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science & technology
Department: Science and Technology
REPUBLIC OF SOUTH AFRICA

DST HySA Infrastructure Centre of Competence:

Advanced Hydrogen Technologies for FC Applications and PGM Beneficiation in South Africa

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HySA Infrastructure Hydrogen South Africa

CSIR

CHEMICAL RESOURCE BENEFICIATION

NORTH-WEST UNIVERSITY
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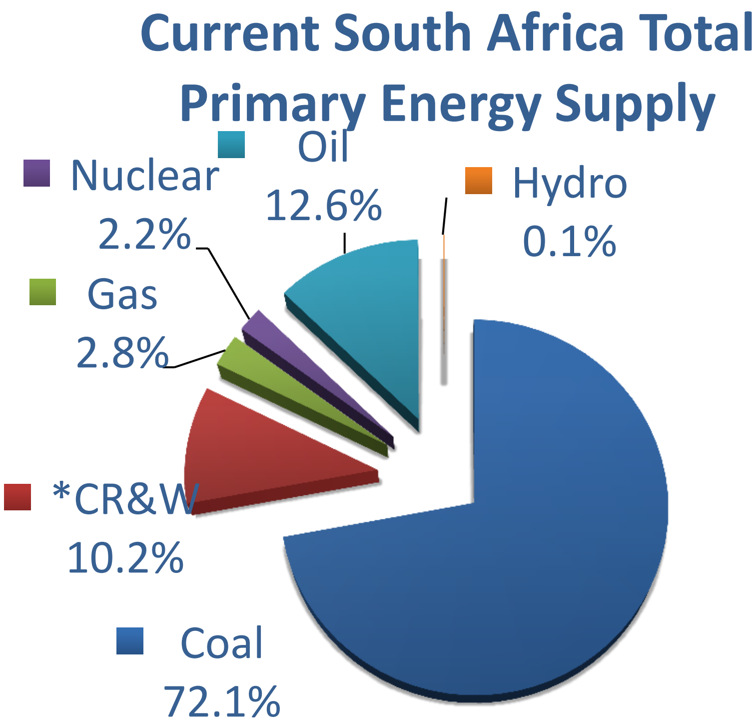
Presentation Outline

- ❑ South African Energy Profile
- ❑ Strategic drivers for investment in H_2 and Fuel Cell Technologies in RSA: Resource base, Environment
- ❑ The RSA H_2 and Fuel Cell Technology R&D and Innovation Strategy: Strategic Goals, Vision, Implementation
- ❑ Scope of HySA Infrastructure Centre of Competence
- ❑ HySA Infrastructure Project Portfolio (Selected)
- ❑ HySA Infrastructure Road Map

South African Energy Profile



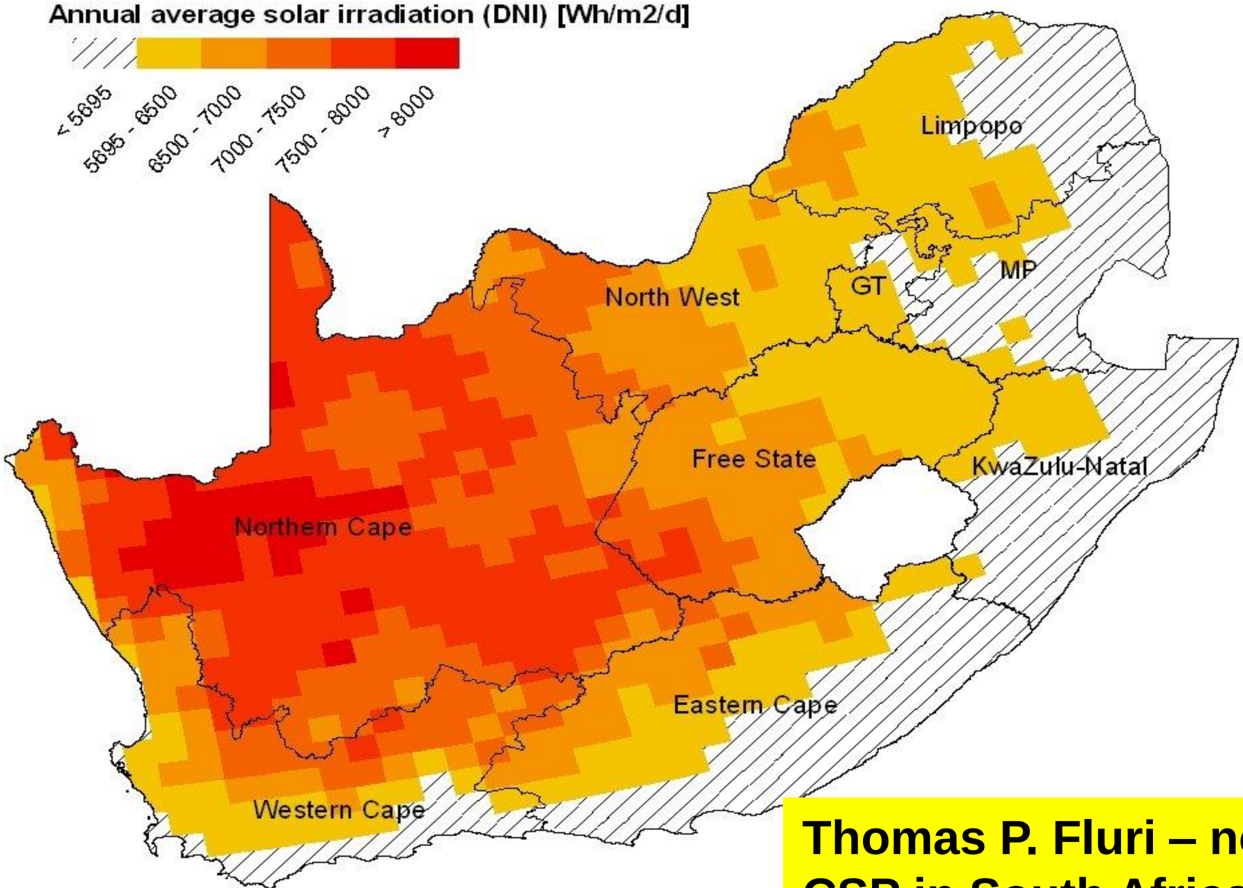
- **Coal supplies ~75 % of South Africa's primary energy and 90 % of its electricity requirements**
- **South Africa has estimated coal reserves of 35 billion tons**
- **Annually ~285 million tons is mined from 73 mines in 19 coalfields**
- **Domestic consumption of coal amounts to ~171 million tons (~ 100 mt for electricity and ~ 70 mt for synfuels) and ~69 million tons is exported**

*CR&W: Combustible Renewable and Waste

Source: International Energy Agency (IEA)

- RSA has energy intensive economy
- RSA has a large SO_2/CO_2 footprint
- RSA's CO_2 footprint per capita ranks among the top 12 in the world

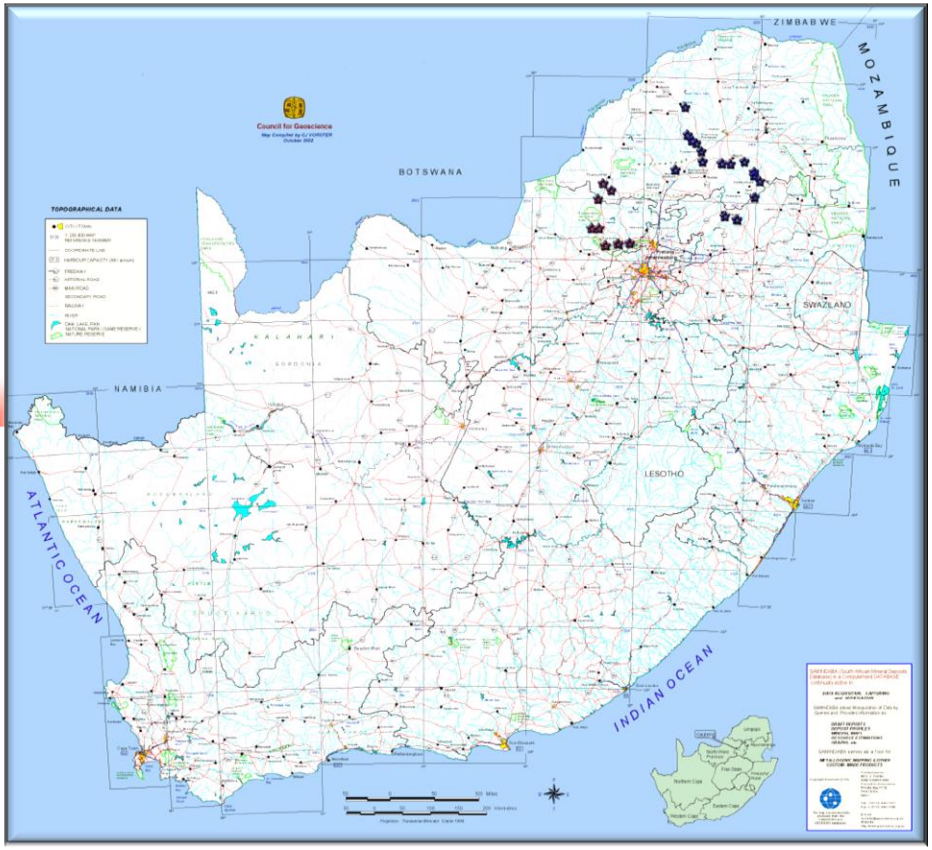
Solar Energy Potential in South Africa



Thomas P. Fluri – nominal capacity for CSP in South Africa is 547.6 GW, Energy Policy, v 37, Issue 12, December 2009, 5075–5080

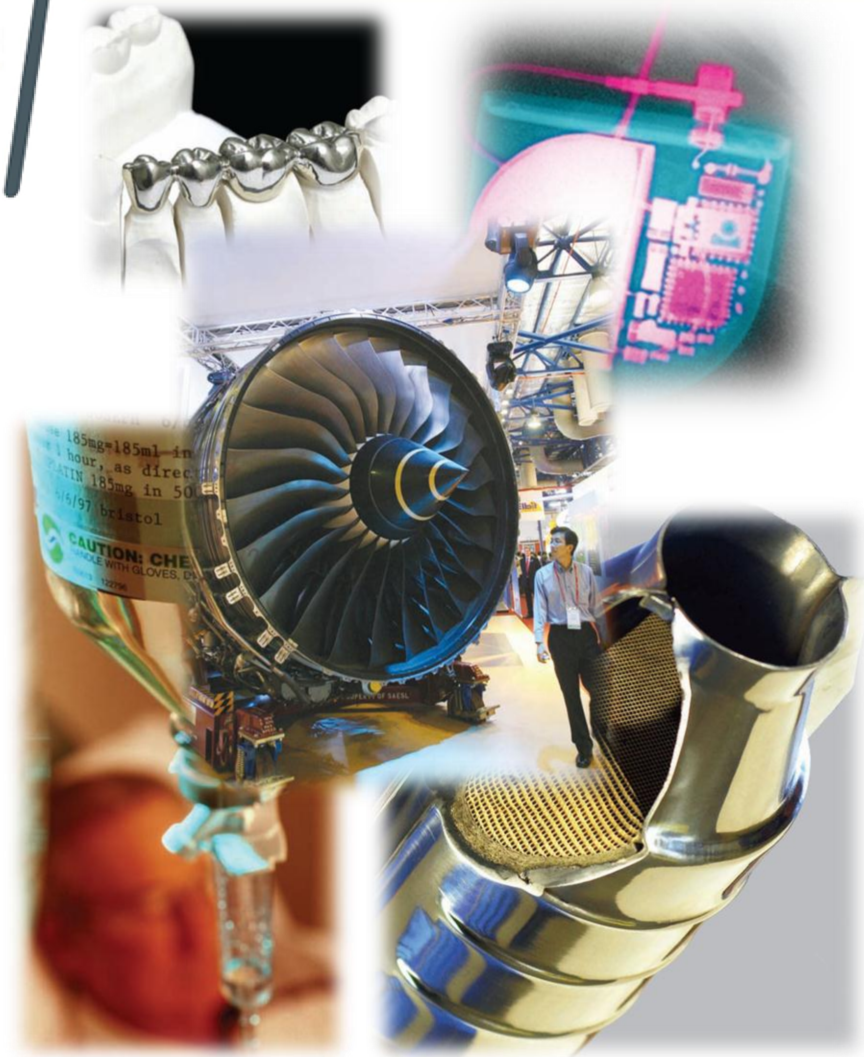
Mineral Resources in South Africa

Rank in the World	SA Mineral Resource
1	Gold
1	Platinum
1	Titanium
1	Chromium
1	Manganese
1	Vanadium
2	Zirconium

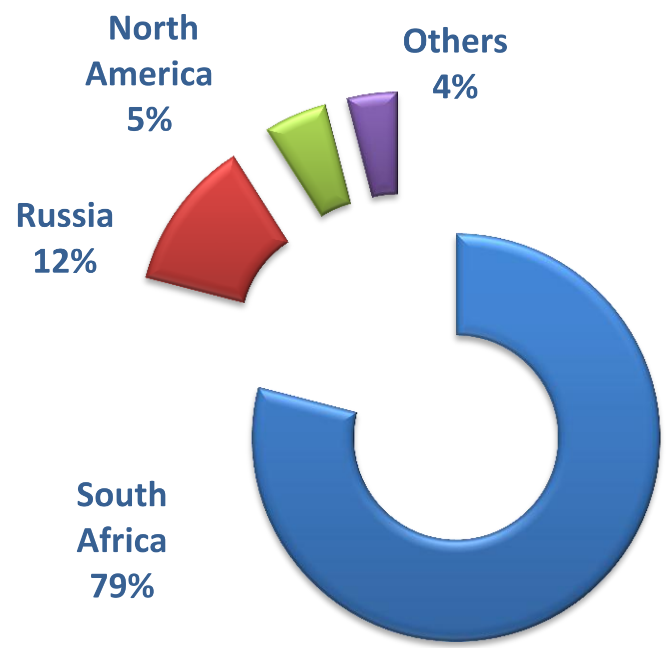


South Africa produces about 59 different minerals from 1115 mines and quarries. South Africa is the world leader in platinum and PGM production, having produced around 4.5 million ounces of platinum and 8 million ounces of PGMs in 2009

South Africa is dominant PGM supplier



PGM Supply by region



South Africa has nearly 80% of the world's PGMs, and these metals contribute US$2,200 billion of the country's total resource value of US$2,494 billion. Russia and Australia came in second and third, with values of US$1,636 billion and US$1,588 billion, respectively.

H&FC R&D Technology and Innovation Strategy

Strategic Goals

- ❑ Establish a base for hydrogen production, storage technologies and processes
- ❑ Establish a base for developing catalysts based on PGMs; supply 25% of PGM catalysts demand by 2020
- ❑ Build on existing global knowledge to develop know-how to leap-frog existing fuel cell technologies for niche applications to address regional developmental challenges

H&FC R&D Technology and Innovation Strategy

Our Hydrogen Vision

“ to create knowledge and human resource capacity that will develop high value commercial activities in hydrogen and fuel cell technologies utilising local resources and existing know-how”

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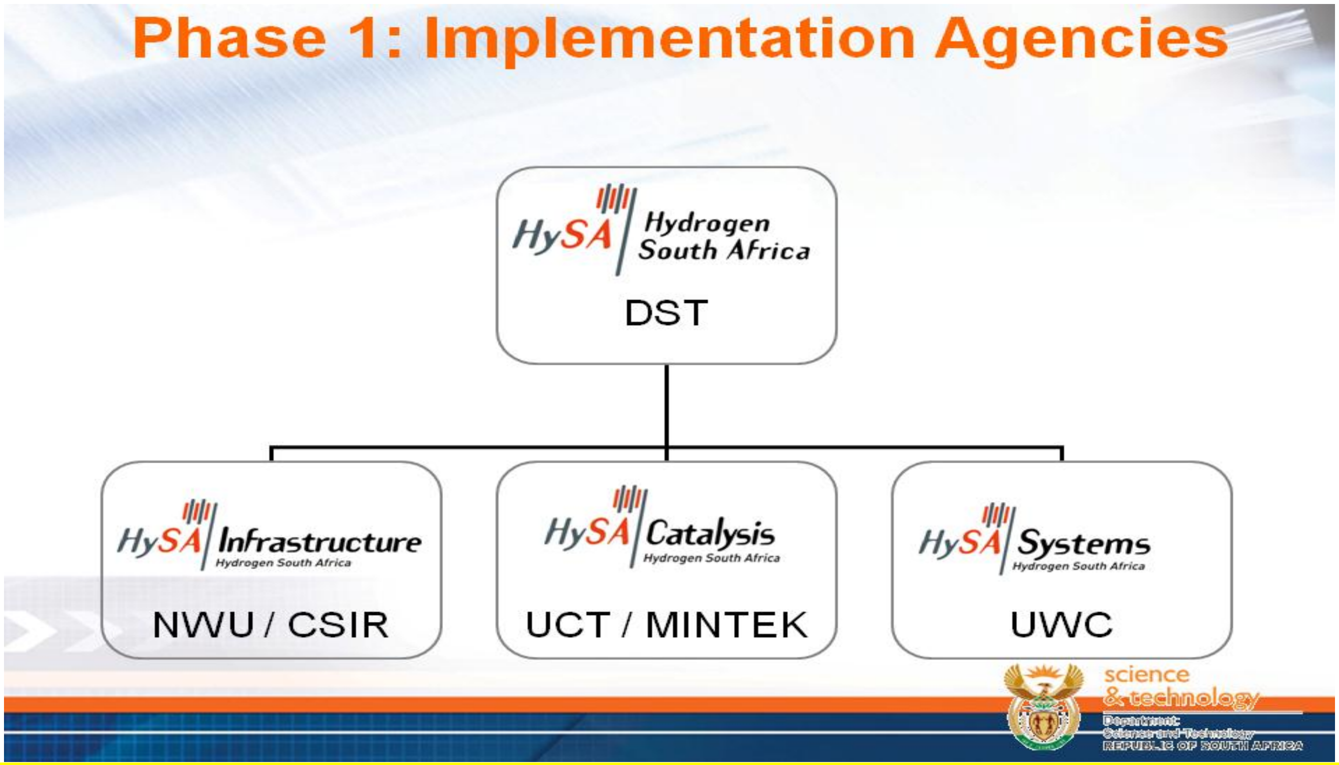
From: Dr Phil Mjwara, DG-DST: “Vision 2030: Hydrogen and Fuel Cells in SA”, IPHE Meeting, Cape Town, 03 May 2012

H&FC R&D Technology and Innovation Strategy

- Phase 1 – Establishment of a national R&D capability, comprising of **three established Centres of Competence**, based on a hub and spoke model.



From: Dr Phil Mjwara, DG-DST: "Vision 2030: Hydrogen and Fuel Cells in SA", IPHE Meeting, Cape Town, 03 May 2012

HySA Infrastructure: Mission

To deliver **technologies** for **H_2 Production, Storage** and **Distribution Infrastructure** that meet set cost targets and provide best balance of safety, reliability, robustness, quality and functionality

HySA Infrastructure: Five-Year Vision

- ❑ Formulate, coordinate and execute **strategic unified research portfolio** aiming at **successful implementation** of **South African H_2 and Fuel Cell Roadmap**

- ❑ Become a **significant player** in mastering of existing and discovery of new solutions for H_2 production, storage and distribution, leading to **development** and **application** of **new products** and **processes**

- ❑ Prepare RSA to participate in H_2–related applications, primarily by **beneficiating** its **resource base** in becoming a **significant supplier** of material, components, products, sub-systems and systems for export

HySA Infrastructure: Programme Scope

HySA/Infrastructure

Electrolysers & Electrolyser Systems linked to Renewable Energy

- PEM electrolyser components development and benchmarking
- PEM electrolyser system development
- Unit cells and Stacks
- PEM electrolyser characterisation tools
- Depolarized electrolysis (e.g. SO_2)
- ECH (electrochemical compression of H_2: components and systems)

H_2 Storage/Production

- Carbon Nanostructures
- Chemical storage (e.g. NH_3)
- MOF, other types
- Modelling
- Compressed H_2

H_2 from appropriate biomass and biological pathways (WGS)

- System Integration (H_2 production and delivery)
- Safety and Codes
- PGM Recycling

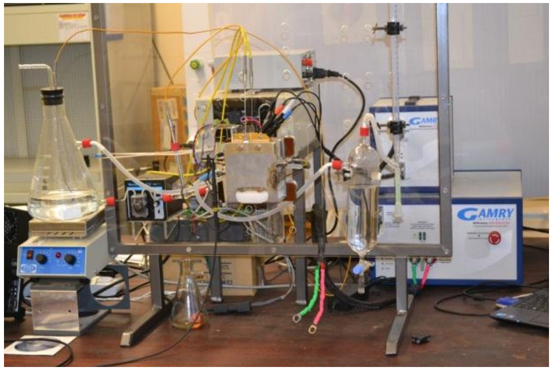
Cross Cutting of Key Programmes within HySA

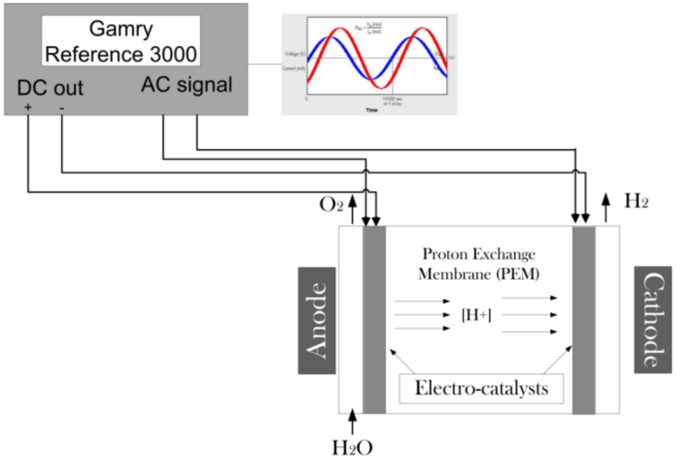
HySA Catalytsis CC
HySA Systems CC
HySA Infrastructure CC

PROGRAMME	CAPACITY	FUEL	ENERGY SOURCE	KP5 - H_2 PRODUCTION TECHNOLOGY	KP4 - H_2 STORAGE OPTION	KP4 - SAFETY
KP1 - Combined Heat and Power	Household: ~10 kW Industrial: ~150 kW	LPG	Fossil	Fuel Processor	Not Applicable	Not Applicable
KP2 - Portable Power	Portable Power: ~1 kW Standby Power: ~5 kW	Hydrogen	Wind Photovoltaïc	PEM Electrolysis NH_3 Cracker	NH_3 Storage Carbon Nano Structure (CNS) Storage High Pressure Hydrogen Cylinders Metal Organic Frameworks (MOF) Metal Hydride Storage	Safety of Production Safety of Storage Safety of Dispensing Safety of Usage
KP3 - Fuel Cell Vehicles	Utility Vehicles: ~15 kW	Hydrogen	Wind Photovoltaïc	PEM Electrolysis NH_3 Cracker	High Pressure Hydrogen Cylinders Metal Organic Frameworks (MOF) Metal Hydride Storage	Safety of Production Safety of Storage Safety of Dispensing Safety of Usage

Characterisation Tools Development for PEM Water Electrolysis

- ❑ Electrochemical Impedance Spectroscopy





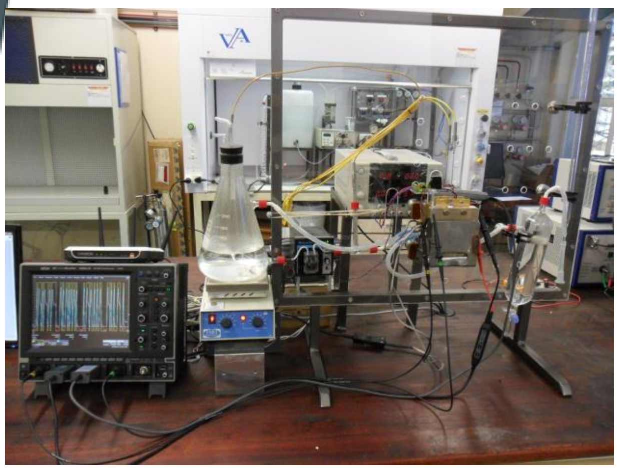
Using EIS to calculate the contribution of the losses at different current densities

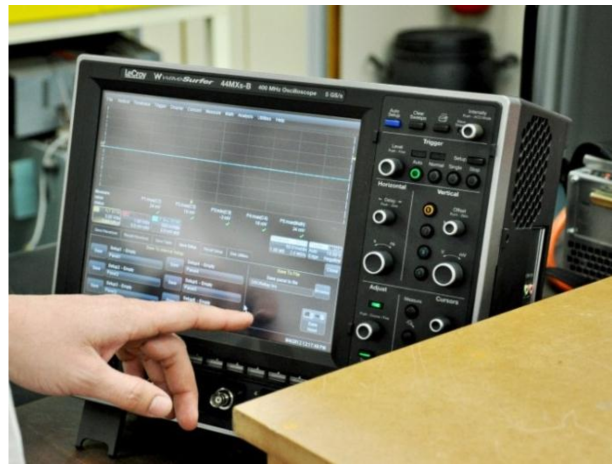
Target:

- ❑ Ohmic losses
- ❑ Mass transfer losses
- ❑ Activation losses

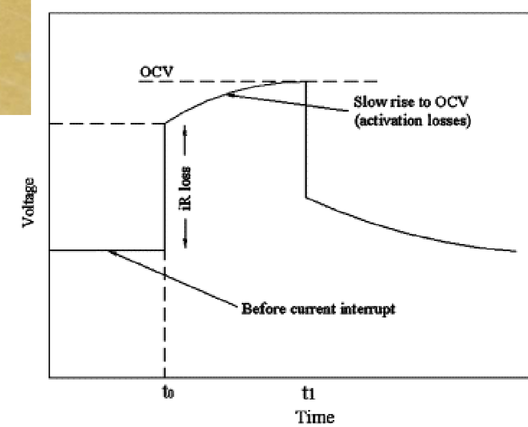
Characterisation Tools Development for PEM Water Electrolysis

❑ Current Interrupt Method





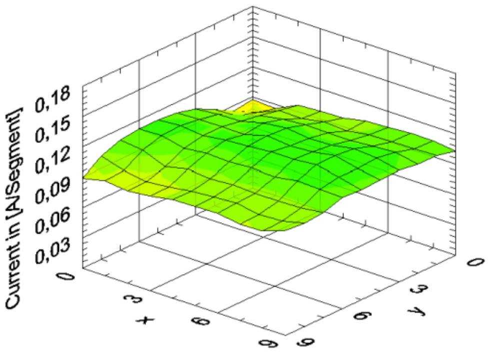
Target:
- ❑ Membrane
- ❑ Fast diagnostic tool



Oscilloscope control interface.
Control oscilloscope through network port.
Configure oscilloscope settings to desired levels.
Generate PRBS signal to be applied.
Capture waveform from oscilloscope into LabVIEW memory.
Sequences to be finalized for autonomous control, data acquisition and data analysis.
After the data is sampled, the current interrupt method can be applied to obtain the values of the Randles cell and Randles-Warburg parameters.

Characterisation Tools Development for PEM Water Electrolysis

- ❑ Current Mapping

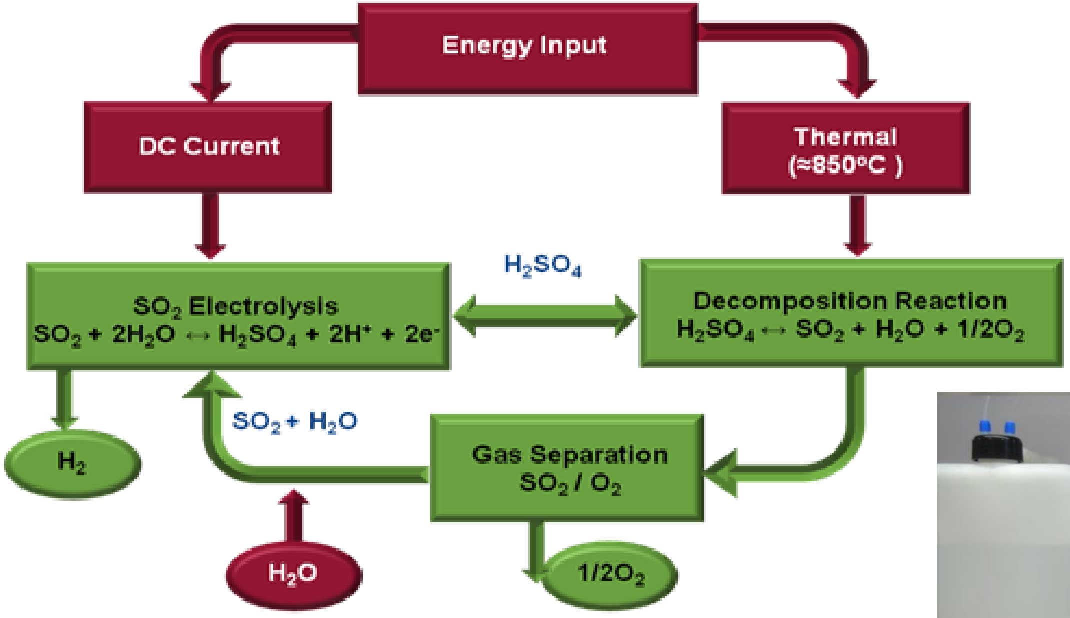


Target:

- ❑ Current distribution
- ❑ Water management

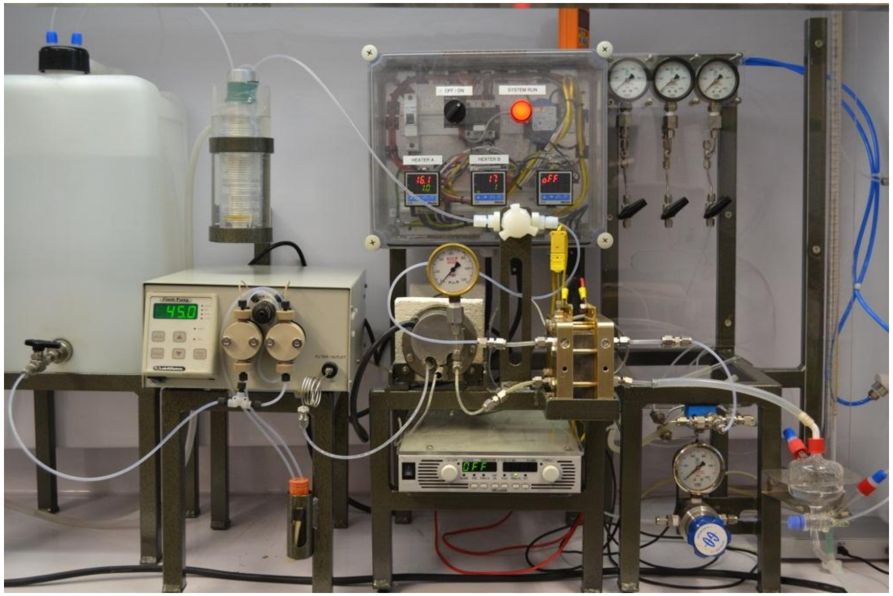
S++ Simulation services

Testing MEAs for SO_2 electrolysis

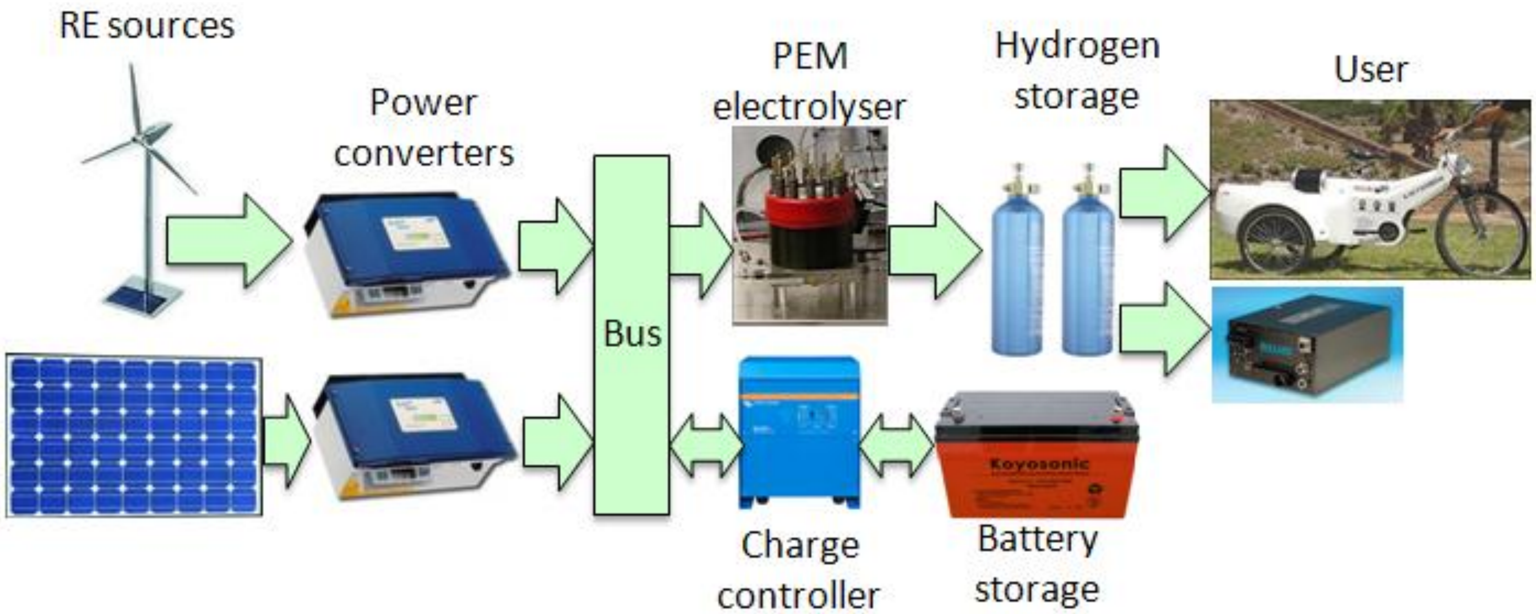


HyS Cycle

Membrane thickness
Operating cell temperature
Cathode water pressure
SO_2 feed concentrations



Electrolyser Integration with Renewables



Purpose:

Improve system efficiency and sizing through a combination of power management strategies and component configurations.

Determine optimal combination of hybrid renewable sources.

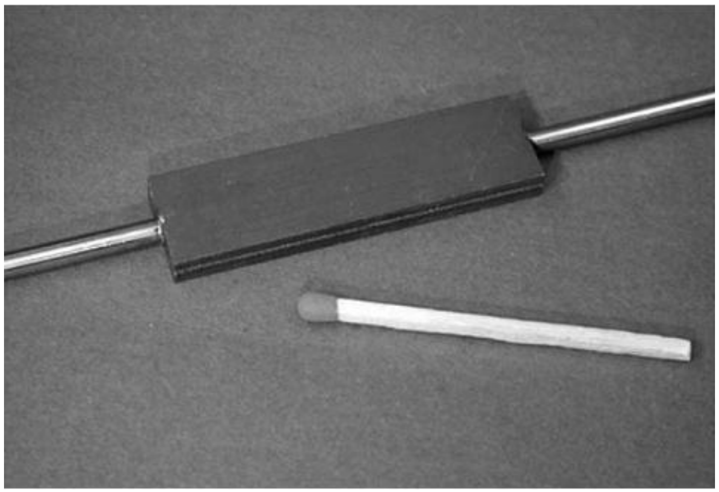
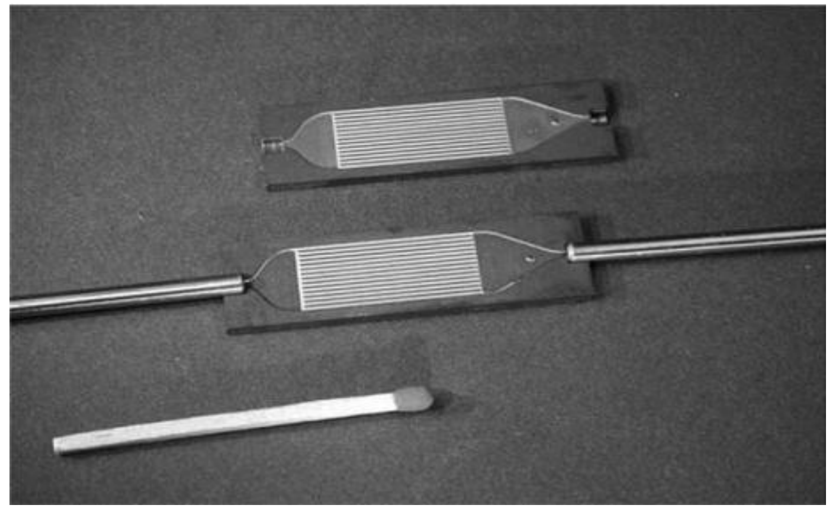
Research aim and objectives:

Modeling – Develop detailed models. Optimisation – Develop algorithm to find optimal component sizing.

Power management/control – Develop control strategy to improve system efficiency. Validation and verification.

Chemical Hydrogen Storage

- Micro-channel reactor for ammonia cracking

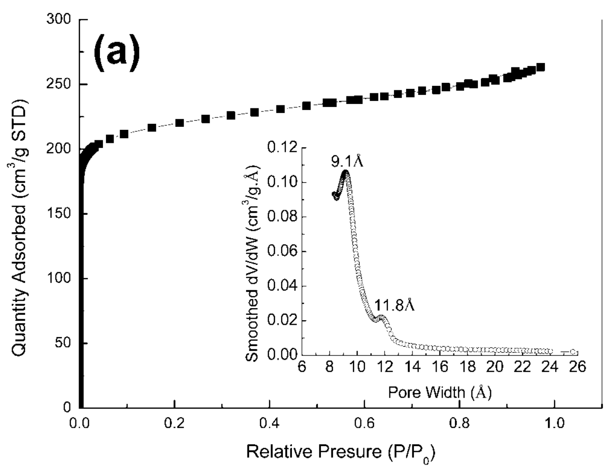
Ammonia decomposition reaction

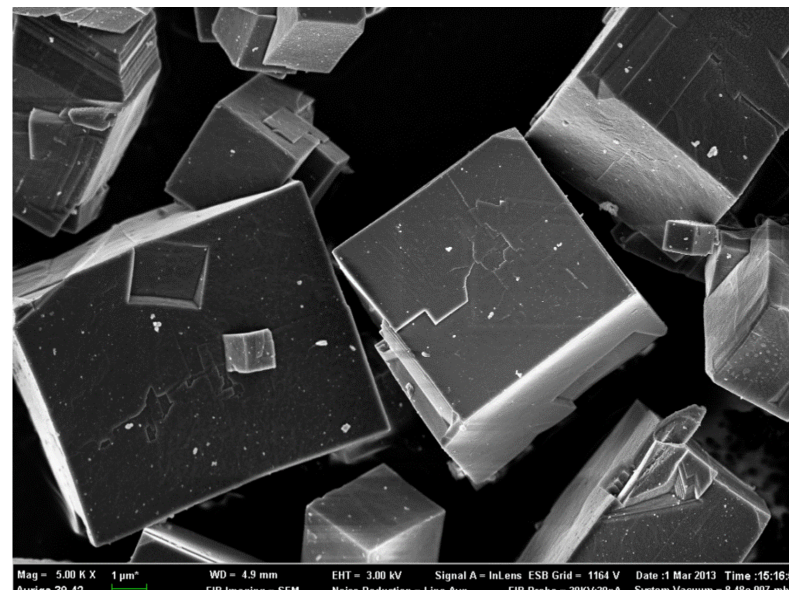
Accomplished in simple reactors using a variety of catalysts including noble metals

Technical readiness of small-scale NH_3 crackers: Diverse Energy, Apollo Energy Systems developing prototype small-scale NH_3 crackers

Hydrogen Storage in MOFs

Surface area
Porosity
Use of PGMs
Crystallinity
Functional groups
Binding strength





HySA Infrastructure: Road Map

Current Programme Focus					
Energy Source	**Energy Harvesting Technology**	**Product**	**Hydrogen Production Technology**	**Hydrogen Fuelling/ Storage Options**	**Applications**
Solar	Photovoltaïc	Electricity	H_2O and SO_2 Electrolysis	MH, Chemical, CNS, Gaseous, MOF	PP, FCV
Wind	Wind Turbines	Electricity	H_2O and SO_2 Electrolysis	MH, Chemical, CNS, Gaseous, MOF	PP, FCV
Biomass	Bio-Digesters	Biogas (Methane)	Water-Gas-Shift reactor	MH, Chemical, CNS, Gaseous, MOF	PP, FCV
LPG	----	---	---	---	CHP
Potential Future Activities					
Energy Source	**Energy Harvesting Technology**	**Product**	**Hydrogen Production Technology**	**Hydrogen Fuelling/ Storage Options**	**Applications**
Solar	CSP	Electricity / Process Heat	Thermo-chemical water splitting	Chemical, Gaseous, Liquid	Transport / Industrial (CTL) / Steel Manufacturing
Uranium	VHTR (Nuclear)	Electricity / Process Heat	Thermo-chemical water splitting	Chemical, Gaseous, Liquid	Transport / Industrial (CTL) / Steel Manufacturing

MH - in cooperation with HySA/Systems

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Thank You