Securing Energy Investments on a Regional Basis: The Sahara Wind Project

Comparative international experience in an era of energy transition

Knowledge Stream II: Investment security and securing the necessary investments in the energy sector: how do get there?

Eighth Executive Training Programme for Young Energy Professionals: Visegrad+ Session

Krakow, Poland
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This project is supported by: The NATO Science for Peace and Security Programme
- Presentation Summary -

- Overview of Morocco’s Energy mix, Renewable Targets, Focus on Wind
- Beyond 2020: Merchant Lines & Export Perspectives of Law 13-09
- Origin of the Sahara Trade Winds & its Fossil Footprints
- Food Security, Fertilizer Industries & Hydrogen in the Economy
- 5~10 GW HVDC point-to-point Grid Architecture
- Morocco’s Success Factors in Renewable Energy Project Investments
REHAUSSEMENT DES OBJECTIFS DE PRODUCTION D’EnR

DANS LE CADRE D’UNE NOUVELLE AMBITION, PLUS FORTE ET PÉRENNE DU ROYAUME

- Objectif : 42 % de la puissance installée en 2020, porté récemment à 52 % à l’horizon 2030, comme annoncé par SM le Roi Mohammed VI que Dieu le Glorifie, à l’occasion de la COP 21

- Choix technologiques variés pour le développement des EnR
- Offre diversifiée d’EnR permettant l’accès à toutes les catégories socio-professionnelles
- Programme de développement du GNL, catalyseur pour l’atteinte des objectifs EnR
- Consolidation de la position du Maroc dans la Région, comme opérateur de référence dans le développement des EnR
### Morocco’s 2020 Wind Capacity: 2 GW
(Building on Experience: 1215 MW under construction)

<table>
<thead>
<tr>
<th>Make</th>
<th>Size (MW)</th>
<th>%Share</th>
<th>Name of Project</th>
<th>Nr of Wind Turbines/Types</th>
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<tbody>
<tr>
<td>Vestas</td>
<td>50</td>
<td>2%</td>
<td>Koudia/A. Torres</td>
<td>84  Vestas V44/600 kW</td>
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<tr>
<td>✔ Vestas</td>
<td>120 MW</td>
<td>6%</td>
<td>Jbel Khalladi</td>
<td>40  Vestas V90-3MW</td>
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<td>Gamesa</td>
<td>10</td>
<td>1%</td>
<td>Lafarge-1</td>
<td>12  Gamesa G52/850 kW</td>
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<td>22</td>
<td>1%</td>
<td>Lafarge-2</td>
<td>11  Gamesa G52/850 kW</td>
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<tr>
<td>Gamesa</td>
<td>5</td>
<td>-%</td>
<td>Cim.Maroc Laayoune</td>
<td>6   Gamesa G52/850 kW</td>
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<tr>
<td>Gamesa</td>
<td>60</td>
<td>3%</td>
<td>Essaouira</td>
<td>71  Gamesa G52/850 kW</td>
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<tr>
<td>Gamesa</td>
<td>140</td>
<td>7%</td>
<td>Tanger</td>
<td>165 Gamesa G52/850 kW</td>
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<tr>
<td>GE</td>
<td>102</td>
<td>5%</td>
<td>Akhfenir</td>
<td>61  Alstom ECO 74 (1,67 MW- 74 m)</td>
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<tr>
<td>✔ GE</td>
<td>95 MW</td>
<td>5%</td>
<td>Akhfenir</td>
<td>56  GE 1.7-100 /1.7 MW</td>
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<tr>
<td>✔ GE</td>
<td>150 MW</td>
<td>7%</td>
<td>Taza</td>
<td>50  GE ECO 100/3MW</td>
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<tr>
<td>Siemens</td>
<td>51</td>
<td>3%</td>
<td>Haouma</td>
<td>22  Siemens SWT2.3-93 (2,3 MW-93 m)</td>
</tr>
<tr>
<td>Siemens</td>
<td>51</td>
<td>3%</td>
<td>Foum el oued</td>
<td>22  Siemens SWT2.3-101 (2,3 MW-101 m)</td>
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<tr>
<td>Siemens</td>
<td>301</td>
<td>15%</td>
<td>Tarfaya</td>
<td>131 Siemens SWT2.3-101 (2,3 MW-101 m)</td>
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<tr>
<td>✔ Siemens</td>
<td>850 MW</td>
<td>42%</td>
<td>ONEEE 850MW</td>
<td>370 Onee E850MW</td>
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</tbody>
</table>

**TOTAL 2.008 GW**

### Market Shares 2016
- Siemens 51%
- Gamesa 30%
- Alstom/GE 13%
- Vestas 6%

### Market Shares 2020
- Siemens 62%
- Gamesa 12%
- GE 17%
- Vestas 8%
Local contents: A learning curve

Local contents/jobs in operating wind projects:
- Civil works, foundations etc. 7-10% (Fully integrated)
- Electrical infrastructure (interconnection Wind farm): 7-10% (Fully integrated)
- Transport Logistics 8-10% (integrated, established JV)
- Engineering studies 3-4%
- Towers (steel & steel works) 5-12%
- Operation & Maintenance: 5%
- Financial costs 5%: Local financial institutions (private) & Multilateral donors

Morocco’s 850 MW Integrated Wind Energy Program: 2.7€cent/kWh
(World lowest with project finance) up to 70% local content by value!

- Blades 10%: Tangier Siemens factory 100 M€ Invst. (Industrial Compensation)
- Towers 12%: local Steel boosts local content from 5% to 12%

Potential integration on Nacelles:
Synergies with Aeronautics & Automotive industries: cabling, controls, composites...
Loi 13-09 relative au Energies Renouvelables

Cette loi décrète de :

L'autorisation provisoire et définitive d'une installation de production d'électricité à partir de sources d'énergies renouvelables concernant les productions supérieures à 2 mégawatts.

La déclaration des installations de production d'électricité à partir de sources d'énergies renouvelables concernant les productions supérieur à 20 kilowatts et inférieure à 2 mégawatts.

La commercialisation de la production d'électricité à partir de sources d'énergies renouvelables.

Des sanctions et pénalités concernant les exploitants des installations de production d'électricité à partir de sources d'énergies renouvelables.
Beyond Morocco’s Integrated Wind Energy Program

- In 2016: 1 GW (787 MW in operation + 200 MW under construction)
- By 2020: + 1 GW (850 MW + 150 MW Integrated Wind Energy Program) 2 GW Total

Accessing the Sahara Trade Winds:
- Wind potential far from load centers 1300 km AC losses/phase: HVDC line needed
- Morocco’s total generating capacity (8154 MW ~ Peak load 5860 MW) Dispatching difficult beyond 2 GW (4.2GW by 2030)

⇒ Regional integrated project development approach needed:

Sahara Wind Project (5GW+ HVDC line)

✓ RE Law13-09 authorizes self-consumption (and surplus exports)
✓ EU 3x20 Directive RE imports from third countries (to meet 2020 targets).
Trade Winds Existed for Millions of years: Geological Evidence provided by largest Sedimentary Phosphate deposits

• Phosphate deposits: 75% of World reserves
  (*U.S. Geological Survey 2014)

• Potash deposits: 55% of World reserves
  (*U.S. Geological Survey 2014)

• Sea Water Desalination Plants

• North Atlantic Trade Winds

• Sahara Wind - NATO SfP-982620 / (SfP-984382) frameworks

• Université de Nouakchott-USTM
  Mauritania

• AUI-ENSAM+EMI
  Morocco

• 5-10 GW HVDC line
Monitoring System Local Grid Industrial End-Uses

380v-125kV Local Grid Distribution

Sahara Trade Winds Powering North-Africa’s Major Phosphates (Fertilizer) & Iron-Ore (Steel) Industries

Phosphoric Acid $\text{H}_3\text{PO}_4$

Reverse Osmosis Sea Water Desalination

Electrolysis
Alkaline/PEM Chlor-Alkali

Iron ore/Steel

Ammonia $\text{NH}_3$

Hydrogen Storage

Grid Stabilization Backup

Processing of Phosphates (Morocco)

Processing of Iron-Ore (Mauritania)
Mauritania’s Iron-ore industry

- Largest industrial conglomerate: SNIM (State-owned 78%)
- Reserves in billion(s) ton range, 28% of Mauritania’s GDP, 50 % Country’s exports
- Africa’s second largest iron-ore exporter (13 Mt/yr., 40 Mt/yr. by 2025)
- Environment constraints dusts emissions in EU-markets (pre-processing required)
- Direct Reduction Iron: purified Ores & Steels
  - Wind-Electrolysis: Hydrogen as feedstock for Direct Iron Reduction (DRI)
  - Hot Direct Reduced Iron + Oxygen fed into Electric Arc Furnace
  - Smaller steel plants suitable for countries with limited supplies of coking coal
    ⇒Creation of a high-grade, sustainable, carbon-free steel industry

Wind measurements for pilot project sites, testing, training, capacity building at Nouakchott University.
Morocco’s Phosphate Industry

• Largest industrial conglomerate: OCP Group (State-owned 94%)
• 75% World Reserves, 33 % of Morocco’s Total exports
• World’s largest exporter of:
  • Phosphate rock: 33 Mt (35% Market share, 50 Mt/yr by 2025)
  • Phosphoric Acid: 4.8 Mt (52% Market share, 10 Mt/yr by 2025)
  • Fertilizer exports: 5.3 Mt (20% Market share, 10 Mt/yr by 2025)

High price fluctuations in current Phosphoric Acid wet-process using Sulfuric Acid (Imports of Sulfur and Ammonia for the production of upgraded Fertilizers)

Endogenous Phosphoric Acid production (electricity intensive):
  1- Thermal (furnace electro-thermal) dry-process
  2- Electrolysis process (Hydrochloric Acid) wet-process
     Co-generated Hydrogen generates Ammonia NH3 (Nitrogen from air)
     Integrated fertilizer industry
     ✓Enhanced resource transformation efficiency
     ✓Sustainability: Renewable H₂ (feedstock & energy carrier)
Hydrogen a Renewable Energy Storage/Carrier
Industrial use in the Economy: Ammonia

- Ammonia consumes ~2% of World's energy (mostly from fossil fuels)
- Fertilizer industries: Captive & integrated (70% near phosphates deposits)
- Fertilizers essential to world food security:
  - 2050: World Population 9.2 billion people (-20% arable land per capita)
  - Climate Change effects & Biofuels (exacerbates yield pressure on arable land)
- 90% of Phosphates used as fertilizers: transforming largest reserves is key to global sustainability
- Low-cost Wind Electricity contributes to Price stability!
50 MW Foum El Oued Wind Farm
300 MW Tarfaya Wind Farm (Africa’s largest)
Sahara Wind Project  Fueling a 100% Renewable Energy transition

Water, Phosphates/Fertilizers, Iron-Ore/Steel Processing …

Electrolysis

Gas Tanks

Gas Pipeline - Network

Underground Cavern

Transmission Grid

Hydrogen

Electric Power

Sahara Wind 1500 km HVDC Line

Automotive Industries

Combined Cycle Power Plant

Natural Gas

Dacia Lodge
Préparez-vous, il arrive bientôt!
Sahara Wind - HVDC Transmission Architecture 5 GW - bipole 1 (Point to Point classical HVDC configuration)

Sahara Wind Farm Areas (1250 MW)

To local Networks (Mineral Processing)

Area1

VHV AC Bus

Rectifier 12 pulse bridge

Metallic return

+500 kV

- 500 kV

Inverter 12 pulse bridge

VHV AC Bus

To local Networks (North African Urban Load Centers)

Surplus Exchanges EU-Grid (ENTSOE)

To local Networks (North African Urban Load Centers)

SVC

Sahara Wind - HVDC Transmission Architecture 5 GW - bipole 1 (Point to Point classical HVDC configuration)

To local Networks (Mineral Processing)

Area2

SVC

765 kV AC

500 kV DC

800 kV DC
ENTSOE Grid Map of North Africa & Europe

Integration of the Sahara Wind Project’s 5~10 GW HVDC line into European Synchronized Grid
The Sahara Wind Project (5GW+ HVDC line)

Integrative RD&D essential for Optimal Deployment of the Sahara Wind Project
Sahara Wind Phase 1: 400~500 MW on existing grid (UNDP/GEF,UNIDO,NATO,UfM) / Extensions through HVDC lines

HVDC Technology: Limited losses over long distances (3% ~1500Km for 5 GW+) 180 GW HVDC Projects Worldwide (30~50 GW added/yr.) China (40% of its new 300 GW grid capacity will be HVDC), USA, India, Brazil..

North African electricity markets are in full growth/expansion (6~8%/yr.)

Wind catchment area:
- **Quality**: Average wind speed: 9 m/s+
  Atlantic Trade Winds: 45% Capacity Factor+
- **Quantity**: Size of Area: 2000 km Saharan coast
  Morocco, Mauritania & Senegal
  Potential Wind Energy >500 GW ~ 1000 TWh+
- **Proximity**: 1300 km from European Union
  500 million citizens, +3000 TWh/yr power market
China installed 33 GW of wind capacity in 2015 (148 GW total) HVDC lines corridors of 40 GW capacity each (by 2020) to transport Renewable electricity to load centers.

Note: this is an indicative map figuring the concept of the West-East electricity transfers. The exact localisation of corridors is still under discussion and subject to possible changes. Source: D. Tyler Gibson and James Conkling/China Environment Forum at the Woodrow Wilson Center.
Morocco’s Success Factors in Renewable Energy Investments

Public Private Partnership experience in energy sector: private, domestic/international

Energy & Trade hubs (Tanger-Med), Free Trade Agreements (EU/USA...)

Tax-free industrial zones with incentives in major cities

Good infrastructures (Railway/Highway/Harbors/Airports, etc.) with interconnectivity

Integrated industrial strategies (Automotive, Aeronautics, Renewables, etc…)

Qualified workforce (well interconnected with European industries for training etc…)

Stable political environment & conducive investment frameworks (FDI driven)

Mobilization of key industries (utilities, mineral processing, manufacturing, services…)

Cheap renewable electricity boosts competitiveness, growth & addresses global challenges (energy transition/climate change/economy/migrations..)

- Morocco’s UN COP-22 Presidency beyond COP-21 (implementation of projects)
- Global Food security &… Access to Water!
Thanks for the attention!

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