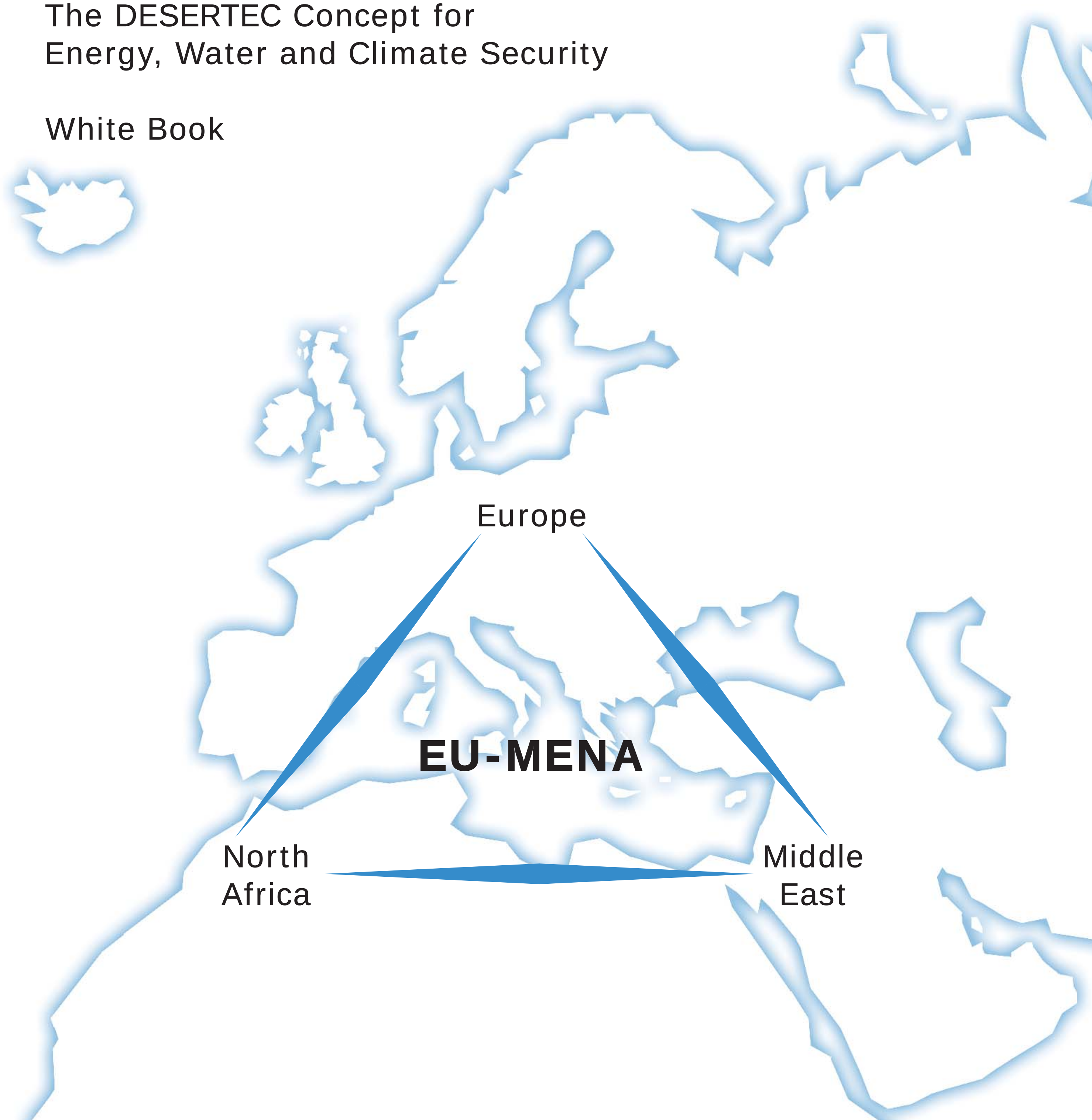
Trans-Mediterranean Renewable Energy Cooperation TREC

Clean Power from Deserts

The DESERTEC Concept for Energy, Water and Climate Security

White Book



Clean Power from Deserts The DESERTEC Concept for Energy, Water and Climate Security

This White Book provides information on the potential of the largest but least tapped source of energy on earth, the solar radiation of deserts, and on how it could be put into service for energy, water and climate security for Europe, the Middle East and North Africa (EUMENA). Further it quantifies the potentials of all major renewable energy sources in the EUMENA region, available for a mix optimized for a fast and low-cost transition to a climate compatible EUMENA-wide power supply system. It describes the present demands for electricity and considers scenarios for their expected development until 2050, and how they could be served in a save and sustainable way by interconnected renewable energy sources in EUMENA. The decarbonisation of the power system for EUMENA is in reach. To this end full cooperation of sunbelt and technology belt regions, their interconnection by a supergrid and an Apollo-Program like effort EUMENA-DESERTEC to tap the clean power from deserts are required. The book is based on the studies MED-CSP, TRANS-CSP and AQUA-CSP conducted by EUMENA-wide study teams lead by DLR.

The White Book effectively summarizes the work of the Trans-Mediterranean Renewable Energy Cooperation. TREC was founded in September 2003 by an initiative of The Club of Rome, the Jordanian National Energy Research Center NERC, and the Hamburg Climate Protection Foundation HKF, with the aim of achieving fast climate, energy and water security by a joint effort of the EU-MENA regions. TREC now is a network of 60 experts in countries "around" the Mediterranean Sea and beyond: from Morocco, Algeria, Tunisia, Libya, Egypt, Palestine, Jordan, Yemen, United Arab Emirates and Bahrain, and from Spain, France, The Netherlands, United Kingdom, Germany, Austria, Italy, Turkey, India and Australia.

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The editors

Gerhard Knies, Co-ordinator of TREC
Uwe Möller, Secretary General, The Club of Rome
Michael Straub, DESERTEC Office Manager

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Contact: Office@DESERTEC.org

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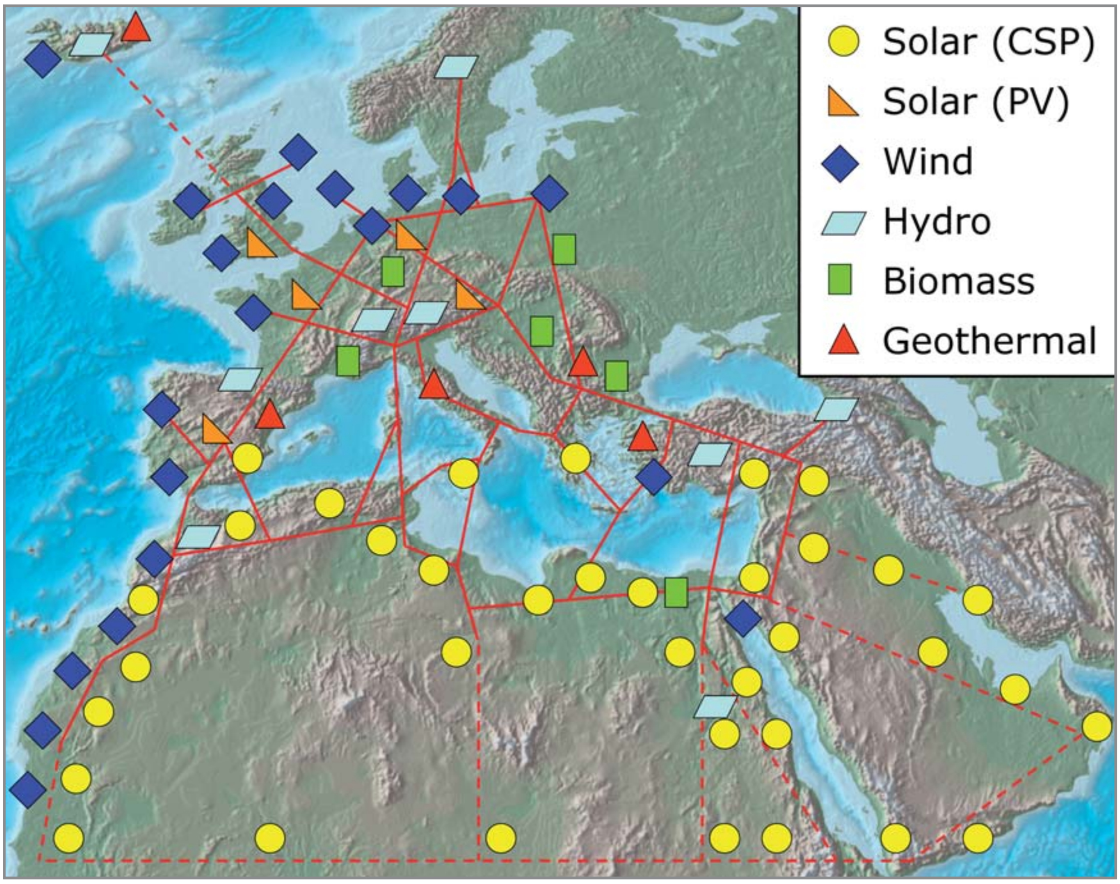

TREC
Clean Power from Deserts
Trans-Mediterranean
Renewable Energy Cooperation
An Initiative of The Club of Rome

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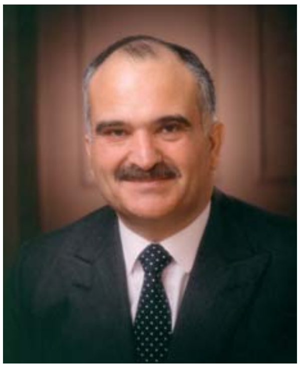
1. Introduction

1.1 EUMENA – Community for a sustainable energy future

His Royal Highness Prince Hassan bin Talal of Jordan
Chairman of the Governing Board of the Arab Thought Forum
Chairman of the Higher Council for Science and Technology, Amman, Jordan
Member of The World Future Council, Former President of The Club of Rome

Thanks to the availability of fossil fuels human populations and human development have developed to a point where continued expansion cannot occur without severely overshooting the carrying capacity of planet Earth. Social and natural systems are endangered.
The most comprehensive threat to the natural world and to the development of civilization is the man-made challenge to the global climate, which comes as a result of powering our present forms of civilization with fossil fuels. The global and the local climates may change faster than natural and social systems can adapt.



By changing our global climate we also change local living conditions with potentially severe implications for plants, animals and humans. Food chains may be interrupted. Populations of plants and animals may change. Infrastructure for human civilization may be flooded or blown away. Climate change is an assault on the developed forms of life which have emerged through long processes of evolution.

The use of fossil fuels, which enabling human civilization to develop and to function, has now become a threat to our natural living conditions.

Can compatibility between civilization and the natural world be restored, in view of a world population approaching 10 Billion with growing economic needs? Such a renewed compatibility would require a form of energy that would not harm our natural living spaces and threaten their resilience. Renewable energy, and in particular solar energy, could be used to power our growing civilization and provide fresh water from desalination without harming our natural living environment.

In fact, there is around 10,000 times more energy coming from the sun than would be needed for powering human civilization. This solar energy comes as light at day and returns to outer space as heat radiation at throughout the day and night, whether it has been "used" or not. The use of solar energy - or of any other form of renewable energy - should then be done in an "environmentally compatible way" which leaves the environment unaffected. As a counter example, the building of large dams for hydropower or growing of energy plants in large monocultures may not fulfill this criterion.

How can we reclaim energy from renewable and clean sources in environmentally compatible ways at a scale that matches present and expected future consumption of energy?

Here the deserts of the earth can play a key role. They receive about 700 times more energy from the sun than humankind consumes by burning fossil fuels, day by day. Deserts are the places with the best solar radiation conditions and with the least possible impact of collector deployment onto the biosphere on earth.

In deserts, clean power can be produced by solar thermal power plants (CSP) in a truly sustainable way and at any volume of conceivable demand. Power can be transmitted with low losses by High Voltage Direct Current (HVDC) lines to more than 90% of the world's population. This gives the deserts a new role: Together with the many other forms of accessible renewable energy the newly utilised desert would enable us to replace fossil fuels and thus end the ongoing destruction of our natural living conditions.

To put this into practice, countries with deserts, countries with high energy demand and countries with technology competence must cooperate. This is an opportunity for the Mediterranean riparian regions of Europe, the Middle East and North Africa (EUMENA) to form a community for energy, water and climate security – with some similarities to the Community of Coal and Steel established in Europe some 60 years ago - for a prosperous and peaceful future.

More than 40 years ago the **Apollo Space Program** was launched to fulfill the old dream of taking man into outer space. Today, we have a bigger dream, to restore balance between man and his home planet, Earth. With the political will, EUMENA countries could now launch an **Apollo-like "EUMENA-DESERTEC" Program**, to bring humankind back into balance with its environment, by putting deserts and technology into service for energy, water and climate security. This would be an important step towards creating a truly sustainable civilization. I very much hope that this White Book will help to make it happen.

1.2 Decarbonisation of energy supply – central challenge for mankind

Professor Dr. Klaus Töpfer
Member of the German Council for Sustainable Development (RNE)
Former Executive Director of the United Nations Environment Programme (UNEP)
Former German Federal Minister for the Environment, Nature Conservation, and Nuclear Safety (BMU)

The figures are well-known since quite a long time: When I was born 70 years ago this planet earth had to carry 2.6 billion human beings. In the last 70 years this figure rose to 6.5 billion. For the year 2050, when my just born grandchildren will be 43 years old, this globe will carry 8.5 billion people at a minimum.

Until today this world is divided in those 25% enjoying a high living standard and consumption pattern unique until now in human history. On the other side 75% of the global population are still confronted with poverty, with no access to safe drinking water, to living conditions in slums and favelas. The Millennium Development Goals (MDG) accepted by all heads of states and heads of governments in the whole world at the Special Session of the General Assembly of the UN in the year 2000 are focussed to half until the year 2015 this shocking number of poor people in a world of affluence.

To overcome poverty in a further growing population makes economic development a must. The overcoming of the bipolar world, most visible in the demolition of the Berlin wall, gave a new chance to decrease the segregation between the rich and the poor in this world. The globalisation process made a new Industrial and Economic Revolution possible. It is well understood that for the stability in this globalised world this Industrial and Economic Revolution must work much better for the poor than it was until now. Especially the development in Africa must benefit much more from the positive Return on Investment of globalisation.

Economic development needs energy. It is not surprising that poverty is first and for most energy poverty. The availability of affordable, secure and environmentally responsible energy supply is therefore the main key to reach the MDG and to decrease the welfare gap on the global scale.

Until today the global energy supply is to more than 70% linked with the use of fossil fuels, of coal, oil and gas.

The substantive increase of energy demand already now in the fast growing economies especially in Asia makes the access to energy resources and the affordable costs of energy one of the main risks for the stability of economic development processes. Tensions and conflicts will be a sober consequence with all the risks for a peaceful development.

The concentration on the use of fossil fuels for energy supply is the main threat for the stability of the global climate system. The scientific community gave evidence that mankind has to decrease the green house gases emissions, mainly CO_2 and methane, until the year 2050 by 60 - 70% as a minimum. This makes a revolution in supply and demand in the energy market unavoidable. Mankind has to do its utmost to develop technologies for energy production which are not or to a much lower degree linked with the emission of greenhouse gases. The economic need to provide secure energy at a competitive price is therefore fully in line with the need to stabilise the climate system. Unluckily, in the past decarbonisation of the energy supply was obstructed by the fact, that CO_2 could be emitted at zero price. The energy price of the fossil fuel economy was and is until today heavily subsidised by nature, by the assimilation capacity of the atmosphere. This must be brought to an end rapidly. The main objective is therefore combined with the need of a price for CO_2 emissions.

This development gives the means for investments in human resources and for financing a new boost concerning research and development of non-carbon energy sources. This common denominator is especially concentrated on the question, how to use the huge, nearly unlimited supply of solar energy. Technologies are already available and the market for solar technologies and production is booming. Nevertheless, we have to stimulate and to accelerate this process. It is a revolutionary idea to use the affluent sun energy especially in the deserts of Africa and Arabia for the production of clean energy, that can also be transported to developed countries in the North. A new development paradigm would be the consequence for Africa on the one side and for the climate targets in Europe on the other side.

This is what makes DESERTEC fascinating. It is necessary to discuss this possibility intensively and to pave the way for the realisation of this revolutionary idea. It is good to know that industry starts to be open for those ideas and it is good to know that more and more scientists from the whole range of scientific disciplines are integrated in this program. To concentrate human and financial capital on this project is not to signal that other possibilities of renewable energies are not necessary any more. Quite in the contrary. The situation of limited fossil energies for global economic development on the one side and the dramatic consequences of greenhouse gas emissions from fossil fuels on the other side make this a most important investment in stability, freedom and peace on this wonderful green planet earth.

1.3 We have to move fast towards Solar Energy

Anders Wijkman, MEP
President of GLOBE EU
Vice President of The Club of Rome
Member of The World Future Council
Former Assistant Secretary-General of United Nations and Policy Director of UNDP

Energy and climate security have all of a sudden become top priorities for policy-makers. For the Club of Rome this is no surprise. We have been seriously concerned about energy and material use for decades. The "Limits to Growth" Report in 1972 modelled the consequences of a rapidly growing world population in combination with conventional growth policies. The report essentially predicted that the world was headed for major problems, in terms of both resource constraints and pollution over-load.

Increasingly we experience the consequences of the policies pursued. Climate change is the most obvious problem facing us. Add to that the ecosystems crisis. According to the Millennium Ecosystem Assessment, two thirds of the most important ecosystems that we depend on – forests, fisheries, wetland, fresh water resources etc. – are overutilized. This can truly not go on. We have to change course and be as concerned by the quality of growth as by its quantity.

To do energy right would represent a good start. More than eighty per cent of our energy still comes from fossil fuels – roughly the same ratio as thirty years ago. It shows how little progress there has been so far in moving towards a cleaner and more efficient energy system.

The current energy debate is dominated by basically three concerns: energy security, carbon emissions and the price of energy. There are all kinds of proposals on the table how to address the problems: energy efficiency, renewables, carbon capture and storage, nuclear, hydrogen, and so on. The strange thing is that solar energy is more or less absent from the debate.

Although the sun daily provides us with something in the range of 10,000 times the energy we commercially use on planet Earth, the efforts to capture this potential have been few and far between. Consequently, when we talk about renewables at large scale we mostly refer to biomass, geothermal, hydro and wind energy.

While I am all for the development of these energy alternatives I deplore the scant attention so far given to utilizing solar energy directly, in particular in the form of solar power.

When listening to the major energy companies, for instance, one gets the impression that the options for the future are limited to enhanced efficiency in the way we use energy, increased use of coal - albeit with CCS (carbon capture and storage) – and increased use of nuclear. Renewables are also mentioned, but primarily for the long-term.

While I strongly support action both on efficiency and CCS – coal will be used massively, whether we like it or not, and we desperately need to make sure that as much as possible of the carbon dioxide generated is captured - I fail to understand why not more interest is given to solar energy applications, notably large-scale solar power. The technology is there and the costs are already more or less competitive with other forms of alternative energy, and at good sites even with those of oil.

Carlo Rubbia, the Nobel Laurate, gave a passionate speech on behalf of solar thermal power technology in Potsdam recently. The occassion was the Nobel Symposium on Sustainable Development, organised by Professor John Schellnhuber. In his talk Rubbia made reference to the huge potential provided by the solar thermal power plants, using mirrors to concentrate solar radiation to spots where a liquid can be heated, stored and used to generate electrical power according to demand. The technology is there and costs are coming down nicely. We would only need an area representing a small fraction, like a per cent of the deserts in North Africa to provide Europe, the Middle East and North Africa with all the electricity needed.

To exploit this option is exactly what TREC (the Trans-Mediterranean Renewable Energy Cooperation) is all about. TREC wants to boost the generation of electricity and desalinated water by solar thermal power plants and transmit the power generated via HVDC transmission lines throughout the Mediterranean region. Power from deserts would, no doubt, speed up the process of cutting European emissions of CO2 and help increase the security of EU energy supplies. What are we waiting for?

Given that TREC was only launched in 2003, the project has gained considerable momentum over a short period of time. However, major decisions about the future orientation of energy policy in the EU will be made in the near future. I am afraid that conventional thinking still dominates in most of the capitals of Europe, and for solar power to have a chance we need to be much more aggressive in terms of advocacy.

As already indicated, TREC so far has received limited attention from the leading energy companies. The reasons behind this are obvious. Huge investments have already been made in coal and nuclear, and renewables - solar power included - are still viewed with a lot of suspicion.

While we cannot think away both coal and nuclear, the challenge - however - is to make sure that the energy system of the future is becoming both more diversified and dominated by clean energy sources. If solar energy can provide us with all the electricity we need and at reasonable cost, it would be a crime not to vigorously pursue that option!

The arguments against TREC have mainly centered around cost and security of supply. Like with all new technologies, costs are high in the beginning. But experience with learning curves tells us that costs will come down. The cost of a kWh produced by solar thermal power in California today is 10-12 cents, but estimates by the World Bank project a cost of 4-6 cents already in 2015. So the cost argument is not really valid.

How about security? Ever since the Russians cut off gas supplies to the Ukraine in early 2006, energy security has been high on the EU agenda. Efforts are now being made to decrease our dependence on imports, notably from "unstable regions and suppliers". These objectives are understandable. But to use them as an argument against a project like TREC is far from reasonable.

Just a few years ago the EU launched its Neighbourhood Policy (ENP). The aim of the policy is to strengthen the framework for the Unions relations with those neighbouring countries that do not currently have the perspective of membership of the EU. The policy offers incentives that are primarily economic: in return for concrete progress on democracy, human rights and institutional reforms the neighbours will benefit from the prospect of a closer economic integration, including a stake in the EU's Internal Market.

The central element of this cooperation is the bilateral ENP Action Plans, agreed between the EU and each partner. Implementation of the first eight ENP Action Plans (Egypt, Israel, Jordan, Moldova, Morocco, the Palestinian Authority, Tunisia and Ukraine) is already underway.

The objectives of the ENP are crystal clear. Every effort should be made to help facilitate economic and social development in the Middle East as well as North Africa (MENA). One of the major instruments will be trade and investment. To promote solar power supplies to Europe would, no doubt, lead to increased investments and business opportunities for the MENA countries. This in turn will help provide new jobs and thereby increase political stability.

Lastly, imports of fuels such as uranium, natural gas and oil, are considered to be politically risky, mainly because supplies are limited. By contrast, solar power is plentiful. Increased demand from the EU for solar thermal power would bring down costs and help initiate somewhat of solar revolution. There are plenty of regions in the world that would benefit from such developments. Oil riches, which to date boost the economies of some countries would be replaced by solar riches. Both from the point of view of climate and energy security such a development would be highly desirable!

2. Why we have to act

2.1 Climate Change is accelerating, but we must slow it down rapidly

Professor Dr. Hartmut Grassl
Former Director of the Max Planck Institute for Meteorology, Hamburg, Germany
Former Director of the World Climate Research Programme, World Meteorological Organization, UNO

Climate as the Key Natural Resource

It is well accepted that climate is an important natural resource, but not that it is the key resource for our life on Earth. Let us ask what the three most important parameters are for our life. The answer is: Energy from the sun, water from the skies and food produced by plants! What are the most important climate parameters at given size of our planet and average distance to the sun? Solar radiation flux density, clouds and precipitation, and surface properties (mainly vegetation). Hence, our life support and key climate parameters are nearly identical. Therefore, even in the absence of climate change, climate variability is a major concern for us and its impact on our activities needs the attention of all decision makers. In the era of anthropogenic climate change it has become a key policy arena and globally co-ordinated action is a must, but proceeds much too slow.

Recent Climate Change is Man-made

The most authoritative statement to date on anthropogenic climate change is contained in the very recent policy makers summary of the Working Group I on Climate Science of the Intergovernmental Panel on Climate Change (IPCC, 2007) issued on 2 February 2007.

The understanding of anthropogenic warming and cooling influences on climate has improved since the Third Assessment Report (TAR), leading to very high confidence that the globally averaged net effect of human activities since 1759 has been one of warming, with a radiative forcing[1] of + 1.6 [0.6 to 2.5] Watts per square meter (Wm^{-2}).

Hence, the linear global mean warming trend observed until 2005, 0.74 ± 0.18°C since 1906, is the sum of warming caused by an increased greenhouse effect of the atmosphere and cooling by increased turbidity of the air.

This constrains climate system sensitivity to a change in atmospheric composition. As stated in IPCC (2007) it lies between 2°C and 4.5°C for a radiation budget change caused by a doubling of carbon dioxide (CO_2). In comparison to earlier assessments the average sensitivity has slightly increased, thereby also enhancing warming at a given greenhouse gas concentration increase. At the same time the calculated contribution to global warming by higher solar irradiance in the 20th century has been reduced, due to an improved understanding of solar physics and better direct observations of solar output with satellites. Also mean sea level rise can be measured with higher accuracy since late 1991 after the advent of precise altimeters on satellites. It is on average slightly above 3 mm per year, clearly above the 1.7 ± 0.5 mm per year average derived from gauging stations for the 20th century (see figure 1).

Climate is in a Non-analogue State

The influencing factors causing natural climate change vary over many time-scales from years, e.g. explosive volcanic eruptions, to many million years (e.g. drifting continents) and have always caused natural climate change. Therefore, no analogue states in climate history exist, which could be used for forecasting future climates. An example: During the Eemian interglacial, about 125,000 years ago, when average surface temperatures where higher by about 1.5°C compared to the pre-industrial period and sea level was higher by 4-6 m, because of a considerable melting of the Greenland ice sheet, eccentricity of the Earth's orbit around the sun was much stronger than today and obliquity of the Earth's rotation axis was also higher than today. This has led to only about 10,000 years duration of the Eemian interglacial, while ours, the holocene, can last for further 30,000 to 40,000 years because eccentricity will shrink and obliquity as well, thereby not repeating a situation with very low insolation in higher northern latitudes and stronger annual cycles, favouring ice sheet formation.

[1] Radiative forcing is a measure of the influence that a factor has in altering the balance incoming and outgoing energy in the Earth atmosphere system and is an index of the importance of the factor as a potential climate change mechanism. If positive the surface warms on average.

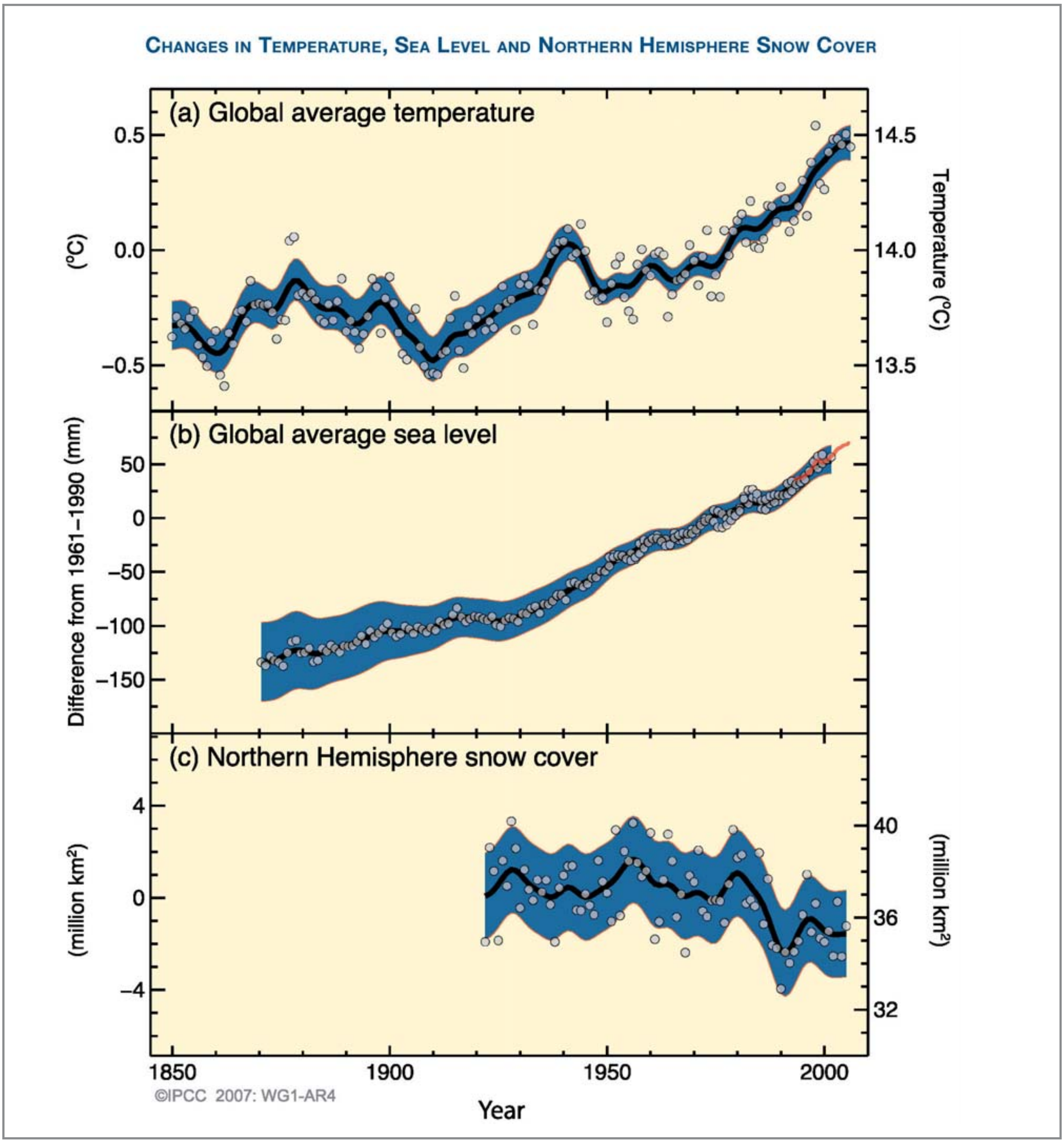


Fig. 1: Observed changes in

(a) global average surface temperature;

(b) global average sea level rise from tide gauge (blue) and satellite (red) data and

(c) Northern Hemisphere snow cover for March-April.

All changes are relative to corresponding averages for the period 1961-1990. Smoothed curves and shaded areas represent decadal averaged values and their assessed uncertainty intervals, while circles show yearly values (IPCC, 2007).

In addition the present extremely rapid change in atmospheric composition pushes the climate system in an extreme non-analogue state, which will certainly cause new hitherto unknown feedbacks. We even cannot rule out rapid transitions into another state, because never before in recent Earth history the greenhouse effect was as high as today when two large ice sheets still exist. Will we trigger the melting of the Greenland ice sheet or have we triggered it already?

What would happen in the 21st century without globally co-ordinated climate change policy?

The only way to project future climate change is by using validated numerical models that solve prognostic equations for prescribed anticipated emissions of greenhouse gases in scenarios of potential socio-economic development. As we do not know the probable emission path the scenarios have to span a wide range.

All these scenario calculations have, however, no feedbacks with the socio-economic system, as we also do not know our reactions to accelerating climate change impacts or rough knowledge on further climate change.

The model projections for scenarios without co-ordinated global climate change policy (see figure 2) can be condensed into one sentence: Warming in the 21st century will be more rapid than ever experienced by homo sapiens, as one century could see warming of the same magnitude as occurring after the end of an intense glaciations, in about 10,000 years. However, different projections also point to major differences in warming and thus climate change is depending on the emission scenarios. Hence, it is in our hands to devise a prudent co-ordinated globally climate change policy.

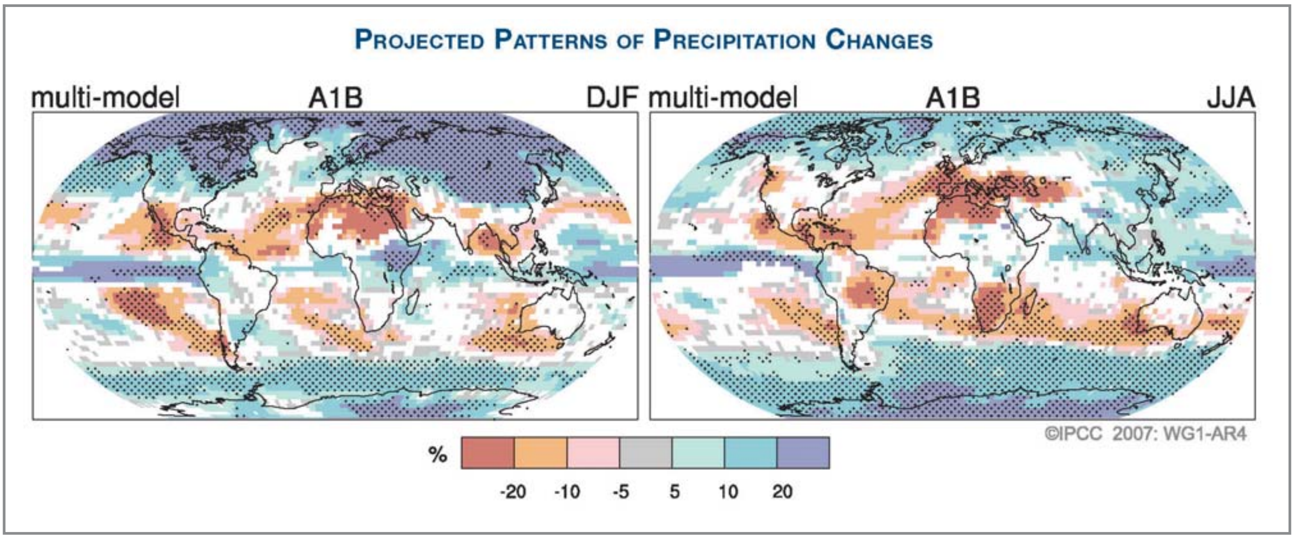


Fig. 2: Relative changes in precipitation (in percent) for the period 2090-2099, relative to 1980-1999. Values are multi-model averages based on the SRES A1B scenario for December to February (left) and June to August (right). White areas are where less than 66% of the models agree in the sign of the change and stippled areas are where more than 90% of the models agree in the sign of the change (IPCC, 2007)

Until which mean global warming value could we avoid a dangerous interference with the climate system?

The answer can still not be given; but when we could give it, it might be too late. What might then be first approaches? Definition of a maximum tolerable mean warming of 2°C until 2100, as it was accepted by the European Union, following earlier proposals by scientific advisory bodies, e.g. the German Global Change Council report of 1996, giving advice to the Federal German Government. This maximum mean warming, it could be called a tolerable climate window, is derived from the following reasoning: Firstly, future climate should not exceed experience of homo sapiens, secondly, natural ecosystems should be able to adapt to climate change, and thirdly, sustainable economic development should remain possible.

Following recent scientific studies, however, it cannot be ruled out that mean global warming of +2°C is already too high in order to avoid melting of substantial parts of the Greenland ice sheet; thus causing inundation of unprotected marsh lands with many mega-cities in the coming centuries.

In combination with the most probable climate sensitivity estimate (IPCC, 2007), +3°C for a doubling of pre-industrial carbon dioxide (CO_2) concentration to 560 parts per million by volume (ppmv), even the probably too high +2°C goal asks for a maximum CO_2 concentration of less than 450 ppmv, in a situation where 380 ppmv have been reached now. Emission reduction policies are the urgent global political task.

Stringent Reduction Goals Follow from the Tolerable Climate Window

The long life-time of anthropogenic carbon dioxide (CO_2) in the atmosphere, it needs several revolutions of the global ocean to store about 85 percent of the emissions, has led at present emission ratios to an ever increasing accumulation of CO_2 in the atmosphere since industrialisation began.

Less than a quarter of present anthropogenic emissions of 8.8 billion tons of carbon per year (GtC/a) enters the deeper ocean for long-term storage. As the recent yearly CO_2 increase rate is about 0.5 percent per year, equivalent to an accumulation of about 3.5 GtC/a in the atmosphere, more than 3 GtC/a must be stored in the terrestrial biosphere, i.e. in soils and forests. How long these carbon reservoirs will grow under accelerating climate stress is still unknown. We cannot count on them. The later parts of the 21st century might well see – under the assumption of weak climate protection measures – carbon releases from soils, for example emissions of methane (CH_4) and CO_2 from melting permafrost soils, and CO_2 emissions from other soils and ill-adapted forests. Both processes would accelerate climate change.

How strong must emission reductions be to stabilize greenhouse gas concentrations at a level avoiding a mean global warming above 2°C? The answer depends on the life-time of the gas. For CO_2 stabilization at present concentrations a reduction of 50 to 60 percent would be needed. Since we depend to about 80 percent on global average on fossil fuels a further growth of CO_2 concentration cannot be avoided. Adopting the +2°C maximum warming goal and a climate system sensitivity of 3°C for a doubling of pre-industrial CO_2 concentration, the global CO_2 emission reduction has to reach about 50 percent until 2050. Because the developing countries will rapidly expand emissions in the coming few decades, industrialized countries have to reach the 80 percent reduction target until 2050. In other words: they have to adopt the strategy to become solar societies as fast as they can in order that the others can take the new technologies. The -20 percent CO_2 emission target of the European Union to be reached in 2020, adopted on 8 March 2007, is a good sign but still only a first major step and other industrialized regions have to follow.

The reduction policy debate has neglected the influences of other greenhouse gases like nitrous oxide (N_2O) and methane (CH_4), whose present contribution of 0.64 Wm^{-2} to radiative forcing is about 40 percent of the CO_2 contribution, thus not negligible at all.

It is clear that mankind cannot wait to introduce renewable energy sources when fossil fuels (often still subsidized) came to an end and reach prices high enough to make renewables competitive. Emission reductions have to be implemented now to avoid a dangerous interference with the climate system, as stipulated by the UNFCCC.

Technical Potential of Renewable Energy Sources

The sun offers on average a radiation flux density of 343 Wm^{-2} of which about 70 percent are absorbed by the Earth system. These remaining 237 Wm^{-2} reach to a large part the surface, namely 165 Wm^{-2}. In comparison to mankind's energy flux density of about 0.03 Wm^{-2} the sun's offers at the surface is by a factor of more than 5000 higher. Hence, the motto of the 21st century could become: <u>Learn to harvest one five-thousandth of the sun's offer</u>! All other renewable energy sources are comparably small parts of the sun's offer. For example the kinetic energy contained in the ceaseless winds amounts to a global mean energy flux density of about 3 Wm^{-2}, often concentrated on the sea or along coastlines. Next comes the energy flux of the sun stored in biomass; on global mean only 0.1 Wm^{-2} are available reaching peak values of about 1.0 Wm^{-2} if humid climates support strong plant growth on fertilized soils. Equivalent in the global mean with 0.1 Wm^{-2} is the geothermal energy flux from the Earth's interior, sustained mainly by radioactive decay. All other renewable energy sources are much smaller, including hydropower, but can be important regionally in mountainous areas or tidal channels. However, the energy supply system of mankind cannot be build on them.

Conclusion

The long-term solution is an energy supply system using solar radiation where it is most plentiful: in deserts. We have learnt to transport oil around the globe in big quantities; hence we will learn to transport solar electric current over long distances, if local production is insufficient and/or to costly. If we do not start research and pilot projects on such new energy supply system now, sustainable development can no longer be reached, because climate change will hit developing countries most strongly, populations of which have not caused the climate change impacts under which they suffer.

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2.2 A brief overview on Global Energy, Water and Carrying Capacity Perspectives

A brief overview compiled by Dr. Gerhard Knies
Coordinator of the Trans-Mediterranean Renewable Energy Cooperation (TREC)
Member of the German Association for The Club of Rome (DGCoR)
Former Scientist at the German Electron Synchrotron (DESY)

2.2.1 Survey on global energy demands, resources and solar capacities

Energy demand

The developing and in particular the developed world depend crucially on the continuous supply of energy. The fossil fuel consumption in 2005 was 107,000 TWh/y. The energy demand is expected to grow, driven by growth of population and of economies. An expectation of the growth has been estimated by the German Advisory Council on Global Change (WBGU, 2003). In this scenario the total energy demand will triple from 2005 to 2050, as shown in Fig.1.

Energy supplies and fossil resources

The global energy supply system of today is mainly built on stored, non-renewable fossil fuels. These fuels deliver energy primarily as heat, mainly from combusting hydro-carbons, and also from nuclear fission. The fossil fuels come from sources which are limited. Here we distinguish reserves and resources. Reserves are known deposits that can be profitably recovered with current technology. Resources are known deposits that cannot be profitably recovered with current technology but might be recoverable in the future, as well as deposits that are geologically possible but not yet found. Reserves, resources and present consumption of the significant fossil fuels are listed in Table 1, according to a compilation by the German Institute for Geology and Resources (BGR, 2005), in columns 2 and 4. The main message from column 6, the so called static depletion time of proven reserves, is that there are by far much more fossil reserves than we could afford to be combusted to CO2 without risking a break-down of our climate system, but that there are not enough for a save long-term operation of our civilization.

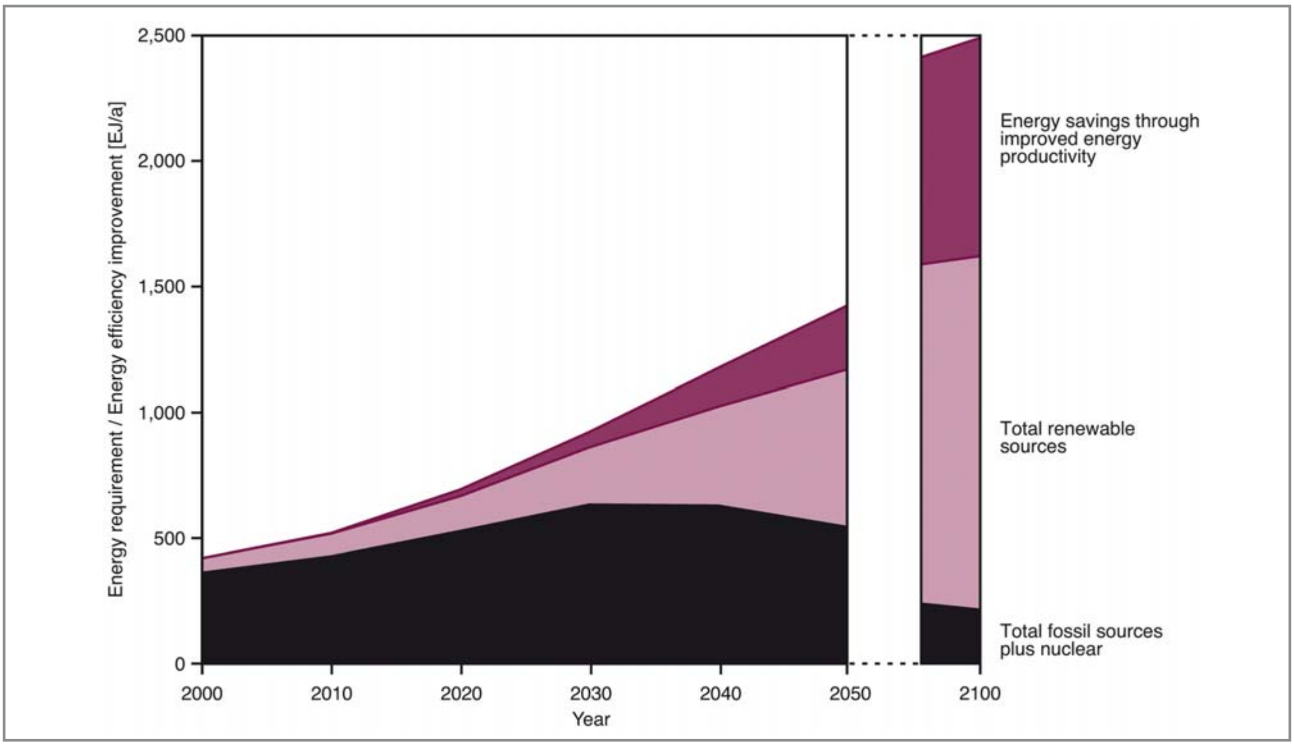

Figure 1: Development of energy demand as in the A1T-450 scenario, but reduced by a stronger energy efficiency enhancement. This path assumes from 2040 onwards a 1.6 per cent annual increase in energy productivity, compared to the historical figure of 1 per cent annually. Source: WBGU

Fossil energy source 1000 TWh (thermal) (= 3.56 EJ = 0.123 Gtce = 614 Million bbl oil)	Annual Production/ consumption 1000 TWh	Equivalent Solar delivery time in deserts, hours	Proven Reserve *(expected additional Resources)* 1000 TWh	Equivalent Solar delivery time in deserts days	Static depletion time of reserves years
All fossil fuels	107	5.7	10,400 *50,700*	47 *227*	98
Oil (conventional)	45	2.4	1,900 *960*	8.5 *4.3*	42
Oil (non-conv.)	0		780 *2,900*	3.5 *13.2*	
Natural gas (conv.)	24	1.3	1,600 *1,900*	7.2 *8.4*	65
Natural gas (non-conv.)	0		2 *1,687*	0.1 *6.2*	
Coal (hard and lignite)	33	1.8	5,700 *29,000*	25 *129*	170
Uranium, Thorium	4	0.2	460 *1,740*	2.0 *7.8*	101

Table 1: Fossil energy reserves and resources (BGR, 2005) and solar energy in deserts.

Solar energy capacity of deserts

The largest accessible but least tapped form of energy on earth is solar radiation on deserts. Its capacity, i.e. the annually received amount can be estimated in a rather straight forward way, since radiation is quite uniform across the desert regions. The hot deserts cover around 36 Million km² (UNEP, 2006) of the 149 Million km² of the earths land surface. The solar energy arriving per 1 year on 1 km² desert is on average 2.2 Terawatt hours (TWh), yielding 80 Mio Terawatt hours/year. This is a factor of 750 more than the fossil energy consumption of 2005, and there is still a factor of 250 if this demand would triple until 2050.

Table 1 shows in column 3 how many hours of sunshine in deserts are needed to receive the same energy as provided annually by the respective fossil fuel in column 2. The global annual fossil energy consumption corresponds to the energy received by 5.7 hours sunshine in deserts. This is about 0.15 % of annually incoming radiation.

We know how to convert 15% of solar radiation into the useful energy form of electricity (MED-CSP, 2005). This means, that 1% of the area of global deserts would be sufficient to produce the entire annual primary energy consumption of humankind as electric power. In other words: Any conceivable global demand of energy, today or in future, could be produced from solar energy in deserts. To this end we show in Fig. 2 the accumulated areas for collectors typically needed to generate 17,000 TWh/y (approx. current world consumption), 3200 TWh/y (approx. EU-25 consumption), and 600 TWh/y (approx. MENA consumption).

It is also interesting to take notice of the times by which the energy content of the various fossil reserves and resources are received as solar radiation in deserts. Column 5 gives the respective times in terms of days. We notice, that all known fossil reserves contain an energy as is arriving in deserts within 47 days.

These numbers tell us that if we develop the technologies for converting solar energy into electricity, if we learn how to store solar heat from day to night and how to transmit power over a few thousand kilometres with small losses, then fossil fuels could be replaced by solar energy from deserts (except for some fraction of the transportation sector), and by the other forms as wind, biomass, and hydropower. In fact, we do have the required technologies for conversion, storage of solar heat, and long distance transmission.

Technology and clean energy resources for a sustainable energy system are there. Also, as desribed in chapter 3, costs of solar power from good locations in deserts are already competitive with power from fossil fuels. The rising cost of fossil fuels is a disaster for poor countries and for the efforts to achieve the Millennium Development Goals. Therefore, a worldwide effort like the former Apollo Space Program should be launched to put deserts and technology into service for energy, water and climate security: an Apollo-like "EUMENA-DESERTEC" Programme.

2.2.2 Water Resources Crises

Different from fossil fuels, water is not shipped around the world. Availability or shortage of water is much more a regional feature. Availability of sweet water varies significantly with the climate zones. Basically, 4 zones can be distinguished:

1. the tropic rain zone
2. the arid belt
3. the moderate climate belt
4. the polar zone

The World Meteorological Organization (WMO) has made a world-wide assessment of water stres on a country base and arrives at the conclusion: *By the year 2025, as much as two-thirds of the world population may be subject to moderate to high water stress.*

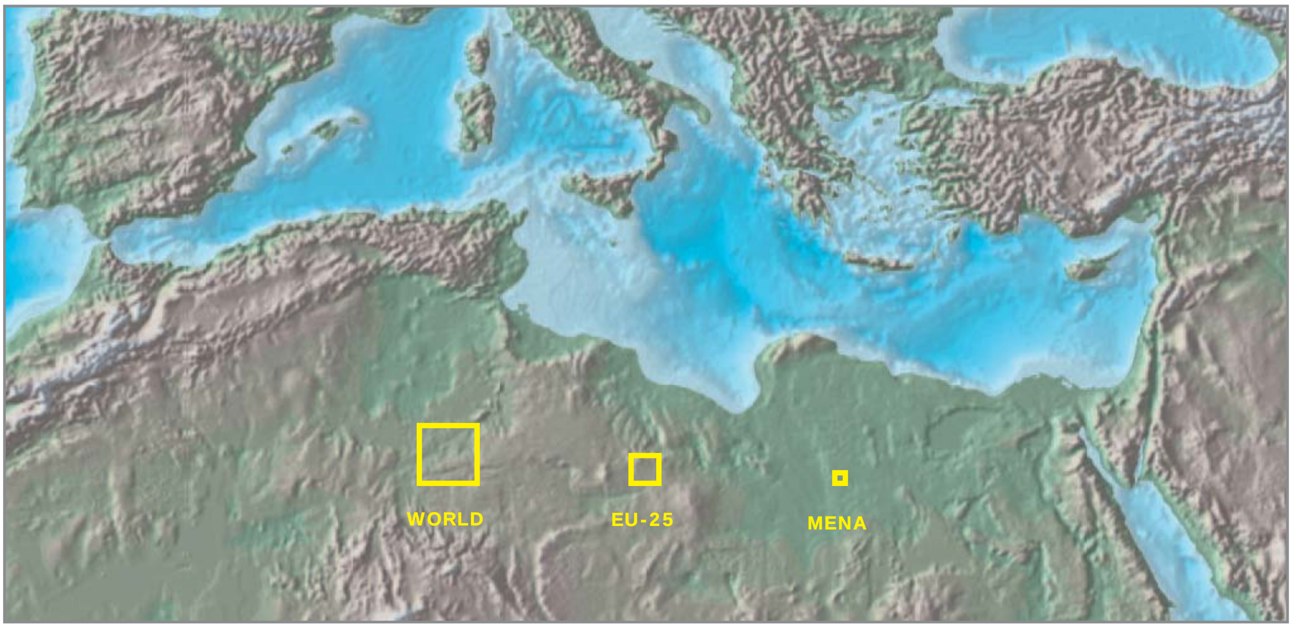

Figure 2: Areas of the size as indicated by the red squares would be sufficient for Solar Thermal Power Plants to generate as much electricity as is currently consumed by the World (17,000 TWh/y), by Europe (EU-25, 3,200 TWh/y) and by MENA (600 TWh/y) respectively.

The International Water Management Institute has made a classification of countries into 3 categories of water stress: physical scarcity, economic scarcity and no scarcity, as shown in Fig. 3:

The Global Environment Outlook (GEO, 2000) states:

Mismatches between human population density and water availability occur mainly in the transition regions from the arid belt to the tropic zone and to the moderate climate belt. About one-third of the world's population lives in countries with moderate to high water stress. The problems are most acute in Africa and West Asia but lack of water is already a major constraint to industrial and socio-economic growth in many other areas, including China, India and Indonesia. If present consumption patterns continue, two out of every three persons on Earth will live in water-stressed conditions by the year 2025. After 2025 world's freshwater resources may degrade even faster, in terms of quantity and quality, due changing precipitation patterns caused by ongoing climate change, and by growing population in particular in the water poor regions. Efforts for establishing water security may become a dominant issue on the environment, development and security agenda of the 21st century.

A wide-spread "quick fix" for pressing water scarcity is over-abstraction of groundwater. This, however, leads to depletion of such resources, as for instance in the Sana'a basin, or to the intrusion of salt water into near shore line aquifers when the groundwater table has sunk below the sea water table. In the latter case the quality of aquifers is destroyed by salinity. As a result, some arable land, such as that on the Batinah coastal plain of Oman, has been completely lost. It is estimated that the saline interface between the sea and groundwater advances at an annual rate of 75-130 metres in Bahrain. Also, the groundwater under Gaza is increasingly spoiled by salt water intrusion from the Mediterranean Sea. Some of the limited wells had to be closed already. Groundwater pumping is cheap, but over-abstraction may become extremely costly afterwards.

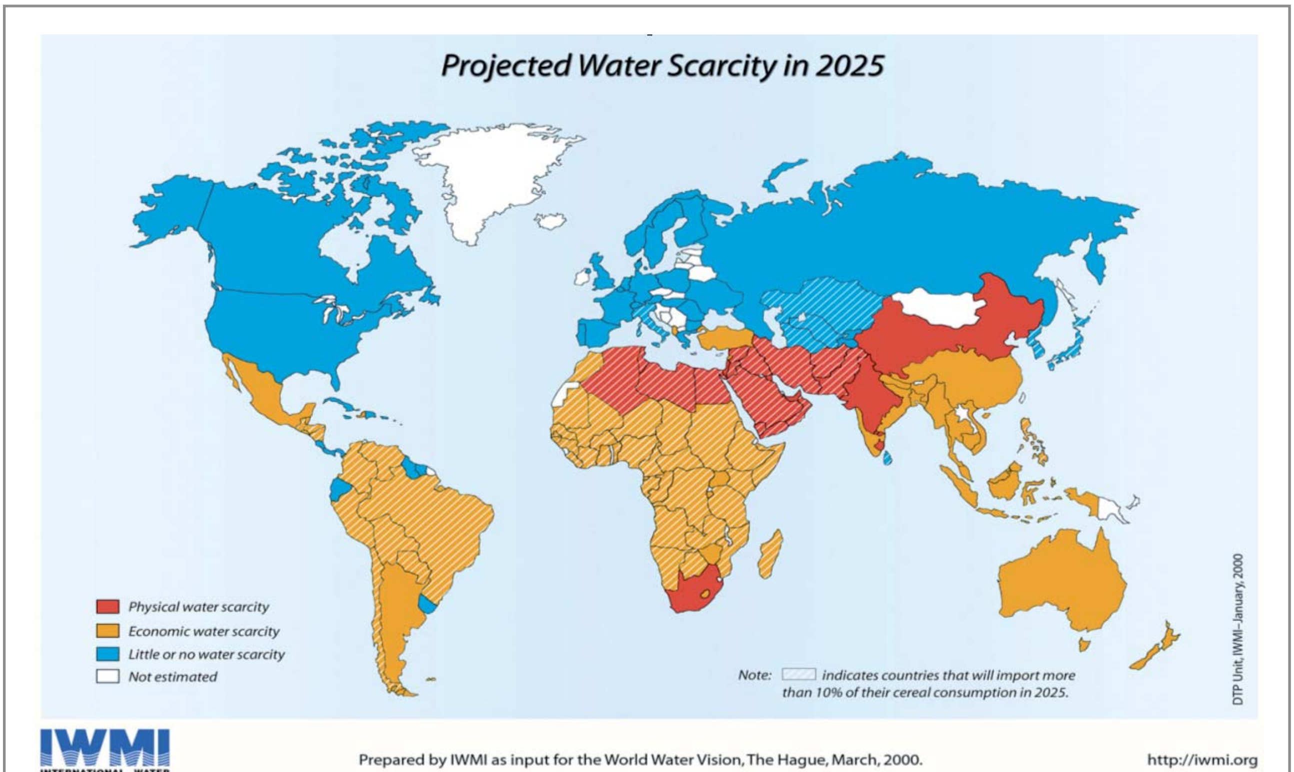

Figure 3: Water scarcity projection for 2025 by International Water Management Institute IWMI

A solution for the MENA REGION

According to the world map of projected water scarcity, the MENA region is the world's most threatened region. The AQUA-CSP study (AQUA_CSP, 2007)quantifies the expected deficits.

In Fig. 4 the deficit expected for a development scenario with medium-strong efforts (reference scenario) to increase the efficiency of water use, water distribution and irrigation and the re-use of waste-water is shown. The deficits may go up to 150 billion m^3/year, corresponding to a volume of 2.4 Nile rivers. Countries with very large upcoming fresh water deficits are Egypt, Saudi Arabia, Syria, Yemen, United Arab Emirates and Libya.

Sea water desalination may be a remedy to fresh water scarcity. Desalination, however, requires large amounts of energy, in the order of 4 kWh-el/m^3.

For building a sustainable water supply by desalination, clean and inexhaustible forms of energy are required at large quantities. The MENA countries can provide such energy from their deserts and make the shore lines of North Africa and of the Middle East to inexhaustible sources of fresh water. In fact, our studies (MED-CSP, 2006, AQUA-CSP, 2007) show how the imminent water crisis in the MENA region could be coped with by desalinating sea water. The White Book will address the potential of clean power from deserts to resolve the water crisis in MENA.

Further information on the global water situation can be found e.g. in the GLOBAL INTERNATIONAL WATERS ASSESSMENT (GIWA, 2006)

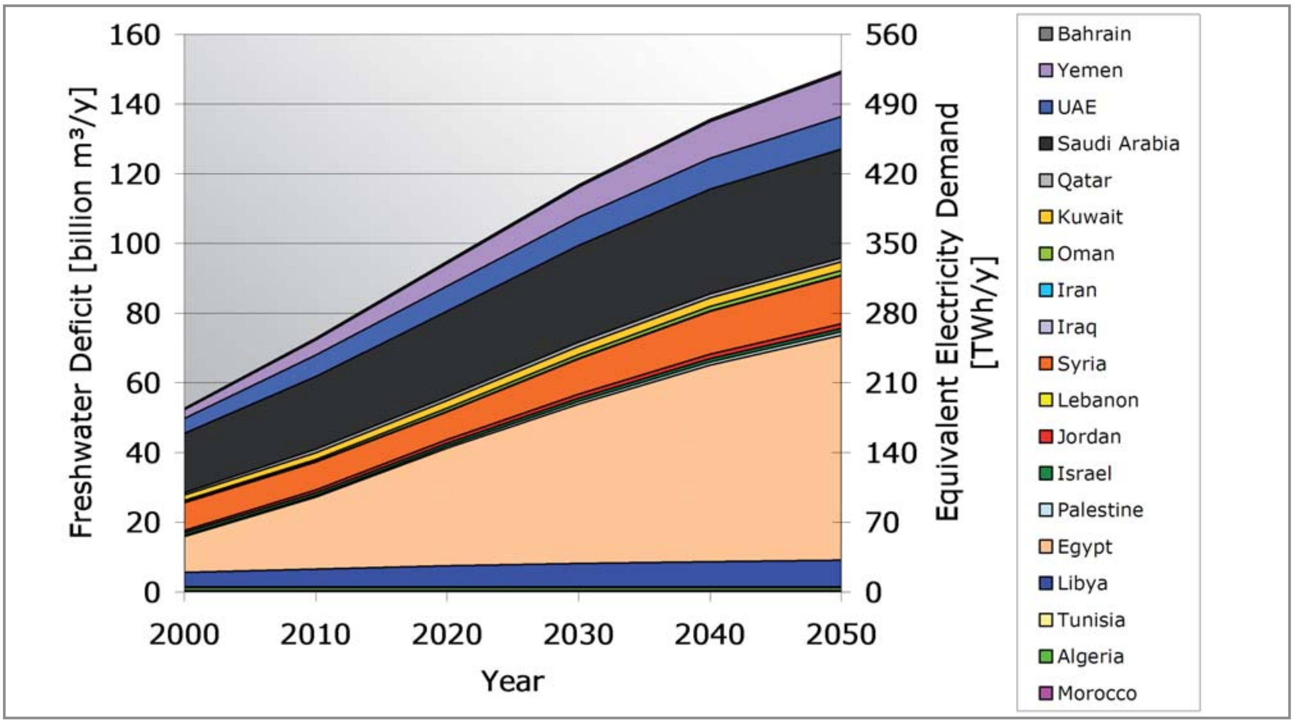

Figure 4: Projected water deficit from a scenario with medium-strong measures to increase the efficiency of water use, water distribution and irrigation and the re-use of waste-water, for all MENA countries.

2.2.3 Earth's Carrying Capacity Crisis

Population growth

World population is on its way to 10 ±1 billion people. This number may be achieved at about 2050. There are several indicators that world population may stabilize at that number by "soft" mechanisms (Kapitza, 2006). An important driver for stabilization is growing wealth, which for its world-wide realization requires world-wide supply of sufficient amounts of affordable and clean energy. Clean power from deserts can make this goal feasible.

Stable living conditions for 10 billion people could never be achieved by fossil fuels. To this end we look at the carrying capacity of earth for humans, as described by the concept of human footprint (Wackernagel, 1997). This method finds that by now the 6.5 billion people are requiring 1.3 earths for not to overshoot earth's carrying capacity. In other words, earth might carry 5 billion people with the present life styles. Beginning climate change confirms that we have left the regime of stability and find ourselves already in the overshoot phase.

How far from or how close we are to the onset of a self-accelerating collapse is not known. We should not risk to cross a line of no return.

Fossil downgrade of carrying capacity

Continued climate change will reduce earth's carrying capacity, in particular by harming – at least temporarily – global food chains and health conditions, and by inundation or desertification of inhabited areas. This may reduce the carrying capacity to 2/3 of the present value, or even more, if run-away processes are triggered. The upcoming shortage of fossil fuels – see for instance the "peak oil" discussion (Peak Oil, 2007) – will reduce earth's carrying capacity as well, mainly by a reduction of the energy available for intensive food production, again by a factor 2/3 or more. Both these reduction factors are our assessment, their real values may well be lower. This will bring down the global carrying capacity in the second half of this century to 1-3 billion people, while population has arrived at 10 billion. Such incompatibility between world population and earth's carrying capacity will lead to major disasters.

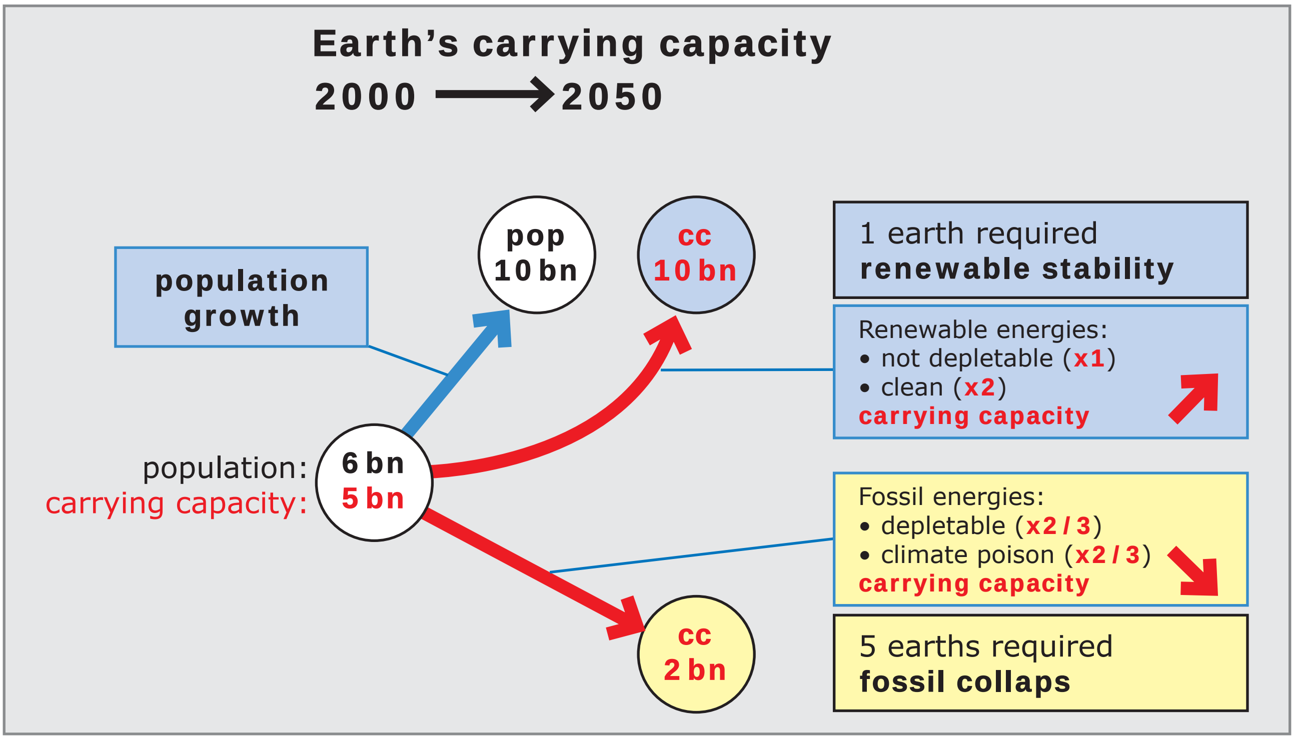

Figure 5: Earths'a carrying capacity until 2050, impact of fossil and renewable energies.

With clean energies towards a planet for 10 billion

This threat to security of life and of humankind's living conditions may be avoided by a fast transition to emission-free and inexhaustible energies, to which clean power from deserts may make a substantial contribution. Clean power from deserts is not the only available source of clean energy, but it is practically the only one which is available without source limitations and simultaneously at economically viable conditions. There are 3 effects:

1. Avoiding collapse of civilization by energy scarcity

2. Stopping of climate change

These two effects might avoid the above mentioned reduction of earth's carrying capacity from 5 to 1-3 billion.

3. 50% of present human footprint is due to the use of fossil fuels. By a transition to clean energy from deserts the energy related part of the footprint could be brought close to zero, since there is enough unused space in deserts.

With a single person's footprint halved the carrying capacity of earth would rise to about 10 billion people (Fig. 5), consistent with the expected value to come.

A transition to clean energies is not yet the solution of all problems, but a fast transition is a precondition for the existence of 10 billion people on earth. This transition we need to master by and large within the extremely short time of about 50 years. An **Apollo-like "EUMENA-DESERTEC" Programme** for putting deserts and technology into service for energy, water and climate security can bring this goal into reach.

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3. The DESERTEC Concept – Sustainable Electricity and Water for Europe, Middle East and North Africa

Dr. Franz Trieb and Professor Dr. Hans Müller-Steinhagen
German Aerospace Center (DLR), Institute of Technical Thermodynamics

Peer Reviewed by
Gunnar Asplund (Asea Brown Boveri AG), Benaîssa Ayadi (Agence Nationale pour la Maîtrise de l'Énergie, Tunis), Adisa Azapagic (University of Manchester), Roland Clift (University of Surrey), Ibrahim Dincer (University of Ontario), Katharina Krell (European Renewable Energy Research Centres Agency), Richard Perez (State University of New York)

and by Leading Authors of the IPCC Report
Terry Barker (University of Cambridge), Juan Llanes-Regueiro (Havana University), Ralph E. H. Sims (International Energy Agency), Julio Torres-Martinez (Academia de Ciencias de Cuba)

Summary

This paper describes the perspective of a sustainable supply of electricity for Europe (EU), the Middle East (ME) and North Africa (NA) up to the year 2050. It shows that a transition to competitive, secure and compatible supply is possible using renewable energy sources and efficiency gains, and fossil fuels as backup for balancing power. A close cooperation between EU and MENA for market introduction of renewable energy and interconnection of electricity grids by high-voltage direct-current transmission are keys for economic and physical survival of the whole region. However, the necessary measures will take at least two decades to become effective. Therefore, adequate policy and economic frameworks for their realization must be introduced immediately. The role of sustainable energy to secure freshwater supplies based on seawater desalination is also addressed.

A Introduction

In order to find a viable transition to an electricity supply that is inexpensive, compatible with the environment and based on secure resources, rigorous criteria must be applied to ensure that the results are compatible with a comprehensive definition of sustainability (Table 1). A central criterion for power generation is its availability at any moment on demand. Today, this is achieved by consuming stored fossil or nuclear energy sources that can provide electricity whenever and wherever required. This is the easiest way to provide power on demand. However, consuming the stored energy reserves of the globe has a high price: they are quickly depleted and their residues contaminate the planet.

With the exception of hydropower, natural flows of energy are not widely used for power generation today, because they are not as easily stored and exploited as fossil or nuclear fuels. Some of them can be stored with a reasonable technical effort for a limited time-span, but others must be taken as provided by nature (Table 1). The challenge of future electricity supply is to find a mix of available technologies and resources that is capable of satisfying not only the criterion of "power on demand", but all the other criteria for sustainability, too.

The paper describes a scenario of electricity demand and supply opportunities by renewable energy in the integrated EUMENA region up to the middle of the century, and confirms the importance of international cooperation to achieve economic and environmental sustainability (MED-CSP 2005, TRANS-CSP 2006).

Criteria for Energy Sustainability	Technology Portfolio	
✓ **Inexpensive** low electricity cost no long term subsidies	✓ **Coal, Lignite** ✓ **Oil, Gas** ✓ **Nuclear Fission, Fusion**	**ideally stored energy**
✓ **Secure** diversified and redundant supply power on demand based on undepletable resources available or at least visible technology	✓ **Concentrating Solar Power (CSP)** ✓ **Geothermal Power (Hot Dry Rock)** ✓ **Biomass** ✓ **Hydropower**	**storable energy**
✓ **Compatible** low pollution climate protection low risks for health and environment fair access	✓ **Wind Power** ✓ **Photovoltaic** ✓ **Wave / Tidal**	**fluctuating energy**

Table 1: Criteria for sustainability and portfolio of technologies and resources for power generation

B Pressure on Electricity and Water is Increasing

As a first step, our analysis quantifies electricity demand in Europe and MENA up to the middle of the century. Growing freshwater deficits in MENA are also part of the energy problem, as there will be an increasing demand for seawater desalination. For simplicity we assume that in the long term, the necessary energy for desalination will also be supplied by electricity.

Population growth is a major driving force for electricity and water consumption. According to the World Population Prospect of the United Nations the population of the European region will stabilize at around 600 million while MENA will grow from 300 million in the year 2000 to a similar 600 million by the middle of the century (UN 2004).

The second driving force is economic growth, which usually has two opposite effects on energy and water demand: on the one hand, the demand increases because new services are requested within a developing economy. On the other hand, efficiency of production, distribution and end-use is enhanced, thus allowing the provision of more services for a given amount of energy. In past decades, all industrial nations observed a typical decoupling of economic growth and energy demand.

In order to be able to afford efficiency measures, a certain economic level beyond sheer subsistence must have been attained, something that is now true of most countries in EUMENA. The demand study is described elsewhere (Trieb, Klann 2006).

Our analysis shows that by 2050 electricity consumption in the Middle East and North Africa is likely to be around 3000 TWh/year (Figure 1), which is comparable with what is consumed in Europe today. Meanwhile, European consumption is likely to increase to and stabilize at a value of about 4000 TWh/year (Figure 2). Due to increased efficiency gains, our model yields lower levels of predicted demand than most other scenarios (IEA 2005, IEA 2006, CEC 2006, Mantzos and Capros 2005). However, there are also scenarios indicating lower demand (Benoit and Comeau 2005, Teske et al., 2007). The reduction of demand in Europe after 2040 (as shown in Figure 2) is however uncertain. Stagnant or slowly growing demand is also a possibility, since efficiency gains may be transformed into new energy services not considered here, such as, for example, electric vehicles or hydrogen for the transport sector.

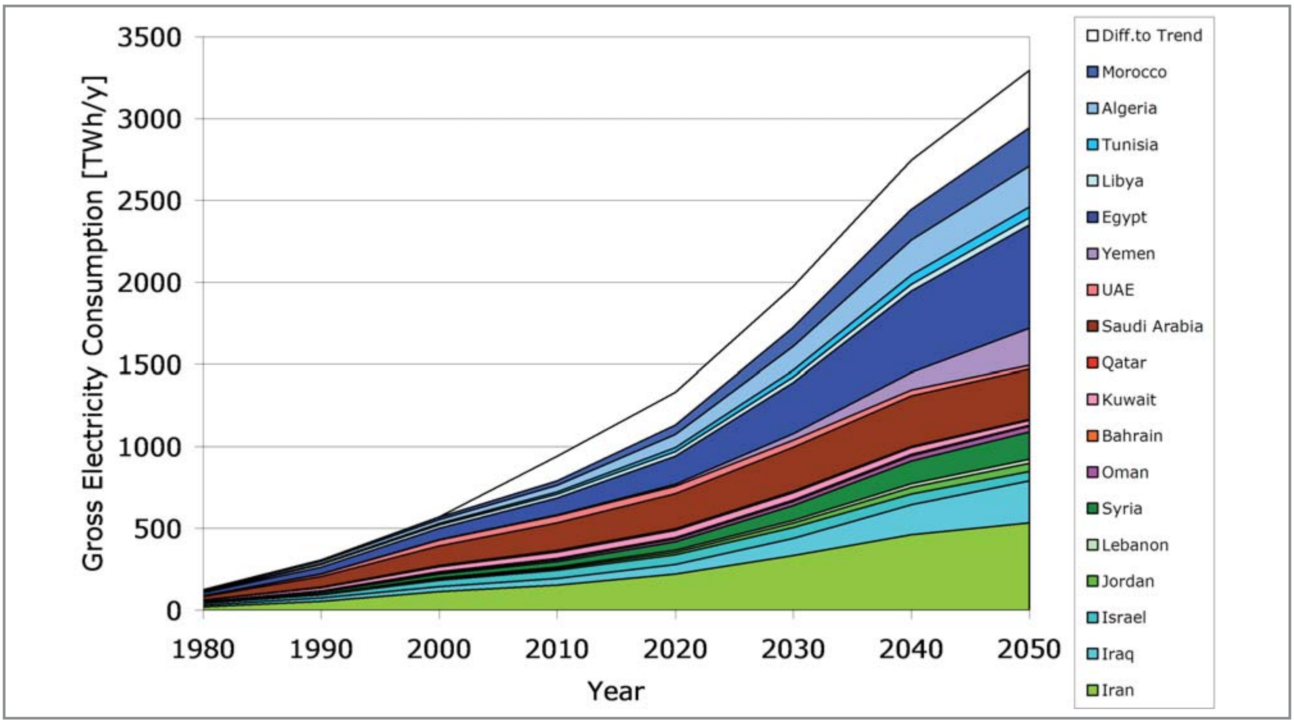

Figure 1: Electricity demand scenario for the MENA countries considered in the study (MED-CSP 2005)

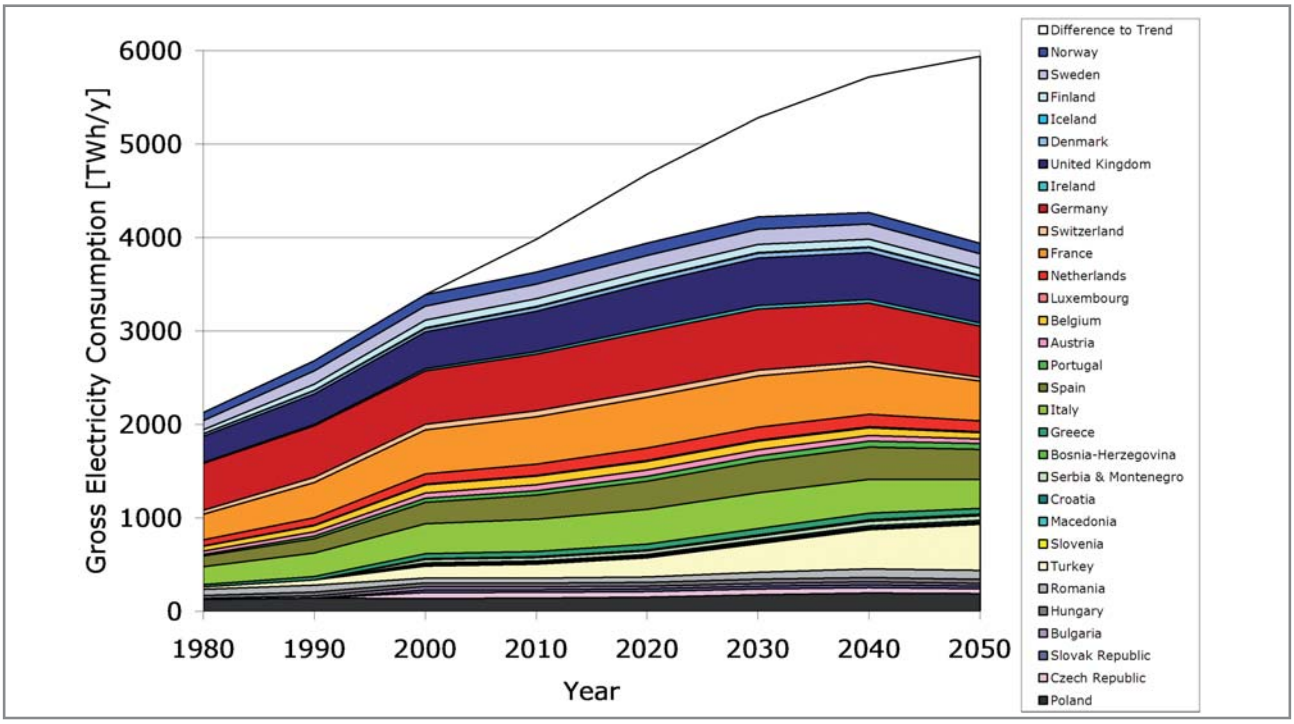

Figure 2: Electricity demand for the European countries considered in the study (TRANS-CSP 2006)

A similar analysis has been done for the water sector in MENA. The difference between the available sources of fresh water that are renewable and growing demands for water leads to the water deficit displayed in Figure 3.

There is already a significant deficit today, which is poorly met by sea-water desalination via fossil fuels and mainly by the over-exploitation of groundwater resources, leading in many regions in MENA to falling levels of groundwater, intrusion of salt water into groundwater reservoirs and to a fast expansion of deserts.

According to our projection, this deficit tends to increase from the current 60 billion m³ per year, which is almost the annual flow of the Nile River, to 150 billion m³ in the year 2050. Egypt, Saudi Arabia, Yemen, and Syria are the countries with the largest deficits. Enhancement of efficiency of water distribution, water (re-)use and water management to achieve best-practice standards is already included in the underlying assumptions of this scenario.

It is obvious that the MENA countries will be confronted with a very serious problem in the not too distant future, if those measures and the necessary additional measures are not initiated in good time. Seawater desalination is one of those additional options. Assuming that, on average, 3.5 kWh of electricity is needed to desalinate one cubic meter of seawater, this would mean an additional demand for almost 550 TWh/y by 2050 for desalination. This would be equivalent to the current electricity demand of a country like Germany (MED-CSP 2005).

C Available Resources and Technology Options

In the financial and insurance business there is a clear answer to the question of security and risk management: the diversification of the assets portfolio (Awerbuch and Berger 2003). This simple truth has been completely ignored in the energy sector. Here, investment decisions were based on "least cost and proven technology" and the portfolio was usually limited to fossil fuel, hydropower and nuclear plants.

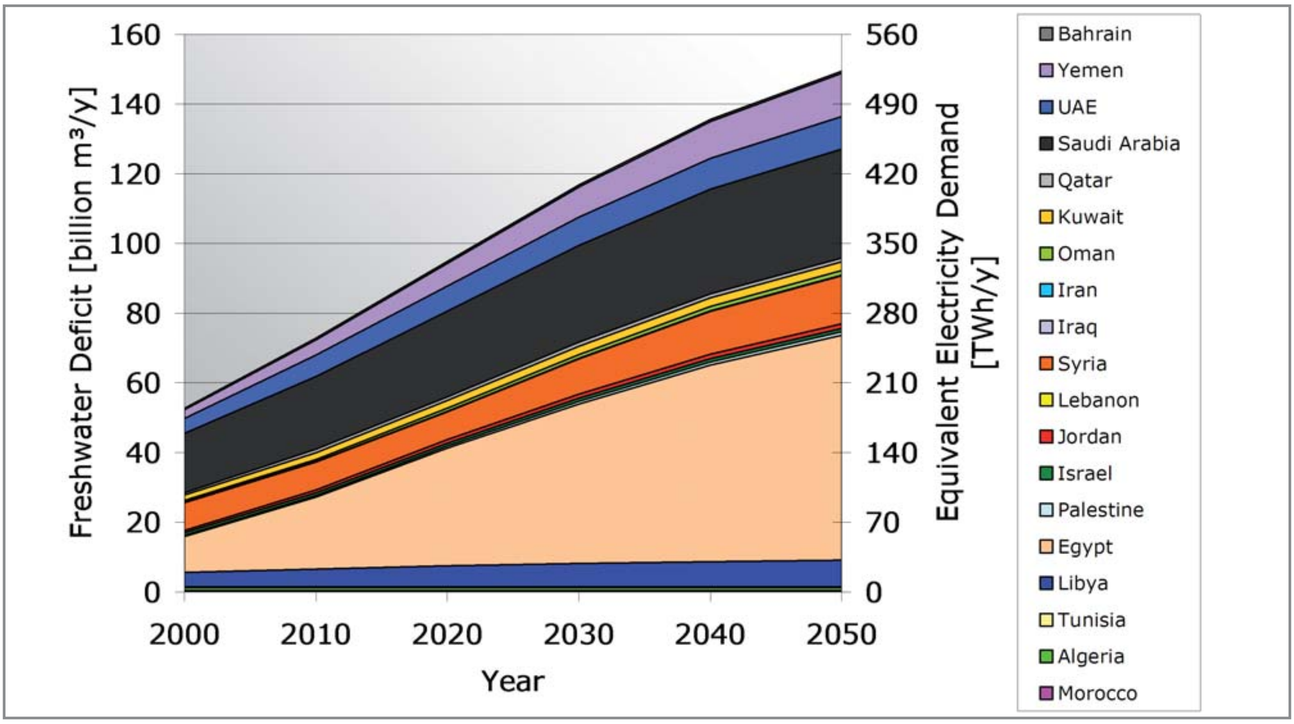

Figure 3: Freshwater deficit defined as the difference between water demand and renewable freshwater resources for each of the MENA countries, and equivalent electricity demand for seawater desalination (Trieb and Müller-Steinhagen 2007)

This short-sighted policy has been harmful both for consumers and for the environment: prices of all kinds of fossil fuels and of uranium have multiplied several times since the year 2000 and the burning of these fuels is seriously contaminating the global atmosphere. Today, consumers and taxpayers have no choice but to pay the higher cost of fossil fuels, as the energy policies of the past failed to build up alternatives in good time and to establish them as part of the energy market. To add insult to injury, fossil and nuclear energy technologies still receive 75 % of current energy subsidies (EEA 2004), a number that increases to over 90 % if the failure to include external costs is also considered.

Nevertheless, an impressive portfolio of renewable energy technologies is available today (Dürrschmidt et al. 2006). Some of these produce fluctuating output, like wind and photovoltaic power (PV), but some of them (such as biomass, hydropower and concentrating solar thermal power (CSP)) can meet both peak- and base-load demands for electricity (Table 2).

The long-term economic potential of renewable energy in EUMENA is much larger than present demand, and the potential of solar energy dwarfs them all. From each km² of desert land, up to 250 GWh of electricity can be harvested each year using the technology of concentrating solar thermal power. This is 250 times more than can be produced per square kilometre by biomass or 5 times more than can be generated by the best available wind and hydropower sites. Each year, each square kilometre of land in MENA receives an amount of solar energy that is equivalent to 1.5 million barrels of crude oil[1]. A concentrating solar collector field with the size of Lake Nasser in Egypt (Aswan) could harvest energy equivalent to the present Middle East oil production[2].

[1] reference solar irradiance 2400 kWh/m²/year, 1600 kWh heating value per barrel

[2] Lake Nasser has a surface of 6000 km², Middle East oil production is currently 9·billion barrels/year

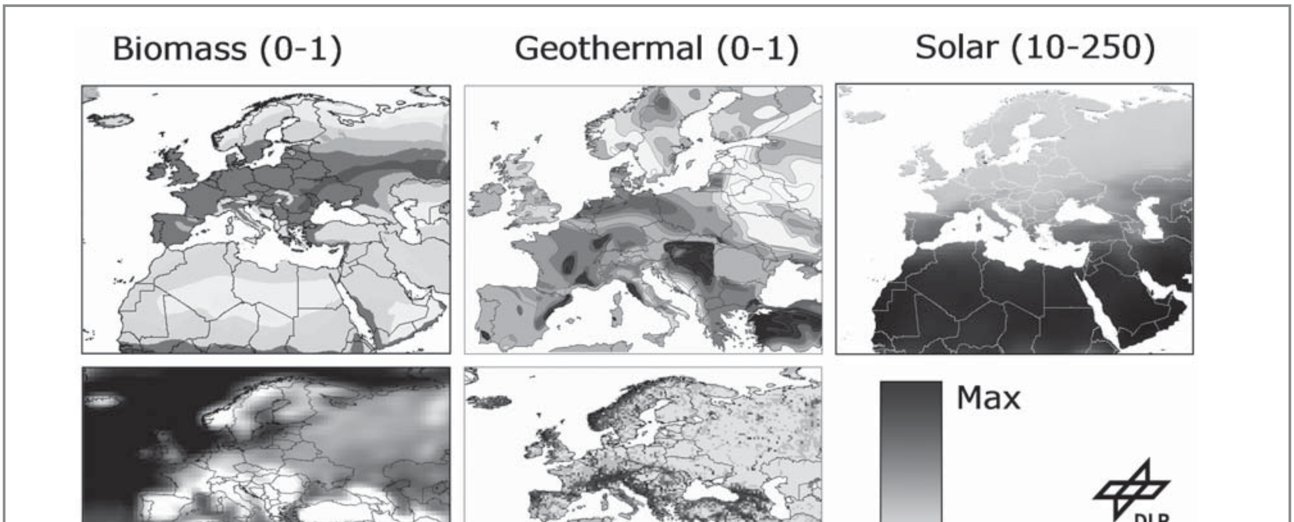

Figure 4: Renewable energy resource maps for EUMENA, showing the minimum and maximum annual electricity yield (as specified in brackets) that can be harvested by each technology from 1 km² of land area. Solar includes both photovoltaic and concentrating solar thermal power technologies. The overall potential and the different characteristics of each resource are given in Table 2 (MED-CSP 2005)

In addition, there are other large sources of renewable energy in EUMENA: there is potential of almost 2000 TWh of wind power and 4000 TWh/y of power from geothermal, hydro and biomass sources including agricultural and municipal waste. Also PV, wave and tidal power have considerable potentials in the region. By contrast with fossil and nuclear fuels, renewable energy sources in the region are over-abundant.

However, each renewable energy resource has a specific geographic distribution (Figure 4). Each country will therefore have its specific mix of resources, with hydropower, biomass and wind energy being the preferred sources in the North, and solar and wind energy being the most powerful sources in the South of EUMENA.

	Unit Capacity	Capacity Credit*	Capacity Factor**	Potential*** (TWh/y)	Type of Resource	Applications	Comment
Wind Power	1 kW -5 MW	0 - 30%	15 - 50%	1950	kinetic energy of the wind	electricity	fluctuating, supply defined by resource
Photovoltaic	1W -5 MW	0%	5 - 25%	325	direct and diffuse irradiance on a surface tilted with latitude	electricity	fluctuating, supply defined by resource
Biomass	1 kW -25 MW	50 - 90%	40 - 90%	1350	municipal and agricultural organic waste and wood	electricity and heat	seasonal fluctuations but good storability, power on demand
Geothermal (Hot Dry Rock)	25 MW -50 MW	90%	40 - 90%	1100	heat from hot dry rocks of several 1000 meters depth	electricity and heat	no fluctuations, power on demand
Hydropower	1 kW -1000 MW	50 - 90%	10 - 90%	1350	kinetic and potential energy from water flows	electricity	seasonal fluctuations, good storability in dams, also used as pump storage for other sources
Solar Updraft Tower	100 MW -200 MW	10 - 70% depending on storage	20 - 70%	part of CSP potential	direct and diffuse irradiance on a horizontal surface	electricity	seasonal fluctuations, good storability, base-load power
Concentrating Solar Thermal Power (CSP)	10 kW -200 MW	0 - 90% depending on storage and hybridisation	20 - 90%	630,000	direct irradiance on a surface tracking the sun	electricity and heat	fluctuations are compensated by thermal storage and (bio)fuel, power on demand
Gas Turbine	0.5 MW -100 MW	90%	10 - 90%	n.a.	natural gas, fuel oil	electricity and heat	power on demand
Steam Cycle	5 MW -500 MW	90%	40 - 90%	n.a.	coal, lignite, fuel oil, natural gas	electricity and heat	power on demand
Nuclear	>500 MW	90%	90%	n.a.	uranium	electricity and heat	base-load power

Table 2: Some characteristics of contemporary power technologies. * Contribution to firm power and reserve capacity. ** Average annual utilisation. *** Technical electricity potential in EUMENA that can be exploited in the long-term at competitive cost considering each technology's learning curve. In the case of PV only the demand-side potential used until 2050 was assessed; the technical potential is comparable to that of CSP

Fossil energy sources like coal, oil and gas can be a useful complement to the renewable energy mix, being stored forms of energy that can easily be used for balancing power and for grid stabilization. If their consumption is reduced to the point where they are used exclusively for this purpose, their cost escalation will be reduced and cause only a minor burden to economic development and their environmental impact will be minimized. Moreover, their availability will be extended for decades or even centuries.

By contrast, nuclear fission plants are not easily combined with renewables because their output cannot, economically, be varied to meet fluctuating demands. Moreover, decommissioning costs of nuclear plants exceed their initial investment (NDA 2002) and, half a century after market introduction, there are still unsolved problems like plutonium proliferation and nuclear waste disposal. The other nuclear option, fusion, is not expected to be commercially available before 2050 and is therefore not relevant for our proposals (HGF 2001).

Several renewable power technologies can also provide base-load and balancing power. These include: geothermal (hot dry rock) systems that are today in a phase of research and development; hydropower plants with large storage dams in Norway, Iceland and the Alps; most biomass plants; and concentrating solar thermal power plants (CSP) in MENA. CSP plants use the high annual solar irradiance of that region, the possibility of solar thermal energy storage for overnight operation and the option of backup firing with fossil fuels or biomass. CSP in Europe is subject to significant seasonal fluctuations. Constant output for base-load power can only be provided with a considerable fossil fuel share. Due to the higher solar irradiance in MENA, the cost of concentrating solar power there is usually lower and its availability is better than in Europe. Therefore, there will be a significant market for solar electricity imports to complement the European sources and provide firm renewable power capacity at competitive cost.

D Concentrating Solar Power as Key Element of the Energy Mix

Steam turbines and gas turbines powered by coal, uranium, oil and natural gas are today's guarantors of electrical grid stability, providing both base-load and balancing power. However, turbines can also be powered by high temperature heat from concentrating solar collector fields (Figure 5). Power plants of this type with 30 - 80 MW unit capacity are operating successfully in California since 20 years, and new plants are currently erected in the U.S. and Spain. The concentrating solar collectors are efficient fuel savers, today producing heat at a cost equivalent to 50 $/barrel of fuel oil, with the perspective to achieve a level below 25 $/barrel within a decade (MED-CSP 2005, Pitz-Paal et al. 2005).

Just like conventional power stations, concentrating solar power plants can deliver base-load or balancing power, directly using sunshine during the day, making use of thermal energy storage facilities during the night and in case there is a longer period without sunshine, using fossil or biomass fuel as backup heat source. Just like fossil fuel fired conventional power stations, CSP plants have an availability that is close to 100 %, but with significantly lower fuel consumption. A CSP plant with a thermal energy storage facility for additional 8 hours of full load operation is currently build in the Spanish Sierra Nevada near Guadix, allowing solar electricity generation also during night-time. This plant with a capacity of 50 MW will have a minimum annual solar share of 85 %.

Another feature that distinguishes CSP is the possibility of combined generation of electricity and heat to achieve the highest possible efficiencies for energy conversion. In addition to electricity, such plants can provide steam for absorption chillers, industrial process heat or thermal seawater desalination. A design study for such a plant was finished late 2006, the plant is scheduled to be commissioned for early 2009 (Figure 5, left). It will provide 10 MW of power, 40 MW of district cooling and 10,000 cubic metres per day of desalted water for a large hotel resort in Aqaba, Jordan (Trieb et al. 2007).

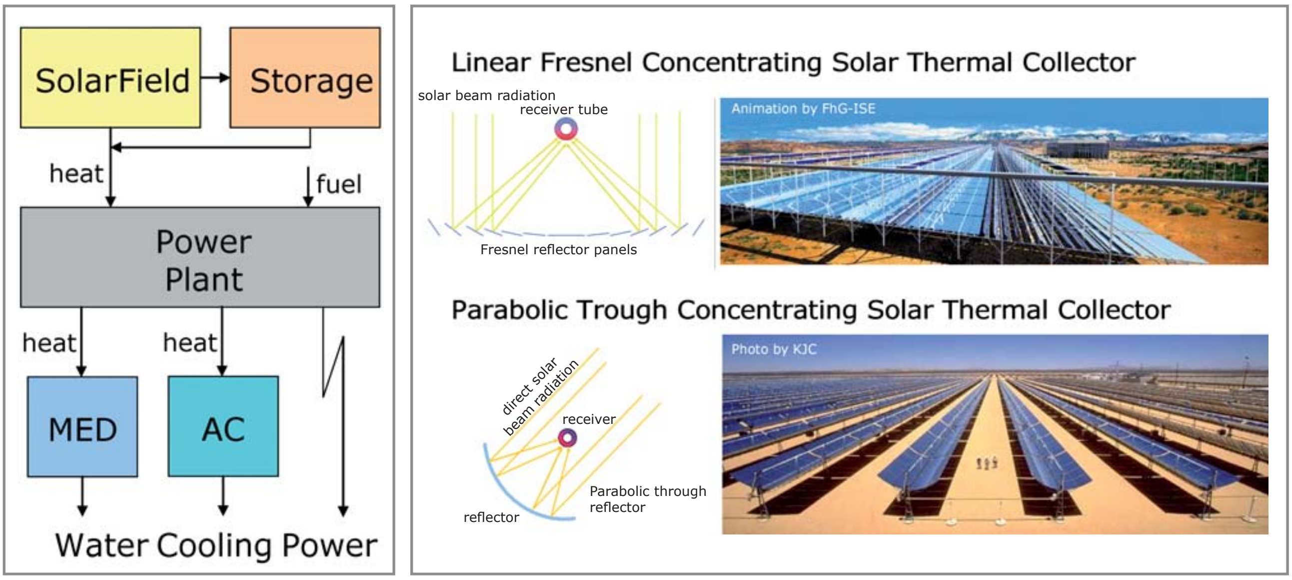

Figure 5: Left: Configuration of a concentrating solar power station for combined generation of electricity and heat for absorption cooling (AC) and multi-effect seawater desalination (MED). Right: Line-concentrating solar thermal collector technologies.

E Sustainable Energy and Water for EUMENA

Following the criteria for sustainability in Table 1 and additional technical, social and economic frame conditions described in other reports (MED-CSP 2005, TRANS-CSP 2006), we have developed a scenario for electricity generation for 50 countries in EUMENA up to the year 2050. Except for wind power that is already booming today, and hydropower that has been established since decades, renewable energy will hardly become visible in the electricity mix before 2020 (Figure 6 and Figure 7). At the same time, phasing out of nuclear power in many European countries and the stagnating use of coal and lignite due to climate protection will generate increasing pressure on natural gas resources, increasing their consumption as well as their installed capacity for power generation. Until 2020, renewables like wind and PV power will mainly have the effect of reducing fuel consumption, but will do little to replace existing capacities of balancing power. Owing to growing demands and the replacement of nuclear power, consumption of fossil fuels cannot be reduced before 2020.

Fuel oil for electricity will largely disappear by 2030 and nuclear power will follow after 2040. The consumption of gas and coal will increase until 2030 and thereafter be reduced to a compatible and affordable level by 2050. In the long term, new services such as electric vehicles may increase the electricity demand further and thus require a higher exploitation of renewables.

The electricity mix in the year 2000 depends mainly on five resources, most of them exhaustable, while the mix in 2050 will be based on ten energy sources, most of them inexhaustable. Thus, our scenario responds positively to the European Strategy for Sustainable, Competitive and Secure Energy declared by the European Commission in the corresponding Green Paper and Background Document, aiming at higher diversification and security of the European energy supply (Commission of the European Communities 2006).

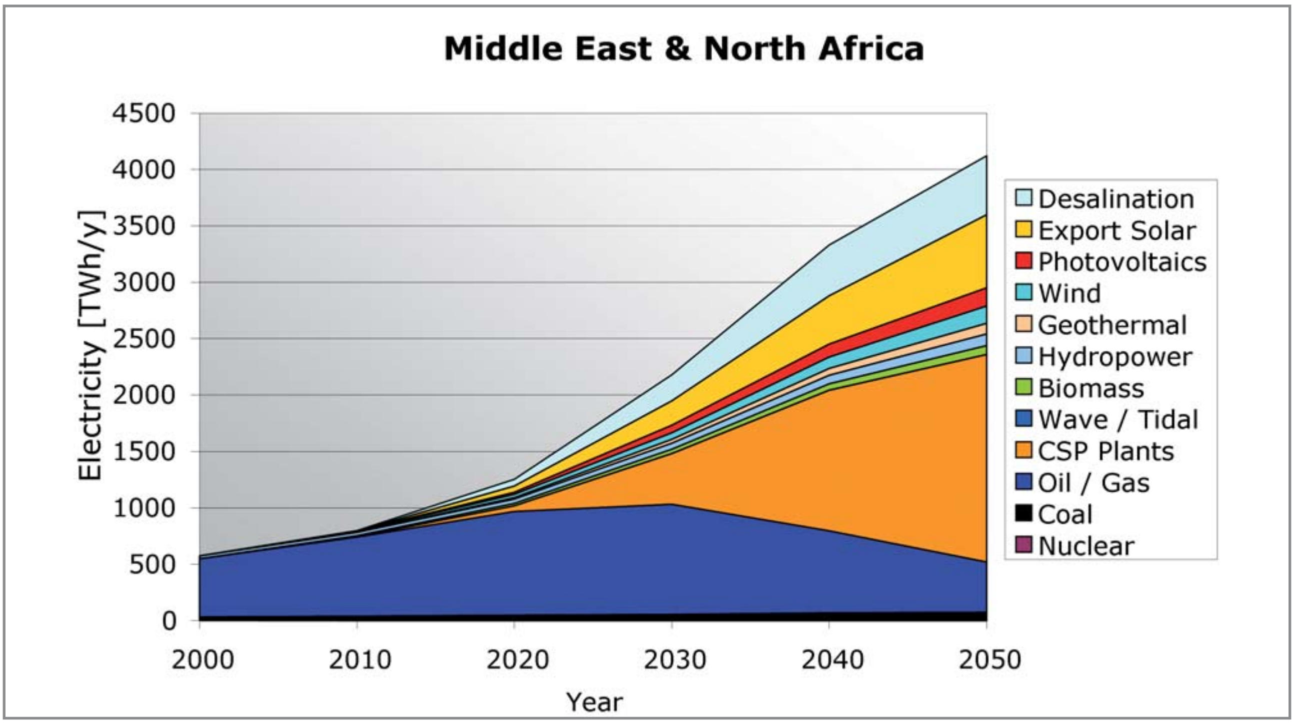

Figure 6: Electricity generated for regional demand according to Figure 1 and in addition for seawater desalination and for export to Europe using the different forms of primary energy available in MENA

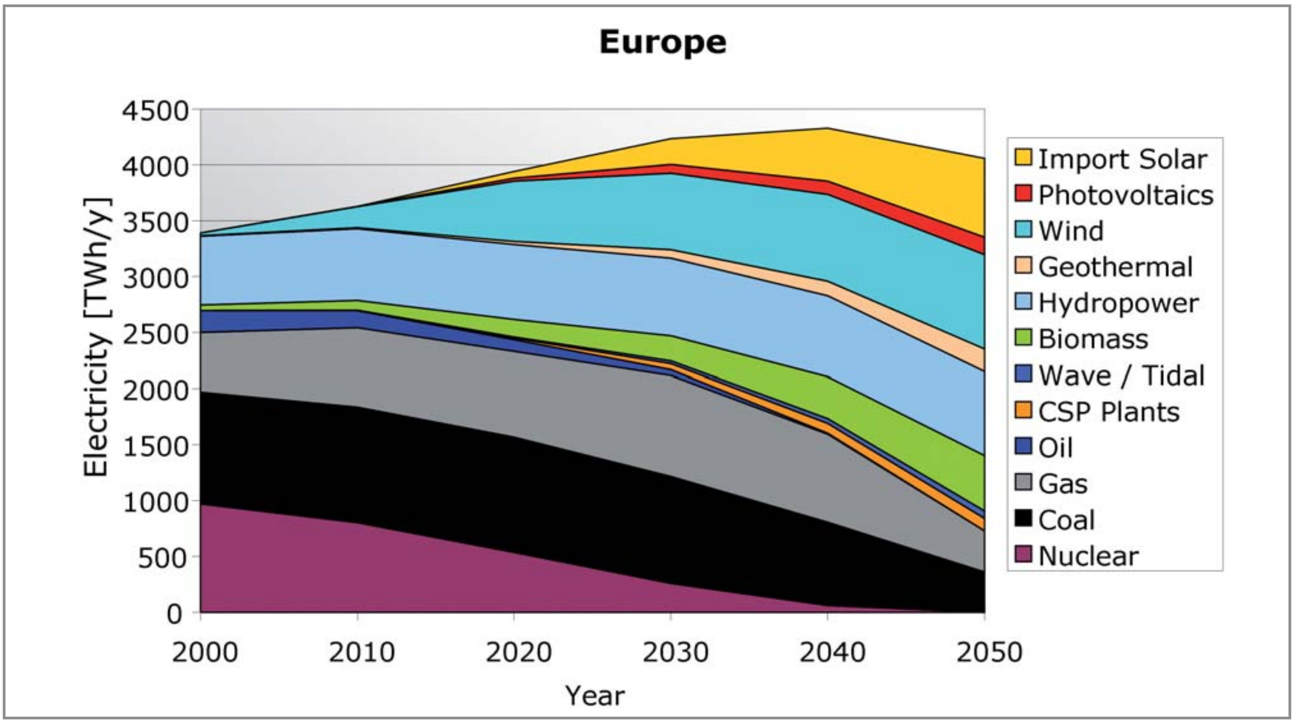

Figure 7: Electricity generated from the different forms of primary energy in Europe including the import of solar electricity from MENA

A prerequisite of the electricity mix is to provide firm capacity with a reserve of about 25 % in addition to the expected peaking load (Figure 8). Before significant CSP transmission starts in the year 2020, this can only be provided by extending the capacity and fuel consumption of gas fired peaking plants based on natural gas and later eventually on coal gasification. In Europe, the consumption of natural gas doubles with respect to the starting year 2000; but it is then brought back to the initial level, after the introduction in 2020 of increasing shares of CSP transmission from MENA as well as geothermal and hydropower from Scandinavia, via High-Voltage Direct-Current (HVDC) interconnections. European renewable energy sources that could provide firm capacity are rather limited from the point of view of their potential. Therefore, CSP transmission from MENA to Europe will be essential to reduce both the installed capacity and the fuel consumption of gas fired peaking plants and to provide firm renewable power capacity.

In MENA, concentrating solar power is the only source that can really cope with rapidly growing electricity consumption, providing both base-load- and balancing power. By 2050, fossil energy sources will be used solely for backup purposes. This will reduce their consumption to a sustainable level and bring down the otherwise rapidly escalating cost of power generation. Fossil fuels will be used to guarantee firm balancing power capacity, while renewables will serve to reduce their consumption for everyday use and base-load supply.

An efficient backup infrastructure will be necessary to complement the renewable electricity mix: on one hand to provide firm capacity on demand by quickly-reacting, natural-gas-fired peaking plants, and on the other hand as an efficient grid infrastructure that allows the transmission of renewable electricity from the best centres of production to the main centres of demand. The best solution is a combination of High-Voltage Direct-Current (HVDC) transmission lines and the conventional Alternating Current (AC) grid.

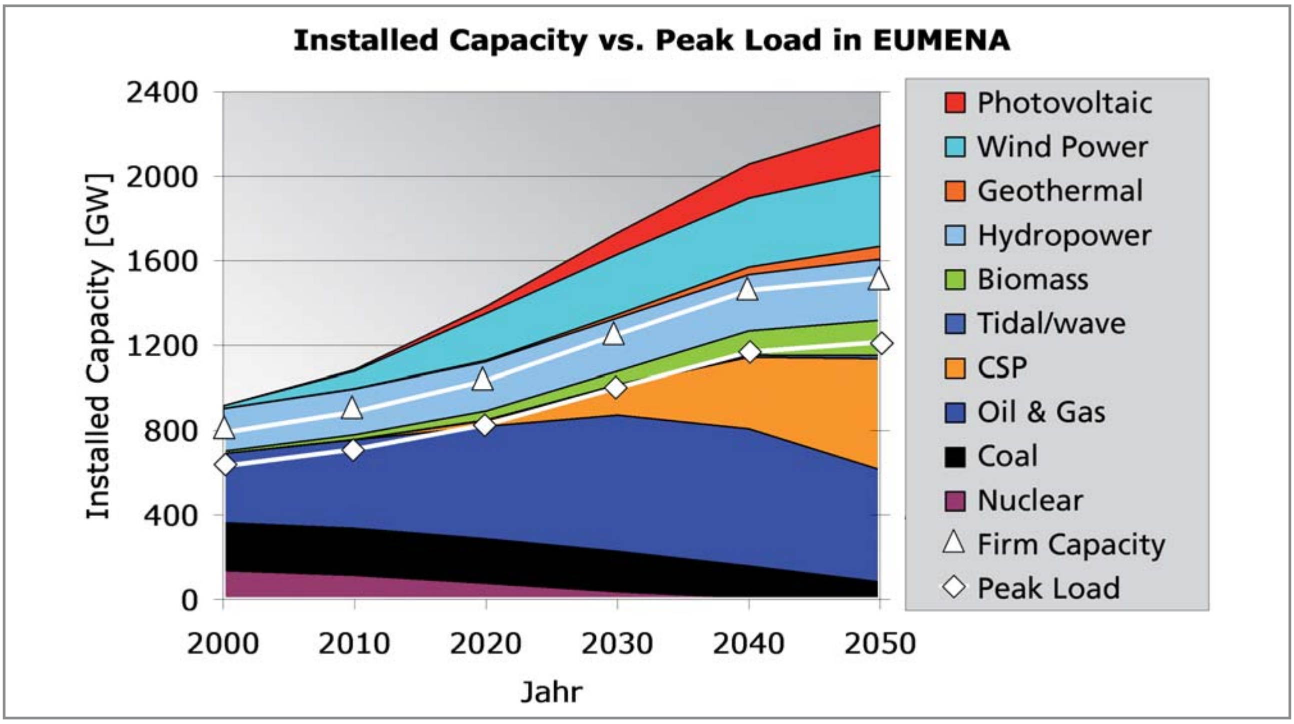

Figure 8: Scenario of the installed power capacity in comparison to the cumulated peak load of all countries in the EUMENA region. Firm power capacity is calculated on the basis of capacity credits for each technology according to Table 2. By the year 2050, 68 % of the installed CSP capacity is used for local supplies, 19 % for long-distance transmission and 13 % for desalination.

At lower voltage levels, decentralised structures will also gain importance, combining, for example, PV, wind and micro-turbines operating together just like a single virtual power plant. Such a grid infrastructure will not be motivated by the use of renewables alone. In fact, its construction will probably take place anyway, in order to stabilize the growing European grid, to provide greater security of supply, and to foster competition (Asplund 2004, Eurelectric 2003). By 2050, transmission lines with a capacity of 2.5-5.0 GW each will transport about 700 TWh/y of solar electricity from 20-40 different locations in the Middle East and North Africa to the main centres of demand in Europe (Figure 9 and Table 3).

HVDC technology has been a mature technology for several decades and is becoming increasingly important for the stabilisation of large-scale electricity grids, especially if more fluctuating resources are incorporated. HVDC transmission over long distances contributes considerably to increase the compensational effects between distant and local energy sources, and it allows failures of large power stations to be accommodated via distant backup capacity. It can be expected that a HVDC backbone will be established in the long term to support the conventional electricity grid and to increase the stability of the future power-supply system.

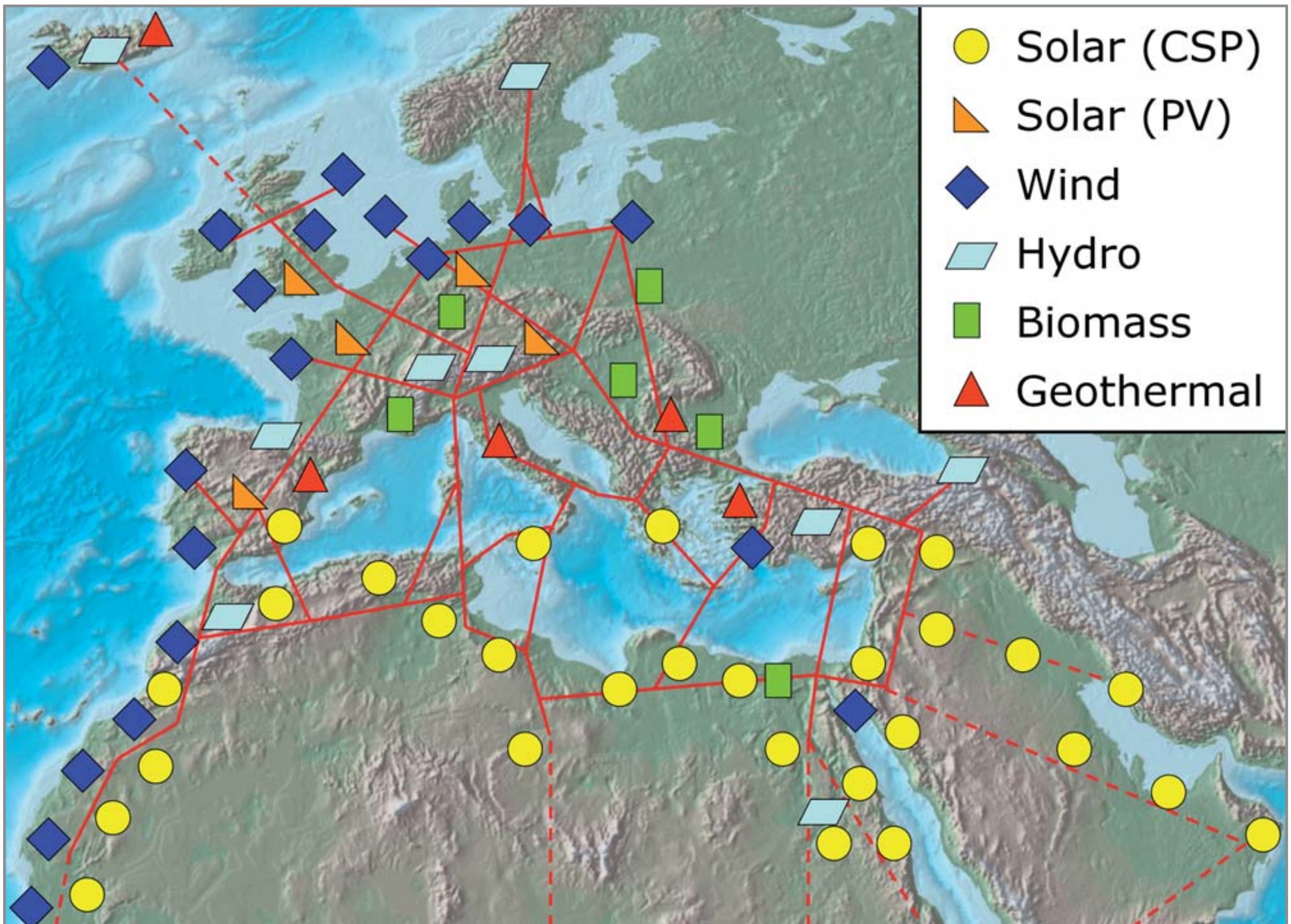

Figure 9: Concept of a EUMENA interconnected electricity grid based on HVDC power transmission as "Electricity Highways" to complement the conventional AC electricity grid. TREC 2006.

As a spin-off effect of this development, solar electricity from MENA will become an attractive means of diversifying the European power-generation portfolio. Due to the abundance and seasonal uniformity of solar energy from deserts it will be cheaper and better available than solar electricity generated in Europe. In a coming renewable energy alliance of Europe and MENA solar and wind energy, hydropower, geothermal power and biomass will be generated in places where they work best and where they are most abundant. This power will be distributed all over Europe and MENA through a highly efficient HVDC grid at high-voltage levels, and delivered to consumers by the conventional interconnected AC grid at low-voltage levels. By analogy with the network of interstate highways, a future HVDC grid will have a low number of inlets to and outlets from the conventional AC system because its primary purpose will be to serve long-distance power transmission, while the AC grid will function in a manner that is analogous to the operation of country roads and city streets. In our calculations we assume that about 10 % of the generated solar electricity will be lost by HVDC transmission from MENA to Europe over 3000 km distance.

In 2050, twenty to forty power lines with 2500 - 5000 MW capacity each could provide about 15 % of the European electricity as clean power from deserts, motivated by a low production cost of around 5 €-cent/kWh (not accounting for further cost reduction via carbon credits) and their high flexibility for base-, intermediate- and peak-load operation. In future transmission losses may be lowered to 5 % per 3,000 km by new developments in HVDC technology (Asplund 2007).

There is a wide-spread belief that for every wind farm or PV plant a fossil fuel fired backup power plant must be installed. However, hourly time series modelling of the power supply system of selected countries according to our scenario showed that even without additional storage capacities for electricity, the existing balancing capacity is sufficient for the purpose of covering fluctuations in demand. No extra backup or storage capacity is needed as long as the fluctuating renewable energy share is smaller than the existing peaking plant capacity, which is the case in our scenario.

Year		2020	2030	2040	2050
Transfer Capacity GW		2 x 5	8 x 5	14 x 5	20 x 5
Electricity Transfer TWh/y		60	230	470	700
Capacity Factor		0.60	0.67	0.75	0.80
Turnover Billion €/y		3.8	12.5	24	35
Land Area km x km	CSP HVDC	15 x 15 3100 x 0.1	30 x 30 3600 x 0.4	40 x 40 3600 x 0.7	50 x 50 3600 x 1.0
Investment Bilion €	CSP HVDC	42 5	143 20	245 31	350 45
Elec. Cost €/kWh	CSP HVDC	0.050 0.014	0.045 0.010	0.040 0.010	0.040 0.010

Concentrating Solar Thermal Power (CSP) plants use mirrors to concentrate sunlight for steam and power generation. Solar heat can be stored in tanks of molten salt and used for nighttime operation of the turbines, which can also be powered by oil, natural gas or biomass fuels.

High Voltage Direct Current (HVDC) transmission lines are used in some 100 projects world wide transmitting today about 80 GW of electricity from remote, mostly renewable sources like large hydropower dams and geothermal plants to large centres of demand.

Table 3: Main indicators of a EUMENA High Voltage Direct Current (HVDC) interconnection for Concentrating Solar Thermal Power (CSP) from 2020 – 2050 according to the TRANS-CSP scenario. In 2050, lines with a capacity of 5 GW each will transmit about 700 TWh/y of electricity from 20-40 different locations in the Middle East and North Africa to the main centres of demand in Europe.

In fact, as a consequence of the increasing share of renewable electricity generation, the need for conventional base load plants with constant output will step by step disappear (Figure 10). Base load will be covered by plants for combined generation of heat and power (CHP) using fossil and biomass fuels, river run-off hydropower, wind power and photovoltaics. Intermediate power capacity will be provided by better storable sources like hydropower from dams, biomass and geothermal power. This combination of power sources will not totally cover, but fairly approximate the daily load curve. The remaining balancing capacity will be supplied by pump storage, hydropower dams, concentrating solar power and fossil fuel fired peaking plants. In addition to that, enhanced demand side management will increasingly be used to minimise the need of pump storage capacity and fossil fuel consumption for peaking power, which both will remain in the same order of magnitude as today (Brischke 2005).

The fossil fuel fired power capacities remaining in 2050 will exclusively serve balancing duties and combined generation of heat and power. This is in line with the strategy of using those valuable, perfectly stored energy sources exclusively for what they are best suited for and not wasting them for quotidian use. Base load plants with constant output fuelled by nuclear fission, fusion or lignite will not fit well into such a system, as they are not capable of providing quickly changing output to fill the gap between the partially fluctuating supply from cogeneration and renewables and the otherwise fluctuating demand. In fact, gas driven plants will be the preferred choice for this purpose. In the very long-term after 2050, renewable sources supported by advanced storage and load management in close coordination with other energy sectors like heating and cooling as well as transport and mobility will finally also take over the remaining demand for balancing power and combined generation.

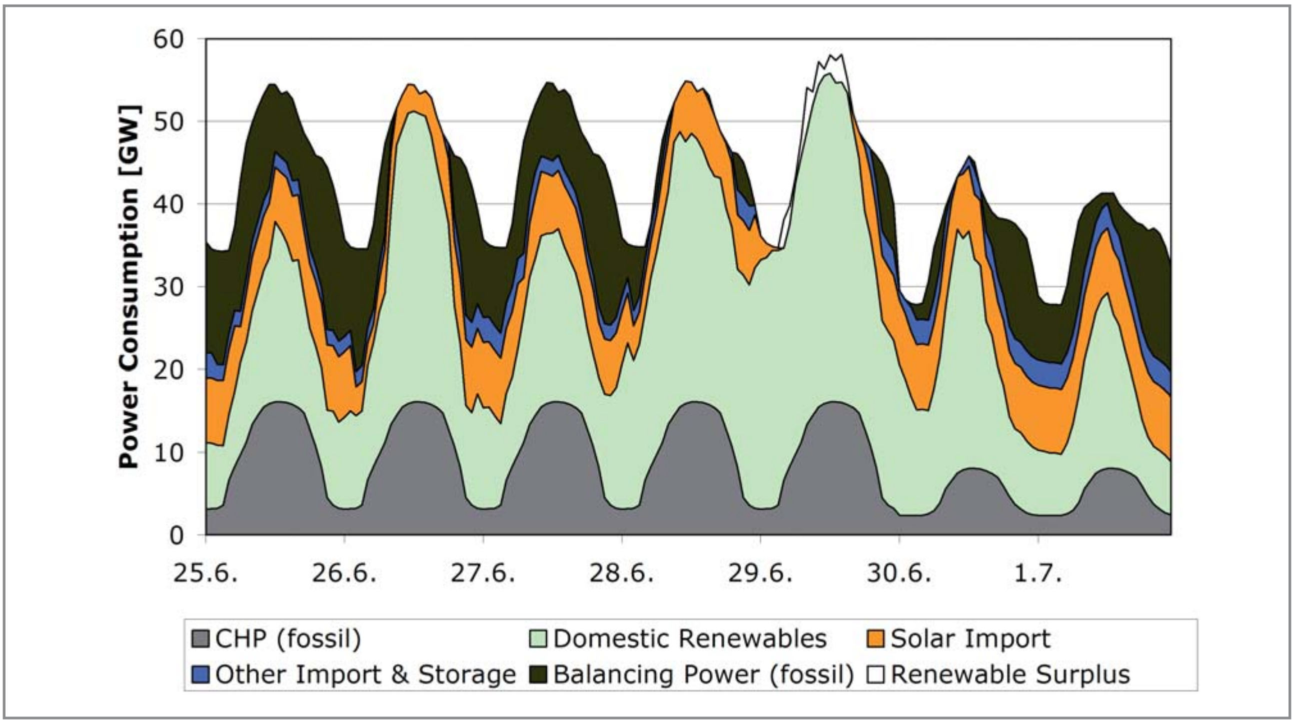

Figure 10: Model of the hourly electricity balance of Germany in 2050 (Brischke 2005)

F Least Cost Electricity from Renewable Sources

Installing CSP plants world wide, a reduction of the solar electricity cost due to economies of scale can be achieved with a progress ratio of about 85-90 %[4] (Pitz-Paal et al. 2005). As an example, a CSP-plant today can produce electricity at about 0.14-0.18 €/kWh depending on solar irradiance (Figure 11). With 5000 MW installed world-wide the cost would drop to about 0.08-0.12 €/kWh, and to 0.04-0.06 €/kWh once a capacity of 100 GW would be installed[5]. A prerequisite for this cost reduction is a global CSP expansion from 415 MW today to about 28 GW by 2020 and roughly 140 GW by 2030 including capacities for seawater desalination (MED-CSP 2005), (TRANS-CSP 2006), (AQUA-CSP 2007). In the long-term, a total of 500 GW could be installed by 2050. For the calculation of this learning curve we have assumed solar only operation, an economic lifetime of 25 years and a real project rate of return of 6.5 %/y.

All renewable energy sources show similar learning curves, becoming cheaper the more they are exploited. While most renewable sources show capacity limits of exploitation, the solar energy resource in MENA is about hundred times larger than demand will ever be. Further, due to better solar radiation costs of clean power from deserts including transmission will be lower than for solar power produced by the same type of power plants located in Europe, as shown for Spain in Figure 12. If we take as example the Spanish electricity mix as described in (TRANS-CSP 2006) a scenario based on a mix of domestic renewable energies, solar electricity from North Africa and fossil fuels for balancing power has the medium-term perspective of stable and even slightly reduced electricity costs (red curves in Fig. 12), while a business-as-usual scenario would lead to steadily escalating costs of energy (black curves) as has happened since the year 2000. In the TRANS-CSP scenario, the expansion of renewable energy will take place in niche markets like the Spanish Renewable Energy Act until about 2020, temporarily leading to slightly higher electricity costs than for a business-as-usual mix. During that time, the share of renewable energy will increase while the cost of renewable energy will decrease. Latest from 2030 onwards solar energy imported to more Northern countries like Germany, will also be clearly cheaper than local production from a fossil-nuclear mix (black curve Germany), and also from fossil sources alone (green curve Germany) as in case of phasing out nuclear as scheduled.

[4] A progress ratio of 90 % means that the specific investment is reduced by 10 % every time the total installed capacity of the solar collectors is doubled (Neij et al. 2003, Pitz-Paal et al. 2005)

[5] This cost is calculated for solar only operation and would be lower in hybrid mode, as there would be a better amortisation of the power block investment.

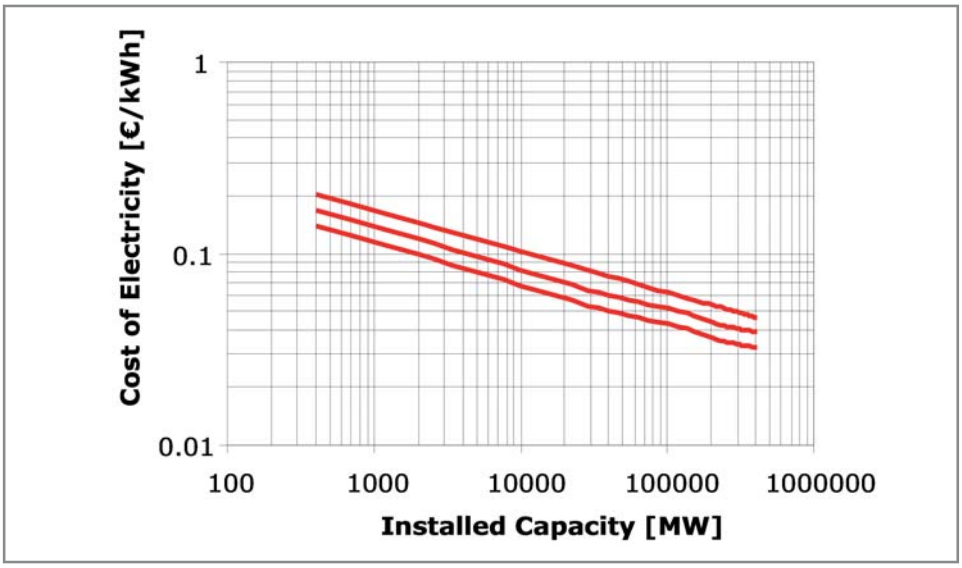

Figure 11: Expected cost of electricity from CSP in solar-only operation as function of installed capacity according to (NEEDS 2007) for an annual irradiance (from top to bottom) of 2000, 2400 and 2800 kWh/m²/y.

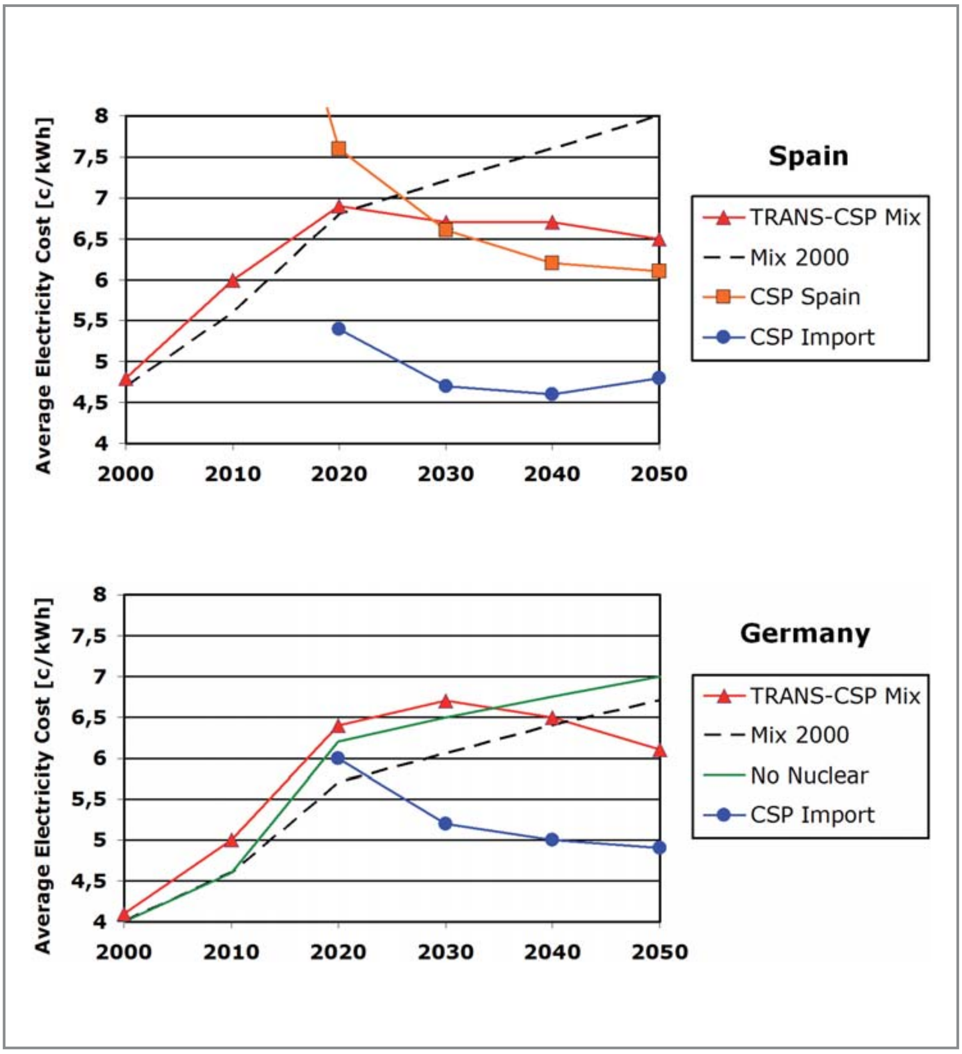

Figure 12: Cost of electricity in Spain and in Germany (TRANS-CSP 2006); red: TRANS-CSP mix with increasing share of renewable sources, black: continuing the mix of the year 2000 with fuel cost escalation, blue: CSP import from Africa, orange: local CSP production in Spain, green: mix 2000 but phasing out nuclear as scheduled in Germany.

Once cost break-even with conventional power is achieved, renewable capacities will be extended faster, avoiding further increases in the nationwide cost of electricity. Thus, the cost of the electricity mix can be maintained constant or in some cases even be brought back to lower levels, by subsequently increasing the share of renewable energy sources. This concept can be realized in all EUMENA countries.

The ongoing electricity cost escalation shows clearly that introducing CSP and other renewable energy sources on a large scale is the only viable solution for avoiding further long-term cost elevation in the power sector and to return to a relatively low cost level for electricity in the medium-term future. This is in line with the utilities' commitment to deliver least cost electricity to their clients. CSP from deserts is a key element of such a strategy.

An affordable and sustainable source of energy is also required for an even more vital commodity: freshwater from seawater desalination. CSP and other renewables can be the solution for this, too (Bennouna and Nokraschy 2006). The AQUA-CSP study shows the potential of CSP for seawater desalination in the MENA region and describes the technical options available, ranging from solar-powered membrane desalination to the combined generation of solar electricity and heat for thermal multi-effect desalination (AQUA-CSP 2007). In fact, there is no other way to avoid a serious water crisis in the MENA region, than to activate all options for better water management, higher efficiency of water distribution and end-use, re-use of waste-water and seawater desalination based on renewable energy sources (Figure 13).

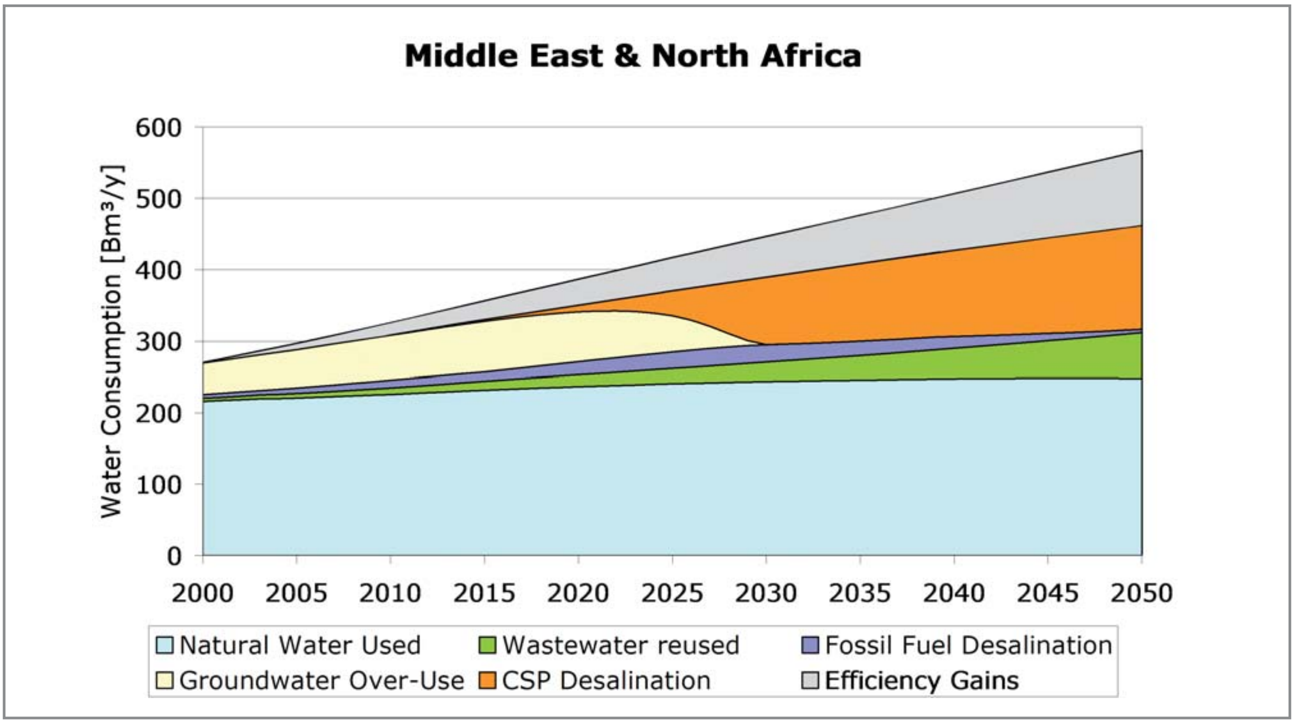

Figure 13: Water demand scenario for MENA until 2050 and coverage of demand by sustainable sources, by unsustainable sources and by solar desalination. (shaded: efficiency gains with respect to business as usual). Source: (AQUA-CSP 2007)

G There is an Alternative to Climate Change and Nuclear Proliferation

By implementing our scenario, carbon emissions can be reduced to values that are compatible with the goal of stabilising the CO2 content of the atmosphere at 450 parts per million that is considered necessary by the Intergovernmental Panel on Climate Change in order to keep global warming in a range of 1.5 to 3.9 °C (IPCC 2001). Starting with 1790 million tons of carbon dioxide per year in the year 2000, emissions can be reduced to 690 Mt/y in 2050, instead of growing to 3700 Mt/y in a business as usual case (Figure 14). The final per capita emission of 0.58 tons/cap/y in the electricity sector is acceptable in terms of a maximum total emission of 1-1.5 tons/cap/y that has been recommended by the German Scientific Council on Global Environmental Change (Graßl 2003). Further reductions can be achieved after 2050. Other pollutants are reduced in a similar way, without any need to expand the use of nuclear energy and its associated risks.

Carbon capture and sequestration (CCS) has been considered in our study as a complement, but not as an alternative to renewable energy, as it will reduce power plant efficiency and thus accelerate the consumption of fossil fuels. The fact that the cost of carbon capturing always adds to the cost of fossil fuels will accelerate cost break-even with renewables and increase the speed of their market introduction.

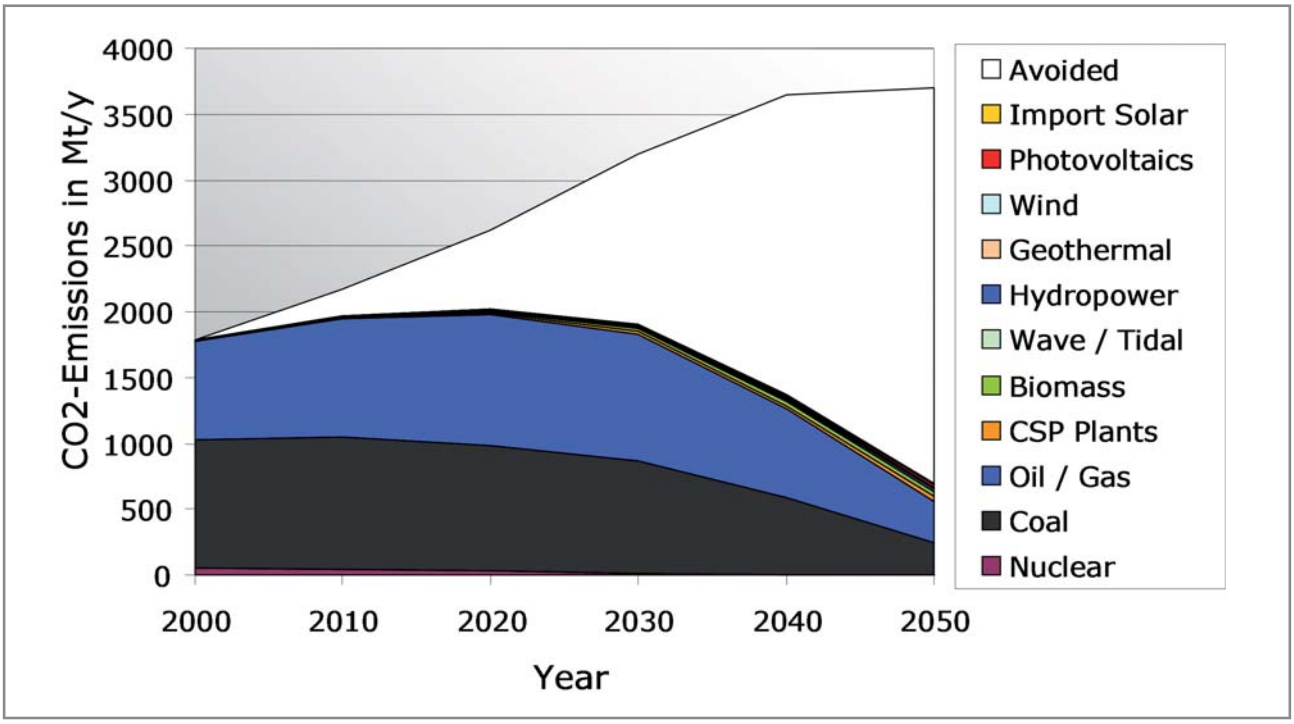

Figure 14: CO_2-emissions from electricity generation in million tons per year for all EUMENA countries and emissions avoided by implementing the proposed scenario with respect to an electricity mix equivalent to that of the year 2000.

The area required for the total renewable energy infrastructure including the proposed HVDC transmission lines for the period up to 2050 amounts to roughly 1 % of the total land area of EUMENA. This is comparable to the land required at present for the transport and mobility infrastructure in Europe. Using a geographic information system (GIS) three examples of HVDC lines connecting very good sites for CSP generation in MENA with three major European centres of demand were analyzed on the basis of a life cycle eco-balance (May 2005). The GIS was programmed to minimize cost, environmental impacts and visibility of the power lines, and we found that the resulting impacts are in an acceptable range. In general, the environmental impacts of HVDC lines are much lower than those of comparable AC overhead lines using conventional technology. Altogether, our scenario shows a way to reduce significantly the negative environmental impacts of power generation, and could also serve as a model for global application. This has been recognized by a study of the U.S. Department of Energy analysing the feasibility of this concept for the U.S. (Price 2007).

If desalination of sea water is powered by solar energy instead by fossil fuels, its environmental impacts are significantly reduced. However, seawater desalination itself is always a considerable burden to the environment, due to the resulting salty brine and the necessary chemical water treatment. Nanofiltration of intake water can mitigate those impacts, but more energy is required in that case. Therefore, activating the existing potential for enhanced efficiency of water use, water management and infrastructure is also a very high priority, in order to minimize the need for desalination. The AQUA-CSP study analyses the environmental impact of a broad application of solar-powered seawater desalination to cover the expected freshwater deficits in MENA (AQUA-CSP 2007). The results will be published by the end of 2007.

Five Focal Points for Sustainable Energy Policy

The timely realization of a scenario that meets all criteria of sustainability will require determined political support and action. Five focal points for national and international policy for all countries in Europe, the Middle East and North Africa (EUMENA) result from our studies:

1. **Increase support for research, for development and for the market introduction of measures for efficient supply, distribution and use of energy (<u>efficiency focus</u>).**

2. **Provide a reliable framework for the market introduction of existing renewable energy technologies, based on best practice experience and increase support for research and development for promising enhancements (<u>renewable energy focus</u>).**

3. **Initiate a EUMENA-wide partnership for sustainable energy. Provide European support to accelerate renewable energy use in MENA (<u>interregional cooperation focus</u>).**

4. **Initiate planning and evaluation of a EUMENA High Voltage Direct Current super-grid to combine the best renewable energy sources in this region and to increase diversity and redundancy of supply (<u>interconnection focus</u>).**

5. **Support research and development for shifting the use of fossil fuels from bulk electricity to balancing power production (<u>balancing power focus</u>)**

H Electricity in other Energy Sectors

A sustainable solution must also be found for the heating, cooling and transport sectors. Energy efficiency and increasing renewable shares are useful guidelines for these sectors. In the long term, there is the option of a partial shift from traditional heat and fuel to electricity. Examples for such a possible shift are electric heat pumps or direct electricity for space and water heating and electric or hybrid vehicles. In terms of sustainability, the higher demand for electricity arising from that shift will not constitute a problem if electricity is mainly produced by renewable energy as assumed in our scenario. In the power sector, each kWh of electricity produced by solar and wind energy will substitute approximately three kWh of primary energy from coal, oil, gas or uranium[6]. This relation depends on the actual efficiency of conventional primary-energy conversion, which ranges from about 20 % in the transport sector to about 80 % in space heating.

Thus, the use of renewable electricity will add to the efficiency gains of primary energy in all energy sectors. A partial long-term shift of other sectors to (clean) electricity is possible, as the renewable electricity potential in EUMENA is large enough to cope with that additional demand. In addition to electricity, direct renewable solutions also exist for those sectors, such as the use of bio-fuels for transport and heating, energy-efficient buildings, absorption cooling and solar water heaters, to give only a few examples (Dürrschmidt et al. 2006).

Combined heat and power is an important measure for increasing the energy efficiency of fossil fuels. Some renewable technologies, such as biomass, geothermal and concentrating solar thermal power plants, can also use this option for the combined generation of electricity and heat – usually via steam – for industrial processes, cooling and desalination, and will gain an increasing share in a future energy supply system.

[6] assuming a typical conventional power plant efficiency of 33%

Conclusions

The report quantifies the renewable electricity potentials in Europe and MENA and confirms their ability to provide firm power capacity on demand. Of great advantage for a fast transition to clean and secure power is an interconnection between the electricity grids of Europe, the Middle East and North Africa (EUMENA). Our study evaluates the potential and benefits of solar power from deserts. The conventional electricity grid is not capable of transferring large amounts of electricity over long distances. Therefore, a combination of the conventional Alternating Current (AC) grid for local distribution and High-Voltage Direct-Current (HVDC) transmission technology for long-distance transfer will be used in a Trans-Mediterranean electricity scheme based mainly on renewable energy sources with some fossil fuel backup. Sustainable energy will also be vital for sustainable freshwater supply by desalination. The results can be summarized in the following statements:

1. A mix of various renewable energy sources backed by fossil fuels can provide sustainable, competitive and secure electricity. Our scenario for EUMENA starts with the 16% share of renewable electricity that existed in the year 2000 and reaches 80 % in 2050. An efficient backup infrastructure will be necessary to complement the renewable electricity mix, providing firm capacity on demand by quickly-reacting gas-fired peaking plants, and by an efficient grid infrastructure to distribute renewable electricity from the best centres of production to the main centres of demand.

2. Market introduction of renewable electricity requires initial support in the form of long term power purchase agreements that cover the costs of operation together with a reasonable return on investment. This will mean only a small increase in national electricity prices, but will avoid their long-term escalation thanks to an increasing proportion of relatively inexpensive renewables and corresponding reductions in cost.

3. If initiated now, the change to a sustainable energy mix will, within a time-span of about 15 years, lead to power generation that is less expensive than it would be in a business-as-usual strategy. Fossil fuels with steadily rising costs will be replaced progressively by renewable forms of energy, most of which will be home-grown. The negative socio-economic impacts of increases in fossil-fuel prices can be reversed by 2020 if an adequate political and legal framework for the introduction of renewables into the market is established in time. Long-term power-purchase agreements like those provided by the German or Spanish Renewable Energy Acts are very effective instruments for the market introduction of renewables. If initial tariff additions are subsequently reduced to zero, they can be considered as a very efficient public investment into affordable and secure power generation rather than as subsidy.

4. Solar electricity generated by concentrating solar thermal power plants in MENA and transferred to Europe via high-voltage direct-current transmission can provide firm capacity for base-load and peaking power, effectively complementing European electricity sources. Starting between 2020 and 2025 with a transfer of 60 TWh/y, solar electricity imports could subsequently be extended to 700 TWh/y by 2050. High solar irradiance in MENA and low transmission losses of around 10 % will yield a competitive price of about 0.05 €/kWh in Europe for import of solar electricity.

5. Instead of a doubling of carbon dioxide emissions in the period up to 2050, which is likely to happen in a business-as-usual scenario, the CO_2 emissions from power generation in EUMENA can be reduced to 38 % of emissions of the year 2000. Only 1 % of the land area will be required for this renewable electricity scheme, which is equivalent to the land used at present for transport and mobility in Europe.

6. Growing freshwater deficits in MENA will increasingly require seawater desalination, but this must be done using sustainable sources of energy. Solar electricity for membrane desalination and combined solar heat and power for thermal seawater desalination are major candidates for such a sustainable solution.

7. European support for MENA for the introduction of renewables into the market can relieve the increasing pressure on fossil fuel resources that would otherwise result from the economic growth of this region, thus helping indirectly to secure fossil fuel supply also in Europe. The necessary political process could be initiated by a renewable energy partnership and a common free trade area for renewable forms of energy in EU-MENA and culminate in a Community for Energy, Water and Climate Security.

In order to achieve those benefits, governments in EUMENA must now take the initiative and establish an adequate legal and financial framework for new investment into this least-cost option for clean and sustainable energy. As energy is also a prerequisite for a sustainable supply of water, a timely decision by EUMENA governments to initiate that path is of vital importance for the total region.

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4. Statements from the MENA region

In the cooperation between MENA region and Europe or partners from Europe for renewable energy utilization, the European side plays a very strong role in this partnership as technology provider, and as a potential clean energy customer. What are the expectations in the MENA countries with regard to such cooperation with Europe? This chapter presents statements by six members of the TREC network from MENA countries, expressing their expectations connected with a EU-MENA cooperation along the lines of the DESERTEC Concept, for the development of their countries, and giving recommendations for how their countries and the European side could make such developments happen fast.

The statements presented in these chapters are the personal views of their authors. They may be close to the official policy of their country, or they may be proposals for what their country's policy should be. For the future it may be desirable to conduct a really comprehensive poll covering all countries, addressing directly their governments and other relevant stakeholders, in a systematic approach, to get a representative picture. Nevertheless, the statements collected here are already quite stimulating, and they show that the expectations described by persons from different countries have a lot of similarities. Insofar, these statements provide already quite a representative assessment.

4.1 Prof. Dr. rer. nat. Abdelaziz Bennouna, Rabat (Morocco)

Former Head of Unit for Technologies and Economy of Renewable Energies,
Centre National Centre for Scientifique and Technical Research (CNRST)
Founding member of TREC

Morocco on its way to an energy exporting country

"More powerful than all the armies in the world
is an idea whose time has come."
Victor Hugo

Morocco is a country that started a very ambitious development in recent years:

- Democratization and strong efforts for improving living conditions, in particular those of the poorer parts of society
- Founding of new cities in the vicinity of Rabat, Marrakech and at other places
- Completion of rural electrification by the end of the current year.
- Construction of highways has been tripling in the last ten years
- By 2010 the number of tourists will be raised to 10 million, from 4.2 in 2002.
- Construction of a new, very large Mediterranean sea port at Tangier
- Big industrial projects in connection with the new sea port, for instance production of 400,000 vehicles per year, in 2012.

Barriers on the path of implantation of those projects are

- Total dependence (over 97%) on imports in the field of commercial energy carriers, and that already under the condition of a rather low per capita consumption of less than 0.5 toe (tonne oil equivalent).
- A decline of precipitation and of fresh water availability, expected as implication of beginning climate change. Fresh water per capita will be further reduced by demographic growth. Present water availability is near 600 m³ per capita and year, already significantly below the internationally accepted water stress limit of 1000 m³. In some regions desalination is required to ensure the supply of drinking water. With 3000 km shore lines Morocco could be rich in water if large scale desalination would be employed.
- Technology for desalination is available leaving energy the bottleneck. For an expected annual desalination of around 5 billion m³ of water, more than 20 TWh of electricity would be required per year. Desalination can only become a solution if sufficient, inexhaustible, economically and environmentally acceptable sources of energy can be found – or made.

Supplies of energy and water, which are so basic for the future of humankind and so questionable at the same time, require well understood, internationally coordinated, courageous and convincing answers. Such answers will have to produce synergies, which will have positive impacts for solutions of climate problem, fundamental changes in the North-South relations and their co-operation. The studies underlying this White Book reveal and quantify the tremendous volumes of renewable energies available in the MENA countries. International developments on the energy sector and the mounting events heralding the onset of climate change and its dangers require global or at least a regionally coordinated reaction. This will only be successful if all concerned parties begin to accept that global or at least their regional commons are at stake. The fast transition to clean energies has become a question of survival of our civilizations and requires radical changes.

Based on my experiences from before the founding of TREC, my experiences within TREC and in parallel with the activities of TREC, I would propose from a Moroccan angle:

1. In the past centuries, North Africa and also Morocco have suffered in their development by occupations through European powers. Now Europe could contribute to the modernization of our industry, technology and science through a large-scale development program on technology for clean power from deserts. Such a program could be defined as an immediate moratorium in Morocco for all fossil energy carriers in the expansion of the Moroccan electricity supplies, so to speak a **freeze of carbon dioxide emissions**. In exchange of such a radical change of direction of a developing country the EU and G-8 will put in force a program of finance and technology transfer and development to make this exemplary path of Morocco a success and a model for many other developing countries in the sun belts.

2. An agreement between the EU and Morocco on a **joint program of producing clean power from deserts (solar and wind) and transmission to Europe**. The studies have demonstrated that solar power from the excellent sites in Morocco would be cheaper in Spain than from local solar power plants, including the costs of transmission. The same is true for the excellent wind sites in Morocco. Within 2 decades Spain and other parts of Europe could receive clean power from deserts at costs less than from their local fossil fuel power plants. Our energy and climate problems could be solved if politics would do what is technically possible and economically clever.

3. Negotiation with EU (mainly with Spain, France and Germany) for achieving **the best possible development** and exploitation of their mutual renewable resources (with human being at position 1), of technologies and of knowledge for our common struggle against poverty, climate change and South-North discrimination.

4. Such program would have to be based on **detailed projects**. Here is a number of proposals to this end:

   a) Solar thermal power plants with thermal energy storage for overnight. The first plant of at least 100 MW should be commissioned by 2010.

   b) A program for capacity building in wind power technology and utilization.

   c) Construction of HVDC transmission lines with multi-GW capacity from Morocco to Europe.

   d) The annually installed clean power capacity (solar, wind, hydro, biomass, ...) should latest in 2012 cover the new demand and the necessary replacements of old plants.

   e) Installation of a pump-storage system at SEBCHAT TAH, with a storage capacity of about 1 TWh. This and other storage capacities (thermal storage inside solar thermal power plants, exchange with the European grid, chemical storage) will allow for grid stability for any share of power from renewable sources.

   f) Reforestation to at least compensate the ongoing deforestation.

   g) National programmes of vocational training, research and development to bring Morocco into a position to take maximum advantage at all levels from the necessary transition to clean energies.

4.2 Eng. Tewfik Hasni, Algiers (Algeria)

CEO, New Energy ALgeria NEAL, Algiers

Europe – Middle East North Africa Cooperation for Sustainable Electricity

The Development of Renewable Energies

The large-scale introduction of renewable energies is of very high importance. The increasing effects of the climate change show that sensitizing people all over the world to this issue is justified. With respect to solar thermal power we emphasize:

- It does not burden the atmosphere with greenhouse gases.
- Unlike fossil and nuclear energy, it represents a renewable form of energy.

Solar Thermal Power as an Alternative

Solar thermal power is the most convincing form of alternative energy, as it is the most important resource regarding its potential. Algeria alone has an economic potential of 170 000 Twh/y in solar thermal power.

A clean source of energy would have to comply with the following criteria:

- **Security:**
  Power supply via electrical distribution supply networks must not be affected by each and every line or power plant interruption. The Hassi R'mel hybrid project is equipped with natural gas backup firing. During summer and winter times because of seasonal fluctuation, there are supply problems for power from wind and nuclear, leading to power failures. By contrast, solar power plants reach maximum power in these same periods.
- **Costs:**
  While costs of solar thermal power are still higher than those of fossil energies, rising prices of fossil energies (80 $/bbl in September 2007) as well as declining ones for CSP projects are expected to balance the costs of fossil and solar thermal energy earlier than expected. Today, power from hybrid CSP plants is competitive with gas at 3$/MMBTU. Solar-only operation will be competitive with gas when the gas price comes up to 6$/MMBTU, which could be the case before the year 2015.
- **Prospects of CSP:**
  The Hassi R'mel hybrid CSP project will serve as trial run for the credibility of CSP technology set up in a North African country. The access to the European power market should soon be facilitated. It should be pointed out that this source of energy is:

  - reliable: In the last 30 years, there has not been a single interruption in energy supply coming from our region to Europe
  - dispatchable: Hybrid systems with an additional unit of gas burners will prove the complementing effect of gas and solar energy regarding production security and the adaptation to the considerable variations in electricity demand.
  - secure: 6 000 MW of CSP in 2020 from Algeria to Europe would comply with energy dependency limits. Of course, this could lead to an equivalent reduction in exports of gas, if necessary.

Finally, access to EU market still has to be facilitated. The difficulties faced by the Algerian national company SONATRACH when entering the Spanish energy market show that there are still problems.

There are also some problems in power transmission: Technically transmission via HVDC is solved. Of concern is the economy of power transmission projects. It is known that infrastructure is not economical without state subsidies. Of very high importance is also security against power failures, as we have already experienced them in Europe. The cost of measures for secure grid operation should be taken care of by EU countries. Both problems requires compensation by the European States.

The actual development the HVDC network supported by the EU-MENA group should be marked by pragmatism. Initially, two or three HVDC lines should be set up: Spain – Northern Europe and Italy – Northern Europe. Algeria has already launched two HVDC lines. The first one, Algeria – Spain, is currently in the testing stage; the second will connect Algeria and Sardinia.

Conclusion:

Solar thermal power is becoming a real alternative to fossil energies. Lowering the costs and facilitating market access requires the support and assistance of the EU for the next ten years.

The first measure the European Union should take is to ensure that the imported solar electricity benefits from the incentives provided by the "feed-in law". These benefits should not be fixed but variable. The bonuses for solar electricity supply should allow a TRI (R.O.I.) of 5 to 8%. In return, the authority granting the bonus for the supplied electricity would benefit from "emission certificates" related to the purchased solar power. This would apply to the period of 2007 to 2017. At the end of this period, the competitiveness of solar energy will make it possible to abandon these incentives.

On the other hand, any attempts of preventing African energy suppliers from supplying Europe with energy, either by direct discrimination or by more subtle approaches, should be abolished since they would jeopardize the entire EU – MENA cooperation program that TREC is pursuing.

4.3 Eng. Malek Kabariti, Amman (Jordan)

President, National Energy Research Center (NERC), Amman, Jordan
Founding Member of TREC

A vision uniting the EU-MENA Region

For a long time the EC and MENA Regions have been considered to be one community in the region, and trade, political and economical relationships have been established long time ago.

Due to economical and cultural differences tension has been rising in this region. One of the best ways to reduce conflicts in the region is through cooperation and better neighbour relationship. A peaceful co-existence of the Mediterranean riparian, of Europe and MENA, based on productive cooperation requires **a joint vision for the entire EUMENA region**. What would be nicer than an energy-water-environment cooperation to put deserts and technology into service for energy, water and climate security? How could we get a closer relationship in this region than by solving these conflicts?

With the abundance of solar energy resources in the region, large solar thermal power plants (CSP technology) would be part of this solution, taking into consideration that Jordan is one of the world's poorest countries when it comes to water resources. Also, Jordan lacks indigenous conventional fossil fuel resources. Just last year the energy bill of Jordan was about 25% of the GDP.

Taking notice of the fact that high voltage grid connection between Africa and Asia has already been started through the Jordanian-Egyptian grid interconnection, and likewise an European-African connection between Spain and Morocco, a beginning of the basic infrastructure for European - Middle Eastern - North African cooperation for clean power from deserts is emerging.

The prospect of building large CSP plants in Jordan would serve two purposes. The first one is to fulfil the need of meeting Jordan's water and energy requirements for the present and future generations as well as enhancing prosperity of Jordan. Second is increasing its capability for the export of very expensive and badly needed commodity (Energy and Electricity) which can be transferred to Europe.

To get started, Jordan and another European country, for instance Germany, could negotiate on a **sustainable development enforcement program**, by which Jordan would consider to **install by 2015 solar thermal power plants of 1 GW total capacity**, when combined with development of local collector production lines and with financial support for their installation to such an extent that clean power from these plants is cost competitive with power from new fossil power plants.

On the micro level, social and economic development would proceed in Jordan and on the macro level this would help to get Europe and MENA closer together.

- If Europe would embrace the option "Clean power from deserts" and support investments into initial CSP plants in MENA countries and into the transmission grid, as it gave – and still gives – subsidy to coal and nuclear industries,

- And if Jordan and other MENA countries would allocate excellent solar sites for CSP plants and give long term commitments to buy their power.

- Then we are on the right track to a sustainable energy era with EU-MENA as a region of energy, water and climate security and of good neighbourhood.

If the two regions merge their complementary strengths, the excellent solar sites and the excellent solar technology, they will enhance substantially their capacity of establishing sustainability and stability. This unifying vision that crosses boundaries of religions, cultures and politics should be made a reality.

4.4 Dr. Eng. Hani El Nokraschy, Hamburg, Cairo (Germany, Egypt)

NOKRASCHY ENGINEERING GmbH, Hamburg, Germany
Founding Member of TREC

Energy Challenges in Egypt

Driven by a population increase of about 1.5% and an increase in GDP of over 7%, electricity demand is growing in Egypt at a yearly rate of about 7%. This demand was covered till now by using hydropower from the Nile dams at the maximum possible and building conventional power stations mainly gas fired. In the near future another challenge will appear, namely water scarcity. As there are no other significant sources for water than the Nile, it will be essential to go to seawater desalination, which will need additional energy.

How can Egypt handle this challenge?

By starting immediately a consequent shift to renewable energies for electricity supply. This is the first step towards sustainable seawater desalination.

The rapidly increasing demand on electricity in Egypt and the available abundant resources of renewable energy in terms of hydro power, wind energy and especially solar irradiance suggest a logical solution, namely generation from renewables.

A complete shift to renewables is possible because of the available excellent CSP potential which allows electricity generation in the night and on demand (hybrid operation or heat storage), however, such a shift needs its time. Even if envisaged that all new plants built use renewables, this will not satisfy the demand growing at a rate of about 7% per year.

In the first decade hydro power shall be used to its full availability as it is already planned, in the first and second decades wind power shall be built up to reach about 15-20% of the installed capacity in the Egyptian grid.

In the following decades Concentrating Solar Power (CSP) plants shall be built on a large scale to replace thermal power stations that are getting out of service and to cover the domestic demand especially the growing demand for desalination and also to have a surplus for export to Europe starting a large scale "Mediterranean Renewable Energy Partnership".

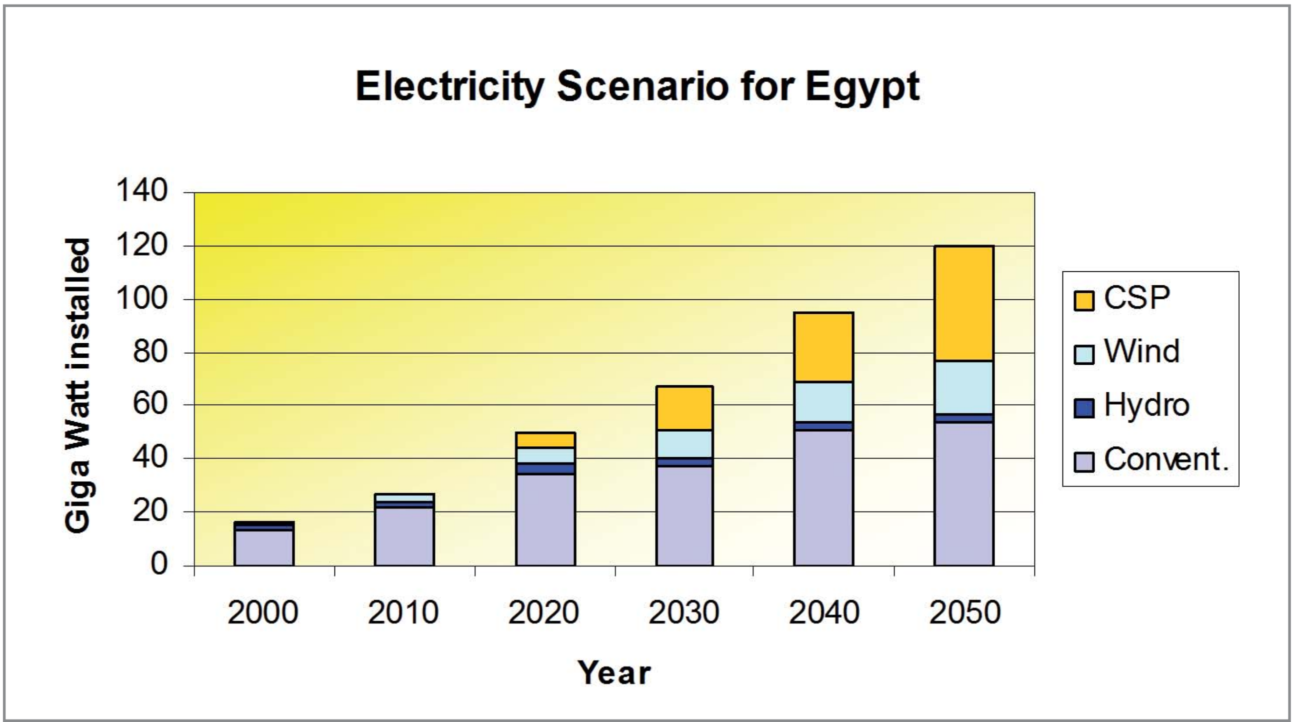

Fig.: Scenario suggested starting a gradual but immediate transition to renewables in Egypt.

The concern that a high percentage of wind energy may destabilise the grid is accounted for by limiting its share to 15-20% and installing compensating capacity of conventional power stations and CSP with thermal storage enabling night operation and supply on demand.

After 2050 the conventional power stations shall be replaced successively with CSP power stations which will produce electricity by that time at considerably lower costs than generated today from oil and gas.

There is a real chance for future cooperation between European and Egyptian experts to establish a master framework for shifting electricity generation in Egypt to 100% renewables during this century and enabling electricity exchange with Europe within a Mediterranean Renewable Energy Partnership.

What is "Mediterranean Renewable Energy Partnership"?

Renewable energy resources are available all over the world with different intensities, however, not always in the regions where energy is needed. Energy partnership means that the renewable energy shall be harvested where it is economic, e.g. wind-power from Northern Europe, Gulf of Suez and Moroccan Atlantic coast, sun-power from North Africa and Middle East. Then transmitted to where it is needed in central Europe, like oil and gas are transported now. It is cheaper and requires less effort than trying to produce renewable energy from weak local resources.

Solar thermal power stations offer the options of hybridisation and thermal storage. Thus enable production of electricity day and night and "on demand" exactly like conventional power stations. Optional seawater desalination in co-generation increases their economical features.

The Mediterranean electricity ring, operating at 400 kV alternating current, is nearly completed now. It can be considered as just the beginning of commercial electricity exchange between the connected countries because it is obvious that its capacity is limited and the losses for long distance transmission are higher than tolerable limits.

For these reasons another transmission technology shall be adopted, namely the High Voltage Direct Current (HVDC) connections. These shall connect with high performance lines, each line capable of transmitting about 5 GW, from collection centres for renewable energies in North Africa and Middle East directly to the demand centres in central Europe.

Realisation

Political will is essential to establish a legal and financial framework to govern actions and activities of such a huge project, whereas it shall be considered that at the start phase strong support from the European countries to the MENA-countries will accelerate this positive development. The target until 2050 shall be to supply 10-15% of Europe's demand from clean electricity from MENA-Countries.

In this framework the industrialised countries shall help developing countries to build up a high potential of renewable energy (RE) using their available resources and establish HVDC lines to transport the surplus energy to Europe. The surplus energy is bought by the industrialised countries, thus enabling the developing countries to buy more equipment from the industrialised countries to raise their RE potential.

Considering that the industrialised countries in Europe will spend money in equipment production creating jobs in their own countries instead of spending it for burning fossil fuels, and that the developing countries in MENA will accelerate their development due to income from selling clean electricity, this will lead to prosperity for all peoples involved.

Conclusion:

The White Book shows that it is possible and even economic on the long run, to cover Egypt's needs for electricity and water from Concentrating Solar Power and other renewable energy sources. A favorable side effect is that the renewable energy available can cover all of Egypt's demands and offer surplus for export to Europe in the frame of a Mediterranean Renewable Energy Partnership. A shift to 100% renewable electricity within this century is possible.

4.5 Prof. Dr. Eng. Galal Osman, Cairo (Egypt)

Renewable Energy Professor & Department Head Mansoura University, Egypt
Egyptian Wind Energy Association, Founding President
World Wind Energy Association WWEA , Founding V. President
WCRE, WEC, IEEE, IEE, ISES, TREC- Member

Clean Energy for Development of Egypt

Sustainable development in Egypt needs development and efficient management of primary energy resources. Energy resources can be classified into conventional resources such as oil, natural gas as well as renewables, mainly hydro, solar, wind and biomass. Growth of demand of electricity for expected socio-economic development during the next decade ranges between 6-8% per year.

Policies of diversifying energy resources, improving energy efficiency, applying energy conservation measures as well as promoting renewable energy utilization are the possible venues to secure the necessary electric energy supplies.

In order to save fossil fuel, to reduce green house gases emissions, to secure job opportunities, and to secure water for development, clean energy cooperation between sun-belt and technology belt countries is considered the only solution for the development plans in Egypt.

More over clean power from solar energy from 94% of Egypt's unutilized land in western and eastern deserts and from wind energy potential of 20 000 MW at the Red Sea and the Mediterranean Sea is a new source of currency. It can be exported directly to Europe via a future EU-MENA grid, or indirectly by substituting domestic power generated from domestic oil and gas and exporting these saved fuels.

Egypt's hydro energy from river Nile has been already exploited.

With growing population and limited quota of water from river Nile, Egypt is approaching water poverty line and there is urgent need to get fresh water by desalination from both the red sea for tourism activity and the Mediterranean for irrigation and drinking water. This can be achieved with solar power and desalination plants at high intensity locations where direct solar radiation reaches 2400 kWh/m²/year and more, and with an extended unified power grid and back-up systems from expanded natural gas pipe lines, and sources of water from river Nile, Red Sea and Mediterranean sea.

Local industrial capabilities for domestic and regional markets will be enhanced by using matured technology from technology belt through technology and knowhow transfer.

This can be made to lead to creation of new job opportunities in relevant fields whether wind energy or solar energy or water desalination.

Emission reduction purchase agreements will allow selling Certified Emission Reductions CERs produced by solar and wind projects to carbon funds around the world for millions of tons of CO_2/year.

In summary:
when Egypt would adopt an aggressive role in acquiring competence and in building capacity for the use of its excellent wind and its vast solar resources by a close cooperation with Europe, it could create jobs, energy and water for its own people, and clean power for the big European market.

4.6 Dr. Amor Ounalli, Tunis (Tunisia)

Director, Renewable Energies Department at ANME, National Agency for Energy Management
Development of renewable energies in Tunisia and partnership with Europe

Development of Renewable Energies in Tunisia and Partnership with Europe

Energy context

During the two last decades, the energy balance of Tunisia was characterized by a falling contribution to the GDP, by the stabilization of the hydrocarbon resources and by the increase in the consumption of energy in the whole of the economic sectors leading to an energy deficit since the year 2000. In 2006, the national energy resources delivered 6.3 Mtoe and the consumption was 7.3 Mtoe. The increase in the prices of oil and of imports of petroleum products resulted in an extremely heavy pressure on the budget of the State. For this reason the State engaged a policy in favour of energy management.

Environmental context

Energy management constitutes a means of greenhouse gas emission reduction. Their increases are due primarily to the energy activities (production and consumption). Thus, Tunisia adopted a policy of energy saving contributing to the reduction of GHG emissions.

Potential of energy saving

The potential of energy saving as evaluated by surveys by 2030 amounts to approximately 80 Mtoe.

Achievements in the field of renewable energies

The development programme of renewable energies stresses the two most mature technologies and whose energy contributions are most significant, namely wind and solar thermal.

1. Wind

For wind energy, the objective is to reach 200 MW by 2011, 1100 MW in 2020 and 1800 MW in 2030 installed capacity. Currently, the wind capacity installed by the national utility STEG (Tunisian Company of Electricity and Gas) in Sidi Daoud reached 20 MW. This capacity is under reinforcement to reach 55 MW. The STEG also launched in 2007 an invitation to tender for the installation of a 120 MW wind farm. The financing of these projects was financed by Spanish credit. The development of wind energy follows national objectives:

- To facilitate the emergence of qualified independent operators;
- To increase the rate of local integration of manufacture and assembly of wind farms;
- To facilitate the development of wind farms using Clean Development Mechanism;
- To satisfy the electric needs of large consuming energy industries (cement factories, iron and steel industry…)

2. Solar thermal water heating

For solar thermal, the objective is to reach 700000 m² in 2011 of installed solar water heaters. Present installation is about 250000 m². The State is supporting solar water heaters installation.

3. Solar photovoltaic

Photovoltaic electricity is produced for the basic requirements in energy of rural population. Until now approximately 12 000 systems were installed. Knowing that the national rate of electrification reached a value close to 99 %, the remaining potential of solar home systems is extremely reduced. Several European countries (Spain, Germany and France) supported the implementation of this program through the initiation of demonstration projects. These supports concern as well the supply and the installation of systems as the reinforcement of local capacity building in the field. In addition, the application of photovoltaic pumping to supply rural population with potable water has reached an installed capacity of 260 kW in total. This technology was introduced with support by the German GTZ, Spanish cooperation and by a European program MEDA. Photovoltaic constitutes one of the most interesting solar technologies in Tunisia for water pumping for drinking water of population and cattle or for irrigation. Another application is brackish water desalination. ANME is carrying out a project for pumping and desalination of the brackish water with 600 kW total capacity.

4. Bio fuels

Here we mention the installation in 2000 of a demonstration project of biogas plant, which treats the chicken waste to produce biogas and electricity. This activity will allow in future the valorisation of domestic waste for the production of electricity. Interest is growing in production of bio diesel which could serve as an additive with the gas oil, and would make it possible to obtain interesting advantages from the economic, social and environmental points of view.

Development prospects of the co-operation with the European Community in the field of renewable energies

In spite of the climatic and political conditions in favour to the development of renewable energies in Tunisia, the contribution of renewable energies in the national energy balance did not reach 1 %. This rate can be clearly improved mainly through the recourse to the use of the wind power and in particular by the installation of wind farms (onshore, offshore, achievement by STEG, IGCE (Large electric energy consumer Industrials). The co-operation with Europe on this level can be very beneficial by supporting the national effort at various levels: to improve the study of the wind potential following the example what is currently accomplished with the Spanish and German co-operation, reinforcement of the local capacity building, realization of technical, economical, financial feasibility studies, to establish grid interconnections between the close European countries and Tunisia in order to make benefit as well Tunisia as the European countries from the electricity which would be produced by wind energy in Tunisia. Solar thermal can also contribute with a significant share in the improvement of the energy balance. Solar thermal water heating in the residential and tertiary sectors is in full rise. European countries could consolidate this effort of development in Tunisia, as done already by the Italian Ministry of Territory and Environment. From another side, it is expected a big development of solar thermal plants to produce heat and electricity (Concentrating Solar Power) which would be installed in the desert areas, is favourable with these technologies in Tunisia. Some European developers of these technologies are studying infrastructure and projects in relation with thermodynamic power to be produced in Tunisia and to be exported to Europe. Solar thermal power generation can be coupled with thermal sea water desalination at large scale. This way should open very interesting co-operation with the European countries (elaborating specific studies, reinforcing local capacity building, achieving projects, transferring technologies, grid interconnection). Solar thermal applications can also meet the needs for heating and air-conditioning of the buildings. It can also cover the cooling needs of the industrial sector and particularly for the food industry. In addition solar energy constitutes an interesting solution to meet the needs for energy of potable and brackish water pumping and desalination in the arid and semi-arid area in Tunisia. The co-operation with some European countries can contribute a lot in order to improve water supplying in remote and desert area. In the same way, other kind of renewable energies can largely contribute to the diversification of energy sources by the production of electricity connected to grid, such as photovoltaic solar plants and biogas plants. The development of these technologies is dependent also on the reinforcement of the building capacities of the stakeholders and on their financial capacities. The technical and financial co-operation with Europe will play a great role in this way. Finally, relations exist already between Tunisia and the European Commission through the achievement of research projects (such as FP6 and FP7) in the fields of energy and water. By this co-operation between Europe and Tunisia links and networks are established in order to exchange data, analysis and competences.

5. Summary and Recommendations

5.1 Conclusions of the White Book

The beginning climate change process bears the risk of running out of control at any time, since there is no analogue in earth's climate history from which we could determine with certainty our distance from the point of no return. Even the $\Delta T<2°C$ goal cannot give us security. With solar and wind technology and with the resources in deserts we can now take powerful steps to defend humankind against a global climate and energy crash. The implications for global economic and social development of exhaustion in supplies of fossil fuels on the one side and the dramatic consequences of greenhouse gas emissions on the other side make clean power from deserts a most important instrument for stability, freedom and peace on this wonderful green planet earth.

How does this translate into a "Clean Power from Deserts" programme? Our analysis says: By the year 2050 we need for the EUMENA-region a CSP capacity of 1 around Terawatt. Can this be achieved? Now, say in 2010, we will have installed 1 Gigawatt. Therefore we need an expansion by a factor 1000 within 40 years, or a factor 2 every 4 years, respectively. A corresponding annual growth rate for CSP power capacity of close to 20% is no problem for industry. The mechanical engineering industry could handle such an APOLLO-like EUMENA-DESERTEC programme.

Our analysis of renewable electricity potentials in Europe and MENA finds that there are excellent sites for wind power and, in the MENA deserts, there are the largest but least tapped sources of solar energy of the world - with an economical **potential for about 100 times the demands of EUMENA**. Via cooperation amongst these regions solar power from deserts

1. can already be generated reliably and cost effectively with today's technology of concentrating solar thermal power (CSP),
2. can also be produced from stored solar heat and thus provide firm power capacity, i.e. power on demand, during the day and also at night,
3. will be cheaper than power produced from fossil fuels at their present cost levels,
4. can provide sustainable power sufficient to meet the demand of fast growing MENA population,
5. can deliver the energy for desalination of sea water as will be required to avoid a fresh-water crisis in the MENA region,
6. can stimulate industrialization and economic development in MENA countries, and become a long-term export product,
7. can be transmitted to Europe with such low losses and costs that it will be cheaper than solar power from local sources in Europe,
8. can accelerate the transition to clean power in Europe without undue cost, by supplementing other European renewable sources, as much as may be required,
9. allows to slow down climate change according to the $\Delta T<2°$ goal and to promote energy and water security, through an Apollo-Program-like effort "EUMENA-DESERTEC" by countries of the EU and MENA to employ their deserts and technologies to these ends,
10. can open a new chapter in the relations amongst the people of EUMENA.

In order to achieve those benefits, governments in EUMENA must establish adequate political, legal and financial frameworks for new forms of North-South cooperation and for investments into this option. To launch the EUMENA-DESERTEC programme, financial support of about 10 billion Euros may be sufficient, comparable with the cost of one month's warfare in Iraq (not including the cost of damages and the cost of recovery efforts), or with the typical cost of damage by a strong hurricane. Financial support of a quick start of a EUMENA-DESERTEC programme should be seen as what it really is: an investment in energy and climate security for present and future generations, which at the same time happens to give us low-cost electricity.

5.2 What Politics could do

Implementation of the DESERTEC concept requires two lines of action:

1. Large-scale production and deployment of solar power plants in the MENA region.

2. Interconnection of MENA and Europe with a Supergrid for multi-Gigawatt power transfer.

Power plant deployment and EU-MENA Supergrid connection can be started in parallel, and they both need political support and some financial support in their early phase.

5.2.1 Solar Power Plant Deployment Programme

Construction of new concentrating solar thermal power plants has begun already in Spain and in the USA. Here the CSP technology and new developments are demonstrated. In the MENA region first projects are under development in Algeria, Egypt and Morocco and are being planned in Jordan, Libya, Tunisia, and United Arab Emirates. Algeria and Morocco have already implemented feed-in regulations for clean power.

Solar thermal power plants can already work economically at good MENA sites, and with some further cost reductions they can make clean power from deserts a profitable export option for MENA within a few years.

To boost the construction of solar thermal power plants and of wind turbines in MENA, the EU and European industry should

1. support a **campaign to inform MENA governments** that, over the lifetime of those plants, they would now be a cheaper source of power than electricity generated from (clean) coal, oil or natural gas. Sun-belt countries could reduce the use of domestic fossil fuels or of costly imports and, at the same time, would acquire the capacity to produce clean power from their own deserts and with their own human resources. There would be the additional advantage that clean power can easily be sold to Europe.

2. support the launch of a **1 Gigawatt MENA-CSP kick-off programme** with plant constructions to begin until 2010 in interested MENA countries.

3. support **industrial capacity building** for CSP and wind technology in interested MENA countries such that by 2020 the latest all new power plants in those countries could be built as wind farms or solar power plants.

4. invite MENA countries to organize jointly an **Apollo-Program-like effort "EUMENA-DESERTEC"** to enable efficient mass production of solar thermal power plants and installation of transmission infrastructure to Europe. Such a programme would be of great economic, developmental and ecological benefit for all participants. It could become the core of an attractive neighbourhood policy of the EU. A EUMENA-DESERTEC initiation group should be formed.

The EU and its member states should

5. express **interest** to the governments of MENA **in importing clean power** from MENA countries by 2020, provided that the power cost would be commercially acceptable. To this end, solar power from MENA should be included immediately as option in the European energy portfolio. Furthermore the planning of an appropriate HVDC grid as infrastructure for energy and climate security should be started forthwith.

6. cooperate with MENA countries in **bilateral climate partnerships** for the development of clean energy technologies and for their deployment throughout their countries. Achieving additional slow down of climate change and accelerating technology development and transfer would be beneficial to both sides.

7. support the **Gaza Solar Power & Water Project**, a 1 GW CSP plant for combined generation of electricity and desalination as part of a potential international recovery programme for Gaza. The plants could be located in the Egyptian Sinai coastal region and serve water and power to 2-3 million people in Gaza. This project could mark a turning point in the disastrous social and economic development of Gaza, in the regional conflicts for water and in the stalled peace process between Israel and Palestine. The total investment required would be about 5 billion Euros.

5.2.2 EU-MENA Supergrid connection

Discussions about the establishment of an HVDC-Supergrid across Europe (Euro-Supergrid) and about building Trans-Mediterranean transmission lines (EU-MENA Supergrid connection) have started already, in Europe and in MENA countries. These connections would facilitate the optimal use of diverse renewable sources in both Europe and MENA, for the fastest transition to clean energies possible. In itself, the initiation of the EU-MENA Supergrid connection would create a boom in investments in wind and solar power in MENA countries, would connect Europe to cheap, clean and inexhaustible sources of electricity, and would give to MENA countries the long-term economic perspective of clean power export. The construction of HVDC grids for the first 10 GW would cost about 5 billion Euros.

If the EU-MENA Supergrid connection is to start transmission by 2020, talks within the EU and with the governments of MENA (e.g. within the Barcelona Process, within the European Neighbourhood Programme, or within a new, special taskforce "EU-MENA Supergrid") must be organized now.

Solar power from North Africa will be cheaper in Southern European countries like Spain and Italy as compared to power from new local fossil and nuclear plants, already with transmission beginning in about 2020, and with progressing cost reduction and EU-MENA grid expansion also in most other European countries, latest in 2030. The 100 GW EU-MENA connection as described in Chapter 3 will require an investment of about 45 billion Euros up to the year 2050, and is likely to yield annual savings approaching 10 billion Euros, as compared to producing power from fossil fuels. This will make clean power from deserts the least-cost option for Europe. Setting up the EU-MENA Supergrid connection really is a "must" for European and MENA economies.

The full EU-MENA Supergrid connection will grow over several decades and will start with the laying of a few submarine cables. To start out properly and to develop fast, the vision of EUMENA as a community for energy, water and climate security should be the guide.

Towards a EUMENA-DESERTEC Programme

Energy and climate security are basics for human life and civilisation. Clean power from deserts together with a combination of other renewables is a realistic option for resolving the global energy crisis without enhancing the risk of nuclear proliferation and of climate change. More than 90% of world population can be served by clean power from deserts

A EU-MENA Supergrid connection and a large-scale deployment of solar thermal and wind power plants in deserts are realistic and powerful tools for energy, climate and developmental security, and for safeguarding the carrying capacity of our globe.

A EUMENA-DESERTEC programme could open up a new era in the relations between Europe and its Southern neighbours, and become the starting point for EUMENA as a region of cooperation, peace and prosperity, much as the coal and steel community was the origin of a cooperating, peaceful and prosperous Europe.

Humankind has mastered to reach the Moon. Now it has everything for a programme to master the energy and climate crises on Earth. – Let's do it!