POTENTIAL OF MOROCCAN RENEWABLE ENERGIES FOR THE DEFENCE AGAINST CLIMATE CHANGE

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Abstract:

Progressing desertification as the main implication of global climate change (GCC) for arid zones will make Morocco to an early victim of GCC. The main contributions to GCC is coming from fossil fuel burning. A proposal for how to replace fossil fuels by clean and inexhaustible energies from wind and from solar radiation at climate scale will be presented. The extremely good wind and solar radiation resources, their supplementary nature to the European ones, and the close neighbourhood to Europe put Morocco into a strong position. Import of technology from and export of electricity to Europe could become a promising strategy to limit the global greenhouse effect and to boost the Moroccan economy. A national emergency plan would be appropriate.

Key words: climate change, desertification, solar energy, wind energy, solar collectors, solar power, solar desalination, solar oasis, North-South synergy, climate protection alliance.

1. Global climate change (GCC) and desertification

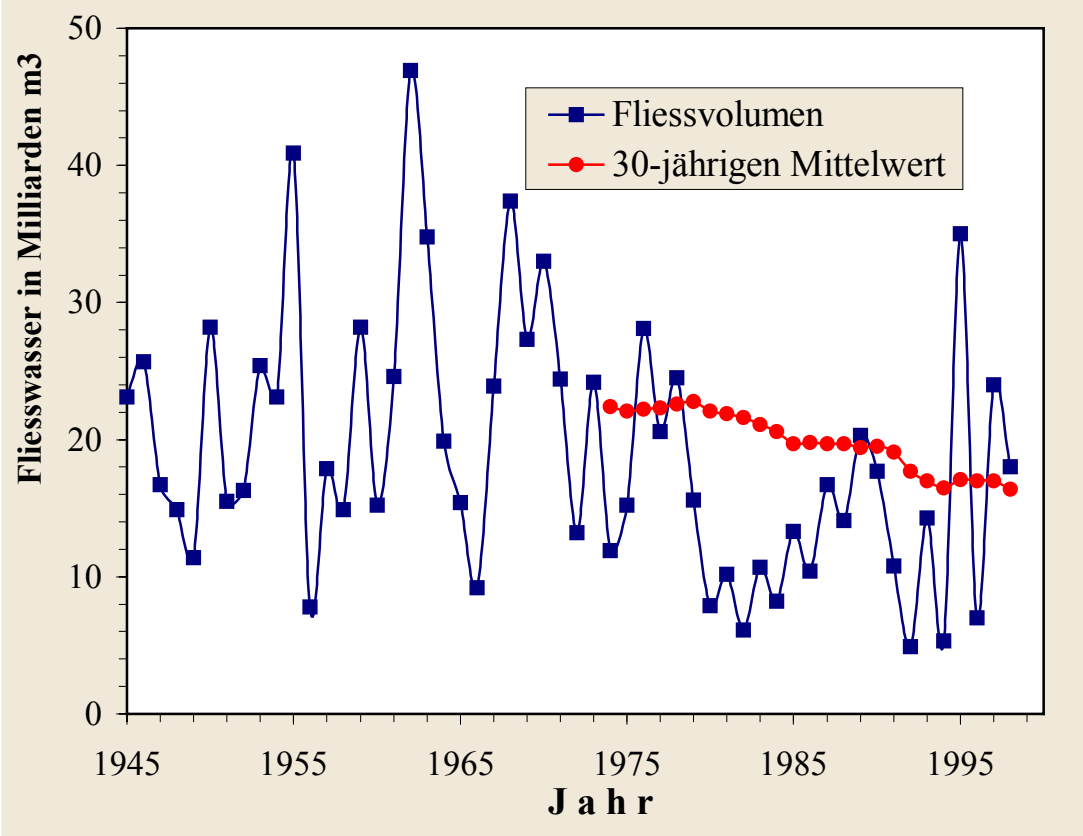

Figure 1: Surface water in Morocco, annual measurements showing the reduction of rainfalls.

It is to be expected that the growing global greenhouse effect, mainly induced by the emission of CO_2 from fossil fuel burning, in this century will lead to a rise of the average temperature

at the surface of the earth between 1.5 to 5.0 degree, and to a rise of the sea water table by some decimetres. There will be also many regional changes of weather, local climate, precipitation, growing conditions for plants and living conditions for animals, coming along with the enhanced greenhouse effect. In the moderate climate zones the weather will become less moderate. The intensity of rainfalls, the levels of floods and the strength of storms will go up. "Century floods, century storms or century draughts" will repeat within decades. Damages to buildings, trees and landscapes will grow. In the sunbelt, the arid zones will expand. This means that the Sahara will intrude into Morocco, Algeria, Southern Spain, and Sicily.

2. Morocco as prominent victim of climate change

In the Maghreb region the most striking effect of climate change will be the reduction of rainfalls, see Figure 1. This is a direct threat to Morocco's life line. When the declining trend continues, Morocco is going to loose it's agriculture. This will constitute tremendous economic, social and cultural damages. The Sahara will move across the Atlas. How fast this process will progress in future does depend on the development of world wide CO_2 emissions, i.e. is subject to human influence. The continued extension of world-wide CO_2 emissions is a direct attack against Morocco as an inhabitable country. Morocco has to take measures – either dealing with the damages or preventing them. We will discuss an option for the latter.

3. The main CO_2 emitters

Climate changes are nothing new in the history of nature. The present climate change, however, is man made. The "Antropogenic Greenhouse Effect" is happening within decades instead of millennia. Who is running this attack against the future of Morocco? It is mainly launched in the Northern hemisphere of the world. The large CO_2 emitters are listed in Table 1. The contribution of Morocco's CO_2 emissions to the global greenhouse effect are marginally small. The big oil producing countries fuel this attack and take profit from it. The numbers in Table 1 suggest 2 important conclusions:

- Morocco (+North Africa) cannot stop climate change by national reduction.
- Morocco (+North Africa) could slow down climate change in an alliance with Europe (+ former SU).

Table 1: Annual CO_2 emissions, 1997 (German Ministry of Economics, Energy Data 2000)

The region	CO_2 emissions per year (Megatons)	Population (Millions)	CO_2 emissions/capita (Tons/person)
World	25,000	6,000	4.2
USA	6,000	280	21.0
Europe (OECD)	3,800	508	7.4
Europe (not OECD) + former SU	3.200	417	7.7
China	3,100	1,250	2.5
South America	910	400	2.3
Africa	900	736	1.2
Morocco	28	28	1.0

4. How much CO_2 is to be mitigated?

Climate experts at the Intergovernmental Panel on Climate Change (IPCC) come to the conclusion that for a slowdown of climate change to a "tolerable" pace, it is required to reduce present world-wide CO_2 emissions by 50%, until the year 2050. This is about 12,000 Megatons (Mt) CO_2 less than now. Out of these, about 5000 Mt CO_2 are to be reduced in Europe and former SU, to bring these regions down to about 20% of their present emissions.

How much energy is this? 5,000 Mt CO_2 correspond to 1,500 Mt oil, (10,000,000,000 barrels), and to 18,000 Tera Watt hours (TWh) thermal energy. At the latitude of Morocco,

energy as in 1.2 Million barrels of oil is radiated by the sun onto an area of 1 km², yearly. The fossil energy to be substituted in the "Northern backyard" of North Africa corresponds to the solar radiation onto 8,300 km² , a square of 90 km side length. If 15% of solar radiation would be converted into usable and transportable energy, like electricity or hydrogen, an area of 55.000 km², or a square of 235 km side length would be sufficient. This is near 0.5% of the area of the Sahara. In the sunbelt areas, there are further suitable desert regions in the Northern and in the Southern hemisphere around the world. In addition there are large areas off-shore in the North Sea and on-shore in the West African trade wind regions with excellent wind. Further, in the moderate climate zones there is a lot of bio-mass available. Space with suitable locations for solar collectors and for wind turbines is not the limitation for a replacement of fossil fuels by solar or wind energy.

Limitations though arise from the fact, that the regions with very good solar and wind conditions are largely low CO_2 emission regions, while the high CO_2 emission regions are rather short of very good solar and wind conditions. But these limitations can be overcome by the technology of High Voltage Direct Current (HVDC) long distance transmission lines, which can transmit electricity from North Africa to middle Europe with losses between 10 and 15% (see Fig. 4b).

5. Potential and technologies for wind and solar radiation

Southern Morocco has large regions with excellent solar and wind conditions.

5.1 The wind potential: In the Southern parts of Morocco, in trade wind regions with a yield between 3000 and over 4000 h/a full load, an electric power of over 1000 TWh/a could be generated. This is 40% of electricity consumption of the EU. The investment cost of wind turbines in the GW class is 0.9+-0.1 €/W for turbine and generator. Here electricity from wind could be generated at costs between 2 - 4 €cent/kWh [1].

5.2 The solar potential: Typical values for the annual solar direct normal irradiation are 2,5 MWh/m² and more or with 2200 and more full load hours per year. Using thermal storage the full load hours for solar power plants can be extended to over 5000 h/a, depending on the collector field size. Three types of concentrating collector have been developed (Fig.2). The new Fresnel collector by Solarmundo NV [2] is the most economic one, with only half the cost of parabolic trough collectors. With the Fresnel collector technology (Fig. 2a), the

Figure 2: Concentrating solar collectors: a) Fresnel type line concentrators of Solarmundo NV, b) parabolic trough concentrators, c) point concentrators with tower for the receiver volume.

collector area for 1TWh$_{el}$/a is 4.0 km² at 2.5 MWh/am². This means that effectively 5 km² are required per TWh/a. Morocco clearly has the space for solar collectors for several 1000 TWh/a .The investment cost for the plant is about (1.1 +/- 0.1) €/Watt, with 40% for the power block and 60% for the collector field, at present.

Table 2: Costs for "1 barrel solar energy" (equivalent to the thermal energy provided by 1 barrel oil)

During amortisation (20 years)	After amortisation
18 +/- 2 €	4.0 +/- 0.5 €

Costs for "1 barrel" solar thermal energy from the Solarmundo collectors at a 2.5 MWh/am² radiation site are below the world market price for oil (22-33€) or similar to natural gas (15-25€), already now. Within 10 to 20 years a further cost reduction for collectors by 50% as result of mass production is to be expected, while fuel prices might go up.

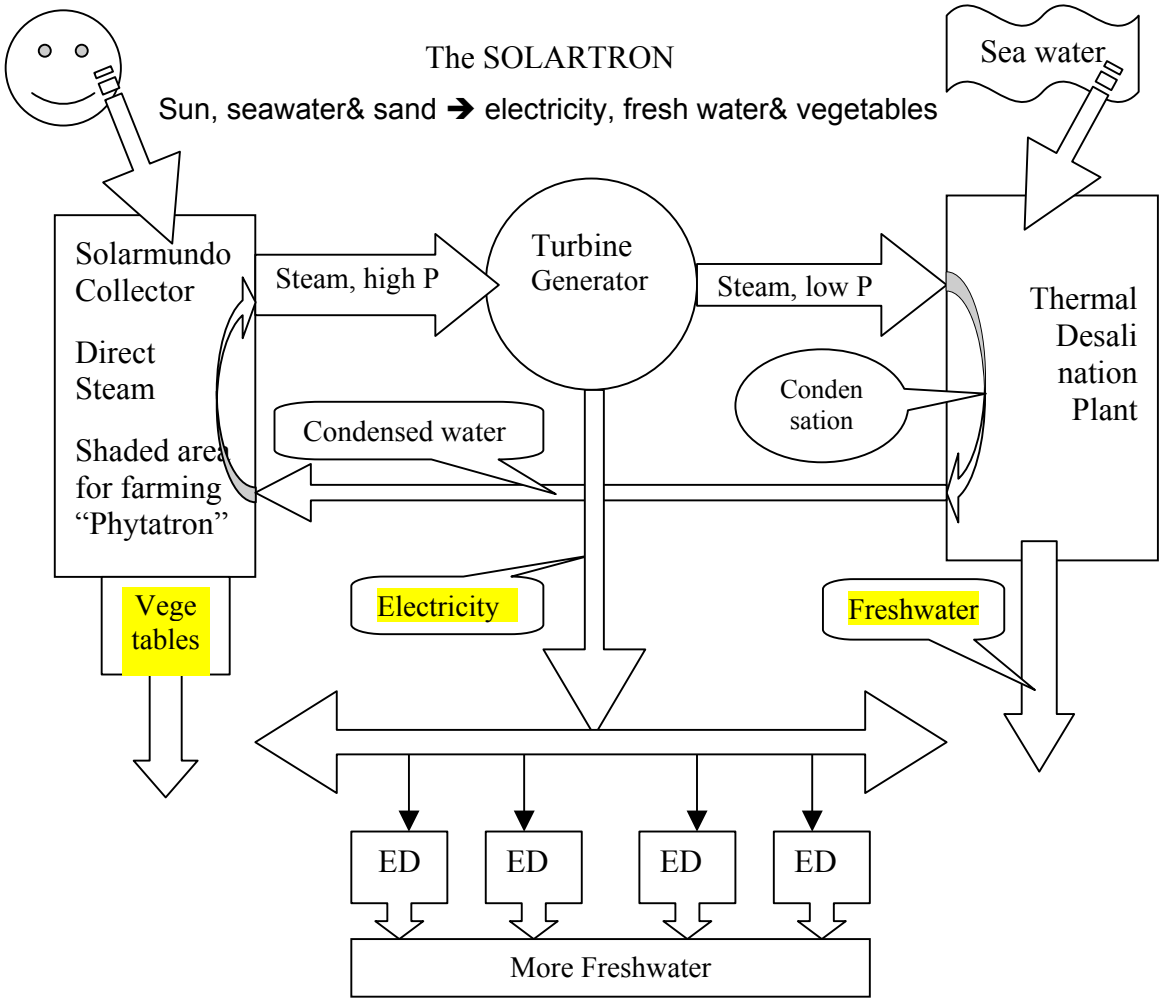

Figure 3: The SOLARTON is a solar power plant with a seawater desalination plant – and optionally chillers - in co-generation, and with agriculture in the shaded land under the collector mirrors. The mirrors are at an elevation of about 4 meters above ground (Fig. 2a). Below them the temperatures are moderate and evaporation of irrigating water is strongly reduced. A 400 MW$_{el}$ electric plant would provide about 3 (8) km² shaded farm land (in brackets: with thermal storage for 24h/d operation), and 130 (380).000 m³ water per day for civil consumption and irrigation. The electricity could power further electrical desalination plants.

A SOLARTRON with 400 MW electric power would provide for 100,000 people 4 kW electricity, and 1.3 (3.8) m³ water per day and person. The SOLARTRON could form the core of a **solar oasis settlement with water, power, chilling and agriculture**. A green belt along the

long coast line of Morocco, where sun and seawater water are available, could be created.

6. Water for Morocco, electricity for Europe, climate stabilisation for both.

Morocco needs water and Europe clean energy. The configuration of the SOLARTRON can generate together with 1 TWh electricity 40 Mio. m³ of water [3]. Electricity can be transmitted to middle Europe with losses around 10 %. Morocco could easily export electricity from wind and solar power at any level of demand and for an attractive price to Europe. In turn, Europe could engage it's tremendous technical and financial resources. The potentials and the needs of both sides can be optimally combined, as shown in Figure 4, [4].

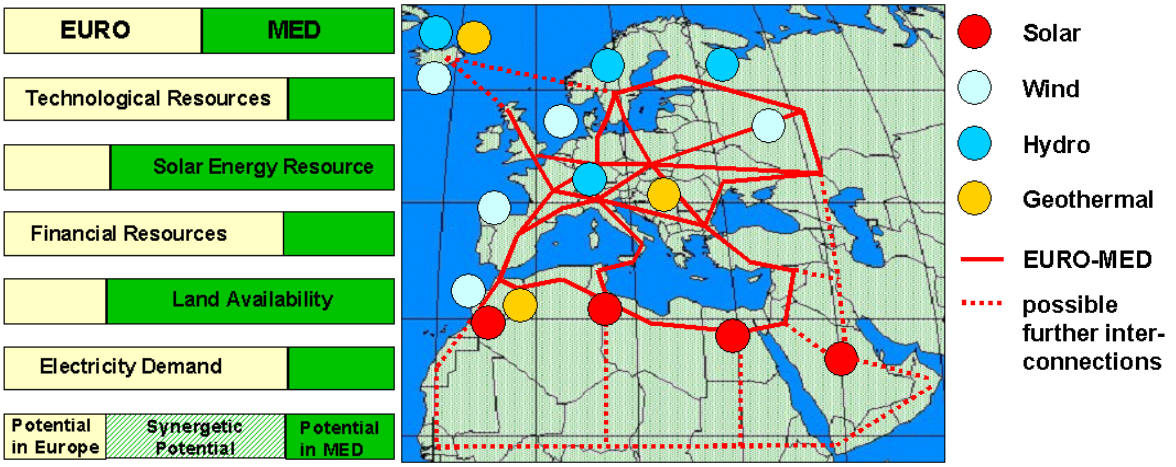

Figure 4: Vision of a large high voltage direct current (HVDC) grid interconnecting the most productive sites for renewable electricity generation in Europe and North Africa. Such a Climate Protection Alliance will activate the large synergetic renewable energy potential of both regions, which otherwise could not be exploited because of national limitations in resources and demands.

In a **Climate Protection Alliance between North Africa and Europe** the climate stabilisation goals can be achieved faster and more economically than by each region separately. Figure 5 [4] shows a scenario for 80% clean electricity in 2050. Here the imported power from North Africa makes up for about 8 GW. This could amount to 40 TWh/a, or 10% of German electric power. The EU could absorb about 5 times as much, i.e. 200 TWh/a from Morocco. This implies a capacity of around 50 - 100 GW.

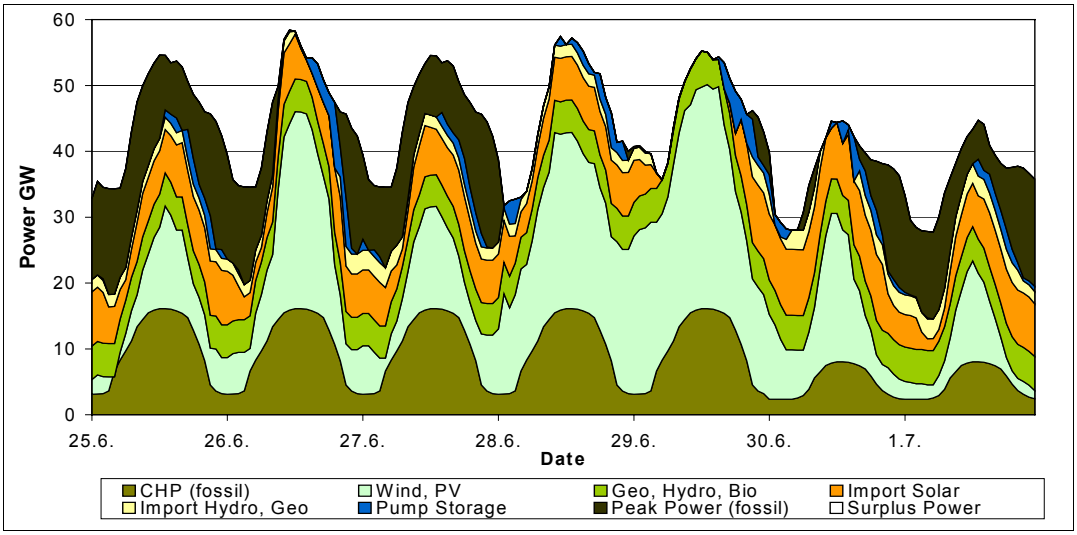

Figure 5: Hourly simulation of the electricity load and generation in Germany in the year 2050 in a scenario assuming a steady expansion of renewables in the power sector.

7. Clean electricity for Europe - big business for Morocco?

Both sides of the Mediterranean have a vital interest in a fast transition to renewable energies. Europe, however, has also renewable resources of it's own. Domestic resources induce local employment. That's why the interest to import clean energy is limited. To get into the market for clean energies in Europe, Morocco has to offer economical advantages. A common clean electricity market with substantial Moroccan shares is much more important for Morocco than for the EU. An export of 200 TWh/a with 4€c/kWh corresponds to a financial volume of 8 Mrd. €, which is 20% of the Moroccan but less than 0.1% of the European GNP.

Clean electricity for Europe could become the most important export product of Morocco, while for the economy of the EU it is a negligible quantity. Hence, **Morocco should take the initiative to come into business.**

8. A strategy for Morocco:

Domestic clean development and climate protection alliance with Europe

The extent to which electricity from North Africa will be included into an European mix will depend on the confidence between the two sides, and on it's market competitiveness. Large investments are involved and an intense dependence of Europe on electricity from Morocco will emerge. I will not enter here the crucial issue of political confidence building between Morocco and EU, but rather point out some practical steps how Morocco can improve the economical card.

To make the Moroccan clean electricity attractive for the European market, four things are important:

1. Technical and political reliability as in EU
2. Availability by demand
3. Supplementary to EU resources
4. Lower costs than EU alternatives

For wind energy all but item 2 are well fulfilled. This is because wind turbines are matured by their large scale application inside the EU, in the last 20 years. In particular, the specific costs for wind turbines went down by a factor 4 in those last 20 years.

A similar process has not yet happened with solar collectors. They could fulfil also item 2 since solar heat can be stored for several hours. However, the solar power plants cannot be deployed at large scale in Europe. Here Morocco is destined to take the lead since it will have the largest advantage and does have excellent climatic conditions for their domestic application. The uncovered costs for a start-up program, i.e. the installation of 1 to 2 GW, will be below 100 Mio. €, i.e. below 0,2% of the GNP of Morocco. They will be returned by it's achievements within a few years. The strategic importance of a start-up program lies in the fact, that then

- collector technology will mature
- solar energy costs will become competitive with oil and gas in other sunbelt countries
- Morocco may begin to export technology and electricity
- by the expected dissemination many countries in the world will join CO_2 emissions reduction on climate scale and thus support Morocco's defence against desertification.

9. Summary:

Morocco has got the keys for an effective anti-desertification program in it's hands. It is waiting for it's own initiative.

[1] G. Czisch, S. Kronshage, F. Trieb: http://www.iset.uni-kassel.de/abt/w3w/projekte/fvs_2001_potsdam.pdf
[2] Solarmundo N.V., Antwerp, Belgium, www.solarmundo-power.com
[3] F. Trieb, J. Nitsch, G. Knies, Strom und Trinkwasser aus solaren Dampfkraftwerken, Energiewirtschaftliche Tagesfragen, 51. Jg., (2001), No.6; and http://www.klimaschutz.com/allianz/solarkwk1.htm
[4] F. Trieb et al., Solar Power and Desalination for the Mediterranean Region, EUROMED 2002, Sinai, Egypt, May 4-7, 2002.