Hydrogen Leading the Green Energy Future

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Climate change evolving as the major concern erratic weather conditions for example heavy rains drought floods, landslides, soil erosion, tsunami, and extreme cold and warm weather, which severely impact the livelihoods of the mankind. Attaining the substance by reducing carbon pollution and other greenhouse gases is the best way to control climate change [**1**]. Considering the suitable climate, habitat variation, and their adverse effects such as glaciers, heatwave, sea levels rise, etc., it is important to understand the climate control and framing combat policy as per the requirement of energy. Biofuels reduce greenhouse gases extensively in comparison to fossil fuels for transport [**2**]. The selection of energy technology is critical to achieve the net-zero emission [**3**]. Energy crisis is a prominent challenge across the globe. Searching and adopting other technologies and sources for energy exploitation may bring risks and challenges [**4,5**]. However, energy demands increasing day by day, and the exploitation of natural resources for energy extraction, making the environment worst.

The importance of armed violence in nurturing environmental degradation and the ecological imbalance was studied [**6**]. Now, country-wise policy for renewable, and net-zero power generation is much required in line with sustainability [**7**]. The most abundant element of the globe is hydrogen, which has a universal presence in water, oil, and natural gases. Hydrogen is now established as a clean and flexible energy carrier [**8**]. Europe and the other nations are progressively walking toward achieving the net-zero objective with the overview of clean hydrogen energy, which will ensure global sustainability faster [**9**]. The International Association of Advanced Materials, IAAM also orchestrates its goal with the European Green Deal through policy initiatives [**10**].

Hydrogen utilization for transport, power, and building sectors will not pollute the air and fulfil the sustainability agenda sooner. World-leading organizations also initiated hydrogen research to solve climate issues [**11**]. The utilization of biowaste for the generation of net-zero energy and hydrogen as commercially used fuels to create a sustainable energy system is the demand of the hour [**12**]. Therefore, a well-developed hydrogen production infrastructure is best for energy carriers and storage across the globe. Although, efforts need more efficient technology, innovation, policy, and management for utilization in the energy sector. Further, despite numerous limiting factors research institutions and industrial players have taken the challenge with a politically driven agenda to combat climate neutrality.

Strives for climate diplomacy

Controlling greenhouse gas emissions and making lead toward the net-zero emissions through carbon sequestration requires climate-neutral research and technology. The historic Paris Agreement sets long-term goals to guide all nations in controlling greenhouse gas, reducing the global

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DOI: 10.5185/amlett.2022.021690

temperature, and review regularly countries' commitments [**13**]. The COP26 conference to the United Nations Framework Convention on Climate Change (UNFCCC), Glasgow, Scotland, focused on climate diplomacy since the 2015 Paris Agreement [**14**]. This carbon neutrality event, address international standard on carbon neutrality through certified emission reductions. COP26 priorities focused on alternative energy sources having low-emission, solar energy, and hydrotreated vegetable oil (HVO) in generators, etc. The India-Nordic Summit 2022 discussed multilateral cooperation, more specifically towards green transitions, climate change, SDGs, innovation, digitalization, and green growth. Prime Ministers of India, Denmark, Iceland, Norway, Sweden, and Finland were participated in the summit to discuss the green innovation and digital initiatives as key to prosperity and sustainable development [**15,16**].

Drastic climate impacts

Controlling the climate change becoming more difficult day by days. Reducing greenhouse gas emissions require extensive efforts to drastically reduce energy prices and zero dependency on fossil fuels. Making suitable action plan with private and government sector around the globe is timely requirement [**17**]. Worsening climate and surging fossil fuels demands strong action on the development of sustainable energy system.

Enhancement of the climate neutrality through fossil fuels control is helpful to reduce global pollution burden [**18**]. The time has come to invent new technology to sustenance expansion and advancement [**19]**. Energy generation through the fossil fuels including coal and oil should be transformed with relatively low-carbon power system and move towards the green and clean electricity model. Such kind of policy and technology transformation make drastic impact of climate neutrality objective.

Research and standards goals

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Consolidated green policy and political outreach

Study shows emissions control through policies as the transport sector accounts for 25% of anthropogenic emissions, with 72% of those in road transport [**20**]. Mitigation policies for climate control action can move forward, with the coal and oil replacement via the hydro, nuclear and hydrogen power, which offer clean energy possibilities.

Accelerating green hydrogen revolution

Using molecular hydrogen by either traditional internal combustion engines, or by fuel cell devices as an efficient technology to utilize electricity and energy carrier [**21**]. Its high time to utilize diverse technologies which can accelerate the green hydrogen revolution effectively [**22**]. Technological integration accelerates the process and enables the optimization, and automation of green hydrogen transition systems efficiently. Using artificial intelligence (AI), the internet of things (IoT), and data analytics established defined management to green hydrogen.

Hydrogen sensors and industrial pace

Energy sustainability depends on hydrogen economy which covers all emerging technological development, industrial manufacturing, easy transportation, storage, control, and management. The development of a regulated hydrogen energy field requires sensors to support the described process and management. There are an enormous number of sensors reported in the literature for hydrogen recognition based on operating principles [**23**]. One of the biggest burdens of environmental pollution is transportation. Hydrogen-powered fuel cell electric vehicles can be a potential driver of sustainable energy solutions. Therefore, the protection of linking the purchaser demands with solutions will bring more competition in the hydrogen-energy market and pace to evaluation of the related technology and products.

Knowledge sharing and transfer for neutrality

Hydrogen-energy adaptive knowledge must be shared and transferred to make the faster development of this sector. Cultural patterns of seasonal activities and their societal relationship sustain transdisciplinary understanding [**24**]. Information for climate adaptation, usability, and criteria based on real-time regional prerequisites, requires a yearly active action plan with a defined roadmap for a "good climate" target [**25**].

Inclusive neutrality attainment

The motive of scientific transformation for climate neutrality should address business, investment, technology development, skilled workforce, and government support. Global requirement needs to lower the risks, through the development of a sustainable energy system. Especially directional motive and pace attain by the policy and guidelines have effective ability to transform the whole scenario for energy sustainability. However, the adaptation and implementation of such a program and system required strong political desire. Hydrogen evolution can play an

important role in nature conservation and energy solutions. Sustainability in energy attain in an interconnected biosphere through innovation and digital transformation easily. Overall, the strategy foresees focused on localized production of hydrogen by refuelling stations for transportation, homes, and cities will impact our life as it develops into a new energy source. Electrochemical techniques are being used on a more sustainable way [**26, 27**] and have been applied for hydrogen evolution too for the electrochemical energy model. To this end, the conception of a clean energy model through the exchange of acquaintance and innovation across world-leading organizations is the only option for the people.

Hydrogen rainbow and its future

To achieve the overall energy requirement, the energy industry is seeing at each prospective technology. Everyone is working to introduce the hydrogen into the nation's energy resource. Nowadays, thousands of vehicles and devices across the globe are fuelled by hydrogen fuel cells. Everyone is focusing on diminishing carbon emissions and driving in the direction of a greener, sustainable future. The hydrogen manufacture process provides various kind of hydrogen having a multi-coloured signature, although there is no universal specifying principle. Sometimes, they also referred as the Hydrogen Rainbow [**28**].

In the rainbow, grey, blue, pink, and green hydrogen is most common. The grey hydrogen is generated from the methane through the steam methane reformation process. It is considered as the most popular form of hydrogen production. On the other side, blue hydrogen depends on the traditional method of steam methane reforming, but here the carbon dioxide generated as a by-product is trapped and isolated. It is known as the resource of clean hydrogen with a low carbon content. Pink hydrogen valves into nuclear energy to power the electrolysis essential to create it. The high temperatures of the nuclear reactors provide an additional benefit — the extreme heat produces steam that can be used for electrolysis or fossil gas-based steam methane reforming in other forms of hydrogen production.

Green hydrogen is considered to manufacture with zero toxic greenhouse gas discharges. It is produced utilizing renewable energy resources like electrolysis that produces hydrogen and oxygen with zero carbon dioxide emission. Among the hydrogen rainbow, green hydrogen is most popular and applying extensively. Recently, the European Union revealed its latest Hydrogen Strategy, which demands for the faster implementation of green hydrogen to attain the European Union's net-zero emissions objective by 2050. The policy also suggests installing around 6 gigawatts of hydrogen electrolyzes on various part of the Continent by 2024 [**29**]. Blue hydrogen assumed to have lot more probability but with its larger greenhouse gas footprint than the burning natural gas or coal and burning diesel limits its application [**30**]. Due to low cost than green hydrogen, blue hydrogen may be adapted in future with modification but with its less green approach, it will be time taking.

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