Energy Security in the Euro-Mediterranean context:
The Sahara Wind Project

Africa /Middle East Renewable Energy Summit 2009

Cairo – Egypt, 12th-13th October 2009

Khalid Benhamou
Managing Director - Sahara Wind Inc.

Effects & Consequences of Climate Change
(US Senator John Kerry, September 10 2009)

"Climate change threatens to bring more famine and drought, worse pandemics, more natural disasters, more resource scarcity, and human displacement on a staggering scale. …."

"Scientists are now warning that the Himalayan glaciers, which supply water to almost a billion people from China to Afghanistan—including three nuclear powers—could disappear completely by 2035."

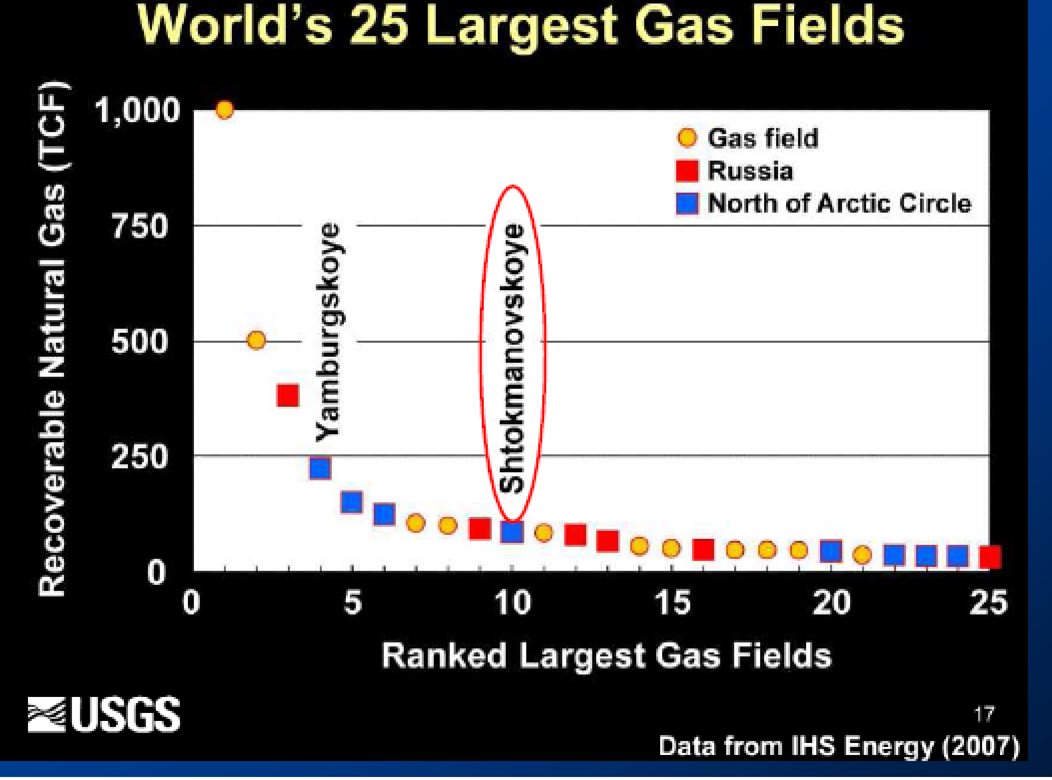
"The Middle East is home to six percent of the world's population but just two percent of the world's water. A demographic boom and a shrinking water supply will only tighten the squeeze on a region that doesn't need another reason to disagree violently.…"

"Africa, no stranger to the instability, conflict, and competition over resources that drive people from their homes and create refugees and internally displaced people, will now confront these same challenges with an ever growing population of "EDPs"—environmentally displaced people."

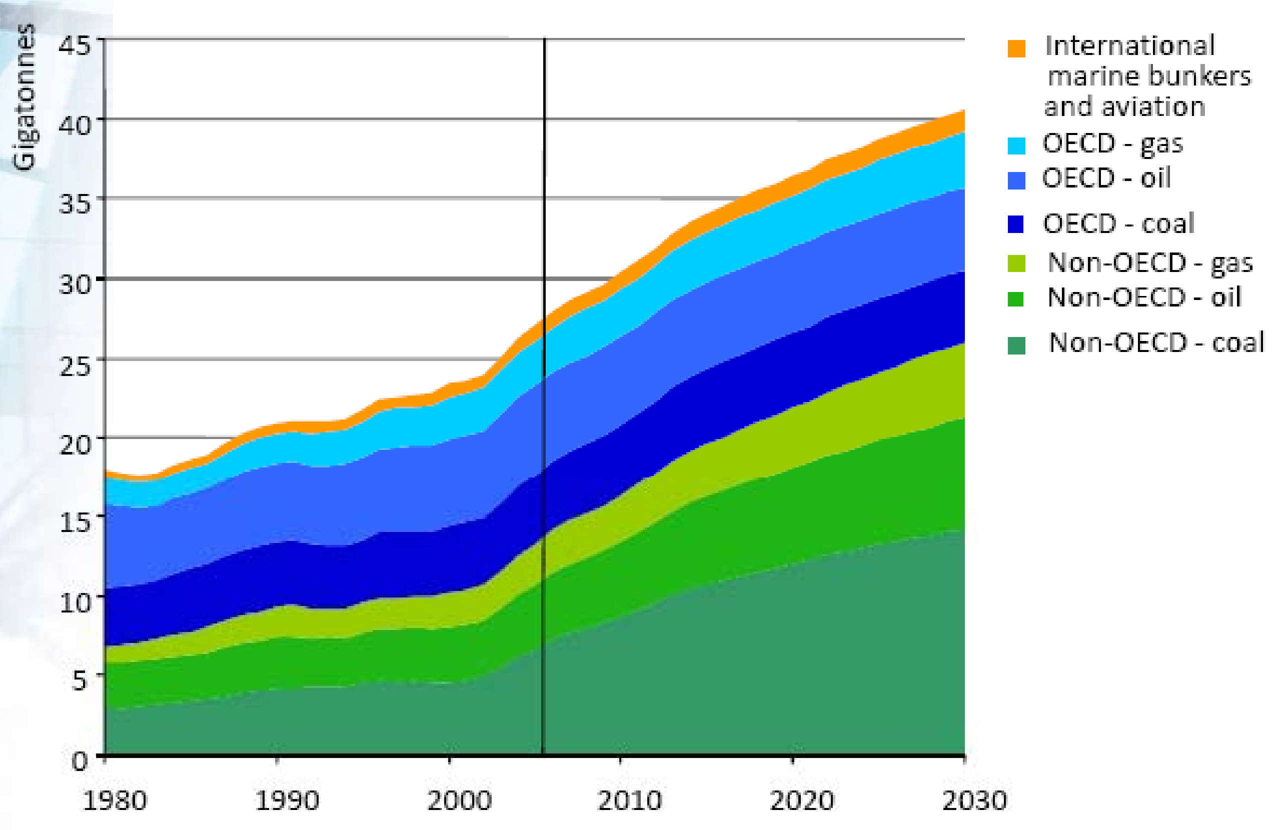
Climate Change (Different Effects/Consequences)

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

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



Energy-related CO_2 emissions
Business as Usual Scenario



97% of the projected increase in emissions between 2006 & 2030 comes from non-OECD countries – three-quarters from China, India & the Middle East alone

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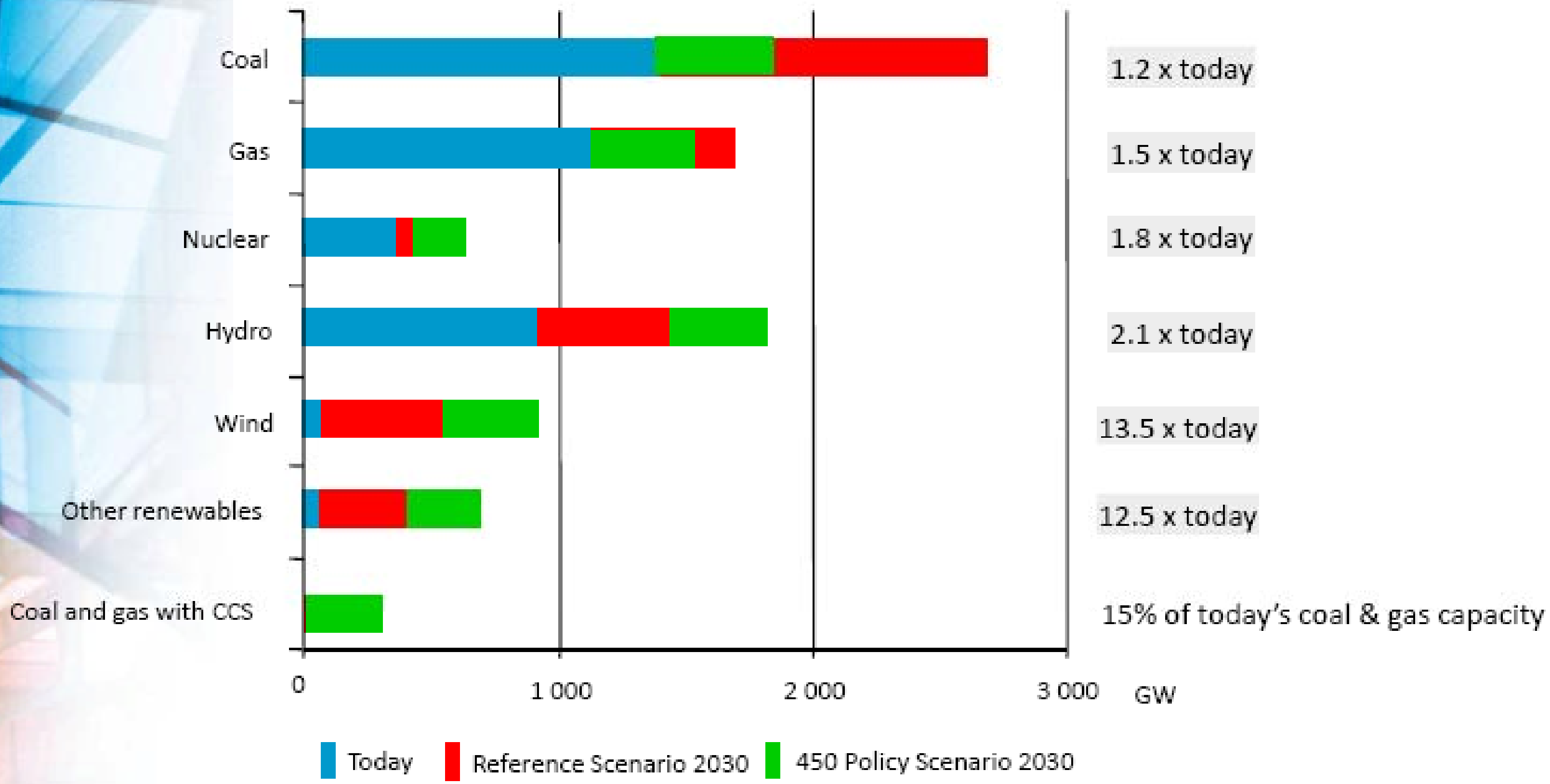
Total power generation capacity today and in 2030 by scenario



In the 450 Policy Scenario, the power sector undergoes a dramatic change – with CCS, renewables and nuclear each playing a crucial role

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.

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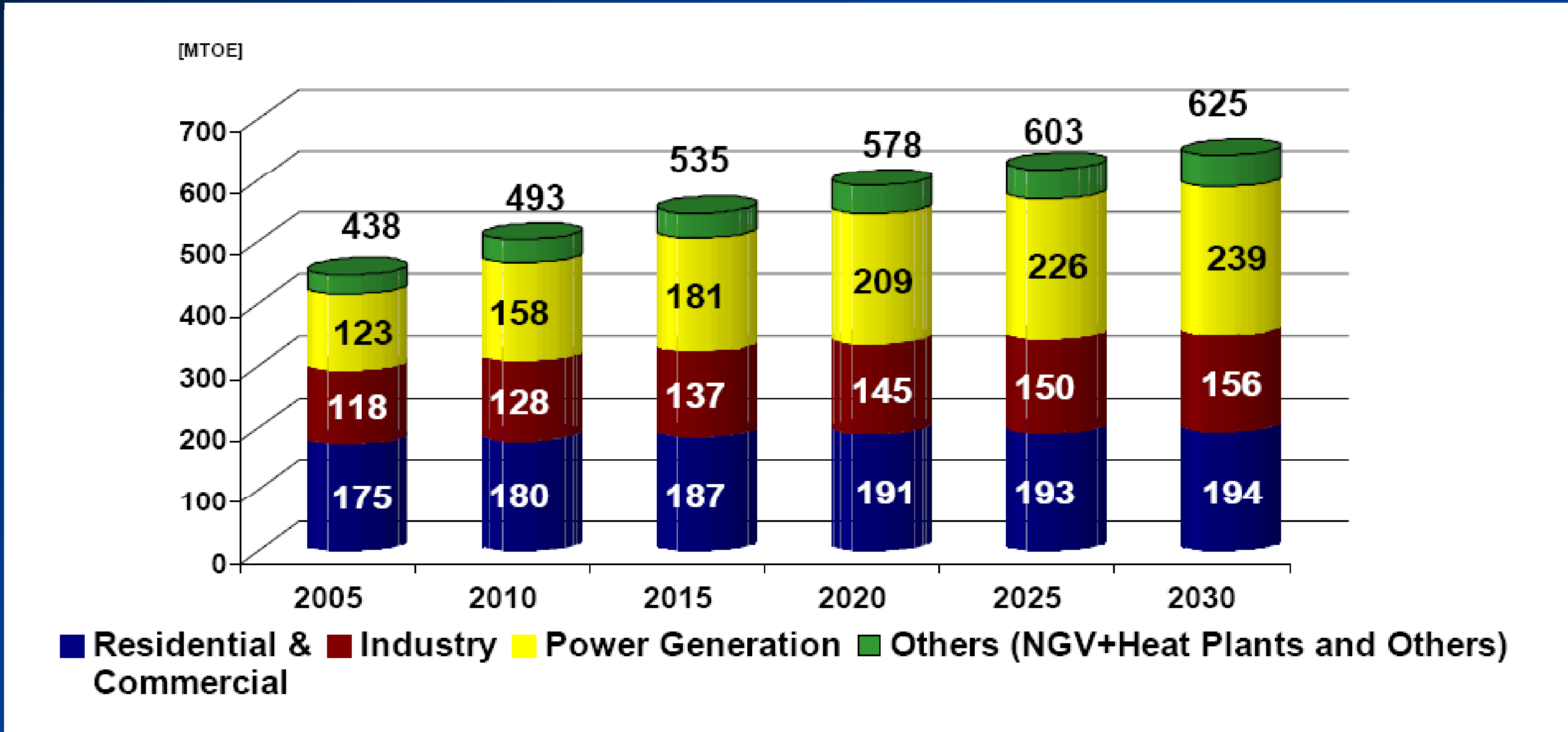
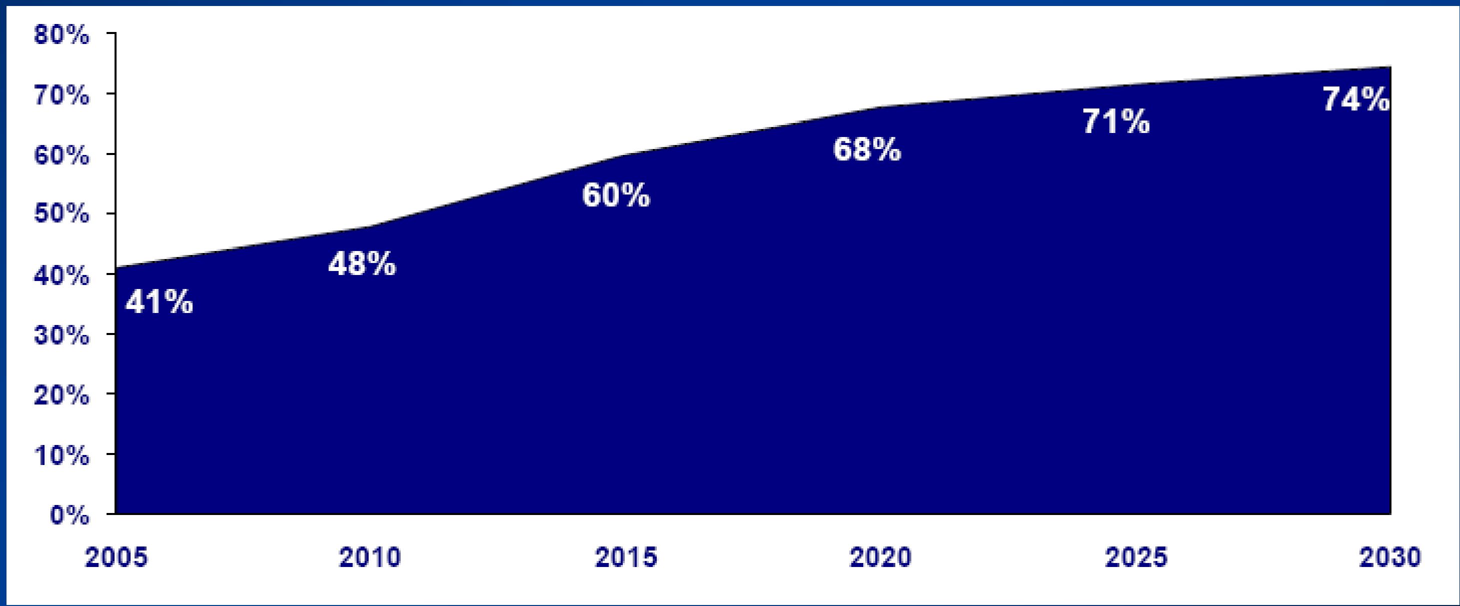
EU27 Natural Gas demand outlook



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

NATURAL GAS DEMAND AND SUPPLY
Long Term Outlook to 2030

EU27 import dependency from outside Europe



Source: EUROGAS

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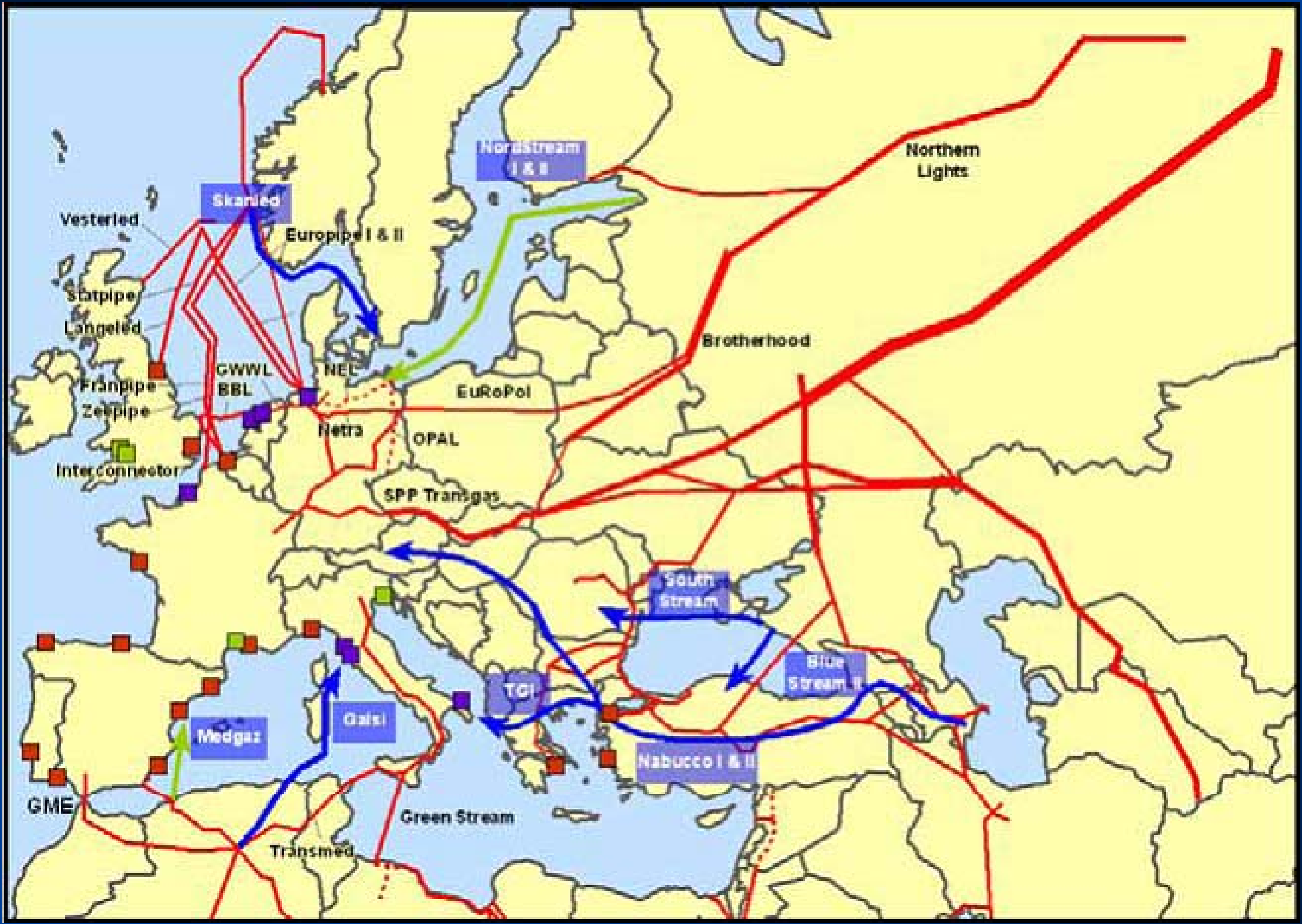
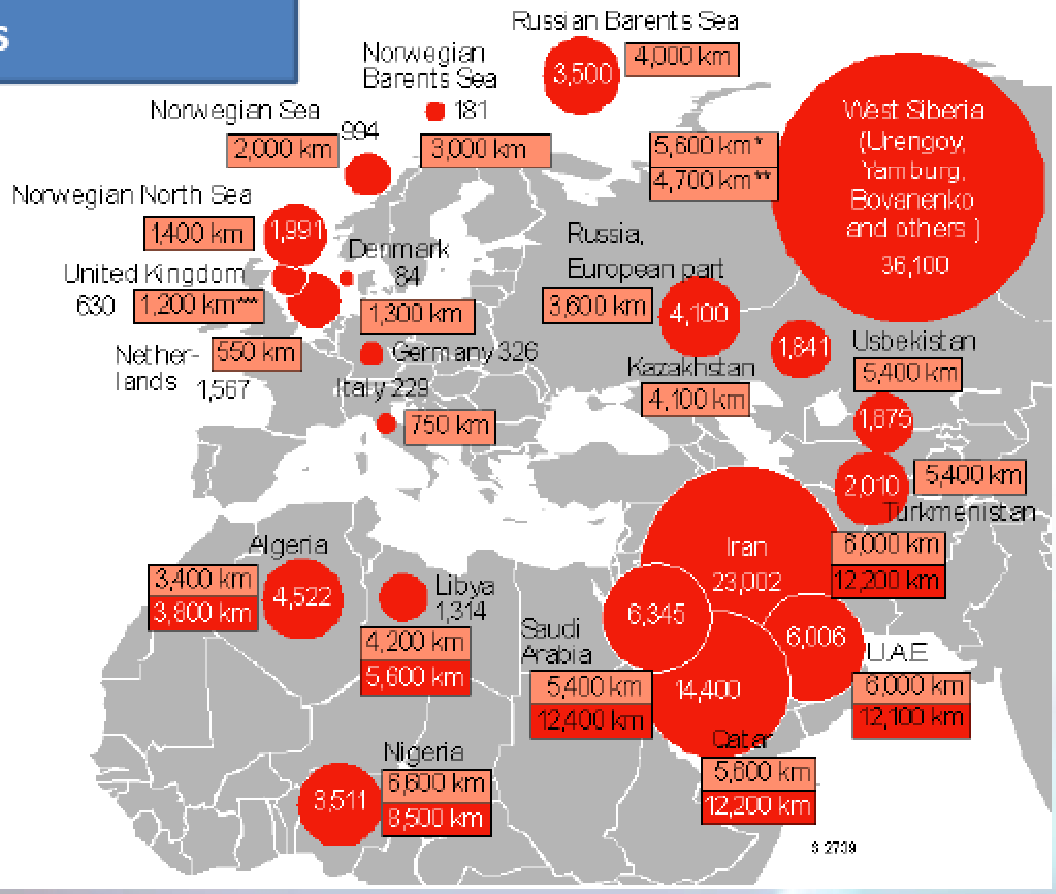


European Gas Networks (Source EU- DG TREN) euro gas

Natural Gas reserves and supply distances



billion m³

Pipelineto Frankfurt/Main

LNGto Wilhelmshave

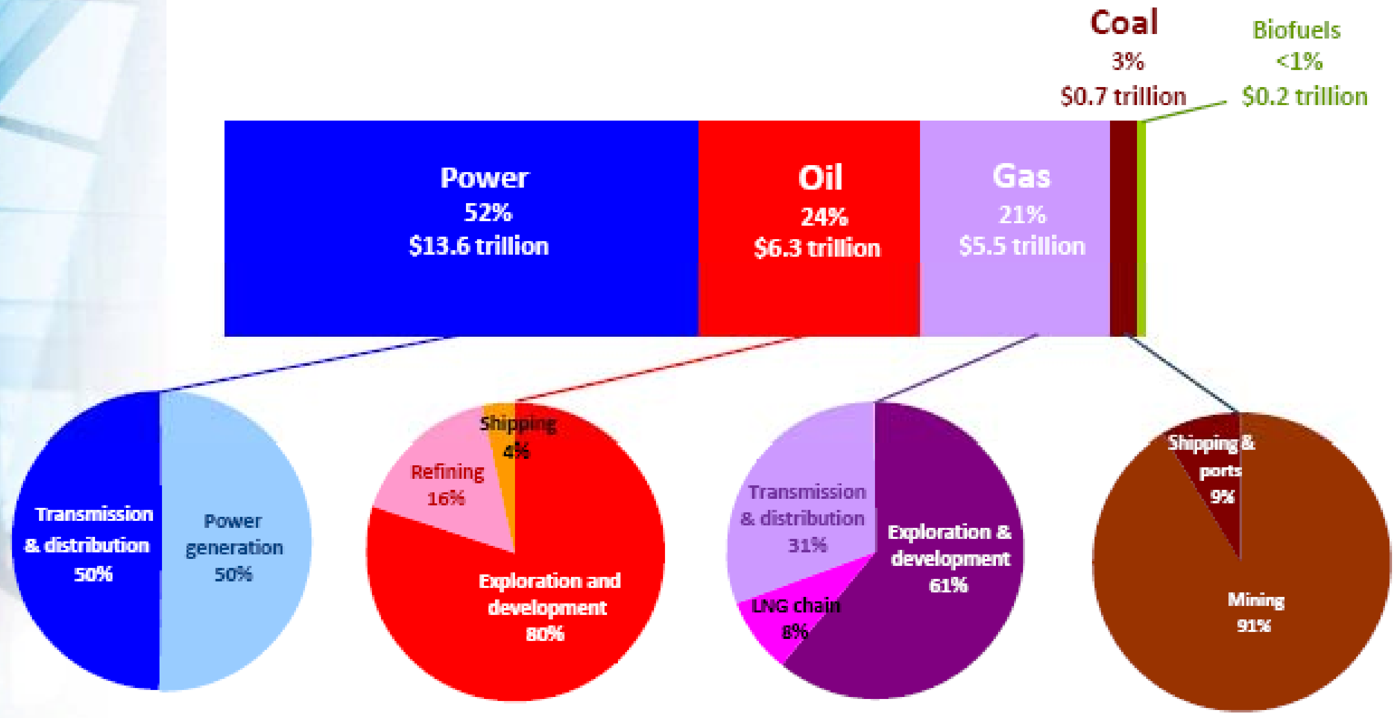
*Yamburg Area
**Yamal Perinsula
***northern area

1 m³ = 11.6 kWh

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

Source: E.ON Ruhrgas AG

Cumulative energy supply investment in Business as Usual, 2007-2030



Investment of $26 trillion, or over $1 trillion/year, is needed, but the credit squeeze could delay spending, potentially setting up a supply-crunch once the economy recovers

Nuclear Energy in North African Context

Energy Security: Stable source for base loads (in the 1500 MW range)

Economic impact of a nuclear power plant:

- High up-front costs
- Limited Technology Transfer/ Industrial integration possibilities
- Limited duplicability (small grids)
  - Expensive safety protocols (not passed on to other plants)
- Limited social impact
  - Little local jobs creation
  - No decentralized/distributed effects

Risks associated with the nuclear option:

- Excessive Centralization of Power Generation (1 plant)
- Construction and commissioning delays
- Dependency on fuels
- Nuclear waste & spent fuel processing issues
- Other security issues…

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Nuclear Energy on the Iberian Peninsula

Abandoned Nuclear Plant Construction Site in Spain’s Basque region (1986)
Photo: ***Sahara Wind Inc*****.**

Conventional Thermal Power Sources (Fossil Fuels)

Coal : Competitive electricity generation (approx. 60% of Morocco's mix)

Gas : Algeria's main resource & electricity generation fuel (99% electric mix)

Socio-Economic impacts:

- Coal is 100% imported for Morocco (Few local jobs & air quality issues)
- Gas is Algeria's main domestic resource (integrated energy industry)

Greenhouse gases emissions

- EU countries (Iberian peninsula):
  - Current emissions are highest in EU (Kyoto)
  - Need to meet EU 20-20-20 targets,
  - Copenhagen upcoming framework..!
- North African countries: Non-Binding CO2 limitations under Kyoto
  - Difficult to assess carbon emission limitations (Post Copenhagen conf.)
  - => Long term Business as usual scenario not likely (unsustainable)

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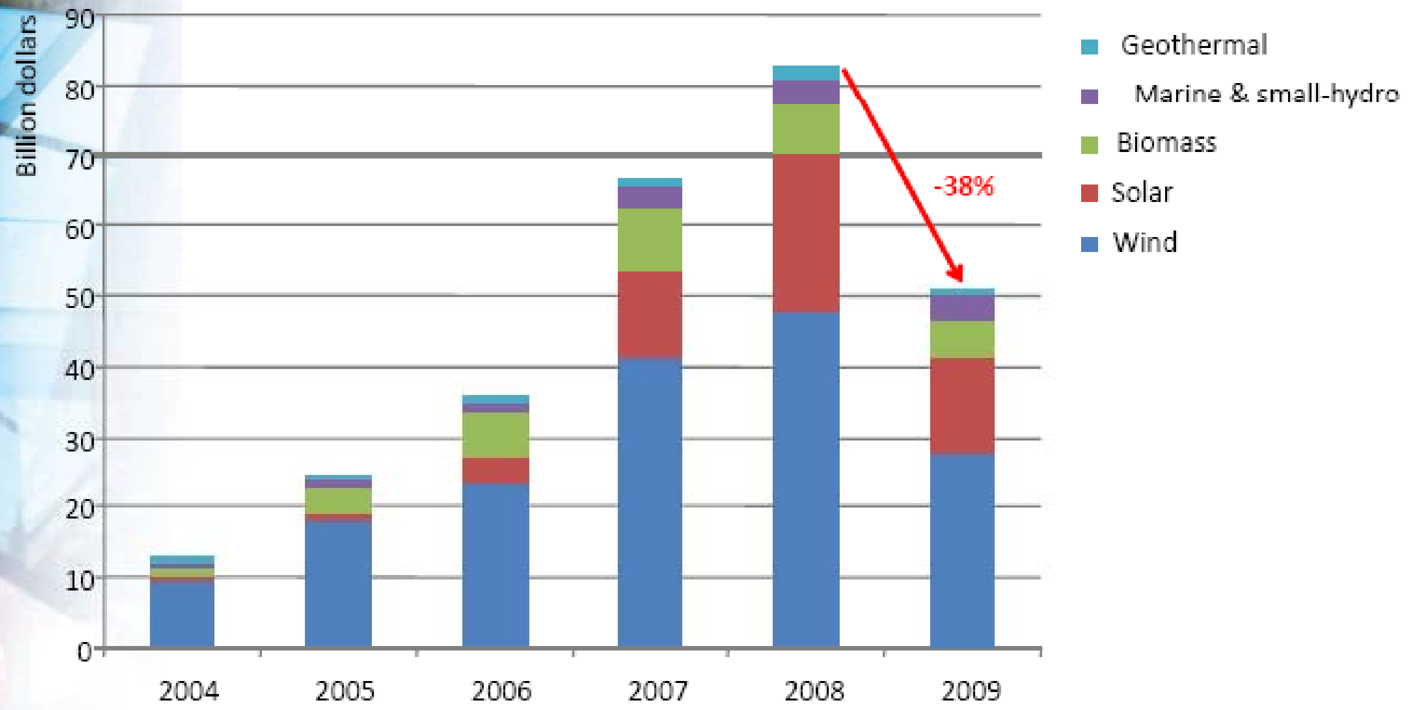
Impact of financial crisis on global investment in renewable energy



Renewable energy investment has collapsed due to the financial crisis – which has dried up sources of project finance – and lower fossil-fuel prices ….

… IEA G-8 paper estimates spending in 2009 will drop by 38% relative to 2008

Source: NEF, IEA analysis

European Union's 20-20-20 Targets

Currently 16% of EU electricity is generated from renewable energy sources.

EU Target of 20% RES share in total energy will imply raising this figure to around 34%. If we assume a steady 1.5% increase in EU power demand up to 2020, that would mean that out of the 3,800 TWh consumed in 2020, some 1,300 TWh would be generated from renewables.
CO_2 emission allowances at auction after 2013 under the new arrangements will have an annual impact of €20-25 billion on the power industry

This represents "a tremendous business opportunity for European power companies, if Member *States involve them in the right way*" *
⇒*Smart Grids*
⇒*Market integration*
(*Source: EURELECTRIC)

EU 20-20-20 Targets: Impact on Smart Grid Developments

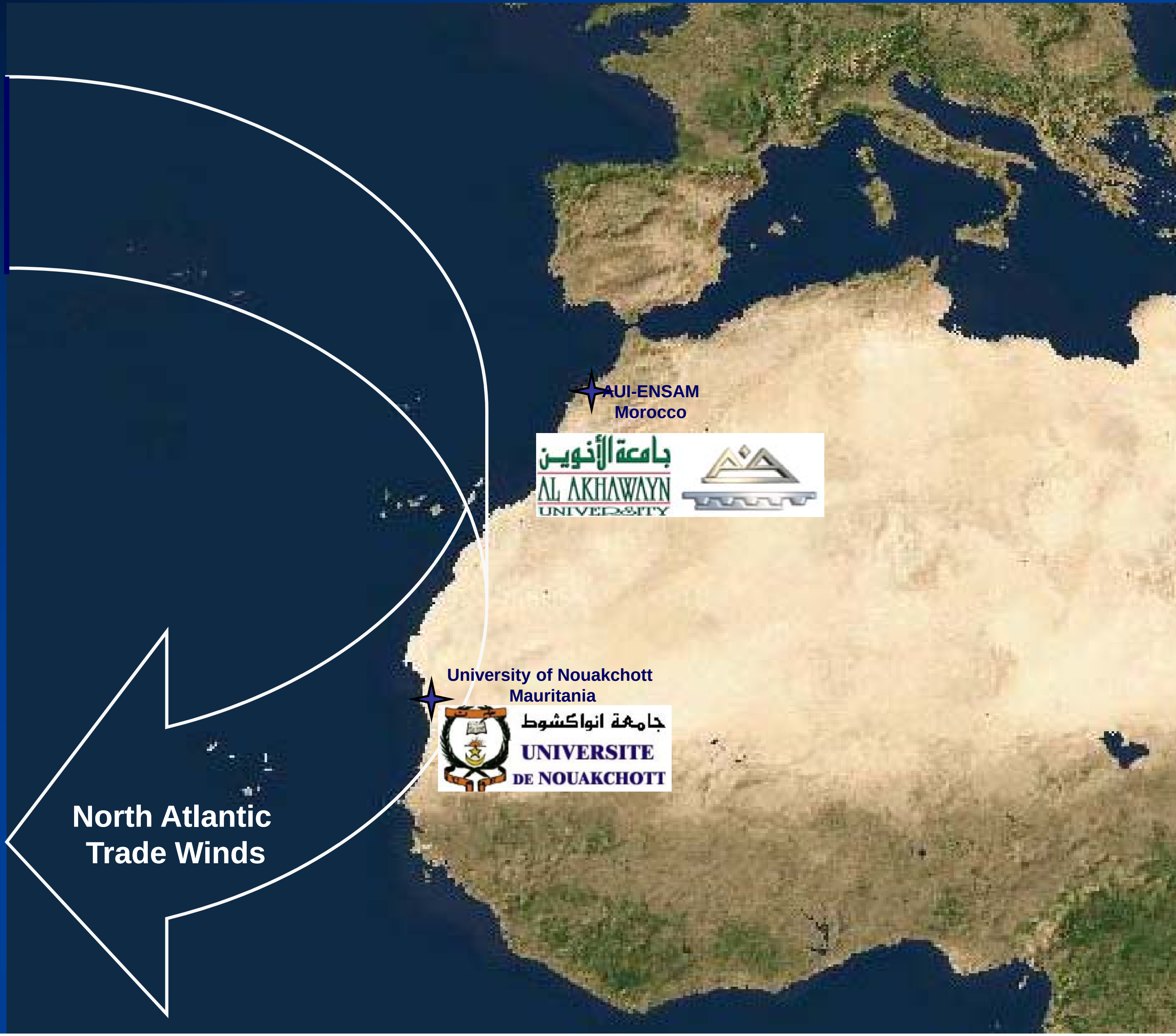
Electricity as basis for innovative energy solutions (among them):

- ✓ **Electric road transport - where carbon-neutral power can drive the ‘de-carbonization’ of mobility.**
- ✓ **Efficient electric heat pumps for spatial heating and cooling, will offer new opportunities for balancing intermittent power sources.**

Existing European electricity infrastructure can be used in most of the countries for charging vehicles. If cars are charged at night even a standard household socket (16 A) would be sufficient. The grid is robust enough to allow a certain number of electric plug-in vehicles (e.g. 10% of market share) to charge simultaneously without any severe impact on the network in off-peak time*.

Need for ‘smart’ grids, will require TECHNOLOGY CAPACITY BUILDING and “smart regulation” by removing barriers to investment and incentivizing electricity distribution companies to develop smart networks (*source: EURELECTRIC)

NATO ‘Science for Peace’ SfP-982620



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

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

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 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

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!)

Wind Resource Assessment & Hydrogen energy : Comprehensive & Integrated R&D Theme

- Holistic approach
- Broad ranging, integrated process
- Bottom-up capacity building
- Capitalize 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!

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REGIONAL CAPACITY BUILDING
NATO 'Science for Peace' Project Coordinated by Sahara Wind Inc.
NATO SfP-982620

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

•Essential for Industrializing North Africa

Sustainable Energy Systems = Sustainable Energy Economy
=>Sustainable Mine Processing Industry

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

• Complementary Working Teams through a Science for Peace Project Platform on a regional level (Academic and Industrial network) in Morocco and Mauritania.

• Partnership can benefit to/from other Mediterranean dialogue countries of NATO, and contributions of NATO member Countries (Europe and North America)

• Success measured not only in terms of intellectual property production, number of patents, etc. but also in terms of relevant end user partnerships essential in all applied research activities.

Technology – University/R&D Platform - Industry

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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
- 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 => End-User Driven Approach

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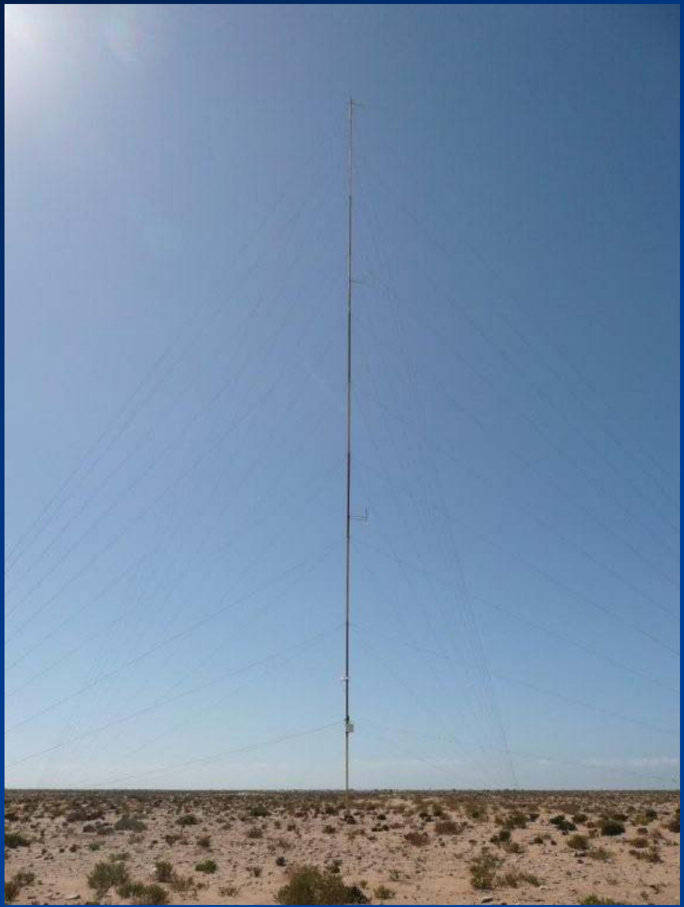
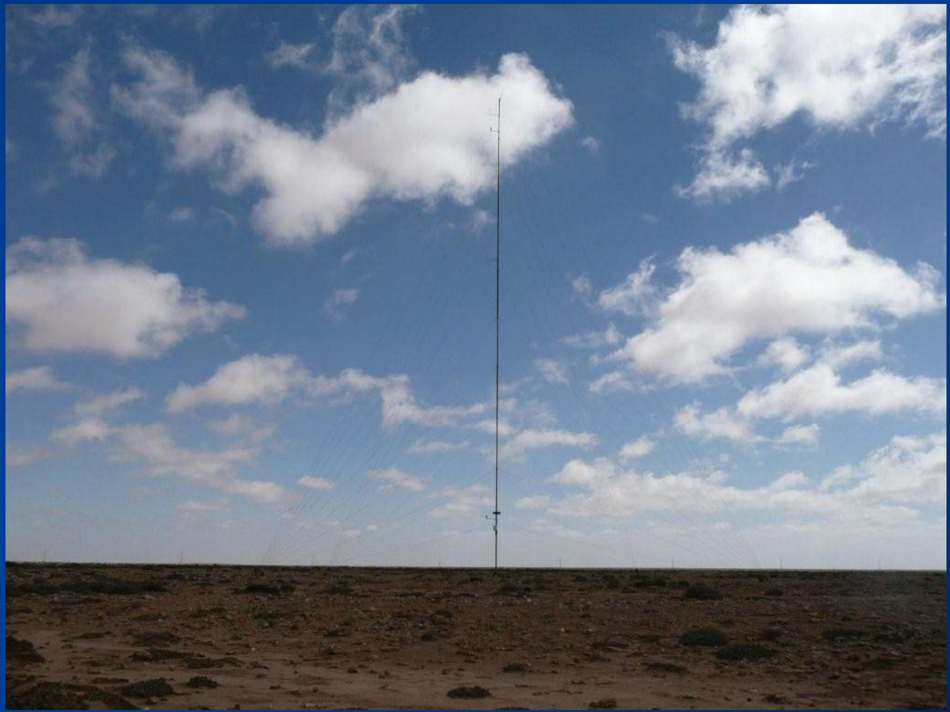
Wind Measurements





Area of Tarfaya

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NATO SfP-982620 PROJECT OBJECTIVES
Build 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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Complementarities within Applied Research Objectives

- Engage End-Users & Develop Effective Collaborative Protocols
  - o Instrumentation (100% SfP Funded)
    - o No quality compromise (integrity of Data)
    - o Integrate site specific measurements constraints
  - ✓ Equipment Installation/deployment (Co-funded)
    - o On-site Supervision (SfP Team)
    - ✓ Installation & access to infrastructures (End User)
  - ✓ Data collection (Co-funded)
    - o Data download (SfP Team)
    - ✓ Access to infrastructures (End User)
  - o Data Processing/Academia (Co-funded)
    - o Software design (SfP Participants)
    - o Equipment & Software purchases (SfP Funded)

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Wind Monitoring

- Ensuring Quality Measurements
    - o Duplicating Measurements
        - o Duplication of Calibrated Instruments
        - o Additional non-calibrated on-site instrument deployed
        - o Wind Measurements Vertical Profiling
    - o Calibrated Instrumentation
        - o EU Standards
        - o Data used as collateral for Financing of Wind Parks
            - o Commercial value & End User interests
            - o Develop Commercial Protocols for Data Processing
                - o Build expertise locally
                - o Sales of Services
                - o Sales of Processed Data (value added service)

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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

✓ Visited Equipment Manufacturer
- Collaboration interests/potential
- 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)
- Rural electrification programs (ONEP/ONE-PERG/APAUS)

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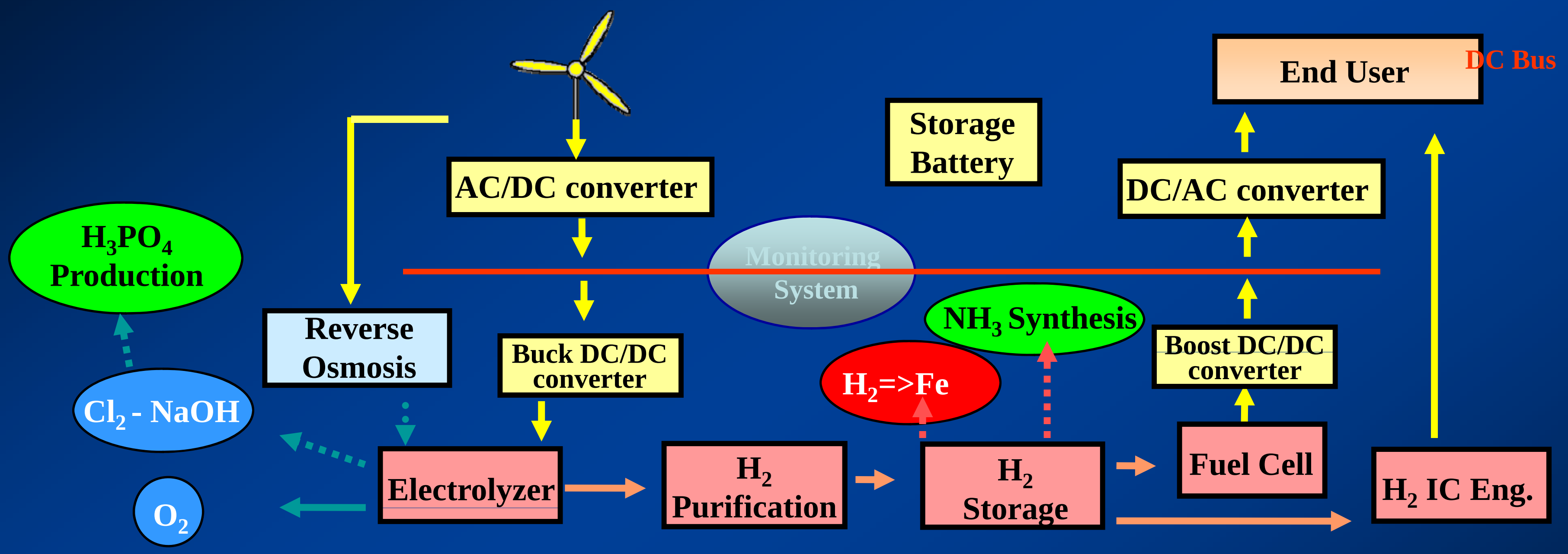
NATO Science for Peace SfP-982620
Electrolysis Test Benches



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

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

Morocco Phosphate Processing Industry: Chlor-Alkali Electrolysis

• Chlorine in Phosphoric Acid Derivatives Production

•Integrate fertilizer industry most comprehensively, beyond export of phosphate based fertilizers.

•Production of Ammonia (Stable H_2 storage medium as well)

•Phosphor-gypsum recycling (12 Million tons/year currently dumped) potentially transformable into Portland Cement, (without any CO_2 emissions).

Mauritania Mining & Iron-Ore Industry: Alkaline Electrolysis

•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

- <u>**Alkaline Electrolyzer**</u>

Lower Costs, Higher efficiency

H_2 Purifier

MW size electrolyser (source IHT)

H2 Industrial (3.6 kW/hour)

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- **Chlor-Alkali Electrolyzer**

Industrial scale Chlorine, Caustic Soda, and Hydrogen

Chlor -Alkali electrolyser at industrial plants (Source : Uhde GmbH)

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- **<u>Hypochlorite (Membrane) Electrolyzer</u> (for water utilities)**

Produces H2, hypochlorite, flexible power production, small scale

Drawback: output pressure

Electrocell Chlor-O-Safe™

Application areas:
Water sanitation
Municipal water plants
Swimming pools
Food processors
Industrial plants
Waste water treatment
Cooling towers
Power plants
Chemical manufacturers

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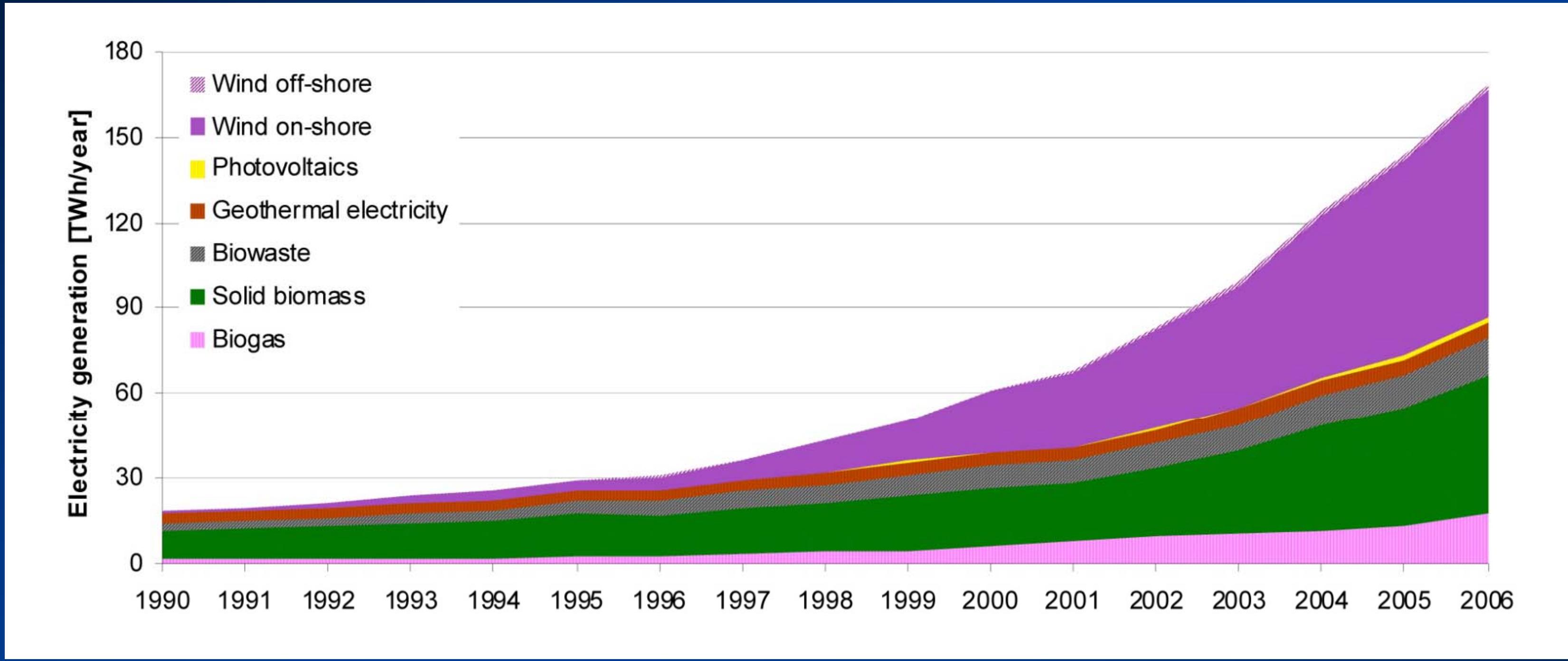

Historical development of electricity generation from RES-E without hydro power in the European Union (EU-27) from 1990 to 2006 **(Source EmployRES Project EU DG Energy and Transport)**

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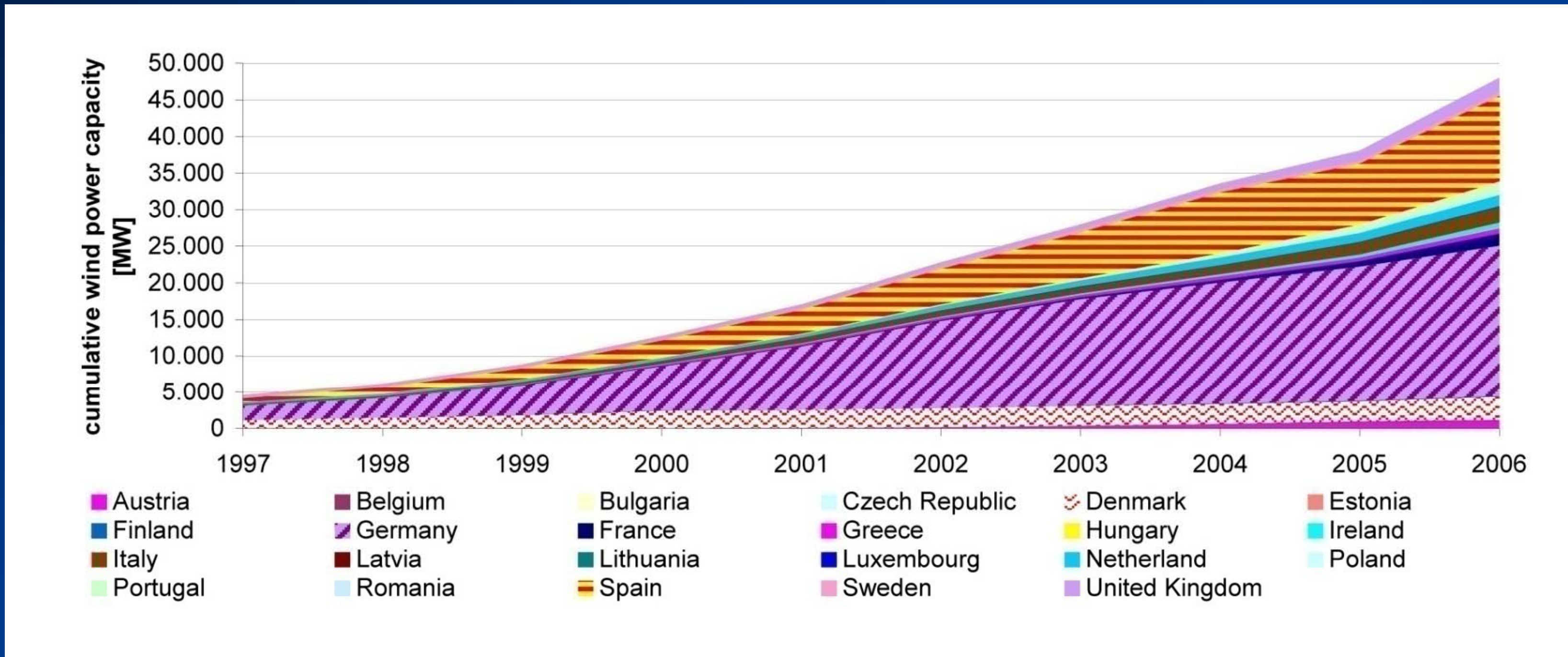

Historical development of cumulative installed wind capacity in EU-27 countries, (Source: EWEA, IEA Renewables Information 2006)

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EU-20-20-20 Targets
Market Integration & Renewable Energy Trading

Allowing full flexibility in trading RES-power across borders could bring savings of up to €17 billion per annum by 2020 versus the total cost of meeting national targets from purely domestic RES-generation

It is vital that Member States make maximum use of the cooperation mechanisms.

In the EU's third energy market package, the emphasis should now be on speedy market integration - an aspect not given sufficient prominence in the package - via progressive regional integration towards the goal of a Europe-wide market…..[and BEYOND!]

(Source: EURELECTRIC)

Morocco’s Current Wind Energy Targets

- 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…!!!

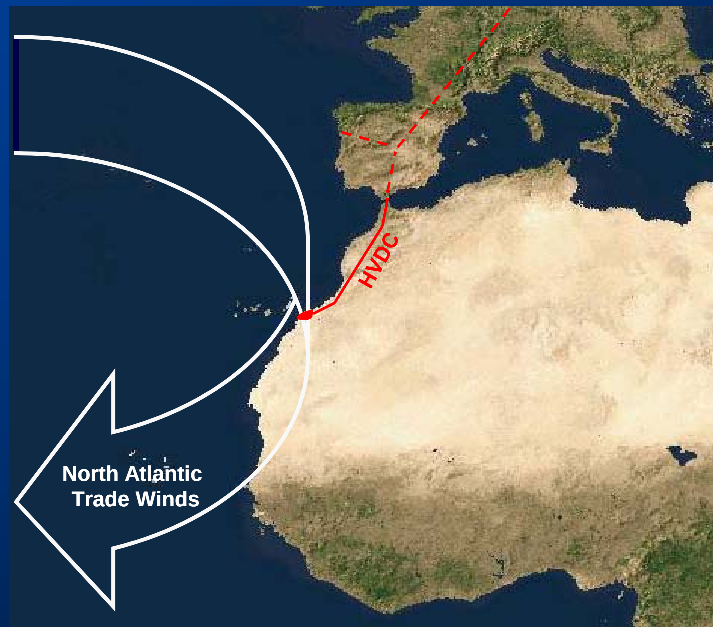
- Total Generating Capacity (5000 MW) / Peak load 3000 MW
  => Possible Wind Power Integration no more then 1000 MW
- Big Wind Potential but Far Away from Load Centers
- No Plans for Transferring Wind Manufacturing Industry

=> Need to develop an integrated approach: The Sahara Wind Project

Sahara wind

Sahara Wind Energy Development Project

- Over 80 GW worldwide in 90 HVDC Projects: India, China, Canada, Brazil..
- Euro-Mediterranean electricity market (Iberian) in full growth/expansion
- Spain & Portugal (EU Members) have ratified Kyoto Protocol
  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)
    Higher Productivity compared to Europe
  -Size of area (Saharan coast):
    at least 2500 km length
    (Morocco, Mauritania & Senegal)
  - Potential of Possible 500-1000 GW(?)+
    of Wind Energy Installed



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

ITAIPU POWER PROJECT

- Installed capacity: 14 GW HYDRO POWER Generated 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 DC)
7 GW at 60Hz: HVAC Technology (losses: 5% over 800 Km 750 kV AC)

Costs (1.3 Billion US$) for both individual systems
Beyond 800 Km distance: HVDC only economical solution

- In operation since 1984

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

Sahara Wind Project

• Resource Assessment and Capacity Building: NATO SfP-982620
• Mediterranean Solar Plan: 50 MW Sahara Wind 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)

Justification:
✓ Wind Energy Potential in the Sahara Trade Wind Region is Very Large.
✓ Energy needs to be transferred to cover Morocco’s Electricity needs (difficult without HVDC technology, load centers 1000 Km+ away from Sahara Trade Wind resource).
✓ HVDC technology best suited for large integrated projects worldwide
✓ Ideal for use in an Integrated Euro-Mediterranean Energy Market

SAHARA WIND POWER PROJECT
Sharing infrastructures
As part of Mediterranean Solar Plan

• Installed capacity: 400 MW to 5,000 MW for initial WIND-HVDC Electricity (2015)
• Nominal capacity: 10,000 MW Wind-Solar (beyond 2020)

• HVDC Electricity TRANSFER CAPACITY: 10,000 MW (Cables)
  •Substations initially for 5 GW before 2015 (doubled after 2020)
  •Cable sizing: 10 GW
  •Distance: 1500 km South of Morocco-Iberian peninsula expanded beyond (France, Germany, UK)

5 GW Wind Energy: HVDC Technology (losses: 3% over 1500 Km ±500kV)
+ 5 GW Solar or Solar/Wind Hybrid (HVDC losses 5% over 1500 Km ±500kV)

Costs (1.3-1.5 Billion EUR) additional substations for Extensions 5GW Solar
(Beyond 800 Km distance: HVDC only economically possible solution)

•Supplies Power below costs of Iberian market 4.5cent€/kWh
•=> Economies of scale expected
•Project Costs are distributed though a Phased deployment (2010-2020)

Figure 1 : Sahara Wind - HVDC Transmission Architecture - bipole 1

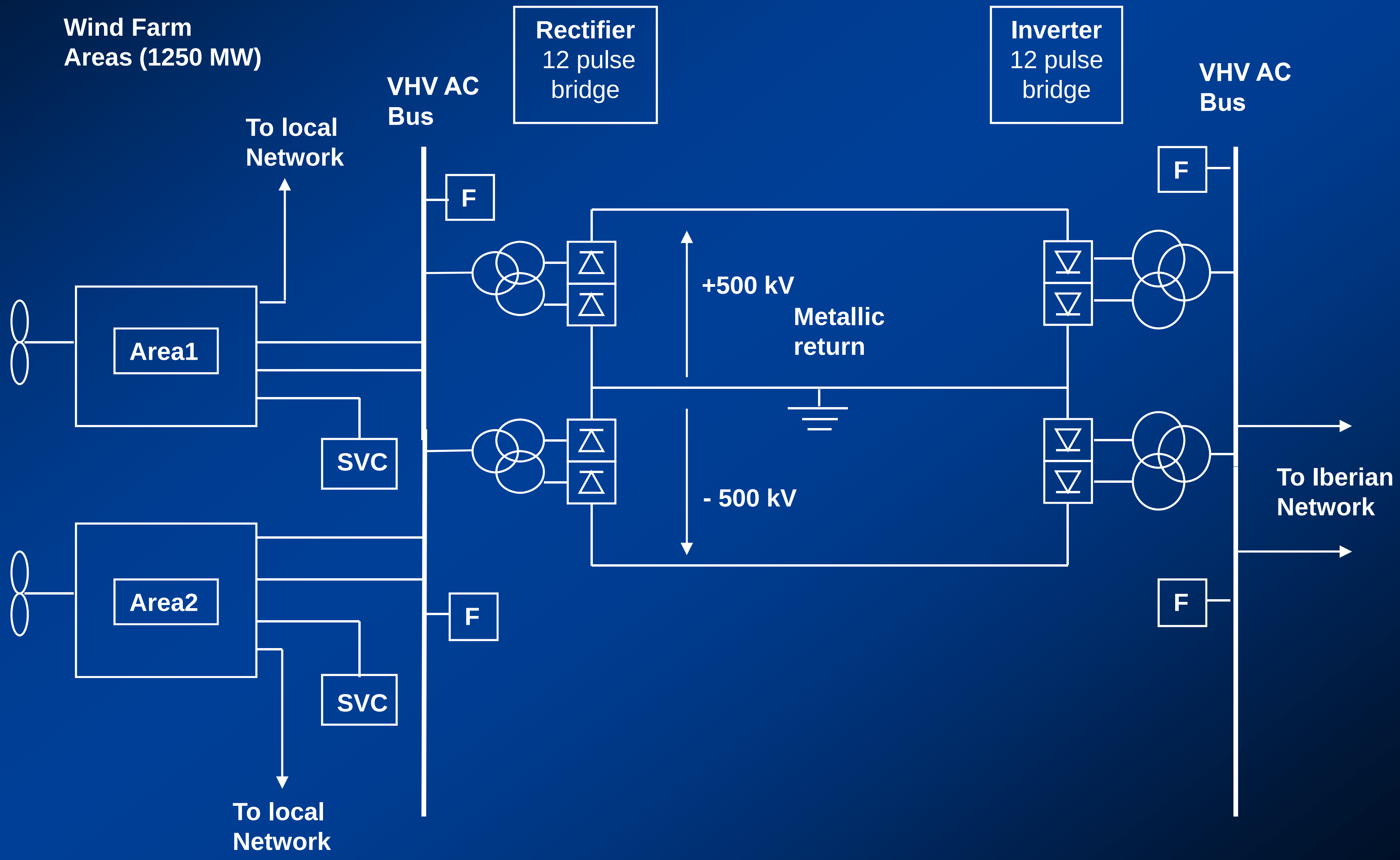


Figure 2 : Sahara Wind - Bipole phasing (information only)

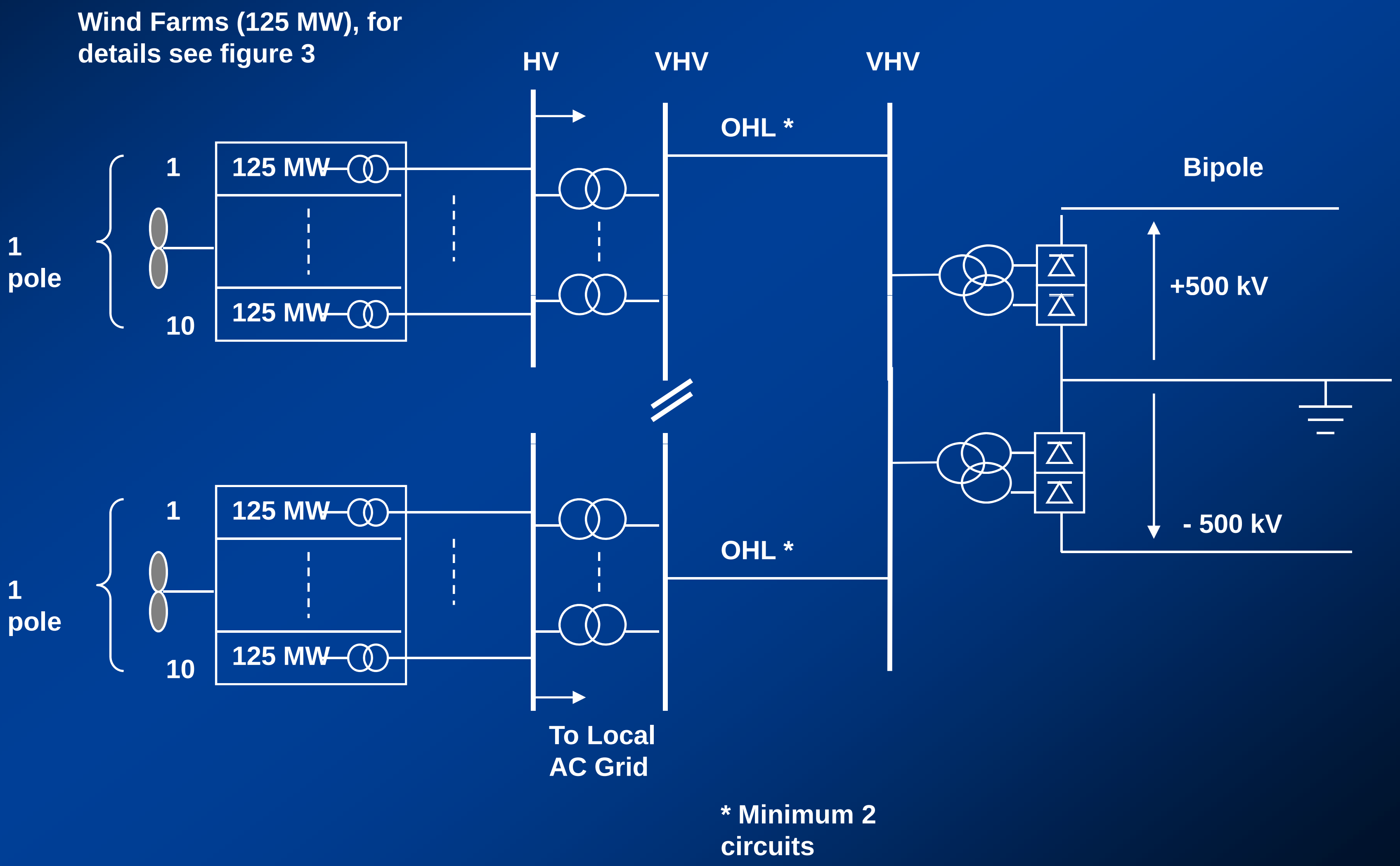


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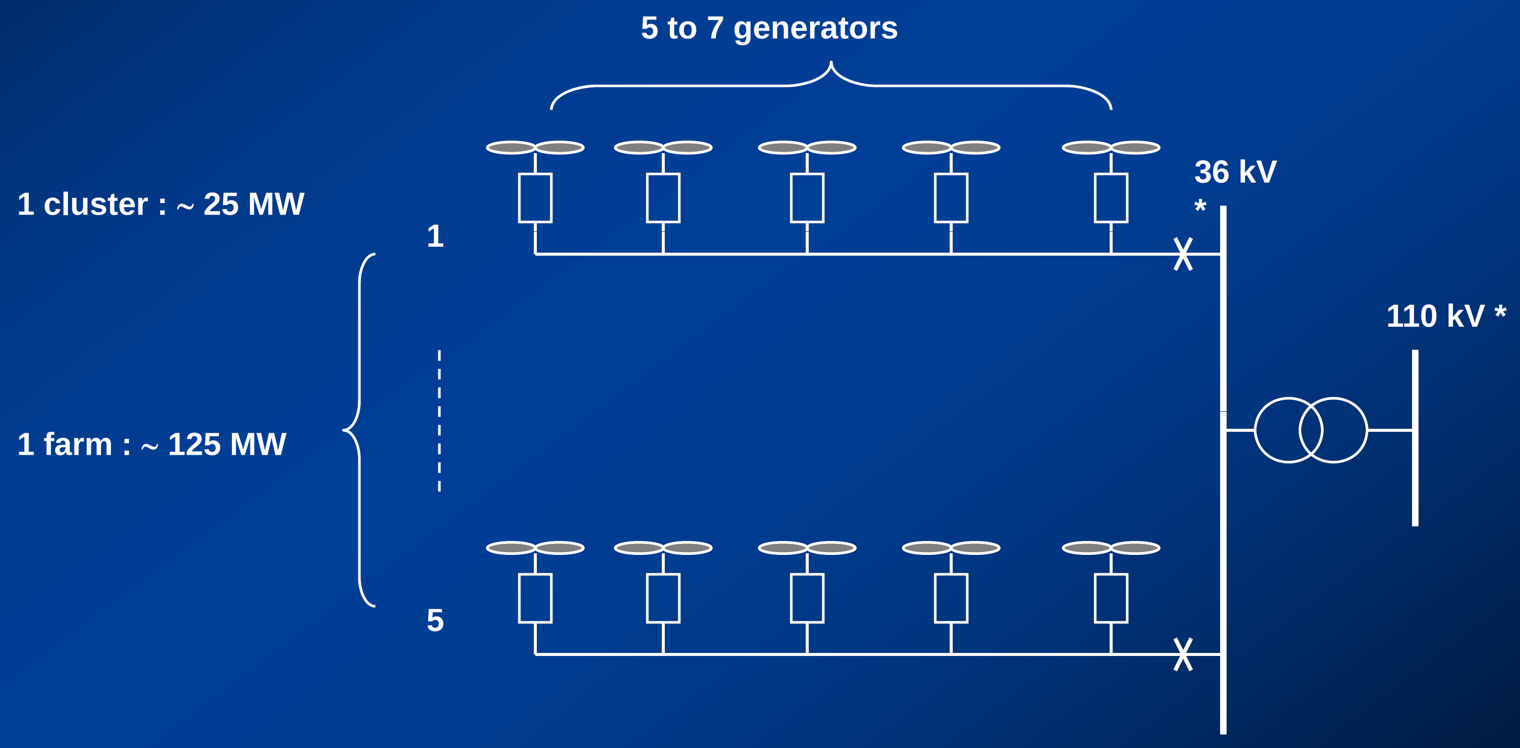
Figure 3 : Sahara Wind - Generator Clustering (for information only)



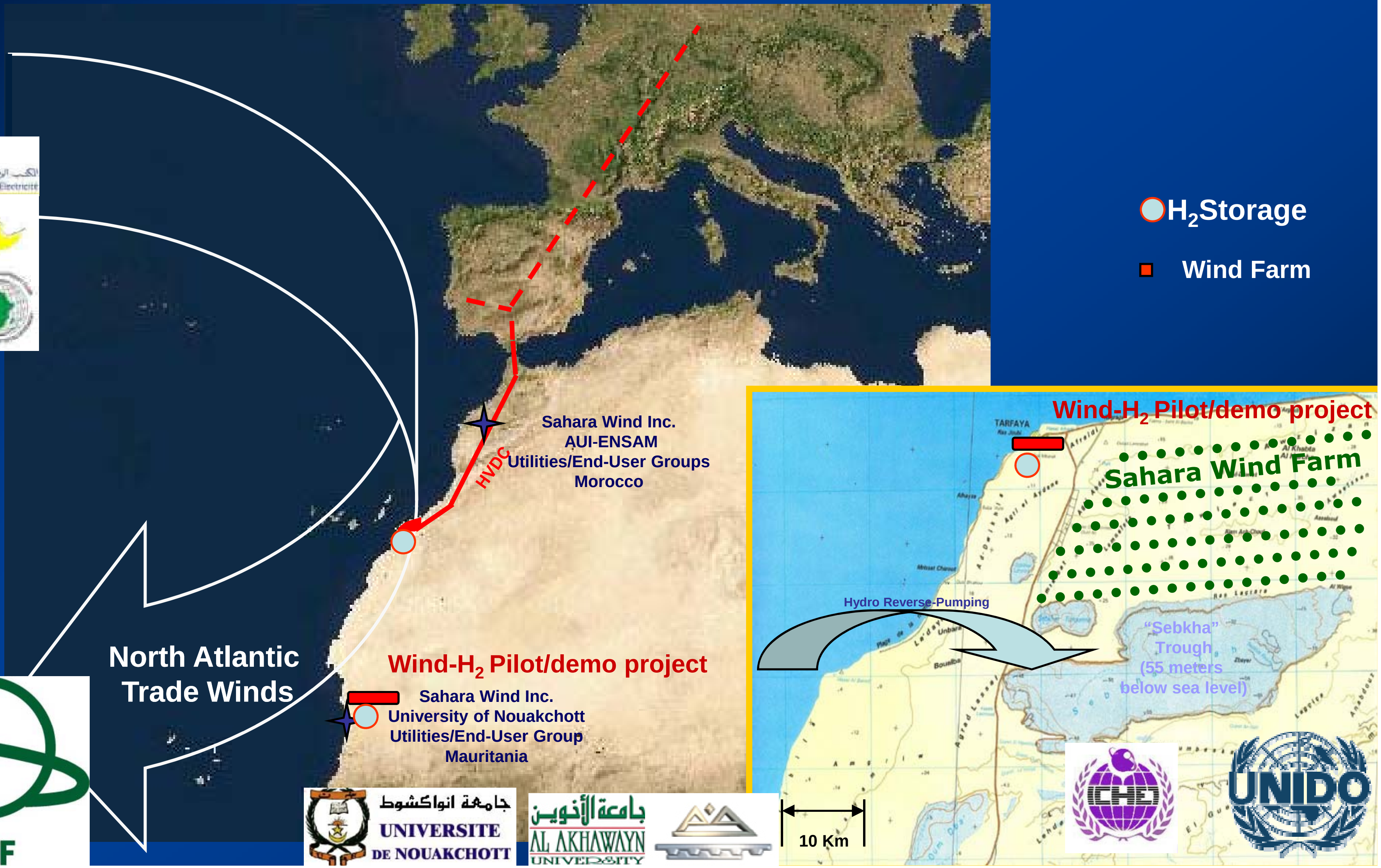
Sahara wind

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

Union for Mediterranean Solar Plan: 50 MW+ Sahara Wind Pilot Project

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

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