Hydrogen Production and Use: An Overview of its Importance in Mitigating Climate Change and its Nexus with Renewable and Power Engineering

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2023 17th International Conference on Engineering of Modern Electric Systems (EMES) | 979-8-3503-1063-4/23/$31.00 ©2023 IEEE | DOI: 10.1109/EMES58375.2023.10171647

Abstract— **Using hydrogen as a substitute for traditional fossil fuels has gained considerable attention as it can be used in various sectors, such as transportation, heating, and electricity production. This paper thoroughly examines the significance of hydrogen in addressing climate change. It will emphasize the association between renewable energy, power engineering, and hydrogen production and utilization. Hydrogen can be produced from renewable and non-renewable sources, like natural gas, solar, and wind power. This versatility positions hydrogen to play an essential role in transitioning to a low-carbon economy and mitigating the effects of climate change. The paper will highlight the advantages of hydrogen over traditional fossil fuels, such as its lower carbon emissions and the potential to reduce reliance on imported oil. Moreover, it will explore various industries where hydrogen can be utilized, like transportation, heating, and electricity production. Additionally, the paper will investigate the potential barriers to the widespread use of hydrogen, including technological, economic, policy, and regulatory challenges. The ultimate goal of this paper is to offer a comprehensive overview of hydrogen's potential to combat climate change, its relationship with renewable energy and power engineering, and the potential roadblocks in its implementation.**

Keywords— Mitigating Climate Change, formatting, Nexus, Renewable Energy, Power Engineering, Hydrogen

I. INTRODUCTION

Increased carbon emissions have resulted from using fossil fuels for energy production, leading to climate change. Consequently, there is an immediate need to transition to cleaner and more sustainable energy sources. Hydrogen is one such source that has the potential to supplant traditional fossil fuels and contribute to climate change mitigation.

Climate change has resulted from the use of fossil fuels for energy production, which has led to an increase in carbon emissions. Therefore, transitioning to cleaner and more sustainable energy sources is urgently necessary. Hydrogen has the potential to replace conventional fossil fuels and contribute to climate change mitigation.

Hydrogen is an adaptable energy source that has the potential to revolutionize a variety of industries. One of hydrogen's primary advantages is its adaptability to various applications, including transportation, heating, and electricity generation.

Hydrogen fuel cells provide a healthier and more efficient alternative to conventional petroleum or diesel engines [1] when used to power vehicles. Hydrogen fuel cells produce electricity by combining hydrogen and oxygen, with only water as a byproduct [2]. Hydrogen fuel cell vehicles are viable for reducing greenhouse gas emissions and air pollution.

Hydrogen provides a low-carbon alternative to natural gas as a fuel for furnaces in the heating industry. Hydrogen boilers function identically to natural gas boilers but produce only water vapor instead of carbon dioxide, thereby reducing the carbon footprint of the heating industry. In the utility sector, hydrogen can store energy from renewable sources such as wind and solar [3]. Hydrogen can be produced from excess electricity during periods of low demand and then used to generate electricity during high demand, making it a flexible and reliable energy source. This power-to-gas technology has the potential to facilitate the integration of renewable energy into the grid and reduce dependence on fossil fuels [4].

Hydrogen has the potential to provide a low-carbon alternative to conventional fossil fuels in multiple industries, including transportation, heating, and electricity generation. Its adaptability and ability to be derived from renewable sources make it an attractive option for mitigating climate change and promoting sustainable development [5-6].

The interconnected water, energy, and food systems constitute the water-energy-food nexus. It emphasizes the interconnectedness of these systems and their mutual influence. For example, energy is needed to extract and purify water, and water is required to produce energy and sustenance. Likewise, food production requires both water and energy. The nexus approach addresses the challenges of managing these interdependent systems holistically to ensure sustainability.

This paper investigates the connection between hydrogen, renewable energy, and power engineering. As climate change mitigation alternatives to fossil fuels, renewable energy sources, such as solar and wind power, are acquiring importance.

Nevertheless, their limitations, such as intermittency and variability, make them unreliable energy sources [7]. By providing a means for storing and disseminating renewable energy, hydrogen production can help overcome some of these limitations. For example, excess energy generated by wind turbines or solar panels can power the electrolysis process, separating water into hydrogen and oxygen. The produced hydrogen can then be stored and utilized as an energy source without renewable sources.

Hydrogen has many advantages over conventional fossil fuels, including lower carbon emissions that contribute to

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climate change mitigation and the potential to reduce our reliance on imported oil, which has geopolitical and economic benefits. However, there are still many obstacles to the widespread implementation of hydrogen as an energy carrier, including technological and economic obstacles, such as the high infrastructure cost for production and distribution and the limited availability of hydrogen fuelling stations. Policy and regulatory factors can also hinder using hydrogen as an energy carrier due to the lack of supportive policies or incentives.

To address these issues, it is essential to emphasize the significance of hydrogen production and utilization in climate change mitigation, particularly emphasizing its relationship to renewable energy and power engineering. By integrating hydrogen production with renewable energy sources such as solar and wind power, hydrogen can become a sustainable and purified source of energy. Additionally, hydrogen can store and distribute energy generated from renewable sources, mitigating their intermittent nature and ensuring a stable and reliable energy supply.

In this context, it is important to investigate the benefits of hydrogen over conventional fossil fuels, the potential obstacles to the widespread adoption of hydrogen as an energy carrier, and possible solutions to overcome these obstacles. For example, developing a more cost-effective production and distribution infrastructure and supportive policies and incentives can help promote the use of hydrogen as a viable energy carrier. Due to its potential to mitigate climate change, the production and utilization of hydrogen have emerged as a promising alternative to traditional fossil fuels in recent years. This paper aims to provide a comprehensive overview of the potential for hydrogen production and utilization to mitigate climate change and its relationship to renewable energy and power engineering [9].

Hydrogen's versatility is one of its primary advantages, as it can be utilized in numerous industries, such as transportation, heating, and electricity production. Hydrogen fuel cells can power conveyance vehicles, providing a healthier alternative to conventional gasoline or diesel engines. Hydrogen provides a low-carbon alternative to natural gas as a fuel for furnaces in the heating industry. In the electricity industry, hydrogen can store energy generated from renewable sources, making it a versatile and reliable energy source. In addition, hydrogen has several benefits over conventional fossil fuels. Hydrogen combustion produces only water as a byproduct, reducing carbon emissions and air pollution [10]. Hydrogen can also be produced domestically, reducing the need for imported fuels.

The connection between hydrogen, renewable energy, and power engineering is crucial for achieving a low-carbon economy. By utilizing renewable energy sources such as solar and wind power, hydrogen production can be merged with these sources to create a sustainable and pure form of hydrogen. Additionally, hydrogen can function as an energy storage and distribution medium for renewable sources, effectively addressing their sporadic nature and ensuring a dependable and steady energy supply.

Despite its potential benefits, hydrogen's widespread adoption as an energy carrier still faces obstacles. Technological and economic obstacles, such as the high cost of producing and storing hydrogen, as well as policy and regulatory concerns, such as the need for policies and incentives to encourage investment in hydrogen infrastructure [12], are among these obstacles.

The production and utilization of hydrogen have the potential to significantly contribute to climate change mitigation, particularly when combined with renewable energy sources and power engineering. Despite remaining obstacles, transitioning to a low-carbon economy will likely necessitate the widespread implementation of hydrogen as an energy carrier [13].

II. Benefits of Hydrogen

A. Hydrogen over traditional fossil fuels

Hydrogen is versatile because it can be derived from numerous sources, including renewable energies such as solar and wind. Hydrogen is also easily stored and transported, making it a practical and versatile energy carrier. Moreover, the high energy density of hydrogen makes it an attractive option for transportation, where weight and volume are crucial factors [14].

Hydrogen emits substantially less carbon dioxide than conventional fossil fuels such as gasoline and diesel. Combustion of hydrogen produces only water vapor and no greenhouse gases, which can help mitigate climate change's negative effects. In addition, using hydrogen in transportation can reduce local air pollution, a significant public health concern in many urban areas.

Hydrogen is a promising alternative to fossil fuels, as it can be produced domestically from renewable energy sources and reduce our reliance on imported oil. This would enhance energy security and reduce geopolitical tensions arising from market events. Moreover, hydrogen emits lower carbon emissions than fossil fuels, making it an environmentally friendly option for a sustainable energy future.

Despite these benefits, there are still challenges to the widespread adoption of hydrogen as an energy carrier. These challenges include technological and economic obstacles, such as the high cost of infrastructure for production and distribution and the limited availability of hydrogen fueling stations. Policy and regulatory factors, such as a lack of supportive policies or incentives, can also hinder using hydrogen as an energy carrier.

Research and development efforts must focus on overcoming these obstacles to fully realize the potential of hydrogen as an alternative energy source. This will require hydrogen production, distribution infrastructure, and fuel cell technology investments. Policy initiatives and regulatory frameworks that incentivize the adoption of hydrogen as an energy carrier can also help overcome these challenges.

B. Renewable energy and power engineering

Electrolysis is a process that uses renewable energy sources, such as solar and wind, to produce hydrogen from water, which can then be stored and utilized as a source of energy. Hydrogen has many advantages, such as not emitting greenhouse gases when burned in power engineering and its potential to reduce carbon emissions in the transportation, heating, and electricity sectors [16]. It can also help address the challenge of intermittency and the constant unavailability of renewable energy sources by serving as a storage and distribution medium for them [17]. The electrolysis process is emission-free, producing a renewable and purified source of energy [18].

In power engineering, fuel cells use hydrogen to generate electricity through a chemical reaction that emits no harmful byproducts, making it an attractive alternative to conventional fossil fuel-based power generation. Hydrogen can also be a backup power source, especially in remote areas with limited utility access [18].

Despite the potential advantages of hydrogen, technological and economic barriers and policy and regulatory concerns continue to impede its widespread adoption. Nevertheless, hydrogen remains a promising candidate for mitigating climate change and transitioning to a more sustainable energy future, especially as it can be produced from renewable sources and help reduce greenhouse gas emissions [19].

C. Hydrogen and Mitigating climate change

Utilizing hydrogen as an alternative to conventional fossil fuels can help reduce carbon emissions, the primary cause of climate change [20]. Hydrogen can generate electricity, heat structures, and propel vehicles without emitting greenhouse gases. Moreover, hydrogen in power engineering can mitigate the intermittent character of renewable energy sources such as solar and wind power [21].

Hydrogen contributes to climate change mitigation beyond its status as a fuel with minimal or no emissions. By utilizing hydrogen derived from renewable sources, the carbon footprint of the energy system can be significantly reduced. This is because hydrogen production from renewable energy sources, such as solar and wind, produces zero carbon emissions. Hydrogen is, therefore, essential to the transition to a low-carbon economy.

In addition, hydrogen can assist in overcoming some of the obstacles associated with integrating renewable energy sources into the grid. Due to the variable nature of solar and wind power, hydrogen can be used as an energy storage medium, permitting the use of excess energy generated during peak periods when demand is high. This can assist in balancing the grid, making it more stable and reducing the need for conventional fossil fuel backup power generation [22-23]. Hydrogen has the potential to substantially contribute to the mitigation of climate change and the transition to a low-carbon economy [24]. We can significantly reduce our dependence on fossil fuels and carbon emissions by producing and utilizing hydrogen from renewable sources.

D. Hydrogen and Nexus

The water-energy-food nexus and climate change mitigation are dependent on hydrogen. Hydrogen can be produced from renewable energy sources such as solar and wind power, which can reduce carbon emissions and improve the sustainability of the energy system [25]. In turn, hydrogen can help counteract the intermittent character of renewable energy sources by providing a flexible and reliable energy source for various applications, including electricity generation and transportation [26]. In addition, using hydrogen can help address the water-energy-food nexus by reducing the dependence of energy and food production on water. Hydrogen can be used as a propellant in transportation, reducing the water requirements of the transportation industry, one of the most water-intensive industries. Hydrogen can also be used to create fertilizers, reducing the water required for crop production. The nexus approach and the utilization of hydrogen in the water-energy-food nexus can aid in addressing the interconnected issues of water, energy, food, and climate change and advancing toward a more sustainable future [27].

Hydrogen has been identified as a potential alternative to conventional fossil fuels, with potential applications in numerous industries, including transportation, heating, and electricity production. The intersection between hydrogen production and utilization, renewable energy, and power engineering is a promising area for research and development [28].

Hydrogen's versatility is one of its greatest benefits, as it can be used in numerous industries. Hydrogen fuel cells can power conveyance vehicles, providing a healthier alternative to conventional gasoline or diesel engines. Hydrogen provides a low-carbon alternative to natural gas as a fuel for furnaces in the heating industry. Hydrogen can store energy from renewable sources in the electricity sector, providing a flexible and dependable power source [29].

Electrolysis, the process of separating water into hydrogen and oxygen, can generate hydrogen from renewable energy sources such as solar and wind. The resulting hydrogen can then be stored and utilized as a source of energy in various applications, including producing electricity. When burned, hydrogen's non-emission of greenhouse gases can reduce carbon emissions when used in power engineering [30]. Hydrogen emits less carbon than conventional fossil fuels and has the potential to lessen our dependence on imported oil. Moreover, the high energy density of hydrogen makes it an attractive option for transportation, where weight and volume are crucial factors. Renewable energy sources like solar and wind can also produce hydrogen. In addition to being easily stored and transported, hydrogen is a versatile and convenient energy carrier. Utilizing hydrogen as an alternative to conventional fossil fuels can help reduce carbon emissions, the primary cause of climate change.

Moreover, hydrogen in power engineering can help mitigate the intermittent character of renewable energy sources such as solar and wind power [31-33]. Hydrogen as an energy carrier can contribute significantly to climate change mitigation. Research and development opportunities exist at the intersection of hydrogen production and utilization with renewable energy and power engineering. The challenges and opportunities associated with the widespread adoption of hydrogen as a renewable energy source require additional research. Hydrogen has indisputable advantages over conventional fossil fuels, and its potential contribution to climate change mitigation cannot be overlooked. Finally, nexus can play a significant role in hydrogen production and mitigate climate change [34-36].

III. CONCLUSION

In conclusion, using hydrogen as an energy carrier can significantly contribute to mitigating climate change. The intersection of hydrogen production and utilization with renewable energy and power engineering is a promising research and development area. Further study is required to investigate the obstacles and opportunities associated with the widespread adoption of hydrogen as a renewable energy source. However, the advantages of hydrogen over conventional fossil fuels are undeniable, and its potential contribution to climate change mitigation cannot be overlooked. Hydrogen is a promising alternative to conventional fossil fuels that can play a critical role in mitigating climate change. The production and use of hydrogen at the intersection of renewable energy, power engineering, and hydrogen storage offer several opportunities to reduce greenhouse gas emissions and transition towards a sustainable energy system [20]. Despite technological and economic barriers, there is potential for additional research and development to overcome these challenges.

Furthermore, policymakers and regulators can support the adoption of hydrogen as an energy carrier by implementing policies and regulations that incentivize its production and use. Hydrogen's versatility, high energy density, and lower carbon emissions make it an attractive option for various applications, including transportation, heating, and electricity generation [21]. As such, the contribution of hydrogen to mitigating climate change is significant, and research and development must continue to investigate the potential opportunities and challenges associated with hydrogen as a sustainable energy source. Using hydrogen in conjunction with renewable energy sources like solar and wind power can help reduce greenhouse gas emissions, decrease our reliance on fossil fuels, and provide a cleaner and more sustainable energy future for us all.

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