Sahara wind

FROM GREEN CAMPUSES TO CORPORATE HEADQUARTERS: PAVING THE WAY TO A SUSTAINED ACCESS TO POWER, WATER, MOBILITY AND NATURAL RESOURCES

MARE PROJECT

International Workshop

"Cooperation between EU and Mediterranean Partner Countries in the energy sector: Challenges and Opportunities".

February 22-23rd 2016
Athens, Greece

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NATO OTAN

This project is supported by:

The NATO Science for Peace and Security Programme

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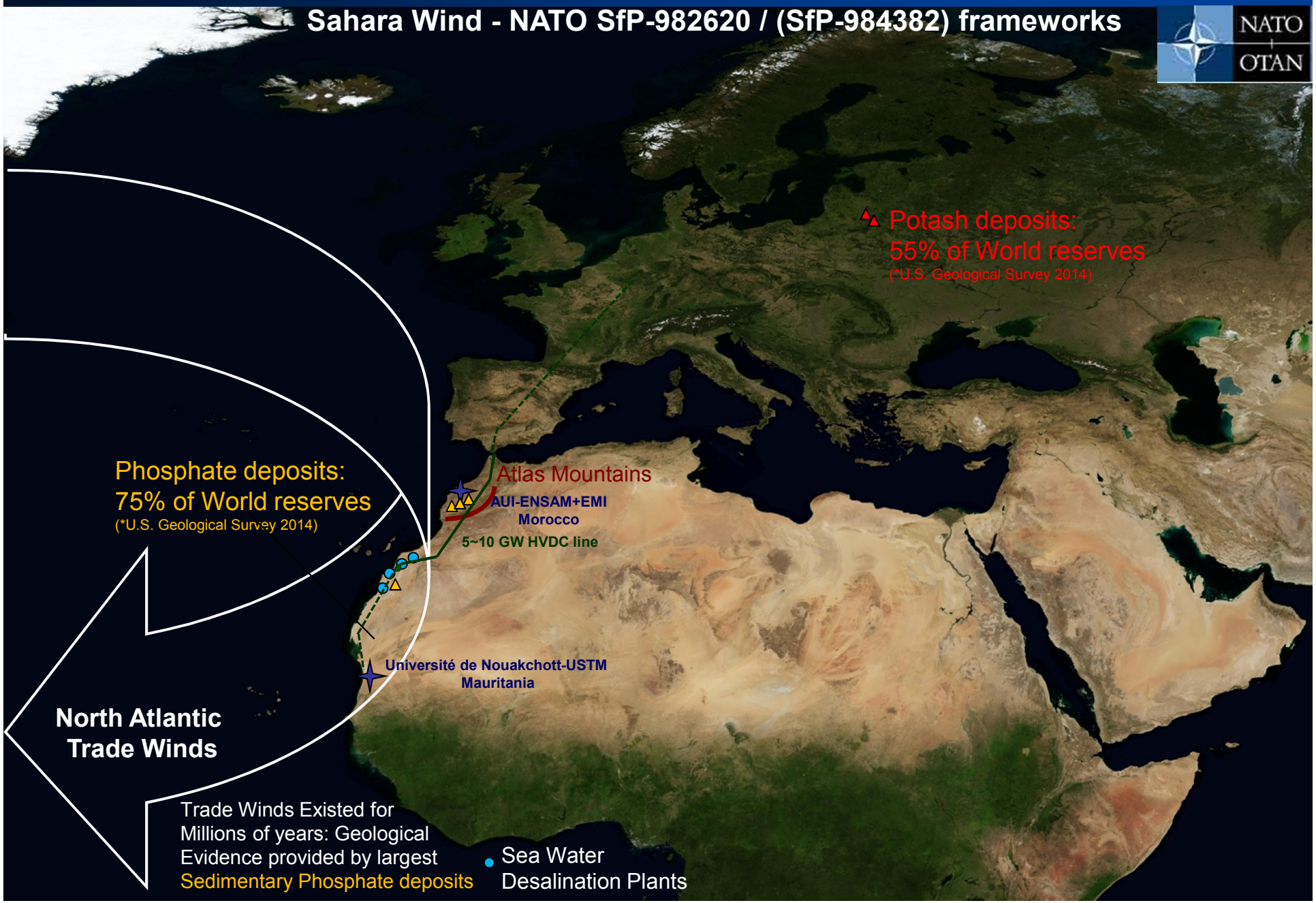
Sahara Wind - NATO SfP-982620 / (SfP-984382) frameworks



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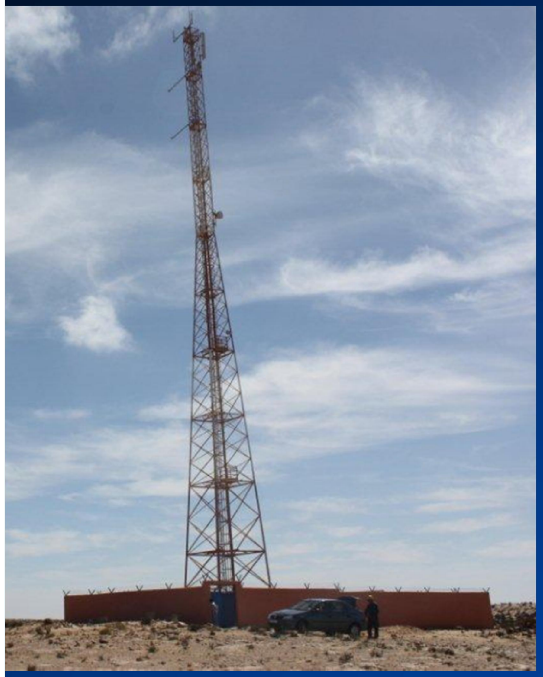

Partnerships with Telecom Operators of Morocco and Mauritania

Mast Measurements at 70, 50 and 40 meters height

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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…

NATO SfP- 984382 Project Plan: Rabat ONEP-IEA Institut International de l'Eau et de l'Assainissement - Station de traitement complexe Bouregreg - Direction Générale (ONEE) 'Green Corporate Centre' Training/Demonstrator (EMI-Rabat)

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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).

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NATO Science for Peace SfP-982620
Integrated Electrolysis End-User Market Application

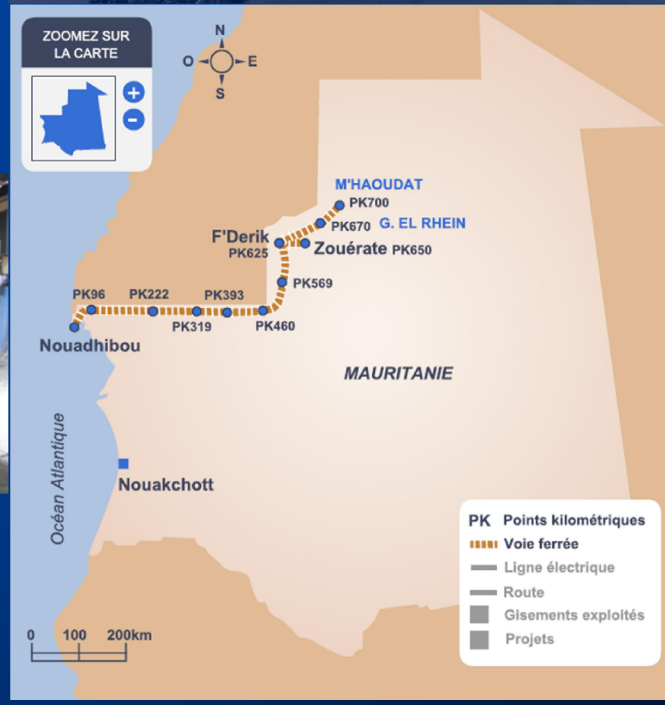
Wind speed: Measured through NATO SfP-982620/(984382)
Wind-Electrolysis for Electricity, Hydrogen,Oxygen

Case Study: SNIM foundry (SAFA company)
Nouadhibou Installed Capacity: Diesels (15+18)+4.5 MW Wind
SAFA power needs: Electric Arc Furnaces: 3 MW + Oxygen plant + Induction Ovens : 2 MW
Objectives for Pilot Project:

- Wind Turbine(s)
- Alkaline Electrolyser
- Hydrogen, Oxygen storage
- FC, ICE-generator (backup power)

SAFA (2 000 t/yr) supplies local needs for construction iron, cast-iron spares, fishing industry, etc.

Potential perspectives: 16~40 Mtons iron-ore annual exports can be processed into higher value iron/steel products (CO2 free) in a high Wind-penetration system.



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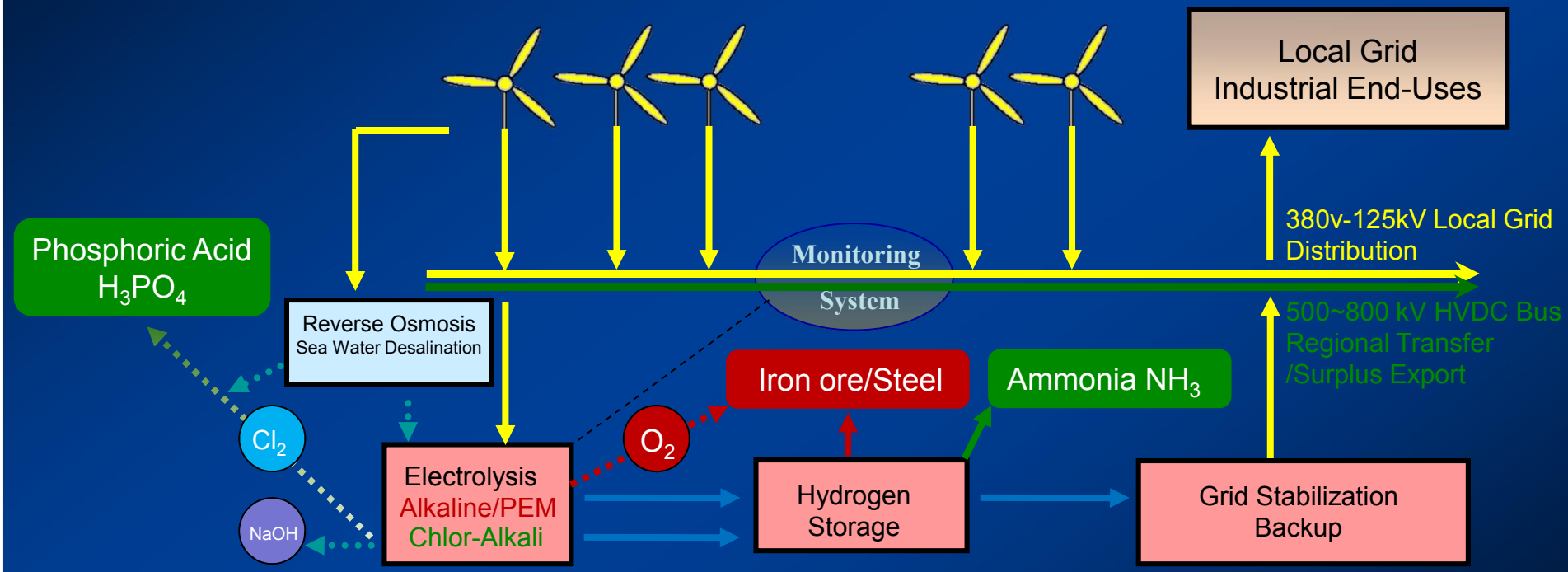
Sahara Trade Winds Powering North-Africa's Major Phosphates (Fertilizer) & Iron-Ore (Steel) Industries



Processing of Phosphates (Morocco)
World Market shares: Phosphate Rock 33%, Phosphoric Acid 47%, Fertilizers 20%

Processing of Iron-Ore (Mauritania)
16 MTons (Actual) 40 MTons by 2025, large Reserves

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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)
- Mauritania's iron-ore markets split between Europe and China
- EU-markets environmental constraints dusts emissions (pre-processing required)
- Endogenous, scalable Direct Reduction Iron into steels & pure-ore exports:
  - Alkaline Wind-Electrolysis: Hydrogen feedstock for Direct Reduction Iron (DRI)
  - Hot Direct Reduced Iron fed into Electric Arc Furnace: Energy efficient Steels
  - Oxygen burned in Electric Arc Furnace, low operating costs (~45% World Steels)
  - Smaller in capacities direct-reduced iron plants enable firming of wind-electricity.
  - Suitable for developing countries with limited supplies of coking coal

  ⇒Creation of a high-grade, sustainable, carbon-free steel industry

Testing, training and capacity building at University of Nouakchott, wind measurements for pilot project sites.

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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 (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 energy+ Water)

✓Enhanced resource transformation efficiency.

✓Price stability

✓Sustainability: Renewable Energy H_2 storage (feedstock & energy carrier)

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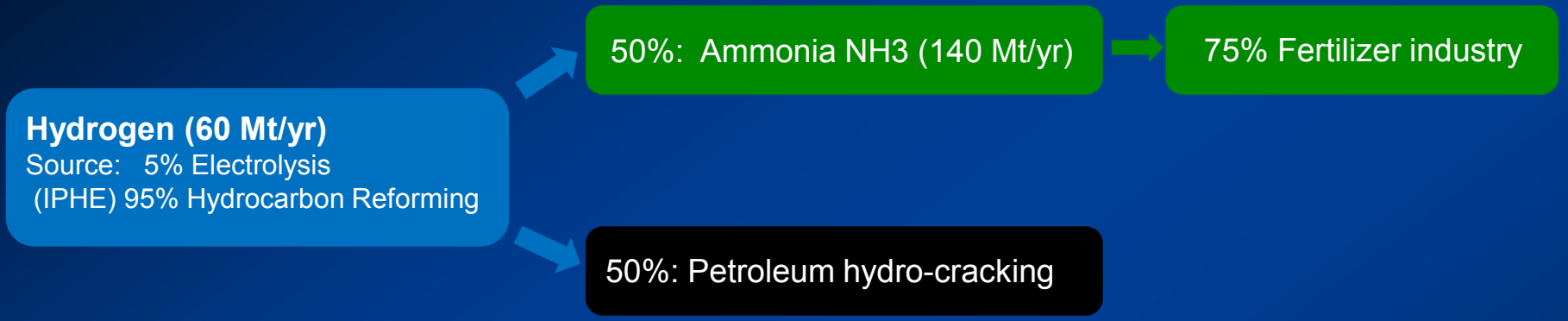
Hydrogen is key Renewable energy storage medium
Industrial use in the Economy: Ammonia



- Ammonia consumes 2% of World's energy (fossil fuels)
- Fertilizers essential to world food security:
  - 2050: World Population 9.2 billion people (20% less arable land per capita)
  - Climate Change Effects & Biofuels exacerbates the 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.

✓Price stability & improved resource efficiency using 'cost-competitive' wind energy.

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50 MW Operating Foum El Oued Wind Farm

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300 MW Operating Tarfaya Wind Farm

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100 MW Operating Akhfennir Wind Farm

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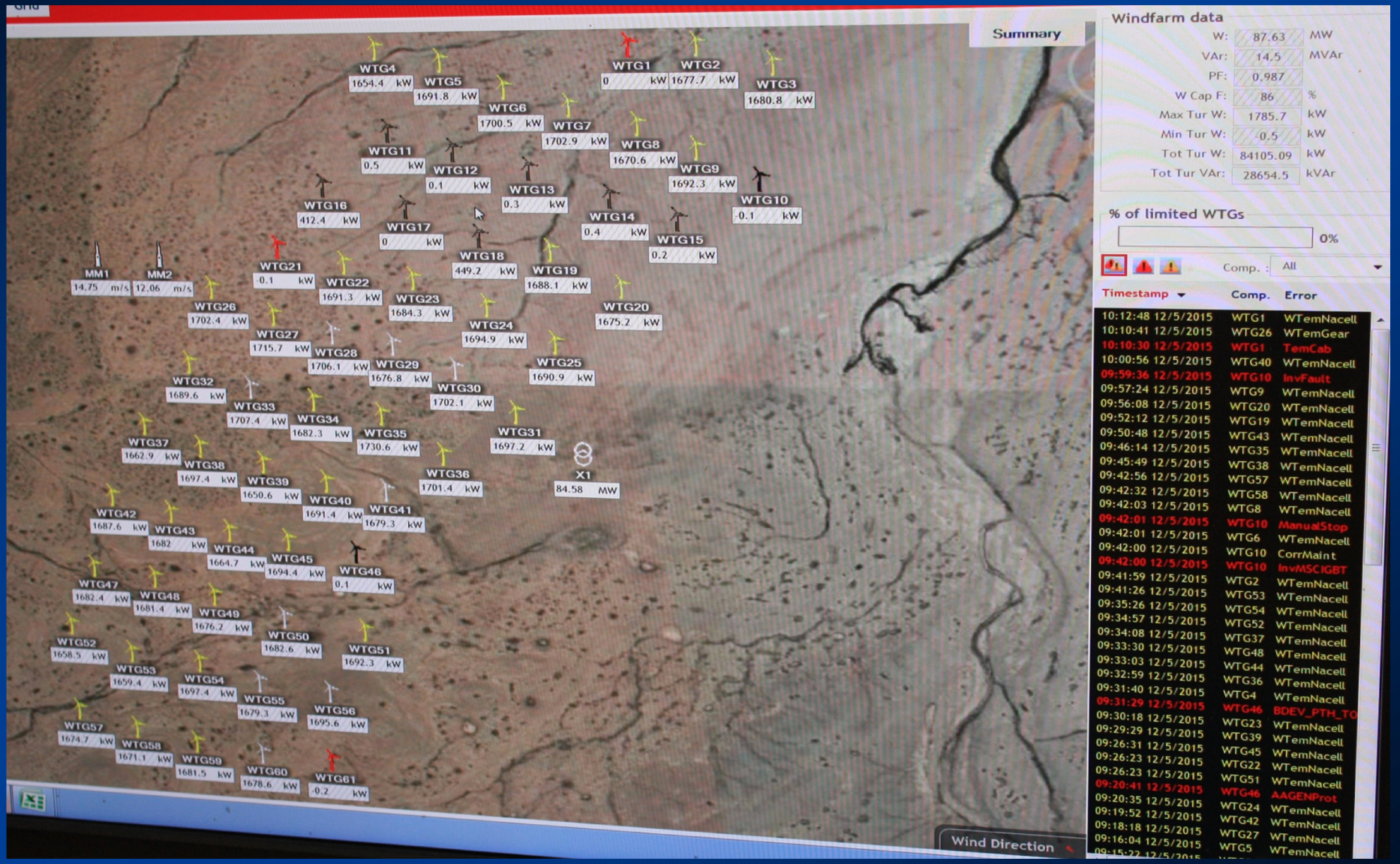
100 MW Akhfennir Wind Farm Instant Power Generation (12.05.2015 11:20)
42°C – East Desert Wind ‘Chergui’



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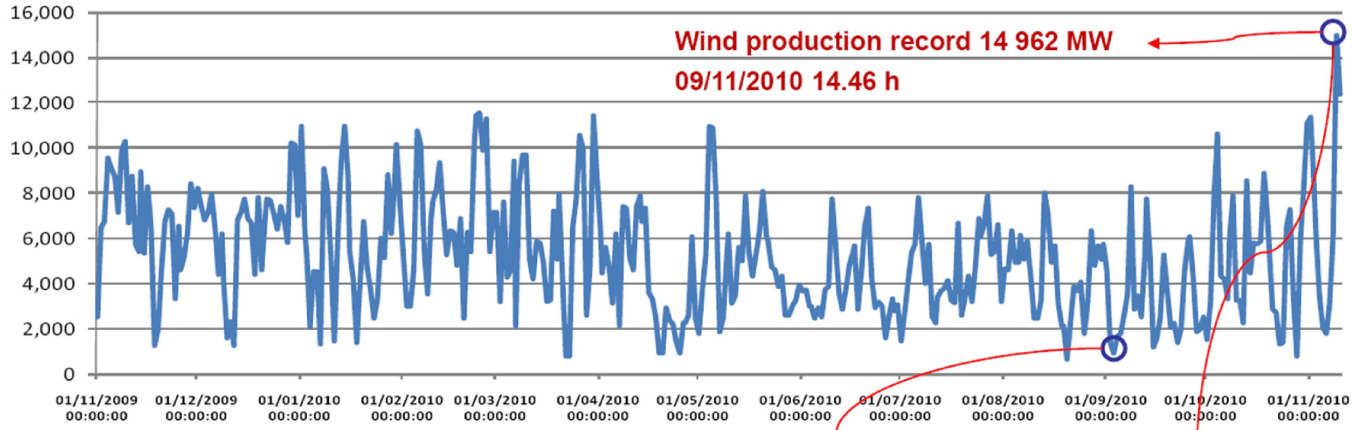
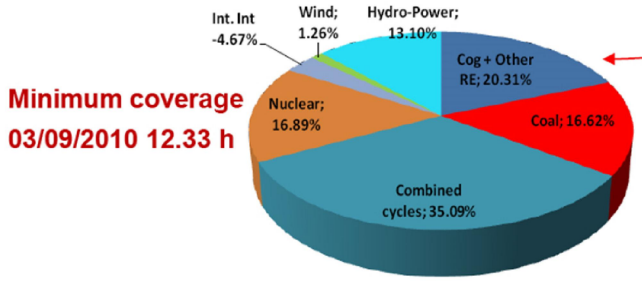
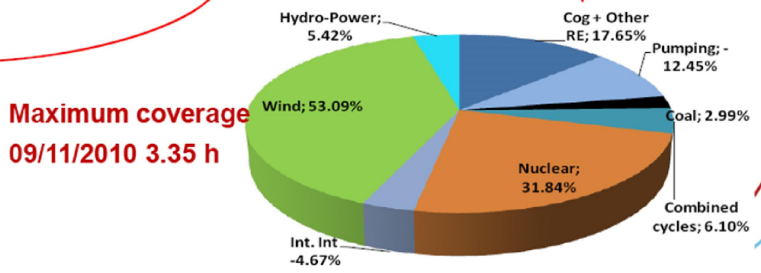
RED ELÉCTRICA DE ESPAÑA

Wind production variability







HYDROGENICS

Not the biggest, most expensive
or most important part of your car

But try driving without 4 good ones!

RED Eléctrica de España: Wind energy is Spain's main source of electricity

North Africa's weaker grids predisposes wind energy to supply growing Steel & Fertilizer industries

- Synergetic processes enables local firming of trade winds.
- Critical to their access for operational power balancing of the Sahara Wind Project's large 5~10 GW HVDC transmission infrastructure.

Sahara Wind Project Fueling a 100% Renewable Energy transition

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

Electrolysis

Gas Tanks

Gas Pipeline - Network

Underground Cavern

Automotive Industries

Natural Gas

Combined Cycle Power Plant

Transmission Grid

Hydrogen

Electric Power

Sahara Wind 1500 km HVDC Line

Sahara Wind-Hydrogen Development Project of the International Partnership for the Hydrogen Economy

Renewable Hydrogen Production

Sahara Wind-Hydrogen Development Project

Morocco and Mauritania

The trade winds that blow along the Atlantic The trade winds that blow along the Atlantic coast from Morocco to Senegal represent one of the largest, most productive wind potentials available on Earth. The same region currently suffers from a limited, decentralized grid infrastructure in need of stabilization. The Sahara Trade Winds to Hydrogen Project aims to utilize these Saharan winds to produce hydrogen in order to enhance the access and integration of wind electricity in Morocco and Mauritania. The project uses a phased approach, beginning with demonstration projects in academic settings to build capacity and knowledge and later moving on to larger projects in industrial settings.

Coordinated by Morocco's Sahara Wind Inc., this project began in the second half of 2007 and is expected to last three years. The project team is composed of 10 partners from Morocco, 8 from Mauritania, and 4 co-directors from the United States, Germany, Turkey, and France.

Objectives

The erratic nature of the trade winds resource means that wind energy cannot provide a sustainable source to the region's weak infrastructure, prohibiting any conventional approach of a continuous feed into smaller local electricity markets. The size of Morocco's grid is also relatively small (~5,000 MW) and cannot handle large amounts of wind-generated electricity before encountering grid stability problems, such as generation intermittency and power margins. These problems escalate further south in Mauritania where the grid capacity is less than 120 MW.

Therefore, the most beneficial approach is believed to be the use of wind electrolysis as a means of grid stabilization within integrated applications utilizing electrolysis by-products such as hydrogen for power storage restitution/backup, or as a fuel or feedstock for specific uses in remote locations.

The Sahara Wind-Hydrogen Project has led to a NATO "Science for Peace" SfP-982620 Sahara-Hydrogen contract aiming to accomplish the following goals:

- Use electrolyzers as a stabilizer in weak electricity grids
- Co-develop wind-electrolyzer systems for local conditions
- Map regional wind resource potential
- Build "Green Campus Concepts" with hydrogen storage
- Develop integrated wind electrolysis applications within the region's industries and load centers

Trade wind resource assessment using telecom tower infrastructures

Project Overview

What

Sahara Wind-Hydrogen Project

Who

Sahara Wind Inc.

When

Started: 2007
Duration: 3 years

Participants

Lead Country
Morocco

Partner Country
Mauritania, US, Germany, Turkey and France

Renewable Technology

Wind

Renewable H_2 Production

This project will demonstrate hydrogen production from wind electricity along with hydrogen storage used as a feedstock for specific industries and hydrogen shipping via pipeline.

Website

www.saharawind.com

Contacts

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Sahara Wind-Hydrogen Development Project

Approach

The initial phase of the project is being carried out through applied research programs in academic settings in order to develop local expertise in the technologies. This is being done through the deployment of wind electrolysis systems within "Green Campus Concepts" programs at several universities in Morocco and Mauritania for demonstration and training purposes. The systems use a series of small 5 kW wind turbines that simultaneously provide power to the grid and to a 30 kW pressurized alkaline electrolyzer. The electrolyzer produces hydrogen, which is then stored in cylinders at a pressure of 12 bar and used in a 1.2 kW fuel cell to produce electricity and stabilize the grid at times of low wind speed.

After being initiated at the universities, the technology will gradually be extended to the region's industries. Current plans are to install demonstration systems followed by larger pilot projects at Morocco's water and electric utility's corporate headquarters and main water treatment plant, as well as at the Tarfaya desalination plant. These systems will consist of small wind turbines powering hypochlorite (membrane) electrolyzers. The hydrogen is stored and used in a fuel cell and internal combustion engine generator for back-power, as well as being used as fuel for electro-mobility applications. A similar project using alkaline electrolyzers and wind turbines will be put in place at Mauritania's iron ore company in the city of Nouadhibou.

Accomplishments

Small wind turbine industrial engineering programs have been established at several universities, enabling development of the technological expertise that will be needed to support the planned and future demonstration projects.

The project has also enabled a wind monitoring infrastructure to be deployed in both Morocco and Mauritania with the help of the project's industrial partners. Both of the telecom operators in Morocco and Mauritania have made their telecommunication mast tower infrastructures available for this project, enabling a regional wind mapping network to be established. Atmospheric parameters such as pressure, temperature, humidity are being recorded in addition to wind direction and speed on International Measuring Network of Wind Energy Institutes (MEASNET) calibrated instruments at several tower heights. The wind mapping network is expected to facilitate future utilization of the area's trade wind resources by providing specific information about the quality of the resource over large geographical areas, thus enabling projects involving utilization of hydrogen to be deployed as part of a large-scale, integrated system using high voltage direct current (HVDC), local use of hydrogen, and hydrogen pipelines for export.

Future Plans

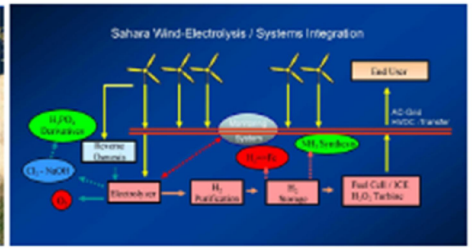
The wind and electrolyzer equipment for training and applied research purposes will be put into operation in early November 2010 at the Al Akhawayn University of Morocco and the University of Nouakchott in Mauritania. These systems will be gradually updated to increase their wind generation capacities, with a goal of providing system stabilization of up to 30% of base load.

Other small, wind-turbine test benches are being delivered to the Ecole Nationale Supérieure d'Arts et Métiers (ENSAM) School of Engineering in Meknes, Morocco, and will be installed in late 2010. The technical economic analysis for end-user pilot project applications has already been completed, including technical equipment configurations.

In the future, the project plans to partner with the region's industries representing the main local energy loads to build an integrated energy system complementary to Sahara Wind's High Voltage DC Transmission project. This system will use hydrogen storage and hydrogen shipping via pipeline. By enhancing the local ownership of wind resources on a regional basis and supporting industrial use of local mining resources using cleaner more sustainable processes, such a system could potentially serve as a secondary power source to both North Africa and Europe.

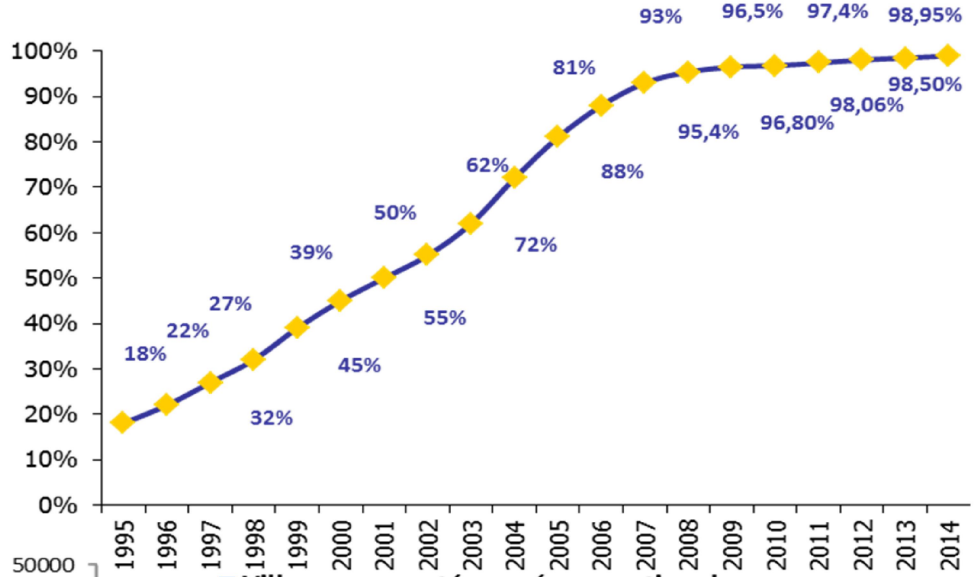
Ultimately, project participants would like to see this project enhance the integration of an end-user-driven, comprehensive, sustainable, applied research program. This is likely to lead to the adoption of a holistic, integrated approach to renewable energy technologies in North Africa.

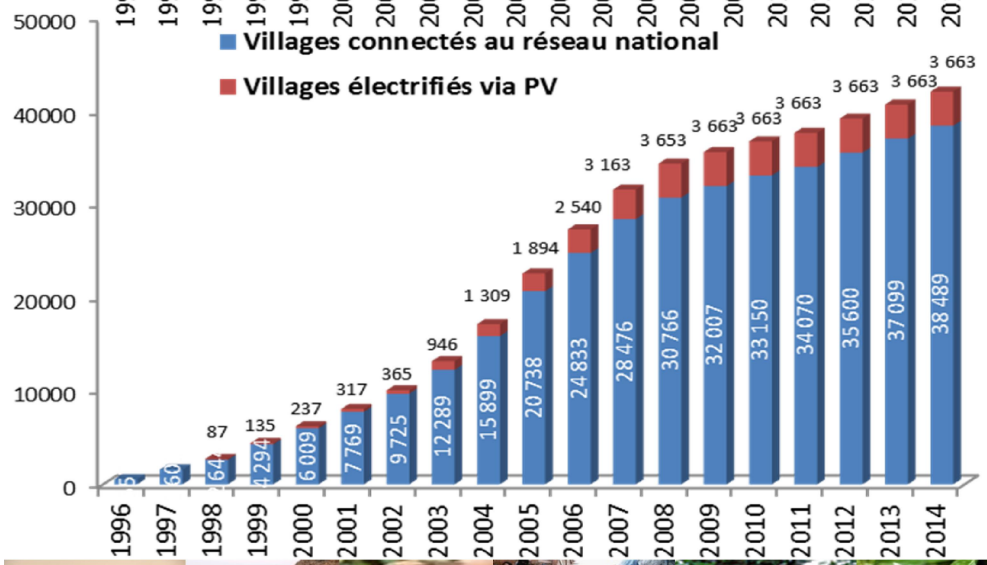
Map showing the locations of two of the university projects (left). Schematic of Sahara Wind wind-hydrogen system (right).



RURAL ELECTRIFICATION PROGRAM

A huge effort in term of access to electricity……





- **Electrification rate: 99%**
- **38 489 villages (3 663 villages photovoltaïques Kits)**
- **More than 12 million citizens**
- **Investing more than 23 billion of MAD (≈ 3 billion USD)**
- **Creating of 100,000 jobs**

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Political will: Morocco‘s 100 DH currency note