Clean Energy Technologies at the CSIR

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1. Introduction

South African primary energy supply is heavily dependent on coal which has made the country to be identified as one of the concerning global CO_2 emitters. The transportation sector is heavily oil dependent with a current introduction of gas-powered alternatives. The CSIR pioneered battery research in the 1970's which was later supplemented by the introduction of the Hydrogen South Africa (HySA) 2006 strategy. The South African energy mix evolved to include renewable energy, mostly solar and wind. There is a nuclear capability in the country as well.

The Paris Agreement became a catalyst for the introduction of renewable energy in the South African energy mix. The national utility Eskom experienced black outs/ load shedding indicating a strained grid and supply challenges. This increased a need for self-generation and energy storage opportunities as civilians plus industries aimed for security of supply.

This abstract will present the CSIR activities along the value chain (see Figure 1 below) with emphasis on clean energy technologies in the areas of: Hydrogen, Carbon Capture, Utilisation and Storage (CCUS), Fuel Cells (FCs) and Lithium Ion Batteries (LIBs).

2. R&D activities related to clean energy technology

CSIR is a premier African Research Institute with an Integrated Energy Research Center (IERC) with several research groups covering energy supply and utilization, including socio-economic aspects. The clean energy technologies R&D indicated in the abstract covers the areas of: hydrogen storage (Metal Organic Frameworks – MOFs and Composite Cylinders), CCUS, fuel cells and LIBs. The innovation cycles moves from materials development to systems assembly and deployment.

The introduction of wind and solar technologies with batteries in South Africa will lead to the creation of manufacturing jobs.

The CSIR started IERC to consolidate the organizational energy activities that will contribute to providing national, continental and global clean energy solutions. IERC was started in 2013. The mission of the center is to be a one stop solution provider for local energy problems.

3. Specific Research activities in hydrogen, CCUS, and related technologies

High temperature steam electrolysis (HTSE)

The CSIR has started work on high temperature steam electrolysis (HTSE) as a way of large-scale hydrogen production. The advantages of HTSE is that it can use waste heat from industrial source, or solar thermal energy, as a means to reduce the electrical demand of the electrolysis process. HTSE can also be used in co-electrolysis mode (electrolysis of water and CO_2) to produce syngas, which can then be further used as a starting block for other chemical manufacturing processes.

The group also develops catalysts for hydrogen and oxygen evolution reactions (HER/OER) for application in water electrolysis. Bi/Tri functional electrocatalysts are synthesized in order to improve stability and to lower overpotentials of the HER and OER.

Hydrogen Storage

Over the last 7 years, the CSIR has been involved in the development of the materials-based hydrogen storage approach with the focus being on porous materials such as metal organic frameworks (MOFs), porous carbon and their composites. Additional research on development of high-pressure composite cylinders (Type IV) with the eventual goal of incorporating the porous materials to derive conditions was done with attractive properties for lightweight hydrogen storage systems. This work is done under the Hydrogen South Africa (HySA) Infrastructure platform, which is under the national HySA programme.

CO_2 Capture

The CSIR has been involved with CO_2 capture research for the past 10 years. Research has been carried out on pre-combustion capture (fluidised bed gasification - FBG), capture during combustion (chemical looping combustion - CLC) and post-combustion capture (calcium looping - CaL). Current research is focused on the CaL process, which consists of a techno-economic analysis (TEA), process modelling and characterisation of South African limestones. Results of the TEA show that the CaL process has a lower efficiency penalty compared to other post-combustion processes such as mono-ethanol amine (MEA) scrubbing. Further work is being carried out to access the effect of the capital cost of CaL and the reactivity of South African limestones on the feasibility of the process.

Carbon dioxide utilization

Catalytic hydrogenation of carbon dioxide (CO_2) to produce chemicals presents a highly desirable means for recycling CO_2 and thus combating the rising CO_2 emissions. In this case, the CSIR is involved in studies that are aimed at utilizing hydrogen (H_2) that is produced from Renewable Energy (RE) sources such as solar photovoltaics (PV), wind energy, tidal energy, among others. In particular, the utilization of this 'green' hydrogen together with the captured CO_2 in the production of the production of methanol (MeOH) and dimethyl ether (DME) presents an attractive pathway for renewable energy utilization in both power generation and in chemical industries since they can be used as feedstocks for other value-added chemical products. Furthermore, methanol is an attractive route for the storage and transportation of hydrogen. Complementary to the methanol-based CO_2 utilization process, there are ongoing studies focused on the development and/or fine-tuning of catalysts in order to derive enhanced CO_2/H_2 conversion efficiencies as well as deal with the existing catalysts deficiencies.

The electrochemical reduction of carbon dioxide (CO_2) offers an alternative route to convert CO_2 and hydrogen to useful liquid fuels such as methanol. These sources of energy can be used in a fuel cell to produce electricity. The catalysts used are obtained via green synthetic methods such as using pomegranate peels as reducing agents.

Carbon mineralisation

The CSIR undertook a study in collaboration with the South African National Energy Development Institute (SANEDI) to assess the potential of Carbon Mineralisation (also known as Mineral Carbonation) to assist South Africa in meeting its CO_2 emissions reduction targets. Carbon Mineralisation involves reacting CO_2 with silicates or alkali materials ("Portlandites") to produce stable carbonates. In order to minimise the cost of the CO_2 removal, the raw material should firstly be as inexpensive as possible, and the carbonate produced should preferably be marketable. South Africa has a large mining industry, and in many cases the residue/waste from the mining industry is carbonatable. A prime example is the kimberlite that is mined to recover diamonds. Kimberlite also contains Olivine (Magnesium Silicate) which readily reacts with CO_2, even atmospheric CO_2. The residue from the mining of Platinum Group Metals, although not as reactive as kimberlite/olivine, is produced in such large tonnages that it could potentially take up over 22 million tonnes per annum (mtpa) of CO_2. The residue from all mining activities could potentially take up 37 mtpa of CO_2. The potential markets for the carbonate products will be the focus of a future study.

Specific Research activities in energy storage

The South Africa's energy storage minerals abundance influenced the CSIR to participate in the national program of **E**nergy **S**torage **R**esearch **D**evelopment **I**nnovation Plan (ES RDI).

South Africa has 80% of global manganese reserves and this is a huge contributor to the energy storage with conversion technologies such as Batteries, Supercapacitors and Fuel cells. The CSIR focus is on the development of high-performance Manganese-rich/Nickel-rich cathode materials for electric vehicles, Na-ion / Zn-ion batteries for cost-effective alternatives to the lithium-ion batteries, and supercapacitors for flexible and wearable electronics.

Africa and in particular South Africa has no manufacturing activities despite their dominance of the energy storage minerals they possess in abundance. The identified risks are that of security of supply due to known and unknown factors.

Fuel cells

The last several decades have witnessed the rapid development of alkaline anion exchange membrane fuel cells (AAEMFCs) that possess a series of advantages as compared to acid proton exchange membrane fuel cells, such as the enhanced electrochemical kinetics of oxygen reduction reaction and the use of inexpensive non-platinum electrocatalysts, both of which are rendered by the alkaline medium. As an emerging power generation technology, the significant progress has been made in developing the alkaline anion exchange membrane fuel cells in recent years. The Energy Materials (EM) competency area is currently conducting fundamental and applied research in the development of electrocatalysts, nanocomposite anion-exchange membranes (AEMs), hybrid membranes materials and membrane electrode assembly (MEA) for potential use in fuel cells; technology development; systems analysis and education activities. Various experimental techniques such as the Electrochemical Atomic Layer Deposition (ECALD), Ultrasound, UV-assisted chemical reduction, microwave assisted ethylene glycol reduction methods and green synthesis methods are used for the preparation of electrodes with good dispersion of the active nanoparticles (Platinum Group Metals (PGMs) and non-PGMs) on the support material.

4. International collaboration

4-1 International alliance/networking development

The CSIR has agreements at institutional and research group levels. South Africa is a BRICS member with benefits from bilateral funded agreements with other bigger projects.

4-2 International joint R&D activities

CSIR with the financial support of the National Research Foundation (NRF) continues to establish bilateral collaborations. The South African research landscape is moving from applied research to deployment of energy storage solutions, which are to be done with collaborators.

- DFID
- SA-China
- South Africa- South Korea
- HySA **R**egulations, **C**odes, **S**tandards and **S**afety **W**orking **G**roup (RCSSWG)

5. Future perspectives

The South African energy mix with its coal based generation challenges has seen the increased uptake of wind and solar. The intermittency of the renewables necessitates the uptake of energy storage solutions. The clean energy technologies developed are geared towards all the sectors such as power tools, stationary and transportation applications. Our R&D aims are for cost reduction, materials security of supply through recycling; create a manufacturing industry for job creation

THULANI DLAMINI

CHIEF EXECUTIVE OFFICER

PROFILE

I am a seasoned executive with more than 15 years' experience leading R&D organizations in the oil and gas well as public sector. A qualified scientist with a Ph.D. in catalysis complemented with a Master's degree in business leadership.

I am currently the Chief Executive Officer of the largest Science Council in South Africa. I initiated and lead a strategic transformation journey to align the organizational strategy with the industrial development needs of the country.

Extensive experience in strategy development, organizational change management, strategic stakeholder relationship management and business transformation.

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HOBBIES

Running, Fishing
Golf, Cycling

EDUCATION

University of the Witwatersrand

1990 – 1998
BSc - Chemistry
BSc (Hon) – Applied Chemistry
Ph.D. – Catalysis

University of South Africa

1999 – 2003
Program in Business Leadership
Master of Business Leadership

WORK EXPERIENCE

Sasol Technology LTD

Scientist, Senior Scientist, Principle Scientist, Chief Scientist

1998 – 2005
Undertook R&D in heterogeneous catalysis for the conversion of syngas to chemicals. Filled five patents in this field. Received various recognition awards for excellence. I was Chief Scientist and research leader for Materials Characterization.

Council for Scientific and Industrial Research

Centre Manager: National Laser Centre

2005 – 2008
Led the growth and transformation of the National Laser Centre.

Council for Scientific and Industrial Research
Group Executive: Research and Development

2008 – 2011
Responsible for the strategic investment of R650m state grant and R&D strategy of the CSIR. Led the development of flagship investment plan in areas such as defense and security, health and water.

Sasol LTD
Executive Manager: Research & Development

2012 – 2014
Executive Manager for Sasol's corporate R&D functions.

Sasol LTD
Vice President: Strategic Research and Technology
2014 – 2017

Led the development and Implementation of long term technology development strategy in adjacent areas of innovation to the Sasol core business.

Council for Scientific and Industrial Research
Chief Executive Officer
2018 – to date

Leading the business transformation of CSIR to make an impact in industry, society and government.

PROFESSIONAL MEMBERSHIPS

Institute of Directors, SA
Academy of Science of South Africa