Saharawind

Sahara Wind: A Regionally Integrated, Market-Based Project of Strategic Importance

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NATO OTAN 1949 - 2009
This project is supported by: The NATO Science for Peace and Security Programme

Sahara Wind: A Regionally Integrated, Market-Based Project of Strategic Importance

Index: Summary

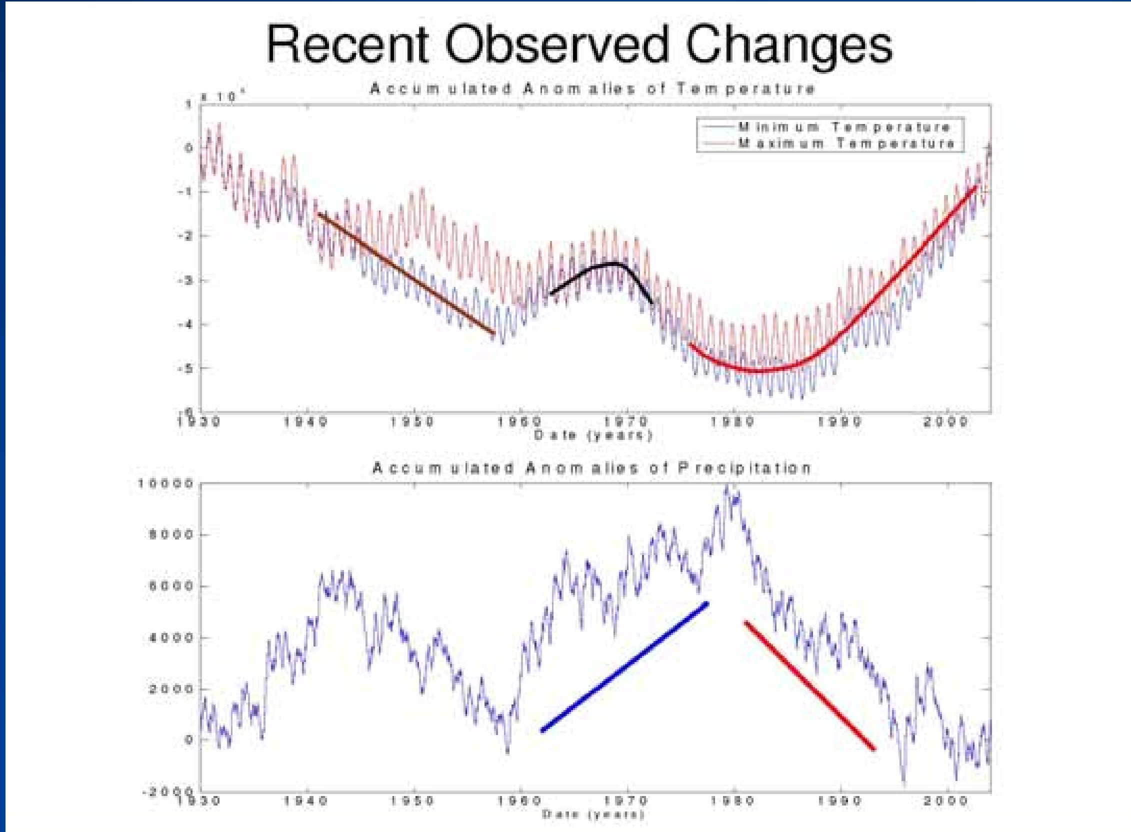
Sahara wind

- Sahara Wind: from Idea to Project -

- **1993:** Initial wind measurements installed (Sahara Trade Wind Region)
- **1994:** Report on Sahara trade wind energy potential to H.M. King Hassan II
- **1994-97:** Wind-Diesel-Hybrid test site with small grids & variable loads
- **1997-1999:** EU-Level discussions (Commission & Parliament) over export of wind electricity to Europe from the Saharan Atlantic trade winds (Sahara Wind Project).
- **2002:** Sahara Wind Inc. presents the Sahara Wind Project at the European Parliament (2002), USA -Africa Ministerial (2002), WWEC 2003, Bonn 2004, etc…
- **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 with Project Phasing & HVDC line with ONE (Morocco utility) on the base of 5000 MW to supply EU-Mediterranean markets.
- **2005-2011+:** Regional project development activities – integrative processes: UNIDO contracts, IPHE (World Hydrogen Project), IEA, USA-Morocco S&T agreement, NATO Science for Peace SfP-982620, capacity building industry-academia partnerships in Morocco & Mauritania, Deployment of UNIDO-ICHET/NATO SfP Pilot Projects with Project Partners, etc.

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

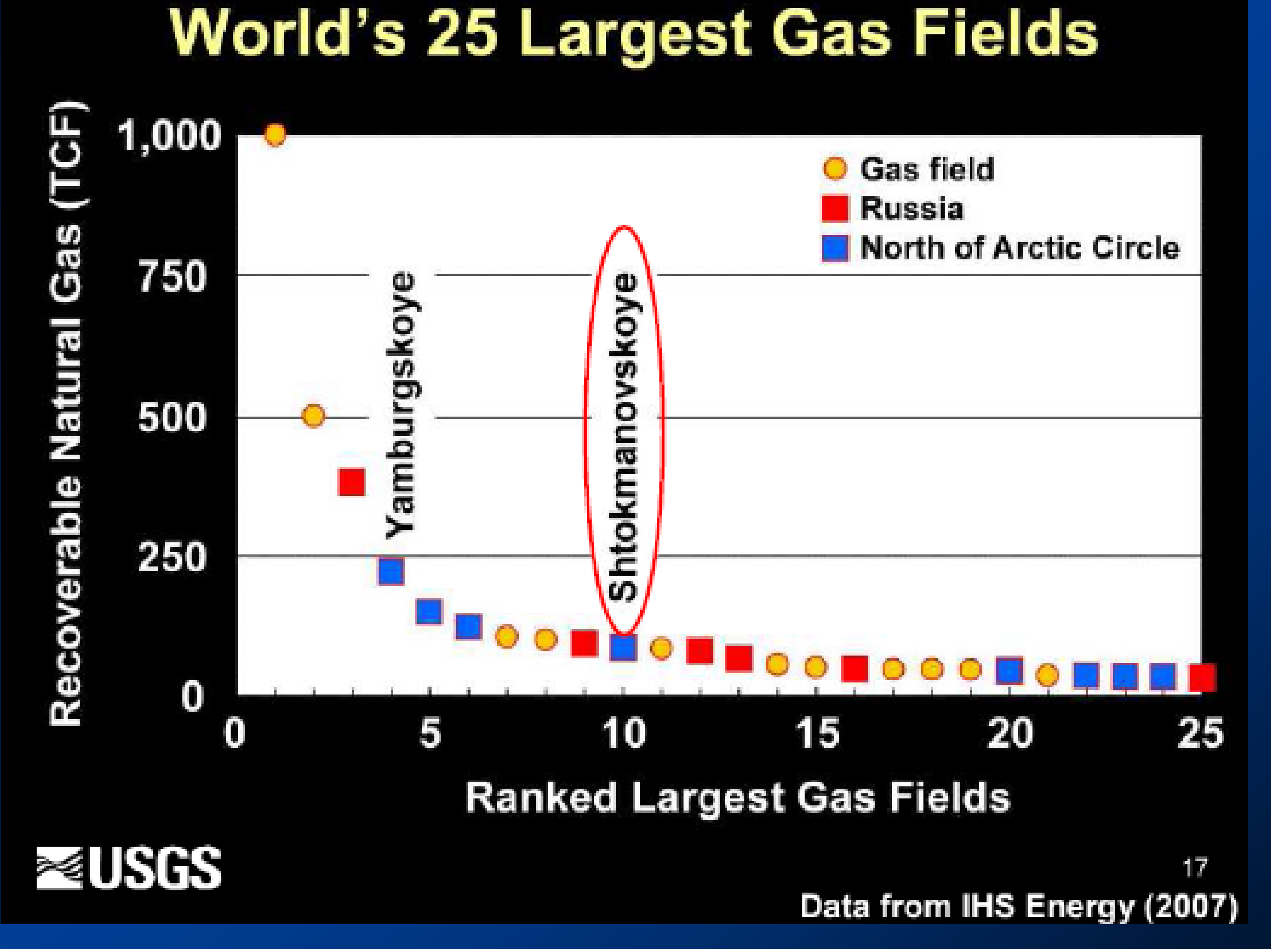


Brunet, M. et. al. (2007), Temporal and spatial temperature variability and change over Spain during 1850–2005, J. Geophys. Res., 112

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.

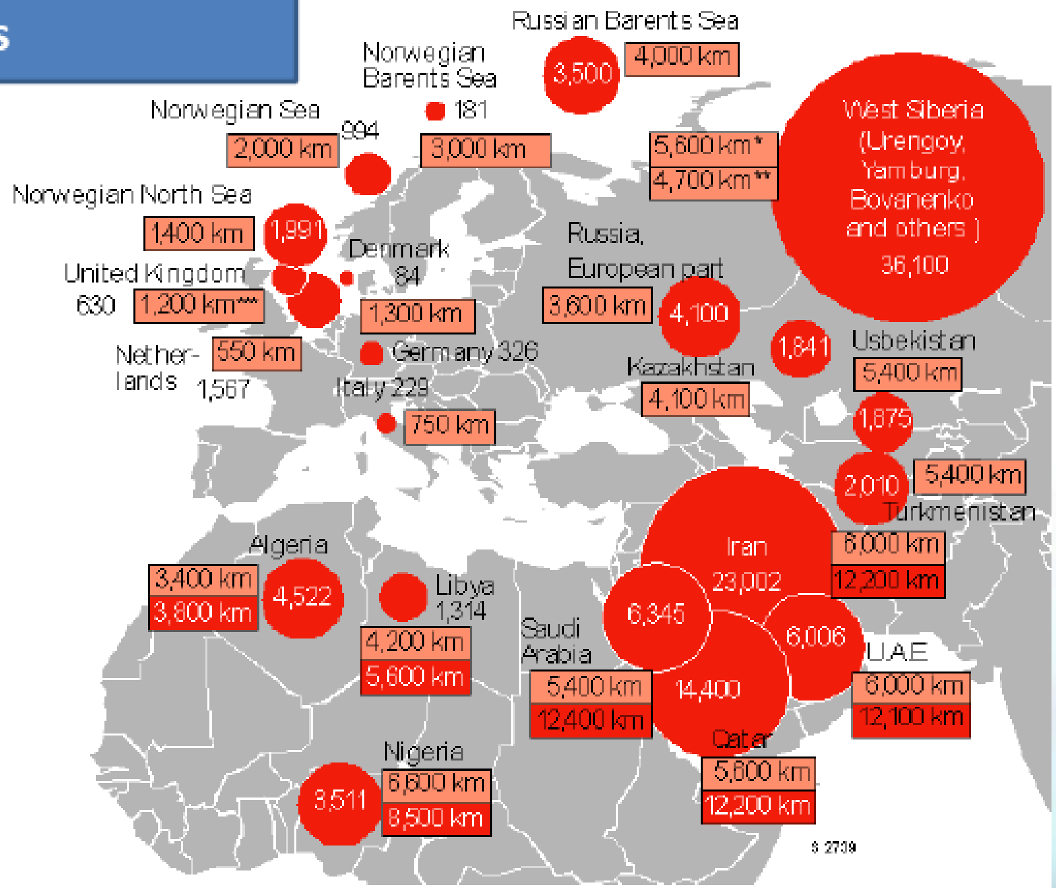
Climate Change (Different Effects/Consequences)

<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 Wilhelmshav

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

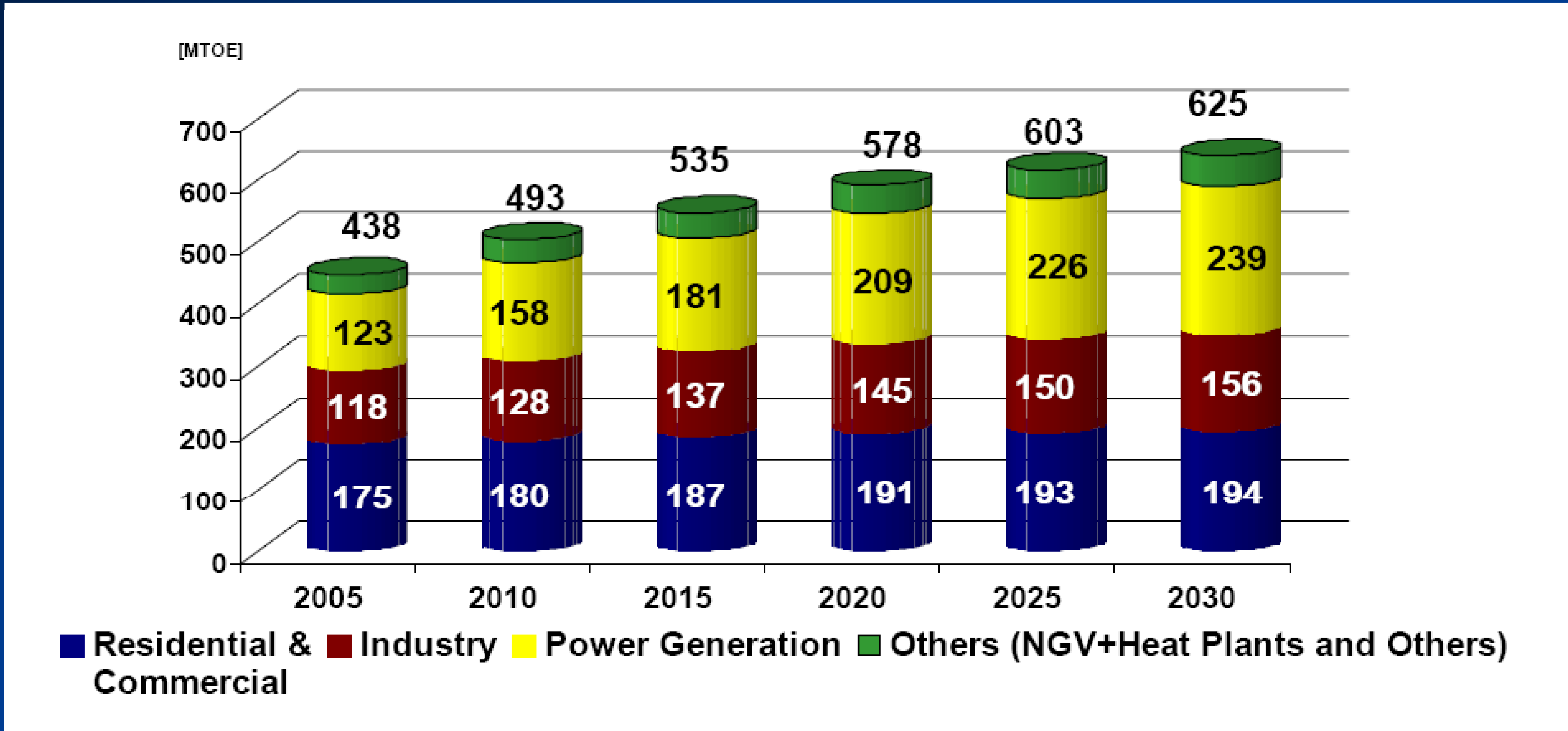
1 m³ = 11.6 kWh

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

Source: E.ON Ruhrgas AG

Sahara wind

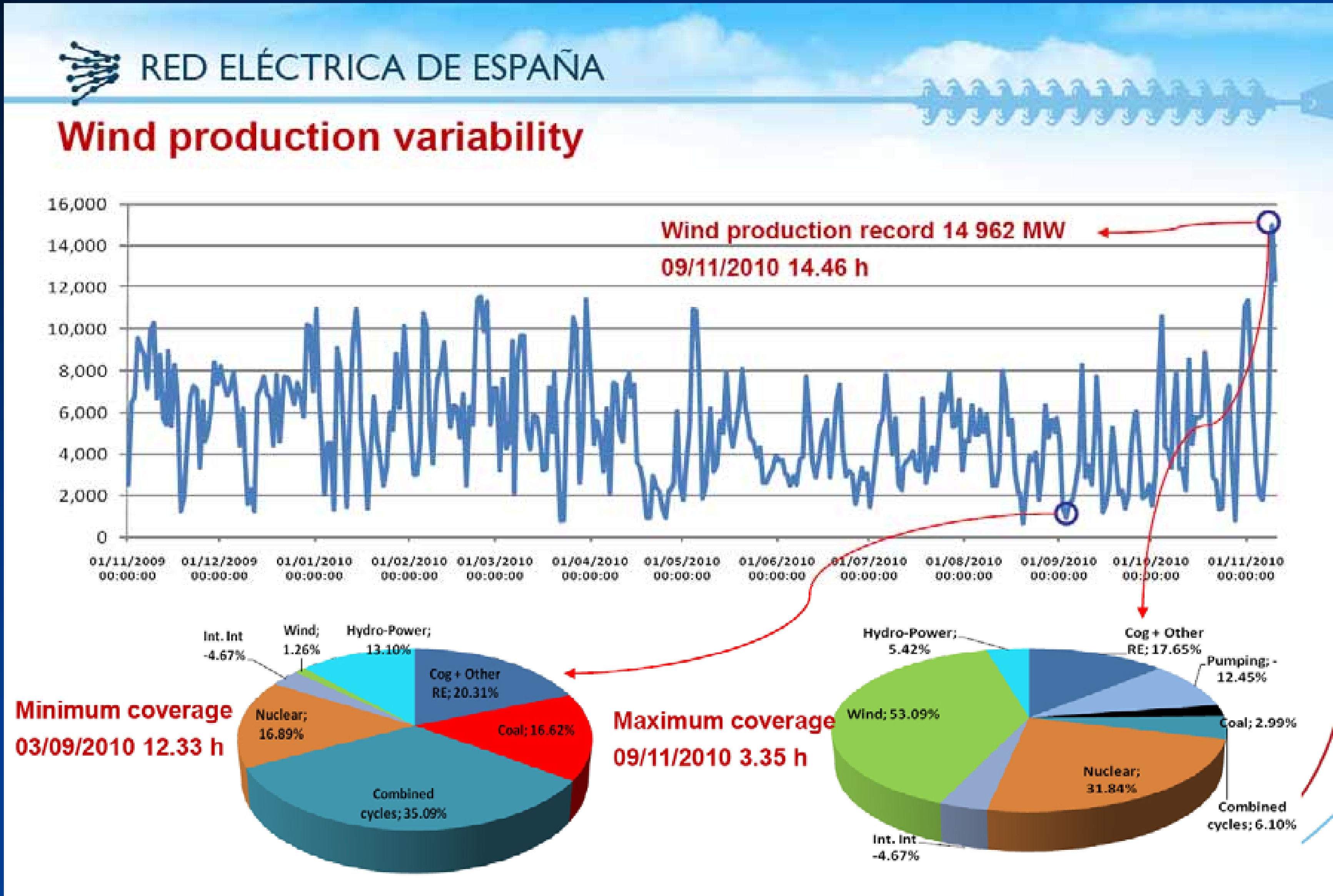
EU27 Natural Gas demand outlook



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

Source: EUROGAS

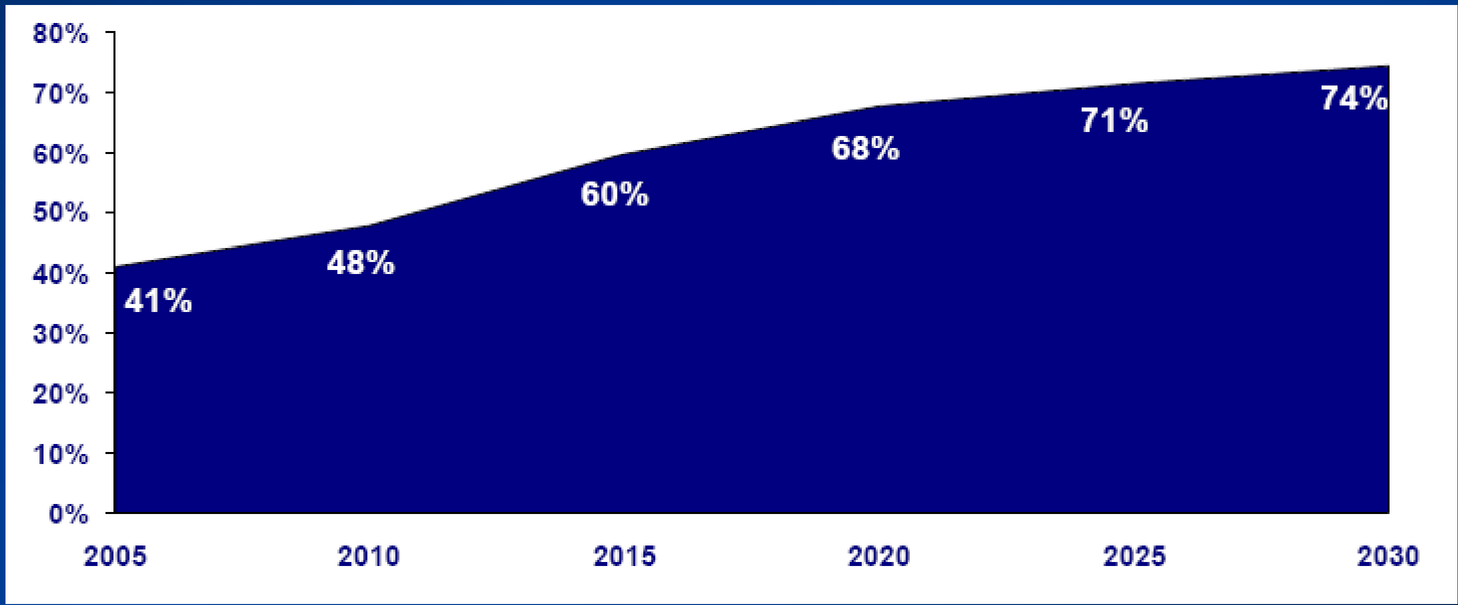
Sahara wind



Corrélation parfaite: Production de l'Énergie Éolienne se fait au détriment du Gas Naturel (cycles combinés)

NATURAL GAS DEMAND AND SUPPLY
Long Term Outlook to 2030

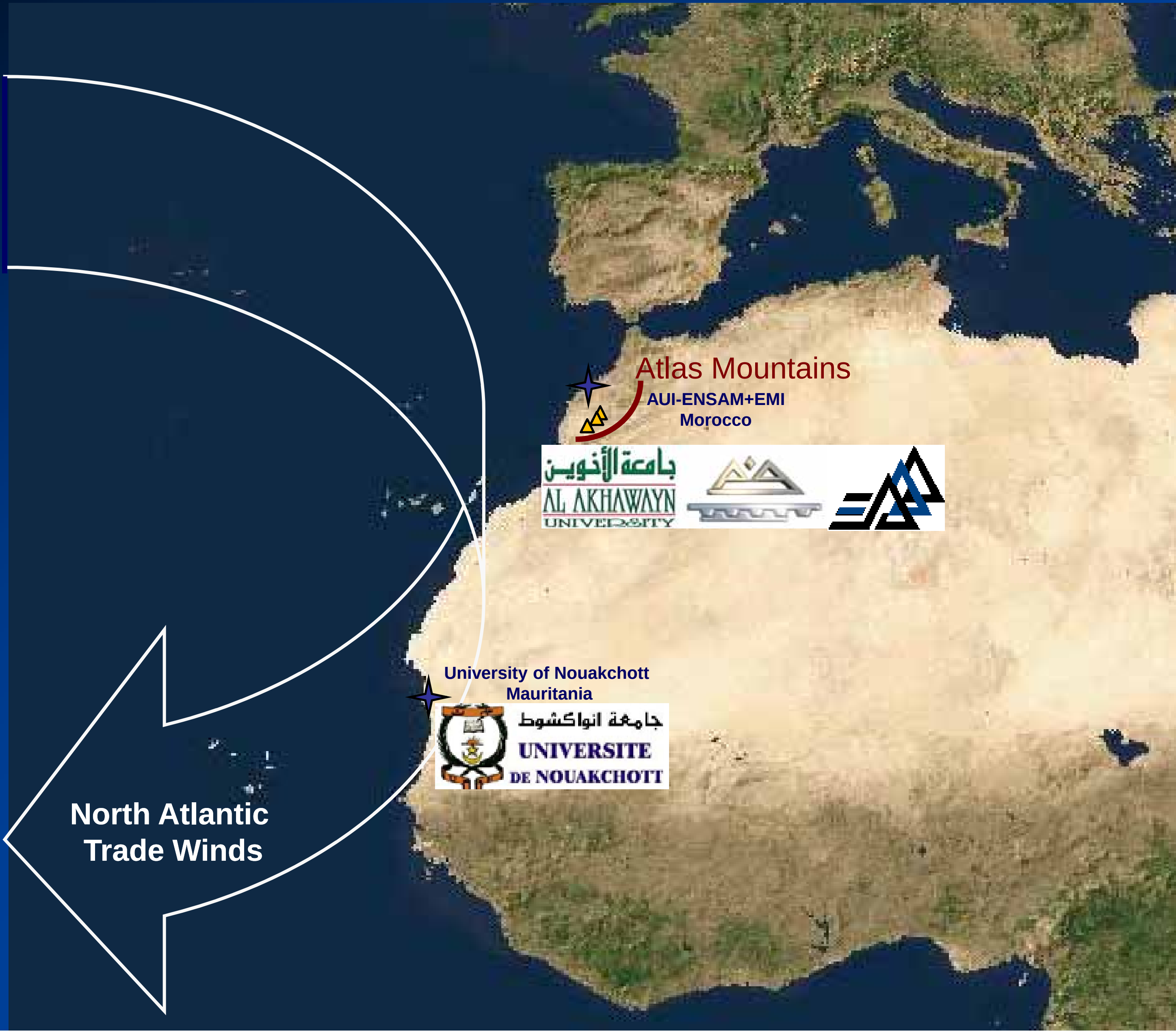
EU27 import dependency from outside Europe



Source: EUROGAS

Sahara Trade Winds: NATO 'Science for Peace' SfP-982620

NATO OTAN



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

- Phosphate deposits (42% of World reserves)

Sahara Wind: A Regionally Integrated, Market-Based Project of Strategic Importance

Regional collaboration:

- Complementary teams: similar trade wind resource
- Bottom-up approach: capacity building on wind technologies
- Securing Intellectual Property on technologies & local processes based on transforming resources (on-site)
- Develop integrated processes before regional markets (limited integration)
- Security of supply: Need to diversify renewable energy supply away from Fossil Fuels & Energy Monopolies
- Strategic objectives: Secure long term transition into renewables

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Sahara Wind Energy Development Project

How to Access Wind Energy?

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

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

Problems are more acute in weak grid conditions !!!

Saharan Countries dispose of very limited electric generation capacities:

In 2008 : Mauritania 253 MW, Mali 280 MW, Niger 145 MW, Chad 32 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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REGIONAL CAPACITY BUILDING
NATO 'Science for Peace' Project Coordinated by Sahara Wind Inc.

Security Issue: Energy Security - Climate Change - Fixing Migrant Populations
- Priority Research Areas of Mediterranean Dialogue Countries Partners of NATO
- NATO's New Strategic Concept: New Emerging Security Challenges Division
- Social Unrest in the Region (Tunisia, Egypt, Libya, Yemen, Syria…)

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 by Securing Intellectual Property Rights within Applied Research Groups (NATO Intellectual Property Rights Committee).
- Complementary Working Teams on a Regional Level (Morocco & Mauritania)
- Public-Private Academia-Industry network

Technology – University/R&D Platform – Industry

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NATO SfP-982620 PROJECT OBJECTIVES
Synergies with Industry

Wind Resource Assessment:

Mauritania: Partnership Sahara Wind-University of Nouakchott-Mauritel

Morocco: Partnership Sahara Wind-Al Akhawayn University-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 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 & 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…)

✓Green Corporate Headquarters (ONEP-IEA-EMI/SNDE/CEA/NASA-JPL)

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Photos: Wind Turbine Mounting at Al Akhawayn University

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Small Wind Turbine Manufacturing Program

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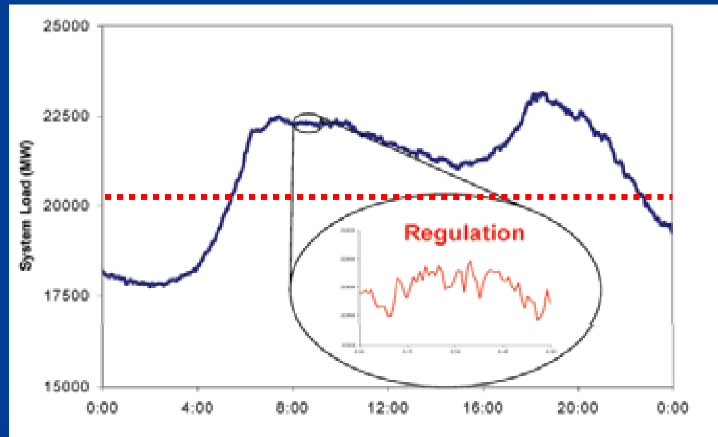
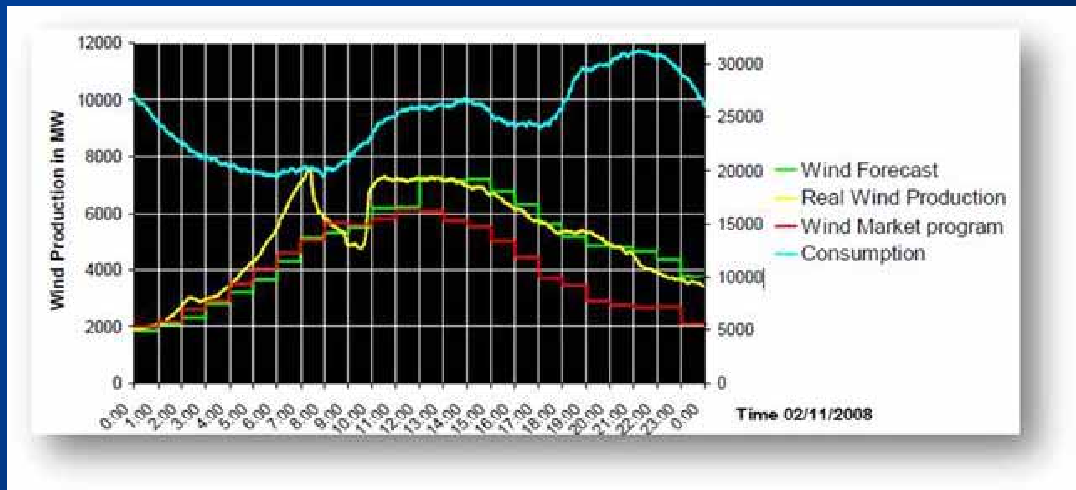
Grid Balancing and Stabilization through Wind-electrolysis

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)





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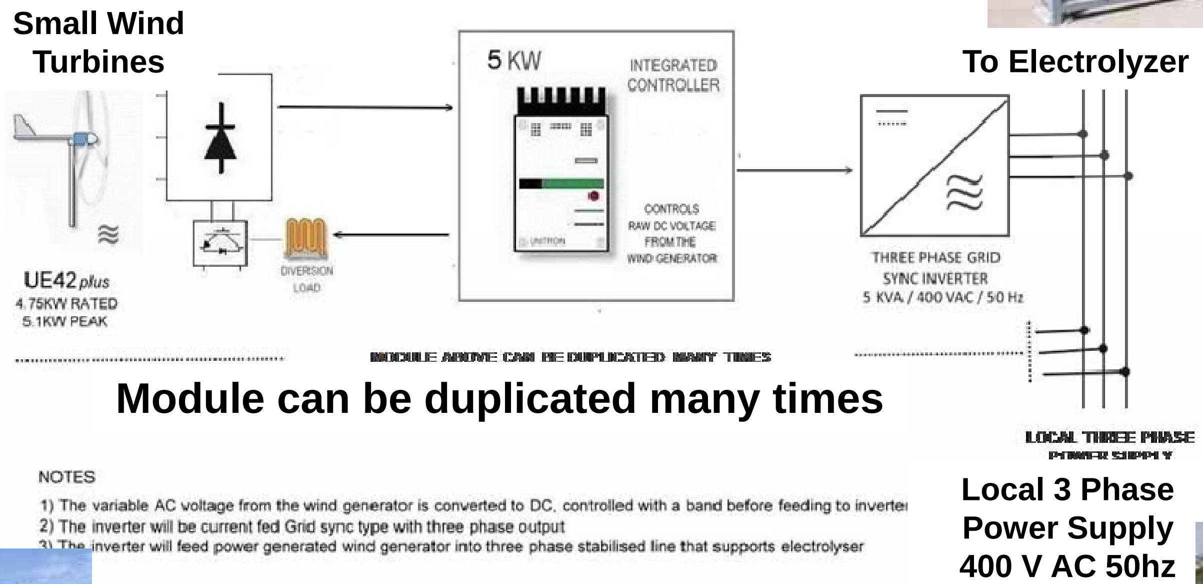
Integrated Renewable Hydrogen Storage Systems within the "Green Campus Concepts" of Al Akhawayn University & University of Nouakchott



جامعة الأخوين
AL AKHAWAYN UNIVERSITY

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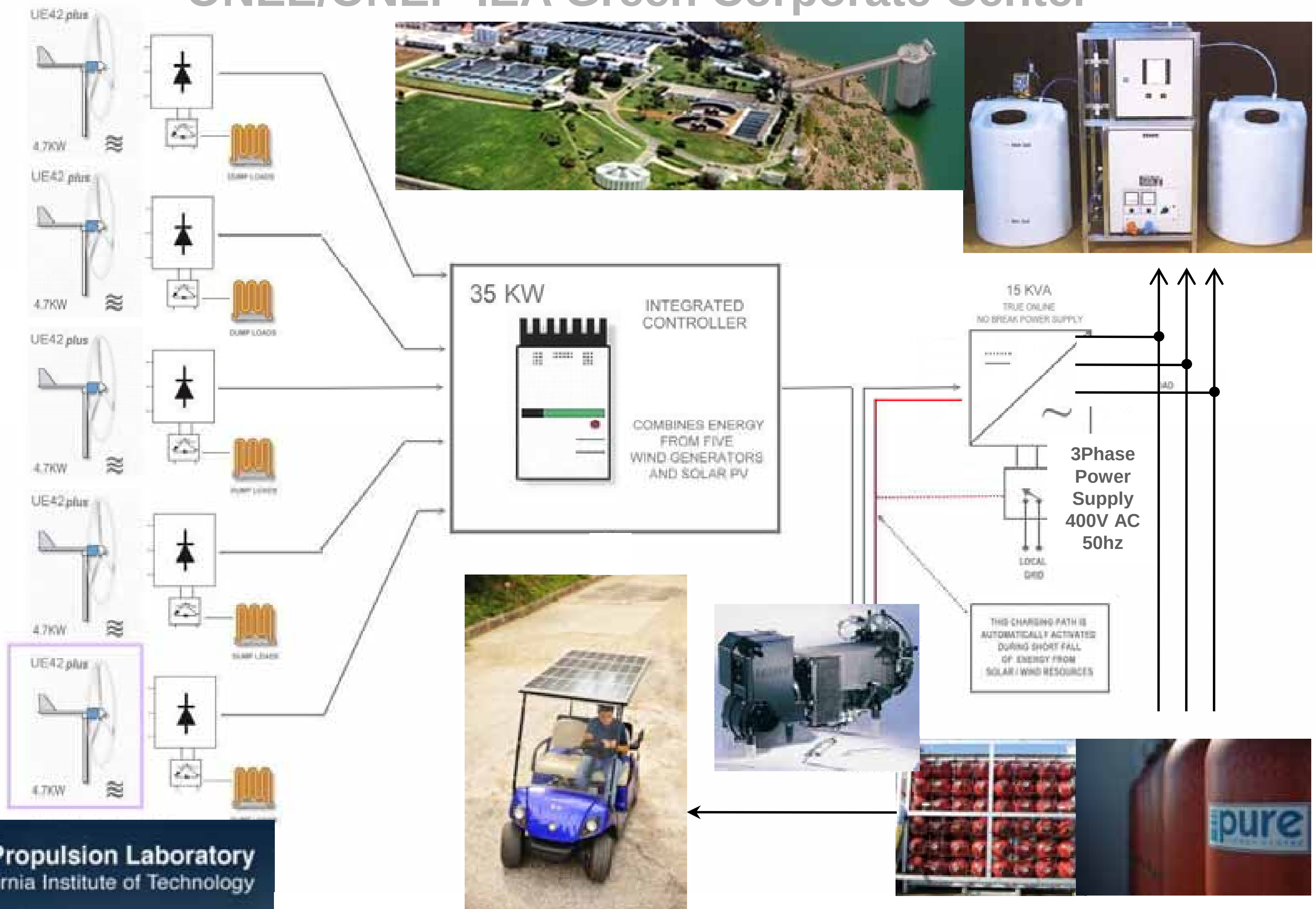
جامعة انواكشوط
UNIVERSITE DE NOUAKCHOTT

Sahara Wind Clean HyWater Purification Project
ONEE/ONEP-IEA Green Corporate Center



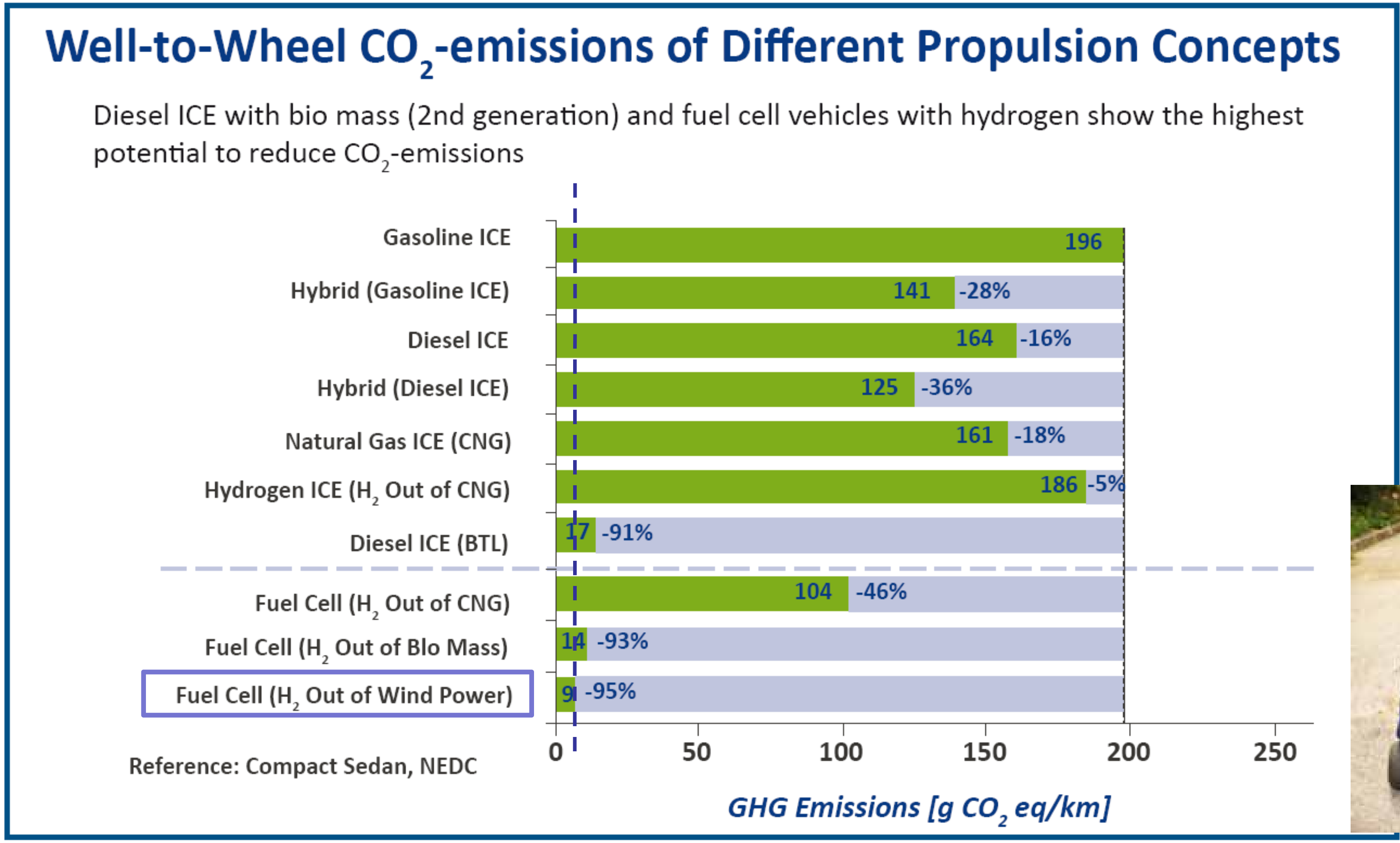


Figure 3. Projections of fuel cell and conventional vehicle well-to-wheels CO_2 emissions (Germany)[3]

Mobility based on Hydrogen from Wind Power has the lowest Well-to-Wheel CO2-emissions (Source: EUCAR/CONCAWE/JRC, 2005)

Sahara Wind : A World Hydrogen 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.

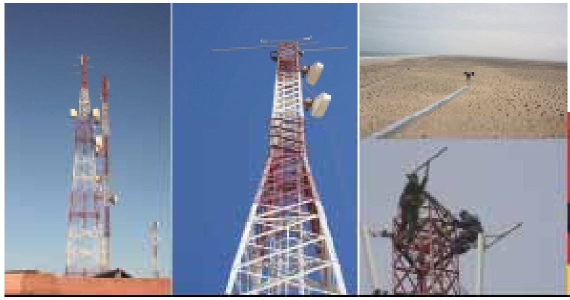
Objectives

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

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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 Noudhibou.

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.

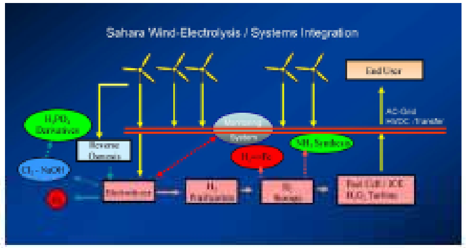
Other small, wind-turbine test benches are being delivered to the Ecole Nationale Supérieure d'Arts et Metiers (ENSAM) School of Engineering in Meknes, Morocco, and will be installed in late 2010. The technical economic analysis for end-user pilot project applications has already been completed, including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

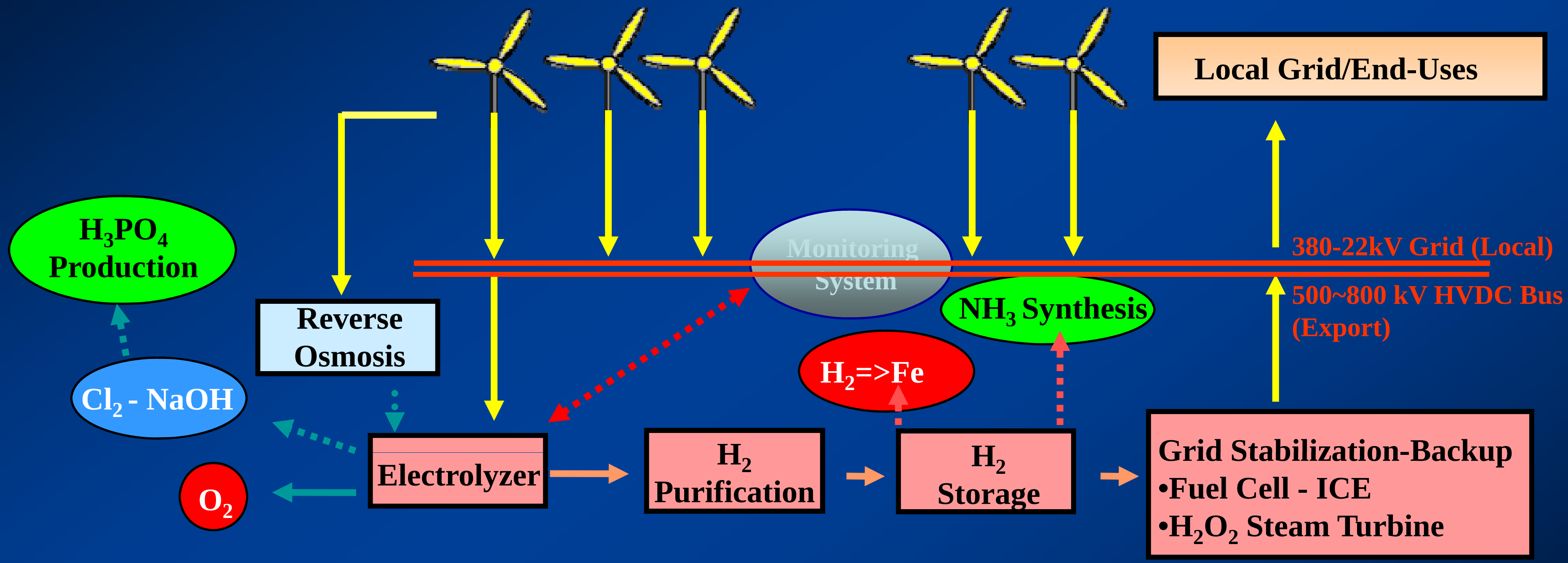
Ultimately, project participants would like to see this project enhance the integration of an end-user-driven, comprehensive, sustainable, applied research program. This is likely to lead to the adoption of a holistic, integrated approach to renewable energy technologies in North Africa.

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

IPHE



Integrating Sahara Trade Wind Resource into Centralized Grids
Sahara Wind-Industrial Electrolysis Systems
To Support North Africa's Major Industries



- Phosphates Processing (Morocco) (green)
- Iron-Ore Processing (Mauritania) (red)

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NATO Science for Peace SfP-982620
Wind-Electrolysis by-products End-User Markets
Integrating Sustainable Carbon Free Processing

Morocco:
Water & Electric Utilities + Phosphate Industry (Chlor-Alkali Wind-Electrolysis)
Hypochlorite (access to water treatment solutions in Sahel regions) + Wind-Electricity
Hydrochloric acid for <u>Phosphoric Acid</u> derivatives (OCP Group: <u>45% World Market</u>)
• Expand fertilizer industry, beyond Phosphate based fertilizers
    • Hydrogen for Production of Ammonia (OCP Group: 1000 T/day imports)
    • Possible Phosphor-gypsum recycling (12 Million tons/year)

Mauritania:
Water & Electric Utilities + Iron-Ore Industry (Alkaline Wind-Electrolysis)
Hypochlorite (access to water treatment solutions in Sahel regions) + Wind-Electricity
• Hydrogen for Direct Iron-ore Reduction Process (DRI) for Production of Purified Iron
• Wind-Electricity+Oxygen: Electric Arc Furnace Steel is 45% Global Steel Production

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Sahara wind

Sahara Wind Clean HyWater Purification Project
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- Desert site ONEP desalination plant

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

Perspectives: Water sanitation, treatment
& Mine Processing Industries in Sahel regions
Collaboration with SNDE & University of Nouakchott…

cea

Jet Propulsion Laboratory
California Institute of Technology

ICHET UNIDO IPHE

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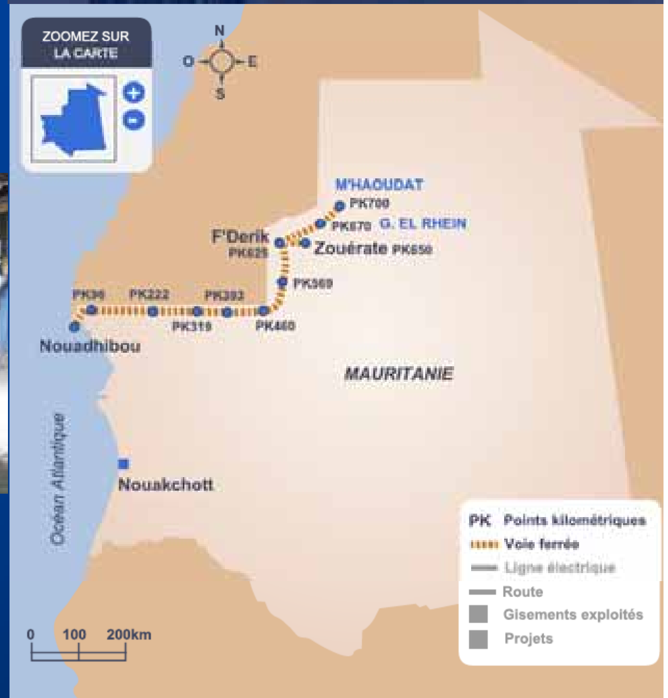
ONEP

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 higher value iron/steel products (CO2 free)

ICHET UNIDO
NATO OTAN 1949-2009
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IPHE

Sahara wind

Energy Access, Job Creation and Industrial Development
Wind Energy Industry

Requirements for the Emergence of a Wind Industry:

•Adequate Wind Resource (Trade Winds)

•Steady Market
- Project Size
- Visibility on Implementation
- Economy of Scale

•Geographically Contained Area (Optimized Logistics)

•Available Labor & Expertise (Comparative Advantages)

•An Existing Industrial Activity
- Build-up energy technology networks/Clusters based on the above
- Develop components industry (single components… one by one)
- Consolidate industrial policies

Moroccan Integrated Wind Energy Program: 2GW (Export Possibilities Not Included)

- Before 2013: 1 GW (280 MW Built + 720 MW planned/under construction)
- By 2020: + 1 GW (1000 MW Morocco Integrated Wind Energy Program)

2 GW Total

Limitation factors: Grid Capacity…!!!

- Total generating capacity (6346 MW) / Peak load (4890 MW)

=> Possible Wind Power integration hardly exceeding 2 GW

- Big Wind Potential but far away from load centers (1000 km+)
- Larger capacities needed for transferring a complete wind industry

⇒Large-scale regional integrated project development approach is needed :

The Sahara Wind-HVDC Project (5GW+)

Royaume du Maroc

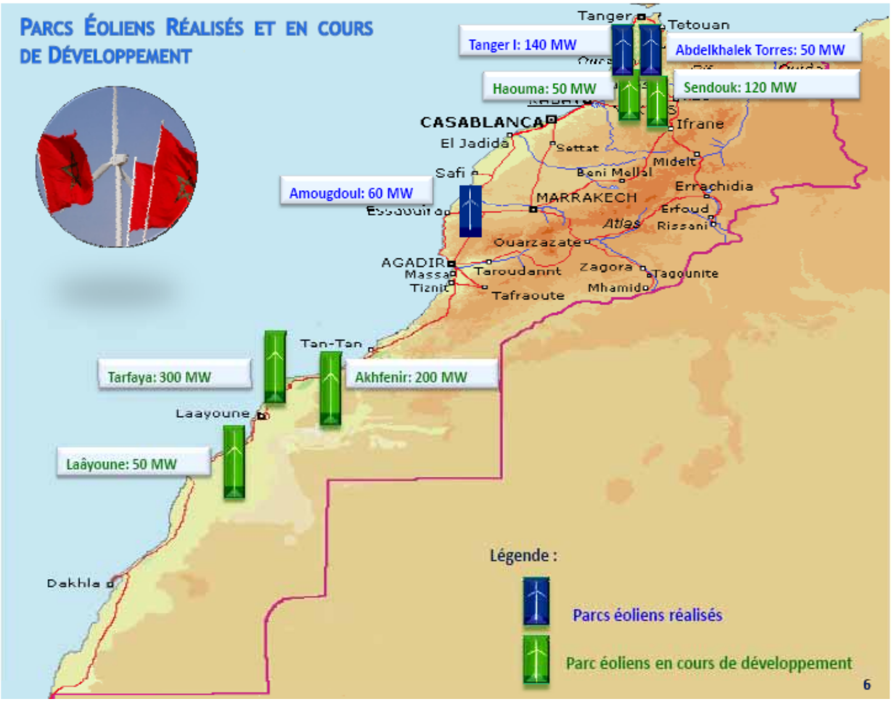
Ministère de l'Energie, des Mines, de l'eau et de l'environnement

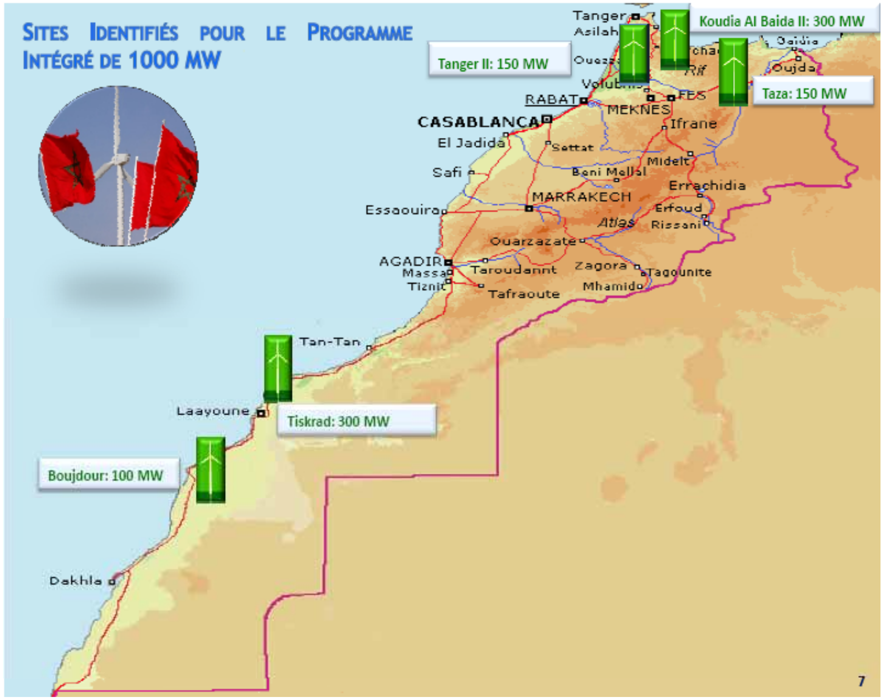
Département de l'Energie et des Mines

ÉTUDE POUR LES SPÉCIFICATIONS DES BESOINS EN COMPÉTENCES DANS LE SECTEUR DES ÉNERGIES RENOUVELABLES ET TOUT SECTEUR IMPACTÉ PAR L'EFFICACITÉ ÉNERGÉTIQUE

Focus Goup 22 février 2011

Hypothèses d'installations



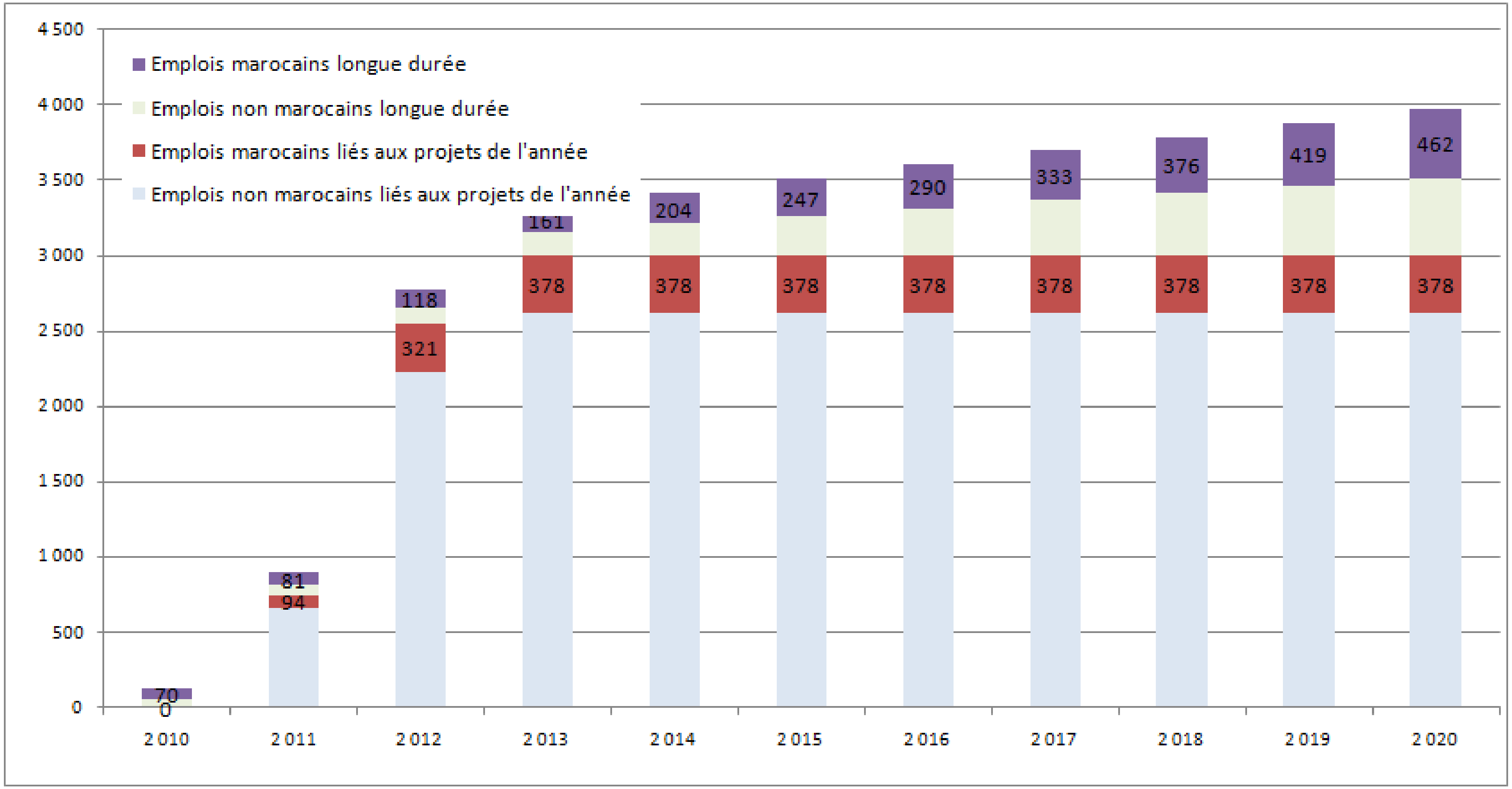


Source : Présentation du « Programme Intégré de Production Electrique Eolienne » à sa Majesté Le Roi par Madame Amina Benkhadra, Ministre de l'Energie, des Mines, de l'Eau et de l'Environnement et Monsieur Ali Fassi Fihri, Directeur Général de l'Office National de l'Electricité - Tanger le 28 juin 2010.

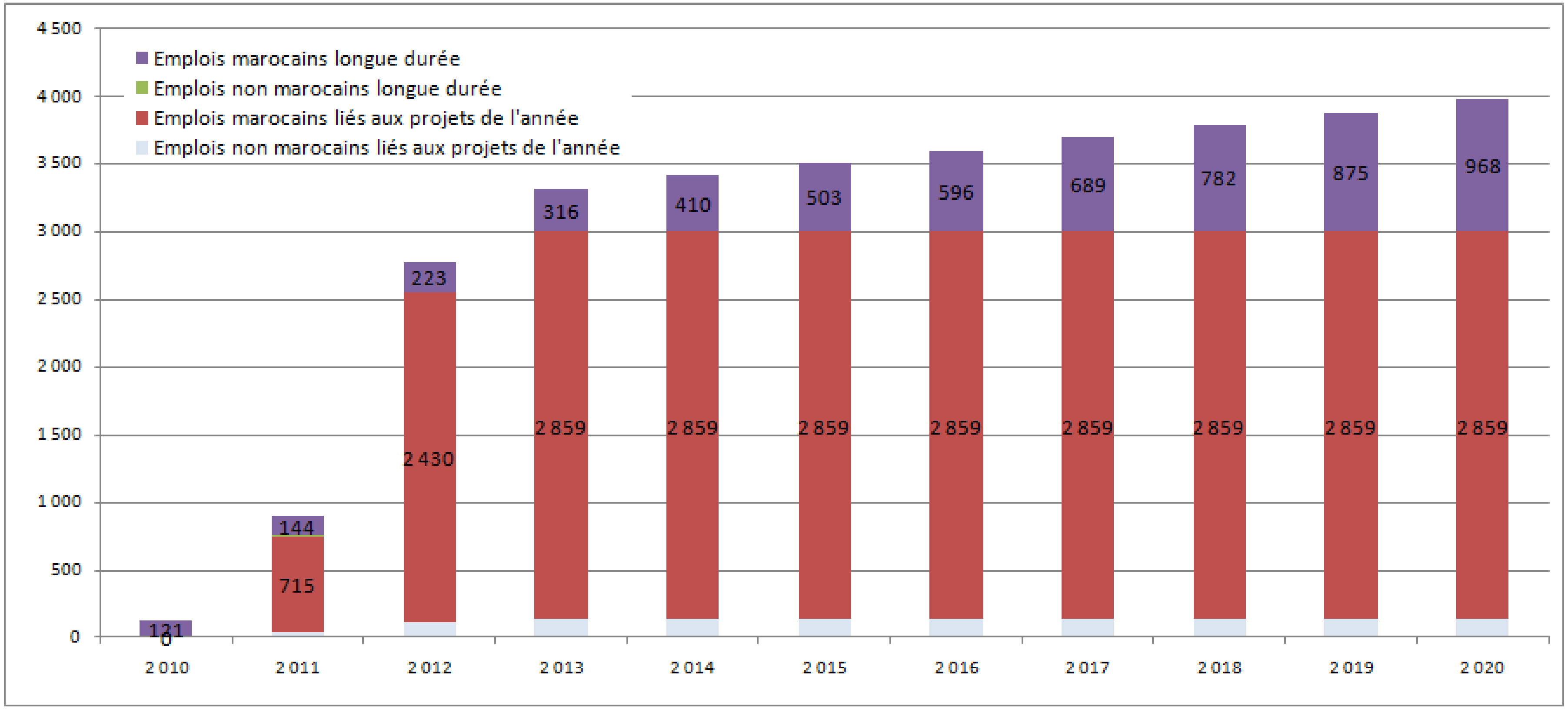
Résultats emplois en ratios

	Emplois Maroc			
	Sans intégration		Intégration industrielle	
	Par MW	Par MW cumulé	Par MW	Par MW cumulé
Fabricants éolienne			4,468	
Fabricants composants			2,657	
Autres fabricants			4,750	
Développeurs		0,056		0,070
Installation	0,960		1,200	
Exploitation Maintenance		0,165		0,330
IPP Utilities	0,836	0,045	0,836	0,045
Consultance ingénierie	0,056	0,003	0,251	0,014
R&D			0,046	0,003
Finance, assurance	0,006		0,022	0,001
Autre	0,033	0,002	0,065	0,004
TOTAL	1,891	0,271	14,295	0,467

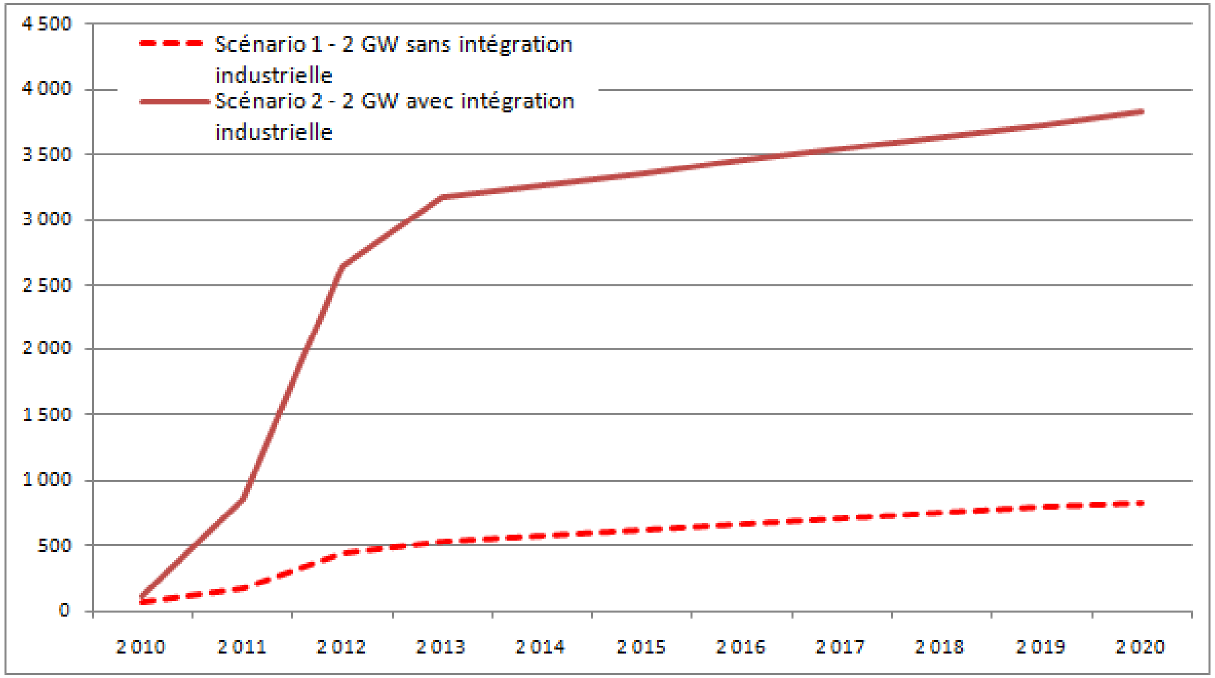
Résultats emplois
Sans intégration industrielle



Résultats emplois
Avec intégration industrielle



Bilan



Pour 1 MW installé générant 15 emplois directs ou indirects pour sa réalisation, **200 MW** d'installation annuels génèreront 3 000 emplois **pour la réalisation** (production et installation) dont **2 859 au Maroc**.

Pour 1 MW générant in-fine 0,47 emplois stables, **2 000 MW** installés en 2020 auront générés 977 emplois **de long terme** dont **968 au Maroc**.

Royaume du Maroc
Ministère de l'Energie, des Mines, de l'eau et de l'environnement
Département de l'Energie et des Mines
Eolien (scénario 2) forte intégration industrielle:

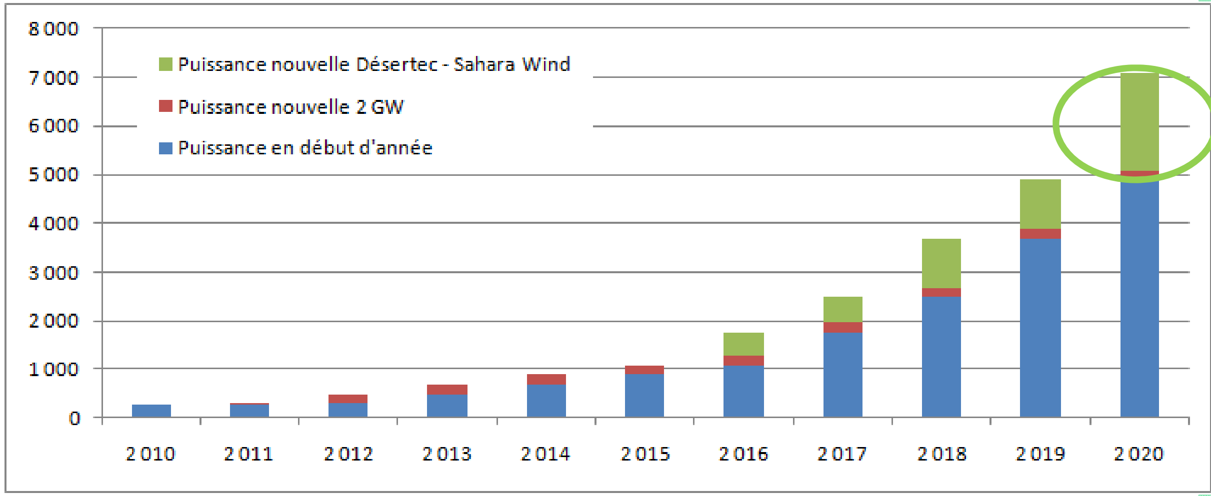
			2 010	2 011	2 012	2 013	2 014	2 015	2 016	2 017	2 018	2 019	2 020
Emplois dépendant de la puissance annuelle installée	Emplois non marocains		0	132	450	529	529	529	529	529	529	529	529
	Emplois marocains	Fabricants éolienne	0	188	640	753	753	753	753	753	753	753	753
		Fabricants composants	0	112	380	447	447	447	447	447	447	447	447
		Autres fabricants	0	200	680	800	800	800	800	800	800	800	800
		Installation	0	60	204	240	240	240	240	240	240	240	240
		IPP Utilities	0	42	142	167	167	167	167	167	167	167	167
		Consultance ingénierie	0	11	38	45	45	45	45	45	45	45	45
		R&D	0	0	2	2	2	2	2	2	2	2	2
		Finance, assurance	0	1	4	4	4	4	4	4	4	4	4
		Autre	0	3	11	13	13	13	13	13	13	13	13
		Total des emplois marocains	0	618	2 100	2 471	2 471	2 471	2 471	2 471	2 471	2 471	2 471
	Total		**0**	**750**	**2 550**	**3 000**	**3 000**	**3 000**	**3 000**	**3 000**	**3 000**	**3 000**	**3 000**
Emplois longue durée	Emplois non marocains		2	2	4	5	7	8	10	12	13	15	16
	Emplois marocains	Développeurs	18	22	34	48	62	76	90	104	118	132	146
		Exploitation Maintenance	86	102	158	224	290	356	422	488	554	620	686
		IPP Utilities	12	14	22	31	40	49	58	67	76	85	94
		Consultance ingénierie	3	4	6	8	11	13	15	18	20	23	25
		R&D	0	0	0	0	0	1	1	1	1	1	1
		Finance, assurance	0	0	1	1	1	1	2	2	2	2	2
		Autre	1	1	2	2	3	4	4	5	6	7	7
		Total des emplois marocains	120	143	222	314	407	499	591	684	776	869	961
	Total		**122**	**145**	**225**	**319**	**413**	**507**	**601**	**695**	**789**	**883**	**977**
		TOTAL	**122**	**895**	**2 775**	**3 319**	**3 413**	**3 507**	**3 601**	**3 695**	**3 789**	**3 883**	**3 977**

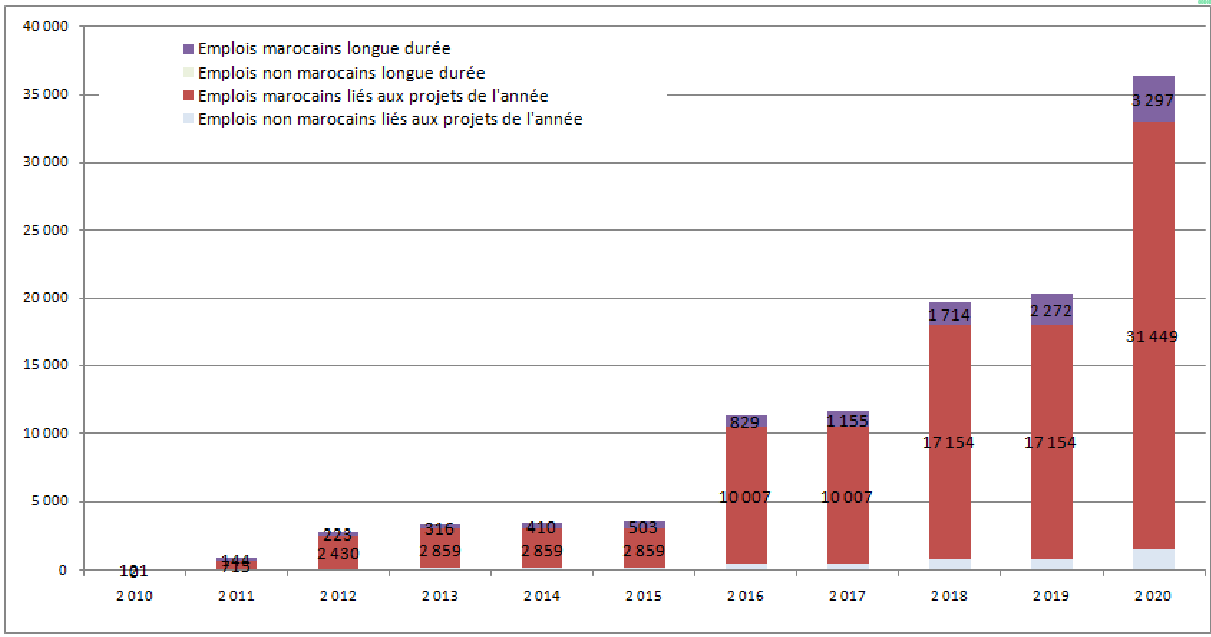
Scénario alternatif : Sahara Wind

Hypothèses :

- 5 GW supplémentaires installés en 2020
- Intégration industrielle 95%
- 500 MW installés/an en 2016 et2017
- 1 000 MW installés/an en 2018 et 2019
- 2 000 MW installés en 2020

Emplois non marocains liés aux projets de l'année	1 551
Emplois marocains liés aux projets de l'année	31 449
Emplois non marocains longue durée	30
Emplois marocains longue durée	3 297
	36 327





Royaume du Maroc
Ministère de l'Energie, des Mines, de l'eau et de l'environnement
Département de l'Energie et des Mines
Tableaux des emplois : Scénario 3 (Incluant Desertec et Sahara Wind)

			2 010	2 011	2 012	2 013	2 014	2 015	2 016	2 017	2 018	2 019	2 020
Emplois dépendant de la puissance annuelle installée	Emplois non marocains		0	298	1 012	1 191	1 191	1 191	4 169	4 169	7 147	7 147	13 102
	Emplois marocains	Fabricants éolienne	0	118	400	470	470	470	1 646	1 646	2 822	2 822	5 174
		Fabricants composants	0	98	333	392	392	392	1 370	1 370	2 349	2 349	4 307
		Autres fabricants	0	125	425	500	500	500	1 750	1 750	3 000	3 000	5 500
		Installation	0	54	184	216	216	216	756	756	1 296	1 296	2 376
		IPP Utilities	0	42	142	167	167	167	585	585	1 003	1 003	1 839
		Consultance ingénierie	0	11	38	45	45	45	156	156	267	267	490
		R&D	0	0	2	2	2	2	7	7	11	11	20
		Finance, assurance	0	1	4	4	4	4	16	16	27	27	49
		Autre	0	3	11	13	13	13	46	46	78	78	143
		Total des emplois marocains	0	452	1 538	1 809	1 809	1 809	6 331	6 331	10 853	10 853	19 898
	Total		**0**	**750**	**2 550**	**3 000**	**3 000**	**3 000**	**10 500**	**10 500**	**18 000**	**18 000**	**33 000**
Emplois longue durée	Emplois non marocains		2	2	4	5	7	8	14	19	29	38	55
	Emplois marocains	Développeurs	18	22	34	48	62	76	125	174	258	342	496
		Exploitation Maintenance	86	102	158	224	290	356	587	818	1 214	1 610	2 336
		IPP Utilities	12	14	22	31	40	49	80	112	166	220	319
		Consultance ingénierie	3	4	6	8	11	13	21	30	44	59	83
		R&D	0	0	0	0	0	1	1	1	2	2	4
		Finance, assurance	0	0	1	1	1	1	2	3	4	6	8
		Autre	1	1	2	2	3	4	6	9	13	17	25
		Total des emplois marocains	120	143	222	314	407	499	822	1 146	1 701	2 255	3 272
	Total		**122**	**145**	**225**	**319**	**413**	**507**	**836**	**1 165**	**1 729**	**2 293**	**3 327**
		TOTAL	**122**	**895**	**2 775**	**3 319**	**3 413**	**3 507**	**11 336**	**11 665**	**19 729**	**20 293**	**36 327**

Sahara wind

Sahara Wind Energy Development Project

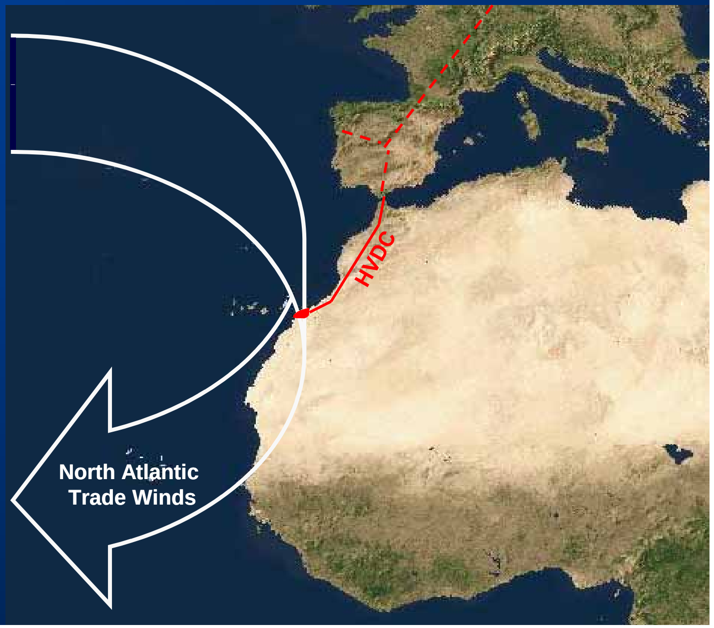
R&D is a Prerequisite for Optimal Development & Deployment of Sahara Wind Project
Sahara Wind Phase 1: 50~500 MW on existing grid (Extensions through HVDC lines)

HVDC Technology:

- Limited losses –long distance (3% over 1500 Km ±500kV for 5000 MW)
- 80 GW of HVDC Projects worldwide: India, China, Canada, Brazil..

Euro-Mediterranean electricity market in growth/expansion with Spain & Portugal (EU Members) CO_2 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(?)+



Sahara wind

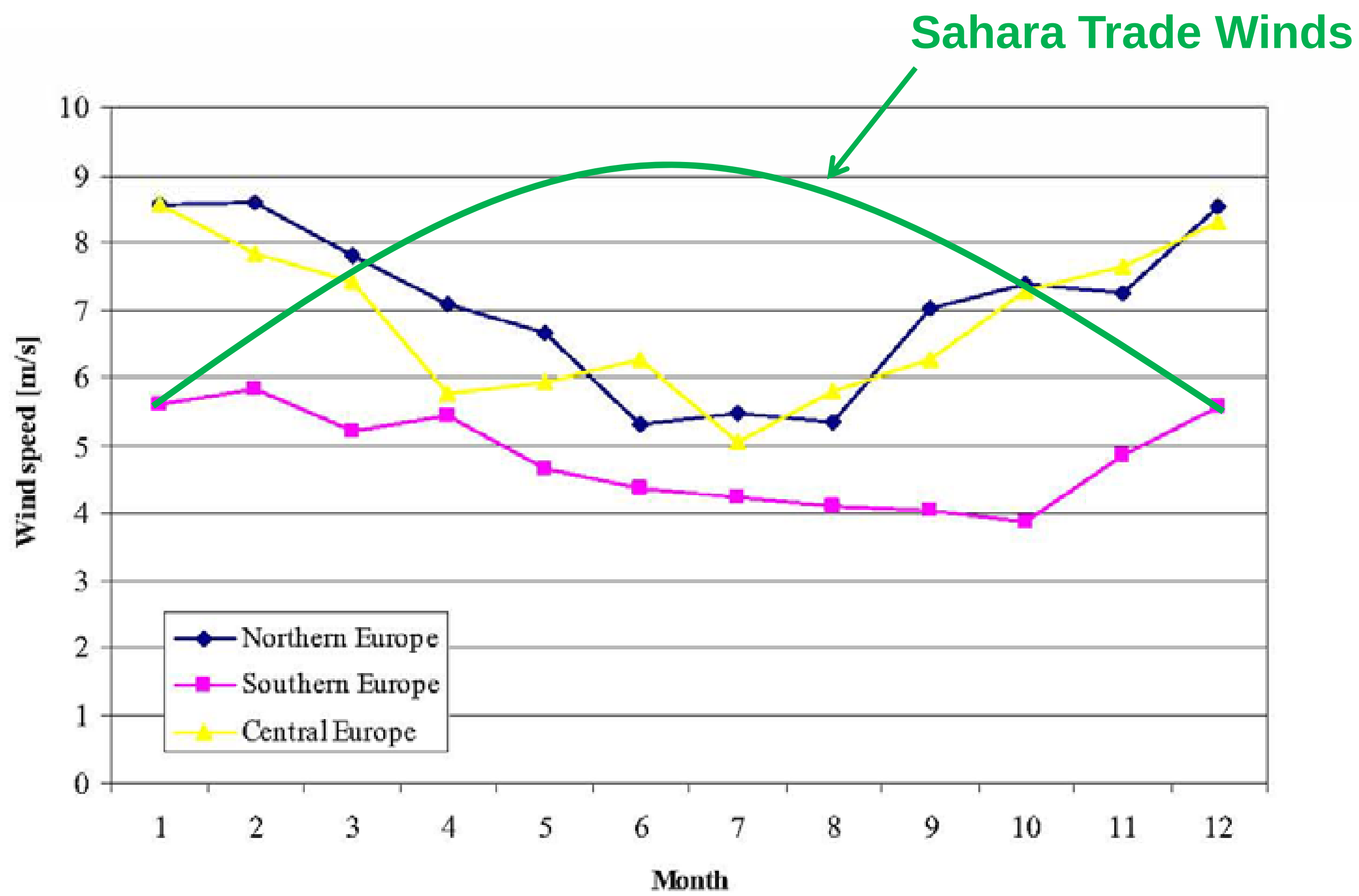
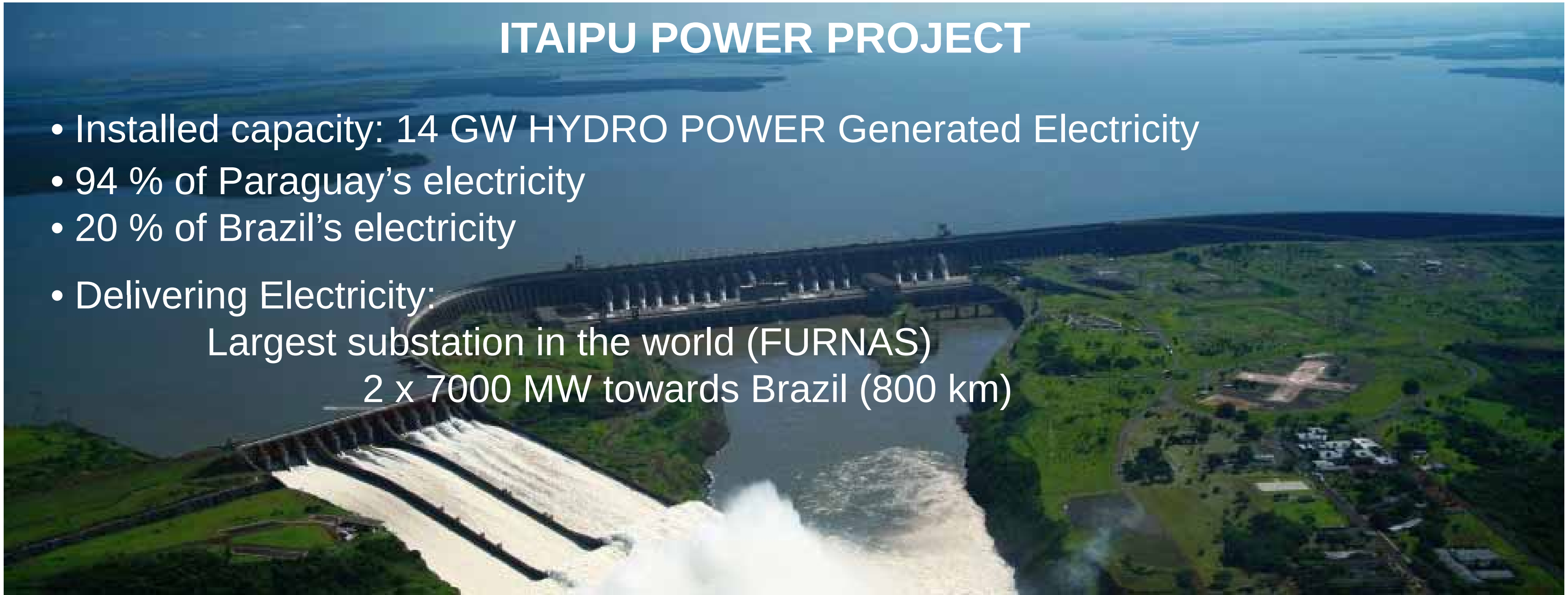


Figure 2.4 Seasonal trends in Reanalysis wind speed

Source: EU funded TradeWind Project, (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,UNIDO…
- Mediterranean Solar Plan: 50 MW Pilot Project(s) (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 transfer technology (losses: 3% for 1500 Km)
•5 GW Wind Energy/Pumped Storage(1TWh)+ Solar (HVDC losses 5% for 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
- => Expected economies of ccale
- Project Costs are distributed though timely & phased deployment (2013-2020+)

Sahara wind

Projet Sahara Wind

Déploiement Graduel en Phases successives

Sahara Wind - Phase I : 50~500 MW (2012-2016) Études Impact Réseau/Phasage Projet avec ONE (Opérateur réseau Maroc), Projet OTAN (SfP-982620) mesures de vent, Projet ONUDI études synergies industrielles avec ONEP, appui d'autres institutions (Fonds Énergie Maroc, BEI, Banque Mondiale, PNUD, FEM, …)

Sahara Wind - Phase II : 500 MW ~ 5 GW (2016-2020)
• 500 MW x 2 tranches (phases) / 2 bi-pôles 5 GW – HVDC
•1000 MW x 2 tranches (phases) / 2 bi-pôles 5 GW - HVDC

Sahara Wind - Phase III : 5 ~ 10 GW (2020+)
•2000 MW x 1 à 2 tranches (phases) / 2 bi-pôles 5 GW – HVDC
Optimisation de l'infrastructure d'évacuation lignes HVDC à 10 GW

Complémentaire au :
•Programme Marocain Intégré de l'Energie Eolienne : 2 GW (2020)
•Programme Marocain Solaire (Solaire Thermique & Photovoltaïque): 2 GW (2020)
•Plan Solaire Méditerranéen (PSM): 20 GW (2020)
Projet Sahara Wind - Phase I présenté au Plan d'Action Immédiat du PSM (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

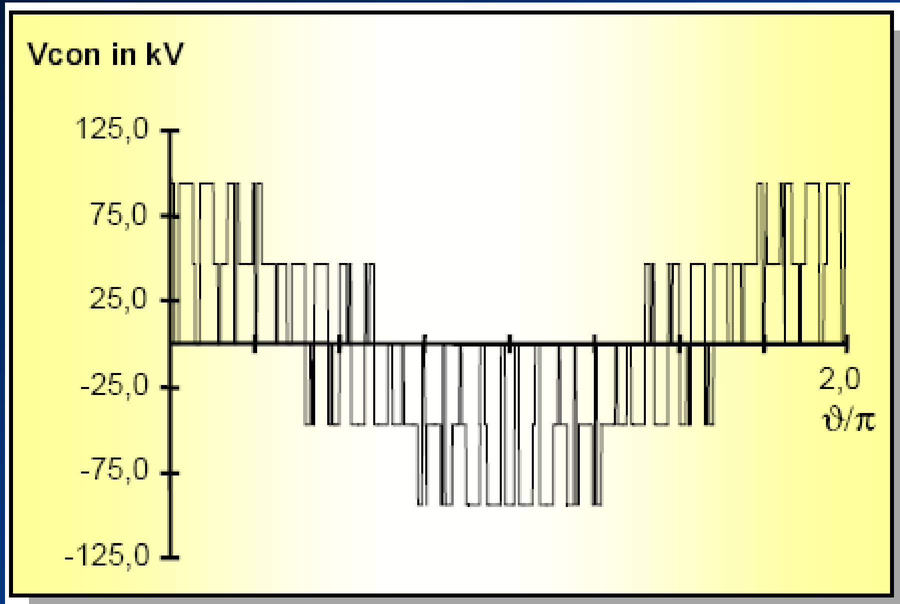
- HVDC is a firewall against faults. In a cascading AC fault, an HVDC interconnection stops the propagation.

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

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

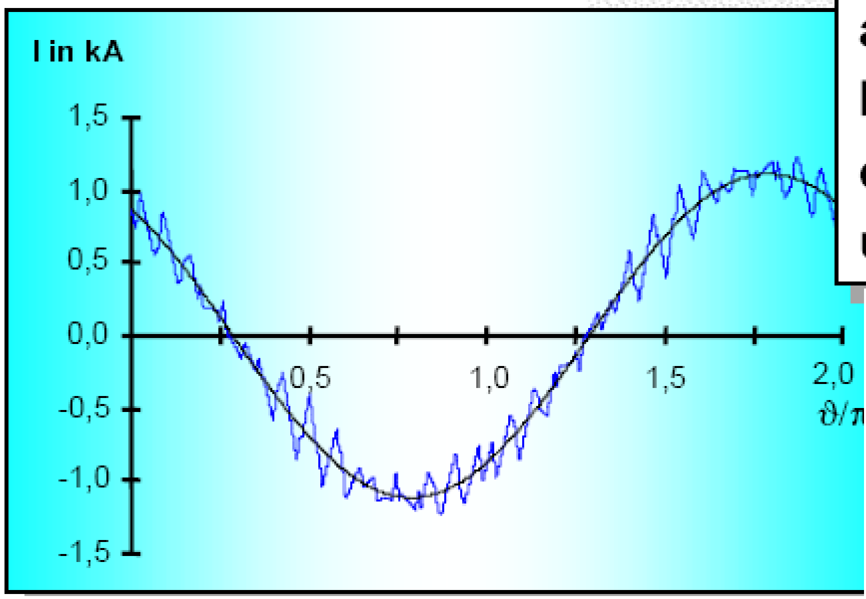
NATO OTAN 1949 - 2009
This project is supported by: The NATO Science for Peace and Security Programme

HVDC Technology for Power Transmission and Distribution



VSC Technology:
2 Level VSC Voltage and Current Waveshapes

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



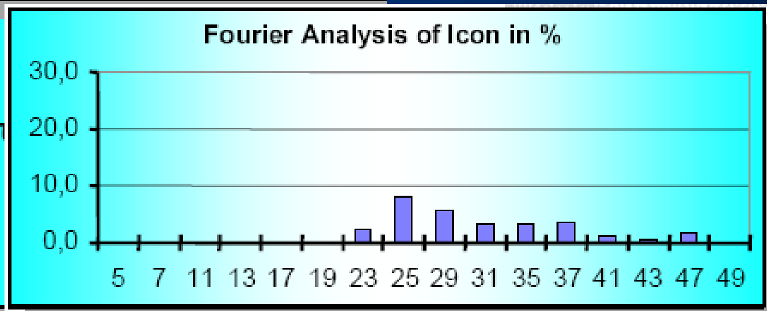
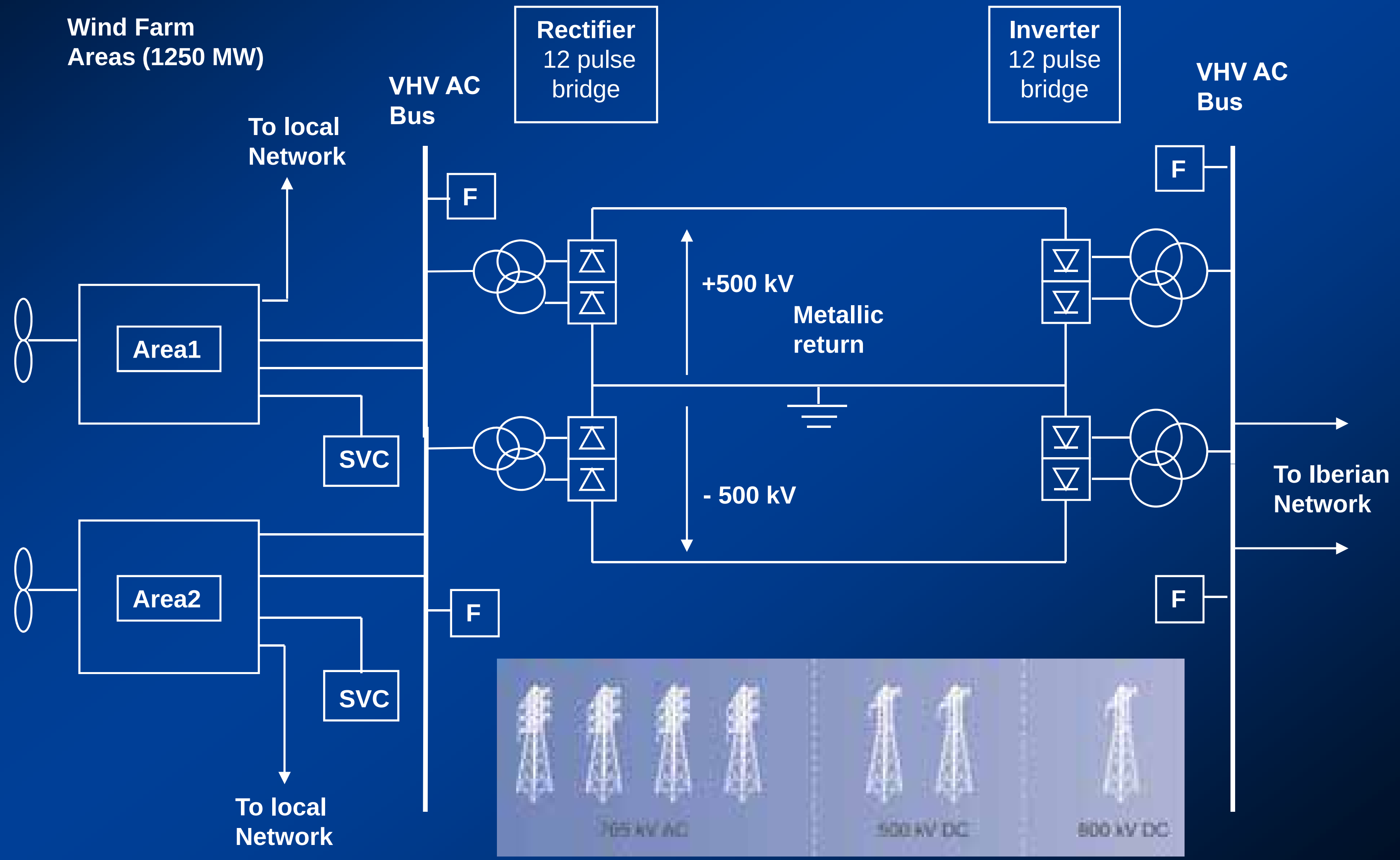
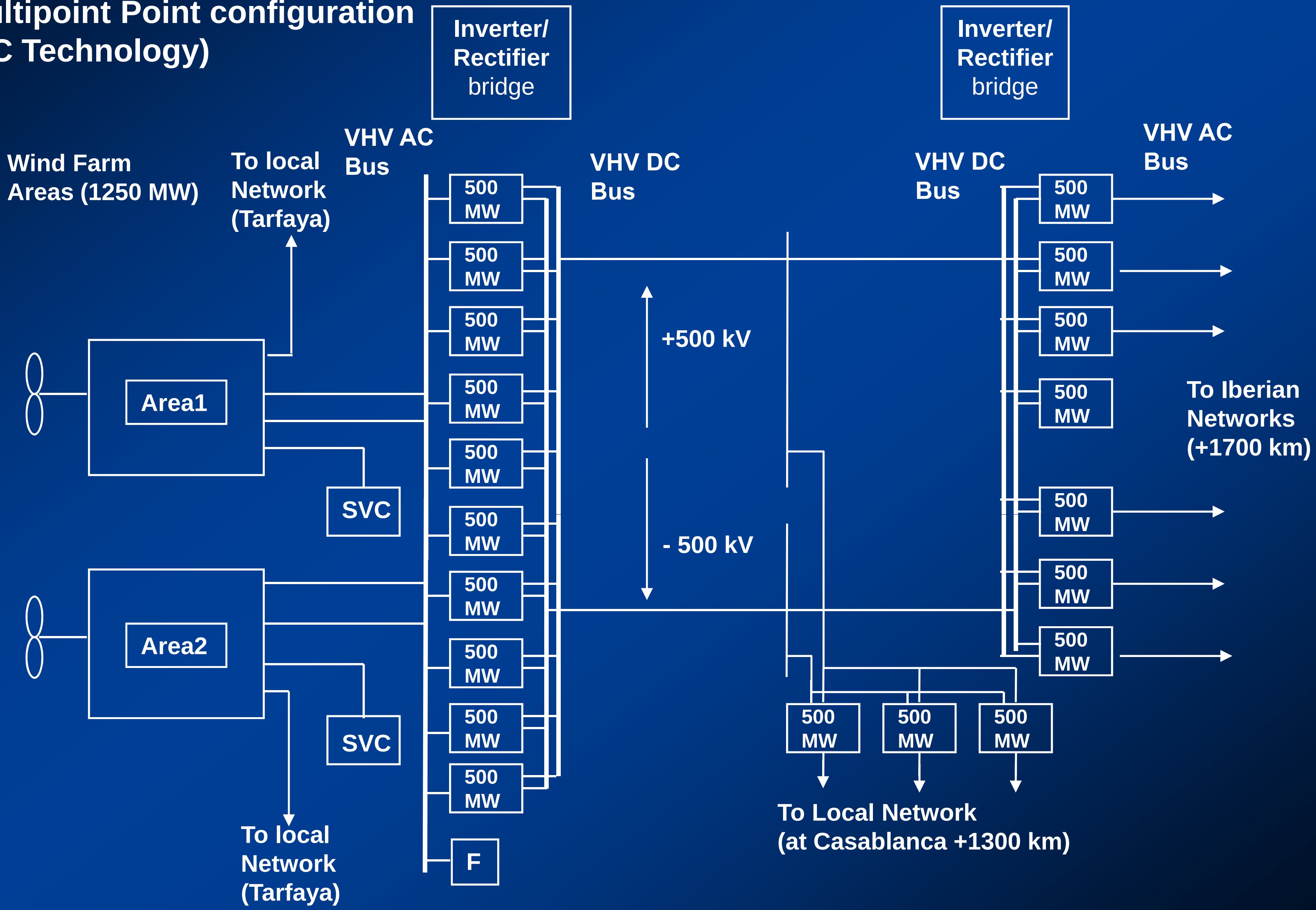


Figure 1 : Sahara Wind - HVDC Transmission Architecture 5 GW - bipole 1 (Point to Point configuration classical HVDC)



Sahara wind

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



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

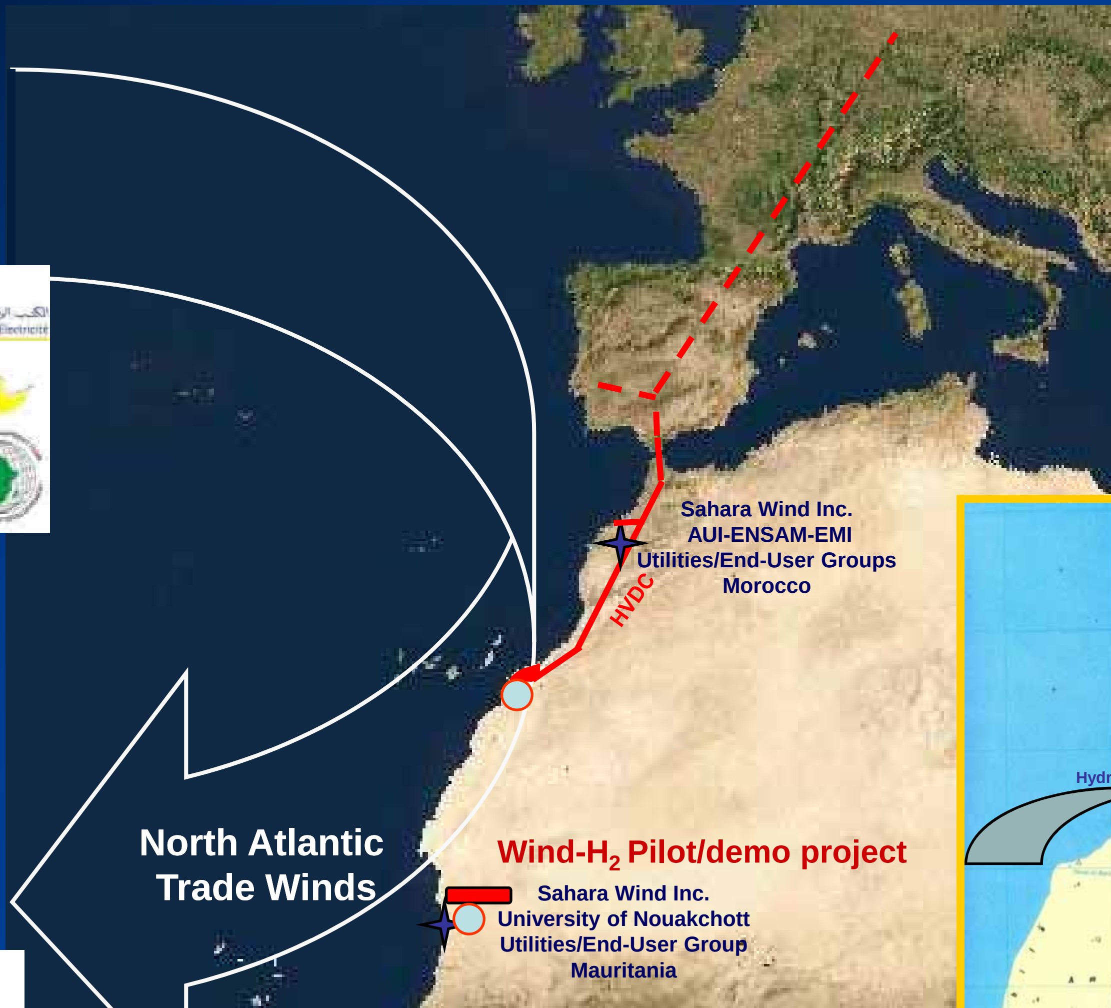
NATO Science for Peace SfP-982620 UNIDO(ICHET) Sahara Wind-H_2 Demo Projects

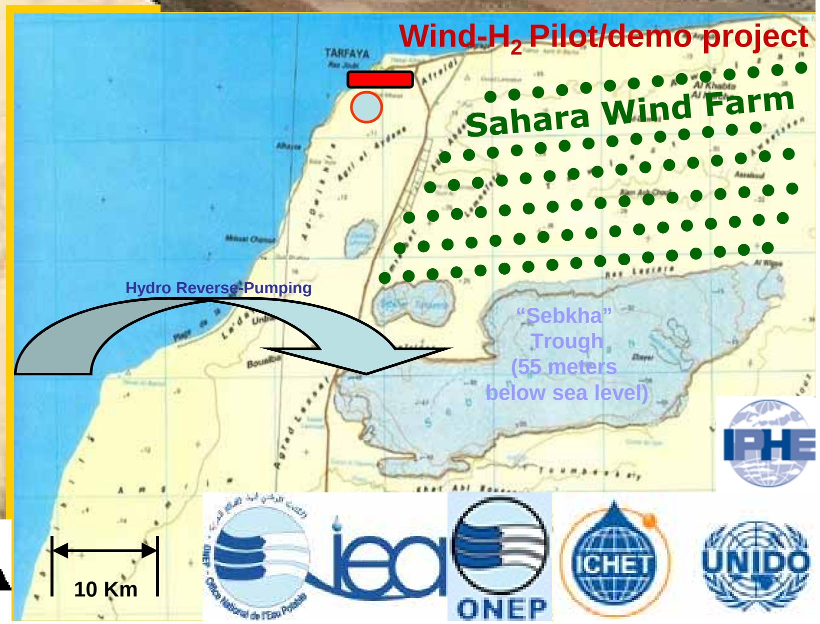
NATO OTAN

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)





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جامعة الأخوين

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Sahara wind

Sahara Wind Project : NATO 'Science for Peace' SfP-982620 Partners…

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