The Status of Hydrogen and Fuel Cell R&D in Greece

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Research Priorities in Greece

H2 Technologies

- ✓ H2 Production (water electrolysis, H_2S electrolysis, Photocatalytic & electrocatalytic production, thermochemical water splitting, reforming processes, allothermal gasification, artificial photosynthesis)
- ✓ Storage (compressed gas, storage in solids, chemical storage)
- ✓ Hydrogen safety & RCS
- ✓ H2 applications
- ✓ Modeling & simulation

Fuel Cells

- ✓PEM FCs
- ✓High Temperature PEM FCs
- ✓Innovative SOFC architectures
- ✓Development of electrodes and systems for Regenerative FCs
- ✓Materials development, Stack design and construction
- ✓Modeling & simulation
- ✓Niche Market Applications for FCs (such as Power production and CHP systems)

Integrated systems

- ✓Real-scale development, demonstration and evaluation of RES – H2 hybrid systems
- ✓Development of Hydrogen refueling stations and the Greek Hydrogen highway
- ✓Integrated system design and analysis
- ✓Techno-economical studies
- ✓Modeling & simulation
- ✓Component testing and evaluation

Major Existing Infrastructures

Area	RTD
Basic Research	❖ Flow systems for catalytic and electrochemical studies, ❖ Synthesis of materials, ❖ Equipment for catalyst, electrodes, cells and MEAs development ❖ Advanced electrochemical characterization ❖ Various H2 production pathways ❖ Various storage methods
Applied research and Tech. Dev.	❖ RES & Hydrogen Technology hybrid laboratory (PV, PEM electrolyser, Alkaline electrolysers, Bioethanol Reformer, Compressed gas & Metal Hydride storage, PEM FCs) ❖ Lab and pilot scale units for FCH materials, synthesis, shaping & characterization/evaluation ❖ Automated & Computerized Biomass Gasification Laboratory ❖ A 66kW_e solar simulator indoors facility ❖ A 10 kW_{th} solar dish bearing a monolithic reactor for CSP-aided thermochemical H_2O/CO_2 splitting for solar fuels production (**under construction)** ❖ SOFC Test Rigs to evaluate single cells ❖ H_2 utilization Laboratory for stationary applications ❖ Test benches for PEM fuel cell and electrolyser single cell testing ❖ Regenerative PEM Fuel Cell / Electrolyser test bench
Lighthouse Pilot Projects	❖ **Wind-hydrogen plant (500 kW synchronous wind turbine, 25 kW alkaline electrolyser, filling station at 220 bar, metal hydride tanks) (CRES)** ❖ **H2Susbuild (an energy self-sustained building of integrated H2/RES technologies) (NTUA)** ❖ **The Green Island Project (under consideration)**
Early Markets	❖ Integration of power production or CHP systems (F.P + F.C) ❖ H2FC forklifts ❖ FC UPS
Products under Commercialization	❖ Bioethanol reformer ❖ Membrane Electrode Assemblies (MEA) for High Temperatures PEM fuel cells ❖ Methanol internal reforming HTPEM for portable applications

Hybrid Renewable & H_2 Technologies Integration

Stationary solid state storage of hydrogen produced from renewables via electrolysis (CRES)

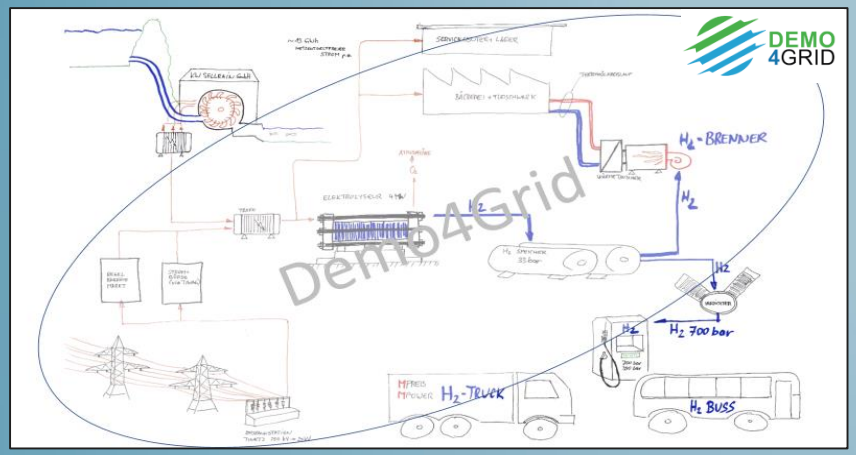
Hydrogen as an attractive means for renewable energy storage

КАПЕ
CRES

Selected Projects in Greece

The Demo4Grid project

Demonstration of 4MW Pressurized Alkaline Electrolyser for Grid Balancing Services



- Manufacture and demonstrate an advanced 4 MW single-stack Pressurized Alkaline Electrolysers (PAE) designed for providing grid balancing services
- Demonstrate feasibility of the target business models through infield business case demonstration (with regards to grid balancing services and other power price opportunities to produce hydrogen on a commercial basis) Performance assessment of individual components and integrated system (filling station 100 Nm3 in cylinders)

DIADIKASIA BUSINESS CONSULTING

The H2SusBuild project

An energy self-sustained building with integrated H2/RES technologies (NTUA)

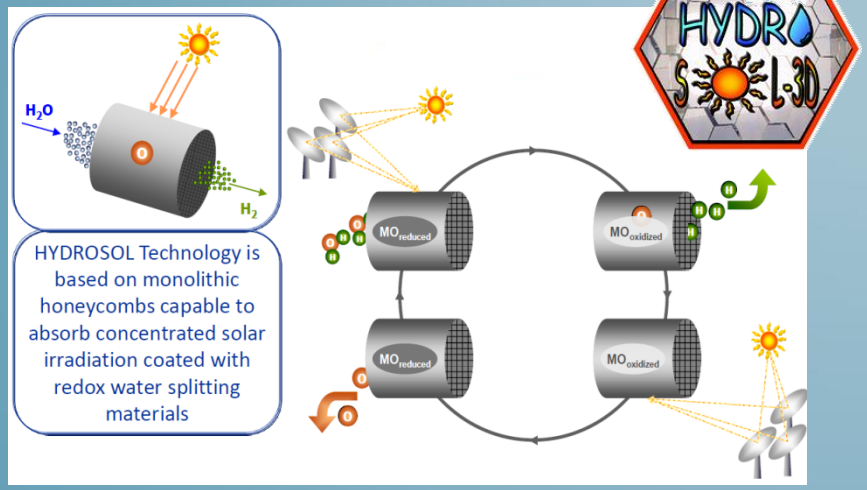
The primary energy is harvested from RES and directly used to cover contingent loads, while the excess energy is converted to hydrogen used as energy storage material and to be further applied as a green fuel to cover the building heating needs through direct combustion or to produce combined heating and electricity by means of fuel cells.

Selected Projects in Greece

Hydrosol 3D

Scale Up of Thermochemical HYDROgen Production in a SOLar Monolithic Reactor: a 3rd Generation Design Study

"2006 Descartes Prize for Collaborative Scientific Research"



Demonstration of a CO_2-free hydrogen production and provision process and related technology, using two-step thermochemical water splitting cycles by concentrated solar radiation.

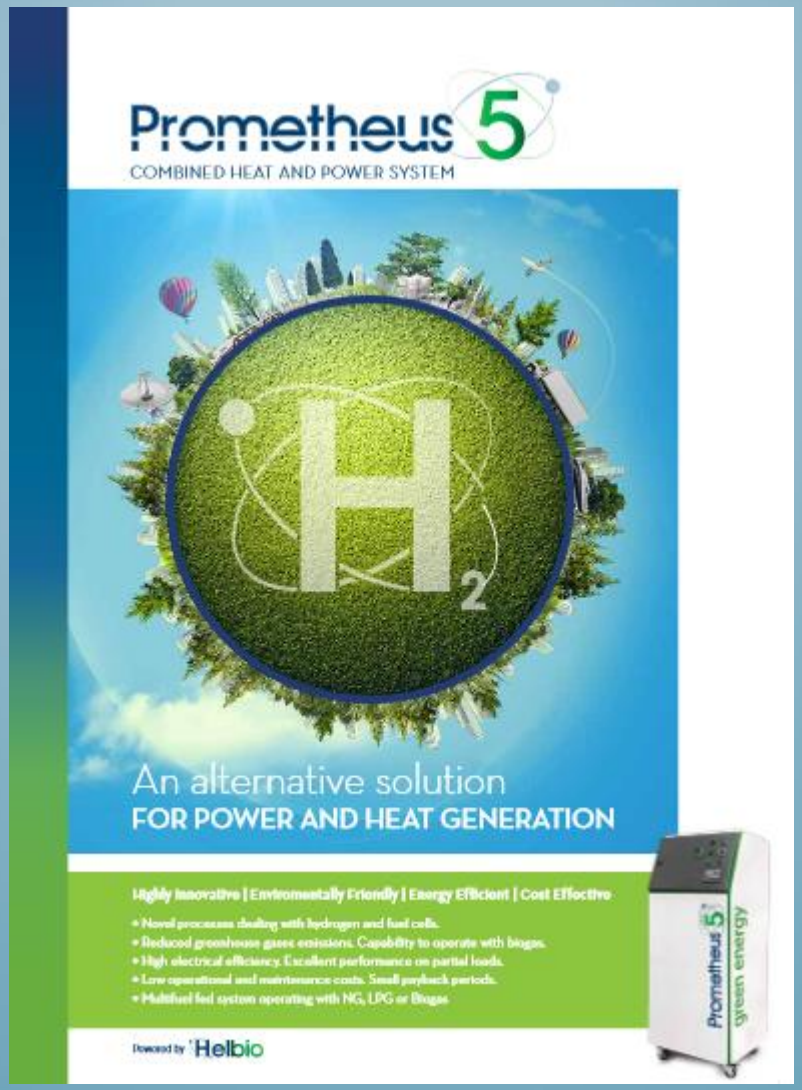
Membrane Electrode Assemblies

Development and production of polymers, membranes and MEAs for High Temperature PEM fuel cells

- Polymeric materials with tailor made properties are produced in order to withstand the conditions prevailing during the fuel cell operation.
- The development of a novel commercial internal reforming methanol HT PEM FC is currently pursued.

Selected Projects in Greece

Prometheus 5 CHP System



Mature concepts for new H2 Projects in Greece

The Green Island Concept (*for small-to-medium size off-grid Greek islands*)

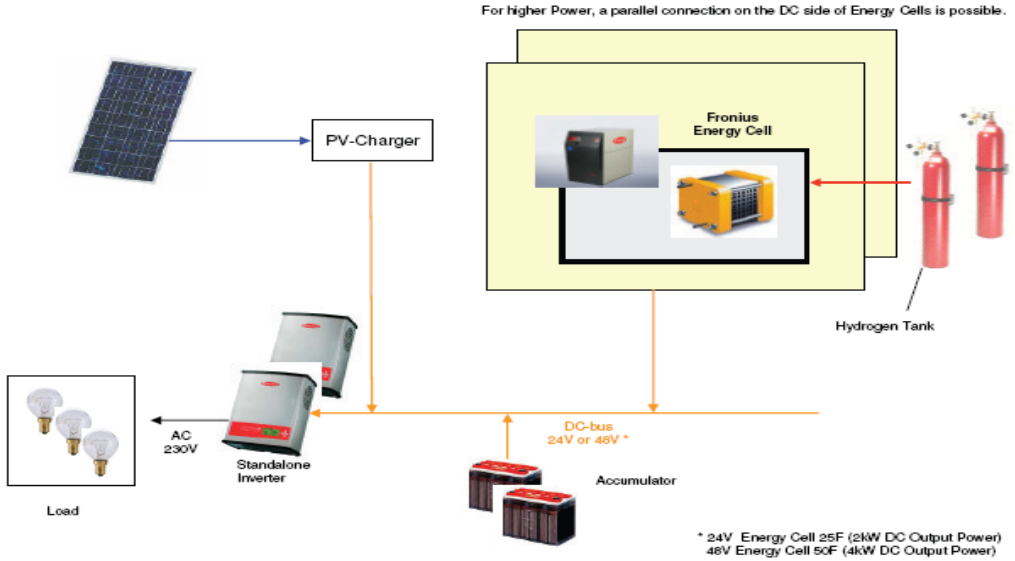
The hybrid power system may consist of:

- *Wind turbines 500-800 kW total*
- *PV 100-200 kW*
- *Batteries ~2000 kWh*
- *1 Electolyser 100 kW*
- *Hydrogen storage 200 kg*
- *2 H2 combustion Engines 75 kW each*
- *Various Hydrogen & electric vehicles*
- *Control system*

Project's innovation → high percentage of RES penetration in the island's autonomous and weak electricity grid

Main objective → create an "Open Lab" for tests and development of knowledge in the fields of green energy and ecology with global reference.

Possible Energy Cell concept
for a stationary energy-autonomous solution



The envisaged Green Island Project

Transport Applications

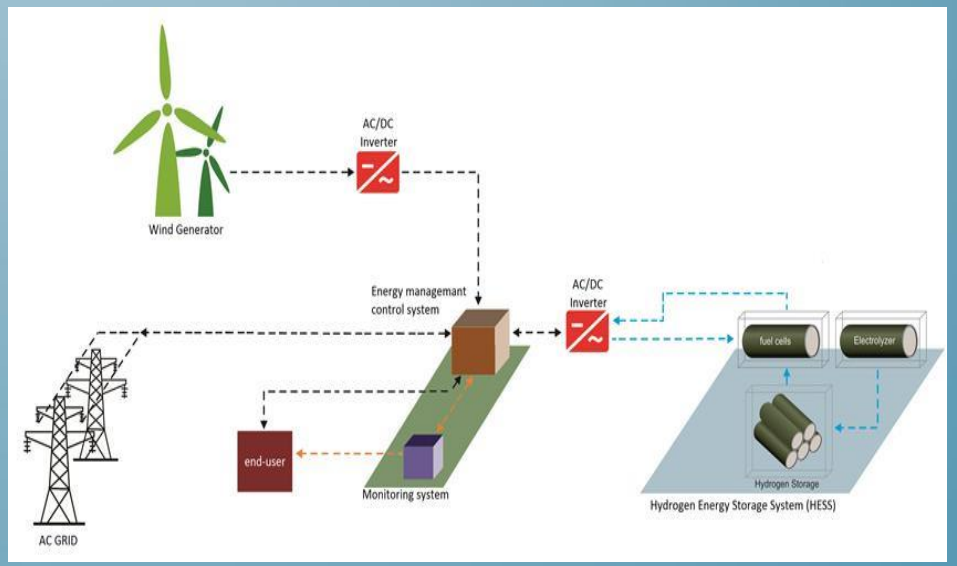
… to create the necessary infrastructure for an integrated hydrogen filling station covering all future needs on the island. H2 transport applications on islands may include:

- ***Complete Hydrogen filling station(s)***
- ***Material handling equipment, such as forklifts***
- ***Touristic busses , Garbage trucks and any other Heavy-duty vehicles***
- ***Boats, ships and ferries***

Stationary Applications

•Pilot H2 FC systems for:

- ***Back-up power systems***
- ***Energy storage from RES and grid services***
- ***Port services***

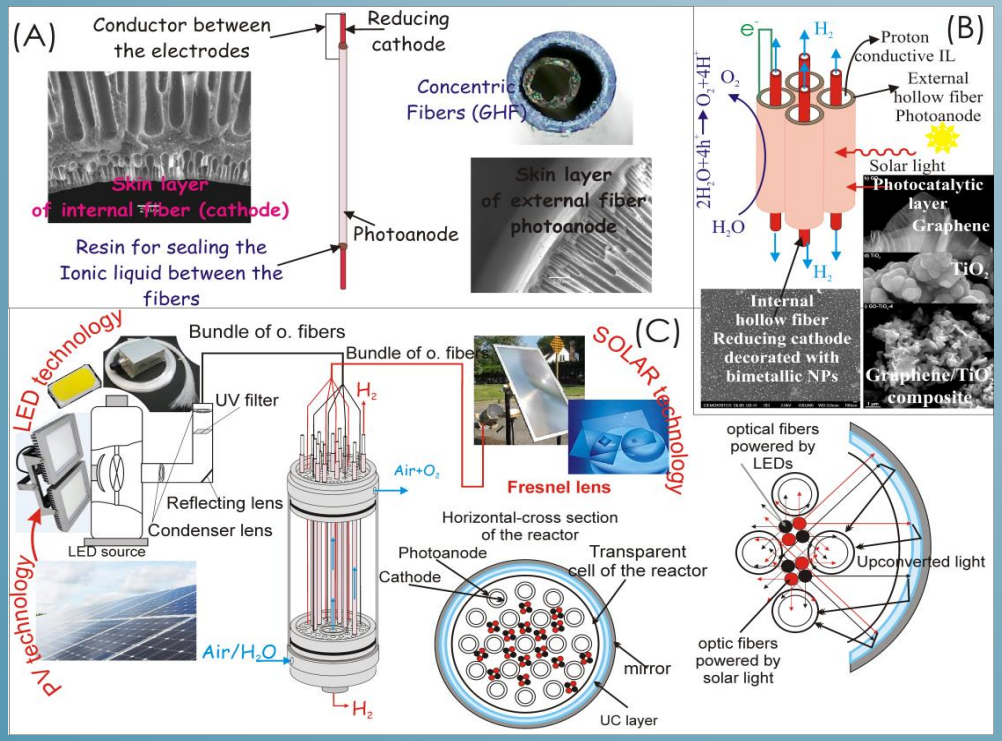


Photoelectrocatalytic (PEC) Conversion of CO_2 for the Production of Valuable Chemicals and H_2

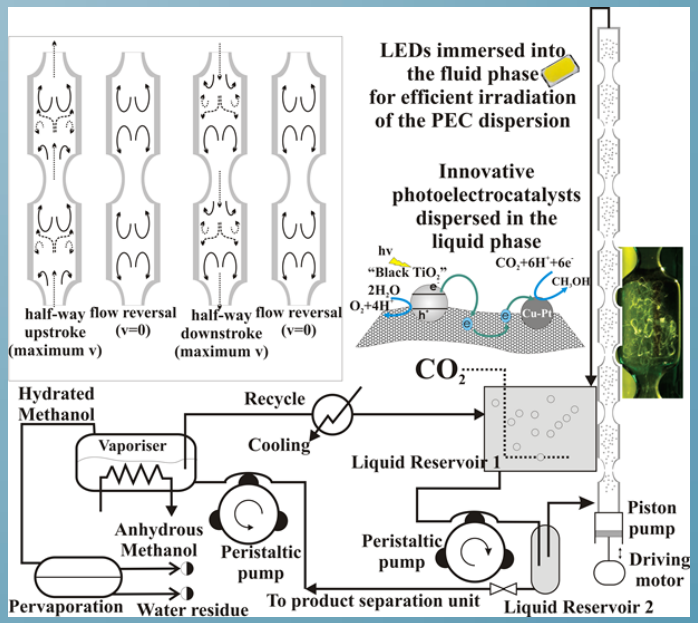
Innovative photoelectrocatalysts and photoanodes based on 3-Dimensional, "Black TiO_2"- pillared graphene derivatives, applied into intensified CO_2 capture and photocatalytic conversion processes

- Advanced photoelectrocatalytic materials and electrodes.
- Highly H^+ conductive and CO_2 absorbing ILs - Post separation processes for the produced chemicals / fuels.
- Design development and operation of SGI-PEC and SLI-OBC reactors.

Gas Phase Process (Solid/Gas Interface Reactor)-(H_2)

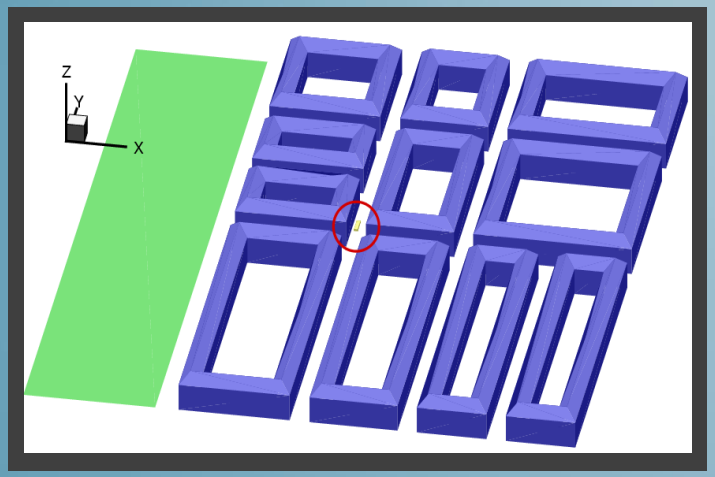


Liquid Phase Process Solid/Liquid Interface Reactor)- $CO_2 \rightarrow CH_4$, CH_3OH, CH_2O

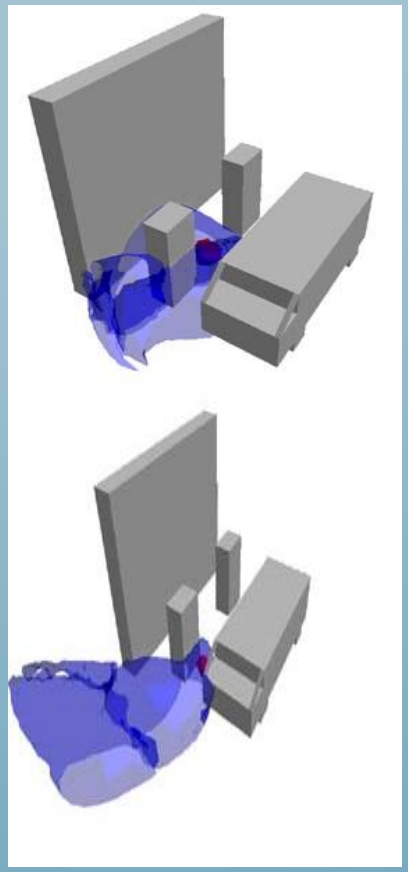


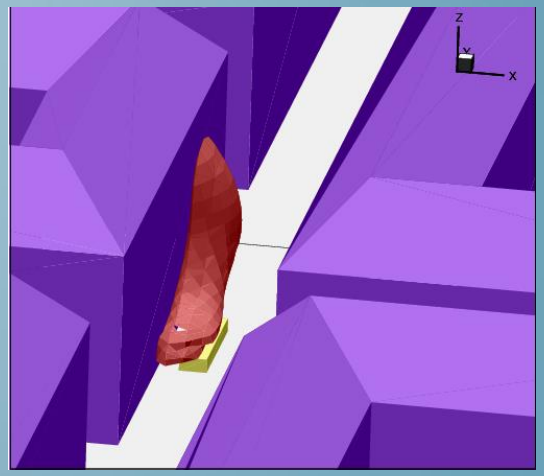
Simulation Tools: Storage Systems & Safety Studies

Safety analysis of hydrogen used as a fuel for vehicles



The 1983 Stockholm H_2 accident. Modeled site and truck carrying 4 kg of H_2 in 18x200 lt, 200 bar bottles





The 1983 Stockholm H_2 accident predicted lower flammability H_2-air cloud for 10 seconds after start of accident.

HySafe

HyApproval

ACKNOWLEDGMENTS