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People's Attitude to Energy from Hydrogen—From the Point of View of Modern Energy Technologies and Social Responsibility

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Abstract: Energy from hydrogen is an appropriate technological choice in the context of sustainable development. The opportunities offered by the use of energy from hydrogen also represent a significant challenge for mobile technologies and daily life. Nevertheless, despite a significant amount of research and information regarding the benefits of hydrogen energy, it creates considerable controversy in many countries. Globally, there is a lack of understanding about the production process of hydrogen energy and the benefits it provides, which leads to concerns regarding the consistency of its use. In this study, an original questionnaire was used as a research tool to determine the opinions of inhabitants of countries in which hydrogen energy is underutilized and where the infrastructure for hydrogen energy is underdeveloped. Respondents presented their attitude to ecology, and indicated their knowledge regarding the operation of hydrogen energy and the use of hydrogen fuel. The results indicate that society is not convinced that the safety levels for energy derived from hydrogen are adequate. It can be concluded that knowledge about hydrogen as an energy source, and the production safety and storage methods of hydrogen, is very low. Negative attitudes to hydrogen energy can be an important barrier in the development of this energy in many countries.

Keywords: energy; hydrogen energies; sustainable development; people's attitude; social responsibility

1. Introduction

Sustainable development, which is conditioned by the limitation of natural resources and care for the environment, means that new challenges and perspectives in the field of energy security are sought. Among the activities indicated in the Kyoto Protocol, which aim, inter alia, to reduce CO_2 emissions, innovative technologies, in particular renewable energy, are promoted. This is particularly important as energy consumption continues to increase and awareness of environmental protection motivates the search for new alternative solutions [1–4]. High energy consumption is related to the development of technology, the automation and robotization of production, and the Internet. In many countries, power shortages are normal. Hence, the search for new solutions and new energy sources, particularly based on green energy, is urgent. It is necessary to rationally and rapidly possible undergo an energy transformation [5].

Fluctuations in wind and solar energy, and insufficient capacity of transmission lines, are significant problems in the use of renewable energy. The most effective way to address the problem of renewable energy absorption is to efficiently convert, store, and reuse excess electricity [6]. However, the success of hydrogen as an energy source requires that its advantages are recognized and accepted by citizens as safe and indispensable. Hydrogen is a clean energy source that can play an important role in the global energy transition. However, its origin is critical, and green hydrogen from renewable sources represents near-zero carbon production. Important synergies exist between accelerated deployment of renewable energy and hydrogen production and use. Hydrogen energy is a means of producing long-term and sustainable energy, and a method to help meet the needs of society.

According to the present renewable energy policies of European countries, hydrogen is at the forefront as an energy source for a sustainable (stable and ecological) energy system. Therefore, technologies for generating energy from hydrogen, and its transport and storage, face significant challenges that can be measured in terms of operational safety. From the perspective of users, it appears that safety and accessibility will determine the success or failure of the proposed solution.

Unfortunately, people's attitudes also represent a significant challenge to the adoption renewable energy. There is a lack of understanding about how renewable energy is created, its advantages, and the definition of renewable. Renewable energy is also feared and treated as a necessary evil. It should be remembered that social barriers that arise when implementing modern technologies, including the development of hydrogen energy, are the hardest to overcome. Social resistance may cause a given investment to be suspended, delayed, or, worse, not realized at all. This type of barrier is the most difficult to overcome. Therefore, general environmental education and ecological awareness in this field is important. However, to identify the kind of social or ecological actions that are needed, the people's knowledge level and attitudes relating to the topic under study should be determined.

Numerous interesting studies have been conducted on hydrogen energy technology and its use. However, most often these studies are conducted from a technical or economic perspective, and few studies exist from a social perspective. Nonetheless, the social perspective is important to ascertain people's attitudes to this type of energy and break the resistance of ordinary people to these solutions. Therefore, the current authors decided to examine the attitude of ordinary people towards the use of hydrogen energy.

The main aim of the research was to determine how hydrogen energy, and in particular energy used in vehicles, is perceived by ordinary citizens. The article presents a short review of the literature, which aims to introduce the reader to the studied issues. An original questionnaire was used as a research tool to determine the opinions of the inhabitants of countries in which hydrogen energy is underutilized and where the infrastructure for hydrogen energy is underdeveloped. Respondents presented their attitude to ecology, and indicated their knowledge of the operation of hydrogen energy and the use of hydrogen fuel.

The authors wanted to present the understanding and approach of ordinary people to hydrogen energy and its use, and aimed to fill the identified research gap by developing a research tool in the form of a questionnaire to assess the attitudes of people toward hydrogen energy. This survey can be used in other countries, for example, or it can be the basis for extensive research on people's opinions on the subject.

2. Literature Review

2.1. Clean Energy Policy in Europe

The European Commission published a multi-year strategy for decarbonization of various sectors of the economy. The main goal of this strategy is to achieve the state of climate neutrality. It also provides for the development of hydrogen technologies, which ensure energy efficiency and use fewer resources [7,8]. The EU aims to promote synergy between the development of renewable energy sources (RES) and hydrogen production [9]. A total of 28 European countries have signed a declaration promoting cooperation in the field of hydrogen technologies. This cooperation encompasses 100 enterprises, organizations, and institutions. It is worth noting that hydrogen is being treated by an increasing number of countries as the fuel of the future, which is crucial for the decarbonization of the transport sector. In European countries, various measures are being introduced to increase the use of hydrogen energy, for example:

- The Austrian government announced the development in the current decade of a strategy for the development of hydrogen based on electricity produced from renewable sources as part of the Austrian 2030 climate and energy strategy.
- In Belgium and the Netherlands, hydrogen roadmaps have been published that set specific targets for 2030 and 2050, and an associated regional investment plan. Hydrogen investments are to be linked to plans for the development of new technologies in the energy sector.
- The French government presented a plan to implement hydrogen technologies in the economy by 2023, with funding in this period of as much as EUR 100 million. A similar amount will be allocated for the years 2023–2028. The goal of these activities is the construction of over 300 hydrogen refueling stations by 2025, and the introduction of over 50,000 hydrogen vehicles by 2028.
- Germany has approved a national hydrogen and fuel cell innovation program with funding of as much as EUR 1.4 billion (for hydrogen refueling stations, fuel cell vehicles, and microgeneration development). The goal is to build 1000 hydrogen refueling stations by 2030. It is assumed that the financing of these activities will be supported by private investors. In addition, the government is already running the "H2mobility" program, which supports, among other projects, the first commercial operation of a hydrogen-powered train.

The involvement of the highly-developed countries of Europe in the development of hydrogen technologies, and the raising of the awareness of their inhabitants, is a model to follow for countries that are now crossing the first barriers in the field of modern energy [10]. Nevertheless, the actions of European countries in the field of decarbonization of mobility (including industry) are an increasingly popular research topic that requires a significant degree of involvement in technological thought and social support [11–13].

Hydrogen energy is assumed to be one of the key elements for the EU to become climate neutral by 2050 [14]. Birgit Honé wrote and published a related opinion, "Towards a Clean Hydrogen Action Plan—the contribution of local and regional authorities to a climate neutral Europe" [15], which was adopted at the plenary session on 2 July 2020. It was noted that "green hydrogen and a strong clean hydrogen economy have an essential role in the energy transition to reach climate neutrality, whilst creating great opportunities for innovation, value creation and employment in many European regions" [16].

The assumption regarding the energy power of hydrogen technologies indicates that this type of energy source will develop most intensively in European countries. The popularity of energy derived from hydrogen is based on three basic advantages [17,18]: The supplied energy volume, high energy conversion efficiency, and respect and protection of the environment. However, these advantages should be developed. Moreover, they should also take into account the attitude and acceptance of the public as the elements of social responsibility. The social responsibility perspective should consider the aspects of the environment; ethics, rights and obligations; and poverty and sustainable development [19,20].

2.2. Processes Related to Hydrogen Production, Storage, and Transport, and the Associated Risks

Hydrogen is not a direct source of energy, but it's very effective carrier. In practice, hydrogen does not exist in the free state, but in the form of chemical compounds such as CH_4 (methane) or H_2O (water). To extract the energy it contains, it must be isolated from molecules of compounds. From a technological perspective, the derivation of energy from hydrogen (i.e., hydrogen as an energy source) can involve thermochemical, electrolytic, biological, and photolytic approaches [21–23]. Thermochemical methods are based on the chemical reactions of the evolution of hydrogen gas that take place at relatively high temperatures (natural gas conversion, hard coal gasification, and biomass gasification) [24].

Electrolytic methods (as the name suggests) are based on electrolysis, which is a reversal of the hydrogen combustion process. Electrolytic methods are one of the simplest and best-known methods of obtaining hydrogen. In these processes, alkaline water electrolyzers and electrolyzers with a solid polymer or ceramic electrolyte are used [25,26]. It should also be noted that electrolytic processes for obtaining hydrogen are highly energy consuming because they require a supply of electricity and are subject to heat losses. This method of hydrogen production can be profitable for countries with cheap electricity (mainly from renewable energy sources) [27].

Biological methods include hydrogen fermentation and photofermentation, in addition to biophotolysis [28]. In the case of photosynthesis, hydrogen is a product of algae, whereas in the case of fermentation, hydrogen is a product of microorganisms. The biggest limitation of the indirect biophotolysis process is the low process rate and the high cost of photobioreactors. The most promising approach in commercial use is the production of hydrogen from biomass using dark hydrogen fermentation; that is, conversion of simple sugars to hydrogen, carbon dioxide, and ethanol or organic acids (the most common acids are acetic, lactic, and butyric acid).

Photolytic methods include photoelectrolysis, which simulates the phenomena occurring in plants, that is, the breakdown of a water molecule into oxygen and hydrogen in the presence of certain substances that are photocatalysts. In this method, the photoelectric cell is combined with a catalyst and acts as an electrolyzer, separating the hydrogen and oxygen directly at the cell surface. The advantage of this method (for commercial use) is its low cost related to the electrolyzer and satisfactory process efficiency.

As presented by Acar et al., hydrogen production options based on solar energy (photocatalysis, photoelectrolysis, and photoelectrochemical methods) appear to be the most advantageous because they provide almost zero global warming potential and air pollution. The highest global warming potential and air pollution result from thermochemical methods, in particular coal gasification. However, in terms of exergy efficiency, biomass gasification yields the highest exergy efficiency, whereas the photoelectrochemical method yields the lowest efficiency [26,29,30]. Generally, renewable energy-based approaches for hydrogen production are more environmentally friendly than fossil-based hydrogen generation approaches [31].

According to numerous publications [32–35], further environmental reductions can be achieved in the future by applying appropriate end of life (EoL) strategies, which is of significant importance in the circular economy for systems based on fuel cell and hydrogen (FCH) technologies [36].

In the use of hydrogen as an energy source, in addition to the production processes (at an industrial scale), hydrogen storage, transport, distribution, and refueling are of significant importance. Energy storage and transport systems are an indispensable element of energy systems. Moreover, energy storage technologies are determined not only by such features as capital expenditure, efficiency, reaction rate, and productivity, but also by access to materials, i.e., also by global and local conditions [37]. Olabi et al. report that the production of hydrogen from water and fossil fuels, and its storage in underground formations, are the best technologies for large-scale production and storage. However, the local conditions of a region play a key role in determining the most appropriate production and storage methods [38].

Hydrogen is indicated as a future alternative fuel due to the lack of CO_2 emissions from its use, high energy content and combustion kinetics [39,40]. However, using hydrogen to decarbonize the economy requires generating it in a non-emissions-generating way. Currently, it is produced mainly in the processes of steam reforming of natural gas or regasification of coal. Both methods emit CO_2, therefore the product produced in this way is called gray hydrogen. Thus, the preferred method is, among others, the electrolysis method, which requires water and electricity from renewable sources. Green hydrogen obtained in this way is considered a basic solution that meets the needs of sustainable development in the long term [41–43].

2.3. Trends in Transport—Cars Powered by Energy from Hydrogen

Hydrogen has the potential to find a wide range of applications in the particularly emissive transport sector where it could be an alternative to the common petroleum-based fuels. The need to use efficient and clean energy sources is an important element for European transport policy. The modern transport industry (i.e., transport of the 21st century) aims to counteract air pollution and climate change, and to improve energy security [44]. The future direction of the transport industry is to supply vehicles with renewable energy, including the use of hydrogen-based technologies. The use of hydrogen and its derivative fuels is in competition with other decarbonization options in various sectors (electricity vs. hydrogen). In general, hydrogen as an energy source competes with other storage technologies, efficient power grids, and demand [17]. However, it is worth noting that the costs, demand, storage, and efficiency in transport, industry, housing, and services depend largely on the technical and economic properties of fuel production processes [13,45]. Hydrogen storage is a key element, particularly in the large-scale use of hydrogen; that is, at an industrial scale and in transport [46]. To meet the demands of the hydrogen energy market, it is essential that solid and reliable storage solutions exist for each application [46]. Three main sources of hydrogen delivery exist, which depend largely on the storage method: Gaseous, liquid, and material-based hydrogen delivery. The choice of delivery depends on market conditions, particularly demand, which depends on demographic conditions and consumer behavior [6,47–49].

Research into the future costs of storage and hydrogen technology for a low-emission energy transition are presented in the literature [50], which predicts the costs of technology in relation to electricity storage and hydrogen technologies, utility-scale batteries, pumped hydro storage (PHS), compressed air energy storage (CAES), and hydrogen electrolysis. This research is important to achieve emissions reductions in the light of climate policies and to reduce the costs of minimizing the effects of climate policy [50,51].

In addition, numerous studies have been conducted on the potential of technologies using hydrogen energy by car manufacturers, customers, and energy suppliers [52–57]. It has been observed that the most effective method of attracting consumers to technological novelties is the promotion of electric vehicles; however, this mainly relates to customers looking for cars powered by alternative fuels [58–61]. Promotion activities should differ significantly between rich and poor, and between highly-developed and poorly-developed countries [19]. Therefore, different practices to strengthen a clean energy industry are applied in different countries, and a comparison of countries may shed more light on the establishment of a more sustainable industry, and particularly the automotive industry [13,62,63]. Marketization and the promotion of the social (hydrogen) movement can contribute to raising the awareness of the main challenges facing the current economy [64]. Hydrogen technologies could stimulate a profound transformation of global transport [65,66].

The safety aspects associated with the use hydrogen are also highly important because hydrogen is known to have extreme properties in many respects. Therefore, the risk assessment and infrastructure optimization should be multifaceted to correctly identify potential threats and introduce preventive actions, taking into account all elements of operational management [37,67,68].

2.4. Social Awareness and Responsibility—How Can the Public Be Convinced about Using Hydrogen Energy?

In general, the supply of hydrogen energy is largely based on the hydrogen vehicle market, and its development is based on the purchasing needs of citizens (e.g., drivers). Therefore, in the strategy to develop hydrogen energy as an alternative to traditional fuels, it is necessary to overcome the mental, social, and economic barriers of society (Figure 1) [69–73].

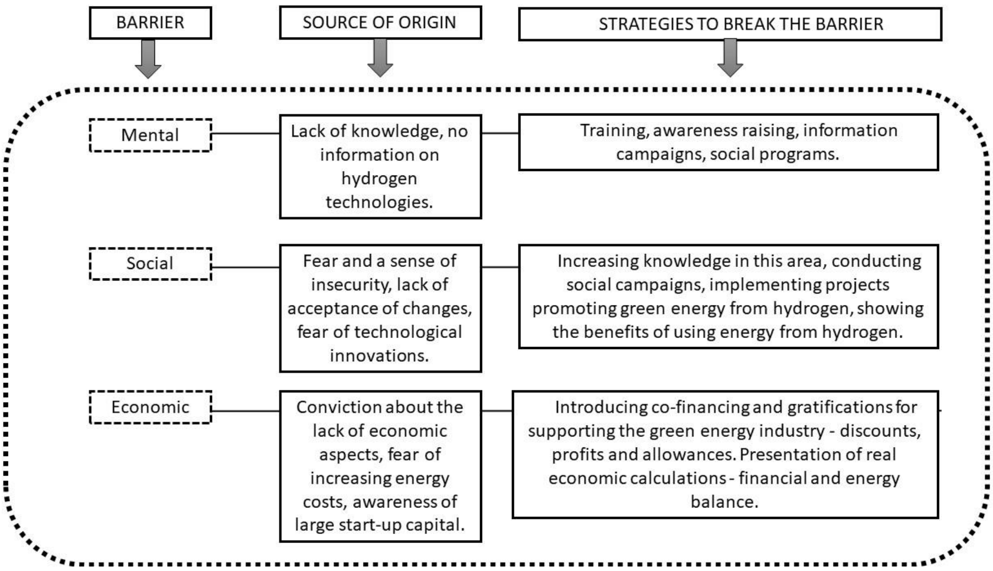

Figure 1. Barriers that arise when implementing modern (new, unknown) technologies—sources and methods (own study).

Mental barriers exist due to low levels of knowledge, and sometimes a complete lack of knowledge, about hydrogen technologies and the possibility of generating energy from hydrogen. The second barrier (the social barrier) is based on social habits, which relate to the familiarity with traditional technologies, and the feeling of insecurity and the threat of new (little known) technologies. The third barrier—the economic barrier—is a natural consequence of the economic situation (lifestyle) of citizens. It is significantly easier to break this barrier in highly-developed and rich societies. However, it is particularly difficult to overcome for developing countries because it forces citizens to provide a large amount of start-up capital. An enhanced level of education is also needed to properly assess the competing technologies in terms of their economic and social benefits [74–76]. In Figure 1 the technological barrier is omitted because it was assumed that the average citizen has no knowledge (and is not required to have knowledge) about hydrogen production, storage, and transport. In contrast, the technological barrier should be taken into account in research on the technology transfer and the commercial use of technology.

Most projects related to the implementation of hydrogen technologies are assessed from the point of view of sustainable development, with the support of the concept of corporate social responsibility (CSR) [77]. CSR is generally defined as the commitment and contribution (impact) of businesses to sustainable development. It is a means to integrate company values into the culture, and to make decisions, strategies, and actions in a transparent and responsible manner, thus voluntarily contributing to improvements in society and the quality of the environment. According to the literature [78,79], increasing social responsibility is possible only by increasing the transparency of social and environmental factors, using simple and more readable language. Breaking the barriers is possible only by increasing the awareness of citizens by conducting numerous educational and cognitive campaigns, in addition to conducting social campaigns, implementing projects promoting green energy from hydrogen, and introducing subsidies and gratuities for supporting the green energy industry, thus enabling discounts, profits, and financial relief [80,81]. Presentation of real economic calculations relates to financial and energy balances. Therefore, the design of a promotional policy should be focused on the most important (readable) factors, e.g., the total price of a vehicle and its fuel economy, i.e., fuel savings over the long term [55,58,82–84]. Financial incentives, an extensive and well-accessible charging infrastructure, and the local presence of production facilities contribute to the development of the electric vehicle industry in a given country [85]. Additionally, the potential impacts of an emerging hydrogen transition requires a broad commitment of social practice [86].

There are numerous reports in the literature showing an increase in awareness and a relatively small improvement in knowledge about hydrogen energy and hydrogen infrastructure. Changes are also observed in the perception of the risk and benefits for society and the social acceptance of the upcoming changes. It could be an effect of the time background, as well as the acceptance of the balanced risks and benefits. Public belief in hydrogen industries being able to conform to international safety standards [87–92].

According to other research conducted in the UK [93], the level of knowledge about energy derived from hydrogen is low. However, regardless of education and socio-economic background, people are eager to learn more about new energy opportunities. People appear to be indifferent about the concept of hydrogen energy. Among older members of society (with higher chemical education), the production of hydrogen is regarded as a concern, although the percentage of such cases was so small that it was not generally considered. However, it can be assumed that the public is preparing (i.e., becoming aware of) the upcoming changes because it expresses concern about the use of fossil fuels (limited resources, climate change, pollution, etc.). Generally, the opinion of hydrogen is favorable, but with the proviso that price and safety should not be compromised. Additionally, Cherryman et al. noted that women generally accept the use of hydrogen energy more favorably, with the main concerns being safety and cost [94].

Data presented by Capellán-Perez et al. (2020) indicate that, in post-socialist European countries, it is significantly more difficult to implement and run projects based on clean energy, as evidenced by the small number of clean energy and renewable energy projects in the Czech Republic, Hungary, Poland, Slovakia, and Slovenia [56].

Based on the above literature review of the subject, a large research gap has been observed in relation to the attitude of society to new energy technologies, and particularly to the use of hydrogen energy. The literature provides research on the general social responsibility towards changes in energy technologies, but does not indicate areas in which citizens' knowledge should be strengthened. Thus, the authors of this paper undertook a pilot study to assess the attitudes of the inhabitants of European countries (in which the infrastructure for hydrogen energy is not highly developed) in relation to the areas that are correlated with the issue: the natural environment, basic knowledge about hydrogen energy, and the use of hydrogen energy. It is assumed that the presented analysis will be valuable primarily for decision-makers to plan methods for the familiarization of society with hydrogen energy technologies. The current study can also be a valuable source of information for industries that are concerned about their impact on the environment, and the impact of their business models on the acceptance of society [14,45,86].

3. Materials and Methods

The main aim of the research was to determine how hydrogen energy, and in particular energy used in vehicles, is perceived by ordinary citizens. The study addressed people living in three countries of Eastern Europe (Poland, Czech Republic, and Slovakia). These are countries in which hydrogen energy is underutilized and the infrastructure for hydrogen energy is underdeveloped.

The design of the survey took into account the literature review, and in particular, similar studies conducted in other countries. An original questionnaire was conducted in the form of an internet survey from October 2019 to February 2020.

It was assumed that adult residents of three countries of Eastern Europe (Poland, Czech Republic, and Slovakia) would take part in the research. Due to the different size of the population of individual countries, it was assumed that the survey would be representative if at least 150 people from the Czech Republic and Slovakia and 200 from Poland would take part in it and that the surveys would be completed correctly (answers to all questions, all answers agree with the used scale). The authors did not fully influence the structure of the sample, because it was an online survey and it depended only on the willingness of respondents to participate in it.

The survey was divided into three parts: Natural environment (A), hydrogen energy (B), and use of hydrogen fuel (C). Each of these three parts contained 5 statements. The respondents were asked to indicate whether they agreed with a given statement. A five-point Likert scale was used to evaluate the statements, where 1 means I completely disagree and 5 means I completely agree. The sets of statements were composed to reveal weaknesses in the incentive of society to develop hydrogen energy, thus identifying the most difficult barriers to overcome. The statements in the survey were as follows:

A. Natural environment.

- A1. I feel responsible for the natural environment.
- A2. My actions have an impact on the environment.
- A3. People should take care of the natural environment more and more due to its enormous damage.
- A4. The use of renewable energy sources is a priority for a developed society.
- A5. People have access to new technologies that have a positive impact on the environment.

B. Hydrogen energy.

- B1. Hydrogen energy is clean energy.
- B2. The use of hydrogen energy does not emit carbon dioxide.
- B3. Hydrogen is a potentially great source of energy.
- B4. Hydrogen energy is safe for people.
- B5. The use of hydrogen energy has a positive impact on the natural environment.

C. Use of hydrogen fuel.

- C1. There are hydrogen powered vehicles available in my country.
- C2. The cost of producing hydrogen energy is high (compared to other types of energy).
- C3. In my country, the infrastructure of hydrogen fuel stations is well-developed.
- C4. The use of hydrogen fuel is safe.
- C5. I am interested in the possibility of having a hydrogen fuel car.

The questions were structured in such a way that high scores mean that the respondent is pro-ecological (part A), and understands the operation of hydrogen energy (part B) and the use of hydrogen fuel (part C).

Additionally, the questionnaire contained a section to gather information about the basic characteristics of the respondents to identify the structure of people taking part in the study. A total of 766 people took part in the survey (247 from Poland, 223 from Czech Republic, and 199 from Slovakia).

The use of the five-point Likert scale allowed analysis of the survey results in terms of the reliability of the answers. For this analysis, the Cronbach Alpha and standardized Cronbach Alpha tests were used both for each group of questions and for all survey, later the results of the analysis were interpreted according to Hair et al. [85]. It is assumed that a Cronbach Alpha index above the value of 0.7 means that the collected data are suitable for further analysis.

A scale analysis was performed to determine which grades were most often given by respondents. Then, the evaluation results were analyzed, i.e., basic statistics and percentages of individual evaluations were calculated.

4. Results and Discussion

As shown in the literature, the identification of areas for improvement is a key element in planning and implementing new projects. Numerous management tools exist that support the achievement of long-term goals based on actual state-of-the-art analysis [72,95,96]. Thus, the authors attempted to identify the area (barrier) that should be overcome to make society feel positively about new energy technologies.

Initially, the completed questionnaires were verified. A total of 766 respondents took part in the survey. Not all of the questionnaires were completed correctly in their entirety, which resulted in 17 questionnaires being rejected. Ultimately, 749 questionnaires were further analyzed (Table 1).

Table 1. Surveys taken into account during the research (own study).

Respondents	Quantity	Percentage Fraction
Number of respondents, including:	766	100.00
correct	17	2.22
rejected	749	97.78

First, the structure of the respondents was analyzed (Table 2). Percentages of individual responses were calculated. It can be seen that the structure of the respondents was varied, but some features were repeated. This could be due to an unusual survey topic, i.e., hydrogen energy. It is likely that a large number of people did not complete the survey precisely because the topic was difficult. However, this also indicates a low level of knowledge and awareness.

Table 2. Characteristics of the respondents (own study).

Feature	Answer	Percentage
Nationality	Polish	45.3
	Czech	29.1
	Slovak	25.6
Gender	female	54.1
	male	45.9
Age	up to 20 years	0
	21–30 years	12.9
	31–40 years	21.6
	41–50 years	43.2
	51–60 years	19.5
	61–70 years	2.8
	Over 70 years old	0
Social/professional status	pupil/university student	7.9
	I work	68.3
	unemployed	1.2
	entrepreneur	18.7
	pensioner	3.9
Education	primary education	0
	lower secondary education	0
	vocational education	21.8
	secondary education	41.8
	higher education	36.4
Residence	village	3.1
	city up to 50k residents	9.1
	city 51 to 100k residents	12.4
	city 101 to 200k residents	11.8
	city 201 to 400k residents	18.9
	city with over 300k residents	44.7

Regard the gender of the respondents, the structure was balanced with a slight majority of women respondents. Most respondents were from Poland. People from 21 to 70 years of age participated in the study, and were most often aged 41–50. Most of the respondents were working. The survey covered respondents with secondary or higher education, which may be related to the subject of the survey. Most often, the respondents came from large cities of over 300,000 residents.

The results of the main part of the survey were analyzed. First, the number of individual ratings for each statement was calculated. On the basis of these data, an analysis of the correlation between individual statements was carried out, taking into account the grades awarded (Table 3). The matrix of the determined correlations was used in the next step to calculate the standardized Cronbach Alpha.

Table 3. Correlation matrix between individual questions (own study).

	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	C4	C5
A1	1.00														
A2	0.81	1.00													
A3	0.71	0.56	1.00												
A4	0.51	0.67	0.64	1.00											
A5	0.01	0.18	0.11	0.33	1.00										
B1	0.12	0.23	0.05	0.39	0.15	1.00									
B2	0.19	0.38	0.02	0.41	0.03	0.82	1.00								
B3	0.49	0.54	0.36	0.56	0.16	0.47	0.44	1.00							
B4	0.44	0.41	0.52	0.51	0.01	0.44	0.46	0.59	1.00						
B5	0.20	0.31	0.06	0.42	−0.03	0.65	0.62	0.63	0.44	1.00					
C1	0.17	0.23	0.33	0.50	0.56	−0.02	−0.13	0.28	0.15	−0.08	1.00				
C2	−0.04	−0.08	0.17	−0.12	−0.11	−0.12	−0.21	−0.38	−0.35	−0.31	0.00	1.00			
C3	−0.07	−0.12	0.08	−0.16	0.06	−0.22	−0.30	0.02	0.10	−0.24	0.18	0.04	1.00		
C4	0.39	0.38	0.33	0.53	0.34	0.37	0.50	0.50	0.63	0.44	0.18	−0.50	0.13	1.00	
C5	0.26	0.19	0.00	0.06	−0.10	0.51	0.56	0.37	0.39	0.69	−0.34	−0.24	−0.33	0.30	1.00

The mean correlation between the questions was 0.27. It can be concluded that the dependence is clear, but this value indicates a low correlation. This means that, on average, there is only a small correlation between the individual statements. The highest correlation coefficient was obtained for statements B1 and B2, i.e., "Hydrogen energy is clean energy" and "The use of hydrogen energy does not emit carbon dioxide", as expected. The smallest (almost zero) correlation was found in the case of statements A3 and C5, i.e., "People should take care of the natural environment more and more due to its enormous damage" and "I am interested in the possibility of having a hydrogen fuel car", which indicates the absence of any dependencies.

The Cronbach Alpha and standardized Cronbach Alpha coefficients were used to assess the reliability of the survey. These coefficients were calculated both for the entire survey and for its individual parts (Table 4). In the case of the overall study and parts A and B, the results were in the range (0.8, 0.9), which indicates a very good strength of association; in the case of part 3, the result was lower, within the range (0.7, 0.8), i.e., good strength of association. However, in line with the earlier assumptions, these results prove the reliability of the study; therefore the study results were subjected to further analysis.

Table 4. Cronbach Alpha coefficients (own study).

Part of the Survey	Cronbach Alpha	Standardized Cronbach Alpha	No of Items
Entire survey	0.812	0.850	15
A. Natural environment	0.815	0.864	5
B. Hydrogen energy	0.870	0.901	5
C. Use of hydrogen fuel	0.764	0.792	5

The analysis of the obtained results began with the scale statistics. Table 5 provides information on the mean, variance, and standard deviation of the scale composed of all five analyzed items. It can be noted that the adopted scale takes values ranging from 5 (if the respondent chose the lowest possible value for all items, i.e., 1) to 75 (if the respondent chose 5 for all values). The mean of 50.2444 on this scale appears to be relatively high (i.e., approx. 2/3 of the whole scale) and indicates a positive attitude of the respondents to environmental protection and hydrogen energy.

Table 5. The scale statistics (own study).

Mean	Variance	Standard Deviation	No of Items
50.3778	94.36840	9.71434	5

Then, the mean and standard deviation were calculated for the scores of individual questions and for each group of questions (Table 6).

Table 6. Statistics of questions and individual groups of questions (own study).

Group/Question	Mean	Standard Deviation
A	3.96	1.23
A1	3.96	1.37
A2	3.84	1.26
A3	4.36	1.14
A4	4.07	1.12
A5	3.60	1.27
B	3.50	1.18
B1	3.93	1.08
B2	3.93	1.25
B3	3.64	1.12
B4	2.56	1.09
B5	3.44	1.38
C	2.58	1.17
C1	2.71	1.20
C2	3.31	1.26
C3	1.44	0.72
C4	2.31	1.38
C5	3.13	1.76

From the analysis of the results for individual groups of statements, it can be seen that group A was rated the highest (mean 3.96), i.e., the respondents agreed, although not completely, with these statements. This is a group related to environmental protection, which is often discussed in public forums. In addition, "being eco" has recently become fashionable, which is why these results are not surprising. The highest standard deviation was also noted for this group of statements, which indicates the ratings in this group differed the most.

The lowest mean was obtained for group C (mean 2.58), which indicates the respondents either disagree or are indifferent to the statements. This group deals with the use of hydrogen fuel. The lowest scores in this group indicate that there is very little knowledge and awareness in society about the benefits of using energy from hydrogen. This proves that the development and expansion of hydrogen technologies must be strongly supported by actions promoting not only ecology but, more importantly, technology. It should be noted that society has a high degree of access to information and requires clean, readable data (which is also a technological factor). This data can be used to help convince the public and improve their perception in terms of safety and accessibility

When analyzing individual questions, it can be noted that the following questions were rated the highest: A3 (People should take care of the natural environment more and more due to its enormous damage) and A4 (The use of renewable energy sources is a priority for a developed society). In both cases, the average was over 4, which indicates the respondents agree with these statements. These are important statements because respondents know that they need to care for the environment and, therefore, use renewable energy sources. This indicates that society has, to some extent, overcome a mental barrier regarding the issue of ecological sustainability. Assessing the remaining statements from group A, it can be said that the respondents agreed with them, although their opinion partially shifted towards indifference.

In group B, the average rating for question B4 (Hydrogen energy is safe for humans) was 2.56, which indicates the respondents were not entirely sure of their answer: Indifference or disagree. In the remaining cases in this group, responses indicated a fluctuation between indifference and agreement with the statement. This result proves that the public knows the benefits of using energy from hydrogen, but feels anxious and uncertain about its safety. The response fluctuations may also result from a two-fold understanding of safety; safety in this category may refer to the safety of technical conditions and safety of the access to the energy source.

The worst assessment was for the statement C3 (i.e., In my country the infrastructure of hydrogen fuel stations is well-developed) achieved an average question score of 1.44, i.e., the respondents did not agree with the statement and often completely disagreed. Interestingly, on the basis of the analysis of the availability of charging stations, it can be concluded that in the countries covered by the study such stations exist, but their number is very low. Charging stations are usually located along major transit roads and in large cities.

When analyzing the results for the statement C5 (I am interested in the possibility of having a hydrogen fuel car), the respondents were on average indifferent. By comparison, responses to the other statements in this group fluctuated between disagreement and indifference. This is expected; if respondents believe that the country has a lack of charging station infrastructure, the public will not be interested in this type of car.

Next, the percentages of the grades assigned to individual statements were calculated, which allowed analysis of the structure of the answers (Table 7).

Table 7. Percentages of answers to particular questions (own study).

Question	Percentage Fraction of Answers				
	1	2	3	4	5
A1	13.4	0	15.2	20.3	51.1
A2	2.2	17.8	13.6	28.7	37.7
A3	8.9	0	0	28.9	62.2
A4	2.4	8.7	15.6	24.4	48.9
A5	6.7	11.1	17.8	35.6	28.8
B1	2.1	8.9	24.5	26.7	37.8
B2	8.9	2.5	24.3	17.6	46.7
B3	2.2	13.4	37.7	13.6	33.1
B4	22.1	17.8	51.1	2.3	6.7
B5	13.3	8.9	31.3	15.4	31.1
C1	15.6	24.7	37.5	8.8	13.4
C2	13.4	2.2	51.1	6.6	26.7
C3	66.7	24.4	6.8	2.1	0
C4	35.5	24.2	20.4	4.3	15.6
C5	33.6	6.5	15.6	2.1	42.2

In the analysis of the ratings of 5, i.e., cases in which the respondents completely agree with a given statement, it can be noted that the highest share of this rating was recorded for the statements A1 (I feel responsible for the natural environment) and A3 (People should take care of the natural environment more and more due to its enormous damage). This indicates the high potential of society to assimilate technologies using renewable energy in their lives.

The rating of 4 (I agree) was dominant for A5 (People have access to new technologies that have a positive impact on the environment). Agreement with the statement (albeit uncertain) may indicate that, in fact, the public does have access to these technologies, but may not always use them. Accessibility in this area may be strongly conditioned by an economic barrier, such as a lack of financial support from the state in the form of subsidies, discounts, or financial incentives

A rating of 3 (neutral; neither yes nor no) prevailed for the statements B4 (Hydrogen energy is safe for people), B3 (Hydrogen is potentially great source of energy), and B5 (The use of hydrogen energy has a positive impact on the natural environment). This indifference shown by the respondents indicates a lack knowledge regarding the technology associated with obtaining energy from hydrogen, and the safety and benefits of using this energy. This confirms earlier observations that society needs clear data on the hydrogen technology and benefits.

When analyzing the rating of 2 (I disagree), no notable observation can be made of this rating. It can only be noted that statements C1 (There are hydrogen powered vehicles available in my country), C2 (The cost of producing hydrogen energy is high (compared to other types of energy)), and C4 (The use of hydrogen fuel is safe) accounted for over 20% of these answers. However, this finding is not significant and does not significantly affect the obtained results.

Rating 1 (I completely disagree) was highly dominant for the C3 statement (In my country, the infrastructure of hydrogen filling stations is well-developed). This is the question with the lowest average rating. It can be concluded that the respondents completely disagree with this statement, and the lack of their confirmation does not indicate a genuine lack of charging infrastructure, but rather the respondents' ignorance in this regard due to lack of interest.

Negative attitudes toward hydrogen energy can be an important barrier in its development in numerous countries, and are an element of social barriers, which were shown in Figure 1. As indicated by part B of the presented survey, particularly question B4, respondents are not sure that hydrogen energy is a safe energy source, and thus do not fully accept this type of energy. This is probably related to the fact that, in the surveyed countries, hydrogen energy receives little attention. Due to the low level of knowledge about hydrogen energy among the inhabitants, the respondents are afraid of its use. This is exacerbated by people's broader fears of the new and the unknown.

Therefore, as shown in Figure 1, public awareness of this subject should be raised through various social campaigns, TV programs, or articles in the press that show the benefits of using green energy, in particular hydrogen energy. Clearly, it is impossible to convince all of society. However, convincing a proportion of society can help to overcome the barriers to implementing hydrogen energy in a given country.

5. Conclusions

The main aim of this research was to identify areas that require improvement from the perspective of the attitudes of respondents towards new technologies for obtaining energy from hydrogen. Based on the presented research results, the most important findings are as follows:

- Even in countries in which modern energy technologies are not popular, society is motivated to introduce changes that will care for the environment; that is, awareness of the constant destruction of the environment is at a high level.
- The respondents are not convinced that an adequate level of safety exists for energy derived from hydrogen, where safety can be understood to be technical and access stability (i.e., availability). Knowledge about hydrogen as an energy source, and its production safety and storage methods, is very low.
- The respondents believe that both hydrogen technologies and hydrogen-powered cars are not available to them. A belief exists that hydrogen cars are not available, the charging infrastructure is poorly developed, and that there are no overall economic benefits. Thus, the level of preparation of countries for intensive hydrogen energy development is low.
- The presented survey and its results helped fill the research gap mentioned in the introduction. It can be a useful tool for determining the level of social barriers related to respondents' fear and lack of knowledge about hydrogen energy. This barrier can be overcome with the help of various social companies that can convince people that hydrogen energy is safe and offers benefits within their country.

The presented research has certain limitations. Although the design of the questionnaire was based on a literature review, it was created for the purposes of this study, and may have been influenced by the subjectivity of the authors. The survey presented results relating to people's attitudes from a social perspective. Important questions about hydrogen energy may have been omitted, and others that were included may have been unnecessary, particularly with regard to the engineering perspective. However, it should be emphasized that this questionnaire was aimed at ordinary people who do not have specialist knowledge related to the research topic, and may have different levels of education. Therefore, this survey was adapted in terms of language and content to the respondents.

The survey topic was not popular. People often complete surveys on product quality, customer service, product satisfaction, etc., relating to everyday matters, in one word. It should be remembered that the subject of the survey presented in the paper was technical, and concerned hydrogen energy, which is not yet well known or popular. In addition, the sample was not large enough, which was likely because only a small number of people were willing to participate in this research due to the nature of the subject.

The study was conducted from a social rather than a technical perspective. The authors were interested in the opinion, behavior, and attitude of the respondents, and the engineering solutions yet to be solved by experts in the hydrogen energy industry.

The survey was made available via different social media platforms and the closest professional contacts of the authors. This may have had an impact on the structure of the respondents themselves, and thus on their answers. In particular, the research focused on respondents from three different countries, including the country of the authors. The authors believe that future studies should include samples from a diverse demographic population. The last limitation relates to respondents' origins. As mentioned previously, respondents were from three neighboring countries of Eastern Europe. However, this opens opportunities for future research to conduct the study in other European countries.

The research will be continued and extended to other countries, and the results will be compared. The aim of this research is to interest the respondents in hydrogen energy. The authors think that participation in the survey may cause respondents to look for information on the subject. This would be regarded as a significant achievement for the authors, but, more importantly, for the natural environment. We also plan to use different statistical methods to more comprehensively analyze the data from different perspectives and enhance the relevant case study, which will also improve the accuracy and scientific conclusions.

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