

Sahara Wind Energy Development Company

**NATO 'Science for Peace'**  
**SfP-982620**

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

**Introduction to Electrolyzer Technologies,  
Hydrogen Fuel Cells & Hydrogen Storage**

First Follow-up meeting

Al Akhawayn University of Ifrane February 12-13, 2009

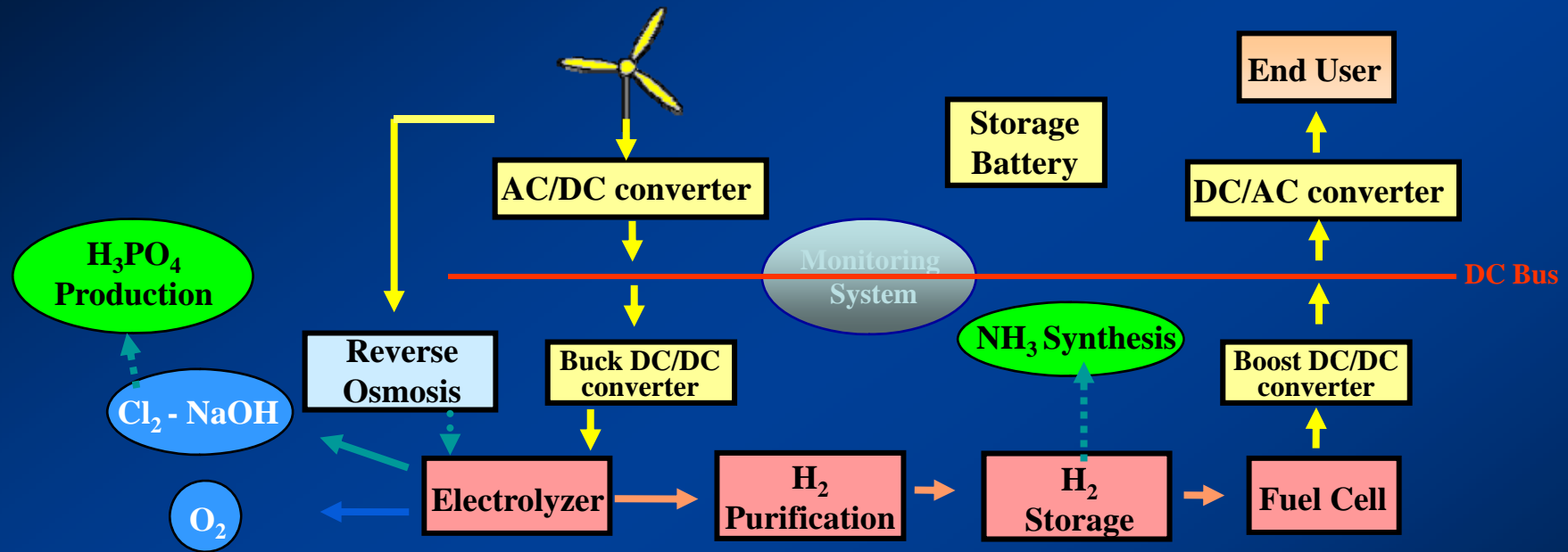
Khalid Benhamou - PPD (Morocco)



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# Configuration of the SfP-982620 Test benches



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## Electrolyzer Technologies

- Alkaline Electrolyzer

Low costs, better efficiency, lower Hydrogen purity, low pressure outputs (unless large ones). Small to very large capacities.

- PEM (Membrane) Electrolyzer

Produces Compact, need less service, Higher Hydrogen purity, pressurized output

Drawbacks: Very High costs (platinum catalyst), small capacities

- Aqueous / Chlor-Alkali (Membrane) Electrolyzer

Produces H<sub>2</sub>, Chlorine and Caustic, pressurized output

Drawback: Handling of chlorine, hard to downscale



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- Alkaline Electrolyzer

Can function without compression and need approx. 4 kWh/m<sup>3</sup>H<sub>2</sub>.

Cost effective systems, manipulation may be an issue.

The purity of Hydrogen is not high enough for fuel cell



H<sub>2</sub> Industrial (3.6 kW/hour)



H<sub>2</sub> Purifier



Can be Very Large (source IHT)



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- PEM (Membrane) Electrolyzer

Produces H<sub>2</sub> & O<sub>2</sub> High purity (99,9995%), pressurized output

Drawbacks: Very High costs (platinum catalyst)



HOGEN® GC 1 kW 220v.



CEHT



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- Hypochlorite (Membrane) Electrolyzer

Produces H<sub>2</sub>, hypochlorite, flexible power production, small scale

Drawback: output pressure



Electrocell Chlor-O-Safe™

Application areas:

Swimming pools

Municipal water plants

Food processors

Industrial plants

Waste water treatment plants

Cooling towers

Power plants

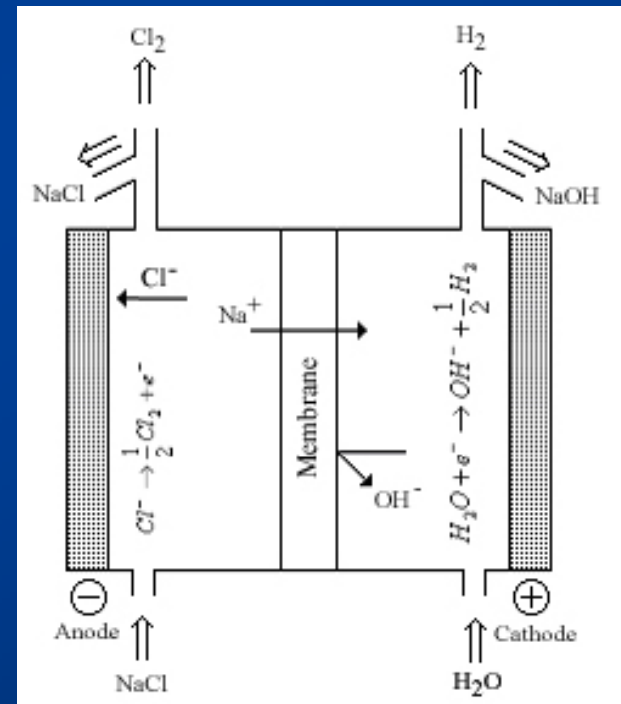
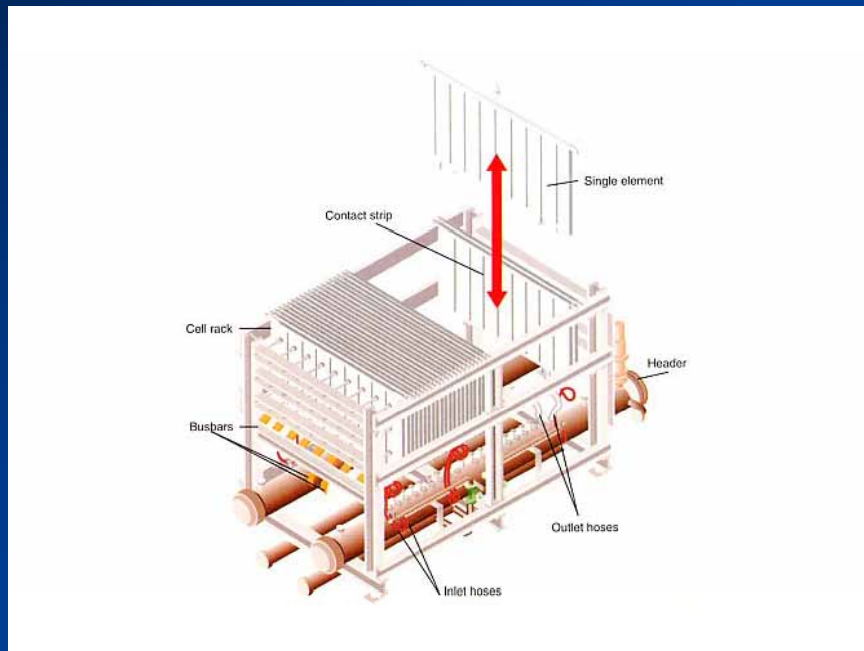
Chemical manufacturers



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- Aqueous Chlor-Alkali (Membrane) Electrolyzer  
 Produces H<sub>2</sub>, Chlorine and Caustic, pressurized output  
 Drawback: Handling of chlorine, hard to downscale



## Hydrogen Storage

- Gaseous Storage (low pressure)

Low Pressure

Cost effective and efficient but large volume required

High Pressure

Energy efficiency problems

Costs of compression equipment

- Metal Hydrides

Small capacities, low costs, modular

Can act as Hydrogen compressor when heated

- Liquid Storage

Small liquefiers available

Efficiency losses



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## Type of Fuel Cells (Low Temperature)

- |                                    | Qualified Power (W) |
|------------------------------------|---------------------|
| • Alkaline Fuel Cell (AFC)         | 10 kW to 100 kW     |
| • Phosphoric Acid Fuel Cell (PAFC) | up to 10 MW         |
| • Proton Exchange Membrane (PEMFC) | 100 W to 500 kW     |
| • Direct Methanol Fuel Cell (DMFC) | 100 kW to 1 MW      |

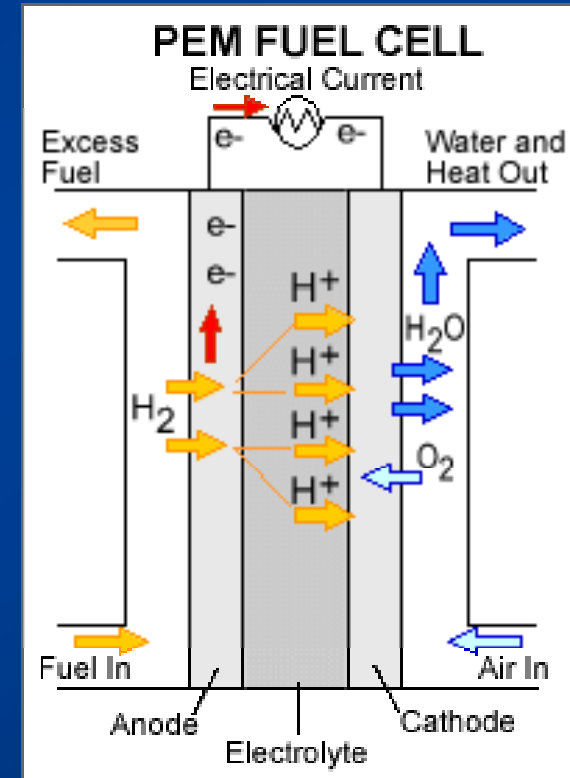


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## Fuel Cells (Low Temp)

- Proton Exchange Membrane
  - Flexible use
  - Low Costs (most common for small capacity)
  - Hydrogen Quality



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AN EPA – AGENCE NATIONALE DE L'EAU  
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CEA

#### GERMANY:

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

#### TURKEY:

UNITED NATIONS INDUSTRIAL  
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INTERNATIONAL CENTRE FOR  
HYDROGEN ENERGY TECHNOLOGIES  
UNIDO-ICHET



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