CENTRE FOR RENEWABLE &
SUSTAINABLE ENERGY STUDIES

Green Hydrogen in the South African context

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Introduction

- Stellenbosch University hosts the Department of Science and Innovation's Renewable and Sustainable Energy Research Hub and Spokes programme.
- The programme is hosted within the Centre for Renewable and Sustainable Energy Studies
- The Hub focuses of various renewable and sustainable energy systems while the spokes are paired institutions the focus on specific renewable energy technologies as follows:

✓ Solar PV systems: Nelson Mandela University and University of Fort Hare
✓ Solar thermal systems: University of Pretoria and Stellenbosch University
✓ Wind Energy systems: Stellenbosch University and University of Cape Town

- The Hub coordinates renewable and sustainable energy research and development activities including coordination of deployments of various technologies emanating from the various DSI programmes, including Hydrogen fuel cells systems.

Demand for Hydrogen

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- Global Hydrogen demand in 2020 was 90 Metric ton, with more than 70 Metric ton used as pure hydrogen and less than 20 Metric ton mixed with carbon-containing gases in methanol production and steel manufacturing. Almost all this demand was for refining and industrial uses.
- Hydrogen is produced mainly from fossil fuels, resulting in close to 900 Mt of CO_2 emissions per year.

Clean energy progress for hydrogen can be tracked by three main indicators:

- The extent to which low-carbon hydrogen production replaces conventional hydrogen in existing industrial applications and meets demand for new applications.
- Demand growth in new sectors (e.g. for some transport and industrial applications, production of synthetic fuels and electricity storage), where it can help reduce CO_2 emissions if production is based on low-carbon technologies.
- Scale-up, cost reductions and improvements (in efficiency, lifetime or process integration) of cross-cutting technologies such as electrolysers, fuel cells and Carbon Capture utilization and storage (CCUS-equipped) hydrogen production. (IEA, 2021)

Demand for Hydrogen by sector

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- **Chemical**s: Amonia and methanol production: H_2 demand rising sharply.
- Iron Ore and Steel sector: demand expected to triple by 2030
- **Transport sector**: There has been limited use of H_2 but a growth on average of 70% annually between 2017 and 2020 mainly in USA and Korea.
- **Electricity sector**: Accounts for less than 0.2% of electricity generation globally. This is linked mostly to the use of hydrogen-containing mixed gases from the steel industry, petrochemical plants and refineries. (IEA, 2021).
- The department of Science and Innovation has identified three Hydrogen Hubs as follows:

✓ **Hub A. Johannesburg (JHB as hub, with spoke extension to Rustenburg and Pretoria for select demand)**

✓ **Hub B: Durban and Richards Bay corridor**

✓ **Hub C: Mogalakwena & Limpopo**

✓ An analysis of the projected demand for Hydrogen in these Hubs is available online a thttps://www.dst.gov.za/images/2021/Hydrogen_Valley_Feasibility_Study_Report_Final_Version.pdf

sanedi South African National Energy Development Institute

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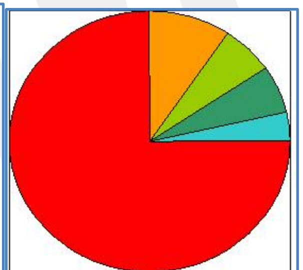
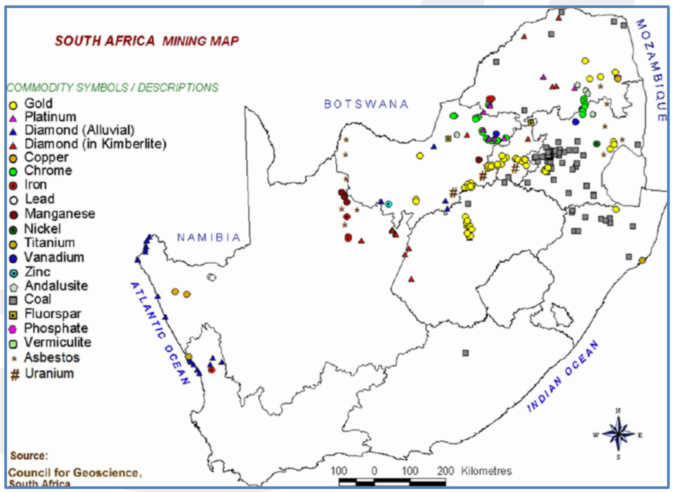
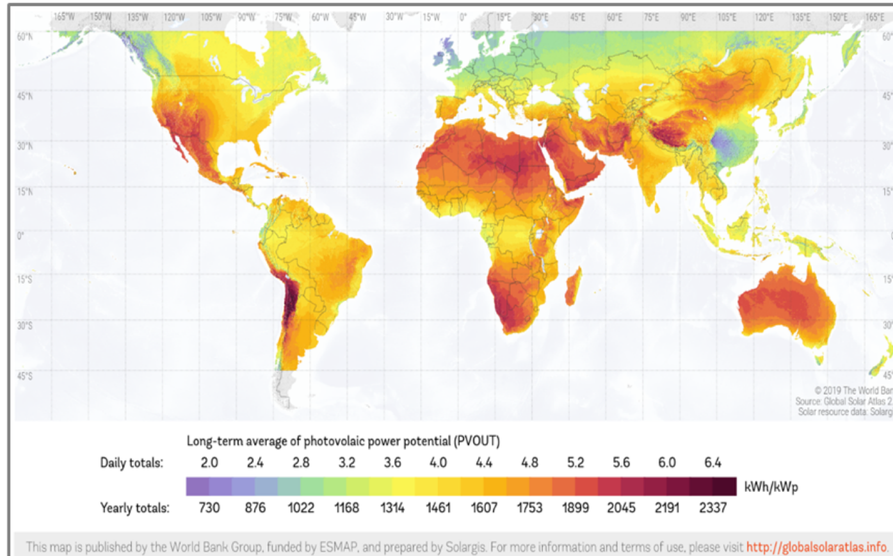
Minerals , Sunshine and Wind…SA is well positioned for the Transition to Hydrogen

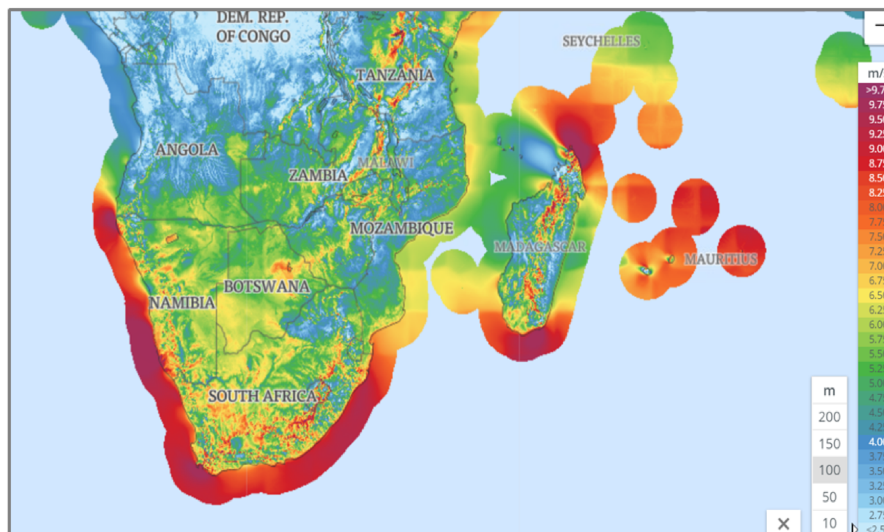
World Platinum Reserves

- Zimbabwe
- Finland
- Russia
- North America
- South Africa









South Africa possesses 75% of global Pt reserves

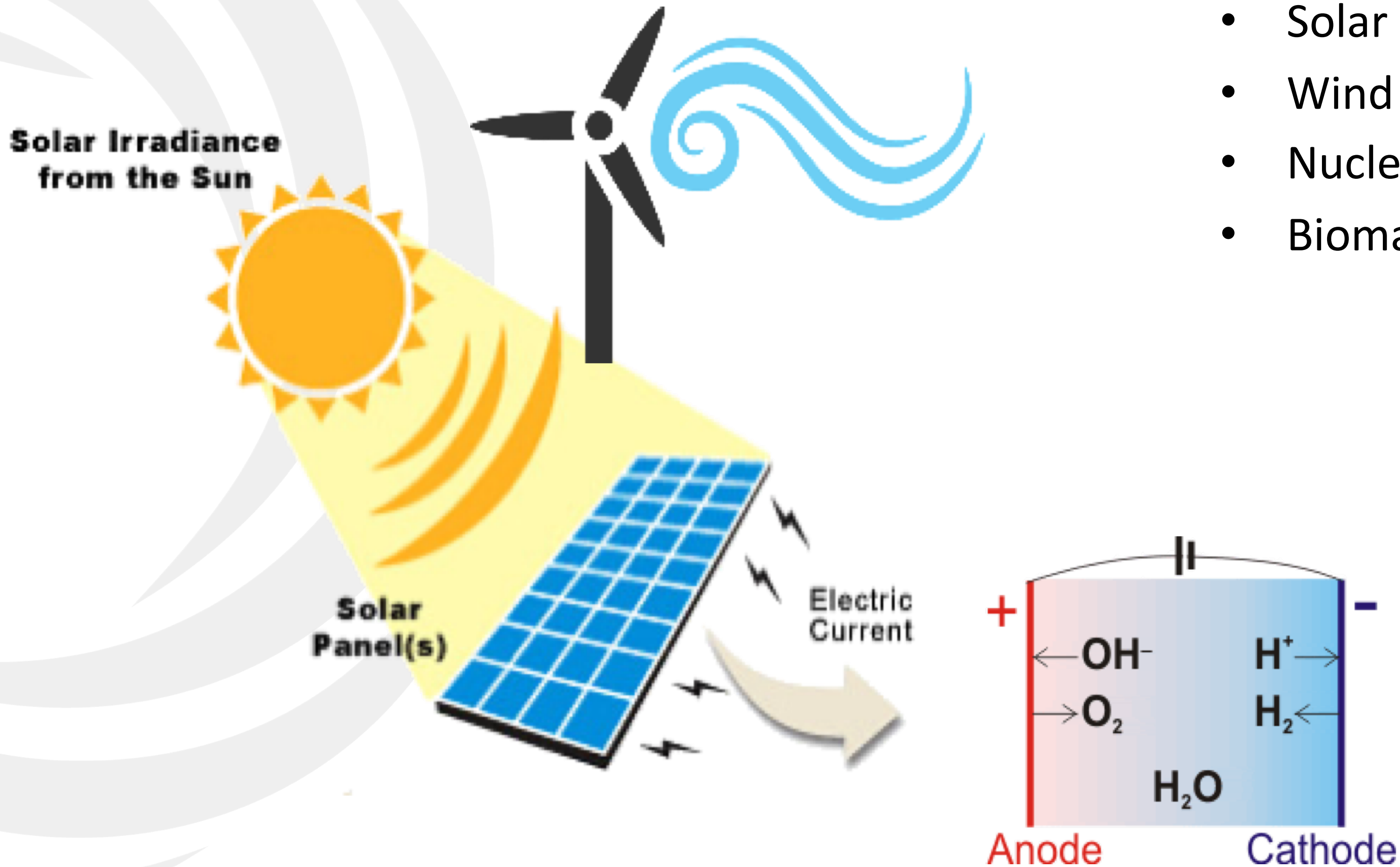
Green Hydrogen Production

- Electrolysis, has the potential to generate carbon-free hydrogen if renewable or nuclear electricity is used.

- Electrolysers are a relatively mature technology that has been long used in certain industrial processes, such as the production of chlorine in the chlor-alkali process (in which hydrogen is produced as a by-product).

- However, its use for dedicated hydrogen production has not yet been widely adopted. Globally, dedicated production of hydrogen from electrolysis contributes 30 kilo tons per year, accounting for 0.03% of all hydrogen produced (EIA, 2021).

Green Hydrogen Production



- Solar
- Wind
- Nuclear
- Biomass

Development of hydrogen infrastructure

- Large-scale hydrogen deployment will need to be underpinned by an effective and cost-efficient system for storage and transport, strategically designed to connect supply sources to demand centres.

- SA has identified the Hydrogen Hubs/corridors that are strategically located (Hydrogen Society Roadmap)

- Of the 5 000 km of hydrogen pipelines currently operational around the world, more than 90% are located in Europe and the United States. Most are closed systems owned by large merchant hydrogen producers concentrated near industrial consumers (mainly refineries and chemical plants) (IEA, 2021)

Policies to support the Hydrogen Economy in SA

SOUTH AFRICAN ECONOMIC RECONSTRUCTION AND RECOVERY PLAN
NATIONAL DEVELOPMENT PLAN

Green Transport Strategy: Dept of Transport

Green Hydrogen Commercialisation Strategy: DTI (Under development

Hydrogen Society Roadmap: DSI

Just Energy Transition Framework: DMRE

South African Renewable Energy Masterplan: DMRE

Hydrogen Research Development & Innovation Strategy: DSI

Electricity generation landscape

- The Integrated Resource Plan for SA does not have provision for Electricity generation from Hydrogen, however there is a provision for storage, which is 6300 MW
- The latter includes pumped storage facilities, 2912 MW of storage is already installed, remainder to be procured in 2023 and 2029.
- Opportunity exists for hydrogen if the cost comes down.

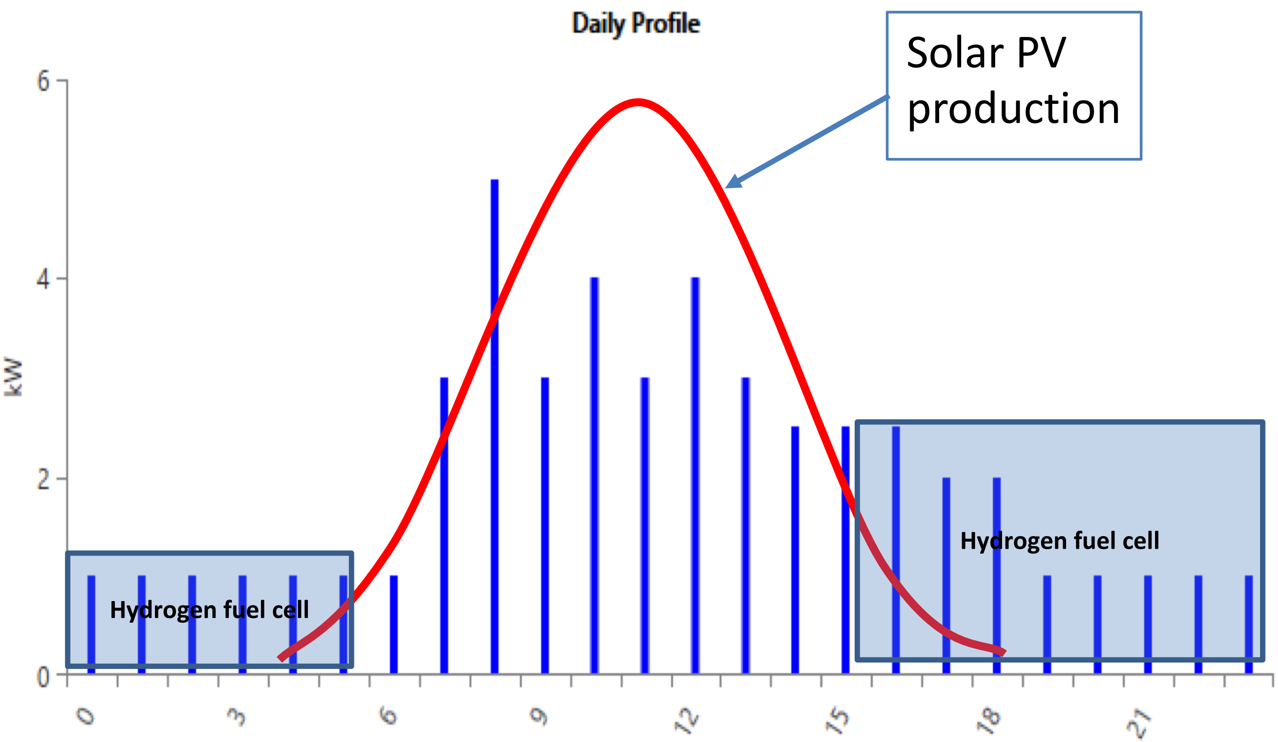
	Coal	Coal (Decommissioning)	Nuclear	Hydro	Storage	PV	Wind	CSP	Gas & Diesel	Other (Distributed Generation, CoGen, Biomass, Landfill)
Current Base	37 149		1 860	2 100	2 912	1 474	1 980	300	3 830	499
2019	2 155	-2373					244	300		Allocation to the extent of the short term capacity and energy gap.
2020	1 433	-557				114	300			
2021	1 433	-1403				300	818			
2022	711	-844			513	400 1000	1600			
2023	750	-555				1000	1600			500
2024			1860				1600		1000	500
2025						1000	1600			500
2026		-1219					1600			500
2027	750	-847					1 600		2000	500
2028		-475				1000	1 600			500
2029		-1694			1575	1000	1 600			500
2030		-1050		2 500		1 000	1 600			500
TOTAL INSTALLED CAPACITY by 2030 (MW)	33364		1860	4600	5000	8288	17742	600	6380	
% Total Installed Capacity (% of MW)	43		2.36	5.84	6.35	10.52	22.53	0.76	8.1	
% Annual Energy Contribution (% of MWh)	58.8		4.5	8.4	1.2*	6.3	17.8	0.6	1.3	

Installed Capacity
Committed / Already Contracted Capacity
Capacity Decommissioned
New Additional Capacity
Extension of Koeberg Plant Design Life
Includes Distributed Generation Capacity for own use

- 2030 Coal Installed Capacity is less capacity decommissioned between years 2020 and 2030
- Koeberg power station rated / installed capacity will revert to 1926 MW (original design capacity) following design life extension work.
- Other / Distributed generation includes all generation facilities in circumstances in which the facility is operated solely to supply electricity to an end-use customer within the same property with the facility
- Short term capacity gap is estimated at 2000 MW

Work done by the DSI RSE Hub on H_2

- The RSE Hub at Stellenbosh University assists the Department of Science and Innovation with techno-economic analysis of Hydrogen fuel cell systems and deployments. (Dedicated Project Engineers and Project Managers).



HOMER study - Masia Village

Assumptions & specifications	Value	Reference
Application	Powering a village	Client
Power requirements	10 kW	Client
Architecture 1	Hydrogen Only	Client
Architecture 2	Combination	Client
System availability	99.0%	Client
Site:	Masia village, Limpopo	Client
Distance from refinery:	142 km (2hrs 1min)	[1]
Grid connectivity	No	Client
System cooling	Natural convection	Client
Project success criteria	Lowest Net Present cost over project lifetime	[1]

Project economics	Value	Reference
Project lifetime	20 years	Client
Inflation (2019)	4.13%	[1]
Discount rate (2019)	10%	[1]
EPC costs (% on top of CAPEX)	30%	[1]
Fuel logistic costs	20%	Client
Fuel theft cost	0%	Client
Fuel bulk buy discount	R0.00 /l on RRP	Client

Component	Parameter	Value	Reference	Comment	
Power conversion system	CAPEX	R4 030 /kW	[1]		
Power conversion system	OPEX (operations and maintenance) p. a.	R0 /kW	Estimate		
Power conversion system	Replacement cost (% of CAPEX)	80%	Calculated		
Power conversion system	Replacement criteria	10 years	[1]		
Power conversion system	Efficiency (round trip)	90%	[1]		
Reformer	CAPEX	R1 /kW	Client	Already purchased	
Reformer	OPEX (operations and maintenance)	R10 000.00	[1]		
Reformer	Cost of fuel (LFP)	R28.55 /kg	[1]		
Reformer	Replacement cost (% of CAPEX)	20%	Client		
Reformer	Replacement criteria	10 000 hours	Client		
Reformer	Salvage value (% of CAPEX)	80%	Client		
Reformer	Efficiency (one way)	75%	[1]		
Reformer	Cold start startup time	30 min	Client		
Reformer	Power hysteresis (depending on inlet)	0%; 90 % - 100 %	Client		
Fuel Cell Generator	CAPEX	R15 000 /kW	Client		
Fuel Cell Generator	OPEX (operations and maintenance)	R0 /kW	Estimate		
Fuel Cell Generator	Cost of fuel (Hydrogen from reformer)	R0.00 /kg	Calculated		
Fuel Cell Generator	Replacement cost (% of CAPEX)	80%	Estimate		
Fuel Cell Generator	Replacement criteria	50 000 hours	Client		
Fuel Cell Generator	Efficiency (one way)	50%	[1]		
Fuel Cell Generator	Power hysteresis (depending on inlet)	0% - 100 %	Estimate		
Fuel Cell Generator	Minimum Load Ratio	30%	[1]		
Electrolyser	CAPEX	R110 954 /kW	[1]	Nel Supplier, S20 model	
Electrolyser	OPEX (operations and maintenance)	R5 000 /p. a.	[1]	Maintenance and refueling	
Electrolyser	Replacement cost (% of CAPEX)	80%	[1]		R88 762.96
Electrolyser	Replacement criteria	20 years	[1]		
Electrolyser	Efficiency (one way)	80%	[1]		
Electrolyser	Minimum Load Ratio	0%	[1]	Max in sim = 0.043kg/hr	
Electrolyser	Minimum runtime	10 min	Estimate		
H2 Cylinder Tank	CAPEX	R1.00	Bambile	Already have, 18 cylinders, R 20k	
H2 Cylinder Tank	OPEX (operations and maintenance)	R1.00			
H2 Cylinder Tank	Replacement cost (% of CAPEX)	80%			R0.80
H2 Cylinder Tank	Replacement criteria	25			
H2 Cylinder Tank	Efficiency (one way)	100%			
Li-ion Battery	CAPEX	R7 803 /kWh	[1]		
Li-ion Battery	OPEX (operations and maintenance)	2% of CAPEX/year	Estimate		R156.06
Li-ion Battery	Replacement cost (% of CAPEX)	80%	Estimate		R6 242.48
Li-ion Battery	Replacement criteria	10 years	[1]		
Li-ion Battery	Efficiency (round trip)	94%	[1]		
Li-ion Battery	Minimum state of charge	20%	[1]		
Li-ion Battery	Backup time requirement	At least 1 hour	Client		
PV	CAPEX	R3 000 /kW	MLT		
PV	OPEX (operations and maintenance)	2% of CAPEX/year	Estimate		R60.00
PV	Replacement cost (% of CAPEX)	80%	Estimate		R2 400.00
PV	Replacement criteria	10 years	Standard		

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Acknowledgements

- Dr Rebecca Maserumule: Chief Director: Hydrogen and Energy, Department of Science and Innovation.
- CRSES Staff members

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