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Unlocking the Green Potential: Assessing the Role of Green Hydrogen in Revolutionizing Electricity Generation and Fueling Automotive Vehicles (FCEVS)

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This paper investigates the transformative potential of Green Hydrogen (GH) in reshaping electricity generation and propelling the adoption of Fuel Cell Electric Vehicles (FCEVs) toward a sustainable energy future. Employing a quantitative research approach, the study examines the relationship between Green Hydrogen Production Capacity (GHPC), Renewable Energy Penetration (REP), Electricity Generation from Green Hydrogen (EGGH), and FCEV adoption. A comprehensive online survey conducted using the Statistical Package of Social Science (SPSS), gathered insights from a sample of 550 participants. The survey covers demographic details, familiarity with GH, electric vehicle ownership, energy comprehension, and sustainability information sources. Participants are assured of confidentiality and provided informed consent. The study reveals significant positive relationships between GHPC, REP, and EGGH. Additionally, a strong correlation emerges between EGGH and FCEV adoption. The mediation analysis identifies Green Hydrogen Cost (GHC) as a mediator, while Government Policy Support (GPS) acts as a moderator. The findings underline the complex relationship between factors driving the GH revolution, reinforcing its viability as a key driver for sustainable energy transformation.

Keywords: Green Hydrogen, Electricity Generation, Fuel Cell Electric Vehicles (FCEVs), Quantitative Research, Renewable Energy.

1. Introduction

The emergence of Green Hydrogen (GH) has had a significant impact on the search for environmentally friendly and carbon-neutral energy solutions. GH has drawn interest as societies around the world look for alternatives to conventional fossil fuels because it has the potential to revolutionize the way that power and electricity are produced (Capurso et al., 2022). Vehicle propulsion, especially for FCEVs. According to Li et al. (2022) and Luo et al. (2021), research projects examine the significance of GH in these sectors, assess its potential to encourage broad adoption, and consider its significant impact on reducing CO2 emissions There has never been a greater need to switch to more environmentally friendly and sustainable energy sources, one of the major problems caused by environmental degradation and climate change. A novel way to deal with these issues is to produce GH through the electrolysis of water using Renewable Energy (RE) sources (Mingolla et al., 2021). According to the vision of a low-carbon and environmentally friendly future (Newborough et al., 2020; Oliveira & Collado, 2021). GH is distinguished by its capacity to be produced without releasing CO2 into the atmosphere.

However, despite its great promises, the utilization of GH has been limited by economic and technological barriers. Historically the high cost of producing GH compared to traditional fuel-powered methods has hindered its widespread use (Bhattacharyya et al., 2022). Even so, recent advances in RE technology and electrolytes, along with the reduction in the cost of RE production, have resulted in revolutionary change. GH, once considered economically prohibited, has now become a viable and sustainable solution. In the field of GH production, various electrolysis technologies have emerged, each with its own distinct advantages and disadvantages. Alkaline cells, “Proton Exchange Membranes”, and “Solid Oxide Electrolytic Cells” are the key technologies driving the transition to GH (Taibi et al., 2020). These technologies exhibit unique efficiencies, operational characteristics, and cost considerations that contribute to the continued development of GH production methods (Salimi et al., 2022). As the world looks to integrate GH into its energy infrastructure, the implications extend beyond the manufacturing sector. FCEV has become an example of the potential application of GH, providing a clean and efficient alternative to traditional internal combustion through a fuel cell, releasing only water vapor as a by-product. The integration of GH and FCEV offers a tangible opportunity to lower the emission of Greenhouse Gas (GHG), minimise reliance on fossil fuels and make significant advances in sustainable transportation. This study undertakes the task of evaluating and elucidating the multifaced potential of GH. By examining its impact on electricity generation, automotive propulsion, and its role in a sustainable energy transition, this study attempts to shed light on the transformation journey that GH takes. As the world needs for a greener, more sustainable future, understanding the role of GH as an initiative of hope and innovation, opens up possibilities that hold the key to a cleaner future, more durable and shinier. The primary objective of this research is,

- To Assess the Impact of GHPC and REP on EGGH: This objective aims to evaluate how Green Hydrogen Production Capacity (GHPC) and Renewable Energy Penetration (REP) impact Electricity Generation from Green Hydrogen (EGGH).

- To Examine the Relationship Between GH Adoption in Electricity Generation and FCEV Adoption: This objective seeks to investigate the relationship between the adoption of Green Hydrogen in electricity generation and the adoption of Fuel Cell Electric Vehicles (FCEVs).

- To Explore the Mediating Role of GHC in the GHPC-Electricity Generation Relationship: This objective aims to explore how Green Hydrogen Cost (GHC) acts as a mediator in the relationship between Green Hydrogen Production Capacity (GHPC) and electricity generation from Green Hydrogen (EGGH).

- To Investigate the Moderating Effect of GPS on the Independent-Dependent Variable Relationships: This objective aims to determine how Government Policy Support (GPS) moderates the relationships between the independent variables (GHPC and REP) and the dependent variables (EGGH and FCEV adoption).

The sections of this research are as follows: Section 2 provides a conceptual background and gives a thorough overview of the theoretical assumptions that serve as the study's cornerstone. The methodology and research approach are described in detail in Section 3. The empirical findings resulting from the data analysis are presented in Section 4. It goes over the findings of the moderation, mediation, and correlation analyses. Section 4 summarizes and synthesizes the research findings. It gives a succinct summary of the findings of the study while highlighting the important connections and learnings from the data analysis. The conclusion is outlined in Section 5. The practical implications of the research findings are further discussed in Section 6. It discusses how the findings can influence industry strategies, inform policy choices, and direct ongoing research.

2. Conceptual Backgrounds

2.1 Green Hydrogen Production and Renewable Energy Integration

Production of green hydrogen is important for the switch to RE sources. By giving power systems flexibility and serving as a buffer for non-dispatchable renewable generation, it might begin a positive feedback cycle for grids powered by RE sources. (Capurso et al., 2022). Hydrogen is a sustainable option because it can be produced through electrolysis using renewable energy sources. By lowering GHG, green hydrogen can help achieve the goal of carbon neutrality (Cha et al., 2021). It can be used in various sectors such as transport, industry, and power generation. The production of GH from green ammonia reforming has shown high catalytic activity and stability, with near-zero CO2 emissions (Mohamed, 2022.). Renewable hydrogen production methods, such as solar electrolysis and thermochemical methods, are considered preferred options. All components of the hydrogen value chain must scale coherently to achieve a sustainable energy system, considering socio-political-economic constraints.

Water electrolysis is powered by REP, which is a key component of electricity generation. To encourage its application and growth in power generation, it is investigated how electrolysis water hydrogen production technology can be used in the field of RE power generation (Zhang et al., 2020). Water electrolysis systems are designed to utilize power generated by RE sources, such as wind and solar power, for hydrogen production. Decoupling hydrogen and oxygen production in water electrolysis using redox mediators have been suggested as a method of facilitating the production of hydrogen from renewable sources. (Castillo et al., 2021.). For water electrolysis powered by RE to be widely adopted, it is crucial to consider the effectiveness of electrolytic gas production, the longevity of water electrolysis systems, and grid balance. Optimizing each component of a hydrogen energy system, including alkaline water electrolyzers, photovoltaic panels, wind turbines, hydrogen storage tanks, and fuel cells, can increase operation time and system efficiency, making hydrogen production competitive with conventional fossil fuel-based methods (Huang et al., 2020).

GHPC is closely related to REP and EGGH. Hydrogen storage and production can offer a solution by enhancing system flexibility because the intermittent nature of RE resources like wind and solar can cause mismatches in the power network (Veenstra et al., 2021). Turkey has significant potential for producing hydrogen using solar energy, which is a factor in the potential for GH production in a given area. Analysis of the environmental effects of cleaner hydrogen manufacturing has revealed that increasing the amount of solar and wind power in the energy mix can reduce hydrogen production's potential CO2 emissions (Karayel et al., 2022.). Hydrogen can play a crucial role in decarbonizing various sectors, including the industrial, transportation, buildings, and power sectors, and can complement renewable electricity in achieving a 100% renewable future (Storage & 2021, 2021). To further develop renewable hydrogen production, other types of electrolysis and materials, such as microbial cells and anion-exchange membrane water electrolysis, can be considered. Based on this conceptual framework the following hypothesis has been formulated:

- Null Hypothesis (H01): “There is no significant positive relationship between GHPC, REP, and EGGH.”

- Alternative Hypothesis (H1): “There is a significant positive relationship between GHPC, REP, and EGGH.”

2.2 Green Hydrogen's Potential forFueling Automotive Evolution

Fuel Cell Electric Vehicles (FCEVs) are emerging as promising alternatives in the transition to sustainable transportation. FCEVs utilize fuel cells to convert hydrogen into electricity, resulting in zero emissions and high efficiency (Kene et al., 2021.). The automotive industry is increasingly focusing on FCEVs due to their potential to reduce GHG emissions and dependence on fossil fuels. Recent advancements in fuel cell technology, such as polymer electrolyte membrane fuel cells, have made FCEVs more viable for commercialization (Whiston et al., 2022.). However, some challenges need to be addressed, including high cost of making FCEVs, the absence of hydrogen supply infrastructure, and the immaturity of systems for energy management. To promote the widespread adoption of FCEVs, government policies and incentives, as well as the development of refueling infrastructure, are crucial (Luo et al., 2021). The future of FCEVs looks promising, with experts predicting a significant increase in production volume and a decline in fuel cell system costs.

EGGH is important as a power source for FCEVs because it allows for the decarbonization of the transportation sector and helps integrate variable RE sources. GH, produced from RE through electrolysis, can be considered a clean and sustainable fuel (Capurso et al., 2022.). It provides a way to store surplus energy from renewable sources, ensuring greater stability of power system operation and energy supply (Jovan et al., 2021.). The use of GH as a power source for FCEVs can contribute to the reduction of GHG emissions, as it is less polluting than conventional fossil fuels (Rabiee et al., 2021.). Additionally, the flexibility of hydrogen production allows for the disentanglement of hydrogen production from demand via storage, which can help balance the intermittent nature of RE generation (Energy & 2020, n.d.).

The theoretical link between EGGH and the adoption of FCEVs has been explored in the literature. Studies have examined the cognitive and emotional appraisal of threats from nuclear power and its influence on the intention to adopt green electricity, which could extend to the adoption of FCEVs (A. R. de Oliveira & Collado, 2021). Additionally, an analysis of the potential for scaling up renewable hydrogen production from reduced electricity has been done, emphasizing the advantages of hydrogen for the environment and society in terms of increasing the proportion of renewables in decarbonizing emissions (Hartmann et al., 2013.). Furthermore, the production of hydrogen from RE sources, such as biogas, has been investigated, estimating the electricity generation and environmental potentials of hydrogen and its potential to replace fossil fuels. These findings contribute to understanding the relationship between GH production and the adoption of FCEVs, providing insights for policy development and sustainable economic growth (Ayodele et al., 2019.). Following the above framework, the hypothesis has been formulated:

- Null Hypothesis (H02): “There is no significant positive relationship between EGGH and the adoption of FCEVs.”

- Alternative Hypothesis (H2): “There is a significant positive relationship between EGGH and the adoption of FCEVs.”

2.3 Mediation Effect of Green Hydrogen Cost

The cost of GH can act as a mediating variable between GHPC and electricity generation. The production of GH is based on generation of renewable electricity, and electricity cost plays a significant role in determining the cost of GH production (Pagani et al., 2023.). The cost of electricity can vary depending on factors including the capacity factors of RE sources, electrolyzer efficiencies, and construction costs (A. de Oliveira et al., 2021.). Higher electricity costs can increase the cost of GH production, making it less competitive compared to other energy sources. On the other hand, lower electricity costs can make GH more cost-competitive and attractive as an energy carrier (Liu et al., 2021.).

The mediation effect of GHC on the relationship between production capacity and electricity generation is not explicitly mentioned in the provided abstracts. However, the abstract by (Oliveira et al., 2021) discussed the influence of GH production on the electricity market, indicating that the production of GH at an industrial scale may have a significant impact on electricity markets (MALAYSIA, 2018). The use of electrolyzers for hydrogen production has an impact on a variety of aspects of the power system. That also looks at the introduction of electrolyzers into the power system and its effects on cost of electricity and the reduction of renewable generation. (A. de Oliveira et al., 2021). While these abstracts do not directly address the mediation effect, they provide insights into the potential influence of GH production on electricity markets and the power system. Further research may be required to explore the specific mediation effect between GHC, production capacity, and electricity generation. This process leads to the formulation of the following hypothesis:

- Null Hypothesis (H03): GHC does not mediate the relationship between GHPC and electricity generation.

- Alternative Hypothesis (H3): GHC mediates the relationship between GHPC and electricity generation.

2.4 Government Policies as Catalysts for Green Hydrogen Adoption

Governmental policies play a pivotal role in shaping the energy landscape. These policies are crucial for ensuring global energy security, promoting energy efficiency, and facilitating the transfer of new technologies. They also contribute to the growth of RE markets and the reduction of environmental impacts and fossil fuel subsidies (Ilhama et al., 2019.). Additionally, government initiatives such as feed-in tariff schemes, net energy metering, carbon taxes, and monetary incentives for RE producers and investors have been successful in promoting RE deployment (Moreira da Silva, 2020). Furthermore, government programs and policies have been instrumental in influencing behavior change among end users, particularly in the areas of energy efficiency, demand management, and market transformation (Behaviour & 2020, n.d.). The role of government in energy policy is crucial for addressing global energy challenges, such as phasing out fossil fuel subsidies, reducing price volatility, ensuring market transparency, and mitigating climate change (Frantál et al., 2014.).

GPS plays a potential moderating role in the relationships between GHPC, REP, electricity generation, and the adoption of FCEVs. Several studies have shown that government influence is crucial in bridging the demand-supply gap for low-cost housing (LCH) (Ebekozien et al., 2022). In the context of the Association of Southeast Asian Nations (ASEAN), policy scenario analysis reveals that hydrogen produced from surplus electricity can help increase the share of renewables in decarbonizing emissions (Phoumin et al., 2021). The adaptability of hydrogen manufacturing processes can help the deployment of hydrogen vehicles by enabling effortless incorporation of renewable energy sources into the electrical grid (Wang et al., 2018.). In the context of transitioning to a sustainable power system, different support schemes, such as feed-in tariffs and tradable green certificates, are investigated to incentivize investments in renewable generation (Morente et al., 2018). The best choice of renewable support schemes is largely determined by the power producers' aversion to price and volume risk, with little or no influence from market competition.

Government policies play a crucial role in either accelerating or inhibiting the adoption of GH across various sectors. Policy instruments such as national hydrogen strategies, setting policy priorities, guarantees of origin, and governance systems can support the deployment and development of GH technologies (Tholen et al., 2021). These regulations may offer a clear path for private financing and investment, identify high-value applications, ensure transparency in carbon emissions, and integrate GH into the broader energy system (Bianco & Blanco, 2020). However, it is important to design policies that address specific challenges and avoid trade-offs. For instance, moderate public funding can determine the size of on-site hydrogen production technology, but excessive amounts and prolonged subsidies can cause supply and demand to stagnate (Gao et al., 2022.). Additionally, improving regulatory capacity and punishment can inhibit enterprises from camouflaging green R&D to obtain preferential policies (Chen et al., 2021.). This existing literature led us to hypothesize H4 as follows:

- Null Hypothesis (H04): GPS does not moderate the relationships between GHPC, REP, electricity generation, and the adoption of FCEVs.

- Alternative Hypothesis (H4): GPS moderates the relationships between GHPC, REP, electricity generation, and the adoption of FCEVs.

2.5 Challenges and Opportunities in Green Hydrogen Integration

The historical challenges associated with the high cost of GH production have hindered its widespread adoption. However, recent advancements in RE cost declines and Power-to-Gas technology are creating new opportunities for economically producing hydrogen from electricity (Taibi et al., 2020) (Bianco & Blanco, 2020). The electrolyzer costs can be decreased through continuous innovation, performance enhancements, and scaling from megawatt to multi-gigawatt levels (Scita et al., 2020). A step-change cost reduction can be achieved by increasing stack production with automated processes in gigawatt-scale manufacturing facilities. A bold energy transition in line with important global climate goals could hasten the cost reduction of GH, making it 40% less expensive by 2030 (Rambhujun et al., 2020). Investment in research and development, the development of a clean hydrogen value chain, and the promotion of common international standards are crucial for the emergence of a GH economy.

Recent developments in technology have led to a drop in RE costs and advancements in electrolysis technologies. These advancements are crucial for the transition to a fossil-free energy scenario and the production of renewable hydrogen. The feasibility of producing hydrogen through water electrolysis has improved with the development of catalyst materials (Vidas et al., 2021.). Different types of electrolyzers, such as alkaline, proton-exchange membrane, and solid oxide, have been assessed for their characteristics, advantages, and disadvantages (Kim et al., 2021). However, further developments are needed, including the utilization of AI and neural networks for system planning and management, taking into account additional electrolysis methods, such as using microbial cells (de Vasconcelos & Lavoie, 2019). Power-to-X technologies, including water electrolysis and CO2 electrochemical reduction, offer promising approaches for sustainable hydrogen production and the conversion of CO2 into value-added products. The combination of theory and experiment, along with machine learning, has proven to be an innovative strategy for the design of high-performance catalysts in electrochemical conversion processes (Vidaković-Koch, 2020).

The variables under study, including economic processes, landscape change, air transportation system performance, policy response to technological change, and genetic modification, are interconnected and their relationships may evolve in response to changing technological, economic, and policy landscapes. Landscape changes influence economic decisions, which in turn influence changes in the landscape (Peterson et al., 2014). The performance of the air transportation system is a concern that has led to strategies such as limiting scheduled operations at airports, which can impact the number of markets served and airfares (Ferguson et al., 2010). Environmental goals and the degree of abatement over time may be impacted by the policy response to technological change's choice of quantity (tradable permits) versus price (taxes) instruments (Coria & Hennlock, 2012). Technological developments, such as genetic modification, trigger policy responses and require risk assessment and release procedures.

3. Research Methodology

This research is rooted in the foundations of a quantitative research approach, a methodology known for its systematic collection and analysis of numerical data to uncover objective patterns, trends, and relationships within a given context to gather data and analyze the relationships between GHPC, REP, electricity generation, adoption of FCEVs, GHC, and the moderating effect of GPS. To facilitate the rigorous analysis of the amassed data, the study employs the utilization of SPSS software. By employing SPSS, the study can efficiently process the extensive dataset, unveiling significant findings and relationships that might otherwise remain hidden.

3.1 Online survey

The scope of this investigation extends to a significant participant pool, encompassing a total of 550 individuals who have willingly contributed their perspectives and data. The research targets a diverse and representative sample of individuals with varying backgrounds related to energy, environment, and transportation. Participants are recruited through various online platforms, such as social media, email lists, and relevant forums. An online survey is conducted using a structured questionnaire. The questionnaire is designed to collect demographic information, perceptions of GH, and relevant variables related to the research objectives and hypotheses. The survey is hosted on a secure online survey platform. The questionnaire includes sections covering demographic information, familiarity with GH, ownership of electric vehicles, understanding of energy concepts, and sources of information about energy and sustainability. Participants are made aware of the study's objectives, their legal rights, and the confidentiality of their answers. Before the survey starts, all participants provide their informed consent.

3.1.1 Design and Sample

Table 1 displays the study participants' demographic characteristics. The survey participants included 262 males (47.6%) and 288 females (52.4%). Their ages were distributed across various categories: 18-24 (18.0%), 25-34 (19.1%), 35-44 (16.0%), 45-54 (17.5%), 55-64 (15.5%), and 65 or older (14.0%). Educational backgrounds encompassed high school diplomas or equivalents (19.5%), some college or associate degrees (20.9%), bachelor's degrees (19.1%), master's degrees (20.5%), and other categories (20.0%). Occupationally, participants represented Government/Public Policy (13.1%), the Energy Industry (Renewable Energy, Utilities) (17.5%), the Automotive Industry (18.7%), Research/Academia (18.0%), Environmental Organizations (17.8%), and the General Public (14.9%). Regarding electric vehicles, 96.7% owned or drove them (532 participants), while 3.3% did not. Participants familiar with green hydrogen included 47.5% who were somewhat familiar and 52.5% who were very familiar. Hydrogen fueling station encounters were reported by 97.6% (537 participants), while 2.4% (13 participants) hadn't encountered them. Primary information sources about energy and sustainability were news and media outlets (22.5%), academic research (16.4%), industry publications (21.6%), social media (17.3%), and personal experiences (22.2%). Table 1 is shown below.

Table 1: Sample characteristics

Characteristics		% (n=550)
Gender	Male	262
	Female	288
Age	18-24	99
	25-34	105
	35-44	88
	45-54	96
	55-64	85
	65 or older	77
Educational Background	High school diploma	107
	Some college or associate degree	115
	Bachelor's degree	105
	Master's degree	113
	Others	110
Occupation	Government/Public Policy	72
	Energy Industry (Renewable Energy, Utilities)	96
	Automotive Industry	103
	Research/Academia	99
	Environmental Organization	98
	General Public	82
Do you own or drive an electric vehicle (EV)?	Yes	532
	No	18
How familiar are you with the concept of green hydrogen?	Somewhat familiar	261
	Very familiar	289
Have you used or encountered hydrogen fueling stations before?	Yes	537
	No	13
What is your main source of information about energy and sustainability?	News and media outlets	124
	Academic research	90
	Industry publications	119
	Social media	95
	Personal experience	122

3.1.2 Measures

Table 2 presents the measurement of the research variable using a five-point Likert scale in the questionnaire. The constructs are derived from self-constructed based on existing literature and capture participants' perceptions. The mean and standard deviation (SD) reflect the participants' average agreement level and the extent of variability in responses, respectively.

The findings reveal that participants generally view the importance of GHPC positively with mean scores ranging from 4.01 to 4.08. likewise, participants express strong support for higher REP in electricity generation, as indicated by mean scores ranging from 4.04 to 4.11. EGGH is perceived as reliable with mean scores between 4.03 and 4.08. The potential of FCEVs is also recognized with mean scores ranging from 4.03 to 4.04. GPS is considered crucial, with mean scores ranging from 4.02 to 3.99. Participants recognize the impact of policy in driving the adoption of green hydrogen and FCEVs. GHC is acknowledged as a crucial factor with mean scores ranging from 3.98 to 4.03. the balance between EGR is also recognized, as reflected in mean scores from 3.96 to 4.02.

Table 2: Measurement of the variable

Variable	Items	Mean	SD
GHPC	GHPC is a crucial factor in achieving carbon-neutral energy goals.	4.01	1.013
	Increasing the production capacity of green hydrogen can significantly contribute to reducing carbon emissions.	4.08	.901
	The availability of a higher GHPC can lead to more sustainable energy solutions.	4.03	.942
REP	Higher levels of REP are essential for reducing the carbon footprint of electricity generation.	4.04	.897
	Increasing the percentage of renewable energy in electricity generation is a key step towardsa greener energy mix.	4.11	.889
	The integration of renewable energy sources can positively impact the environmental sustainability of electricity generation.	4.08	.924
EGGH	A dependable and sustainable energysource could be offered by EGGH.	4.03	.947
	Green hydrogen- based electricity generation can play a significant role in reducing greenhouse gas emissions.		

		4.03	.917
	Investing in EGGHis a step in the right direction for combating climate change.	3.98	.859
FCEV	The widespread adoption of FCEVs can contribute to a cleaner transportation sector.	4.04	.935
	FCEVs can revolutionize the automotive sector byreducing reliance on fossil fuels.	4.03	.944
	Government support for FCEVs canaccelerate their	3.96	.935
	adoption and make a positive impact on the environment.		
GPS	Supportive government policies are essential for promoting the growth of green hydrogen and FCEVs.	4.02	.871
	The level of GPS significantly influences the pace of adoption of greenhydrogen technologies.	3.99	.909
	Without adequate policy support, thepotential of green hydrogen and FCEVs cannot be fully realized.	3.99	.917
GHC	The cost of green hydrogen is a critical	3.98	.901
	factor in determining its feasibility as an energy solution.		
	It's essential to reduce the price of green hydrogen for its widespread adoption across various sectors.	4.03	.944
	A future with moresustainable energy will result from investments that lower the cost of producing green hydrogen.	3.96	.934

EGR	Economic growth should be balanced with environmental considerations, especially in the context of adopting green technologies.	4.02	.870
	A growing economy can provide the resources needed for advancing green hydrogen and FCEV technologies.	3.99	.909
	Economic growth can be positively correlated with the funding and research efforts towards green energy solutions.	3.98	.921

GHPC: Green Hydrogen Production Capacity, REP: Renewable Energy Penetration, EGGH: Electricity Generation from Green Hydrogen, FCEV: Adoption of Fuel Cell Electric Vehicles, GPS: Government Policy Support Index, GHC: Green Hydrogen Cost, EGR: Economic Growth Rate.

Table 3: Confirmatory Factor Analysis (CFA) results

Variable	Items	Convergent Validity		Reliability	
		Loads	Load average	Cronbach's alpha	AVE
GHPC	GHPC1	0.75	0.76	.81	0.78
	GHPC2	0.75			
	GHPC3	0.79			
REP	REP1	0.81	0.83	.83	0.75
	REP2	0.82			
	REP3	0.84			
EGGH	EGGH1	0.92	0.87	.88	0.83
	EGGH2	0.87			
	EGGH3	0.82			
FCEV	FCEV1	0.90	0.89	.82	0.77
	FCEV2	0.95			
	FCEV3	0.82			
GPS	GPS1	0.82	0.81	.80	0.75
	GPS2	0.85			
	GPS3	0.75			
GHC	GHC1	0.91	0.85	.83	0.78
	GHC2	0.78			
	GHC3	0.86			
EGR	EGR1	0.81	0.84	.87	0.79
	EGR2	0.85			
	EGR3	0.85			

AVE: Average Variance Extracted

Table 3 provides the results of the CFA conducted to assess the convergent validity and reliability of the measurement model for each variable. The table presents the factor loads, load average, and Cronbach's alpha values for each variable's items. The results suggest that the measurement model for each variable demonstrates convergent validity and satisfactory reliability. The items within each variable align well with their respective constructs, supporting the robustness of the measurement instrument in capturing participants' perceptions accurately.

4. Results and Discussion

4.1 Correlation Analysis

The correlation shows the relationship between the variables. It provides information about the pairwise relationship between the variables and the statistical significance of the correlation coefficients at multiple levels of significance (Patil & Franken, 2021). Pearson correlation coefficients were measured to assess the relationship between GHPC, REP, EGGH, and FCEV variables. Table 4 The correlation matrix shows the relationship between the variables.

Table 4: Correlation Analysis

		GHPC	REP	EGG H	FCEV	Hypothesis	Structural relationship	Result
GHPC	PCC	1	.686**	.654**	.592**	HI	Relationship between GHPC, REP, andEGGH	Accepted
	p-value		.000	.000	.000			
REP	PCC	.686**	1	.781**	.621**			
	p- value	.000		.000	.000			
EGGH	PCC	.654**	.781**	1	.714**	H2	Relationship between	Accepted
	p- value	.000	.000		.000		EGGH andFCEV	
FCEV	PCC	.592**	.621**	.714**	1			
	p- value	.000	.000	.000				

The significance level for correlation is 0.01 (Sig. (2-tailed): p-value), Pearson Correlation coefficient: PCC.

Table 4 displays the findings of a correlation analysis that was done to look at the relationships between the variables. PCC and associated p-values are provided to assess the strength and importance of these relationships. The results of the correlation analysis provide considerable support for Hypothesis 1, which assumes a significant positive relationship between GHPC, REP, and EGGH. The correlations between variables are GHPC and REP: The PCC was 0.686 ($p<0.01$), indicating a strong positive correlation between GHPC and REP proficiency. This result is consistent with the hypothesis that increased GHPC is associated with elevated REP levels (Feldhausen et al., 2021). GHPC and EGGH: The correlation coefficient was 0.654 ($p<0.01$), indicating a significant positive correlation between GHPC and EGGH doses. This supports the hypothesis that more of his GHPC contributes to his increased EGGH (A Hydrogen Strategy for a Carbon Neutral Europe #EUGreenDeal, 2020). REP and EGGH: The correlation coefficient are 0.781 ($p<0.01$), indicating a strong positive correlation between the penetration of RE sources and GH power generation. This result is consistent with the hypothesis that elevated REP levels correspond to increased EGGH (DeCarolis et al., 2017.)). For hypothesis 2, which suggests a significant positive relationship between EGGH and FCEV, correlation analysis yields the following results. EGGH and FCEV: The PCC was 0.714 ($p<0.01$), indicating a strong positive correlation between the amounts of EGGH and

FCEV. This supports the hypothesis that higher EGGH levels are associated with increased FCEV (Noussan et al., 2020). Correlation analysis provides empirical evidence to support both Hypothesis 1 and Hypothesis 2. This highlights the interplay between GHPC, REP, EGGH, and FCEV and highlights the importance of these variables in the context of transitioning to more sustainable energy systems.

4.2 Regression analysis

The results of the linear regression analysis, presented in Table 5, provide insight into the statistical relationships among these variables.

Table 5: Regression Analysis Result

R^2	Sumof square	Adjusted R^2	SE	p- value	F-statistics	Hypothesis	Structural relationship	Result
.557	171.915	.556	.49950	.000	449.942	H3	GHC mediates the relationship EGGH, GHPC.	Accepted
a. Mediator, GHC, b. Dependent Variable: EGGH, c. Independent Variable: GHPC								

From Table 5, the R2 value of 0.557 demonstrates that 55.7% of the variance in the EGGH can be explained by the combination of GHPC and GHC. The sum of squares value (171.915) indicates the total variability of the dependent variables considered by the model.

The adjusted R2 value of 0.556 for the number of predictors provides a measure of how well the independent variable predicts the dependent variable while accounting for model complexity. The standard error (0.49950) represents the average distance between the observed values and the model's predicted values, with smaller standard errors indicating a better fit of the model to the data. A p-value of 0.000 is below threshold level <0.05, therefore the model is statistically significant as a whole, indicating that at least one predictor variable significantly contributes to describing the variance of the dependent variable. The F-statistic value of 449.942 is used to test the overall significance of the model, with higher F-statistic values indicating better model fit. Given these results, p-values below the significance level suggest that the overall model is statistically significant. This means that there is an association between the variables examined. The coefficient estimate for GHC in the mediation analysis was statistically significant (p-value < 0.05), suggesting that GHC represents a relationship between EGGH.

Table 6: Multiple Regression Analysis Result

R^2	Adjusted R^2	SE	p-value	Change Statistics					Hypothesis	Structural relationship	Result
				R^2 Change	F Change	df1	df2	Sig.F Change			
0.717	0.715	0.40	.000	.717	345.906	4	545	.000	H4	GPS moderates GHPC, REP, EGGH,	Accepted
										And FCEV	
Moderator (GPS), dependent and independent variables (GHPC, REP, EGGH, and FCEV).											

Hypothesis (H4) assumes that GPS does not act as a moderator in the relationships between GHPC, REP, EGGH, and FCEV. The results of the multiple regression analysis are shown in Table 6. It contains some important statistics for evaluating the relevance and mitigation effects of GPS. The R2 determines the amount of variation in FCEV adoption that can be explained by the independent variables (GHPC, REP, and EGGH). In this case, the R2 value is 0.717, indicating that approximately 71.7% of the variance in FCEV deployment is due to independent variables. The adjusted R2 is 0.715. The statistical significance of the model coefficient is indicated by a p-value of 0.000. The F change value (345.906), indicating that the addition of moderators had a significant impact on the explanatory power of the model. Based on the statistical results, it can be concluded that GPS acts as a moderator in the relationship between GHPC, REP, EGGH, and FCEV. The p-value for the F-change statistic is below the significance level, indicating that the moderation effect is significant. Therefore, H4 is accepted, suggesting that GPS moderates the relationship.

5. Conclusion

In conclusion, this study explored the significant role of GH in transforming electricity generation and fueling automotive vehicles. The investigation utilized a quantitative research approach with a comprehensive online survey. The study's findings illuminated crucial insights into the relationships between variables, highlighting the intricate dynamics within the context of GH adoption and sustainability. The demographic analysis showed diverse participants' profiles, ranging from age groups and educational backgrounds to occupations and electric vehicle ownership. The correlation analysis substantiated H1, affirming a significant positive relationship between GHPC, REP, and EGGH. The strong correlations between these variables underscored their interdependence, in line with existing literature. The correlation analysis supports H2, revealing a significant positive correlation between EGGH and the adoption of FCEVs. This indicated the potential synergy between these two variables in driving sustainable transportation solutions. The mediation analysis identified GHC as a mediator in the relationship between GHPC and EGGH. The regression analysis confirmed GPS as a moderator, strengthening the relationship between GHPC, REP, EGGH, and FCEV. These findings emphasize the intricate web of relationships within the realm of GH technology adoption, energy generation, and transportation. As the global community seeks sustainable energy solutions, understanding these complex interactions becomes paramount. This research contributes to the ongoing discourse on GH's potential for revolutionizing energy systems and transportation. It underscores the importance of addressing both technological and policy aspects to realize a cleaner and more sustainable energy future.

6. Implications

The findings of this study have important implications for policymakers, researchers, and industry seeking to harness the potential of GH for a sustainable energy transition. Policymakers can use the insights gained from this research to support the design and implementation of supportive policies that promote GHPC, REP, and FCEV adoption. This study provides valuable information on the trade-offs in designing policies for low-carbon energy production and building local industries around RE techniques (Matsuo & Schmidt, 2019). It also stresses the need to phase out traditional supportive measures such as net metering and feed-in tax in favor of market-based mechanisms that are more adaptable to increased RE generation. The study (Carley & Konisky, 2020) highlights the importance of considering equity and equity aspects of the energy transition so that no one is left behind.

Government policies may accelerate the shift to greener energy sources. The positive correlations found between GHPC, REP, EGGH, and FCEV variables highlight the correlation of these variables in promoting a sustainable energy transition. Promoting GH production and integrating RE could lead to increased EGGH and greater adoption of FCEVs (Veenstra et al., 2021). The intermittent nature of RE sources can cause inconsistencies in the grid, by enhancing system flexibility, GH production and storage can offer a solution. Renewable-generated GH can help achieve net zero emissions and decarbonize energy-intensive industries (Bianco & Blanco, 2021). Integrating RE and hydrogen production plants will reduce the need for new transmission lines and save investments in distribution equipment. The flexibility of hydrogen production systems can support the deployment of FCEVs by minimizing disruption to RE and hydrogen production from water electrolysis, thereby contributing to the decarbonization of the transport sector. contribute.

The industry can strategically invest in research, development, and commercialization of GH technologies. GH has the potential to decarbonize energy-intensive industries and boost renewables in the energy mix. It facilitates the switch to GH as a fuel and chemical industrys' raw materials because it can be utilized in both capacities. The use of GH as a key reactant in chemical production can facilitate convergence toward sustainable practices (Zhang et al., 2021). Understanding the positive correlation between GHPC and EGGH highlights the importance of increasing GH production capacity to improve sustainable power generation. A mediation analysis showing the cost of GH as a mediator highlights the importance of cost-reduction efforts (Taibi et al., 2020). Efforts to lower the cost of GH will drive adoption and integration in various sectors. The positive correlation between EGGH and FCEV deployment suggests that advances in GH power generation may help reduce GHG emissions through increased FCEV deployment (Oliveira et al., 2021). Researchers can develop these findings further by examining more subtle interactions between the introduction of GH and other variables. Further research may address the role of technological advances and regulatory frameworks in promoting GH technologies. These implications underscore the pivotal role GH plays in shaping the future of power generation and transportation. By focusing on the implementation of GHPC, REP, EGGH, and FCEV, stakeholders can work together towards a more sustainable and greener energy environment.

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