Adding Value to South Africa's Minerals

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UWC Professor of Energy Materials and Systems (RSA)
DST HySA Systems Competence Centre Director (RSA)
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HySA Hydrogen South Africa

AN INITIATIVE OF

science & technology
Department: Science and Technology
REPUBLIC OF SOUTH AFRICA
FACTS about Hydrogen!

- Hydrogen is the lightest, most basic & abundant element (90% of the universe by weight) discovered by Henry Cavendish in 1766
- Hydrogen is non-carcinogenic & non-toxic
- Hydrogen is odourless & tasteless
- Hydrogen produces no hazardous combustion products → Hydrogen is non-polluting i.e. NO GHG emissions !!!!
- Hydrogen has an energy content equivalent to 0.34 litres of petrol per cubic metre
- Hydrogen burns with very little heat radiated from the flame → Hydrogen does not auto-ignite
- Hydrogen is not radioactive
- Hydrogen does not decompose
- Hydrogen is much lighter than air; dissipates quickly upwards in open air
How Hydrogen can help!

Source: EC
Energy in 1 gallon of Petrol = 1 kg of Hydrogen

Efficiencies: Petrol ICEs = 18-20%; Hydrogen ICEs = 25% efficient; DMFCs = 38%; HFCVs = 60%

⇒ 3 X better than today’s petrol fuelled engines!!!

Amount of energy produced by hydrogen per unit weight of fuel is about 3 X the amount of energy contained in an equal weight of petrol, & almost 7 X that of coal! Energy Content: 60,958 Btu/lb – highest energy content of all fuels on a weight basis

Hydrogen energy density per volume is quite low at STP
Volumetric energy density can be increased by storing the hydrogen under increased pressure or storing it at extremely low temperatures as a liquid
What is a PEMFC?

Anode Reaction:

\[ \text{H}_2 \rightarrow 2\text{H}^+ + 2\text{e}^- \]

Cathode Reaction:

\[ \text{O}_2 + 4\text{H}^+ + 4\text{e}^- \rightarrow 2\text{H}_2\text{O} \]
Objective: PGM beneficiation & job creation

Will HySA commercialize technology? Indirectly through licensing and through partnerships with companies

Strategy: Prepare South Africa for the global fuel cell market

• Initiate sales of non-South African fuel cell technologies in South Africa.

• Non-South African partners must agree to:
  • Manufacture PGM and non-PGM components in SA
  • Integrate SA technology into future products
  • HySA to integrate SA PGM technologies through international and national partners
**Objective:** PGM beneficiation & job creation

**Will HySA commercialize technology?** Indirectly through licensing and through partnerships with companies

**Strategy:**
- Integrate SA technology into future products
- HySA to integrate SA PGM technologies through international and national partners

**Target:** Sales of 25% global fuel cell catalyst demand by 2020
<table>
<thead>
<tr>
<th>Rank in the World</th>
<th>SA Mineral Resource</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Gold</td>
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<tr>
<td>1</td>
<td>Platinum</td>
</tr>
<tr>
<td>1</td>
<td>Titanium</td>
</tr>
<tr>
<td>1</td>
<td>Chromium</td>
</tr>
<tr>
<td>1</td>
<td>Manganese</td>
</tr>
<tr>
<td>1</td>
<td>Vanadium</td>
</tr>
<tr>
<td>2</td>
<td>Zirconium</td>
</tr>
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</table>
### South Africa is well-endowed with mineral resources

South Africa’s Mineral Reserves, World Ranking, 2009 Production & Nominal Life (assuming no further reserves) at 2009 Extraction Rates

<table>
<thead>
<tr>
<th>Mineral</th>
<th>RESERVES</th>
<th>PRODUCTION 2009</th>
<th>LIFE</th>
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<tbody>
<tr>
<td></td>
<td>Mass</td>
<td>%World</td>
<td>Rank</td>
</tr>
<tr>
<td>Alumino-silicates</td>
<td>Mt 51</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Antimony</td>
<td>kt 350</td>
<td>16.7</td>
<td>3</td>
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<tr>
<td>Chromium Ore</td>
<td>Mt 5500</td>
<td>72.4</td>
<td>1</td>
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<tr>
<td>Coal</td>
<td>Mt 30408</td>
<td>7.4</td>
<td>6</td>
</tr>
<tr>
<td>Copper</td>
<td>Mt 13</td>
<td>2.4</td>
<td>6</td>
</tr>
<tr>
<td>Fluorspar</td>
<td>Mt 80</td>
<td>17</td>
<td>2</td>
</tr>
<tr>
<td>Gold</td>
<td>t 6000</td>
<td>12.7</td>
<td>1</td>
</tr>
<tr>
<td>Iron Ore</td>
<td>Mt 1500</td>
<td>0.8</td>
<td>13</td>
</tr>
<tr>
<td>Iron Ore - incl. BC</td>
<td>Mt 25000</td>
<td>~10</td>
<td>*</td>
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<tr>
<td>Lead</td>
<td>kt 3000</td>
<td>2.1</td>
<td>6</td>
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<td>Manganese Ore</td>
<td>Mt 4000</td>
<td>80</td>
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<tr>
<td>Nickel</td>
<td>Mt 3.7</td>
<td>5.2</td>
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<tr>
<td>PGMs</td>
<td>t 70000</td>
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<td>Phosphate Rock</td>
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<td>Titanium Minerals</td>
<td>Mt 71</td>
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<tr>
<td>Titanium - incl. BC</td>
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<td>65</td>
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<tr>
<td>Uranium</td>
<td>kt 435</td>
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<td>4</td>
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<tr>
<td>Vanadium</td>
<td>kt 12000</td>
<td>32</td>
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<td>Vermiculite</td>
<td>Mt 80</td>
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<tr>
<td>Zirconium</td>
<td>Mt 14</td>
<td>25</td>
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</table>

South Africa’s mineral resources amounts to approximately USD$2.5 trillion and is the predominant supplier of Platinum Group Metals (PGM) to the world.

…but not much beneficiation is currently undertaken in the country!

However, the rise of Hydrogen Fuel Cell Technologies (HFCT) in various markets is about to change the global Platinum landscape with the anticipated increase in Platinum usage in this emerging market.

Thus it is safe to stipulate that if HFCT gains market share in coming years as is anticipated by the large vehicle manufacturers such as Toyota, Hyundai, Honda and BMW, then the PGM market will see profound and sustained growth.
The main goal *is not* to prepare South African markets for the H$_2$ economy – that is a bonus!

The main goal *is* to prepare South Africa to be an exporter of value-added technologies that include PGM to the world.
HySA Roadmap

Department of Science & Technology

Establishment of R&D Capability
Technology Demonstration & Validation
Commercialisation of SA Innovation

Technology catch-up
South African Extension
South African Innovation

2008 - 2013
• Key Personnel is hired
• Research Infrastructure is set up
• Initial markets are identified
• First pre-commercial technologies developed

PHASE I

2013 - 2018
• Establish critical supply chain capability
• Deliver first products to market
• Demonstrate capabilities in pilot markets

PHASE II

2018 - 2023
• Contribute to international innovation
• Compete successfully on world market
• Capture 25% of Catalyst Demand in Hydrogen and Fuel Cells

PHASE III
Who we are

HySA South Africa

HySA Catalysis
[UCT/Mintek]

HySA Systems
[UWC]

HySA Infrastructure
[NWU/CSIR]

DST
Department of Science and Technology

NWU
North West University

CSIR
Council for Scientific and Industrial Research

UCT
University of Cape Town

Mintek
South Africa’s National Mineral Research Organisation

UWC
University of the Western Cape
HySA: Hydrogen South Africa
What we do

- Materials and Components
- Components and Systems
- Systems and Infrastructure
HySA: Hydrogen South Africa

What we do

- Key Programme 1: Combined Heat and Power
- Key Programme 2: Portable Power Systems
- Key Programme 3: Hydrogen Fuelled Vehicles
- Key Programme 4: Hydrogen Filling Stations
- Key Programme 5: Renewable H₂ Production
About
2,000 m² R&D building on the UWC campus hosting world-class and state-of-the-art equipment within the SAIAMC Innovation Centre
HySA Systems
SoA H&FC Equipment
Management
Key Programme Managers (KPM)

Dr Sivakumar Pasupathi
15 years of fuel cell experience, specifically in Electrocatalysis, LT & HT PEM fuel cells and Electrolysers

Gerhard Swart
15+ years Systems Engineer and Engineering Manager. Ex-Chief Technical Officer of Optimal Energy, the developer of SA’s first serious Electric Vehicle, the Joule

Prof. Bruno G. Pollet FRSC AFIChemE
Acting HySA Systems Business Development Manager
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Prof. Bruno G. Pollet FRSC AFIChemE
Acting HySA Systems Business Development Manager

Prof. Vladimir Linkov (SAIAMC Director)
HySA Systems Contract Director

Chief Technical Officer of Optimal Energy, the developer of SA’s first serious Electric Vehicle, the Joule
Management
Key Project Managers (KTS/Eng)

Kobus Mouton – Systems Engineering (Industry) - 20+ years Systems Engineer and Engineering Manager. Ex-Chief Vehicle Engineer at Optimal Energy, the developer of South Africa’s first serious Electric Vehicle, the Joule.

Dr Piotr Bujlo – Stack & Systems Engineering (Academia) - 10+ years fuel cell. Stack development and CHP.

Dr Michael Lototskyy – Hydrogen Storage Materials - 30+ years Metal Hydride materials/compressors & recently Metal Organic Framework

Dr Shan Ji – Battery Technology (acting KTS) - 15+ years Electrochemistry, Fuel Cell & Battery Technologies

Prof. Ben Bladergroen – Pd Membrane (acting KTS) - 15+ years Energy Materials, Hydrogen Production & Hydrogen Energy
HySA Systems’ Strategy

- Innovation & generating IP
- Product Development focused
- Engaging & partnering with key national/international Industries
- Opening Business Opportunities in SA
- Technology Incubator
- Assisting in the manufacture of key HFC components
- Creating & implementing a Hydrogen Fuel Cell chain in South Africa to support local manufacturing
- Being ‘a catalyst’/assisting/supporting commercialisation of products
- Recruiting key staff (national/international)
Low Carbon Technologies

Stationary Applications

Transport Applications
Our Interests

Innovative:

✓ Nanomaterials
✓ Demonstrators
✓ Prototypes
HySA Systems
What we do

HySA Systems

Combined Heat & Power
- HT-MEA
- System Integration
- System Validation
- System/Stack Modelling

Hydrogen Fuelled Vehicles
- HT-MEA
- HT-PEMFC Stacks
- System Integration
- System Validation
- System/Stack Modelling

Key Technologies
- High Temperature PEM Fuel Cell Stacks (>120°C)
- HT-MEAs for HT-PEMFCs
- Solid State Hydrogen Storage (Metal Hydride)
- MH Systems
- Li-ion Batteries (CombiLit)
- Pd-membranes
- Power Modules for Hybrid Hydrogen Fuel Cell Vehicles
HySA Systems’ Other Outputs & Achievements

Pilot Plant Component Manufacturing

1. HT-MEA

2. HT-PEMFC Stack

3. Li-ion Battery (CombiLit)

4. Metal Hydride (samples to be dispatched soon)
Metal Hydride Manufacturing

**Raw Materials**
(RE+Ni+M1, or Ti+Zr+M2);
M1=Al, Mn, ...; M2=Cr, Mn, Ni, V, Fe, ...

- **Melting**
- **Ingot**
- **Annealing**
- **Crushing & Milling**

**Hydrogen storage alloy powder**

- New melting & annealing facilities developed by South African company
- Start-up of 25 kg/day manufacturing line at HySA Systems is scheduled for 2014
- Next step – processing of SA oxide feedstock (e.g., TiFeO₃)
Towards the implementation of a HFC Supply Chain
Niche Markets

- Desalination plants
- Telecommunication
- Tourism & Agro-tourism Applications
- Shopping Centres
- Hospitals
- Remote Areas (mini-grid elec)
- Refrigeration
- Forklift
- Mining vehicles & other (game parks)
Start development of Vehicle Power Module integrating an FC and Battery Pack

- Modelling and concept definition
- FC life-modelling and testing
- Emulator preparation
Integration of a 1.2kW FC into a 5kW Battery Electric Vehicle (BEV) – Golf Cart
Integration of a 1.2kW FC into a 3kW Battery Electric Vehicle (BEV) – Tuk-Tuk
Integration of a 1kW FC into a 5kW BEV – e-Scooter
Integration of a 100W FC into a 250W BEV – e-Bike

Expected Range Increase: 30km

LT H₂ PEM Fuel Cell + Metal Hydride H₂ Storage

36V 10Ah Li-ION Battery Pack
Hydrogen Forklift

Continue integration of a 10kW FC into a 27kW_{peak} BEV – Forklift

- 80V 700Ah PbA Battery Pack to be replaced
- Significant reduction in re-energising time expected
  - Compressed Gas Cylinders to be substituted with Metal Hydride Cylinders in 2014/15
Hydrogen Energy Generator
Portable charger

Gadget plugs into power supply via USB jack
Hydrogen Metal Hydride Cartridges
Hydrogen Fuel Cell Power Generator
Technical Outputs: *by years*

Department of Science & Technology

![Graph showing technical outputs by years from 2008 to 2014.](image)

- Prototypes
- Patents
- Conferences
- Chapters in books
- Journal articles

**ON THE INCREASE**
HCD Objectives

• Expand collaboration with other engineering institutions in the sustainable energy field

• Increase community involvement in application demonstration (community vehicle planned)

• Mentor engineering students (starting with BTech, MTech) and establish new Engineering capabilities in support of HySA & other programmes

• Longer-term objectives to establish industry-focused Systems Engineering programmes
### PGR Students Graduated (Total)

#### Department of Science & Technology

<table>
<thead>
<tr>
<th>Year</th>
<th>MSc</th>
<th>MTech</th>
<th>PhD</th>
<th>DTech</th>
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<td>0</td>
<td>0</td>
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<td>0</td>
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<td>3</td>
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<tr>
<td>2012</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>3</td>
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<tr>
<td>2013</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>0</td>
<td>8</td>
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<td>2014</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Total</td>
<td>10</td>
<td>4</td>
<td>9</td>
<td>0</td>
<td>23</td>
</tr>
</tbody>
</table>
HySA Systems on track for the implementation of a Fuel Cell Industry in South Africa involving:

1. International commercial partners
2. South African supply chain
3. South African manufacturers
## Measurement of Success (per DST’s criterion)

### Business creation (Industry Cluster)
- Spin offs
- Job creation
- Licenses and royalties
  - Not yet (No mechanisms in place)
  - YES (UWC & SMMEs)
  - Not yet

### Human Capital Development
- Postgraduates
  - 23 (since 2008)
  - Not yet
- Absorption into HFCT and related industries

### Industry participation
- R&D co-funding
- Joint IP creatorship plus co-funding
- Joint commercialisation (Private sector partners)
  - Impala & Airbus
  - CONFIDENTIAL
  - CONFIDENTIAL

### Knowledge Creation
- Publications
  - > 100
- Patents
  - > 5
Cost Targets
Performance Targets
Durability Targets
Niche Markets
Fast Track Commercial Projects (FTCP)

Uninterruptible Power Supply
Utility Vehicles
Passenger Vehicles

Combined Heat & Power
Telecommunication

Portable

2-3 Wheelers

Innovation
Fuel Cell Components
Fuel Cell Stack

Domestic
PGM beneficiation

Platinum Group Metals & Minerals

Hydrogen Storage
South African Hydrogen Association

Co-founders:
Dmitri Bessarabov
Gordon Freer
Bruno G. Pollet

south african hydrogen association
The Chairs invite you to join them at the CARISMA 2014 Conference in the beautiful city of Cape Town, South Africa
Monday 1 – Wednesday 3 December 2014

The CARISMA conference series is specifically devoted to the challenges in developing Fuel Cell materials (inc. catalysts, GDL, PEM etc) and Membrane Electrode Assemblies for the low, medium and high temperature range targeted for transport and stationary applications. The conference will be the opportunity for presentation of recent results, discussion and debate on the solutions sought internationally to the bottlenecks associated with...
Thank you
Beautiful South Africa…

Camps Bay
Pringle Bay Area