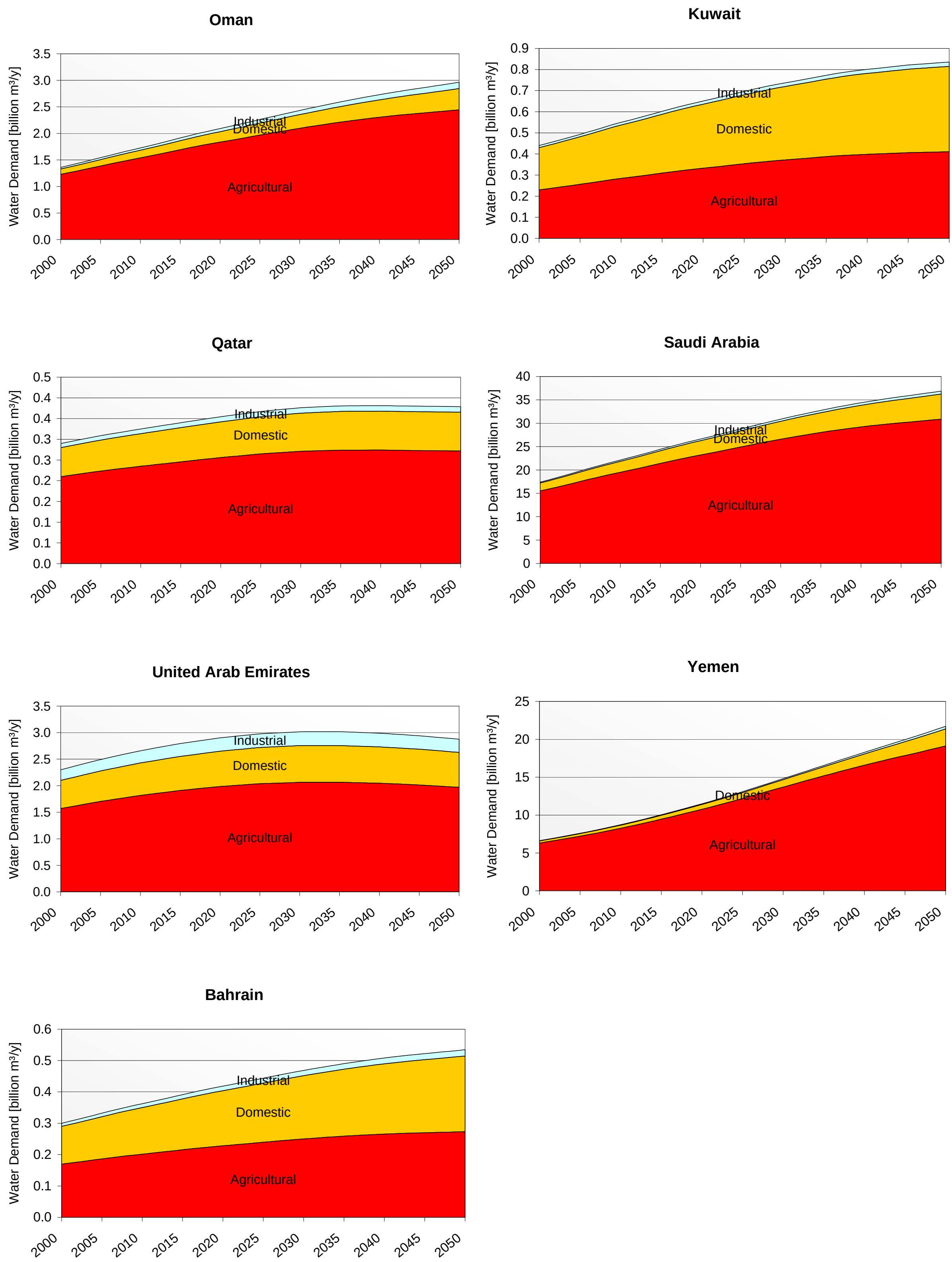
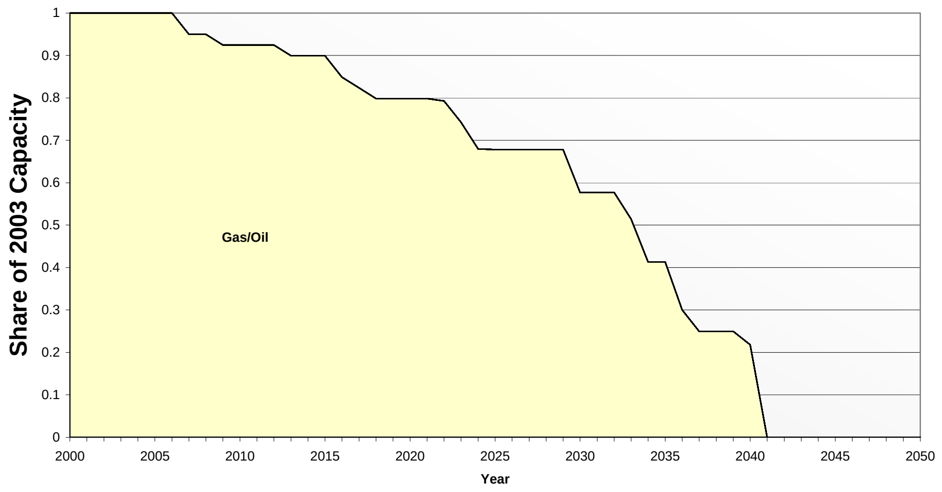


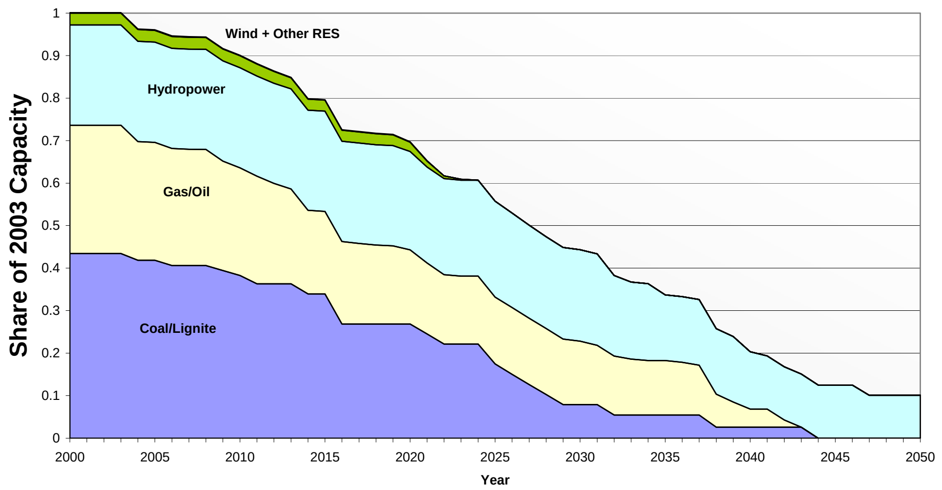
Figure A-11: Development of the water demand structure for the countries of the Arabian Peninsula until 2050

Annex 5: Life Curves of the National Power Plant Inventory and Projections until 2050

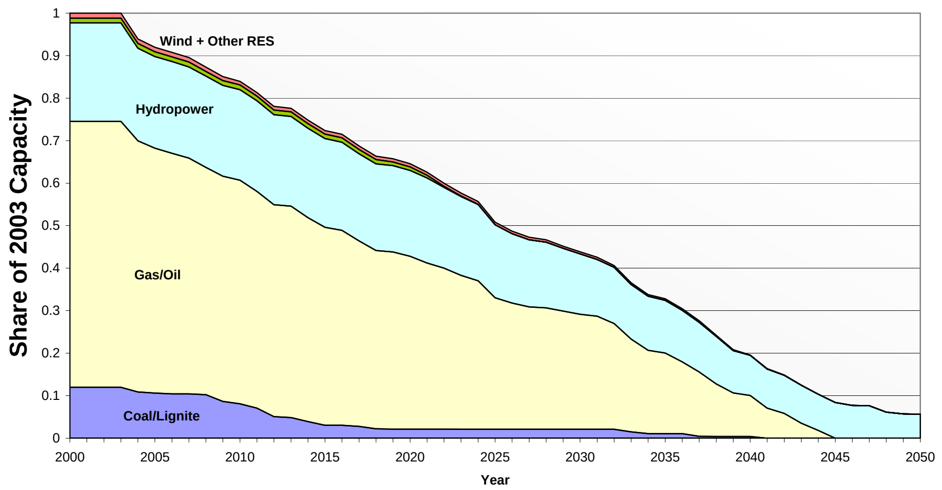
Old Power Plants in Cyprus since 2003
Total Capacity 2003 = 1 191 MW



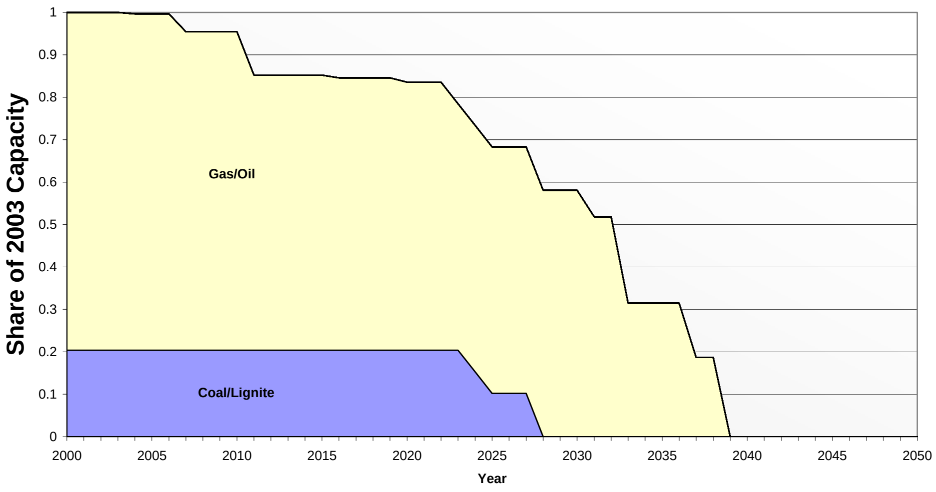
Old Power Plants in Greece since 2003
Total Capacity 2003 = 12 745 MW



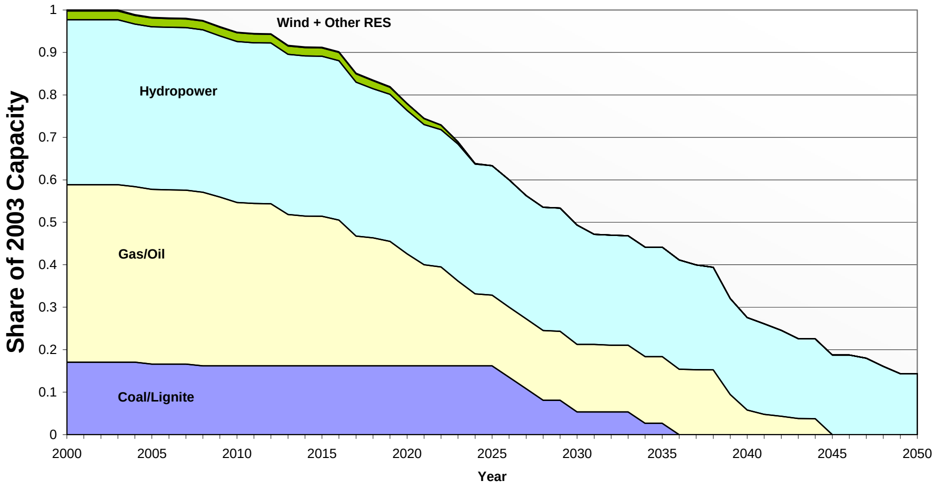
Old Power Plants in Italy since 2003
Total Capacity 2003 = 82 565 MW



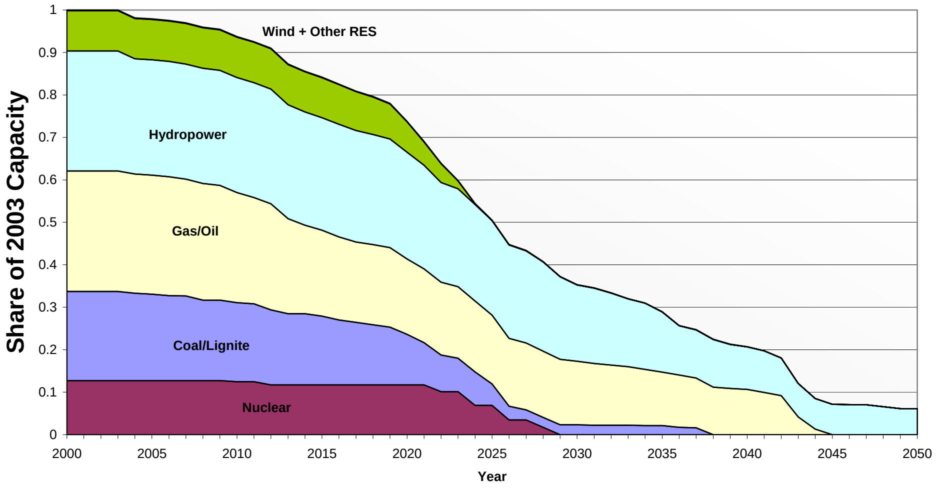
Old Power Plants in Malta since 2003
Total Capacity 2003 = 589 MW



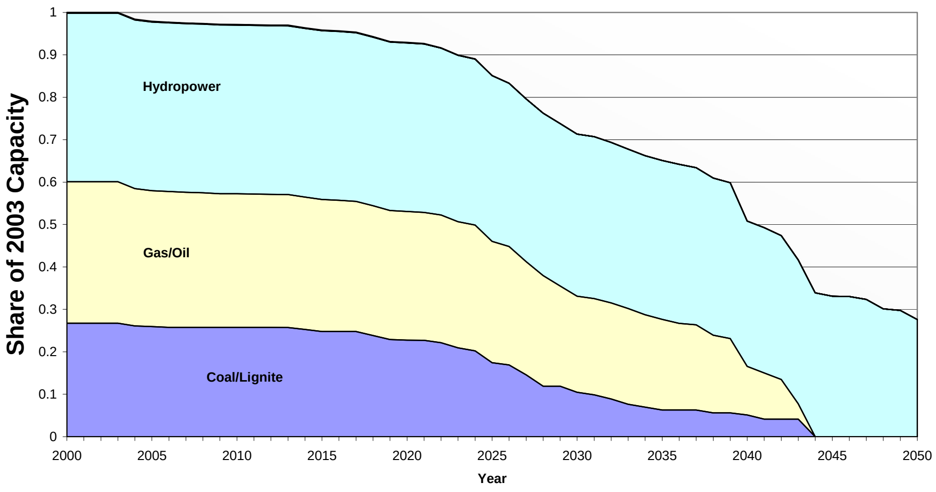
Old Power Plants in Portugal since 2003
Total Capacity 2003 = 11 524 MW



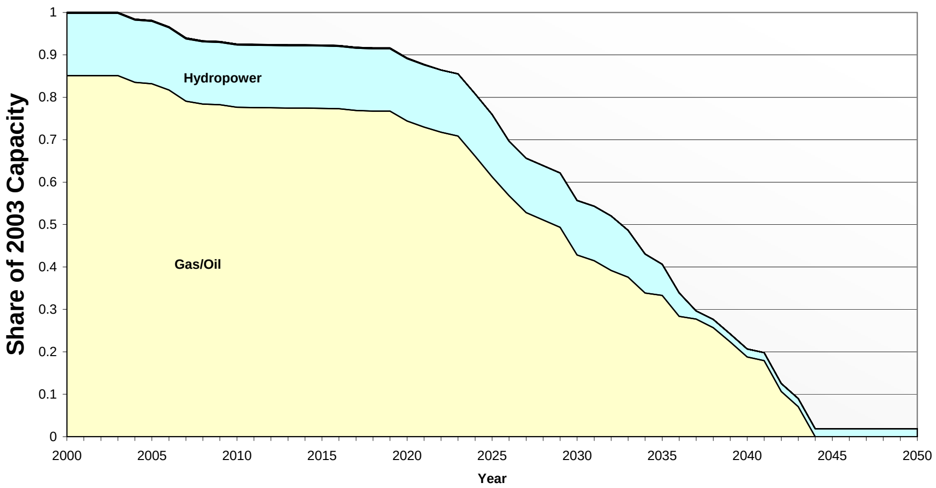
Old Power Plants in Spain since 2003
Total Capacity 2003 = 61 977 MW



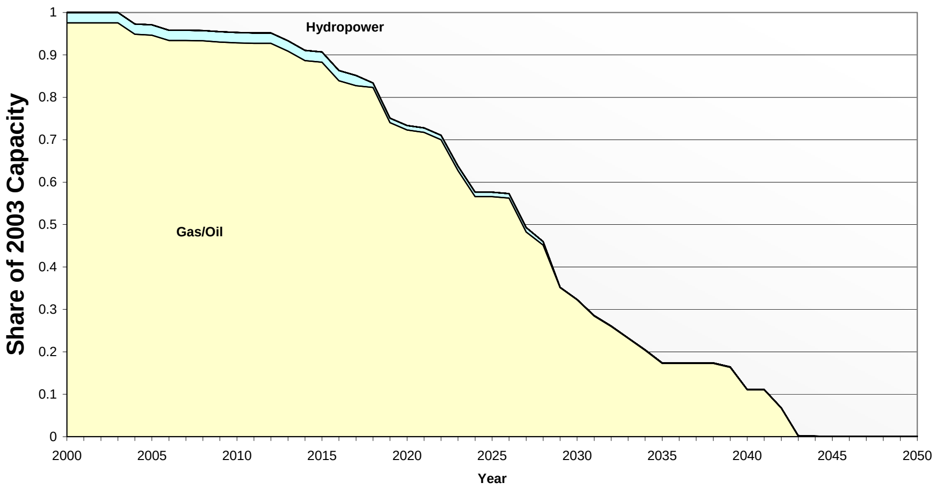
Old Power Plants in Turkey since 2003
Total Capacity 2003 = 31 786 MW

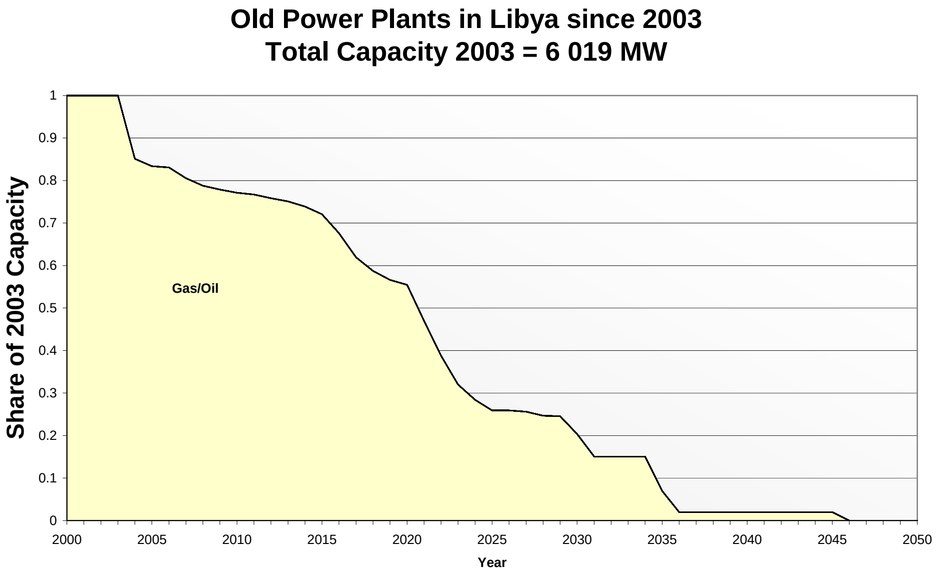


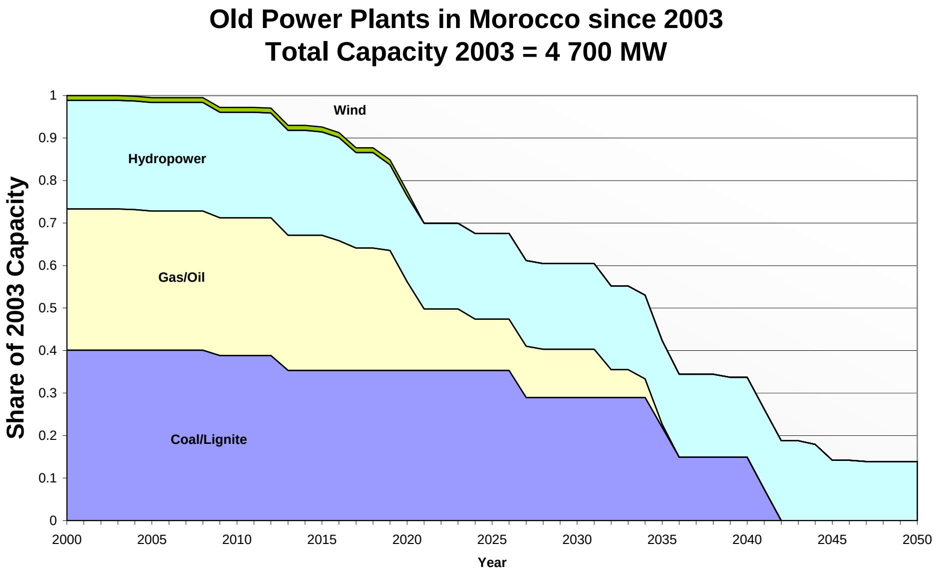
Old Power Plants in Egypt since 2003
Total Capacity 2003 = 19 180 MW

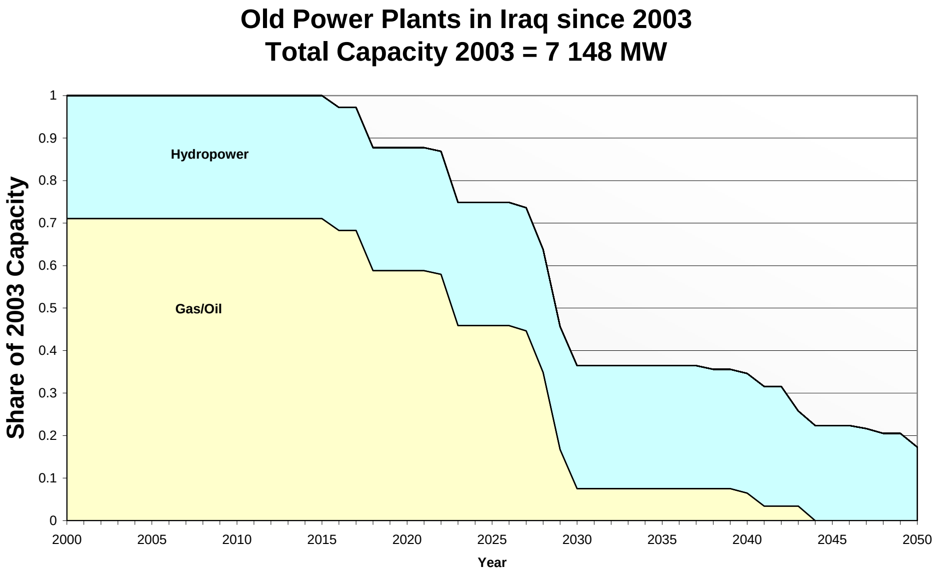


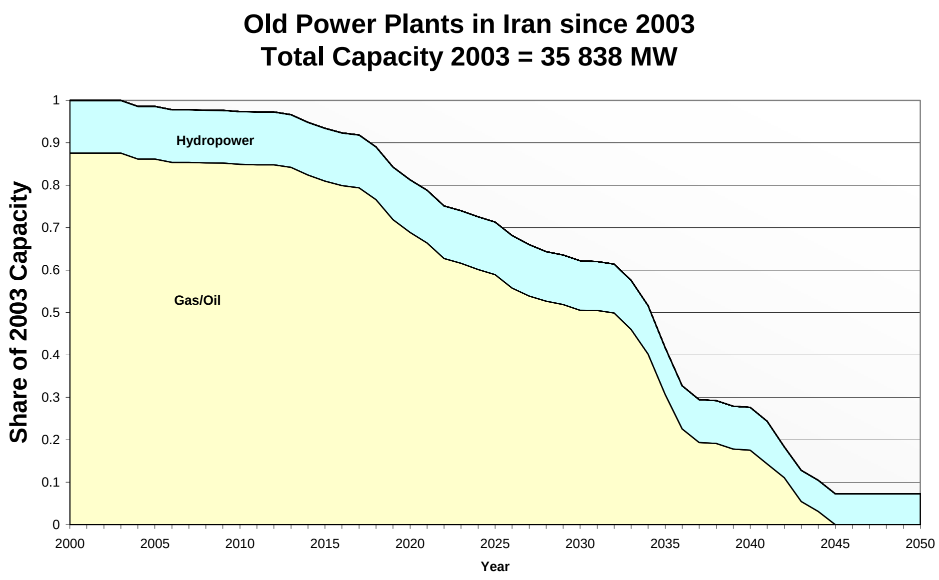
Old Power Plants in Algeria since 2003
Total Capacity 2003 = 6 969 MW

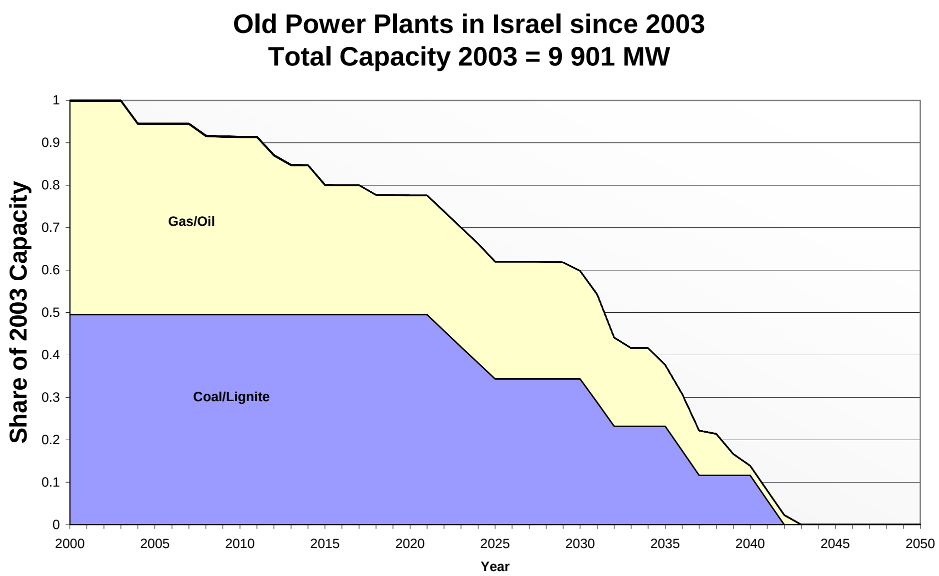


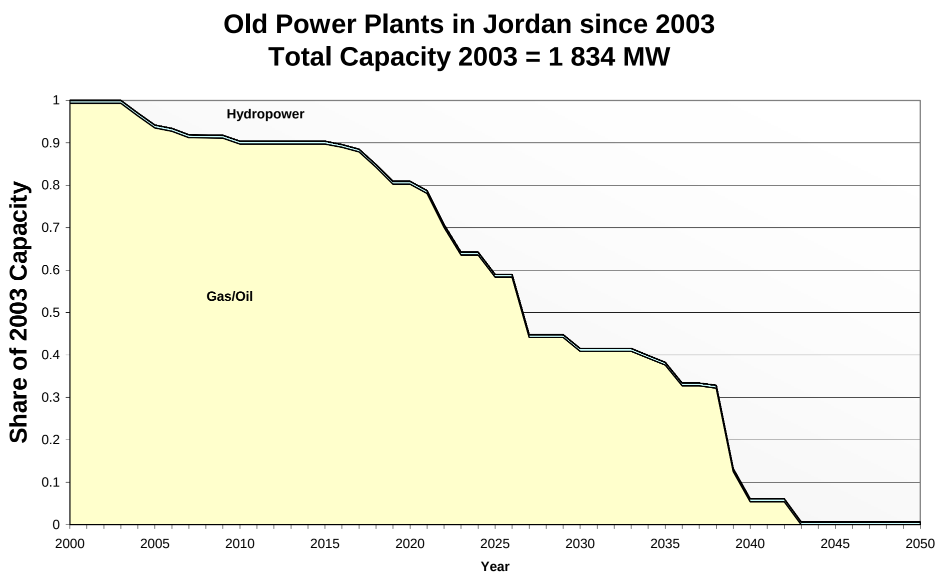

Old Power Plants in Libya since 2003
Total Capacity 2003 = 6 019 MW
Share of 2003 Capacity
Gas/Oil
Year
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050

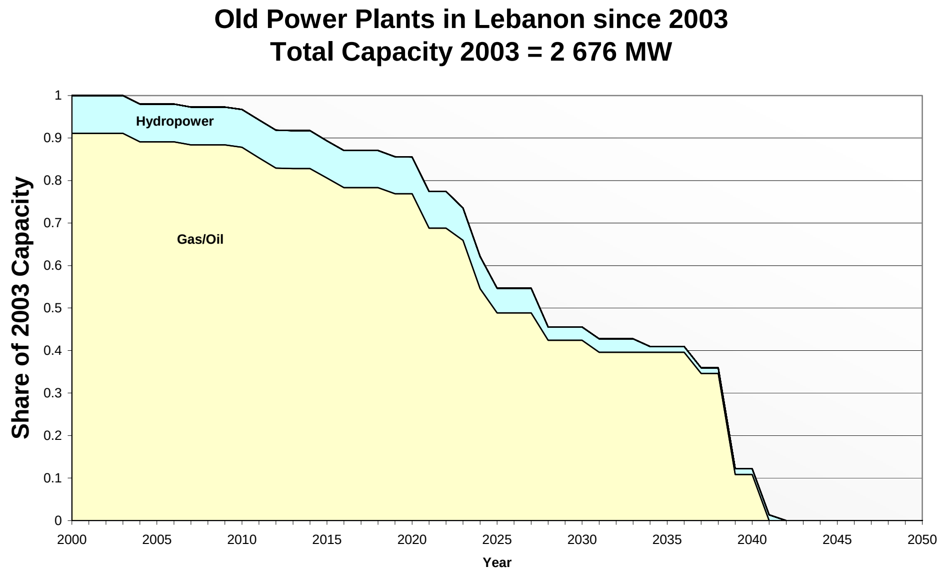

Old Power Plants in Morocco since 2003
Total Capacity 2003 = 4 700 MW
Share of 2003 Capacity
Wind
Hydropower
Gas/Oil
Coal/Lignite
Year
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050

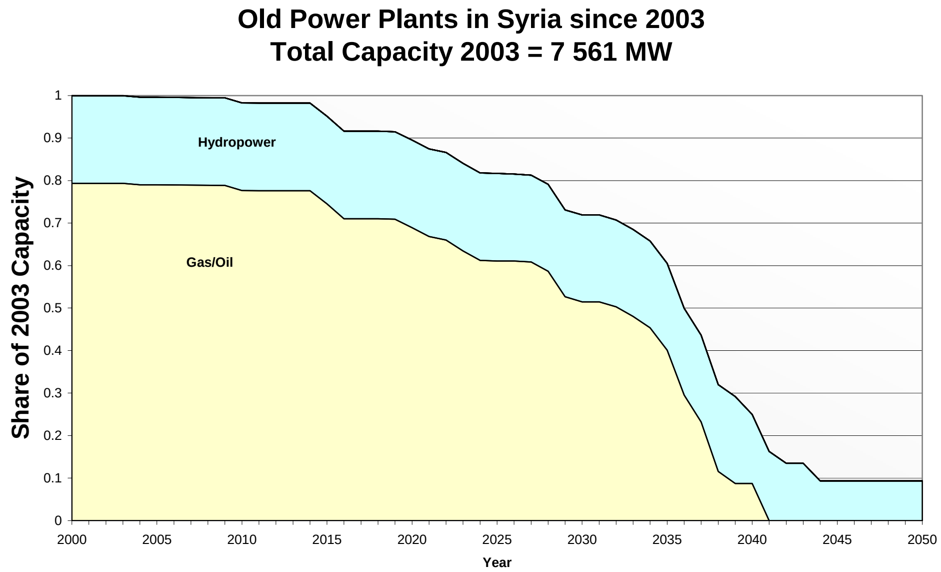

Old Power Plants in Iraq since 2003
Total Capacity 2003 = 7 148 MW
Share of 2003 Capacity
Hydropower
Gas/Oil
Year
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050

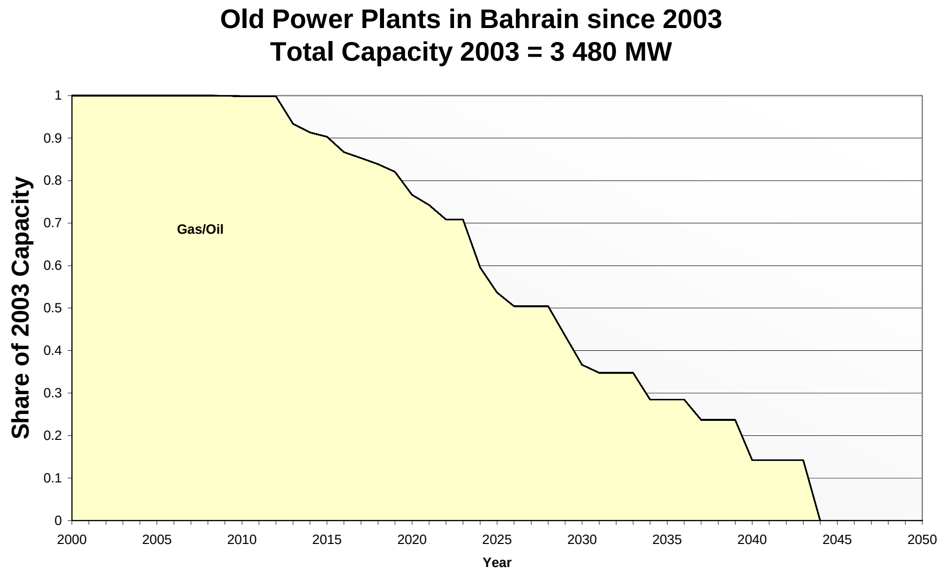

Old Power Plants in Iran since 2003
Total Capacity 2003 = 35 838 MW
Hydropower
Gas/Oil
Share of 2003 Capacity
Year
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050

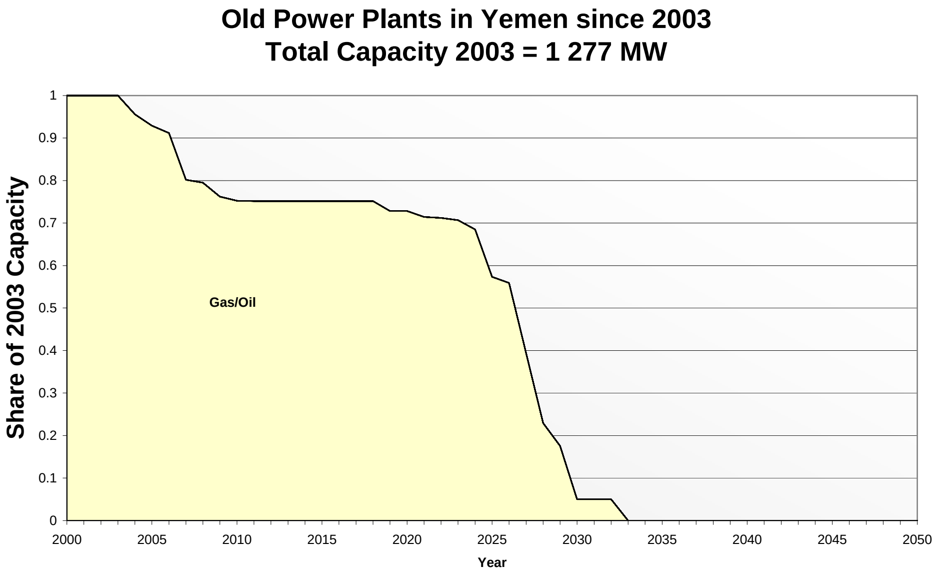

Old Power Plants in Israel since 2003
Total Capacity 2003 = 9 901 MW
Gas/Oil
Coal/Lignite
Share of 2003 Capacity
Year
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050

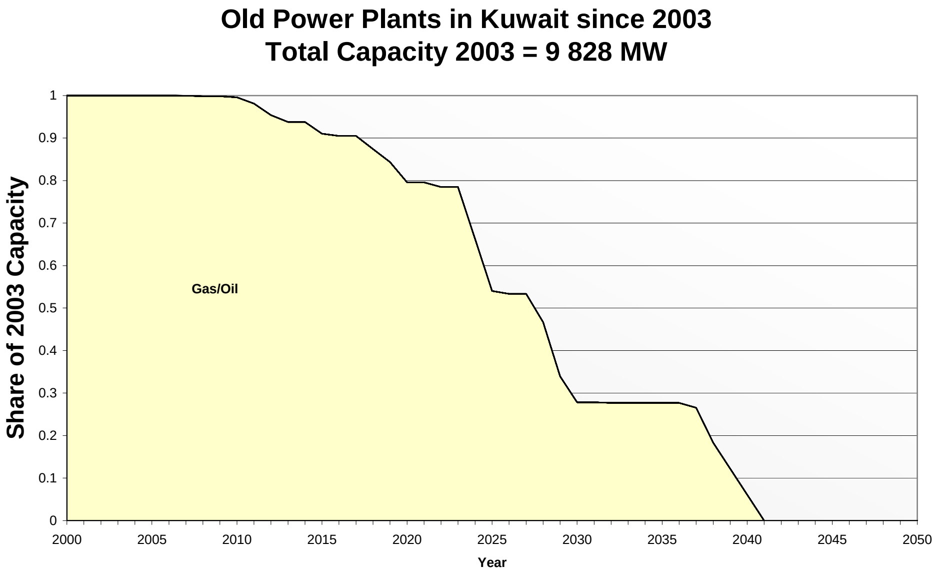

Old Power Plants in Jordan since 2003
Total Capacity 2003 = 1 834 MW
Hydropower
Gas/Oil
Share of 2003 Capacity
Year
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050

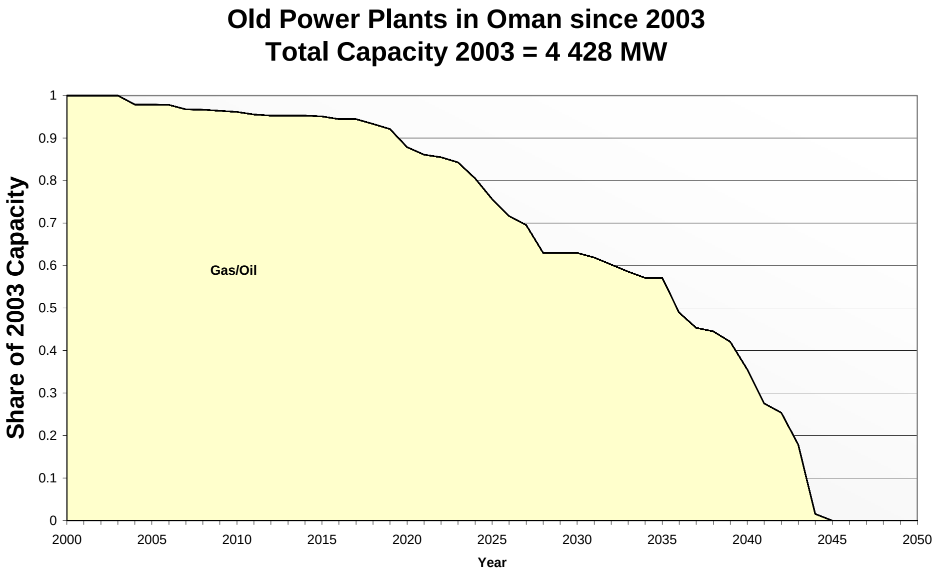

Old Power Plants in Lebanon since 2003
Total Capacity 2003 = 2 676 MW
Hydropower
Gas/Oil
Share of 2003 Capacity
Year


Old Power Plants in Syria since 2003
Total Capacity 2003 = 7 561 MW
Hydropower
Gas/Oil
Share of 2003 Capacity
Year

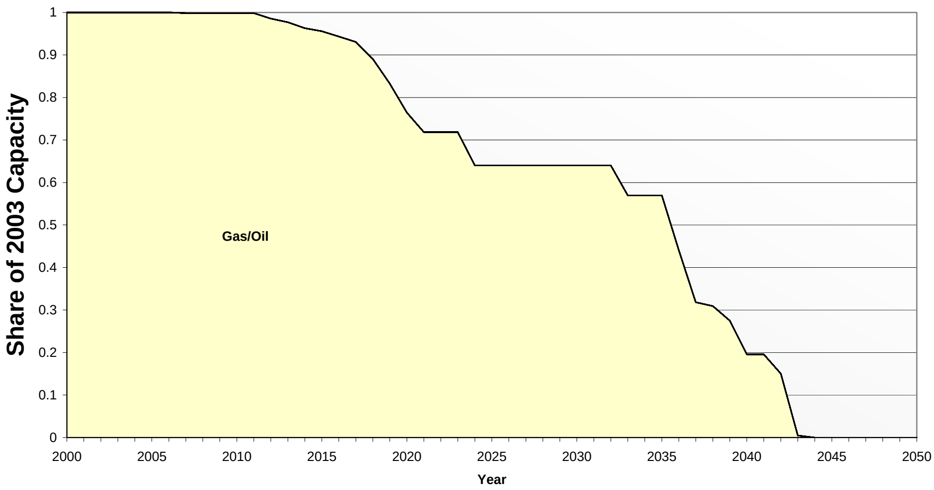

Old Power Plants in Bahrain since 2003
Total Capacity 2003 = 3 480 MW
Gas/Oil
Share of 2003 Capacity
Year


Old Power Plants in Yemen since 2003
Total Capacity 2003 = 1 277 MW
Share of 2003 Capacity
Gas/Oil
Year

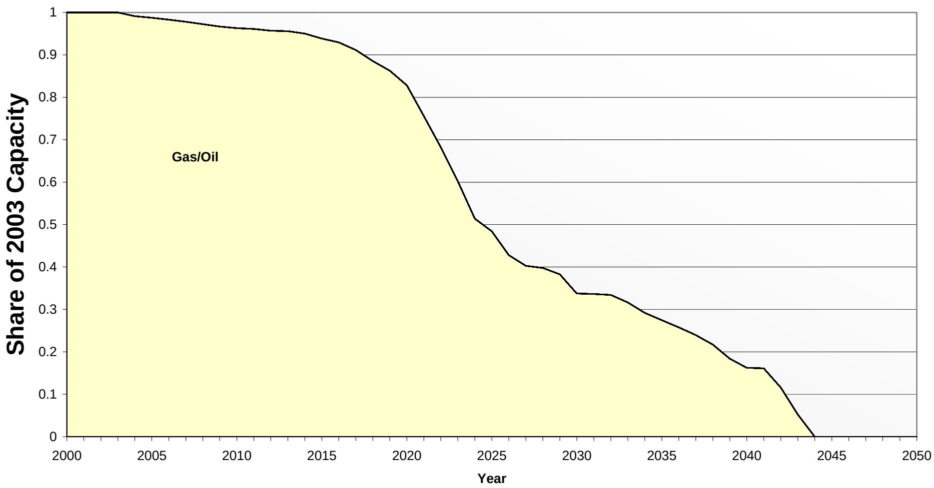

Old Power Plants in Kuwait since 2003
Total Capacity 2003 = 9 828 MW
Share of 2003 Capacity
Gas/Oil
Year


Old Power Plants in Oman since 2003
Total Capacity 2003 = 4 428 MW
Share of 2003 Capacity
Gas/Oil
Year

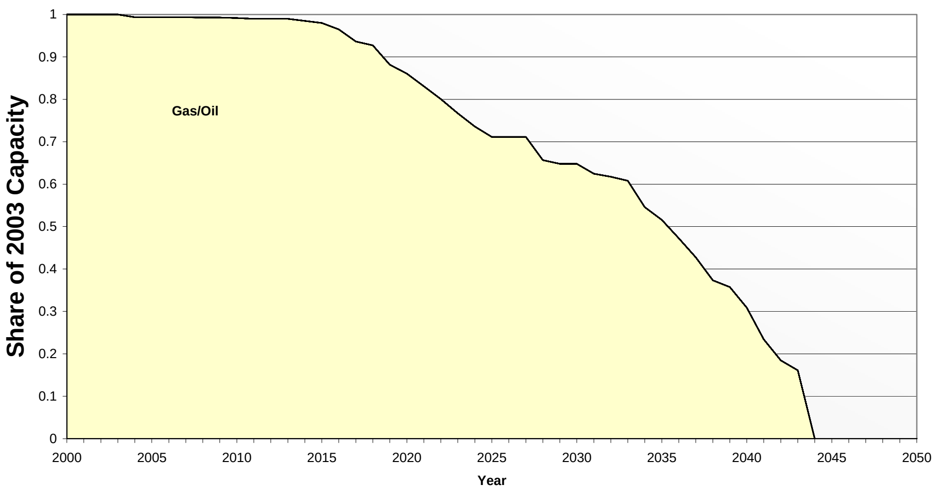
Old Power Plants in Quatar since 2003
Total Capacity 2003 = 3 408 MW



Old Power Plants in Saudi Arabia since 2003
Total Capacity 2003 = 37 300 MW



Old Power Plants in United Arabian Emirates since 2003
Total Capacity 2003 = 18 539 MW



Annex 6: Electricity Generation, Installed Capacity, Electricity Cost and Carbon Dioxide Emissions of the Scenario CG/HE and Projections until 2050

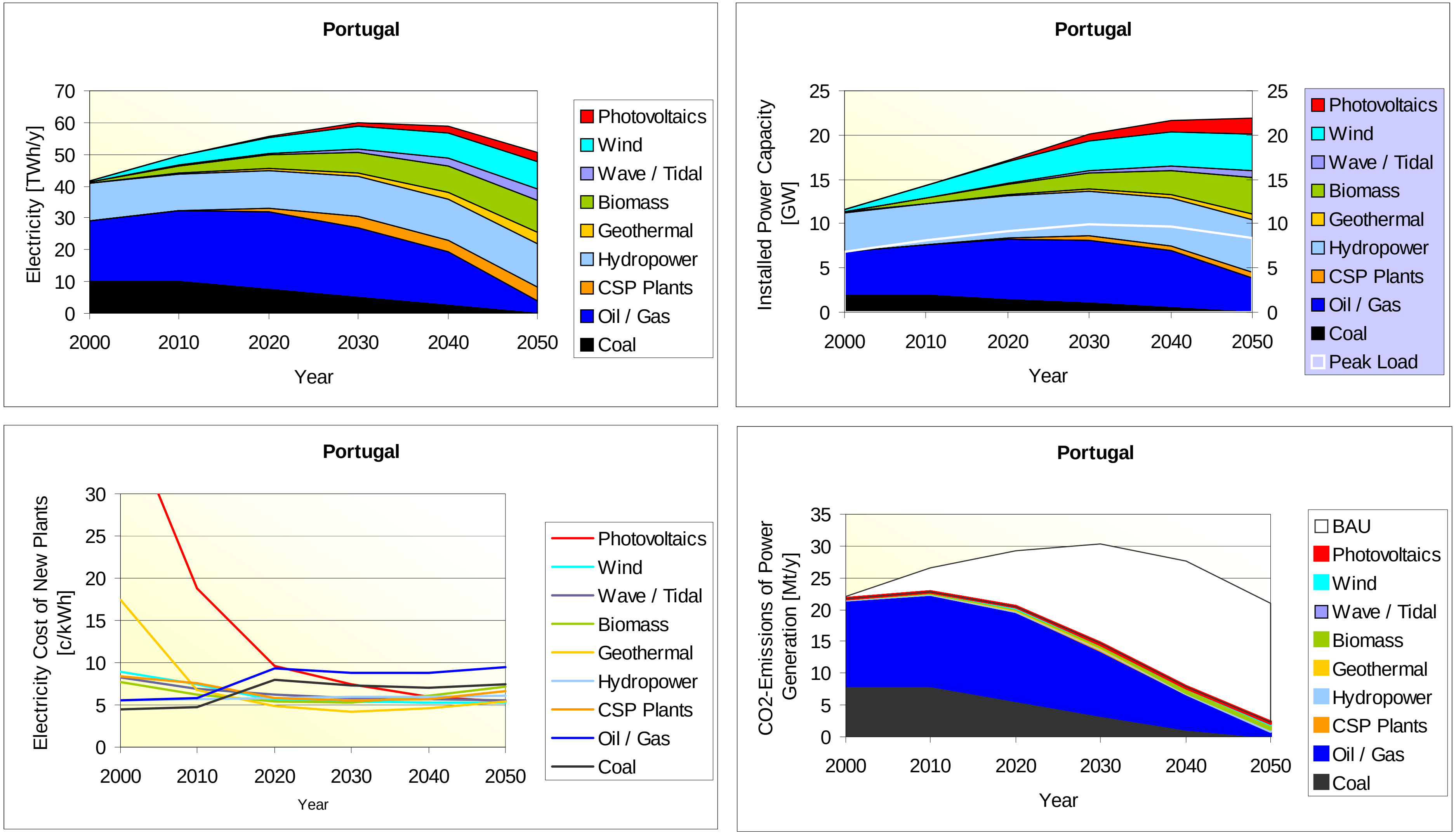


Figure A-12: Scenario CG/HE for Portugal

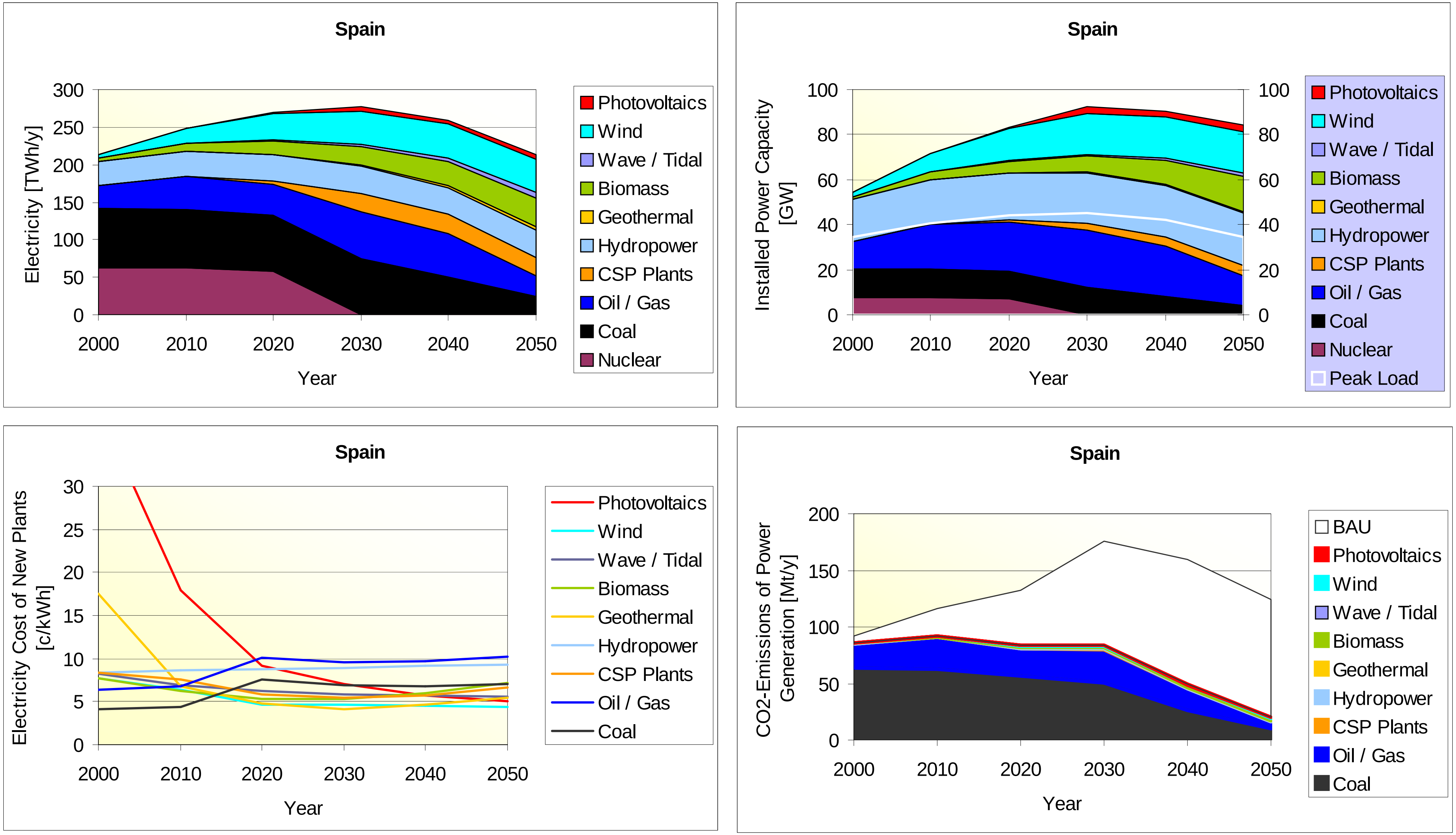


Figure A-13: Scenario CG/HE for Spain

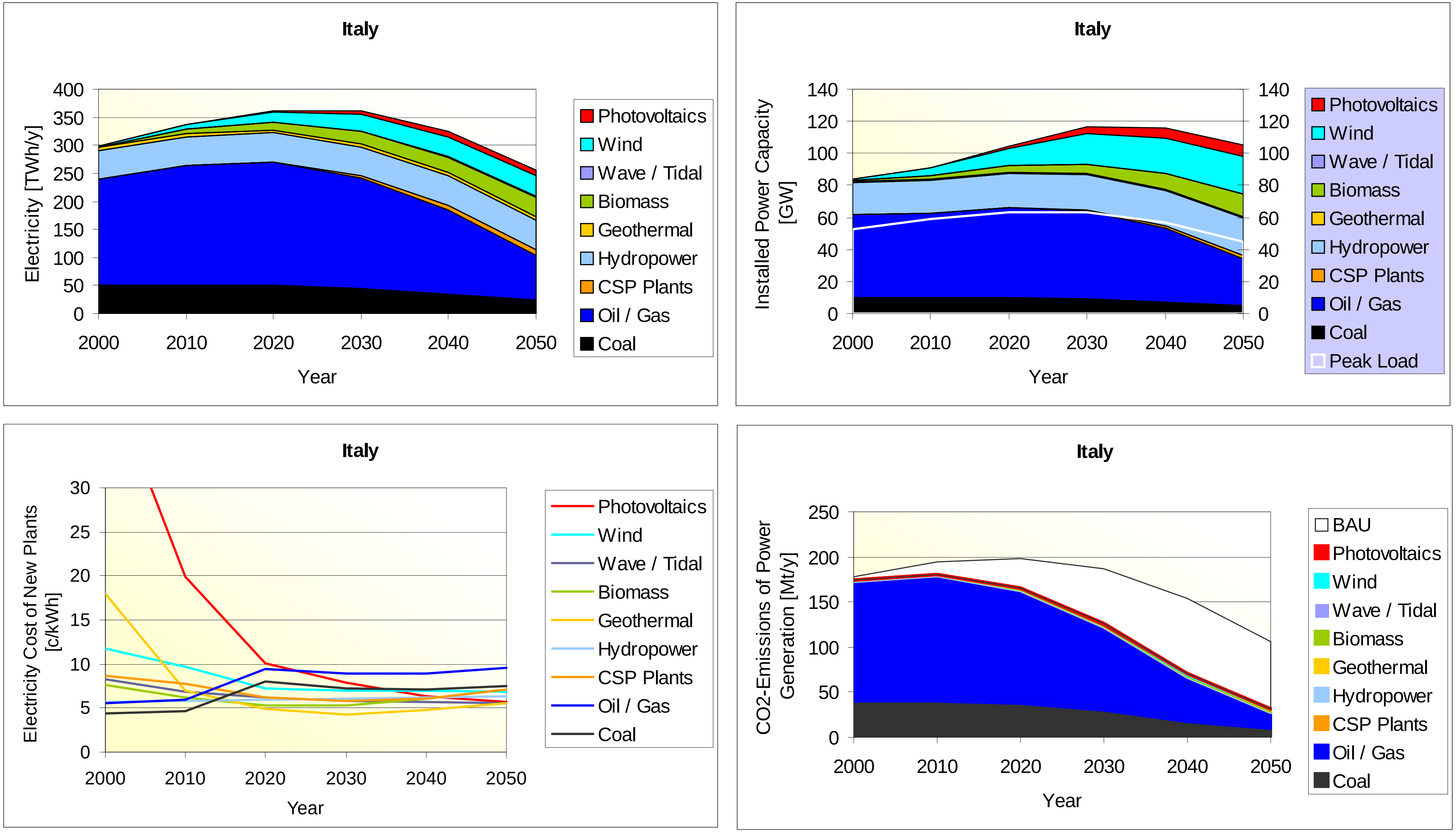


Figure A-14: Scenario CG/HE for Italy

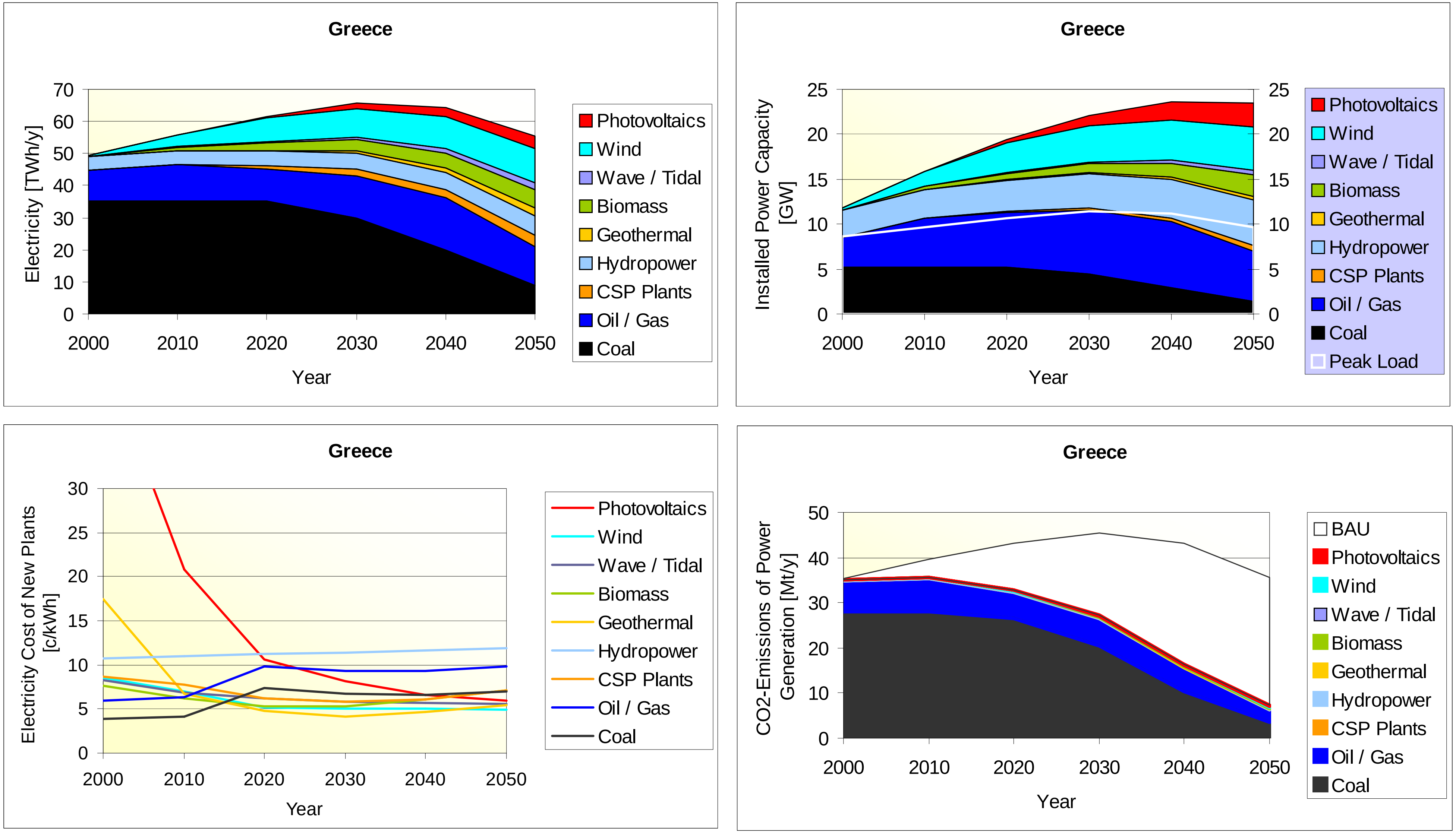


Figure A-15: Scenario CG/HE for Greece

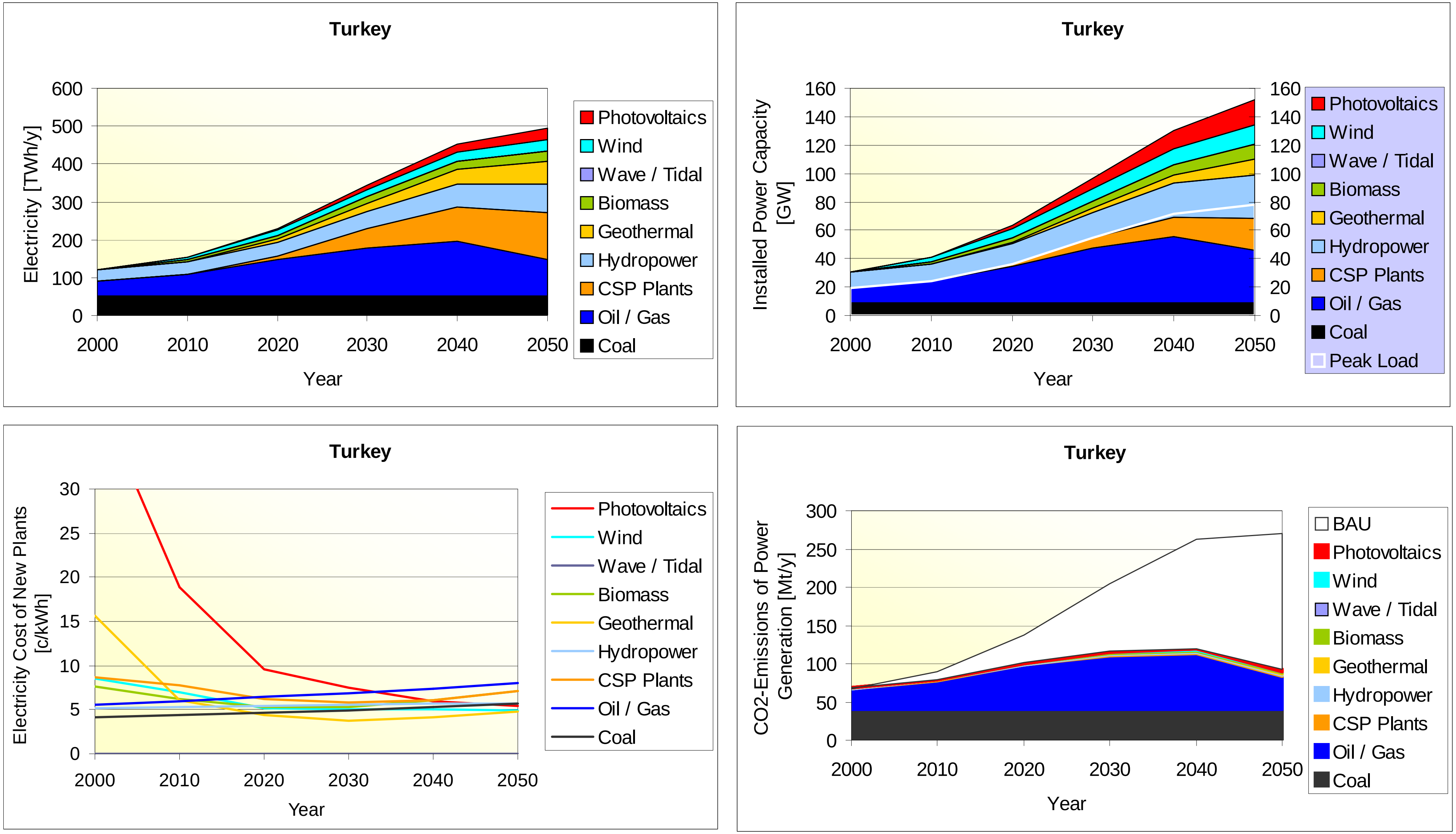


Figure A-16: Scenario CG/HE for Turkey

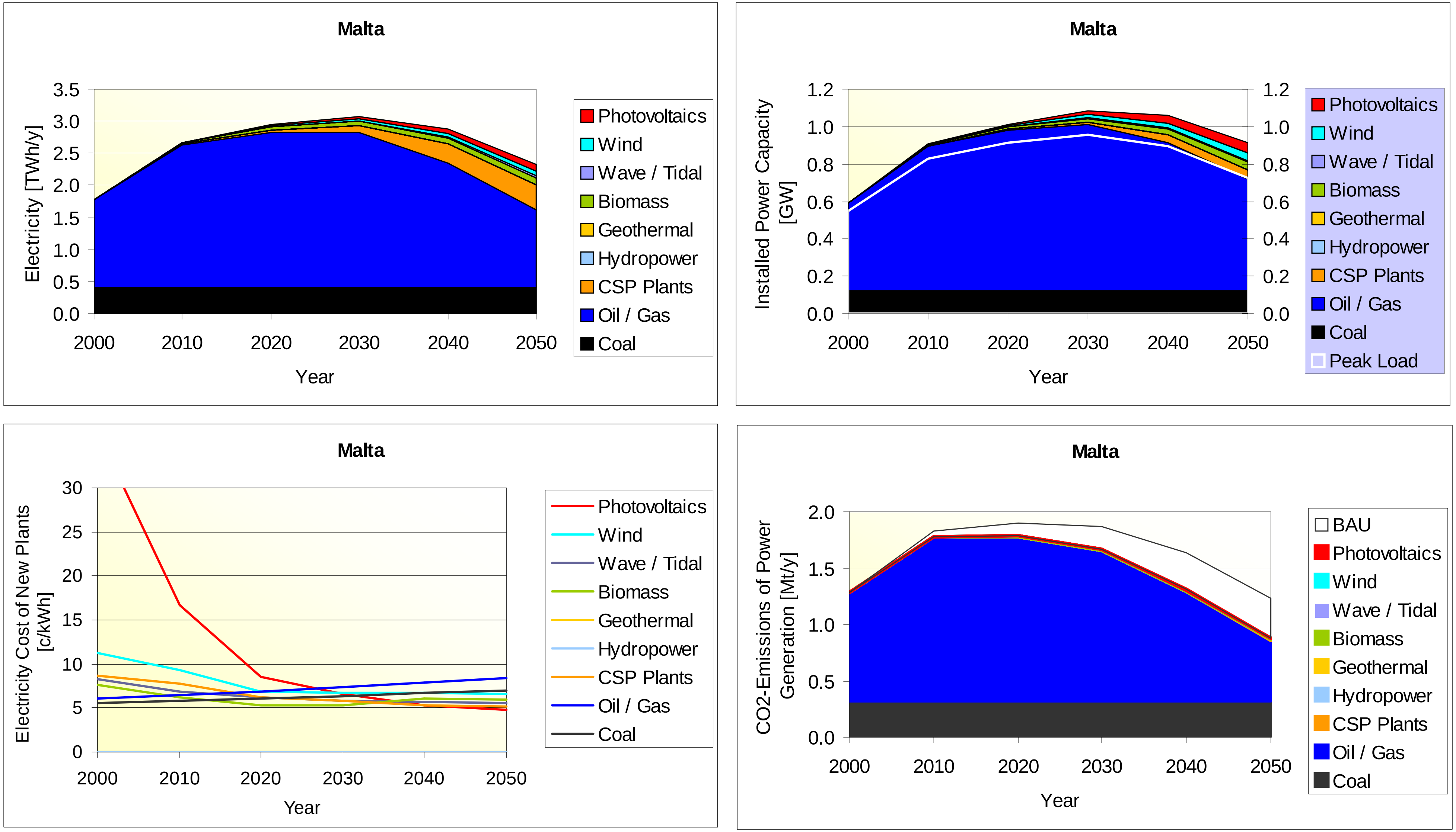


Figure A-17: Scenario CG/HE for Malta

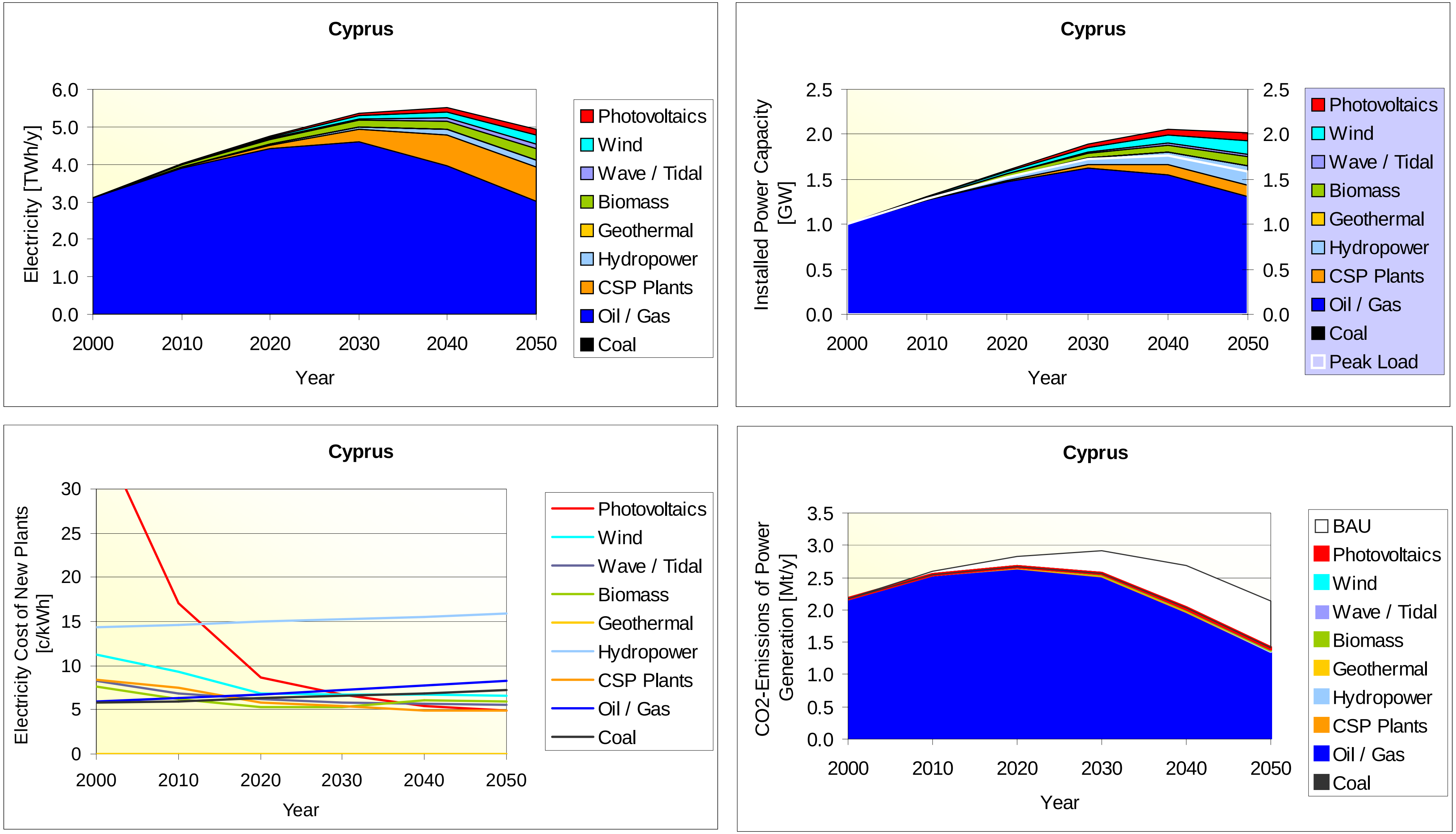


Figure A-18: Scenario CG/HE for Cyprus

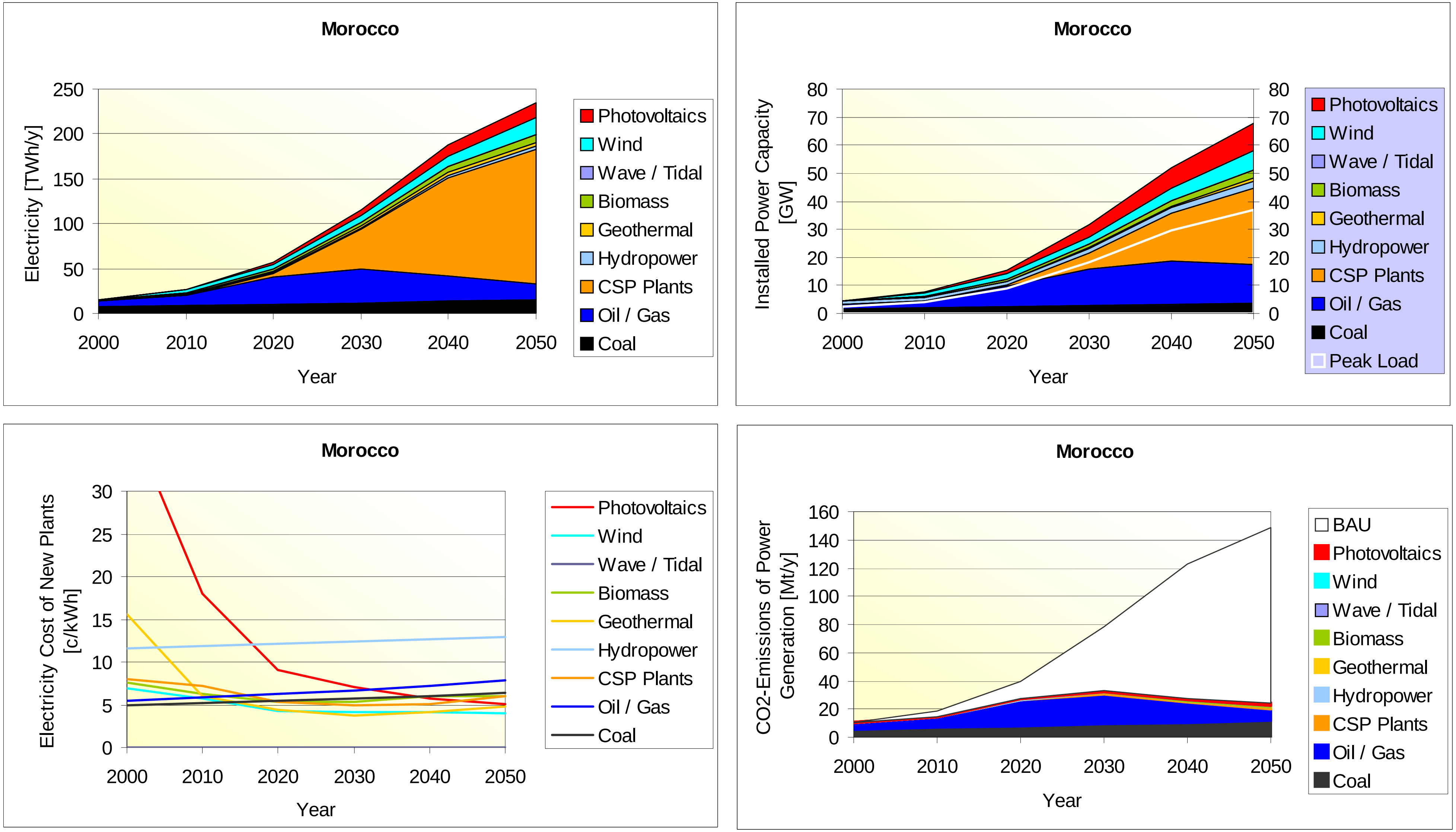


Figure A-19: Scenario CG/HE for Morocco

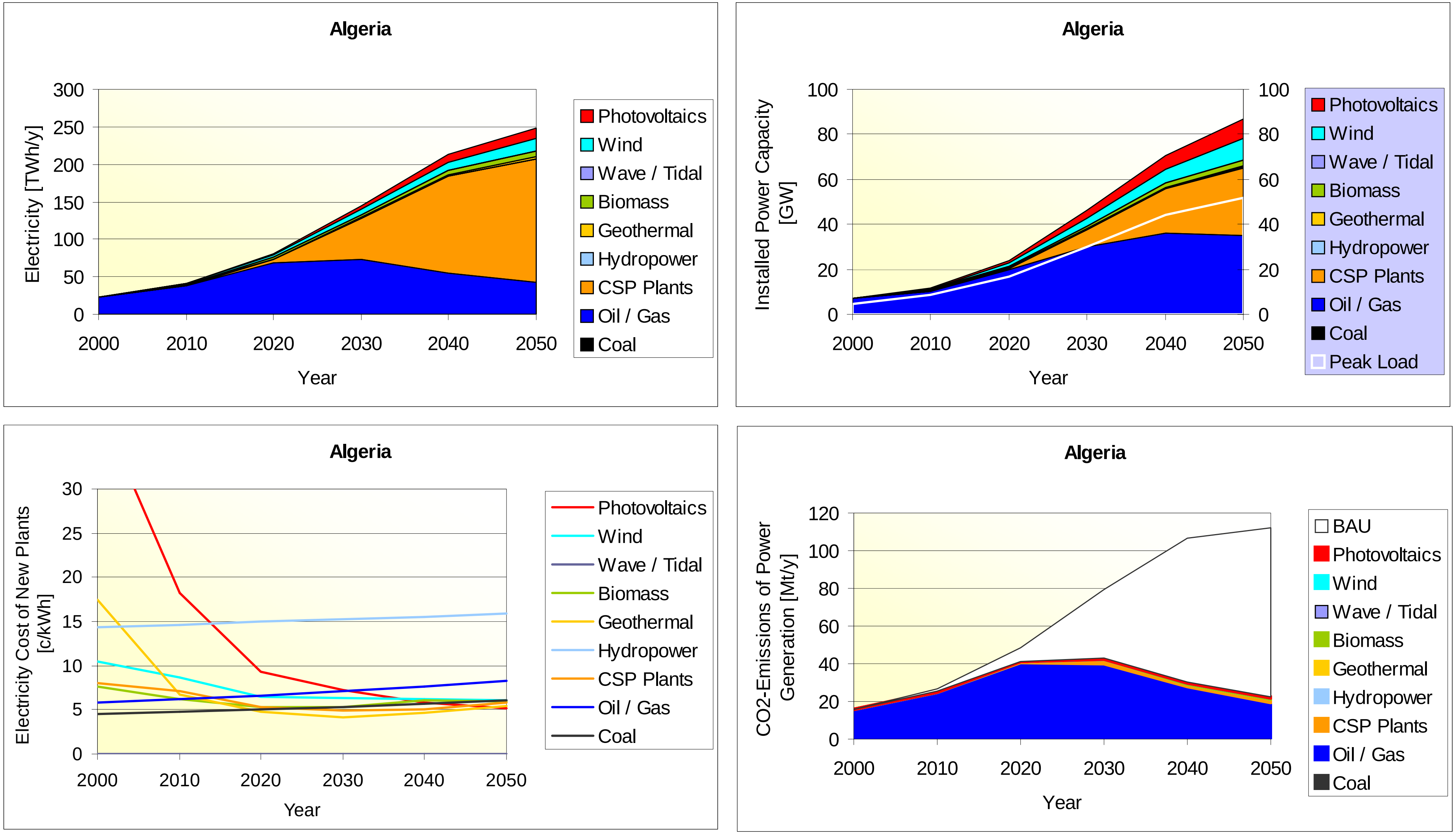


Figure A-20: Scenario CG/HE for Algeria

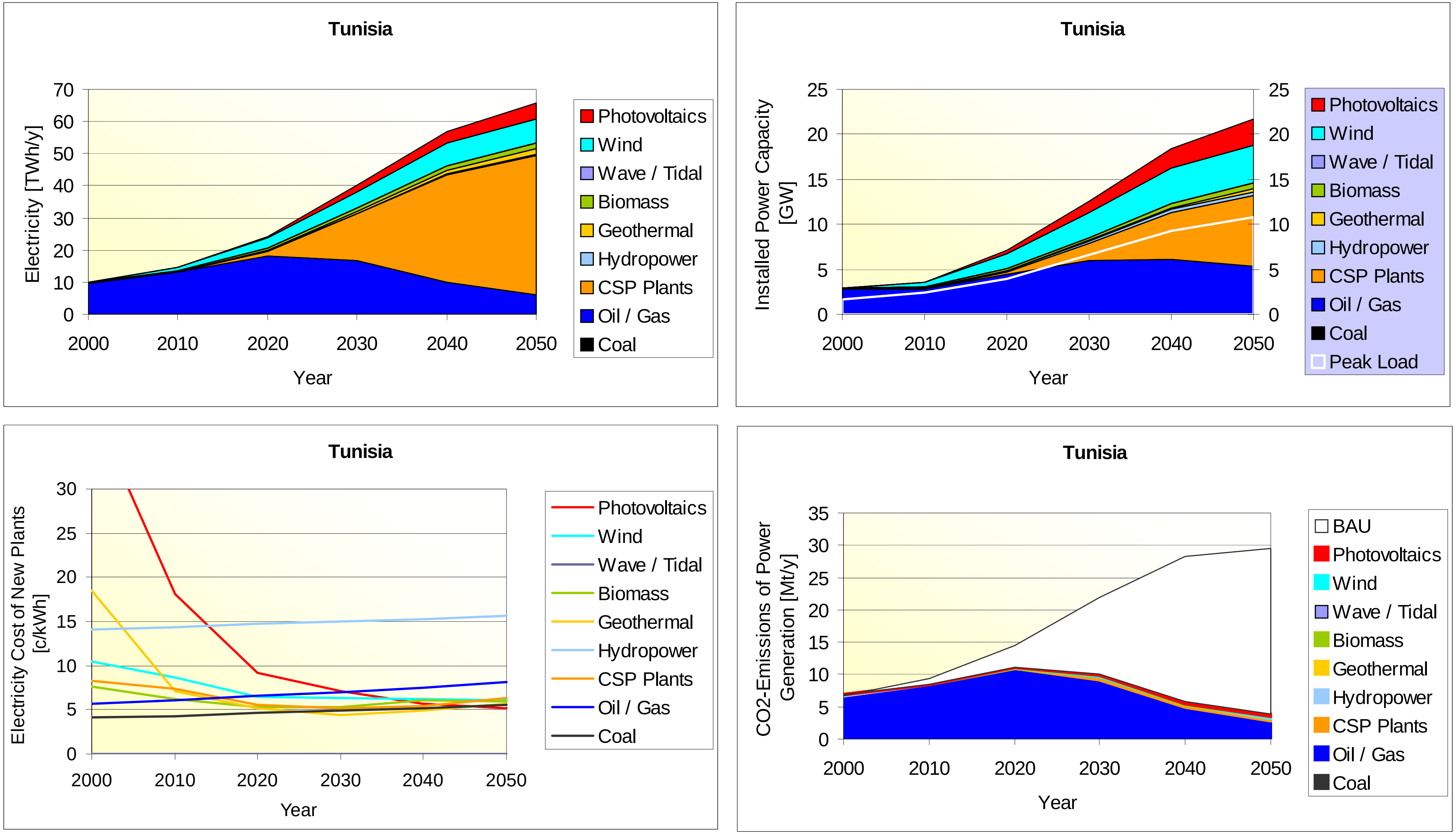
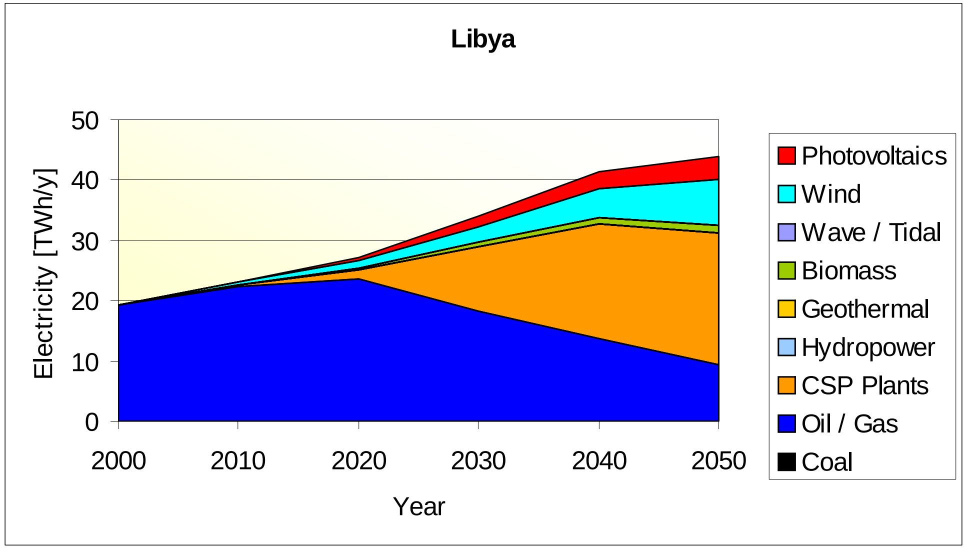
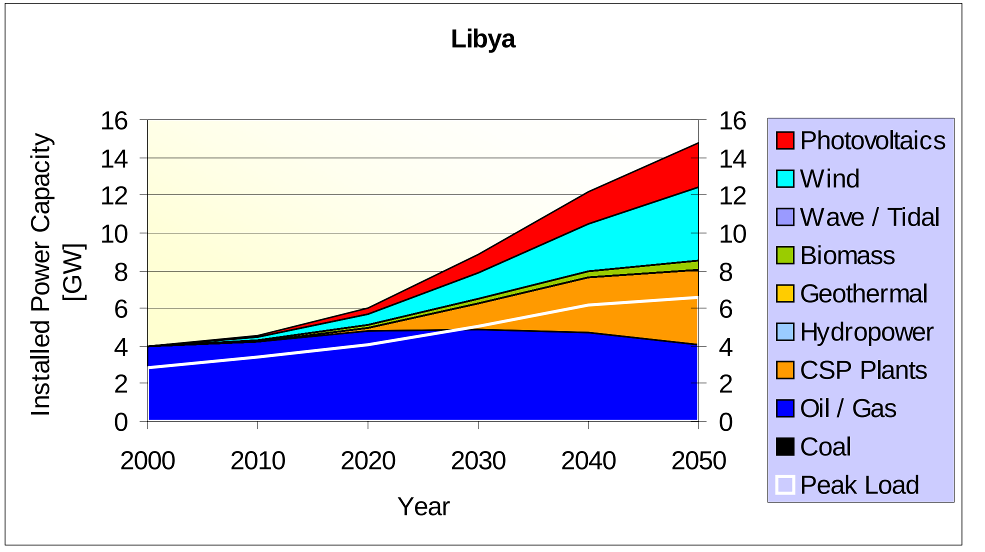
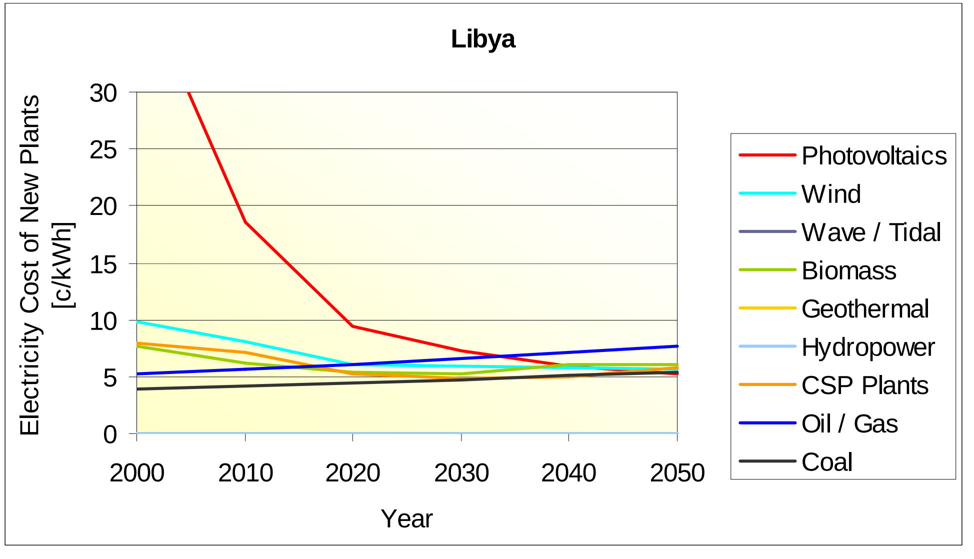


Figure A-21: Scenario CG/HE for Tunisia







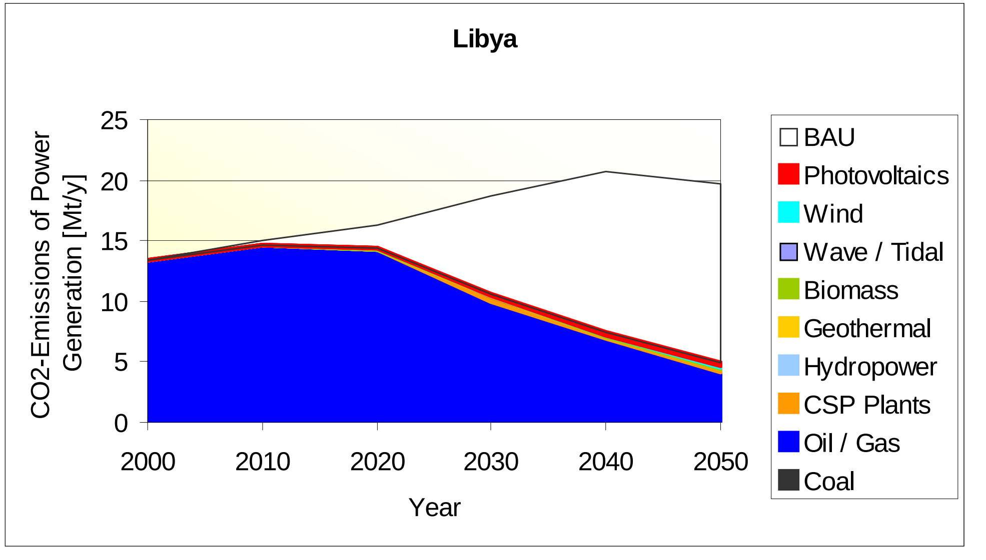


Figure A-22: Scenario CG/HE for Libya

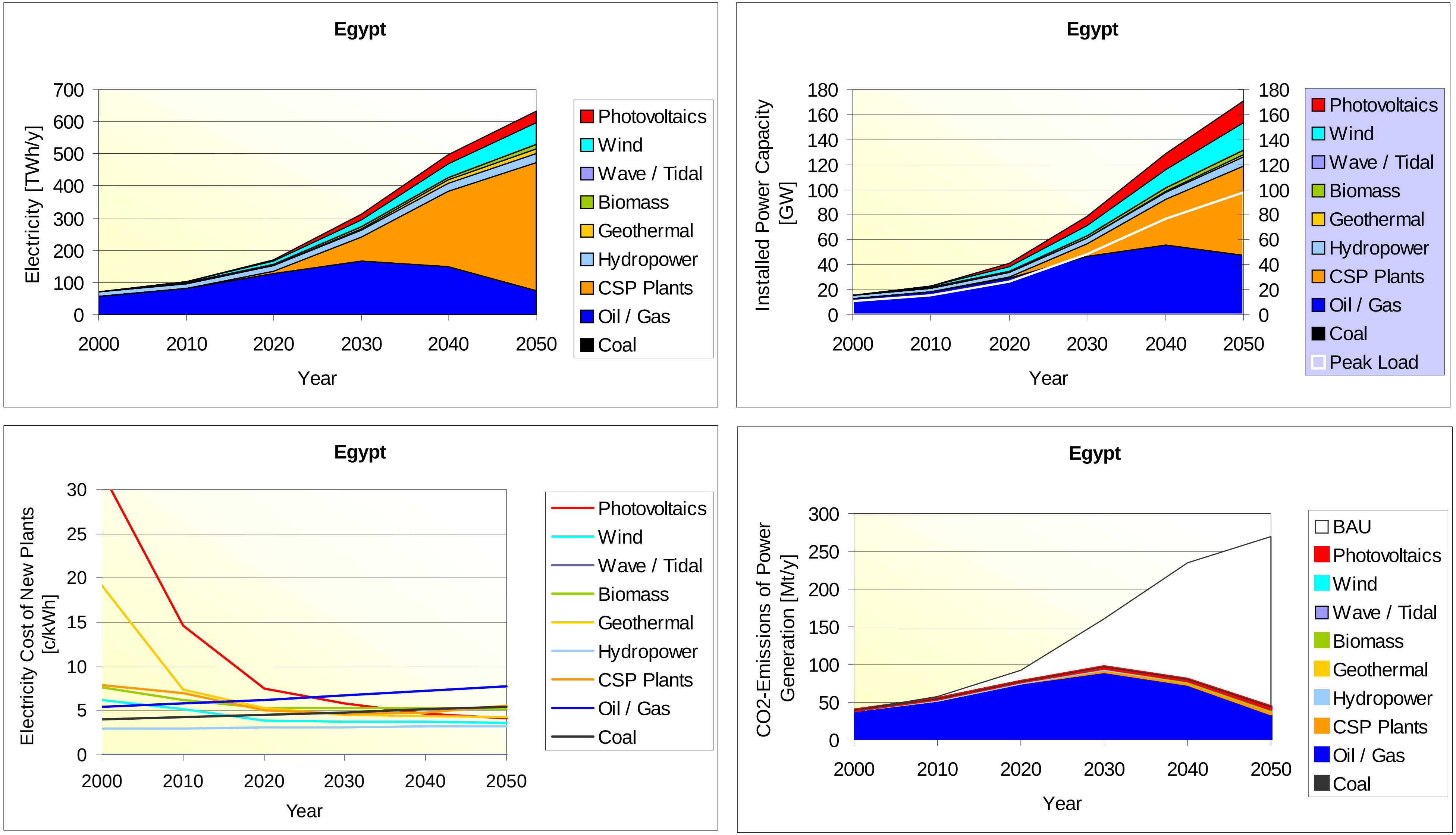


Figure A-23: Scenario CG/HE for Egypt

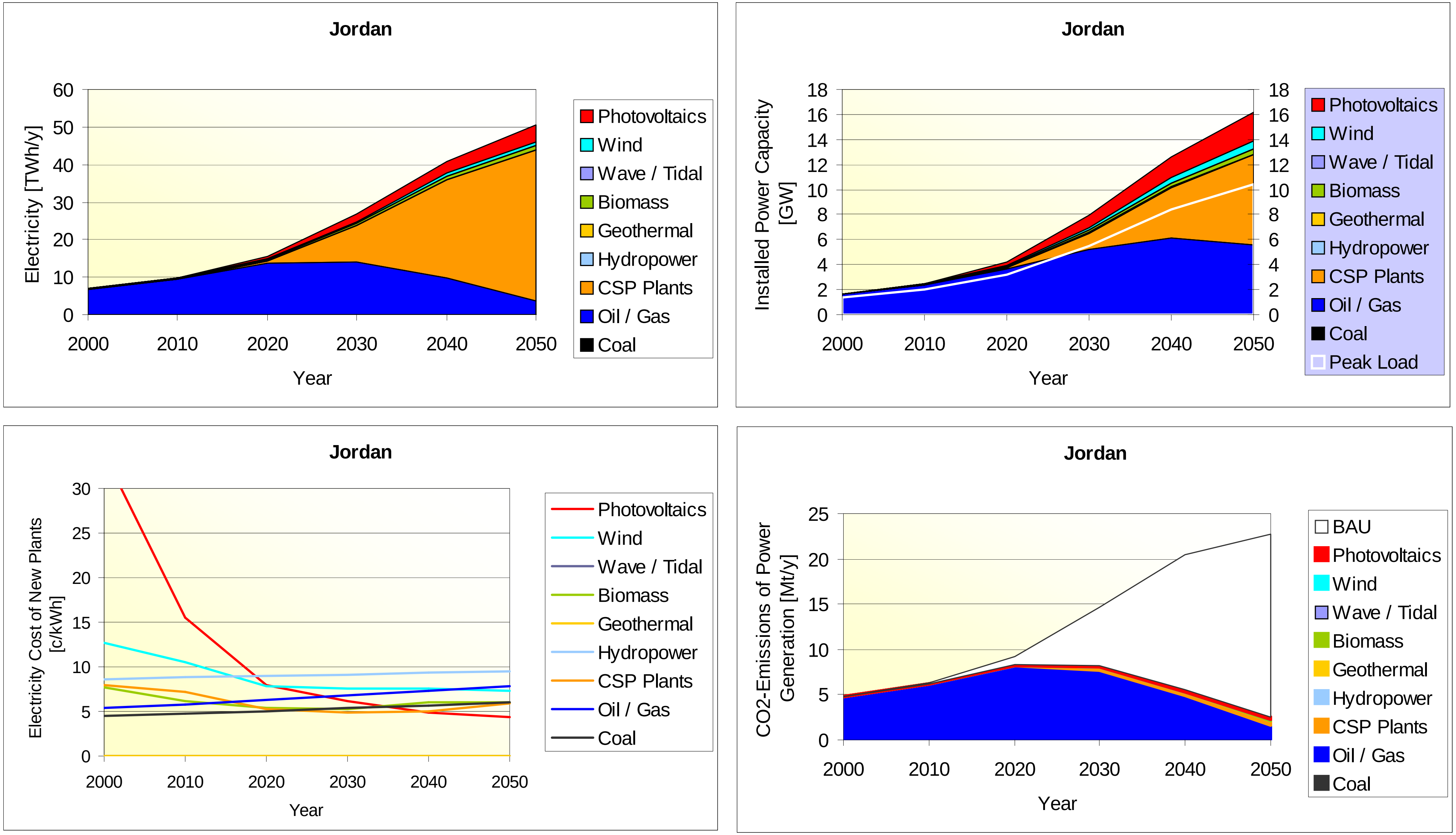


Figure A-24: Scenario CG/HE for Jordan

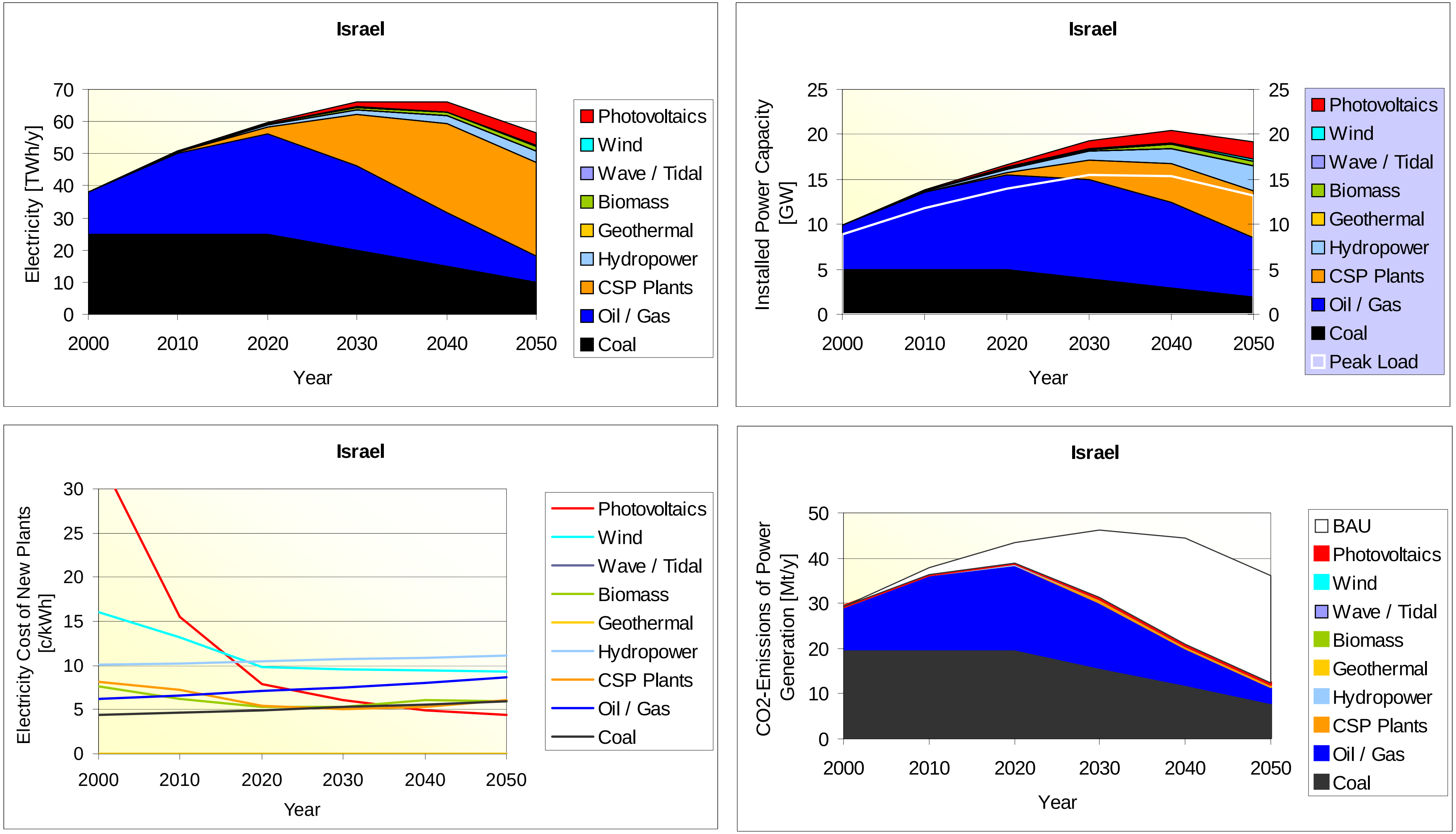


Figure A-25: Scenario CG/HE for Israel

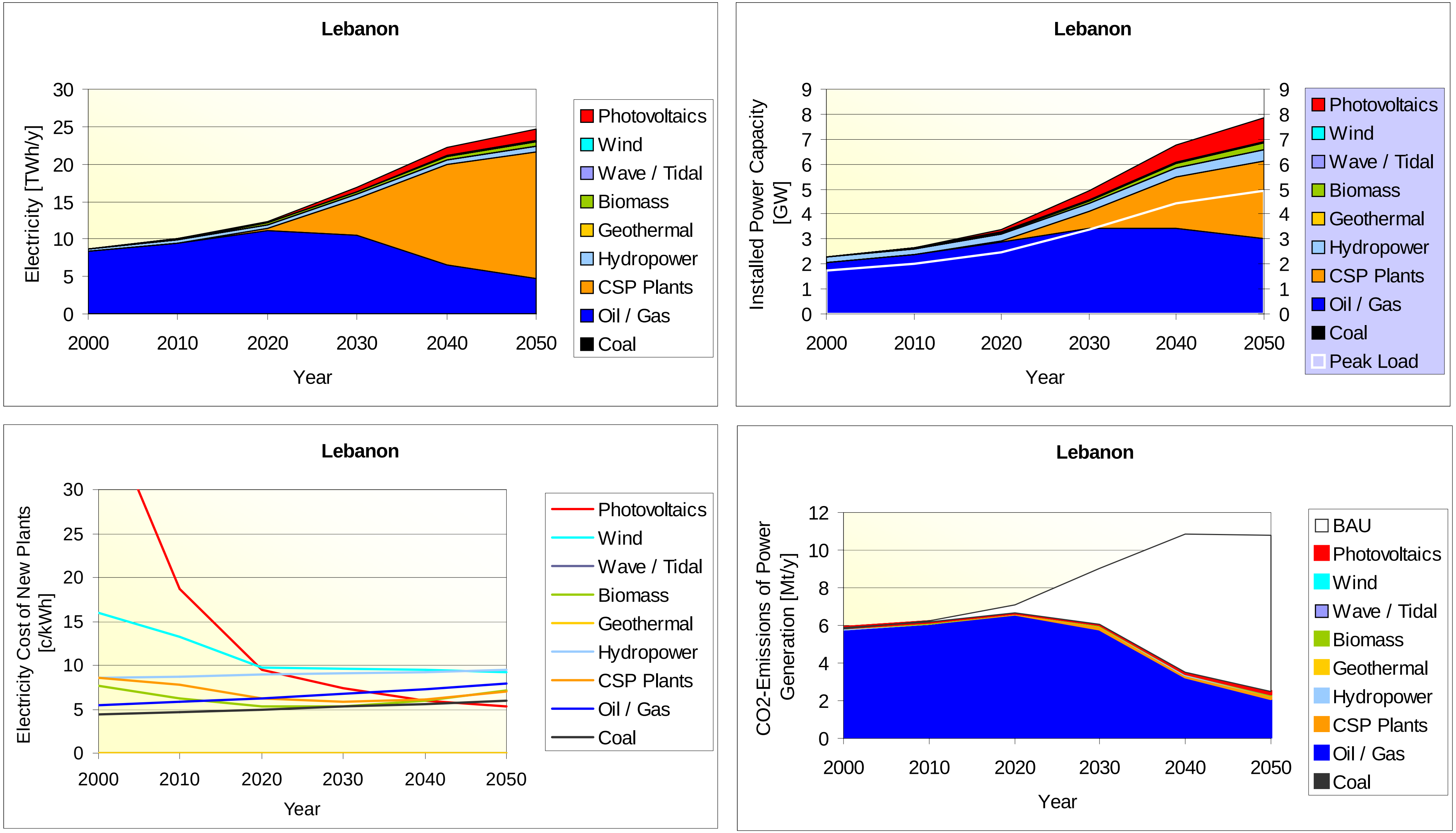


Figure A-26: Scenario CG/HE for Lebanon

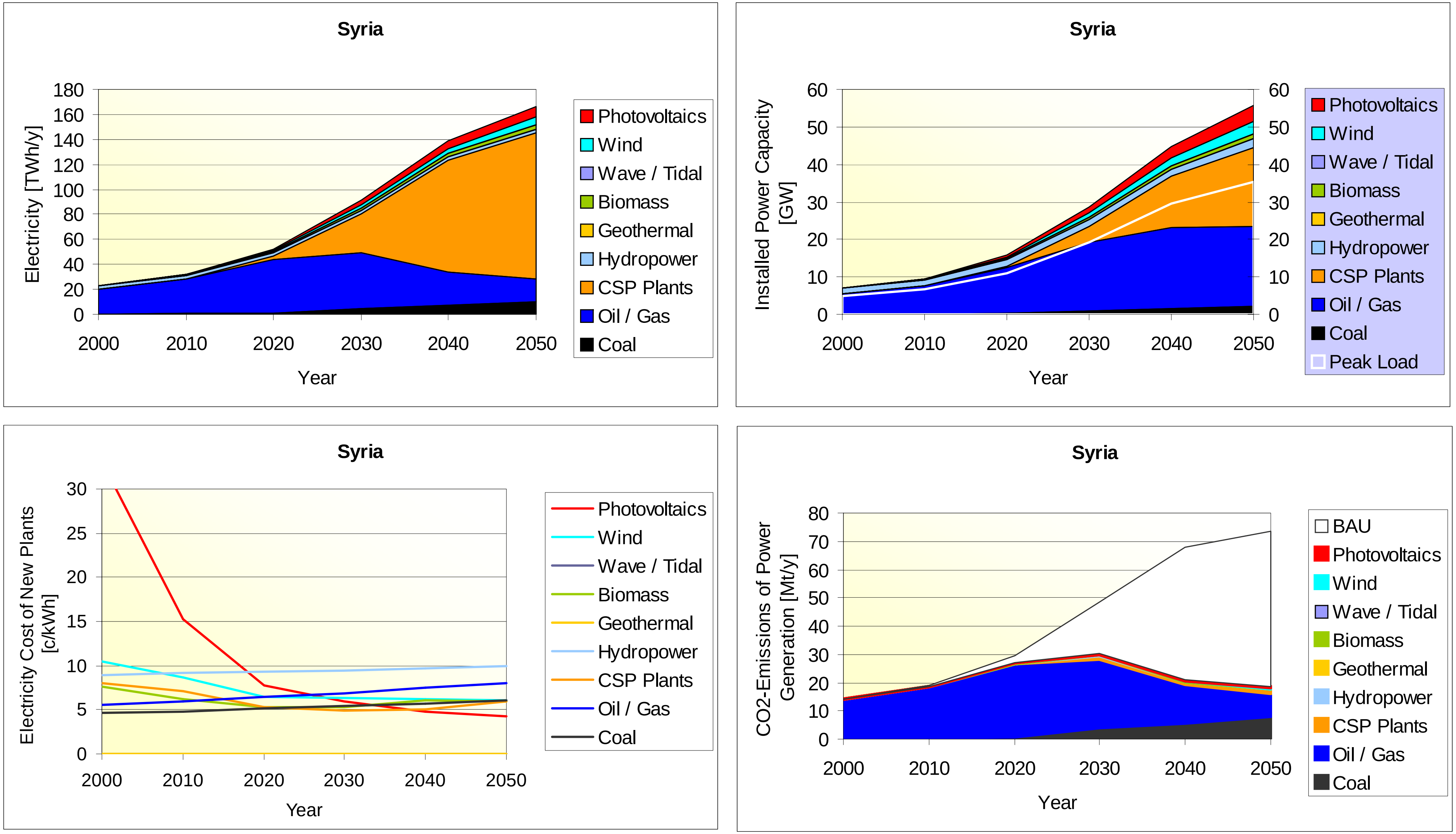


Figure A-27: Scenario CG/HE for Syria

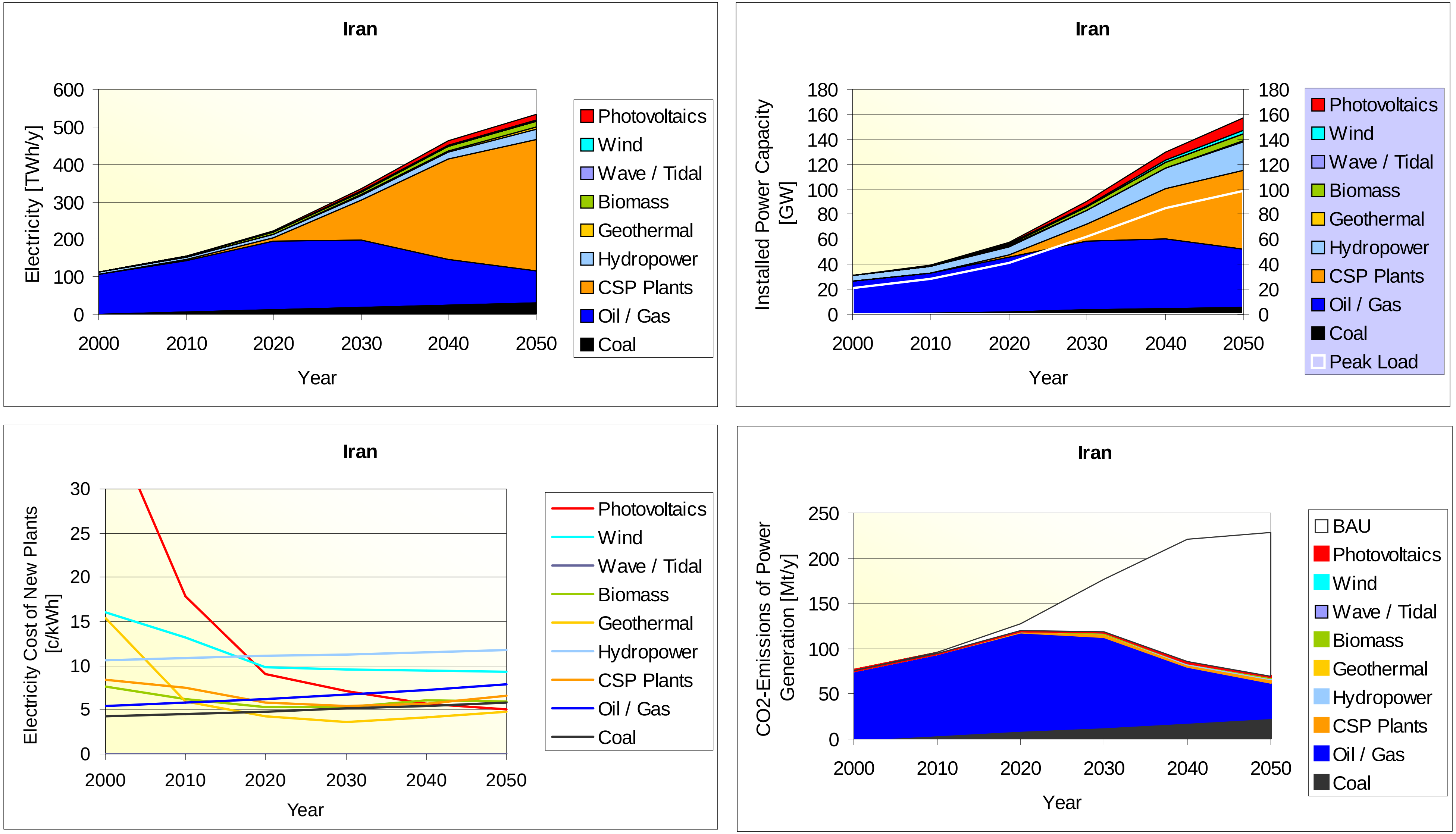


Figure A-28: Scenario CG/HE for Iran

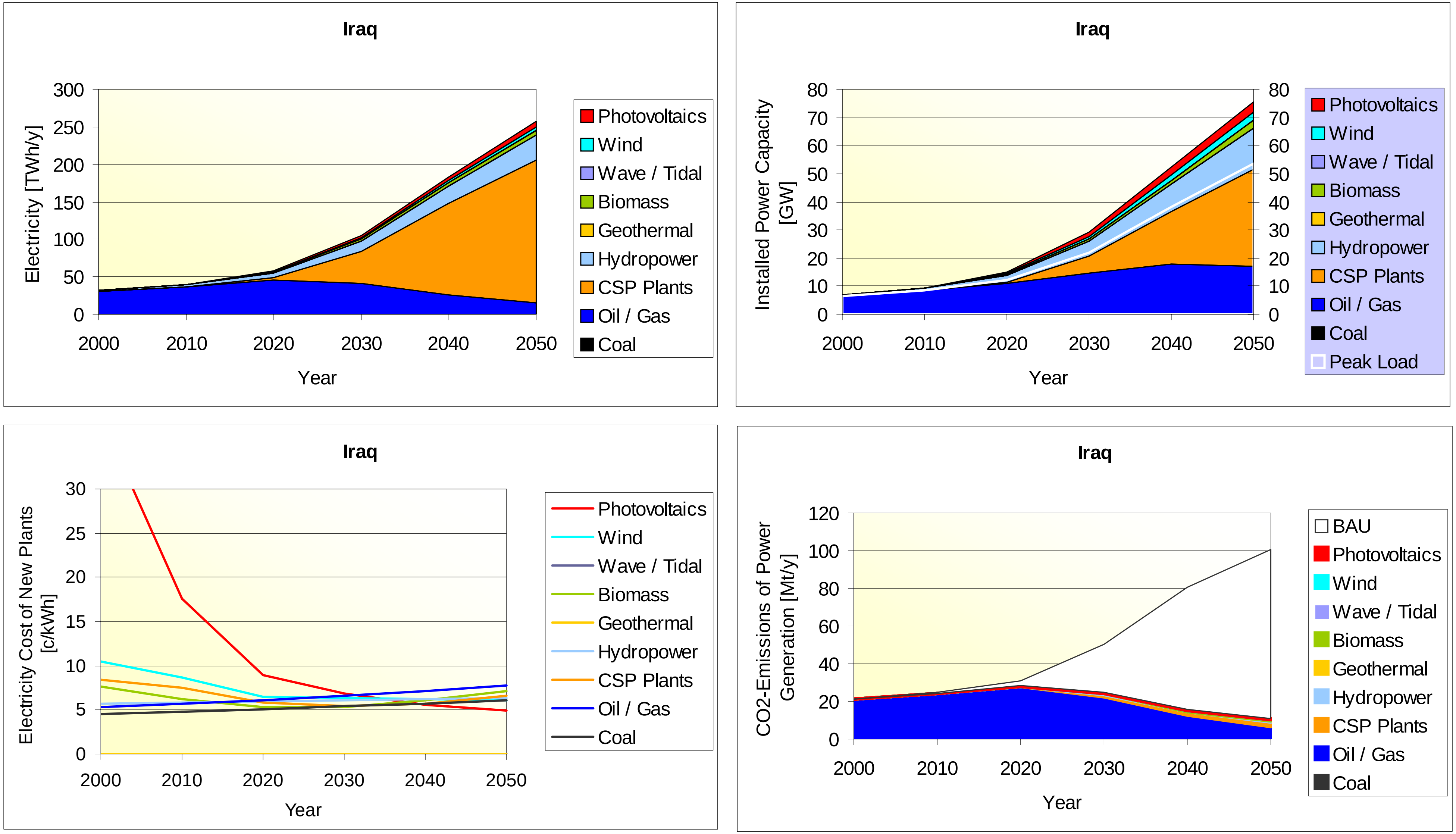


Figure A-29: Scenario CG/HE for Iraq

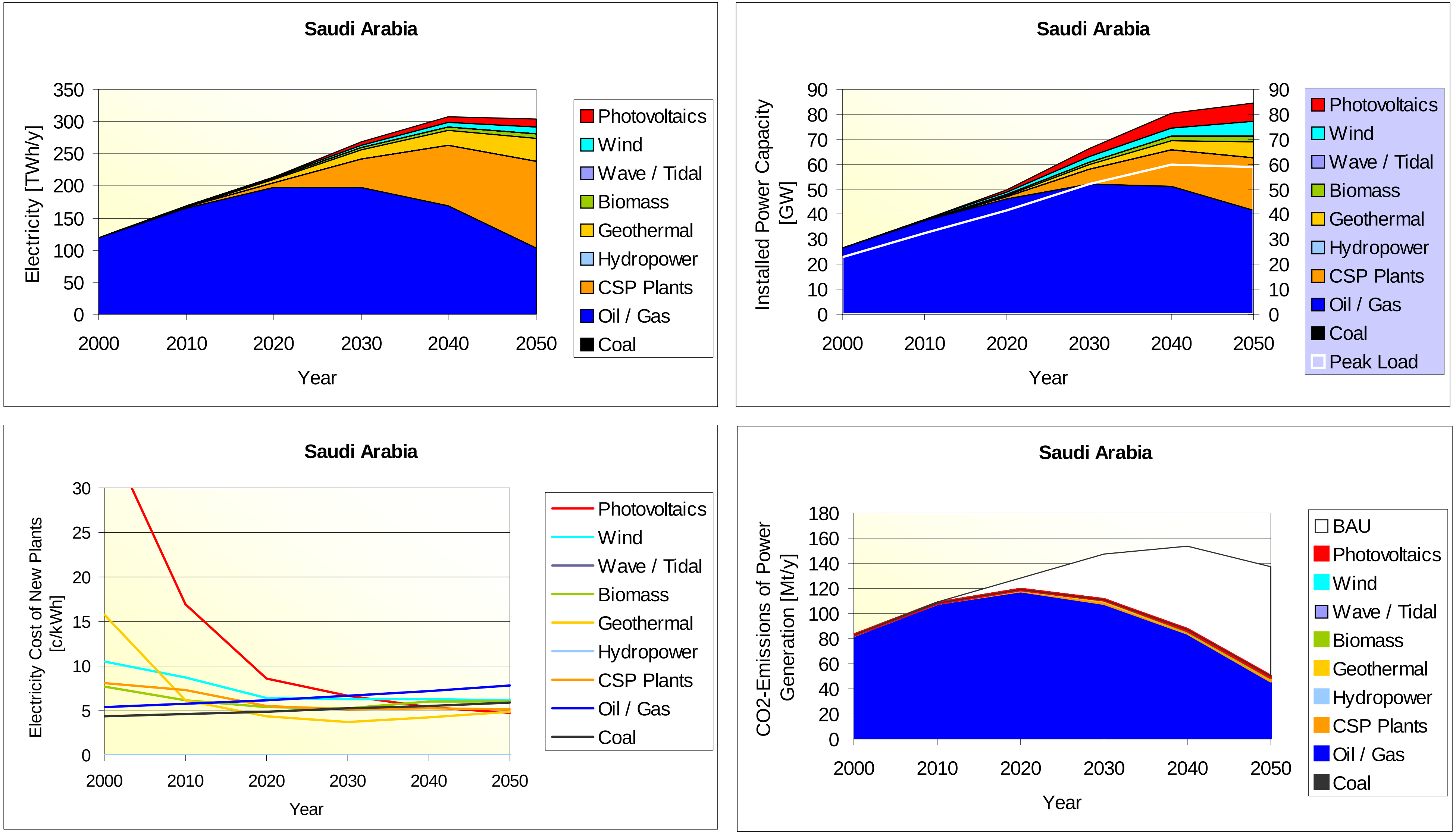


Figure A-30: Scenario CG/HE for Saudi Arabia

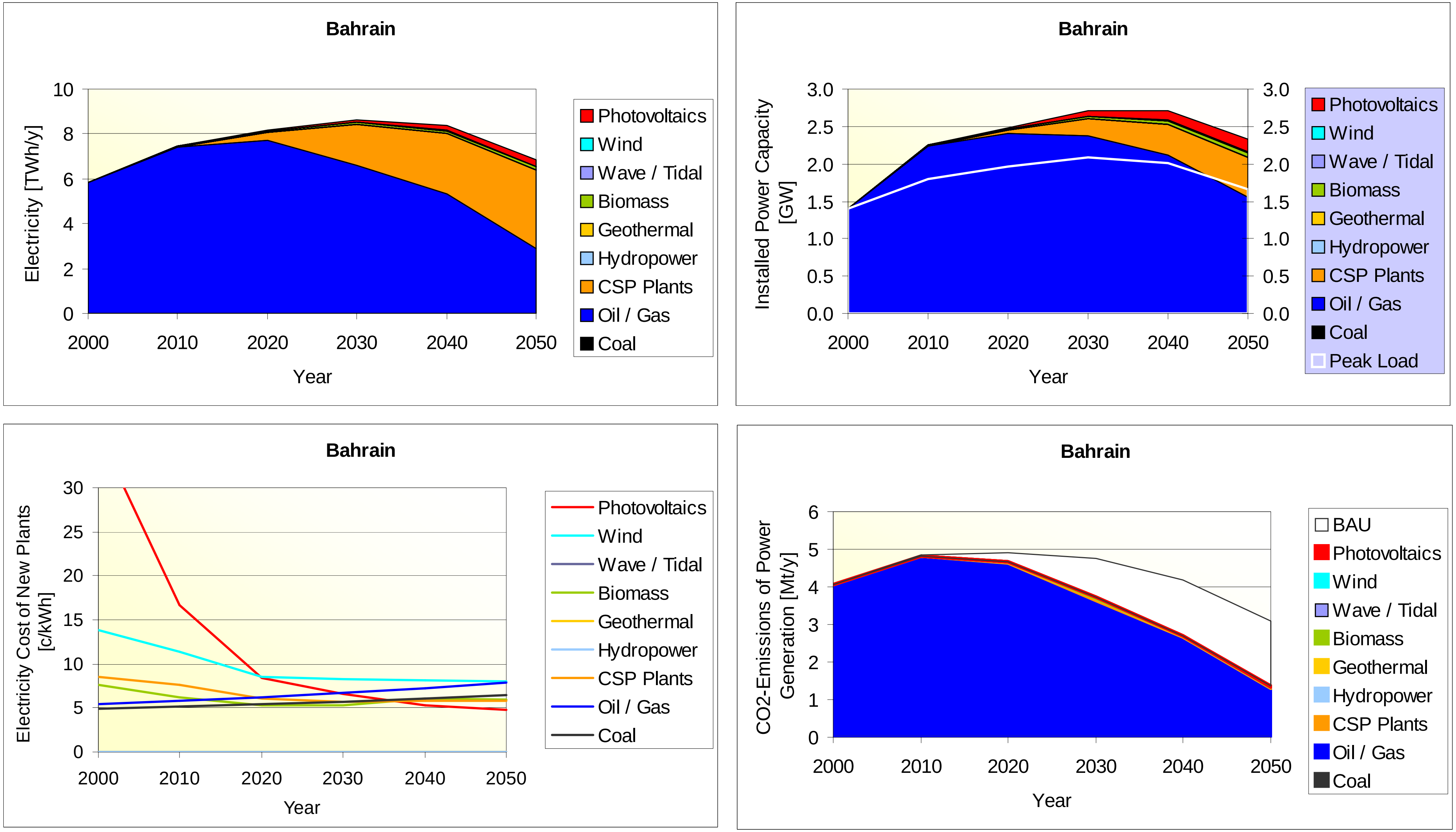


Figure A-31: Scenario CG/HE for Bahrain

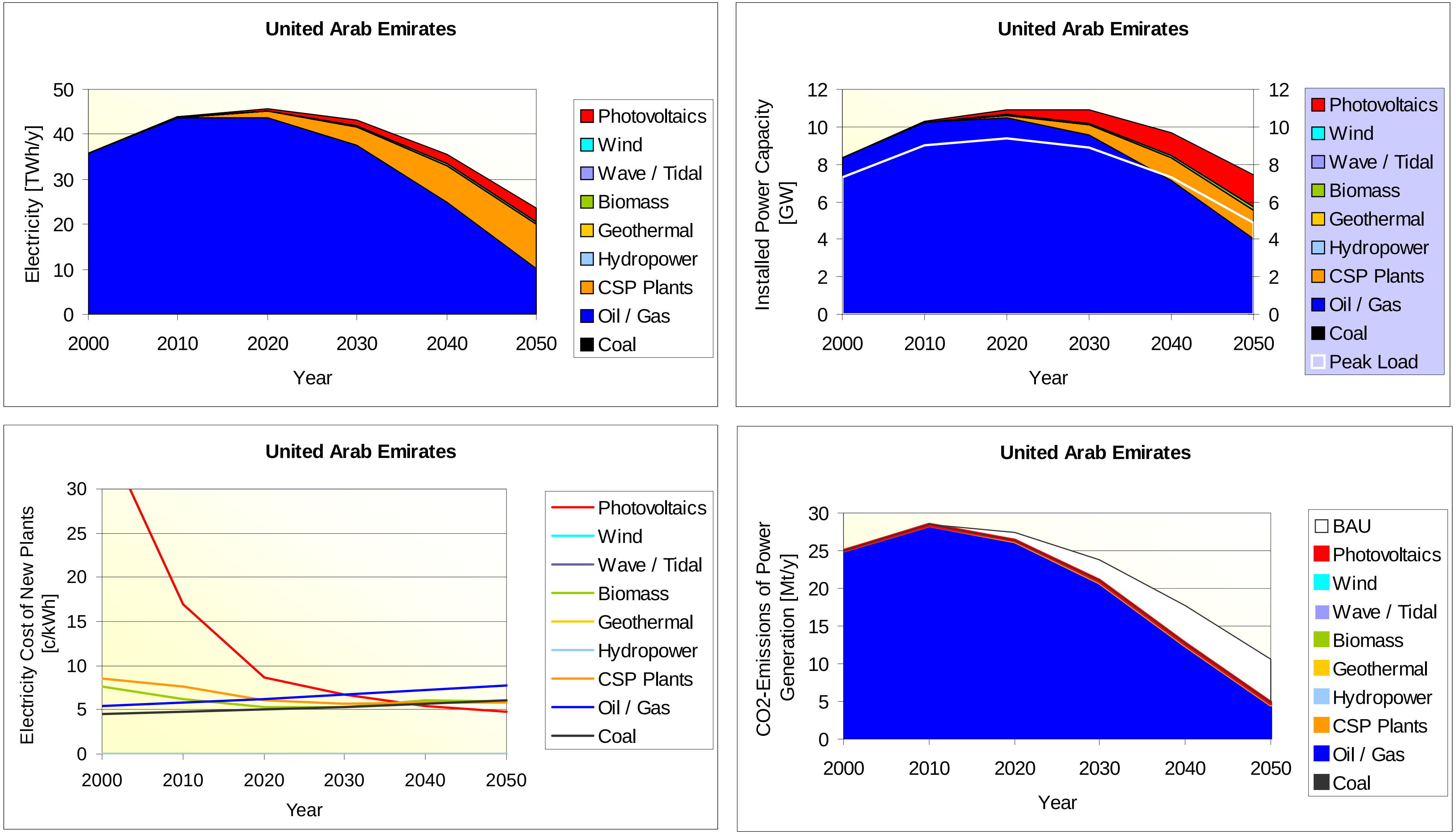


Figure A-32: Scenario CG/HE for United Arab Emirates

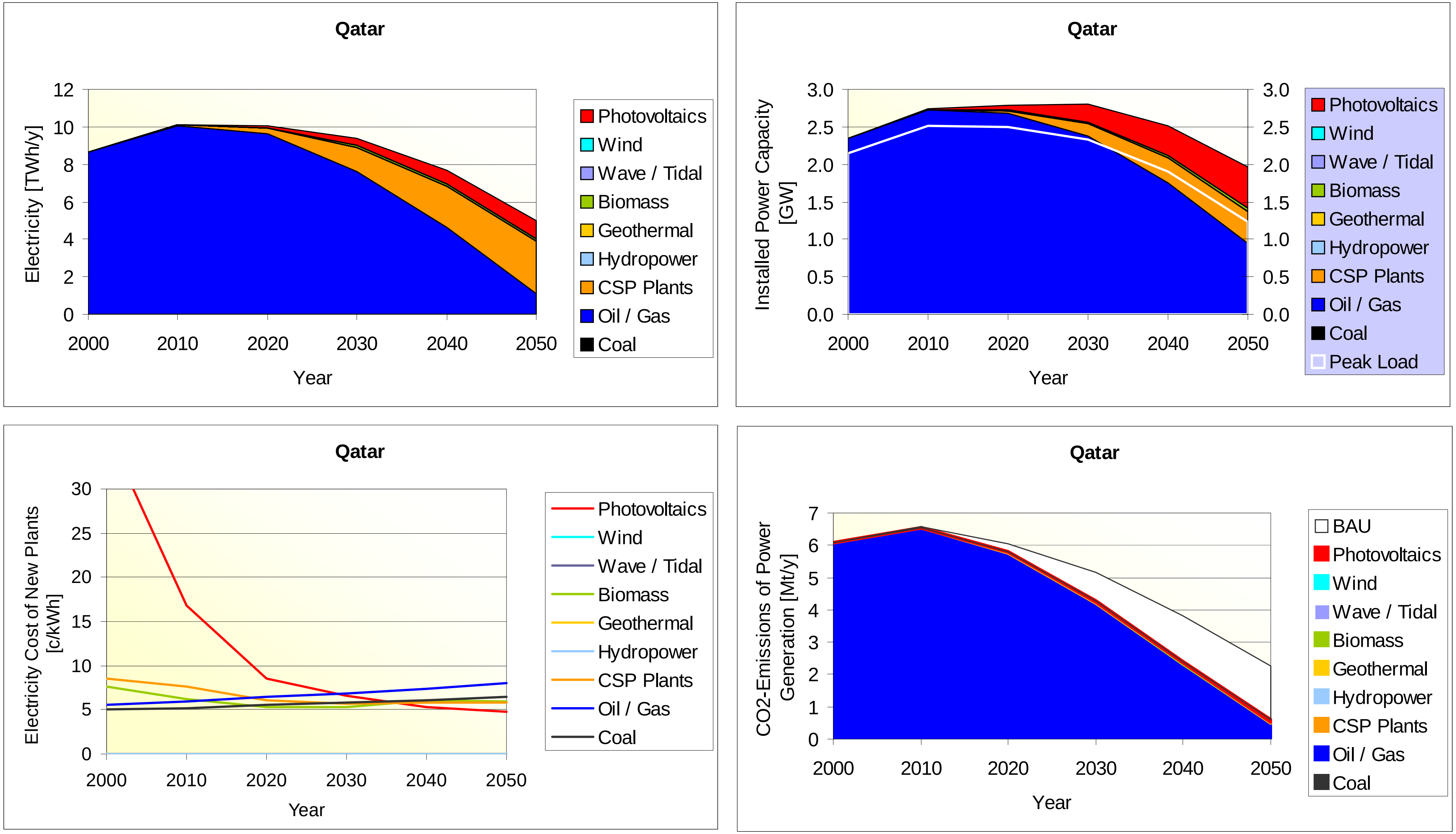


Figure A-33: Scenario CG/HE for Qatar

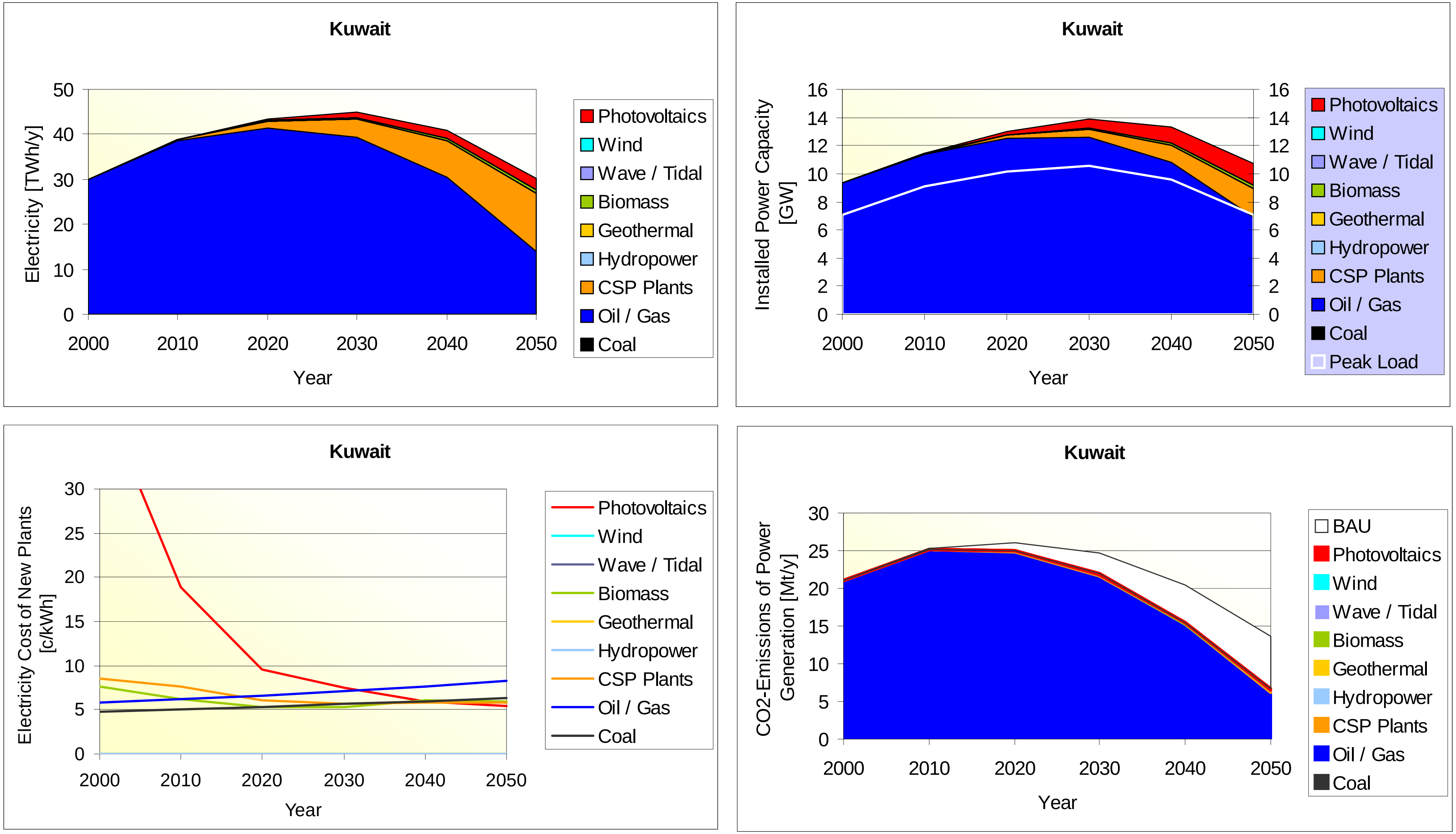


Figure A-34: Scenario CG/HE for Kuwait

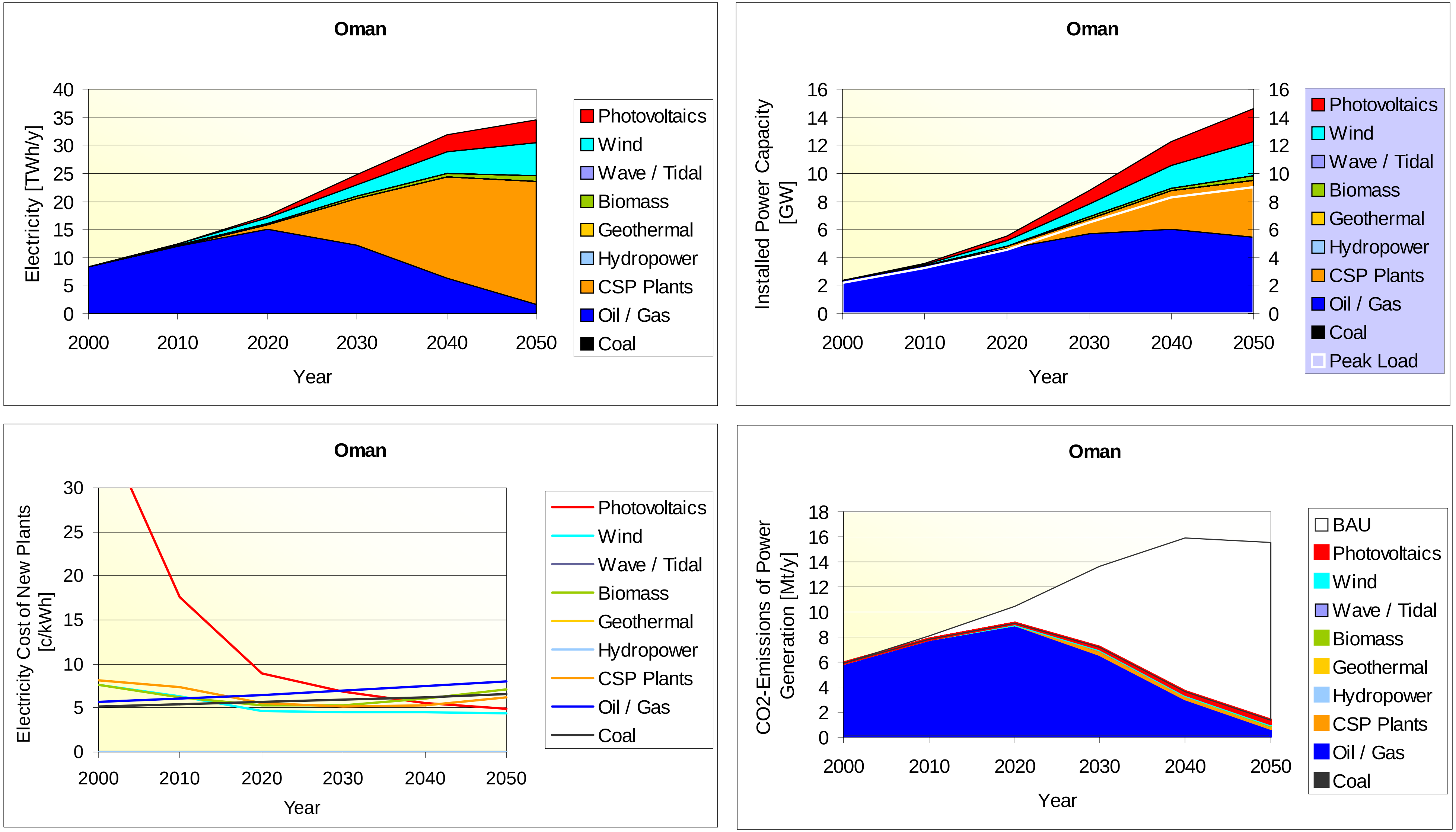
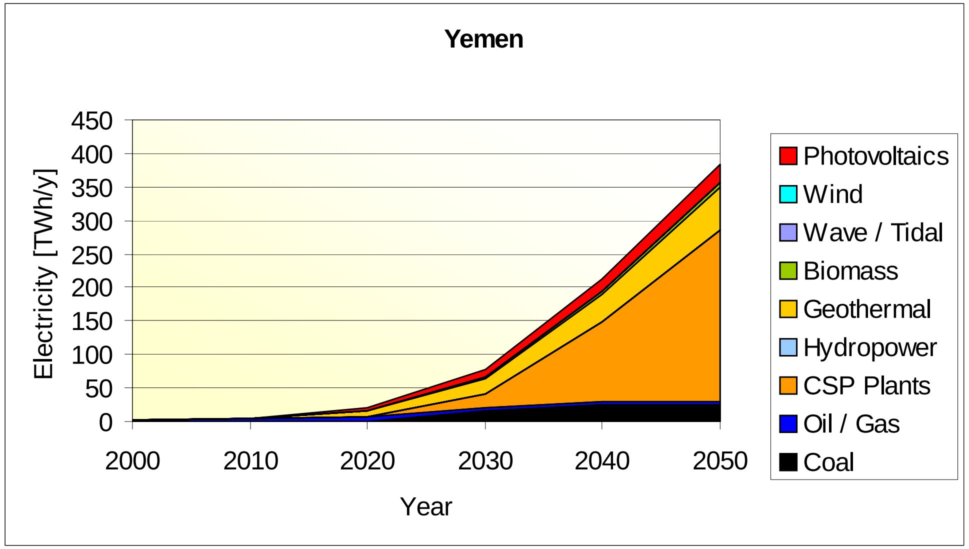
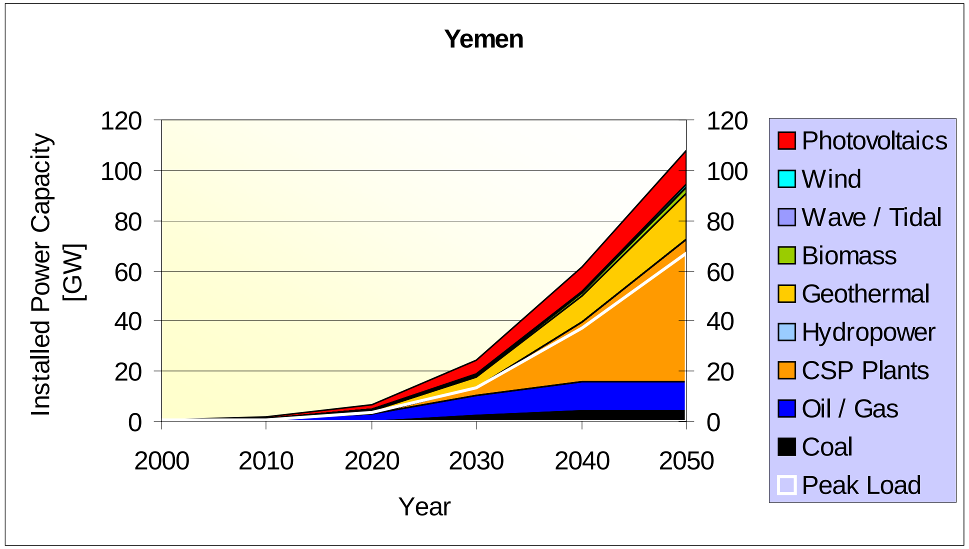
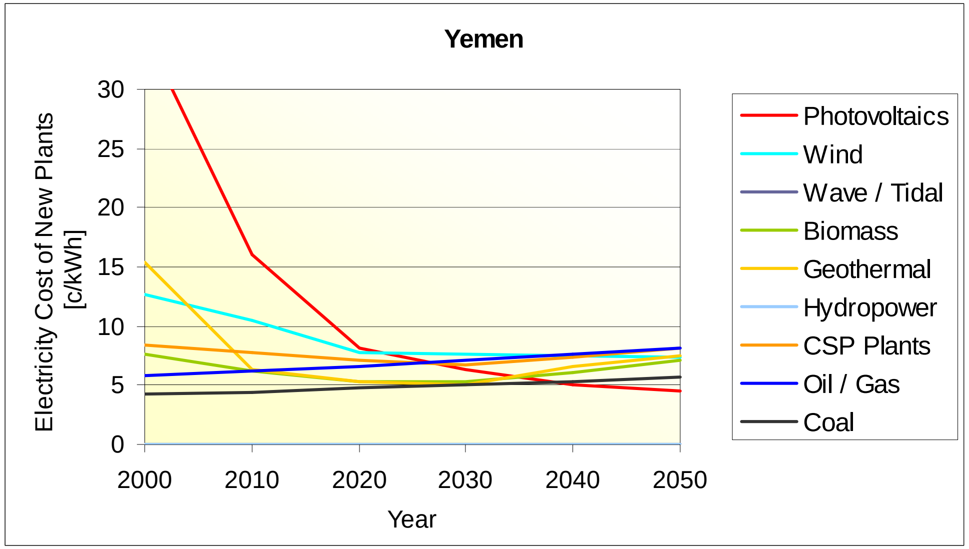


Figure A-35: Scenario CG/HE for Oman







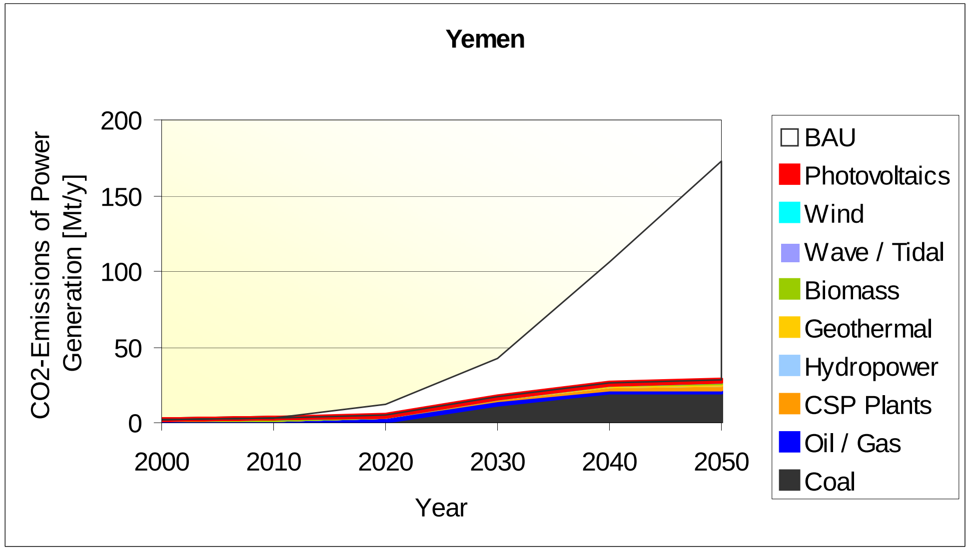


Figure A-36: Scenario CG/HE for Yemen

Annex 7: Water Demand and Supply Structure and Outlook until 2050 in the Scenario CG/HE

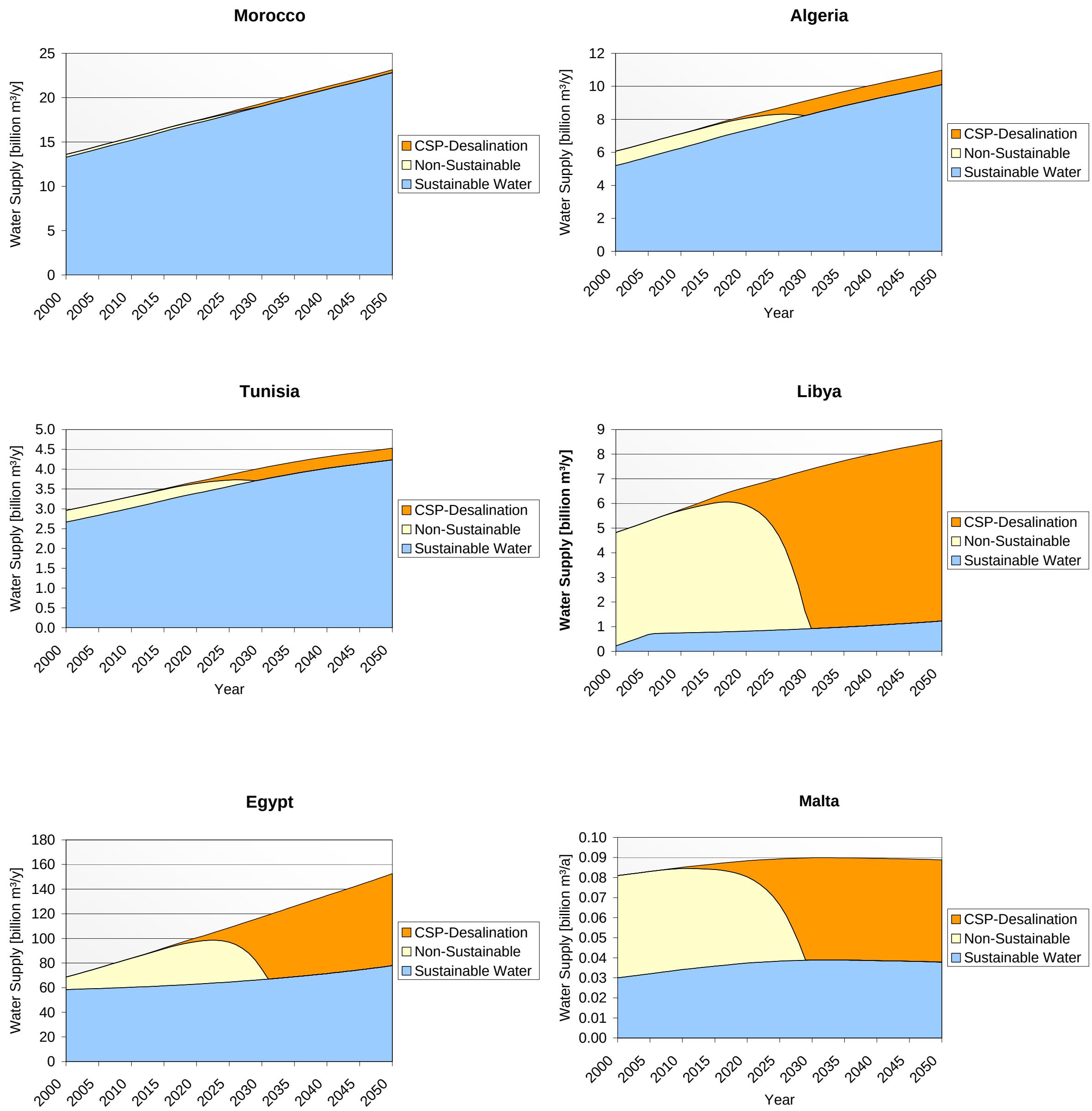


Figure A-37: Water demand and supply structure in the Northern African countries until 2050 in the scenario CG/HE

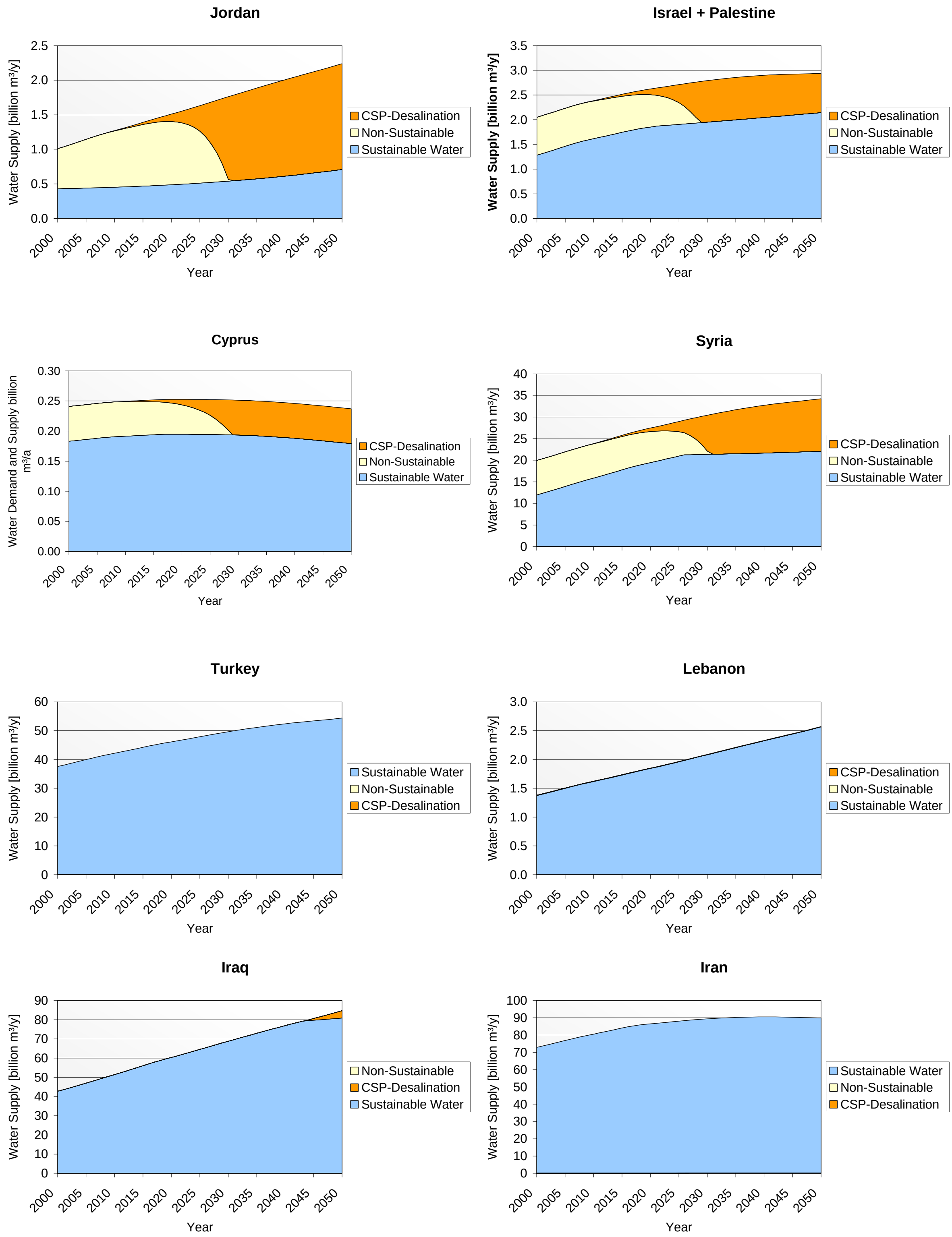


Figure A-38: Water demand and supply structure in the Western Asian countries until 2050 in the scenario CG/HE

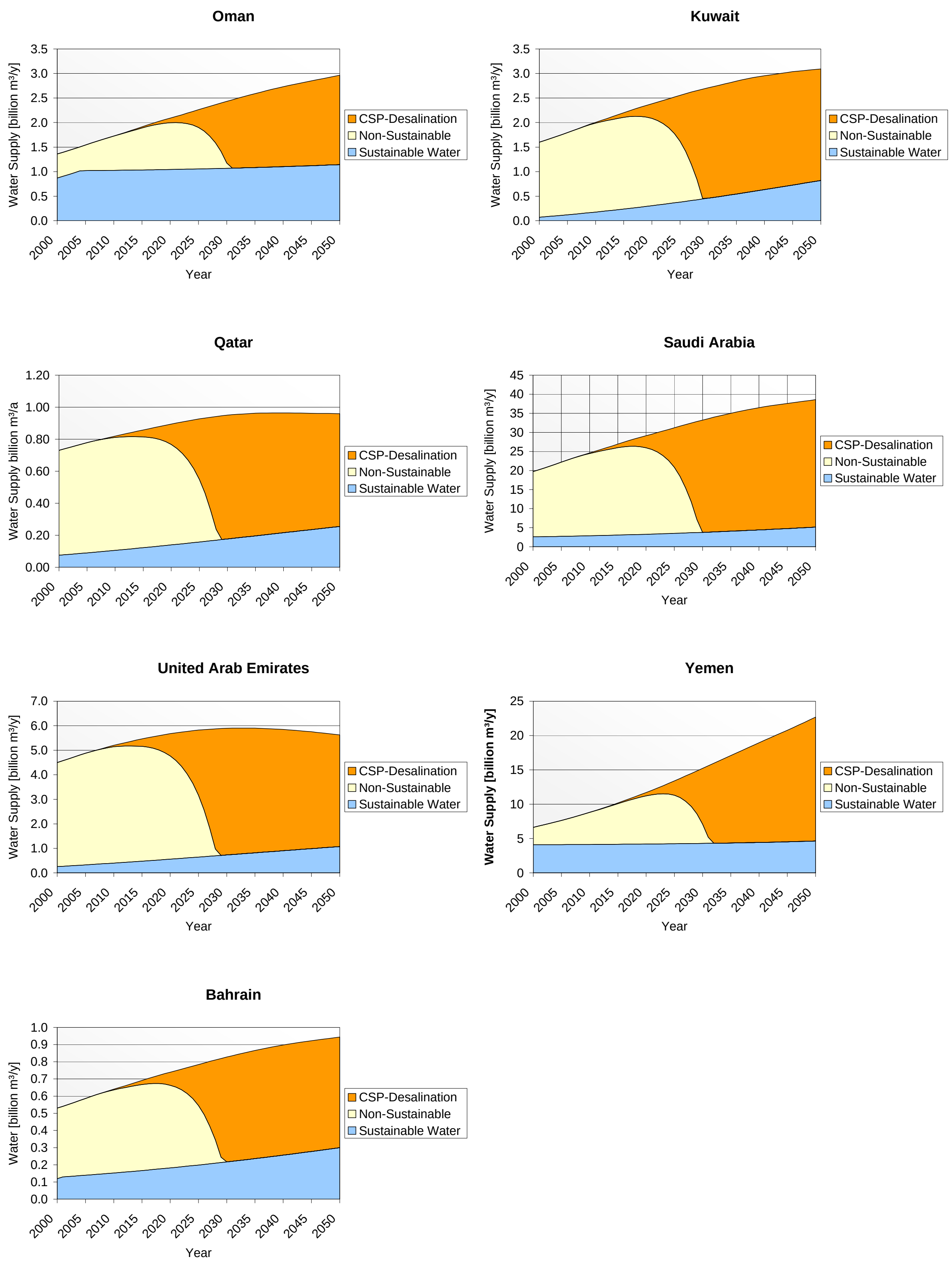


Figure A-39: Water demand and supply structure on the Arabian Peninsula until 2050 in the scenario CG/HE

Annex 8: National CDM Projects in selected MENA Countries

Type of project	Name of project	Initial capital investment (million US$)	Carbon dioxide avoided (million Tons CO2-eq)
Landfill gas capture and use	1. Methane capture and use at the Ouest Smar landfill in Algiers	0,85	15
Promotion of renewable energy in rural and Saharan regions	2. Wind farm in Adrar (southern Algeria)	2,1	0,17
	3. Solarphotovoltaic and Windmill power for water pumping in rural area	5,0	0,21
Sequestration of CO_2 through forest and fruit tree plantations	4. Integrated management in the rural Hodna basin	5,6	4,6
	5. Forest and fruit tree plantations in rural areas	9,6	12,8
Improving energy efficiency of cement production	6. Improving energy efficiency of cement production in Algeria: the meftah facility pilot project	10	3,9
Transitioning to the use of clean vehicles in the transport sector	7. Switch to LPG/CNG & development of control/maintenance programs	27	1,0
	Total	**60,2**	**37,8**

Source: Algerian portfolio of projects for reducing greenhouse gas emissions (Ministry of Land-Use Management, Water and the Environment, 2002).

Table A-1: The Algerian CDM projects in the pipeline and investment needed

Type of project	Name of project	Initial capital investment (million US$)	Carbon dioxide avoided (million Tons CO2-eq)
Renewable Energy	Zafarana Wind park (120 MW)		1,59
Renewable Energy	CDM 60 MW wind farm on red sea	54	0,80
Renewable Energy	CDM integrated solar thermal combined cycle system 300 MW	240	0,5
Renewable Energy	Toschka PW water pumping	0,65	0,003
Renewable Energy	Solar food dehydration	2	0,002

Source: Egyptian portfolio of projects for reducing Greenhouse gas emissions (Ministry of Land-Use Management, Water and the Environment, 2002).

Table A-2: Egyptian project pipeline, 21 GHG emission reductions project ideas out of which 6 renewable energy projects with an investment of 310 MUS$

Type of project	Name of project	Initial capital investment (million US$)	Carbon dioxide avoided (million Tons CO2-eq)
Installed electricity wind farms 200MW	Essaouira wind park power (20 years)	82,5	1,5 (over 10 years)
Methane recovery in the waste sector	Rabat Akreuch landfill biogas collection and flaring (21years)	2	1,59 (over 21 years)
Energy efficiency in industrial sector	Heat recovery enhancement for power generation at the Morocco's phosphoric acid and fertilizer production plant of Jorf Lasfar (10 years)	27,5	0,848895
Renewable energy production	Kits Photovoltaiques (10 Years) (Khmisset, Khénifra, Khouribga, and Settat)	NA	0,110

Source: Moroccan portfolio of projects for reducing greenhouse gas emissions (Ministry of Land-Use Management, Water and the Environment, 2002).

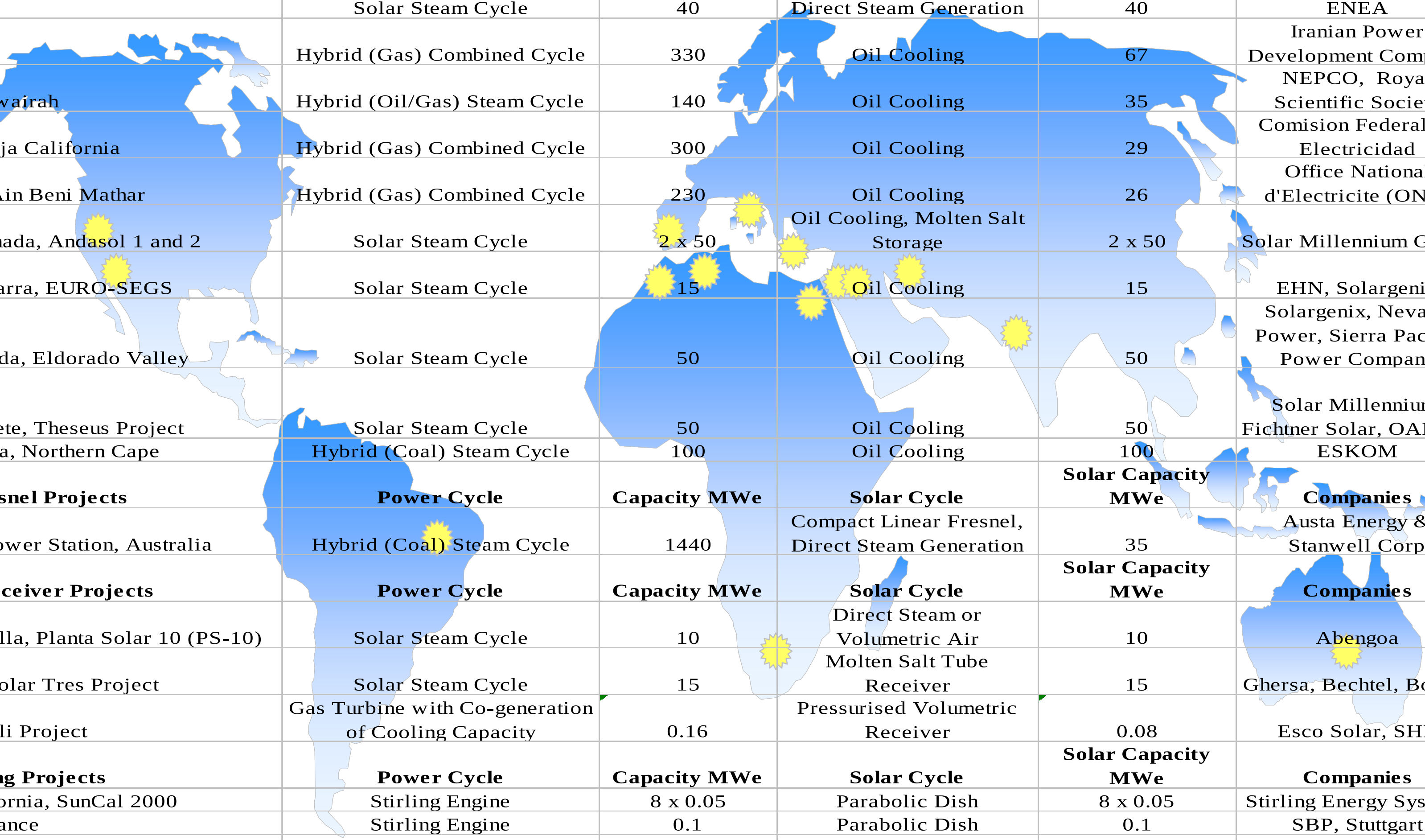
Table A-3: Moroccan most advanced renewable energy projects

Type of project	Name of project	Initial capital investment (million US$)	Carbon dioxide avoided (million Tons CO2-eq)
Cogeneration		34,5	1,4
Energy Efficiency	Revolving Fund for ESCOs	24,0	3,7
Renewable Energy	Wind power development for electricity generation	155.0	8,2
Landfill	Capture and use of methane for electricity generation	4,8	0,3
Renewable Energy	Solar hot water heating in the residential and commercial sectors	11,7	0,5
Energy Efficiency	High efficiency freight transport	6,0	1,2
Energy Efficiency	High efficiency street lights	6,0	1,2
Energy Efficiency	Higher efficiency lighting in the residential sector	1,2	0,18
Total		**237,5**	**16,3**

Source: Tunisian portfolio of projects for reducing greenhouse gas emissions (Ministry of Land-Use Management, Water and the Environment, 2002).

Table A-4: Tunisian project pipeline: 237.5 MUS$

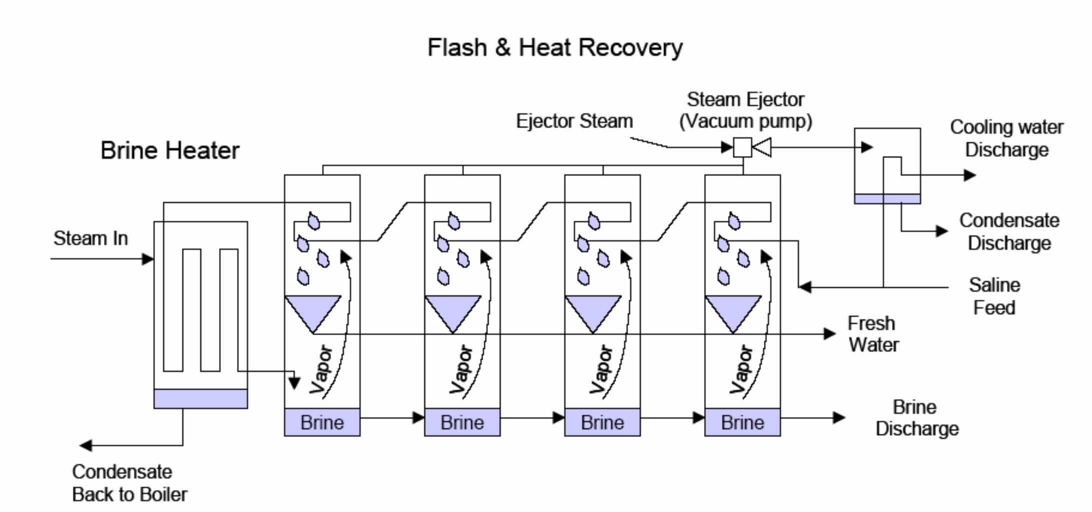
Annex 9: World Wide Concentrating Solar Thermal Power Projects



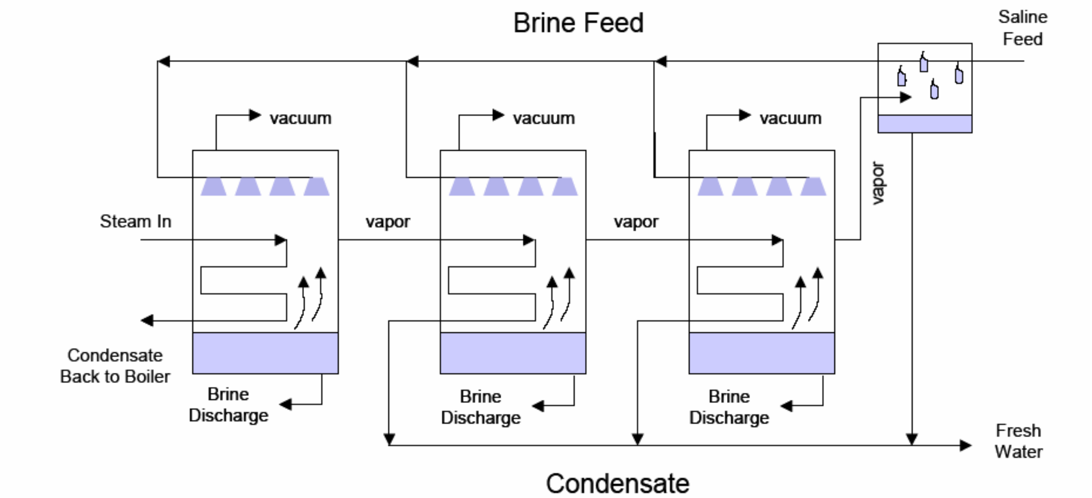
Parabolic Trough Projects	Power Cycle	Capacity MWe	Solar Cycle	Solar Capacity MWe	Companies
Algeria	Hybrid (Gas) Combined Cycle	140	Oil Cooling	35	New Energy Algeria, Sonatrach, Sonelgaz
Egypt, Kuraymat	Hybrid (Gas) Combined Cycle	127	Oil Cooling	29	EEA, NREA
Mathania, India	Hybrid (Gas) Combined Cycle	140	Oil Cooling	35	Rajasthan Renewable Energy Corporation Ltd.
Israel	Hybrid (Coal) Steam Cycle	100	Oil Cooling	100	Israel Ministry of National Infrastructure
Italy	Solar Steam Cycle	40	Direct Steam Generation	40	ENEA
Iran, Yazd	Hybrid (Gas) Combined Cycle	330	Oil Cooling	67	Iranian Power Development Company
Jordan, Quwairah	Hybrid (Oil/Gas) Steam Cycle	140	Oil Cooling	35	NEPCO, Royal Scientific Society
Mexico, Baja California	Hybrid (Gas) Combined Cycle	300	Oil Cooling	29	Comision Federal de Electricidad
Morocco, Ain Beni Mathar	Hybrid (Gas) Combined Cycle	230	Oil Cooling	26	Office National d'Electricite (ONE)
Spain, Granada, Andasol 1 and 2	Solar Steam Cycle	2 x 50	Oil Cooling, Molten Salt Storage	2 x 50	Solar Millennium Group
Spain, Navarra, EURO-SEGS	Solar Steam Cycle	15	Oil Cooling	15	EHN, Solargenix
USA, Nevada, Eldorado Valley	Solar Steam Cycle	50	Oil Cooling	50	Solargenix, Nevada Power, Sierra Pacific Power Company
Greece, Crete, Theseus Project	Solar Steam Cycle	50	Oil Cooling	50	Solar Millennium, Fichtner Solar, OADYX
South Africa, Northern Cape	Hybrid (Coal) Steam Cycle	100	Oil Cooling	100	ESKOM
Linear Fresnel Projects	**Power Cycle**	**Capacity MWe**	**Solar Cycle**	**Solar Capacity MWe**	**Companies**
Stanwell Power Station, Australia	Hybrid (Coal) Steam Cycle	1440	Compact Linear Fresnel, Direct Steam Generation	35	Austa Energy & Stanwell Corp
Central Receiver Projects	**Power Cycle**	**Capacity MWe**	**Solar Cycle**	**Solar Capacity MWe**	**Companies**
Spain, Sevilla, Planta Solar 10 (PS-10)	Solar Steam Cycle	10	Direct Steam or Volumetric Air	10	Abengoa
Cordoba, Solar Tres Project	Solar Steam Cycle	15	Molten Salt Tube Receiver	15	Ghersa, Bechtel, Boeing
Italy, Empoli Project	Gas Turbine with Co-generation of Cooling Capacity	0.16	Pressurised Volumetric Receiver	0.08	Esco Solar, SHP
Dish-Stirling Projects	**Power Cycle**	**Capacity MWe**	**Solar Cycle**	**Solar Capacity MWe**	**Companies**
USA, California, SunCal 2000	Stirling Engine	8 x 0.05	Parabolic Dish	8 x 0.05	Stirling Energy Systems
Odeillo, France	Stirling Engine	0.1	Parabolic Dish	0.1	SBP, Stuttgart
Vellore, India	Stirling Engine	0.1	Parabolic Dish	0.1	SBP, Stuttgart
Milano, Italy	Stirling Engine	0.1	Parabolic Dish	0.1	SBP, Stuttgart
PSA, Almeria, Spain	Stirling Engine	7 x 0.1	Parabolic Dish	7 x 0.1	SBP, Stuttgart

Annex 10: Options for the Co-generation of Solar Thermal Heat and Power

a) Multi-Stage-Flash Desalination (MSF)



b) Multi-Effect-Desalination (MED)



c) Reverse Osmosis (RO)

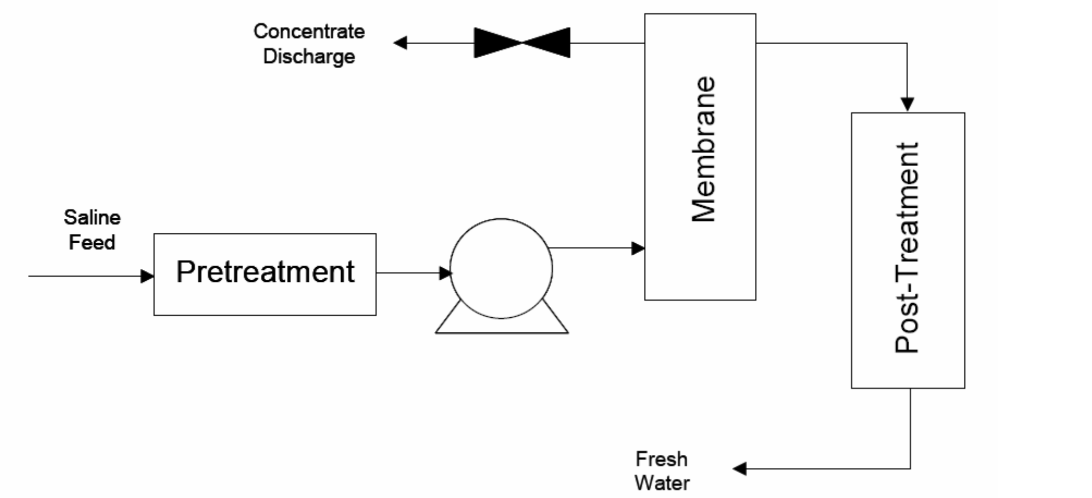


Figure A-40: Desalination technologies can be powered by renewable electricity or co-generation /Sandia 2003/

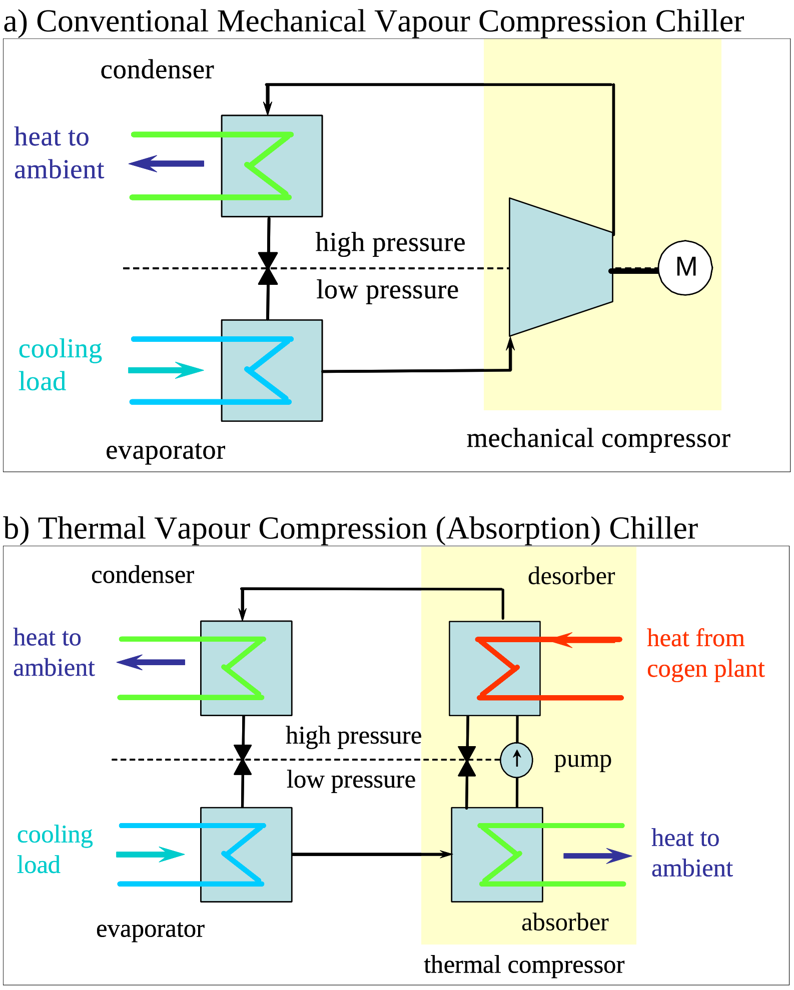
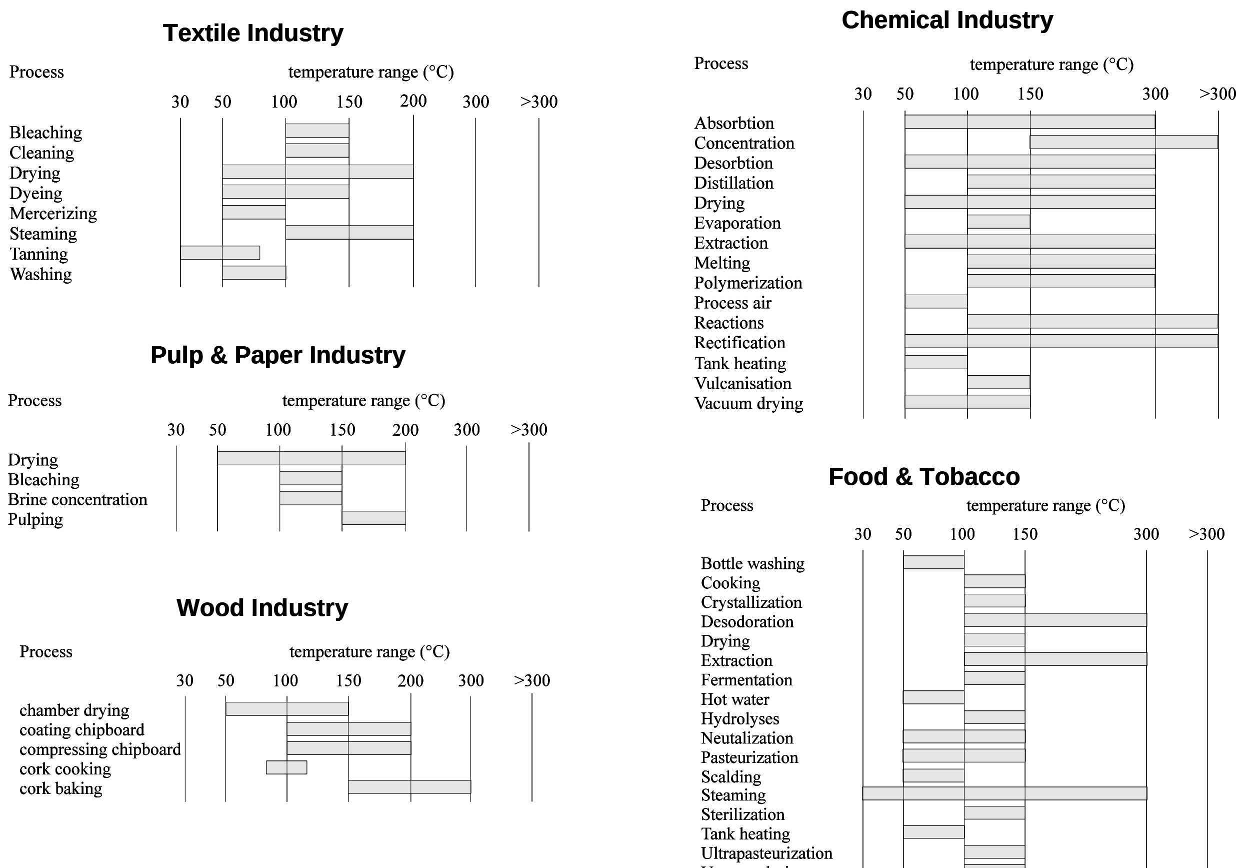


Figure A-41: Principle of cooling with mechanical (electric) or thermal energy

Figure A-42: Parabolic trough collector field for heating and cooling purposes of the Iberotel in Dalaman, Turkey. Source: /SOLITEM 2004/



Source: SOLGAS Study

Figure A-43: Temperature range of different industrial applications for process heat or co-generation /SOLGAS 1997/

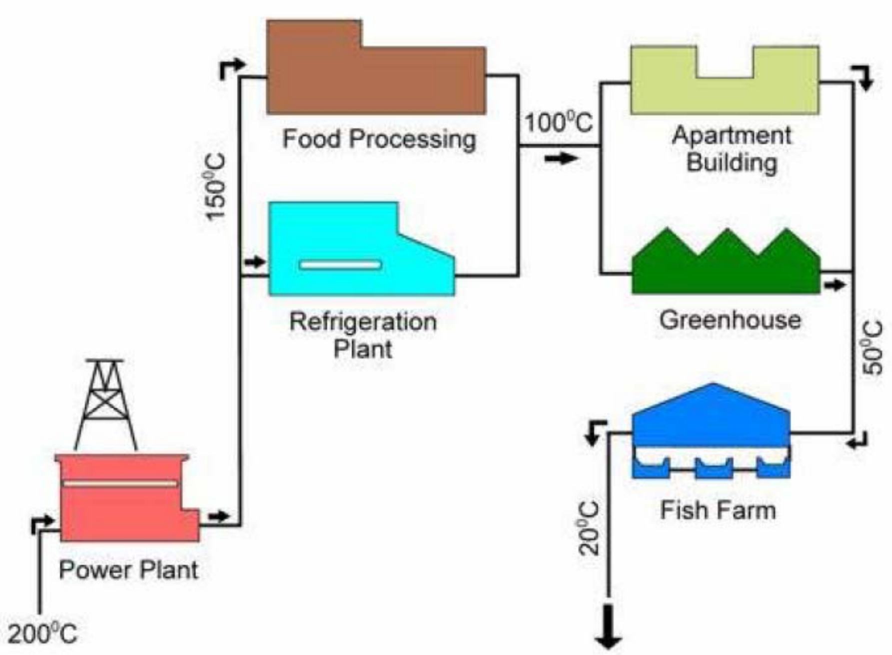


Figure A-44: Cascade uses of geothermal energy /IGA 2004/

Figure A-45: Energy production above and horticulture underneath a linear Fresnel collector field in a multipurpose concentrating solar thermal power plant. Photos of the collector field by Solarmundo, greenhouse visualisation by DLR.

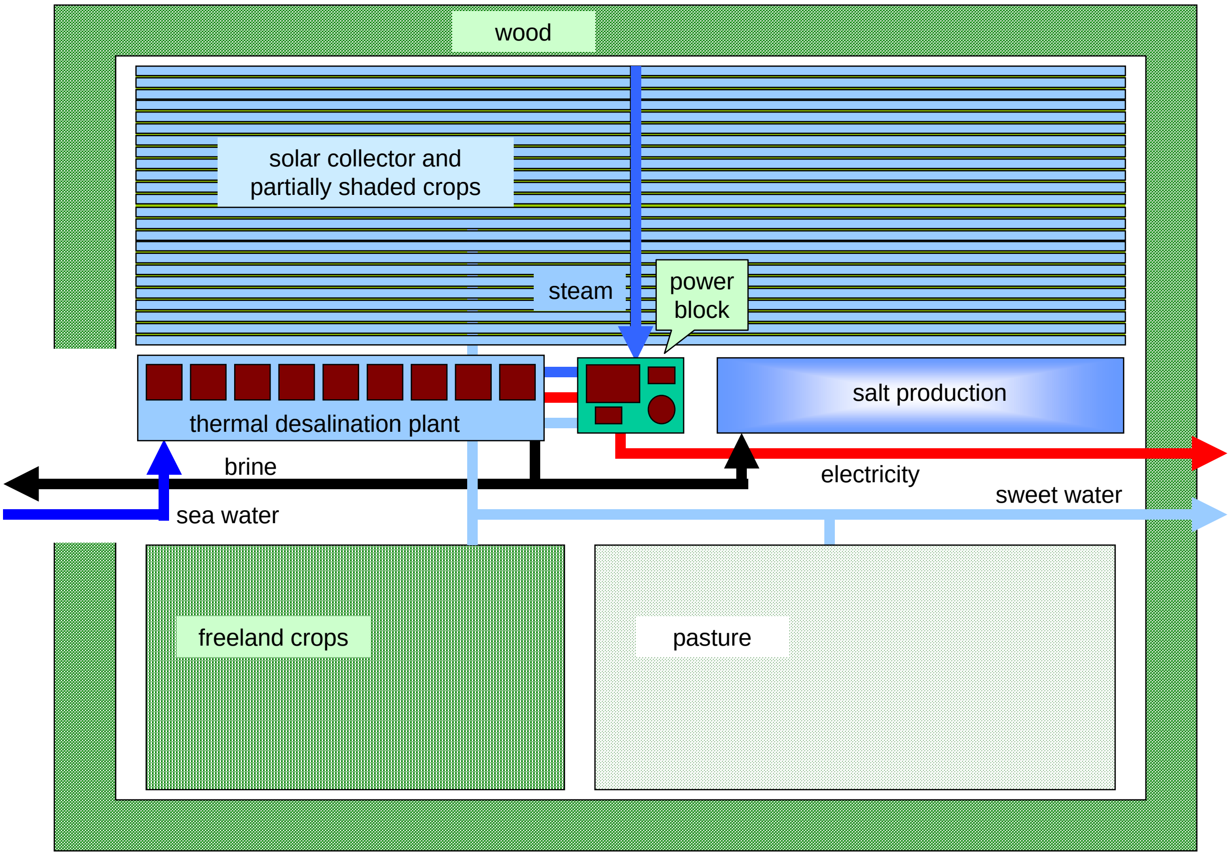


Figure A-46: Multipurpose plant for the development of arid regions

Annex 11: Abbreviations

A1F1	Business as Usual Scenario of the IPCC
BGR	Bundesanstalt für Geowissenschaften und Rohstoffe
BMU	German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
CDM	Clean development Mechanism
CED	Cumulated Energy Demand
CF	Capacity Factor
CIEMAT	Centro de Investigaciones Energeticas y Medioambientales, Spain
CSP	Concentrating Solar Power
CHP	Combined Heat and Power
CLFR	Compact Linear Fresnel Collector
CO_2	Carbon Dioxide (greenhouse gas)
DNI	Direct Normal Irradiation (beam radiation on ideal sun-tracking collectors)
EPC	Engineering, Procurement, Construction
EUMETSAT	Eurepean Meteorological Organisation for the Exploitation of Meteorological Satellites
EU	Europe
EU-MENA	Europe, Middle East, North Africa
Fresnel	Inventor of a facetted concentrating mirror assembly
GACP	Global Aerosol Climatology Project
GEF	Global Environmental Facility
GHG	Greenhouse Gases (emissions responsible for climate change)
GIS	Geographic Information System (electronic geographic data base)
GWh	1 million kWh
HTF	Heat Transfer Fluid
HVDC	High Voltage Direct Current Transmission of Electricity
Hybrid	Mixture of solar and fossil primary energy
IEA	International Energy Agency
IPCC	International Panel on Climate Change
JI	Joint Implementation
KfW	Kreditanstalt für Wiederaufbau
KJC	Kramer Junction Company, California
kW	kilowatt (unit of power)
kWh	kilowatt-hour (unit of energy)
LCA	Life Cycle Assessment of Emissions, Materials and Energy Consumption
LEC	Levelised Electricity Cost
LS-3	Parabolic Trough Collector Luz Systems Version 3
ME	Middle East
MED	Multi-Effect-Desalination Plant / Mediterranean Region
MENA	Middle East & North Africa
MSF	Multi-Stage-Flash Desalination Plant
MTSA	Multi-Tower Solar Array
MWh	1000 kWh
NA	North Africa
NCAR	National Center for Atmospheric Research (USA)
NCEP	National Centers for Environmental Prediction (USA)
NOAA	National Oceanographic and Atmospheric Administration
NPV	Net Present Value
OECD	Organisation for Economic Co-operation and Development

O&M	Operation and Maintenance
PPA	Power Purchase Agreement
PSA	Test Centre Plataforma Solar de Almeria, Southern Spain
PS10	Planta Solar 10 (solar tower project in Spain)
R&D	Research and Development
RD&D	Research, Development and Demonstration
REA	Renewable Energy Act
RES	Renewable Energy System
RO	Reverse Osmosis Membrane Desalination
SBP	Schlaich, Bergermann and Partner
SEGS	Solar Electricity Generating System
SOLEMI	Solar Energy Mining
STEPS	Evaluation System for Solar Thermal Electric Power Stations
Stirling	Inventor of an external combustion piston engine
TOMS	Total Ozone Mapping Spectrometer
TWh	1 billion kWh
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
WBGU	Wissenschaftlicher Beirat für Globale Umweltveränderungen, German Scientific Council for Global Environmental Affairs
WEC	World Energy Council