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Article

Bridging the Gap: Public Perception and Acceptance of Hydrogen Technology in the Philippines

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Abstract: The study examines the effects of transitioning to hydrogen production in the National Capital Region (NCR) and Palawan Province, Philippines, focusing on technology, environment, and stakeholder impact. The research, conducted through a July 2022 survey, aimed to assess public awareness, knowledge, risk perception, and acceptance of hydrogen and its environmentally friendly variant, green hydrogen, infrastructure. Disparities were found between urban NCR and rural Palawan, with lower awareness in Palawan. Safety concerns were highlighted, with NCR respondents generally considering hydrogen production safe, while Palawan respondents had mixed feelings, particularly regarding nuclear-based hydrogen generation. The report emphasizes the potential ecological advantages of hydrogen technology but highlights potential issues concerning water usage and land impacts. It suggests targeted public awareness campaigns, robust safety assurance programs, regional pilot projects, and integrated environmental plans to facilitate the seamless integration of hydrogen technology into the Philippines' energy portfolio. This collective effort aims to help the country meet climate action obligations, foster sustainable development, and enhance energy resilience.

Keywords: hydrogen; energy transition; green hydrogen; acceptance; renewable energy philippines; public perception; hydrogen infrastructure; sustainable energy

Introduction

Background of the Study

The Philippines committed in 2015 to the 2016 Paris agreement to meet its pledge by implementing the national climate action plan by integrating climate change into national and local development plans for sustainable electricity production in the country [1]. Renewable Energy (RE) resources, such as solar and wind, need to expand their penetration into the country's national energy mix to attain its commitment to the 1.5 Paris agreement. However, solar and wind energy technology's intermittent output and mismatched peak production with peak demand pose a significant challenge for existing island grid integrations, resulting in grid instability and curtailment of electricity supplies to its end users [2]. The high generation cost of electricity during a peak-demand period is another fundamental concern in the electricity market. The price of electricity at peak-demand periods is higher than during off-peak periods. In peak periods, electricity consumption is higher than average, power supplies must complement the low-cost base-load power plants (coal and nuclear) with less cost-effective but more flexible forms of generation, such as diesel, bunker fuels, and gas-fired generators. During off-peak periods, when less electricity is consumed, costly types of generation can be stopped. This is the chance for the electrical energy storage systems to benefit financially by storing excess energy from low-cost energy sources such as solar and wind. When solar and wind energy conversion technology is not feeding the grid, electrochemical energy storage technologies such as batteries are used to store energy for later use which resolves the electricity production challenges faced by these RE technologies. But batteries have a low electrical

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energy return by a device over its lifetime ratio [3]. This makes batteries have low output energy from energy stored than the joule invested in manufacturing a battery system [4]. Another issue with battery storage is that it is difficult to dispose of safely [5]. In hydrogen storage systems, the catalyst can be reclaimed in a Hydrogen electrolyzer (PEM) at the end of its life, which is not the same for batteries, thus reducing the impact on the environment [6]. Another pressing issue with batteries as a storage facility for the grid in support of RE is that existing commercial batteries developed today are for short-term energy storage and can only provide enough energy to support local grids for approximately four hours or less [7]. Grid-scale hydrogen energy storage system is another viable electrochemical energy storage technology that can be integrated into low-cost solar and wind energy conversion technologies to complement its variable nature and meet end-use requirements as a zero-emission massive energy storage capacity for the grid. As seen in nuclear power, public perception and acceptance of hydrogen, its utilization, and supply technologies are considered important factors for future hydrogen penetration. However, hydrogen utilization is an emerging technology and new to the public, so the current status of public acceptance is still unknown. It should also be noted that public perception and acceptance of the technology could be influenced by trends and incidents of the time. Such examples include the Hindenburg disaster in 1937 and the hydrogen explosion at the Fukushima nuclear plant in 2011, which can be associated with green hydrogen by the public. This study analyzes the current status, public perception, and acceptance of green hydrogen infrastructure. The results will help facilitate communication when promoting hydrogen use all over the Philippines in the coming years as a sustainable grid-size energy storage system.

Related Literature

Outside of the Philippines, there has been considerable research on the societal acceptability of hydrogen and its usage methods. There are two major academic approaches to such studies: the economic and the social-psychological. The former researches social acceptability from an economic standpoint, primarily via consumer surveys of devices and equipment, concentrating on "willingness to pay" for, e.g., hydrogen reformers used as backup power in cell sites, to provide recommendations for legislators and the marketing profession. The latter evaluates societal acceptability and risk awareness of facility placements, such as hydrogen stations and pipelines, to guide facility location choices in communications and dialogues, but not from an economic standpoint. When combining the two methodologies outlined above in a single research project, the social-psychological approach is prioritized, while the economic approach is partially utilized. Hydrogen is seen as an essential component of future low-carbon energy systems. However, social acceptance must be considered to apply hydrogen technology broadly. Studies on the acceptability of hydrogen technology have shown neutral to favorable results. Reports build on prior research by concentrating on large-scale hydrogen infrastructure in countries like Germany. Quantitative data on acceptability was acquired among the German people as part of the reported study. The findings support the widespread good impression of hydrogen. However, acceptability is dwindling regarding infrastructure deployment in one's neighborhood [8], examining which socio-psychological and communal elements influence opposition to Green Hydrogen, including, but not limited to, perceived procedural and distributive justice, as well as investigating the origins of the Not in My Backyard (NIMBY) notion and proposing alternatives based on what may influence the rollout of Green Hydrogen.

This literature review crucially highlights the significant opportunities that hydrogen technology presents for the Philippines to tackle its variable renewable energy challenges and achieve its sustainability goals. The paper is dedicated to closing the knowledge gap on hydrogen technology adoption and offering actionable insights for stakeholders.

Some problematic aspects of prospective hydrogen futures include hydrogen generation from nuclear power, massive onshore wind, and solar farms, or fossil fuels with carbon capture and storage [9]. Therefore, public familiarity with hydrogen technology applications, attitudes toward safety, and the capacity of hydrogen technologies to satisfy desired affordability, convenience, and performance are expected to be crucial factors in its broad adoption; consider the dissemination of these technologies is viable and ready for mass commercialization. In that case, the public must be

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informed about hydrogen technologies' possible uses and consequences and be involved in their early manifestations in various places.

To assess how social acceptance of green hydrogen changes with economic development, a panel data methodology was used by Bing Wang et al. in their research to examine the forces encouraging hydrogen-based renewable energy use in a group of 32 nations[10]. The main findings over the research of Bing Wang et al. show that:

1. GDP per capita is a significant positive contributor to renewable energy consumption, whereas oil prices do not have a strong relationship with renewables.
2. Social awareness about climate change and concerns about energy security are insufficient to motivate the switch from traditional to renewable energy sources.
3. The role of urbanization in renewable energy consumption is dependent on the different stages of urbanization.

These findings indicate that the market mechanism is not to blame for increasing the use of renewables. Instead, future research should expand energy security concerns in renewable use and should be extended further on social acceptance of Hydrogen-renewable energy. The prospects of using hydrogen energy in electricity production pose a substantial challenge. Nonetheless, despite much study and knowledge on the benefits of hydrogen energy, it is fraught with controversy in many nations. Moreover, globally, there is a lack of awareness of the hydrogen energy generation process and its benefits, raising worries about its consistency [11]. Therefore, an innovative questionnaire must be employed as a research method in this study to examine residents' attitudes toward nations where hydrogen energy is underused and the infrastructure for hydrogen energy is inadequate. Respondents discussed their environmental attitudes and their understanding of hydrogen energy and the utilization of hydrogen fuel. The findings reveal that society is not satisfied that the safety requirements for hydrogen-derived energy are appropriate. Furthermore, it is a fact that information regarding Hydrogen as an energy carrier and its product safety and storage techniques is quite limited, especially in countries where Hydrogen is in its infancy. Therefore, negative attitudes against hydrogen energy can significantly impede its growth in many nations, including the Philippines.

Statistical Analysis

In the works of Lapham et al. on the perception of safety to park use, they first assessed the characteristics of survey participants using descriptive statistics. Then they used chi-square tests to see if there were significant differences across their four identified sites. Following this, they performed statistical modeling for the binary and categorical outcomes of park visitation. Finally, they use statistics to model park visitors' binary and categorical consequences. Their research generated outcome variables from the primary inquiry, "How often do you visit this park?" (answers ranged from 'everyday' to 'never'), and 'What do you often do in this park?' Next, using a logistic regression model, they analyzed the binary outcome, 'ever visited your park.' When the 'felt safety' variable emerged as a crucial predictor of park utilization, they studied its related components in further detail. Finally, they performed a mediation study on the model examining the elements associated with ever visiting the park, using 'felt safety' as a possible mediator for the influence of neighborhood physical incivilities on the models using the traditional mediation analyses from Baron and Kenny (1986) [12]. This method of interpreting Likert data is an excellent way to visualize and analyze the collected data.

Senlier et al. conducted an Urban Audit of 31 European cities using subjective indicators. Satisfaction related to urban Quality of Life (QoL) was measured from the perspectives of employment opportunities, housing costs, urban safety, cleanliness of cities, satisfaction with public transport, air quality, and integration of residents, and comparisons were made between the cities. Based on the Urban Audit surveys, 300 perception questionnaires were conducted with Kocaeli residents for this research. Researchers utilize techniques and methodologies in these studies like ANNOVA, NULL hypothesis, LISREL, SEM, and Regression Analysis. Utilizing SPSS (Statistical Package for the Social Sciences) statistical analysis software, the survey findings were analyzed using

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factor analysis and regression analysis. In addition, Kocaeli's urban QoL indicators were subjected to factor analysis, a form of multivariate analysis, to determine their factor structure. The purpose of factor analysis is to reduce the number of interconnected data structures to a smaller number of unconnected data structures and to uncover common factors by grouping the variables. The Linear Regression Analysis exposes the causal connection between one connected and one unrelated set of variables to discover the functional relationship between the variables. Consider, for instance, that variable X is unconnected and variable Y is related. The operative connection between the two variables may thus be expressed as Y = f. (X). Y may be generated by giving the value Xi to X. [13]

The Mann-Whitney U test is another well-known nonparametric test for comparing outcomes between two independent groups. The Mann-Whitney U test, also known as the Mann-Whitney Wilcoxon Test or Wilcoxon Rank Sum Test, is used to determine whether or not two samples were likely drawn from the same population (i.e., that the two populations have the same shape) [14] [15] [16]. According to some academics, this compares the populations' medians. The parametric test, for instance, compares the means of independent groups (H0: 1=2). This test is often administered as a two-sided test; hence, the study hypothesis suggests that the populations are unequal rather than identifying their direction. A one-sided study hypothesis is used whenever finding a positive or negative change in one group relative to the other is relevant. The process for the test consists of combining the observations from the two samples into a single sample, keeping account of which sample each observation is from, and then rating the observations from lowest to highest, from 1 to n1+n2, respectively. A similar but different way of analyzing our proposed study is using a Nonlinear (categorical) principal component analysis, or CATPCA is a statistical technique that simultaneously quantifies categorical variables and reduces the dimensionality of the data. It may also be used to interpret Likert data. The main components analysis aims to facilitate an initial collection of variables to a smaller group of uncorrelated components that capture most of the information in the original variables. The approach is especially beneficial when several variables prevent a practical understanding of the connections between items (subjects and units). Lowering the dimension allows you to comprehend a few components instead of many variables. The conventional principal component analysis assumes linear correlations between numeric variables.

In contrast, the optimal scaling method permits variables to be scaled to various values. As a consequence, categorical variables are optimally quantified in the dimension given. Thus, Likert data can easily be described between variables in this method.

Methodology

Implementation of the Survey

Here, we studied the public's awareness, knowledge, risk perception, and acceptance of hydrogen and green hydrogen infrastructure in the National Capital Region (NCR) and Palawan, Philippines. A quantitative analysis of the societal acceptability of green hydrogen technologies was conducted using a socio-psychological methodology. The questionnaire[1] was developed to support the development of a green hydrogen storage infrastructure in Palawan and NCR, Philippines.

The poll was performed online using a Google form in July 2022. Using an online Google form makes it very simple to collect a small sample in a short amount of time during the pandemic. However, the drawback of utilizing a Google form survey online is that response rates are often low, and respondents are voluntary participants. Table 1 displays the implementation of fundamental data and the characteristics of the survey sample. Cochran's sample size (n_0) formula was adopted to calculate the desired sample size of the survey.

Table 1. Data implementation of the survey and the characteristic of the sample.

	NCR	Palawan	PPC	Narra

[1] See Appendix A

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N	22	72	61	11
Average Response Rate	42.307%	45.860%	47.656%	36.667%

In this study, we carefully selected regression analysis and Mann-Whitney U tests to understand the factors influencing public acceptance of hydrogen technology in the Philippines. The backward regression analysis was especially effective in pinpointing the critical determinants of public perception. At the same time, the Mann-Whitney U test facilitated a thorough comparison of awareness levels across various regions.

Analytical Method

We use cross-tabulation to compare the survey results to those of NCR and Palawan. To find the influence of respondents' awareness, knowledge, and perception of green hydrogen and hydrogen infrastructure on their acceptance of hydrogen as a grid-scale hydrogen energy storage system, we use a stepwise backward regression method to include or exclude variables, adopting 0.05 for inclusion and 0.10 for exclusion in the significance level of F-statistics.

Discussion and Data Analysis

Awareness

The survey[2] findings reveal the current state of hydrogen technology awareness and its immense potential. Notably, there are disparities in awareness between the metropolitan National Capital Region (NCR) and the rural regions of Palawan. Within the NCR, almost 40% of the participants exhibited knowledge of hydrogen energy; however, in Palawan, just 30% of the respondents possessed this awareness. The initial data suggested that respondents predominantly linked hydrogen with electric automobiles rather than broader energy applications, indicating the untapped potential of hydrogen technology.

The Philippines Department of Energy (DOE) is not just a participant but a leader in the country's energy transition. The Green Energy Option Program (GEOP) and large-scale battery energy storage projects are critical elements of their strategy to integrate Renewable Energy (RE) into the national energy mix by 2024 [17]. This underscores the DOE's authority and responsibility in driving the adoption of grid-size energy storage, such as green hydrogen technology and other renewable energy sources.

The study results underscore the necessity of tailored policy-making to address the regional disparities in hydrogen technology awareness. In the NCR, where awareness levels are relatively higher (see Figure 1), policymakers should focus on promoting the broader applications of hydrogen technology beyond electric vehicles. The DOE can achieve this by implementing public

[2] AQ1 Are you aware that hydrogen can be used instead of a battery to store electricity produced from intermittent renewable energy sources such as Solar and Wind?

AQ2 Hydrogen is being used for industrial and communication applications.

AQ3 Hydrogen is being used in residential and commercial applications.

AQ4 Hydrogen can be used to provide power for the transport sector (buses, cars, planes, etc.)

AQ5 Hydrogen can be supplied using excess energy from solar and wind conversion technologies which can benefit the grid by addressing the variable, unpredictable renewable power, and provide high capacity and long-term energy storage for seasonal shifting.

AQ6 Electricity from a renewable energy source, e.g. wind power, photovoltaics, hydropower, and geothermal power, is used for the electrolysis of water to produce Hydrogen

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communication campaigns, such as social media awareness drives and community forums, organizing seminars with industry experts, and fostering collaborations with educational institutions to include hydrogen technology in their curriculum. This localized approach is crucial for highlighting the importance of hydrogen in energy storage and grid stability maintenance.

More significant efforts are needed to establish a solid foundation for raising awareness in Palawan. The key to this lies in community participation, which should be the primary focus of policies. By utilizing local leaders and influencers, who are trusted and respected figures in the community, we can effectively communicate the advantages and potential ecological consequences of hydrogen technology. Customized educational initiatives that are adapted to specific local circumstances can play a crucial role in clarifying the intricacies of hydrogen technology and fostering public confidence, making the community feel involved and important in this process.

Consciousness is crucial in accepting and implementing novel technology [18]. The elevated levels of awareness in the National Capital Region (NCR) indicate preparedness for conducting pilot projects and demonstrations of hydrogen technology. These initiatives can demonstrate the tangible advantages of hydrogen energy, such as its high energy density, zero greenhouse gas emissions when used in fuel cells, and its potential to be produced from diverse, locally available resources, promoting broader recognition and implementation.

In Palawan, the limited awareness levels emphasize the necessity for smaller-scale, community-based initiatives that engage local stakeholders from the beginning. These programs should prioritize showcasing hydrogen technology's safety, dependability, and ecological advantages, progressively fostering public trust. People in Palawan have never heard of using green Hydrogen for electricity production, and they associate Hydrogen only with electric vehicles. On the other hand, people in Palawan associate hydrogen with fuels derived freely in the water and perceive it as a long-term solution based on their direct experience with the extremely high cost of petroleum products in the entire province of Palawan.

Regarding awareness of PPC, there is still have an upward trend in green hydrogen used as an energy carrier with application to the transport sector by about 30% of respondents. However, there is a downward trend of awareness among residents of PPC and Narra for green Hydrogen in providing electricity for communication, residential, industrial, and commercial sectors despite the fact most telecommunication companies have been using Hydrogen as backup power for their cell towers for decades [19] [20] [21] though none for commercial generation of electricity.

Integrating hydrogen technology with renewable energy sources can effectively decrease greenhouse gas emissions [22], which aligns with the Philippines' climate action obligations. However, it is important to openly and honestly address the potential environmental issues associated with hydrogen production, including water use [23] and land effects [24]. For instance, hydrogen production through electrolysis can lead to increased water consumption, and large-scale hydrogen storage facilities may require significant land area. Rest assured, policy-making and project implementation will incorporate thorough environmental assessments and sustainable practices, giving you confidence in the proposed strategies.

The poll revealed a need for more comprehension of hydrogen technology, specifically in rural regions such as Palawan (see Figure 1). Lack of knowledge and misunderstanding about hydrogen in general are some of the identified obstacles. To tackle awareness issues, educational efforts should prioritize the dissemination of scientific knowledge and the advantages of hydrogen energy, employing language that is both comprehensible and easily understandable.

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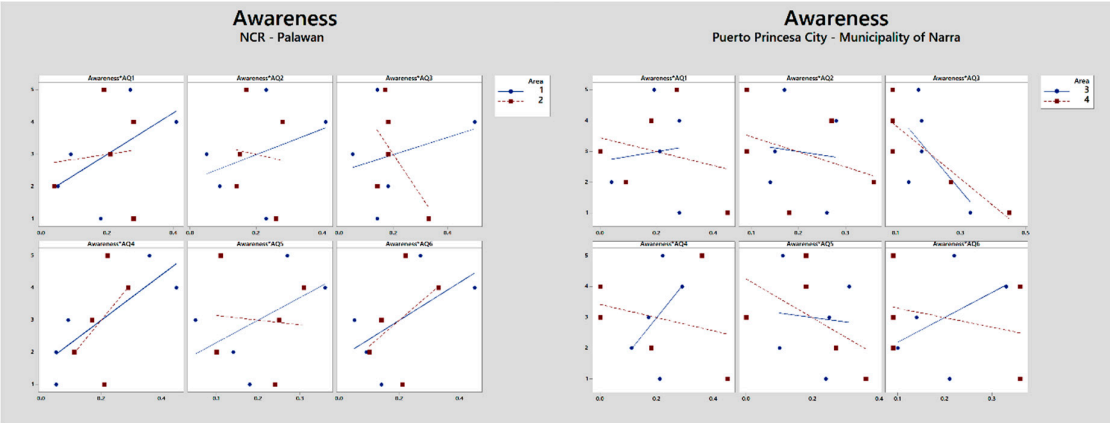

Figure 1. This figure shows the awareness levels of green hydrogen and hydrogen infrastructure for NCR (1), Palawan (2), Puerto Princesa City (PPC) (3), and Narra (4). The differences in awareness levels highlight the need for regional-specific educational campaigns.

Developing the essential infrastructure for hydrogen technology necessitates substantial expenditure. Enacting policies encouraging private sector involvement and offering financial assistance for hydrogen projects might address this obstacle. Public-private partnerships and international cooperation are also essential in contributing significantly.

A well-defined and facilitative regulatory framework is crucial for advancing and implementing hydrogen technology. Regulations guarantee the preservation of safety, the safeguarding of the environment, and the promotion of technical advancement. Consistent updates and conversations with stakeholders can assist in refining these policies to tackle growing difficulties and capitalize on new opportunities effectively.

Establishing public trust and acceptance is crucial for effectively implementing hydrogen technology. By utilizing participatory methodologies, ensuring transparency in project planning, and addressing local issues, hydrogen projects can effectively engage local communities and create a favorable climate [25].

By overcoming these obstacles and implementing the suggested remedies, the Philippines may bolster public consciousness and backing for hydrogen technology, thus advancing its sustainable development objectives and climate action obligations.

Knowledge

The survey revealed significant knowledge of hydrogen technology differences between respondents in the metropolitan National Capital Region (NCR) and those in the rural districts of Palawan. In the NCR, over half of the participants demonstrated a fundamental understanding of hydrogen energy and its potential uses, while in Palawan, this percentage decreased to approximately 30%. These disparities highlight the need for focused educational programs to bridge the information gap and promote a consistent understanding of hydrogen technology across different geographical areas.

We conducted a survey[3] with questions covering various aspects of hydrogen, including efficiency, flammability, cost, emissions, water impact, sustainability, technology viability, and the

[3] KQ1 Do you think making green hydrogen uses more energy than it yields, so it is prohibitively inefficient?*
KQ2 Do you think Hydrogen is too dangerous, explosive, or volatile for everyday use as fuel for electricity production?*
KQ3 Do you think delivering hydrogen to users would consume almost the same amount of energy it contains?*

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need for other energy sources to produce hydrogen. Most respondents provided neutral answers to most questions, except for question KQ2, where respondents viewed hydrogen as a volatile and flammable fuel similar to fossil fuels. Additionally, most respondents expressed skepticism about the sustainability of green hydrogen. Recent concerns about hydrogen's safety and sustainability and its association with the Fukushima nuclear accident influenced respondents' views. Moreover, due to the increase in natural gas terminal infrastructure projects, respondents mistakenly associated hydrogen with natural gas. We also provided a brief description of how hydrogen is produced from splitting water molecules in the survey materials. About 40% of respondents expressed concerns about the potential impact of hydrogen production on local water supplies in the event of a large-scale hydrogen economy. Despite their knowledge of hydrogen, most respondents are unfamiliar with how green hydrogen infrastructure operates.

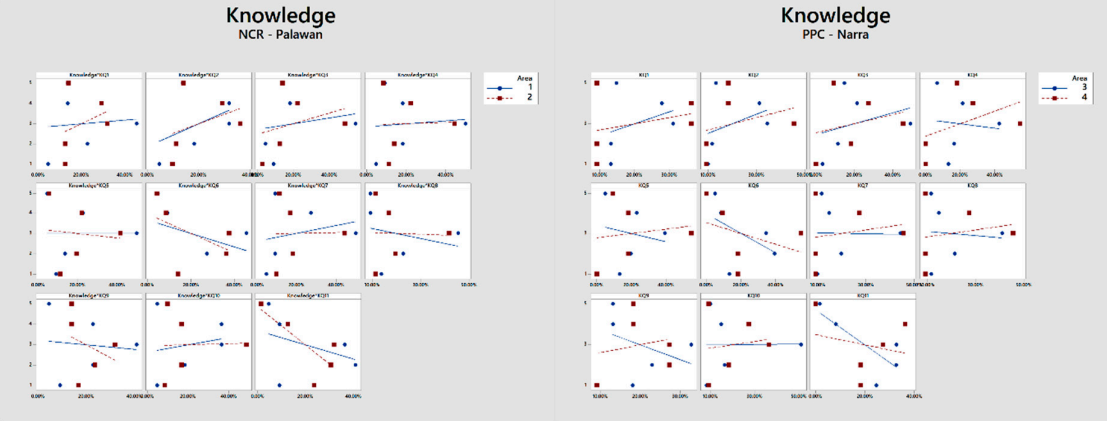

Figure 2. Knowledge of green hydrogen and hydrogen infrastructure for NCR (1), Palawan (2), Puerto Princesa City (PPC) (3), and Narra (4).

The study findings suggest that policymakers should develop tailored educational initiatives to enhance public awareness and understanding of hydrogen technology in specific regions. In the NCR, where basic knowledge is already advanced, policies should concentrate on improving understanding and highlighting the practical uses of hydrogen in daily life and industrial settings. In Palawan, the primary focus should be on providing comprehensive education about hydrogen technology, including its benefits and significance in promoting sustainable energy transitions.

Acquiring knowledge is crucial for successfully implementing new technology. The elevated level of foundational knowledge in NCR indicates readiness to participate actively in and embrace

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KQ4 Do you think renewable energy is too costly that hydrogen would have to utilize electricity produced from fossil fuels or nuclear power?*

KQ5 Do you think a viable hydrogen transition in the Philippines would take 30-50 years or more to complete, and hardly anything worthwhile could be done sooner than 10-20 years?

KQ6 Do you think there are more attractive ways to provide sustainable electricity and fuels than adopting green hydrogen?*

KQ7 Would a large-scale hydrogen economy harm the Earth s climate, water balance, or atmospheric chemistry?*

KQ8 Do you think Green Hydrogen is too expensive to compete with coal and liquid fossil fuels?*

KQ9 Do you think Incumbent industries (e.g., Coal, Petroleum) oppose hydrogen as a competitive threat?*

KQ10 Do you think a hydrogen economy would retard the adoption of renewable energy by competing for research and development budget, being misspent, and taking away future market?

KQ11 Do you think a sustainable production of electricity and fuels is possible with Green Hydrogen.?*

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hydrogen technology. Therefore, public demonstrations, seminars, and partnerships with educational institutions may enhance the acceptance and utilization of technology in this area. Conversely, in Palawan, it is imperative to implement educational programs that establish a solid knowledge base and rectify any misunderstandings regarding hydrogen technology.

Integrating hydrogen technology with renewable energy sources can significantly reduce greenhouse gas emissions in line with the Philippines' climate action objectives [22]. However, effectively conveying the environmental benefits of hydrogen technology to the public is crucial in obtaining support and facilitating its adoption. Emphasizing successful case studies and tangible benefits can help cultivate a favorable attitude and widespread adoption of hydrogen technology.

To address the significant knowledge gaps, particularly in rural regions like Palawan, specific educational programs focusing on the scientific aspects, benefits, and practical uses of hydrogen technology are necessary. Partnerships with nearby educational institutions and community leaders can enhance the scope and effectiveness of these efforts.

Developing the necessary infrastructure for hydrogen technology requires substantial investment. Enacting policies encouraging private sector involvement and offering financial assistance for hydrogen initiatives will help overcome this obstacle. Public-private partnerships and international cooperation are also essential for making significant contributions.

Establishing a distinct and supportive regulatory framework is crucial for advancing and implementing hydrogen technology. Regulations should be designed to ensure safety, protect the environment, and promote technological advancement. Regular updates and discussions with stakeholders can help improve these regulations and effectively address new challenges and opportunities.

Community Engagement: Establishing public trust and acceptance is crucial for the effective implementation of hydrogen technology. By implementing participatory methodologies, ensuring transparency in project planning, and addressing local issues, hydrogen projects can effectively engage local communities and create a favorable climate.

By overcoming these obstacles and implementing the suggested remedies, the Philippines can enhance public awareness and endorsement of hydrogen technology, thus advancing its sustainable development objectives and climate action obligations.

Risk Perception

Our survey found that the perception of risk associated with hydrogen generation differs dramatically between the urban National Capital Region (NCR) and the rural districts of Palawan. Respondents from the National Capital Region (NCR) generally perceive hydrogen as safe, regardless of the energy source. On the other hand, respondents from Palawan have a more neutral position, especially when it comes to using nuclear energy for hydrogen generation. This discrepancy is crucial in comprehending geographical variations in the adoption of hydrogen technology. Initially, the data revealed from our survey questions[4] on risk perception that approximately 40% of Puerto Princesa City (PPC) participants and 80% in Narra maintained a neutral stance toward

[4] RPQ1 How safe do you think the Hydrogen Production is operated using energy from Solar?

RPQ2 How safe do you think the Hydrogen Production is operated using energy from Wind?

RPQ3 How safe do you think the Hydrogen Production is operated using energy from Natural gas?

RPQ4 How safe do you think the Hydrogen Production is operated using nuclear energy?

RPQ5 How safe do you think the Hydrogen Production is operated using energy from Hydropower?

RPQ6 How safe do you think the Hydrogen Production is operated using energy from Geothermal?

RPQ7 How safe do you think the Hydrogen Production is operated using energy from waste biomass (e.g., agricultural, commercial, residential, industrial wastes)?

RPQ8 How safe do you think the Hydrogen Production is operated using energy from Coal?

RPQ9 How safe do you think the Hydrogen Production is operated using energy from Petroleum?

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utilizing nuclear energy for hydrogen production. Furthermore, 40% of respondents in PPC and 50% in Narra had neutral risk views about using coal and petroleum for hydrogen production. PPC and Narra exhibited an optimistic attitude toward green hydrogen, indicating an increasingly favorable perspective on reducing reliance on fossil fuels and mitigating global warming.

By 2024, the energy landscape in the Philippines is undergoing significant changes as renewable energy sources are being more extensively integrated [26]. The goal is to meet the country's climate action goals by substantially cutting greenhouse gas emissions [27]. This situation underscores the importance of tailored policies that specifically address regional perspectives and promote the development of hydrogen technology. Metropolitan regions like the National Capital Region (NCR) show greater receptiveness, indicating readiness for rapid implementation of hydrogen infrastructure, while remote areas like Palawan require targeted educational initiatives to foster understanding and confidence. The survey has highlighted environmental challenges such as land usage and hazardous waste management, emphasizing the need for comprehensive environmental measures. Leveraging positive perceptions of hydrogen's potential to reduce reliance on fossil fuels can enhance acceptability. However, addressing safety concerns and ensuring thorough environmental evaluations is crucial to maintaining public confidence and support for hydrogen projects.

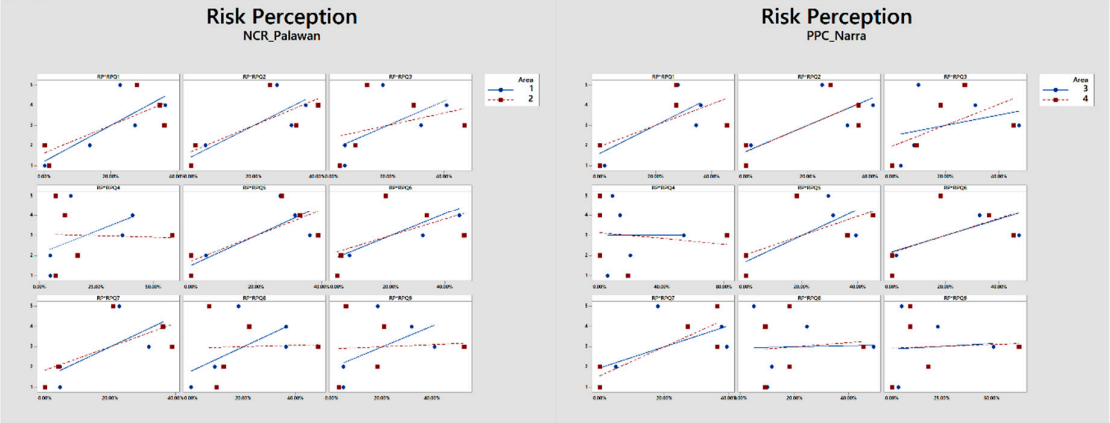

Figure 3. Risk Perception of green hydrogen and hydrogen infrastructure for NCR (1), Palawan (2), Puerto Princesa City (PPC) (3), and Narra (4).

Recommendations:

a. Implement focused public awareness initiatives in Palawan to enhance knowledge and comprehension of hydrogen technology and its advantages.
b. Safety assurance programs involve implementing safety demonstration projects and establishing transparent communication channels to address safety issues related to hydrogen production based on nuclear energy.
c. Policy support for pilot projects: Promote the implementation of regional pilot projects in urban and rural areas to showcase the feasibility and security of hydrogen technology.
d. Implement integrated environmental strategies to build extensive environmental management plans specifically targeting land use and waste management concerns related to hydrogen generation.

Acceptance

The poll[5] we conducted showed notable geographical disparities in the level of acceptance for hydrogen generation between the metropolitan National Capital Region (NCR) and the rural districts

[5] AccptQ1 : Would you support Green Hydrogen Production for power generation in your locality?

AccptQ2 : Would you support Green Hydrogen Production for power generation in other parts of the Philippines?

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of Palawan. Approximately 39% of National Capital Region (NCR) respondents expressed favorable support for the local production of green hydrogen for power generation. In contrast, 38% of respondents in Palawan indicated a preference for hydrogen production to be situated in other regions of the Philippines, citing environmental concerns. Initially, the results showed that respondents from NCR were more receptive to embracing hydrogen technology in their local area, in contrast to those in Palawan who had reservations due to potential environmental effects and desired hydrogen production to be located elsewhere (See Figure 4). We also conducted a regression analysis to elucidate how respondents' characteristics and perceptions of green Hydrogen and hydrogen infrastructure are influenced by the acceptance of locating Hydrogen production near the respondents' homes. This statistical analysis answers "Would you support Green Hydrogen Production for power generation in your locality?" as the dependent variable, and endogenous variables from answers to questions on awareness, knowledge, and risk perception about green Hydrogen and Hydrogen infrastructure in the questionnaire. The result of the regression is shown in Tables 2 and 3.

By 2024, the Philippines will explicitly concentrate on developing solar, wind, and hydroelectric power while utilizing energy storage facilities like hydrogen as a energy storage as a supplementary energy source [28]. The changing energy landscape requires policies tailored to each region that tackle local attitudes and encourage hydrogen technology deployment. In promoting the adoption of hydrogen technology in NCR, it is crucial to prioritize policies that expedite the establishment of hydrogen infrastructure and its integration with pre-existing renewable energy sources. Palawan's policies should prioritize rural and urban Community interaction and education to foster trust and effectively solve environmental problems.

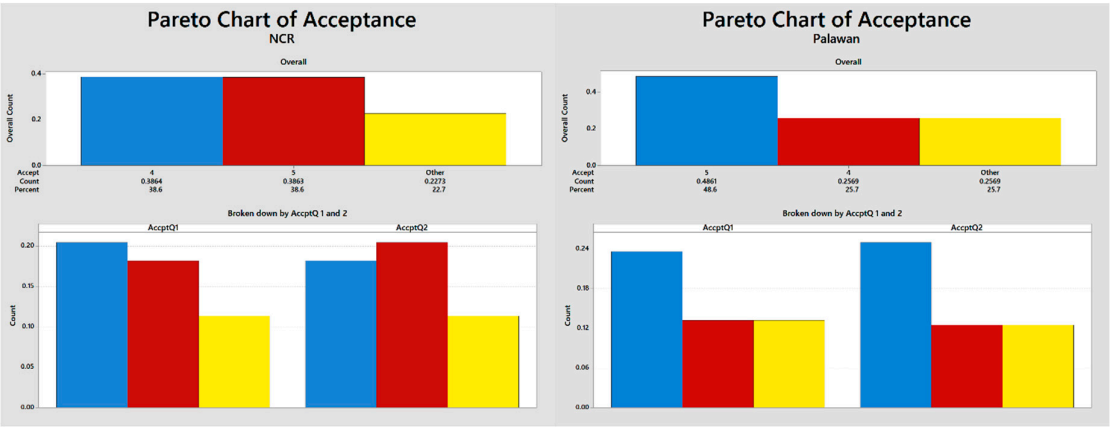

Figure 4. Acceptance of green hydrogen and hydrogen infrastructure for NCR (1), Palawan (2).

Our environmental profiling has revealed promising results, with hydrogen technology showing potential for significant decreases in greenhouse gas emissions and global warming potential. While there are challenges associated with land use and hazardous waste management, the ecological advantages of hydrogen, such as reduced greenhouse gas emissions, offer a beacon of hope. By conducting thorough environmental evaluations and implementing robust management techniques, we can confidently navigate these challenges and pave the way for a greener future.

The varying acceptance levels suggest a universal approach to adopting technology may yield different results. Within the NCR, where there is a higher level of acceptance towards hydrogen generation, it is possible to commence pilot projects and demonstrations to demonstrate the advantages and safety of hydrogen technology effectively. Conversely, implementing smaller-scale initiatives alongside comprehensive community involvement in Palawan can effectively address concerns and establish a basis for wider acceptability.

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Table 2. Results of regression analysis (Backward Elimination) using endogenous variable in the survey.

	Variable	P-Value
Knowledge	Do you think a viable hydrogen transition in the Philippines would take 30-50 years or more to complete, and hardly anything worthwhile could be done sooner than 10-20 years?	0.045
Risk Perception	How safe do you think the Hydrogen Production is operated using energy from Solar?	0.011
Risk Perception	How safe do you think the Hydrogen Production is operated using energy from Hydropower?	0.005

Dependent Variable: Would you support Green Hydrogen Production for power generation in your locality? The adjusted R-squared value: 0.3179, α to remove = 0.10.

Table 3. Results of regression analysis (Backward Elimination) using endogenous variable in the survey.

	Variable	P-Value
Knowledge	Do you think there are more attractive ways to provide sustainable electricity and fuels than adopting green hydrogen?	0.022
Risk Perception	How safe do you think the Hydrogen Production is operated using energy from Solar?	0.001
Risk Perception	How safe do you think the Hydrogen Production is operated using energy from Geothermal?	0.012

Dependent Variable: Would you support Green Hydrogen Production for power generation in other parts of the Philippines? The adjusted R-squared value: 0.3407, α to remove = 0.10.

For respondents who favor green Hydrogen production outside of their locality, we found that most respondents feel there are more sustainable ways of producing electricity than Hydrogen (see Table 3). In addition, the respondents' risk perception of associating hydrogen production with nuclear energy is that they view the technology readiness of hydrogen as not viable with the current electricity distribution infrastructure in the Philippines.

It is essential to acknowledge that the sample size used in this study is relatively small, especially for Palawan. This is significant as it may affect the confidence level of the statistical analysis and the strength of policy recommendations derived from this study. To enhance the reliability and applicability of the findings, future research should aim for larger and more representative samples to gain a more comprehensive understanding of the public perception of hydrogen technology.

Our findings emphasize the need for targeted policy interventions to tackle regional hydrogen awareness and acceptance differences. Negative risk perception significantly impedes the acceptance of green hydrogen and hydrogen infrastructure while recognizing the necessity of these technologies positively impacts public willingness to support hydrogen production facilities near their locality or residence. This highlights the crucial role of targeted policy interventions to bridge these gaps.

In NCR, where hydrogen awareness is relatively high, it is important to concentrate on expanding public understanding of hydrogen's broader applications. This will increase hydrogen awareness and aid in the acceptance of hydrogen technology. Conversely, Palawan requires grassroots-level awareness campaigns and pilot projects to build trust in hydrogen technology.

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Addressing the potential obstacles to the widespread adoption of hydrogen technology is essential. The survey results revealed a need for greater awareness and understanding of hydrogen technology, particularly in Palawan. Awareness of hydrogen-related issues is crucial for developing focused educational programs to inform the public about the advantages and safety of hydrogen generation. Respondents in Palawan also raised environmental concerns, especially regarding the impact on water resources and land usage. These issues underscore the necessity of conducting comprehensive ecological impact assessments and effectively communicating the results to the public.

Additionally, a substantial allocation of funds for infrastructure development is needed to support the implementation of hydrogen technology. Policies encouraging private sector investment and offering financial assistance for hydrogen projects can help overcome these barriers. Ultimately, it is crucial to establish a transparent and supportive regulatory framework that prioritizes safety, environmental preservation, and technological advancement.

Recommendations:

a. Implement focused public awareness initiatives in Palawan to enhance knowledge and comprehension of hydrogen technology and its advantages.
b. Safety Assurance Programs aim to execute safety demonstration projects and establish transparent communication channels to effectively resolve safety concerns, specifically about hydrogen production based on nuclear energy.
c. Policy assistance for experimental initiatives: Promote localized pilot initiatives in urban and rural regions to showcase the feasibility and security of hydrogen technologies.
d. Implement Integrated Environmental Strategies to create thorough environmental management strategies specifically targeting land use and waste management concerns related to hydrogen generation.

Conclusions

The study found that people in NCR and Palawan have different views on hydrogen technology. This difference is mainly due to varying levels of awareness and understanding of hydrogen-related issues and differences in environmental concerns and risk perceptions. People in NCR are more familiar with and accepting of hydrogen technology. In contrast, people in Palawan have more reservations due to perceived risks associated with hydrogen production and storage.

Our analysis reveals that higher risk perception leads to lower public acceptance of hydrogen infrastructure. This underscores the importance of addressing safety concerns and improving public awareness, especially in regions like Palawan. It also highlights the need for targeted awareness campaigns and safety programs that are tailored to the specific needs and concerns of the public in these areas.

Addressing these issues is crucial for successfully implementing and accepting hydrogen technology. Public resistance may hinder the broader adoption of hydrogen as a sustainable energy solution without understanding and mitigating perceived risks. Therefore, promoting transparent communication and public engagement is essential to build trust and support for hydrogen infrastructure development in both NCR and Palawan.

The study also underscores the significant potential of hydrogen technology to reduce greenhouse gas emissions and mitigate the effects of global warming. However, it also highlights the need for thorough environmental evaluations and sustainable practices to address potential environmental concerns, such as water consumption and land impacts. The active involvement of the community is crucial in achieving this.

The report suggests the implementation of focused public awareness campaigns in Palawan, the establishment of safety assurance programs, the promotion of regional pilot projects, and the formulation of comprehensive environmental strategies. These measures will tackle deficiencies in information, apprehensions over safety, and adverse effects on the environment, facilitating the smooth incorporation of hydrogen technology into the energy composition of the Philippines. This

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strategic maneuver will bolster the nation's efforts to address climate change, foster sustainable economic development, and strengthen energy independence.

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Appendix A (Survey Questions)

Awareness on Green Hydrogen

I would also like to know your awareness of Green Hydrogen Technology. Green hydrogen is defined as hydrogen production by splitting water into hydrogen and oxygen using electricity from renewable energy such as solar, wind, and water. Please put check (✓) on the appropriate choice.

Are you aware that hydrogen can be used instead of a battery to store electricity produced from intermittent renewable energy sources such as Solar and Wind?

Please select your level of awareness:

- Extremely aware
- Moderately aware
- Somewhat aware
- Slightly aware
- Not at all aware

Hydrogen is being used for industrial and communication applications.

Please select your level of awareness:

- Extremely aware
- Moderately aware
- Somewhat aware
- Slightly aware
- Not at all aware

Hydrogen is being used in residential and commercial applications.

Please select your level of awareness:

- Extremely aware
- Moderately aware
- Somewhat aware
- Slightly aware
- Not at all aware

Hydrogen can be used to provide power for the transport sector (e.g., buses, cars, planes, etc.).

Please select your level of awareness:

- Extremely aware
- Moderately aware
- Somewhat aware
- Slightly aware

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- Not at all aware

Hydrogen can be supplied using excess energy from solar and wind conversion technologies, which can benefit the grid by addressing the variable, unpredictable renewable power, and provide high capacity and long-term energy storage for seasonal shifting.

Please select your level of awareness:

- Extremely aware
- Moderately aware
- Somewhat aware
- Slightly aware
- Not at all aware

Electricity from a renewable energy source (e.g., wind power, photovoltaics, hydropower, and geothermal power) is used for the electrolysis of water to produce Hydrogen.

Please select your level of awareness:

- Extremely aware
- Moderately aware
- Somewhat aware
- Slightly aware
- Not at all aware

Use of Green Hydrogen (knowledge)

I would like to know your initial views on the possible use of Green Hydrogen. Green hydrogen is defined as hydrogen production by splitting water into hydrogen and oxygen using electricity from renewable energy such as solar, wind, and water. Please put a check (✓) on the appropriate space indicating how much you agree on the scale of one (1) strongly agree and five (5) strongly disagree with the statement below.

Do you think making green hydrogen uses more energy than it yields, so it is prohibitively inefficient?

Please indicate your level of agreement:

1. Strongly Agree
2. Agree
3. Neutral
4. Disagree
5. Strongly Disagree

Do you think Hydrogen is too dangerous, explosive, or volatile for everyday use as fuel for electricity production?

Please indicate your level of agreement:

1. Strongly Agree
2. Agree
3. Neutral
4. Disagree
5. Strongly Disagree

Do you think delivering hydrogen to users would consume almost the same amount of energy it contains?

Please indicate your level of agreement:

1. Strongly Agree
2. Agree
3. Neutral
4. Disagree
5. Strongly Disagree

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Do you think renewable energy is too costly that hydrogen would have to utilize electricity produced from fossil fuels or nuclear power?

Please indicate your level of agreement:

1. Strongly Agree
2. Agree
3. Neutral
4. Disagree
5. Strongly Disagree

Do you think a viable hydrogen transition in the Philippines would take 30-50 years or more to complete, and hardly anything worthwhile could be done sooner than 10-20 years?

Please indicate your level of agreement:

1. Strongly Agree
2. Agree
3. Neutral
4. Disagree
5. Strongly Disagree

Do you think there are more attractive ways to provide sustainable electricity and fuels than adopting Green Hydrogen?

Please indicate your level of agreement:

1. Strongly Agree
2. Agree
3. Neutral
4. Disagree
5. Strongly Disagree

Would a large-scale hydrogen economy harm the Earth's climate, water balance, or atmospheric chemistry?

Please indicate your level of agreement:

1. Strongly Agree
2. Agree
3. Neutral
4. Disagree
5. Strongly Disagree

Do you think Green Hydrogen is too expensive to compete with coal and liquid fossil fuels?

Please indicate your level of agreement:

1. Strongly Agree
2. Agree
3. Neutral
4. Disagree
5. Strongly Disagree

Do you think incumbent industries (e.g., Coal, Petroleum) oppose hydrogen as a competitive threat?

Please indicate your level of agreement:

1. Strongly Agree
2. Agree
3. Neutral
4. Disagree
5. Strongly Disagree

Do you think a hydrogen economy would retard the adoption of renewable energy by competing for research and development budget, being misspent, and taking away future market?

Please indicate your level of agreement:

1. Strongly Agree

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2. Agree
3. Neutral
4. Disagree
5. Strongly Disagree

Do you think a sustainable production of electricity and fuels is possible with Green Hydrogen?

Please indicate your level of agreement:

1. Strongly Agree
2. Agree
3. Neutral
4. Disagree
5. Strongly Disagree

Risk or Safety Concern (Risk perception)

I would like to know what you think of the risks or safety concerns of the possible use of Green Hydrogen production. Would you please put a check (✓) on the appropriate space and tell us how much you agree on the scale of one (1) being not safe and five (5) being safe?

How safe do you think the Hydrogen Production is when operated using energy from Solar?

Please indicate how safe you believe it is on a scale of 1 to 5:

- 1 (Not Safe)
- 2
- 3
- 4
- 5 (Safe)

How safe do you think the Hydrogen Production is when operated using energy from Wind?

Please indicate how safe you believe it is on a scale of 1 to 5:

- 1 (Not Safe)
- 2
- 3
- 4
- 5 (Safe)

How safe do you think the Hydrogen Production is when operated using energy from Natural Gas?

Please indicate how safe you believe it is on a scale of 1 to 5:

- 1 (Not Safe)
- 2
- 3
- 4
- 5 (Safe)

How safe do you think the Hydrogen Production is when operated using Nuclear Energy?

Please indicate how safe you believe it is on a scale of 1 to 5:

- 1 (Not Safe)
- 2
- 3
- 4
- 5 (Safe)

How safe do you think the Hydrogen Production is when operated using energy from Hydropower?

Please indicate how safe you believe it is on a scale of 1 to 5:

- 1 (Not Safe)
- 2
- 3
- 4
- 5 (Safe)

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How safe do you think the Hydrogen Production is when operated using energy from Geothermal?

Please indicate how safe you believe it is on a scale of 1 to 5:

- 1 (Not Safe)
- 2
- 3
- 4
- 5 (Safe)

How safe do you think the Hydrogen Production is when operated using energy from Waste Biomass (e.g., agricultural, commercial, residential, industrial wastes)?

Please indicate how safe you believe it is on a scale of 1 to 5:

- 1 (Not Safe)
- 2
- 3
- 4
- 5 (Safe)

How safe do you think the Hydrogen Production is when operated using energy from Coal?

Please indicate how safe you believe it is on a scale of 1 to 5:

- 1 (Not Safe)
- 2
- 3
- 4
- 5 (Safe)

How safe do you think the Hydrogen Production is when operated using energy from Petroleum?

Please indicate how safe you believe it is on a scale of 1 to 5:

- 1 (Not Safe)
- 2
- 3
- 4
- 5 (Safe)

Acceptance Question

Would you support Green Hydrogen Production for power generation in your locality?

Please indicate your level of support:

1. Strongly Oppose
2. Oppose
3. Neutral
4. Support
5. Strongly Support

Would you support Green Hydrogen Production for power generation in other parts of the Philippines?

Please indicate your level of support:

1. Strongly Oppose
2. Oppose
3. Neutral
4. Support
5. Strongly Support

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