Wind energy use in high energy & water consuming industries: Case study of phosphate and fertilizer sectors in Morocco

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Partnerships with Telecom Operators of Morocco and Mauritania
Mast Measurements at 70, 50 and 40 meters height
Trade Winds Existed for Millions of years: Geological Evidence provided by largest Sedimentary Phosphate deposits

Phosphate deposits: 75% of World reserves
(US Geological Survey 2014)

Sea Water Desalination Plants

North Atlantic Trade Winds

Potash deposits: 33% of World reserves
(US Geological Survey 2014)

5~10 GW HVDC line

Al Akhawayn & Nouakchott Universities Green Campuses
Capacity Building through Applied R&D

- Industrial engineering program on small wind turbines (ENSAM)
- Wind turbines connected to Universities electric grid (AUI & UNkt):
  - 30 kW-Alkaline Electrolyser system integrated into the grid
  - 48 cylinder pressurized hydrogen storage
- Excess Wind-electricity stored as hydrogen & converted into electricity (through stationary fuel cell) for grid back-up/Telecom power supply...
Integrated Electrolysis Applications
Drinking Water & Mineral Processing

1- ‘Green Corporate Centre’ at Headquarters of ONEE (Morocco’s Power & Water utility)
Station de traitement complexe Bouregreg (767 millions m³ water/yr)
Institut International de l’Eau et de l’Assainissement - Training/Demonstrator (SfP- 984382)
  • Small Wind Turbines
  • Chlorine Chlor-Alkali Electrolyser
  • Hydrogen/Fuel Cell (Grid Backup, E-mobility)

2- Desert pilot project site: ONEE desalination plant
  • Larger Wind Turbine(s)
  • Chlor-Alkali (Membrane) Electrolyser
  Wind Measurements NATO SfP-982620
  Integrated industrial applications

✓ Develop Water treatment solutions in Sahel region
  Collaboration with SNDE & University of Nouakchott

✓ Engage energy-intensive mineral processing industries (Phosphates & Fertilizers industries)
  using Renewable Energy Law 13-09 for self-consumption (electricity export clause matching
  EU-2020 3x20 directive).

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: 27 Mt in 2013 (35% Market share, 50 Mt/yr by 2025)
  • Phosphoric Acid: 3.3 Mt (47% Market share, 10 Mt/yr by 2025)
  • Fertilizer exports: 4.5 Mt (20% Market share, 10 Mt/yr by 2025)

High price fluctuations in current Phosphoric Acid wet-process using Sulfuric Acid
(Sulfur and Ammonia imports needed 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 used for Ammonia NH₃ (Nitrogen from air)
    Integrated fertilizer industry (Phosphates + Wind + Water)
    ✓ Enhanced resource transformation efficiency.
    ✓ Price stability
    ✓ Sustainability: Renewable Energy H₂ storage (feedstock & energy carrier)
Hydrogen/Ammonia in the World Economy

- Ammonia consumes 2% of World’s energy (mostly from fossil fuels)
- Fertilizers essential to world food security:
  - 2050: World Population 9.2 billion people (-20% arable land per capita)
  - Climate Change Effects & Biofuels will exacerbate situation
- Fertilizer industries: Captive & integrated (70% near phosphates deposits)
- As 90% of Phosphates used as fertilizers: the transformation of largest reserves is key to global sustainability
- Improved resource efficiency through ‘cost-competitive’ incorporation of wind energy.

Integrating the Sahara Trade Wind Resource to North-Africa’s Major Phosphates/Fertilizer (& Iron-Ore/Steel) Industries

- Processing of Phosphates (Morocco)
  - World Market shares: Phosphate Rock 33%, Phosphoric Acid 47%, Fertilizers 20%
- Processing of Iron-Ore (Mauritania)
  - 16 Mt/yr (Actual) 40 Mt/yr by 2025, large Reserves
North Africa’s weaker grids predisposes wind energy to supply its growing fertilizer industry.

- Scale of Phosphate resources with synergetic processes enables local firming of trade winds.
- Critical to their access by improving phased deployment and operational power balancing of the Sahara Wind Project’s large HVDC transmission infrastructure.

**Sahara Wind Project**

- Fueling a 100% Renewable Energy transition
- Water, Phosphates/Fertilizers, Iron-Ore/Steel Processing...
- Electrolysis
- Hydrogen
- Gas Tanks
- Natural Gas
- Automotive Industries
- Combined Cycle Power Plant
- Gas Pipeline - Network
- Gas Tanks
- Undergroind Cavern
- Transmission Grid
- Sahara Wind 1500 km HVDC Line

**Wind production variability**

Wind production record 14,962 MW

- Maximum coverage 09/11/2010 14.46 h
- Minimum coverage 03/09/2010 12.03 h
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
SVC

Area2
SVC
To local Networks (Mineral Processing)

VHV AC Bus
Rectifier 12 pulse bridge
+500 kV
Metallic return
- 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)

ENTSOE Grid Map of North Africa & Europe
Integration of the Sahara Wind Project’s 5~10 GW HVDC line into European Synchronized Grid