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ADVANCEMENTS IN THE GLOBAL GREEN HYDROGEN ECONOMY

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Abstract

Hydrogen has proved itself to be a viable alternative to the fossil fuels due to its flexibility in applications and easy production. The authors have through their extensive research on the viability of transforming the present fossil-based economy to a much cleaner and robust hydrogen-based economy, have suggested methods for a smooth transition. According to them it is possible to transform the global economy to almost 25% cleaner energy-based economy by 2035 if sufficient measures are taken by the countries in a unified manner. Through a survey undertaken globally, the authors have proved that cost of green hydrogen production will fall, and it will be a deciding factor in the decades to come.

Key words: *Green Hydrogen Economy, Net-zero emission, Carbon neutral, Global green hydrogen cost and Electrolysers.*

1. Introduction

Hydrogen is the smallest and the lightest element on earth and available in abundance in air and water. Our task is to harness the potential available in our earth to meet our energy needs in the cleanest possible manner. Green Hydrogen which is produced from electrolysis process as normal hydrogen but the fuel used to power the process is obtained from renewable energy sources like wind , solar and hydro –power. Thus the carbon emissions in the whole process is minimized leading to a cleaner environment. A lot of research is going on around the world on Hydrogen production , storage and transportation which involves a lot of brain-storming to minimize costs. First to get renewable energy sources which will be used in electrolysers to produce green hydrogen, then storing hydrogen in compressed gas form or liquid form (-253 degree Celsius) in cryogenic containers and then transporting the same to places of end usage involves a lot of costs and care.

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It also involves trained personnel to handle the very volatile gas. For rich countries like USA , EU countries and China , the whole process may be a small percentage of their GDP but for emerging economies like India , Pakistan , African countries and even South American countries , the costs involved are a substantial part of their GDP. We need to have a parity wherein all countries rich and poor may utilize their resources towards a common goal of making our planet carbon neutral (Kakoulaki et al., 2021).

2. Developments in the Electrolyser front

The cost of electrolysers could reduce by 40 per cent by 2030 with 100 GW of capacity deployment; and in a close to zero emissions system, the cost of electrolysers is expected to reduce by about 70 per cent by 2050 with a deployment of 1700 GW. These estimates are in line with the estimates provided by the Hydrogen Council which aims at 60 per cent reduction in cost by 2030, India has recently announced the National Hydrogen Mission which aims for generation of hydrogen from green power resources. The proposed mission would aim to lay down Government of India's vision, intent and direction for hydrogen energy and suggest strategy and approaches for realisation of the vision. The mission aims to develop India into a global hub for manufacturing of hydrogen and fuel cells technologies across the value chain. Major activities under the Mission include: creating volumes and infrastructure; demonstrations in niche applications (including for transport, industry); goal-oriented research & development; facilitative policy support; and putting in place a robust framework for standards and regulations for hydrogen technologies . The India H2 Alliance, led by Chart Industries and Reliance Industries, has come against the backdrop of the proposed National Hydrogen Mission, which may mandate fertilizer, steel and petrochemicals industries to shift to green hydrogen.

The increasing ambition of climate targets creates a major role for hydrogen especially in achieving carbon-neutrality in sectors presently difficult to decarbonise. This work examines to what extent the currently carbon-intensive hydrogen production in Europe could be replaced by water electrolysis using electricity from renewable energy resources (RES) such as solar photovoltaic, onshore/offshore wind and hydropower (green hydrogen). The study assesses the technical potential of RES at regional and national levels considering environmental constraints, land use limitations and various techno-economic parameters. It estimates localised clean hydrogen production and examines the capacity to replace carbon-intensive hydrogen hubs with ones that use RES-based water electrolysis.

A major finding in our study is that most of the examined European regions have sufficiently high technical potentials to be self-reliant using renewable energy. Furthermore, clean hydrogen offers new opportunities for re-designing Europe's energy partnerships with both neighbouring countries and regions and its international , regional and bilateral partners, advancing supply diversification and helping design stable and secure supply chains. As for example several major

hydrogen-producing regions and especially densely populated regions (large cities, metropolitan areas) would not have sufficient green electricity to cover both current electricity consumption as well electrolytic production of hydrogen.

Switching the current annual EU hydrogen production of 9.75 Mt to electrolysis would require 290 TWh of electricity (about 10% of current production). The available technical potential for producing green electricity from wind, solar and hydro is easily sufficient to cover all current electricity consumption as well as this additional demand for green hydrogen, showing that a partial utilisation of prime locations could suffice. It was possible to geo-locate approximately 75% of current hydrogen production to 109 out of the 309 regions in the EU and UK. (Data collected is of 2019 from Bloomberg , ARENA and Indian Government websites).

2.1 Strides by the EU in the green hydrogen arena

The European Union aims at becoming a world leader in green hydrogen. The European Commission's hydrogen strategy represents an ambitious goal, given that it aims at making hydrogen an integral part of the future energy mix, accounting for 13- 14% of Europe's energy mix by 2050 – now it is only 2%. The European interest for green hydrogen results from its commitment to become carbon neutral by 2050. Thus, the EU seeks to represent itself as the major global player in renewable energy, developing the most advanced technologies and pursuing innovative policies. Moreover, the EU seeks to diversify its energy sources, becoming independent from oil and natural gas imports, and enhancing security of energy supply. The European Union also counts on partnerships with third countries for imports of renewable hydrogen, mainly using the existing gas pipelines which connect Southern Europe to North Africa. The European Union has always been a leader in climate policies, implementing the Paris Agreement and adopting carbon-neutrality goals as part of its agenda. In July 2020, following its commitment to reach carbon neutrality by 2050, the EU decided to adopt a Hydrogen Strategy48. Even though the European Union is composed of diverse realities, with countries following different pathways towards climate neutrality, its common strategy sent a clear message, believing in the potential of hydrogen as a sustainable energy carrier. Particularly, the EU encouraged the production and use of green hydrogen, as a long-term alternative to fossil fuels. Part of the European Green Deal, the Hydrogen Strategy will contribute to consolidate the EU's global position as a norm and standard setter on energy transition, promoting its technological leadership, increasing its energy security, and strengthening partnerships with third countries. The EU Hydrogen Strategy, linked to funds from the EU Recovery Plan, represents an opportunity for Southern European countries, including Italy and Spain, which could become renewable hydrogen hubs, by importing hydrogen produced in North Africa from solar power and exporting it to other European countries, through the existing gas pipelines (Kakoulaki et al., 2021).

3. Discussions

A clean hydrogen economy offers promising opportunities not only to fight climate change, but also to redraw geopolitical relations between states. The energy transition is already taking place, with renewable energies gradually eroding the global energy system based on fossil fuels. A global transformation, set in motion by the need to decarbonise the energy system, will have the potential to redraw international alliances and conflicts. In this context, hydrogen may play a crucial role (Fan et al., 2021).

By 2050, hydrogen could indeed meet up to 24% of the world's energy needs, thus highly influencing the geopolitical landscape. In this regard, the choice over which pathway to take for the creation of hydrogen value chains will have a huge geopolitical impact, resulting in new dependencies and rivalries between states. Conclusively, if national governments are willing to spur the emergence of a green hydrogen economy, they should heavily invest in research and development, encourage the development of a clean hydrogen value chain, and promote common international standards. Moreover, they should also take into account hydrogen's geopolitical implications. If the hydrogen economy is well-managed, it could indeed increase energy security, diversify the economy, and strengthen partnerships with third countries.

4. Figures

The authors had framed 30-questions and took feedback from a wide cross-sections of the society globally including DBA students, industrial experts , professors , Doctors and environmentalists. The results are produced below:

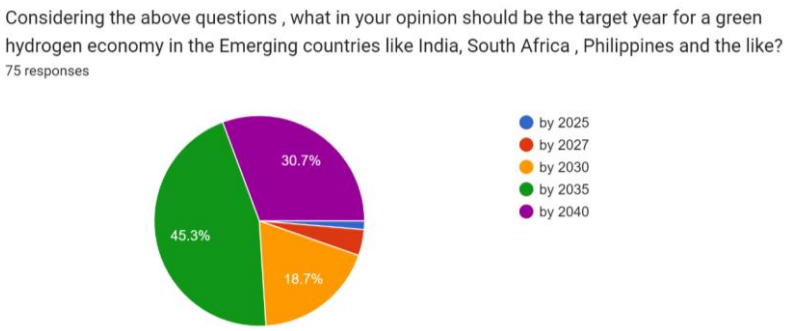

Figure 1. Opinion regarding the target year for green hydrogen economy

The above responses reflect that globally people are aware of a transition towards a "Green Hydrogen Economy" and are hopeful of getting the results by 2035-2040. The responses from 75 persons on the questionnaire, supports our findings from our research model and our conviction that a "Green Hydrogen Economy is possible by 2035" is confirmed. The cost reduction to about $ 2 per Kg

by 2035, predicted by our model is also supported by the survey . For emerging nations of Asia , Africa & Europe to have a 25% contribution from green hydrogen of their total energy requirements , they would spend about $ 500-600 billion on green hydrogen and other renewable energies during 2030-2040. Support from developed countries in this matter is also a must. The survey also supports that a larger public-private participation is required in all the emerging nations , to contribute to enhanced production of electrolyzers and for funding of a larger infrastructure to enable green hydrogen production , storage and transportation. The following table shows the expenditure profile of various countries on the green hydrogen front.

Table 1: Datasheet on Green Hydrogen in Emerging Nations

Serial No	Country	Cost of production (in $/kg)	Expenditure/ Investments (in billion $)in 2019	Growth % on 2018	Stakeholder participation (Govt/private)
1	India	6-10	9.3	-14	Both
2	Taiwan	6-9	8.8	390	Both
3	Vietnam	6-10	2.6	-64	Both
4	Brazil	6-12	6.8	74	Both
5	UAE	6-10	4.5	1223	Both
6	Mexico	6-9	4.3	17	Both
7	Korea (Republic)	6-11	2.4	31	Both
8	Sweden	6-9	3.7	-19	Both
9	South Africa	6-10	1.0	-76	Both
10	Netherlands	6-9	5.5	25	Both
11	Poland	6-10	1.8	349	Both
12	Italy	6-8	1.3	-35	Both
13	Finland	6-8	1.5	41	Both
14	Australia	6-11	5.6	-40	Both
15	Spain	6-9	8.4	25	Both

Source: Expenditure in 2019 & growth over 2018 has been taken from UNEP Centre-Bloomberg NEF

5. Conclusion

The authors have concluded from their extensive research that the present trend in renewable energy investments is about 10% growth year to year. In the next 10 years with the average trend of 10% per year, we can forecast an investment of 100 % over the investment in 2019, i.e of around billion US $ 135 , which comes to around billion US $ 9 for each of the 15-countries shown in Table-1. For six countries like India, Brazil, Taiwan, Netherlands, Australia & Spain, whose investments in 2019 are more than 5 US billion $, the forecasted investments in2029 will be about 10-18 billion US $. This will further increase to 16 – 29 billion US $ in 2035 with the same trend.

Similarly in developed countries if we consider the same trend of 10% growth in investments per year, the investments in 2035 for renewable energy would be in billion US $ for : USA- 153, Europe- 152 & China – 234. So total investments in 2035 for the 3-developed countries as above would be 539 billion US$. Whereas the 15-

developing nations would require an investment of 345 billion US$. The above investments in renewables and green hydrogen in the countries considered above would depend upon the socio-political scenario as well as the economic strength of the individual countries.

PwC *evaluated the production cost trajectory of green hydrogen worldwide and the key findings are:* Hydrogen production costs will decrease by around 50% through 2030, and then continue to fall steadily at a slightly slower rate until 2050. By 2050, green hydrogen production costs in some parts of the Middle East, Africa, Russia, China, the US and Australia will be in the range of €1 to €1.5/kg. The above results corroborate our findings on the "Green Hydrogen Economy" and re-iterate the importance of the world order shifting towards green hydrogen from the dependency on fossil-fuels at present.

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