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**RENEWABLE ENERGIES TO PROVIDE SUSTAINABLE
DEVELOPMENT PERSPECTIVES FOR NORTH AFRICA:
THE SAHARA WIND PROJECT**

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Abstract The trade winds that blow along the Atlantic coast from Morocco to Senegal represent one of the largest and most productive wind potentials available on earth. Because of the extremely harsh climatic conditions, populations in these areas are concentrated in a few remote cities where economic activities such as mining or fishing can be sustained. Although growing, the local electricity demand remains very low, and unless this vast renewable energy resource can be utilized in a broader context to supply regional electricity markets, economic development alternatives within the region will be limited. This by itself can be considered a threat to regional security, as a lack of economic development over vast desert areas increases the exposure of the region to illegal activities such as trafficking which may have a potential to grow into broader transnational security threats. While local urban centers are witnessing very high unemployment rates, the region is also under pressure from sub-Saharan migrant population fluxes. Ideally, the supplying of regional electricity markets could pave the way for an integrated development of the region, as trade wind generated electricity can be transferred via High Voltage Direct Current infrastructures at relatively low costs. Such energy options are likely to reduce the reliance on fossil fuel generated electricity for Spain and Portugal which boast Europe's highest CO₂ emission increases from Kyoto's 1990 base reference levels. In creating an integrated, job generating, socially acceptable renewable energy industry, such option could also eliminate the need for countries like Morocco or Portugal to consider Nuclear Energy as a viable option for meeting their growing electricity needs, knowing that Spain has suspended the construction of new nuclear power plants for over 2 decades. This paper aims at describing the renewable energy options of countries in North Africa integrated to the

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Euro-Mediterranean power market, and their potential impact on the region's security.

Keywords: Security threats, energy security, nuclear energy, distributed energy, capacity building, Sahara trade winds, climate change, sustainable development, energy options, High Voltage Direct Current transmission technology, Union for the Mediterranean, Solar Plan

1. Current Status – Security and Development Challenges in the Saharan Regions

1.1. GEOGRAPHIC AND HISTORIC BACKGROUND

The Sahara Desert is the world's largest desert. Agricultural resources for subsistence are very scarce. Furthermore, these areas have been administratively divided (rather artificially) during decolonization processes into independent countries that currently dispose of very limited resources, or possibilities to access them. These are sorely needed for the states to be able to secure or assert their own authorities within their own territories.

As has been seen during the colonization process, low population densities and the remoteness of these areas make it difficult even for the most developed economies to be able to secure territories of that size. A glimpse of this phenomenon is currently highlighted in parts of the South Western United States of America, where federal authorities are trying to support States in asserting more control over international border areas.

As a result of historical, geographical and also conjectural challenges, central authorities in the Saharan countries are either weak -enabling thereby the emergence of security threats- or relying on some form of traditional allegiances for delegating the central authority. The latter option can be either seen as an effective, legitimate form of governance or, in some cases, as a very controversial tool used to dilute responsibilities of a government in case of a conflict where exactions are being committed.

The fact that most countries in the Sahel region have had artificial border delimitations made with limited historical considerations; where economics and territorial control by previous colonizing power justified their rationale, these often times do not reflect the countries' own ethnic groups and thereby senses of identities. As borders are by nature incompatible with the regions traditional and nomadic ways of life, conflicts between neighboring countries are often times the norm rather than the exception in this vast area.

1.2. LIVING CONDITIONS

While quality of life may be improving in Morocco, living conditions in Mauritania and overall in the Sahara desert remains very difficult. Access to electricity, water and other services is significantly limited by the natural conditions under which these regions have been subjected to. The extreme dryness and high solar radiation prevents any vegetation from growing, making human presence and traditional economic activities such as agriculture hardly sustainable. Because of the extremely harsh climatic conditions, the population densities of these areas are in the order of less than one person/km². Most of the population is concentrated around water supply sources that constitute attraction poles, shaping communities into a few cities spread within a very large region.

1.3. ECONOMY

As the local economy can hardly sustain itself through agriculture, the main economic activities are based on mining or fishing and fish processing industries where possible. It is important to note that fishing and agriculture, North West Africa's main economic drivers, are under severe constraints. The first one, due to high demographics is the threat of overexploitation of the fishing resources the second one being the effects of climate change which contributed to furthering the erosion and desertification of the region's few agricultural areas. In this context, and as most mineral resources remain largely untapped in this vast region, mining and mine processing activities are likely to become the sector bearing the most promising economic development perspectives.

1.4. DEMOGRAPHY

Due to improved living conditions, particularly in the cities, the region's population has been witnessing significant growth rates. Boasting one the world's highest demographic growth, the population densities increased in urban areas, and as a consequence, cities have grown tremendously. This is bringing new challenges, as infrastructures, access to electricity and water supplies have to accommodate these changes. As an example, the lack in power generation capacities and the construction of a pipeline project to bring water from the Senegal River to supply Mauritania's capital city Nouakchott from many hundreds of kilometers away, is quite edifying.

1.5. SECURITY CHALLENGES

Besides infrastructure problems created by the concentration of populations, there are significant other challenges that need to be addressed within the growing cities of the Saharan/Sahelian Countries. Being mostly nomadic by tradition, the living conditions of populations concentrated in urban centers require significant social, cultural and behavioral adjustments. In such contexts, the necessity to maintain economic activities and employment figures at higher levels may be a critical element that should be taken in consideration with respect to the region's social and political stability. In order to foster a stable environment with long term political stability, economic opportunities for the creation of jobs remains very important. Providing decent incomes, sometimes rather artificially as in some oil rich North African or Gulf States may not necessarily contribute to the security of the region in this particular context, as has been seen in recent years. These local security issues can have global security ramifications as well, which constitutes a significant global security threat that needs to be addressed.

1.5.1. *Terrorism (safe heavens)*

Current transnational security threats are hardly better characterized than with the existence of areas with very little governmental control or authority, where subsistence can only be guaranteed through some form of illegal activity. The impingement of these activities on the notion of human dignity and self esteem with the psychological frustrations they induce can be very easily exploited to shatter one's own identity, in the radicalization of minds and becoming part of a global ideological struggle. This is particularly true when fundamentals or the moral grounds of an activity (such as trafficking) may be questioned. Providing a sense of purpose is important to all human beings. Absent the legitimacy of accepting the natural struggle of ensuring ones survival in difficult circumstances, as by tradition in these areas, any lack of purpose will be particularly effective in the radicalization of minds. It unfortunately must be mentioned that these are not exclusively confined to isolated or remote environments as in the Saharan desert. The main problem there lies in the fact that these areas are much more difficult to access which makes such threat very difficult to contain or even assess. This makes it therefore a very serious hazard.

1.5.2. *Drug Trafficking*

Government resources for territorial oversight are fairly limited in the Sahel region, hence more lucrative contraband and smuggling activities have recently superseded century old traditions of Trans-Saharan commerce.

When considering the broader context of the extension of Latin American drug-trafficking smuggling routes, which have established solid bases in several sub-Saharan countries, taking almost political control in some of them, it may be expected that some level of lawlessness in this vast Sahara desert is likely to prevail.

1.5.3. *Illegal immigration*

Tackling the global consequences of climate change, environmental degradations and rampant desertification on largely agricultural based societies currently under high demographic pressure is a key social priority, as they do generate economic distress leading to mass migration. Being net exporters of immigrants, Morocco and Mauritania for instance are located on the main routes of migrant populations from sub-Saharan Africa which constitutes a significant security threat to the stability of the region and their European neighbors. The North African continent is currently a “protection zone” for southern European borders (Lahlou) and migrant populations have already altered the workforce and demographics of entire economic sectors. The construction sector in Morocco or the fishing industry in Mauritania already employ significant amounts of sub-Saharan migrants, and in the context of the wider illegal immigration trends that the region is witnessing, human trafficking is likely to remain a lucrative market niche. Hence, if nothing is being done to alter the current situation, the prospects for peace and stability within the region may be affected. This in turn can have dangerous consequences on the broader, global security scheme.

2. Energy Supply, Energy Access a Development Imperative

With a 96% energy dependency from fossil fuel imports absorbing most of Morocco's export revenues, the impact of such dependency on budgetary spending is quite significant. Since close to 30% of National budgets are dedicated to education in the region, one can easily understand how critical the development of sustainable energy consumption schemes can be. While Mauritania enjoys a slightly improved situation regarding its energy dependency, its scarce population is distributed over a vast territory in which access to electricity is virtually impossible to grant through conventional grid infrastructures. Within such context, granting basic access to energy services such as electricity is essential to develop local, sustainable economic activities capable of preventing and fixing migrant populations.

3. Renewable Energy Resources and the New Energy Economy

Since this region is located on the edge of one of the largest electricity grids (EU grid), its large renewable energy potential could produce significant amounts of cheap renewable energies that could be gradually developed and ultimately end up supplying larger electricity markets. The trade winds that blow along the Atlantic coast from Morocco to Senegal represent one of the largest and most productive wind energy potentials available on earth (Fig. 1). As renewable energies have a strong social component, they tend to generate local industrial activities (green jobs), and developing mechanisms to initially firm this energy locally is very important as they lie on the critical path of major alternative, sustainable energy developments.

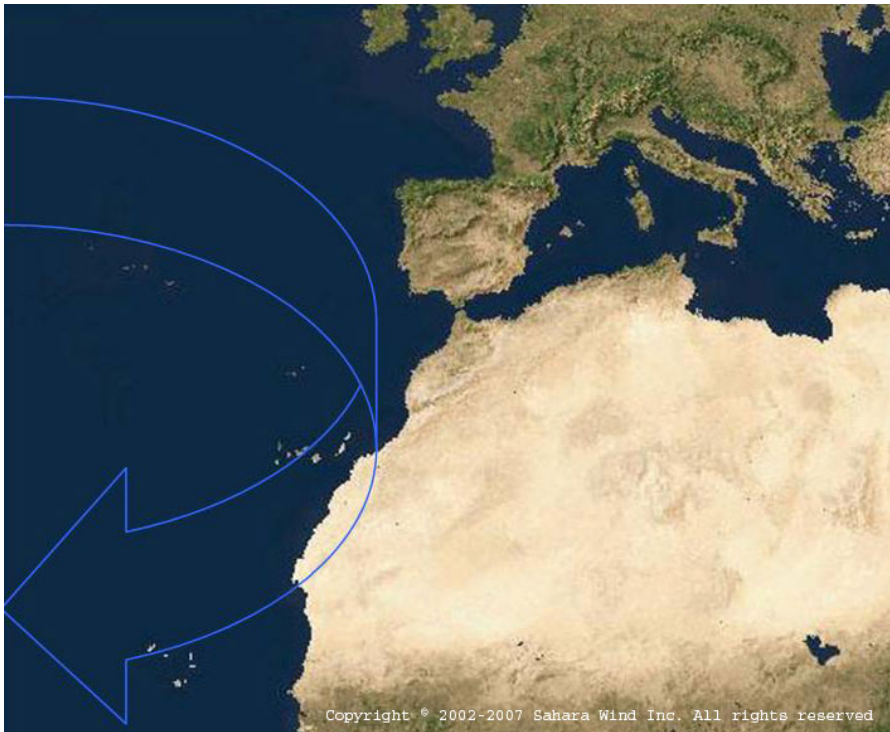


Figure 1. A vast renewable resource potential: global Trade Winds over North West Africa

Due to the geographical dimensions of the areas involved, only isolated distributed grid infrastructures are capable of supplying the cities of the Sahel region. These are very difficult to integrate in a renewable energy system, as their larger size tends to exceed smaller wind or photovoltaic distributed generation systems of the kW range. Solar photovoltaic cells are

still very expensive, and because of the erratic nature of winds, wind energy cannot be integrated locally on any significant scale unless coordinated deployments of these technologies are initiated in the region. These will enable a gradual introduction of renewable energy technologies and their integration within the local economy, namely the supplying of urban center and their mine processing industries. Provided an effect of scale can be achieved, these could pave the way to major renewable energy developments. Indeed, the saturation of the larger North African electricity grids to further wind developments – essentially due to grid stability problems – will quickly highlight a need to develop a more comprehensive and integrated approach.

The example of Denmark, as one of the world's wind energy leader is quite edifying in that regard. While relying on a highly interconnected grid, the country has not managed to cover more than 25% of its domestic electricity consumption through wind before encountering major grid stability problems. The country has frozen its domestic wind development activity for many years focusing its wind turbine manufacturing business – one of Denmark's main industrial employers – towards the servicing of export markets. The export of expensive European made wind turbines to lucrative markets (such as in the USA) may not be meant to provide a solution to Africa's electricity access challenges. Although 25% of Denmark's domestic electricity consumption may be quite significant, the same proportion (if achievable...) in the Saharan or sub-Saharan context will translate into very little quantities of wind turbines installed. Furthermore, the limited numbers of large wind turbines and their remoteness will make their maintenance extremely difficult to handle. With about 120 MW of total installed capacities, decentralized and distributed over territories that are twice the size of France, countries like Mauritania, Mali, Niger and Chad to name a few, will hardly make it possible for any imported wind energy technology from Europe to become commercially viable. Hence, developing alternative wind energy technologies to feed smaller electricity markets could be essential for tackling the region's decentralized energy access issues and enable the development of a local, viable wind energy industry which could be essential for tackling the region's economic and security challenges.

4. Wind Power, a Social Energy Economy

In the Saharan isolated urban environments, local diesel units or thermal power plants to provide basic electricity services (if the demand is large enough) are expensive and, maintenance and logistics are challenging issues. In these areas, distances between cities that represent marginal electricity markets in terms of sizes can stretch over 1,000 km. Developing

alternative wind energy solutions to feed smaller electricity markets is essential for tackling the region's decentralized energy access issues and enabling the development of a local, viable wind energy industry. Unless mechanisms are developed for integrating renewable energy technologies such as wind power, that is relatively easy to manufacture for small capacities and inexpensive to generate, no basic electricity service can be secured on a sustainable basis.

Initially encouraged to provide employment in the relatively poor North Sea regions of Germany, the wind energy industry has emerged in the last 10 years, as a major business providing competitive prices of electricity even when operated under marginal European wind conditions. As the trade winds that blow along the Atlantic coast from Morocco to Senegal represent one of the largest and most productive wind potentials available on earth, this may open a realm of possibilities for a sustainable development of the region. These countries dispose of a vast wind energy source, and as they face similar social pressure from domestic and sub-Saharan migrant populations fleeing deteriorating environmental conditions, fostering collaboration on integrating clean and more sustainable energy technologies for tackling energy access on a regional base appears to be quite relevant. As mentioned previously, the import of expensive European made wind turbines may not provide a solution to Africa's electricity access challenges. However, since this region is located on the edge of one of the largest electricity grids (that of the EU), local capacity buildup would enable its large renewable energy potential to produce significant amounts of cheap wind energy that could ultimately end up supplying larger electricity markets as well. This however, will require an effect of scale. Developing initial mechanisms to progressively firm these intermittent energy sources locally is an imperative first step as this lies on the critical path of major alternative, sustainable energy developments.

5. Access to Basic Services Water, Electricity, Communications and Security

Although providing access to energy and basic services in a secure environment remains the fundamental responsibility of authorities and governments in these regions, least cost solutions and adequate support systems have to be provided for local populations distributed over very large areas. Conducting applied research on renewable energy technologies within Morocco and Mauritania's research institutions with local industries is critical as they may foster collaboration and regional synergies among developing countries that face common security threats in their loosely controlled remote

areas. Indeed, areas of great economic importance are currently lost due to security considerations, particularly in the Sahel region where states rarely dispose of material means to secure their vast territories. It is therefore important that scientific communities integrate the security costs that this lack of alternatives represents to their own economies.

Energy access solutions and applications are relevant to communication infrastructures and permanent power supply systems in remote sites as well. Mobile phone networks and basic security infrastructures do rely on permanent power systems that have to be deployed within broad areas. The development of these infrastructure services and systems contribute to the prevention of security related problems which ultimately falls within the responsibility of sovereign states and governments. Indeed, in the Sahara desert, Mauritania is twice the size of a country like France as are Mali, Niger, Chad and other Saharan countries further to the east. This makes any logistics to service infrastructures for access to electricity, water or communication very challenging due to logistics. Utilizing wind or any other intermittent renewable energy source for distributed electricity supply solutions, or local electricity integrated applications, as the production of chlorine for water treatment, oxygen and even hydrogen as alternative fuels could also be explored. These could be relevant in local mine processing operations and will require adequate training and a capacity build-up in the field of scientific education. This is a fundamental step for harnessing renewable energies and their associated technologies. High tech storage of renewables in the form of hydrogen that can power everything from electronics to life support systems or even vehicles, open perspectives for integrated mine processing applications as well. Mobilizing academia in fulfilling these objectives may be appropriate, since complex hydrogen related technologies are likely to have greater importance in the future. These would enable researchers to identify local synergies and specific applications where these technologies may be relevant.

Providing access in exposing researchers, Engineers and Ph.D. students to these technologies may open a realm of opportunities for them, as well as for their countries. Besides preventing any technological gaps to widen in time, fields of specialization and excellence can be developed regionally, provided a targeted support and appropriate focus can be put on such installations.

The need to develop storage mechanisms is fundamental. If basic electricity service cannot be secured, local economies cannot thrive. Exactly this lack of local economic future leads to employment and population instability which represents a common security concern to both NATO and the countries of the region.

Building regional scientific capacities, and developing a common vision that can generate economic growth in integrating an environmentally friendly and sustainable energy industry (wind energy has 25% growth rates worldwide focused in Europe, the USA and China) could in the long term, become an alternative in fixing migrant population, and contribute to their social integration.

Hence, Involving local scientific communities, industries and end user groups to participate into an applied research program aimed at developing exploitable energy systems to integrate widely available renewable energies is essential in addressing this problematic. Coordinated by Sahara Wind Inc., the NATO Science for Peace Sfp-982620 project is for that matter deploying applied research platforms within Morocco and Mauritania's main educational centers around which a far ranging, comprehensive strategy aimed at integrating intermittent sources of renewable energies in the weak grid infrastructure of the Saharan/Sahel region has been envisioned.

Perspectives of a hydrogen energy economy will enable North Africa's scientific communities to take a comprehensive look at energy systems and adopt a holistic, integrated approach to energy technologies which are linked to development issues that have been driven thus far mostly by external market forces providing unsuited ready-made solutions. Indeed, experiences in North Africa have clearly shown that efforts aimed at introducing (new) wind energy technologies in these developing countries amounts ultimately to the simple import of turn-key equipment through concessionary sources of financing and export credit packages. These policies have done very little in terms of local impact for a technology that could have been promising in terms of economic returns, in addressing energy access, energy security, and the creation of an accessible integrated industrial activity.

6. The EU Neighborhood Policy, the Mediterranean Solar Plan

The Mediterranean Solar Plan, is one of six projects of the Union For the Mediterranean (UPM – Union Pour la Méditerranée). The UPM, launched with 43 Member States, by the President of the French Republic under the French Presidency of the European Union on July 13, 2008, aims at implementing common projects with the countries of the two shores of the Mediterranean. To this end, the UPM seeks to foster a new cooperation and development policy in the whole region of the Mediterranean basin. The Mediterranean Solar Plan (PSM – Plan Solaire Méditerranéen) is the flagship project of the UPM. Its goals are the development of new energy production capacities using renewable energy, in particular solar technologies, on the southern side of the Mediterranean, in order to satisfy demand at

local level and to export part of the production towards Europe, as well as the implementation of major progress in reducing energy demand and increasing energy efficiency in the whole region. The concrete target is the construction, by 2020, of 20 GW of new electricity production capacities using low carbon technologies.

7. The Sahara Wind Project

Under the preparation phase of the Mediterranean Solar Plan, whose protagonists the Sahara Wind Energy Development Project helped inspire, and in order to support this political initiative, a pilot project has been submitted under this framework. The deployment of such pilot scale project is aimed at enabling the testing, configuration and adaptation of wind turbine technologies which could subsequently be manufactured locally and gradually deployed in the region as part of a larger project. In a first stage, taking into account the current Moroccan regulation, the Sahara Wind Energy Development Project's installed power capacity will be limited to 50 MW. Then, in subsequent clusters, the wind farm capacities will be progressively developed and extended in order to tap the whole 100 km² of land which has been reserved for the project in the region, for a capacity of 500 MW. The initial building phase of the large-scale Sahara Wind Project "PIMS#3292 Morocco: Sahara Wind Phase I/Tarfaya (400–500 MW) on – Grid Wind Electricity in a Liberalized Market ", submitted to the United Nations Development Program (UNDP) and the World Bank's Global Environment Facility (GEF), with the support of several other multilateral institutions would thereby be achieved. This multilateral backed framework would allow for a quick development of the additional capacities while guaranteeing effective, transparent regulations for the project's long term implementation. This would pave the way to the phased deployment of the High Voltage Direct Current Infrastructure that would link the region's vast wind resource to major regional load centers. At the final stage of the project, 5,000 MW will be installed in the region of Tarfaya (500 MW for the first 100 km² land). An interconnected 33/90/225 kV wind farm network will be developed; HVDC system will be used for long distance transmission lines whose technical terms of references – for assessing optimal transfer capacities – have already been established with ONE, the Moroccan State owned electric utility company operating the local grid infrastructures. These on-going developments will be further developed and expanded upon insuring the sustained wind energy developments in the region.

Since efficient power transfers over long distances are currently only available for large-scale integrated projects worldwide, the prospect of

adding a hydrogen production component in the initial building phase of the Sahara Wind Project is likely to provide an alternative that could enhance the prospects and phasing of this large-scale project. As its original concept developer, Sahara Wind Inc. highlighted the production of hydrogen as an integrated and complementary component of the Sahara Wind Project that enhances prospective uses, perspectives and overall energy efficiencies of large scale renewable energy systems located in remote areas and operating in weaker grid infrastructures. These activities, along with the wind resource assessment of the region are currently being funded by the North Atlantic Treaty Organization under its Science for Peace and security program (under NATO Sfp-982620), and the United Nation's Industrial Development Organization under UNIDO assignment post TF/INT/03/002/11-68.

8. Other Alternatives or Lack of Renewable Energy Alternatives

8.1. ELECTRICITY FROM FOSSIL FUELS

Among European Union countries, both Spain and Portugal have in recent years boasted the highest electrical consumption growth rates. Taking these in consideration together with the even higher growth rates of North African countries, where yearly growth rates of up to 8% have been reached, as in Morocco (Hajroun), the need for deploying rapidly additional electric generation capacities becomes quite obvious. Among the options that are sought, and because of their lower costs to the kW/h generated, large coal fired power plants represent the main alternatives that are currently envisioned. Although no coal deposits are available in the region, coal fired power plants relying on imported coal purchased on the international market, remain the most competitive alternative. Within this context, and while North African countries are not bound by Emission limitations under the current Kyoto agreement, it is important to mention that Spain and Portugal have witnessed the highest growth rates within the EU's country greenhouse gas emissions since 1990. Reducing the carbon footprint on the Iberian Peninsula is a particularly important issue as these countries will be among the ones that will need to benefit from of the EU-wide carbon trading/compensation mechanisms.

Regarding the use of natural gas as a fuel, the GME natural gas pipeline supplies most of Spain and Portugal from the Algerian gas fields (Fig. 2). As this country represents their main natural gas supplier via its pipeline networks, some concerns over energy dependencies have been raised. To this extent, it is interesting to note that the Iberian Peninsula disposes of more Liquefied Natural Gas (LNG) terminals than are available in the rest of the EU (Barcélo, 2009).

incident effectively halted the construction of the plant, bringing the Spanish nuclear energy program effectively to a standstill.



Figure 3. Abandoned Nuclear Plant in Spain's Basque country (Photo: Sahara Wind Inc.)

It may be relevant to note that this event occurred in the mid-1980s when oil prices hit record lows. The more recent peaking of oil prices have not had any impact on the position of the Spanish government to remain opposed to the implementation of a nuclear energy program, preferring instead to support the development of a green energy industry. The green economy is often referred to by the current government as a promising example for the future. Indeed, Spain, along with Portugal has been very active in both the manufacturing and the deployment of renewable energy technologies domestically and abroad. The social dimension of the renewable energy industry may in fact represent one the key arguments playing against the nuclear energy option. Indeed, and as the sector grows, the employment levels from renewable energy industries tend to gain in significance, hence popular support, whereas their geographic distributions are spread in areas where economic activities are most needed. Desolated country sides are indeed one of the main areas benefiting from new wind turbine installations. These generate local jobs, and most importantly tax revenues that remain within the region where the systems have been installed. As jobs created by the nuclear industry tend to be generally concentrated in larger industrial

centers where nuclear power plants parts are designed and built, renewable energies provide employments and tax revenues that are geographically much better distributed. Once installed and operational, a nuclear power plant requires fairly limited human attendance, in comparison to the power it generates. This, off course translates into very little employment positions at the plant level. As a comparison, in Germany the Nuclear Industry, which provides over 20% of the country's electricity supply, employs some 30,000 person. As a comparison, the renewable energy sector has, only in the year 2008, created 30,000 new jobs. It is important to mention that in the German context renewable energies account for less than 10% of the overall electricity supply and some 280,000 people are currently employed in the renewable energy sector in Germany alone, according to that country's Ministry of Economy (Fachblatt-Aktion Neue Energie Deutschland, 2009). The figures in Spain are likely to boast similar ratios and one can easily understand why the new Obama administration in the US has singled out renewable energies and related technologies in its stimulus package by providing it with US\$78 billion of funding, with the objective to generate thousands of "new green jobs". It is important to mention that the Chinese government is putting the finishing touches to a US\$440 billion incentive package designed to boost amongst others the use of solar and wind power in the country (Chan). Hence, the social dimension and growth of the renewables sector will definitely play a key role in the energy options of countries that have initiated industrial programs toward the building of their renewable energy economies.

In the case of North Africa, the Nuclear Energy option will provide very little added value in terms of industrial and economic impact as the high costs of a nuclear power plant is likely to be spent on a turnkey plant imported from abroad. The fact that these plants are hardly duplicable, due to the exiguity of the local electricity markets (smaller grids) will make any industrial integration hardly justifiable whereas stringent and mandatory procedural safety costs for running a single plant cannot be distributed over to other plants. It is also important to mention that base load generated nuclear power, does not match very well with intermittent sources of renewable energies, where more expensive fossils fuels can be saved on an operational basis. Funding for such type of plants is not likely to be easily available due to high upfront investments, and the type of guarantees required from local operators. Although this may less likely to be an issue for countries like Algeria which disposes of large foreign currency reserves from its gas revenues, Morocco may find some difficulties in financing such a program. Seen the high upfront capital costs and the delays associated to the implementation of a nuclear energy program before nuclear power plants can effectively be built and put on-line, alternative options may have

an influence on such long term decisions. The renewable energy options followed by larger electricity markets on a regional basis, as on the Iberian Peninsula, will make a nuclear option very difficult to justify in North Africa. The ease for instance, with which a renewable energy industry can be built or transferred in the North African economic context on the basis of what has been achieved in Spain some 13 years ago, when the country did not dispose of any wind energy industry for instance, is likely to favor this alternative. This will be furthermore justified as the renewable energy resources such as wind and solar energies are capable of providing much higher productivities on the North African continent than what is currently being harvested on the Iberian Peninsula.

9. Conclusions

The potential of these resources are vastly higher, as the main limitations relative to their access will remain a weaker grid infrastructure network. The lower, although growing electricity demands versus the long distances from the vast Saharan Trade Wind resources to North Africa's load centers will constitute a major challenge. The access to these renewable energy potentials will in fact require the use of different technologies currently available only for much higher energy transfer capabilities than the size of North African load centers simply cannot absorb.

High Voltage Direct Current (HVDC) transmission lines for instance, can allow vast amounts of electricity (in the GW range) to be transported over long distances at minimal losses. If we were to connect the North African renewable energy resources into a Euro-Mediterranean electricity market as envisioned through our 5,000 MW Sahara Wind Energy Development Project, then a significant share of Europe's wind energy production would be complemented by these large productive sites, making wind energy more affordable.

Comparative advantages rather than a mere displacement of European wind energy productions would be achieved, as the High Voltage Direct Current (HVDC) transmission technologies used would contribute to stabilize surrounding grids on both ends, enabling them to integrate more wind energy. The advantages of integrating wind resources on a continental basis become even more obvious, as the seasonal distribution of winds in terms of peak power production are quite complementary. While winter highs are characteristics of European wind energy generations, the Saharan Trade Winds have their peak production in the summer season. This is particularly relevant as in Southern Europe; the tourism driven economy induces higher electricity consumptions at this time of a year, which would, in such cases, be

matched by a carbon-free renewable source of wind energy made available at competitive prices.

These perspectives highlighted by the 5,000 MW Sahara Wind Energy Development Project have been presented at the European Parliament in 2002, as they would also contribute to improve the economic prospects of marginal desert regions that currently dispose of very limited endogenous development possibilities.

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