Deserts as sustainable powerhouses and inexhaustible waterworks for the world

Gerhard Knies
Trans-Mediterranean Renewable Energy Cooperation
TREC
gerhard.knies@trec-eumena.org

Abstract

The Earths deserts and their coast lines might provide a solution to the global energy and water problems. The deserts receive at day time large amounts of energy from outside the Earth, and they return this energy as heat radiation to outer space day and night. The sun is radiating about 1000 times as much energy onto the Earths deserts as humankind is using. At each km² of desert energy as in 1.5 million barrels of oil is arriving annually. Energy as the present annual world wide consumption arrives within 5.7hours of sunshine at Earths deserts. We do have the technology to convert at least 50% of it into useful energy as heat for steam production, for power plants and for seawater desalination. Thermal solar power and desalination plants in deserts can provide Humankind with clean power and fresh water at any conceivable demand, if the sun-belt and the technology belt begin to cooperate. An Apollo DESERT program to this end is proposed. Sun-belt and technology-belt could solve the world's energy, water and climate problem and bring Humankind back to balance with its home planet Earth if they would cooperate as if there were no boarders.

1. The global energy problematique

The discussions on energy supply security, on fossil fuel reserves and on Green House Gas emissions are escalating. Acceptable solutions to the energy problem seem to be difficult or even out of reach. The climate change is questioning our civilization and the basic living conditions. Already in the year 1972 the Club of Rome pointed out that development of humankind was about to approach limits to growth. Such limits were to come in two (or even more) ways: from depletion of resources, and from polluting the environment in excess of its regeneration capacity. Depletion of resources will hit those doing the overexploitation. Shortages will provoke reactions for coping with the problem. Pollution, however, may back fire with large delay in time, such that we did it for too long, created irreversible damages and created overshoot situations beyond limits of stability. The result may be collapses of live supporting systems. Repair may not be possible. Avoiding overshoot is possible but requires preventive instead of reactive measures. There is no global actor responsible for or in charge of global ecological security.

The *depletion problem* and the *overshoot problem* are very prominent in the energy sector: The depletion of one particular energy source may induce introduction of alternatives. Climate change bears the threat of irreversibly changing living conditions on Earth faster than developed natural and social systems will be able to adjust to.

The question we want to pursue here is: can solar energy from the deserts become a remedy to both of these problems. This requires that we address three questions:

1. Is there enough solar energy in the deserts for avoiding depletion of resources, and for a return to the conditions for climate stability?
2. Can solar energy from the deserts supply power as demands occur in time?
3. Can energy be transmitted from deserts to large enough regions of demand?

Solar energy is an extraterrestrial alternative to the limited terrestrial sources. It does not contribute to depletion of terrestrial resources nor to polluting the terrestrial environment. Solar energy comes from outside at day as light, and it returns to outer space as heat radiation at day and night – whether we "use " it or not. With sun light the driving force for all life on Earth, the terrestrial environment is naturally in balance with solar radiation.

2. The solar energy potentials in deserts:

Solar radiation can be converted into useful energy and thus provide most energy services the fossil fuels are employed for now, as electricity, mobility, and heat. The question is, however, if there is enough solar energy available and accessible.

The most effective places to collect solar energy are the deserts. The solar energy potential of the deserts can be estimated by the size of (sunbelt-) deserts, and by the average energy they receive annually from the sun. Since the definition of desert size has some arbitrariness, the following numbers are not more accurate than 10%. But because of the large excess of solar resources over all possible demands a better precision is not required.

Table 1: Annual solar energy potentials of the world deserts

Desert size according to UNEP(www.)	Average annual energy yield per m²	Annually received energy in world wide deserts
33 Mio km²	2.4 MWh (thermal), equal to 0.3 t coal 0.24 m³ oil, or a layer 24 cm deep 1.5 barrel oil	80 Million TWh 10,000 Billion ("Giga") ton coal 50,000 Billion barrel 300,000 Exajoules

3. The fossil resources depletion problem

The rising oil prices show that oil depletion has already come into sight. Also the reserves of natural gas, coal, and nuclear fission fuels are limited. Fig.1 /BGR 2005/ shows the presently known (confirmed) reserves, the present production-consumption and the resources of fossil energies expected to exist based on geological considerations.

Comparing these numbers with the solar energy potentials (Tab. 1) there are two noteworthy results (Tab. 2):

1. The total presently known fossil energy reserves on Earth are equivalent to only 47 days of solar energy in deserts.
2. The 2004 world-wide annual fossil energy consumption of 13.1 Gtoe (=380 EJ) is equivalent to ½ day (5.7 hours) of sunshine onto the deserts.

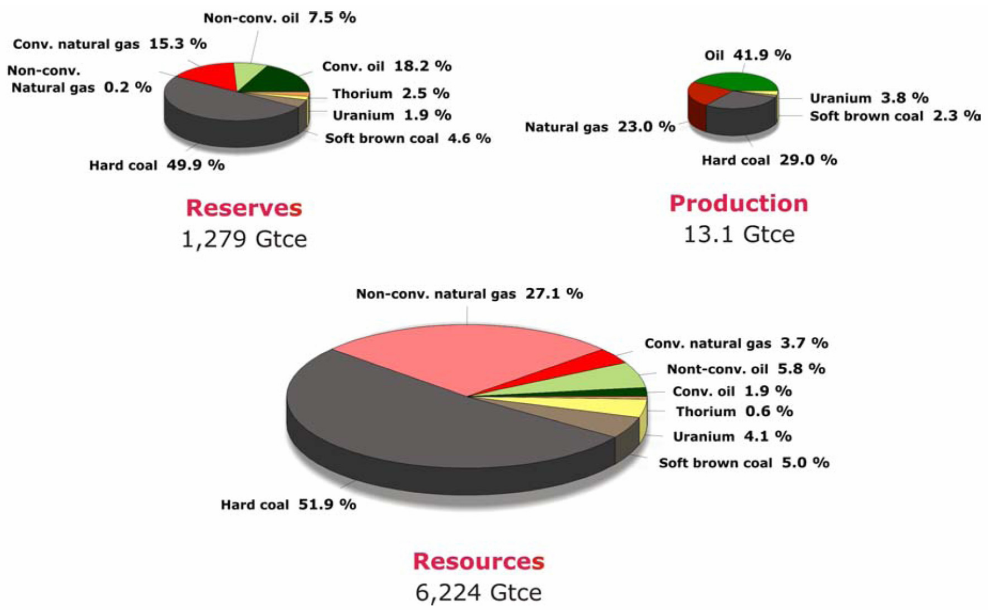


Figure 1: Production, reserves, and resources of the individual non-renewable fuels in 2004, in Gigatons of hard coal equivalent: 1Gtce = 29 EJ = 8,140 TWh-thermal.

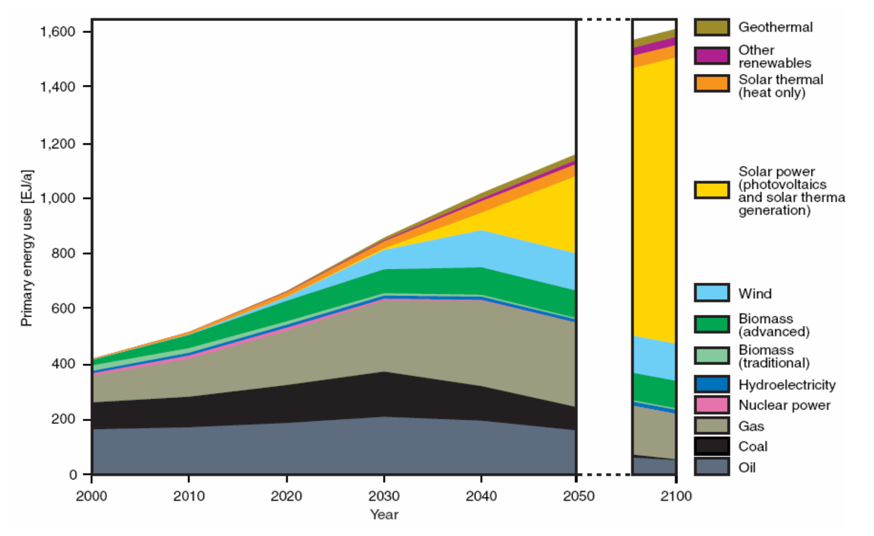
Table 2: Fossil reserves, resources, consumption rates, depletion time, and solar delivery times

Fossil energy source	Reserve (Resource)	Production Rate	Static Depletion time (Reserve/P) In years	Equivalent solar delivery time in deserts,	
				Reserve (Resource) In days	Annual Production In hours
Total	1.279 (6224)	13.1	98	47 (227)	5.7
Oil (conventional)	233 (118)	5.5	42	8.5 (4.3)	2.4
Oil (non-conv.)	96 (361)				
Natural gas (conv.)	196 (230)	3.0	65		1.3
Natural gas (non-conv.)	2 (1687)				
Coal (hard and lignite)	697 (3541)	4.1	170		1.8
Uranium, Thorium	56 (293)	0.5	101		0.2

Since 10% of solar energy can be converted into "useful" energy such as electricity, we can conclude that the present total annual world energy demand could be generated in deserts within less than 5 days. This raises the question: Where is the energy resources problem?

The numbers in Table 2 for production/consumption of energy will grow with growing human population, and with developing consumption patterns. In Fig. 2 we show the scenario "exemplary path" proposed by the scientific advisory board on global change of

Figure 2: Development of global primary energy demand according to the scenario "exemplary path" by the scientific advisory board (WBGU) to the German government



the German government /WBGU/, which assumes a rise of global primary energy consumption by a factor 4 to 1600 EJ or 55 Gtce, respectively, from the year 2000 until 2100. The latter is 0.55% of the solar energy arriving in deserts. Again: Where is the depletion problem?

When fossil resources are facing depletion, it should be no problem to fill deficits from the solar energy in deserts. This would be possible even if present global energy demand would grow by a factor 10, provided the solar energy harvesting technology is available and has been installed before it comes to depletion.

Therefore we can conclude with certainty:

Deserts can supply energy for any presently conceivable demand of humankind.

4. The fossil fuel pollution problem – climate change

The other problem of using fossil energy sources is accumulating pollution of the atmosphere. This is part of a more general problem of expanding humankind: it is growing beyond the carrying capacity of the eco-system Earth in several ways. Hence, in the 30-year Update of the Limits to Growth report, from 2004, The Club of Rome is pointing to the **overshoot problem**. To quantify the "Ecological Earth consumption" the ecological human footprint has been defined /Wackernagel…/. Its development since 1961 is shown in Fig. 3 . The human ecological footprint is a resource management tool that measures how much area land and water a human population requires to produce the resources it consumes and to absorb its wastes under prevailing technology. The global human footprint (HF) is defined by means an average individual human footprint derived from consumption pattern, and the total number of world population:

Human Footprint = HF = (individual human footprint) times (world population)

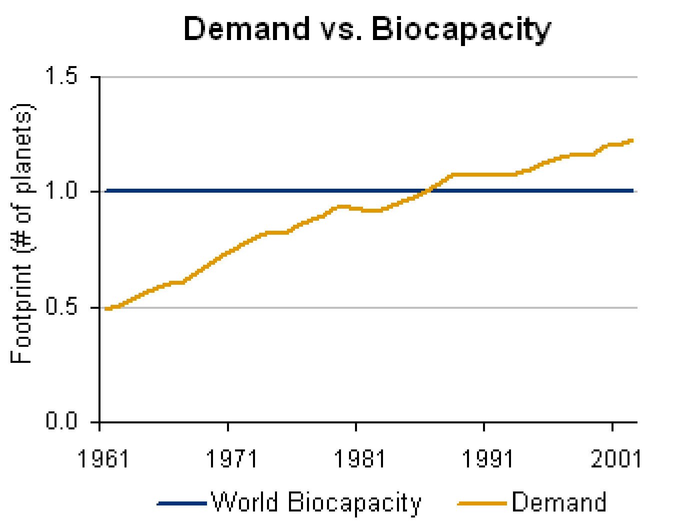


Figure 3. The ratio between the world's demand and the world's biocapacity in each year, and how this ratio has changed over time. Expressed in terms of "number of planets". The biocapacity of the Earth is always 1 (represented by the horizontal blue line).

The overshoot of human footprint over Earth's ecological capacity (EEC) is displayed in Fig. 3. It shows how humanity has moved from using, in net terms, about half the planet's biocapacity in 1961 to over 1.2 times the biocapacity of the Earth in 2002. The important message is that HF did cross over EEC at around 1980, and is in excess now by about 25%. This will lead to deteriorations and eventually to collapses of natural systems.

The beginning climate change that we observe tells us that the overshoot concept is not only a theoretical idea. Climate change is a real process with dangerous implications since it will reduce Earth's biocapacity. Climate is the leading environmental factor coining our natural living conditions. Climate change will change or demolish our "home" on Earth. Rapid climate change may render us "homeless". Potential collapse events are massive melting of polar ice caps and an end of the Gulf Stream circulation into the North Atlantic. For the sake of restoring stability of natural living conditions the overshoot needs to be removed. To this end, the footprint has to be reduced by at least 25%, while human population keeps growing.

Figure 4 shows the various parts of the human footprint in terms of hectares of average bio-productivity each person is demanding. It amounts to 2.2 hectares, with 1.2 hectares for fossil energies out of which 89% are required for CO_2 absorption, 7% for nuclear power, and 4% for wood fuel production.

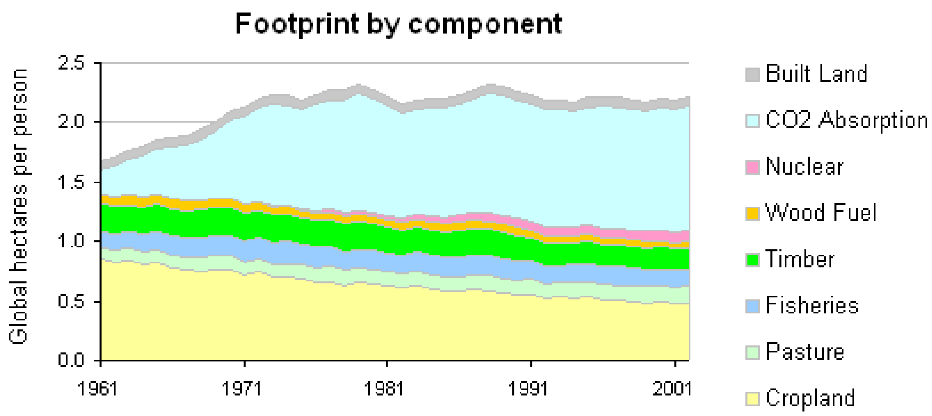


Figure 4: components of the world's average Ecological Footprint per person, in terms of average global hectares.

Table 3: contributions to the human terrestrial capacity demand

	Earth use for	Available for HF reduction	Reason
1	Cropland	NO	Population growth
2	Pasture	NO	Population growth
3	Fisheries	NO	Population growth
4	Timber	NO	Deforestation
5	Wood fuel	?	
6	Nuclear	Yes	Replace by extraterrestrial source: solar energy from deserts
7	CO_2 absorption	YES	Replace by extraterrestrial source: solar energy from deserts
8	Build ups	NO	Population growth

The fossil energies, the combustible and nuclear ones, are responsible for more than 50% of the ecological footprint. Nuclear energy contributes 7% to the energy footprint, but according to Fig.1 only 3.8% to the primary energy. Hence **a replacement of fossil by nuclear energy would not yield a reduction of the ecological footprint**.

The demand for food (items 1-3 in Table 3) and for buildings (items 4,8) cannot be much reduced per person. Wood fuel has too small a share for reducing the footprint, and it is not easy to replace either. By far the largest and the fastest growing contribution to Earth capacity consumption is caused by the fossil energy sector (6,7). The necessary reduction of the full footprint by (at least) 25% could be achieved with a 50% reduction of the energy footprint.

In contrast to fossil fuels, which are taken from Earth by mining and after combustion are dumped into earths biosphere as long-lived pollutants, CO_2 in the atmosphere and radioactive waste in many deposits, solar power does not contribute to the human ecological footprint, since solar radiation, arrives on Earth anyway. Its “left overs” in terms of immaterial heat will be exactly the same as produced by the otherwise “unused” solar energy. This is the key point for ecology: **Using and saving solar energy and solar power have no impact on the Earth’s energy balance.**

With 50% of present fossil fuel consumption as tolerable for the footprint, the data in Fig. 1 imply that the use of fossil fuels should be reduced to an amount of at most 6 gigaton/year hard coal equivalent per year, corresponding to about 12 gigaton CO_2.

The same limit has been inferred from considerations on climate security, i.e. for to limit average global temperature rise to 2° (Kelvin) and to keep CO_2 concentration in the atmosphere to below 450 ppm, emission of CO_2 into the atmosphere must be limited to 13 gigaton/year /WBGU/, corresponding to 6.5 Gtce fossil energy per year. This implies that out of the 55 Gtce total consumption expected for 2100 about 50 Gtce should come from clean renewable sources. This is not a problem in view of the 10.000 Gtce of solar energy radiated onto deserts. The only resource problem could arise from shortage of materials for constructing suitable desert technology.

5. Technology for deserts as sustainable power house

A straight forward way of converting solar energy of deserts into useful energy for the world is by generating electricity which readily can be transmitted by over thousands of kilometres to the regions of big demands. For electricity to meet the actual demands it needs to be supplied in time as demand occurs, if costly efforts for energy storage are to be avoided. Extreme fluctuations in demand may be smoothened by demand side management which can coordinate demand with production to some extent. On the other hand capability for demand-driven production would allow to match production with demand. This capability is best offered by the technology of Solar Thermal Power plants. Here, solar light has to be concentrated to generate heat at sufficiently high temperature (higher than about 300 centigrades) which is then used to raise steam to drive steam turbines. To this end solar collectors need to concentrate the solar radiation by a factor of 40 or more. The concentration can be in 1 dimension (parabolic troughs, Fresnel concentrator) or in 2 dimensions (solar tower, solar dishes).

Figure 5:

Parabolic through concentrating solar collectors, at Kramer Junction, California, USA.

This so called Concentrated Solar Power (CSP) technology requires locations with a large fraction of direct solar radiation, and with free land available for collector arrays. Such site conditions are well fulfilled in deserts. Under the radiation conditions of North Africa and of the Arabic peninsula CSP plants can generate at a site of 1 km² about 0.25 TWh/year. Of course, deployment of collectors is restricted in deserts by sand dunes and also by mountain slopes. Their locations are well known, however.

Energy storage

Energy storage from day to night would make solar power available 24 hours per day. This can be facilitated by thermal heat storage, either in liquid molten salt or in big blocks of concrete. At day time, additional collectors deliver steam to these storage devices and heat them up to 400 – 500 centigrades. At night time steam is raised by the hot storage. This allows also for power production by demand at day time. If there is more solar steam generated than needed the surplus steam is directed into storage, and if there is less, energy from storage is used to generate additional steam.

Hybrid operation

If there is no solar radiation for several days or even weeks, the plant can continue operation by using a fossil fuel burner to raise steam. This way a CSP plant does not require a fossil spare plant as reserve somewhere else. The features of heat storage and hybrid operation make CSP plants to sources for secured capacity.

Seawater desalination in co-generation

There is the very interesting possibility to make use of the "waste" heat from cooling the thermal power plant for desalination. If power plants are located in sufficient vicinity to the seashore, the cooling of the steam turbine can be done by sea water, giving rise to evaporation yielding desalinated vapour. In co-generating multi-effect distillation (MED) plants the waste heat can be employed for desalination with high efficiency. The MED desalination plant replaces the condenser of the power plant. With the waste heat from 1 kWh electric power about 40 litres of fresh water can be produced.

6. Costs of "solar fuel"

The cost of "solar" steam for power plants from parabolic trough collectors is the key figure for competing with fossil fuels. It depends on several factors like capital costs, annual solar radiation yield, and costs of 1 m² of collector. These latter costs will come down in the near future with growing production volumes of such collectors and will reduce solar steam costs. The expected cost reduction is shown in Fig. 6. Already now "solar fuel" cost can compete with oil at 50$/barrel, or any other fossil fuel at 3.2 $c/kWh-thermal.

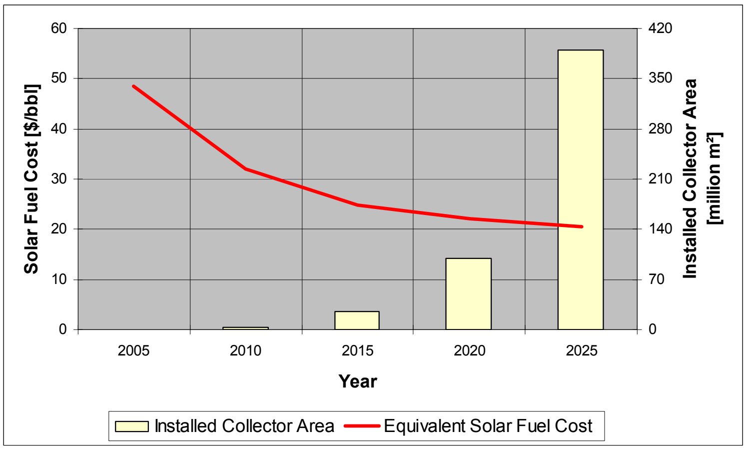


Figure 6: 1 barrel of oil (1580 kWh thermal) equivalent solar energy cost ("solar barrel"), from parabolic trough collector, at a location with 2500 kWh/m²/year direct solar radiation, economic plant life time 20 years, and a discount rate of 5%/year. The curve shows the cost of solar steam expected for the capacity expansion shown by the histogram.

In the year 2025, when about 400 km² may be installed, the solar steam is expected to cost 1.3 $c/kWh-thermal.

Since the physical life time of the collector may be 40 years, after 20 years the solar steam will cost less than 0.5$c/kWh-th. Since none of the materials required for building concentrating collectors, mainly glass and iron, such an expansion of collectors is possible without driving up glass and iron costs, or facing shortages in their supply. For solar power from CSP we can therefore expect continuously sinking costs and unrestricted expansion.

The costs for transmission of power from MENA to Europe are not prohibitive. They are addressed below (Tab. 5 and Fig.12). The increased radiation in North Africa over-compensates transmission costs and losses.

7. Deserts as sustainable powerhouses

The various renewable energies available in countries indicated in Fig. 7 have been assessed as to their economic potential in the studies MED-CSP and TRANS-CSP.

A technical RE potential, which can be tapped with a given technology is classified as economic potential, when the production cost for 1 kWh can reach near 5 cent until 2050 (here we assume that 1 $cent = 1 €cent), and if it fits economically into a supply system.

It turns out that the economical potential for solar power from CSP is typically a factor 1000 larger than any other RE energy economical potential. In Fig. 8 these potentials are compared to the demands for power in Europe and in MENA as in the year 2000 and to the demands as expected for 2050.

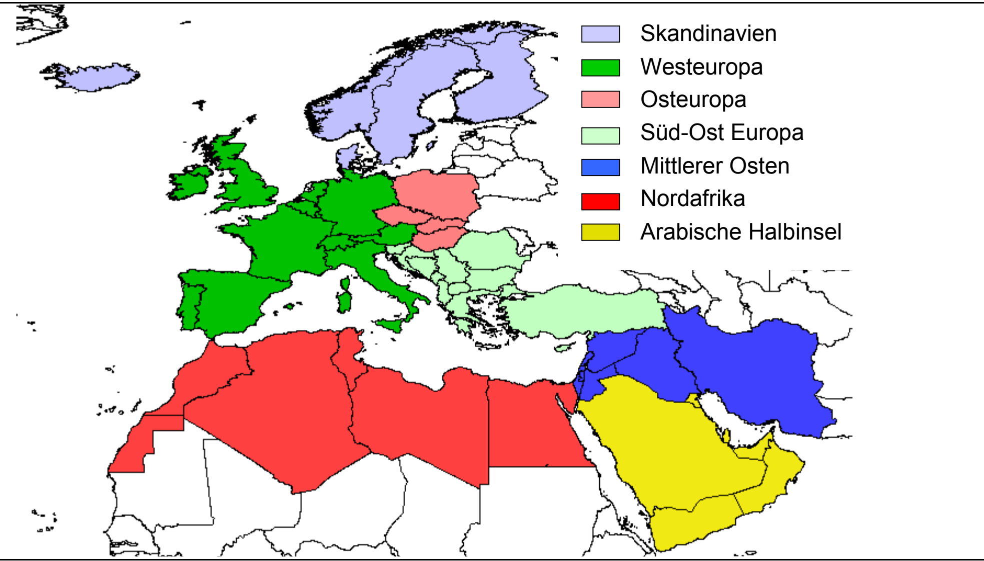


Figure 7: The 50 countries in Europe, the Middle East and North Africa which were analysed in the MED-CSP and TRANS-CSP studies.

Table 4: Economical renewable power resources in Europe and MENA region, in TWh/y.

RE Source		Hydro	Geothermal	Biomass	CSP	Wind	PV	Wave/Tidal
Annual Capacity TWh	MENA	300	380	170	630,500	290	190	0
	Europe	790	370	720	1,450	1,410	140	140
	EUMENA	1090	750	890	632,000	1,700	330	140

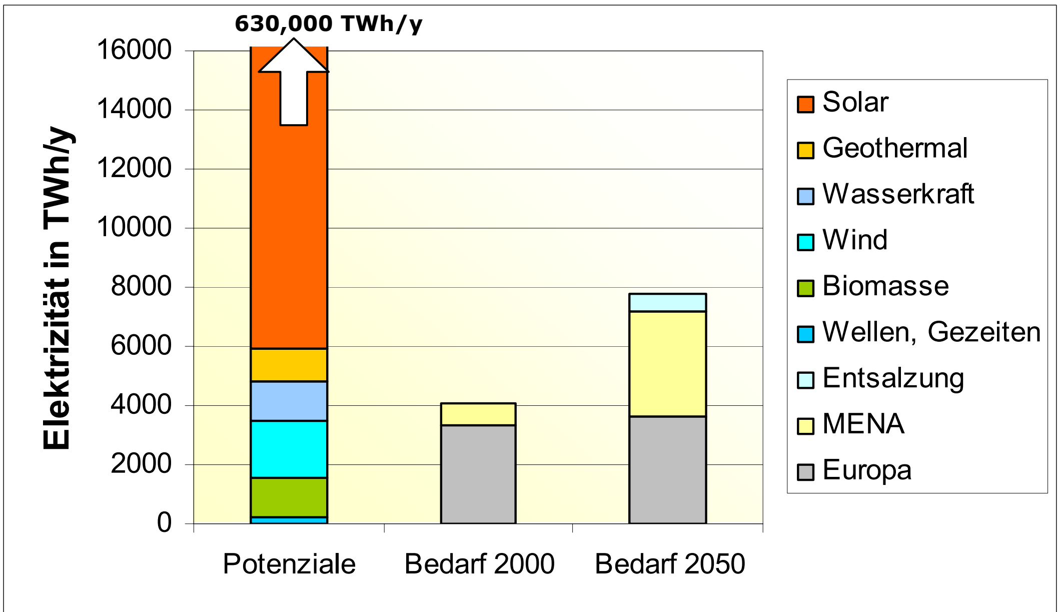


Figure 8: RE economic potentials in EUMENA, as listed in Tab. 4, and demands in Europe and in MENA. The left bar for RE potentials is cut off since it would be 40 times higher than the histogram. For more details see www.dlr.de/tt/med-csp www.dlr.de/tt/trans-csp

The result is that the potentials from wind, biomass, wave/tidal, geothermal and hydro are each smaller than the demands, while the CSP potential is larger by about a factor of 100. Here investment in improvement of CSP technology will pay off most. The global power consumption of about 35,000 TWh/y expected for the year of 2050 is only 6%, and the 8,000 TWh/y expected for EU-MENA only 1.3% of the economical CSP potential in MENA.

These are the features making CSP a most attractive technology:

1. It can provide secured power at low cost and without pollution.
2. It will in practice never hit limits of resources – neither of solar radiation, nor of sites for deployment nor of materials (iron, glass) for constructing collectors. Absorption capacities for waste are not required. Any technological improvement will be beneficial ”for ever”.
3. By means of HVDC transmission sunbelts of northern and southern hemispheres around the globe can serve power to more than 90% of world population.

8. Deserts as inexhaustible waterworks

As pointed out before, generation of power can be combined with desalination of water, in “co-generation” by employing the waste heat as energy for thermal desalination, and by using power for reverse osmosis (RO) desalination.

Heat of about 40 kWh-th., available as waste heat from about 25 kWh electricty production, is sufficient for desalinating 1 m³ of sea water with the Multi Effect Distillation (MED) method. In addition, with electric power of about 4 kWh 1 m³ seawater can be desalinated with the RO method. The RO method is preferable for salt water with low salinity. For enhanced salinity and enhanced temperature water, as in the Persian Gulf and in the Red Sea, the MED method is more suitable. The remaining salinity is below 30 ppm (200 to 500 ppm) for the MED (RO) method. With these two well developed methods desalination can produce fresh water for all salt water conditions, and for all applications from drinking to irrigation with their different requirements as to the remaining salinity. Desalination capacities of Billions of m³/year can be achieved. This allows to produce water for Millions of people, with costs of around 1 $/m³. Desalination plants have to be located in reasonable proximity to the shore line. In case of MED desalination in cogeneration, also the power plant needs to be located there.

Because of the strongly growing population, from 370 Million in 2000 to an expected number of 740 Million in 2050, the demand for water will grow substantially in MENA. Water consumption already now is above the sustainable (rechargeable) level. The non-sustainable supply is provided by pumping from aquifers, ground-water and fossil resources. Pumping in coastal regions bears the danger of lowering the ground water table to below the close by sea level such that salt water begins to intrude and to spoil the groundwater. This is observed in several coastal region of Arab Peninsula, and in particular at the city of Gaza.

The up-coming need for desalination is tremendous in the MENA countries. Fig. 9a shows what is expected until 2050: The excess of demand over the sustainable (rechargeable) supply will grow from about 40 billion m³/y to about 170 billion m³/y. The growth in the sustainable supply until 2050 shown in Fig.9a is caused by improving water use efficiency. Because of reduction of fossil fuel availability for desalination, and because of reduction of present water production from fossil water reserves (like for the Sana’a region), the non-sustainable supply cannot be continued until 2050. This requires that about 170 billion m³/y, i.e. water as carried by 3 Niles, has to be desalinated by using solar or other renewable energies, unless other sustainable sources for water become available, or the use of water for agriculture (see Fig.9b) is reduced significantly. Cutting to 50% the consumption of water for agriculture would free the missing water – but this may not be realistic during a period in which population doubles.

It is no technical or logistic problem, however, to produce water as in 3 Niles by desalination with power and energy from CSP power plants. The costs for desalinated water might drop even below 50$cent/m³.

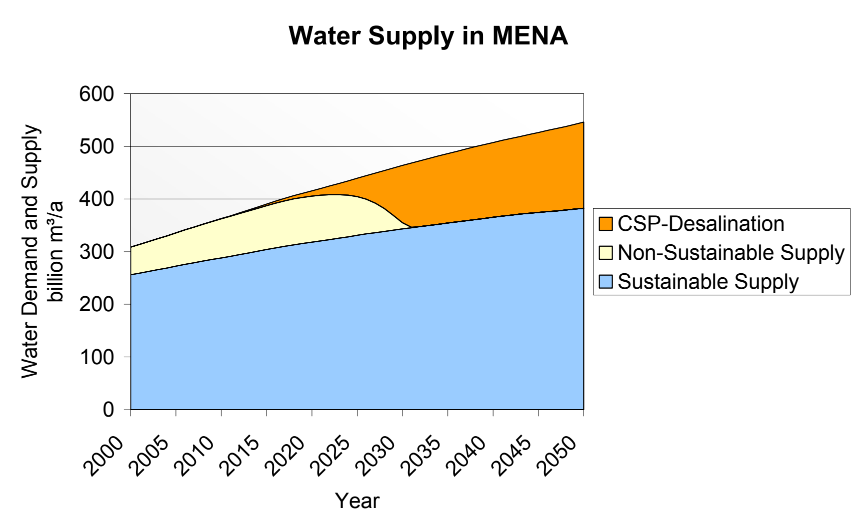


Figure 9a: Water demand expected for MENA countries according to the MED-CSP study. The growth in sustainable supply is due to growing water reuse.

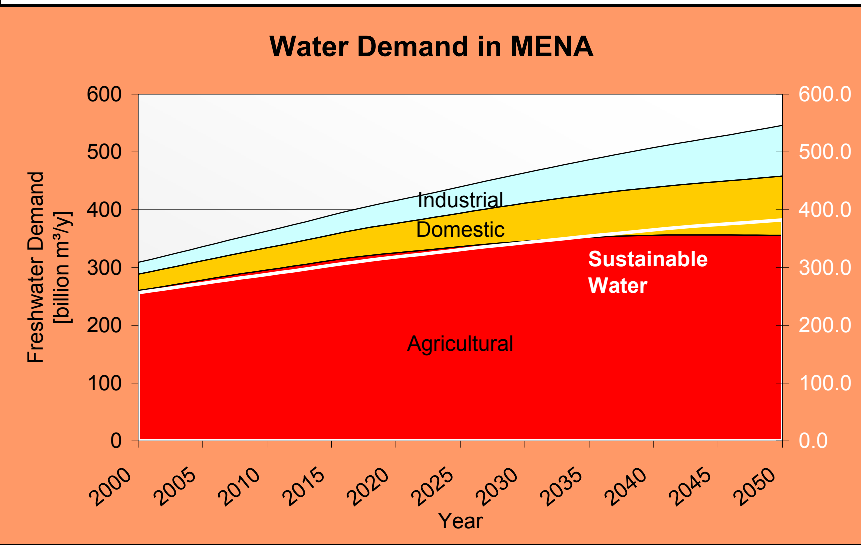


Figure 9b: Break down of water demand into water use sectors, for the development scenario with high technology development, and with improving efficiency in water use and reprocessing.

9. Climate security by clean power from deserts

For an eliminating the polluting fossil fuels the renewable energies need to be combined to a mix that is able to generate the power for the demand as it occurs in time. In the TRANS-CSP study a scenario for building up such a mix has been studied in detail. The resulting power production of such an evolving mix of capacities matching the expected demand in South Europe and MENA is shown in Fig.10a until 2050.

Fig.10b shows the CO2 emissions from this mix. Even though power generation grows from 1300 to 4100 TWh/y, i.e. more than triples, the emissions come down from 750 to 500 Mt CO2/y, i.e. to 2/3. This is a reduction of “specific CO2 emission” by the power sector from 0.58 to 0.12 kg/kWh.

With the specific emission of 0.12 Mt CO2/TWh the expected world-wide 35,000 TWh in 2050 would emit 4.2 Gt CO2. This is to be compared to 12 GT CO2 per year which should be achieved world-wide for a stabilized climate /WBGU2003/. Such a transition brings the goal of climate stabilization already into reach. Further replacement of fossil by solar fuel can and must be achieved after 2050, since more solar energy will be needed to produce fuels for mobility and power for heating and process heat.

In conclusion we can say that with power from the deserts the world energy problems in terms of looming fossil fuel reserve depletion and growing desalination demands, and of already running climate change, can be eliminated provided there is the political will.

The resources and the technologies are at hand. The transition could start immediately. We propose a coordinated EU-MEMA wide effort to this end, with the same determination and ambitious character as the Apollo space program to bring man to the moon.

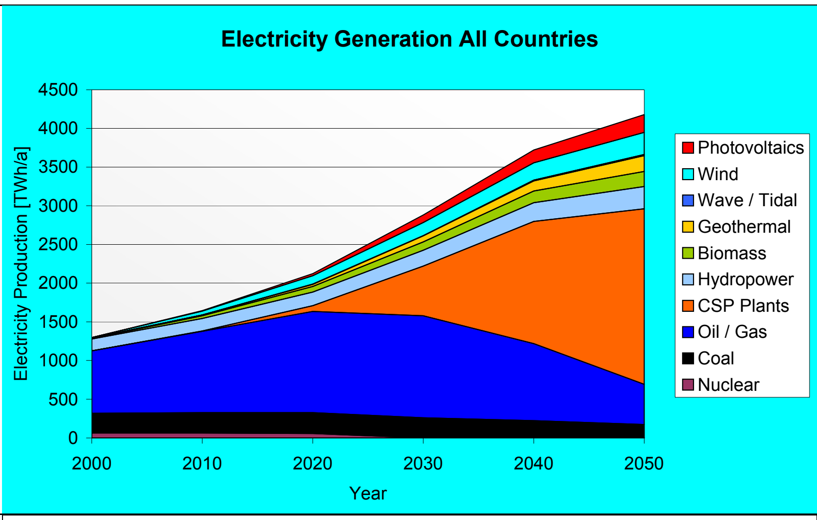


Figure 10a: Power generation MENA and South Europe (Cyprus, Turkey, Greece, Malta, Italy, Spain, Portugal)

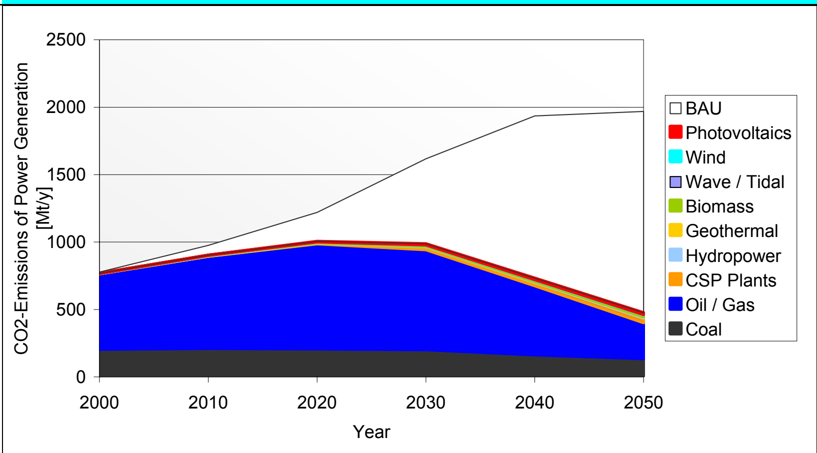


Figure 10b: CO_2 emissions MENA and South Europe. The avoided emissions have been calculated for an electricity mix equivalent to that of the year 2000 ("business as usual").

10. An Apollo Program DESERT for water, energy and climate security

There are a number of threats to global, international, national, economical, ecological, social and individual security. Climate change and break-downs of energy and water supplies will affect almost all sectors of security mentioned above and generate further ones – for instance new de ceases. Without water, energy and climate security none of the 10 Millennium Development Goals can be achieved. Water, energy and climate (WEC) security is at the core of our existence. WEC insecurity cannot be confined or repelled by national boarders.

To re-establish WEC security, and to bring the human footprint back from overshooting the Earth's ecological carrying capacity, should be security goal of highest priority for humankind.

At the World Energy Dialogue at the Hanover Industrial Fair 2006 Prince Hassan bin Talal from Jordan, in his capacity as President of The Club of Rome has made a plea to the countries from technology-belt and from sun-belt for co-operation towards this goal:

"Can the sun-belt in tandem with the technology belt, make solar energy the fuel of our civilization and the basis for a secure, affordable and attainable energy system? …

*More than 40 years ago, President Kennedy launched the **US Apollo Space Program** to fulfil the old dream of taking man into outer space.*

*Today, we have a bigger dream, to **restore the balance between man and his home planet, Earth.***

I invite you all to look at our deserts through new eyes as an overabundant and inexhaustible source of clean energy and fresh water. I challenge you to *put technology (the work of man) and deserts (the work of God), to the service of mankind and nature. Billions of people, animal and plant species would benefit from a stabilised climate. I challenge the European industry to take action and make this vision a reality, as the President of the Club of Rome, I propose that Europe, the Middle East and North Africa launch a* ***EUMENA Apollo Desert Program****, the first steps of which The Club of Rome is willing to assist in organizing."*

Such a program could be started immediately. It consists of technical, financial and political parts.

The technical part

The technical part has been largely studied. All necessary steps are possible if EU and MENA countries co-operate as if there were no boarders. It requires in addition to the technological components mentioned before a Trans-Mediterranean Power transmission Grid (TMPG) as sketched in Figure 11.

This TMPG is the infrastructure for energy security for EUMENA, and for global climate security.

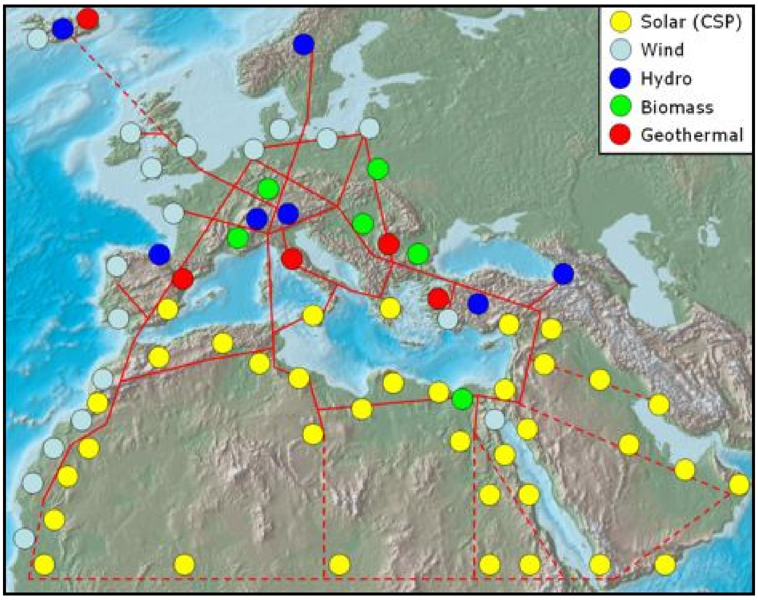


Figure 11: Sketch of a Trans-Mediterranean Power Grid (TMPG) as infrastructure for sustainability and for energy security in EUMENA, using High Voltage Direct Current (HVDC) transmission, with power losses from MENA to EU < 15%

stage 1 (Phase 2 of the proposed Apollo DESERT program, see text),

and future extension,

There will be 3 phases of implementation:

1. Deployment of CSP plants for local power and water supply in MENA countries.
2. Installation of transmission lines as indicated by the full red lines, and of further power plants.
3. Extension of the TMPG to the South.

Phase 1 has effectively been started, but should be boosted to achieve cost reduction as fast as possible. When costs for collectors will be reduced to 2/3, as can be achieved within 5 years (Fig. 6), an avalanche could be set in motion. Solar energy would become cheaper than fossil energy in a growing number of places. Becoming the least cost option conventional market forces would generate a CSP deployment avalanche, since local demand for new capacities is high in MENA countries.

Phase 2 has also been started. There is already a HVDC sea cable bringing power from fossil plants in Spain to Morocco. Deployment of transmission lines from Algeria to Spain has been agreed on. Further North African countries have interests in such connections. A political partnership between EU and MENA countries for WEC security would be of great help for enabling planning and installation of a full fledged TMPG, and for securing the necessary investments.

Phase 1 and 2 are subject of the 2 CSP studies. Phase 3 has not been studied yet.

The financial part

It will be incalculably much cheaper - and invaluably much better - to avoid a water and energy crisis in EUMENA and to stop global climate change, than to let them happen as result of business as usual, or even to conduct wars for expiring energy and water resources. Climate change disasters, military expenses for "securing" access to oil and gas, and expanding nuclear weapon competence as follow-up to nuclear power technology, induce costs in the range of several hundred billion $/year. With 1%of these expenses as seed money the overwhelming "fringe" benefits of the proposed Apollo DESERT program could be made available. For the avalanche to gain momentum it is needed that the main product, solar power for MENA and for transmission to Europe, must be able to compete economically with fossil production locally, and with European power production in European markets.

Costs expected for imported solar power have been calculated in the TRANS-CSP study for an expansion scenario in 7 phases. Table 5 shows the results for the related investments and the average transmission to Europe, and Figure 12 shows over the time how solar power imports in Spain and in Germany compare in costs with power generated by new plants, built according to the present mix (pink line), and according to the present mix but without new nuclear power plants (blue line). The red line shows the costs for a mix in transition to re-newables, as assumed in the TRANS-CSP scenario, and the yellow line shows the cost of imported CSP. The calculations show that solar power from North Africa is clearly cheaper than the Spanish and even the German mix. It can become the least cost option for power at large scale even in Germany and other European countries, and can help to end the growth of power costs in Europe. Solar power from North Africa has a great potential on European power markets. Proper financial support for phase 1 should be made available. The investments into the following phases could be refinanced by solar power sales.

Table 5: Power production and transmission capacities for solar power supply to Europe

Phase	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Year	2020	2025	2030	2035	2040	2045	2050
Capacity, GW	1	10	20	30	40	50	60
Transfer, TWh/y	5	65	130	195	275	370	450
Turn over, G€/a	0.3	4	8	12	17	22	27
Area, kmxkm, coll. *Grid*	5 x 5 *0*	16 x 16 *3120x0.1*	25 x 25 *3110x0.1*	30 x 30 *4480x0.1*	37 x37 *3800x0.2*	41 x 41 *3110x0.2*	46 x 46 *4480x0.2*
Investment, CSP TMPG (G€)	5 *0*	40 *3*	75 *8*	115 *12*	175 *17*	220 *24*	250 *30*
Cost (€/kWh) **power** ***Transmission***	**0.055**	**0.051** ***0.014***	**0.049** ***0.018***	**0.048** ***0.019***	**0.047** ***0.013***	**0.046** ***0.016***	**0.045** ***0.017***

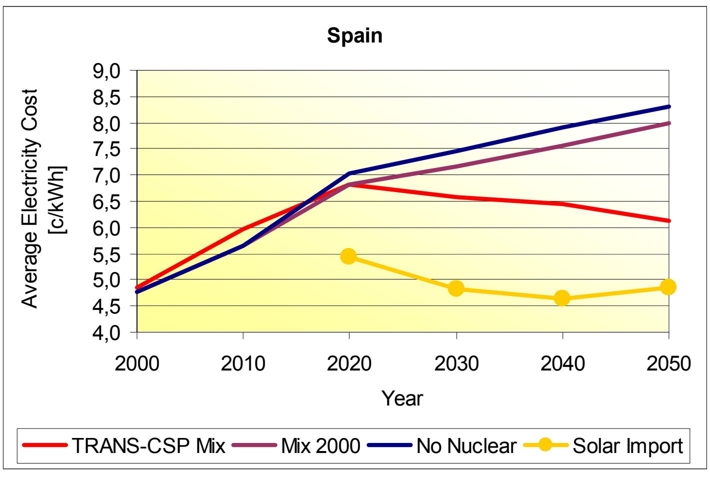


Figure 12a: Average cost of electricity from new plants in the TRANS-CSP scenario and in a conservative scenario based on the electricity mix of the year 2000, in comparison to the cost of electricity imports from MENA for the example of Spain.

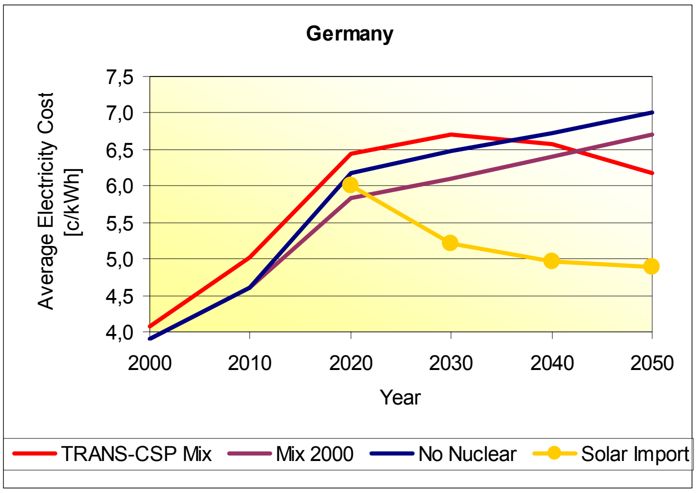


Figure 12 b: Same as a) but for the example of Germany

The political part

Clean power from the deserts is for all countries in EUMENA a win-win option and an opportunity for mutually beneficial co-operation, bilaterally and multilaterally. Technology belt and sun-belt, EU and MENA, are ideal players of a *dream team for sustainability*, and for water, energy and climate security. In addition to WEC security it will create jobs and good neighbourhood between EU and MENA. In particular, such co-operation could bring about a renaissance of science and technology in the Arab world.

Solar power from the deserts is fulfilling the 3 main objectives stated in the GREEN PAPER of a new EU energy strategy:

1. **Sustainability**
2. **Competitiveness**
3. **Security of supply**

Energies from the deserts and synergies of the sun- and the technology belt, will enable for a major step towards return to balance with the ecosystem Earth.

The EU-MENA framework for co-operation, the Barcelona process, should provide a perfect frame work to launch the Apollo DESERT program. The founding statement for the Barcelona process from 1955 emphasises:

"The participants express their conviction that the peace, stability and security of the Mediterranean region are a common asset which they pledge to promote and strengthen by all means at their disposal."

However, in the new *FIVE YEARS WORk PROGRAM* document, issued in December 2005 at the occasion of the 10 year Barcelona anniversary, renewable energies as subject of Mediterranean cooperation are not even mentioned. Here is a major deficit in politics, presumably largely due to a lack of knowledge on the potential of renewable energies, and a major opportunity for the future.

To put renewable energies onto the agenda EU-MENA politics for water, energy and climate security, The Club of Rome has started to prepare a kick-off conference:

DESERTEC, a conference on

Deserts and Technology in service for global water, energy and climate security,

as joint sun-belt and technology-belt effort for solving their and global problems

The DESERTEC will address technical and political issues. It will be organized jointly by The Club of Rome, the Spanish Center for Research on Energy, Environment and Technologies (CIEMAT), and further organizations. Present planning is to hold it in spring 2007. Experts from science, technology, industry, finance and politics will be invited.

Acknowledgement.

The insights, the concepts and results for renewable energies presented in this paper are the work of many people involved in the TREC network. Even though the contributions from some members of TREC are particularly important, it is too arbitrary to mention some names and not almost all. The members of TREC can be found under www.TRECers.net. I am grateful to all of them for their participation and cooperation.

References (t.b.d.)