Sahara wind

The Sahara Wind Project: A Regional Catalyst for Renewables

Maghreb/Middle East Renewable Energy Summit
18th of October 2010, Marrakech, Morocco

Khalid Benhamou
Managing Director - Sahara Wind Inc.

Dr. Hermann Scheer (1944-2010)

Member German Bundestag, Author of German Feed in Law, Leading Supporter of Renewables Energies Worldwide

Member of the Science & Ethics Committee of the Sahara Wind Project

Died at age 66 (last week on October 14th)

Hermann Scheer's advices, thoughts and plans live on because he succeeded in turning them into tangible results and experiences.

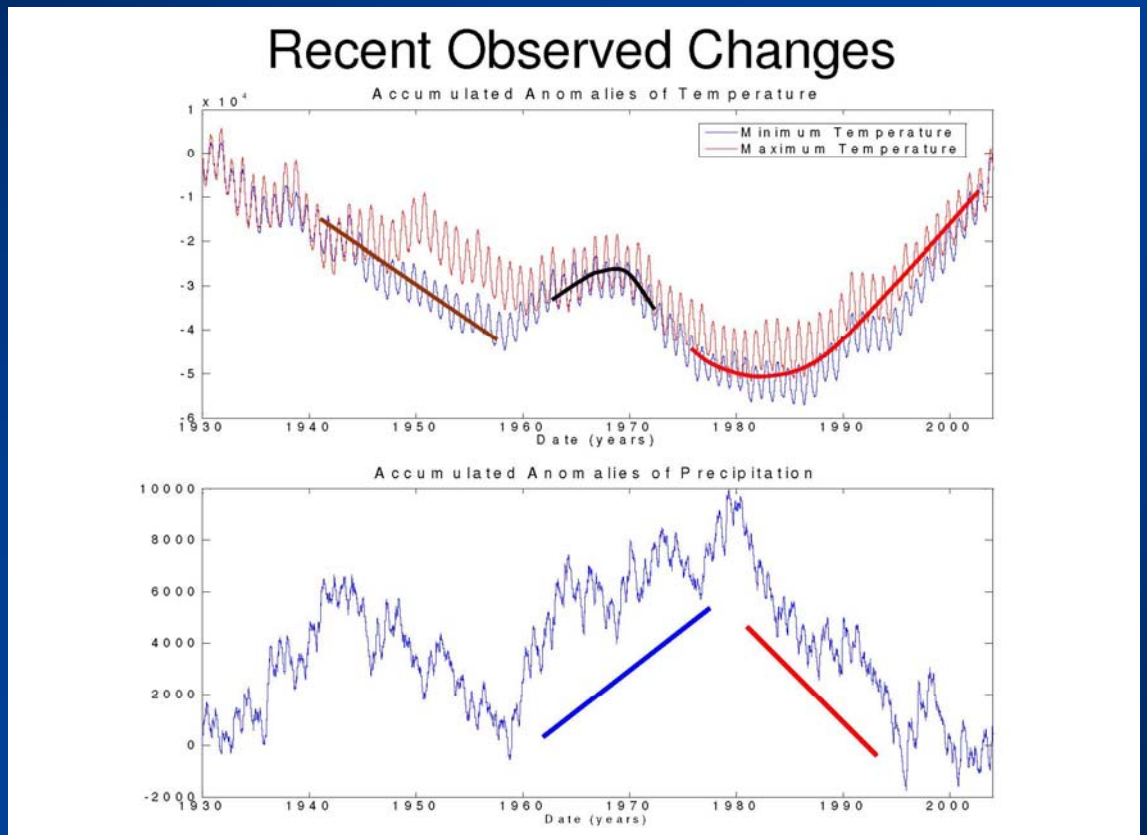
Sahara wind

- Sahara Wind: from Idea to Project -

- **1993:** Wind Measurements Installed (Sahara Trade Wind Region)
- **1994:** Report on Sahara Trade Wind Energy Potential (H.M. King Hassan II)
- **1994-97:** Wind-Diesel-Hybrid System with Distribution Grid: Test Site with Integrated Variable Loads Applications (Tiniguir Site)
- **1997-1999:** Discussions at EU-Commission/Parliament over Export of Wind Electricity to Europe (Sahara Wind Project)
- **2002:** Creation of Sahara Wind Inc. dedicated to Sahara Wind Project Presented at European Parliament (2002), USA -Africa Ministerial (2002)…
- **2003-2005:** Joint World Bank-AfDB UNDP/GEF PIMS #3292 "Morocco Sahara Wind Phase I / Tarfaya (400-500 MW) On-Grid Wind Electricity in a Liberalized Market". Public Private Partnership with Ministry of Energy - Renewable Energy Agency (now ADEREE) with HVDC line & Project Phasing with ONE (Morocco utility) on the base of 5000 MW to supply EU-Mediterranean markets.
- **2005-2010:** Upstream Project Development Activities to support Sahara Wind Project through integrative processes: UNIDO Contract, IPHE (World Hydrogen Project), IEA, USA-Morocco S&T Agreement (with IPR clauses), NATO Science for Peace SfP-982620 Capacity building with Industrial Partners and Academia of Morocco & Mauritania, Pilot Projects with Project Partners.

Security: Climate Change (Different Effects/Consequences)

<u>In the South:</u> Desertification, lack of water, food…. all of which can lead to conflicts over scarce resources



Brunet, M. et. al. (2007), Temporal and spatial temperature variability and change over Spain during 1850–2005, J. Geophys. Res., 112

According to a new report by the EEA (European Environment Agency), Spain and Portugal will be most affected within the EU by coming climate change.

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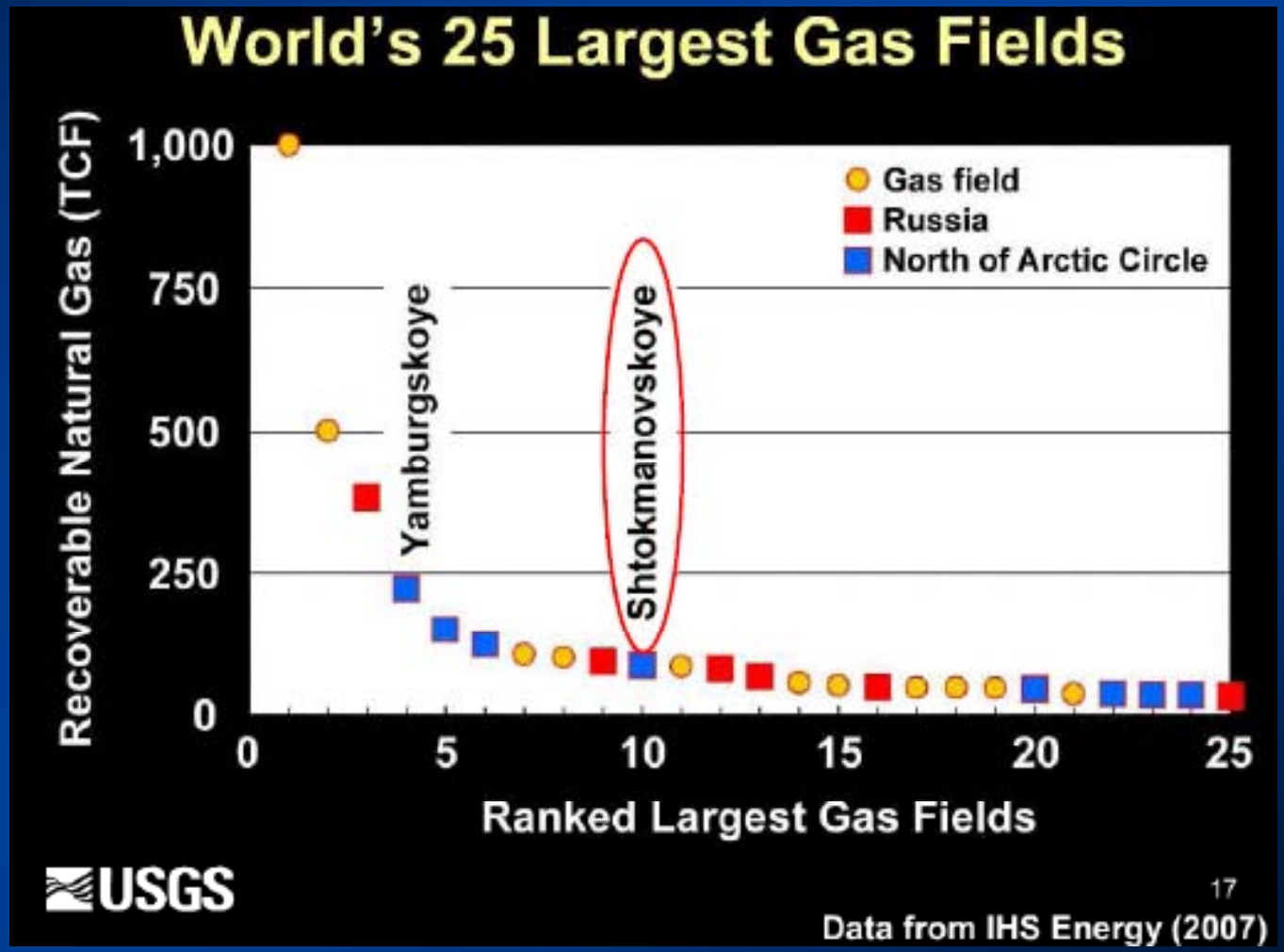
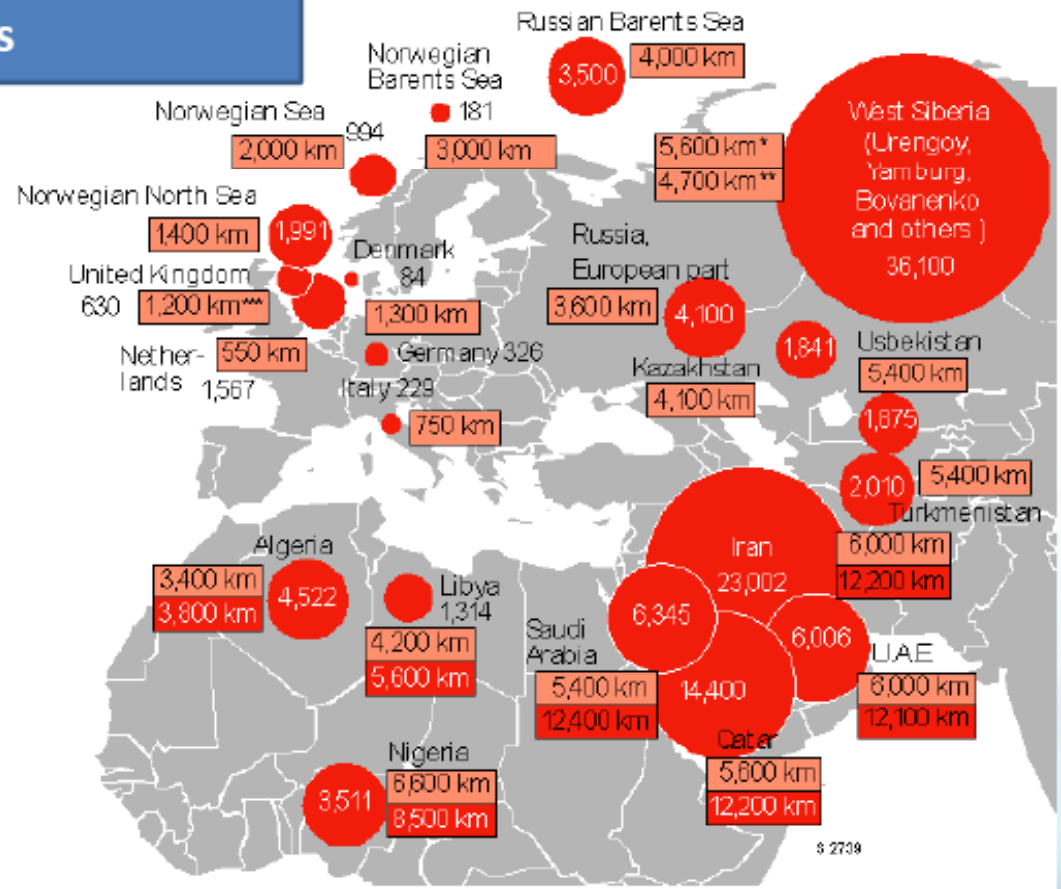
Security: Climate Change (Different Effects/Consequences)

<u>In the North:</u> Melting Arctic ice will open new sea route for navigation and facilitate access to resources among them energy…



euro gas

Natural Gas reserves and supply distances



billion m³

Pipelineto Frankfurt/Main

LNGto Wilhelmshave

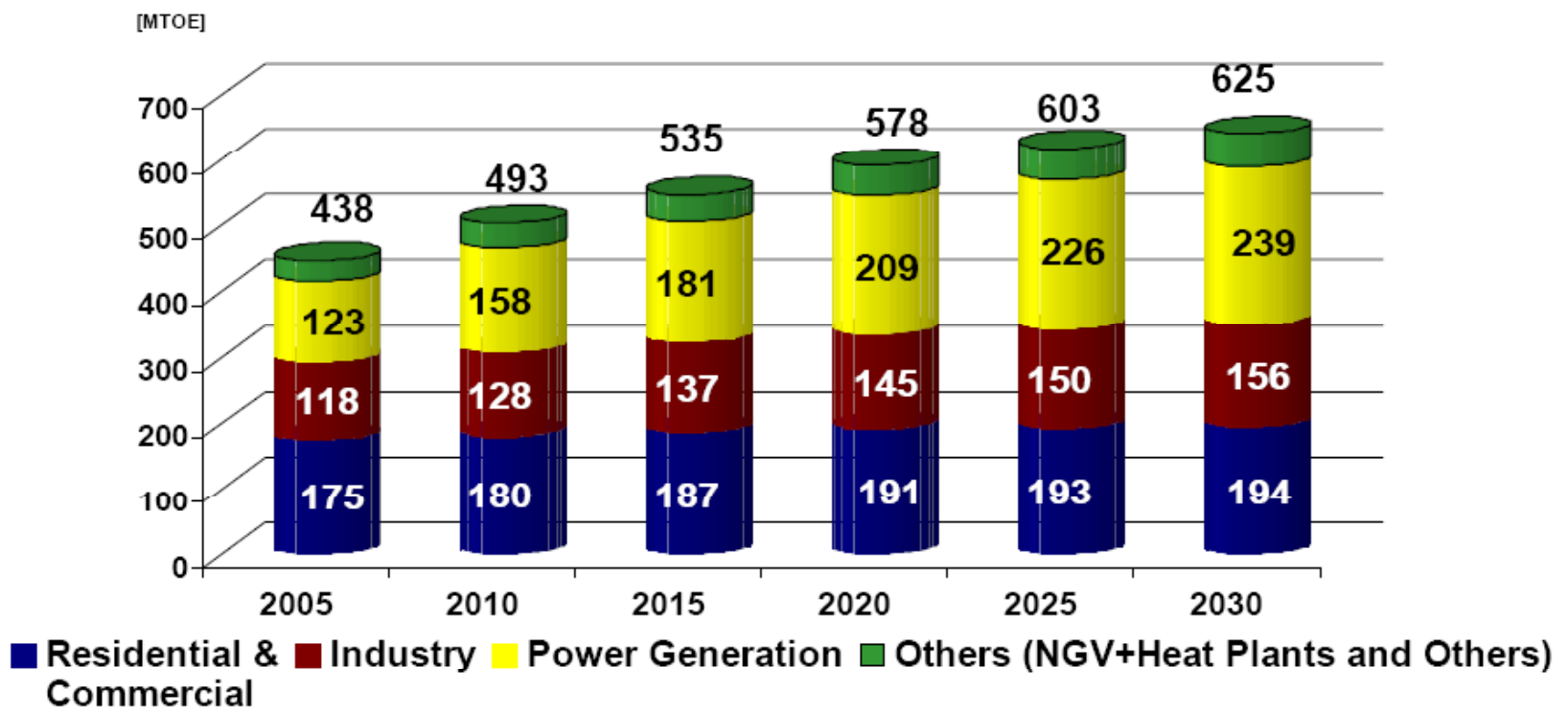
*Yamburg Area
**Yamal Peninsula
***northern area

1 m³ = 11.6 kWh

Source for natural gas reserves: Oil and Gas Journal, Norwegian Petroleum Directorate, others

Source: E.ON Ruhrgas AG

EU27 Natural Gas demand outlook



At 60% of the total demand increase, most of the growth will come from power generation.

Source: EUROGAS

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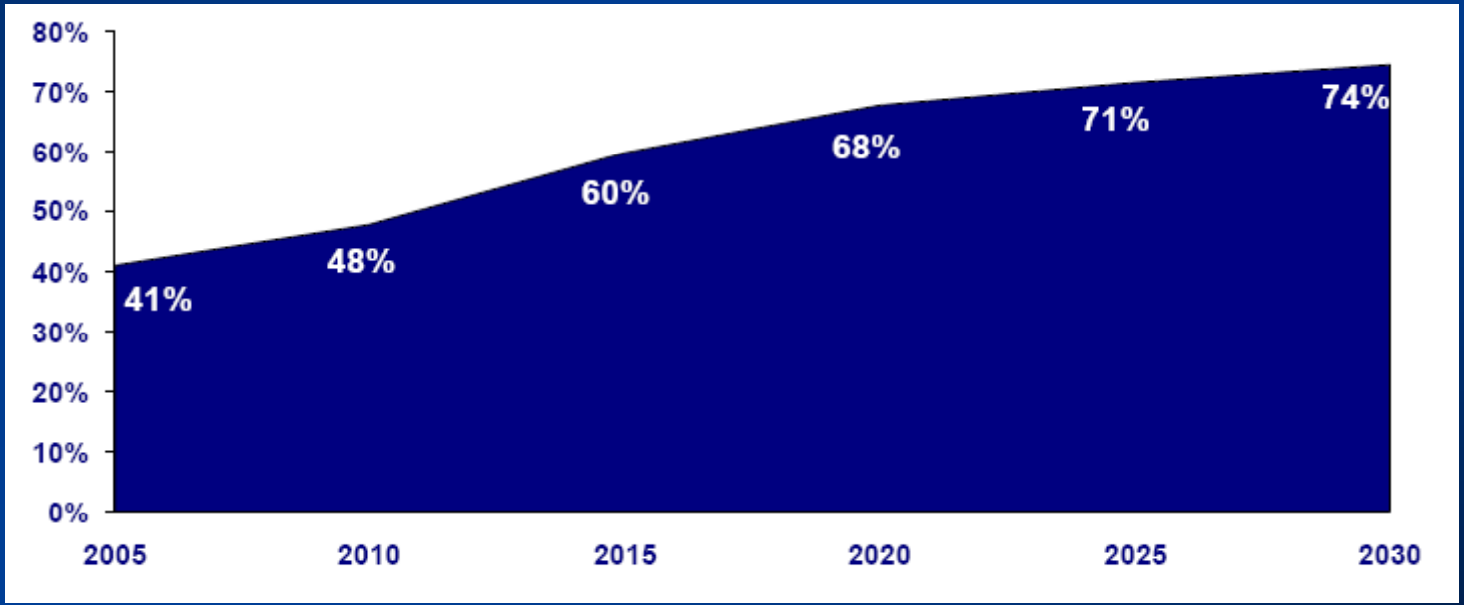
NATURAL GAS DEMAND AND SUPPLY
Long Term Outlook to 2030

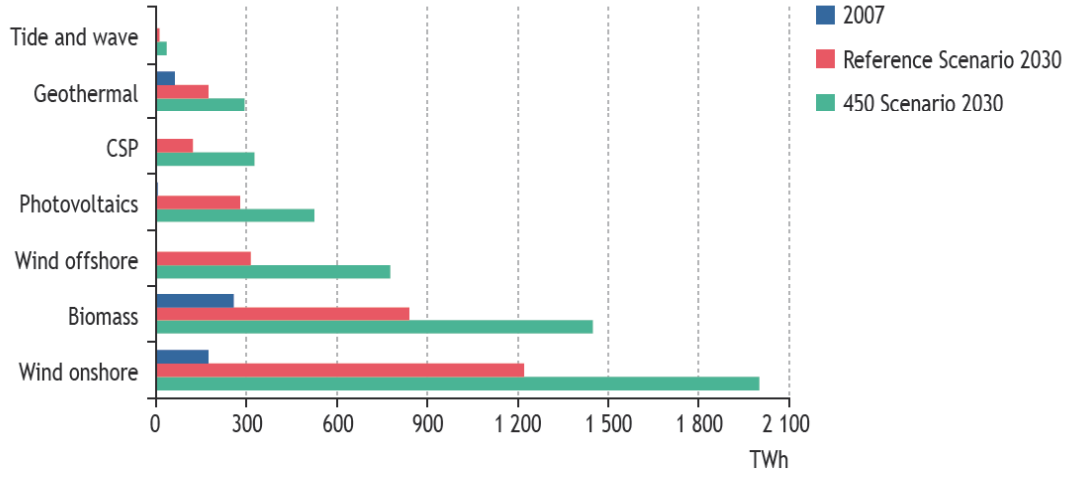
EU27 import dependency from outside Europe



Source: EUROGAS

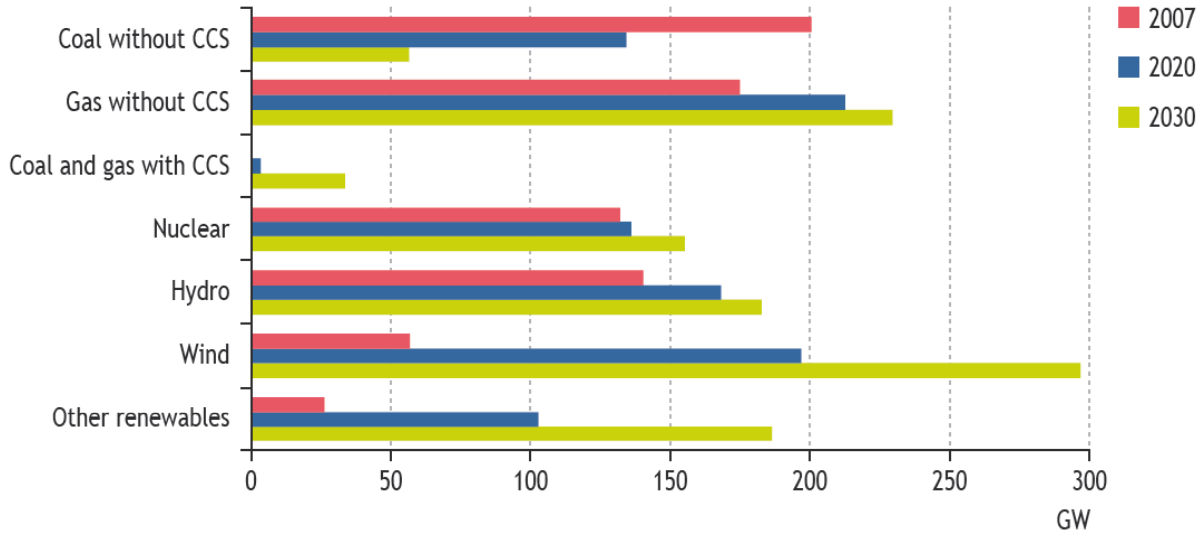
Wind Energy Production Prospects
at
IEA World Energy Outlook 2009
450 Scenario

Figure 5.11 • World electricity generation from non-hydro renewables by type in the 450 Scenario



Note: CSP refers to concentrating solar power.

Figure 9.18 • EU power-generation capacity in the 450 Scenario



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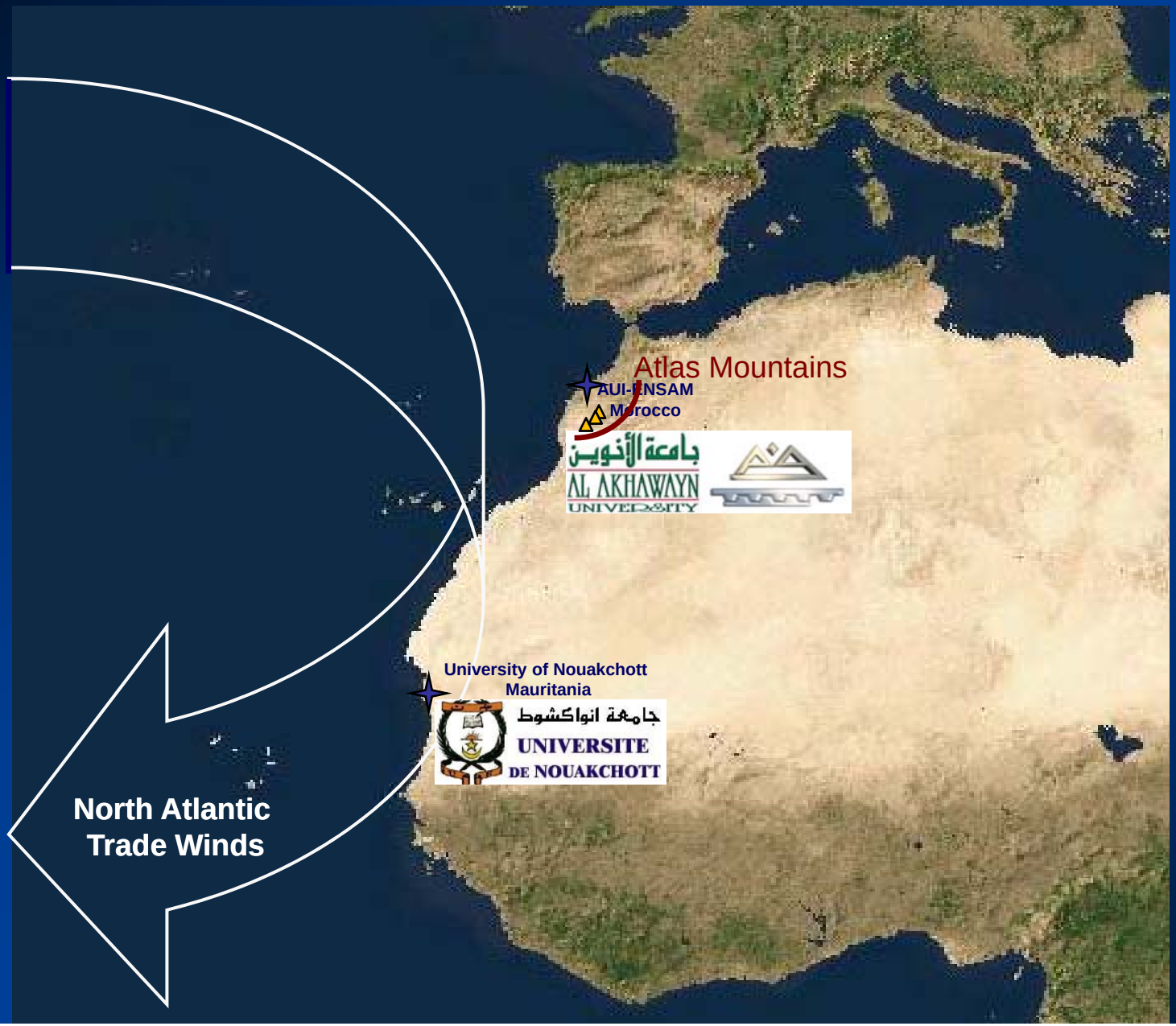
NATO 'Science for Peace' SfP-982620



Trade Winds Existed for Millions of years: Geological Evidence Provided by World's Largest Phosphate deposits

- Phosphate deposits (42% of World reserves)

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Sahara Wind Energy Development Project

Local Energy Access Issue

•The Trade Winds largest, most productive wind energy potentials on earth.

•Wind Energy: Competitive Renewable Energy Technology.
Technical issues with intermittency and grid stability (power margins, dispatching, reactive compensation, voltage, frequency regulation, flickers, harmonics…)

Problems are more acute in weak grid conditions !!!

Saharan Countries Total installed electric generation capacities:

Mauritania 160 MW, Senegal 239 MW, Mali 280 MW, Niger 105 MW, Chad 30 MW…

Unless far ranging, more advanced (flexible) energy technologies are considered
Wind Energy cannot be integrated on any significant scale (locally).

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Wind Energy, Capacity Building and Energy Access

A strategy has to be developed for integrating Wind/RE technologies.

Potential risks of not deploying a strategy: Grid quickly saturates to Wind Energy (small grids!)

Wind Energy Integration through Local Synergies : Academia /Industry Partnership

- Co-Develop Integrated RE Processes (Regionally)
- Capitalize on Available Human Resources at Academic & Research Institutions
- Bottom-up Capacity Building, Prevent Technology Gaps from Widening
- Develop Research Networks Sensitized on Issue
- Enhance Local Ownership of Resources to Support 'Proof of Concepts'
- Stimulate Wider Regional Cooperation (EU 20-20-20, IPHE, IEA , bilateral S&T agreements…)
- Support a Global Transition Towards more Renewable Energy Technologies and their Related Economies

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REGIONAL CAPACITY BUILDING
NATO 'Science for Peace' Project Coordinated by Sahara Wind Inc.

Security Issue: Mitigate Effects of Climate Change - Fixing Migrant Population
- Priority Research Areas of Mediterranean Dialogue Countries Partners of NATO
- NATO's New Strategic Concept: Emerging Threats (Lisbon Conference)

Integrating Wind Energy is a Key Priority for **Morocco** & **Mauritania**:

- Enhance Role of Education and Research in National Energy Choices
- Mobilize Largest Energy Consumers (RD&D programs)
- Support Development of Integrated, Sustainable Industries (GEF, CTF, CDM...)
- Develop Scientific Competence in Securing Intellectual Property Rights of Applied Research Groups (NATO Intellectual Property Rights Committee).
- Complementary Working Teams through Science for Peace Project Platform on a Regional Level (Morocco & Mauritania) Academic and Industrial network

Technology – University/R&D Platform – Industry

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NATO SfP-982620 PROJECT OBJECTIVES
Develop Synergies with Industry

Wind Resource Assessment:

Mauritania: Partnership Between University of Nouakchott and Mauritel

Morocco: Partnership Sahara Wind Inc. and Maroc Telecom

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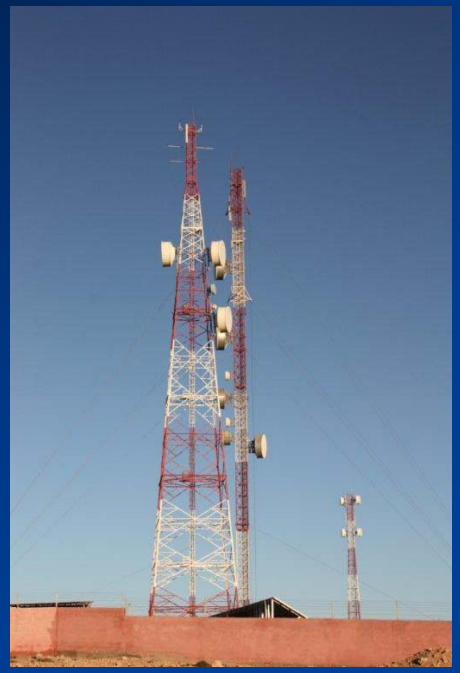





Secured Data Collection

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Mast Measurements at 70, 50 and 40 meters height

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Small Wind Turbine Manufacturing Program

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Small Wind Turbine Technology for Local Manufacturing

Identified type of Equipment (Small Wind Turbine)

- Technology used and reliability interests/potential
- Quality materials and design
- Costs

Collaboration with Equipment Manufacturer

- Thorough Evaluation of local integration possibilities
- Design & construction (SWT parts)

Install wind turbines in test benches

Gain Expertise on Systems integration

Deployment

- ✓Green Campus concepts (Al Akhawayn, Univ. of Nouakchott…)
- ✓Telecoms (Maroc Telecom / MAURITEL)
- ✓Distributed Electrification Solutions (ONEP/ONE-PERG/APAUS…)

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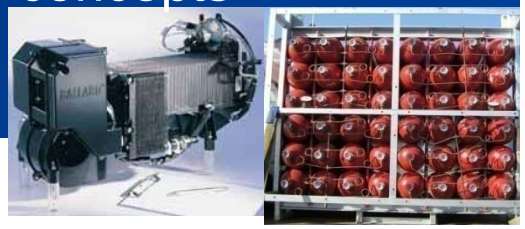
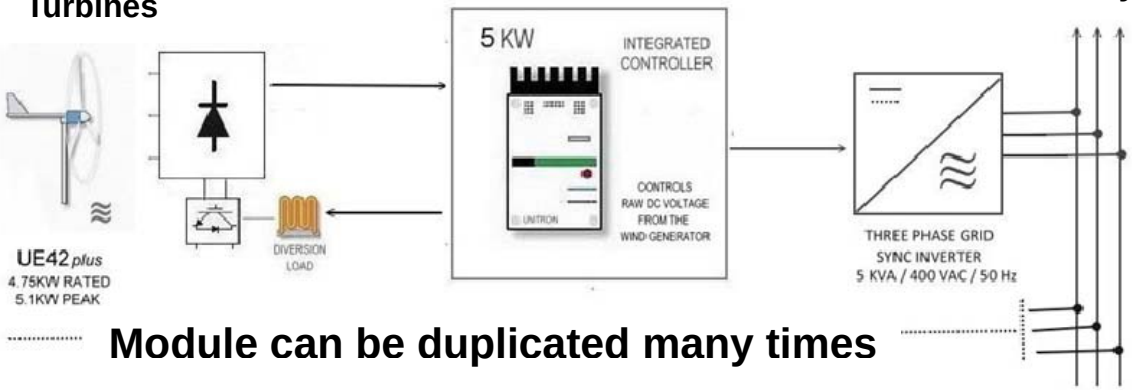
NATO SfP-982620 Renewable Hydrogen Storage Technologies within "Green Campus" concepts



Small Wind Turbines

To Electrolyzer



Module can be duplicated many times

NOTES

1) The variable AC voltage from the wind generator is converted to DC, controlled with a band before feeding to inverter
2) The inverter will be current fed Grid sync type with three phase output
3) The inverter will feed power generated wind generator into three phase stabilised line that supports electrolyser

Local 3 Phase Power Supply 400 V AC 50hz

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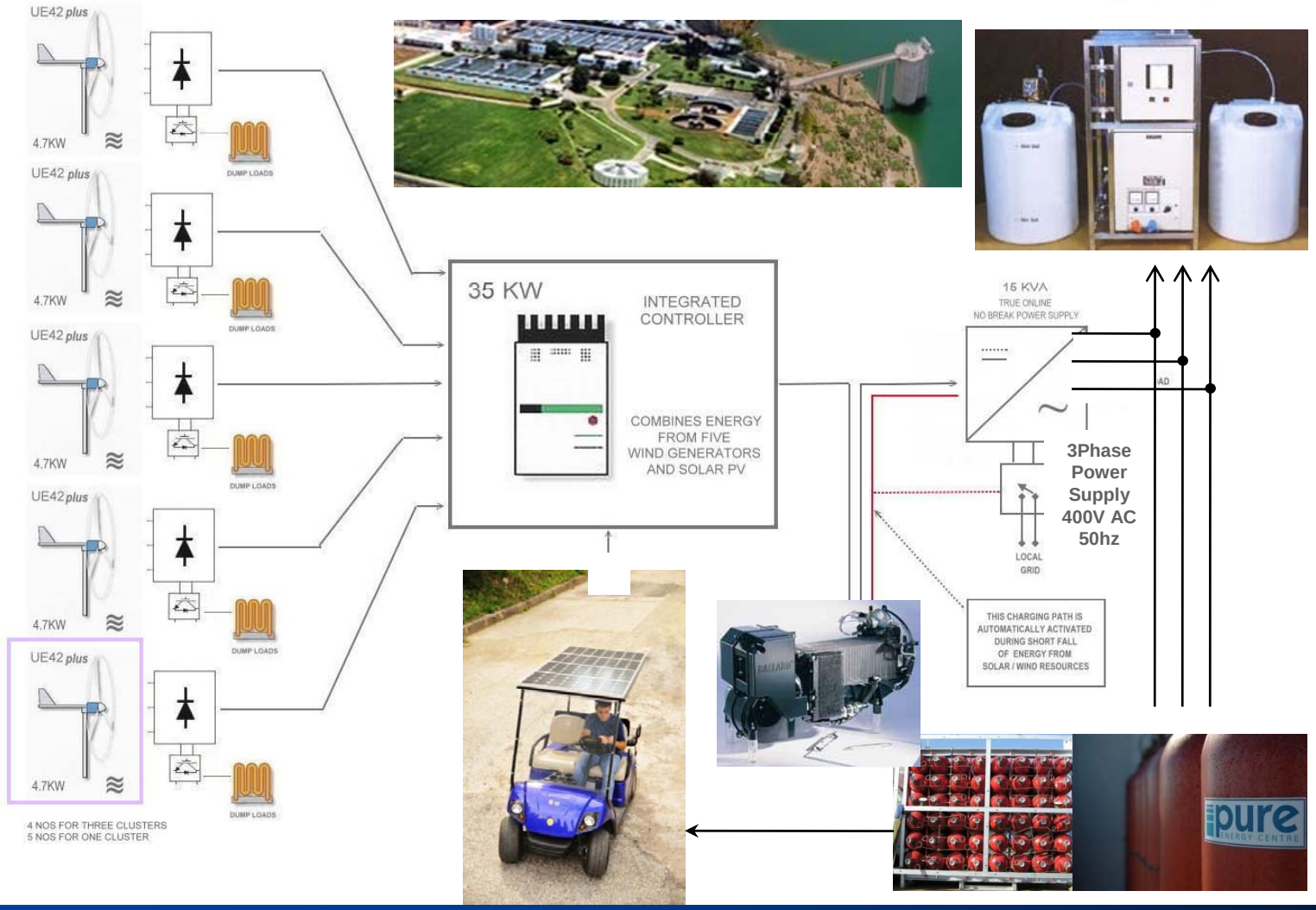
ONEE/ONEP-IEA Green Corporate Campus



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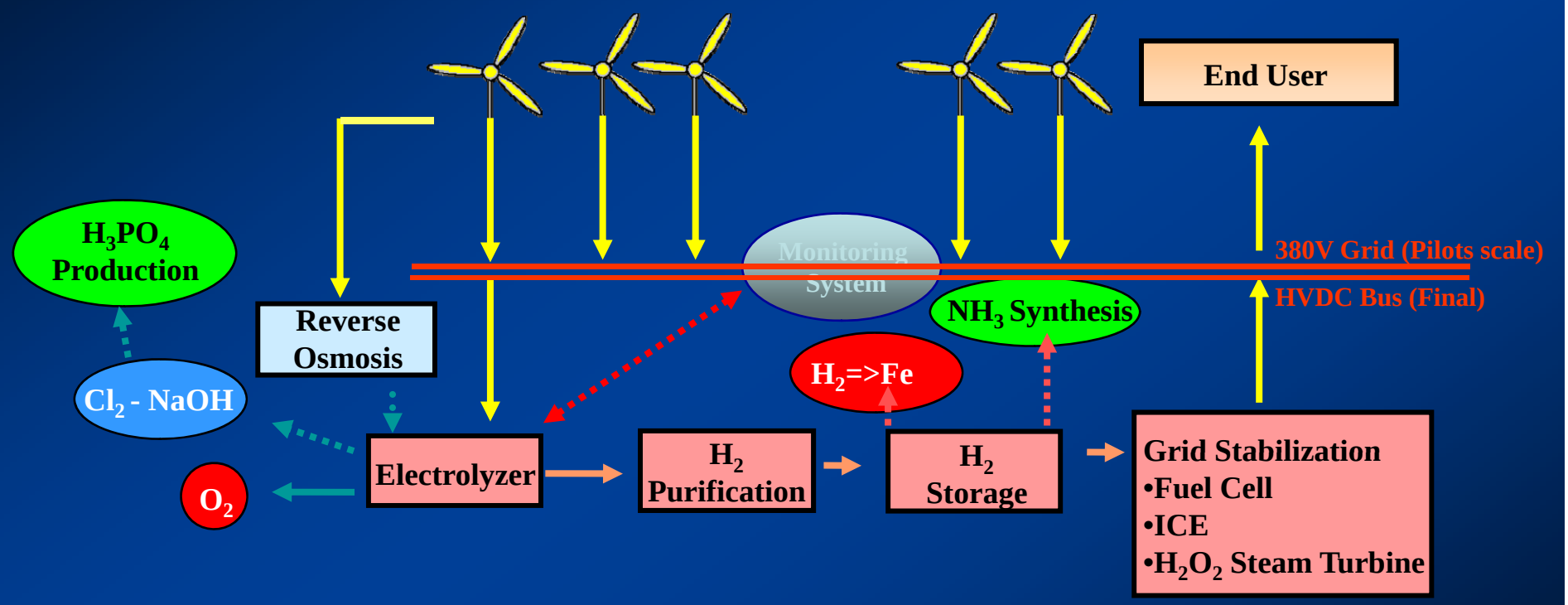
Integrating Sahara Trade Wind Resource into Centralized Grids
Sahara Wind-Industrial Electrolysis Systems



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

Wind speed: 7.5 m/s On-site (Measured through NATO SfP-982620 in Tarfaya)
Wind-Electrolysis for Electricity, Hypochlorite and Hydrogen

ONEP Morocco (767 millions m3 water/yr)
1- Rabat ONEE (ONEP-ONE) corporate headquarters at water treatment plant
'Green Corporate Campus' concept (Demo-Training)

- Small Wind Turbines
- Hypochlorite (Membrane) Electrolyzer
- Hydrogen storage
- Fuel Cell (Grid backup+ Eco-mobility Demo)

2- Tarfaya ONEP desalination plant

- Larger Wind Turbine(s)
- Hypochlorite (Membrane) Electrolyzer
- Integrated processing industries

Perspectives: Water sanitation, treatment
Mine Processing Industries in Sahel regions …

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IPHE

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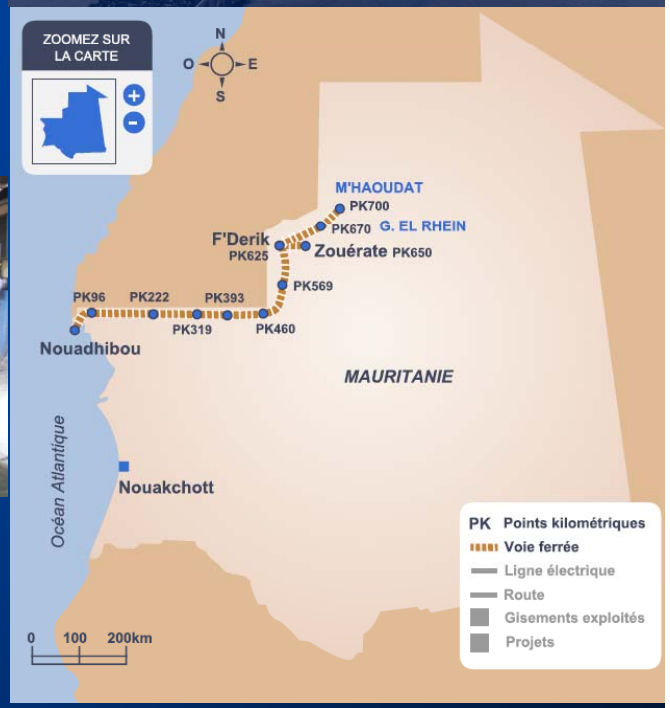
NATO Science for Peace SfP-982620 / UNIDO-ICHET
Integrated Electrolysis End-User Market Application

Wind speed: 8.5 m/s On-site in Nouadhibou
(Measured through NATO SfP-982620)
Wind-Electrolysis for Electricity, Oxygen and Hydrogen

Case Study: SNIM foundry (SAFA company)
Nouadhibou Installed Capacity: 15 MW + 18 MW (in 2010)
SAFA electricity needs: Electric Arc Furnace: 3 MW + Oxygen plant + Induction Ovens : 2 MW
Pilot Project:

- Wind Turbine(s)
- Alkaline Electrolyzer
- Hydrogen + Oxygen storage
- ICE-generator (backup power)



SAFA capacity (2 000 t) Local needs to supply construction iron, cast iron spares, fishing industry, etc.
Perspectives: 12~16 M.tons iron-ore annual exports can be processed into high value iron/steel products (CO_2 free)

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NATO Science for Peace SfP-982620
Wind-Electrolysis by-products and Hydrogen End-User Markets

Mauritania : Iron-Ore Industry (Alkaline Wind-Electrolysis)

- Hydrogen: Direct Iron Reduction process (DRI) 4% of World's iron production
- Electricity + Oxygen: Steel Production through Electric Arc Furnace (EAF) (used in 45% of World Steel production)

Morocco: Water Utilities & Phosphate Industry (Chlor-Alkali Wind-Electrolysis)

- Hypochlorite (access to water treatment solutions in Sahel regions)
- Hydrochloric acid for Phosphoric Acid derivatives (45% of World Market)
- Hydrogen for Production of Ammonia (Stable storage medium)
    - Integrated fertilizer industry, beyond Phosphate based fertilizers
    - Phosphor-gypsum recycling (12 Million tons/year)

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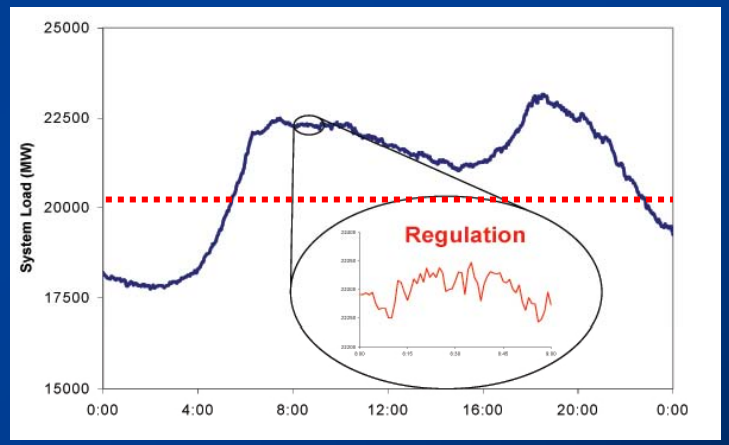
Grid Balancing and Stabilization through Wind-electrolysis

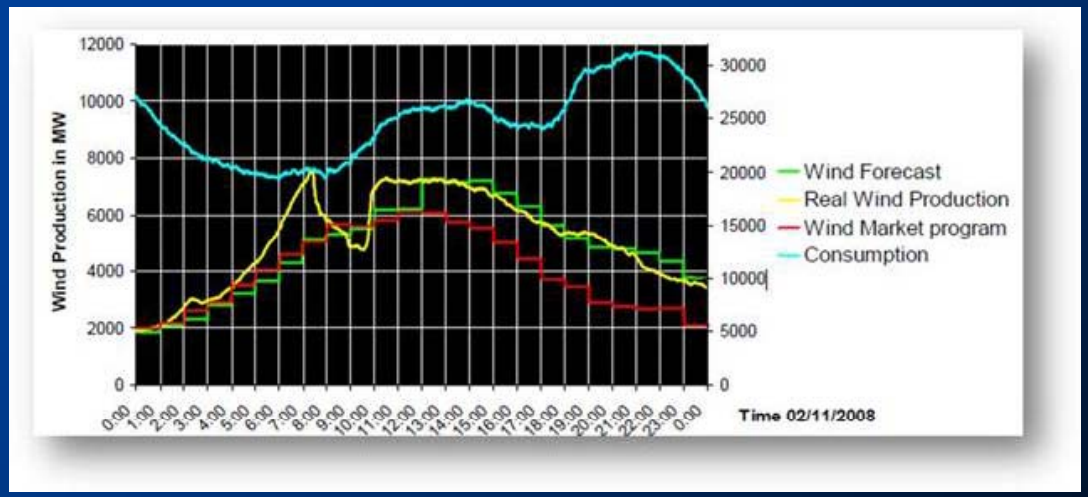
Wind power is erratic, power output fluctuates

Electrolyzers used as grid stabilizers and 'dump loads'



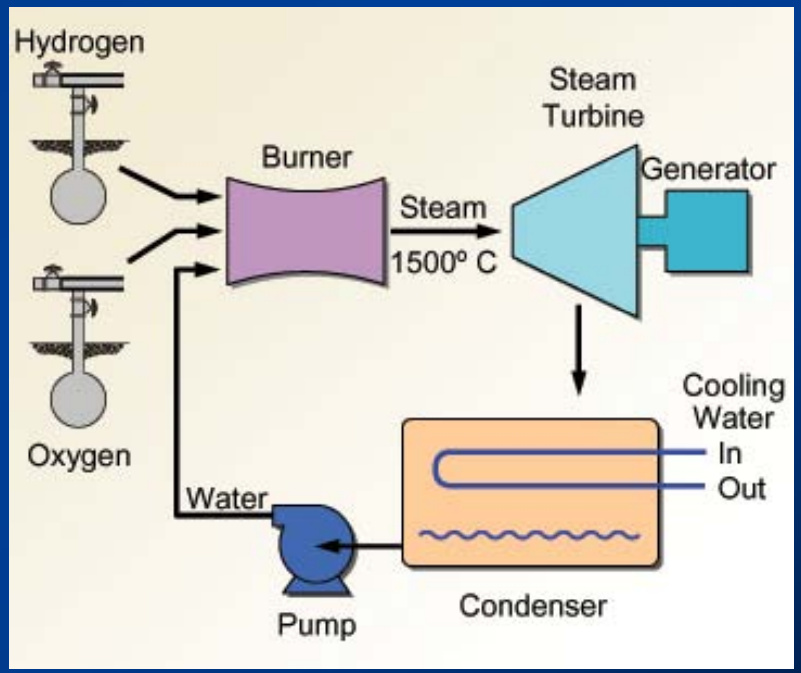
- ✓Power Balancing in Grid
- ✓Eliminates wind fluctuation effects
- ✓Enhances power quality, flickers…
- ✓Frequency control

- ✓Generates H_2,O_2 …
  fuel (transport), feedstock
- ✓Grid stabilization
- ✓Back up (spinning reserve)



Hydrogen-Oxygen Steam turbine

Burning in H2-O2 Steam Turbine
H2 (Fuel) & O2 (Oxidizer) mixture
into Electricity within milliseconds



Frequency response (RE Grid):
- Low investment costs
- Large units 50 MW
- High efficiency 70%
- Extremely fast response (ms)

Integrated Reactive System for High Wind Energy Penetration into Grids
Frequency control, grid stabilization, peak power, spinning reserve, and back-up

Morocco's Wind Energy Objectives

- Before 2012: 280MW (Built) + 720 MW (planned/under construction)

- By 2020: + 1 GW additional (Morocco Wind Energy Program)

Limitation factors: Grid Capacity…!!!

- Total Generating Capacity (6000 MW) / Peak load (3500~4000 MW)
  => Possible Wind Power Integration no more then 2 GW
- Big Wind Potential but Far Away from Load Centers (1000 km)
- Aforementioned Capacity too Small for Transferring Wind Industry

⇒Need to develop an integrated approach:

The Sahara Wind-HVDC Project (5GW)

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Sahara Wind Energy Development Project

Sahara Wind Phase 1: 50~500 MW on existing grid (Extensions through HVDC lines)

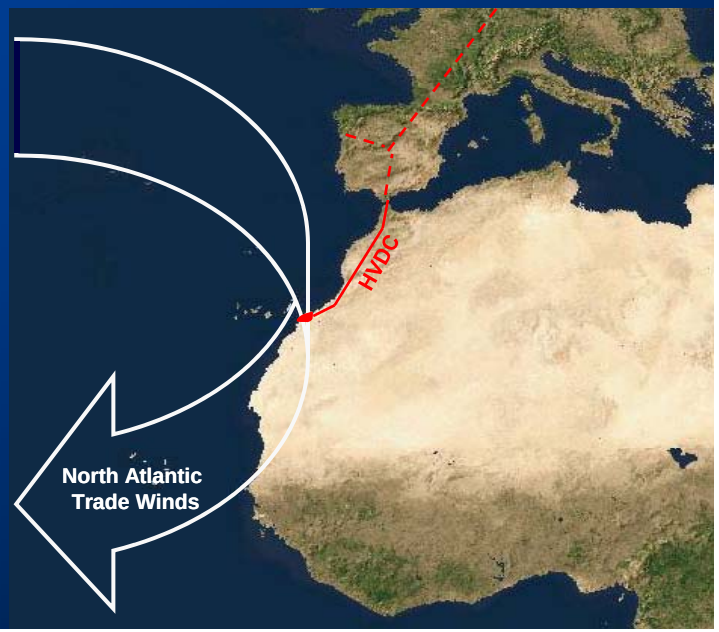
Limited losses –long distance (3% over 1500 Km ±500kV for 5000 MW)

Over 80 GW worldwide in 90 HVDC Projects: India, China, Canada, Brazil..

Euro-Mediterranean electricity market in full growth/expansion

Spain & Portugal (EU Members) ratified Kyoto Protocol
but Current CGH emissions 40~50% above Kyoto targets, highest in the EU

Impressive Wind catchment's area:
-Average wind speed: 8m/s (Trade Winds)
(measured at 9m height)
-Size of Area (Saharan coast 2000 km+
(Morocco, Mauritania & Senegal)
- Potential Wind Energy 500~1000 GW(?)+



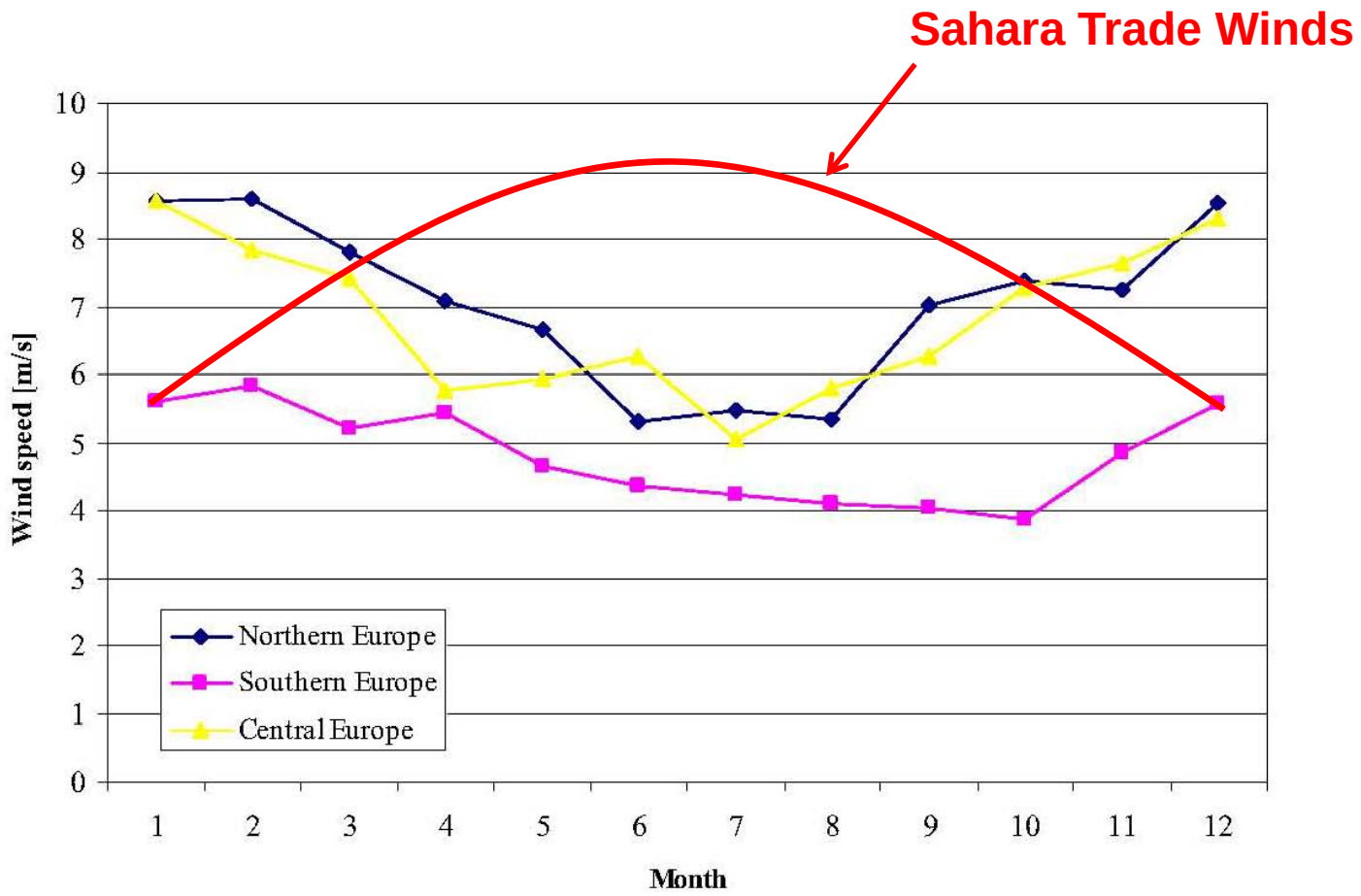
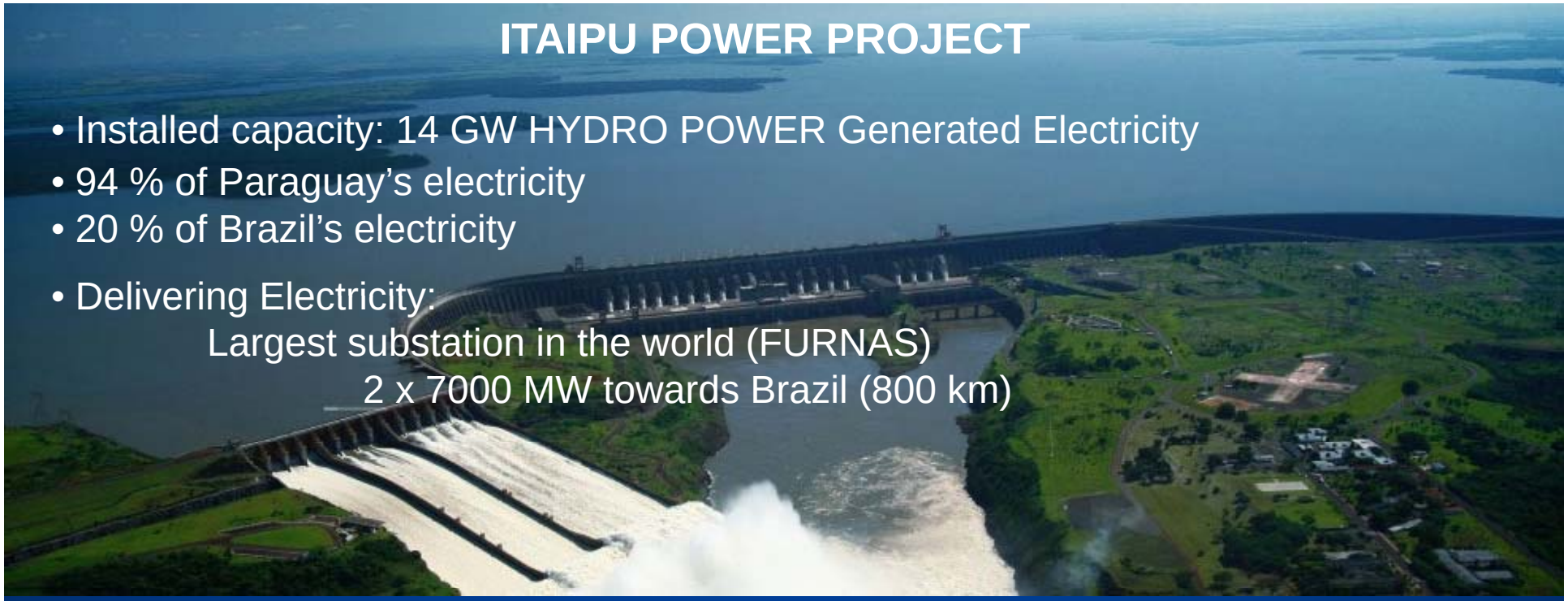


Figure 2.4 Seasonal trends in Reanalysis wind speed

Source: EU funded TradeWind Project, (Document Name: WP2.4; Characteristic Wind Speed Time Series - Document Number: 11914/BT/01C)

ITAIPU POWER PROJECT



- Installed capacity: 14 GW HYDRO POWER Generated Electricity
- 94 % of Paraguay's electricity
- 20 % of Brazil's electricity
- Delivering Electricity:
  Largest substation in the world (FURNAS)
  2 x 7000 MW towards Brazil (800 km)

7 GW at 50Hz: HVDC Technology (losses: 3% over 800 Km ± 600kV DC)
7 GW at 60Hz: HVAC Technology (losses: 5% over 800 Km 750 kV AC)

Costs (1.3 Billion US$) per HVDC & HVAC lines
Beyond 800 Km distance: HVDC only economical solution

- In operation since 1984

- Supplies Power below costs of 2.5centUS$/kWh => Economy of scale
- Project's Total Costs actualized (World's Most productive Hydro Dam): 27 Billion US$

Sahara Wind Project

- Regional Resource Assessment and Capacity Building: NATO SfP-982620
- Mediterranean Solar Plan: 50 MW Pilot Project (small clusters)
- Multilateral Platform: Joint WB-AfDB UNDP/GEF PIMS #3292 “Sahara Wind Phase I / Tarfaya (400-500 MW) On-Grid Wind Electricity in a Liberalized Market” on existing grid
- Grid impact study: Deployment of HVDC line & Project Phasing with ONE (Morocco utility) on the base of 5000 MW to EU-Mediterranean markets.

•5 GW Wind Energy: HVDC Technology (losses: 3% over 1500 Km)
•5 GW Wind Energy/Pumped Storage(1TWh) +Solar(HVDC losses 5% over 1500 Km)

*Costs (1.5 Billion EUR) for HVDC line of 10 GW (double bi-poles 1500 Km)
Cable diameter Increased for 10 GW (*with substations for 5GW)

• Supply Renewable Electricity at Competitive Prices to North-African & Iberian Markets
•=> Economies of scale expected
•Project Costs are distributed though a Timely & Phased deployment (2010-2020)

Sahara wind

Sahara Wind Project

Integrating the North African Trade Wind Resource (through HVDC Line)

Sahara Wind - Phase I : 50~500 MW (2011-2014) Grid Impact studies/Phasing with ONE (Utility of Morocco), NATO SfP-982620 wind measurements, UNIDO Pilot Projects Industrial Synergies with ONEP –ONEE.., and support from other institutions (Morocco Energy Fund, GEF, WB-CTF, EBI …)

Sahara Wind - Phase II : 500 MW ~ 5 GW (2014-2016)
•1250 MW x 4 Project Clusters / 1st bi-pole 5 GW – HVDC

Sahara Wind - Phase III : 5 ~ 10 GW (2017-2020+)
•1250 MW x 2 Project Clusters / 2nd bi-pole 5 GW – HVDC
•Pumping Storage System + Solar Capacities
Optimization of HVDC line infrastructure (up to 10 GW of HVDC Transfer capacity)
Sahara Wind Morocco-Iberian Line can be extended further into France, Germany…

Complementary to :
•Moroccan Integrated Wind Program : 2 GW (by 2020)
•Moroccan Solar Plan (Concentrated Solar Thermal + PV): 2 GW (by 2020)
•Mediterranean Solar Plan (MSP): 20 GW (by 2020)
Sahara Wind Project - Phase I presented to Immediate Action Plan of MSP (11/2008)

Sahara Wind Project

Integrating the North African Trade Wind Resource (through HVDC Line)

HVDC = Greater Controllability

• When an HVDC link is embedded in an existing AC network, it allows the transmitted power to be ‘dialed up’ and even modulated in response to inter-area power oscillations. HVDC dramatically improves power flow controllability in the interconnected networks.

HVDC = Greater Stability/System Security

• HVDC is a firewall against faults. In a cascading AC fault, an HVDC interconnection stops the propagation.

HVDC solutions are based on a project-by-project assessment

• Topics of Cooperation with major teaching universities, utility owners and industry partners , R&D …

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Saharawind

HVDC Technology for Power Transmission and Distribution with VSC

✓Back to Back Converters

- Connection to weak or isolated Systems
- Coupling of asynchronous AC systems
- Uninterruptible Power Supply
- Increase of Transmission Capacity

✓DC Long Distance transmission

Sea cable transmission for Offshore Systems
Long distance transmission with Cable / OHL
Cost effective solution with „PE-extruded cable“
The only solution for connecting remote passive loads

✓STACOM/SVC PLUS

Dynamic Reactive Power Compensation
Dynamic Voltage Control
Constant Current Characteristics
Compact Design
Improvement of Power Quality / Flicker compensation

High Voltage Direct Current Technology
(Possible use of HVDC technology with VSC)

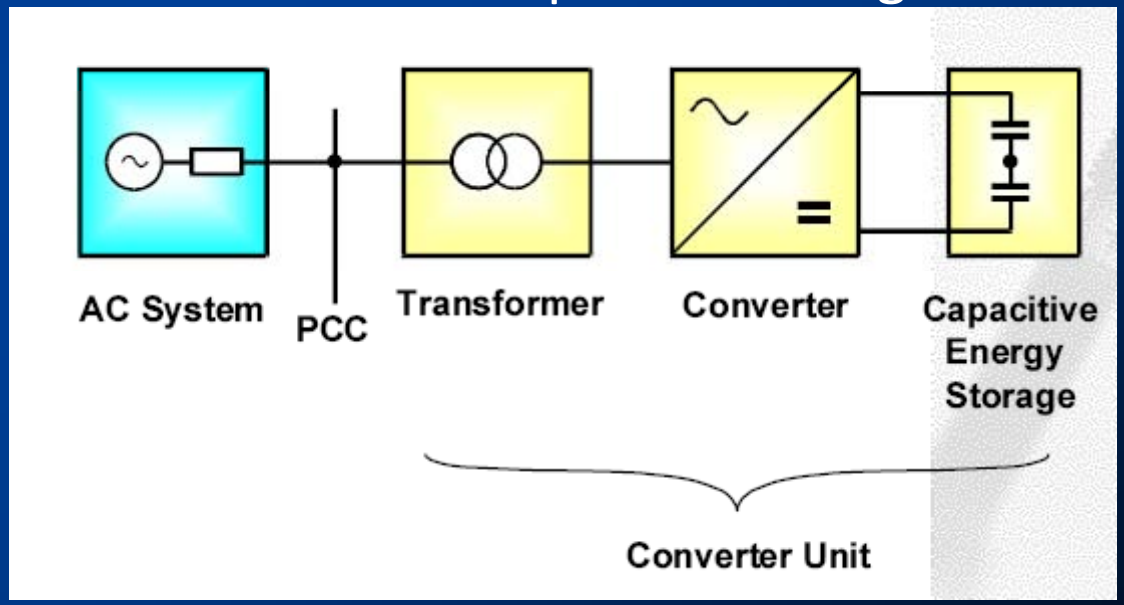
VSC : Voltage Source Controller Technology (using IGBT : Insulated Gate Bipolar Transistor)

Main features:

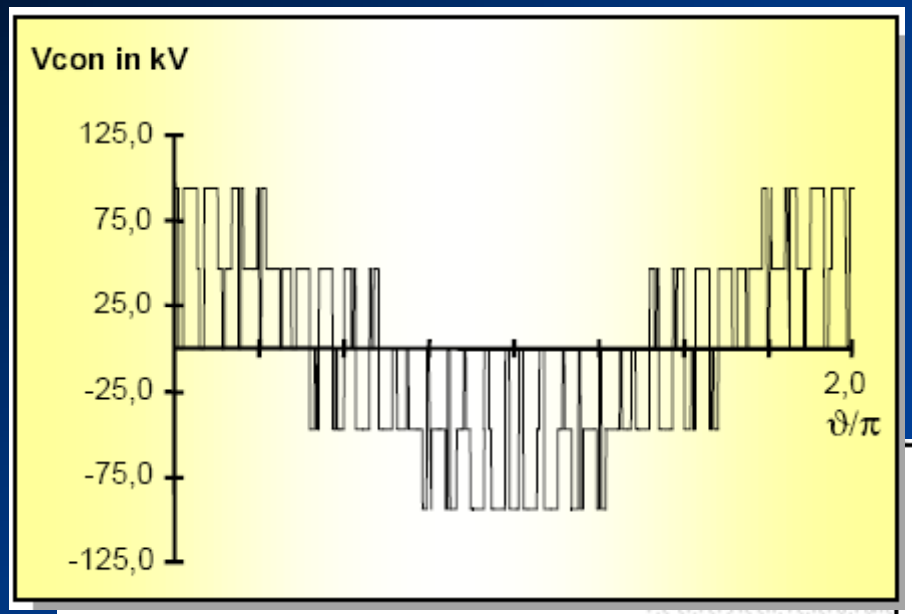
- Power control in both directions (in real time)
- Control of both Active and Reactive Power
- Use of Multi-Terminal DC link Examples: HVDC light

Press Pack IGBT (PPI)

switching frequency 750 Hz (1000 Hz)

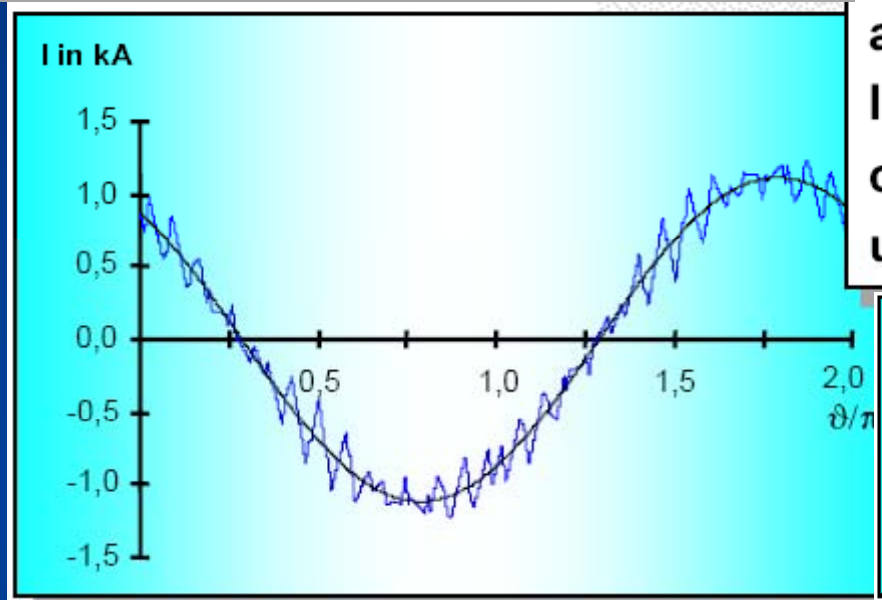


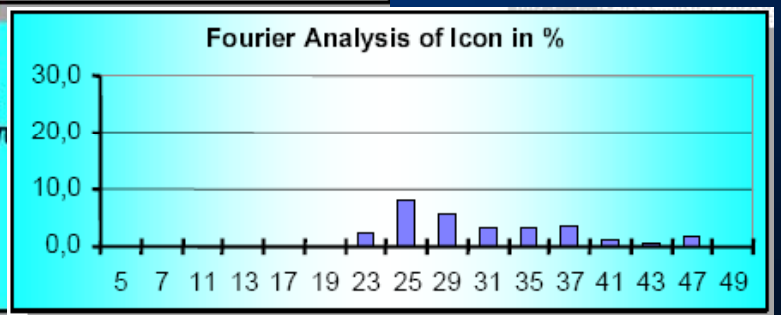
HVDC Technology for Power Transmission and Distribution



VSC Technology:
2 Level VSC Voltage and Current Waveshapes

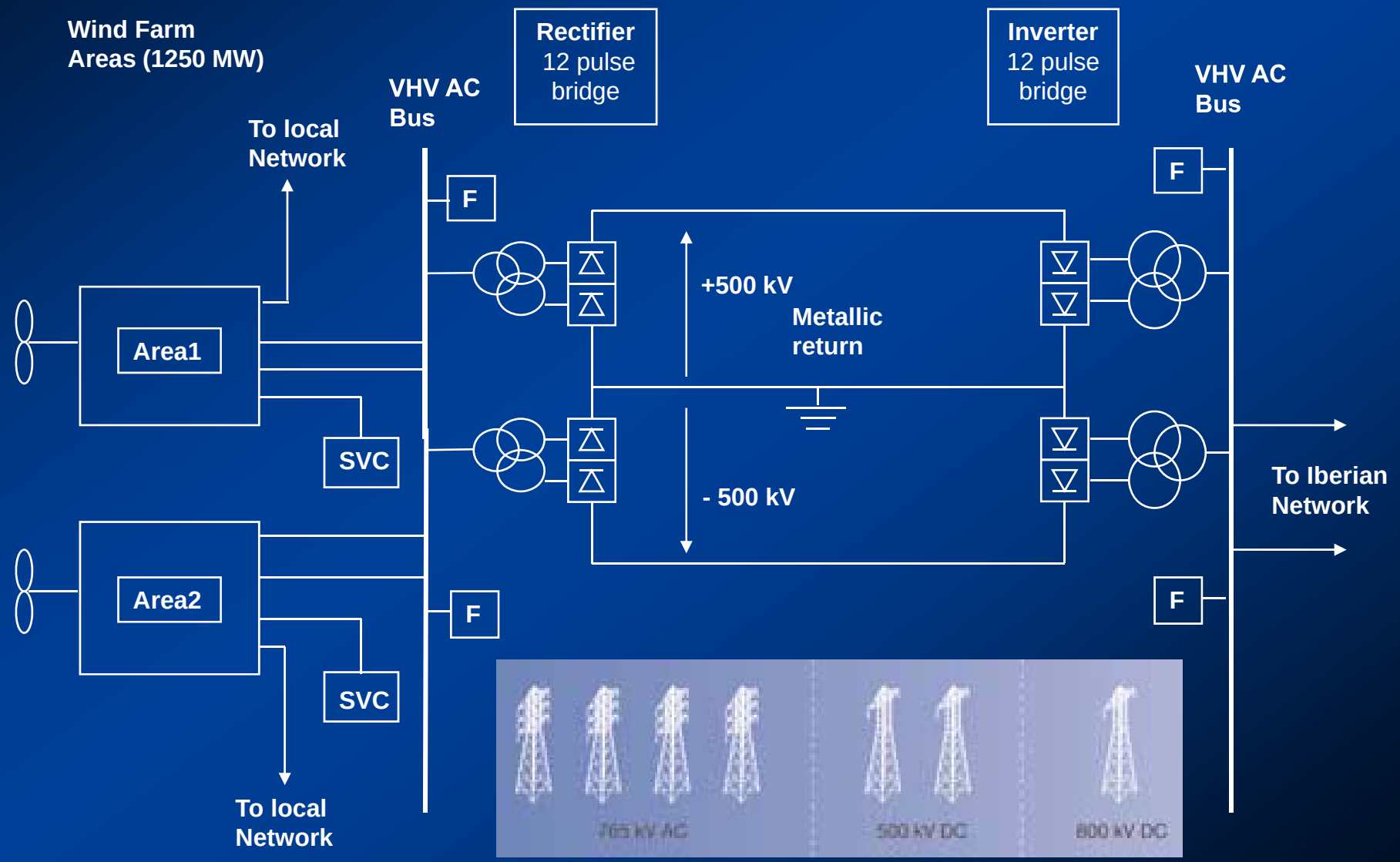
f_s	19 x f_N
V_d	140 kV
a	0.8
I_1	780 A
$\cos\phi_N$	0.909_{cap}
u_k	15 %





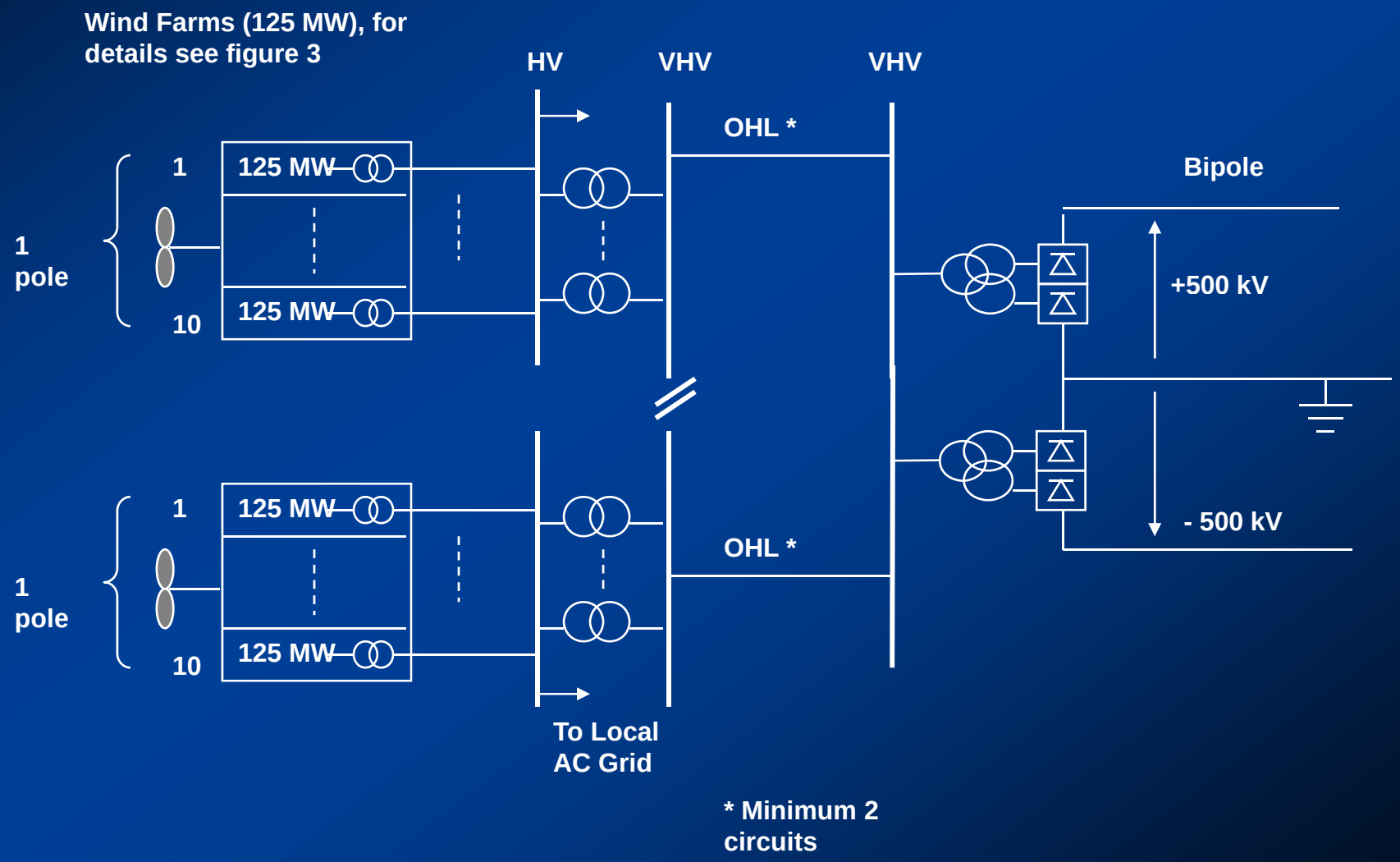
Sahara wind

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



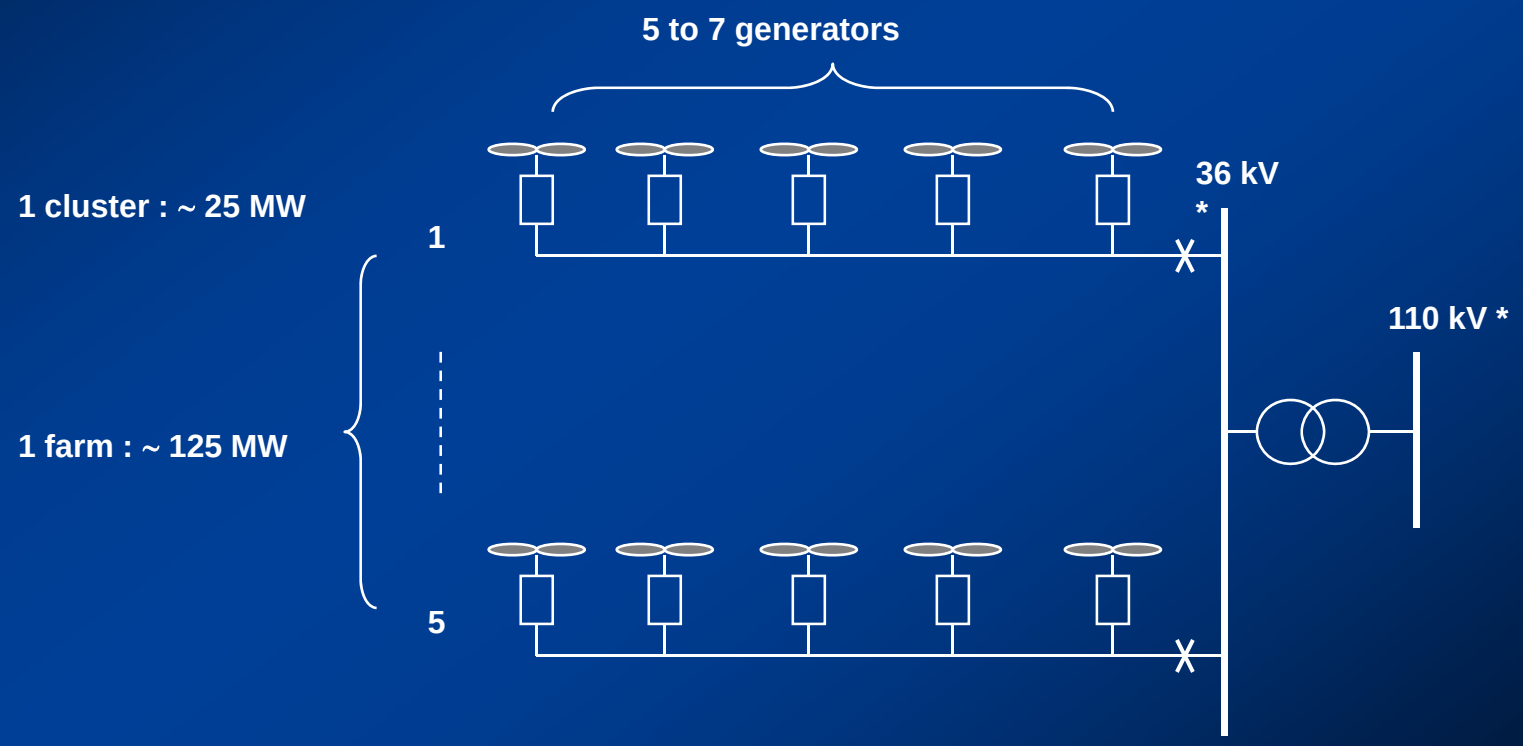
Sahara wind

Figure 2 : Sahara Wind - Bipole phasing (information only)



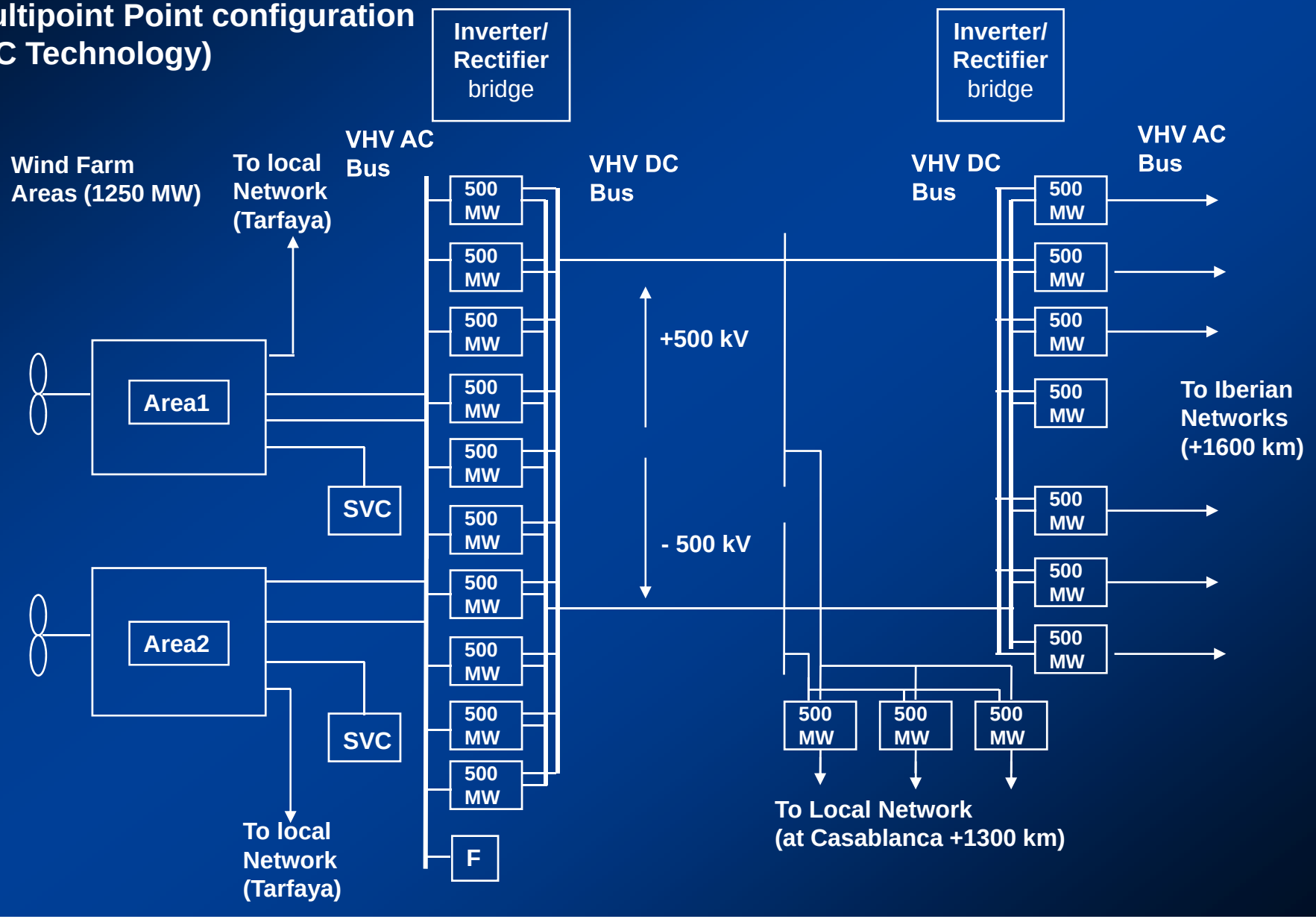
Sahara wind

Figure 3 : Sahara Wind - Generator Clustering (for information only)

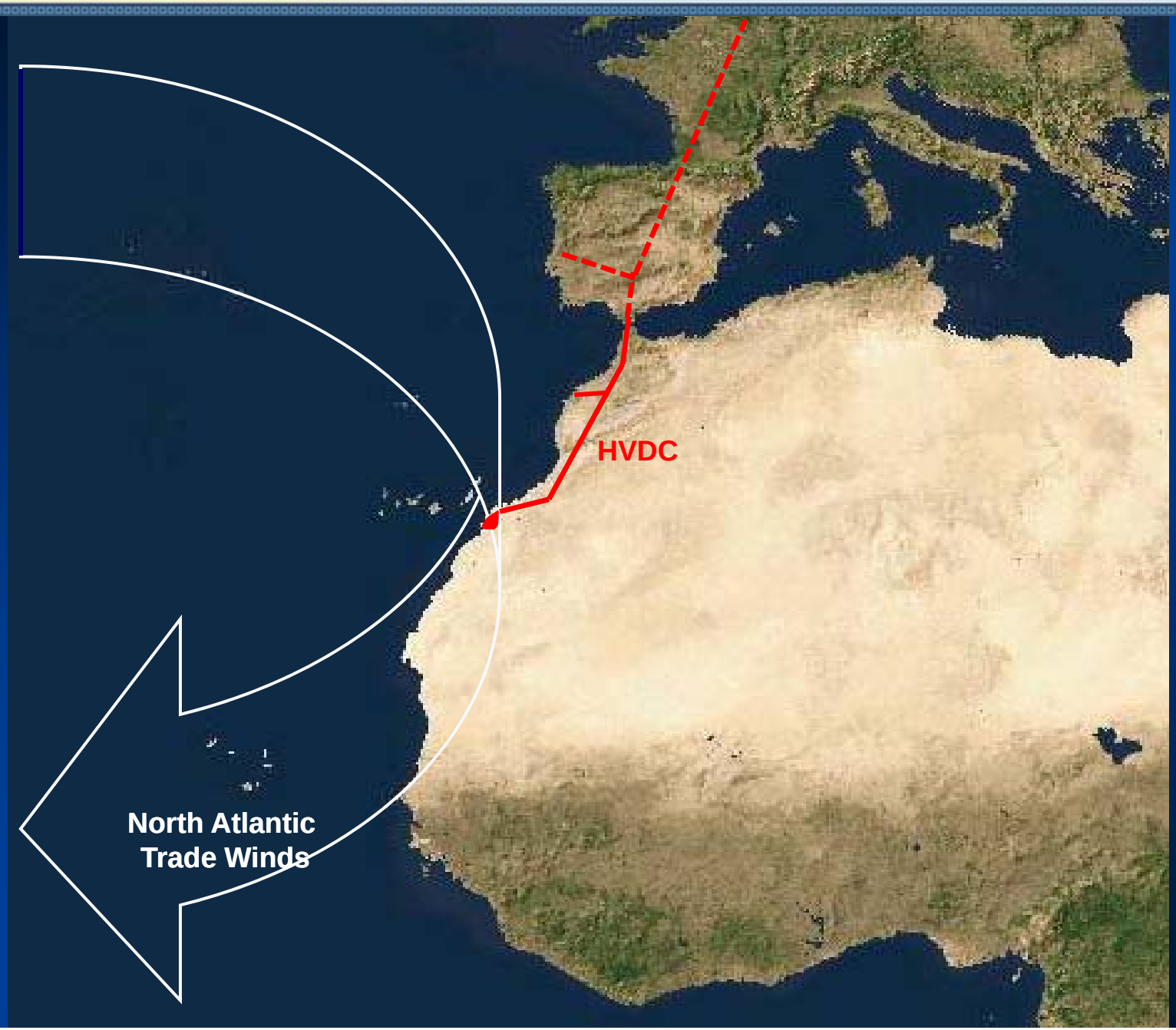


Sahara wind

Figure 4 : Sahara Wind - HVDC Transmission Architecture - bipole 1 (5GW) (Multipoint Point configuration SVC Technology)



Saharawind



NATO
OTAN

Sahara Wind Energy Development Project

Electricity High Voltage Line technologies

High Voltage Direct Current (HVDC) *versus* High Voltage Alternating Current (HVAC)

Left: 3,000 MW HVDC (Pacific DC Intertie, PDCI) **Right: 300 MW HVAC**

Near Bishop, California USA

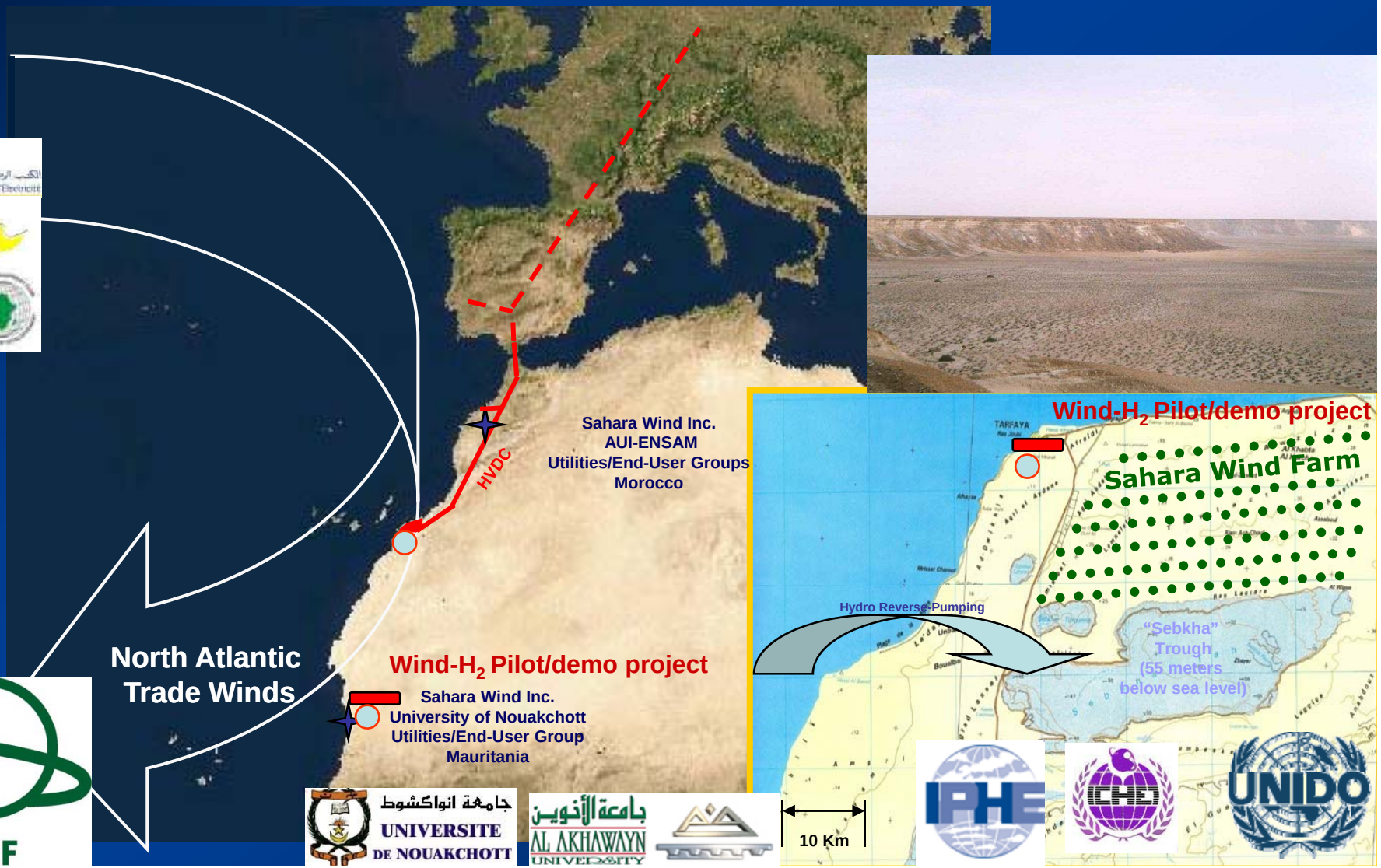
Sahara wind

NATO Science for Peace SfP-982620 UNIDO(ICHET) Sahara Wind-H_2 Demo Projects

Union for Mediterranean Solar Plan: 50 MW (Pilot Project Clusters)

Morocco: Sahara Wind Phase I / Tarfaya (400-500 MW) 5~10 GW HVDC Extension

On-Grid Wind Electricity in a Liberalized Market: Joint WB-AfDB UNDP/GEF (PDF-B PIMS #3292)



Sahara Wind : A project of the International Partnership for the Hydrogen Economy

Renewable Hydrogen Production

Sahara Wind-Hydrogen Development Project

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

Project Director:
Mr. Khalid Benhamou
Sahara Wind Inc.
kb@saharawind.com

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

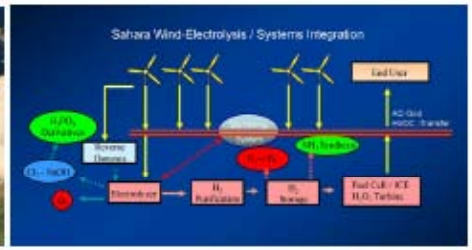
The wind and electrolyzer equipment for training and applied research purposes will be put into operation in early November 2010 at the Al Akhawayn University of Morocco and the University of Nouakchott in Mauritania. These systems will be gradually updated to increase their wind generation capacities, 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).



NATO ‘Science for Peace’ SfP-982620 PROJECT PARTNERS

NATO MEDITERRANEAN DIALOGUE PARTNERS

MOROCCO:

AL AKHAWAYN UNIVERSITY- IFRANE

ENSAM - ECOLE NATIONALE SUPÉRIEURE DES ARTS ET MÉTIERS

ENSET-ECOLE NORMALE SUPERIEURE DE L'ENSEIGNEMENT TECHNIQUE MOHAMMEDIA

FST – FACULTÉ DES SCIENCES DE TETOUAN

FSR - FACULTE DES SCIENCES DE RABAT

FSTM - FACULTÉ DES SCIENCES ET TECHNOLOGIES DE MOHAMMADIA

FST – FACULTÉ DES SCIENCES DE KENITRA

CERPHOS: CENTRE D'ÉTUDES ET DE RECHERCHES DES PHOSPHATES MINÉRAUX

ONEP - OFFICE NATIONAL DE L’EAU POTABLE

SAHARA WIND INC. (PPD)

MAURITANIA:

UNVERSITE DE NOUAKCHOTT - FACULTE DES SCIENCES ET TECHNIQUES

CRAER – CENTRE DE RECHERCHE APPLIQUE ENERGIES RENOUVELABLES

ISET ROSSO – INSTITUT SUPERIEUR D’ENSEIGNEMENT TECHNOLOGIQUE

MAURITEL MOBILE – MAURITEL S.A.

APAUS – AGENCE DE PROMOTION POUR L’ACCES UNIVERSEL AUX SERVICES

SNDE – SOCIETE NATIONALE DE L’EAU

SNIM – SOCIETE NATIONALE INDUSTRIELLE ET MINIERES

SAFA – SOCIETE ARABE DES FERS ET D’ACIERS.

ANEPA – AGENCE NATIONALE DE L’EAU POTABLE ET D’ASSAINISSEMENT

NATO COUNTRIES PARTNERS

UNITED STATES: (NPD)
U.S DEPARTMENT OF STATE -OFFICE OF GLOBAL CHANGE – BUREAU OF OCEANS AND INTERNATIONAL ENVIRONMENTAL AND SCIENTIFIC AFFAIRS (OES)

FRANCE:
COMMISSARIAT A L’ENERGIE ATOMIQUE CEA

GERMANY:
MINISTRY OF ECONOMIC AFFAIRS AND ENERGY OF THE STATE OF NORTH RHINE-WESTPHALIA - M.NRW

TURKEY:
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION – INTERNATIONAL CENTRE FOR HYDROGEN ENERGY TECHNOLOGIES UNIDO-ICHET

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This project is supported by: The NATO Science for Peace and Security Programme