NATO 'Science for Peace'

SfP-982620

Sahara Trade Winds to Hydrogen: Applied Research for Sustainable Energy Systems

Kick-Off Meeting

29th – 30th November 2007, Rabat Morocco

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

- Energy Security and the environment: Resource limitations – the push for renewables

- Energy access: A social priority

- Enabling technologies for integrating renewables – a new approach

- Capacity building: Potential for synergies and coordinated approach involving Industry, Education and Science

- The Sahara Wind Project

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North Africa's energy challenges: energy access, resource limitations and economic sustainability

Morocco: 96% energy dependency from fossil fuels (imported)

The case is very similar in most sub-Saharan Countries

1.6 Billion people do not have access to Electricity Worldwide

situation is simply not acceptable… nor accepted!

Saharan Countries Total installed electric generation capacities:
Mauritania 120 MW, Senegal 239 MW, Mali 280 MW, Niger 105 MW, Chad 30 MW

Land degradation, desertification and demographic pressure on largely agricultural based societies (most vulnerable to climate changes) tends to generate economic distress…

NATO Security Related Issues: Illegal Immigration

‘Cayucos’ Boats carrying illegal immigrants off the Canaries Islands

NATO Security Related Issues: Illegal Immigration

Fishing is a Traditional Economic Activity

'Cayucos' fishing vessels in Sub-Saharan Africa

(Similar technology as Wind Turbine wood epoxy blades)

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
of which cogeneration plants	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.

‘HySociety’ (EU funded 2003-2005) project conclusions:

Prerequisite Strategic question on Hydrogen energy: Energy Supply

HySociety scenario (2030) 20% Energy end use of EU-25

=> 85 million Hydrogen Fuel Cell vehicles in EU (25 MT H_2)

•Savings in EU primary energy demand in transport sector by 2030: 5% only!

•Emissions reductions in EU transport sector by 2030: 5% only!

Why? 85% of that hydrogen is derived from fossil fuels (HySociety scenario)

In order to be VIABLE a HYDROGEN economy needs to be:

Energy efficient, meet emission targets, and sustainable in terms of resources

=> Hydrogen economy needs to be closely associated with renewable energies

It is mandatory that Hydrogen economy opens supply perspectives!

Beyond the energy resource debate

Hydrogen, an enabling energy technology

Hydrogen is a clean, universal energy carrier

Hydrogen processes “as enabling technologies” in developing sustainable energy systems have greatest potential => “Harnessing Renewables”

•Hydrogen technologies need to be initially deployed where more relevant: that is distributed applications with high integration potential.

Critical to initiate <u>bottom up process</u> whose gradual integration will enable the building of large sustainable energy systems.

=> These will ultimately lead to the building of a hydrogen economy.

Sahara Wind Energy Development Project

Energy Access

The Trade Winds along the Atlantic coast from Morocco to Senegal: largest, most productive wind energy potential available on earth.

Wind Energy: fastest growing, most competitive renewable energy.

The erratic nature of winds however, limit the extent to which wind energy can be used.

Intermittency and grid stability problems represent MAJOR limiting factors (power margins, dispatching, reactive compensation, voltage, frequency regulation, flickers, harmonics…)

Denmark: 'only' 22% of electric consumption from wind

Germany: Europe's most powerful grid (125.000 MW) 8% from wind energy

Problems are more acute in weak grid conditions

(handling wind energy fluxes with no interconnection possibilities)

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.

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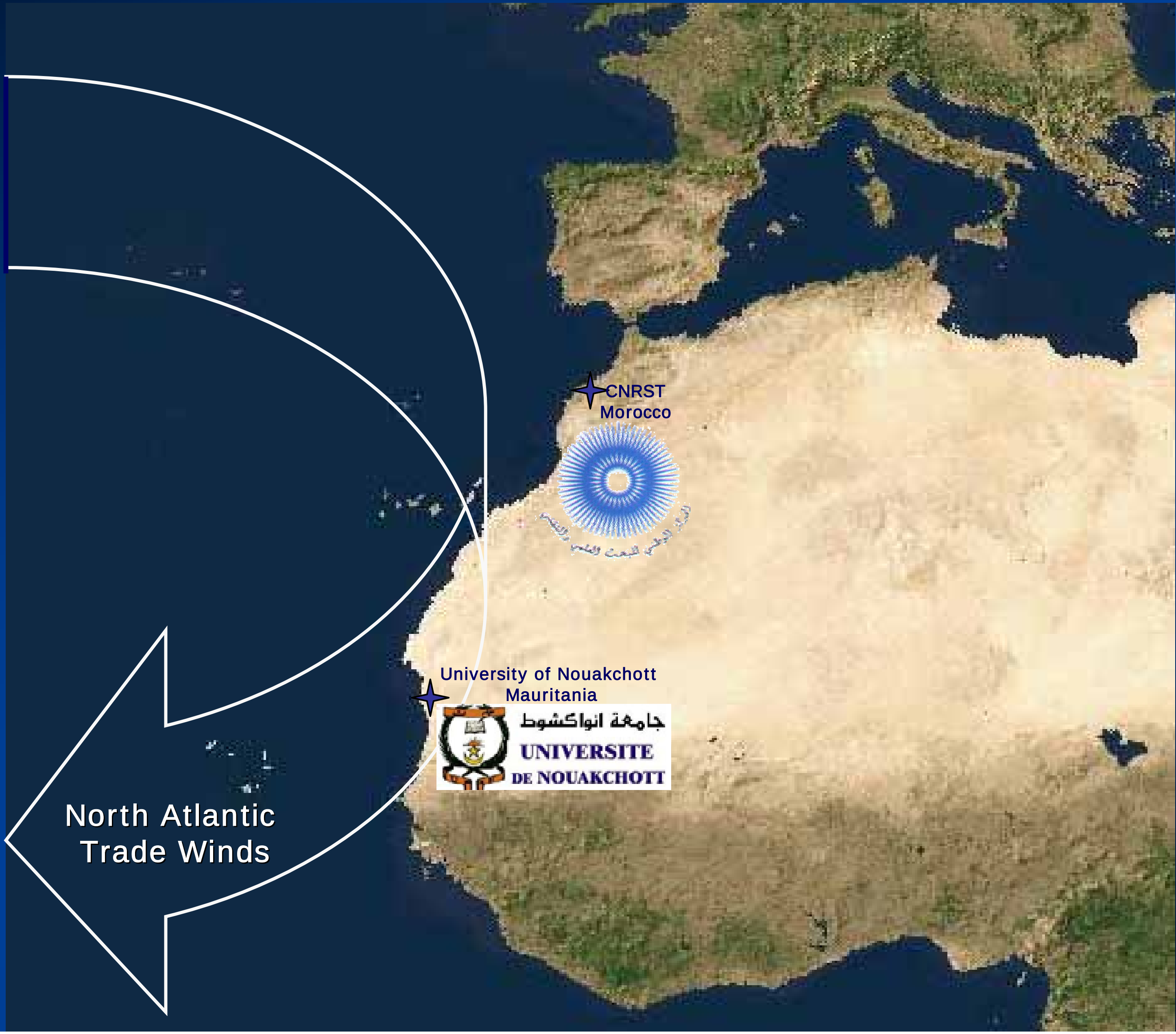

Wind Energy, Capacity Building and Energy Access

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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 Alternative : Needs to be Comprehensive & Integrated

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

NATO SfP-982620 Project Objectives

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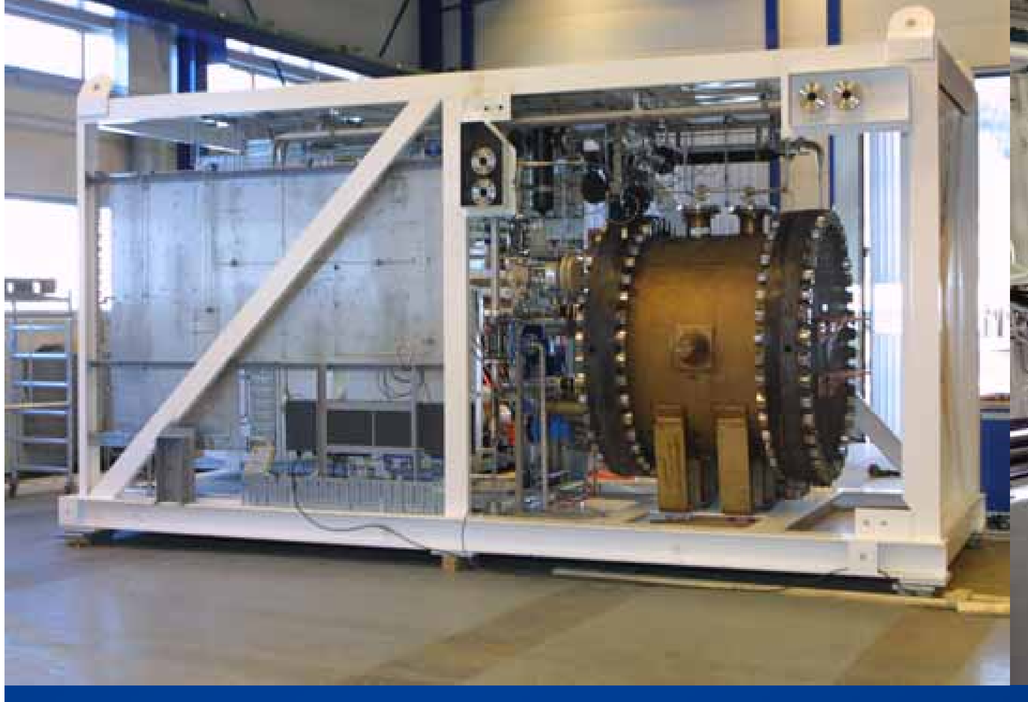
- Overcoming Limits of Wind Energy Utilization in Weak Grids (Stabilization through Wind Electrolysis, Hydrogen & byproducts integration)

- Map out 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 NATO IPR committee)

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

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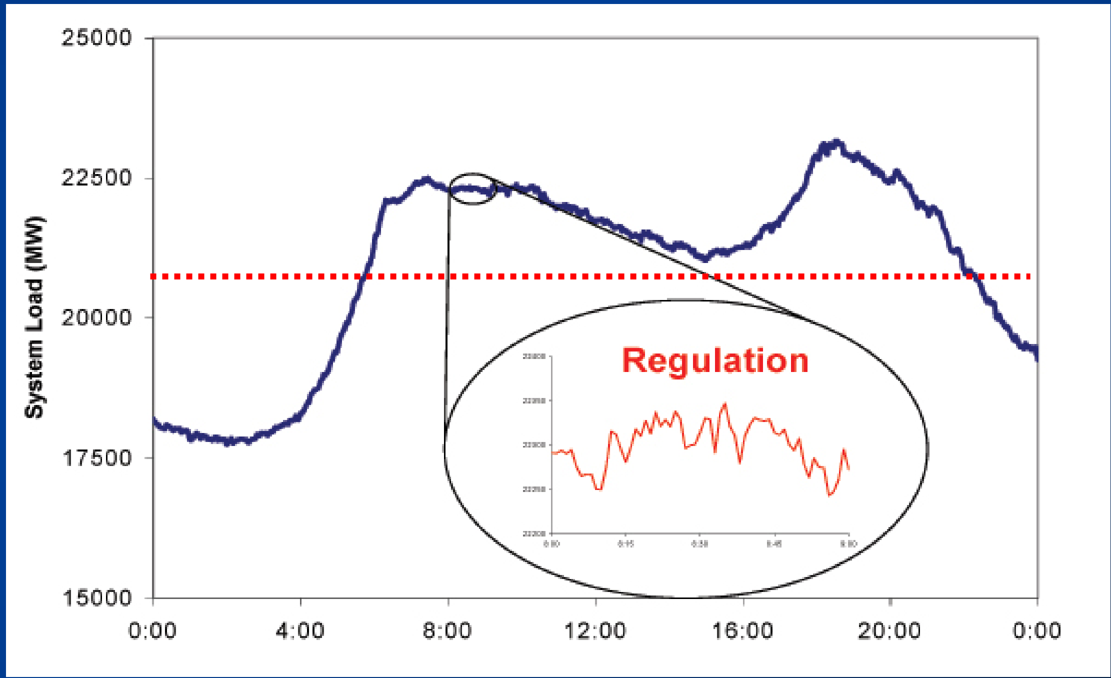
Grid Stabilization through Wind-electrolysis

Wind power is erratic, power output fluctuates
Electrolyzers used as grid stabilizing 'dump loads'

✓**Eliminates wind fluctuations effects**
✓**Enhances power quality, flickers…**
✓**Frequency control**

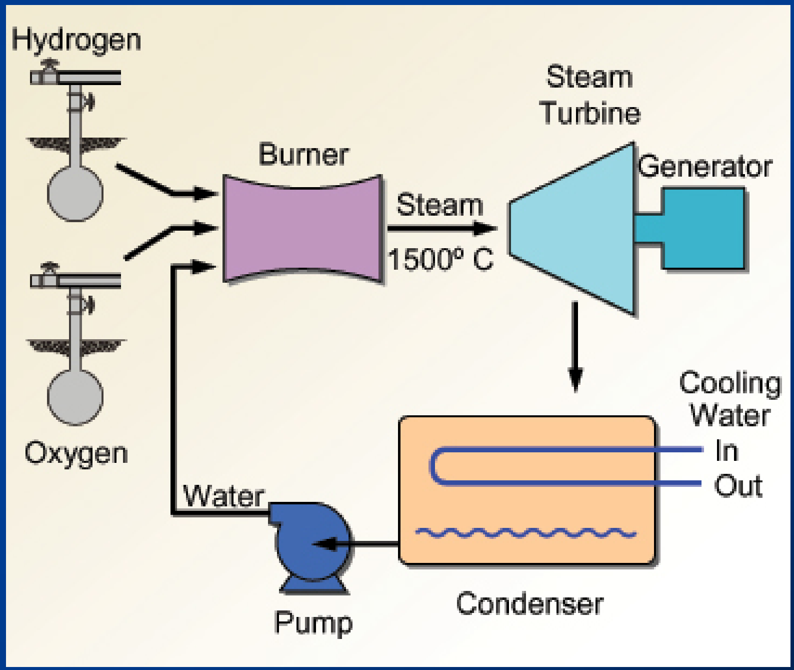
✓**Generates H_2 & O_2 for back up (spinning reserve), as fuels or for chemical uses.**



Evaluation of existing technologies maximizing renewable energy uptake in weak grids through Wind-electrolysis

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)**

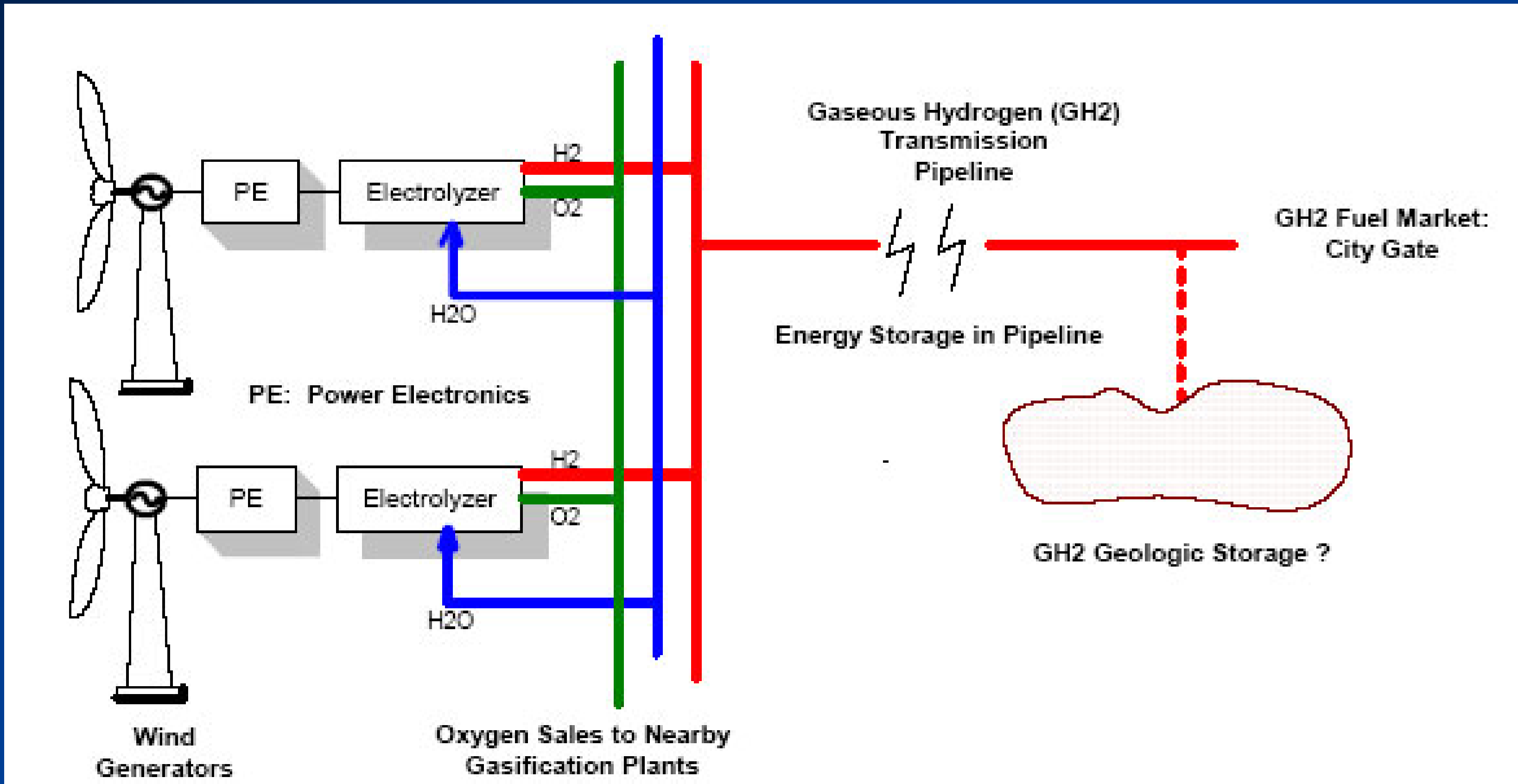


Hydrogen for peak power, spinning reserve, grid stabilization and back-up

Sahara wind

Sahara Wind Energy Development

Integrated Large Scale Wind-Hydrogen Production



Compressor less Wind-Electrolysis-Gaseous Hydrogen GH2 Pipeline system

Hydrogen Storage & GH2 Networks for Fuel Market at City gate

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Sahara Wind Energy Development Project
Electrolysis by-products and Hydrogen End User Markets

Integrating Hydrogen into local/regional economy:
Hydrogen could be integrated to the region's main industries

Phosphate Processing Industry:
- Integrate fertilizer industry most comprehensively, beyond export of phosphate based fertilizers.
- Production of Ammonia (Stable H_2 storage medium as well)
- Sea water Alkali-Electrolysis: Chlorine for Phosphoric Acid Production
- Phosphor-gypsum recycling (12 Million tons/year currently dumped) potentially transformable into Portland Cement, (without any CO_2 emissions).

Mining & Iron-Ore Industry:
- Hydrogen: Direct Iron Reduction process (DRI) 4% of primary iron production
- Electricity + Oxygen: Steel Production through Electric Arc Furnace (EAF) 45% of world production

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Potential End Users

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Morocco

Office Chérifien des Phosphates - **OCP Group**:

19.500 employees (830 engineers), Annual Exports 1 Billion+ Euro, 3 % of National GDP Share

- 75% of the World's Phosphates reserves
- World's Market shares: Phosphates 45%, Phosphoric Acid 47%, Fertilizers 12%

NATO SfP-982620 interests in: Wind Electricity, Desalination, Electrolysis for Hydrogen (Ammonia), Oxygen (Oxy-combustion) and Chlorine (Hydrochloric acid for Phosphoric acid production).

Water Utilities of Morocco – **ONEP**:

6.856 employees (14% Engineers or equivalent)

751 Million m3 of potable water per year, 96% of urban population of Morocco

256 Million Euro investments per year

NATO SfP-982620 interests in: Wind Electricity, Desalination, Electrolysis for Chlorine, Oxygen

Mauritania

Société Nationale Industrielle et Minière – **SNIM**:

4.000 employees, Annual Revenues 600 Million Dollars, 12% of National GDP share

11~12 Million tones of Iron-Ore Exports/year

3 x 80 MW installed co-generation capacity, reverse osmosis demineralization units

NATO SfP-982620 interests in: Wind Electricity (Electric Arc Furnaces), Desalination (processes), Electrolysis for Oxygen (Metallurgy) & Hydrogen (Direct reduction of Iron-Ore) & integrated Backup systems.

Water Utilities of Mauritania – **SNDE**:

NATO SfP-982620 interests in: Wind Electricity, Desalination, Electrolysis for Chlorine or Oxygen

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Sahara Wind Project
Wind Energy, Capacity Building and Energy Access

The critical size of the Sahara Wind Project enables:
•Building a broad project development platform
•Involve Several multilateral institutions
•Develop Long term strategy (protects project's concepts & integrity)
•Sustainable development and capacity building objectives can be leveraged

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

Further steps: Expand this platform into the Sahara/Sahel region

Sahara Wind-Hydrogen demo/pilot projects (UNIDO funding) likely to be included into the International Partnership for the Hydrogen Economy (IPHE) G8 + China, India, Brazil… list of collaborative projects

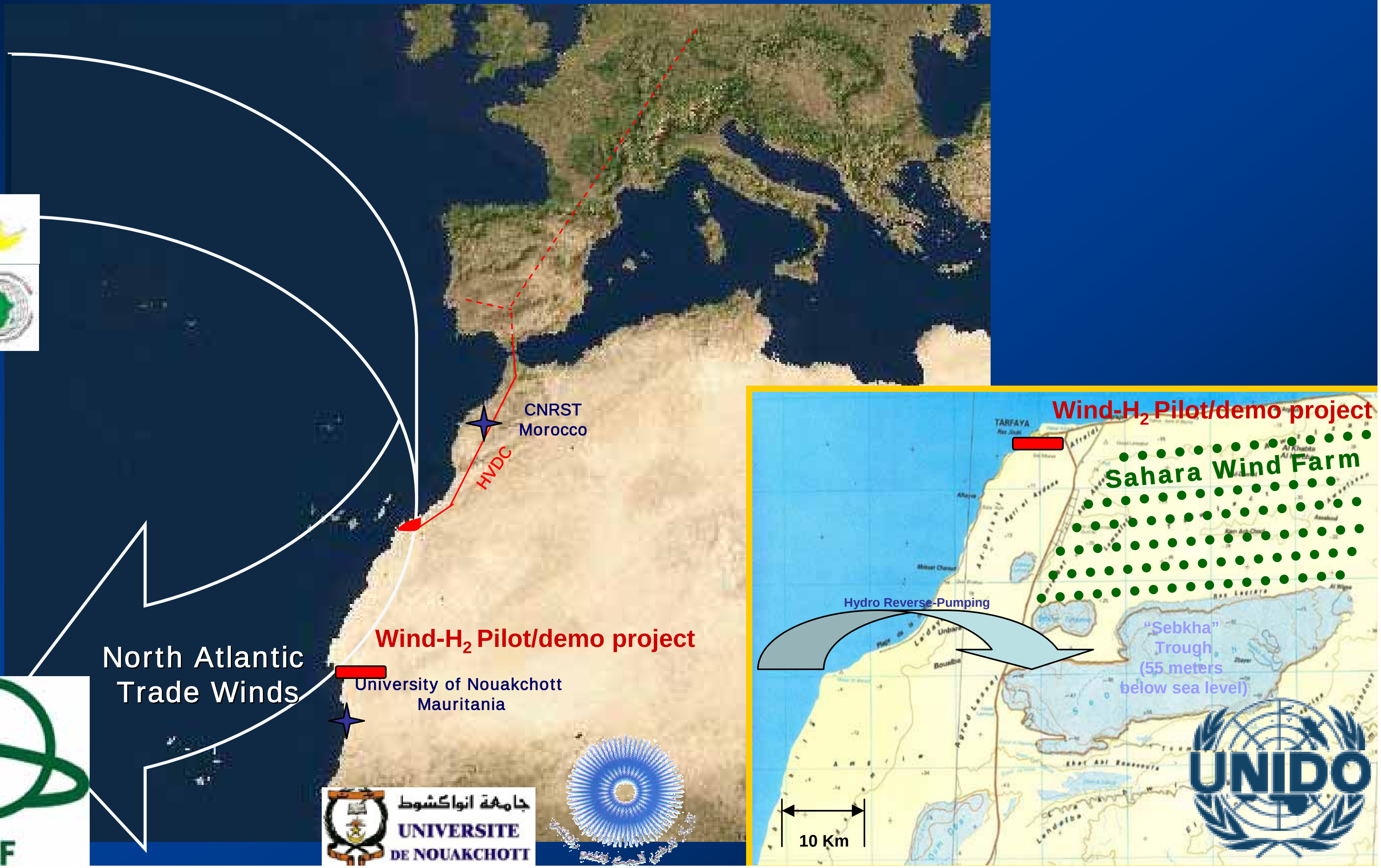
Bridge hydrogen production technologies with needs of developing countries.

Sahara wind

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

Joint WB-AfDB UNDP/GEF (PDF-B PIMS #3292) / Extensions HVDC (5 GW)

Morocco: Sahara Wind Phase I / Tarfaya (400-500 MW) on-grid wind electricity in a liberalized market:



ITAIPU POWER PROJECT

- Installed capacity: 14,000 MW HYDRO POWER Electricity
- 90 % of Paraguay’s electricity
- 22 % 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)
7 GW at 60Hz: HVAC Technology (losses: 5% over 800 Km 750 kV)

Similar costs (1.3 Billion US$) for both systems
Beyond 800 Km threshold only HVDC is economically possible

- Project’s Total Costs actualized: 27 Billion US$
- Supplies Power below costs of 2.5centUS$/kWh => Economy of scale

- In operation since 1984

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ONEP - OFFICE NATIONAL DE L'EAU POTABLE

SAHARA WIND INC.

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SNDE – SOCIETE NATIONALE DE L'EAU

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

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

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