FN Clarivate Analytics Web of Science
VR 1.0
PT J
AU Pistorius, PC
AF Pistorius, Petrus Christiaan
TI Steelmaking Decarbonization Options with Current Technology
SO METALLURGICAL AND MATERIALS TRANSACTIONS B-PROCESS METALLURGY AND
MATERIALS PROCESSING SCIENCE
LA English
DT Article
AB Potential reduction in carbon intensity of steelmaking (for integrated plants and electric furnaces) is estimated, based on published consumption figures. The analysis shows that substantial reductions in carbon intensity are feasible with existing process options. In future, ironmaking with green hydrogen would be a competitive option should the anticipated reductions in the relative cost of green hydrogen be realized.
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Zhang W, 2021, STEEL RES INT, V92, DOI 10.1002/srin.202000326
NR 17
TC 3
Z9 4
U1 3
U2 23
PU SPRINGER
PI NEW YORK
PA ONE NEW YORK PLAZA, SUITE 4600, NEW YORK, NY, UNITED STATES
SN 1073-5615
EI 1543-1916
J9 METALL MATER TRANS B
JI Metall. Mater. Trans. B-Proc. Metall. Mater. Proc. Sci.
PD JUN
PY 2022
VL 53
IS 3
BP 1335
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DI 10.1007/s11663-022-02463-z
EA FEB 2022
PG 4
WC Materials Science, Multidisciplinary; Metallurgy & Metallurgical
Engineering
WE Science Citation Index Expanded (SCI-EXPANDED)
SC Materials Science; Metallurgy & Metallurgical Engineering

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PT J
AU Perpiñán, J
Bailera, M
Peña, B
Romeo, LM
Eveloy, V
AF Perpinan, Jorge
Bailera, Manuel
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TI Technical and economic assessment of iron and steelmaking decarbonization via power to gas and amine scrubbing
SO ENERGY
LA English
DT Article
DE Ironmaking; Power-to-gas; Iron and steel industry; Methanation; CO2 capture; Decarbonization
ID BLAST-FURNACE OPERATION; AIR SEPARATION; TO-GAS; CARBON; INJECTION; ENERGY; METHANATION; EMISSIONS; EXERGY; SYSTEM
AB The iron and steel industry is one of the most energy-intensive industries, emitting 5% of the total anthropogenic carbon dioxide (CO2). The control of CO2 emissions has become increasingly stringent in the European Union (EU), resulting in EU allowance above 90 euro/tCO2. Carbon capture will be required to achieve CO2 emissions control, and carbon utilization via power-to-gas could significantly increase interest in carbon capture in the iron and steel sector. This paper presents a new concept that combines amine scrubbing with power-to-gas to reduce emissions in blast furnace-basic oxygen furnace steelmaking plants. Synthetic natural gas (SNG) is produced using green hydrogen from water electrolysis and CO2 from steelmaking. The synthetic natural gas is later used as a reducing agent in the blast furnace, constantly recycling carbon in a closed loop and avoiding geological storage. The oxygen by-produced via electrolysis eliminates the necessity of an air separation unit. By applying these innovations to steelmaking, a reduction in CO2 emissions of 9.4% is obtained with an energy penalty of 16.2 MJ/kgCO2, and economic costs of 52 euro/tHM or 283 euro/tCO2. A sensitivity analysis with respect to electricity and the CO2 allowances prices is also performed.
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FU University of Zaragoza [UZ2020-TEC-06]; Khalifa University [CIRA-2020-080]; European Union's Horizon 2020 research and innovation program under the Marie Sklodowska-Curie grant agreement [887077]; RD project [PID2021-126164OB-I00, MCIN/AEI/10.13039/501100011033/]; ERDF A way of making Europe; Marie Curie Actions (MSCA) [887077] Funding Source: Marie Curie Actions (MSCA)
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NR 65
TC 15
Z9 15
U1 6
U2 26
PU PERGAMON-ELSEVIER SCIENCE LTD
PI OXFORD
PA THE BOULEVARD, LANGFORD LANE, KIDLINGTON, OXFORD OX5 1GB, ENGLAND
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JI Energy
PD AUG 1
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WE Science Citation Index Expanded (SCI-EXPANDED)
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PT J
AU Cavaliere, PD
Perrone, A
Silvello, A
AF Cavaliere, Pasquale Daniele
Perrone, Angelo
Silvello, Alessio
TI Water Electrolysis for the Production of Hydrogen to Be Employed in the Ironmaking and Steelmaking Industry
SO METALS
LA English
DT Review
DE water electrolysis; ironmaking; steelmaking; purification; desalinization; direct reduction; energy; renewables; high temperature; low temperature
ID ALKALINE; PERFORMANCE; SIMULATION; EFFICIENCY; SYSTEM
AB The way to decarbonization will be characterized by the huge production of hydrogen through sustainable routes. Thus, the basic production way is water electrolysis sustained by renewable energy sources allowing for obtaining "green hydrogen ". The present paper reviews the main available technologies for the water electrolysis finalized to the hydrogen production. We describe the fundamental of water electrolysis and the problems related to purification and/or desalinization of water before electrolysis. As a matter of fact, we describe the energy efficiency issues with particular attention to the potential application in the steel industry. The fundamental aspects related to the choice of high-temperature or low-temperature technologies are analyzed.
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NR 0
TC 30
Z9 31
U1 12
U2 91
PU MDPI
PI BASEL
PA MDPI AG, Grosspeteranlage 5, CH-4052 BASEL, SWITZERLAND
EI 2075-4701
J9 METALS-BASEL
JI Metals
PD NOV
PY 2021
VL 11
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AR 1816
DI 10.3390/met11111816
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WC Materials Science, Multidisciplinary; Metallurgy & Metallurgical
   Engineering
WE Science Citation Index Expanded (SCI-EXPANDED)
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PT J
AU Patnaik, D
   Pattanaik, AK
   Bagal, DK
   Rath, A
AF Patnaik, Dulu
   Pattanaik, Ajit Kumar
   Bagal, Dilip Kumar
   Rath, Arati
TI Reducing CO2 emissions in the iron industry with green hydrogen
SO INTERNATIONAL JOURNAL OF HYDROGEN ENERGY
LA English
DT Article
DE CO 2 emissions; Green hydrogen; Renewable energy
ID STEEL-INDUSTRY; ENERGY; IRONMAKING
AB The different methods of producing Green Hydrogen have been discussed in detail in this article. The implications and significance of employing green hydrogen in the steel and iron industries have been brought to light. Carbon Dioxide (CO2) is a significant environmental gas pollutant which is released in large quantities by steel mills and other industrial facilities. It is hoped that the appropriate measures would be taken to minimize the emission of hazardous gases, such as CO2, from each facility. The green hydrogen idea is a new technology that is being used as an alternative energy source for the sectors listed above. The most important step in reducing CO2 emissions is to collect it and store it in a secure location. In this article, the main goal and scope is to analyse various methodologies to minimize CO2 emissions in Iron and Steel Industries as well as compare with noble green hydrogen technology. Here, the state of art for the emission of CO2 as well as the recommendations of Green Hydrogen Technology are emphasized which is the novelty of this article.& COPY; 2023 Hydrogen Energy Publications LLC. Published by Elsevier Ltd. All rights reserved.
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NR 41
TC 31
Z9 31
U1 6
U2 35
PU PERGAMON-ELSEVIER SCIENCE LTD
PI OXFORD
PA THE BOULEVARD, LANGFORD LANE, KIDLINGTON, OXFORD OX5 1GB, ENGLAND
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JI Int. J. Hydrog. Energy
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WC Chemistry, Physical; Electrochemistry; Energy & Fuels
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SC Chemistry; Electrochemistry; Energy & Fuels
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PT J
AU Roshchin, VE
   Drozin, AD
   Gamov, PA
   Smirnov, KI
AF Roshchin, V. E.
   Drozin, A. D.
   Gamov, P. A.
   Smirnov, K. I.
TI Decarbonization of Steelmaking from the Standpoint of the Electronic
   Theory of Metal Reduction
SO RUSSIAN METALLURGY
LA English
DT Article
DE <bold>Keywords:</bold> decarbonization; "green" hydrogen; "green" steel;
   solid-phase reduction; electronic reduction theory; reduction kinetics
   and thermodynamics; electrolysis
AB The necessity of restructuring the existing steelmaking scheme is justified not only under the pressure of environmental decarbonization requirements, but also under the need to bring steelmaking technologies in line with the level of modern science. The scientific basis of new reduction technologies is shown to be the electronic theory of metal oxidation/reduction, which allows one to consider the thermodynamic and kinetic conditions of processes with partial or complete replacement of fossil carbon-containing reducing agents with hydrogen from a unified standpoint. A comparison of two well-known technologies with zero carbon dioxide emission, namely, iron reduction with "green" hydrogen or iron production by electrolysis of ore, shows a multiple advantage of electrolysis in terms of energy consumption and more favorable kinetic conditions for its implementation. It is concluded that, when an industry development strategy is designed, priority should be given to the electrolysis of ore rather than to the production and use of green hydrogen. The use of hydrogen as a reducing agent can be justified for selective iron extraction from complex ores in plants, such as plasma mine furnaces, plasma reactors, and suspended-slurry reduction reactors, where nitriding would also take place to transform soft iron into steel along with reduction.
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CR decarbonization, H2 Green Steel is Building a Hydrogen-Powered 2.5Billion Euros Steel Mill
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TI Future Scenarios for Reducing Emissions and Consumption in the Italian
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SO STEEL RESEARCH INTERNATIONAL
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DE carbon capture; CO2 emissions reduction; green investment; steelmaking;

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ID CARBONATE FUEL-CELLS; CO2 CAPTURE; ENERGY-PRODUCTION; DIRECT REDUCTION; STEEL PRODUCTION; BIOMASS; IRON; TECHNOLOGY; BIOENERGY; FURNACE
AB The amount of CO2 emissions, water and electricity consumption, and soil exploitation of the main steel production routes (integrated cycle, scrap recycling, and direct reduction) are analyzed applying three possible future scenarios: use of carbon capture and storage (CCS); use of green hydrogen in substitution of natural gas; use of biomethane. Using actual process data and theoretical assumptions, the emissions and consumptions of the whole steel production cycle (from the iron ore extraction to the final steel product) are computed, taking into account also the auxiliary sources of emissions (i.e., limestone calcination and gas compression). The assessment results have highlighted the huge energy requirements and soil exploitation related to the application of green hydrogen in the steelmaking cycle, despite its low CO2 emissions. On the contrary, the use of biomethane appears more attractive if combined with carbon capture and storage systems. Overall, the results of the assessment provide a starting point for understanding the current level of sustainability of steel production and allow the identification of the most promising and plausible scenario for the steel industry of the future and the possible criticalities of each.
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TI Towards low-carbon steel: System dynamics simulation of policies impact
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SO ENERGY POLICY
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DE Green hydrogen; Steel industry; Carbon reduction; Policy; System
   dynamics
ID COST
AB Green hydrogen (GH) has been included in the steel emission reduction plans of many countries. This study evaluates the status quo of GH and steel industry and the related subsidy and regulatory policies in two major steelmaking countries/regions: China and the European Union. A system dynamics model coupling GH and steel industry is established to conduct simulation analysis of the low-carbon transition path of GH replacing fossil fuels in these two countries/regions' steel industry under several carbon emission reduction scenarios. Results verify the feasibility of using GH in the steelmaking and GH's contribution to the steel industry's carbon emission reduction. And this study assesses the policy impacts on the development of green hydrogen steel and gives specific policy implications on the timing and measures. The methodology and policy tools in this study also provide the reference for other countries who are still in wait-and-see attitude towards the development of GH steel.
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TI Process of Transformation to Net Zero Steelmaking: Decarbonisation Scenarios Based on the Analysis of the Polish Steel Industry
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DE decarbonisation; steel industry; Poland; scenarios; net zero steelmaking
ID DIRECT REDUCED IRON; GREEN HYDROGEN; CO2 EMISSIONS; GAS; DECARBONIZATION; GASIFICATION; TECHNOLOGIES; TRANSITION; EFFICIENCY; REDUCTION
AB The European steel industry is experiencing new challenges related to the market situation and climate policy. Experience from the period of pandemic restrictions and the effects of Russia's armed invasion of Ukraine has given many countries a basis for including steel along with raw materials (coke, iron ore, electricity) in economic security products (CRMA). Steel is needed for economic infrastructure and construction development as well as a material for other industries (without steel, factories will not produce cars, machinery, ships, washing machines, etc.). In 2022, steelmakers faced a deepening energy crisis and economic slowdown. The market situation prompted steelmakers to impose restrictions on production volumes (worldwide production fell by 4% compared to the previous year). Despite the difficult economic situation of the steel industry (production in EU countries fell by 11% in 2022 compared to the previous year), the EU is strengthening its industrial decarbonisation policy ("Fit for 55"). The decarbonisation of steel production is set to accelerate by 2050. To sharply reduce carbon emissions, steel mills need new steelmaking technologies. The largest global, steelmakers are already investing in new technologies that will use green hydrogen (produced from

renewable energy sources). Reducing iron ore with hydrogen plasma will drastically reduce CO2 emissions (steel production using hydrogen could emit up to 95% less CO2 than the current BF + BOF blast furnace + basic oxygen furnace integrated method). Investments in new technologies must be tailored to the steel industry. A net zero strategy (deep decarbonisation goal) may have different scenarios in different EU countries. The purpose of this paper was to introduce the conditions for investing in low-carbon steelmaking technologies in the Polish steel market and to develop (based on expert opinion) scenarios for the decarbonisation of the Polish steel industry.
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TI Characteristics and applications of iron oxide reduction processes
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DT Article
DE ironmaking; iron oxides; reduction; extractive metallurgy; green hydrogen
ID MGO-DOPED FE2O3; CAO AND/OR MGO; NATURAL-GAS INJECTION; GASEOUS REDUCTION; CARBON-MONOXIDE; SMELTING-REDUCTION; STEPWISE REDUCTION; WHISKER FORMATION; ORE SINTER; HEMATITE
AB The present review handles the main characteristics of iron oxide reduction and its industrial applications. The reduction of iron oxide is the basis of all ironmaking processes, whether in a blast furnace or by direct reduction and/or direct smelting processes. The reduction characteristics of iron ores control the efficiency of any ironmaking process and the quality of the produced iron as well. Many controlling parameters should be considered when discussing the reducibility of iron ores such as equilibrium phase diagrams, reduction temperature, pressure, gas composition, and the nature of both iron ores and reducing agent. The different factors affecting the main routes of ironmaking will be highlighted in the present review to give a clear picture of each technology. Moreover, further innovations regarding the reduction of iron oxides such as the reduction by green hydrogen will be discussed.
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NR 91
TC 1
Z9 1
U1 10
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PU SCIENDO
PI WARSAW
PA BOGUMILA ZUGA 32A, WARSAW, MAZOVIA, POLAND
SN 1509-8117
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J9 POL J CHEM TECHNOL
JI Pol. J. Chem. Technol.
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AU Halim, KSA
El-Geassy, AA
Nasr, MI
Ramadan, M
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AF Halim, K. S. Abdel
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TI Characteristics and applications of iron oxides reduction processes
SO POLISH JOURNAL OF CHEMICAL TECHNOLOGY
LA English
DT Article
DE ironmaking; iron oxides; reduction; extractive metallurgy; green hydrogen
ID NATURAL-GAS INJECTION; GASEOUS REDUCTION; SMELTING-REDUCTION; CARBON-MONOXIDE; FE2O3 COMPACTS; ORE SINTER; HEMATITE; BEHAVIOR; DECOMPOSITION; KINETICS
AB The present review handles the main characteristics of iron oxide reduction and its industrial applications. The reduction of iron oxide is the basis of all ironmaking

processes, whether in a blast furnace or by direct reduction and/or direct smelting processes. The reduction characteristics of iron ores control the efficiency of any ironmaking process and the quality of the produced iron as well. Many controlling parameters should be considered when discussing the reducibility of iron ores such as equilibrium phase diagrams, reduction temperature, pressure, gas composition, and the nature of both iron ores and reducing agent. The different factors affecting the main routes of ironmaking will be highlighted in the present review to give a clear picture for each technology. Moreover, further innovations regarding the reduction of iron oxides such as reduction by green hydrogen will be discussed.
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FU Scientific Research Deanship at University of Ha'il - Saudi Arabia [RG-22 028]
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PT J
AU Yi, SH
Lee, WJ
Lee, YS
Kim, WH
AF Yi, Sang-Ho
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Kim, Wan-Ho
TI Hydrogen-Based Reduction Ironmaking Process and Conversion Technology
SO KOREAN JOURNAL OF METALS AND MATERIALS
LA Korean
DT Article
DE ironmaking; reduction; CO2; H-2
ID CARBON-DIOXIDE; GAS; KINETICS
AB This study analyzed the current state of technical development of the BF-based process, to determine ways to reduce carbon consumption. The technical features of the hydrogen reduction ironmaking process were also examined as a decarbonized ironmaking method, and related issues that should be considered when converting to hydrogen reduction are discussed. The coal rate consumed by the reduction reaction in the coal-based BF process should be less than 50%. The heat requirement for indirect reduction in hydrogen reduction is higher than that of CO reduction, since hydrogen reduction is endothermic. The BF-based integrated steel mill is an energy independent process, since coal is used for the reduction of iron ore and melting, and the by-product gases evolved from the BF process are utilized for reheating the furnace, the power plant, and steam production. For hydrogen reduction, only green hydrogen should be used for the reduction of iron ore, and the power required to melt the iron and for the downstream rolling process will have to be provided from the external grid. Therefore, to convert to hydrogen reduction, green power should be supplied from an external infrastructure system of the steel industry. It will be necessary to discuss an optimized pathway for the step-by-step replacement of current coal-based facilities, and to reach agreement on the socio-economic industrial transition to hydrogen reduction steel.
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JI Korean J. Met. Mater.
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SC Materials Science; Metallurgy & Metallurgical Engineering
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PT J
AU Watari, T
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TI Global demand for green hydrogen-based steel: Insights from 28 scenarios
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LA English
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DE Zero emissions; Hydrogen Economy; Direct reduction; Resource efficiency
ID IRON
AB Growing expectations are being placed on green hydrogen-based steel for decarbonising the global steel industry. However, the scale of the expected demand is dispersed across numerous case studies, resulting in a fragmented picture. This study examines 28 existing scenarios to provide a cohesive view of future global demand. In the short term, the demand for green hydrogen-based steel is expected to be limited, constituting 2% of current total steel production by 2030. However, a transformation phase is expected around 2040, marked by accelerated growth. By 2050, global demand is projected to reach 660 Mt (with an interquartile range of 368-1000 Mt), equivalent to 35% (19%-53%) of current total steel production. To meet such growing demand, green hydrogen supply and electrolyser capacity will need to increase to more than 1000 times current levels by 2050. These trends highlight both short-term limitations and long-term potential. Decarbonisation efforts will therefore require immediate emission reductions with already scalable options, while simultaneously building the enabling infrastructure for green hydrogen-based steelmaking to ensure long-term impacts.
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FU JSPS KAKENHI [24K03142, 22K18433]; Environment Research and Technology Development Fund [JPMEERF20223001]
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TI Enabling the transition to a fossil-free steel sector: The conditions
   for technology transfer for hydrogen-based steelmaking in Europe
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DT Article
DE Hydrogen; Iron and steel; Industry; Decarbonisation; Energy; Climate
ID INNOVATION; ENERGY; PERSPECTIVES; TYPOLOGY; INDUSTRY; IRON
AB Deep decarbonisation of energy-intensive industries, such as steel production, will be required to achieve the European Union's climate targets. Green hydrogen technology has the potential to reduce the carbon dioxide emissions from iron and steelmaking to nearly zero and mitigate climate change from the industrial sector. The paper is based on an ongoing case in Sweden, where the established firms SSAB, LKAB, and Vattenfall are operating the HYBRIT joint venture. This paper aims to explore the conditions for transferring this technology from Sweden to three primary steel producing countries in Europe: Germany, France and Italy. As a theoretical point of departure, we integrate some concepts from the multi-level perspective and technology transfer theories to better

understand transition pathways for hydrogen-based steel production in Europe. We use a case study methodology, including the analysis of more than 20 qualitative interviews and secondary data. The findings of the study conclude that the Swedish iron and steel industry is unique in many ways, yet other European countries are rapidly catching up in hydrogen-based steel production, particularly Germany. Sweden however remains unique in its nearly zero carbon electricity generation and low-cost electricity prices, which can enable green hydrogen production throughout the country. In order to overcome the barriers and create an enabling environment for hydrogen-based steel production, it is key that energy and industry transitions are aligned, that a policy framework that supports these transitions is in place, and that key actors representing all aspects of these transitions cooperate, from industry and research, to academia, policymakers, and civil society.
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AU Eshkaftaki, AT
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AF Eshkaftaki, Amin Taji
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TI In-house green hydrogen production for steelmaking decarbonization using
   steel slag as thermal energy storage material: A life cycle assessment
SO ENERGY
LA English
DT Article
DE Green hydrogen production; Solid oxide electrolyzer; Waste heat
   recovery; Thermal energy storage; Steel slag; Life cycle assessment
ID ELECTRIC-ARC FURNACE; SYSTEM

AB Steel production is a highly energy-intensive industry, responsible for significant greenhouse gas emissions. Electrification of this sector is challenging, making green hydrogen technology a promising alternative. This research performs a thermodynamic analysis of green hydrogen production for steel manufacturing using the direct reduction method. Four solid oxide electrolyzer (SOE) modules replace the traditional reformer to produce 2.88 kg/s of hydrogen gas, serving as a reducing agent for iron pellets to yield 30 kg/s of molten steel. These modules are powered by 37,801 photovoltaic units. Additionally, a thermal storage system utilizing 1342 tons of steel slag stores waste heat from Electric Arc Furnace (EAF) exhaust gases. This stored energy preheats iron scraps charged into the EAF, reducing energy consumption by 5 %. A life cycle assessment, conducted using open LCA software, reveals that the global warming potential (GWP) for the entire process, with a capacity of 30 kg/s, equates to 93 kg of CO2. The study also assesses other environmental impacts such as acidification potential, ozone formation, fine particle formation, and human toxicity. Results indicate that the EAF significantly contributes to global warming and fine particle formation, while the direct reduction process notably impacts ozone formation and acidification potential.
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TI Trends in the global steel industry: Evolutionary projections and
   defossilisation pathways through power-to-steel
SO JOURNAL OF CLEANER PRODUCTION
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DT Article
DE Steel production; Decarbonisation; Industry evolution; Steel recycling;
   Hydrogen direct reduction; Electrowinning
ID DIRECT REDUCTION; ENERGY SYSTEM; IRON; FUTURE; CO2; BIOMASS;
   OPPORTUNITIES; CAPTURE; CEMENT; STEELMAKING
AB Steel production is a carbon and energy intensive activity, releasing 1.9 tons of CO2 and requiring 5.17 MWh of primary energy per ton produced, on average, globally, resulting in 9% of all anthropogenic CO2 emissions. To achieve the goals of the Paris Agreement of limiting global temperature increase to below 1.5 degrees C compared to pre-industrial levels, the structure of the global steel production must change fundamentally. There are several technological paths towards a lower carbon intensity for steelmaking, which bring with them a paradigm shift decoupling CO2 emissions from crude steel production by transitioning from traditional methods of steel production using fossil coal and fossil methane to those based on low-cost renewable electricity and green hydrogen. However, the energy system consequences of fully defossilised steelmaking has not yet been examined in detail. This research examines the energy system requirements of a global defossilised power-to-steel industry using a GDP-based demand model for global steel demands, which projects a growth in steel demand from 1.6 Gt in 2020 to 2.4 Gt in 2100. Three scenarios are developed to investigate the emissions trajectory, energy

demands, and economics of a high penetration of direct hydrogen reduction and electrowinning in global steel production. Results indicate that the global steel industry will see green hydrogen demands grow significantly, ranging from 2809 to 4371 TWhH2 by 2050. Under the studied conditions, global steel production is projected to see reductions in final thermal energy demand of between 38.3% and 57.7% and increases in total electricity demand by factors between 15.1 and 13.3 by 2050, depending on the scenario. Furthermore, CO2 emissions from steelmaking can be reduced to zero.
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FU Tekes [40101/14]; Business Finland [8588/31/2019]; Academy of Finland [329313]; LUT University Research Platform 'GreenRenew'; Academy of Finland (AKA) [329313] Funding Source: Academy of Finland (AKA)
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TI Iron-Ore Reduction Using Green Hydrogen: A Study for Recycling Wastes in
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   Developing Tomorrow's Technical Cycles
CY FEB 27-MAR 03, 2022
CL Anaheim, CA
SP Minerals Metals & Mat Soc
DE Egyptian steelmaking industry; Direct reduction process; CO2 emissions;
   Blast furnace-basic oxygen furnace; Waste imported lump iron ores
AB A new prospective in the Egyptian steelmaking industry using pure hydrogen to reduce waste iron ores in a two-stage fluidized bed reactor through direct reduction process is presented, modeled, and analyzed. The main advantage of applying this route to the steel industry is the enormous reduction in CO2 emissions compared to today's dominant routes that rely on the blast furnace-basic oxygen furnace (BF/BOF). Moreover, the hydrogen direct reduction (H-DR) process could be directly applied for the reuse of the waste imported lump iron ores that are been crashed during the transportation process to a small fines particles; making them unusable in blast furnace processes unless sintering process is applied. A complete study to verify the applicability of this idea in Egypt has been investigated and comparing it to current fluidized bed reactor using syngas as the reducing agent.
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CR [Anonymous], 2013, WORLD DIRECT REDUCTI
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TI Global trade of green iron as a game changer for a near-zero global steel industry? - A scenario-based assessment of regionalized impacts
SO ENERGY AND CLIMATE CHANGE
LA English
DT Article
DE Green iron trade; Global steel decarbonization; Scenario analysis; Hydrogen direct reduction; Climate change mitigation
ID CAPTURE
AB The currently most promising approach for reducing CO2 emissions of the global steel production is reducing iron ore in shaft furnaces with (green) hydrogen instead of blast furnaces. Unlike to the liquid iron produced in blast furnaces, the direct reduced iron produced in this route (green iron) exists in a solid state and can be transported at reasonable costs over long distances. This allows for spatial decoupling of the iron reduction step from the steelmaking step and may lead to global trade in green iron as a new intermediate product in the steelmaking value chain. This article assesses the potential impact of a global green iron trade in terms of shifting energy demand between regions and in terms of cost savings by comparing three scenarios for a global near-zero GHG steel industry: The Domestic scenario, assuming strict regional co-location of green iron and steel production; The Max Trade scenario, assuming early emergence of a global green iron market and the Intermediate Trade scenario, assuming late emergence of a global green iron market. In the trade scenarios, 12-21% of global crude steel is produced from traded green iron in 2050. 15-26 Mt/a of hydrogen consumption is relocated to global "sweet spots", resulting in cost savings of 2.2-3.9% of the global annual steel production costs, which can provide important support for the development of net zero steel production. Enablers and barriers for global green iron trade are discussed.
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TI Mitigating emissions in the global steel industry: Representing CCS and
   hydrogen technologies in integrated assessment modeling
SO INTERNATIONAL JOURNAL OF GREENHOUSE GAS CONTROL
LA English
DT Article
DE Carbon capture; Hydrogen; Steel production; Decarbonization; Integrated
   assessment
ID CO2 CAPTURE; REANALYSIS; IRON
AB We conduct a techno-economic assessment of two low-emissions steel production
technologies and evaluate their deployment in emissions mitigation scenarios utilizing
the MIT Economic Projection and Policy Analysis (EPPA) model. Specifically, we assess
direct reduced iron-electric arc furnace with carbon capture and storage (DRI-EAF with
CCS) and H2-based direct reduced iron-electric arc furnace (H2 DRI-EAF) which utilizes
low carbon hydrogen to reduce CO2 emissions. Our techno-economic analysis based on the
current state of technologies found that DRI-EAF with CCS increased costs-7% relative to
the conventional steel technology. H2 DRI-EAF increased costs by-18% when utilizing Blue
hydrogen and-79% when using Green hydrogen. The exact pathways for hydrogen production in
different world regions, including the extent of CCS and hydrogen deployment in
steelmaking are highly speculative at this point. In illustrative scenarios using EPPA,
we find that, using base cost assumptions, switching from BF-BOF to DRI-EAF or scrap EAF
can provide significant emissions mitigation within steelmaking. With further reductions
in the cost of advanced steelmaking, we find a greater role for DRI-EAF with CCS, whereas
reductions in both the cost of advanced steelmaking and hydrogen pro-duction lead to a
greater role for H2 DRI-EAF. Our findings can be used to help decision-makers assess
various decarbonization options and design economically efficient pathways to reduce
emissions in the steel industry. Our cost evaluation can also be used to inform other
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energy-economic and integrated assessment models designed to provide insights about future decarbonization pathways.
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AU Swennenhuis, F
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TI Towards a CO₂-neutral steel industry: Justice aspects of CO₂ capture and storage, biomass- and green hydrogen-based emission reductions
SO ENERGY RESEARCH & SOCIAL SCIENCE
LA English
DT Article
DE Carbon dioxide capture and storage; Biomass-based steelmaking; Hydrogen-based steelmaking; Just transition; Steel industry; Sustainability transitions
ID ENERGY JUSTICE; ENVIRONMENTAL JUSTICE; PROCEDURAL JUSTICE; CARBON CAPTURE; SOCIAL DIMENSIONS; SOLAR-ENERGY; COAL; TRANSITIONS; POVERTY; EMPLOYMENT
AB A rapid transition towards a CO2-neutral steel industry is required to limit climate change. Such a transition raises questions of justice, as it entails positive and negative impacts unevenly distributed across societal stakeholders. To enable stakeholders to address such concerns, this paper assesses the justice implications of three options that reduce emissions: CO2 capture and storage (CCS) on steel (up to 70%), bio-based steelmaking (up to 50%), and green hydrogen-based steel production (up to 100%). We select justice indicators from the energy, climate, labour and environmental justice literature and assess these indicators qualitatively for each of the technological routes based on literature and desk research. We find context-dependent differences in justness between the different technological routes. The impact on stakeholders varies across regions. There are justice concerns for local communities because of economic dependence on, and environmental impact of the industry. Communities elsewhere are impacted through the siting of infrastructure and feedstock production. CCS and biobased steelmaking routes can help retain industry and associated economic benefits on location, while hydrogen based steelmaking may deal better with environmental concerns. We conclude that, besides techno-economic and environmental information, transparency on sector-specific justice implications of transforming steel industries is essential for decision-making on technological routes.
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AB Hydrogen direct reduction is one of the technological process solutions for making steel, explored in the framework of reducing GHG emissions from the steel sector (Net-Zero steel). However, there are many other solutions, which have been explored since the 1980s or earlier. The present paper starts by comparing all these different options in terms of 3 criteria: energy needs, GHG emissions and total production cost of steel. The extensive simulations carried out as part of the ULCOS Program, which are still fully valid, indeed show that, while energy is always rather close to the efficient integrated steel mill benchmark (within 15-20%), there are a series of solutions for significantly cutting GHG emissions, some of which even leading to negative emissions. Two families of solutions can usefully be compared with each other, as they are both based on the use of electricity: hydrogen direct reduction, from green hydrogen generated from green electricity, and electrolysis of iron ore, such as the Sigma IDERWIN process, also based on zero-carbon electricity. They are quite close with regards to the 3 above criteria, with a slight advantage for electrolysis. Focusing now on hydrogen steelmaking, the process developed over the last 70 years: the H-Iron process was first explored in 1957 at laboratory level, then it was followed by an industrial first plant in the late 1980s, which did not fully deliver (CIRCORED); a sub-project within ULCOS (2000s) followed, then some projects in Germany and Austria (SALCOS, SUSTEEL, MATOR, based on direct reduction and smelting reduction, 2010s) and then, very recently, occurred an explosion of projects and announcements of industrial ventures, both for generating hydrogen and for producing DRI, located in Europe, Russia and China. Broader questions are then tackled: how much hydrogen will be called upon, compared to today and future needs, regarding in particular H-2-e-mobility; carbon footprint and costs; maturity of the various processes; and geopolitical issues, such as possible locations of H-2-generation and H-2-steel production.
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AU Li, HF
Chen, JR
AF Li, Haifeng
Chen, Jingran
TI An Analysis of Long-Process Ironmaking in a Reduction Smelting Furnace with Hydrogen-Enriched Conditions
SO METALS
LA English
DT Article
DE long process; hydrogen metallurgy; oxygen; low carbon; reduction smelting furnace
ID OXYGEN BLAST-FURNACE; COURSE50 PROJECT; GAS INJECTION; IRON
AB The blast furnace and basic oxygen furnace (BF-BOF) is still the main process used for the production of iron and steel in China. With the approach of the "dual carbon" target, the iron and steel industry needs to transform and upgrade to "green" and "low-carbon" practices. At present, the low-carbon hydrogen metallurgy technology route based on hydrogen instead of carbon is mainly adopted at home and abroad, and the domestic route is mainly based on oxygen-rich BFs and hydrogen-based shaft furnaces (SFs). It promotes the transformation of the traditional BF to hydrogen-rich, oxygen-rich, and carbon-recycled (Hy-O-CR) technology. A new ironmaking system and method for a reduction smelting furnace (RSF) with Hy-O-CR is presented in this paper. The ironmaking system includes nine sets of equipment, such as an RSF, gas dust collector, dryer, CO_2 separator, electrolytic water device, blower, heat exchanger, storage tank of reduction gas, and chimney. From top to bottom, the RSF includes an indirect reduction zone, a soft melting dripping zone, and a coke combustion zone. The ironmaking methods include coke and ore mixed charging, injection of the mixed reduction gas composed of electrolytic green hydrogen and circulating gas from the furnace gas into the indirect reduction zone, injection of oxygen into the coke combustion zone, CO_2 recovery of the furnace top gas, and slag and iron treatment. By redesigning the size of the furnace type and optimizing the parameters, the metallization rate of the indirect reduction zone can be as high as 85-95%, and the carbon consumption per ton of hot metal can be greatly reduced. By using oxygen to recycle the reduction gas produced by its reactor, the process achieves the goal of reducing CO_2 emissions by more than 50%, thus realizing green and low-carbon metallurgy.
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TI Optimum investment strategy for hydrogen-based steelmaking project
   coupled with multiple uncertainties
SO JOURNAL OF ENVIRONMENTAL MANAGEMENT
LA English
DT Article
DE Hydrogen steelmaking project; Multiple uncertainties; Real options
   model; Optimum investment decision
ID REAL OPTIONS; TECHNOLOGY; POLICY; IRON
AB The large-scale application of hydrogen steelmaking technology is expected to substantially accelerate the decarbonization process of the iron and steel industry. However, hydrogen steelmaking projects are still in the experimental or demonstration stage, and scientific investment decision-making methods are urgently needed to support the large-scale development of the technology. When assessing the investment value, existing studies usually only consider the intrinsic project value under a specific pathway, while ignoring the option value under realistic multiple uncertainties in terms of technology, market, and policy, leading to an underestimation of the investment value. To address this issue, this study constructs a real options model to explore the optimal investment timing and revenue of the hydrogen steelmaking project, by taking into account multi-dimensional uncertainties stemming from price fluctuations in the steel market, the development of the carbon market, and technological advances. Additionally, the impacts of various subsidy policies on the investment strategy are also investigated. Least Squares Monte Carlo method is applied to overcome computational challenges posed by dynamic programming under multi-dimensional uncertainties. The results show that: (i) Investment is not recommended based on current crude steel price and hydrogen price. (ii) When the annual reduction rate of hydrogen price reaches 5%, the optimal investment timing would advance to 2036. (iii) On this basis, with the introduction of a 20% green hydrogen subsidy policy, the optimal investment timing would be further brought forward to 2033. The implementation of tax incentives would significantly increase the investment value. The investment value would surge from 170 million CNY to 262 million CNY as the tax rate decreases from 20% to zero. The findings could provide reasonable suggestions for investment decisions under realistic volatile environments, as well as scientific references for policy design, thus facilitating the large-scale and high-level development of hydrogen-based steelmaking technology.
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TI Green hydrogen in the iron and steel industry increases resilience
   against shocks in energy prices
SO ENVIRONMENTAL RESEARCH LETTERS
LA English
DT Article
DE green hydrogen; hard-to-abate sectors; climate policy; steel industry
   decarbonization; energy security; integrated assessment model
ID OPTIONS; TRENDS; COST
AB Geopolitical tensions and conflicts can disrupt energy markets, threatening international energy supply security and imposing financial stress on energy-intensive industries reliant on imported fossil fuels. Exploring the challenges and opportunities associated with supply diversification is crucial for understanding the potential for hard-to-abate industry decarbonization under the risk of future energy price shocks. In this context, we investigate the role of green hydrogen as a viable and sustainable alternative to natural gas applications in iron and steel manufacturing. We first quantify how the integration of green hydrogen into the existing infrastructure can complement stringent climate action ambitions in reducing CO2 emissions over the next five decades. We find that green hydrogen acts as a transitional technology, enabling a gradual shift towards electrification of heat supply while bridging the gap until low-carbon steel technologies become commercially feasible. Furthermore, we assess the

benefits of timely green hydrogen investments in mitigating the economic repercussions of unforeseen natural gas price surges. Overall, this study underscores the potential of green hydrogen in decarbonizing the iron and steel industry while promoting energy independence, but it also highlights its contingency on sufficiently ambitious climate policies and adequate technological advancements.
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TI Minimum Emissions Configuration of a Green Energy-Steel System: An Analytical Model
SO ENERGIES
LA English
DT Article
DE green steel; green hydrogen; renewable energy; analytical model
ID DIRECT REDUCTION; ENVIRONMENTAL-IMPACT; IRON-ORE; BIOMASS; PERFORMANCE; GENERATION; INDUSTRY; FURNACE
AB The need to significantly reduce emissions from the steelmaking sector requires effective and ready-to-use technical solutions. With this aim, different decarbonization strategies have been investigated by both researchers and practitioners. To this concern, the most promising pathway is represented by the replacement of natural gas with pure hydrogen in the direct reduced iron (DRI) production process to feed an electric arc furnace (EAF). This solution allows to significantly reduce direct emissions of carbon dioxide from the DRI process but requires a significant amount of electricity to power electrolyzers adopted to produce hydrogen. The adoption of renewable electricity sources (green hydrogen) would reduce emissions by 95-100% compared to the blast furnace-basic oxygen furnace (BF-BOF) route. In this work, an analytical model for the identification of the minimum emission configuration of a green energy-steel system consisting of a secondary route supported by a DRI production process and a renewable energy conversion system is proposed. In the model, both technological features of the hydrogen steel plant and renewable energy production potential of the site where it is to be located are considered. Compared to previous studies, the novelty of this work consists of the joint modeling of a renewable energy system and a steel plant. This allows to optimize the overall system from an environmental point of view, considering the availability of green hydrogen as an inherent part of the model. Numerical experiments proved the effectiveness of the model proposed in evaluating the suitability of using green hydrogen in the

steelmaking process. Depending on the characteristics of the site and the renewable energy conversion system adopted, decreases in emissions ranging from 60% to 91%, compared to the BF-BOF route, were observed for the green energy-steel system considered It was found that the environmental benefit of using hydrogen in the secondary route is strictly related to the national energy mix and to the electrolyzers' technology. Depending on the reference context, it was found that there exists a maximum value of the emission factor from the national electricity grid below which is environmentally convenient to produce DRI by using only hydrogen. It was moreover found that the lower the electricity consumption of the electrolyzer, the higher the value assumed by the emission factor from the electricity grid, which makes the use of hydrogen convenient.
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AU Lopez, G
   Galimova, T
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TI Towards defossilised steel: Supply chain options for a green European
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SO ENERGY
LA English
DT Article
DE Hydrogen direct reduction; Decarbonised steel; Supply chains; Green
   hydrogen
ID HYDROGEN INFRASTRUCTURE; TECHNOECONOMIC ANALYSIS; ENERGY USE; AMMONIA;
   REDUCTION; SCENARIOS; EMISSIONS; STORAGE; SECTOR; RAISE
AB As the European Union intensifies its response to the climate emergency, increased focus has been placed on the hard-to-abate energy-intensive industries. Primary among these is the steel industry, a cornerstone of the Eu-ropean economy and industry. With the emergence of new hydrogen-based steelmaking options, particularly through hydrogen direct reduction, the structure of global steel production and supply chains will transition from being based on low-cost coal resources to that based on low-cost electricity and therefore hydrogen production. This study examines the techno-economic options for three European countries of Germany, Spain, and Finland under five different steel supply chain configurations compared to local production. Results suggest that the high costs of hydrogen transportation make a European steelmaking supply chain cost competitive to steel produced with imported hydrogen, with local production costs ranging from 465 to 545 euro/t of crude steel (CS) and 380-494 euro/tCS for 2030 and 2040, respectively. Conversely, imports of hot briquetted iron and crude steel from Morocco become economically competitive with European supply chains. Given the capital and energy intensive nature of the steel industry, critical investment decisions are required in this decade, and this research serves to provide a deeper understanding of supply chain options for Europe.
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AF Superchi, Francesco
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TI Techno-economic analysis of wind-powered green hydrogen production to
   facilitate the decarbonization of hard-to-abate sectors: A case study on
   steelmaking
SO APPLIED ENERGY
LA English
DT Article
ID INTEGRATED STEELMAKING; ELECTROLYSIS; ENERGY; BIOMASS; STORAGE; IRON;
   COST
AB Green hydrogen is among the most promising energy vectors that may enable the decarbonization of our society. The present study addresses the decarbonization of hard-to-abate sectors via the deployment of sustainable alternatives to current technologies and processes where the complete replacement of fossil fuels is deemed not nearly immediate. In particular, the investigated case study tackles the emission reduction potential of steelmaking in the Italian industrial framework via the implementation of dedicated green hydrogen production systems to feed Hydrogen Direct Reduction process, the main alternative to the traditional polluting routes towards emissions abatement. Green hydrogen is produced via the coupling of an onshore wind farm with lithium-ion batteries, alkaline type electrolyzers and the interaction with the electricity grid. Building on a power generation dataset from a real utility-scale wind farm, techno-economic analyses are carried out for a large number of system configurations, varying components size and layout to assess its performance on the basis of two main key parameters, the levelized cost of hydrogen (LCOH) and the Green Index (GI), the latter presented for the first time in this study. The optimal system design and operation logics are investigated accounting for the necessity of providing a constant mass flow rate of H2 and thus considering the interaction with the electricity network instead of relying solely on RES surplus. In-house-developed models that account for performances degradation over time of different technologies are adapted and used for the case study.

The effect of different storage technologies is evaluated via a sensitivity analysis on different components and electricity pricing strategy to understand how to favour green hydrogen penetration in the heavy industry. Furthermore, for a better comprehension and contextualization of the proposed solutions, their emission-reduction potential is quantified and presented in comparison with the current scenario of EU-27 countries. In the optimal case, the emission intensity related to the steel-making process can be lowered to 235 kg of CO2 per ton of output steel, 88 % less than the traditional route. A higher cost of the process must be accounted, resulting in an LCOH of such solutions around 6.5 euro/kg.
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NR 83
TC 48
Z9 48
U1 11
U2 29
PU ELSEVIER SCI LTD
PI London
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SN 0306-2619
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J9 APPL ENERG
JI Appl. Energy
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WC Energy & Fuels; Engineering, Chemical
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PT J
AU Rechberger, K
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AF Rechberger, Katharina
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Wolfmeir, Hermann
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TI Green Hydrogen-Based Direct Reduction for Low-Carbon Steelmaking
SO STEEL RESEARCH INTERNATIONAL
LA English
DT Article
DE CO(2)emissions; direct reduction; energy demand; hydrogen; natural gas
ID FURNACE; IRON
AB The European steel industry aims at a CO(2)reduction of 80-95% by 2050, ensuring that Europe will meet the requirements of the Paris Agreement. As the reduction potentials of the current steelmaking routes are low, the transfer toward breakthrough-technologies is essential to reach these goals. Hydrogen-based steelmaking is one approach to realize CO2-lean steelmaking. Therefore, the natural gas (NG)-based direct reduction (DR) acts as a basis for the first step of this transition. The high flexibility of this route allows the gradual addition of hydrogen and, in a long-term view, runs the process with pure hydrogen. Model-based calculations are performed to assess the possibilities for injecting hydrogen. Therefore, NG- and hydrogen-based DR models are developed to create new process know-how and enable an evaluation of these processes in terms of energy demand, CO2-reduction potentials, and so on. The examinations show that the hydrogen-based route offers a huge potential for green steelmaking which is strongly depending on the carbon footprint of the electricity used for the production of hydrogen. Only if the carbon intensity is less than about 120 g CO2 kWh(-1), the hydrogen-based process emits less CO(2)than the NG-based DR process.
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Raabe, D
AF Ma, Yan
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Raabe, Dierk
TI Reducing Iron Oxide with Ammonia: A Sustainable Path to Green Steel
SO ADVANCED SCIENCE
LA English
DT Article
DE ammonia; autocatalytic reaction; carbon dioxide emissions; iron oxide; renewable energy; sustainable iron making
ID ALKALINE-SOLUTION; HYDROGEN; ENERGY; REDUCTION; DECOMPOSITION; CATALYST; FE; DISSOCIATION; STEELMAKING; ADSORPTION
AB Iron making is the biggest single cause of global warming. The reduction of iron ores with carbon generates about 7% of the global carbon dioxide emissions to produce approximate to 1.85 billion tons of steel per year. This dramatic scenario fuels efforts to re-invent this sector by using renewable and carbon-free reductants and electricity. Here, the authors show how to make sustainable steel by reducing solid iron oxides with hydrogen released from ammonia. Ammonia is an annually 180 million ton traded chemical energy carrier, with established transcontinental logistics and low liquefaction costs. It can be synthesized with green hydrogen and release hydrogen again through the reduction reaction. This advantage connects it with green iron making, for replacing fossil reductants. the authors show that ammonia-based reduction of iron oxide proceeds through an autocatalytic reaction, is kinetically as effective as hydrogen-based direct reduction, yields the same metallization, and can be industrially realized with existing technologies. The produced iron/iron nitride mixture can be subsequently melted in an electric arc furnace (or co-charged into a converter) to adjust the chemical composition to the target steel grades. A novel approach is thus presented to deploying intermittent renewable energy, mediated by green ammonia, for a disruptive technology transition toward sustainable iron making.
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OI Ma, Yan/0000-0002-1206-7822; Jovicevic-Klug, Matic/0000-0003-2783-4649; Li, Kejiang/0000-0002-7807-8241
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PA 111 RIVER ST, HOBOKEN 07030-5774, NJ USA

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WE Science Citation Index Expanded (SCI-EXPANDED)
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AU Diez, JR
   Tomé-Torquemada, S
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   Reyes, Jon
   Orcajo, G. Alonso
TI Decarbonization Pathways, Strategies, and Use Cases to Achieve Net-Zero
   CO₂ Emissions in the Steelmaking Industry
SO ENERGIES
LA English
DT Article
DE decarbonization; steelmaking industry; renewable energy; green hydrogen;
   CO2 reduction; scrap; energy efficiency strategies; hydrogen
   integration; steel production; DRI
ID HOT-ROLLING MILL; CARBON CAPTURE; STEEL; IRON; TECHNOLOGY; OPTIONS
AB The steelmaking industry is responsible for 7% of global CO2 emissions, making decarbonization a significant challenge. This review provides a comprehensive analysis of current steel-production processes, assessing their environmental impact in terms of CO2 emissions at a global level. Limitations of the current pathways are outlined by using objective criteria and a detailed review of the relevant literature. Decarbonization strategies are rigorously evaluated across various scenarios, emphasizing technology feasibility. Focusing on three pivotal areas-scrap utilization, hydrogen integration, and electricity consumption-in-depth assessments are provided, backed by notable contributions from both industrial and scientific fields. The intricate interplay of technical, economic, and regulatory considerations substantially affects CO2 emissions, particularly considering the EU Emissions Trading System. Leading steel producers have established challenging targets for achieving carbon neutrality, requiring a thorough evaluation of industry practices. This paper emphasizes tactics to be employed within short-, medium-, and long-term periods. This article explores two distinct case studies: One involves a hot rolling mill that utilizes advanced energy techniques and uses H-2 for the reheating furnace, resulting in a reduction of 229 kt CO2-eq per year. The second case examines DRI production incorporating H-2 and achieves over 90% CO2 reduction per ton of DRI.
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AU Sen, PK
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AF Sen, Prodip Kumar
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TI Climate Change and Emission Reduction Pathways for a Large Capacity Coal-Based Steel Sector: Implementation Issues
SO TRANSACTIONS OF THE INDIAN INSTITUTE OF METALS
LA English
DT Review
DE Climate change; Emission; Energy; Iron and steel sector; Blast furnace; Alternative routes of ironmaking; Circularity; Process redesign
ID POSTCOMBUSTION CAPTURE; BLAST-FURNACE; CARBON; IRON; CO2; BIOMASS; SIMULATION; INJECTION; INDUSTRY; MILL
AB Following the international climate change policy and the major use of coal-based blast furnace-basic oxygen furnace (BF-BOF) in the steel sector, with an average emission of 2.0 t CO2/t steel, alternative processing routes must be considered to reduce the emission intensities. An approach of progressive amalgamation with alternative gas and renewable energy-based processes is indicated for a coal-based sector. The approach also retains coal use for major production with technology changes like smelting reduction technology, HISARNA with carbon capture and storage, or top gas recycling blast furnace. Combining renewable energy-based 'green electrolytic hydrogen' processes with/without natural gas with existing coal-based processing is an important option in achieving global climate change targets for emission reduction. Capacity limitations of alternative processing routes and high green hydrogen costs are hurdles to overcome in progressive amalgamation. An approach to redesigning mixed circuits for minimizing sectoral emissions involving BF-BOF with available scrap is presented.
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TI Greenhouse gas reduction and economic cost of technologies using green
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SO JOURNAL OF ENVIRONMENTAL MANAGEMENT
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DT Article
DE Hydrogen; Renewable electricity; Steelmaking; Greenhouse gas; Byproduct
   gas -to -chemicals; Economic analysis
ID PERFORMANCE; CO2
AB Reducing greenhouse gas (GHG) emissions from the steel industry is one of the top priorities for mitigating climate change. Although hydrogen has been considered as a key element to accomplish this task, the effects of various hydrogen-using technologies in steel mills have not been analysed and compared to each other. This paper quantitatively analysed the greenhouse gas reduction in steel mills by the use of hydrogen produced from electrolysis with renewable electricity. The four following methods of using green hydrogen were proposed and analysed: 1) use of hydrogen directly in the hydrogen steelmaking process, 2) use of hydrogen to convert byproduct gases produced from steel mills into methanol, 3) use hydrogen to convert the byproduct gases into methane, and 4) sell hydrogen to the hydrogen station and use of oxygen, another product of electrolysis, to reduce the use of air separating unit in steel mills. Not only the greenhouse gas reduction benefits but also the economic cost of these four methods were evaluated. As those results can vary according to country, the economic cost and GHG reduction benefits were determined for the representative steel-producing countries of China, India, Japan, the United States, Russia, South Korea, and Germany. The economic cost was evaluated not only for the present (2020) but also for the future (similar to 2040) because these methods are more likely to be implemented in the future. Currently, in the representative steel-producing countries, Method 1 was analysed to have the largest GHG reduction among the four methods; but it also showed the largest cost because of its large capital expenditures and electricity cost. Method 2, which converts the byproduct gases into methanol, was shown to offer larger GHG reduction and smaller economic cost than Method 3, which converts the byproduct gases into methane. Comparing Methods 1 and 2, Method 2 offered smaller GHG reduction but a much smaller economic cost than Method 1. Although the cost of Method 4 is currently the smallest, the economic cost of Method 2 is predicted to become lower than that of Method 4 in the future, near 2030, because the future prices of hydrogen and the CO2 allowance are expected to decrease and increase, respectively. These results can be utilized when steelmaking country or steelmaking company make their decision on how to decrease the GHG emissions by using green hydrogen.
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Z9 20
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PI LONDON
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J9 J ENVIRON MANAGE
JI J. Environ. Manage.
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WC Environmental Sciences
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PT J
AU Perpiñán, J
   Bailera, M
   Peña, B
   Romeo, LM
   Eveloy, V
AF Perpinan, Jorge
   Bailera, Manuel
   Pena, Begona
   Romeo, Luis M.
   Eveloy, Valerie
TI High oxygen and SNG injection in blast furnace ironmaking with Power to
   Gas integration and CO2 recycling
SO JOURNAL OF CLEANER PRODUCTION
LA English
DT Article
DE Steel industry; Oxygen blast furnace; Power -to -Gas; Amine scrubbing;
   Decarbonization
ID PART II; EXERGY; ENERGY; CAPTURE; PLANTS; MITIGATION; SYSTEM
AB In the last years, reduction of CO2 emissions from the steel industry has been of great importance. Carbon capture, oxygen blast furnaces and top gas recycling technologies, among others, have been deeply studied as low carbon solutions. In this paper, a novel integration of carbon capture and power to gas technologies in the steelmaking industry is presented. Green hydrogen via proton exchange membrane (PEM) electrolysis and CO2 via methyldiethanolamine (MDEA) scrubbing from the blast furnace gas (BFG) are used to produce synthetic natural gas in an isothermal fixed bed methanation plant. The latter gas is injected into the blast furnace, closing a carbon loop and reducing coal consumption. The oxygen by-produced in the electrolyser covers the entire oxygen demand of the steelmaking plant and avoids the need for an air separation unit (ASU). The novelty of this work relies on the variation of the oxygen enrichment and its temperature in the hot blast, and how it influences the power to gas integration concept. This power to gas integration is compared with a conventional BF-BOF plant from a technical, economic, energy and environmental point of view. Both plant process configurations were implemented in Aspen Plus simulations, assessing the fossil fuel

demand, energy penalty, cost and CO2 emissions. Emission reduction up to 34% can be achieved with power to gas integration, with an energy penalty of 17 MJ/tHM and a cost of 352 euro/tCO2.
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FU Khalifa University [CIRA-2020-080]; European Union's Horizon 2020 research and innovation program under the Marie Sklodowska-Curie grant [887077]; MCIN/AEI [TED2021-130000B-I00]; European Union NextGenerationEU/PRTR; University of Zaragoza; Fundacion Bancaria Ibercaja; Fundacion CAI, through the program "Programa Ibercaja-Cai Estancias de Investigacion" [IT 16/12]; Marie Curie Actions (MSCA) [887077] Funding Source: Marie Curie Actions (MSCA)
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Z9 18
U1 8
U2 33
PU ELSEVIER SCI LTD
PI London
PA 125 London Wall, London, ENGLAND
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JI J. Clean Prod.
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SC Science & Technology - Other Topics; Engineering; Environmental Sciences
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PT J
AU Maruoka, N
Purwanto, H
Akiyama, T
AF Maruoka, Nobuhiro
Purwanto, Hadi
Akiyama, Tomohiro
TI Exergy Analysis of Methane Steam Reformer Utilizing Steelmaking Waste
Heat
SO ISIJ INTERNATIONAL

LA English
DT Article
DE steam reforming; hydrogen production; system evaluation; exergy
   analysis; waste heat recovery; steelmaking
ID PHASE-CHANGE MATERIAL; CARBON-DIOXIDE EMISSION; HYDROGEN-PRODUCTION;
   TRANSPORTATION SYSTEM; LATENT-HEAT; FEASIBILITY; RECOVERY; INDUSTRY;
   CONSUMPTION; IRONMAKING
AB System analysis was conducted on a proposed combined system for methane steam reforming comprising conventional hydrogen production and waste heat recovery from steelmaking. Operating data for a conventional methane steam reforming system were collected and analyzed. The results showed that the conventional system utilized only 60% of the natural gas as raw material and the rest is consumed for supplying the reaction heat for methane steam reforming. On the basis of this data, the proposed system was evaluated on five factors-natural gas consumption, enthalpy flow, CO(2) emission, cost, and exergy loss. For the proposed system, the factors were only 59.6%, 59.7%, 62.8%, 86.5%, and 65.8% of those of the conventional system, respectively. This supports the feasibility of hydrogen production from recovered waste heat. Furthermore, the proposed system is expected to contribute to the production of 'green' hydrogen that incurs less CO(2) emission.
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FU New Energy and Industrial Technology Development Organization (NEDO),
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FX This research was partially supported by the New Energy and Industrial
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U2 16

PU IRON STEEL INST JAPAN KEIDANREN KAIKAN
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SN 0915-1559
J9 ISIJ INT
JI ISIJ Int.
PY 2010
VL 50
IS 9
SI SI
BP 1311
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WC Metallurgy & Metallurgical Engineering
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PT C
AU Boldrini, A
Koolen, D
Crijns-Graus, W
van den Broek, M
AF Boldrini, Annika
Koolen, Derck
Crijns-Graus, Wina
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GP IEEE
TI The demand response potential of a hydrogen-based iron and steel plant
SO 2022 18TH INTERNATIONAL CONFERENCE ON THE EUROPEAN ENERGY MARKET, EEM
SE International Conference on the European Energy Market
LA English
DT Proceedings Paper
CT 18th International Conference on the European Energy Market (EEM)
CY SEP 13-15, 2022
CL Ljubljana, SLOVENIA
DE Demand Response; Direct reduction of iron; Electricity Markets;
Flexibility; Green Hydrogen; Iron and Steel Industry
AB The decarbonisation of the iron and steel industry (ISI) plays an important role in the European ambition to become climate neutral by 2050. The electrification of manufacturing processes and green hydrogen utilisation could, however, put a strain on existing power systems. The aim of this study is to assess the potential of demand response (DR) in decarbonising the ISI. We thereby look at the hydrogen-based direct reduction of iron with electric arc furnace (H2-DRI-EAF), which is currently regarded as the primary technology to decarbonise the industry but it also is the most power intensive low-carbon technology. A linear programming (LP) model is developed to assess the flexibility potential of an exemplary European steel plant that minimises electricity operating costs while maintaining steel production levels. The largest benefits are achieved when increasing the electrolyser size to operate at the times of lowest electricity prices.
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NR 20
TC 0
Z9 0
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PI NEW YORK
PA 345 E 47TH ST, NEW YORK, NY 10017 USA
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WC Green & Sustainable Science & Technology; Economics; Energy & Fuels;
   Engineering, Electrical & Electronic
WE Conference Proceedings Citation Index - Science (CPCI-S); Conference Proceedings
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SC Science & Technology - Other Topics; Business & Economics; Energy &
   Fuels; Engineering
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PT J
AU Devlin, A
   Mykhnenko, V
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AF Devlin, Alexandra
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   Zagoruichyk, Anastasiia
   Salmon, Nicholas
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TI Techno-economic optimisation of steel supply chains in the clean energy

transition: A case study of post-war Ukraine
SO JOURNAL OF CLEANER PRODUCTION
LA English
DT Article
DE Green steel; Green iron; Supply chains; Energy transition; Ukraine; European Union
ID IRON; OPTIONS
AB The steel industry's clean energy transition can enable new market creation and economic growth stimulation. Yet, the most efficient and feasible pathway to decouple the sector from fossil fuels remains unclear, particularly within developing nations and unstable socio-political contexts. Here, a blueprint for reconfiguring plant locations and reallocating resources is developed through a Ukrainian case study under two scenarios, which capture potential post-war conditions. Framed by regrowth of Ukraine's export-oriented steel industry and prospective European Union accession, green iron and steel trade strategies are devised. A steel supply chain optimisation model underpins the techno-economic, spatially granular analysis of energy and material flows, which utilises the inputs from a separate cost-minimised renewable energy, green hydrogen, and green ammonia production model. Results show that optimal supply chain configurations rely on mixed emissions-free energy profiles, the emergence of new steelmaking sites nearby high-quality renewables, regional alliances for green iron and steel market creation, and multi-billion-dollar investment. Mature nuclear and hydro power critically reduce costs in the near-term, whilst the rapid expansion of solar and wind energy infrastructure underpins production system scale-up. To simultaneously rebuild the 22 million-tonnes-a-year Ukrainian steel industry and transition to nearzero emissions by 2050, infrastructure investment surmounts to $62 billion, given full liberation of Ukrainian territory. Near-term investment is necessary to ease the pace of change, and although mobilising capital of this magnitude will be challenging, convincing carbon prices favour decarbonisation efforts.
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OI Soldak, Myroslava/0000-0002-4762-3083; Mykhnenko, Vlad/0000-0001-8944-0608
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TI Dynamic modeling of a direct reduced iron shaft furnace to enable pathways towards decarbonized steel production
SO CHEMICAL ENGINEERING SCIENCE
LA English
DT Article
DE Green steel; Hydrogen; Industrial decarbonization; Direct reduced iron; Dynamic modeling
ID DIRECT REDUCTION; CARBON-MONOXIDE; HEAT-TRANSFER; GAS; SIMULATION; METHANE; PERFORMANCE; PELLETS; FLOW
AB Steel production can be decarbonized by utilizing direct reduced iron (DRI) shaft furnaces that use green hydrogen or a mixture of green hydrogen and natural-gas-derived syngas. To further the implementation of these steel decarbonization methods, the development of a physics-based dynamic model of a DRI shaft furnace is presented and its applications are shown through transient case studies. The model is validated with industrial data and has mean average errors of 0.3 wt% for outlet solids composition and 1.2 mol% for outlet gas composition. Transient results are presented for a furnace shifting from syngas to a mix of syngas and green hydrogen as well as a furnace using only hydrogen that varies hydrogen flow and the inlet reducing gas temperature. The model can simulate 4-hour transient tests in under 3 min on a modest computer, highlighting its future use for control algorithm development, plant-scale simulations, and online, real-time, model predictions.
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TI Carbon reduction cost of hydrogen steelmaking technology in China
SO ENERGY
LA English
DT Article
DE Hydrogen supply chain; Hydrogen-based steelmaking; Steelmaking costs;
   Emission reduction costs; Greenhouse-gas emissions; China
ID CYCLE ENERGY-CONSUMPTION; GREENHOUSE-GAS EMISSIONS; STEEL PRODUCTION;
   BLAST-FURNACE; SIMULATION; IRON
AB Hydrogen energy is a key deep de-carbonization technology option for steel production. This study aims to provide a reference for the selection of technological routes by conducting a fair comparison with the evaluation of other deep de-carbonization technologies, such as scrap-based electric arc furnace (EAF) steelmaking, under the same research framework. This study updates the direct/indirect GHG emissions and steelmaking costs of blast furnace-basic oxygen furnace (BF-BOF), scrap-based EAF, fossil fuel-based direct reduced iron (DRI), hydrogen steelmaking, and CCS technologies in China. Using the H-DR (part) process can only achieve a 43.4 % reduction compared to BF-BOF, while the H-DR (full) process results in GHG emissions comparable to scrap-EAF. The study also discusses the unit abatement costs of hydrogen steelmaking technology compared to other emission reduction technologies. The cost of H-DR (full) is 6186 RMB/tcs, which is twice that of BF-BOF and 1.3 times that of scrap-EAF. The main conclusions are that green hydrogen steelmaking is expected to achieve nearzero emissions and can complement scrap-based EAF. The abatement costs of pure hydrogen steelmaking are relatively high, but by using partial hydrogen or by-product hydrogen, the abatement costs can be reduced to the level of scrap-based EAF.
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PT J
AU Ammasi, A
Karthik, PMR
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AF Ammasi, A.
Karthik, P. M. Rahul
Vishal, D.
TI Slag-Metal- Refractory Interactions During Dissolution of Hydrogen-Based

Directly Reduced Iron (H-DRI) in Liquid Iron Melt
SO JOURNAL OF SUSTAINABLE METALLURGY
LA English
DT Article
DE Hydrogen-based DRI; Green steelmaking; Slag-metal-refractory
interaction; Thermodynamic modelling
AB The steel industry is regarded as the most critical industry in the nation and is crucial to economic prosperity; however, its high energy use and carbon emissions significantly impact climate change and global warming. In view of achieving carbon neutrality, one of the most promising technologies is using green hydrogen gas as a reductant for producing carbon emission-free direct reduced iron (H-DRI) from iron ores/pellets. Moreover, the produced H-DRI is subsequently used for steel making in the induction furnace/electric arc furnace. However, the study on the melting behavior of H-DRI, interaction among slag and metal produced from H-DRI with refractory during the steel making in induction furnace/electric arc furnace has yet to be thoroughly studied. Therefore, in this study, DRI's dissolution/melting behavior in the liquid iron at 1600 +/- 10 degrees C has been studied. Then, interactions among slag generated during the melting/dissolution of DRI, refractory of the induction furnace, and metal produced from H-DRI have been studied using the SEM backscatter electron method. The thermodynamics modelling for the slag formation and interactions among slag-metal-refractory systems have been studied using FactSage 8.2. The penetration of iron from a liquid melt into porous refractory and the formation of complexes like mullite, spinal, and olivine has been observed. The boundaries between the slag-metal-refractory system and the dissolution of Mg and Fe have been identified using backscattered electron mode. Thermodynamics modelling has been validated with experimental observations.
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AU Wang, R
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AF Wang, Rou
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Paymooni, Khadijeh
Honeyands, Tom
TI Sticking in Shaft Furnace and Fluidized Bed Ironmaking Processes: A
Comprehensive Review Focusing on the Effect of Coating Materials
SO METALLURGICAL AND MATERIALS TRANSACTIONS B-PROCESS METALLURGY AND
MATERIALS PROCESSING SCIENCE
LA English
DT Review
ID FINE IRON-ORE; DOPED FE2O3 COMPACTS; CAO AND/OR MGO; DIRECT REDUCTION;
METALLIC IRON; STEPWISE REDUCTION; SWELLING BEHAVIOR; GASEOUS REDUCTION;
CARBON-MONOXIDE; STEEL-INDUSTRY
AB Production of direct reduced iron (DRI), particularly with green hydrogen, is a key pathway to the decarbonization of the iron and steel industry. However, the sticking tendency during the production of DRI creates serious operational issues and limits production outputs. Coating inert materials on the surface of iron ores can act as a barrier to effectively prevent the bonding between newly formed iron surfaces, and can interfere with the formation of iron whiskers. However, the principle of coating has not been systematically studied. This review covers the mechanism of sticking in both shaft furnaces and fluidized bed-based gaseous DRI production. The factors that influence the reduction kinetics and morphology, including physical and chemical ore properties, pellet induration conditions, and reduction conditions are summarized as well. Understanding the relationship between these factors and morphology change is critical to eliminating the sticking issues of DRI. Findings from this study suggest that coating with inert additives (e.g., metal oxides) can successfully prevent sticking in both shaft furnaces and fluidized bed processes. The types of additives and coating methods, the stage of reduction where the coating is applied, and reduction temperature will dramatically affect the coating performance. The outlook is discussed as well given the need for further work to improve the performance of coating (methods, timing, and cheaper alternatives), to further de-risk DRI technologies.
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Babich, A
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TI Hydrogen direct reduction (H-DR) in steel industry-An overview of
challenges and opportunities
SO JOURNAL OF CLEANER PRODUCTION
LA English
DT Article
DE Carbon emissions; H-2 production; Green hydrogen; Hydrogen direct
reduction (H-DR); Feasibility assessment
ID PROGRESS; FUTURE

AB The steel industry is considered the most important basic industry and is crucial role for strengthening the national economy; however, its high energy intensity and carbon emissions render it a major contributor to global warming and climate change. To reduce the carbon footprint of the steel industry, and ultimately achieve the vision of carbon neutrality, countries and steel companies around the world are engaged in developing low-carbon steelmaking technologies. Hydrogen direct reduction (H-DR) technology, which uses 100% green H-2 rather than conventional natural gas in the process, is currently considered the most promising technology. Thus, in this study, the feasibility of H-DR technology was discussed from the perspective of green hydrogen production and process adaptability. In the short term, the economic feasibility of H-DR is heavily dependent on the low-cost green hydrogen or high carbon emissions, the low efficiency of process and carbon-free product are problems that need to be solved, and H-2-rich shaft furnace direct reduction technology is considered a key transitional technology. In the long term, 80-90% of carbon emissions can be avoided on application of H-DR in the steel industry; therefore, the widespread application of H-DR technology is expected to be a milestone in the transition of the steel industry to cleaner production.
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OI Wang, Rongrong/0000-0002-9326-0324
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Z9 154
U1 15
U2 111
PU ELSEVIER SCI LTD
PI London
PA 125 London Wall, London, ENGLAND
SN 0959-6526
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J9 J CLEAN PROD
JI J. Clean Prod.
PD DEC 20
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WC Green & Sustainable Science & Technology; Engineering, Environmental;
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PT J
AU Li, S
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AF Li, Shuo
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Dewil, Raf
Baeyens, Jan
Deng, Yimin
TI The Direct Reduction of Iron Ore with Hydrogen
SO SUSTAINABILITY
LA English
DT Article
DE hydrogen; iron ore; direct reduction; fluidized bed; solar energy
ID MAGNETITE CONCENTRATE PARTICLES; KINETICS; BEHAVIOR; GAS; FLUIDIZATION; STEELMAKING; DESIGN; POWDER; ENERGY; FINES
AB The steel industry represents about 7% of the world's anthropogenic CO2 emissions due to the high use of fossil fuels. The CO2-lean direct reduction of iron ore with hydrogen is considered to offer a high potential to reduce CO2 emissions, and this direct reduction of Fe2O3 powder is investigated in this research. The H-2 reduction reaction kinetics and fluidization characteristics of fine and cohesive Fe2O3 particles were examined in a vibrated fluidized bed reactor. A smooth bubbling fluidization was achieved. An increase in external force due to vibration slightly increased the pressure drop. The minimum fluidization velocity was nearly independent of the operating temperature. The yield of the direct H-2-driven reduction was examined and found to exceed 90%, with a maximum of 98% under the vibration of similar to 47 Hz with an amplitude of 0.6 mm, and operating temperatures close to 500 degrees C. Towards the future of direct steel ore reduction, cheap and "green" hydrogen sources need to be developed. H-2 can be formed through various techniques with the catalytic decomposition of NH3 (and CH4), methanol and ethanol offering an important potential towards production cost, yield and environmental CO2 emission reductions.
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RI Baeyens, Jan/J-4864-2019; Deng, Yimin/AAF-2028-2019; Li, Shuo/AAY-5467-2020; Dewil, Raf/A-6890-2008
OI Li, Shuo/0000-0003-3286-0745; Dewil, Raf/0000-0003-4717-5484; Deng, Yimin/0000-0002-3940-2918
FU Beijing Advanced Innovation Centre for Soft Matter Science and Engineering of the Beijing University of Chemical Technology
FX This work was supported by the Beijing Advanced Innovation Centre for Soft Matter Science and Engineering of the Beijing University of Chemical Technology.
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NR 42
TC 57
Z9 57
U1 12
U2 121
PU MDPI
PI BASEL
PA ST ALBAN-ANLAGE 66, CH-4052 BASEL, SWITZERLAND
EI 2071-1050
J9 SUSTAINABILITY-BASEL
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AU Dall'Osto, G
   Mombelli, D
   Mapelli, C
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   Mombelli, Davide
   Mapelli, Carlo
TI Consequences of the Direct Reduction and Electric Steelmaking Grid
   Creation on the Italian Steel Sector
SO METALS
LA English
DT Article

DE CO2 emissions; iron and steel industry; direct reduction;
   decarbonization; green H-2; biomethane
AB The consequences on the Italian steel sector following the conversion of the sole integrated steel plant and the establishment of a direct reduction/electric arc furnace (DR/EAF) grid in the period 2022-2050 were analyzed. Imported natural gas (pathway 0), green hydrogen (pathway 1) and biomethane (pathway 2) were studied as possible reducing gases to be exploited in the DR plant and to be introduced as a methane substitute in EAFs. The results showed that the environmental targets for the sustainable development scenario could be achieved in both 2030 and 2050. In particular, the main reduction would occur by 2030 as a result of the cease of the integrated plant itself, allowing for an overall reduction of 71% of the CO2 emitted in 2022. On the other hand, reaching the maximum production capacity of the DR plants by 2050 (6 Mton) would result in final emission reductions of 25%, 80% and 35% for pathways 0, 1 and 2, respectively. Finally, the creation of a DR/EAF grid would increase the energy demand burden, especially for pathway 1, which would require three times as much green energy as pathway 0 and/or 2 (36 TWh/y vs. ca. 12 TWh/y).
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TC 2
Z9 2
U1 0
U2 4
PU MDPI
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PA ST ALBAN-ANLAGE 66, CH-4052 BASEL, SWITZERLAND
EI 2075-4701
J9 METALS-BASEL
JI Metals
PD MAR
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VL 14
IS 3
AR 311
DI 10.3390/met14030311
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WC Materials Science, Multidisciplinary; Metallurgy & Metallurgical Engineering
WE Science Citation Index Expanded (SCI-EXPANDED)
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PT C
AU Nikas, A
Arsenopoulos, A
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Romero, AL
AF Nikas, A.
Arsenopoulos, A.
Doukas, H.
Labella Romero, A.
BE Li, Z
Yuan, C
Lu, J
Kerre, EE
TI Prioritisation of risks associated with decarbonisation pathways for the Austrian iron and steel sector using 2-tuple TOPSIS
SO DEVELOPMENTS OF ARTIFICIAL INTELLIGENCE TECHNOLOGIES IN COMPUTATION AND ROBOTICS
SE World Scientific Proceedings Series on Computer Engineering and Information Science
LA English
DT Proceedings Paper
CT 15th Symposium of Intelligent Systems and Knowledge Engineering (ISKE) held jointly with 14th International FLINS Conference (FLINS)
CY AUG 18-21, 2020
CL Cologne, GERMANY
SP Fern Univ, TH Koln Univ Appl Sci, Univ Technol Sydney, SW Jiaotong Univ, Shunde Polytechn, Minnan Normal Univ, Natl Assoc Non Class Log & Computat China
DE 2-tuple TOPSIS; risk analysis; Austria; iron and steel; decarbonization

ID TARGETS; WORDS
AB Decarbonising emissions-heavy industrial sectors is key to delivering on the Paris Agreement. In Austria, the iron and steel sector holds a large share of the country's greenhouse gas emissions and is in need of introduction of new technologies, orienting on green hydrogen and renewable energies. Acknowledging that such a transition features diverse exogenous risks and possible consequences, our research attempts to prioritise the risks associated with a pathway promoting a low-carbon iron and steel sector in Austria, from the stakeholders' perspective. We use a 2-tuple TOPSIS model and carry out group decision making based on the Computing with Words methodology.
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FU H2020 European Commission Project "PARIS REINFORCE" [820846]
FX This research was supported by the H2020 European Commission Project "PARIS REINFORCE" under grant Agreement No. 820846. The sole responsibility for the content of this paper lies with the authors; the paper does not necessarily reflect the opinions of the European Commission.
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AU Wang, CL
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AF Wang, Changlong
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   Weng, Zhehan
   Haynes, Marcus W.
   Summerfield, Daisy
   Feitz, Andrew
TI Green steel: Synergies between the Australian iron ore industry and the
   production of green hydrogen
SO INTERNATIONAL JOURNAL OF HYDROGEN ENERGY
LA English
DT Article
DE Green hydrogen; Green steel; Energy system modelling; Industry
   decarbonization; Renewable energy
ID REANALYSIS; AMMONIA; POWER
AB Green steel, produced using renewable energy and hydrogen, presents a promising avenue to decarbonize steel manufacturing and expand the hydrogen industry. Australia, endowed with abundant renewable resources and iron ore deposits, is ideally placed to support this global effort. This paper's two-step analytical approach offers the first comprehensive assessment of Australia's potential to develop green steel as a value-added export commodity. The Economic Fairways modelling reveals a strong alignment between prospective hydrogen hubs and current and future iron ore operations, enabling shared infrastructure development and first-mover advantages. By employing a site-based system optimization that integrates both wind and solar power sources, the cost of producing green steel could decrease significantly to around AU$900 per tonne by 2030 and AU$750 per tonne by 2050. Moreover, replacing 1% of global steel production would require 35 GW of well-optimized wind and solar photovoltaics, 11 GW of hydrogen electrolysers, and 1000 square kilometres of land. Sensitivity analysis further indicates that iron ore prices would exert a long-term influence on green steel prices. Overall, this study highlights the opportunities and challenges facing the Australian iron ore industry in contributing to thedecarbonization of the global steel sector, underscoring the crucial role of government support in driving the growth and development of the green steel industry.(c) 2023 The Author(s). Published by Elsevier Ltd on behalf of Hydrogen Energy Publications LLC. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
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TI Green hydrogen transformation of the iron and steel production system:
   An integrated operating concept for system-internal balance, lower
   emissions, and support for power system stability
SO APPLIED ENERGY
LA English
DT Article
DE Water electrolysis; Green hydrogen; Power system; Steel industry; Case
   study
ID ENERGY; STORAGE
AB The green hydrogen transformation of the iron and steel industry is considered a technically viable option. Concretely, large-scale renewable energy generation and water electrolyzer capacity are to be added to the production system. Given that renewables are

intermittent and H 2 demand is high, there is continued reliance on the CO2 emitting upstream power system. This paper introduces a novel operating concept that regards an extended production system that includes not only the renewables and water electrolyzer but also a dedicated conventional generator and onsite customer and prioritizes loads with the aim to create an internal balance. The paper studies different production system configurations and load prioritization strategies, evaluating technoeconomic properties, CO2 emissions, the internal balance, and the support for the stability of the upstream power system. It finds that local, emission-free production of H 2 is not only techno-economically viable, but that the integrated operating concept leads to lower Scope I and II emissions and to significant reduction of electrical loads on the upstream power system.
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AF Devlin, Alexandra
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TI Global green hydrogen-based steel opportunities surrounding high quality
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DT Article
ID DIRECT REDUCTION; GAS EMISSIONS; TECHNOLOGY; CHALLENGES; FURNACE; SOLAR
AB Facility-level analysis of green H2- based steel production demonstrates co-location of high-quality renewables and iron ore resources is imperative for cost minimisation.
   The steel sector currently accounts for 7% of global energy-related CO2 emissions and requires deep reform to disconnect from fossil fuels. Here, we investigate the market competitiveness of one of the widely considered decarbonisation routes for primary steel production: green hydrogen-based direct reduction of iron ore followed by electric arc furnace steelmaking. Through analysing over 300 locations by combined use of optimisation and machine learning, we show that competitive renewables-based steel production is located nearby the tropic of Capricorn and Cancer, characterised by superior solar with supplementary onshore wind, in addition to high-quality iron ore and low steelworker wages. If coking coal prices remain high, fossil-free steel could attain competitiveness in favourable locations from 2030, further improving towards 2050. Large-scale implementation requires attention to the abundance of suitable iron ore and other resources such as land and water, technical challenges associated with direct reduction, and future supply chain configuration.
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TI Green Hydrogen as a Forced Opportunity - A Transformation of the
Business Model Canvas using the example of the German steel industry
SO BETRIEBSWIRTSCHAFTLICHE FORSCHUNG UND PRAXIS
LA German
DT Article
ID STRATEGY; IRON; EFFICIENCY; PRODUCT; DESIGN
AB Innovation-driven economies such as Germany and the companies based there, which are active or want to become active in the lead markets of the Green Economy, can benefit from new entrepreneurial opportunities - for example, through newly created jobs and economic growth. The adaptation of existing business models to the resulting market changes can also involve such entrepreneurial opportunities. However, if companies are forced to implement them, for instance due to government regulations, this results in a concept that deviates from the entrepreneurial opportunity and requires a special adaptation of the business model. This concerns, for example, the decarbonization of industrial steel production through green hydrogen. In addition to the derivation of green hydrogen as such a forced opportunity, the article analyzes the influences and

their effects on the business model of German crude steel producers. The result is an extension of the generally applicable Business Model Canvas to include the level of regulatory challenges.

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TI Green steel at its crossroads: Hybrid hydrogen-based reduction of iron ores
SO JOURNAL OF CLEANER PRODUCTION
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DE Green steel; Hybrid hydrogen-based reduction of iron ores; Efficiency in H-2 consumption; Process stability
ID ELECTRIC-ARC FURNACE; GASEOUS REDUCTION; BLAST-FURNACE; HEMATITE; KINETICS; OXIDES; SIMULATION; MIXTURES; PROGRESS; PLASMA
AB Iron-and steelmaking cause-7% of the global CO2 emissions, due to the use of carbon for the reduction of iron ores. Replacing carbon by hydrogen as the reductant offers a pathway to massively reduce these emissions. However, the production of hydrogen using renewable energy will remain as one of the bottlenecks at least during the next two decades, because making the gigantic annual crude steel production of 1.8 billion tons sustainable requires a minimum stoichiometric amount of similar to 97 million tons of green hydrogen per year. Another fundamental aspect to render the ironmaking sector more sustainable lies in an optimal utilization of green hydrogen and energy, thus reducing efforts for costly in-process hydrogen recycling. We therefore demonstrate here how the efficiency in hydrogen and energy consumption during iron ore reduction can be dramatically improved by the knowledge-based combination of two technologies: partially reducing the ore at low temper-ature via solid-state direct reduction (DR) to a kinetically defined degree, and subsequently melting and completely transforming it to iron under a reducing plasma (i.e. via hydrogen plasma reduction, HPR). Results suggest that an optimal transition point between these two technologies occurs where their efficiency in hydrogen utilization is equal. We found that the reduction of hematite through magnetite into wustite via DR is clean and efficient, but it gets sluggish and inefficient when iron forms at the outermost layers of the iron ore pellets. Conversely, HPR starts violent and unstable with arc delocalization, but proceeds smoothly and efficiently when processing semi-reduced oxides, an effect which might be related to the material's high electrical conductivity. We performed hybrid reduction experiments by partially reducing hematite pellets via DR at 700 degrees C to 38% global reduction (using a standard thermogravimetry system) and subsequently transferring them to HPR, conducted with a lean gas mixture of Ar-10%H-2 in an arc-melting furnace, to achieve full conversion into liquid iron. This hybrid approach allows to exploit the specific characteristics and kinetically favourable regimes of both technologies, while simultaneously showing the potential to keep the consumption of energy and hydrogen low and improve both, process stability and furnace longevity by limiting its overexposure to plasma radiation.
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TI Cobalt-based molecular electrocatalyst-mediated green hydrogen generation: A potential pathway for decarbonising steel industry
SO ENERGY AND CLIMATE CHANGE
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DT Article
DE Green hydrogen; Molecular electrocatalyst; Cobaloxime; Multi-stack electrolyser
ID H-2 PRODUCTION; IRON COMPLEX; WATER; EVOLUTION; CATALYST; SEPARATION; REDUCTION; SYSTEMS
AB Amid the climate change crisis, researchers are investigating the transformative potential of green hydrogen produced by renewable energy electrolysis to decarbonize the steel sector, a significant contributor to global carbon emissions. It aims to lower the carbon footprint of the steel industry by showcasing green hydrogen's potential as a cleaner substitute for traditional fossil fuels in the production process. Despite its potential, issues such as high costs, restricted availability, and infrastructural alterations must be addressed. Cobalt-based synthetic catalysts, especially cobaloximes, are being considered as a key electrocatalytic component for hydrogen production via water-splitting. Cobaloximes, noted for their efficiency and stability in catalysing hydrogen evolution, have made considerable advances in the field of molecular catalysis. Recently, advanced immobilisation procedures have appreciably enhanced their overall catalytic output and application. This article discusses several electrolyser technologies, such as proton exchange membrane (PEM) and alkaline electrolysis, highlighting the benefits of multi-stacked electrolyser systems for boosting hydrogen generation efficiency. These encouraging results are vital for unravelling a durable catalytic material that can be scaled up without much financial stringency. In light of the global climate pledges, the document concludes that green hydrogen might provide 24 % of the world's energy needs by 2050, resulting in a considerable reduction in CO2 emissions.
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NR 79
TC 0
Z9 0
U1 4
U2 4
PU ELSEVIER
PI AMSTERDAM
PA RADARWEG 29, 1043 NX AMSTERDAM, NETHERLANDS
EI 2666-2787
J9 ENERGY CLIM CHANG-UK
JI Energy Clim. Change
PD DEC
PY 2024
VL 5
AR 100168
DI 10.1016/j.egycc.2024.100168
PG 10
WC Energy & Fuels
WE Emerging Sources Citation Index (ESCI)
SC Energy & Fuels
GA M7M3G
UT WOS:001359332200001
OA gold
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ER

PT J
AU Souza, AM
Ribeiro, R
Oliveira, LD
da Silva, APA
AF Souza, Amaury M.
Ribeiro, Rilei, V
Oliveira, Leandro D.

da Silva, Alexandre P. Alves
TI How upstream methane emissions can impact cost and emissions of
steelmaking routes?
SO JOURNAL OF MATERIALS RESEARCH AND TECHNOLOGY-JMR&T
LA English
DT Article
DE Green steel; Hydrogen; CO2 reduction; Methane leakage; Decarbonization
ID REDUCTION; OIL
AB The steel industry is facing increasing pressure to reduce greenhouse gas (GHG) emissions, resulting in a shift towards direct reduction (DR) with electric arc furnaces (DR-EAF) for primary steel production. A key assumption is that DR reactors could operate with increasingly hydrogen enriched reducing gas. In addition, prior to using green hydrogen, they would be able to use blue hydrogen produced from steam methane reforming with carbon capture and storage, the so-called blue hydrogen. This assumption is supported by the allegation that blue hydrogen is a lower CO2eq emitter than the natural gas used to produce the reducing gas in the DR processes. However, life cycle assessments of blue hydrogen production have shown that the carbon footprint associated with the use of such gas is only about 10% less intense than the carbon footprint associated with the use of natural gas, due to the inefficiencies of carbon capture systems, and upstream and downstream methane emissions associated with the blue hydrogen production. In this paper, the GHG footprints of different decarbonization alternatives for the steel industry are evaluated. In fact, the reduction claim of 43% in CO2eq emission from the migration of BF-BOF route to natural gas-based DR-EAF (NG-DRI-EAF) may be reduced to only 22%, when methane emissions are considered. Hence, only DR-EAF with green hydrogen and renewable energy supply could lead to the production of truly low GHG footprint steel, with less than 600 kg of CO2eq emission per ton of crude steel.
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SN 2238-7854
EI 2214-0697
J9 J MATER RES TECHNOL
JI J. Mater. Res. Technol-JMRT
PD MAY-JUN
PY 2023
VL 24
BP 7153
EP 7161
DI 10.1016/j.jmrt.2023.04.238
EA MAY 2023
PG 9
WC Materials Science, Multidisciplinary; Metallurgy & Metallurgical
   Engineering
WE Science Citation Index Expanded (SCI-EXPANDED)
SC Materials Science; Metallurgy & Metallurgical Engineering
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PT J
AU Bhaskar, A
   Assadi, M
   Somehsaraei, HN
AF Bhaskar, Abhinav
   Assadi, Mohsen
   Somehsaraei, Homam Nikpey
TI Decarbonization of the Iron and Steel Industry with Direct Reduction of
   Iron Ore with Green Hydrogen
SO ENERGIES
LA English
DT Article
DE hydrogen; direct reduction of iron ore; green steel production;
   industrial decarbonization
ID DEEP DECARBONIZATION; ADSORPTION; KINETICS; ELECTROLYSIS; PELLETS;
   POLICY; H-2
AB Production of iron and steel releases seven percent of the global greenhouse gas (GHG) emissions. Incremental changes in present primary steel production technologies would not be sufficient to meet the emission reduction targets. Replacing coke, used in the blast furnaces as a reducing agent, with hydrogen produced from water electrolysis has the potential to reduce emissions from iron and steel production substantially. Mass and energy flow model based on an open-source software (Python) has been developed in this work to explore the feasibility of using hydrogen direct reduction of iron ore (HDRI) coupled with electric arc furnace (EAF) for carbon-free steel production. Modeling results show that HDRI-EAF technology could reduce specific emissions from steel production in the EU by more than 35%, at present grid emission levels (295 kgCO(2)/MWh). The energy consumption for 1 ton of liquid steel (tls) production through the HDRI-EAF route was found to be 3.72 MWh, which is slightly more than the 3.48 MWh required for steel production through the blast furnace (BF) basic oxygen furnace route (BOF). Pellet making and steel finishing processes have not been considered. Sensitivity analysis revealed that electrolyzer efficiency is the most important factor affecting the system energy consumption, while the grid emission factor is strongly correlated with the overall system emissions.
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FU European Unions Horizon 2020 research and innovation programme under the
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FX This project has received funding from the European Unions Horizon 2020
   research and innovation programme under the Marie Sklodowska-Curie grant
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PA ST ALBAN-ANLAGE 66, CH-4052 BASEL, SWITZERLAND
EI 1996-1073
J9 ENERGIES
JI Energies
PD FEB
PY 2020
VL 13
IS 3
AR 758
DI 10.3390/en13030758
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WE Science Citation Index Expanded (SCI-EXPANDED)
SC Energy & Fuels
GA KY3RQ
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OA Green Published, gold
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PT J
AU Boretti, A
AF Boretti, Alberto
TI The perspective of hydrogen direct reduction of iron
SO JOURNAL OF CLEANER PRODUCTION
LA English
DT Article
DE Iron ore; Iron making; Direct reduction of iron; Greenhouse gases emission; Hydrogen
ID BLAST-FURNACE
AB The work proposes a perspective on the direct reduction of iron (DRI) using hydrogen. Typically, iron is produced in blast furnaces (BFI) by the reduction of iron ore with carbon-rich materials such as coal or coke. Greenhouse emissions may be drastically reduced by introducing DRI coal/oil-based, and further reduced by using methanebased DRI. By increasing the share of hydrogen in the reducing gas by the addition of green hydrogen, the GHG emission further reduces. While hydrogen DRI becomes competitive for GHG emission with methane-based DRI once the electricity indirect emissions of GHG fall below 120 g CO2 per kWh, the full potential of hydrogen DRI is achieved phased with the complete uptake of green hydrogen, which is an essential component of a zeroemission stable electric grid fed with non-dispatchable renewables, as well as zero-emission non-electric total primary energy uses. The market perspective for hydrogen DRI in the short

term is quite promising, and it is gaining significant attention and interest within the iron and steel industry. Key factors contributing to its market perspective are decarbonization and climate goals, policy support and incentives, investor interest, industry collaboration, technological advancements, sustainability, and brand value.
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U2 48
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PI London
PA 125 London Wall, London, ENGLAND
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EI 1879-1786
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JI J. Clean Prod.
PD DEC 1
PY 2023
VL 429
AR 139585
DI 10.1016/j.jclepro.2023.139585
EA NOV 2023
PG 6
WC Green & Sustainable Science & Technology; Engineering, Environmental;

Environmental Sciences
WE Science Citation Index Expanded (SCI-EXPANDED)
SC Science & Technology - Other Topics; Engineering; Environmental Sciences
& Ecology
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Patrizi, D
Verdone, N
Bassano, C
Vilardi, G
AF Trinca, Antonio
Patrizi, Daniele
Verdone, Nicola
Bassano, Claudia
Vilardi, Giorgio
TI Toward green steel: Modeling and environmental economic analysis of iron
direct reduction with different reducing gases
SO JOURNAL OF CLEANER PRODUCTION
LA English
DT Article
DE Decarbonization; Hydrogen; Electrolysis; MSW gasification; Process
simulation; Carbon capture
ID CO2 EMISSIONS; FURNACE; MIDREX; TECHNOLOGY; KINETICS; OXIDE
AB The objective of the paper is to simulate the whole steelmaking process cycle based on Direct Reduced Iron and Electric Arc Furnace technologies, by modeling for the first time the reduction furnace based on kinetic approach, to be used as a basis for the environmental and techno-economic plant analysis by adopting different reducing gases. In addition, the impact of carbon capture section is discussed. A complete profitability analysis has been conducted for the first time, adopting a Monte Carlo simulation approach. In detail, the use of syngas from methane reforming, syngas and hydrogen from gasification of municipal solid waste, and green hydrogen from water electrolysis are analyzed. The results show that the Direct Reduced Iron process with methane can reduce CO2 emissions by more than half compared to the blast furnace based-cycle, and with the adoption of carbon capture, greenhouse gas emissions can be reduced by an additional 40%. The use of carbon capture by amine scrubbing has a limited economic disadvantage compared to the scenario without it, becoming profitable once carbon tax is included in the analysis. However, it is with the use of green hydrogen from electrolyzer that greenhouse gas emissions can be cut down almost completely. To have an environmental benefit compared with the methane-based Direct Reduced Iron process, the green hydrogen plant must operate for at least 5136 h per year (64.2% of the plant's annual operating hours) on renewable energy. In addition, the use of syngas and separated hydrogen from municipal solid waste gasification is evaluated, demonstrating its possible use with no negative effects on the quality of produced steel. The results show that hydrogen use from waste gasification is more economic with respect to green hydrogen from electrolysis, but from the environmental viewpoint the latter results the best alternative. Comparing the use of hydrogen and syngas from waste gasification, it can be stated that the use of the former reducing gas results preferable, from both the economic and environmental viewpoint.
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TI Tools and Frameworks for Sustainable Business Model Innovation for German Steel, Cement, and Chemical Industries
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DE sustainable business model innovation; decarbonization; sustainable business model; climate change; framework; energy-intensive industries
ID CIRCULAR ECONOMY; DESIGN
AB In the decarbonization of the steel, cement, and chemical industries in Germany, green hydrogen is expected to play a crucial role. The utilization of green hydrogen in the production processes of said industries requires organizations to modify their business model, requiring sustainable business model innovation (SBMI). Numerous tools and frameworks that support organizations in the process of SBMI have been proposed in the literature in recent years. However, the applicability of these tools and frameworks for steel, cement, and chemical companies that intend to utilize green hydrogen to produce their goods remains unexplored. This paper aims to assess the suitability of SBMI tools and frameworks for steel, cement, and chemical companies planning to use green hydrogen in their production. It conducts a systematic literature review on SBMI tools and frameworks, reviews current green hydrogen projects in these industries, and evaluates the identified tools and frameworks using an evaluation matrix. Based on the evaluation, the Cambridge Business Model Innovation Process (CBMIP) was identified as the most suitable SBMI framework.
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AU Ocenic, E
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TI "Green" Hydrogen Products and Their Economic End-Uses: A Statistical
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CL Bucharest, ROMANIA
DE green hydrogen production; green hydrogen products; renewable energy
   sources; climate change mitigation; energy transition
AB Mitigation of greenhouse gasses heightens attention on hydrogen as a crucial element in the global energy transition, while combating climate change. Building on previous analyses of hydrogen projects compiled by the International Energy Agency (IEA), this paper provides an updated and comprehensive analysis of this database while delving deeper into the intricacies of hydrogen products and their economic end-uses. Given the availability of alternative technologies in some sectors, it is crucial to understand the nuances of hydrogen projects, particularly in "hard-to-decarbonize" or "hard-to-abate" sectors such as iron and steelmaking, where the key benefit of using green hydrogen is to reduce greenhouse gas emissions from the process and energy use. Therefore, this paper's objective is to provide insights into the distribution, technologies, and trends of hydrogen projects produced with renewable power, while unraveling the diverse products of these projects and identify the sectors benefiting most from them. Employing a rigorous statistical data analysis, a dataset encompassing approximately 2000 hydrogen projects worldwide is scrutinized. These questions guide the investigation: a) What is the distribution of hydrogen projects across different countries globally? b) What are the key trends in technology choice over time? c) What are the key trends of hydrogen projects using renewable energy? d) What are the primary products of green hydrogen projects? e) Which end-use sectors are benefiting from the "green" hydrogen products the most? The findings reveal a spectrum of internationally pursued hydrogen-derived products, ranging from hydrogen to ammonia and beyond. Moreover, they provide insights into industries that stand to gain from innovation, including mobility, ammonia production and other industrial applications. This paper significantly contributes to the understanding of "green" hydrogen products, and their end-uses. Governments and businesses can leverage this knowledge to make informed policy and investment decisions in a rapidly evolving market.
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TI Decarbonizing rotary kiln-induction furnace based sponge iron production
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   curve; Green premium curves; Green hydrogen
ID CO2 EMISSION REDUCTION; STEEL-INDUSTRY; CHINA IRON; CAPTURE; POWER; COST
AB The direct carbon dioxide (CO2) emissions from the iron and steel sector are nearly 7 % of the global CO2 emissions from energy use. India is the world's second-largest producer of steel and the largest sponge iron producer. India produces one-third of the global sponge iron, mostly from rotary kilns using coal as an energy source, resulting in higher energy and emission intensities than the global average. This study evaluates major options for CO2 abatement in the rotary kiln-induction furnace process for steel production. Based on the mass and energy balances of a typical sponge iron plant, this study evaluates the techno-economic potential of nine major decarbonization measures. The proposed decarbonization measures include improved energy efficiency, improved material efficiency, renewable energy use, and fuel substitution. Marginal abatement and green premium curves are generated by incorporating the dependency of different measures. Depending upon the set of options chosen, carbon abatement is in the range of 55.8 %-99.2 %. It is observed that 11.5 %-20.6 % of decarbonization potential can be achieved without any additional cost to the customer. These findings are insightful for policymakers and industry stakeholders and provide a foundation for designing and implementing a net-zero pathway for the sector.
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AU Ghorbani, M
   Nazififard, M
AF Ghorbani, Mohammad
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TI Optimizing Renewable Microgrids for Green Hydrogen in Industrial
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SO 2024 11TH IRANIAN CONFERENCE ON RENEWABLE ENERGY AND DISTRIBUTION
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CT 11th Iranian Conference on Renewable Energy and Distribution Generation
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CL Yazd Univ, Yazd, IRAN
HO Yazd Univ
DE Renewable energies; Microgrid; Hydrogen
ID POWER-SYSTEMS; ENERGY; FUEL
AB The steel industry is under mounting pressure to minimize its carbon emissions and shift towards sustainable energy sources. This research explores the potential of integrating renewable microgrids to facilitate green hydrogen production for use in steel manufacturing processes. The study offers a comprehensive examination of the technical, economic, and environmental aspects of this integration, shedding light on the advantages and obstacles linked to the adoption of green hydrogen technology in industrial settings. HOMER Pro software was employed to model the systems under investigation. The findings indicate that the PV/WT/Grid/EL system makes green hydrogen production feasible for industrial consumers, with hydrogen and electric energy production costs of 33.8 $/kg and 0.012 $/kWh, respectively. Furthermore, the PV/Grid/EL system emerges as the most optimal choice in terms of greenhouse gas emissions.
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AU Matino, I
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TI Hydrogen role in the valorization of integrated steelworks process off-gases through methane and methanol syntheses
SO MATERIAUX & TECHNIQUES
LA English
DT Article
DE process-off gases valorization; green hydrogen use; methane and methanol syntheses; advanced control; steelmaking industry sustainability
ID CARBON PRICE
AB The valorization of integrated steelworks process off-gases as feedstock for synthesizing methane and methanol is in line with European Green Deal challenges. However, this target can be generally achieved only through process off-gases enrichment with hydrogen and use of cutting-edge syntheses reactors coupled to advanced control systems. These aspects are addressed in the RFCS project i(3)upgrade and the central role of hydrogen was evident from the first stages of the project. First stationary scenario analyses showed that the required hydrogen amount is significant and existing renewable hydrogen production technologies are not ready to satisfy the demand in an economic perspective. The poor availability of low-cost green hydrogen as one of the main barriers for producing methane and methanol from process off-gases is further highlighted in the application of an ad-hoc developed dispatch controller for managing hydrogen intensified syntheses in integrated steelworks. The dispatch controller considers both economic and environmental impacts in the cost function and, although significant environmental benefits are obtainable by exploiting process off-gases in the syntheses, the current hydrogen costs highly affect the dispatch controller decisions. This underlines the need for big scale green hydrogen production processes and dedicated green markets for hydrogen-intensive industries, which would ensure easy access to this fundamental gas paving the way for a C-lean and more sustainable steel production.
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RI Rompalski, Przemysław/U-5424-2018; Iannino, Vincenzo/AAQ-7435-2021; Matino, Ismael/AAR-7455-2020; Colla, Valentina/H-4126-2012
OI Colla, Valentina/0000-0002-9574-0575; Iannino,

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FX The work described in this paper was developed within the project
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TI Flexible industrial power-to-X production enabling large-scale wind
power integration: A case study of future hydrogen direct reduction iron
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SO APPLIED ENERGY
LA English
DT Article
DE Steel; Green hydrogen; Zero emissions; Sector coupling; Industry
decarbonization; Energy transition; Optimization; Hydrogen storage
ID STEEL PRODUCTION; STORAGE
AB Hydrogen Direct Reduction of Iron (HDRI) combined with renewable electricity is an attractive option for lowcarbon steel production. In this paper, we present a novel and computationally efficient techno-economic powerto-x-plant optimization model which is then applied to an HDRI plant located in Finland. Plant dimensioning was carried out in several current and future power market and regulatory scenarios. We predict a production cost of 373 <euro>/t for hot briquetted iron, and 351 <euro>/t for a future scenario of 2025-2030. When the recently introduced EU rules for renewable fuels of non-biological origin are applied, the production costs increased by 30-46 <euro>/t. The rules also have a significant increasing effect on the required hydrogen storage. The flexibility of the direct reduction shaft emerged as an important parameter affecting the required hydrogen storage as well as total production cost. The results of this paper hold significance for the optimal design of future low-carbon steel plants.
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FU Business Finland, VTT [Dnro 50/31/2021]
FX This research was carried out in the FFS - Towards Fossil Free Steel
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PT J
AU Lumbers, B
Barley, J
Platte, F
AF Lumbers, Brock
Barley, Joshua
Platte, Frank
TI Low-emission hydrogen production via the thermo-catalytic decomposition of methane for the decarbonisation of iron ore mines in Western Australia
SO INTERNATIONAL JOURNAL OF HYDROGEN ENERGY
LA English
DT Article
DE Turquoise hydrogen; Green hydrogen; Thermo-catalytic methane decomposition; Iron ore mining; Decarbonisation; Techno-economic analysis

ID FUEL-CELL; ENERGY; SIMULATION; KINETICS; ECONOMY; STORAGE; DESIGN; COST
AB The Pilbara, located in Western Australia is one of the largest iron ore-mining regions in the world and will need to achieve significant emission reductions in the short term to conserve the limited carbon budget and abide by the Paris Agreement targets. Green hydrogen has been communicated as the desired solution, however, the high production cost limits the deployment of these systems. The thermo-catalytic methane decomposition (TCMD) process is an alternative solution, which could be implemented as a bridge technology to produce low-emission hydrogen at a potentially lower cost. This is especially attractive for iron ore mines due to the utilisation of iron ore as a process catalyst, which reduces the catalyst turnover costs and can increase the grade of spent iron ore catalyst. In this study, a preliminary techno-economic assessment was carried out in comparison with green hydrogen to determine the feasibility of the TCMD process for the decarbonisation of iron ore mine sites in the Pilbara. The results show that the TCMD process had a CO2 abatement cost between 25 and 40% less than green hydrogen, however, the magnitude of these costs was lowest for mining operations > 60 Mt/yr at approximately $150 and $200 USD/t CO2 respectively. Since green hydrogen is expected to have significant cost re-ductions in the future, integrating renewables already into the mine could reduce emis-sions in the short term, which could then be extended for green hydrogen production once it becomes viable. The TCMD process, therefore, only has a narrow window of opportunity, although considering the uncertainty of the process and that green hydrogen is a proven technology with greater emission-reduction potential, green hydrogen may be the most suitable solution despite the model results presented in this work.
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U1 2
U2 18
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AU Wang, K
   Liu, FM
   Liu, JL
AF Wang, Ke
   Liu, Fangming
   Liu, Junling
TI Techno-economic assessment of different clean hydrogen development
   pathways across industries in China
SO APPLIED ENERGY
LA English
DT Article
DE Clean hydrogen; Hydrogen pathway; Hard-to-abate industries;
   Techno-economic assessment; Bottom-up model
ID TECHNOLOGY; WIND; IRON
AB Clean hydrogen, including green and blue hydrogen, presents a promising option to decarbonize hard-to-abate (HTA) industries. However, the focus on the diffusion pathways for blue and green hydrogen and cross-sector comparisons is limited. Therefore, a bottom-up techno-economic assessment model is established for four Chinese HTA industries that consider hydrogen demand and supply sides. An S-shaped growth curve is used to simulate the possible clean hydrogen supply paths with various blue and green hydrogen mix structures. Two pathway scenarios with different mixtures of clean hydrogen are developed. Despite similar mitigation potential, the green hydrogen-dominant pathway exhibits superior economic performance than the blue hydrogendominant pathway. It saves $115.5 billion compared to the blue hydrogen-dominant scenario and incurs only an additional $73.7 billion in total costs compared to a traditional technology pathway. Clean hydrogen utilization in the iron and steel industry requires significant technology investments from both the supply and demand sides. In contrast, the methanol, ammonia, and oil refining industries primarily incur hydrogen supply costs, with minimal demand-side investment needs, leading to greater mid- to long-term economic advantages and lower mitigation costs as technology advances. These comprehensive and dynamic comparisons of technoeconomic performance aid in industry-specific policy-making.
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FU National Natural Science Foundation of China [72004043]; Shenzhen Basic
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   Social Sciences Key Research Base for Carbon Emission Peaking and Carbon
   Neutral Technology, Policy, and Management, Harbin Institute of
   Technology, Shenzhen
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PA 125 London Wall, London, ENGLAND
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PT J
AU Alsheimer, S
AF Alsheimer, Sven
TI Does the public want green hydrogen in industry? Local and national acceptance of methanol and steel transitions in Germany
SO ENERGY RESEARCH & SOCIAL SCIENCE
LA English
DT Article
DE Climate change mitigation; Acceptance; Industrial transitions; Green methanol; Green steel
ID ENERGY TECHNOLOGY ACCEPTANCE; SOCIAL ACCEPTANCE; SUPPORT; WIND; STAKEHOLDERS; PERCEPTIONS; LEGITIMACY; ATTITUDES; TRUST
AB Public perceptions might determine the ease of the transition from a fossil-based to a green hydrogen-based production pathway in the industrial sector. The primary objective of this paper is to empirically identify the antecedents of the acceptance of two relevant industrial applications of green hydrogen: green methanol and green steel. The analysis, relying on linear regression models, utilises survey data from samples of residents near a chemical park and a steel plant (509 and 502 participants, respectively), contrasting them with a representative sample of 1502 individuals in Germany. The findings suggest that acceptance of the transitions to green methanol and green steel is high both locally and nationally. In all surveys, >59 % of the participants are in favour, while the share of those who are opposed to the respective transitions is below 9 %. Key antecedents of acceptance, which are conducive in all models, relate to individuals' attitudes towards green hydrogen and perceptions of the legitimacy of the industry actors involved, with varying results across legitimacy types.

In general, the findings were similar across industrial applications and across levels of observation, but varied across regions. This study highlights the importance of civil society perceptions and suggests that relationship management efforts aimed at maintaining positive perceptions of industrial hydrogen applications should consider their broader physical and social contexts.
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NR 74
TC 0
Z9 0
U1 0
U2 0
PU ELSEVIER
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PA RADARWEG 29, 1043 NX AMSTERDAM, NETHERLANDS
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J9 ENERGY RES SOC SCI
JI Energy Res. Soc. Sci.
PD MAR
PY 2025
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AR 103973
DI 10.1016/j.erss.2025.103973
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WC Green & Sustainable Science & Technology; Environmental Studies
WE Social Science Citation Index (SSCI)
SC Science & Technology - Other Topics; Environmental Sciences & Ecology
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AU Zou, BK
Zhang, YS
Chen, QR
Hu, QR
Hu, XY
Shi, J
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Wang, Q
AF Zou, Bokang
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Wang, Qi
TI Low-carbon economic schedule of the H₂DRI-EAF steel plant
integrated with a power-to-hydrogen system driven by blue hydrogen and
green hydrogen
SO IET RENEWABLE POWER GENERATION
LA English
DT Article
DE electricity supply industry; hydrogen production; hydrogen storage;
renewable energy sources; steel
AB Hydrogen direct reduction iron coupled with electronic arc furnace (H2DRI-EAF) technology, as an important technology for decarbonisation in the iron and steel industry, has the advantages of high electrification and low carbon emissions. However, the large demand for hydrogen in this technology relies significantly on the production of electrolytic hydrogen, leading to a substantial increase in power consumption in the steel production process. Moreover, the use of an unclean power source in electrolytic hydrogen production leads to increases in indirect carbon emissions, reducing the low-carbon attributes of the technology. This study investigates the integrated flexible operation mode of a steel plant. An illustrating method is utilised for modelling the entire steel production process and power to hydrogen (PtH2) process in detail for the H2DRI-EAF steel plant, which includes natural gas, photovoltaic, wind power self-provided power plants, and carbon capture and storage (CCS) systems. A mixed integer linear programming (MILP) model is developed for the comprehensive scheduling of the steel mill. The results of the case studies indicate that by reliably integrating the production of renewable energy and natural gas power plants, the PtH2 system can fully consume the renewable energy output while ensuring the smooth progress of steel production and maximising the reduction of carbon emissions from hydrogen production and the total cost of steel production.
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FU Natural Science Foundation of Jiangsu Province [BK20230027]; Jiangsu
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FX This research was supported by the Natural Science Foundation of Jiangsu
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Project of Smart Grid Technology and Equipment.
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TC 3
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U1 16
U2 20
PU INST ENGINEERING TECHNOLOGY-IET
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PA MICHAEL FARADAY HOUSE SIX HILLS WAY STEVENAGE, HERTFORD SG1 2AY, ENGLAND
SN 1752-1416
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J9 IET RENEW POWER GEN
JI IET Renew. Power Gener.
PD DEC 1
PY 2024
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IS 16
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WC Green & Sustainable Science & Technology; Energy & Fuels; Engineering, Electrical & Electronic
WE Science Citation Index Expanded (SCI-EXPANDED)
SC Science & Technology - Other Topics; Energy & Fuels; Engineering
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AU Conde, AS
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Harris, C
AF Conde, Amaia Sasiain
Rechberger, Katharina
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Wolfmeir, Hermann
Harris, Christopher
TI Decarbonization of the steel industry. A techno-economic analysis
SO MATERIAUX & TECHNIQUES
LA English
DT Article
DE direct reduction; CO2-emissions; production costs; break even ranges; energy demand; hydrogen demand
AB A substantial CO2-emmissions abatement from the steel sector seems to be a challenging task without support of so-called "breakthrough technologies", such as the hydrogen-based direct reduction process. The scope of this work is to evaluate both the potential for the implementation of green hydrogen, generated via electrolysis in the direct reduction process as well as the constraints. The results for this process route are compared with both the well-established blast furnace route as well as the natural gas-based direct reduction, which is considered as a bridge technology towards decarbonization, as it already operates with H-2 and CO as main reducing agents. The outcomes obtained from the operation of a 6-MW PEM electrolysis system installed as part of the H2FUTURE project provide a basis for this analysis. The CO2 reduction potential for the various routes together with an economic study are the main results of this analysis. Additionally, the corresponding hydrogen- and electricity demands for large-scale adoption across Europe are presented in order to rate possible scenarios for the future of steelmaking towards a carbon-lean industry.
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FU Fuel Cells and Hydrogen 2 Joint Undertaking [735503]; European Union; Hydrogen Europe; N.ERGHY; H2020 Societal Challenges Programme [735503]
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FX This study was carried out during the H2FUTURE project, which received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under the grant agreement No. 735503. This Joint Undertaking receives support from the European Union's Horizon2020 research and innovation programme and Hydrogen Europe and N.ERGHY.
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   FRANCE
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JI Mater. Tech.
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AR 305
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WE Emerging Sources Citation Index (ESCI)
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AU Doucet, F
   Blohm, M
   von Düsterlho, E
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AF Doucet, Felix
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GP IEEE
TI Green Hydrogen for the Energy Transition in Germany - Potentials,
   Limits, and Priorities
SO 2024 20TH INTERNATIONAL CONFERENCE ON THE EUROPEAN ENERGY MARKET, EEM
   2024
SE International Conference on the European Energy Market
LA English
DT Proceedings Paper
CT 20th International Conference on the European Energy Market (EEM)
CY JUN 10-12, 2024
CL Istanbul, TURKEY
SP IEEE, Kadir Has Univ, Ctr Energy & Sustainable Dev, Senkron Energy Digital Serv, IEEE Turkiye Sect, IEEE Power & Energy Soc
DE Green Hydrogen Priorities; industry sector; building sector; transport
   sector; electricity production and district heating
AB This paper explores the potentials, limits, and prioritization of green hydrogen deployment in Germany across the sectors: industry, buildings, electricity production, district heating, and transport. Green hydrogen offers a unique opportunity to decarbonize hard-to-abate sectors such as steel, copper, and chemical industries. On the other hand, the deployment is limited by the efficiency, which leads to high demand of renewable electricity and high costs. The paper discusses the two opposing trends in green hydrogen setting sector priorities. While efficiency considerations suggest prioritizing the industrial sector, market competitiveness is likely to be achieved in the transport sector first, and the industrial sector last. The paper concludes by emphasizing the need for strategic planning and policy support to optimize the deployment of green hydrogen across these sectors, balancing efficiency considerations with market dynamics. It also highlights the importance of continued research and investment in green hydrogen technologies to reduce costs and enhance performance.
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OI Blohm, Marina/0000-0002-4804-8439; Doucet, ne Roben,
Felix/0000-0002-5209-8746
CR Agora Energiewende, 2019, Klimaneutrale Industrie. Juristische Kurzbewertung der Politikoptionen
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NR 16
TC 3
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PU IEEE
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PA 345 E 47TH ST, NEW YORK, NY 10017 USA
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WE Conference Proceedings Citation Index - Science (CPCI-S); Conference Proceedings Citation Index - Social Science & Humanities (CPCI-SSH)
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Fuels; Engineering
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PT J
AU Galitskaya, E
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AF Galitskaya, Elena
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TI Development of electrolysis technologies for hydrogen production: A case

study of green steel manufacturing in the Russian Federation
SO ENVIRONMENTAL TECHNOLOGY & INNOVATION
LA English
DT Article
DE Hydrogen technologies; Electrolyzer; Wind power plant; Green steel; Decarbonization; Global warming
ID SUSTAINABLE ENERGY; REDUCTION; POWER; COST
AB The article reviews a list of solutions to reduce the carbon intensity of the Russian fuel and energy complex. The technological scheme of green hydrogen production that is the most optimal for the Russian Federation has been determined. It is shown that by 2040, the net present value of hydrogen production units by the alkaline electrolysis method will amount to US $ 35 thousand/ kW while the cost of plants with a solid polymer or a solid-oxide electrolyzer will be at US$30 thousand/ kW and US $ 26 thousand/ kW accordingly. This paper presents a feasibility study of green hydrogen production from wind-powered electrolysis with further direct reduction of iron ore for green steel manufacturing. According to the analysis, the difference in cash flows between standard steelmaking technology and direct reduction of iron ore with hydrogen is 20% which in the long term could be reduced to 5%. Compared to the European Carbon Border Adjustment Mechanism, companies will be able to save about 3% of the present value. To achieve the commercial attractiveness of hydrogen production by electrolysis, the minimum amount of government subsidies should be at least 10% of capital expenditures from 2021 with a gradual increase to 20% by 2040 to support the emerging market. (C) 2022 The Author(s). Published by Elsevier B.V.
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TI Green hydrogen value chains in the industrial sector-Geopolitical and
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DE Green hydrogen; Geopolitics; Energy transition; Industry; Energy policy;
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AB The global transition to a low-carbon economy will significantly impact existing energy value chains and transform the production to consumption lifecycle, dramatically altering interactions among stakeholders. Thanks to its versatility, green hydrogen could play a significant role in reaching a carbon-free future by 2050. Its adoption will be critical for decarbonizing industrial processes at scale, especially hard-to-abate ones such as steel and cement production. This paper maps the role countries could play in future green hydrogen industrial markets based on three criteria: resource endowment, existing industrial production, and economic relatedness. Our analysis shows how the potential for green hydrogen production and leadership in industrial applications is distributed unequally around the globe. Countries like the United States and China could emerge as frontrunners in future green hydrogen markets and lead in industrial applications, such as ammonia, methanol, and steel production. Other resource-rich countries could upgrade along value chains and compete with import-dependent industrial powers for jobs and market shares. A transition in existing value chains will also give rise to new market and geopolitical dynamics and dependencies. This paper contributes empirical evidence to the debate on the geopolitics of hydrogen and guides in defining strategic industrial policies.
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TI Circular Steel for Fast Decarbonization: Thermodynamics, Kinetics, and
   Microstructure Behind Upcycling Scrap into High-Performance Sheet Steel
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DT Review
DE recycling; green steel; scrap; sustainability; metallurgy;
   decarbonization; microstructure
ID GRAIN-BOUNDARY SEGREGATION; SURFACE HOT-SHORTNESS; HIGH-TEMPERATURE
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   TOMOGRAPHY; LOW-CARBON STEEL; MECHANICAL-PROPERTIES; ALLOYING ELEMENTS;
   TRAMP ELEMENTS
AB Steel production accounts for approximately 8% of all global CO2 emissions, with the primary steelmaking route using iron ores contributing approximately 80% of those emissions, mainly due to the use of fossil-based reductants and fuel. Hydrogen-based reduction of iron oxide is an alternative for primary synthesis. However, to counteract global warming, decarbonization of the steel sector must proceed much faster than the ongoing transition kinetics in primary steelmaking. Insufficient supply of green hydrogen is a particular bottleneck. Realizing a higher fraction of secondary steelmaking is thus gaining momentum as a sustainable alternative to primary production. Steel production from scrap is well established for long products (rails, bars, wire), but there are two main challenges. First, there is not sufficient scrap available to satisfy market needs. Today, only one-third of global steel demand can be met by secondary metallurgy using scrap since many steel products have a lifetime of several decades. However, scrap availability will increase to about two-thirds of total demand by 2050 such that this sector will grow massively in the next decades. Second, scrap is often too contaminated to produce high-performance sheet steels. This is a serious obstacle because advanced products demand explicit low-tolerance specifications for safety-critical and high-strength steels, such as for electric vehicles, energy conversion and grids, high-speed trains, sustainable buildings, and infrastructure. Therefore,we review the metallurgical and microstructural challenges and opportunities for producing high-performance sheet steels via secondary synthesis. Focus is placed on the thermodynamic, kinetic, chemical, and microstructural fundamentals as well as the effects of scrap-related impurities on steel properties.
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DE Green hydrogen; Hydrogen economy; Hydrogen storage; Electrolyser cost; Green hydrogen applications; Decarbonisation
ID ENERGY-SYSTEMS; AMMONIA
AB Green hydrogen is one of the attractive alternatives to the current carbon-based energy system. It can be produced from diverse renewable resources and used as a carbon-free energy carrier for industrial, residential, and transport purposes. This study uses a systematic and critical review of previous studies on green hydrogen economy using multiple databases like Scopus and Web of Science, and other published sources. This study critically analyses green hydrogen value chain of India. Further, this study proposes the key areas where green hydrogen can be strategically applied as a potent economic and political tool for creating smart and sustainable cities and societies. The study recommends policy directives that will be beneficial to the key stakeholders like government, industry partners, and research institutions. India needs action centric approaches for green hydrogen demand creation in key strategic sectors like shipping, road transport, steel, fertiliser, refinery, and other industries. Government should

provide strategic support and financial incentives for commercial production of green hydrogen. A robust green hydrogen value chain will create additional job opportunities, reduce fossil fuel import dependency, lower trade deficit, eliminate energy poverty, enhance energy inclusion, cut down greenhouse gas emissions, and improve energy governance.
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Z9 36
U1 11
U2 60
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AF Doucet, Felix
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GP IEEE
TI Decarbonization of the Industry - Demand and Cost Comparison of Green Hydrogen in Germany
SO 2023 19TH INTERNATIONAL CONFERENCE ON THE EUROPEAN ENERGY MARKET, EEM
SE International Conference on the European Energy Market
LA English
DT Proceedings Paper
CT 19th International Conference on the European Energy Market (EEM)
CY JUN 06-08, 2023
CL Lappeenranta, FINLAND
SP IEEE, LUT Univ
DE green hydrogen; industrial demand; cost comparison
AB Of the industrial goods considered, hydrogen is identified as applicable for the decarbonization of several goods. While anode copper and pig iron production can be partially or fully decarbonized with green hydrogen, this approach is not an option for aluminum production. The chemical industry can decarbonize ammonia with green hydrogen. Methanol and refinery products can also be produced with green hydrogen, but this requires an additional source of green carbon. The decarbonization of the cement industry faces another challenge.

The demand of green hydrogen for historic production volumes of the industrial goods sums up to 1296 TWh, most of it for refinery products (fuels and chemicals). The economic comparison of green hydrogen with natural gas shows a short-term increase of costs, which differ from good to good.
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FU German Federal Ministry for Economic Affairs and Climate Action (BMWK)
FX This paper was developed within the project NRL (Northern German Living Lab) which is partly funded by the German Federal Ministry for Economic Affairs and Climate Action (BMWK).
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NR 22
TC 3
Z9 3
U1 2
U2 19
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PI NEW YORK
PA 345 E 47TH ST, NEW YORK, NY 10017 USA
SN 2165-4077
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J9 INT CONF EUR ENERG
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WC Green & Sustainable Science & Technology; Economics; Energy & Fuels;
Engineering, Electrical & Electronic
WE Conference Proceedings Citation Index - Science (CPCI-S); Conference Proceedings
Citation Index - Social Science & Humanities (CPCI-SSH)
SC Science & Technology - Other Topics; Business & Economics; Energy &
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TI Green hydrogen supply chain risk analysis: A european hard-to-abate
sectors perspective
SO RENEWABLE & SUSTAINABLE ENERGY REVIEWS
LA English
DT Article
DE Renewable energy; Green hydrogen supply chain; Risk management;
Hard-to-abate sectors; Best-worst-method
ID RENEWABLE ENERGY; CLASSIFICATION; MANAGEMENT; BARRIERS
AB Green hydrogen is a tentative solution for the decarbonisation of hard-to-abate sectors such as steel, chemical, cement, and refinery industries. Green hydrogen is a form of hydrogen gas that is produced using renewable energy sources, such as wind or solar power, through a process called electrolysis. The green hydrogen supply chain includes several interconnected entities such as renewable energy providers, electrolysers, distribution facilities, and consumers. Although there have been many studies about green hydrogen, little attention has been devoted to green hydrogen supply chain risk identification and analysis, especially for hard-to-abate sectors in Europe. This research contributes to existing knowledge by identifying and analysing the European region's green hydrogen supply chain risk factors. Using a Delphi method 7 categories and 43 risk factors are identified based on the green hydrogen supply chain experts' opinions. The best-worst method is utilised to determine the importance weights of the risk categories and risk factors. High investment of capital for hydrogen production and delivery technology was the highest-ranked risk factor followed by the lack of enough capacity for electrolyser, and policy & regulation development. Several mitigation strategies and policy recommendations are proposed for high-importance risk factors. This

study provides novelty in the form of an integrated approach resulting in a scientific ranking of the risk factors for the green hydrogen supply chain. The results of this study provide empirical evidence which corroborates with previous studies that European countries should endeavour to create comprehensive and supportive standards and regulations for green hydrogen supply chain implementation.
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WC Green & Sustainable Science & Technology; Energy & Fuels
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AF Lv, Zepeng
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Jiang, Yinzhu
Sun, Wenping
He, Jilin
Jiao, Shuqiang
Song, Jianxun
TI Emerging Opportunities of Steel-Based Electrode at Mesoscale Design
SO ADVANCED FUNCTIONAL MATERIALS
LA English
DT Review; Early Access
DE catalyst; electrocatalysis; mesoscale; steel; water splitting
ID HYDROGEN EVOLUTION REACTION; 316L STAINLESS-STEEL; OXYGEN-EVOLUTION;
BIFUNCTIONAL ELECTROCATALYSTS; LOW-COST; EFFICIENT; NANOSHEETS; CO3O4;
IRON; INDUCTION
AB The electrochemical water splitting technology, a cornerstone for the production of
"green hydrogen", holds paramount significance in the global pursuit of carbon

neutrality. Steel-based electrocatalysts, when judiciously designed at the mesoscale, emerge as pivotal players in the quest for cost-effective and highly active catalysts for industrial-scale deployment. This domain has witnessed remarkable progress in recent times, prompting this review to offer a holistic overview of the design and synthesis methodologies for steel-based electrocatalysts. The focus of this review lies in three primary aspects: the intricate phase transition design of the exterior layer, the strategic manipulation of 3D steel-based substrate architectures, and the ingenious coupling of multifarious heterointerfaces. These strategies collectively contribute to the enhancement of catalytic performance. Concluding the discussion, the key insights are briefly summarized and delved into the challenges and prospects surrounding the advancement of steel-based electrocatalysts for sustainable, large-scale hydrogen production. Against the strategic backdrop of integrating computational chemistry, paired electrocatalysis, and industrial-grade high-current direct electrolysis of seawater, a roadmap is envisioned that aims to overcome existing barriers and propel the field toward new horizons.
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ID IRON; GENERATION; CATALYST; GAS; CO2

AB Currently green hydrogen production is attracting global attention. In this context, sustainable hydrogen production processes have been explored by using variety of materials and methods. Generation of hydrogen without CO2 emissions is the key for carbon-free energy economy in future. Enormous amounts of scrap iron, metallurgical wastes and ferrous metals are produced in industrial processes. In this work, the reaction between metal scrap and steam is studied for hydrogen production. The scrap materials are loaded in a packed-bed reactor to produce green hydrogen by water splitting at high temperatures. This method produced 500 mL of green H2 per gram of scrap material at 1150 degrees C with a conversion efficiency of about 94%. This is a potential method to utilize the scrap metals for large scale production of green hydrogen without carbon emissions.(c) 2023 Hydrogen Energy Publications LLC. Published by Elsevier Ltd. All rights reserved.
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NR 41
TC 2
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U1 5
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PN A
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WE Science Citation Index Expanded (SCI-EXPANDED)
SC Chemistry; Electrochemistry; Energy & Fuels
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PT J
AU Davies, M
AF Davies, Mark
TI The Role of Strategic Mine Planning in Decarbonising the Mining Industry
SO MINING METALLURGY & EXPLORATION
LA English
DT Editorial Material; Early Access
DE Strategic mine planning; Decarbonisation; Mining industry; Greenhouse
   gas (GHG) emissions; Sustainability; Renewable energy; Electrification;
   Biofuels; Autonomous driving trucks; Green hydrogen; Green steel; Inert
   anode; Energy demand management; Energy transition; Technology;
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NR 0
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Z9 0
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U2 1
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PT C
AU Steinbacher, LM
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AF Steinbacher, Lennart M.
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BE Freitag, M
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TI Literature Review-Based Synthesis of a Framework for Evaluating
   Transformation of Hydrogen-Based Logistics
SO DYNAMICS IN LOGISTICS, LDIC 2024
SE Lecture Notes in Logistics
LA English
DT Proceedings Paper
CT 9th International Conference on Dynamics in Logistics (LDIC)
CY FEB 14-16, 2024
CL Bremen, GERMANY
DE Hydrogen economy; hydrogen based logistics; regional hydrogen hubs;
   framework
ID TRANSPORT; ONTOLOGY; DESIGN; SYSTEM; FUEL
AB Green hydrogen, produced mainly by electrolysis, is a promising energy carrier to de-fossilise different economy sectors, from heavy industry to logistics. A fully transformed economy would use hydrogen as a process gas and a fuel for heat generation and vehicles. However, since the technology to produce green hydrogen has yet to be available at an industrial scale, there are no projections for forming regional hydrogen hubs. This article contributes to synthesising a holistic framework to specify and optimise hydrogen-based applications in logistics from an ecological and economic perspective. These applications utilise logistics macrostructures, like logistics hubs. Alternatively, they may utilise industrial supply chains, like direct reduced iron (DRI) based steel plants, which modify their operations and transform their logistic ecosystems. The framework includes a configuration of policies and economic boundary conditions that influence the logistic hubs' transformation paths. The article describes the synthesis of the framework based on an initial problem analysis and a systematic literature review. The framework helps policymakers and planners evaluate and optimise the composition and design of hydrogen and logistics hubs.

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RI Oelker, Stephan/G-1120-2018; Broda, Eike/AAO-3740-2020
OI Freitag, Michael/0000-0003-1767-9104; Steinbacher, Lennart/0000-0002-9160-631X; Broda, Eike/0000-0002-8150-4715; Ait-Alla, Abderrahim/0000-0001-7031-0969
FU German Federal Ministry of Education and Research (BMBF) [03SF0687B]
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PT J
AU Crawford, N
AF Crawford, Nicholas
TI The Green Transition and European Industry
SO SURVIVAL
LA English
DT Article
DE aluminium; Europe; decarbonisation; deindustrialisation,
energy-intensive industries; green hydrogen; green transition;
industrial efficiency; industrial security; industrial sustainability;
primary steelmaking; renewables
ID GEOPOLITICS
AB Western Europe is spearheading efforts to decarbonise energy-intensive industries.
However, the region's climate, population density and economic development set it at a
disadvantage in generating cheap renewables. Although European governments have assumed
that they will import resources like green-hydrogen derivatives to decarbonise industry
in Europe, the region is likely to see several major industries relocate overseas
instead. Although Europe will not experience wholesale deindustrialisation, the
dislocations will still have a significant political impact. European governments will
want to prop up their energy-intensive industries, but the strategic and economic
rationale for doing so is weak. The region faces a tricky trilemma for energy-intensive
industries, with trade-offs among industrial efficiency, industrial sustainability and
industrial security - especially where governments assume that industrial security
requires autonomy or local production. They can resolve the trilemma by shaping diverse

global supply chains for energy-intensive goods and mitigating the impact of dislocations on local economies.
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AU Kashiwaya, Y
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TI Thermodynamics of Impurities in Pure Iron Obtained by Hydrogen Reduction
SO ISIJ INTERNATIONAL
LA English
DT Article
DE hydrogen reduction; clean steel; thermodynamic study of inclusion;
   activity; direct steelmaking
ID PHASE BOUNDARIES; OXIDE
AB Hydrogen itself is not a primary energy and needs an energy for its production, which means that CO2 will be exhausted during the production process, more or less. However, when a Green Hydrogen can be produced, it is a best way to use the hydrogen instead of carbon.
   In this study, two kinds of iron ore were reduced and melted both under hydrogen and carbon atmosphere. The obtained iron metal under hydrogen atmosphere was quite pure one. The impurities in the metal were chemically and thermodynamically analyzed. The characteristics and benefits of hydrogen reduction were discussed in comparison with the carbon reduction.
   The content of silicon in the metal under hydrogen atmosphere was one tenth to the iron obtained by carbon reduction. Manganese was about one third to one tenth against the carbon reduction. However, phosphorus in the hydrogen reduction was almost the same level to the carbon reduction. Sulfur content became half in the hydrogen reduction. Moreover, the content of hydrogen in the metal was the same level between the hydrogen reduction and the carbon reduction. It was found that the rate of hydrogen evolution from a molten metal during solidification was fast significantly. The activities of elements in the metal were calculated through the thermochemical data, and the relationships among those elements were elucidated.
   From the thermodynamic analysis, a high oxygen activity in the metal obtained under hydrogen atmosphere caused to a low content of impurities and high activity of oxides related.
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RI Hasegawa, Masakatsu/IUM-8305-2023
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YAGI T, 1968, T IRON STEEL I JPN, V8, P377
NR 16
TC 15
Z9 15
U1 5
U2 29
PU IRON STEEL INST JAPAN KEIDANREN KAIKAN
PI TOKYO
PA NIIKURA BLDG 2F, 2 KANDA-TSUKASACHO 2-CHOME, TOKYO, CHIYODA-KU 101-0048,
JAPAN
SN 0915-1559
J9 ISIJ INT
JI ISIJ Int.
PY 2012
VL 52
IS 8
SI SI
BP 1513
EP 1522
DI 10.2355/isijinternational.52.1513
PG 10
WC Metallurgy & Metallurgical Engineering
WE Science Citation Index Expanded (SCI-EXPANDED)
SC Metallurgy & Metallurgical Engineering
GA 990EM
UT WOS:000307613800020
OA Green Submitted, gold
DA 2025-03-13
ER

PT J
AU Kashiwaya, Y
Hasegawa, M
AF Kashiwaya, Yoshiaki
Hasegawa, Masakatsu
TI Thermodynamics of Impurities in Pure Iron Obtained by Hydrogen Reduction
SO TETSU TO HAGANE-JOURNAL OF THE IRON AND STEEL INSTITUTE OF JAPAN
LA Japanese
DT Article
DE hydrogen reduction; clean steel; thermodynamic study of inclusion;
activity; direct steelmaking
ID PHASE BOUNDARIES
AB Hydrogen itself is not a primary energy and needs an energy for its production, which means that CO2 will be exhausted during the production process, more or less. However, when a Green Hydrogen can be produced, it is a best way to use the hydrogen instead of carbon. In this study, two kinds of iron ore were reduced and melted both under hydrogen and carbon atmosphere. The obtained iron metal under hydrogen atmosphere was quite pure one. The impurities in the metal were chemically and thermodynamically analyzed. The characteristics and benefits of hydrogen reduction were discussed in comparison with the carbon reduction.

The content of silicon in the metal under hydrogen atmosphere was one tenth to the iron obtained by carbon reduction. Manganese was about one third to one tenth against the carbon reduction. However, phosphorus in the hydrogen reduction was almost the same level to the carbon reduction. Sulfur content became half in the hydrogen reduction. Moreover, the content of hydrogen in the metal was the same level between the hydrogen reduction and the carbon reduction. It was found that the rate of hydrogen evolution from a molten metal during solidification was fast significantly. The activities of elements in the metal were calculated through the thermochemical data, and the relationships among those elements were elucidated.
From the thermodynamic analysis, a high oxygen activity in the metal obtained under hydrogen atmosphere caused to a low content of impurities and high activity of oxides related.
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RI Hasegawa, Masakatsu/IUM-8305-2023
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YAGI T, 1968, T IRON STEEL I JPN, V8, P377
NR 16
TC 2
Z9 2
U1 2
U2 14
PU IRON STEEL INST JAPAN KEIDANREN KAIKAN
PI TOKYO
PA TEKKO KAIKAN-5F, 3-2-10, NIHONBASHI-KAYABACHO, TOKYO, CHUO-KU 103-0025, JAPAN
SN 0021-1575
EI 1883-2954
J9 TETSU TO HAGANE
JI Tetsu To Hagane-J. Iron Steel Inst. Jpn.
PY 2014
VL 100
IS 2
BP 302
EP 311
DI 10.2355/tetsutohagane.100.302
PG 10
WC Metallurgy & Metallurgical Engineering
WE Science Citation Index Expanded (SCI-EXPANDED)
SC Metallurgy & Metallurgical Engineering
GA AA9PJ
UT WOS:000331425100023
OA gold, Green Submitted
DA 2025-03-13
ER

PT J

AU Tian, BH
   Wei, GS
   Hu, H
   Zhu, R
   Bai, H
   Wang, ZM
   Yang, LZ
AF Tian, Bohan
   Wei, Guangsheng
   Hu, Hang
   Zhu, Rong
   Bai, Hao
   Wang, Ziming
   Yang, Lingzhi
TI Effects of fuel injection and energy efficiency on the production and environmental parameters of electric arc furnace -heat recovery systems
SO JOURNAL OF CLEANER PRODUCTION
LA English
DT Article
DE Exergy; Carbon emissions; EAF steelmaking; Off-gas heat recovery
ID CO2 EMISSION REDUCTION; LIFE-CYCLE ASSESSMENT; OFF-GAS; STEEL; IRON; STEELMAKING; TECHNOLOGY; EXERGY; CARBON; COGENERATION
AB A stoichiometric model of an electric arc furnace (EAF)-heat recovery system was constructed to display material, energy, and exergy behaviors, as well as production and environmental parameters, in order to study the effects of different fuel injection indexes. The injection of high-calorific value fuel (rather than hydrogen and biomass) reduces power consumption more effectively, but hydrogen utilization reduces the amount of off-gas and improves heat recovery slightly (0.06 MJ/Nm(3)) in the case of 30% energy efficiency. It is more efficient to directly use the energy released from fuel combustion in the furnace than to recover the heat in the off-gas, showing the importance to increase energy efficiency. In the scenario of improved equipment and technology using large amounts of hydrogen (20 m(3)/t) and biomass (40 kg/t), power consumption will reach 322 kWh/t. Near-zero carbon emissions (41.20 kg CO2/t) can be achieved in an EAF by using green power, green hydrogen, and advanced equipment and processes. However, realizing this process requires long-term transformation, including the use of coke oven gas rather than gray hydrogen, which has high upstream emissions. Moreover, there is a significant exergy loss in the off-gas heat recovery system (>70%), which requires the adoption of stoichiometric combustion and an increase in the efficiency of heat exchange.
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RI Hu, Hang/HOC-2376-2023
OI Hu, Hang/0000-0003-0837-2768
FU National Natural Science Foundation of China [52293392, 52074024, 52004023, 20214BBG74005]; Key R amp; D Projects of Jiangxi Province; Project of "Spring City Scholar"; [52274313]
FX This work was supported by the National Natural Science Foundation of China Grant Nos. 52274313 & 52293392 & 52074024 & 52004023; Key R & D Projects of Jiangxi Province 20214BBG74005; Project of "Spring City Scholar".
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NR 60
TC 8
Z9 9
U1 9
U2 21
PU ELSEVIER SCI LTD
PI London

PA 125 London Wall, London, ENGLAND
SN 0959-6526
EI 1879-1786
J9 J CLEAN PROD
JI J. Clean Prod.
PD JUN 15
PY 2023
VL 405
AR 136909
DI 10.1016/j.jclepro.2023.136909
EA APR 2023
PG 12
WC Green & Sustainable Science & Technology; Engineering, Environmental;
   Environmental Sciences
WE Science Citation Index Expanded (SCI-EXPANDED)
SC Science & Technology - Other Topics; Engineering; Environmental Sciences
   & Ecology
GA Q1XF7
UT WOS:001055511100001
DA 2025-03-13
ER

PT J
AU Zhou, PF
   Bai, HY
   Feng, JX
   Liu, D
   Qiao, LL
   Liu, CF
   Wang, SP
   Pan, H
AF Zhou, Pengfei
   Bai, Haoyun
   Feng, Jinxian
   Liu, Di
   Qiao, Lulu
   Liu, Chunfa
   Wang, Shuangpeng
   Pan, Hui
TI Recent progress on bulk Fe-based alloys for industrial alkaline water
   electrolysis
SO JOURNAL OF MATERIALS CHEMISTRY A
LA English
DT Review
ID OXYGEN EVOLUTION REACTION; HIGH-ENTROPY-ALLOY; STAINLESS-STEEL MESH;
   LAYERED DOUBLE HYDROXIDE; EFFICIENT ELECTROCATALYST; HIGHLY EFFICIENT;
   ROBUST ELECTROCATALYST; SURFACE OXIDATION; NANOSHEET ARRAY; ACTIVE-SITES
AB Alkaline water electrolysis (AWE) is the most mature technology to produce green hydrogen for achieving carbon neutrality. However, the high cost of green hydrogen leads to its low market-occupation rate. The key to improving the rate is to develop low-cost and efficient electrocatalysts that can be easily fabricated on a large scale in industry. Bulk Fe-based alloys stand out because they are cheap, abundant, very stable, and suitable for mass production, leading to high potential for achieving green hydrogen production commercially by AWE. In this review, we systemically summarize recent development on strategies to improve the catalytic activity of bulk Fe-based alloys, including constructing porous structures, alloying, doping, in situ activation, dealloying, corrosion, and anodization. Prospects for the use of bulk Fe-based alloys in industrial AWE are given at the end. We expect that this review can provide guidelines for the manufacturing of bulk Fe-based alloys for the mass production of green hydrogen in AWE.
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RI Zhou, Peng/JRW-0804-2023; Liu, Di/IWU-5327-2023; Liu, Chunfa/AAS-4766-2021; WANG, Shuang-Peng/D-7640-2015; Pan, Hui/GQH-1900-2022
OI Liu, Chunfa/0000-0003-3343-123X; WANG, Shuang-Peng/0000-0001-8464-4994; Pan, Hui/0000-0002-6515-4970
FU Science and Technology Development Fund from Macau SAR (FDCT) [0081/2019/AMJ, 0154/2019/A3, 0033/2019/AMJ, 0125/2018/A3, 0111/2022/A2]; University of Macau [MYRG-00026-FST, MYRG2020-00207-IAPME a, MYRG2022-00026-IAPME]; Shenzhen-Hong Kong-Macao Science and Technology Research Programme (Type C) [SGDX20210823103803017]; UM Macao Ph.D. Scholarship
FX This work was supported by the Science and Technology Development Fund from Macau SAR (FDCT) (No. 0081/2019/AMJ, 0154/2019/A3, 0033/2019/AMJ, 0125/2018/A3, and 0111/2022/A2), Multi-Year Research Grants (MYRG-00026-FST, MYRG2020-00207-IAPME and MYRG2022-00026-IAPME) from the University of Macau, and the Shenzhen-Hong Kong-Macao Science and Technology Research Programme (Type C) (SGDX20210823103803017). P. F. Zhou acknowledges the support of the UM Macao Ph.D. Scholarship.
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TI Optimal CCUS Supply Chain toward Carbon Neutrality: Novel Framework for Thermal Power, Iron-Steel, and Cement Sectors
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DT Article
ID POSTCOMBUSTION CO2 CAPTURE; VARIABLE FEED CONCENTRATION; STORAGE;
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AB Carbon capture, utilization, and storage (CCUS) technology plays a crucial role in the pursuit of carbon neutrality. To reduce the cost of carbon neutrality, it is necessary to optimally design the supply chain of CCUS, which leads to mega scale problems for vast countries such as China. In this paper, a novel three-module framework including source-sink matching, meshing, and pipeline transportation network allocating, which has the advantage of plant-level decision and trunk transportation while keeping the size of the model solvable, is proposed. In addition, a database including major CO2 emission sources in thermal power, cement, and iron-steel sectors as well as major CO2 storage sinks in China is set up. By comparison of scenarios with and without offshore storage, offshore storage is found to be superior in those southern coastal provinces. With a transportation distance not exceeding 250 km, around 4.2 Gt of CO2 can be captured and stored. Simultaneously, establishing sensible CCUS deployment objectives is crucial. As the planned deployment capacity rises from 601.8 to 1203.5 Mt/year, the unit net supply chain cost will elevate from 28.5 $/tonCO(2) to 36.0 $/ton, marking a 26% increase. Moreover, the evolution of CCUS deployment toward achieving carbon neutrality between 2025 and 2050 is analyzed. Notably, early stage deployment is suitable for provinces in northern China, while other provinces are anticipated to engage in subsequent phases. The comparative study indicates that CCUS is more economically viable than introducing green power and green hydrogen in the thermal power, iron-steel, and cement sectors for emission reduction.
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TI Advancing Green Hydrogen Purity with Iron-Based Self-Cleaning Oxygen
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DE Hydrogen production; oxygen carrier; chemical looping hydrogen;
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ID THIN-FILM; SHELL; GENERATION; COMBUSTION; DEPOSITION; OXIDE
AB Green hydrogen is central to the energy transition, but its production often requires expensive materials and poses environmental risks due to the perfluorinated substances used in electrolysis. This study introduces a transformative approach to green hydrogen production via chemical looping, utilizing an iron-based oxygen carrier with yttrium-stabilized zirconium oxide (YSZ). A significant innovation is the replacement of Al2O3 with SiO2 as an inert support pellet, enhancing process efficiency and reducing CO2 contamination by minimizing carbon deposition by up to 700%. The major findings include achieving a remarkable hydrogen purity of 99.994% without the need for additional purification methods. The Fe-YSZ oxygen carrier possesses a significantly higher pore volume of 323 mm(3)/g and pore surface area of 18.3 m(2)/g, increasing the pore volume in the iron matrix by up to 50%, further improving efficiency. The catalytic system exhibits a unique self-cleaning effect, substantially reducing CO2 contamination. Fe-YSZ-SiO2 demonstrated CO2 contamination levels below 100 ppm, which is particularly noteworthy. This research advances our understanding of chemical looping mechanisms and offers practical, sustainable solutions for green hydrogen production, highlighting the crucial synergy between support pellets and oxygen carriers. These findings underscore the potential of chemical looping hydrogen (CLH) technology for use in efficient and environmentally friendly hydrogen production, contributing to the transition to cleaner energy sources.
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FU Austrian Science Fund (FWF); COMET (Competence Centers for Excellent Technologies); Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology; Federal Ministry for Digital and Economic Affairs; [10.55776/P 34824]
FX This research was funded, in part, by the Austrian Science Fund (FWF) [10.55776/P 34824]. For the purpose of open access, the author has applied a CC BY public copyright licence to any Author Accepted Manuscript version arising from this submission. The micro-CT measurement was funded as part of the project "BIO-LOOP". The COMET Module BIO-LOOP (Grant number 10.55776/P 34824) is funded within COMET (Competence Centers for Excellent Technologies) by the Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology and the Federal Ministry for Digital and Economic Affairs as well as the co-financing federal province Styria. The COMET program is managed by FFG (Austrian Research Promotion Agency, www.ffg.at/comet).
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TI The Potential of Green Hydrogen and Power-to-X Utilization in Jordanian
   Industries: Opportunities and Future Prospects
SO ENERGIES
LA English
DT Article
DE market analysis; industrial decarbonization; clean energy; green
   hydrogen; power-to-X; hydrogen applications; Jordan context
ID ENERGY; HYDROCRACKING; OIL
AB Green hydrogen and power-to-X technologies hold significant potential in the global energy transition towards net-zero emissions. This is attributed to the premise that these technologies can decarbonize numerous sectors worldwide by providing versatile and sustainable energy carriers and industrial feedstocks to replace fossil-based fuels and chemicals. To this end, the qualitative benefits of green hydrogen and power-to-X technologies have been thoroughly examined for various applications in past years. In contrast, quantifying the potential penetration of such technologies on national and

global levels still requires extensive research. Therefore, this paper investigates the prospective integration of green hydrogen and power-to-X technologies within Jordanian industries, considering their quantitative utilization potential for current and future capacities. The findings showed that the Jordanian food processing and heavy industries emerged as major sectors with substantial potential for incorporating green hydrogen and power-to-X products as alternative fuels or chemical feedstocks. In detail, the total potential utilization capacity for these sectors stood at around 57 thousand tons per year. Specifically, fertilizers production, cement industry, steel reforming, and oil refinery possess an annual potential capacity of around 6.8, 11.8, 12.7, and 25.8 thousand tons, respectively. It is also worth mentioning that the current utilization capacity of hydrogen in Jordanian industries was found to be around 8.9 thousand tons per annum, which is completely covered by fossil-based hydrogen to date. These results imply that there will be a promising market for green hydrogen and power-to-X utilization in Jordanian industries, which will play a significant role in integrated energy transition efforts in the future.
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TI Challenges and Opportunities in Green Hydrogen Adoption for
   Decarbonizing Hard-to-Abate Industries: A Comprehensive Review
SO IEEE ACCESS
LA English
DT Review
DE Green hydrogen; clean energy; renewable electricity storage;
   decarbonization on hard-to-abate industries; carbon neutrality; net-zero
   goals
ID FUEL-CELL; GAS; TRANSPORTATION; STORAGE; ELECTROCATALYST; PERFORMANCE;

TECHNOLOGY; AMMONIA; ECONOMY
AB The decarbonization of hard-to-abate industries is crucial for keeping global warming to below 2(degrees)C . Green or renewable hydrogen, synthesized through water electrolysis, has emerged as a sustainable alternative for fossil fuels in energy-intensive sectors such as aluminum, cement, chemicals, steel, and transportation. However, the scalability of green hydrogen production faces challenges including infrastructure gaps, energy losses, excessive power consumption, and high costs throughout the value chain. Therefore, this study analyzes the challenges within the green hydrogen value chain, focusing on the development of nascent technologies. Presenting a comprehensive synthesis of contemporary knowledge, this study assesses the potential impacts of green hydrogen on hard-to-abate sectors, emphasizing the expansion of clean energy infrastructure. Through an exploration of emerging renewable hydrogen technologies, the study investigates aspects such as economic feasibility, sustainability assessments, and the achievement of carbon neutrality. Additionally, considerations extend to the potential for large-scale renewable electricity storage and the realization of net-zero goals. The findings of this study suggest that emerging technologies have the potential to significantly increase green hydrogen production, offering affordable solutions for decarbonization. The study affirms that global-scale green hydrogen production could satisfy up to 24% of global energy needs by 2050, resulting in the abatement of 60 gigatons of greenhouse gas (GHG) emissions - equivalent to 6% of total cumulative CO2 emission reductions. To comprehensively evaluate the impact of the hydrogen economy on ecosystem decarbonization, this article analyzes the feasibility of three business models that emphasize choices for green hydrogen production and delivery. Finally, the study proposes potential directions for future research on hydrogen valleys, aiming to foster interconnected hydrogen ecosystems.
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AB This paper investigates hydrogen's potential to accelerate the energy transition in hard-to-abate sectors, such as steel, petrochemicals, glass, cement, and paper. The goal is to assess how hydrogen, produced from renewable sources, can foster both industrial decarbonization and the expansion of renewable energy installations, especially solar and wind. Hydrogen's dual role as a fuel and a chemical agent for process innovation is explored, with a focus on its ability to enhance energy efficiency and reduce CO2 emissions. Integrating hydrogen with continuous industrial processes minimizes the need for energy storage, making it a more efficient solution. Advances in electrolysis, achieving efficiencies up to 60%, and storage methods, consuming about 10% of stored energy for compression, are discussed. Specifically, in the steel sector, hydrogen can replace carbon as a reductant in the direct reduced iron (DRI) process, which accounts for around 7% of global steel production. A next-generation DRI plant producing one million tons of steel annually would require approximately 3200 MW of photovoltaic capacity to integrate hydrogen effectively. This study also discusses hydrogen's role as a co-fuel in steel furnaces. Quantitative analyses show that to support typical industrial plants, hydrogen facilities of several hundred to a few thousand MW are necessary. "Virtual" power plants integrating with both the electrical grid and energy-

intensive systems are proposed highlighting hydrogen's critical role in industrial decarbonization and renewable energy growth.
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TI Feasible supply of steel and cement within a carbon budget is likely to
   fall short of expected global demand
SO NATURE COMMUNICATIONS
LA English
DT Article
ID MATERIAL EFFICIENCY; EMISSIONS; INFRASTRUCTURE; ENERGY; REDUCTION;
   CAPTURE; IRON; WELL; END
AB The current decarbonization strategy for the steel and cement industries is inherently dependent on the build-out of infrastructure, including for CO2 transport and storage, renewable electricity, and green hydrogen. However, the deployment of this infrastructure entails considerable uncertainty. Here we explore the global feasible supply of steel and cement within Paris-compliant carbon budgets, explicitly considering uncertainties in the deployment of infrastructure. Our scenario analysis reveals that despite substantial growth in recycling- and hydrogen-based production, the feasible steel supply will only meet 58-65% (interquartile range) of the expected baseline demand in 2050. Cement supply is even more uncertain due to limited mitigation options, meeting only 22-56% (interquartile range) of the expected baseline demand in 2050. These findings pose a two-fold challenge for decarbonizing the steel and cement industries: on the one hand, governments need to expand essential infrastructure rapidly; on the other hand, industries need to prepare for the risk of deployment failures, rather than solely waiting for large-scale infrastructure to emerge. Our feasible supply scenarios provide compelling evidence of the urgency of demand-side actions and establish benchmarks for the required level of resource efficiency.
   A new study explores the global feasible supply of steel and cement within Paris-compliant carbon budgets, explicitly considering uncertainties in the deployment of infrastructure and it shows that feasible supply may fall short of expected global demand.

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TI A comprehensive review of production, applications, and the path to a
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SO RSC ADVANCES
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DT Review
ID CARBON-DIOXIDE; PLASMA GASIFICATION; REDUCTION BEHAVIOR; STORAGE; GAS;
   TECHNOLOGIES; AMMONIA; METHANOL; IRON; SYSTEMS
AB Green hydrogen, a versatile and sustainable energy carrier, has garnered increasing attention as a critical element in the global transition to a low-carbon economy. This review article comprehensively examines the production, applications, and potential of green hydrogen, accompanied by the challenges and future prospects associated with its widespread adoption. The production of green hydrogen is a central focus, due to its environmental benefits and distinctive characteristics. The article delves into the various techniques and technologies employed in green hydrogen production, emphasizing the need for cost reduction and increased scale for economic viability. Focusing particularly on applications, the review discusses the diverse sectors where green hydrogen demonstrates immense promise. Challenges and limitations are explored, including the intermittent nature of renewable energy sources, high production costs, and the need for extensive hydrogen infrastructure. The article also highlights the pressing need for innovation in electrolysis technology and materials, emphasizing the potential for cost reduction and increased efficiency. As industries gradually transition to green hydrogen as a cleaner feedstock, its demand and cost-competitiveness are projected to increase. This review article thoroughly evaluates the current status of green hydrogen and provides valuable insights into its potential role in the transition to a sustainable energy system.
   Green hydrogen, a versatile and sustainable energy carrier, has garnered increasing attention as a critical element in the global transition to a low-carbon economy.
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DE Green hydrogen; Ferrous metal scrap; Water splitting; Thermochemical
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AB Thermochemical water splitting is one of the methods to produce green hydrogen. In this study, metal scrap is used to split water by thermochemical process in a packed-bed reactor. Hydrogen production conditions are optimized by varying the particle size of the metal wastes in the range of 250 mu m to greater than 1000 mu m and the temperatures from 900 degrees C to 1200 degrees C. The maximum yield of hydrogen obtained is similar to 500 mL of H-2 per gram of the scrap sample. This study demonstrates that the discarded metal wastes can be utilized as feed-materials for thermochemical production of green hydrogen. The process has good conversion efficiency and is a promising solution for both metal waste management and the production of green hydrogen. Medium size metal particles show higher hydrogen production capacity compared to both smaller (<250 mu m) and larger (600-1180 mu m) size particles.(c) 2023 Hydrogen Energy Publications LLC. Published by Elsevier Ltd. All rights reserved.
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DE green hydrogen; climate-neutral industry; carbon dioxide emissions; policy package; multi-criteria analysis
ID CLIMATE
AB Green hydrogen will play a key role in building a climate-neutral energy-intensive industry, as key technologies for defossilising the production of steel and basic chemicals depend on it. Thus, policy-making needs to support the creation of a market for green hydrogen and its use in industry. However, it is unclear how appropriate policies should be designed, and a number of challenges need to be addressed. Based on an analysis of the ongoing German debate on hydrogen policies, this paper analyses how policy-making for green hydrogen development may support industry defossilisation. For the assessment of policy instruments, a simplified multi-criteria analysis (MCA) is used with an

innovative approach that derives criteria from specific challenges. Four challenges and seven relevant policy instruments are identified. The results of the MCA reveal the potential of each of the selected instruments to address the challenges. The paper furthermore outlines how instruments might be combined in a policy package that supports industry defossilisation, creates synergies and avoids trade-offs. The paper's impact may reach beyond the German case, as the challenges are not specific to the country. The results are relevant for policy-makers in other countries with energy-intensive industries aiming to set the course towards a hydrogen future.
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PA MDPI AG, Grosspeteranlage 5, CH-4052 BASEL, SWITZERLAND
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J9 SUSTAINABILITY-BASEL
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AF Schmitt, Bennett
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TI Scalable one-pot synthesis of amorphous iron-nickel-boride bifunctional electrocatalysts for enhanced alkaline water electrolysis
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AB Green hydrogen is considered an attractive energy vector that can easily replace fossil fuel consumption, meeting global energy demands. Therefore, developing easily scalable, efficient and cost-effective electrocatalysts for water electrolysis is imperative for our transition to a more sustainable energy future. To this end, we demonstrate here a simple and scalable one-pot chemical reduction method for the synthesis of amorphous iron nickel boride nanoparticles with a spherical morphology. The iron to nickel ratio was easily adjusted during synthesis, and how it effects electrocatalytic performance was evaluated. The electrocatalyst powder with the highest concentration of metallic iron, or iron bonded to nickel, exhibited enhanced bifunctional OER and HER electrocatalytic activity, outperforming RuO2, the current state-of-the-art electrocatalyst; reaching industrial current densities, with an OER overpotential of 252 mV at 10 mA cm-2 and 349 mV at 100 mA cm-2. In our view, this work delivers an important method for the scalable synthesis of amorphous bimetallic boride nanoparticles with adjustable electronic structure for achieving enhanced water electrolysis at a minimum cost.

Making green hydrogen cost effective by scalable iron nickel boride bifunctional electrocatalysts that can easily reach industrial current densities.
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OI Bekarevich, Raman/0000-0002-5634-9397; Rodriguez, Brian/0000-0001-9419-2717; Ersek, Gabor/0009-0002-1060-8020; Portale, Giuseppe/0000-0002-4903-3159; Sofianos, Maria Veronica/0000-0002-9654-1463
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PU ROYAL SOC CHEMISTRY
PI CAMBRIDGE
PA THOMAS GRAHAM HOUSE, SCIENCE PARK, MILTON RD, CAMBRIDGE CB4 0WF, CAMBS,
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AU Zhu, YX
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AF Zhu, Yongxian
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Cooper, Daniel R.
TI The role of hydrogen in decarbonizing US industry: A review
SO RENEWABLE & SUSTAINABLE ENERGY REVIEWS
LA English
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ID REDUCTION; EMISSIONS; IRON; TECHNOLOGY; COMBUSTION; OPTIONS; FUELS
AB There is a growing interest in hydrogen for decarbonizing hard-to-abate industries. However, determining which industries to target, the scale of the opportunity, and how to meet the hydrogen demand out to 2050 is complex and highly uncertain. The most significant decarbonization opportunity identified in this review is in the refining and chemicals industries, where annual emissions could reduce by up to 24% by 2050 from 2021 levels if emissions-intensive grey hydrogen is replaced with clean hydrogen. New (clean) hydrogen applications include replacements for carbon-based reductants in steelmaking (<= 18% steelmaking emissions reduction by 2050) and fuel for high-temperature heat in cement, aluminum, and glassmaking, with annual sectoral emissions reductions by 2050 of up to 23%, 3%, and 32% respectively. Hydrogen technologies have high readiness levels and face modest technical barriers in burner and furnace design. The primary challenge lies in reducing clean hydrogen production and delivery costs to $0.4-0.7/kgH(2) to compete with natural gas and scale its production from <1% of all U.S. hydrogen production today. The literature presents diverse U.S. industry clean hydrogen demand predictions (4-22 Mt/year by 2050) due to conflicting projections of industrial output, some incompatible with decarbonization goals; e.g., growth in gasoline production. After reconciling literature on hydrogen technology readiness, alternative decarbonization strategies, and U.S. climate targets, we estimate 2050 industrial clean hydrogen demand at 3.8-14.9 Mt/year, saving 28-133 MtCO(2eq) (1.5-7.0% of current U.S. industry emissions). Green hydrogen production will require up to 682 TWh of low-carbon electricity, equivalent to 90% of current renewable generation.
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AF Voglar, Jure
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TI Critical perspective on green hydrogen-based seasonal operation of
   energy-intensive industry sectors with solid products
SO INTERNATIONAL JOURNAL OF HYDROGEN ENERGY
LA English
DT Article
DE Hydrogen economy; Decarbonization; Industrial production; Commodities;
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ID RENEWABLE HYDROGEN; NATURAL-GAS; STORAGE; IRON; INJECTION; BURNERS;
   POWER; TERM
AB In the light of a future decarbonized power grid based primarily on non-dispatchable renewable energy sources, the operation of industrial plants should be decarbonized and flexible. An innovative, novel concept combining industrial plants with (i) a water electrolysis unit, (ii) a hydrogen storage unit and (iii) a fuel cell unit would enable seasonal supply-demand balancing in the local power grid and storage of surplus energy in the form of stable solid products. The feasibility of this concept was demonstrated in a case study, taking into account the overall energy balance and economics. The characteristics of the local power grid and the hydrogen round-trip efficiency must be carefully considered when dimensioning the hydrogen units. It was found that industries producing iron and steel, cement, ceramics, glass, aluminum, paper and other metals have the potential for seasonal operation. Future research efforts in the fields of technology, economics and social sciences should support the sustainable flexibility transition of energy-intensive industries with solid products.
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TI Pathways Toward Efficient and Durable Anion Exchange Membrane Water
Electrolyzers Enabled By Electro-Active Porous Transport Layers
SO ADVANCED ENERGY MATERIALS
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DT Article
DE AEM; durability; hydrogen; PTL; water electrolysis
ID XPS SPECTRA; HYDROGEN; PEM; POLYELECTROLYTES; STABILITY; CATALYST
AB Green hydrogen, produced via water electrolysis using renewable electricity, will play a crucial role in decarbonizing industrial and heavy-duty transportation sectors. Anion exchange membrane water electrolyzers (AEMWEs) can overcome many of the performance and

cost limitations of incumbent technologies, however, still suffer from durability challenges due to oxidative instability of anion-exchange ionomers. Herein, the use of an electro-active porous transport layer as anode (PTL-electrode) is demonstrated to enable efficient and durable AEMWEs. The stainless-steel PTL-electrodes are shown to have superior performance and durability compared to traditional catalyst layers containing ionomer and nanoparticle catalysts. An AEMWE cell operating at 2 A cm-2 for over 600 h exhibited a degradation rate of just 5 mu V h-1. During operation, the surface composition of the stainless steel transforms into a mixture of iron and nickel oxyhydroxides, contributing to enhanced oxygen-evolution reaction activity. The combination of experimental work and modeling elucidates how the bulk structure of the PTL-electrode offers an additional design dimension to further improve electrolyzer performance. Lastly, a surface modification strategy is applied to a PTL-electrode to achieve an even higher performing AEMWE (2.3 vs 2.0 A cm-2 at 1.8 V). Overall, this work lays out pathways toward more efficient, durable, and affordable AEMWEs.
This work combines experimental design and numerical simulation to present a promising pathway toward accelerating the deployment of anion-exchange-membrane water electrolyzers as more efficient, affordable, and reliable green hydrogen production infrastructures.image
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ID ENERGY-EFFICIENCY; DIRECT REDUCTION; IRON; TECHNOLOGIES; EMISSIONS;
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AB Whole-of-economy greenhouse gas emissions reduction is one of the most important targets of transitioning to sustainable energy systems. With 7% of global emissions, the steel industry is one of the most carbon-intensive industries. Approximately two-thirds of annual steel production is attributed to the conventional blast furnace (BF)/converter route with high carbon emissions. Many countries in the world have developed large-scale lab-oratory pilots in line with steel production processes with green hydrogen or syngas. In this study, the experienced strategies of green, gray, and blue steel generation in the world are studied. Accordingly, the technology development approach of different countries, their targets, and implemented international motivations to improve the green-commodity supply chain are reviewed. The results show that in order to achieve low/zero carbon steel generation, the technology development approach in each country is consistent with its national circumstances, availability of resources, and constraints. Therefore, concerning the economic and environmental approaches of the biocompatible technologies for the steel industry development, it is important to identify the countries' strategies and plans for adapting the current industry based on local capacities and constraints. These considerations are analyzed for greening steel production in various regions of the world and recommendations are made for low-carbon steel production in developing countries. According to the findings of this research, it is advisable for nations that possess fossil fuel resources to adopt the production of blue steel, as the transition to green steel production entails a high cost of technology. Conversely, nations that have limited access to fossil fuels and abundant water resources can justify their policies on green steel production through the use of electrolysis technology and renewable energy. Additionally, some nations that have extensive agricultural land and biomass resources can benefit from the development of brown steel. Therefore, the strategy of low carbon steel is contingent on the geographical constraints and cannot be uniformly applied to all regions.

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TI Principles of Water Electrolysis and Recent Progress in Cobalt-,
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DT Review
DE cobalt; iron; nickel; oxygen evolution reaction; water splitting
ID LAYERED DOUBLE HYDROXIDE; ELECTROCHEMICAL EVOLUTION; IN-SITU; OXIDATION
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AB Water electrolysis that results in green hydrogen is the key process towards a circular economy. The supply of sustainable electricity and availability of oxygen evolution reaction (OER) electrocatalysts are the main bottlenecks of the process for large-scale production of green hydrogen. A broad range of OER electrocatalysts have been explored to decrease the overpotential and boost the kinetics of this sluggish half-reaction. Co-, Ni-, and Fe-based catalysts have been considered to be potential candidates to replace noble metals due to their tunable 3d electron configuration and spin state, versatility in terms of crystal and electronic structures, as well as abundance in nature. This Review provides some basic principles of water electrolysis, key aspects of OER, and significant criteria for the development of the catalysts. It provides also some insights on recent advances of Co-, Ni-, and Fe-based oxides and a brief perspective on green hydrogen production and the challenges of water electrolysis.
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TI Sector-coupling Green Hydrogen to Electrify Steel Production - A Case
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DE hydrogen; steel; electric arc furnace; sustainable development goals;
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AB With a global energy system in rapid transformation from fossil fuels, Green Hydrogen is one of the few solutions to hard-to-abate emissions within the industry. While most hydrogen projects are in the planning phase, the Ovako hydrogen facility in Hofors, with a scrap-based Electric Arc Furnace process, was inaugurated in September 2023. This project studies wider system benefits of the electrolyser such as power grid support, oxygen byproduct, providing hydrogen to external actors, and district heating. This is analysed both with current capacity and in regards to possible future development. Replacing fossil fuel with hydrogen produced by an atmospheric alkaline electrolyser is an indirect electrification with the potential to decrease Green House Gas emissions. Industry-wide electrification increases the electricity demand, affecting all existing users. Therefore, system benefits and sector couplings such as enabling ancillary services to the grid, producing low-marginal cost hydrogen for hydrogen-powered trucks, and using waste heat for district heating, are important to ascertain system-wide improvements.
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TI XPS study of electroless NiP coating on iron substrate
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AB X-ray photoelectron spectroscopy and x-ray-induced Auger electron spectroscopy analyses were performed to characterize NiP coating on the iron substrate. This electroless coating is commonly used for its outstanding corrosion resistance, but it is currently of interest as a hydrogen permeation barrier (HPB) for green hydrogen storage and transportation; thus, NiP coatings are relevant for energy and for the environment.
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ID GREEN HYDROGEN; ENERGY TRANSITIONS; CELL VEHICLES; SECTOR; TECHNOLOGIES; ELECTRICITY; POLITICS; IMPACT; FUTURE; GAS
AB Because of the pressure to meet carbon neutrality targets, carbon reduction has become a challenge for fossil fuel resource-based regions. Even though China has become the most active country in carbon reduction, its extensive energy supply and security demand make it difficult to turn away from its dependence on coal-based fossil energy. This paper analyzes the Chinese coal capital-Shanxi Province-to determine whether the green, low-carbon energy transition should be focused on coal resource areas. In these locations, the selection and effect of transition tools are key to ensuring that China meets its carbon reduction goal. Due to the time window of clean coal utilization, the pressure of local governments, and the survival demands of local high energy-consuming enterprises, Shanxi Province chose hydrogen as its important transition tool. A path for developing hydrogen resources has been established through lobbying and corporative influence on local and provincial governments. Based on such policy guidance, Shanxi has realized hydrogen applications in large-scale industrial parks, regional public transport, and the

iron and steel industry. This paper distinguishes between the development strategies of gray and green hydrogen. It shows that hydrogen can be an effective development model for resource-based regions as it balances economic stability and energy transition.
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TI Scenarios for deep decarbonisation of industry in Lithuania
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DE Decarbonisation; Industry; Carbon dioxide emissions; Scenario analysis;
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   CAPTURE; STEEL; IRON; TECHNOLOGY; EFFICIENCY; STORAGE; SECTOR
AB Achieving an ambitious EU long-term vision of climate neutrality requires efforts across all Member States and economic sectors. Lithuania 's industrial carbon dioxide (CO 2) emissions are expected to maintain current trends under a business-as-usual case. We applied a bottom-up modelling approach to analyse deep decarbonisation scenarios for the Lithuanian industry up to 2050 to advance the wider debate and provide insights into the measures needed to make a difference. The results show that the deep decarbonisation of the Lithuanian industry by 2050 is feasible. However, to avoid large-scale emissions from industrial processes, it is requisite to utilise green hydrogen (H 2) as a feedstock for ammonia production and carbon capture and storage (CCS) for clinker production. It requires significant investments and increases operating costs. Without CCS and H 2 , only up to 17 % of industrial emissions could be avoided by 2050.
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TI Industry in a net-zero emissions world: New mitigation pathways, new
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SO ENERGY AND CLIMATE CHANGE
LA English
DT Article
DE Industry; Net-zero; Decarbonization; Decarbonisation; Modelling;
   Modeling; Trade; Policy
ID OPTIONS; STEEL; TECHNOLOGY; CEMENT; IRON
AB The objective implicit in the Paris Agreement, net-zero emissions around mid-century, has transformed the debate about heavy industry decarbonisation. Prior to Paris, the iron and steel, cement and concrete, chemicals, and other materials sectors were expected to reduce absolute emissions by perhaps half by 2050, through measures like energy efficiency, biofuels and carbon capture and storage. Global net-zero emissions means that these industries face far deeper transformation and potentially costly offsetting. It is also becoming clear, however, that very low emissions in heavy industry are technically possible using a spectrum of new options, including demand management, materials efficiency, and direct and green hydrogen-based electrification of primary materials production, facilitated by the falling cost of renewable electricity. Very low emissions production chains mean changes to the location of the world's heavy industry, including splitting processes into components to allow use of large-scale low-cost renewable energy or access to geological CO2 storage, with implications for trade. Existing models used for decarbonisation analysis typically do not represent the detail necessary for a full understanding of the range of mitigation options. Better representation of industry in systems modelling, along with analysis and learning about policy options and sequencing as industry transformations unfold, will be important for reaching net-zero and net-negative emissions in cost-effective and just ways. Key options, implications for the geography of heavy industry, and implications for systems modelling and policy are outlined here.
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TI Direct Solar Thermal Water-Splitting Using Iron and Iron Oxides at High
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SO APPLIED SCIENCES-BASEL
LA English
DT Review
DE solar thermochemical water-splitting; iron corrosion; solar reactor
ID CIRCULATING FLUIDIZED-BED; INTEGRATED RECEIVER-STORAGE;
   HYDROGEN-PRODUCTION; BEAM-DOWN; OXIDATION-KINETICS; REDUCTION;
   CORROSION; HEAT; DECOMPOSITION; REACTOR

AB Green hydrogen is poised to play a crucial role in the energy-transition process in developed countries over the coming years, particularly in those countries aiming to achieve net-zero emissions. Consequently, the for green hydrogen is expected to rise significantly. This article explores the fundamental methods of producing hydrogen, focusing on the oxidation reaction within a thermochemical solar cycle for the dissociation of steam. Solar thermochemical cycles have been extensively researched, yet they remain in the development stage as research groups strive to identify optimal materials and conditions to enhance process efficiency, especially at high temperatures. The article analyses theoretical foundations drawn from exhaustive scientific studies related to the oxidation of iron in steam, the relationship with the activation energy of the corrosive process, thermodynamic aspects, and the kinetic model of a heterogeneous reaction. Additionally, it presents various mechanisms of high-temperature oxidation, pH effects, reactors, and materials (including fluidized beds). This scientific review suggests that hydrogen production via a thermochemical cycle is more efficient than production via electrochemical processes (such as electrolysis), provided the limitations of the cycle's reduction stage can be overcome.
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RI Pulido, Diego/AAH-3990-2019; Toro, Norman/AAK-7766-2020; Fuentealba, Edward/O-1490-2018; Sagade, Atul/B-6494-2012
OI Soliz, Alvaro/0000-0002-6548-956X; Sagade, Atul/0000-0002-0776-6725; Toro Villarroel, Norman Rodrigo/0000-0003-4273-3563; Galleguillos Madrid, Felipe M./0000-0002-1347-3726; Pulido-Iparraguirre, Diego/0000-0001-5944-2899; Fuentealba, Edward/0000-0002-8808-2615
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AU Lee, H
AF Lee, Hwarang
TI Decarbonization strategies for steel production with uncertainty in
   hydrogen direct reduction
SO ENERGY
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DE Hydrogen direct reduction; Green hydrogen; Uncertainty; Steel industry;
   Energy system model; Monte Carlo simulation
AB The steel industry remains difficult to decarbonize because of its high dependence on coal. This industry plans to use hydrogen instead of coal via hydrogen direct reduction. Although this technology reduces steel emissions significantly, considerable uncertainty remains. This study aimed to explore how internal and external uncertainties in hydrogen direct reduction affect uncertainties in steel decarbonization using an energy system

model and Monte Carlo simulation. This study assumed that the investment cost of hydrogen direct reduction, hydrogen price, and emission coefficient of hydrogen are uncertain. The uncertainty in hydrogen prices was the most important factor affecting hydrogen use, emissions, and emission reduction costs. Moreover, the probability of steel emissions deviating from their target level was highest when hydrogen price was uncertain. This study contributes to the development of strategies for steel decarbonization and assists policymakers in probabilistic decision making with uncertainty regarding hydrogen direct reduction. Policymakers should understand the relationship between the steel, power, and hydrogen sectors and manage external uncertainties in the power and hydrogen sectors because steel decarbonization largely depends on renewable electricity and electrolyzer costs.
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TI Solar-driven hydrogen generation coupled with urea electrolysis by an oxygen vacancy-rich catalyst
SO CHEMICAL ENGINEERING JOURNAL
LA English
DT Article
DE Solar-to-hydrogen; Waste-to-value; Plasma engineering; Green hydrogen; Urea oxidation
ID EFFICIENT BIFUNCTIONAL ELECTROCATALYST; ELECTRONIC-STRUCTURE; TI-MESH; EVOLUTION; OXIDATION; NI; NANOHYBRIDS; DESIGN; ARRAY
AB Urea, an environmental pollutant for both soil and water, is widely present in wastewater. On the other hand, a strategy utilizing renewable electricity to decrease the cost of green hydrogen, which holds the key to a sustainable energy future, is promising but challenging. Gas crossover that generates explosive hydrogen?oxygen mixture becomes very serious with intermittent renewable power source (partial load issue). Herein, we address these issues in one device, i.e., a hybrid electrolyzer where water oxidation that produces oxygen is replaced by urea oxidation which generates inert gases. A self-supported electrocatalyst of nitrogen-doped nickel-iron oxyhydroxide derived from waste rusty iron foam is synthesized via an in situ ?waste-to-value? synthetic route followed by an ammonia/argon plasma treatment, which reconstructs the surface of the catalyst to a 3D nanosheetlike porous network with abundant oxygen vacancies. The as-prepared catalyst shows a small potential of 1.45 V vs. RHE at 500 mA cm? 2 for urea oxidation. Overall water-urea electrolysis only requires 1.58 V to deliver 100 mA cm-2, which is 0.33 V less than that in urea-free water splitting, and thus lowers the overall energy consumption by 17.3%. Without oxygen evolution, the hybrid electrolysis does not suffer from the safety hazard caused by explosive hydrogen?oxygen mixture. We demonstrate the safe production of green hydrogen (3.1% oxygen in the gaseous product) in the hybrid electrolysis powered by solar energy via a photovoltaic panel. Our work provides a method to address the urea-caused environmental issues and simultaneously generate green hydrogen safely using solar energy.
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TI Analysis of the techno-economics and CO2 emissions of DME production
   using by-product gases in the steel industries
SO JOURNAL OF CLEANER PRODUCTION
LA English
DT Article
DE DME process; Techno-economics; CO 2 emissions; Separation and recycling
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ID COKE-OVEN GAS; DIMETHYL ETHER SYNTHESIS; METHANOL PRODUCTION;
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AB A dimethyl ether (DME) synthesis process using steelmaking by-product gases (a mixture of coke oven gas (COG) and furnace top gas (FTG)) was developed to evaluate the effects of process configurations on techno-economics and CO2 emissions based on a natural gas-based conventional process. The performance of a catalytic reactor combining pellet-type methanol synthesis and methanol dehydration catalysts through physical mixing was validated against experimental data. Two separation strategies--flash vessels vs. absorber--for DME separation were considered. The recycling of the entire light gas or pure hydrogen was also compared, resulting in four combinatorial cases for the DME production process. Further analysis, exploring variations in the purge and bypass fractions of the recycling stream, showed that recycling pure hydrogen achieved the most

favorable techno-economics and CO2 emissions. When auxiliary hydrogen feed was applied, gray hydrogen deteriorated the techno-economics and CO2 emissions, whereas green hydrogen enhanced the CO2 emissions but led to poor techno-economic outcomes. The sale of partial amounts of pure hydrogen by pressure swing adsorption (PSA) adversely affected both CO2 emissions and DME production, though an increase in hydrogen price could potentially improve techno-economics. The case of absorber-based separation and recycling of pure hydrogen showed the highest CO2 reduction, approximately 8.5% reduction compared to the use of natural gas for DME production at the cost of techno-economics (an increase of minimum selling price by 2.2 $/kgDME), indicating that CO2 reduction comes at a cost. The developed model offers valuable insights into the design of efficient CO2 utilization processes within the steel industry.
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NR 72
TC 0
Z9 0
U1 1
U2 1
PU ELSEVIER SCI LTD
PI London
PA 125 London Wall, London, ENGLAND
SN 0959-6526
EI 1879-1786
J9 J CLEAN PROD
JI J. Clean Prod.
PD FEB 10
PY 2025
VL 492
AR 144893
DI 10.1016/j.jclepro.2025.144893
PG 18
WC Green & Sustainable Science & Technology; Engineering, Environmental;

Environmental Sciences
WE Science Citation Index Expanded (SCI-EXPANDED)
SC Science & Technology - Other Topics; Engineering; Environmental Sciences & Ecology
GA W8R5N
UT WOS:001421176800001
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ER

PT C
AU Schütte, C
Neubauer, N
Röben, F
Hölling, M
Genz, L
Edens, T
Henne, HC
Schweininger, K
AF Schuette, Carsten
Neubauer, Nicolas
Roeben, Felix
Hoelling, Marc
Genz, Luisa
Edens, Torben
Henne, Hans-Christian
Schweininger, Klaus
GP IEEE
TI Decarbonization of the Metal Industry in Hamburg - Demand, Efficiency and Costs of Green Hydrogen
SO 2022 18TH INTERNATIONAL CONFERENCE ON THE EUROPEAN ENERGY MARKET, EEM
SE International Conference on the European Energy Market
LA English
DT Proceedings Paper
CT 18th International Conference on the European Energy Market (EEM)
CY SEP 13-15, 2022
CL Ljubljana, SLOVENIA
DE Decarbonization; Green hydrogen costs; Hydrogen demand; Energy price forecast; Metal industry Hamburg
AB The metal industry is energy and therefore CO2 intensive, which causes challenges with regard to the urgent need to reduce greenhouse gas emissions. The German Climate Protection Law aims to reduce industrial CO(2)e emissions from 186 million t per year in 2020 to 118 million t per year in 2030. Germany's stated goal is to achieve net greenhouse gas neutrality by 2045. This study focuses on the process-related hydrogen (H-2) demand in Hamburg's copper, steel, and aluminum industries, as part of the project "Northern German Living Lab". The H-2 demand is used to size on-site Power-to-Hydrogen (PtH2) units. Finally, different pricing scenarios are developed to compare the costs of H-2 based to the as-is natural gas (NG) based metal reduction over time.
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FU German Federal Ministry for Economic Affairs and Climate Action (BMWK)
FX This paper was developed within the project NRL ("Northern German Living Lab") which is partly funded by the German Federal Ministry for Economic Affairs and Climate Action (BMWK). (sponsors)
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NR 41
TC 1
Z9 1
U1 0
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PU IEEE
PI NEW YORK
PA 345 E 47TH ST, NEW YORK, NY 10017 USA
SN 2165-4077
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WC Green & Sustainable Science & Technology; Economics; Energy & Fuels;
   Engineering, Electrical & Electronic
WE Conference Proceedings Citation Index - Science (CPCI-S); Conference Proceedings Citation Index - Social Science & Humanities (CPCI-SSH)
SC Science & Technology - Other Topics; Business & Economics; Energy &
   Fuels; Engineering
GA BX5KX
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PT J
AU Yu, KP
   Feng, SH
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AF Yu, Kaiping
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TI A sequential dual-passivation strategy for designing stainless steel
   used above water oxidation
SO MATERIALS TODAY
LA English
DT Article
DE Anti-corrosion; Stainless steel; Sequential dual-passivation; Water
   electrolysis
ID LOCALIZED CORROSION BEHAVIOR; POINT-DEFECT MODEL; PITTING CORROSION;
   OXYGEN EVOLUTION; MINERALS; ALLOYS; ACID; FILM; MN; PH
AB Stainless steel is critical material used in a wide variety of industries. Unfortunately, current development of stainless steel has reached a stagnant stage due to the fundamental limitation of the conventional Cr-based single-passivation mechanism. Here, we show that, by using a sequential dualpassivation mechanism, substantially enhanced anti-corrosion properties can be achieved in Mncontained stainless steel, with a high breakdown potential of -1700 mV (saturated calomel electrode, SCE) in a 3.5 wt% NaCl solution. Specifically, the conventional Cr-based and counter-intuitive Mnbased passivation is sequentially activated during potentiodynamic polarization. The Cr-based passive layer prevents corrosion at low potentials below -720 mV(SCE), while the Mn-based passive layer resists corrosion at high potentials up to -1700 mV(SCE). The present "sequential dual-passivation" strategy enlarges the passive region of stainless steel to high potentials above water oxidation, enabling them as potential anodic materials for green hydrogen production via water electrolysis.
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OI Ding, Chao/0000-0002-5124-1053; Shihui, Feng/0000-0002-9881-3493; Huang,
   M.X./0000-0002-8038-431X; Yu, Kaiping/0000-0001-9333-8630
FU National Key Research and Development Program of China [2019YFA0209900];
   National Natural Science Foundation of China [U1764252]; Research Grants
   Council of Hong Kong [R7066-18]; New Cornerstone Science Foundation
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   Committee [KQJSCX20180322152424539]; Shenzhen DRC project; Shenzhen
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NR 62
TC 5
Z9 5
U1 11
U2 41
PU ELSEVIER SCI LTD
PI London
PA 125 London Wall, London, ENGLAND
SN 1369-7021
EI 1873-4103
J9 MATER TODAY
JI Mater. Today
PD NOV
PY 2023
VL 70
BP 8
EP 16
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EA DEC 2023
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WC Materials Science, Multidisciplinary
WE Science Citation Index Expanded (SCI-EXPANDED)
SC Materials Science
GA EA3E8
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PT J
AU [Anonymous]
AF [Anonymous]
TI Scientists from the Saar University and Dillinger want to protect
   pipelines from damage caused by hydrogen
SO PRAKTISCHE METALLOGRAPHIE-PRACTICAL METALLOGRAPHY
LA German
DT News Item
AB Politics and industry agree: With "green" hydrogen, energy-intensive companies, such as those in the steel industry, should become climate-neutral. But hydrogen has a catch: it causes materials that come into contact with it to become brittle. Hydrogen pipelines could be damaged as a result. Scientists at Saarland University are therefore working with Dillinger to find a better, standardized method for testing materials for their resistance to hydrogen.
NR 0
TC 0
Z9 0
U1 0
U2 0
PU WALTER DE GRUYTER GMBH
PI BERLIN
PA GENTHINER STRASSE 13, D-10785 BERLIN, GERMANY
SN 0032-678X
EI 2195-8599
J9 PRAKT METALLOGR-PR M
JI Prakt. Metallogr.-Pract. Metallogr.
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WC Metallurgy & Metallurgical Engineering
WE Science Citation Index Expanded (SCI-EXPANDED)
SC Metallurgy & Metallurgical Engineering
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PT J
AU Ren, BY
Zhang, H
Jia, XK
Gao, JP
Xie, J
Wang, XK
AF Ren, Biying
Zhang, Huan
Jia, Xiangkun
Gao, Jianping
Xie, Jun
Wang, Xikui
TI A Self-Supported Electrode for the Alkaline HER Based on
Electrodeposition of Platinum on Metal Fiber Felt
SO CHEMISTRYSELECT
LA English
DT Article
DE Electrodeposition; Hydrogen evolution reaction; Self-supported
electrode; Stainless steel fiber felt
ID HYDROGEN EVOLUTION REACTION; STAINLESS-STEEL 316L; MECHANICAL-PROPERTIES
AB Electrocatalytic hydrogen evolution is an important topic in the preparation of low-carbon green hydrogen energy sources. This paper reports an efficient electrocatalytic electrode using platinum on a stainless steel fiber felt (SSF) substrate by the electrodeposition method. The surface of SSF is loaded with electrodeposited Pt nanoparticles, which enhance the electrochemical properties of SSF. The overpotential eta 10 of the synthesized electrode for hydrogen evolution reaction (HER) in 1 M KOH is just 21 mV, indicating that it has excellent electrocatalytic performance. Long-time durability tests showed good stability of the synthesized electrode. All these excellent properties indicate that the prepared self-supported electrodes are promising for a new direction in industrial water electrolysis.
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FU Central Guiding Local Science and Technology Development Foundation of
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Guiding Local Science and Technology Development Foundation of China
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CR Abbas SA, 2018, SCI REP-UK, V8, DOI 10.1038/s41598-018-21396-9
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TI Supplying hydrogen for green steel through renewable energy sources: A case study of Turkiye
SO JOURNAL OF CLEANER PRODUCTION
LA English
DT Article
DE Green steel; Site selection; Offshore wind energy; BWM; Hydrogen energy
ID HYBRID OFFSHORE WIND; FARM SITE SELECTION; DECISION-ANALYSIS; FUZZY; INDUSTRY; SYSTEMS; POWER; TECHNOLOGY; CRITERIA; BWM
AB Steel is the most common industrial material worldwide due to its numerous applications, high strength and recyclability. Steel production involves alloying iron with various amounts of carbon and other elements to produce thousands of different grades and types of steel for various purposes. However, the intensive use of carbon in steel production is one of the factors contributing to global climate change. To use of hydrogen and renewable energy sources in steel production has emerged as a significant solution to reduce carbon emissions. The aim of this study is to obtain green hydrogen

for the production of green steel. The focus is on utilizing offshore wind energy as a renewable energy source to give us the energy we need to electrolyze seawater. The study uses the seas of Turkiye for case analysis. In this paper, an integrated Multi-criteria decision-making method is used to integrate hybrid energy systems and their application for green industry and to select a location for a power generation plant. The study is a new contribution to the literature in terms of its scope. Green steel's location selection is addressed for the first time in the literature. The weights of the criteria are determined by employing the Best-Worst Method (BWM) as a multi-criteria decision-making technique, and the alternatives are evaluated using the Analytic Hierarchy Process (AHP). By using the BWM method, decision makers can have a clear understanding of the evaluation range for pairwise comparisons of criteria, which reduces potential biases. According to the study, the northern part of the Aegean Sea in Turkiye is the most suitable alternative for green steel production, with offshore wind energy being used for hydrogen production. The study also revealed that the most important main criterion for this hybrid system is "natural factors", and the subcriteria are "wind speed and power density" by far compared to other sub-criteria. The fact that the area determined for the facility is suitable for construction and the possibility that the customer of the energy produced is other industrial establishments here is the most important indicator that the methods applied give good results.
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SO ENERGY CONVERSION AND MANAGEMENT
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DT Article
DE Alkaline water electrolysis; Performance degradation; Multiphysics modeling; Iron electrodeposition; Economic analysis
ID NICKEL CATHODES; EVOLUTION; MEMBRANE; HYDROGEN; CELLS
AB Alkaline water electrolysis (AWE) plays a pivotal role in green hydrogen production, garnering significant global interest in the fields of electrical and energy research. The degradation of water electrolyzers presents a major challenge for industrial applications, as it directly impacts the economic viability of hydrogen production, influencing investment decisions and technological advancements. Despite its importance, revealing and validating the mechanisms responsible for the long-term degradation of stable industrial AWE systems remains complex. This complexity arises from the intricate interplay of multiple physical processes within the system, complicating the quantitative analysis of degradation mechanisms. The dominant factor contributing to AWE system performance degradation is the iron electrodeposition reaction (IER). The IER results in a reduction of the cathode catalyst surface area and membrane porosity, which in turn leads to an increase in both activation and ohmic overpotentials. To investigate this hypothesis, accelerated experiments were conducted, and a multiphysics model was developed to quantify the impact of IER on voltage degradation. The results indicate that an iron ion concentration of 3 ppm leads to an approximately 10 % increase in voltage over a 10-year operational period. These findings highlight the critical need for effective operational strategies to ensure both economic and operational sustainability in the green hydrogen sector.
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FU National Natural Science Foundation of China [52177089]
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NR 33
TC 0
Z9 0
U1 6
U2 6
PU PERGAMON-ELSEVIER SCIENCE LTD
PI OXFORD
PA THE BOULEVARD, LANGFORD LANE, KIDLINGTON, OXFORD OX5 1GB, ENGLAND
SN 0196-8904
EI 1879-2227
J9 ENERG CONVERS MANAGE
JI Energy Conv. Manag.
PD FEB 15
PY 2025
VL 326
AR 119487
DI 10.1016/j.enconman.2025.119487
EA JAN 2025
PG 11
WC Thermodynamics; Energy & Fuels; Mechanics
WE Science Citation Index Expanded (SCI-EXPANDED)
SC Thermodynamics; Energy & Fuels; Mechanics
GA W1M4C
UT WOS:001416299000001
DA 2025-03-13
ER

PT J
AU Baasch, S
Maschke, J
Buhk, J
AF Baasch, Stefanie
Maschke, Judith
Buhk, Jaqueline
TI An (in-)just transition? Sociotechnical imaginaries of the "green" hydrogen and steel transition in Bremen, Germany
SO FUTURES
LA English
DT Article
DE Hydrogen transition; Energy transition; Industrial decarbonization; Green steel; Energy justice; Sociotechnical imaginaries
ID JUSTICE
AB Hydrogen is considered one of the most important energy sources of the future, especially for the decarbonization of industry and the zero-carbon target in 2050. Despite high expectations, the transition to clean or green hydrogen is still in its infancy, although strategies and measures are being developed under considerable time pressure. In Germany, hydrogen strategies have been published at both national and state level, and significant funding programs have been initiated to support a fast ramp-up. This paper presents the results of a qualitative interview study with Bremen stakeholders

on the sociotechnical imaginaries around the state's hydrogen transition, which is strongly focused on the decarbonization of the local steelworks. Conceptually, this study combines two strands: sociotechnical imaginaries and multiple energy justices. The results show that ideas about the future hydrogen transition are largely embedded in ecological modernization thinking, although they are still very vague and sometimes controversial. So far, justice aspects have been addressed almost exclusively in the narrow context of local job preservation, and not or hardly at all in the context of global hydrogen strategies. This carries the risk of designing a transition that further exacerbates the inequalities and injustices of existing energy systems.
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FX Thank you to the participants who gave their time to be interviewed.
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NR 60
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Z9 1
U1 3
U2 3
PU ELSEVIER SCI LTD
PI London
PA 125 London Wall, London, ENGLAND
SN 0016-3287
EI 1873-6378
J9 FUTURES
JI Futures
PD DEC
PY 2024
VL 164
AR 103489
DI 10.1016/j.futures.2024.103489
EA OCT 2024
PG 12
WC Economics; Regional & Urban Planning
WE Social Science Citation Index (SSCI)
SC Business & Economics; Public Administration
GA L1I7A
UT WOS:001348333900001
OA hybrid
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ER

PT J
AU Zhong, J
Bollen, MHJ
AF Zhong, Jin
Bollen, Math H. J.
TI On the Way to Utilizing Green Hydrogen as an Energy Carrier-A Case of
Northern Sweden
SO ENERGIES
LA English
DT Article
DE carbon neutral; power transmission and power flow; hydrogen; Swedish

power grid; carbon emission; renewable energy; energy carrier;
   electricity supply
AB Low or even zero carbon dioxide emissions will be an essential requirement for energy supplies in the near future. Besides transport and electricity generation, industry is another large carbon emitter. Hydrogen produced by renewable energy provides a flexible way of utilizing that energy. Hydrogen, as an energy carrier, could be stored in a large capacity compared to electricity. In Sweden, hydrogen will be used to replace coal for steel production. This paper discusses how the need for electricity to produce hydrogen will affect the electricity supply and power flow in the Swedish power grid, and whether it will result in increased emissions in other regions. Data of the Swedish system will be used to study the feasibility of implementing the hydrogen system from the power system viewpoint, and discuss the electricity price and emission issues caused by the hydrogen production in different scenarios. This paper concludes that the Swedish power grid is feasible for accommodating the additional electricity capacity requirement of producing green hydrogen for the steel industry. The obtained results could be references for decision makers, investors, and power system operators.
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NR 7
TC 1
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U1 5
U2 7
PU MDPI
PI BASEL
PA ST ALBAN-ANLAGE 66, CH-4052 BASEL, SWITZERLAND
EI 1996-1073
J9 ENERGIES
JI Energies
PD APR
PY 2024
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IS 7
AR 1514
DI 10.3390/en17071514
PG 12
WC Energy & Fuels
WE Science Citation Index Expanded (SCI-EXPANDED)
SC Energy & Fuels
GA NM7H9
UT WOS:001200930400001
OA Green Published, gold
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PT J
AU Perego, M
   Scilabra, P
AF Perego, Michele
   Scilabra, Patrick
TI Shaping the future of green hydrogen: De Nora's electrochemical

technologies for fueling the energy transition
SO PURE AND APPLIED CHEMISTRY
LA English
DT Article
DE Electrochemistry; energy transition; green hydrogen; water electrolysis;
Avogadro Colloquia 2022
AB De Nora, an Italian multinational corporation listed on Euronext Milan, stands as a notable leader in sustainable technologies, especially within the growing field of green hydrogen. Over its century-long existence, the company has undergone distinct phases, culminating in a significant global role for a greener and more sustainable future. De Nora has substantiated its international presence with a robust network of 25 operational entities, five research centers, and a workforce exceeding 2000 employees. Originating in 1923 under Oronzio De Nora's vision, the establishment of Oronzio De Nora Impianti Elettrochimici propelled the company into pioneering electrochemical advancements. Initially focusing on chlor-alkali technologies, De Nora's strategic collaborations and acquisitions facilitated its evolution from a specialized enterprise to a versatile multinational entity. The contemporary phase of De Nora's journey has been fortified by strategic partnerships, notably with Blackstone Tactical Opportunities and later Snam S.p.A. These alliances align with the need to face climate change and underscore De Nora's commitment to achieving carbon neutrality by 2050. As the transition to cleaner energy solutions accelerates worldwide, De Nora's expertise in electrode technology and electrochemical processes positions it as a frontrunner in the green hydrogen revolution. Central to this evolution is the rise of green hydrogen, produced through water electrolysis using renewable sources. De Nora's research and development initiatives have yielded transformative outcomes, including energy-efficient electrodes and innovative electrode packages tailored for alkaline electrolysis. This focus on efficiency and cost reduction enhances De Nora's potential to drive the widespread adoption of green hydrogen technology, amplifying its influence on the global energy landscape. De Nora's impact extends to pivotal global initiatives, exemplified by its role as a strategic partner in NEOM project, an ambitious green hydrogen production facility in Saudi Arabia. Furthermore, De Nora's contributions resonate in Europe's largest green hydrogen generation project through collaboration with H2 Green Steel in Sweden. Moreover, a crowning achievement in De Nora's trajectory is the visionary 'GigaFactory', a model of innovation and sustainability made in partnership with Snam. Located near Milan, this pioneering manufacturing hub will embody principles of Industry 4.0, flexibility and automation practices. Supported by the European IPCEI Hydrogen program and the European Commission, this initiative represents a significant stride towards a renewable hydrogen value chain. In conclusion, De Nora's journey encapsulates a century-long evolution from its electrochemical roots to a dynamic global company propelling sustainable technologies. Anchored by an unwavering commitment to carbon neutrality and bolstered by transformative partnerships, the company embodies innovation and collaborative engagement - essential elements for steering industries towards a sustainable future. In a world united by the necessity of decarbonization, De Nora stands steadfast, carving its role as a symbol of a sustainable future.
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FU European Union - NextGenerationEU
FX No Statement Available
CR [Anonymous], 2022, Global Hydrogen Review 2022
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IRENA, 2020, Green Hydrogen Cost Reduction
NR 5
TC 0
Z9 0
U1 2
U2 6
PU WALTER DE GRUYTER GMBH
PI BERLIN
PA GENTHINER STRASSE 13, D-10785 BERLIN, GERMANY
SN 0033-4545
EI 1365-3075
J9 PURE APPL CHEM

JI Pure Appl. Chem.
PD APR 25
PY 2024
VL 96
IS 4
BP 487
EP 491
DI 10.1515/pac-2023-0810
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PG 5
WC Chemistry, Multidisciplinary
WE Science Citation Index Expanded (SCI-EXPANDED)
SC Chemistry
GA ST9K7
UT WOS:001176340500001
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ER

PT J
AU Norvaisa, E
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Neniskis, E
AF Norvaisa, Egidijus
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TI Assessment of decarbonization possibilities in Lithuania's chemical industry
SO ENERGY SOURCES PART B-ECONOMICS PLANNING AND POLICY
LA English
DT Article
DE Ammonia production; bottom-up model; chemical industry; decarbonization; emissions
ID DEEP DECARBONIZATION; ENERGY EFFICIENCY; EMISSION REDUCTION; CARBON CAPTURE; STEEL; SECTOR; IRON; CONSUMPTION; TECHNOLOGY; CHINA
AB The main objectives of this paper are to present the developed model and to explore and discuss the decarbonization possibilities of the Lithuanian chemical industry. The sector has high energy consumption and struggles to achieve emission reductions. The developed model is based on a bottom-up modeling approach representing the industry's current and emerging technology mix. We conclude that the deep decarbonization of Lithuania's chemical industry is technically feasible under certain conditions. The deployment of carbon capture technology is necessary to decrease carbon dioxide (CO2) emissions by at least 40% in 2030. To achieve deep decarbonization of the sector, green hydrogen as feedstock for ammonia production should be utilized before 2050. Decarbonization scenarios cause an increase of undiscounted costs by more than 618-3132 million Euros depending on CO2 reduction targets when cumulated over the 2018-2050 period. The ammonia production facility should cover a substantial share of these costs until 2030, which could negatively affect its competitiveness.
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FU Research Council of Lithuania (LMTLT) [S-MIP-19-36]
FX The work was supported by the~Research Council of Lithuania (LMTLT) [S-MIP-19-36]
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AF Lin, Jingkai
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TI Tandem microplastic degradation and hydrogen production by hierarchical
   carbon nitride-supported single-atom iron catalysts
SO NATURE COMMUNICATIONS
LA English
DT Article
AB Microplastic pollution, an emerging environmental issue, poses significant threats to aquatic ecosystems and human health. In tackling microplastic pollution and advancing green hydrogen production, this study reveals a tandem catalytic microplastic degradation-hydrogen evolution reaction (MPD-HER) process using hierarchical porous carbon nitride-supported single-atom iron catalysts (FeSA-hCN). Through hydrothermal-

assisted Fenton-like reactions, we accomplish near-total ultrahigh-molecular-weight-polyethylene degradation into C3-C20 organics with 64% selectivity of carboxylic acid under neutral pH, a leap beyond current capabilities in efficiency, selectivity, eco-friendliness, and stability over six cycles. The system demonstrates versatility by degrading various daily-use plastics across different aquatic settings. The mixture of FeSA-hCN and plastic degradation products further achieves a hydrogen evolution of 42 mu mol h-1 under illumination, outperforming most existing plastic photoreforming methods. This tandem MPD-HER process not only provides a scalable and economically feasible strategy to combat plastic pollution but also contributes to the hydrogen economy, with far-reaching implications for global sustainability initiatives.
Developing sustainable strategies to tackle microplastic pollution and advance energy solutions is crucial for a green future. Here, authors designed carbon nitride-supported single-atom iron catalysts, with a tandem catalytic process, for microplastic degradation and green hydrogen production.
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FU Australian Research Council; Australian Research Council Discovery Early Career Researcher Award (ARC-DECRA) [DE220101074]; Deutsche Forschungsgemeinschaft [EXC 2089/1-390776260]; Bavarian program Solar Energies Go Hybrid (SolTech); Center for NanoScience (CeNS); University of Adelaide; Deutsche Forschungsgemeinschaft (DFG) [EXC 2089/1-390776260]; [DP230102406]; [FL230100178]
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PI BERLIN
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AU Lee, JM
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AF Lee, Jae Myung
   Shin, Jaechul
   Lee, Min Ju
   Kim, Wha Jung
   Song, Hyoungwoon
   Kim, Shin Dong
TI SIMULTANEOUS REMOVAL PROCESS OF HYDROGEN SULFIDE AND SILOXANES AND FIELD
   APPLICATION OF IRON HYDROXIDE DESULFURIZATION AGENT FOR GREEN HYDROGEN
   PRODUCTION FROM BIOGAS
SO DETRITUS
LA English
DT Article
DE Iron hydroxide desulfurization agent; steam methane reforming; Hydrogen
   sulfide; Biogas pretreatment; Siloxanes
ID ADSORBENT
AB Biogas, one of renewable energies, is a key element necessary for a carbon-neutral policy and to build a hydrogen economy. In order to utilize biogas, impurities of biogas such as moisture, hydrogen sulfide (H2S), siloxanes, and VOCs should be removed. In particular, since H2S causes corrosiveness of equipment by sulfur oxides, and is very harmful to the human body if leaked, it is a major target material to be removed. The minimum concentration of H2S obtainable from the wet method is several ppm. It is known, however that the iron hydroxide-based adsorbent in the dry method can obtain ultimately low concentration of H2S down to 0.1 ppm or less. The DeHyS was manufactured through a series of processes such as mixing iron cloride solution or iron sulfate solution, NaOH solution, and inorganic binder. During the adsorption process, H2S was removed in the form of iron sulfide through a chemical reaction, and siloxanes are known to be removed through physical adsorption. It was also applied to various biogas plant sites such as landfill gas, sewage sludge, livestock manure, and food waste. At this time, the H2S removal efficiency was known to be 99.9% or more, while simultaneous removal of 90% or more of the total siloxanes was possible. Moreover, the biogas produced at the Chungju Food Bioenergy Center was pretreated using the DeHyS and supplied to the nearby Chungju Bio Green Hydrogen Charging Station to produce hydrogen through steam methane reforming (SMR), producing 500 kg of hydrogen from 8,000 m(3) of biogas per day.
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FU Ministry of SME (Green Venture Program for commercialization); Korea
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AU Jiang, YY
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AF Jiang, Yuanyuan
Sun, Meng
Zheng, Mei
Zhong, Dongying
Yao, Ye
Yin, Chuanming
Ma, Yuheng
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Ma, Weimin

TI Iron deficiency suppresses the Fenton reaction and boosts photosynthetic
H2 production in bisulfite-treated<i> Chlamydomonas</i> cells
SO CHEMICAL ENGINEERING JOURNAL
LA English
DT Article
DE Iron deficiency; Bisulfite treatment; Iron poisoning; H 2
photoproduction; Chlamydomonas reinhardtii
ID PHOTOBIOLOGICAL H-2 PRODUCTION; HYDROGEN-PRODUCTION; PHOTOSYSTEM-II;
CHLOROPHYLL FLUORESCENCE; SYNECHOCOCCUS-ELONGATUS; ELECTRON-TRANSPORT;
CRYSTAL-STRUCTURE; HEAT-STRESS; CYANOBACTERIUM; PHOTOINHIBITION
AB Adding bisulfite is a significant strategy to enhance H2 photoproduction, but it adversely affects photosystem II (PSII) activity in microalgae, consequently limiting H2 production. Nevertheless, the exact mechanism through which bisulfite disrupts PSII remains unclear. Here, the addition of NaHSO3 to Chlamydomonas reinhardtii cultures suppresses growth by inducing iron poisoning through the Fenton reaction, driven by reduced iron demand and the resultant accumulation of iron. Consequently, the removal of iron from C. reinhardtii cultures eliminates the iron poisoning triggered by the Fenton reaction. This, in turn, mitigates PSII impairment and leads to a significant increase in photosynthetic H2 production in C. reinhardtii cells. Collectively, these discoveries unveil the precise mechanism by which bisulfite disrupts PSII, opening up a new avenue for substantially enhancing green hydrogen production from microalgae through the bisulfite addition strategy.
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AF Zhou, Pengfei
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TI Anodized Steel: The Most Promising Bifunctional Electrocatalyst for Alkaline Water Electrolysis in Industry
SO ADVANCED FUNCTIONAL MATERIALS
LA English
DT Article
DE alkaline water electrolysis; anodization; electrocatalysis; industrial application; martensitic steel
ID STAINLESS-STEEL; ACTIVE-SITES; EVOLUTION; EFFICIENT; CATALYST; PERFORMANCE; OXIDATION; LAYER; RUST
AB Electrolysis of water, especially alkaline water electrolysis (AWE), is the most promising technology to produce hydrogen in industry. However, only 4% of the total hydrogen is produced in this way because the electrode materials are expensive, inefficient, or unstable. Here, it is reported that the large-scale 3D printed martensitic steel (AerMet100) can be the bifunctional electrode for AWE with high catalytic performance, which may dramatically increase the green-hydrogen percentage in the market and provide strategic planning for energy management. It is found that the martensitic steel by fast anodization (3 min) can realize ultra-high hydrogen and oxygen evolution reactions (HER and OER), and excellent stability at high current densities. Particularly, this electrocatalyst shows a low overpotential of 3.18 V and long-term stability over 140 h at 570 mA cm(-2) in overall water splitting. Additionally, the treated large-scale steel can work well under a very high current up to 20 A. This study demonstrates that martensitic steel can be commercialized as a highly efficient catalyst for industrial hydrogen production in AWE, which should provide solutions to the energy crisis and environmental pollution.
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AU Shu, KQ
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TI 3D/2D photocatalyst fabricated from Pt loading TiO2 nanoparticles and converter slag-derived Fe-doped hydroxyapatite for efficient H2 evolution
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DT Article
DE Steel-making converter slag; Fe-doped hydroxyapatite; Titanium dioxide; H2 generation; Pt cocatalyst
ID H-2 EVOLUTION; DEGRADATION; NANOCRYSTALS; FACETS; ACID
AB H2 generation for partially substituting coke by the photocatalysts fabricated from steel slag presents a desirable approach to on-site carbon footprint reduction in the iron and steel-making industry, both environmentally and economically. However, achieving high photocatalytic H2 production activity is primarily limited by the scarcity of active sites due to a small specific surface area, inefficient charge transfer, and partly restricted by slow kinetics of the H2 generation reaction. In this study, 1 wt% Pt clusters are photo-reduced onto sub-15 nm TiO2 nanoparticles (TiO2-Pt) in 20 vol% methanol. Subsequently, the electrostatic assembling method has been employed to combine steel-making converter slag-derived Fe-doped hydroxyapatite (FeHAp) with TiO2-Pt, forming a type II 3D/2D TiO2-Pt/FeHAp heterojunction. Excellent connectivity between these two phases con-tributes to efficient charge separation, forming a built-in electric field that drives the photo-generated electrons to flow from FeHAp to the Pt cocatalyst on TiO2 nanoparticles through the type-II path. By the synergistic effects, including the large specific surface of sub-15 nm TiO2, Pt cocatalyst-offered rapid H2 generation kinetics,. and the heterostructure-provided enhancement of interfacial charge migration and separation, 60 mg TiO2-Pt/5FeHAp presents an enhanced H2 production activity in 120 mL of 10 vol% triethanolamine (TEOA), enabling the H2 generation rate (3026 mu mol center dot g- 1 center dot h-1) to reach 1.85 and 75.78 times greater than that of pristine TiO2-Pt (1638 mu mol center dot g- 1 center dot h-1) and FeHAp-Pt (40 mu mol center dot g- 1 center dot h-1), respectively, under UV-visible light irradiation for 3 h at 8 degrees C and obtaining an apparent quantum yield of 4.72 % at 370 nm. This study provides a promising strategy for green hydrogen-based steel-making in the sustainable development of the steel industry.
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AU Diesing, P
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AF Diesing, Philipp
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Breyer, Christian
TI From knowledge gaps to technological maturity: A comparative review of pathways to deep emission reduction for energy-intensive industries
SO RENEWABLE & SUSTAINABLE ENERGY REVIEWS
LA English
DT Review
DE Energy transition; Industry transition; Electrification; Green hydrogen; Secondary production
ID CARBON CAPTURE; TECHNOECONOMIC EVALUATION; STEEL-INDUSTRY; CO2 CAPTURE; METHANOL; POWER; STORAGE; BIOMASS; CEMENT; HYDROGEN
AB Energy intensive industries, such as steel, cement, basic chemicals, aluminium, glass as well as pulp and paper contribute substantial amounts of greenhouse gas emissions, which further accelerate climate change. The emissions from industry are generally considered hard-to-abate and technological solutions are often not yet mature. Additionally, the ideal technologies for each industry sector are not yet clearly researched in a structured and comparative manner, which is the key research gap addressed by this study. To focus on this, an extensive, systemic literature review has been conducted, following a strict protocol. A vast number of studies have been carefully read and information obtained. The comparative approach of the study is expressed in a Likert-type scale-based scoring approach, providing a robust framework to gain insights into favourable pathways, which is the first of its kind. It could be demonstrated that the steel industry is the best researched industry sector while knowledge gaps exist for the cement and glass industry. The results further show that secondary production via recycling serves as a low-risk option for most industry sectors, providing benefits such as high technological maturity, energy efficiency, and low production costs, without compromising sustainability standards. Direct electrification of heat and green electricity-based hydrogen feedstocks are essential to reach zero emissions for primary production. The results indicate that substantial efforts are imperative for achieving significant emission reductions in energy-intensive industries, necessitating robust financial support from governments. Emphasis should be placed on renewable electricity, green hydrogen, and recycling as pivotal components of these efforts.
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DE Water splitting; Hydrogen evolution; Nickel oxide; Cobalt oxide; Green
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AB Developing robust, inexpensive, and efficient electrocatalysts for hydrogen evolution via water splitting is crucial for the improvement of green hydrogen production technology. Herein, a standard three-electrode system is useful to assess the activity of single and mixed NiOx and CoOx electrocatalysts, assembled onto a glassy carbon (GC) electrode via the electrodeposition technique, toward the hydrogen evolution reaction (HER) in an alkaline medium of 0.5 M NaOH. The net results of several electrochemical experiments (linear sweep voltammetry (LSV), current transients (i-t curves), Nyquist and Tafel plots) confirm the superiority of the NiOx/CoOx/GC (binary modified catalyst at which CoOx and NiOx are introduced to the GC surface, respectively) in terms of achieving a higher activity (61.49 mA cm-2 at - 2 V) and stability (ca. 6.8 mA cm-2 after 8 h of continuous electrolysis), a lower charge transfer resistance (Rct, 21 Omega), and a lower Tafel slope (34 mV/decade) indicating the improved charge transfer mobility and accordingly the fastest kinetics toward HER.
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TI GREEN AND SUSTAINABLE HYDROGEN IN EMERGING EUROPEAN SMART ENERGY
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AB Green and sustainable hydrogen has a major role in moving towards decarbonization of energy, providing viable solutions in all most challenging sectors of the national economies. It would penetrate practically all sectors of economic activity, such as long-haul transport, steel and chemical industries, power generation and energy storage. Green and sustainable hydrogen cost competitiveness is also closely linked to developments of large-scale renewable energy sources (in case of green hydrogen; hereinafter - RES) and further commercialization of carbon dioxide (in case of sustainable hydrogen produced from natural gas; hereinafter - CO2) capture and storage (hereinafter - CCS) technologies.In the European Union (hereinafter - EU), sustainable and especially green hydrogen is gaining strong political and business momentum, emerging as one of major components in governments' net zero plans within the European Green Deal and beyond. Being extremely versatile both in production and consumption sides, it is light, storable, has high energy content per unit mass and can be readily produced at an industrial scale. The key challenge comes from the fact that hydrogen is the lightest known chemical element and so has a low energy density per unit of volume, making some forms of long-distance transportation and storage complex and costly.In this paper, green and sustainable hydrogen is reviewed as a vital part of emerging European smart energy framework, which could contribute significantly to economy decarbonization agenda of the EU and Latvia in both in short- and mid-term perspective.
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TI Steam electrolysis for green hydrogen generation. State of the art and
   research perspective
SO RENEWABLE & SUSTAINABLE ENERGY REVIEWS
LA English
DT Article
DE Steam electrolysis; SOEC; PEM; Hydrogen production; Industrial

integration
ID HIGH-TEMPERATURE ELECTROLYSIS; CERAMIC ELECTROCHEMICAL-CELLS; RESEARCH-AND-DEVELOPMENT; HIGHLY EFFICIENT; AIR ELECTRODE; ANODE ELECTROCATALYST; PERFORMANCE; DEGRADATION; PRESSURE; GAS
AB With renewable energy sources projected to become the dominant source of electricity, hydrogen has emerged as a crucial energy carrier to mitigate their intermittency issues. Water electrolysis is the most developed alternative to generate green hydrogen so far. However, in the past two decades steam electrolysis has attracted increasing interest and aims to become a key player in the portfolio of electrolytic hydrogen. In practice, steam electrolysis follows two distinct operational approaches: Solid Oxide Electrolysis Cell (SOEC) and Proton Exchange Membrane (PEM) at high temperature. For both technologies, this work analyses critical cell components outlining material characteristics and degradation issues. The influence of operational conditions on the performance and cell durability of both technologies is thoroughly reviewed. The analytical comparison of the two electrolysis alternatives underscores their distinct advantages and drawbacks, highlighting their niche of applications: SOECs thrive in high temperature industries like steel production and nuclear power plants whereas PEM steam electrolysis suits lower temperature applications such as textile and paper. Being PEM steam electrolysis less explored, this work ends up by suggesting research lines in the domain of i) cell components (membranes, catalysts and gas diffusion layers) to optimize and scale the technology, ii) integration strategies with renewable energies and iii) use of seawater as feedstock for green hydrogen production.
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TI Screening Nickel-Doped Mo₂C Nanorod Arrays for Ultrastable
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DE composite electrodes; electrocatalysis; hydrogen evolution reaction;
   nanorods; nickel
ID STAINLESS-STEEL; ELECTROCATALYST; FOAM
AB Green hydrogen, using sustainable energy to decompose water to produce hydrogen, is regarded as the ideal and effective connection to convert electricity into chemical energy. Herein, well designed Ni-doped Mo2C nanorod electrodes self-supported on three types of substrates (Ni foam, Cu foam and stainless steel wire mesh) with outstanding gas resistance and prominent corrosion resistance were assembled together to build up a wide pH applicable electrode for Hydrogen Evolution. In particular, Ni-doped Mo2C nanorod arrays on stainless steel wire mesh donated as Ni-Mo2C@SSW exhibited remarkable electrocatalytic properties towards hydrogen evolution reaction with superior overpotentials both in 1 M KOH and 0.5 M H2SO4 (102 mV and 106 mV at the current density of 10 mA cm(-2)) and incomparable continuous durability. This work provides the possibility for the realization of low cost, high activity and ultra-stable durability HER electrocatalysts in practical industrial application.
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TI Effecting the adoption of blockchain technology enablers in supply chain
   sustainability with green hydrogen acceptance role as a mediator:

Evidence from complex decarbonization industries in the United Arab Emirates
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DE Blockchain technology enablers; Green hydrogen; Sustainable supply chain; Complex decarbonization industries; Structural equation modeling
ID FIT INDEX; MANAGEMENT; PERFORMANCE; MODELS; CHALLENGES
AB The industrial sector is undergoing a pervasive digital transformation in the current landscape, particularly in steel, cement, chemicals, and refineries. These are collectively termed "complex decarbonization industries (CDI)," where reducing emissions poses a significant challenge. Green hydrogen (GH) production, conducted sustainability, represents an innovative solution that facilitates energy storage and reduces reliance on fossil fuels. However, producing green hydrogen requires effective management and flexible strategic decisions to ensure transparency and environmental friendliness. This paper utilizes blockchain technology enablers (BCTE) to track carbon emissions and ensure the origin of green gas in these sectors while independently exploring its relationship to a sustainable supply chain (SSC). GH is presented as a mediating variable in this relationship. Utilizing a cross-sectional methodology, the research gathered data via interviews and an online survey from 462 employees in companies participating in the 2022 Shams Dubai program under the aegis of the Dubai Electricity and Water Authority in the UAE. The Structural Equation Modeling- Analysis of Moment Structures (SEMAMOS) technique was used to perform the statistical analyses. Based on interviews and survey results in the UAE's CDI, the findings show that BCTE directly impacts SSC's social and environmental dimensions, while its effect on the economic dimension is negative. However, when GH mediated this relationship, the results were indirectly positive in enhancing the SSC in complex decarbonization industries without any negative environmental effects. Adopting GH is a way to reward sustainable behavior. The findings of this study could inform the UAE's policymaking, particularly in designing incentives for GH adoption in industrial sectors and creating regulatory frameworks that encourage BCTE integration for energy tracking and emissions reduction. This approach could serve as a model for similar economies striving for sustainable industrial practices.
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and Technology Cooperation Project (No. 2018-GH 006 and No. 2019-MS5-100) ; Open Fund of China Academy of Railway Sciences Group Corporation (2021YJ049) ; Fundamental Research Funds for the Central Universities (No. 300102282601) ; and Science and Technology Project of Henan Provincial Department of Transportation: Research on Key Technologies for Low-Carbon Construction Operations and Process Carbon Emission Control in Highway Construction (No.2022-5-1) .
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TI Core-shell iron-based oxygen carrier material for highly efficient green
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AB The provision of green hydrogen on an industrial scale is one of the challenges for a successful CO2-neutral energy transition. Sintering is still the bottleneck for the use of iron-based oxygen carriers for efficient hydrogen production and storing performance in chemical looping in a large-scale system. In this work, we demonstrate an effective way for hydrogen production by the synthesis of structured oxygen carriers (OC) from cost efficient, green and environment-friendly materials. The novel structured oxygen carriers with a core-shell architecture show an innovative concept to prevent the agglomeration of pellets in the fixed bed reactor system. The environment-friendly iron-based material maintained an oxygen exchange capacity of over 80 % for 100 cycles. The pore network of the catalytic system was preserved by incorporating a structure with separate compartments. A synergistic effect between the sintering, especially of the porous network, and the gas transport was revealed. In addition, an undiscovered leach-out effect of the OC system on the Al2O3 support material, which is associated with a deactivation phenomenon, was also revealed. The work provides fundamental new insights for understanding the phenomena that occur during the sintering process in the OC material and the influence on the lifetime of the chemical looping process. Finally, we present that the structured OC exhibits excellent performance and provides a new approach in material design for successful implementation in high temperature catalytic fixed bed system for long term operation.
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AU Burke, PJ
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TI Contributing to regional decarbonization: Australia's potential to
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ID RENEWABLE ELECTRICITY; DIRECT REDUCTION; STEEL-INDUSTRY; ENERGY; POWER;
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AB The Asia-Pacific has experienced prodigious growth in energy use and is by far the world's largest greenhouse-gas emitting region. Australia has played a leading role in meeting the region's energy and resource needs, becoming the world's largest exporter of coal, liquefied natural gas, iron ore, and alumina. Our analysis shows that these exports are tied to sizeable consequential emissions at the point of use or processing, accounting for about 8.6% of the total greenhouse gas emissions of the Asia-Pacific. The paper investigates three pathways by which Australia could instead export zero-carbon energy and products: direct exports of renewable electricity via sub-sea cables, exports of zero-carbon fuels such as green hydrogen, and the export of "green" metals processed from Australian ores using renewable en-ergy. Carrying out robust, high-level calculations we find that Australia has the land and renewable energy resources to become a key exporter of these commodities. Realization of this potential relies on ongoing cost reductions, growing demand-side interest linked to meeting ambitious emission reduction targets in the region, and the development of cross-border frameworks for clean energy trade. If it were to achieve this goal, Australia could make a sizeable contribution to regional decarbonization via renewable-energy based exports.
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OI Beck, Fiona J/0000-0001-9631-938X; Burke, Paul/0000-0003-2715-2672; Stocks, Matthew/0000-0002-4115-321X; Venkataraman, Mahesh/0000-0002-2920-4934; Aisbett, Emma/0000-0003-4649-3579; Baldwin, Kenneth/0000-0002-2043-5330; Bai, Xuemei/0000-0001-6556-8041
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FX This work has been carried out under the Zero-Carbon Energyfor the Asia-Pacific Grand Challenge at the Australian NationalUniversity. The authors are grateful to the IEA for data and to KylieCatchpole, Christian Downie, Frank Jotzo, and anonymous re-viewers for comments. Fig. 2 was sourced from the Global SolarAtlas 2.0, a free, web-based application developed and operated bySolargis s.r.o. on behalf of the World Bank Group, utilising Solargisdata, with funding provided by the Energy Sector ManagementAssistance Program (ESMAP)eseehttps://globalsolaratlas.info.Fig. 3 uses wind resource data from Global Wind Atlas 3.0, a free,web-based application developed, owned and operated by theTechnical University of Denmark (DTU). The Global Wind Atlas 3.0is released in partnership with the World Bank Group, utilising dataprovided by Vortex and funding provided by the Energy SectorManagement Assistance Program (ESMAP)eseehttps://globalwindatlas.info
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TI Analysis of the Implementation of Functional Hydrogen Assumptions in
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SO ENERGIES
LA English
DT Review
DE hydrogen; green energy; renewable energy; transport; decarbonization;
   Poland; Germany; individuals; enterprises
ID ENERGY TRANSITION; GREEN HYDROGEN; TECHNOLOGIES; STORAGE
AB The use of hydrogen exists in various sectors in Poland and Germany. Hydrogen can be used in industry, transport, decarbonisation of the Polish steel industry and as one of the low-emission alternatives to the existing coal applications in this sector. Limiting climate change requires efforts on a global scale from all countries of the world.

Significant economic benefits will be realized by stimulating the development of new technologies to deal with climate change. The scenarios show an increasing demand for industrial hydrogen in the future. The key is to replace gray hydrogen with green, and to convert industrial processes, which will create additional hydrogen demand. The condition for the development of a green hydrogen economy is access to adequate installed capacity in renewable energy. Germany will become the leading market in the era of energy transformation in the coming years. The implementation of the hydrogen assumptions in Poland is possible, to a greater extent, by the efforts of entrepreneurs.
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FU War Studies University
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PA ST ALBAN-ANLAGE 66, CH-4052 BASEL, SWITZERLAND
EI 1996-1073
J9 ENERGIES
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IS 22
AR 8383
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WC Energy & Fuels
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AU Schultheis, SE
   Herold, F
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   Drochner, A
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AF Schultheis, Stephan E.
   Herold, Felix
   Koh, Ezra S.
   Oefner, Niklas
   Hungsberg, Maximilian
   Drochner, Alfons
   Etzold, Bastian J. M.
TI Iron supported on beaded carbon black as active, selective and stable
   catalyst for direct CO2 to olefin conversion
SO CATALYSIS COMMUNICATIONS
LA English
DT Article
DE Fischer-tropsch-synthesis; Olefins; Carbon black; Iron
ID FISCHER-TROPSCH SYNTHESIS; SULFUR; HYDROGENATION; REDUCIBILITY;
   POTASSIUM; PROMOTER; SODIUM; SIZE
AB The Fischer-Tropsch-to-Olefins process allows to convert waste stemming CO2 with green hydrogen to olefins. Iron can catalyse both core reactions: 1) reverse-water-gas-shift as well as 2) Fischer-Tropsch. Carbon supported catalysts were reported to be highly attractive in this context, but until now mainly non technically applicable research carbons like nanotubes or ordered mesoporous carbons were studied and long term stability studies are missing. Here, beaded carbon blacks, were studied as available and inexpensive support materials for Fe catalysts in CO2-based FTO. The most promising support yielded selectivities towards olefins of almost 40% and showed for 170 h high stability.
C1 [Schultheis, Stephan E.; Koh, Ezra S.; Oefner, Niklas; Hungsberg, Maximilian; Drochner, Alfons; Etzold, Bastian J. M.] Tech Univ Darmstadt, Ernst Berl Inst Tech & Makromol Chem, Dept Chem, D-64287 Darmstadt, Germany.
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PA RADARWEG 29, 1043 NX AMSTERDAM, NETHERLANDS
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AU Ibitoye, SE
   Mahamood, RM
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AF Ibitoye, Segun E.
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   Akinlabi, Esther T.
TI Design and construction of low-cost biomass pyrolysis reactor for
   research and teaching in universities and colleges
SO BIOMASS CONVERSION AND BIOREFINERY
LA English
DT Article; Early Access
DE Biomass energy; Corncob; Pyrolysis reactor; Rice husk; Reactor design;
   Reactor fabrication
ID LABORATORY EXPERIMENTS; TECHNOLOGIES; BIOCHAR
AB Research on biomass pyrolysis for energy production is limited in developing countries due to a lack of equipment for research. In this study, a portable, low-cost biomass pyrolysis reactor was designed and constructed at a laboratory scale to facilitate teaching and research applications. The fabricated reactor was tested using rice husk and corncob at different temperatures (450, 500, 550 oC) and a residence time of 60 min. The pyrolysis reactor is capable of processing a variety of feedstocks, with a maximum batch size of 1 kg. The product yields for rice husk samples were 43.93-48.01, 21.14-24.06, and 30.85-32.01% for char, oil, and syngas, respectively. For corncob biomass, the corresponding yields were 45.14-49.26, 25.11-29.22, and 25.63-26.44%. As the pyrolysis temperature increased, oil and syngas production rose, while char yield decreased. The favorable product properties and the alignment of yield distribution with other reactors underscore the reactor's effectiveness for teaching and research purposes. This reactor uniquely enables the collection of all pyrolysis products, including syngas, allowing for renewable gas research like green hydrogen. Improved heat transfer via direct heating boosts the efficiency of the reactor chamber, addressing prior limitations. Its portability supports both field research and practical education in remote areas. The fabricated reactor involves much lower capital costs by eliminating shipping, tariffs, and currency exchange fees. Maintenance is also more affordable, as spare parts and expertise are locally accessible. This research promotes technical skill development, supporting long-term savings and fostering sustainable bioenergy sectors, especially in developing countries. The biochar and syngas produced in this study can be used as sustainable carbon sources in the iron and steel industry, with syngas also serving as a potential source for green hydrogen production.
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FU University of Johannesburg, South Africa; University of Ilorin, Nigeria
FX The University of Johannesburg, South Africa, and the University of Ilorin, Nigeria, provided support for this work.
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NR 57
TC 0
Z9 0
U1 2
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PU SPRINGER HEIDELBERG
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PA TIERGARTENSTRASSE 17, D-69121 HEIDELBERG, GERMANY
SN 2190-6815
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J9 BIOMASS CONVERS BIOR
JI Biomass Convers. Biorefinery
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Zhang, Lei
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TI Synergistic modulation of the d-band center in Ni3S2 by selenium and iron for enhanced oxygen evolution reaction (OER) and urea oxidation reaction (UOR)
SO JOURNAL OF COLLOID AND INTERFACE SCIENCE
LA English
DT Article
DE Transition metal catalyst; Urea oxidation reaction; Hydrogen production; Photoelectrochemical urea splitting; Oxygen evolution reaction; Electrocatalyst
ID NICKEL-HYDROXIDE; EFFICIENT; ELECTROOXIDATION; ELECTROCATALYST; GROWTH; SITES; FOAM
AB Efficient production of green hydrogen energy is crucial in addressing the energy crisis and environmental concerns. The oxygen evolution reaction (OER) poses a challenge in conventional overall water electrolysis due to its slow thermodynamically process. Urea oxidation reaction (UOR) offers an alternative anodic oxidation method that is highly efficient and cost-effective, with favorable thermodynamics and sustainability. Recently, there has been limited research on bifunctional catalysts that exhibit excellent activity for both OER and UOR reactions. In this study, we developed a selenium and iron co-doped nickel sulfide (SeFe-Ni3S2) catalyst that demonstrated excellent Tafel slopes of 53.9 mV dec -1 and 16.4 mV dec -1 for OER and UOR, respectively. Density Functional Theory (DFT) calculations revealed that the introduction of metal (iron) and nonmetallic elements (selenium) was found to coordinate the d -band center, resulting in improved adsorption/desorption energies of the catalysts and reduced the overpotentials and limiting potentials for OER and UOR, respectively. This activity enhancement can be attributed to the altered electronic coordination structure after the introduction of selenium (Se) and iron (Fe), leading to an increase in the intrinsic activity of the catalyst. This work offers a new strategy for bifunctional catalysts for OER and UOR, presenting new possibilities for the future development of hydrogen production and novel energy conversion technologies. It contributes towards the urgent search for technologies that efficiently produce green hydrogen energy, providing potential solutions to mitigate the energy crisis and protect the environment.
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AU Kuhn, C
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AF Kuhn, C.
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TI Iron as recyclable energy carrier: Feasibility study and kinetic
   analysis of iron oxide reduction
SO APPLICATIONS IN ENERGY AND COMBUSTION SCIENCE
LA English
DT Article
DE Metal fuels; Iron; Cycle efficiency; Reduction; Kinetics
ID LOW-TEMPERATURE REDUCTION; PULVERIZED SPONGE IRON; ZERO-CARBON;
   LIQUID-HYDROGEN; METAL FUELS; COMBUSTION; BEHAVIOR; STORAGE; AMMONIA;
   FE2O3
AB Carbon-free and sustainable energy storage solutions are required to mitigate climate change. One possible solution, especially for stationary applications, could be the storage of energy in metal fuels. Energy can be stored through reduction of the oxide with green hydrogen and be released by combustion. In this work a feasibility study for iron as possible metal fuel considering the complete energy cycle is conducted. On the basis of equilibrium calculations it could be shown that the power-to-power efficiency of the iron/iron oxide cycle is 27 %. As technology development requires a more detailed description of both the reduction and the oxidation, a first outlook is given on the kinetic analysis of the reduction of iron oxides with hydrogen. Thermogravimetric experiments using Fe2O3, Fe3O4 and FeO indicate a three-step process for the reduction. The maximum reduction rate can be achieved with a hydrogen content of 25 %. Based on the experimental results a reaction mechanism and accompanied kinetic data were developed for description of Fe2O3 reduction with H2 under varying experimental conditions.
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   Association; Karlsruhe Institute of Technology
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TI Investigating Periodic Table Interpolation for the Rational Design of
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SO CATALYSIS LETTERS
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DE Green hydrogen; Ammonia decomposition; Ammonia cracking; Catalyst
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ID COX-FREE HYDROGEN; NH3 DECOMPOSITION; BIMETALLIC NANOPARTICLES; H-2
PRODUCTION; KINETICS; RU; GENERATION; STORAGE; ADSORPTION; MECHANISM
AB Developing highly active catalysts for the decomposition of ammonia to produce hydrogen is an important goal in the context of renewable energy. Allied with this is a need for identification strategies to efficiently design novel catalysts integral to ensuring rapid progress in this research field. We investigated the efficacy of N-binding energy and periodic table interpolation to predict active bimetallic nanoparticle catalysts. Supported iron-platinum and iron-palladium were identified and experimentally shown to be more active than their monometallic analogues. Atomic resolution electron microscopy indicated that the most active catalyst (5 wt% Fe80Pt20/& gamma;-Al2O3) was principally formed of alloyed nanoparticles. It restructured during testing, yet no activity loss was noted at 20 h time-on-line. While these findings show that periodic table interpolation may be a viable tool for identifying active combinations of metals, the activity of the catalysts in the current work were not able to outperform the Ru/Al2O3 benchmark. Further catalyst optimization or refinement of reaction descriptors may facilitate the development of catalysts with higher intrinsic activity than the current state-of-the-art catalysts.
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FX We would like to thank the ERC for financial support through the funding
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SC Chemistry
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PT J
AU Prestat, M
AF Prestat, Michel
TI Corrosion of structural components of proton exchange membrane water
   electrolyzer anodes: A review
SO JOURNAL OF POWER SOURCES
LA English
DT Review
DE Proton exchange membrane water electrolysis; Porous transport layers;
   Bipolar plates; Corrosion; Coatings
ID YTTRIA-STABILIZED-ZIRCONIA; STEEL BIPOLAR PLATES; LIQUID/GAS DIFFUSION
   LAYERS; POROUS TRANSPORT LAYER; STAINLESS-STEEL; THIN-FILMS; FUEL-CELLS;
   TITANIUM; HYDROGEN; PERFORMANCE
AB Proton exchange membrane (PEM) water electrolysis is one of the low temperature processes for producing green hydrogen when coupled with renewable energy sources. Although this technology has already reached a certain level of maturity and is being implemented at industrial scale, its high capital expenditures deriving from the utilization of expensive corrosion-resistant materials limit its economic competitiveness compared to the widespread fossil fuel-based hydrogen production, such as steam reforming. In particular, the structural elements, like bipolar plates (BPP) and porous transports layers (PTL), are essentially made of titanium protected by precious metal layers in order to withstand the harsh oxidizing conditions in the anode compartment. This review provides an analysis of literature on structural element degradation on the oxygen side of PEM water electrolyzers, from the early investigations to the recent developments involving novel anti-corrosion coatings that protect more cost-effective BPP and PTL materials like stainless steels.
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AU Lee, S
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TI Tracking high-valent surface iron species in the oxygen evolution
reaction on cobalt iron (oxy)hydroxides
SO ENERGY & ENVIRONMENTAL SCIENCE
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DT Article
ID WATER OXIDATION; ELECTROCATALYSTS; IDENTIFICATION; OXIDE; NANOPARTICLES;
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AB The oxygen evolution reaction (OER) is the bottleneck reaction of water splitting, which can be used to generate green hydrogen from renewable electricity. Cobalt iron oxyhydroxides (CoFeOxHy) are among the most active OER catalysts in alkaline medium. However, the active sites of these catalysts remain unclear. Here we use operando ultraviolet-visible (UV-Vis), X-ray absorption, and Raman spectroscopy to reveal oxidations of both Fe and Co ions in CoFeOxHy during the OER. By analyzing samples with different Fe contents and thickness, we find that the concentration of Fe4+ species at the surface, but not the concentration of Co4+ in the bulk, scales with the catalytic activity. These results indicate an Fe4+-containing active site in CoFeOxHy.
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OI Chen, Hao/0009-0001-6480-7976; Hu, Xile/0000-0001-8335-1196; Moysiadou, Aliki/0000-0001-5619-5116; Chu, You-Chiuan/0009-0006-6006-3080; CHEN, HAO-MING/0000-0002-7480-9940; Lee, Seunghwa/0000-0002-5988-4440
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Z9 78
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PU ROYAL SOC CHEMISTRY
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PA THOMAS GRAHAM HOUSE, SCIENCE PARK, MILTON RD, CAMBRIDGE CB4 0WF, CAMBS,
   ENGLAND
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J9 ENERG ENVIRON SCI
JI Energy Environ. Sci.
PD JAN 19
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WC Chemistry, Multidisciplinary; Energy & Fuels; Engineering, Chemical;
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SC Chemistry; Energy & Fuels; Engineering; Environmental Sciences & Ecology
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PT J
AU Jansons, L
   Zemite, L
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   Bode,
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AF Jansons, L.
   Zemite, L.
   Zeltins, N.
   Bode, I
   Geipele, I
   Kiesners, K.
TI THE GREEN HYDROGEN AND THE EU GASEOUS FUEL DIVERSIFICATION RISKS
SO LATVIAN JOURNAL OF PHYSICS AND TECHNICAL SCIENCES
LA English
DT Article
DE Diversification risks; gaseous fuels; green hydrogen; hydrogen
   technologies
ID STORAGE
AB Hydrogen is the most abundant chemical element on the Earth. and it has really a wide variety of applications, starting from use in refining. petrochemical industry, steel manufacturing. and ending with use in energy production and renewable gas (hereinafter - RG) blending for gradual replacement of natural gas in all sectors of the national economy. Being practically emission-free, if produced in sustainable way or from renewable energy sources (hereinafter- RES), hydrogen is regarded as one of the most promising energy sources for decarbonisation of practically the entire segment of industrial and energy production. Growing pressure of the European climate neutrality targets has triggered special interest in production, use, storage and transportation of hydrogen - especially the green one, which can be used in at least four fundamental ways: as a basic material, a fuel, an energy carrier and an energy storage medium. In the context of sector coupling, however, hydrogen facilitates decarbonisation of those industrial processes and economic sectors in which carbon dioxide (hereinafter - CO2) emissions can either not be reduced by electrification or this reduction would be minimal

and linked to very high implementation costs. At the same time, development of an extensive hydrogen economy is the key to the achievement of the European climate protection targets, with the European Commission's (hereinafter - EC) Hydrogen Strategy. a framework created in 2020 to develop and promote sustainable hydrogen economy in the European Union (hereinafter - EU), in its centre.

Green hydrogen also will take its legitimate place in the gaseous fuel diversification risk management strategy. as this gaseous fuel is not only one of the most perspective future energy sources, but also one of the most volatile and demanding sources. In the process of gaseous fuel diversification in the EU and worldwide, new logistical chains and supply - demand networks of green hydrogen will emerge. Therefore, adequate addressing of potential challenges of this new regional and global production. delivery and consumption framework will be of utmost importance for secure. safe and predictable functioning of future energy systems.

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OI Zemite, Laila/0000-0001-9672-1969; Zemite, Laila/0009-0009-2629-0521
FU National Research Programme, project "Trends, Challenges and Solutions of Latvian Gas Infrastructure Development" (LAGAS) [VPP-EM-INFRA-2018/10003]
FX The research has been supported by the National Research Programme, project "Trends, Challenges and Solutions of Latvian Gas Infrastructure Development" (LAGAS) (No. VPP-EM-INFRA-2018/10003).
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NR 52
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PU SCIENDO
PI WARSAW
PA BOGUMILA ZUGA 32A, WARSAW, MAZOVIA, POLAND
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WE Emerging Sources Citation Index (ESCI)
SC Physics
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AU Wang, XX
Bi, SJ
Zhang, JM
Tao, HB
AF Wang, Xiangxi
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Tao, Huabing
TI Towards the Rational Design of Stable Electrocatalysts for Green Hydrogen Production
SO CATALYSTS
LA English
DT Article
DE core-shell; stability; water splitting; hydrogen production; oxygen

production
ID OXYGEN EVOLUTION REACTION; ANION-EXCHANGE MEMBRANE; WATER ELECTROLYSIS;
STABILITY; IRON; DISSOLUTION; OXIDES; TRENDS; IMPACT; CO2
AB Now, it is time to set up reliable water electrolysis stacks with active and robust electrocatalysts to produce green hydrogen. Compared with catalytic kinetics, much less attention has been paid to catalyst stability, and the weak understanding of the catalyst deactivation mechanism restricts the design of robust electrocatalysts. Herein, we discuss the issues of catalysts' stability evaluation and characterization, and the degradation mechanism. The systematic understanding of the degradation mechanism would help us to formulate principles for the design of stable catalysts. Particularly, we found that the dissolution rate for different 3d transition metals differed greatly: Fe dissolves 114 and 84 times faster than Co and Ni. Based on this trend, we designed Fe@Ni and FeNi@Ni core-shell structures to achieve excellent stability in a 1 A cm(-2) current density, as well as good catalytic activity at the same time.
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OI Wang, Xiangxi/0000-0002-6527-2061; Tao, Huabing/0000-0002-3269-3812
NR 0
TC 2
Z9 2
U1 1
U2 30
PU MDPI
PI BASEL
PA MDPI AG, Grosspeteranlage 5, CH-4052 BASEL, SWITZERLAND
EI 2073-4344
J9 CATALYSTS
JI Catalysts
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VL 12
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AR 204
DI 10.3390/catal12020204
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WC Chemistry, Physical
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SC Chemistry
GA ZM6RH
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PT J
AU Rodríguez-Gutiérrez, I
Bedin, KC
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TI Advances in Engineered Metal Oxide Thin Films by Low-Cost, Solution-Based Techniques for Green Hydrogen Production
SO NANOMATERIALS
LA English
DT Article
DE iron oxide; solution chemistry; photoanodes; hydrothermal synthesis; sol-gel method
ID PHOTOELECTROCHEMICAL WATER OXIDATION; DOPED HEMATITE NANOSTRUCTURES; ELECTRONIC-STRUCTURE; NANOROD ARRAYS; SURFACE MODIFICATION; THERMAL-TREATMENT; SOLUTION GROWTH; ALPHA-FE2O3; PHOTOANODES; EFFICIENT
AB Functional oxide materials have become crucial in the continuous development of various fields, including those for energy applications. In this aspect, the synthesis of nanomaterials for low-cost green hydrogen production represents a huge challenge that needs to be overcome to move toward the next generation of efficient systems and devices. This perspective presents a critical assessment of hydrothermal and polymeric precursor methods as potential approaches to designing photoelectrodes for future industrial implementation. The main conditions that can affect the photoanode's physical and chemical characteristics, such as morphology, particle size, defects chemistry, dimensionality, and crystal orientation, and how they influence the photoelectrochemical performance are highlighted in this report. Strategies to tune and engineer photoelectrode and an outlook for developing efficient solar-to-hydrogen conversion using an inexpensive and stable material will also be addressed.
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OI Mourino, Beatriz/0000-0003-1670-3985; Rodriguez-Gutierrez, Ingrid/0000-0001-6345-7321
FU CNPq; CAPES; FAPESP [17/11986-5, 13/07296-2, 2019/06654-9, 17/02317-2]; Shell; ANP (Brazil's National Oil, Natural Gas, and Biofuels Agency) through the R&D levy regulation; Fundacao de Amparo a Pesquisa do Estado de Sao Paulo (FAPESP) [17/11986-5] Funding Source: FAPESP
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U1 3
U2 34
PU MDPI
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PA ST ALBAN-ANLAGE 66, CH-4052 BASEL, SWITZERLAND
EI 2079-4991
J9 NANOMATERIALS-BASEL
JI Nanomaterials
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AR 1957
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Science, Multidisciplinary; Physics, Applied
WE Science Citation Index Expanded (SCI-EXPANDED)
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AU Perret, F
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AF Perret, F.
Demirci, F.
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Peter, R.
Semleit, T.
Schulte, S.
TI Start-up and usage of coke oven gas at HKM on our mission to green steel
saand CO₂ reduction
SO METALLURGIA ITALIANA
LA English

DT Article
DE CO2 REDUCTION; BLAST FURNACE; COKE OVEN GAS; GREEN STEEL; HYDROGEN
CONTAINING INJECTANTS
AB By developing decarbonisation plans, the European steel industry shows its commitment to the European climate change targets. The main element in these plans is a transformation step involving a transition from carbon-based blast furnaces to green hydrogen-based direct reduction processes. This will take place around 2030 and will result in significant CO2 reductions. H & uuml;ttenwerke Krupp Mannesmann (HKM) has committed itself to the European climate change targets and has already started to take actions to significantly reduce CO2 emissions under the brand H2KM. As presented at the 8th ECIC in Bremen, HKM has upgraded its installation to inject compressed coke oven gas (COG) at the two blast furnaces "A" and "B". Since the injection station was commissioned and started in June 2023, HKM has been able to consistently inject up to of 45 kg/tHM of COG per month replacing PCI. This article discusses the usage of COG injection as an additional reducing agent for the blast furnace and presents results from start-up and data analyses on the injection, showing how it affects the blast furnace process and helps to reduce the carbon footprint of HKM's crude steel significantly
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CR [Anonymous], 2021, Sustainability Indicators
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U1 0
U2 0
PU ASSOC ITALIANA METALLURGIA
PI MILAN
PA PIAZZALE RODOLFO MORANDI, 2, MILAN, 20121, ITALY
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J9 METALL ITAL
JI Metall. Ital.
PD NOV-DEC
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PG 84
WC Metallurgy & Metallurgical Engineering
WE Science Citation Index Expanded (SCI-EXPANDED)
SC Metallurgy & Metallurgical Engineering
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AU Shankar, A
Marimuthu, S
Maduraiveeran, G
AF Shankar, Ayyavu
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TI High-valent iron single-atom catalysts for improved overall water
splitting <i>via</i> a reduced energy barrier and stabilization of the
active center
SO JOURNAL OF MATERIALS CHEMISTRY A

LA English
DT Article
ID METAL-ORGANIC FRAMEWORKS
AB The design of earth-abundant and non-precious transition-metal-based single-atom catalysts (TM-SACs) for promoting the oxygen evolution reaction (OER) and hydrogen evolution reaction (HER) is of great importance for generating green hydrogen (H-2). Herein, we demonstrate iron (Fe) single atoms stabilized on carbon-nickel nanosheets (C-Ni) (Fe-SACs|C-Ni NSs) using a facile and single-step metal-organic-framework (MOF)-assisted electrochemical approach. Single-atom iron sites (Fe4+ active center), generated in situ on the C-Ni heterostructure, assist in regulating the binding abilities of hydroxyl ions (OH*) and hydrogen (H*) to accelerate alkaline water splitting reactions. Overpotentials (eta) of similar to 246 mV and similar to 164 mV are required to reach similar to 10 mA cm(-2) for the OER and HER, respectively, outperforming other recently reported bifunctional catalysts.
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FX This work was financially supported by the Central Power Research Institute (CPRI), Bangalore (Ref. CPRI/R&D/TC/GDEC/2022). The authors acknowledge the SRM Institute of Science and Technology (SRM IST) for providing all the research facilities, including the SRM-SCIF and NRC for SEM, TEM, and XPS measurements.
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TC 22
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U1 18
U2 56
PU ROYAL SOC CHEMISTRY
PI CAMBRIDGE
PA THOMAS GRAHAM HOUSE, SCIENCE PARK, MILTON RD, CAMBRIDGE CB4 0WF, CAMBS, ENGLAND
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J9 J MATER CHEM A
JI J. Mater. Chem. A
PD DEC 19
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VL 12
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EP 127
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PG 7
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Goekce, Bilal
TI FeNi nanoparticle-modified reduced graphene oxide as a durable electrocatalyst for oxygen evolution
SO JOURNAL OF CATALYSIS
LA English
DT Article
DE Iron-nickel catalyst; PLAL; Rare element free; Precious metal free; Electrode fabrication; Green hydrogen
ID LAYERED DOUBLE HYDROXIDE; WATER OXIDATION CATALYSTS; EFFICIENT ELECTROCATALYSTS; PLATINUM NANOPARTICLES; LASER SYNTHESIS; PULSED-LASER; IN-SITU; IRON; REDUCTION; NANOCRYSTALS
AB Clean energy transition and decarbonization through hydrogen technology hold a crucial role in revitalizing a sustainable world. The development of catalysts free of precious elements to facilitate the water splitting process in an electrolyser represents a key sustainable goal to lower the production cost of green hydrogen fuel, therefore improving its accessibility and affordability. Here we report a hybrid electrocatalyst for oxygen evolution reaction (OER) in alkaline media with high stability and low overpotential, free of precious metals and rare elements. The hybrid catalyst is composed of laser-generated Fe50Ni50 nanoparticles (FeNi NPs) dispersed on reduced graphene oxide (rGO) and deposited on FeNi layered double hydroxide (FeNi LDH) grown on Ni foam substrate. The prepared FeNi-rGO/FeNi/Ni foam hybrid catalyst requires an overpotential of only 234 mV at a current density of 10 mA/cm2, which is 37 mV lower than the tested commercial RuO2 catalyst on Ni foam substrate. Besides, the hybrid catalyst is extremely robust; it stands 10,000 cycles of accelerated deterioration and runs for more than 1,300 h at a current density of 10 mA/cm2 without performance decay.
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FU European Union's Horizon 2020 research and innovation program; Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) [GO 2566/7-2]; NRW [503865051]; DFG [RI_00313, 233,512,597, 324659309, GO 2566/10-1]; MCIN/AEI [CEX2019-000910-S, FJC2020-043223-I]; BIST; Fundacio Cellex; Fundacio Mir-Puig; Generalitat de Catalunya through CERCA; Generalitat Valenciana [CIDEIG/2023/08]; DFG; Secretaria d'Universitats i Recerca del Departament de Recerca Universitats de la Generalitat de Catalunya [2024 FI-3 00390]; European Social Fund Plus; Severo Ochoa Excellence Post-doctoral Fellowship [CEX2019-000910-S]; [952,068]; [GO 2566/14]; [INST 218/87-1]
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AF Ostadi, Mohammad
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TI Process Integration of Green Hydrogen: Decarbonization of Chemical
   Industries
SO ENERGIES
LA English
DT Article
DE green hydrogen; electrolysis; process integration; calcination; iron
   reduction; oxy-combustion; pulp production; municipal waste
   incineration; fermentation; biogas upgrading
ID RENEWABLE POWER; LIQUID PROCESS; CONVERSION; ENERGY; GAS; CO2;
   EFFICIENCY; SYSTEMS; STORAGE
AB Integrated water electrolysis is a core principle of new process configurations for decarbonized heavy industries. Water electrolysis generates H(2)and O(2)and involves an exchange of thermal energy. In this manuscript, we investigate specific traditional heavy industrial processes that have previously been performed in nitrogen-rich air environments. We show that the individual process streams may be holistically integrated

to establish new decarbonized industrial processes. In new process configurations, CO(2)capture is facilitated by avoiding inert gases in reactant streams. The primary energy required to drive electrolysis may be obtained from emerging renewable power sources (wind, solar, etc.) which have enjoyed substantial industrial development and cost reductions over the last decade. The new industrial designs uniquely harmonize the intermittency of renewable energy, allowing chemical energy storage. We show that fully integrated electrolysis promotes the viability of decarbonized industrial processes. Specifically, new process designs uniquely exploit intermittent renewable energy for CO(2)conversion, enabling thermal integration, H(2)and O(2)utilization, and sub-process harmonization for economic feasibility. The new designs are increasingly viable for decarbonizing ferric iron reduction, municipal waste incineration, biomass gasification, fermentation, pulp production, biogas upgrading, and calcination, and are an essential step forward in reducing anthropogenic CO(2)emissions.
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TI Alcohol-alkali hydrolysis for high-throughput PET waste electroreforming-assisted green hydrogen generation
SO JOURNAL OF MATERIALS CHEMISTRY A
LA English
DT Article
ID EVOLUTION REACTION; BIFUNCTIONAL ELECTROCATALYST; POLYETHYLENE TEREPHTHALATE; EFFICIENT ELECTROCATALYST; HOLLOW POLYHEDRON; NANOWIRE ARRAYS; NANOSHEETS; CATALYST; DEGRADATION; NICKEL
AB Electroreforming of plastic wastes into value-added chemicals is considered as a promising method for waste valorization and resource recovery. However, it remains a grand challenge because low solubility of PET in the electrolyte limits the practical

application and potential for scale up. Herein, we demonstrate an alcohol-alkali combined depolymerization strategy to improve the solubility of PET waste bottles by 4.5 times (to 91 g L-1) compared with pure alkaline hydrolysis, and then recycle PET bottles into terephthalic acid and formate. By using an iron, cobalt co-modified nickel phosphide nanosheet on nickel foam electrocatalyst (FeCo-Ni2P/NF), we achieve ultrahigh hydrogen evolution activity and alcohol oxidation activity with 71 mV and 76 mV overpotentials, respectively, at 10 mA cm-2 current density. Moreover, we employed photovoltaic modules to power the cogeneration of formate and H2 by recycling of PET waste bottles, which showed immense potential for sustainable collaborative production of H2 fuel and value-added chemicals from the waste plastic.

The solubility of PET waste bottles was improved to 91 g L-1 by alcohol-alkali combined depolymerization. Iron, cobalt co-modified nickel phosphide nanosheet arrays on nickel foam were used as a bifunctional electrocatalyst for PET hydrolysate electroreforming-assisted green hydrogen evolution.
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NR 61
TC 5
Z9 5
U1 13
U2 45
PU ROYAL SOC CHEMISTRY
PI CAMBRIDGE
PA THOMAS GRAHAM HOUSE, SCIENCE PARK, MILTON RD, CAMBRIDGE CB4 0WF, CAMBS,
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SN 2050-7488
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J9 J MATER CHEM A
JI J. Mater. Chem. A
PD JAN 23
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WC Chemistry, Physical; Energy & Fuels; Materials Science,
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WE Science Citation Index Expanded (SCI-EXPANDED)
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ER

PT J
AU Li, DY
   Xiang, R
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   Liao, Liling
   Zhang, Yan
   Tang, Dongsheng
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TI In Situ Regulating Cobalt/Iron Oxide-Oxyhydroxide Exchange by Dynamic
   Iron Incorporation for Robust Oxygen Evolution at Large Current Density
SO ADVANCED MATERIALS
LA English
DT Article
DE electrocatalyst; in situ characterization; non-noble; oxygen evolution
   reaction; water electrolysis
ID ELECTROCATALYSTS; PERFORMANCE; CATALYSTS; ARRAYS
AB The key dilemma for green hydrogen production via electrocatalytic water splitting is the high overpotential required for anodic oxygen evolution reaction (OER). Co/Fe-based materials show superior catalytic OER activity to noble metal-based catalysts, but still lag far behind the state-of-the-art Ni/Fe-based catalysts probably due to undesirable side segregation of FeOOH with poor conductivity and unsatisfied structural durability under large current density. Here, a robust and durable OER catalyst affording current densities of 500 and 1000 mA cm-2 at extremely low overpotentials of 290 and 304 mV in base is reported. This catalyst evolves from amorphous bimetallic FeOOH/Co(OH)2 heterostructure microsheet arrays fabricated by a facile mechanical stirring strategy. Especially, in situ X-ray photoelectron spectroscopy (XPS) and Raman analysis decipher the rapid reconstruction of FeOOH/Co(OH)2 into dynamically stable Co1-xFexOOH active phase through in situ iron incorporation into CoOOH, which perform as the real active sites accelerating the rate-determining step supported by density functional theory calculations. By coupling with MoNi4/MoO2 cathode, the self-assembled alkaline electrolyzer can deliver 500 mA cm-2 at a low cell voltage of 1.613 V, better than commercial IrO2(+)||Pt/C(-) and most of reported transition metal-based electrolyzers. This work provides a feasible strategy for the exploration and design of industrial water-splitting catalysts for large-scale green hydrogen production.
   An exceptional and stable oxygen-evolving electrocatalyst is developed from self-reconstruction of amorphous bimetallic FeOOH/Co(OH)2 microsheet arrays through a mechanical stirring strategy, yielding a current densities of 500 and 1000 mA cm-2 at low overpotentials of 290 and 304 mV. This catalyst rapidly reconstructs into Co1-xFexOOH species through in situ iron incorporation into CoOOH as confirmed by in situ X-ray photoelectron, Raman spectroscopic studies, and theoretical calculations.image
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NR 61
TC 69
Z9 69
U1 55
U2 304
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J9 ADV MATER
JI Adv. Mater.
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WC Chemistry, Multidisciplinary; Chemistry, Physical; Nanoscience &
Nanotechnology; Materials Science, Multidisciplinary; Physics, Applied;
Physics, Condensed Matter
WE Science Citation Index Expanded (SCI-EXPANDED)
SC Chemistry; Science & Technology - Other Topics; Materials Science;
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PT J
AU Rabia, M
Alnuwaiser, MA
AF Rabia, Mohamed
Alnuwaiser, Maha Abdallah
TI One-pot fabrication of highly porous morphology of ferric oxide-ferric
oxychloride/poly-<i>O</i>-chloroaniline nanocomposite seeded on
poly-1<i>H</i> pyrrole: Photocathode for green hydrogen generation from
natural and artificial seawater
SO OPEN CHEMISTRY
LA English
DT Article
DE ferric oxide-ferric oxychloride; poly-<italic>O</italic>-chloroaniline;
nanocomposite; renewable energy; green hydrogen
ID SCHERRER EQUATION; HETEROJUNCTION; PERFORMANCE
AB A novel photocathode has been fabricated, featuring a highly porous ferric oxide-ferric oxychloride/poly-O-chloroaniline (Fe2O3-FeOCl/POCA) nanocomposite, integrated onto a poly-1H pyrrole substrate. This photocathode was synthesized using a one-pot technique,

which involves the oxidation of o-chloroaniline in the presence of iron sources, resulting in the incorporation of iron oxide and iron oxychloride within the polymer matrix. The photocathode exhibits broad optical absorption extending into the IR region and has a promising bandgap of 1.74 eV, making it a strong candidate for hydrogen gas generation within a constructed three-electrode cell. The photocathode's performance in natural seawater is impressive, with an estimated hydrogen production rate of 20 mu mol/h per 10 cm2. Electrochemical measurements indicate a current density of -0.015 mA/cm2 under these conditions. When tested with artificial seawater that is free of heavy metals, the current density (J ph) is slightly lower at -0.013 mA/cm2. Furthermore, the photocathode demonstrates excellent sensitivity to various photon energies across wavelengths ranging from 730 to 340 nm, achieving J ph values of -0.0145 and -0.012 mA/cm2, respectively. The green chemistry approach used in this photocathode's fabrication, combined with its environmentally friendly operation, highlights its potential for commercial applications. This development could pave the way for industrial-scale production of photoelectrodes designed to convert seawater into hydrogen gas, contributing to sustainable energy solutions.
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NR 29
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PT J
AU Wang, B
   Liu, YH
   Guan, Y
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AF Wang, Bo
   Liu, Yinhe
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   Zhang, Guohong
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TI Hydrogen production and coke resistance characteristic during volatile
   reforming over Fe2O3-Ce2O3/sludge char catalyst
SO JOURNAL OF CLEANER PRODUCTION
LA English
DT Article
DE Sludge char-derived catalyst; Reforming; Green hydrogen; Coke; Oxygen
   vacancy
ID STEAM GASIFICATION; SYNGAS PRODUCTION; OXYGEN-VACANCY; SEWAGE-SLUDGE;
   PYROLYSIS; CARBON
AB The development of sludge to green hydrogen is a win-win solution for alleviating the environmental pollution caused by sludge and low-carbon hydrogen production. A series of iron-cerium bimetallic oxide catalysts on sludge char (SC) were prepared for catalytic volatile reforming in this work. The physicochemical properties of the catalysts were adjusted by doping with different metals and changing the proportion. The results showed that 50Fe50Ce/SC possessing the minimum coke deposition rate (12.79 mg h-1 & sdot;gcat-1) obtained a hydrogen yield of 280.55 ml g-1 from catalytic reforming at 800 degrees C with a steam-to-carbon ratio of 4:1. Analysis of the catalyst structure and activity suggested that the excellent activity mainly originated from the large number of oxygen vacancies. Oxygen vacancies promote the migration of lattice oxygen inside the catalyst bulk to the surface to react with the coke deposition, while the missing oxygen of the catalyst is replenished by steam, and oxygen vacancies play an important role in the enhancement of the catalyst activity and the elimination of coke deposition. The positive potential of this study in hydrogen production and carbon reduction were assessed. The study could provide new ideas for organic solid waste to generate green hydrogen and the development of efficient and low-cost catalysts.
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TI Design of hydrogen production systems powered by solar and wind energy:
   An insight into the optimal size ratios

SO ENERGY CONVERSION AND MANAGEMENT
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DT Article
DE Power-to-hydrogen; Hydrogen; Electrolysis; Renewable energy sources;
   Optimal design
AB Green hydrogen is expected to play a crucial role in the future energy landscape, particularly in the pursuit of deep decarbonisation strategies within hard-to-abate sectors, such as the chemical and steel industries and heavy-duty transport. However, competitive production costs are vital to unlock the full potential of green hydrogen. In the case of green hydrogen produced via water electrolysis powered by fluctuating renewable energy sources, the design of the plant plays a pivotal role in achieving market-competitive production costs. The present work investigates the optimal design of power-to-hydrogen systems powered by renewable sources (solar and wind energy). A detailed model of a power-to-hydrogen system is developed: an energy simulation framework, coupled with an economic assessment, provides the hydrogen production cost as a function of the component sizes. By spanning a wide range of size ratios, namely the ratio between the size of the renewable generator and the size of the electrolyser, the cost-optimal design point (minimum hydrogen production cost) is identified. This investigation is carried out for three plant configurations: solar-only, wind-only and hybrid. The objective is to extend beyond the analysis of a specific case study and provide broadly applicable considerations for the optimal design of green hydrogen production systems. In particular, the rationale behind the cost-optimal size ratio is unveiled and discussed through energy (utilisation factors) and economic (hydrogen production cost) indicators. A sensitivity analysis on investment costs for the power-to-hydrogen technologies is also conducted to explore various technological learning paths from today to 2050. The optimal size ratio is found to be a trade-off between the utilisation factors of the electrolyser and the renewable generator, which exhibit opposite trends. Moreover, the costs of the power-to-hydrogen technologies are a key factor in determining the optimal size ratio: depending on these costs, the optimal solution tends to improve one of the two utilization factors at the expense of the other. Finally, the optimal size ratio is foreseen to decrease in the upcoming years, primarily due to the reduction in the investment cost of the electrolyser.
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TI Optimization of Small-Scale Hydrogen Production with Membrane Reactors
SO MEMBRANES
LA English
DT Article
DE green hydrogen production; biogas; membrane reactors; fluidized bed; modelling
ID CONCENTRATION POLARIZATION; METHANE; MODEL
AB In the pathway towards decarbonization, hydrogen can provide valid support in different sectors, such as transportation, iron and steel industries, and domestic heating, concurrently reducing air pollution. Thanks to its versatility, hydrogen can be produced in different ways, among which steam reforming of natural gas is still the most commonly used method. Today, less than 0.7% of global hydrogen production can be considered low-carbon-emission. Among the various solutions under investigation for low-carbon hydrogen production, membrane reactor technology has the potential, especially at a small scale, to efficiently convert biogas into green hydrogen, leading to a substantial process intensification. Fluidized bed membrane reactors for autothermal reforming of biogas have reached industrial maturity. Reliable modelling support is thus necessary to develop their full potential. In this work, a mathematical model of the reactor is used to provide guidelines for their design and operations in off-design conditions. The analysis shows the influence of temperature, pressures, catalyst and steam amounts, and inlet temperature. Moreover, the influence of different membrane lengths, numbers, and pitches is investigated. From the results, guidelines are provided to properly design the geometry to obtain a set recovery factor value and hydrogen production. For a given reactor geometry and fluidization velocity, operating the reactor at 12 bar and the permeate-side pressure of 0.1 bar while increasing reactor temperature from 450 to 500 degrees C leads to an increase of 33% in hydrogen production and about 40% in HRF. At a reactor temperature of 50 degrees C, going from 8 to 20 bar inside the reactor doubled hydrogen production with a loss in recovery factor of about 16%. With the reactor at 12 bar, a vacuum pressure of 0.5 bar reduces hydrogen production by 43% and HRF by 45%. With the given catalyst, it is sufficient to have only 20% of solids filled into the reactor being catalytic particles. With the fixed operating conditions, it is worth mentioning that by adding membranes and maintaining the same spacing, it is possible to increase hydrogen production proportionally to the membrane area, maintaining the same HRF.
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U1 1
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PA ST ALBAN-ANLAGE 66, CH-4052 BASEL, SWITZERLAND
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TI Hydrogen production from coke oven gas using pressure swing adsorption
   process - a mathematical modelling approach
SO MATERIAUX & TECHNIQUES
LA English
DT Article
DE Hydrogen; coke oven gas; gas separation; pressure swing adsorption;
   activated carbon; zeolite
ID ACTIVATED CARBON; PURIFICATION; SEPARATION; CH4; CO2
AB Coal is playing a major role as a reductant and as an energy source in the present world steel production due to its low cost and widespread distribution around the world. At the same time, being the largest contributor to global CO2 emissions, coal faces significant environmental challenges in terms of air pollution and global warming. Hydrogen is a promising alternative for coal in lowering the steel industry's CO2 footprint, but the availability of green hydrogen is currently limited by its high production cost. This research study focuses on developing a pressure swing adsorption (PSA) technology that will allow for continued use of coal for a smooth transition towards green hydrogen-based steel production, by better utilisation of its by-product coke oven gas to produce high purity hydrogen. A generic, fast and robust simulation tool for simulating a variety of PSA processes considering both equilibrium and kinetic effects using a detailed non-isothermal and non-isobaric model is developed in the study. The adsorption equilibrium data required for the model are calculated from experimental results using the non-linear regression data fitting method. A series of rigorous parametric studies and breakthrough tests are performed using the developed mathematical model for better understanding of the effects of different factors on the PSA process performance. With the better understanding obtained from the above-mentioned parametric studies, the model is optimised by performing several simulation tests to achieve a high process performance in terms of purity and recovery of the H-2 product, productivity of the adsorbents and energy consumption for compression of gases. The optimised 14-step multi-bed PSA cycle developed in this study allows for an improved energy efficiency of coal usage by better utilisation of its by-product coke oven gas by converting it into valuable high purity (>99.999%) hydrogen product with a recovery of over 75%.
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TI Direct conversion of carbon dioxide into liquid fuels and chemicals by
coupling green hydrogen at high temperature
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DE Zeolite; Liquid fuels; CO2 reduction; Bifunctional; Hydrogen storage
ID CO2 HYDROGENATION; SELECTIVE CONVERSION; BIFUNCTIONAL CATALYSTS; LOWER OLEFINS; AROMATICS; SYNGAS; ACID; HYDROCARBONS; ZEOLITES; TRANSFORMATIONS
AB The chemical conversion of CO2 into hydrocarbon fuels and chemicals using green hydrogen not only utilizes abundant CO2 as a carbon feedstock but also enables the storage of hydrogen. Herein, we investigate the direct hydrogenation of CO2 to gasoline and olefins over a series of bifunctional iron-zeolite tandem catalysts operated at high temperatures (> 300 degrees C). This process may efficiently utilize CO2 discharged from industrial combustion and green H2 produced by solid oxide electrolytic cells (SOEC). The optimized FeMnK+H-ZSM-5 catalyst offers a 70% selectivity of C5-C11 range hydrocarbons together with a 17% selectivity of C2-C4 lower olefins at 320 degrees C. The CO2 conversion levels and the aromatics contents could be greatly enhanced as the temperature increases from 320 degrees C to 400 degrees C. The hydrocarbon distribution is mainly determined by the micropore size of the zeolites. The dynamic evolution of bifunctional catalysts and its impact on bifunctional catalysis was systematically investigated.
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TI NiFe on CeO₂, TiO₂, and ZrO₂ Supports
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DE NiFe; oxygenevolution reaction; electrocatalysts; AEM ionomer; alkaline
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ID WATER ELECTROLYSIS; SURFACE-AREA; PERFORMANCE; ELECTROCATALYSTS
AB The high cost and low energy efficiency of conventional water electrolysis methods continue to restrict the widespread adoption of green hydrogen. Anion exchange membrane (AEM) water electrolysis is a promising technology that can produce hydrogen using cost-effective transition-metal catalysts at high energy efficiency. Herein, we investigate the catalytic activity of nickel and iron nanoparticles dispersed on metal-oxide supports for the oxygen evolution reaction (OER), employing electrochemical testing with an anion exchange ionomer to evaluate their potential for application in AEM electrolyzers. We report the electrochemical performance of NiFe nanoparticles of varying Ni:Fe ratios on CeO2 for OER reaction, assessing the overpotential, Tafel slope, and electrochemical stability of the catalysts. Our findings indicate that Ni90Fe10 has the highest catalytic activity as well as stability. To further understand the role of different supports, we assess the electrocatalytic performance of Ni90Fe10 nanoparticles on two more supports - TiO2 and ZrO2. While CeO2 has the lowest overpotential, the other supports also show high activity and good performance at high current densities. TiO2 exhibits superior stability and its overpotential after chronopotentiometry measurements approaches that of CeO2 at high current densities. These results underscore the critical role of iron addition in enhancing nickel nanoparticles' catalytic activity and further emphasize the importance of metal oxide supports in improving catalyst stability and performance.
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JI ACS Appl. Energ. Mater.
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DI 10.1021/acsaem.4c03268
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WC Chemistry, Physical; Energy & Fuels; Materials Science,
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SC Chemistry; Energy & Fuels; Materials Science
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PT J
AU Kuhn, C
Kirn, M
Tischer, S
Deutschmann, O
AF Kuhn, Carola
Kirn, Marco
Tischer, Steffen
Deutschmann, Olaf
TI Micron-sized iron particles as energy carrier: Cycling experiments in a
fixed-bed reactor
SO PROCEEDINGS OF THE COMBUSTION INSTITUTE

LA English
DT Article
DE Energy storage; Iron particles; Oxidation behavior; Cyclization;
   Fixed-bed reactor
ID OXIDATION; KINETICS
AB Iron is a promising energy carrier with the potential to store substantial amounts of energy over extended time periods with minimal losses. For instance, the energy from green hydrogen sources can be used to reduce iron oxides, be stored or transported, and thus be regained by exothermic oxidation of the iron. This work explores the influence of oxygen partial pressure and temperature on the oxidation process in a fixed-bed reactor. Furthermore, the analysis extends to the reduction of oxidized iron particles at varying temperatures. The experimental findings highlight that both oxidation and reduction progress through the fixed-bed reactor as distinct reaction fronts. In the oxidation process, the speed of the reaction front increases with rising oxygen content and temperature, resulting in a higher reaction rate and a correspondingly increased heat release. Conversely, the reaction rate for reduction experiences a notable decrease for 600 degrees C and 700 degrees C. The reprocessability of the iron powder was validated for up to 16 cycles under the optimal reaction conditions established. Furthermore, it was demonstrated that the performance improves with an increasing number of cycles. This improvement is attributed to the formation of pores due to density changes and the subsequent creation of a larger surface area, mitigating the negative effects of sintering and agglomeration.
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C3 Helmholtz Association; Karlsruhe Institute of Technology; Helmholtz
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FU Strategy Fund of the KIT Presidium
FX This work was performed within the cluster project Clean Circles.
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   gratefully acknowledged.
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   Ying, Binwu
   Tang, Bo
   Sun, Xuping
   Hu, Wenchuang
TI Improved Electrochemical Alkaline Seawater Oxidation over Cobalt
   Carbonate Hydroxide Nanowire Array by Iron Doping
SO INORGANIC CHEMISTRY
LA English
DT Article
ID HIGHLY EFFICIENT; WATER OXIDATION; ELECTROCATALYSTS; DESIGN
AB Constructing efficient and low-cost oxygen evolutionreaction (OER)catalysts operating in seawater is essential for green hydrogen productionbut remains a great challenge. In this study, we report an iron dopedcobalt carbonate hydroxide nanowire array on nickel foam (Fe-CoCH/NF)as a high-efficiency OER electrocatalyst. In alkaline seawater, suchFe-CoCH/NF demands an overpotential of 387 mV to drive 500 mA cm(-2), superior to that of

CoCH/NF (597 mV). Moreover,it achieves excellent electrochemical and structural stability inalkaline seawater.
Fe-CoCH/NF is paired withPt/C/NF, forming a two-electrodeelectrolytic cell, only requiring a cell voltage of 1.76 V to obtaina large current density of 100 mA cm(-2) in alkalineseawater, superior to RuO2/NF & PAR;Pt/C/NF.
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RI Cai, Zhengwei/KUD-1340-2024; Dong, Kai/KRP-5239-2024; Longcheng, Zhang/AAL-9527-2020; Sun, Xuping/T-7163-2018; Wang, Yu-Chih/AFR-0750-2022; hu, walter/N-2469-2015; Sun, Yuntong/GQG-8965-2022; He, Xun/JGC-8028-2023
OI Hu, Wenchuang (Walter)/0000-0002-6748-1916; Dong, Kai/0000-0003-3845-5230; He, Xun/0000-0002-2525-9102
FU Free Exploration Project of Frontier Technology for Laoshan Laboratory [16-02]; National Natural Science Foundation of China [22072015, 21927811]
FX This work was supported by the Free Exploration Project of Frontier Technology for Laoshan Laboratory (No. 16-02) and the National Natural Science Foundation of China (Nos. 22072015 and 21927811).
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NR 44
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AU Yang, CX
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AF Yang, Chaoxin
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Zheng, Dongdong
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Ying, Binwu
Liu, Qian
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Hamdy, Mohamed S.
Sun, Xuping
TI Improved Alkaline Seawater Splitting of NiS Nanosheets by Iron Doping
SO INORGANIC CHEMISTRY
LA English
DT Article
ID HIGHLY EFFICIENT; ELECTROCATALYST; NANOPARTICLES; GRAPHENE
AB Seawater electrolysis driven by renewable electricity is deemed a promising and sustainable strategy for green hydrogen production, but it is still formidably challenging. Here, we report an iron-doped NiS nanosheet array on Ni foam (Fe- NiS/NF) as a high-performance and stable seawater splitting electrocatalyst. Such Fe-NiS/NF catalyst needs overpotentials of only 420 and 270 mV at 1000 mA cm-2 for the oxygen evolution reaction and hydrogen evolution reaction in alkaline seawater, respectively. Furthermore, its two-electrode electrolyzer needs a cell voltage of 1.88 V for 1000 mA cm-2 with 50 h of long-term electrochemical durability in alkaline seawater. Additionally, in situ electrochemical Raman and infrared spectroscopy were employed to detect the reconstitution process of NiOOH and the generation of oxygen intermediates under reaction conditions.
C1 [Yang, Chaoxin; He, Xun; Sun, Shengjun; Yue, Meng; Zhang, Min; Zheng, Dongdong; Sun, Xuping] Shandong Normal Univ, Coll Chem, Chem Engn & Mat Sci, Jinan, Peoples R China.
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RI Dong, Kai/KRP-5239-2024; Hamdy, Mohamed/HTN-3465-2023; Longcheng, Zhang/AAL-9527-2020; Wang, Yu-Chih/AFR-0750-2022; Sun, Xuping/T-7163-2018; Zhang, MingJ/GYV-4894-2022; Asiri, Abdullah/C-3458-2009; He, Xun/JGC-8028-2023
OI Chaoxin, Yang/0009-0009-9528-0538; Asiri, Abdullah/0000-0001-7905-3209; Dong, Kai/0000-0003-3845-5230; He, Xun/0000-0002-2525-9102
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PT C
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TI Hydrogen Utilization in Industry. A Cost Comparison between On-Site
   Production and External Supply
SO 2023 ASIA MEETING ON ENVIRONMENT AND ELECTRICAL ENGINEERING, EEE-AM
LA English
DT Proceedings Paper
CT IEEE Asia Meeting on Environment and Electrical Engineering (IEEE-AM)
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SP IEEE, IEEE Ind Applicat Soc, Dai Hoc Dien Luc Elect Power Univ
DE cost; decarbonization; green hydrogen; industry
AB Hydrogen has gained prominence as a versatile and sustainable energy carrier with significant potential for decarbonizing various industrial processes. This paper explores the utilization of hydrogen in an industrial context, focusing on its applications, benefits, challenges, and future prospects. Key industrial sectors, such as refining, chemicals, and steel production, are discussed, highlighting the role of hydrogen in reducing greenhouse gas emissions and enhancing energy efficiency. Additionally, the paper addresses the technical and economic challenges associated with hydrogen adoption and outlines the research and development efforts required to unlock its full industrial potential. Furthermore, the economic convenience of on-site hydrogen production is compared against the supply from an external source, proposing a formula for a quick assessment of the most profitable alternative.
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RI Montana, Francesco/HHS-9659-2022; Sanseverino, Eleonora/R-6856-2016
OI Montana, Francesco/0000-0002-4427-5300; Ruffino,
   Salvatore/0009-0000-7508-3662; MASSARO, Fabio/0000-0002-7044-0349; Riva
   Sanseverino, Eleonora/0000-0003-0113-7650
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   [Anonymous], Energiamercato press release
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NR 23
TC 0
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U2 3
PU IEEE
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Yan, Hao
Feng, Xiang
Chen, De
TI Review of Iron-Based Catalysts for Carbon Dioxide Fischer-Tropsch
Synthesis
SO TRANSACTIONS OF TIANJIN UNIVERSITY
LA English
DT Review
DE CO2 hydrogenation; Olefins; CO2-FTS; Iron-based catalysts
ID CO ACTIVATION PATHWAYS; FE-BASED CATALYST; LIGHT OLEFINS; HYDROGENATION;
SELECTIVITY; NANOPARTICLES; HYDROCARBONS; SURFACE; 1ST-PRINCIPLES;
MECHANISMS
AB Capturing and utilizing CO2 from the production process is the key to solving the excessive CO2 emission problem. CO2 hydrogenation with green hydrogen to produce olefins is an effective and promising way to utilize CO2 and produce valuable chemicals. The olefins can be produced by CO2 hydrogenation through two routes, i.e., CO2-FTS (carbon dioxide Fischer-Tropsch synthesis) and MeOH (methanol-mediated), among which CO2-FTS has significant advantages over MeOH in practical applications due to its relatively high CO2 conversion and low energy consumption potentials. However, the CO2-FTS faces challenges of difficult CO2 activation and low olefins selectivity. Iron-based catalysts are promising for CO2-FTS due to their dual functionality of catalyzing RWGS and CO-FTS reactions. This review summarizes the recent progress on iron-based catalysts for CO2 hydrogenation via the FTS route and analyzes the catalyst optimization from the perspectives of additives, active sites, and reaction mechanisms. Furthermore, we also outline principles and challenges for rational design of high-performance CO2-FTS catalysts.
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U1 15
U2 45
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AF Schwarze, K.
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TI Operational Results of an 150/30 kW RSOC System in an Industrial
   Environment
SO FUEL CELLS
LA English
DT Article; Proceedings Paper
CT 13th European Solid Oxide Fuel Cells (SOFC) and Solid Oxide
   Electrolysers (SOE) Forum (EFCE)
CY JUL 03-06, 2018
CL Lucerne, SWITZERLAND
SP European Fuel Cells Forum
DE Energy Conversion; High Temperature; Hydrogen; Natural Gas; Renewable
   Energy; RSOC; Solid Oxide Fuel Cell; Steam Electrolysis; Waste Heat;
   Water Splitting
AB The integration of renewable energy into industrial processes has a high potential for moving to a competitive low-carbon economy in 2050, as targeted by the European Commission. The vision of the GrInHy project is to provide 'green' hydrogen via electrolysis using renewable electricity and to provide grid management services as a reversible generator in the iron-and-steel works of Salzgitter Flachstahl GmbH (Germany). Therefore, an reverse solid oxide cell (RSOC) system was built with a nominal electrolyzer power consumption of 150 kW(AC) and a power output of 30 kW(AC) in fuel cell operation with hydrogen, respectively, 25 kW(AC) with natural gas. A key outcome of the project is to prove high system efficiencies up to 84%(LHV) in electrolysis mode and more than 50%(LHV) in fuel cell mode with natural gas are achievable in a real life system. It also showed long-term operability at degradation rates < 1% kh(-1). The findings and results of the first 5,000 h of operation are presented in this paper. The GrInHy prototype demonstrates the technical feasibility of the integration of an RSOC system in an industrial environment as flexible load or power source. It proves that steam electrolyzers have reached a technical readiness that allows their scale-up to a level at which real life customer demands can be covered.
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NR 3
TC 17
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U1 4
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PU WILEY-V C H VERLAG GMBH
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PA POSTFACH 101161, 69451 WEINHEIM, GERMANY
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J9 FUEL CELLS
JI Fuel Cells
PD AUG
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WE Science Citation Index Expanded (SCI-EXPANDED); Conference Proceedings Citation Index - Science (CPCI-S)
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AU Qiu, Z
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Henriksson, G
Cornell, A
AF Qiu, Zhen
Martin-Yerga, Daniel
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TI Green hydrogen production via electrochemical conversion of components from alkaline carbohydrate degradation
SO INTERNATIONAL JOURNAL OF HYDROGEN ENERGY
LA English
DT Article
DE Hydrogen production; Electrolysis; Biomass waste stream; PdNi; NiO
ID STEEL PRODUCTION; WATER OXIDATION; BLACK LIQUOR; FORMIC-ACID; ELECTROLYSIS; CATALYST; ELECTROOXIDATION; IRON; ELECTROCATALYSTS; STABILITY
AB Water electrolysis is a promising approach for the sustainable production of hydrogen, however, the unfavorable thermodynamics and sluggish kinetics of oxygen evolution reaction (OER) are associated with high anodic potentials. To lower the required potentials, an effective strategy is proposed to substitute OER with partial oxidation of degradation products of carbohydrate origin from the waste stream of a chemical pulping industry. In this work, two different catalytic materials - PdNi and NiO are investigated comparatively to understand their catalytic performance for the oxidation of carbohydrate alkaline degradation products (CHADs). PdNi can catalyze CHADs with low potential requirements (-0.11 V vs. Hg/HgO at 150 mA cm(-2)) but is limited to current densities <200 mA cm(-2). In contrast, NiO can operate at very high current densities but required relatively higher potentials (0.53 V vs. Hg/HgO at 500 mA cm(-2)). The performance of this non-noble metal catalyst compares favorably with that of Pd-based catalysts for hydrogen production from CHADs at high conversion rates. This work shows the potential to utilize waste streams from a large-scale process industry for sustainable hydrogen production, and also opens up opportunities to study earth-abundant electrocatalysts to efficiently oxidize biomass-derived substances. (C) 2021 KTH Royal Institute of Technology. Published by Elsevier Ltd on behalf of Hydrogen Energy Publications LLC.
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AB Biohydrogen has gained several advantages due to its high-energy content, pollution-free byproduct emission, ambient operating conditions, and ability to use various substrates for production. Further, the use of organic waste can be considered as a promising source for the production of biohydrogen while overcoming the possible environmental issues upon its disposal. However, the routes of biohydrogen production i.e. photo and dark fermentation encounter several challenges for commercialization due to lower yields. To make the process more expedient, nanomaterials such as metal, metal oxides, carbon-based, and inorganic are used to improve the hydrogen production owing to their unique physical and physical properties. In view of this, the current review highlights the role of these nanomaterials in the biological conversion of organic waste to biohydrogen. Further, emphasis is given on the mechanisms of nanomaterials' interaction with microorganisms, life cycle, and techno-economic analyses along with its major challenges and future prospects.
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TI Review of the hydrogen supply chain and use in Africa
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DE Hydrogen production; Hydrogen trading; Hydrogen utilization; Africa; Hydrogen infrastructure
ID SOLAR HYDROGEN; SOUTH-AFRICA; WIND ENERGY; TECHNOECONOMIC ANALYSIS; ELECTRICITY-GENERATION; REFUELING STATION; STORAGE-SYSTEM; NORTH-AFRICA; TRANSPORT; POWER
AB The high potential in renewable energy sources (RES) and the availability of strategic minerals for green hydrogen technologies place Africa in a promising position for the development of a climate-compatible economy leveraging on hydrogen. This study reviews the potential hydrogen value chain in Africa considering production and final uses while addressing perspectives on policies, possible infrastructures, and facilities for hydrogen logistics. Through scientific studies research and searching in relevant repositories, this review features the collection, analysis of technical data and georeferenced information about key aspects of the hydrogen value chain. Detailed maps and technical data for gas transport infrastructure and liquefaction terminals in the continent are reported to inform and elaborate findings about readiness for hydrogen trading and domestic use in Africa. Specific maps and technical data have been also collected for the identification of potential hydrogen offtakers focusing on individual industrial installations to produce iron and steel, chemicals, and oil refineries. Finally, georeferenced data are presented for main road and railway corridors as well as for most important African ports as further end-use and logistic platforms. Beyond technical information, this study collects and discusses more recent perspectives about policies and implementation initiatives specifically addressing hydrogen production, logistics, and final use also introducing potential criticalities associated with environmental and social impacts.
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NR 182
TC 0
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U1 15
U2 15
PU PERGAMON-ELSEVIER SCIENCE LTD
PI OXFORD
PA THE BOULEVARD, LANGFORD LANE, KIDLINGTON, OXFORD OX5 1GB, ENGLAND
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J9 RENEW SUST ENERG REV
JI Renew. Sust. Energ. Rev.
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WC Green & Sustainable Science & Technology; Energy & Fuels
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SC Science & Technology - Other Topics; Energy & Fuels
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PT J
AU Hourtoule, M
Trienes, S
Ackermann, L
AF Hourtoule, Maxime
Trienes, Sven
Ackermann, Lutz
TI Anodic Commodity Polymer Recycling: The Merger of Iron-Electrocatalysis
with Scalable Hydrogen Evolution Reaction
SO ANGEWANDTE CHEMIE-INTERNATIONAL EDITION
LA English
DT Article
DE Plastic Degradation; Electrocatalysis; Iron catalysis; Oxidation;
Polymers
ID C-H BONDS; PLASTICS; POLYETHYLENES; HYDROXYLATION; REDUCTION; OXIDATION;
COMPLEXES; DIOXYGEN
AB Plastics are omnipresent in our everyday life, and accumulation of post-consumer plastic waste in our environment represents a major societal challenge. Hence, methods for plastic waste recycling are in high demand for a future circular economy. Specifically, the degradation of post-consumer polymers towards value-added small molecules constitutes a sustainable strategy for a carbon circular economy. Despite of recent advances, chemical polymer degradation continues to be largely limited to chemical redox agents or low energy efficiency in photochemical processes. We herein report a

powerful iron-catalyzed degradation of high molecular weight polystyrenes through electrochemistry to efficiently deliver monomeric benzoyl products. The robustness of the ferraelectrocatalysis was mirrored by the degradation of various real-life post-consumer plastics, also on gram scale. The cathodic half reaction was largely represented by the hydrogen evolution reaction (HER). The scalable electro-polymer degradation could be solely fueled by solar energy through a commercially available solar panel, indicating an outstanding potential for a decentralized green hydrogen economy.
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NR 61
TC 1
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U1 22
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PA POSTFACH 101161, 69451 WEINHEIM, GERMANY
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Zidki, Tomer
Mizrahi, Amir
Meyerstein, Dan
TI First-row transition metal carbonates catalyze the electrochemical
oxygen evolution reaction: iron is master of them all
SO DALTON TRANSACTIONS
LA English
DT Article
ID WATER; ELECTROCATALYST; MECHANISMS; MORPHOLOGY; NIO
AB In pursuing green hydrogen fuel, electrochemical water-splitting emerges as the optimal method. A critical challenge in advancing this process is identifying a cost-effective electrocatalyst for oxygen evolution on the anode. Recent research has

demonstrated the efficacy of first-row transition metal carbonates as catalysts for various oxidation reactions. In this study, Earth-abundant first-row transition metal carbonates were electrodeposited onto nickel foam (NF) electrodes and evaluated for their performance in the oxygen evolution reaction. The investigation compares the activity of these carbonates on NF electrodes against bare NF electrodes. Notably, Fe2(CO3)3/NF exhibited superior oxygen evolution activity, characterized by low overpotential values, i.e. Iron is master of them all (R. Kipling, Cold Iron, Rewards and Fairies, Macmillan and Co. Ltd., 1910). Comprehensive catalytic stability and durability tests also indicate that these transition metal carbonates maintain stable activity, positioning them as durable and efficient electrocatalysts for the oxygen evolution reaction.
The electrochemically deposited metal carbonates were tested for their Oxygen evolution reaction activity
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FX The authors are indebted to the Pazy Foundation (Grant No. RA1700000176) for financial support, and I. U. is thankful to Ariel University for a Ph.D. Fellowship.
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NR 46
TC 0
Z9 0
U1 5
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PU ROYAL SOC CHEMISTRY
PI CAMBRIDGE
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SC Chemistry
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PT J
AU Mcgregor, C
Young, BD
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AF Mcgregor, C.
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Hildebrandt, D.
TI Risk assessment framework for green hydrogen megaprojects: Balancing
climate goals with project viability
SO APPLIED THERMAL ENGINEERING
LA English
DT Article
DE Hydrogen economy; Green hydrogen production; Project risk assessment;
Energy infrastructure investment; Renewable energy transition; Hydrogen
technology commercialisation; Hydrogen megaprojects
ID ENERGY; OPPORTUNITIES; CHALLENGES; ACCEPTANCE; EFFICIENCY; IMPACTS;
CHAIN
AB Green hydrogen presents a promising solution for decarbonisation, but its widespread adoption faces significant challenges. To meet Europe's 2030 targets, a 250-fold increase in electrolyser capacity is required, necessitating an investment of <euro>170-240 billion. This involves constructing 20-40 pioneering megaprojects, each with a 1-5 GW capacity. Historically, pioneering energy projects have seen capital costs double or triple from initial estimates, with over 50% failing to meet production goals at startup due to new technology introductions, sitespecific characteristics, and project complexity. Additionally, megaprojects, costing more than <euro>1 billion, frequently

succumb to the "iron law," which states they are often over budget, take longer than anticipated, and yield fewer benefits than expected, mainly because key players consistently underestimate costs and risks. Pursuing multiple pioneering megaprojects simultaneously restricts opportunities for iterative learning, which raises risks related to untested technologies and infrastructure demands. This vision paper introduces a novel risk assessment framework that combines insights from pioneering and megaprojects with technology readiness evaluations and comparative CO2 reduction analyses to tackle these challenges. The framework aims to guide investment decisions and risk mitigation strategies, such as staged scaling and limiting the introduction of new technology. The analysis highlights that using green ammonia for fertiliser production can reduce CO2 emissions by 51 tons of CO2 per ton of hydrogen, significantly outperforming hydrogen use in transportation and heating. This structured approach considers risks and environmental benefits while promoting equitable risk distribution between developed and developing nations.
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FX Craig McGregor received support for this work from the Strategic Fund of Stellenbosch University through the Hydrogen Engineering Research Platform (B922A) .
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PT J
AU Gamisch, B
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Dawoud, B
AF Gamisch, Bernd
Gaderer, Matthias
Dawoud, Belal
TI On the Development of Thermochemical Hydrogen Storage: An Experimental Study of the Kinetics of the Redox Reactions under Different Operating Conditions
SO APPLIED SCIENCES-BASEL

LA English
DT Article
DE hydrogen storage; iron/iron oxide; redox reactions; reaction kinetics
ID METAL-HYDRIDES; ENERGY; OXIDE; TEMPERATURE; REDUCTION; GENERATION;
BEHAVIOR; CARRIERS
AB This work aims at investigating the reduction/oxidation (redox) reaction kinetics on iron oxide pellets under different operating conditions of thermochemical hydrogen storage. In order to reduce the iron oxide pellets (90% Fe2O3, 10% stabilizing cement), hydrogen (H-2) is applied in different concentrations with nitrogen (N-2), as a carrier gas, at temperatures between between 700 degrees C and 900 degrees C, thus simulating the charging phase. The discharge phase is triggered by the flow of a mixture out of steam (H2O) and N-2 at different concentrations in the same temperature range, resulting in the oxidizing of the previously reduced pellets. All investigations were carried out in a thermo-gravimetric analyzer (TGA) with a flow rate of 250 mL/min. To describe the obtained kinetic results, a simplified analytical model, based on the linear driving force model, was developed. The investigated iron oxide pellets showed a stable redox performance of 23.8% weight reduction/gain, which corresponds to a volumetric storage density of 2.8 kWh/ (L bulk), also after the 29 performed redox cycles. Recalling that there is no H-2 stored during the storage phase but iron, the introduced hydrogen storage technology is deemed very promising for applications in urban areas as day-night or seasonal storage for green hydrogen.
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Z9 6
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PU MDPI
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PA ST ALBAN-ANLAGE 66, CH-4052 BASEL, SWITZERLAND
EI 2076-3417
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TI Numerical studies on the propagation of iron dust flames in confinement
SO PROCEEDINGS OF THE COMBUSTION INSTITUTE
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DT Article
DE Iron fuel; Dust explosion; Quenching limits
AB Iron powder is a promising alternative fuel owing to its high energy density, non-volatile combustion, and recyclability using green hydrogen. For the safe storage, transportation, and use of iron powder as a reactive energy source, the physical mechanisms behind pressurising dust flames in explosions must be understood. Here, we study the propagation of one-dimensional iron dust flames in confinement using an Euler-Lagrange framework with reflective adiabatic boundary conditions. The gas phase is described by the compressible Navier-Stokes equations, and heterogeneously burning iron particles follow the parabolic rate law for solid- phase oxidation, and diffusion-limited combustion during liquid-phase combustion. We demonstrate that the pressurisation in a closed vessel leads to an increase in unburnt gas density, decelerating flame propagation via a decrease in thermal diffusivity. Flames through dust suspensions at concentrations above the thermodynamic limit are quenched, while for concentrations near the quenching limit, flames are quenched before re-ignition. The trajectories of particles and gas parcels demonstrate that particles are strongly entrained in the gas streams, causing fluctuations in local dust concentrations. The transient evolution of flame speeds in confinement is used to inform a pressure-rise model, which predicts the time to peak pressure in a 20-L vessel with good agreement to experimental measurements. Our insights provide mechanistic understandings about dust flame propagation under pressurising conditions, particularly relevant to the informed design of explosion protection measures.
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TI Ambient Electrosynthesis toward Single-Atom Sites for Electrocatalytic
Green Hydrogen Cycling
SO ADVANCED MATERIALS
LA English
DT Article
DE ambient electrosynthesis; electrocatalysis; fuel cells; single-atom
sites; water splitting
ID OXYGEN EVOLUTION REACTION; STABLE SINGLE; PLATINUM ATOMS;
HIGH-PERFORMANCE; LEVEL INSIGHT; CO2 REDUCTION; ACTIVE-SITES; NICKEL
FOAM; FUEL-CELLS; IRON SITE
AB With the ultimate atomic utilization, well-defined configuration of active sites and unique electronic properties, catalysts with single-atom sites (SASs) exhibit appealing performance for electrocatalytic green hydrogen generation from water splitting and further utilization via hydrogen-oxygen fuel cells, such that a vast majority of synthetic strategies toward SAS-based catalysts (SASCs) are exploited. In particular, room-temperature electrosynthesis under atmospheric pressure offers a novel, safe, and effective route to access SASs. Herein, the recent progress in ambient electrosynthesis toward SASs for electrocatalytic sustainable hydrogen generation and utilization, and future opportunities are discussed. A systematic summary is started on three kinds of ambient electrochemically synthetic routes for SASs, including electrochemical etching (ECE), direct electrodeposition (DED), and electrochemical leaching-redeposition (ELR), associated with advanced characterization techniques. Next, their electrocatalytic

applications for hydrogen energy conversion including hydrogen evolution reaction, oxygen evolution reaction, overall water splitting, and oxygen reduction reaction are reviewed. Finally, a brief conclusion and remarks on future challenges regarding further development of ambient electrosynthesis of high-performance and cost-effective SASCs for many other electrocatalytic applications are presented.
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TI Emerging trends of pseudobrookite Fe2TiO5 photocatalyst: A versatile
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AB Renewable energy production from diverse sources (such as solar, wind) is essential for achieving a sus-tainable and CO2-free society within a short duration. Green hydrogen is regarded as the most feasible fuel for the next generation of fuel-cell electric vehicles and associated technologies. Solar water splitting is a promising strategy for green hydrogen production because it is based on renewable sources with the po-tential to minimize the power costs in the production of H2 via electrolysis, which presents significant barriers. Iron titanate (Fe2TiO5), a visible-light-active photocatalyst, has emerged as a possible material for designing the next generation of water splitting photoelectrodes, as it is a low-cost, plentiful, and non-toxic oxide with favorable electronic, optical, and chemical properties for this application. This review sum-marizes recent advances in the use of Fe2TiO5 as a semiconducting material for solar water splitting ap-plications, covering single photocatalytic systems and heterostructures such as Fe2TiO5/TiO2, Fe2TiO5/BiVO4, and Fe2TiO5/Fe2O3. Furthermore, this perspective review discusses and highlights strategies for developing effective Fe2TiO5 based water-oxidation materials.

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ID HIGH-STRENGTH STEELS; SUBSURFACE CRACK INITIATION; METALLIC MATERIALS; BEARING STEEL; EMBRITTLEMENT; MECHANISM; FAILURE; PROPAGATION; REGIME; GROWTH
AB Global warming and extreme climate problems caused by the intensive exploitation of fossil fuels have become increasingly serious. With the urgent global demand for clean energy, green hydrogen energy has become one of the important directions for future energy transformation due to its zero carbon emissions and wide source. However, embrittlement occurs in almost all metals when exposed to hydrogen, which greatly hinders the development of the hydrogen energy industry. Furthermore, the key application terminals of hydrogen energy are found in engineering equipment for aerospace, civil engineering, transportation and other fields. These equipments must endure long life with high reliability operation requirements. Therefore, accurately evaluating their Very High Cycle Fatigue (VHCF) characteristics in a hydrogen environment is the key for the future advancement of the hydrogen energy industry. In this article, the latest related research on VHCF failure behavior and hydrogen embrittlement mechanisms are briefly reviewed. At the same time, this work focuses on the impact of hydrogen on VHCF behavior, with the aim to provide some guidance for the research on VHCF characteristics and the design of metal equipment in hydrogen environment. Finally, this review summarizes the current higher-level challenges of VHCF research in hydrogen environments and provides some potential tools that may further address these challenges.
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TI Regional supply chains for decarbonising steel: Energy efficiency and
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DE Decarbonised steel; Green hydrogen; Regional alliances; Supply chains;
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ID LIQUID-HYDROGEN; AMMONIA; STORAGE; FUTURE; REDUCTION; IMPACT
AB Decarbonised steel, enabled by green hydrogen-based iron ore reduction and renewable
electricity-based steel making, will disrupt the traditional supply chain. Focusing on
the energetic and techno-economic assessment of potential green supply chains, this study
investigates the direct reduced iron-electric arc furnace production route enabled by
renewable energy and deployed in regional settings. The hypothesis, that co-locating

manufacturing processes with renewable energy resources would offer highest energy efficiency and cost reduction, is tested through an Australia-Japan case study. The binational partnership is structured to meet Japanese steel demand (for domestic use and regional exports) and source both energy and iron ore from the Pilbara region of Western Australia. A total of 12 unique supply chains differentiated by spatial configuration, timeline and energy carrier were simulated, which validated the hypothesis: direct energy and ore exports to remote steel producers (i.e. Japan-based production), as opposed to co-locating iron and steel production with abundant ore and renewable energy resources (i.e. Australia-based production), increased energy consumption and the levelised cost of steel by 45% and 32%, respectively, when averaged across 2030 and 2050. Two decades of technological development and economies of scale realisation would be crucial; 2030 supply chains were on average 12% more energy-intense and 23% more expensive than 2050 equivalents. On energy vectors, liquefied hydrogen was more efficient than ammonia for export-dominant supply chains due to the pairing of its process flexibility and the intermittent solar energy profile, as well as the avoidance of the need for ammonia cracking prior to direct reduction. To mitigate the green premium, a carbon tax in the range of A$66-192/t CO2 would be required in 2030 and A$0-70/t CO2 in 2050; the diminished carbon tax requirement in the latter is achievable only by wholly Australia-based production. Further, the modelled system scale was immense; producing 40 Mtpa of decarbonised steel will require 74-129% of Australia's current electricity output and A$137-328 billion in capital investment for solar power, production, and shipping vessel infrastructure. These results call for strategic planning of regional resource pairing to drive energy and cost efficiencies which accelerate the global decar-bonisation of steel.
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TI New age chloride shielding strategies for corrosion resistant direct seawater splitting
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ID SELECTIVE OXYGEN EVOLUTION; HYDROGEN EVOLUTION; OXIDE ANODES; MANGANESE OXIDE; MILD-STEEL; ELECTROCATALYST; DISSOLUTION; INHIBITORS; CATALYST; PLATINUM
AB Electrocatalytic direct seawater splitting is considered to be one of the most desirable and necessary approach to produce substantial amount of green hydrogen to meet the energy demand. However, practical seawater splitting remains far-fetched due to the electrochemical interference of multiple elements present in seawater, among which chlorine chemistry is the most aggravating one, causing severe damages to electrodes. To overcome such limitations, apart from robust electrocatalyst design, electrolyte engineering along with in depth corrosion engineering are essential aspects, which needs to be thoroughly judged and explored. Indeed, extensive studies and various approaches including smart electrolyzer design have been attempted in the last couple of years on this matter. The present review offers a comprehensive discussion on various strategies to achieve effective and sustainable direct seawater splitting, avoiding chlorine electrochemistry to achieve industry-level performances.
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AU Wang, YF
Williamson, N
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TI Electrodeposition of nickel-iron on stainless steel as an efficient electrocatalyst coating for the oxygen evolution reaction in alkaline conditions
SO JOURNAL OF APPLIED ELECTROCHEMISTRY
LA English
DT Article
DE Hydrogen; Alkaline electrolysis; Nickel-iron; Oxygen evolution reaction; Clean energy; Electrocatalyst
ID SURFACE OXIDATION; HYDROGEN; MECHANISM; CATALYSTS; RUST
AB Significant amount of effort has been devoted in the development of water electrolysis technology as the prime technology for green hydrogen production. In this paper, we investigate nickel-iron-based electrocatalytic coatings on stainless-steel substrates for commercial alkaline water electrolysers. Stainless steel electrodes for water

electrolysis have received attention lately, showing that they can be a low-cost substrate for water electrolysis. Coating stainless steel with low-cost electrocatalysts can prove beneficial to lower overpotential for the oxygen evolution reaction (OER), thereby reducing the overall energy consumption of water electrolysis at an affordable cost. We show that NiFe-deposited substrates have an overpotential of 514 mV at 10 mA cm(-2) current. The substrates also exhibited excellent stability in strong alkaline condition for 60 h under continuous 1.2 V working potential vs SCE. The results in full-cell electrolysers demonstrate that the electrolyser with the NiFe-coated anode could generate nearly six times as much current density compared with the bare stainless-steel substrate.
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PI DORDRECHT
PA VAN GODEWIJCKSTRAAT 30, 3311 GZ DORDRECHT, NETHERLANDS
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TI A Facile Ultrapure Water Production Method for Electrolysis via Multilayered Photovoltaic/Membrane Distillation
SO ENERGIES
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DT Article
DE ultrapure water; photovoltaic; membrane distillation; electrolysis; hydrogen production
ID SYSTEM
AB Ultrapure water production is vital for sustainable green hydrogen production by electrolysis. The current industrial process to generate ultrapure water involves energy-intensive processes, such as reverse osmosis. This study demonstrates a facile method to produce ultrapure water from simulated seawater using a low capital cost and low-energy-consuming membrane distillation (MD) approach that is driven by the waste heat from photovoltaic (PV) panels. To optimize the PV-MD operation, modeling efforts to design a multilayered MD system were carried out. The results were used to guide the construction

of several prototype devices using different materials. The best performing PV-MD device, containing evaporation and condensation regions made from steel sheets and polytetrafluoroethylene (PTFE) membranes, can produce high-purity water with conductivity less than 40 mS and flux higher than 100 g/m(2) h, which is suitable for typical electrolyzer use.
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TI Iron-magnesium ball milling alloying nitrogen fixation and heating hydrogenation constitute an efficient chemical looping ammonia synthesis process
SO MATERIALS LETTERS
LA English
DT Article
DE Iron-magnesium alloy; Ball milling nitrogen fixation; Synthetic ammonia; Chemical looping
AB Green hydrogen is the future direction of energy development, and green ammonia is one of the keys to solve its storage and transportation problems. Industrial ammonia synthesis relies on fossil energy, and the development of a new green ammonia synthesis process is the focus of research. In this paper, a two-step ammonia synthesis process of nitrogen fixation by ball milling and ammonia production by heating hydrogenation was constructed, and the performance of the nitrogen carrier was improved by alloying. The nitrogen fixation capacity of the developed FeMg10 nitrogen carrier is three times that of Fe, and it can rapidly hydrogenate and release ammonia at 500 degrees C. The nitrogen conversion rate is about 75 %. This process is facile and easy to couple with renewable energy to achieve distributed green ammonia synthesis, which is expected to compete with industrial synthetic ammonia in the future.
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NR 9
TC 0
Z9 0
U1 3
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PI AMSTERDAM
PA RADARWEG 29, 1043 NX AMSTERDAM, NETHERLANDS
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JI Mater. Lett.
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EA DEC 2024
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WC Materials Science, Multidisciplinary; Physics, Applied
WE Science Citation Index Expanded (SCI-EXPANDED)
SC Materials Science; Physics
GA W2D7U
UT WOS:001416752000001
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ER

PT J
AU Cao, NND
Andrianov, D
Vecchi, A
Davis, D
Brear, MJ
AF Cao, Nguyen N. D.
Andrianov, Denis
Vecchi, Andrea
Davis, Dominic
Brear, Michael John
TI Achieving affordable, clean shipping by integrating ship design and
clean fuels
SO TRANSPORTATION RESEARCH PART D-TRANSPORT AND ENVIRONMENT
LA English
DT Article
DE Shipping; Clean fuel; Propulsion system; Techno-economic analysis;
Decarbonization
AB This work assesses the technical, economic and greenhouse gas (GHG) emission performance of different, low emission shipping options. It shows how the levelized cost of shipping (LCOS) and lifecycle GHG emissions depend not only on the fuels and propulsion systems used, but also on key vessel design parameters. A case study of a conventional, 250 kt deadweight, iron ore carrier is shown to have a similar LCOS as a 350 kt deadweight vessel with a reduced range, lower design speed and green hydrogen gas fuelling, without compromising on the cargo delivered over some period. The resulting 'green premium' is much smaller than historical iron ore price fluctuations and towards the lower end of the IMO's currently discussed carbon price range, with similar results also achievable with other, low emission fuels. This suggests that significant increases in shipping costs may not be inevitable as carbon-based emission policies are implemented.
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FU Future Energy Exports Cooperative Research Centre (FEnEx CRC); Clean
Marine Fuel Institute (CMFI)
FX The authors would like to thank the Future Energy Exports Cooperative
Research Centre (FEnEx CRC) and the Clean Marine Fuel Institute (CMFI)
for their financial support.
CR [Anonymous], 2022, Kawasaki Obtains AIP for Large. 160,000 m3 liquefied hydrogen carrier
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NR 73
TC 0
Z9 0
U1 1
U2 1
PU PERGAMON-ELSEVIER SCIENCE LTD
PI OXFORD
PA THE BOULEVARD, LANGFORD LANE, KIDLINGTON, OXFORD OX5 1GB, ENGLAND
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JI Transport. Res. Part D-Transport. Environ.
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WC Environmental Studies; Transportation; Transportation Science & Technology
WE Science Citation Index Expanded (SCI-EXPANDED); Social Science Citation Index (SSCI)
SC Environmental Sciences & Ecology; Transportation
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PT J
AU Guo, ZQ
Xu, XQ
Li, SW
Zhu, DQ
Pan, J
Yang, CC
AF Guo, Zhengqi
Xu, Xianqing
Li, Siwei
Zhu, Deqing
Pan, Jian
Yang, Congcong
TI Hydrogen reduction process for zinc-bearing dust treatment: Reduction kinetic mechanism and microstructure transformations in a novel and environmentally friendly metallurgical technique
SO JOURNAL OF ENVIRONMENTAL CHEMICAL ENGINEERING
LA English
DT Article
DE Zinc-bearing dust; Hydrogen reduction; Reduction kinetic; Hazardous wastes
ID ARC FURNACE DUST; BEHAVIOR; PELLETS
AB The iron and steel sector generates 80 million tons of zinc-containing dust annually, traditionally treated using carbon-based pyrometallurgical processes, which have significant drawbacks, including large carbon emissions, high energy consumption, and low production value. To address the above issues, a green hydrogen reduction method was developed for zinc-bearing dust treatment. This study examined the thermodynamics,

reduction kinetics, and phase transformation during the process, revealing that at 800 degrees C, the hydrogen partial pressure for zinc oxide reduction is only 45.56 %. The direct reduction of zinc-containing dust pellets with hydrogen reveals that the limiting step of iron oxide and zinc reductions both are interfacial chemical reaction control at the reduction temperature of 800-950 degrees C, with an apparent activation energy of 16.42 kJ/mol and 71.39 kJ/mol. The kinetic mechanism indicates that reducing iron and zinc oxides is more accessible in a hydrogen reduction system, with lower apparent activation energies than carbothermal reduction. Consequently, hydrogen reduction offers a more efficient and environmentally friendly solution for treating zinc-bearing dust.
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OI Li, bohua/0009-0008-6839-1753; xianqing, xu/0000-0002-6819-9082
FU National Natural Science Foundation of China [52274343]; China Baowu Low Carbon Metallurgy Innovation Foundation [BWLCF202102]; Hunan Provincial Key Research and Development Project [2022SK2075]
FX This work was supported by the financial support from the National Natural Science Foundation of China (No. 52274343) , China Baowu Low Carbon Metallurgy Innovation Foundation (No. BWLCF202102) and Hunan Provincial Key Research and Development Project (No. 2022SK2075) .
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NR 26
TC 7
Z9 8
U1 16
U2 34
PU ELSEVIER SCI LTD
PI London
PA 125 London Wall, London, ENGLAND
SN 2213-2929
EI 2213-3437
J9 J ENVIRON CHEM ENG
JI J. Environ. Chem. Eng.
PD OCT
PY 2023
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AR 110836
DI 10.1016/j.jece.2023.110836
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WC Engineering, Environmental; Engineering, Chemical
WE Science Citation Index Expanded (SCI-EXPANDED)
SC Engineering
GA X0WU3
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ER

PT J
AU Tang, QM
Huang, KV
AF Tang, Qiming
Huang, Kevin
TI Determining the kinetic rate constants of
Fe₃O₄-to-Fe and FeO-to-Fe reduction by
H₂
SO CHEMICAL ENGINEERING JOURNAL
LA English
DT Article
DE Hydrogen; Iron oxide reduction; Kinetics; Modeling; One-step reduction
ID AIR REDOX BATTERY; IRON-OXIDE REDUCTION; INTERMEDIATE-TEMPERATURE;
HYDROGEN-PRODUCTION; ENERGY-STORAGE; THIN-FILMS; HEMATITE; GAS; WUSTITE;
PELLETS
AB Steel production using coal accounts for ~ 8% of global carbon emissions. "Green Steel " is a new grand concept proposed recently to make steel from iron ores using renewable derived "Green Hydrogen " to achieve zero carbon emission. The kinetics and rate-limiting steps of iron ore reduction into iron with H-2 as a reducing agent is critically important to the success of this new technology. While reduction of Fe2O3 into Fe by H-2 follows multiple steps, the past research on this topic mainly deals with the overall averaged kinetics, giving little information on the elemental and rate-limiting steps. Here we report a kinetic study specifically design to attain kinetic rate constants of one-step reduction of Fe3O4-to-Fe and FeO-to-Fe. Guided by thermodynamics, we show first how to create in situ the desirable starting oxide phases, i.e., Fe3O4 and FeO, with precisely controlled the ratio of partial pressures of H2O and H-2. We then show time-dependent raw H2O content data collected by a mass spectrometer and the processed reduction data to extract kinetic rate constants. We found that the kinetics of the two one-step reduction reactions follows nicely the Johnson-Mehl-Avrami (JMA) phase transformation model. The one-step reduction mechanisms and activation energy are also discussed.
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OI Huang, Kevin/0000-0002-1232-4593; Tang, Qiming/0000-0003-4151-0501
FU National Science Foundation [1801284]; Department of Energy, Of-fice
Fossil Fuels, National Energy technology Laboratory [DE-FE-0031671];
Directorate For Engineering; Div Of Chem, Bioeng, Env, & Transp Sys
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NR 38
TC 35
Z9 36
U1 11
U2 61
PU ELSEVIER SCIENCE SA
PI LAUSANNE
PA PO BOX 564, 1001 LAUSANNE, SWITZERLAND
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JI Chem. Eng. J.
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AR 134771
DI 10.1016/j.cej.2022.134771
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WC Engineering, Environmental; Engineering, Chemical
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SC Engineering
GA ZZ8VS
UT WOS:000773542900003
OA Green Submitted, Bronze
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ER

PT J
AU Pivetta, D
   Dall'Armi, C

Taccani, R
AF Pivetta, Davide
Dall'Armi, Chiara
Taccani, Rodolfo
TI Multi-Objective Optimization of a Hydrogen Hub for the Decarbonization of a Port Industrial Area
SO JOURNAL OF MARINE SCIENCE AND ENGINEERING
LA English
DT Article
DE hydrogen hub; renewable energy storage; Mixed-Integer Linear Programming (MILP) optimization; industrial port area; hard-to-abate sector; hydrogen refueling station; multi-objective optimization; hydrogen in port; steel plant; port decarbonization
ID SYSTEM; COST
AB Green hydrogen is addressed as a promising solution to decarbonize industrial and mobility sectors. In this context, ports could play a key role not only as hydrogen users but also as suppliers for industrial plants with which they have strong commercial ties. The implementation of hydrogen technologies in ports has started to be addressed as a strategy for renewable energy transition but still requires a detailed evaluation of the involved costs, which cannot be separated from the correct design and operation of the plant. Hence, this study proposes the design and operation optimization of a hydrogen production and storage system in a typical Italian port. Multi-objective optimization is performed to determine the optimal levelized cost of hydrogen in environmental and techno-economic terms. A Polymer Electrolyte Membrane (PEM) electrolyzer powered by a grid-integrated photovoltaic (PV) plant, a compression station and two-pressure level storage systems are chosen to provide hydrogen to a hydrogen refueling station for a 20-car fleet and satisfy the demand of the hydrogen batch annealing in a steel plant. The results report that a 341 kW(P) PV plant, 89 kW electrolyzer and 17 kg hydrogen storage could provide hydrogen at 7.80 euro/kgH(2), potentially avoiding about 153 tCO(2,eq)/year (120 tCO(2,eq)/year only for the steel plant).
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TI Design and multilevel regulation of transition metal phosphides for efficient and industrial water electrolysis
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ID HYDROGEN-EVOLUTION REACTION; RICH P VACANCIES; ELECTROCATALYTIC HYDROGEN; HIGHLY EFFICIENT; OXYGEN EVOLUTION; NICKEL PHOSPHIDE; IRON PHOSPHIDE; ELECTRONIC-STRUCTURE; COP NANOSHEETS; ACTIVE-SITES
AB Renewable energy electrolysis of water to produce hydrogen is an effective measure to break the energy dilemma. However, achieving activity and stability at a high current density is still a key problem in water electrolyzers. Transition metal phosphides (TMPs), with high activity and relative inexpensiveness, have become excellent candidates for the production of highly pure green hydrogen for industrial applications. In this mini-review, multilevel regulation strategies including nanoscale control, surface composition and interface structure design of high-performance TMPs for hydrogen evolution are systematically summarized. On this basis, in order to achieve large-scale hydrogen production in industry, the hydrogen evolution performance and stability of TMPs at a high current density are also discussed. Peculiarly, the practical application and requirements in proton exchange membrane (PEM) or anion exchange membrane (AEM) electrolyzers can guide the advanced design of regulatory strategies of TMPs for green hydrogen production from renewable energy. Finally, the challenges and prospects in the

future development trend of TMPs for efficient and industrial water electrolysis are given.

The hydrogen evolution regulation strategies of high performance and stable TMP are systematically reviewed. The advanced design of hydrogen production control strategy for TMP is guided according to the application requirements of electrolyzer.

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AF Budama, Vishnu Kumar
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TI Potential of solar thermochemical water-splitting cycles: A review
SO SOLAR ENERGY
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DT Review
DE Solar thermochemical cycles; Hydrogen production; Multi-receiver models;
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ID RENEWABLE HYDROGEN-PRODUCTION; TECHNOECONOMIC ANALYSIS; HEAT-TRANSFER;
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   PERFORMANCE ANALYSIS; COAL-GASIFICATION; SYNGAS PRODUCTION
AB Hydrogen fuel is a valuable tool to achieve the energy transition process, and according to the 2050 net zero emissions scenario its demand is expected to increase by more than 530 Mt H2. This article discusses several routes available to produce hydrogen fuel, with a special focus on solar thermochemical cycles for Water Splitting (WS). Solar thermochemical WS cycles are a potential technology to produce green hydrogen and CO in the future due to their great potential to become a commercial scale process. This technology is still under development and some challenges related to components and sub-processes are being addressed by several research groups in order to make green hydrogen production by this route technically and economically feasible. Specific technological aspects such as particle heating methods, suitability and properties of redox materials for two-step cycles, methods to achieve low oxygen pressure in the reduction chamber, as well as the importance of implementing heat recovery are analysed in detail, as their performance have a significant effect on the overall efficiency and economic of the whole process. Current progress indicates that the realisation of a sufficiently efficient thermochemical cycle is possible within the few years, if the mentioned limitations are overcome.
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TI Upcycling of Spent LiFePO₄ Cathodes to Heterostructured
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DE direct seawater electrolysis; heterojunction; oxygen evolution reaction;
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ID OXYGEN EVOLUTION; FE; NANOPARTICLES; ENHANCEMENT; IRON
AB The pursuit of carbon-neutral energy has intensified the interest in green hydrogen production from direct seawater electrolysis, given the scarcity of freshwater resources. While Ni-based catalysts are known for their robust activity in alkaline water oxidation, their catalytic sites are prone to rapid degradation in the chlorine-rich environments of seawater, leading to limited operation time. Herein, we report a Ni(OH)(2) catalyst interfaced with laser-ablated LiFePO4 (Ni(OH)(2)/L-LFP), derived from spent Li-ion batteries (LIBs), as an effective and stable electrocatalyst for direct seawater oxidation. Our comprehensive analyses reveal that the PO43- species, formed around L-LFP, effectively repels Cl- ions during seawater oxidation, mitigating corrosion. Simultaneously, the interface between in situ generated NiOOH and Fe-3(PO4)(2) enhances OH- adsorption and electron transfer during the oxygen evolution reaction. This synergistic effect leads to a low overpotential of 237 mV to attain a current density of 10 mA cm(-2) and remarkable durability, with only a 3.3 % activity loss after 600 h at 100 mA cm(-2) in alkaline seawater. Our findings present a viable strategy for repurposing spent LIBs into high-performance catalysts for sustainable seawater electrolysis, contributing to the advancement of green hydrogen production technologies.
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NR 58
TC 5
Z9 5
U1 56
U2 67
PU WILEY-V C H VERLAG GMBH
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PA POSTFACH 101161, 69451 WEINHEIM, GERMANY
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AU Pattanaik, S
   Nayak, B
AF Pattanaik, Suchismita
   Nayak, Bibhuranjan
TI A Review on CO₂ Sequestration: The Indian Scenario
SO JOURNAL OF THE GEOLOGICAL SOCIETY OF INDIA
LA English
DT Review
ID CARBON-DIOXIDE CAPTURE; FLUE-GAS; FLY-ASH; STORAGE; EMISSION; FIXATION;
   COAL; MITIGATION; STEELMAKING; PERCEPTIONS
AB To address the carbon dioxide (CO2) and other green-house gas (GHG) emission issues and combat climate change, various world summits have taken place starting with the United Nations Framework Convention on Climate Change (UNFCCC) at Rio in 1992 to the COP26 at Glasgow in 2021. Although the Paris Agreement of 2015, a legally binding international treaty intended to keep global average temperature rise below 2 & DEG;C (preferably 1.5 & DEG;C), it appears too tough a target considering the present day scenarios of insincerity by the advanced and rich nations. On the other hand, adaptation of CCS (carbon capture and storage) technologies in industrial scale have not yet been possible because of economic unviability. Although the western countries such as the USA and the EU have invested considerable amount of funds for R & D to make the CCS technologies successful, the developed technologies are only up to the pilot scale. More funding and focused R & D are needed to make the proven CCS technologies economic in industrial scales. The R & D efforts by other countries are still insignificant. India being the fourth largest emitter of GHGs in the world, is a signatory to most of the global treaties and is trying to adopt various CCS technologies. However, no significant progress has been made so far although some initiations have been observed after the recent pledge made by the Hon. Prime Minister of India in COP26 at Glasgow for a 'net zero' carbon by 2070. Industrial utilization of CO2 is negligible in the country except that Tata Steel Ltd. recently installed a demonstration carbon capture plant (5 TPD CO2) at its Jamshedpur works. There are no visible efforts from the power sectors who are one of the major contributors of CO2. Future availability of CCS technologies to Indian industries shall primarily be determined by the investments they make in R & D to develop the technologies on their own or in collaboration with research laboratories. Substituting carbon with green hydrogen and using renewable energy to run the steel plants would be desirable. Implementation of costly CCS technologies in India would need incentives from government as well as involvement and financial commitment from private industries which has been very low over the years. In this article we have taken a fresh stock of the situation with respect to the global targets set, efforts being made, technological interventions and their adaptability, R & D efforts required, funding opportunities, promises made, the gaps in available technologies, and target accomplishments. Indian status has been reviewed with respect to CCS: where does it stand, what are the challenges and what is the way forward for this fast-growing developing country to address the climate change keeping a balance with its fast growth rate.
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NR 76
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U1 0
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PU GEOLOGICAL SOC INDIA
PI BANGALORE
PA NO 63, 12TH CORSS, BASAPPA LAY OUT, GAVIPURAM PO, PO BOX 1922,
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WC Geosciences, Multidisciplinary
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AU Chen, JH
Li, T
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AF Chen, Jiahui
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Song, Zihao
Shen, Guhao
Feng, Wei
TI Ruthenium-doped FeNi3@Nickel-Iron hydroxide nanoparticles aerogel for
highly efficient oxygen evolution reaction
SO INTERNATIONAL JOURNAL OF HYDROGEN ENERGY
LA English
DT Article
DE Core@Shell; FeNi 3 @Nickel-iron hydroxide; Oxygen evolution reaction;

Aerogel
ID ELECTROCATALYSTS; NANOSHEETS; MECHANISM; FRAMEWORK; CATALYSTS; NI
AB Electrolytic water splitting for hydrogen production is crucial for obtaining "green hydrogen." Currently, commercial catalysts for water electrolysis primarily rely on precious metals such as platinum, ruthenium, and iridium. However, their high costs and low reserves have significantly limited their widespread and large-scale applications. Developing cost-effective, highly efficient, and stable oxygen evolution reaction (OER) catalysts is still a formidable challenge. In this work, an ionic liquid-phase reduction system was designed with DMAB as the reducing agent and Fe-Ni double hydroxide as the matrix. FeNi3 crystals were grown in situ within the Fe-Ni hydroxide. By controlling the reaction time and maintaining a moderate reaction rate, a core@shell structured bimetallic Fe-Ni-based aerogel RuxFe2Ni5 was synthesized, featuring FeNi3 alloy as the core and amorphous iron- nickel hydroxide as the shell. The results indicate that the RuxFe2Ni5 catalyst exhibited an overpotential of only 235 mV at a current density equal to 10 mA cm-2 for OER and 76 mV dec-1 of Tafel slope. After 24 h of testing, the catalyst demonstrated excellent stability, with both OER performance and stability surpassing that of industrial RuO2.
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FU Sichuan Science and Technology Pro-gram [2023YFG0229]
FX This work was supported by Sichuan Science and Technology Pro-gram (2023YFG0229) .
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AU Kwon, M
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AF Kwon, Minsol
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   Kwon, Taehyun
   Kim, Minseo
   Jeong, Young-Hun

Kim, Han Seul
Ditter, Alex
Shapiro, David A.
Yu, Young-Sang
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TI Boosting the Performance of Alkaline Anion Exchange Membrane Water
Electrolyzer with Vanadium-Doped NiFe₂O₄
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DT Article; Early Access
DE anion exchange membrane water electrolysis (AEMWE); electrocatalyst;
nickel iron oxide; oxygen evolution reaction (OER); vanadium doping
ID OXYGEN EVOLUTION; NANOPARTICLES; ELECTROCATALYST; EFFICIENT; ULTRALOW;
COFE2O4; METAL
AB Developing efficient, economical, and stable catalysts for the oxygen evolution reaction is pivotal for producing large-scale green hydrogen in the future. Herein, a vanadium-doped nickel-iron oxide supported on nickel foam (V-NiFe2O4/NF) is introduced, and synthesized via a facile hydrothermal method as a highly efficient electrocatalyst for water electrolysis. X-ray photoelectron and absorption spectroscopies reveal a synergistic interaction between the vanadium dopant and nickel/iron in the host material, which tunes the electronic structure of NiFe2O4 to increase the number of electrochemically active sites. The V-NiFe2O4/NF electrode exhibited superior electrochemical performance, with a low overpotential of 186 mV at a current density of 10 mA cm-2, a Tafel slope value of 54.45 mV dec-1, and minimal charge transfer resistance. Employing the V-NiFe2O4/NF electrode as an anode in an alkaline anion exchange membrane water electrolyzer single-cell, a cell voltage of 1.711 V is required to achieve a high current density of 1.0 A cm-2. Remarkably, the cell delivered an energy conversion efficiency of 73.30% with enduring stability, making it a promising candidate for industrial applications.
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NR 72
TC 0
Z9 0
U1 17
U2 17
PU WILEY-V C H VERLAG GMBH
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PA POSTFACH 101161, 69451 WEINHEIM, GERMANY
SN 1613-6810
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WE Science Citation Index Expanded (SCI-EXPANDED)
SC Chemistry; Science & Technology - Other Topics; Materials Science;
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AF Yun, Mun Sang
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TI Ultrasmall molybdenum-iron nitride nanoparticles confined carbon
nanotubes hybrids for efficient overall water splitting
SO FUNCTIONAL COMPOSITES AND STRUCTURES
LA English
DT Article
DE molybdenum-iron nitrides; carbon nanotubes; bifunctional catalyst; green
hydrogen production
ID OXYGEN-REDUCTION; ELECTROCATALYST; EVOLUTION; PERFORMANCE; GRAPHENE;
SPHERES
AB In an attempt to find an alternative approach to reduce the use of noble metal-based electrocatalysts, a new hybrid nanostructure based on molybdenum-iron nitride nanoparticles (Mo-Fe-N NPs) deposited carbon nanotubes (CNTs) supported on nickel foam substrate is fabricated via a facile synthetic approach. Highly uniform and dense Mo-Fe-N NPs achieves full coverage on surface of the CNTs with good interactions and enhanced hetero-charge transfer, thus leading to improvements in both the hydrogen evolution reaction (HER) and the oxygen evolution reaction (OER). The fabricated hybrid shows small overpotential of 106 mV at 10 mA cm(-2) for HER and 420 mV at 100 mA cm(-2) for OER, along with prospective stability after 20 h of continuous testing in alkaline electrolyte (1.0 M KOH). The catalytic activities of the Mo-Fe-N/CNTs material are shown to be superior to those of other synthesized catalysts as well as of commercial Pt/C and RuO2 catalysts. These results may pave a potential route to the fabrication of novel

electrocatalysts having high performance that can effectively replace precious metal-based catalysts in electrochemical water splitting technology.
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   Yu, Bo
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   Zhang, Weizhe
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TI Electrospun porous carbon nanofibers decorated with iron-doped cobalt
   phosphide nanoparticles for hydrogen evolution
SO JOURNAL OF ALLOYS AND COMPOUNDS
LA English
DT Article
DE Metal phosphide; Electrospun carbon nanofiber; Electrocatalyst; Hydrogen
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ID EFFICIENT; ELECTROCATALYST; NANOSHEETS; FOAM
AB Developing highly active and cost-effective electrocatalysts to replace noble metal catalysts is the main route for the efficient production of green hydrogen. Herein, we have successfully fabricated iron-doped cobalt phosphide nanoparticles-decorated porous carbon nanofibers (Fe-CoP/PCNF) by a facile three-step method. On one hand, the electrospun nanofibers could serve as porous and conductive substrate for the exposure of active sites and the fast charge transfer; On the other hand, the Fe-CoP nanoparticles with optimized hydrogen adsorption free energy showed high intrinsic catalytic activity. Hence, the Fe-CoP/PCNF achieves excellent HER performance, which affords overpotential of 151 mV to support the current density of 10 mA cm-2 in acid media. Moreover, the nanoparticles were protected by a carbon layer, preventing the electrocatalyst from

corrosion during long-term operation. The findings may shed light on the rational exploration of nanofibrous electrocatalysts for highly efficient hydrogen evolution.
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AB Water splitting is a critical process for the production of green hydrogen, contributing to the advancement of a circular economy. However, the application of water splitting devices on a large scale is primarily impeded by the sluggish oxygen evolution reaction (OER) at the anode. Thus, developing and designing efficient OER catalysts is a significant target. NiFe-based catalysts are extensively researched as excellent OER electrocatalysts due to their affordability, abundant reserves, and intrinsic activities. However, they still suffer from long-term stability challenges. To date, few systematic strategies for improving OER durability have been reported. In this review, various advanced NiFe-based catalysts are introduced. Moreover, the OER stability challenges of NiFe-based electrocatalysts in alkaline media, including iron segregation, structural degradation, and peeling from the substrate are summarized. More importantly, strategies to enhance OER stability are highlighted and opportunities are discussed to facilitate future stability studies for alkaline water electrolysis. This review presents a design strategy for NiFe-based electrocatalysts and anion exchange membrane (AEM) electrolyzers to overcome stability challenges in OER, which also emphasizes the importance of long-term stability in alkaline media and its significance for achieving large-scale commercialization.

Water splitting is a pivotal process in the production of green hydrogen, a cornerstone of the transition to a circular economy, and NiFe-based electrocatalysts have garnered extensive attention as promising oxygen evolution reaction (OER) catalysts. In this review, we outline the recent developments of NiFe-based electrocatalysts and summarize the challenges to the stability of NiFe-based electrocatalysts. We also summarize the strategies to improve OER stability and provide prospects to bridge laboratory advancements with practical applications. image
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NR 178
TC 27
Z9 27
U1 42
U2 62
PU WILEY
PI HOBOKEN
PA 111 RIVER ST, HOBOKEN 07030-5774, NJ USA
SN 2769-3333
EI 2769-3325
J9 CARBON NEUTRALIZAT
JI Carbon Neutralization
PD MAR
PY 2024
VL 3
IS 2
BP 172
EP 198
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WC Green & Sustainable Science & Technology; Materials Science,
   Multidisciplinary
WE Emerging Sources Citation Index (ESCI)
SC Science & Technology - Other Topics; Materials Science
GA SO5X5
UT WOS:001235417500003
OA gold
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ER

PT J
AU Nan, J
   Ye, BR
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   Li, C
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   Sun, XP
   Zhang, YQ
AF Nan, Jue
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   Li, Luming
   Chu, Wei
   Sun, Xuping
   Zhang, Yongqi
TI Enhancing alkaline water oxidation with NiFe alloy-encapsulated
   nitrogen-doped vertical graphene array
SO NANO RESEARCH
LA English
DT Article
DE NiFe alloy; N-doped vertical graphene array; electrocatalyst; oxygen
   evolution reaction; density functional theory
ID OXYGEN EVOLUTION REACTION; NICKEL-IRON ALLOY; HIGHLY EFFICIENT;
   NANOPARTICLES; CATALYSTS
AB Advancing efficient and affordable electrocatalysts to boost the oxygen evolution reaction (OER) is pivotal for sustainable green hydrogen production. Herein, we propose the fabrication of nickel-iron alloy nanoparticles-encapsulated on N-doped vertically aligned graphene array on carbon cloth (NiFe@NVG/CC) as a highly active three-dimensional (3D) catalyst electrode for OER. In 1 M KOH, such NiFe@NVG/CC demonstrates outstanding catalytic performance, necessitating merely overpotential of 245 mV for achieving a current density of 10 mA.cm(-2), a remarkably low Tafel slope of 36.2 mV.dec(-1). Furthermore, density functional theory calculations validate that the incorporate of N species into graphene can reinforce the electrocatalytic activity though reducing the reaction energy barrier during the conversion of O to OOH intermediates. The outstanding performance and structural benefits of NiFe@NVG/CC offer valuable insights for the development of innovative and efficient electrocatalysts for water oxidation.
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OI He, Xun/0000-0002-2525-9102
FU National Natural Science Foundation of China [52202214, 52001059, 52202215]; Sichuan Natural Science Foundation [23NSFSC3565]; China National Postdoctoral Program for Innovative Talents [BX2021053]; China Postdoctoral Science Foundation [2021M700680]
FX This work was financially supported by the National Natural Science Foundation of China (Nos. 52202214, 52001059, 52001059, and 52202215), Sichuan Natural Science Foundation (No. 23NSFSC3565), China National Postdoctoral Program for Innovative Talents (No. BX2021053), and China Postdoctoral Science Foundation (No. 2021M700680).
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NR 51
TC 9
Z9 9
U1 20
U2 58
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SN 1998-0124
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J9 NANO RES
JI Nano Res.
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PY 2024
VL 17
IS 6
BP 4790
EP 4796
DI 10.1007/s12274-024-6431-x
EA JAN 2024
PG 7
WC Chemistry, Physical; Nanoscience & Nanotechnology; Materials Science, Multidisciplinary; Physics, Applied
WE Science Citation Index Expanded (SCI-EXPANDED)
SC Chemistry; Science & Technology - Other Topics; Materials Science; Physics
GA C3K7D
UT WOS:001151264000004
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PT J
AU Paul-Navarrón, M
Lloreda-Jurado, PJ
Chicardi, E
Balu, K
Dieuzeide, ML
Tejeda, R
Avendaño, R
Sepúlveda, R
AF Paul-Navarron, M.
Lloreda-Jurado, P. J.
Chicardi, E.
Balu, Krishnakumar
Dieuzeide, Maria Laura
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Avendano, Roger
Sepulveda, R.
TI Development and characterization of Fe2O3 nanoparticles doped with Al2O3 / TiO2 for green hydrogen production
SO CERAMICS INTERNATIONAL
LA English
DT Article
DE Nanoparticles; Fe2O3; Al2O3; TiO2; Chemical looping; Porosity
ID SYSTEM IRON OXIDE; OXIDATION; NANOSTRUCTURES
AB Iron oxide is an inexpensive raw material capable of producing hydrogen based on the water-splitting reaction. However, the reaction is limited by the active surface area available on the particle. In this study, Fe2O3 nanoparticles doped with Al2O3 and TiO2 oxide (95 wt% Fe2O3- X wt% Al2O3- (5-X) wt% TiO2; X = 2, 2.5 and 3) were prepared by a double coprecipitation method to obtain a single solid solution. The synthesis of a solid solution resulted in particles with higher porosity. The use of Al resulted in the formation of pores of approximately 3 mu m, which effectively prevented grain growth.

Conversely, the substitution of Ti ions increased the oxygen mobility, resulting in a higher hydrogen consumption at temperatures below 700 degrees C, leading to a deeper reduction reaction. Indeed, the reactivity of the particle surface was strongly influenced by the Al/Ti atomic ratio, and the Fe3Al2Ti formulation seems to be the most promising due to its compositional and morphological design to create an oxide functional ceramic for H2 production.
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OI Balu, Krishnakumar/0000-0003-0957-4978
FU MCIN/AEI; ERDF/EU; European Union NextGenerationEU/PRTR; [PID2021-123010OB-I00]; [TED2021-129920B-C41-C42-C43-C44]
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NR 41
TC 1
Z9 1
U1 0
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PA 125 London Wall, London, ENGLAND
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J9 CERAM INT
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PD FEB
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BP 6579
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WC Materials Science, Ceramics
WE Science Citation Index Expanded (SCI-EXPANDED)
SC Materials Science
GA X3C1A
UT WOS:001424160900001
OA hybrid
DA 2025-03-13
ER

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Du, LG
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Gao, ZY
AF Li, Jinzhou
Du, Lan 'ge
Guo, Songtao
Chang, Jiuli
Wu, Dapeng
Jiang, Kai
Gao, Zhiyong
TI Molybdenum iron carbide-copper hybrid as efficient electrooxidation catalyst for oxygen evolution reaction and synthesis of cinnamaldehyde/ benzalacetone
SO JOURNAL OF COLLOID AND INTERFACE SCIENCE
LA English
DT Article
DE Electrocatalysis; Cinnamaldehyde; Benzalacetone; Electrooxidation; Aldol condensation reaction
ID HYDROGEN
AB Oxygen evolution reaction (OER) is the efficiency limiting half-reaction in water electrolysis for green hydrogen production due to the 4-electron multistep process with sluggish kinetics. The electrooxidation of thermodynamically more favorable organics accompanied by C - C coupling is a promising way to synthesize value-added chemicals

instead of OER. Efficient catalyst is of paramount importance to fulfill such a goal. Herein, a molybdenum iron carbide-copper hybrid (Mo 2 C-FeCu) was designed as anodic catalyst, which demonstrated decent OER catalytic capability with low overpotential of 238 mV at response current density of 10 mA cm -2 and fine stability. More importantly, the Mo 2 C-FeCu enabled electrooxidation assisted aldol condensation of phenylcarbinol with alpha-H containing alcohol/ketone in weak alkali electrolyte to selective synthesize cinnamaldehyde/ benzalacetone at reduced potential. The hydroxyl and superoxide intermediate radicals generated at high potential are deemed to be responsible for the electrooxidation of phenylcarbinol and aldol condensation reactions to afford cinnamaldehyde/benzalacetone. The current work showcases an electrochemical-chemical combined
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FX This work was supported by NSFC (Nos. 51802084 and U21A2082) , the 111 Project (No. D17007) and Henan Center for Outstanding Oversea Scientists (No. GZS2022017) .
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AF Fang, Dufei
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TI Towards the Optimization of a Photovoltaic/Membrane Distillation System for the Production of Pure Water
SO MEMBRANES
LA English
DT Article
DE pure water; photovoltaic; membrane distillation; electrolysis; hydrogen production
AB The production of pure water plays a pivotal role in enabling sustainable green hydrogen production through electrolysis. The current industrial approach for generating pure water relies on energy-intensive techniques such as reverse osmosis. This study unveils a straightforward method to produce pure water, employing real-world units derived from previously simulated and developed laboratory devices. This demonstrated system is cost-effective and boasts low energy consumption, utilizing membrane distillation (MD) driven by the waste heat harnessed from photovoltaic (PV) panels. In a previous study, modeling simulations were conducted to optimize the multi-layered MD system, serving as a blueprint for the construction of prototype devices with a suitable selection of materials, enabling the construction of field-testable units. The most efficient PV-MD device, featuring evaporation and condensation zones constructed from steel sheets and polytetrafluoroethylene (PTFE) membranes, is capable of yielding high-purity water with conductivity levels below 145 mu S with high flux rates.
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OI Mahajan, Devinder/0000-0003-3161-4526; , Benjamin/0000-0002-3180-1826
FU Office of Naval Research
FX No Statement Available
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TI Robust iron-doped nickel phosphides in membrane-electrode assembly for industrial water electrolysis
SO ELECTROCHIMICA ACTA
LA English
DT Article
DE Water electrolysis; Operando; X-ray absorption spectroscopy; Phosphide
ID OXYGEN-EVOLUTION; POLYETHYLENE TEREPHTHALATE; HIGHLY EFFICIENT; OXIDE; SINGLE; ELECTROCATALYSTS; PERFORMANCE; CHEMICALS; CATALYSTS; PH
AB Water electrolysis, a pivotal process for the production of green hydrogen, is a crucial step toward realizing the hydrogen economy. To advance its industrialization, it is essential to develop a highly efficient and economical catalyst along with a low-resistance electrolyzers. In pursuit of this goal, we synthesize a cost-effective iron-doped nickel phosphide electrocatalyst through a hydrothermal synthesis followed by post-phosphorization process. This catalyst exhibits exceptional performance, with an overpotential at 10 mA cm-2 (ti10) of 216 mV for oxygen evolution reaction, the rate-determining step for water electrolysis. It overperforms the that of pristine nickel phosphide (NiPx, ti10 = 284 mV). Operando X-ray absorption spectroscopy reveals the robust nature of the iron-doped nickel phosphide catalyst during water electrolysis, in stark contrast to the pristine nickel phosphide, which undergoes oxidation, thereby impacting overall catalytic activity. When integrated into a membrane-electrode assembly (MEA) system, our iron-doped nickel phosphide displays voltages of 1.51 Vat 10 mA cm-2 (EE = 81.5%) and 1.66 V at 100 mA cm-2 (EE = 76.4%) without iR-correction. Moreover, it achieves a current density of 345 mA cm-2 at an applied voltage of 2 V without iR-correction, meeting industrial criteria. These findings underscore the superior catalytic activity of the robust phosphide phase for water electrolysis.
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FU Ministry of Science and Technology
FX The supports from the National Science and Technology Council, Taiwan (Contract No. NSTC 112-2628-M-A49-001) are gratefully acknowledged. We also thank the support from the Yushan Young Scholar Program and the Center for Emergent Functional Matter Science, Ministry of Education, Taiwan. Thanks to Ms. C.-Y. Chien of theMinistry of Science and Technology (National Taiwan University) for the assistance in FE-TEM and EDS experiments.r Ministry of Science and Technology (National Taiwan University) for the assistance in FE-TEM and EDS experiments.
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Ghosh, Suptish
Nicolaus, Victor C. J.
Laun, Konstantin
Zebger, Ingo
Driess, Matthias
Menezes, Prashanth W.
TI In Situ Reconstruction of Helical Iron Borophosphate Precatalyst toward Durable Industrial Alkaline Water Electrolysis and Selective Oxidation of Alcohols
SO ADVANCED FUNCTIONAL MATERIALS
LA English
DT Article
DE alcohol oxidation; alkaline water electrolysis; borophosphate; formic acid production; industrial conditions; surface reconstruction
ID OXYGEN EVOLUTION; ELECTROCATALYSTS; HYDROGEN; CATALYST; ELECTRODES; CARBON
AB Iron-based (pre)catalysts have attracted enormous attention for various electrooxidation reactions due to the low cost, high abundance, and multiple accessible redox states of iron. Herein, a well-defined helical iron borophosphate (LiFeBPO) is developed as an electro(pre)catalyst for the oxygen evolution reaction (OER) and selective alcohol oxidation. When deposited on nickel foam (NF), LiFeBPO exhibits an exceptional OER performance at ambient conditions attaining a current density of 100 mA cm(-2) at approximate to 276 mV overpotential in 1 m KOH. Notably, this anode sustains durable alkaline water electrolysis at 500 mA cm(-2) for over 330 h under industrial conditions (6 m KOH and 85 degrees C). In -situ and ex situ investigations reveal a deep reconstruction of LiFeBPO during OER, which transforms into a 3D open porous skeleton assembled by ultrasmall, low-crystalline alpha-FeOOH nanoparticles (interfacing with NiOOH of NF). This structure contributes to exposing accessible surface active sites, as well as accelerating mass transport and bubble detachment. Moreover, this electrode also catalyzes the electrooxidation of alcohols (methanol, ethylene glycol, and glycerol) to formic acid (FA) with high selectivity and full conversion. This study provides promising

solutions for designing suitable anodes for the simultaneous production of green hydrogen fuel and value-added FA from electrooxidation reactions.
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TI Interpretation and explanation of convolutional neural network-based
   fault diagnosis model at the feature-level for building energy systems
SO ENERGY AND BUILDINGS
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DT Article
DE Building energy system; Deep learning; Fault diagnosis; Model
   interpretation and explanation; Shapley additive explanations (SHAP);
   Layer-wise relevance propagation (LRP)
ID STRATEGY; METHODOLOGY
AB electrolyte membrane electrolysis. to one based on clean energy requires implementing policies, stakeholders, technological adchallenges. While the UAE is clean energy, the contribution energy mix remains relatively Barakah plant) and solar (2000 constitute steps toward clean contribution to the 37 GW More support is critical to a at 8% share in 2021) under an more ambitious approach is needed to eliminate the reliance on coal, which has a 12% target by 2050. Hydrogen energy can significantly promote renewable energy adoption in hard-to-decarbonize sectors like energy-intensive industries, and utilizing solar energy for green hydrogen production can decarbonize industries such as aluminum, steel, and cement. A national hydrogen strategy is necessary to drive hydrogen energy applications and accelerate the deployment of clean hydrogen projects domestically and internationally. Credit author statement
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