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RESEARCH INTERESTS

Applied Thermodynamics, Hydrogen Production using Thermochemical cycles and Renewable, Exergy Analysis, Sustainable Energy Systems, Waste Management, High Temperature Electrolysis, Fuel Cells, Nuclear Desalination, Green Buildings, Multi-generation Systems, Solar Desalination

TEACHING INTERESTS

Applied Thermodynamics, Process Engineering, Fluid Mechanics, Heat Transfer, Energy and Fossil Fuels, Internal Combustion Engines, Gas Turbines, Power Production, Fuel Cells and Hydrogen Systems, Sustainability: Energy, Exergy Environment and Economics, Energy Storage Devices and Systems, Renewable Energy Systems, Desalination Technologies: Focus on Solar and Nuclear

EDUCATION

PhD in Mechanical Engineering, August 2017

Ontario Tech University, Oshawa, Ontario, Canada

Thesis Title: Development and Analysis of a High Temperature Electrolyser for the Cu-Cl Cycle for Hydrogen Production.

Supervisor: Dr. Ibrahim Dincer (Highly Cited Researcher, Clarivate Analytics)

Co-Supervisor: Dr. Marc A Rosen (Highly Cited Researcher, Clarivate Analytics)

MASc in Mechanical Engineering, December 2014

Ontario Tech University, Oshawa, Ontario, Canada

Thesis Title: Development and Analysis of New Energy Systems for Sustainable Buildings.

Supervisor: Dr. Ibrahim Dincer (Highly Cited Researcher, Clarivate Analytics)

Co-Supervisor: Dr. Marc A Rosen (Highly Cited Researcher, Clarivate Analytics)

B.Tech (BS) in Mechanical Engineering, June 2012

Project Title: Thermodynamic Analysis of Modified Combustion Mode Hydrogen Fuel Engine.

Aligarh Muslim University, Aligarh-202002 Uttar Pradesh (India)

RESEARCH PROJECTS

- Dynamic modeling of a gasoline engine and prototyping of an electronic control unit for optimum control purposes, Istanbul, Turkey
- Development of novel and sustainable cooling technologies for self-sufficient greenhouses and buildings-NPRP, QNRF, Qatar (Award Cost 600,000 USD, Awarded)-NPRP12S-0123-190011
- Pre-aeration in Sewage Pipe for Wastewater Treatment Plant to Control Hydrogen Sulfide Production
- Entropy Generation in a Pipe Having Different Nano-Fluids Subjected to Constant Wall Temperature

PUBLICATIONS IN PEER REVIEWED JOURNALS (24 Published, 1 Under review, 2 Under Preparation,

Total Citation 552; h-index: 12)

- F Khalid, R Kumar, **F Khalid** "Feasibility study of a novel solar based trigeneration system for fresh water, cooling and electricity production", International Journal of Energy Research, 2021 (**Accepted, SCI- Expanded indexed and Scopus-indexed**; Impact Factor: 5.164)
- R El-Emam, **F Khalid**, M Ezzat "Assessment of PV-assisted Grid-Connected System for El-Mostakbal City in Egypt – Case Study", Energy, 2021 (**Under Review, SCI-indexed**; Impact Factor: 6.082)

- R Bhattacharya, **F Khalid** “Technoeconomic assessment of hydrogen based metal hydrides for energy storage in residential applications”, International Journal of Hydrogen Energy, 2021 (**Under Preparation, SCI- Expanded indexed and Scopus-indexed**; Impact Factor: 4.939)
- M A Chowdury, **F Khalid** “Application of microfluidic paper-based analytical device (μ PADs) to detect COVID-19 in resource-limited settings”, International Journal of Energy Research, 2021 (**Accepted, SCI- Expanded indexed and Scopus-indexed**; Impact Factor: 5.164)
- R Bhattacharya, **F Khalid** “Development of Multi-criteria Indices for Nuclear Cogeneration Project Evaluation in the Light of Sustainability and Climate Change”, International Journal of Energy Research, 2021 (**Accepted, SCI- Expanded indexed and Scopus-indexed**; Impact Factor: 5.164)
- N Sezer, **F Khalid**, Y Bicer, M Koc “Electrochemical Modeling and Performance Assessment of H₂S/Air Solid Oxide Fuel Cell”, Energy Technology, 8 (12), 2000531, 2020 (**SCI- Expanded indexed and Scopus-indexed**; Impact Factor: 3.404)
- **F Khalid**, Y Bicer “Methanol Production by high temperature thermochemical cycle” International Journal of Energy Research, 2020 (**In Press, SCI- Expanded indexed and Scopus-indexed**; Impact Factor: 5.164) <https://doi.org/10.1002/er.5521>
- Y Bicer, **F Khalid**, A Mohamed, M Al-Breiki, M M Ali “Electrochemical modeling of ammonia synthesis in molten salt medium for renewable fuel production using wind power”, International Journal of Hydrogen Energy, 45 (60), 34938-34948, 2020 (**SCI- Expanded indexed and Scopus-indexed**; Cited 3 times, Impact Factor: 4.939)
- Y Bicer, **F Khalid** “Life Cycle Comparison of Solid Oxide Fuel Cells Fed by Natural Gas, Hydrogen, Ammonia and Methanol for Combined Heat and Power Generation”, International Journal of Hydrogen Energy, 45 (5), 3670-3685, 2020 (**SCI- Expanded indexed and Scopus-indexed**; Cited 25 times, Impact Factor: 4.939)
- **F Khalid**, Y Bicer “High Temperature Electrolysis of Hydrogen Bromide Gas for Hydrogen Production using Solid Oxide Membrane Electrolyser”, International Journal of Hydrogen Energy, 45 (9), 5629-5635, 2020 (**SCI- Expanded indexed and Scopus-indexed**; Cited 1 times, Impact Factor: 4.939)
- Y Bicer, **F Khalid** “Two-step hybrid thermochemical cycle using hydrogen chloride for hydrogen production: An energy and exergy assessment”, International Journal of Hydrogen Energy, 44 (56), 29460-29466, 2019 (**SCI- Expanded indexed and Scopus-indexed**; Cited 8 times, Impact Factor: 4.939)
- **F Khalid**, Y Bicer “Energy and exergy analyses of a hybrid small modular reactor and wind turbine system for trigeneration”, Energy Science and Engineering, Wiley, 7 (6), 2336-2350, 2019 (<https://doi.org/10.1002/ese3.327> ; **SCI- Expanded indexed**; Impact Factor: 2.893)
- **F Khalid**, R S El-Emam, J Hogerwaard, I Dincer “Techno-Economic Feasibility of Renewable Energy Based Stand-Alone Energy System for A Green House: Case Study”. Future Cities and Environment 2018, 4(1), p.12 (**Invited Article, Scopus-indexed**; Cited 11 times)
- **F Khalid**, I Dincer, M A Rosen “Thermodynamic Viability of a New Three Step High Temperature Cu-Cl Cycle for Hydrogen Production”, International Journal of Hydrogen Energy 43, 18783-18789, 2018 (**SCI-Expanded indexed and Scopus-indexed**; Cited 21 times, Impact Factor: 4.939)
- **F Khalid**, I Dincer, M A Rosen “Co-Production of Hydrogen and Copper from Copper Waste using a Thermochemical Cu-Cl Cycle” Energy and Fuels 32, 2137-2144, ACS Publications, 2018 (**Web of Science-indexed and Scopus-indexed**; Cited 11 times, Impact Factor: 3.421)
- **F Khalid**, I Dincer, M A Rosen “Model Development and Analysis of a Novel High Temperature Electrolyser for the Gas Phase Electrolysis of Hydrogen Chloride for Hydrogen Production”, International Journal of Hydrogen Energy, 43 (19), 9112-9118, Elsevier, 2018 (**SCI-Expanded indexed and Scopus-indexed**; Cited 10 times, Impact Factor: 4.939)
- **F Khalid**, I Dincer, M A Rosen “Thermoeconomic Analysis of a Solar-Biomass Integrated Multigeneration System for a Community” Applied Thermal Engineering, 120, 645-653, Elsevier, 2017 (**SCI-Expanded indexed and Scopus-indexed**; Cited 84 times, Impact Factor: 4.7275)
- **F Khalid**, I Dincer, M A Rosen “Techno-economic Assessment of a Solar-Geothermal Multigeneration System for Buildings” International Journal of Hydrogen Energy, 42, 21454-21462, Elsevier, 2017 (**SCI-Expanded indexed and Scopus-indexed**; Cited 25 times, Impact Factor: 4.939)

- **F Khalid**, M Aydin, I Dincer, M A Rosen “Comparative Assessment of Two Integrated Hydrogen Energy Systems Using Electrolyzers and Fuel Cells” International Journal of Hydrogen Energy, 41(44), 19836-19846, Elsevier, 2016 (*SCI-Expanded indexed and Scopus-indexed*; Cited 25 times, Impact Factor: 4.939)
- **F Khalid**, I Dincer, M A Rosen “Analysis and Assessment of an Integrated Hydrogen Energy System” International Journal of Hydrogen Energy 41(19), 7960-7967, Elsevier, 2016 (*SCI-Expanded indexed and Scopus-indexed*; Cited 60 times, Impact Factor: 4.939)
- **F Khalid**, I Dincer, M A Rosen “Analysis and Assessment of a Gas Turbine-Modular Helium Reactor for Nuclear Desalination” Journal of Nuclear Engineering and Radiation Science 2(3), 031014, ASME Transaction, 2016 (*Scopus-indexed*; Cited 10 times)
- **F Khalid**, I Dincer, M A Rosen “Techno-economic Assessment of a Renewable Energy Based Integrated Multigeneration System for Green Buildings” Applied Thermal Engineering 99, 1286-1294, Elsevier, 2016 (*SCI-Expanded indexed and Scopus-indexed*; Cited 50 times, Impact Factor: 4.725)
- **F Khalid**, I Dincer, M A Rosen “Comparative Assessment of CANDU 6 and Sodium-cooled Fast Reactors for Nuclear Desalination” Desalination, 379, 182-192, Elsevier, 2016 (*SCI and Scopus-indexed*; Cited 21 times, Impact Factor: 7.098)
- **F Khalid**, I Dincer, M A Rosen “Energy and Exergy Analyses of a Solar-Biomass Integrated Cycle for Multigeneration” Solar Energy 112, 290-299, Elsevier, 2015 (**One of the Most Cited Articles in Solar Energy Journal Since 2015, SCI and Scopus-indexed**; Cited 115 times, Impact Factor: 4.608)
- **F Khalid**, I Dincer, M A Rosen “Development and Analysis of Sustainable Energy Systems for Building HVAC Applications” Applied Thermal Engineering 87, 389-401, Elsevier, 2015 (*SCI-Expanded indexed and Scopus-indexed*; Cited 37 times, Impact Factor: 4.725)
- A Khaliq, R Kumar, I Dincer, **F Khalid** “Energy and Exergy Analyses of a New Triple-Stage Refrigeration Cycle Using Solar Heat Source” Journal of Solar Energy Engineering 136 (1), 011004, ASME Transaction, 2014 (*Science Citation Index Expanded*; Cited 14 times, Impact Factor: 1.641)
- A Khaliq, **F Khalid**, PB Sharma, I Dincer “Energetic and Exergetic Analyses of a Hydrogen-Fueled HCCI Engine for Environmentally Benign Operation” International Journal of Sustainable Energy, 33 (2), 367-385, Taylor and Francis, 2014 (*Scopus Indexed*; Cited 10 times)

PUBLICATIONS IN INTERNATIONAL CONFERENCES

- Y Bicer, **F Khalid** “Thermodynamic Evaluation of Two Step High Temperature Electrolytic Cycle for Methanol Production”, 11th International Exergy, Energy and Environment Symposium (IEEEES-11), July 14-18, Chennai, India, 2019
- **F Khalid**, Y Bicer “Comparative Assessment of Different High Temperature Electrolytic Methanol Production Cycles” World Energy Strategies Congress and Exhibition (WESCE’19), 26-28 August 2019, Istanbul, Turkey
- Y Bicer, **F Khalid** “Electrochemical modeling of molten salt-based electrolytic ammonia synthesis for solar fuel applications” 4th International Hydrogen Technologies Congress (IHTEC-2019), June 20-23, 2019, Edirne, Turkey
- **F Khalid**, M M Ali, Yusuf Bicer “Thermodynamic feasibility of a biomass and wind assisted system for electricity and synthetic methanol production” 8th Global Conference on Global Warming (GCGW-2019), 22-25 April, Doha, Qatar 2019 (**Abstract published**)
- M M Ali, **F Khalid**, Yusuf Bicer “Integrated Multigeneration System for Clean Biodiesel and Methanol Production from Waste Water Sludge” 8th Global Conference on Global Warming (GCGW-2019), 22-25 April, Doha, Qatar 2019 (**Abstract published**)
- Y Bicer, **F Khalid** “Thermodynamic feasibility of a two-step hydrogen chloride cycle for hydrogen production”. HEET 2018, 15-16 November, Nagoya, Japan.
- Y Bicer, **F Khalid** “Life Cycle Comparison of Solid Oxide Fuel Cells Fed by Methane, Hydrogen, Ammonia and Methanol for Power Generation in Qatar Conditions” 7th Global Conference on Global Warming (GCGW-2018), 24-28 June, Izmir, Turkey 2018
- **F Khalid**, Y Bicer “High Temperature Electrolysis of Hydrogen Bromide Gas in Two-Step Thermochemical Cycle for Hydrogen Production”, 10th International Exergy, Energy and Environment Symposium (IEEEES-10), July 1-4, Katowice, Poland, 2018

- **F Khalid**, I Dincer, M A Rosen “Techno-Economic Assessment of Solar-Geothermal Based Multigeneration System for a Community” 8th International Exergy, Energy and Environment Symposium (IEEEES-8), May 1-4, Antalya, Turkey, 2016
- **F Khalid**, I Dincer, M A Rosen “Analysis of an Integrated Hydrogen Energy System” International Conference on Hydrogen Production, University of Ontario Institute of Technology (UOIT), Oshawa, Canada, 2015

REFERRED BOOK CONTRIBUTIONS

- Y Bicer, **F Khalid** “Sustainability Assessment of Renewable-Energy Based Hydrogen and Ammonia Pathways”, Renewable-Energy-Driven Future: Technologies, Applications, Sustainability, and Policies, J Ren, Ed., Elsevier, 2021, pp: 435-468
- Materializing and Preparing Case Studies for a chapter in Integrated Energy Systems for Multigeneration by I Dincer and Y Bicer, 2019, 1st Edition, Elsevier
- I Dincer, M A Rosen, **F Khalid**, “Thermal Energy Production”, Comprehensive Energy System Vol. 3, I. Dincer, Ed. Elsevier, 2018, pp: 673-706
- I Dincer, M A Rosen, **F Khalid**, “Ocean (Marine) Energy Production”, Comprehensive Energy System Vol. 3, I. Dincer, Ed. Elsevier, 2018, pp: 335-379 (Cited 1 time)
- Preparation of examples and case studies for **Refrigeration Systems and Applications** by I. Dincer, 2017, 3rd Edition, Wiley Interscience
- Contribution of a book chapter in Exergy Analysis of Heating, Refrigerating, and Air Conditioning: Methods and Applications by I. Dincer and M A Rosen, 2015, 1st Edition, Elsevier

PRESENTATIONS/ LECTURES

Invited Talks/Lectures

- Sustainable Energy Systems, Department of Mechanical Engineering, Izmir Institute of Technology, 25th June, 2019, Izmir, Turkey
- Exergy Analysis of Industrial Processes, **Global Initiative of Academic Networks (GIAN) Course**, National Institute of Technology, Warangal, Telangana, India, February 11-15, 2019 (Served as the **principal speaker** of the course)
- Advanced Refrigeration System, **Global Initiative of Academic Networks (GIAN) Course**, National Institute of Technology, Rourkela, Orissa, India, December 17-22, 2018 (Served as the speaker for six days)
- Guest Lecture in SENR 744-Renewable Energy Systems taught by Dr. Yusuf Bicer about Ocean Energy and Hydropower, March 31st, 2019
- Guest Lecture in SENR 740-Energy Resources, Generation, Science and Technology taught by Dr. Yusuf Bicer about integrated energy systems, Nov 26th, 2018
- ORF Workshop: Clean Hydrogen Production with Water Splitting Technologies; Modeling and Implementation, Wednesday, June 14th, UOIT, Oshawa, Ontario, Canada, 2017
- ORF Workshop: Clean Hydrogen Production with Water Splitting Technologies, Monday, June 20th, UOIT, Oshawa, Ontario, Canada, 2016

Session Chair at International Conferences

- 12th International Exergy, Energy and Environment Symposium (IEEEES-12), December 20-24, 2020, Doha, Qatar
- Hydrogen & Fuel Cells; World Energy Strategies Congress and Exhibition (WESCE'19), 26-28 August 2019, Istanbul, Turkey

Conference Presentation

- World Energy Strategies Congress and Exhibition (WESCE'19), 26-28 August 2019, Istanbul, Turkey
- 11th International Exergy, Energy and Environment Symposium (IEEEES-11), July 14-18, Chennai, India, 2019
- 8th Global Conference on Global Warming (GCGW-2019), 22-25 April, Doha, Qatar, 2019
- 7th Global Conference on Global Warming (GCGW-2018), 24-28 June, Izmir, Turkey, 2018
- International Conference on Hydrogen Production, University of Ontario Institute of Technology (UOIT), May 3-6, Oshawa, Canada, 2015

Invited Graduate Student Presenter

- Participated as Invited Graduate Student Presenter in Research Day, Faculty of Engineering and Applied Science, University of Ontario Institute of Technology (UOIT), March 24, 2017, Oshawa, Canada, 2017

ACADEMIC EXPERIENCE

Assistant Professor, July 2020- till now

Department of Mechanical Engineering, ISU, Turkey

Post Doc Research Associate, 2018-2020

Division of Sustainable Development, College of Science and Engineering, HBKU, Qatar

- Carrying out research for water desalination and solar hydrogen production methods
- Guiding graduate students in their master's and PhD Studies

Teaching Assistant, September 2013- October 2017

Faculty of Engineering and Applied Science University of Ontario Institute of Technology, Canada

- Facilitating experiments on thermodynamics, fossil fuel and energy conversion, fluid mechanics and heat transfer for undergraduate students
- Conducting tutorials for fluid mechanics, and fossil fuel & energy conversion
- Solving and building EES algorithm for complex thermodynamics, fluid mechanics and heat transfer problems
- Weekly preparation and conducting of Lab for undergrads students
- Helping students to overcome difficulties in assigned subjects
- Monitoring progress and grading lab reports for undergrad students

AWARDS & HONORS

- Technical Consultant for International Atomic Energy Agency, Vienna, Austria
- UOIT Dean Scholarship for outstanding academics
- Topic Editor, Environment MDPI Journal (Scopus Indexed)
- Topic Editor, Atmosphere, MDPI Journal (SCIE Indexed; IF: 2.39)
- Guest Editor, International Journal of Hydrogen Energy, Elsevier
- Outstanding Reviewer Awards for Applied Thermal Engineering, Sustainable Energy Technologies and Assessment, and International Journal of Hydrogen Energy
- Nominated and selected for Young Scientist Award by Venus International Foundation, India
- **Google Scholar Citation: 547 (hitherto)**
- **Scopus Citation: 341**
- **H-index: 12, i10-index: 16**

SKILLS

- HOMER, Engineering Equation Solver (EES), MATLAB, MS Office, ASPEN Plus
- Thermodynamic feasibility analysis
- Technoeconomic analysis

PROFESSIONAL AFFILIATION

- **Topic Editor, Environments, MDPI Journal**
- **Topic Editor, Atmosphere, MDPI Journal**
- **Publication Committee Member, World Hydrogen Energy Conference (WHEC2022), Istanbul, Turkey**
- **Publication Committee Member, International Exergy, Energy and Environment Symposium (IEEEES-13), Mecca, Saudi Arabia**
- **Technical Committee Member, International Exergy, Energy and Environment Symposium (IEEEES-12), Doha, Qatar**
- **Reviewer Board Member for Sustainability, MDPI**

- **Reviewer Board Member for Membranes, MDPI**
- Reviewer for Frontiers in Energy Research, Frontiers
- Reviewer for Applied Energy, Elsevier
- Reviewer for Journal of Energy Storage, Elsevier
- Reviewer for Sustainable Cities and Society, Elsevier
- Reviewer for Energy and Conversion Management, Elsevier
- Reviewer for International Journal of Hydrogen Energy, Elsevier
- Reviewer for International Journal of Energy Research, Wiley Interscience
- Reviewer for Biofuel, Taylor and Francis
- Reviewer for Energy Storage, Wiley Interscience
- Reviewer for Energies, MDPI
- Reviewer for Sustainability, MDPI
- Reviewer for Applied Sciences, MDPI
- Reviewer for Energy, Elsevier
- Reviewer for Applied Thermal Engineering, Elsevier
- Reviewer for International Journal of Exergy (IJEX), Inderscience
- Reviewer for International Journal of Environmental Engineering (IJEE), Inderscience
- Reviewer for Transactions of the Canadian Society for Mechanical Engineering
- Reviewer for Entropy, MDPI
- Reviewer for Environments, MDPI
- Reviewer for Processes, MDPI
- Reviewer for Atmosphere, MDPI
- Reviewer for Molecules, MDPI
- Reviewer for Sustainable Energy Technologies and Assessment, Elsevier
- Reviewer for Biomass Conversion and Biorefinery, Springer
- Reviewer for Waste Disposal and Sustainable Energy, Springer
- Member at **International Association for Hydrogen Energy (IAHE)**
- Member at **World Society of Sustainable Energy Technologies (WSSET)**
- Member at **International Advisory Committee**, 3rd and 4th International Conference & Expo on Advances in Power Generation from Renewable Energy, Government Engineering College Banswara, Rajasthan, India

NAMES OF THE REFEREES

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Publications

Received: 1 March 2021 | Revised: 13 April 2021 | Accepted: 28 April 2021
DOI: 10.1002/er.7012

RESEARCH ARTICLE

INTERNATIONAL JOURNAL OF
ENERGY RESEARCH WILEY

Rapid assessment of integrated nuclear cogeneration projects using multi-criteria indices

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Summary

Nuclear power plants provide clean, carbon free, stable, reliable electricity and can offer nonelectric products and services via cogeneration operations to multiple sectors. This contributes to decarbonization of the current energy and industrial systems, supports climate change mitigation and adaptation efforts and ensures sustainable development over the long term, according to the United Nations Sustainable Development Goals (UN SDGs) framework and the provisions of the Conference of Parties 21 (COP21) Paris Agreement, 2015. This work surveys the potential role of nuclear cogeneration projects in meeting these objectives based on the current technological landscape. It focuses on nuclear assisted desalination for freshwater production and electrolytic hydrogen production as the use cases and suggests an assessment framework for their holistic evaluation. New integrated metrics and multi-criteria performance indicators beyond the levelized cost of production are developed to quantify the likely multi-dimensional impacts of such projects. The use of these for screening alternatives illustrates the fact that depending on weightage given to different criteria, different technologies may appear to be better suited to deployment under given set of conditions. These metrics are expected to be useful for creation of a decision support system for deployment of nuclear cogeneration projects.

KEYWORDS

climate change, desalination, hydrogen, multi-criteria indices, nuclear cogeneration, sustainable development goals

Electrochemical Modeling and Performance Assessment of H₂S/Air Solid Oxide Fuel Cell

Nurettin Sezer,* Farrukh Khalid, Yusuf Biçer, and Muammer Koç

Hydrogen sulfide (H₂S) is an abundantly present, corrosive, and noxious compound. Though the Claus process is effective in processing H₂S, it extracts minimal energy from H₂S. Solid oxide fuel cell (SOFC) can harvest the chemical energy of H₂S to generate electric power. For practical implementations, the performance of H₂S/air SOFCs and the potential losses in the system are determined. The present study aims to develop the complete electrochemical model of H₂S/air SOFC system and to analyze its performance. The theoretical cell potential of H₂S/air SOFC is determined, and the deviations from the theoretical cell potential due to polarization are studied. According to the results, H₂S/air SOFC generates electric power with energetic, exergetic, and voltaic efficiencies of 59.0%, 43.0%, and 89.7%, respectively, at atmospheric pressure and a temperature of 1100 K. Further efficiencies can be achieved if the output heat is utilized for useful applications. Moreover, the SO₂ formed by the electrochemical reactions in SOFC can be recovered as elemental sulfur or sulfuric acid as an additional useful commodity. In brief, this study demonstrates the performance of H₂S/air SOFC to serve as a basis for the implementation of H₂S/air SOFC toward eliminating the environmental impact of H₂S and converting it into electric power.

1. Introduction

Hydrogen sulfide (H₂S) is naturally present in aqueous form mainly in hot springs and in deep water in the Black Sea, and in gaseous form in the natural gas wells and natural gas hydrates.^[1,2] In addition, it is anthropogenically generated by the oil processing, coal gasification, and biomass processing industries.^[3] It is a highly corrosive and noxious pollutant. Therefore, stringent regulations have been imposed on H₂S emission by environmental enforcement agencies worldwide.^[4]

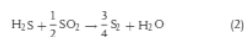
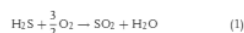
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Many known natural gas reserves have been either temporarily shut or permanently abandoned for the reason that one natural gas accompanied toxic component, H₂S, cannot be utilized at the reserve development area. Today, H₂S concentrations in the developed natural gas reserves can reach as high as 25 vol%, for example, in Astrakhan, Tengiz.^[5] It is anticipated that the processing of H₂S-rich natural gas reserves will further increase with mastering of deep gas deposits since it is known that the H₂S concentration increases with depth.

Today, the most widely used method of H₂S processing is the Claus process,^[5,6] which uses a two-step chemical cycle that can be summarized by the following reactions




The first step involves a noncatalytic combustion process (Reaction 1), through which the feed H₂S is partially oxidized to SO₂ and H₂O at ≈1400 K. The second step uses a catalytic process where the unreacted portion of H₂S reacts with SO₂ to obtain elemental sulfur and steam (Reaction 2).

Although it is effective in treating H₂S to protect human health, quite a little value is extracted from H₂S through the Claus process.^[1,6–9] Overall, this method produces elemental sulfur along with low-grade steam through the partial oxidation of H₂S with air.^[10] Instead of the low-grade steam, it would be possible to generate electrical power and high-grade steam if the combustion furnace in the first step of the Claus process is replaced by H₂S/air-fed solid oxide fuel cell (SOFC).^[11–13]

A fuel cell is an electrochemical device that directly converts the chemical energy of reactants into electricity.^[14,15] The basic components of a fuel cell system are porous anode, cathode, and an electrolyte membrane separating these two electrodes. Half-cell reactions take place in the cell anode and cathode with the continuous supply of fuel and oxidant to these electrodes, respectively. The mixing of the oxidant and fuel is prevented by the electrolyte membrane, which allows the passage of only ionic species. Fuel cells can be classified based on the type of electrolyte used in the cell.

SOFC is a promising energy conversion system since it has

Application of microfluidic paper-based analytical device (μ PAD) to detect COVID-19 in energy deprived countries

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Summary

Coronavirus disease (COVID-19) has spread all across the world. Low- and medium-income countries are more affected economically and socially compared to developed countries due to the lack of a rapid, robust, and affordable testing infrastructure. Furthermore, the high cost of real-time polymerase chain reaction (PCR) system, sophisticated user-handling procedure, and high expense of the conventional clinical tests are the root causes of the less accessibility of the testing systems to the users. In this study, a COVID-19 Point-of-Care (POC) ecosystem model is proposed for the low- and medium-income countries (or energy deprived countries) that will facilitate the technological development with locally available fabrication components. In addition, the nontechnological development phases have also been discussed, which encompasses the collaboration among academia, local as well as government bodies, and entrepreneurial ventures. In addition, a hypothetical design of a microfluidic paper-based analytical (μ PADs) POC platform is proposed to detect COVID-19 analyte using unprocessed patient-derived saliva, which is a miniaturized form-factor of conventional real-time polymerase chain reaction (PCR) technique. The device contains four major reaction zones, which are sample zone, buffer zone, loop-mediated isothermal amplification (LAMP) Master Mix zone, Ethylenediamine tetraacetic acid (EDTA) zone, and sensor zone. To obtain quicker test results and easier operation, a handheld image acquisition technique is introduced in this study. It is hypothesized that in a remote setting, the proposed design could be used as an initial guideline to develop a POC COVID-19 testing system, which may be simple, easy-to-use, and cost-effective.

KEYWORDS

COVID, microfluidic, Point-of-Care

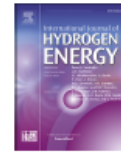
1 | INTRODUCTION

COVID-19 was first discovered in Hubei Province, China, in December 2019, which further spread globally due to human transmission. We have witnessed the rapid increase in the epidemiology of this disease across the

world, which resulted in personal, social, and economic losses to individuals. One such industry that is badly affected by the novel corona virus is the airline industry as most of the aviation operation is ceased resulting in greater economic losses.^{1,2} According to World Health Organization (WHO), PCR is the designated clinical

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Electrochemical modelling of ammonia synthesis in molten salt medium for renewable fuel production using wind power

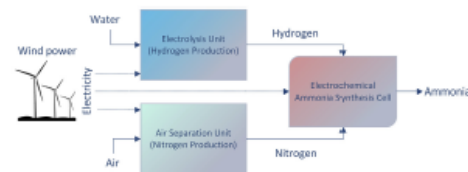
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HIGHLIGHTS

- Ammonia production is studied via an electrochemical process in molten salt medium.
- Electrochemical modeling is conducted via electrochemical impedance spectroscopy.
- A case study in Qatar is proposed for renewable ammonia production from wind energy.
- Renewable-based ammonia can play an important role for hydrogen and energy storage.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 25 October 2019
Received in revised form
23 February 2020
Accepted 5 March 2020
Available online 2 April 2020

Keywords:
Ammonia
Wind power
Electrochemical
Molten salt
Impedance
Ambient pressure

ABSTRACT

Ammonia is one of the most abundantly used chemicals in the world, and it is a potential hydrogen carrier for possible solutions of hydrogen storage and transportation. The conventional method of ammonia production is energy-intensive that requires high pressure and it is dominantly dependent on fossil fuels for hydrogen and nitrogen production. With the electrochemical synthesis option, ammonia can be produced at atmospheric pressures and lower temperature levels. Hydrogen production via water electrolysis using renewable energy can further reduce carbon emissions. In this work, ammonia production via an electrochemical process in a molten salt medium is modelled through electrochemical impedance spectroscopy using several equivalent circuit models. Then, afterwards, for a case study in Qatar to produce renewable ammonia, wind data are used to predict the annual ammonia production rates where the wind turbine rated power is 6 MW. The electrochemical modelling results show that two main parameters emerged as the most influential on the modelling of the low frequencies region; the capacitance of the electrolyte, and the capacitance of the electrode. Furthermore, it is found that the Warburg

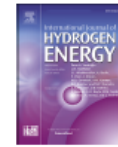
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<https://doi.org/10.1016/j.ijhydene.2020.03.085>

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Available online at www.sciencedirect.com

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journal homepage: www.elsevier.com/locate/he

Life cycle environmental impact comparison of solid oxide fuel cells fueled by natural gas, hydrogen, ammonia and methanol for combined heat and power generation

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ARTICLE INFO

Article history:

Received 4 September 2018

Received in revised form

13 November 2018

Accepted 16 November 2018

Available online 12 December 2018

Keywords:

Life cycle assessment

Environmental impact

Electrochemical conversion

Natural gas

Clean power production

ABSTRACT

This study aims to provide a comprehensive environmental life cycle assessment of heat and power production through solid oxide fuel cells (SOFCs) fueled by various chemical feeds namely, natural gas, hydrogen, ammonia and methanol. The life cycle assessment (LCA) includes the complete phases from raw material extraction or chemical fuel synthesis to consumption in the electrochemical reaction as a cradle-to-grave approach. The LCA study is performed using GaBi software, where the selected impact assessment methodology is ReCiPe 1.08. The selected environmental impact categories are climate change, fossil depletion, human toxicity, water depletion, particulate matter formation, and photochemical oxidant formation. The production pathways of the feed gases are selected based on the mature technologies as well as emerging water electrolysis via wind electricity. Natural gas is extracted from the wells and processed in the processing plant to be fed to SOFC. Hydrogen is generated by steam methane reforming method using the natural gas in the plant. Methanol is also produced by steam methane reforming and methanol synthesis reaction. Ammonia is synthesized using the hydrogen obtained from steam methane reforming and combined with nitrogen from air in a Haber-Bosch plant. Both hydrogen and ammonia are also produced via wind energy-driven decentralized electrolysis in order to emphasize the cleaner fuel production. The results of this study show that feeding SOFC systems with carbon-free fuels eliminates the greenhouse gas emissions during operation, however additional steps required for natural gas to hydrogen, ammonia and methanol conversion, make the complete process more environmentally problematic. However, if hydrogen and ammonia are produced from renewable sources such as wind-based electricity, the environmental impacts reduce significantly, yielding about 0.05 and 0.16 kg CO₂ eq., respectively, per kWh electricity generation from SOFC.

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<https://doi.org/10.1016/j.ijhydene.2018.11.122>

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