

International Cooperation on Research to Support Large Scale Integrated Sustainable Energy Perspectives: The Sahara Wind Project

10th World Renewable Energy Congress and Exhibition

European Workshop on
Success factors for International Cooperation on
Research, Technological Development and Demonstration
in the Area of Renewable Energy

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SfP-982620

European Energy Security: Profile of Electricity Supply Sources (2003)

EU DG Transport and Energy: Previsions of installed electric generating capacities in Europe

Power generation capacity by type of plant in EU-25, 1995-2030.

| | GWe | | | | | %Share | |
|-------------------------------------|------------|------------|------------|------------|-------------|------------|------------|
| | 1995 | 2000 | 2010 | 2020 | 2030 | 2000 | 2030 |
| Nuclear | 134.7 | 140.3 | 129.8 | 108.0 | 107.8 | 21.4 | 9.5 |
| Large Hydro (pumping excl.) | 91.0 | 93.9 | 95.8 | 96.3 | 97.0 | 14.3 | 8.6 |
| Small Hydro | 2.0 | 2.1 | 8.1 | 12.2 | 14.5 | 0.3 | 1.3 |
| Wind | 2.5 | 12.8 | 73.5 | 104.7 | 135.0 | 2.0 | 11.9 |
| Other renewables | 0.0 | 0.2 | 0.5 | 0.7 | 14.3 | 0.0 | 1.3 |
| Thermal plants | 381.4 | 406.1 | 484.8 | 639.0 | 762.9 | 62.0 | 67.4 |
| <i>of which cogeneration plants</i> | 80.7 | 93.2 | 117.6 | 150.9 | 179.5 | 14.2 | 15.9 |
| Open cycle - Fossil fuel | 339.4 | 335.2 | 278.9 | 210.0 | 196.8 | 51.1 | 17.4 |
| Clean Coal and Lignite | 0.0 | 0.0 | 0.0 | 0.8 | 5.5 | 0.0 | 0.5 |
| Supercritical Polyvalent | 0.0 | 0.0 | 0.8 | 55.3 | 126.3 | 0.0 | 11.2 |
| Gas Turbines Combined Cycle | 20.0 | 47.3 | 173.3 | 313.8 | 367.4 | 7.2 | 32.5 |
| Small Gas Turbines | 21.2 | 22.7 | 30.6 | 57.8 | 65.5 | 3.5 | 5.8 |
| Fuel Cells | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Geothermal | 0.7 | 1.0 | 1.2 | 1.3 | 1.4 | 0.2 | 0.1 |
| Total | 612 | 655 | 793 | 961 | 1132 | 100 | 100 |
| current EU | 539 | 579 | 689 | 813 | 951 | 88 | 84 |
| acceding countries | 73 | 77 | 104 | 148 | 181 | 12 | 16 |

Source: PRIMES, ACE.

Morocco's Development Targets in Wind Energy

- Morocco's Current Targets before 2012: 1000 MW
- ONE -Morocco Utilities- Planned Projects ENERGIE Pro (1120 MW) Cogeneration Projects Under Development.
- Legislative Approval for Generalizing Purchase Power of 50 MW size Wind Farms into grid (Offset Cogeneration projects).

Limitation factors: Grid Capacity...!!!

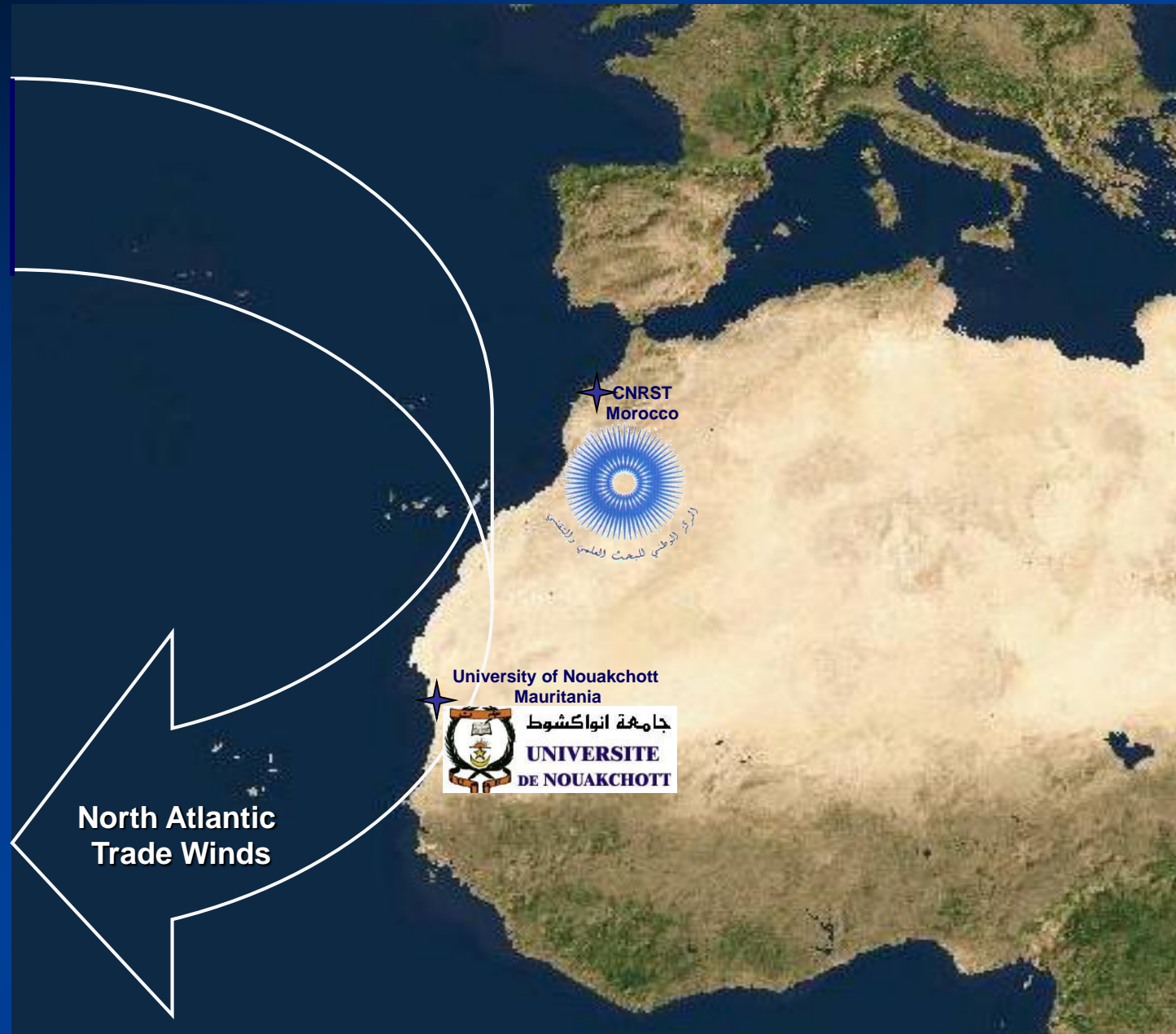
- Total Grid Size (5000 MW) / Possible Wind Power Integration 1000 MW
- Big Wind Potential but Far Away from Load Centers
- No Plans for Transferring Wind Industry

=> Need to develop integrated approach: The Sahara Wind Project (5GW)



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NATO SfP-982620 PROJECT OBJECTIVES

- Integrating Wind Energy Locally is a Key Priority for Morocco & Mauritania

- Essential for Industrializing North Africa
Sustainable Energy Systems = Sustainable Energy Economy

Mobilize Largest Energy Consumers (RD&D program)

- Build SYNERGIES
- Stimulate Local Innovation & Research
- Provide Integrated Solutions
- Mechanisms Against Global Climate Change
- Security Issue: Fixing Migrant Population Fluxes



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NATO SfP-982620 PROJECT OBJECTIVES

Build Synergies with Industry



Wind Resource Assessment:
Partnership Between University of Nouakchott and Mauritania Telecom



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NATO SfP-982620 PROJECT OBJECTIVES

- Reinforce Research Capacities Around Common Strategy – (on Regional basis)
 - Sustainability of Energy
 - Energy Technology Integration
 - Industrial Synergies (End Uses)
 - Leverage Human Resources
- Reinforce Role of Education and Research in National Energy Choices (Debate)
- Expand Knowledge Base in Energy Technologies of the Future
- Develop Scientific Competence in Securing Intellectual Property Rights of Research Groups & individual members.
- NATO Intellectual Property Rights Committee



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Context of R&D in Developing Countries

Challenges of Human Resources, Investment in Scientific Production

- Huge Unbalances regarding R&D activities compared with EU countries

Most Researchers are Employed in Universities or in Public Administrations (Institutions).

Intellectual Property & Scientific Production is Very Limited

Average Yearly Publications per 100 Scientists (*):

- Egypt, Algeria, Tunisia (6 per year)
- Morocco (5 per year)
- Mauritania, Libya, Soudan (1~2 per year)

Private Sector Involvement is Negligible (High Risk inherent to R&D activities discourages majority of SME's, even in Developed Countries)

(*) Results for 1995-2005 of Number of Publications (10 years)

Source: Jorge E.Hirsch- UC California Index for measuring productivity of Scientific Researchers (2005)

Issues Over Intellectual Property Rights

- Intellectual Property Rights: **Positive Side** Enables Frameworks & Agreements to be Developed between Industry & Research Community
- Intellectual Property Rights: **Negative Side**
Not an Incentive: Rules of Ownership Public Institutions vs Researchers
- Intellectual Property Rights: **Negative Side**
Hampers Collaboration with Major Industrial Conglomerates (State Owned)
 - Exclusive Ownership on all IPR on processes related to their activities
 - Collaboration on Technology shared ownership (often undesirable)
 - Public-Private Partnerships on Technology Development leading to shared IPR Hardly Existing nor Accepted (State Monopoly Situation)



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Regional Barriers and Facilitators for RES Development

Two Distinctive Research Environments: Morocco & Mauritania

➤ Morocco:

- Better Established Academia and Independent Research Teams
- Little Incentives to Pursue PhD Thesis at Universities (current reforms)

➤ Mauritania:

- Smaller More Polyvalent Research Teams
- Lack of Research Experience & Equipment Infrastructures
- Priorities is Teaching, 4 Year Colleges
- Very Little Exchanges with Industry
- Government Hiring Competence Among Faculty Staff (preventing research activities)



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Morocco: Barriers for RES Development

- Syndrome of Centralized Institutions (National Centres and Agencies)
 - Infrastructures mainly focused on processing administrative tasks
 - Research Budgets doesn't provide real incentive
 - IPR is not an incentive because not owned by researchers but public institutions.
 - Human Resources (productivity)
 - Beyond Self Managed Grants: limited experience in the functioning of collaborative research activities with private sector.
 - Rules of International Collaborative Research Mechanisms will take time to be fully effective.
- Decentralized Approach with Universities: Much more efficient



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Mauritania: Barriers for RES Development

- **Limited Institutions, one University (essentially teaching: Hence Pressure from Intl institutions to create labeled “National Agencies” or “Centers”)**
 - **Personal Relationship Very important factor for success (Right Chemistry)**
 - **High availability: Collaboration is seen very positively (value added activity)**
 - **Hardware & Equipment sorely needed to boost research**
 - **Collaboration of Academia with Economic Actors is Relatively New and Welcomed. Genuine Effort and Availability to Help boost local Education System**
- **Once Trust is established => win-win situation: significant opportunities with very good potentials (on applied research themes).**
- **Creativity and Flexibility of Operation (Very Good Assets)**
- **Local Environment, Culture & Particularities Very Important Aspects**
- **Necessary Administrative hold on budgets at Universities slow down processes**



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NATO 'Science for Peace' SfP-982620 Project Objectives

- Overcome Limits of Wind Energy Utilization in Weak Grids (Stabilization through Wind Electrolysis, Hydrogen & byproducts integration)
- Consider wind resource potential as a basis for evaluation of new market opportunities in the fields of Renewable Hydrogen, Oxygen, and other electrolysis by-products.
- Expand knowledge-sharing opportunities where partnerships in Research-Development and Learning Demonstration can be established
- Co-development of Electrolyzer prototypes dedicated to specific local conditions/applications (Manufacturer agreements with patent protection Under IPR committee)



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Sahara Wind Energy Development Project

Energy Access

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

Wind Energy: fastest growing, most competitive renewable energy.

Erratic nature of winds is a MAJOR limiting factor

Intermittency and grid stability problems (power margins, dispatching, reactive compensation, voltage, frequency regulation, flickers, harmonics...)

Denmark: 22% Wind energy Penetration rate (World's Maximum)

Germany: (125.000 MW) encounters problems in integrating & stabilizing only 7% of its electricity consumption through wind energy.

Problems are more acute in weak grid conditions
(handling wind energy fluxes with no interconnection possibilities)

Saharan Countries Total installed electric generation capacities:

Mauritania 120 MW, Senegal 239 MW, Mali 280 MW, Niger 105 MW, Chad 30 MW !

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

Wind Energy, Capacity Building and Energy Access

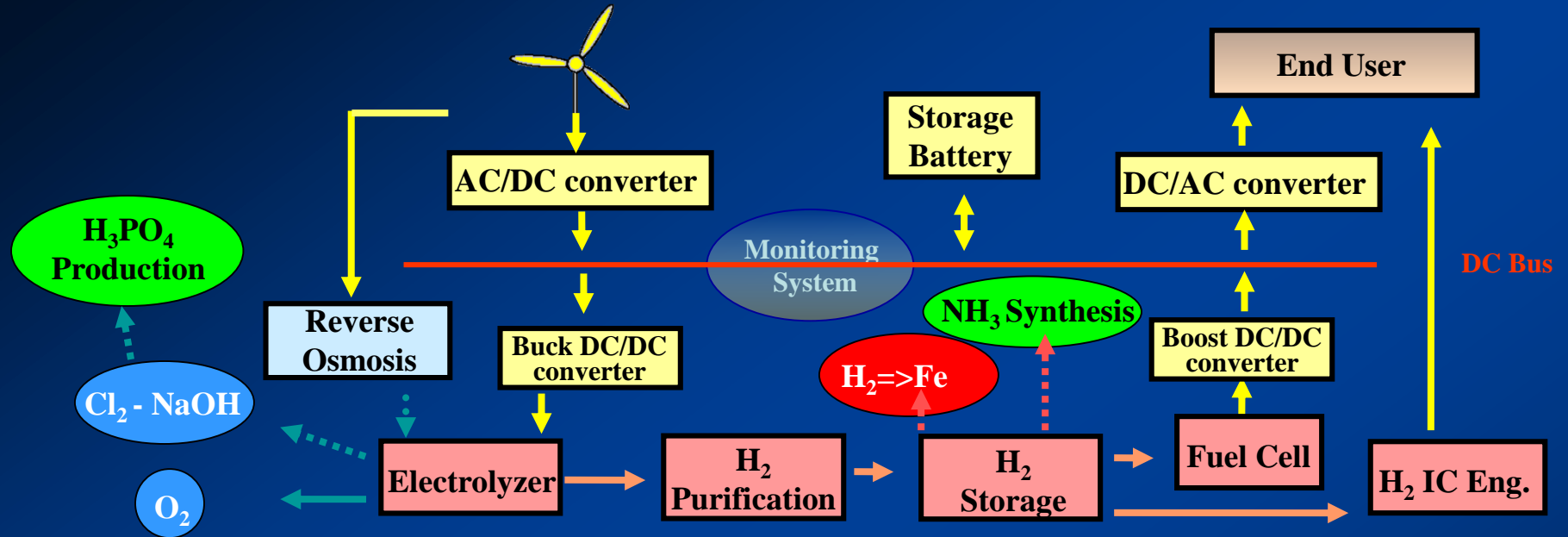
A strategy has to be developed for integrating Wind/RE technologies.

Potential risks of not integrating a strategy: Grid quickly saturates to Wind Energy (20% Wind easily reached in small grids!)

Hydrogen Energy : Comprehensive & Integrated R&D Theme

- Holistic approach
- Broad ranging, integrated process
- Bottom-up capacity building
- Capitalizes on available human resources & research institutions
- Creates research networks sensitized on issue
- Prevents energy technology gaps from widening
- Generates synergies with local industries
- Potential for technology co-development & industrial integration
- Countries with large Renewable Energy potentials & limited energy intensity more accessible to Hydrogen technology scales.
- Stimulates wider regional cooperation to support integrated carbon free, sustainable energy technologies perspectives on unprecedented levels!

Pilot Project Test Benches R&D themes



Wind Electricity Direct Use

Wind Desalination: Test of Reverse Osmosis Unit Prototype

Wind Stabilized Electricity for Industry Processes: PO_4 , Fe, EAF...

Real Time Simulation: Case Studies

Wind Resource & Hydrogen Processes Assessment

Electronic Power Regulation - Systems Integration – Applications & Economic Analysis

Wind Electricity Storage

Hydrogen/Oxygen Purification & Storage

Electrolyzer Technologies

Power Units: Fuel Cells – IC Engines

Chlorine-Uses/ H_2 -Ammonia Production
Direct Reduction of Iron-Ore

NATO Science for Peace SfP-982620

Electrolysis by-products and Hydrogen End User Markets

Hydrogen could be integrated to the region's main industries:

Morocco Phosphate Processing Industry:

- Sea Water Electrolysis: Chlorine for Phosphoric Acid Production
- Integrate fertilizer industry most comprehensively, beyond export of phosphate based fertilizers.
- Production of Ammonia (Stable H₂ storage medium as well)
- Phosphor-gypsum recycling (12 Million tons/year currently dumped) potentially transformable into Portland Cement, (without any CO₂ emissions).

Mauritania Mining & Iron-Ore Industry:

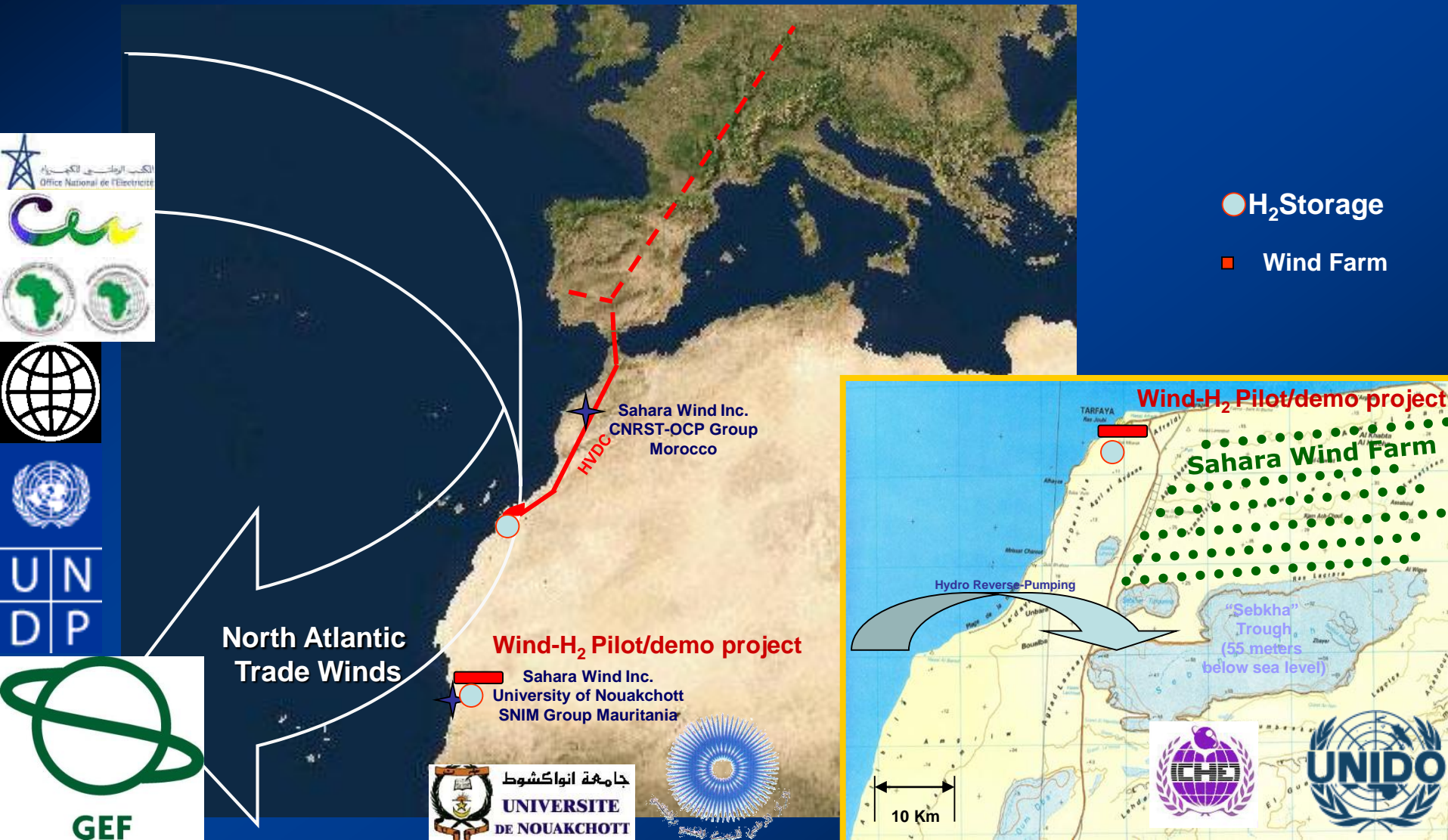
- Hydrogen: Direct Iron Reduction process (DRI) 4% of primary iron production
- Electricity + Oxygen: Steel Production through Electric Arc Furnace (EAF) processes used in 45% of world steel production



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



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)

Near Bishop, California USA

Right: 300 MW HVAC

Sahara Wind Project

Wind Energy, Capacity Building, Energy Access, Integrated Power System

The critical size of the Sahara Wind Project enables:

- Building a Broad Project Development Platform**
- Involve Several Multilateral Institutions**
- Develop Long Term Strategy**
- Leverage Sustainable Development and Capacity Building objectives**

NATO Science for Peace SfP 982620 project a first step into gradual introduction of state-of-the-art energy technologies.

Expand this platform into the Sahara/Sahel region

Sahara Wind-Hydrogen demo/pilot projects (UNIDO-ICHET co-funded) likely to be included into IPHE list of collaborative projects (several participating IPHE member countries).

Bridge hydrogen production technologies and applied research with needs of developing countries.

Enables Transition from raw mineral extractive economy into value added sustainable processing industries (G8 objectives for Africa).

Sahara Wind Energy Development Project

Wind Energy integration & Alternative Energy Technologies

Capitalize on Industry and University/Research institutions

- **Limited Size of Electricity Markets and Grid Infrastructures**
- **Reinforce Link with Industry (Largest Energy Consumers)**
- **Test and Disseminate Technology (Clusters)**
- **Incubators for Newer Technologies**
- **Build Pilot Projects to Support Integrated Solutions**

Sahara Wind's Upstream Project Development Activities to Pave Way to Future Large Scale Wind/HVDC Transfer and Wind/Hydrogen Applications.

Wind-Hydrogen electrolysis provides an ideal testing ground for applying the latest research and technological breakthroughs in the development of renewables and hydrogen driven economy.

Non-Energy Local Hydrogen End User Market: Morocco's Phosphate Industry, Mauritania's Iron Ore processing.



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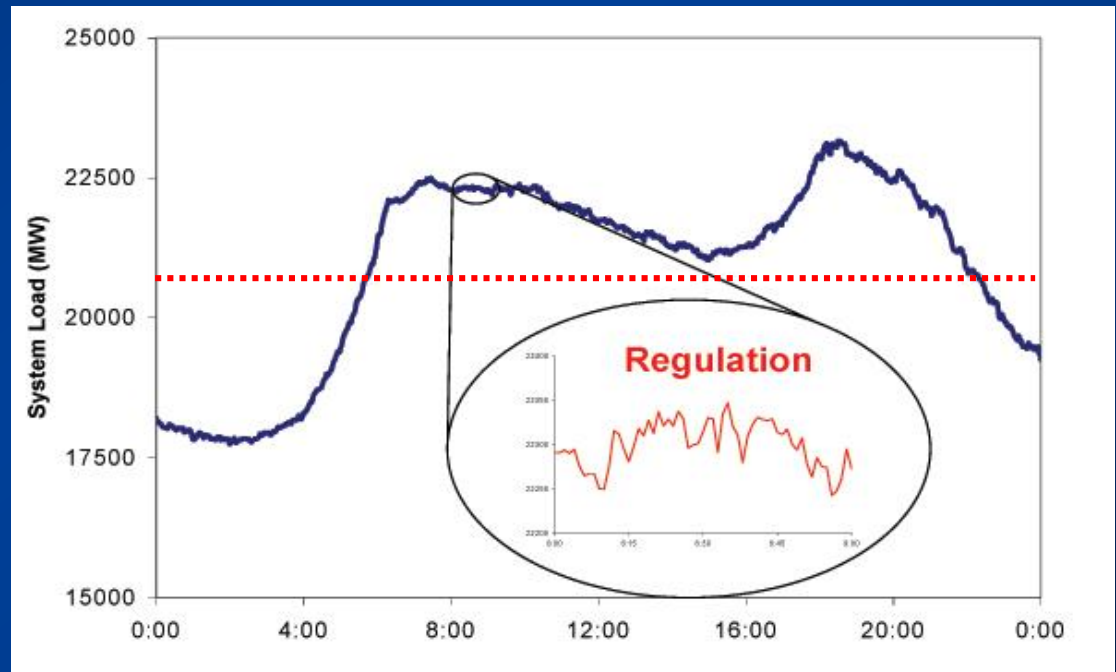
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Grid Stabilization through Wind-electrolysis

Wind power is erratic, power output fluctuates

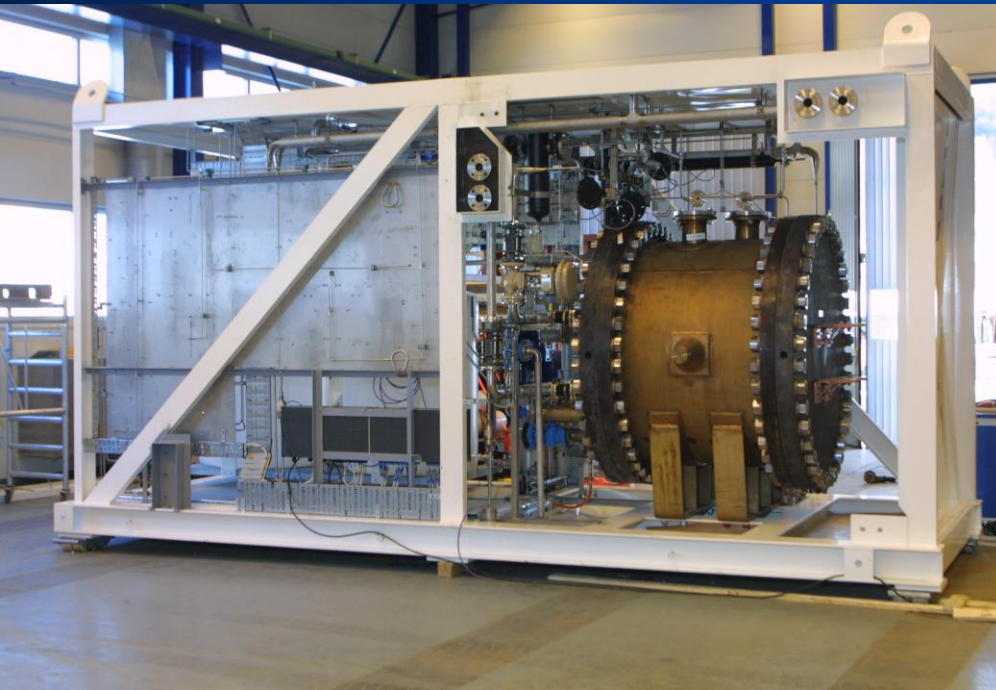
Electrolyzers used as grid stabilizing 'dump loads'

- ✓ Eliminates wind fluctuations effects
- ✓ Enhances power quality, flickers...
- ✓ Frequency control
- ✓ Generates H_2 & O_2 for back up (spinning reserve), as fuel (transport) or chemical feedstock (industry).



Sahara Wind Energy Development Project

Wind-Hydrogen Electrolyser types (Pressurized)



Norsk Hydro electrolyzer, KOH type 560 kW
130 Nm³ / hour at 450 psi (30 bar)

Photo: Norsk Hydro Electrolysers



Norsk Hydro Electrolyzers 2 MW each

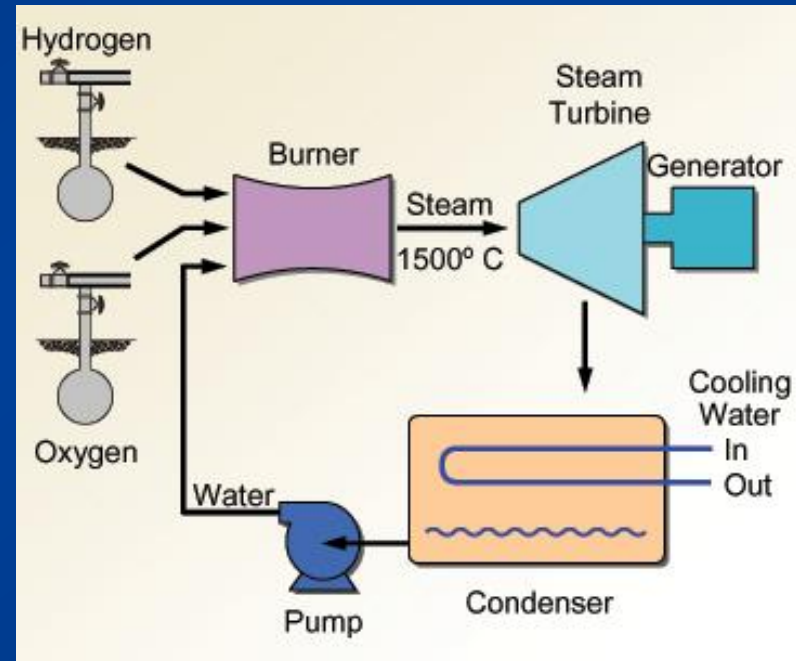
Evaluate latest technologies aimed at maximizing renewable energy uptake in weak grids through Wind-electrolysis

H₂&O₂ Steam turbine

Special Steam turbine:
Converts H₂ (Fuel) & O₂ (Oxidizer) mixture to Electricity

Used for Peak hours:

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



Hydrogen for peak power, spinning reserve,
grid stabilization and back-up

Sahara Wind Energy Development Project

New Energy Technologies and Capacity Building

The introduction of new energy technologies at an early stage, through regional applied research projects will establish and identify areas where potential breakthroughs can become significant in the future.

Involving domestic scientific communities enables newer, wide-ranging approaches to better integrate the Region's real Renewable Energy Potentials.

The Region disposes of a qualified pool of University Professors, Engineers and Scientists that currently lack appropriate Research Infrastructures.

Wind-electrolysis for Hydrogen production can be used for grid stabilization, power restitution/backup in remote locations and as fuel or feedstock in specific applications.

Hydrogen as an energy carrier to store intermittent sources of renewable energies is scalable and can be worked into modules, small medium and large integrated applications.

Equipping and networking the main research institutions in Morocco and Mauritania is critical before extending it beyond the Sahara/Sahel region. This is a first step towards a successful, gradual introduction of state-of-the-art energy technologies.



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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.

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UNIVERSITE DE NOUAKCHOTT - FACULTE
DES SCIENCES ET TECHNIQUES

CRAER – CENTRE DE RECHERCHE
APPLIQUE ENERGIES RENOUVELABLES

ISSET ROSO – 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
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SAFA – SOCIETE ARABE DES FERS ET
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