Sahara Trade Winds to Hydrogen: Towards the Development of Large Scale Integrated Sustainable Energy Systems

9th IPHE Steering Committee

II Forum

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SfP-982620

Hydrogen Deployment Strategy

Hydrogen is an intruder in large energy markets:

- **Hydrogen can be used as buffer matching energy demand vs. energy supply**
- **Critical mass needed => chicken & egg situation**
- **Thus, initial developments need to be focused on firm objectives**

For High volume hydrogen production :

- **Define production requirements (purity, pressure, volumes…)**
- **Create industrial partnerships**
- **Co-Develop technologies/solutions**

Expand market niches of hydrogen (50 MT/yr) in industries where strong synergetic potentials can emerge with hydrogen (integrated processes, electrolysis…).

- **Energy intensive industries**
- **Oil refineries**
- **Mineral processing, Steel, Chemical plants (Ammonia 25 MT/yr)**
- **Food industry**

Energy Supply: Prerequisite Strategic issue for Hydrogen

'HySociety' (EU funded 2003-2005) project conclusions:

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 the HYDROGEN economy needs to be:

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

=> Hydrogen economy must be closely associated with renewable energies

It is mandatory that Hydrogen economy opens New supply perspectives!

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.

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 where Hydrogen leads to Sustainable Development

Critical to initiate bottom up process 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

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 Alternative : Needs to be Comprehensive & Integrated

- **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!**

Sahara wind

NATO ‘Science for Peace’ SfP-982620

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NATO ‘Science for Peace’ SfP-982620 Project Objectives

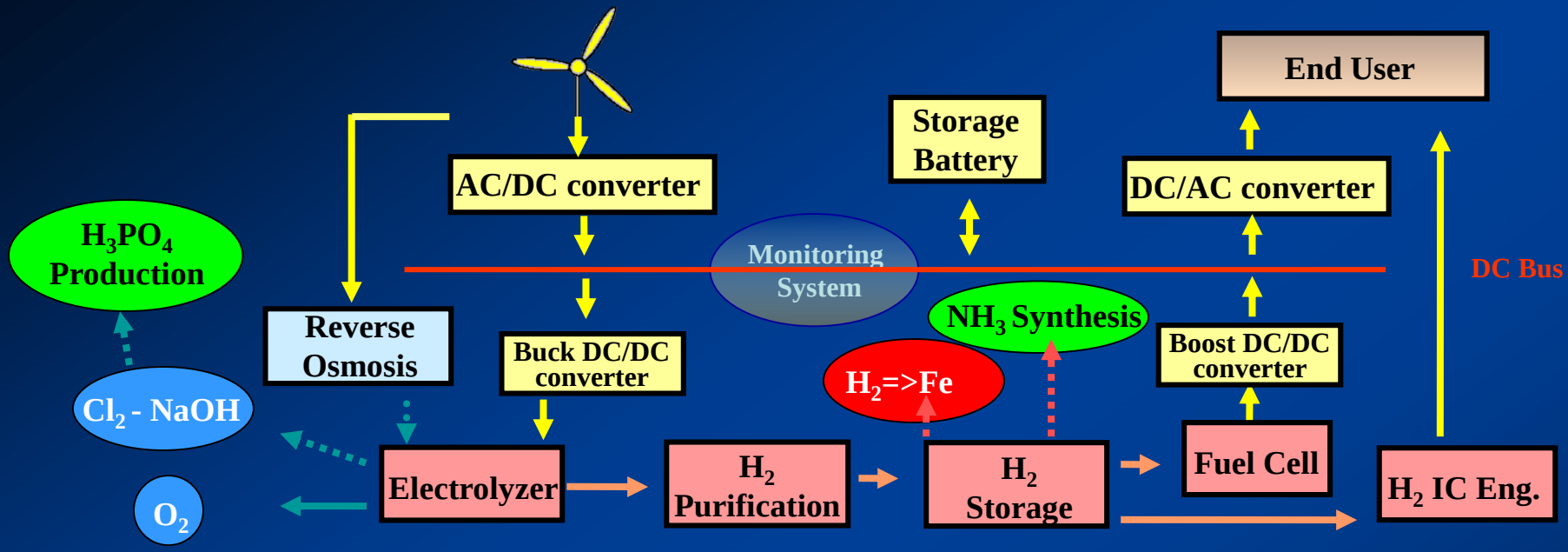
- **Overcome Limits of Wind Energy Utilization in Weak Grids (Stabilization through Wind Electrolysis, Hydrogen & byproducts integration)**

- **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)**

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

Wind Electricity Storage

- Hydrogen/Oxygen Purification & Storage
- Electrolyzer Technologies
- Power Units: Fuel Cells – IC Engines
- Chlorine-Uses/H2-Ammonia Production Direct Reduction of Iron-Ore

Electronic Power Regulation - Systems Integration – Applications & Economic Analysis

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

Hydrogen as a catalyst for the region's main industries

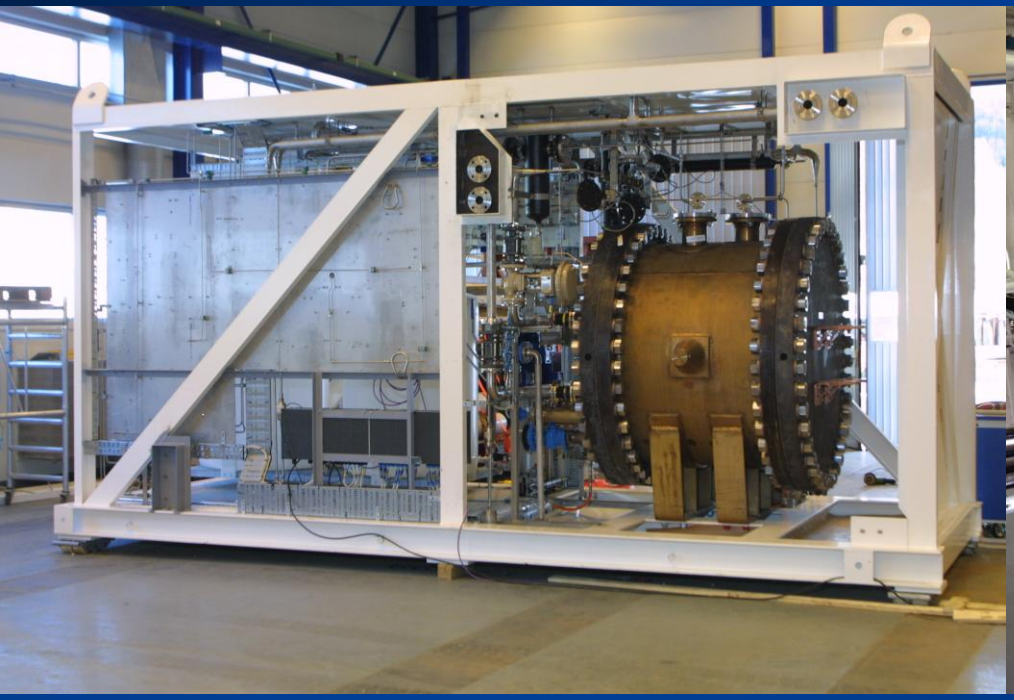
Phosphate Processing Industry:

- **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**
- **Hydrogen for Phosphor-gypsum recycling (12 Million tons/year currently dumped) potentially transformable into 'Clean' Portland Cement.**

Mining & Iron-Ore Industry:

- **Hydrogen: Direct Iron Reduction process (DRI) using Hydrogen 4% of primary iron production worldwide**
- **Wind-Electricity: Local Production of Steel through Electric Arc Furnaces low investment costs, 45% of World Steel production**
- **Oxygen: burned in steel furnace (recycling)**

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

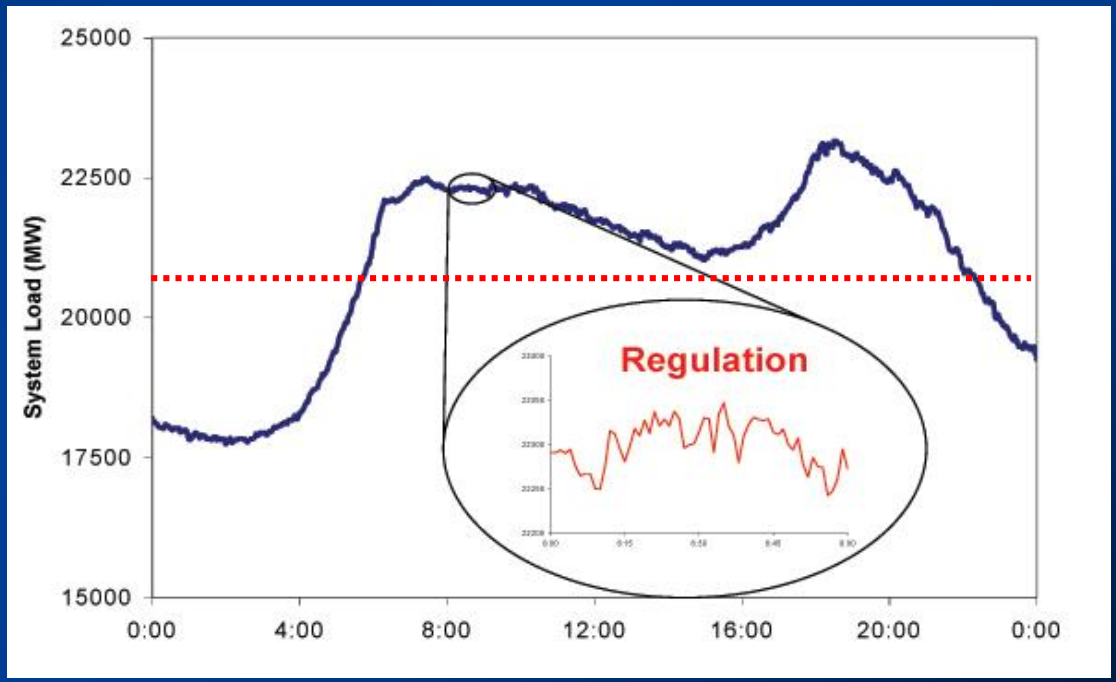
Grid Stabilization through Wind-electrolysis

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).

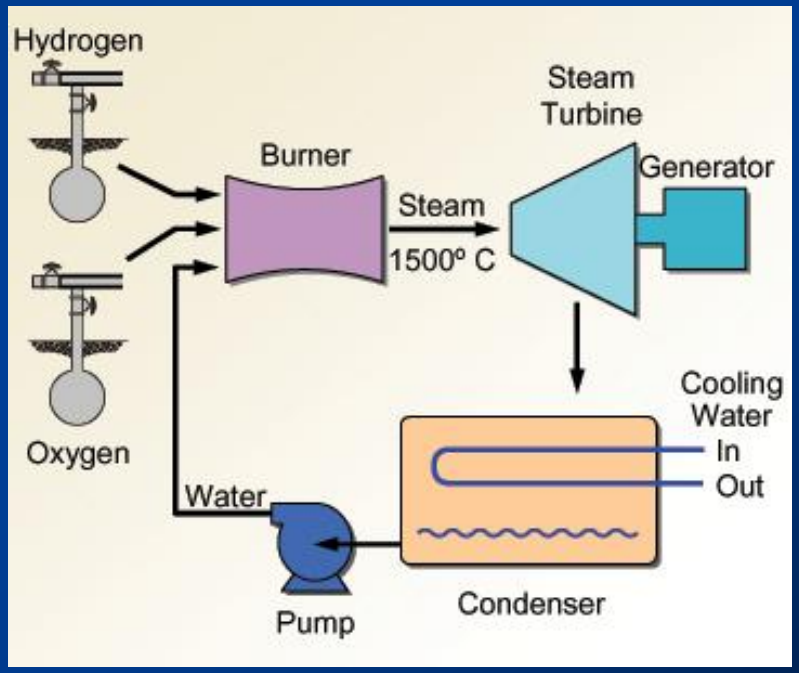


Evaluate technologies aimed at maximizing renewable energy uptake in weak grids through Wind-electrolysis

H_2&O_2 Steam turbine

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

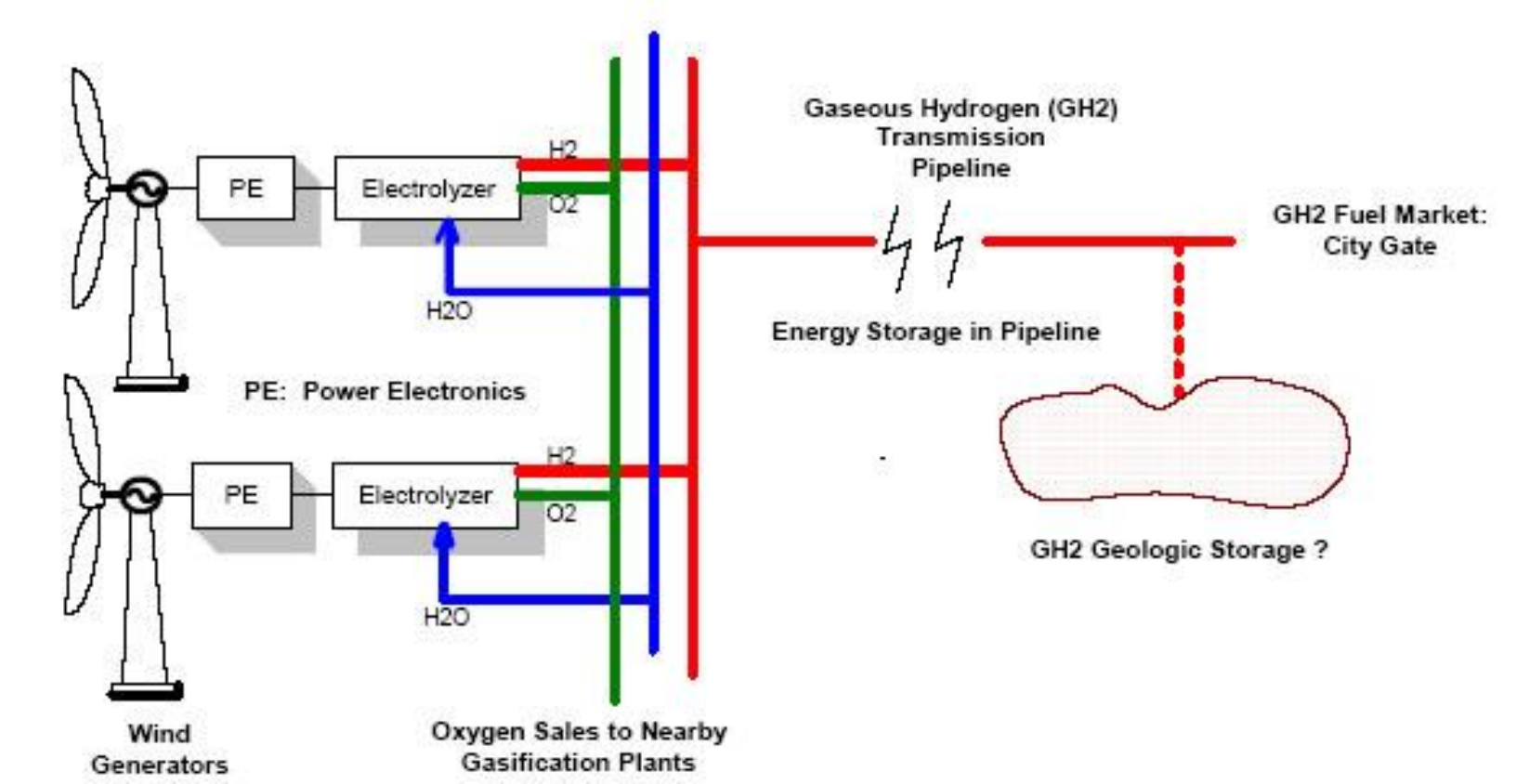
Used for Peak hours:
- **Low investment costs**
- **Large units 50 MW**
- **High efficiency 70%**
- **Extremely fast response (ms)**



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

Sahara Wind Energy Development

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

Sahara wind

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

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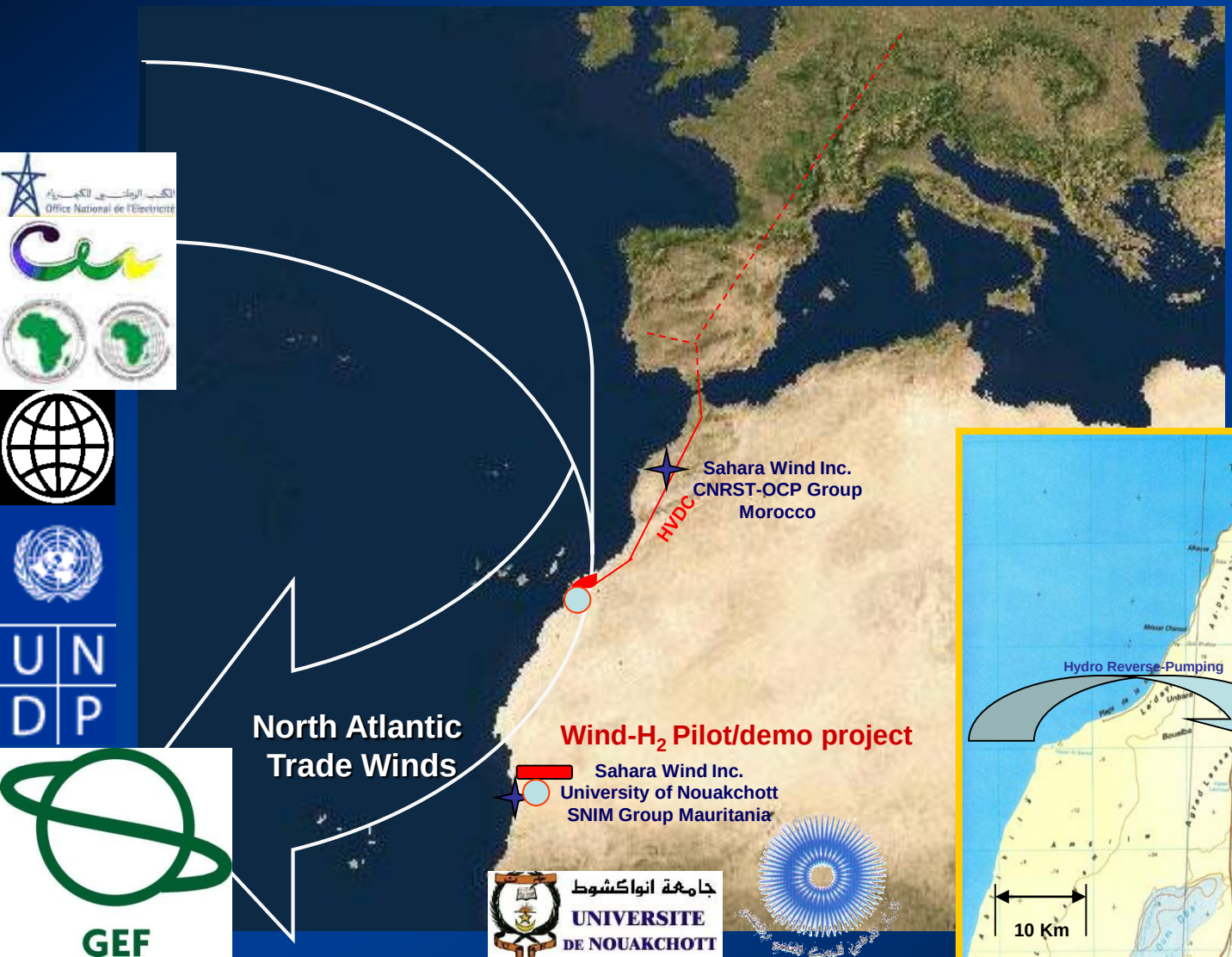
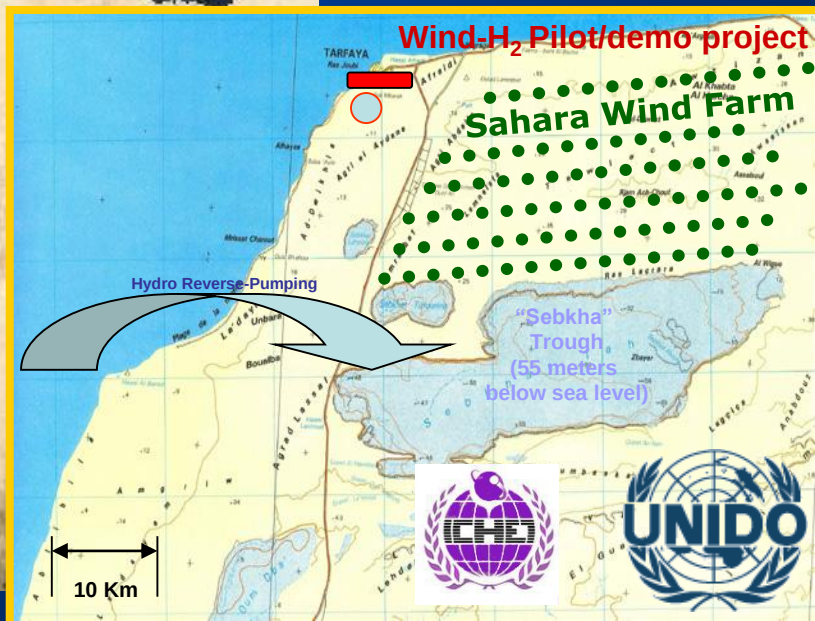
Morocco: Sahara Wind Phase I / Tarfaya (400-500 MW) / Extensions HVDC (5 GW)

on-grid wind electricity in a liberalized market: Joint WB-AfDB UNDP/GEF (PDF-B PIMS #3292)





GEF

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 with needs of developing countries.

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

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