Africa Center of Excellence in Future Energies & Electrochemical Systems

ACE-FUELS e-Symposium on HYDROGEN ENERGY

HANDBOOK OF PROCEEDINGS

SCOPE

1. Hydrogen Production
2. Hydrogen Storage
3. Computational Modelling/AI
4. Fuel Cells & Batteries
5. Novel Materials
6. Economics & Socioeconomics
7. Case Studies

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Africa Centre of Excellence in Future Energies and Electrochemical Systems (ACE-FUELS)

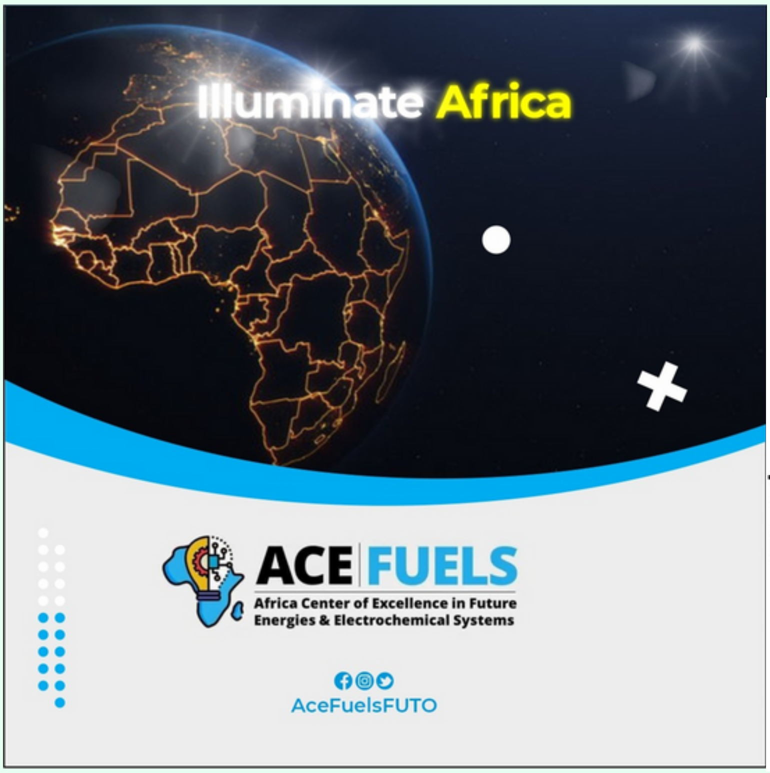
The Africa Centre of Excellence in Future Energies and Electrochemical Systems (ACE-FUELS) at the Federal University of Technology Owerri (FUTO), Nigeria, was established in 2019, with funding support from the World Bank and the French Development Agency, to: provide postgraduate level training to nurture and develop a critical mass of well-trained technocrats to meet requirement of top-rate professionals for clean energy and related high technology applications. The Centre prioritizes training, research, development & innovation, knowledge sharing and dissemination, community education, technical skills and capacity development, stakeholder engagement, industry partnerships, research translation and research commercialization as its core functions. The core objectives of the Centre include:

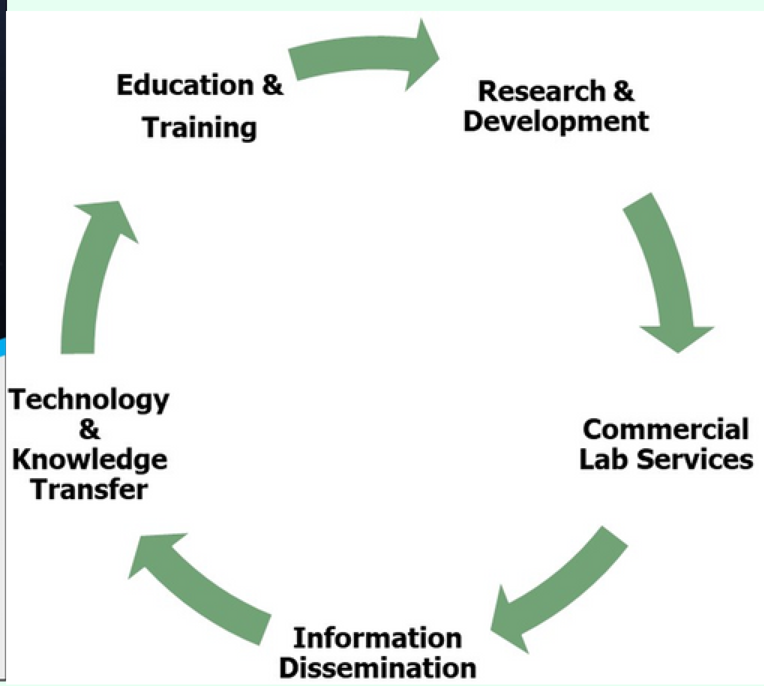
- Develop a critical mass of well-trained researchers to meet requirement of R&D professionals for clean energy and related high technology applications.

- Initiate and support high end research, to extend knowledge beyond the existing practice in the industry.

- Promote local content in research and innovations by initiating necessary value-driven industry-academia collaborations.

- Partner with local industry initiatives within the Sub-Saharan Africa region to help develop competencies by providing bespoke work-based learning events, activities and tools in line with global best practices.





ACE-FUELS Programmes

Postgraduate Degree Programmes

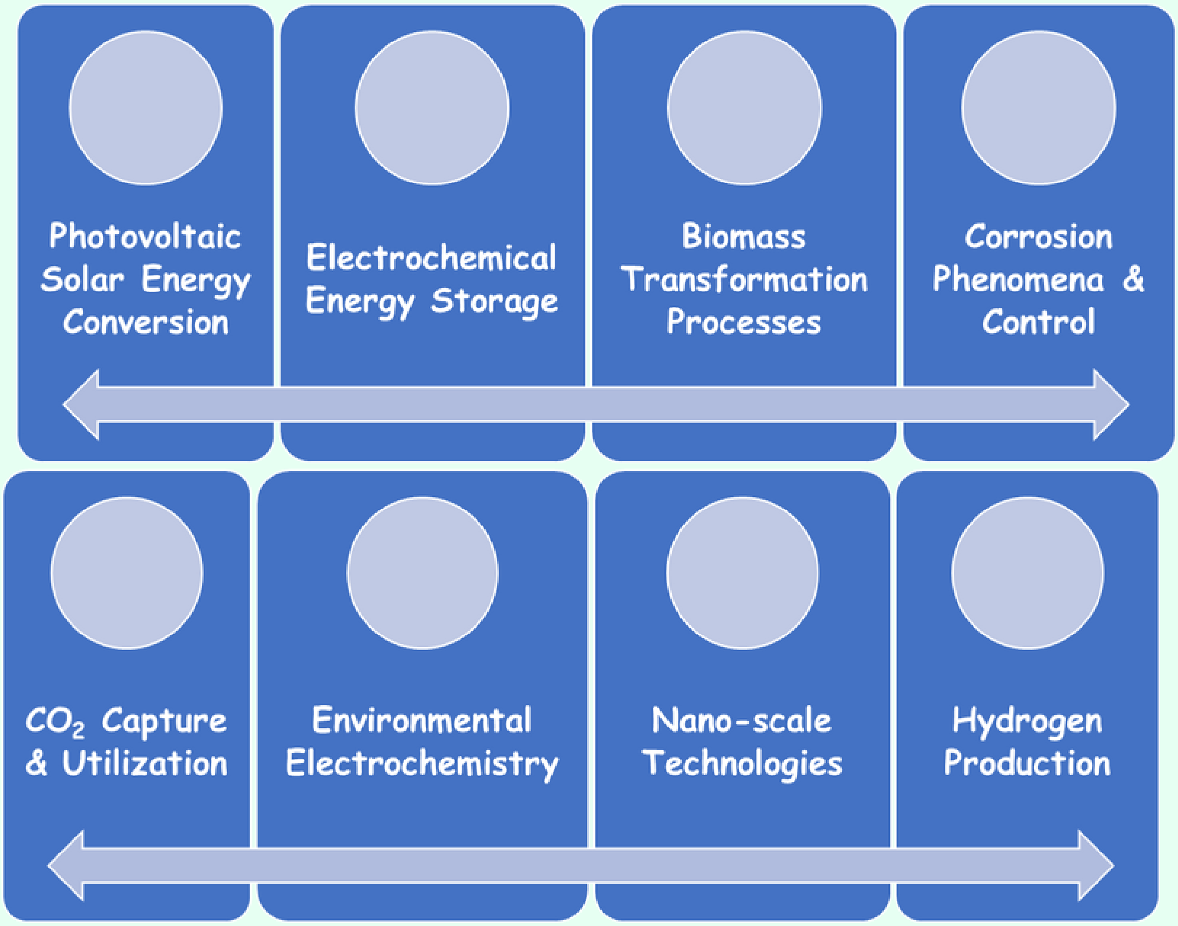
PROGRAMME	SCOPE
MSc/PhD, Future Energies	Renewable energy (solar, wind, hydro, geothermal, biomass), clean hydrocarbon fuels, carbon capture & sequestration
MSc/PhD, Nanotechnology	Nano synthesis & characterization, functional materials, energy materials, natural nanomaterials, nanocatalysis
MSc/PhD, Electrochemical Technology	Electrochemical energy & storage devices (fuel cells, batteries), Environmental electrochemistry, water electrolysis/hydrogen
MSc/PhD, Corrosion Technology	Corrosion monitoring and protection, anticorrosion additives, coatings, corrosion modelling

- All programmes are fully accredited by the National Universities Commission (NUC)
- Currently undergoing international accreditation

Short Term Certificate Programmes

- ACE-FUELS Course on Energy Transition and Renewable Energy Technologies
- ACE-FUELS Course on Hydrogen Production by Electrolysis
- ACE-FUELS Course on Energy Management
- ACE-FUELS Course on Technical Writing and Research Communication

ACE-FUELS Research Focus Areas



HYDROGEN AND FUEL CELLS FOR TELECOMMUNICATIONS BACKUP POWER PROJECT (HY4TEL)

Hydrogen and fuel cells are key energy system solutions for the 21st century, efficiently capturing and using the energy-carrying capacity of hydrogen for clean and efficient production of power. This involves the use of hydrogen and/or hydrogen-containing compounds to generate energy with high energy efficiency, overwhelming environmental and social benefits, as well as economic competitiveness. Fuel cells are electrochemical devices that converts the chemical energy of a fuel and an oxidant into electricity, with heat and water as by product. Fuel cells have the capacity to continually produce electricity, in as much as fuel and oxygen are supplied and thus provide extended run time like that of diesel generators. Fuels cells are cleaner, quieter, less polluting and more reliable than generators and are cheaper, more predictable and longer lasting than batteries. Fuel cells are thus more effective than diesel generators and batteries for backup power applications.

The goal of the Hydrogen and Fuel Cells for Telecommunications Backup Power Project (HY4TEL), funded by the Nigerian Communications Commission, NCC, is to develop an innovative and efficient fuel cell system for the generation of electrical energy from hydrogen.

The specific objective of the HY4TEL project is to develop national scientific and engineering basis for the development of hydrogen and fuel cell energy systems for telecommunications back up power applications. The project shall play a key role towards creation of a “hydrogen economy” in Nigeria, which is considered an important energy storage strategy to exploit fully the benefits of renewable and sustainable energy. Indeed, the International Energy Agency (IEA) advises that “The world should not miss this unique chance to make hydrogen an important part of our clean and secure energy future”.

Through the completion of the HY4TEL project, novel designs and models of formic acid fuel cells will be developed, for use as backup power applications in the telecommunications and related sectors. More importantly, this HY4TEL project shall expose faculty and students to the basics of hydrogen and fuel cell technologies. This exposure will arouse sufficient interest and promote training and research that will provide students with the know-how and ability to work to support industry and government in development of transformational hydrogen energy technologies.

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	PROGRAMME
14:00	**Welcome Address: Introducing the NCC HY4TEL Project** Prof. Emeka E. Oguzie, Centre Leader, ACE-FUELS
14:10	**Green Hydrogen Generation Plants to reduce CAPEX and related OPEX to support Hydrogen fueled power generators.** Ibe Egbunam Okolie, Blue River Seal Company Limited
14:30	**Hydrogen economy and Nigeria: Analysis of the potential economic and socioeconomic impact** Natasha Aduloju-Ajijola, PhD, Vitalera Integrated Consults
14:40	**Climate change & role of green hydrogen: a path to a sustainable future** Kezire Abdallah, Abdou MoumouniUniversity, Niamey, Niger
14:50	**Assessment of hydro-climatic trends and green hydrogen production potentials from Jebba dam in the Niger river basin, Nigeria** Emmanuel O. Aremu, University of Abomey-Calavi, Cotonou, Benin
15:00	**Electrochemistry Contributing to the Hydrogen Future** Prof. Frank Marken, University of Bath, UK
15:20	**Electrochemical Hydrogen Generation: Monitoring the half-cell voltages EWE and ECE and the full cell voltage simultaneously.** Dr. A. Aashish, Bio-Logic Science Instruments
15:40	**Room Temperature Indirect Fuel Cell Based on Hydrogen-Permeable Palladium Membrane** Chris O. Akalezi, ACE-FUELS, Federal University of Technology Owerri
15:50	**Concurrent Hydrogen and Power Generation in Direct Biomass Redox Flow Fuel Cell** Boniface I. Ugwu, ACE-FUELS, Federal University of Technology Owerri
16:00	**Electrocatalytic properties of porous organic porphyrins on oxygen evolution reaction - effect of graphene** Dr. Nnaemeka Nnaji, Stellenbosch University, South Afr
16:10	**Green hydrogen: The energy-water nexus** Gina Lagunes, German Agency for International Cooperation (GIZ)
16:30	**Waste wood beneficiation for hydrogen-rich syngas fuel** Nnanna-jnr M. Okoro, PhD, Federal University of Technology Owerri, Nigeria
16:40	**Harnessing Coal Beds for Hydrogen Storage and Utilization** Victor I. Fagorite, ACE-FUELS, Federal University of Technology Owerri
16:50	**Accelerated Decarbonization of Hydrogen Production Pathways using Artificial Intelligence Techniques** Ikechukwu I. Ayogu, ACE-FUELS, Federal University of Technology Owerri
17:00	Closing Remarks

SPEED PRESENTATION ABSTRACTS

HYDROGEN ECONOMY AND NIGERIA: ANALYSIS OF THE POTENTIAL ECONOMIC AND SOCIOECONOMIC IMPACT

Natasha Aduloju-Ajijola, PhD, MPH1
Vitalera Integrated Consults, Abuja, Nigeria

ABSTRACT

The hydrogen economy has emerged as a promising pathway towards a sustainable and decarbonized future, presenting significant potential for economic and socio-economic transformation. Nigeria, as a resource-rich nation, possesses a unique opportunity to leverage its abundant renewable energy resources for hydrogenproduction. Green hydrogen, produced through electrolysis powered by renewable sources, holds immense potential for the country's energy transition. By investing in hydrogen infrastructure, Nigeria can diversify its energy mix and promote sustainable development. The adoption of a hydrogen economy in Nigeria would have substantial economic benefits through creating new avenues for revenue generation through hydrogen export. The global demand for clean energy sources is increasing, and Nigeria can position itself as a key player in the export market, attracting foreign investments and boosting its GDP. Additionally, the domestic consumption of green hydrogen can drive industrial growth, particularly in sectors like transportation, power generation, and manufacturing, leading to increased productivity and economic competitiveness. The deployment of hydrogen infrastructure would necessitate the creation of a skilled workforce, generating employment opportunities and addressing unemployment challenges. Furthermore, knowledge transfer and technology exchange through collaborations with international partners can enhance Nigeria's scientific and technological capabilities, stimulating innovation and human capital development. The hydrogen economy holds significant promise for Nigeria, both economically and socio-economically. By embracing hydrogen production, especially blue and green production, Nigeria can capitalize on its renewable energy resources, meet global energy demands, create jobs locally, and foster knowledge transfer. However, realizing these benefits requires strong policy support, strategic investments, and international collaborations to harness the full potential of the hydrogen economy.

CLIMATE CHANGE AND THE ROLE OF GREEN HYDROGEN: A PATH TO A SUSTAINABLE FUTURE

Kezire Abdallah
Abdou Moumouni University, Niamey, Niger Republic

ABSTRACT

Biomass, photovoltaics, hydroelectricity, and wind power offer renewable energy alternatives, but they are subject to seasonal variations in availability. It is in this context that the significance of green hydrogen emerges. Green hydrogen serves as both an energy carrier and a means of energy storage. By utilizing excess renewable electricity during periods of abundance, it can be produced through electrolysis, enabling the conversion of water into hydrogen and oxygen. This hydrogen can then be stored and utilized when renewable energy generation is low, ensuring a continuous and reliable energy supply. Moreover, green hydrogen holds the potential to revolutionize various sectors, such as transportation and industry, by decarbonizing their operations and reducing greenhouse gas emissions. The importance of green hydrogen is underscored by the global initiatives, programs, and investments focused on its development and implementation. It presents an opportunity to transition away from fossil fuels and mitigate the adverse effects of climate change. The growth of the hydrogen industry is poised to contribute significantly to the broader goal of achieving a sustainable future. Climate change stands as one of the greatest challenges humanity has ever faced. It requires collective action and innovative solutions. Through the ingenuity of scientists and the utilization of green hydrogen, we have the potential to address this crisis and forge a brighter and more sustainable path forward. By embracing the transformative power of green hydrogen, we can pave the way for a resilient and environmentally conscious future, ensuring the well-being of present and future generations on our precious planet Earth.

ASSESSMENT OF HYDRO-CLIMATIC TRENDS AND GREEN HYDROGEN PRODUCTION POTENTIALS FROM JEBBA DAM IN THE NIGER RIVER BASIN, NIGERIA

Emmanuel Olorunyomi Aremu(1), Agnidé Emmanuel Lawin(2), David Olukanni(3), Harrie Jan Hendricks Franssen(4)

(1) Graduate Research Program (GRP) Climate Change and Water Resources, West African Science Service Centre on Climate Change and Adapted Land Use (WASCAL), University of Abomey-Calavi, Cotonou, Benin
(2) Laboratory of Applied Hydrology, Faculty of Sciences and Technology, University of Abomey-Calavi, Abomey-Calavi, Benin
(3) Department of Civil Engineering, Covenant University, Ota, Ogun State, Nigeria
(4) Forschungszentrum Jülich GmbH, Institute of Bio- and Geosciences, IBG-3 (Agrosphere), Jülich, Germany.

ABSTRACT

Hydropower has the potential to play a major role in advancing the production of green hydrogen; however, hydro-climatic trends and variability can have an impact on hydropower energy output. The anomaly, trends, and, abrupt changes in Jebba dam neighboring stations' 30 years rainfall (1992-2021), Jebba dam hydro-climatic variables (rainfall, maximum temperature, inflow, outflow, evaporation loss), energy generation from 1988-2018, and turbine discharge from 1984-2009 were analyzed using parametric and non-parametric tests. Furthermore, the impact of hydro-climatic variability on hydropower generation was evaluated through Pearson correlation coefficient and sensitivity analysis. The green hydrogen production potential from total hydroelectric energy output (2002-2010) and re-electrification potential using hydrogen was estimated. The results reveal that Ilorin and Minna have the highest negative anomalies. Also, Ilorin and Bida rainfall, Jebba dam's inflow, outflow, turbine discharge, and energy generation have increased significantly nevertheless evaporation loss shows a decreasing trend while other variables show no trend. Abrupt changes (change year) are detected in all variables except Bida, Minna, and Lokoja rainfall. Moreover, energy generation is highly dependent on reservoir inflow, outflow, and turbine discharge, although the sensitivity analysis shows that hydropower generation is more sensitive to turbine discharge. The estimated green hydrogen production potential using 100% hydropower energy from Jebba dam indicated that the highest and lowest potential was 53,750 tons/year and 40,125 tons/year in the years 2008 and 2002 respectively while the highest and lowest re-electrification potential using hydrogen is 1,075 GWh and 803 GWh in the year 2008 and 2002 respectively. The study concludes that hydro-climatic changes will impact hydropower generation which will in turn affect green hydrogen production, however, using a percentage of hydropower energy for green hydrogen production can be a niche opportunity to lead the country toward green hydrogen energy production as part of its energy mix.

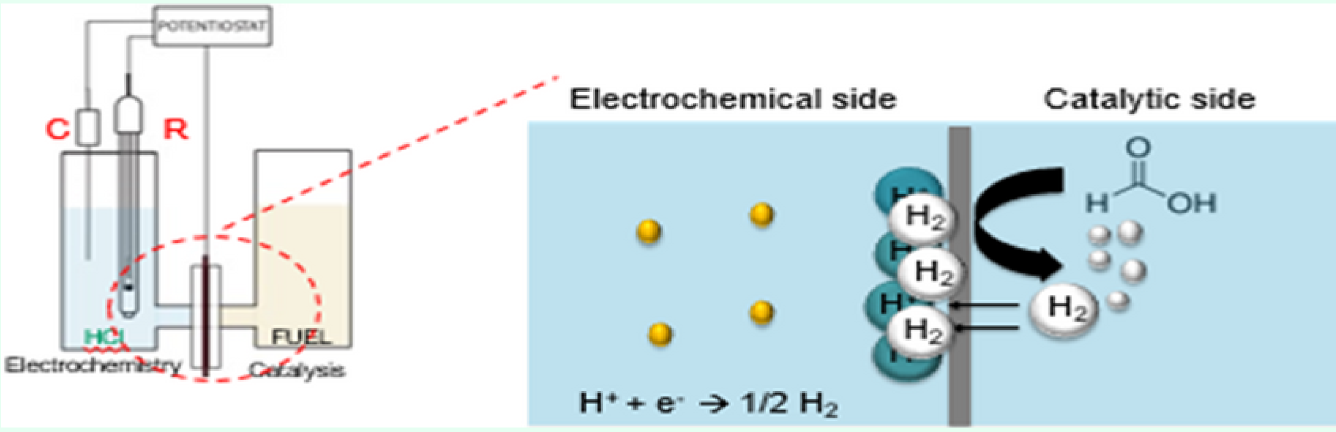
ROOM TEMPERATURE INDIRECT FUEL CELL BASED ON HYDROGEN-PERMEABLE PALLADIUM MEMBRANE

Chris O. Akalezi, Emeka E. Oguzie

Africa Centre of Excellence in Future Energies and Electrochemical Systems, Federal University of Technology Owerri, Imo State, Nigeria

ABSTRACT

Electrocatalysis provides a method of driving organic reaction chemistry under ambient conditions to produce electricity. Here we present the electrocatalysis of formic acid with the concomitant formation of hydrogen in an electrochemical cell. These reaction chambers are separated by a dense palladium membrane that oxidizes hydrogen formed at the anode to hydrogen ions and electrons that can permeate through the palladium foil to produce electricity. The palladium membrane enables two reactions to be performed simultaneously at ambient conditions.



CONCURRENT HYDROGEN AND POWER GENERATIONS IN DIRECT BIOMASS REDOX FLOW FUEL CELL

Boniface I. Ugwu, Chris O. Akalezi, Emeka E. Oguzie

Africa Centre of Excellence in Future Energies and Electrochemical Systems, Federal University of Technology Owerri, Imo State, Nigeria

ABSTRACT

Hydrogen fuel is the potential fuel of the future, for a net-zero global carbon economy needed to mitigate global warming. Concurrent biohydrogen energy and power generation from direct biomass redox flow fuel cell (DBRFFC) involves biohydrogen production from the lignocellulosic biomass (LCB), which is used as fuel in DBRFFC for in-situ generation of electric power, with suitable catalysts that will drive the biomass oxidation, firstly into glucose, and subsequently into formic acid. The aim is to improve the power output of the current DBRFFC and also eliminate the hydrogen storage challenge experienced in its production and management by further oxidizing the formic acid into hydrogen by indirect means. If achieved, power output of DBRFFC is expected to increase tremendously as low-energy dense LCB will be upgraded to high energy-density hydrogen. The outcome will also revolutionize DBRFFC research.

ELECTROCATALYTIC PROPERTIES OF POROUS ORGANIC PORPHYRINS ON OXYGEN EVOLUTION REACTION- EFFECT OF GRAPHENE

Nnaemeka Nnaji, Emile Maggott and Selwyn Mapolie

DST-NRF Centre of Excellence in Catalysis (c*change), Department of Chemistry and Polymer Science, Stellenbosch University, Stellenbosch 7601, South Africa

ABSTRACT

Hydrogen fuel is the potential fuel of the future, for a net-zero global carbon economy needed to mitigate global warming. Concurrent biohydrogen energy and power generation from direct biomass redox flow fuel cell (DBRFFC) involves biohydrogen production from the lignocellulosic biomass (LCB), which is used as fuel in DBRFFC for in-situ generation of electric power, with suitable catalysts that will drive the biomass oxidation, firstly into glucose, and subsequently into formic acid. The aim is to improve the power output of the current DBRFFC and also eliminate the hydrogen storage challenge experienced in its production and management by further oxidizing the formic acid into hydrogen by indirect means. If achieved, power output of DBRFFC is expected to increase tremendously as low-energy dense LCB will be upgraded to high energy-density hydrogen. The outcome will also revolutionize DBRFFC research.

WASTE WOOD BENEFICIATION FOR HYDROGEN-RICH SYNGAS FUEL

Nnanna-jnr M. Okoro, PhD

Sustainable Energy & Environment Research Unit (SEERU)
Department of Environmental Management, Federal University of Technology Owerri, Imo State, Nigeria

ABSTRACT

Deficiencies in energy supply for both domestic cooking and power generation in Nigeria and other Sub-Sahara Africa (SSA) economies create a bottleneck to development and cause severe economic, environmental and social hardship in the region despite its diverse energy resources. One such untapped resource continually being generated in abundance yet have proved difficult to manage is waste wood from sawmills. Due to their zero economic value, enormous amounts of waste sawdust, wood chips, shavings and offcuts generated from large lucrative sawmills across Nigeria find their way to rivers where they increase sedimentation and disrupt aquatic life, and landfills where they are incinerated in open air, causing severe air pollution and carbon emissions. This presentation gives an overview of the steam-oxidized pyro-gasification technology for the conversion of waste sawdust to hydrogen-rich syngas. Similar to natural gas, syngas can serve as a viable alternative fuel for domestic cooking and embedded power generation and has the potential to not only mitigate the environmental catastrophe of poor sawmill waste management, meet the demands of the Sustainable Development Goals 3, 6, 7, 9, 11, 12, 13 and 14.

Harnessing Coal Beds for Hydrogen Storage and Utilization

Victor I. Fagorite, Samuel O. Onyekuru

Africa Centre of Excellence in Future Energies and Electrochemical Systems, Federal University of Technology Owerri, Imo State, Nigeria

ABSTRACT

The utilization of coal beds for hydrogen storage and utilization presents a promising avenue for addressing the challenges of energy storage and clean energy production. This study provides an overview of the concept and potential benefits of harnessing coal beds for hydrogen storage and utilization. By exploiting the unique properties of coal, such as its high carbon content and porosity, hydrogen can be stored within coal beds, serving as a secure and abundant reservoir. Furthermore, coal's catalytic properties enable the conversion of stored hydrogen into usable energy through processes like coal gasification and steam methane reforming. This study highlights the key advantages of coal bed hydrogen storage and utilization, including its potential to facilitate the integration of intermittent renewable energy sources, enhance energy security, and reduce greenhouse gas emissions while retrofitting Carbon Capture Utilization and Storage (CCUS). However, challenges related to coal bed characterization, hydrogen extraction, and environmental considerations need to be addressed for the widespread implementation of this technology. Generally, harnessing coal beds for hydrogen storage and utilization holds promise as a pathway toward a sustainable and resilient energy future.

Accelerated Decarbonization of Hydrogen Production Pathways using Artificial Intelligence Techniques

Ikechukwu I. Ayogu, Emeka E. Oguzie

Africa Centre of Excellence in Future Energies and Electrochemical Systems, Federal University of Technology Owerri, Imo State, Nigeria

ABSTRACT

Hydrogen is the cleanest form of fuel, once produced. However, there are currently multiple barriers to the attainment of the desired low-carbon hydrogen energy-driven economy. Most of the existing challenges are associated with either the high-carbon footprint of the high hydrogen-yield production methods that are currently top of the hydrogen supply chain, or the costs and scalability issues associated with current technologies for green hydrogen production. To achieve the hydrogen economy in the near future, current production technologies, especially the market-ready options, must be increasingly decarbonized while the renewable, low-carbon hydrogen production processes, are optimized for efficiency in terms of yield and costs. No doubt, artificial intelligence (AI) approaches have huge potential to accelerate decarbonization of hydrogen production and attention in this regard has mainly been on yield forecast, demand-supply management, and plant-health management. Meanwhile, AI-driven interventions for accelerated decarbonization of well-established and emerging hydrogen production technologies should be the main focus of AI interventions. It is thus the target of this presentation to identify the niche areas for implementation of AI to decarbonize a typical hydrogen production pathway.