THE SAHARA WIND PROJECT

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Khalid Benhamou (Born in Brussels, Belgium 1967) graduated in the US as an Engineer in 1991 from the California Polytechnic State University. Occupied various technical management positions within the 'Groupe des Domaines Agricoles' that runs H.M. the King of Morocco's private agricultural assets. Started to promote the use of Wind Energy in 1993 as a way to optimize Morocco's vast Wind potential and reduce its dependency on fossil fuel imports. Erected in 1995 Morocco's first wind turbine on the Saharan desert coastline as a demonstration project to show what this potential energy source could bring in terms of capacity building, energy security and sustainable development for the region. Has thereafter been actively involved in promoting this resource as a sustainable energy supply source and alternative for both European and African continents. With the subsequent wind power developments that occurred later on in Europe (mainly through the German Market), the financial, technical & legal framework of large scale exports of wind generated electricity production from the Sahara to Europe were discussed within the EU commission in Brussels in 1998 mainly through the optimization of existing integrated electric grid infrastructures already in place, linking the European continent with the African continent. Founded subsequently Sahara Wind Inc. a private project development company whose mandate is essentially to establish the adequate framework (enabling the creation of a consortium of local and International Firms venturing their own private capital in the initial equity requirement of the project) and to close up all financial needs for the project to materialize.

Abstract: Although the vast majority of the world's wind energy capacity is currently installed in Europe, the wind resource of this continent is rather limited. Indeed, very few countries in continental Europe are exposed to windy climatic conditions, whereas a very high population density limits the available use of land. Instead of expanding into new markets in order to take advantage of better conditions and possible synergies that may be developed on a regional basis, the European wind power industry is currently focusing its efforts on the development of its off-shore wind potential. This solution, even if it cannot be applied to every EU country, has the advantage to overcome most of the natural limitations that hamper the development of wind power in Europe. Since this industry has thrived on subsidized premium prices paid for wind generated electricity available almost exclusively in Europe, the development of the costly off-shore wind power option reinforces further the justifications for sustaining the prices. As a result, the EU market represented 88% of world's wind market in 2002, whereas the largest share of the world's wind energy potential lies in developing countries that have much better possibilities. Some preliminary estimates based on almost a decade of on-site wind measurements, have proven that North Africa, particularly the Trade Wind blown Atlantic coastline of Morocco and Mauritania, has one of the world's largest wind energy potential. Because of its relative geographical proximity with Europe a large scale wind energy project involving energy exports through a 1200 km High Voltage Direct Current (HVDC) line linking the Saharan coastal areas to the other side of the 14 km wide Straight of Gibraltar (Iberian peninsula) on Africa's Northern tip, can be commercially viable and self-sustaining in the context of the European "clean" energy supply and possibly beyond. The Sahara Wind project serves as a market based renewable energy option that addresses global climate change issues, while creating large business and investment opportunities in the region through a win-win setting. Such a large scale project would provide a tremendous boost to the Wind power industry clearing its path to a bright sustainable future into the developing world.

Background: With over 580 GW of generating capacity serving close to 400 Million inhabitants, the EU is one of the world's largest Electricity market. The European Union is also the world's largest energy importer, which makes it most vulnerable to supply disruptions, fossil fuel price volatility and middle-East turmoil. Additionally, it is expected that the EU's foreign energy dependency, that currently represents 50% of gross EU energy production, is expected to rise up to 70% within two decades. By that time, over 90% of EU's oil and gas could come from external sources.

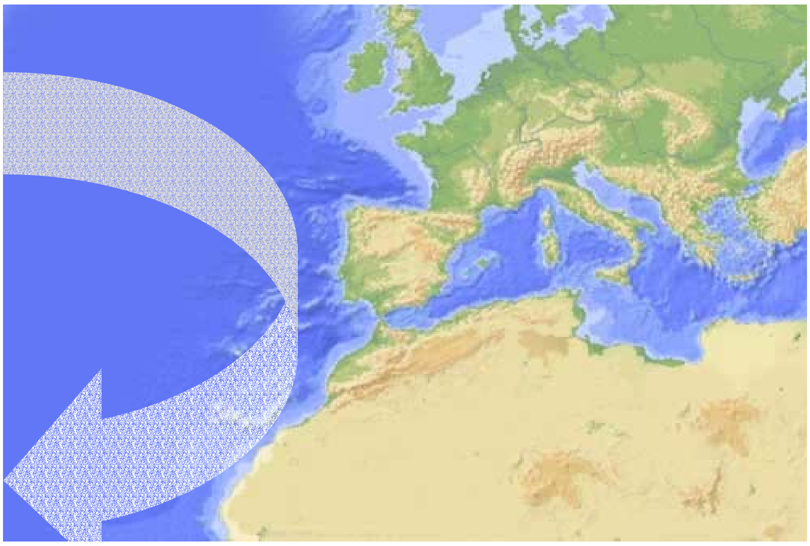
In order to address the EU's energy security problems in a timely fashion, EU legislators are making several efforts to transform the domestic European energy market into a single largest and most integrated energy market with a conducive regulatory and legislative framework appealing to credible private investors to support energy network infrastructures. The trans-european Energy Networks are aimed at reinforcing Europe's energy security while helping to cross-fertilize the various experiences collected to date within the EU. The emergence of a single European energy market also underlines the need for greater co-ordination in energy policies to stage the implementation of concrete measures and consensual policies to fulfill the Europe's current ambitious renewable electricity generation program that is expected to increase the share of renewable energy within the EU's power supply from 15% to 22% in 2010.

At the heart of the above concern is the important issue of global climate change mitigation and the continued search for ways in which market-based incentives will elicit national and regional cooperation as a complement to command and control schemes where appropriate. Within this context, some EU member States are gradually phasing-out their nuclear power plants as they endeavor to increase their renewable energy capacities. The fact that Germany's wind energy sector has created over 130,000 new jobs in recent years underscores the social impact that renewables can have in addressing the employment challenges faced by the entire Mediterranean basin. Hence, for the EU the development of renewable electricity generation serves several purposes including the diversification of energy supply, the creation of jobs and greenhouse gas reductions.

Although not without merit, recent EU efforts will need to be further consolidated as the carbon density reduction objectives of the Kyoto protocol are in stark contrast with the increased emissions trends that have been recorded in some EU countries. Due to its rapid economic development, the Iberian Peninsula has for instance, increased its greenhouse gases emission by over 30% since 1990. This clearly indicates that some member states such as Spain and Portugal (that are among the furthest away within the EU from their target share) will not be able to meet their emissions targets. As a result and despite the EU's burden sharing agreements and 'over-cutting' measures by other member countries, the EU may not be in a position to meet its Kyoto target requirements by 2010 unless alternative clean options are pursued aggressively. It is estimated for that matter, that with existing policies and measures, the Gap between the Kyoto target and the EU projected emissions in 2010 will be +7.4% (in % 1990 emissions) and +3.3% with 'over-cutting' measures by countries.

In contrast with the European situation which is characterized by low wind resource availability, high population density and limited geographical space, the Saharan coastline is richly endowed in renewable energy/wind-system owing to: (i) the strong Trade Winds that are superimposed to local wind systems; and, (ii) the large available open areas (2000 kms/1,300 miles coastal length), typically flat eroded plateaus, with no rainfall, no or little vegetation, hardly any life or sustainable economic activity, but high steady winds. The Saharan coast stretching from Morocco through Mauritania has a wind energy potential estimated at over 1,000 TWh/year (EU's current total electricity production is in the tune of 2,400 TWh/year). This represents several dozen times the North African Electricity production requirements. Figure 1 provides a geographical description of the Trade wind resource system.

Figure 1: Trade Wind Resource



The Trade winds are global winds driven by “Global” temperature differences resulting from the “coriolis” effect or rotation of the earth and direct sunlight over the equator versus sensibly none in the poles. The wind rises from the equator in the higher layers of the atmosphere and moves north towards the earth’s colder temperatures. Because of the rotation of the earth, at around 30° latitude the air masses are deviated clockwise. The air begins sinking down over the North Atlantic Ocean creating a high pressure area (called Anticyclone). The junction of the Sahara desert with the Atlantic Ocean creates a zone of global energy exchange were the climate is dominated by Global Winds that are high and steady. The Trade winds, that are actually the main factor responsible for the Sahara’s extreme dryness by moving away the clouds have shaped the vast majority of this inert area into rocky plateaus, called “Hammadas”. These flat wind worn and stony surfaces relatively close to the European continent spread on the Atlantic coastline from Morocco to Mauritania on over 2000 km. They represent one of the largest, windiest and least inhabited areas on earth. The measured wind speeds that have been accurately monitored on site for the last eight years, could supply Europe with plenty amounts of renewable wind generated electricity produced at very low costs. It is actually estimated that the energy potential of this region, because of the availability of the winds, could supply over one half of Europe’s entire electricity needs, and represents probably one of the world's largest untapped source of wind generated electricity. Below, Figure 2 compares the Gross Electricity consumption of Morocco, Spain and the UE, whereas Figure 3 compares their growth over the same period.

Figure 2: Gross Electricity consumption in Morocco, Spain and the UE

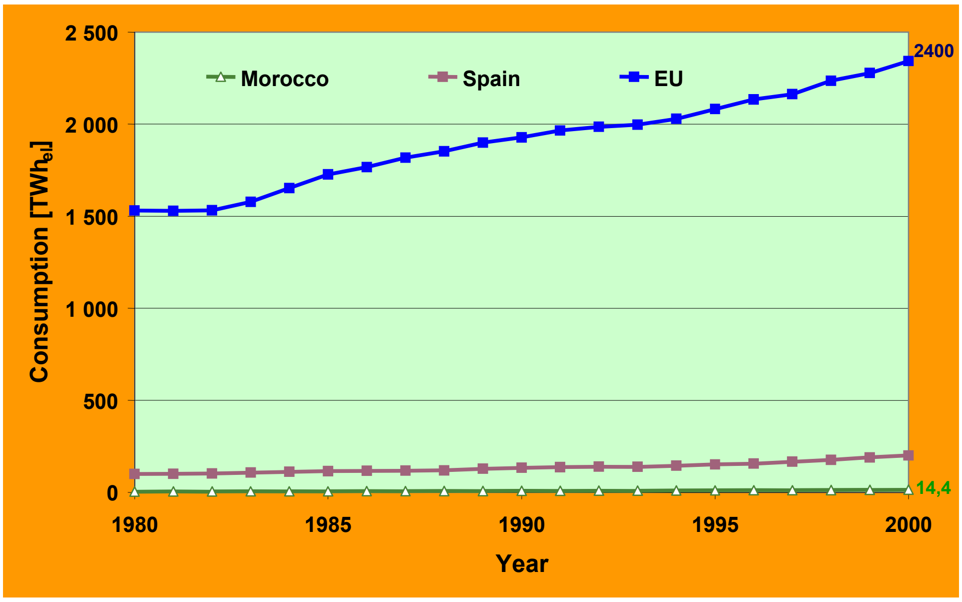
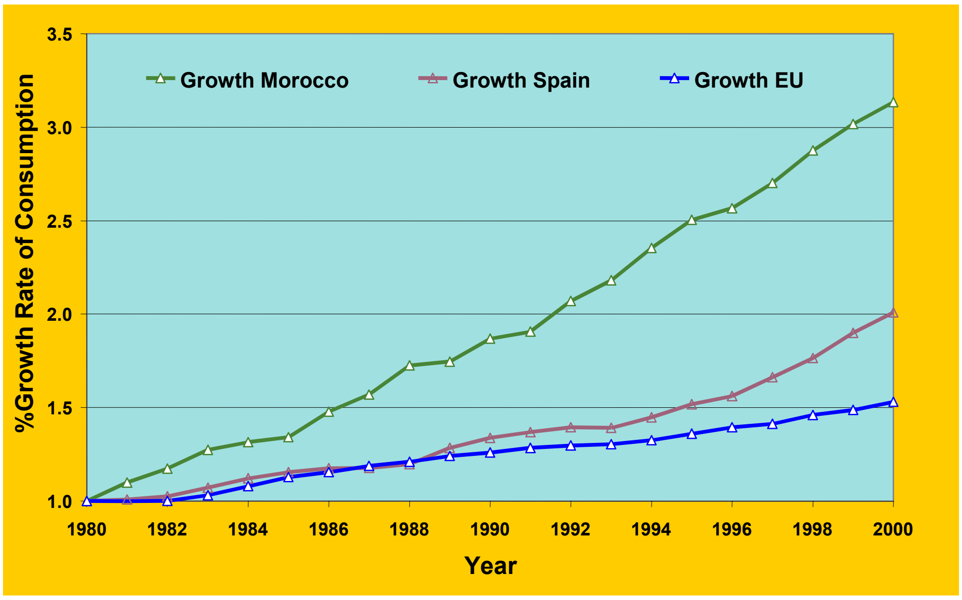


Figure 3: Electricity consumption growth trends in Morocco, Spain and the EU



Project objective: The overall goal of the project is to significantly increase the share of renewable energy use in the aggregate power production of the region and reduce the emission of greenhouse gases in Morocco, the Iberian Peninsula and possibly beyond in a complementary way. By enabling the extensive desert wind energy potential located in the Tarfaya region to supply the Iberian Peninsula with large quantities of renewable energy, while covering much of the Maghreb region's needs with optimal quantities of renewable energies, a sizeable share of Morocco's electricity needs will be met and fossil fuel consumption will be displaced. In the context of a widened liberalized energy market currently being prepared on both sides of the Mediterranean, the proposed initiative will allow some EU countries to tap the additional source of renewable energy available within their grid's reach, to meet stated environmental objectives at competitive costs.

Therefore, the intended Sahara Wind Energy Program is principally aimed at: **(i)** enhancing Europe's energy security by adding new "clean" capacity to its grid; **(ii)** addressing global climate change issues; **(iii)** shaping the wind-energy industry in ways that create jobs to match the Mediterranean basin's economic challenges, **(iv)** demonstrate how this project contributes to help the region meet its growing electricity needs while reducing a costly reliance (i.e. balance of payments) on fossil fuel imports.

(i) to ***show-case how the removal of significant regulatory, market, legal/legislative and institutional barriers that are underway will enable a private-sector led large-scale adoption of wind-energy technology*** in a middle income economic environment such as Morocco;

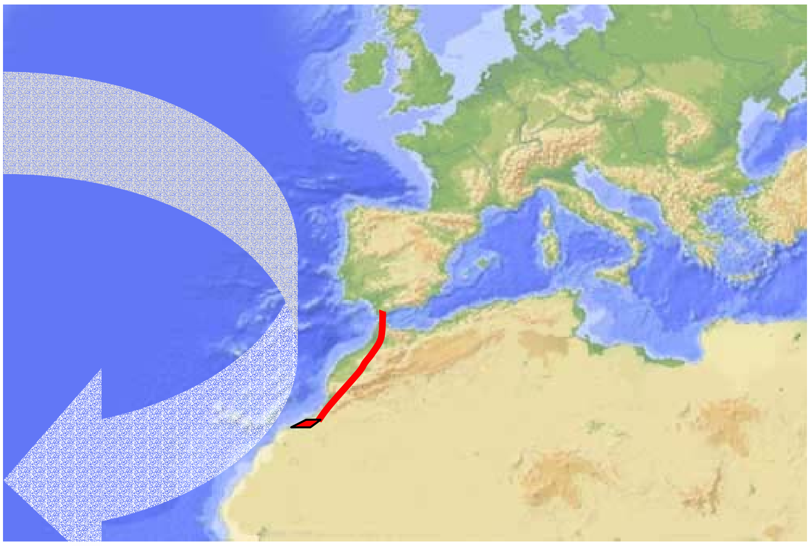
(ii) to ***displace sizable fossil fuel consumption in Europe*** by helping to break the grip of the dependence of some EU countries on middle-East and North African oil imports through the supply of the Iberian electricity market with renewable electricity at competitive costs;

(iii) to ***leverage private sector financial, technological and human resources*** by engaging both the local and international private sector actors within the established conducive renewable energy sector policy and business environment. In setting out to build a multi-phase/multi-year 5 GW on-grid wind energy plant in the Tarfaya area, the project will attract significant economies of scale to impact the global wind energy market structure (i.e. corporate or private wind industry associations, financial service providers) in ways that demonstrate the commercial viability and local socio-economic advantages of wind energy technology transfer in addition to the associated environmental pay-offs;

(iv) to evaluate the impact of the project on Morocco's electricity grid and its long term energy supply in order to ***demonstrate the advantages, that a regional integrated approach in a liberalized market framework can provide***, compared to what can be achieved on a domestic basis for developing renewable energies. The rationale behind the development of renewable energies on a regional basis may actually be key to break the current costs issue linked to physical resource limitations found in most developed countries capable of sustaining proactive policies towards the development of renewables.

It is expected that Morocco's existing power grid infrastructure that extends all the way to the proposed wind-farm areas will be utilized in a way that would benefit and strengthen the liberalized electricity market that is currently being prepared by the government of Morocco. In addition to the expected relief on the balance of payments of Morocco the scope of the project and proper sequencing of construction phases will make it possible to adequately service liberalized regional electricity market segments overtime within Morocco and beyond before the entire interconnection facility of the project with Spain is fully operational.

Figure 4: Sahara Wind Project



Through HVDC (High Voltage Direct Current) technology, an important technological progress with demonstrated maturity it can make it possible to bridge the "clean energy" resource gap between EU/Spain and Morocco/Africa, by feeding the output of a large scale Wind Power Project located in the Sahara Coastal region into the European market. Over 60 GW in 80 projects worldwide utilize HVDC technology to date. It has a remarkably low kWh transportation cost for large capacities with minimal losses over long distances. Average power losses are estimated at less than 10% over 4,500 km for a single 5 GW aerial line. The Itaipu HVDC 6.3 GW Transmission project in operation since 1987 with +/- 600 kV is a good illustration of HVDC technology in application. This project that currently supplies up to $1/3^{rd}$ of Brazil's aggregate power consumption has demonstrated that HVDC technology is perfectly suited to transfer 6.3 GW of electric capacity well over a distance of 800 kilometers. The 1200 kilometer High Voltage Direct Current line connecting an installed wind power capacity of 5 GW in the Tarfaya region (in Morocco) to the Spanish mainland grid should make use of the latest developments in HVDC technology.

Table 1: Project description & estimated economics: Investments & Costs of 5 GW Sahara Wind Project with HVDC line from the Tarfaya area to Europe (Spain).

Features	base informations	Investment Costs
Wind Turbines	5 GW	1000 €/kWel.ratedpower
Rated voltage	+-600 kV	
Type	Double bipol	
Converting station	2 * 60 €/kW	120 €/kWel. ratedpower
Line Distance	1300 km	
Aerial line (1300 km)	70 €/(kW * 1000 km)	91 €/kWel. ratedcapacity
Sea cable (40 km)	700 €/(kW * 1000 km)	28 €/kWel. ratedpower
Total Investment cost		**1239 €/kWel. ratedpower**
Life time	20 (25) years Wind (HVDC)	
O & M Costs	2% of investment costs / year	
Real Interest rate	5.0%	
Transmission losses	4,5%	
Operating time	3400 FLh	
Cost of electricicty		**~ 3,5 €cent/ kWh**

The aforementioned estimates are based on a number of key assumptions; namely: a yearly average production of 3400 Full Load Hours, with a price of 1000 €/kW rated capacity of Wind Turbines, 5 % real interest rate, 20 years lifetime, 2% of total investment as annual Operation & Maintenance costs. This yields Euro € 0.035 /kWh (3.5 € cents/kWh). This price takes into account all infrastructure costs, HVDC aerial lines with 40 km of sea cables, converting stations, and transmission losses. Since the specific costs of wind energy have dropped significantly in the last 20 years, the price of the installed capacity will be probably lower than the 1000 €/kW that have been assumed for the project. In Spain, the average costs of installed wind power were down already to 850 €/kW in the year 2000. If we consider the fact that wind turbines used in the Sahara desert won't require any of the costly design features required in Europe, the price of wind turbines are expected to drop even further. Besides, on such large integrated power project, roughly equivalent to Spain's entire wind power capacity installed to date, all cost inherently linked to the wind power industry such as manufacturing, transport, and erection costs will improve significantly. Local manufacturing will enable tremendous cost reductions to be made, owing to the project's size and lower labor costs.

With such an extensive project, large economies of scale through industrial integration of various components can be achieved and the local manufacturing of wind turbines and other related components that are easily transferable for much smaller capacities, would reinforce Morocco's industrial sector, providing skilled jobs and contributing significantly to the country's current diversification efforts from volatile sectors, such as agriculture that is affected by recurring droughts.

The Sahara Wind project would provide, as a wind-energy industry catalyst, an ideal development setting at a critical time for the wind power industry that is currently faced with a relatively high level of uncertainty about its future in the years to come. The deprecations of listed wind power companies values in the stock markets and a recent drop in new wind turbines orders coming from the German market underscores the seriousness of the problem. While the recent efforts to develop the offshore wind resource around Europe remains a costly alternative, the tremendous wind power markets growths that have taken place initially in Germany and Spain seem to confirm, as they get ever closer to the Sahara desert, the importance of the development potential that the Sahara desert wind resource can have on the region. The potential utilization of the Saharan desert coastline for large-scale wind power production could also provide ample grounds for the mostly European wind power industry to be further developed in an integrated energy supply approach.

An important aspect of the proposed initiative will be focused on industrial capacity building and the creation of new jobs for the region's economies. Hence, a thorough and comprehensive analysis of the local/national industries in terms of supply/manufacturing capabilities of wind turbines and associated parts, together with the local maintenance and operation of the proposed wind-energy system will be conducted. Essential project preparation activities will include an investigation of the incidence of a renewable project the size and scope of Sahara Wind on the long-term development of the Wind-energy sector in Morocco, and beyond.

In terms of environmental benefits, a preliminary assessment of this project would enable 20 Million Ton CO_2/Year from being released in the atmosphere. Over the lifetime of the project (a period of 25 years by conservative estimates) this represents up to one half Billion tons of carbon dioxide (CO_2) from being released in the atmosphere. These numbers are based on the production of 5000 MW of wind turbines, assuming that the wind energy production units would replace the current production profile of Morocco's conventional electricity. It may be significant to note that this represents an unmatched carbon sequestration possibility (emissions avoidance), as these carbon reduction figures are obtained out of desert areas, where not a single tree can be planted. The overall potential of wind energy would even then, be far from being fully exploited as the project can be replicated further South where huge areas remain unexplored and where the wind resource is even more promising.

Figure 3b: Satellite image taken on Wednesday, March 12, 2003 of a dust storm over Tarfaya, Morocco, with strong winds sweeping thick Saharan Desert dust over to the Canary Islands in the Atlantic Ocean.
(AP Photo/MODIS Rapid Response Team at NASA GSFC)