Integrating North Africa's Trade Wind Resources into the Euro-Mediterranean zone: The Sahara Wind Project

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Abstract: As a genuine, regional initiative from the African continent, the Sahara Wind Project is supported by the North Atlantic Treaty Organization. In responding to Morocco and Mauritania's priorities, the Project has focused on a market based, locally integrated economic development model which can be derived from the significant trade wind resource blowing over North Africa's Atlantic coastline. In this area, a yearly production of more than 4500 Full Load Hours can be derived at some sites, where wind measurements are carried out. The size of the wind catchment area spreads for over 2000 Km (1250 miles) enabling considerable amounts of wind electricity to be generated at competitive costs and transferred to Euro-Mediterranean markets. For a nominal capacity exceeding 5GW, the Sahara Wind Project relies upon existing HVDC technologies to limit transfer losses at full load, to less than 5% to a point of entry into these markets. With a threshold capacity of 400-500 MW and a phased deployment of its interconnected 33/90/225 kV wind farm network, the technical terms of references of the Sahara Wind Project -for assessing the optimal transfer capacities on the basis of a 5 GW HVDC line - have already been established with ONE, the Moroccan public electric utility operating the local grid infrastructures. With funding from NATO, energy intensive synergetic processes are being developed with local industries enhancing access to electricity, drinking water, clean mobility, telecommunications and the processing of the region's minerals. Carried out in partnership with Morocco and Mauritania's Universities, and complementary to Morocco's integrated Wind Energy Program launched in 2010, these on-going developments reinforce the project's regional integration. Initiated from 1993 and presented at the European Parliament in 2002, the Sahara Wind Project is of strategic importance to the region. It has since inspired several industrial and political initiatives.

1. Background of the Sahara Wind Project

Upon installing wind measurement instruments on the Atlantic coastline of the Sahara desert in 1993, one of the largest potential for the production of wind generated electricity has been uncovered. Subsequent visits to wind farms in the United States which at that time housed close to three quarters of the world's wind energy capacity confirmed the importance wind power can have when deployed on a large scale, in current energy supply schemes (that are largely unsustainable). When launched nearly a decade ago, the Sahara Wind Project proposed a transformative model in wind energy development. Connecting a wind capacity as large as 5 GW to a High Voltage Direct Current line to supply North African and European electricity markets on pure economic grounds sidestepped a variety of technical challenges that the wind industry was facing. Today, many recognize the tremendous opportunity that the Sahara trade winds blowing steadily through one of the most desolate region on earth can offer as a low-cost renewable energy. The Sahara Wind Project however provides a comprehensive approach to leverage the full potential of this resource for the benefit of North Africa's economic developments.

2. North Atlantic Trade Wind Resources

Resulting from the combined influences of the rotation of the earth (Coriolis forces) and its temperature differences from Equator to Poles, the Trade Winds are global winds of significant magnitude. Shaping by wind stress surface oceanic current in similar pathways, the Trade Winds convey the warm waters of the gulf-stream that are responsible for Northern Europe's milder climate. Geological evidence provided by the existence of the world's largest sedimentary phosphate deposits (42 % of World reserve base*) trapped at the bottom of Morocco's Atlas Mountains, confirm that Trade Winds have been active for millions of years. Phosphate-rich debris generated over the Atlantic Ocean have been consistently pushed towards the North African coast. Their sustainability, regardless of any climate or ocean level considerations is thereby proven.

On the junction between the Sahara desert and the Atlantic Ocean, the Trade Winds created a zone of global energy exchange characterized by a dry climate dominated by steady winds. Thermal winds generated daily over the Sahara's hot surfaces are actually superimposed upon the larger Trade Wind system coming from the Atlantic. This generates one of the most extensive and steadiest wind systems available on earth.

With funding made available by the North Atlantic Treaty Organization, regional measurements established through a regional academic and industrial partnerships in support of the Sahara Wind Project confirmed the exceptional quality and scale of the aforementioned North-African Trade wind resource. In this area, a yearly production of more than 4500 Full Load Hours can be derived at some desert sites in Morocco and Mauritania where wind measurements have been made.

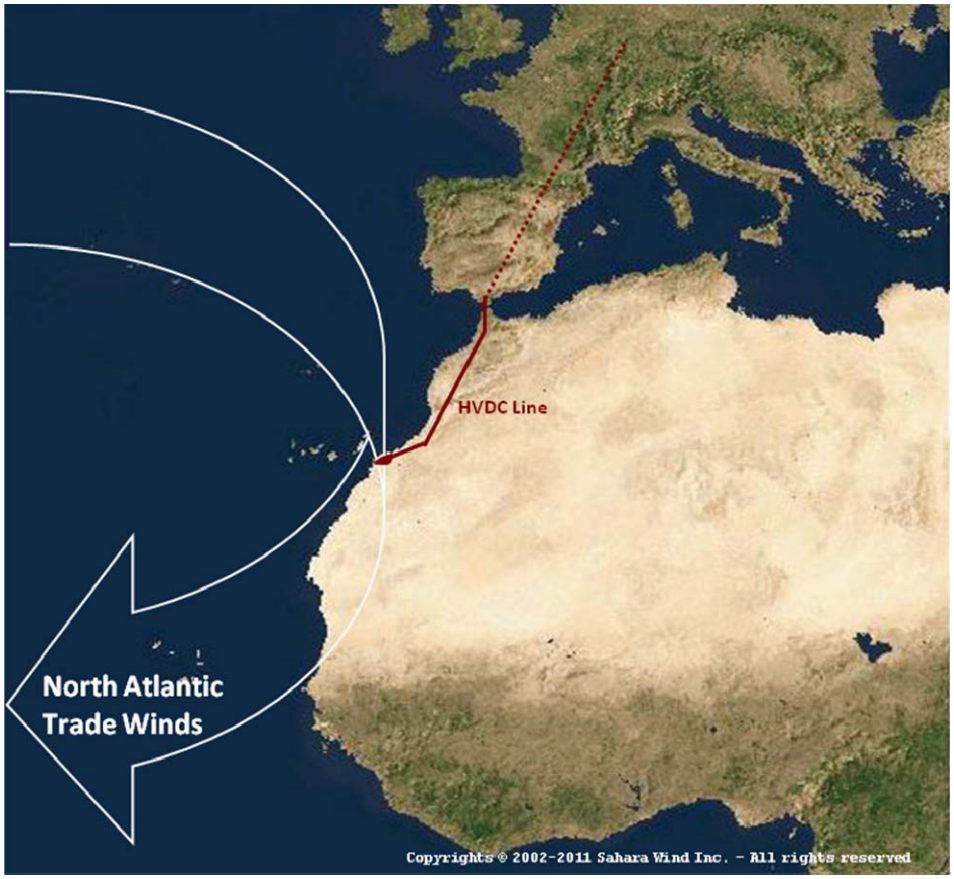

Figure 1: North Atlantic Trade Winds powering the 5GW HVDC Sahara Wind Project

3. Sahara Trade Wind Energy Potential

The junction of the Sahara desert with the Atlantic Ocean creates a zone of global energy exchange were the climate is dominated by steady winds spreading inland over a long distance. The combination of high daily temperature differences and a lengthy erosion process have significantly affected the morphology of the Saharan region. Over 90 % of the Sahara desert is made out of large flat rocky surfaces or plateaus called Hammada's. These stony areas made of broken bare rock structures are actually characterized by a very small surface roughness to wind. The large Atlantic desert coastline from Morocco to Senegal is about 2000 kilometers long and represents one of the largest and windiest areas on earth.

A wind turbine spacing of only 2.4 MW/km² on parts of the 2000 kilometers long desert coastline from Morocco to Senegal could potentially generate a production of more than 1000 TWh per year (1). This would be sufficient to cover close to half of the entire electricity needs of the European Union estimated at (2300 TWh). This very large potential represents several dozen times the electrical requirements of the North African countries combined, and cannot be utilized locally. The distances of North African electric load centers are indeed

quite remote from this region. Access to these renewable energy potentials require the use of different technologies that are currently only available for much higher energy transfer capabilities that the size of North African load centers simply cannot absorb.

4. The Sahara Wind Project

As the Saharan trade windblown coastline is already accessed by the extensions of the European electricity grid, considerable amounts of wind-generated electricity could be transferred into regional markets. Although local grids are fully synchronized in the European Network of Transmission System Operators for Electricity ENTSO-E Current network (2), these perspectives would require the building of optimized transmission lines. In order to avoid unacceptably high losses, High Voltage DC techniques could be engaged. For large capacities exceeding 5 GW, existing technologies can limit transfer losses for a single power line, to less than 10% over 3000 Km (1800 miles). This theoretical distance is long enough to deliver wind generated electricity from the Saharan plateaus of Tarfaya all the way to Germany.

While the 5 GW High Voltage Direct Current HVDC transmission line infrastructure envisioned by the Sahara Wind Project to serve Euro-Mediterranean markets would enable significant amounts of energy to be transferred, its sheer size requires an effect of scale. In order to address this issue most effectively, as original project concept developer the joint WB-AfDB-UNDP-GEF "PIMS#3292 MOROCCO Sahara Wind Phase I/Tarfaya (400-500 MW) on–Grid Wind Electricity in a Liberalized Market" project was submitted to the Global Environment Facility. The Project consists in the phased deployment of 5 GW of wind energy starting with a threshold capacity of 400-500 MW in the area of Tarfaya. The technical terms of references of the Sahara Wind Project -for assessing the optimal transfer capacities on the basis of a 5 GW HVDC line interconnected to a 33/90/225 kV wind farm network – have been established with ONE, the Moroccan public electric utility operating the local grid infrastructures.

Endorsed by the Government of Morocco, the Ministry of Energy, Mine, Water and the Environment, with support of the electric utilities of Morocco ONE, the Sahara Wind Project enabled multilateral institutions such as UNDP, GEF, and the World Bank to consider wind energy as an effective driver for economic development. As a result, funding from multilateral institutions was provided to public institutions associated to this framework enabling a long-term renewable energy transition of the sector.

5. Meeting the region's training, education and capacity building needs

While this future source of energy is indisputably of great importance to the economies of North Africa and Europe, efforts have been mobilized to meet the region's education, training and capacity building needs. The Sahara Wind Project's phased implementation and threshold capacity of 400-500 MW submitted to international funding institutions provided a market based, locally integrated economic development rationale justifying the transfer of wind technologies into developing countries. Although significant amounts of electricity can be effectively injected into Euro-Mediterranean markets, the sheer size of the Project's High Voltage Direct Current HVDC transmission line infrastructure requires an effect of scale. Hence, supporting mechanisms aimed at integrating this energy locally within the region's industries is of critical importance.

Considering Morocco's 97% energy dependency from imported fossil fuels and Mauritania's dire electricity access situation, problems related to energy scarcity, higher costs of energy and limited access to water could in the long-term if combined with environmental degradations, desertification and demographic pressure, generate economic distress. Building scientific capacities that can generate constructive dynamics around a fast growing and well integrated sustainable energy industry could provide economic alternatives in fixing migrant population, contributing thereby to their social integration. Fostering regional (south/south) collaboration in clean energy technologies to tackle energy access challenges is a critical issue. Beyond addressing Morocco and Mauritania's immediate needs,

supporting the region's transition from fossil fuels into renewables is a strategic priority for the long term security and stability of both NATO and Mediterranean dialogue countries.

Coordinated under the Sahara Wind Project and with funding from the North Atlantic Treaty Organization, a long-term regional collaborative applied research framework has been established between educational institutions of Morocco and Mauritania. The multi-year NATO SfP-982620 "Sahara Trade Winds to Hydrogen: Applied Research for Sustainable Energy Systems" program involves 18 institutions from 6 countries. This end-user driven applied research project is focused on the integrated access to wind energy through industrial synergies. The project with intellectual property rights clauses is carried out in partnership with local industries, public utilities and universities of Morocco and Mauritania. The NATO Mediterranean Dialogue countries Project Partners are ENSAM and Al Akhawayn Universities (Morocco), and the University of Nouakchott (Mauritania). The NATO countries Project Partners are the USA (State Dept-OES), France (CEA), Germany (M.NRW) and Turkey (UNIDO-ICHET). Presented as a first deliverable during the USA-Morocco Science & Technology Agreement signing ceremony in 2006, the project opened regional perspectives on integrated renewable energy applications such as green campuses, smart grids, green mobility and synergetic industrial processes.

By engaging simultaneous demonstrative and capacity-building objectives within industry-academic settings, stand-alone fully integrated processes are to be reinforced. Co-development of wind-electrolysis technologies enable University Campuses fed by small wind turbines to stabilize their power grids with electrolyzers as part of their respective "green campus concepts". The Campus becomes a living laboratory of renewable energy integration through hydrogen storage and a variety of downstream applications. An industrial engineering program for building small wind turbines enables engineering students to better address the operation and maintenance of these systems, when deployed either around their campuses, or in remote sites. In seeking stand-alone power supply solutions, the telecom operators agreed to provide their extensive mast infrastructures network for wind measurements. Hence, an exhaustive network of telecom masts towers has been made available in Morocco and Mauritania for a regional assessment of the trade wind resources.

To match needs of local industries, a new training curriculum is considered at the University of Nouakchott. The Al Akhawayn University's Master of Science in Sustainable Energy Management program received a first-year record enrollment. As a consequence, the university is purchasing additional small wind turbines to power its campus. Within this context, fuel-cell vehicles prototypes co-developed at Ecole Mohammedia d'Ingenieurs Morocco's largest engineering school partnering with local automotive industries will be tested utilizing on-campus green-hydrogen filling station.

A more comprehensive approach on the access and potential applications of the Saharan trade winds will enable social, economic, and political challenges that the region is currently faced with to be more effectively addressed. Mineral resource processing utilizing the region's wind potential for instance can provide enhanced sustainability criteria's. Indeed, when applied to Phosphates - a critical element to world food security- or iron-ore processing, resource efficiencies may be seen under a different light. Once training and expertise is available, renewable energy access can be addressed through a much broader synergetic context. Besides enhancing local ownership of resources, this approach is complementary to renewable energy developments occurring in Europe. This enables a leveraging of both social and technological benefits that can be derived from green energies.

Building upon experiences, efforts are currently under way to assess the training and education needs to support Morocco's Solar and Wind Energy plans of 2 GW each by 2020. Within such context the Sahara Wind Project is involved in focus groups established in the relevant Ministries to assess the training and education needs that these plans will require. Within such context, applied research and development is a key aspect to consider, particularly when ownership of a technology or process is sought.

Building capacities and adapting technologies to local conditions is critical to a sustainable deployment of green technologies in developing countries. Efforts to introduce wind energy in Morocco have been driven thus far mostly by external market forces which tended to provide unsuited ready-made solutions. The example of a local cement producer wishing to reduce its energy bill by installing 32 MW of wind capacity is quite edifying in that regard. Following a significant upfront investment, the cement plant currently spends 80% of its entire maintenance budget on the wind turbines alone. As skills for the technologies are not locally available, Operation and Maintenance costs have risen accordingly. Problems such as these highlight the need to build local capacities, streamline costs, create local jobs and consolidate wind farms into large programs as envisioned in the Sahara Wind Project. Capacity building, local project integration and an effect of scale are critical elements, if not prerequisites to consider in the context of large wind energy deployments.

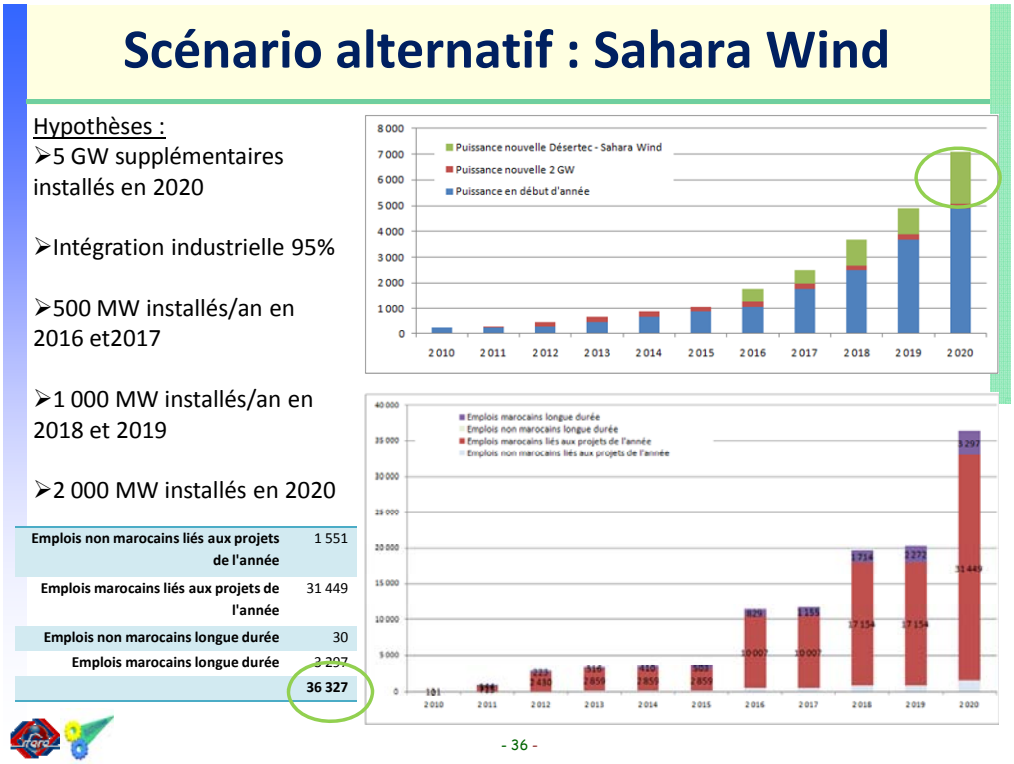

Figure 2: Sahara Wind Project phased implementation correlating training needs, industrial integration and local employment[3]

Complementary to Morocco's integrated wind energy plan launched in 2010, the phased implementation of the Sahara Wind Project provides such a framework. This Project can benefit from the Renewable Energy Law No. 13-09 (4) introduced in Morocco. The law allows for industrial end-users to operate in the renewable energy sector, and generate renewable electricity by feeding it into the grid. The electricity is wheeled by the electric utilities to any point of use. The law opens the possibility of renewable electricity exports via interconnections to neighboring countries as well.

6. The Sahara Wind Project in the Euro-Mediterranean context

The Projects under Article 9 of the EU Renewable Energy Directive on the promotion of the use of energy from renewable sources (5) allows European Union countries to import electricity from non-EU members to meet their individual targets of at least 20% of renewable energy by 2020. As a market based, locally integrated economic development model, this directive provides an important legal framework for the integration of electricity from the Sahara Wind Project into European energy markets. The summer peak seasonal offsetting of the Sahara trade winds (Figure 3) matches well into North-European winter high winds. This will enable the gradual introduction of wind energy from the Sahara Wind Project to be quite complementary.

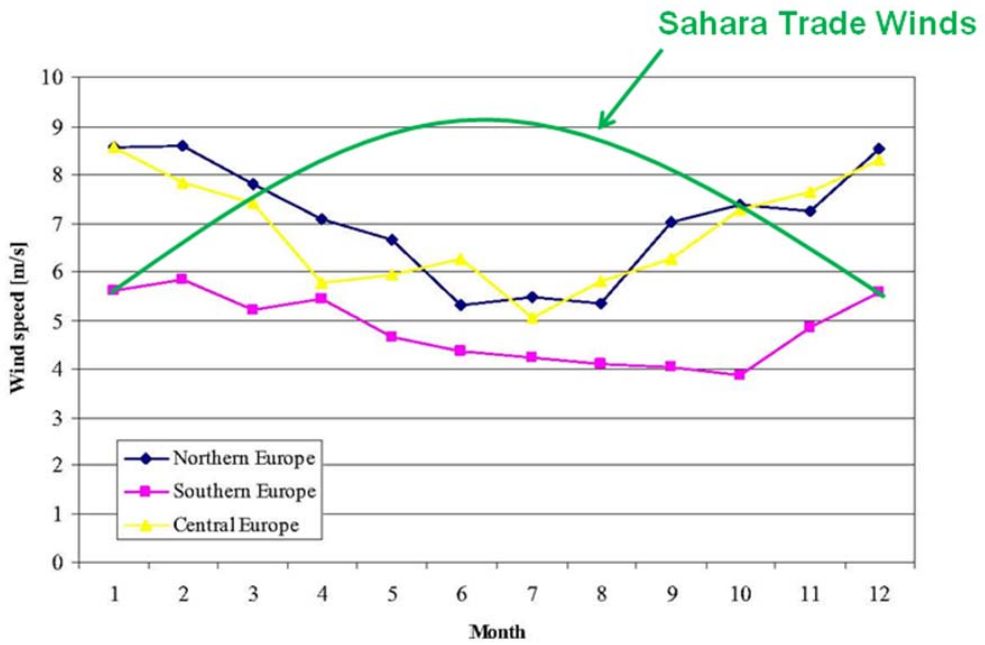

Figure 3: The Sahara Trade Winds bell-shaped Curve superposed on Seasonal Trends in Reanalysis wind speed of EU funded TradeWind Project (WP2.4; Characteristic Wind Speed Time Series - Document Number: 11914/BT/01C).

The Mediterranean Solar Plan (MSP), a flagship for the Union for the Mediterranean has listed renewable energy as an industrial policy tool. One of its key targets is the deployment of an additional 20 GW of renewable energy capacities by 2020. This requires building a shared medium term roadmap, supporting individual pilot projects and developing innovative financial tools according to the Union for the Mediterranean secretariat (6). As part of this framework, the Sahara Wind Project submitted a Pilot Project application to the Mediterranean Solar Plan (MSP) Immediate Action Plan in 2008.

7. Conclusion

The Sahara Wind Project provides a comprehensive approach already in its initial phases of implementation that will guide the shift to low-cost wind energy on a massive scale in the North African, and Euro-Mediterranean region. Reaching out to academia by equipping universities in Morocco and Mauritania, enables new generations of scientists and engineers in countries with a shared resource to work towards developing integrated solutions aimed at serving the region's basic needs. Regional collaboration on technologies through integrated project development frameworks will facilitate the establishment of job-generating manufacturing industries. Supplying the region's industries with renewables will ensure that wind energy surpluses generated from the Saharan trade winds can be most effectively transferred to the Euro-Mediterranean markets.

References:

1- Czisch, Giebel on Sahara Wind Project "Effects of Large scale distribution of wind energy in and around Europe" (2003)
2- European Network of Transmission System Operators for Electricity (ENTSO-E)
3- Scénario Alternatif Projet Sahara Wind : Rapport relatif à l'évaluation des emplois de la filière éolienne au Maroc à l'horizon 2020 Ministère de l'Energie, des Mines, de l'eau et de l'environnement Département de l'Energie et des Mines, Royaume du Maroc (2011).
4- Loi 13-09 relative aux énergies renouvelables, Bulletin Officiel, Secretariat General du Gouvernement, Royaume du Maroc (2010)
5- Article 9 of DIRECTIVE 2009/28/EC Official Journal of the European Union, 5.6.2009
6- "The UfM Mediterranean Solar Plan is on its way", Union for the Mediterranean Secretariat (2011)