Clean Energy Technologies at the CSIR

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1. Introduction (Times New Roman or Times-Roman 12 pt)

Background of clean energy technologies in your institute.
History and current status of clean energy technologies including energy policy in your country.

South African primary energy supply is heavily dependent on coal which has made the country to be identified as one of the concerning global CO2 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 with emphasis on clean energy technologies in the areas of: Hydrogen, Carbon Capture, Utilisation and Storage (CCUS), Fuel Cells (FCs), Lithium Ion Batteries (LIBs) and thermal energy storage.

2. R&D activities related to clean energy technology

Review of research and development (R&D) status of clean energy technologies at your institute.

CSIR is a premier African Research Institute with an Energy Research Center (CSIR Energy Centre) 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, LIBs and thermal energy storage. The innovation cycles moves from materials development to systems assembly and deployment.

The introduction of renewable energy and storage technologies in South Africa will lead to the localisation of technology, creation of manufacturing jobs, as will directly support the objective to ensure that the transition to sustainable energy resources is a "Just Energy Transition".

3. Specific research activities in renewable energies, next generation energy management system with batteries, hydrogen, CCUS, and related technologies

Review of R&D status of particular interest, such as renewable energies, next generation energy management system with batteries, hydrogen, CCUS, and related technologies.

Related programs/projects conducted by the institute (further information on programs/projects can be found in the template)

Thermal energy storage

South African industry has previously developed in a context of low energy prices for coal and electricity. This has resulted in a wide range of industrial processes that are inefficient and carbon intensive. A technology demonstrator for waste heat recovery and heat storage using zeolite has been developed to TRL 4 and tested at lab scale - further testing and piloting at an industrial company are to follow. In an externally funded project on solar thermal process heat for industry, a pilot plant is under development at an industrial company. A thermal systems laboratory has been designed, and a funding agreement with a government agency has been signed in support of the laboratory. An ice storage system is being considered for the upgrade of the CSIR International Conference Centre.

Green Hydrogen production and conversion

South Africa possesses excellent Renewable Energy resources, which enables the production of green hydrogen through water electrolysis. An analysis has been undertaken to assess South Africa's competitive position to produce and export green hydrogen. Japan has a hydrogen import cost target of $3/kg H2. South Africa will be able to generate hydrogen by electrolysis using renewable electricity at this cost by approximately 2030, and will be able to chemically store it and transport it to Japan at this cost before 2040. Options for transporting the Hydrogen include LH2, Liquid Organic Hydrogen Carriers (LOHCs) and Methanol. Options are being investigated to enable the increased supply of potable water whilst generating water for electrolysis from saline and brackish water.
The Electro-Chemical Energy Technology Research 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. The catalysts are developed together with industry in order to accelerate the commercialization of electrolyzers.

The Green Hydrogen production research is very complementary to the Carbon Dioxide Utilisation research discussed below.

Hydrogen Storage

Over the last 7 years, the CSIR has been involved in the development of high-pressure composite cylinders (Type IV) with the eventual goal of incorporating porous materials to derive conditions for lightweight hydrogen storage systems.

Upgrading of raw biogas to produce biomethane

Upgrading of raw biogas to pure or more concentrated methane (biomethane) is known to increase the biogas calorific value and thus expands its use to other high-value applications such as transport fuel, in high efficiency gas turbines, among others. One of the strategies for lowering the cost of a pressure Swing Adsorption (PSA) technology is through the development and utilization of low-cost and high efficiency sorbents. It is on this basis that the CSIR is developing low-cost sorbent materials through the application of a holistic strategy that utilises acid mine drainage, coal combustion by-products and waste polyethylene terephthalate (PET) bottles as feedstock. Furthermore, this study lays foundation for development of customized/stand-alone containerized PSA unit customizable for small-scale biogas producers. The recovered carbon dioxide will be utilized in the production of clean synthetic fuels and chemicals.

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.

The CSIR is in the process of developing a dedicated CO_2 conversion platform. The focus will span the development of CO_2 capture technologies and the conversion of CO_2 to fuels and chemicals, as well as integration with other ongoing work that focuses on direct and biological CO_2 use.

Batteries and super capacitors

The South Africa's energy storage minerals abundance influenced the CSIR to participate in the national program of Energy Storage Research Development Innovation 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 Manganese-rich/Nickel-rich cathode materials for stimulating the battery manufacturing industries in South Africa and Africa to support the renewable energy, transport and portable sectors. Another focus is on developing supercapacitors for flexible and wearable electronics. The activities are aimed at addressing the cost-performance ratio and environmental friendly materials.

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

Fuel cell activities are focused on developing ultra-low Platinum Group Metals (PGM) and non-PGM based catalysts for the alcohol oxidation and oxygen reduction reactions to support the fuel cell manufacturing and chemical industries

4. International collaboration
4-1 International alliance/networking development

International activities at your institute, including comprehensive MOUs, joint projects, researcher exchanges, joint workshops and seminars, etc.

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

4-2 International joint R&D activities
International joint research programs for innovation in clean energy technologies at your institute.

CSIR with the financial support of the National Research Foundation (NRF) and the DSI 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
- SA-France
- SA-Poland
- HySA **I**nternational **P**artnership for **H**ydrogen and Fuel Cells in the **E**conomy (IPHE) **R**egulations, **C**odes, **S**tandards and **S**afety **W**orking **G**roup (RCSSWG).
- South Africa- South Korea: **Developing energy materials for hydrolysis and fuel cell systems through multiscale modeling coupled with experimental approaches.**

South Africa is continuously developing hydrolysis and fuel cell technologies to create value-added industries based on abundant precious metal resources. South Korea is possible to open brand new avenues for innovation in efficiently solving national challenges through advanced quantum mechanics and molecular dynamics simulation developed the force field in own system, Based on these research, it is expected to contribute to expanding the renewable energy market in both countries.

5. Future perspectives (beyond 2030)

Future challenges in clean energy technologies, expected international collaborative framework at your institute.

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.

South Africa has an excellent local renewable energy resource (solar and wind) as positions the country as a potential international supplier of green hydrogen and related PtX products. The CSIR sees substantial opportunity for collaboration in the future hydrogen production, storage, transportation and utilisation markets and related technology development.

(Please attach the CV of participant (with photo))