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Review: Uninterrupted Liquid Hydrogen (E-Methanol) Production framework to deliver Clean & Green Energy

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Abstract—*Potential broad impact: Integrating solar, wind, and conventional energy to feed the electrolyze after completion of the electrochemical process will produce two streams of O2 and H2. The hydrogen stream will be stored and provided with uninterrupted feed to a catalytic reactor in the presence of CO2. It will produce E-Methanol[1]. However, this depends on these resources' reliability, cost, and availability, with the highest potential for expansion to the size needed for large-scale deployment to produce e-methanol[2]. This is known as electro-fuel, which provides electricity and fuel for electric and diesel vehicles[3][4].*

As witnessed the versatility of Hydrogen in these applications highlights its significance in various industrial sectors. As the world looks towards sustainable and clean energy solutions, the role of Hydrogen is expected to grow even further [5]. However, the central part of Hydrogen is produced from fossil fuels (known as gray and brown Hydrogen) [6], and only a minimal amount of almost 4% is delivered through an electrolysis process using renewable energy to complete the chemical process [7], known as green Hydrogen. The transition to a more sustainable hydrogen economy involves scaling up the production of green Hydrogen through electrolysis and advancing technologies to improve efficiency and reduce costs associated with this process [8],[9].

Recently research indicated that production and consumption of the Green Hydrogen is the future of sustainable power delivery by replacing fossil fuel [10]. The fossil and Biomass also catalyzing the GHG (Green House Gases) with high carbon intensity, this is biggest challenge to deliver clean energy [11]. In the first instance, this research proposed an integrated Modular, which incorporate Renewable(photovoltaic) and Conventional Power sources to complete electrolysis process and its port equipment(s) to deliver uninterrupted clean Energy inform of Liquid Green Hydrogen for Electricity and to replace diesel [12]]13].

Keywords—E-methanol, carbon Dioxide, Hydrogen, diesel vehicle's reliability and sustainability

I. INTRODUCTION (*HEADING 1*)

Green Hydrogen refers to Hydrogen produced using renewable energy sources and a process called electrolysis. Advancements in the efficiency and durability of electrolysis technologies are crucial for making green hydrogen production economically viable and competitive with other forms of hydrogen production[14]. Pure Hydrogen is a versatile and vital resource in various industrial processes. It serves as a critical feedstock and energy carrier, playing a crucial role in different sectors such as ammonia production, petroleum refining, methanol production [15], hydrogenation processes, electronics and semiconductor manufacturing, power generation, hydrogen fuel cells in transportation[16], etc.

Figure No.1. whereas the pure hydrogen is playing vital role in petrochemical industries in the large spectrum[17]. Essentially the Hydrogen catalyzing diverse range of petrochemical industries, including the chemical (for methanol, ammonia, and polymers), refining (for hydrocracking and hydrotreating), metal processing [18], aerospace, glass, and food industries. Interest in green hydrogen as a renewable fuel is also growing. Hydrogen is still produced from fossil fuels (brown and grey hydrogen)[19]. This also produced high intensity of carbon footprints which is non-renewable. Whereas 48% produced from natural gas, 30% from light/heavy oil and 18% from coal respectively[20]. Only about 4% of green and blue hydrogen is obtained by electrolysis using either electric power from the grid or a renewable source that is green/ blue hydrogen [4]. Fig.2 also demonstrate Anthropogenetic carbon cycle for a circular economy of green Hydrogen[21].

To design sustainable photovoltaic by integrating UPS (Uninterrupted Power Supply) to store and deliver energy for longer period by using lithium battery Bank [22]. Advancements in the efficiency and durability of electrolysis technologies are crucial for making green hydrogen production economically viable and competitive with other forms of hydrogen production [23]. Pure Hydrogen is a versatile and vital resource in various industrial processes [24].

II. PROJECT DESCRIPTION

A. *Electrolysis of water to hydrogen method*

A liquid product is easily obtainable from CO2 and green Hydrogen through a one-step catalytic process through an electrolysis process to feed the electrolyzer after completion of the electrochemical process will produce two streams of O2 and

H2 [25]. The hydrogen stream will be stored and provided with interrupted feed to a catalytic reactor in the presence of CO2. It will produce E- Methanol. However, this depends on these resources' reliability[26], cost, and availability, with the highest potential for expansion to the size needed for large-scale deployment to produce e-methanol[27]. There are numerous ways to produce Green/Blue Hydrogen in liquid form (E-Methanol) through an electrochemical process[28]. Fig.3 indicates the most established method is to make Green/Blue hydrogen through water electrolysis using Solar/ Wind renewable electricity, followed by a catalytic reaction with CO2 to form Green Hydrogen in liquid form (e-methanol), also known as Electro-Fuel [29].

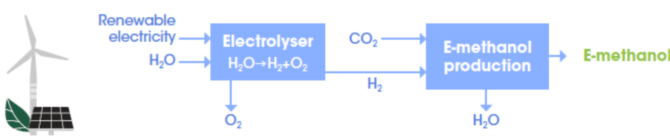


Fig.3 Electrolysis of water to hydrogen catalytic process to produce E-methanol.

B. *Electrolysis of water and carbon dioxide to syngas method*

Fig.4 indicates another way to produce both components of Synthesis, Carbon Monoxide, and Green/Blue Hydrogen, is through electrolysis, followed by conversion of the e-methanol (a liquid form of Green Hydrogen). Higher conversion efficiency can be obtained through this process at minimum losses or effluent[30]. But this is a less developed co-electrolysis route at the lab level to produce a kilowatt scale. Conventional water electrolysis can produce up to a megawatt range [31].

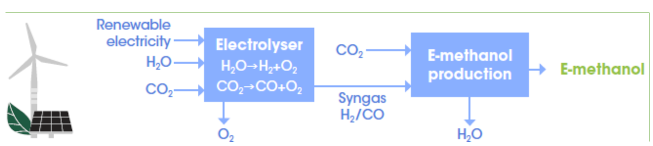


Fig.4 electrolysis of water & Carbon dioxide to catalytic process to produce E-methanol.

C. *Direct electrocatlytic synthesis method*

Fig.5 indicates the third route to produce e-methanol this process is known as the electrochemical process, the conversion of CO2 and water to produce Methanol. However, this process has limited efficiency up to laboratory scale. In the general process, each molecule of CO2 entering the process will exit as a methanol molecule; this requires three molecules of Hydrogen and will produce one molecule of water for each molecule of Methanol. Statistically, to deliver one tone of Methanol, for the complete process, 1.38 tone CO2 and 0.19 tone of Hydrogen, approximately 1.7 tons of water are needed, and 10-11 MWh of electricity is required from renewable sources.

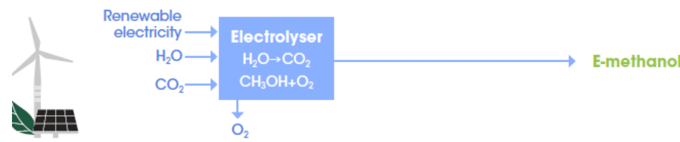


Fig.5 Direct electrocatalytic synthesis of water and CO_2 to produce E-methanol.

III. Critical Aspects Green & Clean Energy Operations

1. **Renewable Energy Integration Modular with port equipment**: Examine how solar and wind energy sources can be effectively integrated into the electrolysis process also known Chemisorption as shown Fig.5 and its port equipment(s) (1) Electorylzer, (2) Separator of Liquid and gas, (3) Compressor, (4) Boiler, (5) Catalytic Reactor, (6) Reducing valve, (7) Absorber, (8) Stripper and (9) Distillation column Renewable and Conventional Power Utilities. Consider the variability of these renewable sources and explore methods to ensure a consistent and reliable energy supply for the electrolyzer[32].
2. **Hybrid Renewable Systems**: Investigate the benefits of creating a hybrid renewable energy system that combines solar and wind technologies. This can enhance the overall efficiency and reliability of the system, especially in locations with variable weather conditions[33].
3. **Electrolyzer Technology: Explore** different types of electrolyzers, such as alkaline electrolyzers, proton exchange membrane (PEM) electrolyzers, and solid oxide electrolyzers. Evaluate their efficiencies, durability, and suitability for integration with renewable energy sources[34].

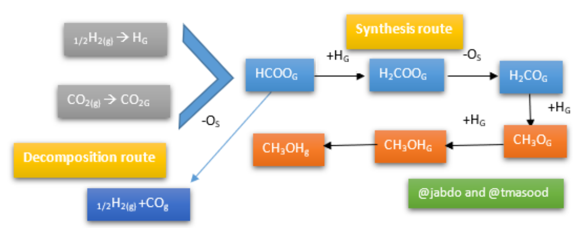


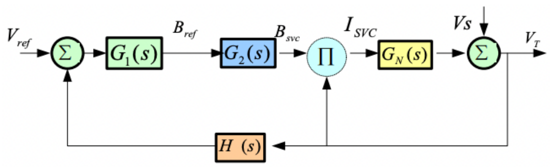
Fig.6 Chemisorption and industrial catalytic process

IV. Voltage Control Model

In the linear operating control model's Buck and Boost Converters designed to control the voltage, the AC system terminal internal voltage V and reference voltage V_{Ref} as given in the equation 3 and its parameters are also defined [26].

$$V_T = V\frac{1}{1+G_1G_2HX} + V_{Ref}\frac{G_1G_2X}{1+G_1G_2HX} \quad \text{............(1)}$$

In the second form of operation's control model has been developed to produce the results as per defined as mathematical model. The control transfer functions which have been verified to maintain it operational credibility which has been formulated in control as given below [26].



The concept is to develop and customize the Smart control Devices to optimize its operating parameters by incorporating new control compensation control parameters. In this method, the control system has three operating and control boundaries in order to run the system successful to achieve the following [18],[19].

- Increased Power Transfer capability [23]
- Improved reliability [23]
- Improved controllability [23]
- Enhanced angle and voltage stability [23].

V. CONCLSUION & DISCUSSION

Introducing clean and green energy initiatives is essential to crafting the right policies and incentives, which is crucial to meeting the goals of carbon emission reduction, energy security, sustainability, and improvement in quality of life in the world by large. Green Energy initiatives would only happen with confidence in strong, stable, predictable, and sustained government policy. In the transport sector, especially for passenger cars, policy must focus on electromobility and support for increasing the share of EVs.

Meanwhile, Green Hydrogen fuel cells and batteries are strong candidates to serve the purpose, essentially inroads, and charging infrastructure needs to expand. Renewable Electricity and renewable fuels (Green Hydrogen and E-Methanol) will play a critical role in finding different pathways to carbon neutrality, and public policy should create a level playing field to expand and not limit opportunities for e-methanol strong candidates to produce clean and green energy. This fuel can be yielded in regions with sufficient means of renewable Electricity, using carbon as a carrier in the form of an easily transportable liquid molecule. Advancing e-methanol manufacturing capability in diverse countries worldwide will expand energy allocation and moderate political risks. Regulation and guidelines for methanol consumed as a road transportation fuel are already operational.

Over the last 15 years, different provinces in China have instituted guidelines for methanol mixtures in transportation, going from 5% methanol in gasoline (M5) to 100% methanol (M100). China's central government has implemented a policy of commercial introduction of M100 cars, trucks, and buses.

The United Kingdom presented its Renewable Transport Fuel Responsibility scheme in 2008. Fuel branded as Renewable Fuels of Non-Biological Origin, such as e-methanol, are incentivized by awarding double credits per liter or kilogram supplied. The European Union has launched its "Green Deal" roadmap, aiming to become carbon neutral by 2050 (EU, 2020a).

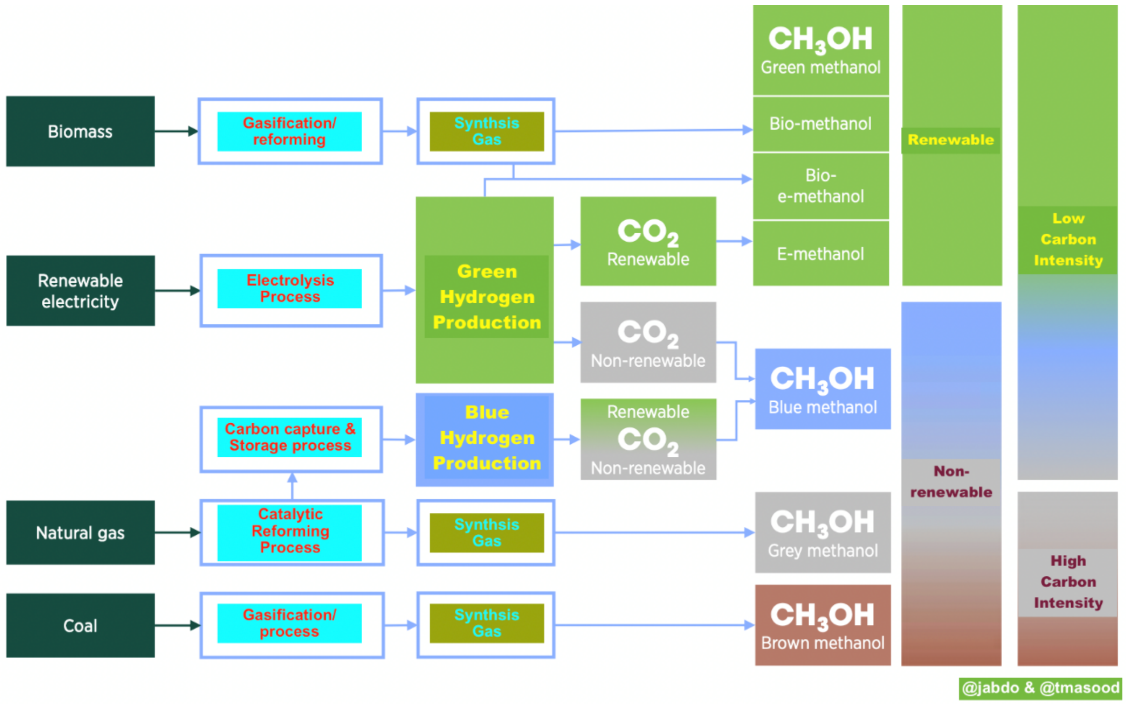


Fig.1 Types of hydrogen according to production process

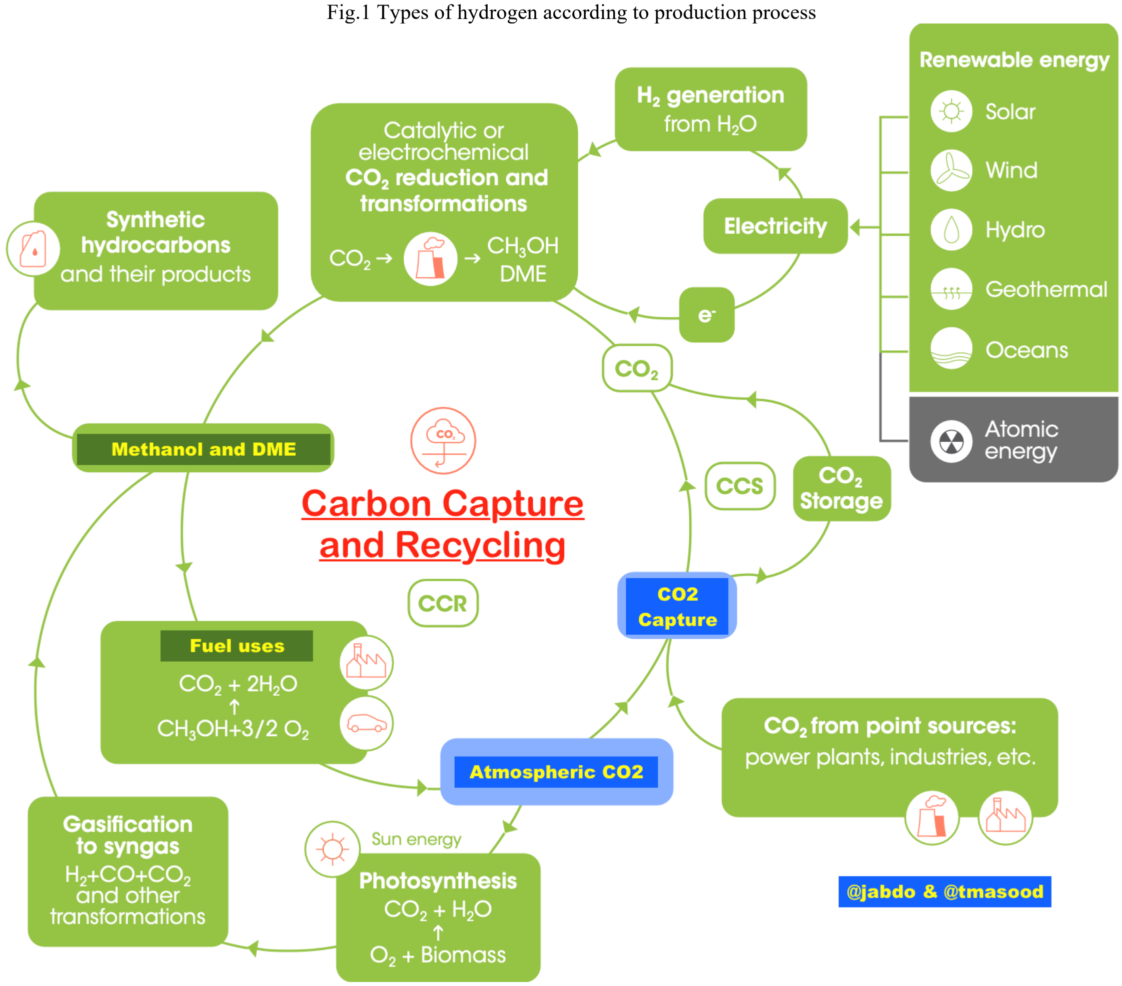


Fig.2 Anthropogenetic carbon cycle for a circular economy

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