NPHyCo
Nuclear Powered Hydrogen Cogeneration

SOCIO-ECONOMIC STUDY

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(D6.3, V5)

Revisions

IND REV	RELEASE DATE	PARAGRAPH	SCOPE OF THE REVISION
1	08/10/2024	NRG	First Issue
2	03/12/2024	Nucleareurope	Addition European Survey version 1
3	24/01/2025	Nucleareurope	Addition European Survey version 2
4	07/02/2025	ES Group	Addition Ukrainian Survey
5	10/02/2025	Nucleareurope	Final version

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Abbreviations and acronyms

Acronym	Description
HPP	Hydrogen production plant
NPP	Nuclear power plant
SMR	Small Modular Reactors
EU	European Union
NIMBY	Not in my backyard

Summary

One aspect which will be key to the deployment of a hydrogen production plant (HPP) connected to an existing nuclear power plant (NPP) is public acceptance. If utilities have the support of the local community, then this can help facilitate the deployment of such cogeneration. However, if public acceptance is not handled in the right way, this could lead to opposition and thus making such deployment more challenging.

The first goal of this deliverable was to identify existing work which has been undertaken to assess the public's acceptance of nuclear, hydrogen and a combination of the two. In this respect, whilst a lot has been done to measure public acceptance of nuclear and hydrogen separately, there is very little research into how the public would respond to coupling an NPP with an HPP.

As a result, the second objective was to develop and test a public acceptance survey to see what information would be needed, how to phrase questions and ultimately see if the information obtained would provide some insights. This survey was split into two target audiences. The first one was an EU level survey, which aimed to target Europeans in general. The second was focused on Ukraine.

In the first instance, the survey only provided a limited amount of information. As such a second survey was issued with more focused questions to enable a greater gathering of information. In addition, more was done to reach people who did not necessarily come from the nuclear/energy sector (as in the first version this had an impact on the feedback received). In the case of Ukraine, it is important to note that national circumstances also had an impact on responses (for example in terms of what is currently of greatest concerns to citizens). At the same time, it also showed that there are differences in the way people respond depending on where they are located.

The results of these surveys provide some indication as a to a way forward and as such the recommendations will be shared with the nuclear sector with the goal of including some of the questions into existing surveys already ongoing at national and local level.

In addition, the information obtained can also be used to help define messaging of relevance when engaging in a conversation with stakeholders at different levels (European, national and local). The results show which benefits citizens can obtain from having such a cogeneration facility in the country/community (to answer the "what's in it for me" question) whilst at the same time preparing to answer questions around concerns which people may have (such as safety and cost).

What is notable from the surveys is that in many instances, those who answered 'don't know' to questions relating to level of support very often indicated that this was due to the fact that they did not have the information necessary (knowledge) to take an informed decision on this matter. As such, this demonstrates the importance of engaging in a conversation with citizens in order to share information with them and answer any questions which they may have to enable them to take an informed decision.

1 Public Acceptance Overview

A preliminary acceptance study was undertaken to explore the public's reception of coupling an existing nuclear power plant with a hydrogen production facility (previously referred to as pink hydrogen). This investigation began with a comprehensive literature review, aimed at addressing how and to what extent a hydrogen production plant coupled to a nuclear plant could influence public awareness/acceptance about nuclear power generation.

To establish a foundation for this study, existing public acceptance models were examined. These models investigate how various factors influence public perception and acceptance towards a technology. Understanding these factors is crucial for predicting how the public might respond to the novel integration of nuclear and hydrogen technologies.

Following this, the current landscape of public acceptance for both nuclear energy and hydrogen production individually was reviewed. The acceptance of nuclear power is often challenged by concerns over safety, radioactive waste, and historical incidents. Conversely, hydrogen production, particularly when derived from renewable sources, generally enjoys more favourable public opinion due to its potential for reducing carbon emissions and supporting sustainable energy systems.

With insights from these individual assessments, we formulated initial hypotheses on the public's potential acceptance of combining nuclear power with hydrogen production to be validated with the results of the public survey. We posited that public perception might be influenced by the perceived benefits of hydrogen as a clean energy source, potentially mitigating some of the negative views associated with nuclear energy. However, we also recognised that concerns specific to nuclear power might persist or even be exacerbated by the integration of a new technology.

1.1 Public acceptance models

Studies on public acceptance of energy technologies are based on the responses from public surveys and can be divided into two main categories: individual-level research and country-level research [1].

At the individual level, the research primarily analyses attitudes within a specific country, considering how individual variables such as knowledge, trust, risk perception, and perceived benefits relate to public acceptance. These individual acceptance theories are based on psychological theories of human behaviour that suggests that people's perception is influenced by one's beliefs about the technology, perceived personal and social norms, emotional responses, and other contextual factors (e.g., social trust) [2]. These studies therefore do not fully account for the significant influence of structural factors like national or neighbourhood context, or contextual variables such as economic welfare and social capital [3].

In contrast, country-level studies emphasise the importance of contextual or institutional variables such as energy capacity and consumption, electricity prices, national GDP, political, ideological institutional factors and national perception [1]. However, country-level studies often overlook the critical role of individual perceptions in shaping acceptance of energy technology.

As in reality all of these levels contribute to the overall acceptance of the public, each research approach has its strengths and weaknesses. Therefore, a more comprehensive framework is needed that incorporates variables from both individual-level and country-level studies to fully understand public acceptance of energy technologies [4].

Over the past decades, numerous models have been developed to investigate public acceptance of nuclear energy production. Figure 1 illustrates the Multilevel Model proposed by Wang et al. [1], which emerged from a comparative analysis of public attitudes toward nuclear power across 27 European countries.

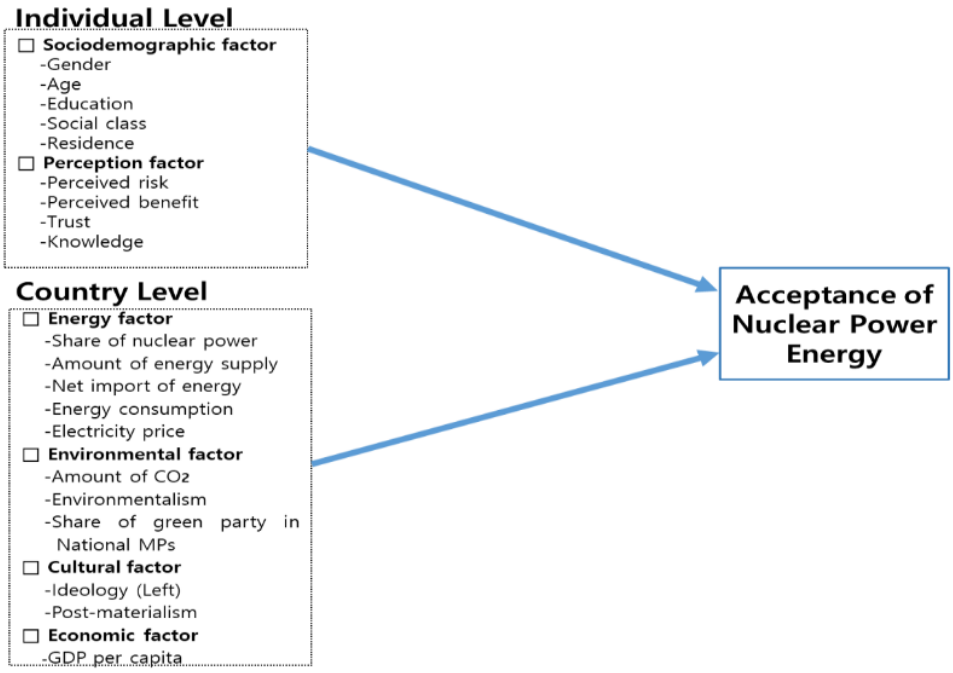

Figure 1. Research model from Wang et al [1].

Within the NPHyCo survey campaign, local communities living in the vicinity of an existing NPP selected as a pilot plant will be analysed. Due to the specific nature of this sample, a country-level approach is less relevant as the aim of the survey is to investigate the public acceptance of the NPHyCo initiative at an individual-level. It is therefore valuable to present more in detail the primary individual factors influencing public response and their interdependencies.

Numerous theoretical models have been proposed and validated through surveys, showing that acceptability is primarily linked to perceptions of risks and benefits [3, 2, 5]. Given the unique challenges confronting the energy sector, the primary benefits of a particular energy technology are closely tied to its climate impact and its economic competitiveness. From an environmental perspective, technologies that significantly reduce greenhouse gas emissions and contribute to mitigating climate change are evaluated positively [6, 7, 8, 9, 10]. Conversely, economic competitiveness encompasses several dimensions. One key aspect is energy security, which refers to the reliability and stability of the energy supply. Technologies that can provide a consistent and dependable energy source contribute to greater energy security, reducing dependence on volatile foreign energy supplies and enhancing national resilience [11]. Another critical factor is energy cost [12]. Affordable energy is essential for both consumers and industries as technologies that lower energy costs can drive economic growth and improve the standard of living [9]. Perceived benefits have therefore a positive effect on public acceptance.

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On the other hand, perceived risks associated with an energy technology can hinder its acceptance [2]. Safety concerns are predominant, especially with technologies such as nuclear power, where they can be a major barrier to the adoption of a specific energy solution [1]. Additionally, investment costs are a significant factor in perceived risks. The high initial capital required for the development and deployment of certain energy technologies can be deterring [10]. These costs include not only the financial investment but also the time and resources needed to build the necessary infrastructure. For many stakeholders, including governments, investors, and the public, the perceived economic risk associated with these upfront costs can influence their willingness to support or adopt a new technology [9]. High perceived risks have a negative impact on public acceptance.

Figure 2 gives a visual representation of a general perception-acceptance model. The graph depicts public acceptance as the result of a trade-off between perceived risks and benefits which are in turn influenced by multiple individual-level factors. The impact of each factor is not always straightforward, having sometimes a positive or negative effect on overall acceptance. The significance of each factor has been studied by various authors focusing on specific aspects of the proposed scheme [2, 13].

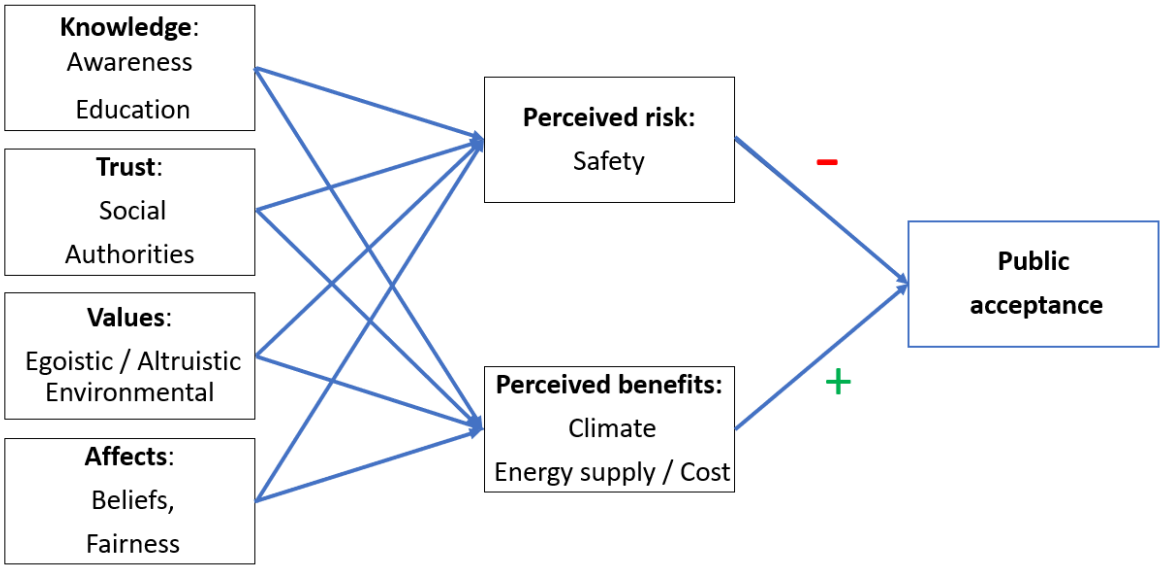

Figure 2. Perception-acceptance model.

Knowledge is a critical element in shaping acceptance. This encompasses both formal education and general awareness about a technology. Generally, increased knowledge has a positive effect on acceptance, as it helps reduce perceived risks and enhances awareness of the benefits [14]. However, perceived knowledge can also negatively impact acceptance when it is partial or biased. Most of the people lack a comprehensive knowledge about the risks and benefits and thus tend to rely on their trust in relevant actors involved in the technology. Trust in authorities—such as government bodies, institutions, researchers, and operators—becomes a critical predictor of acceptance [2]. The higher the trust in these authorities, the more likely people are to accept new energy solutions promoted by them. This highlights the importance of transparent and reliable communication from these entities to build and maintain public trust [15]. Moreover, there is a significant moral and affective component that influences public acceptance. People's values and beliefs can strongly change their attitudes towards a proposed technology. For example, individuals who prioritise the well-being of other

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humans or the environment may perceive different risks and benefits compared to those who prioritise self-interest [16].

Figure 3 illustrates a graph similar to the one presented in Figure 2, but with a particular emphasis on the role of public communication. As previously mentioned, public communication plays a critical role in shaping public acceptance. Effective communication can enhance knowledge and build trust in the technology, which, in turn, influences people's perceptions of the benefits and risks associated with the technology, ultimately determining their level of acceptance [14].

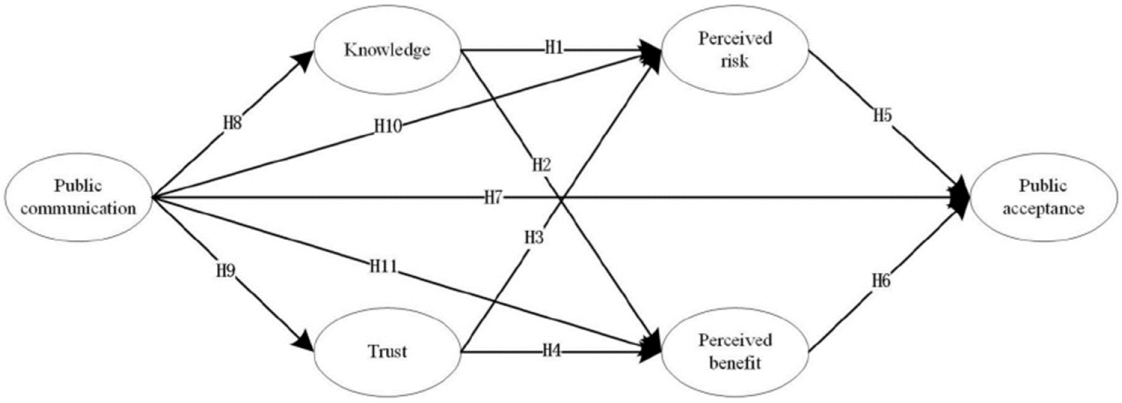

Figure 3. Role of public communication within the perception-acceptance model [14].

Continuous and transparent communication is essential to maintain and improve public acceptance throughout the various stages of technological implementation [14]. Effective public communication ensures that the public is well-informed about the technology, understands its benefits and risks, and trusts the entities promoting it. This communication must be clear, consistent, and honest to build and sustain this trust [17]. Given the importance of public communication, a comprehensive communication campaign is planned to follow the analysis of the first NPHyCo public survey results. This campaign will aim to address the people's needs, provide detailed information about the technology, and respond to public concerns. By doing so, it will help to foster a more informed and supportive public attitude towards the project.

As a conclusive remark, it is important to emphasize that public acceptance is not constant in time. Even in the absence of major events such as accidents or geopolitical crises, public acceptance tends to exhibit a wave-like trend. Initially, acceptance may be very high when a new technology is first promoted and its benefits are widely advertised. However, this acceptance typically declines during the planning and site selection phases—consider the example of wind turbines, where public enthusiasm often wanes due to concerns about location and impact [12]. Acceptance usually rises again post-completion and operation, as people begin to experience the tangible benefits of the technology [8].

1.2 Current public acceptance of Nuclear Energy

Numerous studies on public acceptance have been conducted since the 1970s to assess levels of support for nuclear energy initiatives across various countries [18]. The nuclear sector experienced significant backlash especially following high-profile accidents such as Chernobyl in 1986 and Fukushima in 2011 [19, 20]. These incidents severely damaged public trust and led to widespread opposition to nuclear technologies. As a result, many countries that previously relied on nuclear power began phasing out their existing nuclear power plants or abandoned plans for new ones. This opposition, combined with a lack of political will, contributed to a prolonged period of stagnation and a persistently negative image for the nuclear industry.

Despite these challenges, in recent years there has been a notable shift with public acceptance reaching its highest levels, especially in the past five years. A study released in 2023 by the Radiant Energy group [21] found that across the 20 countries surveyed, 28% of survey respondents oppose the use of nuclear energy while 46% (1.5x more) support it. In 17 out of the 20 countries surveyed a positive net support (support exceeding opposition) for nuclear energy was measured. Overall, preference for nuclear energy is larger than for onshore wind, biomass from trees, or gas with carbon capture and storage and 25% of those surveyed say their country should focus on nuclear energy, second only to large-scale solar farm with 33%. Figure 4 summarises the results of the study.

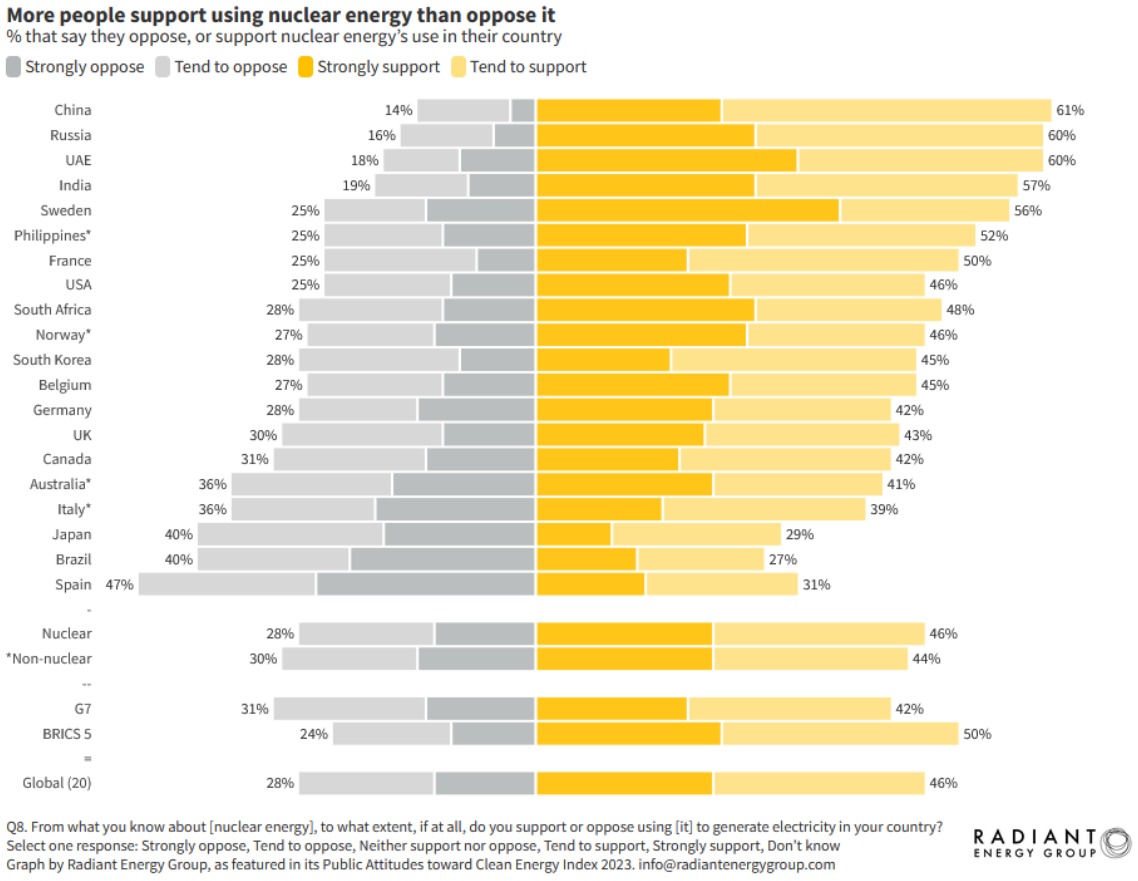

Figure 4. Public support for nuclear [21].

Whilst the survey above provides a picture of the situation in different countries in 2023, it should be born in mind that several EU Member States have been carrying out surveys for several decades. Thanks to these surveys, it is possible to identify how support for nuclear has increased (or diminished) over time. As a result, by examining the trend over time across different countries reveals that

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particularly in the last five years, there has been a consistent and steady increase in public support for nuclear energy. In Figure 5, public support for Finland over the last 40 years is reported.

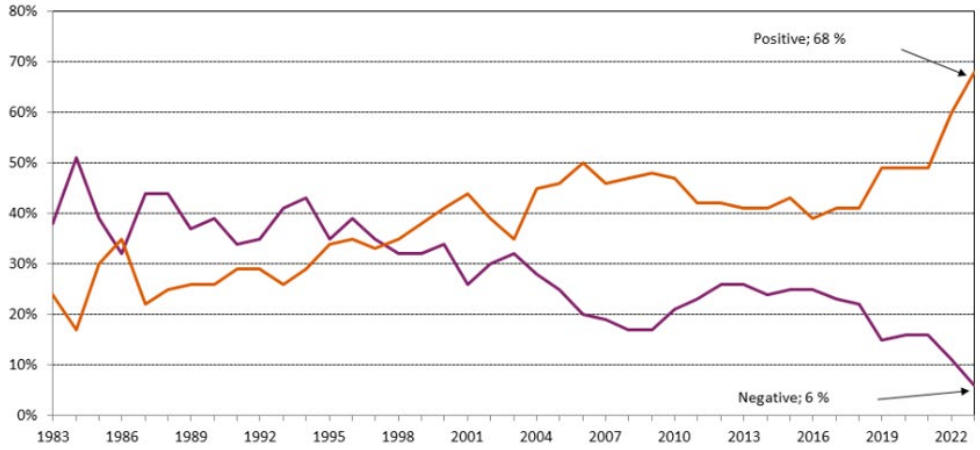

Figure 5. Development of the acceptance of nuclear power in Finland 1983-2023 [22].

Similarly, public support for nuclear in France has risen from 29% in 2011 to 46% in 2023 [23], in the Netherlands from 45% in 2011 to 60% in 2021 [24] and in Czech Republic from 40% (2016) to 65% in 2021 [25]. Also, some of the most anti-nuclear European countries have seen a sharp decrease in their degree of rejection: the proportion of those rejecting nuclear energy in Austria has gone from 78% in 2016 to 47% in 2022 and in Germany from 65% to 20% [26].

From the literature review, several factors were identified contributing to this growing acceptance. The pressing issue of climate change has led to a greater recognition of the need for low-carbon energy sources. Nuclear power, being an efficient and large-scale source of low-carbon energy, has emerged as a possible option for many nations seeking to reduce their greenhouse gas emissions and transition to more sustainable energy systems [11], [27]. Additionally, advancements in nuclear technology, including small modular reactors (SMRs), with an emphasis on intrinsic safety features and sustainability are crucial in addressing many of the historical concerns associated with nuclear power [28]. These technological improvements, though still under development, have made nuclear energy more attractive and more reliable to the public eye [29]. Economic considerations have also influenced this trend. As European countries strive for energy security and independence, especially in the aftermath of the Russia-Ukraine war and the subsequent energy crisis, nuclear energy offers a viable solution that can reduce reliance on imported fuels and protect against volatile energy markets [30], [31].The rising public interest in nuclear energy has spurred a renewed focus from both government and industry sectors: governments are revisiting nuclear energy policies, investing in advanced nuclear technologies, and reconsidering it as a key component in their energy mix [32]; additionally, industry players are showing support for nuclear projects, recognising the growing demand for sustainable and dependable energy sources [33].

Despite the positive momentum around nuclear energy, public support remains split as acceptance is hampered by several perceived risks and challenges. The main concerns come from the fear of nuclear accidents and radiation leakage, such as those at Chernobyl and Fukushima, which have left lasting impressions on the public opinion and fuelled apprehension about the safety of nuclear power plants, while the topic of radioactive waste management and disposal remains a challenge that raises

environmental and safety concerns [21], [29]. Uncertainty surrounding these issues often results in public scepticism and resistance to expanding nuclear energy infrastructure [34]. Beyond safety and security concerns, there are also significant economic challenges associated with nuclear power. Building new nuclear power plants requires substantial financial investment and long construction times. The costs of construction, operation, and maintenance can be prohibitively high, making nuclear energy a less attractive option to investors compared to other renewable energy sources. Moreover, the lengthy timeframes involved in constructing NPPs often exceed initial estimates due to delays caused by regulatory hurdles, technological complexities, and unforeseen obstacles. These delays can lead to increased costs and uncertainty, further dampening enthusiasm for nuclear energy development [35].

Figure 6 gives an overview of the reasons why the public wants more nuclear for 6 European countries: carbon-free technology and constant energy source are the two main reasons driving people choice in favour of an increase in nuclear energy.

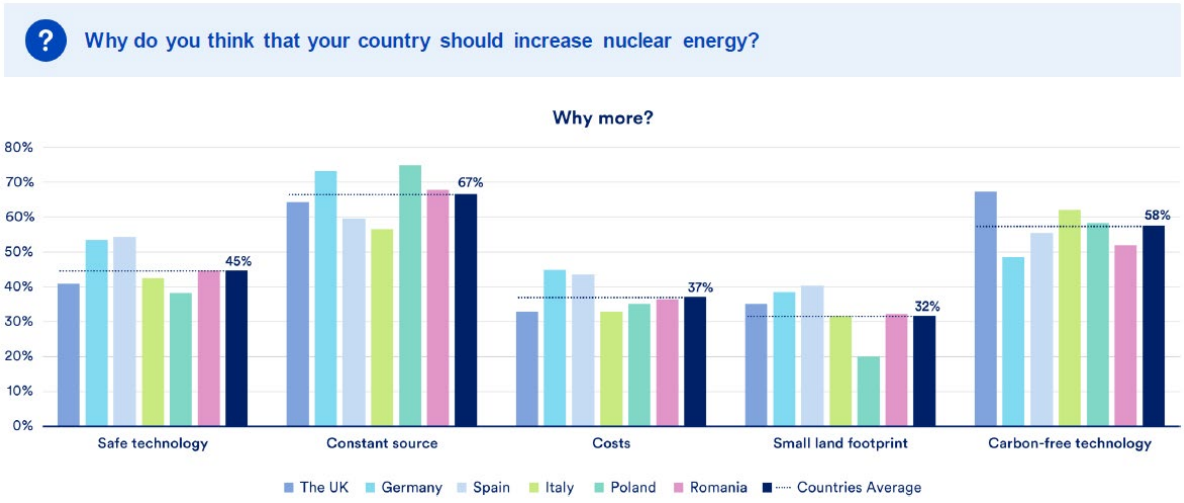

Figure 6. Reasons why the public wants more nuclear: it's a carbon-free technology and a constant energy source [34].

In Figure 7, a counterpart to the previous graph is offered showing the main reasons given by the public of 6 European countries for wanting a reduction of nuclear in their energy mix: safety and nuclear waste concerns are the predominant factors.

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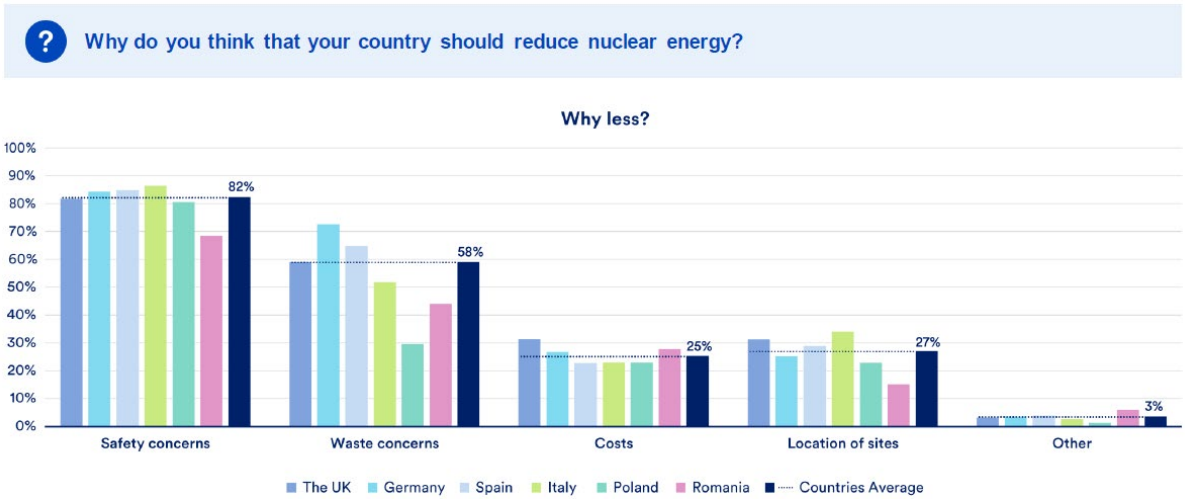

Figure 7. Main reasons for wanting a decrease of nuclear in country's energy mix: safety and waste concerns are the predominant factors [34].

1.3 Current public acceptance of hydrogen technologies

While global interest in hydrogen technologies has gained momentum relatively recently, researchers have been exploring public acceptance of hydrogen for the past three decades. Most studies take a quantitative approach, using questionnaire-based surveys administered in various ways. These acceptance studies cover a range of hydrogen technology applications, including domestic use, vehicles, fuel stations, and the technology overall. Since the publication of the European hydrogen roadmap, the number of acceptance studies has increased. This includes several review studies that compare questionnaire results and aim to explain acceptance from different angles [2, 36, 37].

Over the last two decades, acceptance of hydrogen technology has been relatively high across Europe, with 60–90% of respondents expressing a positive attitude. On average, survey results show acceptance levels ranging from 3 to 4 on a 5-point scale [38, 36, 39, 34]. While attitudes toward hydrogen technology are generally positive, acceptance varies depending on its specific application: domestic uses of hydrogen technology receive less support compared to hydrogen fuel cell applications, such as vehicles and fuel stations.

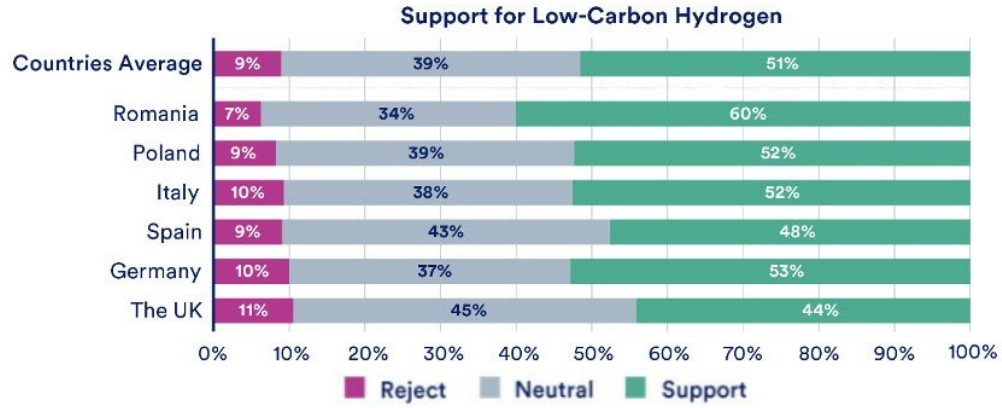

Figure 8. Support for Low-Carbon Hydrogen (Question asked: "Based on what you've read, how in favour are you of Low-Carbon Hydrogen being rolled out across [COUNTRY] on a scale of 0- 10?)". Graph shows aggregated percentages for "Reject" (0-3), "Neutral" (4-6), and "Support" (7-10) [34].

Despite growing interest in hydrogen technology, there is limited data on how its acceptance has evolved over time. Unlike nuclear energy, there are no recurring surveys that track public acceptance of hydrogen over an extended period. A significant decline in support for hydrogen technology in the Netherlands between 2008 and 2015 was recorded [40]. However, support remained relatively high, and this decline was attributed to a broader decrease in trust in science and technology in the Netherlands during that period.

It is remarkable that public awareness of hydrogen technology is relatively low compared to nuclear energy, with a widespread lack of knowledge across most countries. Respondents with an interest in new technologies and positive environmental attitudes were more informed about the use of hydrogen as a fuel. In 2023, the Clean Hydrogen Joint Undertaking, an EU public-private partnership, conducted a survey in each EU member state [38]. The results revealed that over eight in ten respondents had heard of hydrogen as an alternative to fossil fuels. However, familiarity with hydrogen technology remained low, with 53% of respondents acknowledging that, despite having heard of it, they were not at all familiar with the technology. Other studies also highlight this lack of knowledge, as evidenced by the high percentage of neutral responses to survey questions, reaching up to 30% [34, 41].

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Hydrogen technology awareness is higher in southern European countries compared to northern Europe. Overall, awareness of hydrogen energy is highest in Germany and Austria. It is also notably high in the Netherlands and Portugal. Slovakia stands out, with 49% of respondents have not only heard of hydrogen but are also familiar with the technology. In contrast, awareness is lowest in Cyprus, Denmark, and Greece. This variation in hydrogen technology awareness can be attributed to the level of media coverage and the extent to which the technology is applied in each country. There is a relatively high number of studies on hydrogen technology acceptance in Germany, the Netherlands, and Spain.

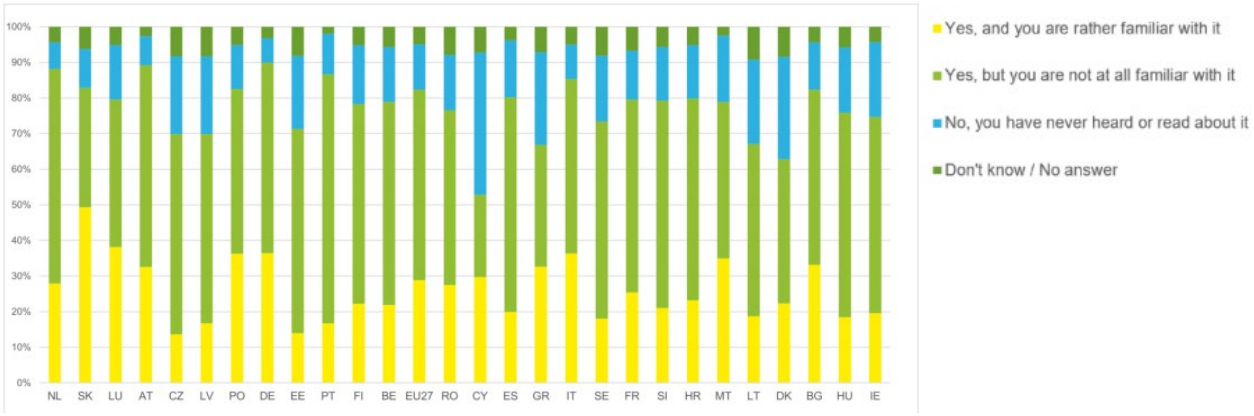

Figure 9. Have you seen, read or heard anything about Hydrogen as an energy source? Shown as % per member state [38]

Low-carbon and green hydrogen technologies receive greater support than hydrogen technology in general [42]. Hydrogen as part of the energy system is received as environmentally positive: benefits mainly associated with hydrogen being a clean energy carrier that can aid in decarbonization. Beyond the perceived environmental advantages—such as replacing fossil fuels and emitting only water vapor—there are also recognised economic benefits (such as creating a new value chain and competitive costs) and technical benefits (including flexibility of use, storage capacity, decarbonisation of hard-to-abate sectors, and enhanced energy system security). Given the energy crisis triggered by the Russian invasion of Ukraine, it is unsurprising that a vast majority of respondents believe hydrogen can play a crucial role in reducing their country's energy dependence [38].

A recurrent assumption is that the public holds a largely negative view of hydrogen, often associating it with the Hindenburg airship disaster of 1937 in New Jersey. However, acceptance studies show that top-of-mind thoughts associated the word "hydrogen" are generally neutral (people think of water) and that hydrogen is rarely linked to explosions [43]. Six in ten respondents in the EU believe that hydrogen is as safe as any other energy source [38]. However, a quarter of respondents were uncertain, indicating a notable gap in public knowledge. Besides safety, perceived risks include the substantial investments required for hydrogen technology implementation and the uncertainty surrounding hydrogen technology. Furthermore, the willingness to pay varies significantly between countries.

The combination of positive attitudes, relatively high acceptance but low familiarity, strongly suggests that hydrogen technology acceptance is still at its initial high state and might decline during the implementation phase, to raise again after. The widespread unfamiliarity with hydrogen energy technologies presents both a risk and an opportunity. Greater awareness could lead to a mix of positive perceptions, concerns, and confusion. Research shows that in the early stage of technology diffusion, information generally has a positive impact on attitudes toward the new technology [44,

36]. Increased familiarity with hydrogen technology can further promote acceptance, as shown by Huijts et al. (2019), where the acceptability of hydrogen technology increased following the introduction of a hydrogen fuelling station [8]. Overall, there is a clear demand for more knowledge about hydrogen technology and its potential applications. As mentioned previously, effective communication is key to fostering acceptance.

1.4 Hypotheses on NPHyCo public acceptance (shared risks and benefits)

In this chapter, we provide an overview of the potential perceived benefits and risks associated with nuclear-powered hydrogen cogeneration. This analysis is based on the discussions of the individual technologies outlined in previous chapters, where their unique advantages and challenges were identified. The elements of this assessment are grouped in four categories: environmental, technical, economic, and social, as illustrated in Table 1. Among these, we identified some key points which are highlighted in bold.

Table 1: Shared perceived benefits and risks of nuclear energy and hydrogen technology

Shared perceived benefits	***Shared perceived risks***
Environmental: - Replacement of fossil fuel - **Decarbonisation** of 'hard to abate' sectors	*Environmental:* - Impacts on biodiversity - Resource scarcity (Uranium and purified water)
Technical: - Flexibility of use as compared to other sustainable sources - Storage capacity for electrical power	*Technical:* - Technical and human failures - **Accidents** - Transport & storage of hydrogen and nuclear waste
Economic: - **Energy self-sufficiency** - Stable energy costs	*Economic:* - **Large investment** and uncertainty in costs - Raw material dependence
Social: - Technological innovation - Job creation	*Social:* - Conflicts of interest (Local vs global) - Dependence on political will

Firstly, hydrogen production from NPPs holds significant promise for the decarbonisation of sectors that are traditionally difficult to decarbonise, such as transportation—especially aviation—alongside chemical processes, the steel industry etc. These sectors are among the most challenging to transition away from fossil fuels, and hydrogen is recognised as key player as long as it is produced from low carbon sources like nuclear, wind or solar. From a technical and economic standpoint, the integration of hydrogen cogeneration with NPPs presents several potential advantages. Notably, during periods when renewable energy sources dominate the grid, nuclear power plants often face the need to reduce their output due to excess electricity supply. Hydrogen cogeneration offers a solution to this challenge by allowing nuclear plants to redirect their energy output toward hydrogen production. This flexibility and storage capacity not only optimizes the use of nuclear energy but also enhances the economic viability of NPPs by providing an additional revenue stream and decreasing the need for output reduction.

However, despite these advantages, several perceived risks accompany the coupling of these technologies. One of the primary concerns is the high upfront cost associated with nuclear power, which is often seen as a risky investment due to the long payback period required to recoup these costs. When coupled with the relatively new nature of hydrogen cogeneration technology there is a risk for unforeseen extra costs and economic losses. The uncertainties surrounding the integration of these technologies could amplify investor concerns. In addition to economic risks, there are social and public perception challenges to consider. Although previous discussions suggest that safety concerns are not a major barrier to the public acceptance of hydrogen, the association of hydrogen production

with nuclear technology could introduce new resistance. Nuclear energy, despite its low-carbon benefits, is still perceived by many as a high-risk technology due to historical accidents and the potential consequences of a nuclear incident. The coupling of hydrogen production with nuclear power may exacerbate these fears, leading to public opposition or at least hesitation in embracing this combined technology.

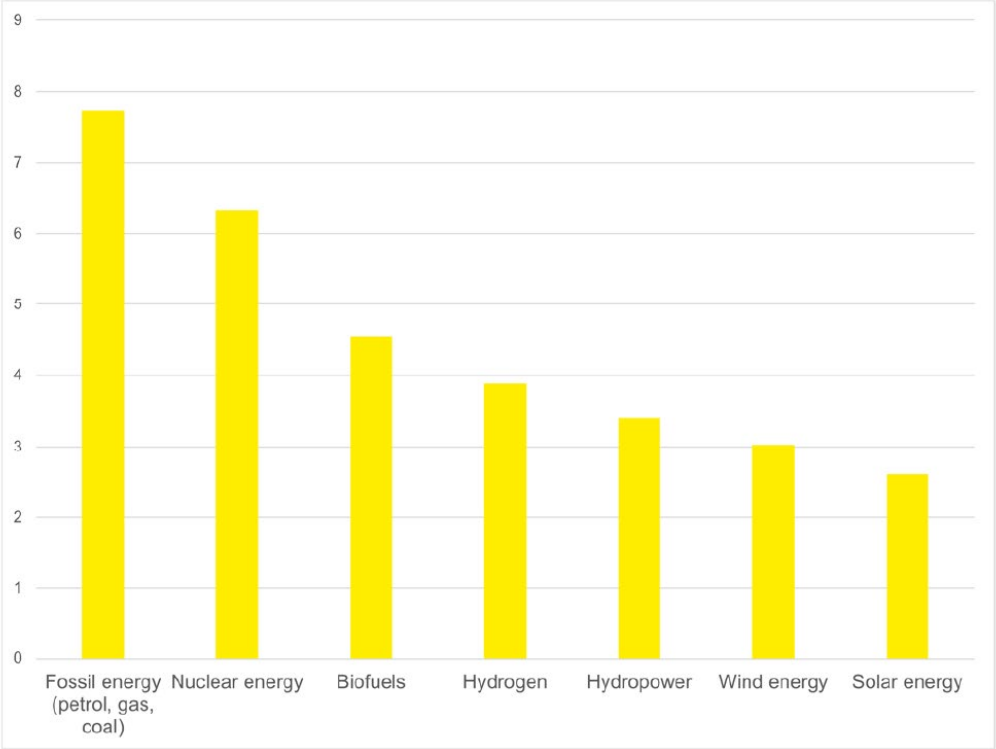

Figure 10. Perception of environmental impact at EU level on scale of 0-10 where 0 has absolutely no impact on the environment and 10 has a very negative impact on the environment [38]**.**

It is important to recognize that hydrogen's strong association with sustainability and its relatively low safety concerns compared to other energy sources could play a crucial role in improving the public perception of nuclear energy. By presenting nuclear power as a key component of a broader, sustainable energy future—one that includes hydrogen production for difficult-to-decarbonise sectors—the public's negative perceptions of nuclear energy's environmental impact could be mitigated. As depicted in the Figure 10, nuclear energy still faces significant challenges in terms of public perception regarding its environmental impact, where it ranks poorly, second only to fossil fuels. Integrating hydrogen production into the nuclear energy narrative could help reposition nuclear power as a critical enabler of a sustainable and low-carbon energy future [45].

A comprehensive research of scientific databases about hydrogen from nuclear energy was recently presented by *Energies* [45] and it revealed a steady increase in the number of publications in the latest years about the topic. This increase suggests a growing interest in and recognition of the importance of nuclear-powered hydrogen cogeneration in the transition to cleaner and more sustainable energy sources.

2 Proposed Survey

The aim of WP 6.3 is to investigate how and to what extent a H_2 plant coupled to an NPP could influence public awareness/acceptance about nuclear power generation, and therefore an EU wide survey was developed. The results of the survey were expected to provide input for a set of recommendations on communication strategies based on the outcomes, i.e. the outcome of the survey should be used as a toolbox for messaging purposes. Furthermore, this survey format could be taken into consideration for future surveys on this topic beyond the NPHyCo project, particularly for those sites looking to deploy such co-generation activities at local level. Below is an overview of the survey.

Aim of the survey:

- Investigate current public awareness and acceptance.
- Start a dialogue with local communities. Gain local support for implementation.
- Hooking on citizens' concerns. Recommendations on communications should focus on citizens and their problems and concerns and bring them a solution. ''What's in it for me?''
- Check if the messaging has worked by repeating the survey annually.

How to perform the survey:

Designing a survey through an iterative process of question design, that will be distributed to various focus groups in various ways, including the following steps:

- Try out the questions in a first survey and see if the result is meaningful.
- Based on the results adjust the questions to come to a set of recommended of questions to potentially include in other, already existing long lived surveys. The focus should be on which questions give the most valuable output.
- After the first survey, provide information and run the survey again to investigate the effect of messaging on public awareness/acceptance.

Target group:

People in the vicinity of powerplants. Local support is most important for new developments and this group should be the first to consult.

The test-phase of the survey was undertaken at EU level by distributing the questionnaire through the nucleareurope official channels (see next section). The information which the survey aimed to obtain can be summarised as follows:

- Demographic information, level of education, gender (special interest in the opinion of women who are statistically less in favour of nuclear).
- Knowledge on nuclear, hydrogen and the two combined
- What is the acceptance of nuclear
- What is the acceptance of hydrogen
- What is the acceptance combined (does a cogeneration increase or decrease NP acceptance?).
- Benefits of the coupling
- Risks of the coupling
- Support for coupling
- Identifying why acceptance is high or low
- What the main concern would be if a cogeneration site was placed nearby.

2.1 Survey at European level

In order to trial the survey and see whether the questions help obtain the information the project is looking for, an initial version was launched at European level. To identify the questions to be included in the survey, a brainstorming workshop was organised in Brussels in May 2024. Based on this brainstorming, the following questions were identified:

Section 1 – General information:

- In which city/town do you live?
- What are – in your opinion - the main concerns of your local community?

Section 2 – Level of knowledge

- How much do you know about nuclear power? Scale: Nothing – A lot
- How much do you know about what hydrogen can be used for? Scale: Nothing – A lot
- How much do you know about hydrogen use? Scale: Nothing – A lot
- Did you know you can produce hydrogen from nuclear power? Yes/No

Section 3 – Level of acceptance

- What is your level of support for nuclear power? Scale: Strongly Support – Strongly Oppose
  - Why?
- What is your level of support for hydrogen? Scale: Strongly Support – Strongly Oppose
  - Why?
- Do you think coupling a nuclear power plant with a hydrogen production facility can bring benefits in your country?
  - Why?
- Would you be willing to consider coupling a nuclear power plant with a hydrogen production facility in your community?
  - Why?

Section 4 – General information:

- Age group
- Gender
- Which sector do you work in?

The tool used to conduct the survey was Microsoft Forms. It was promoted widely via the NPHyCo Linked In account and the project partners also shared it amongst their networks, via social media and newsletters.

In terms of responses, 31 people responded to the survey. Location wise, the majority came from the Czech Republic, Germany and the Netherlands, and in terms of what they believed to be the main concerns of their local community housing was seen as the top issue followed by energy.

Below is a screen shot of the answers received:

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Level of knowledge

How much do you know about nuclear power?

Nothing	0
Not so much	3
A little	11
A lot	17

How much do you know about hydrogen production?

Nothing	1
Not so much	3
A little	14
A lot	13

How much do you know about what hydrogen can be used for?

Nothing	0
Not so much	2
A little	12
A lot	17

Did you know you can produce hydrogen from nuclear power?

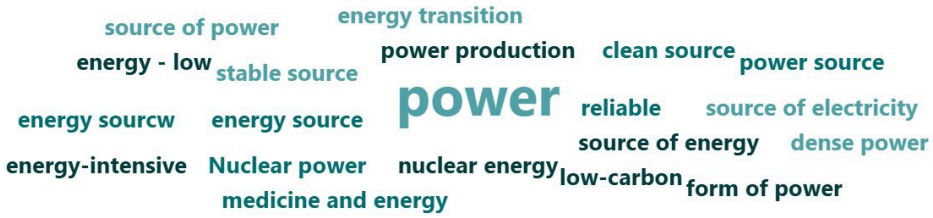
Yes	27
No	4

Level of support

What is your level of support for nuclear power and why?

Strongly Support	19
Support	6
Neutral	5
Oppose	0
Strongly Oppose	1

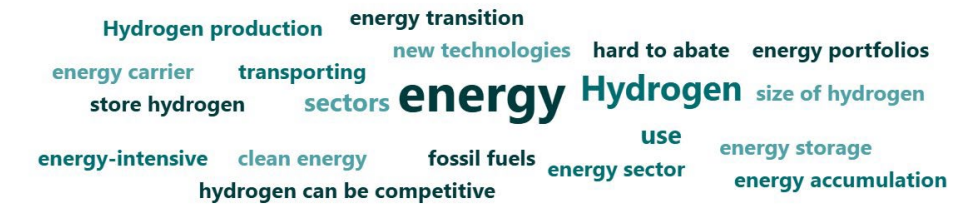
11 respondents (**35**%) answered **power** for this question.



What is your level of support for hydrogen and why?

Strongly Support	8
Support	15
Neutral	7
Oppose	1
Strongly Oppose	0

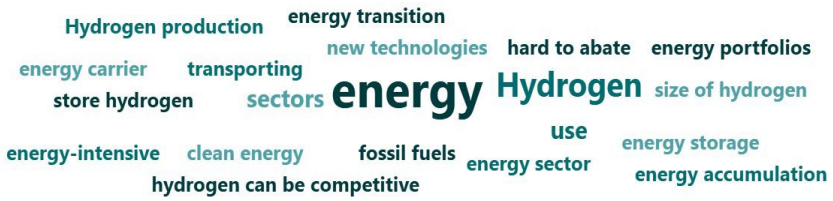
10 respondents (**32**%) answered **energy** for this question.



What is your level of support for hydrogen and why?

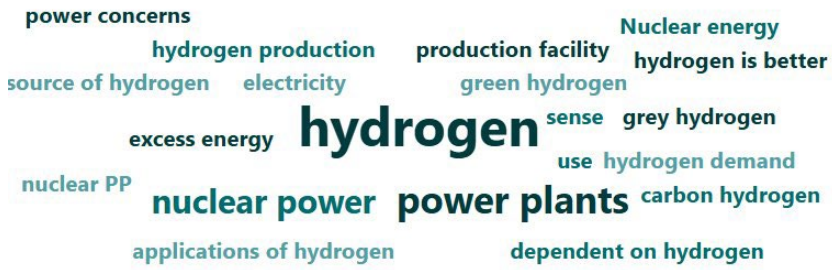
Strongly Support	8
Support	15
Neutral	7
Oppose	1
Strongly Oppose	0

10 respondents (**32**%) answered **energy** for this question.



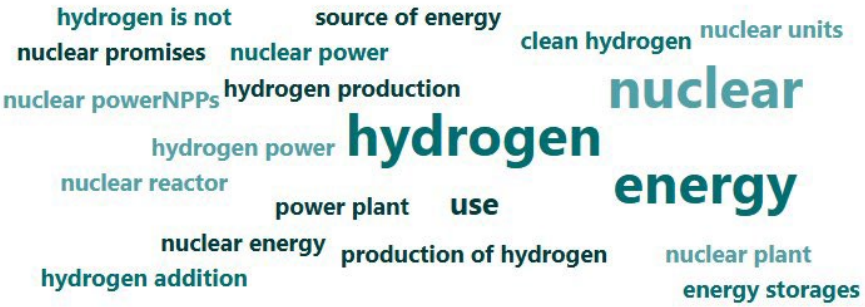
Do you think coupling a nuclear power plant with a hydrogen production facility can bring benefits in your country and why?

Yes	20
No	3
Don't Know	8



Would you be willing to consider coupling a nuclear power plant with a hydrogen production facility in your community and why?

Yes	23
No	4
Don't Know	4



Based on the responses received it was concluded that the majority of those responding to the survey came from the nuclear sector (either directly or indirectly). Therefore, it was agreed that a new survey should be launched with the goal of reaching broader non-nuclear/hydrogen/industry citizens. This would enable the development of communication messages more adapted to non-expert audiences, which is the ultimate goal of work in the field of public acceptance.

Furthermore, whilst the first version of the survey provided many 'open' questions (which allowed respondents to complete with whatever information they wished to provide), the revised version would provide a series of multiple-choice answers, based on the results of the first survey (whilst still keeping the 'other' option to be completed manually).

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2.1.1 European Survey 2.0

Based on the feedback from the first survey, which was discussed during a second brainstorming session in Erlangen (Germany) in October 2024, the questionnaire was adapted to include more multiple-choice options, as well as to try and identify which sectors the respondents were active in (and see how this affected their perception of nuclear, hydrogen and coupling potential):

Section 1 – General information:

- In which city/town do you live?
- What are – in your opinion - the main concerns of your local community?
  - Housing (availability/affordability)
  - Energy (availability/affordability)
  - Employment
  - Cost of living
  - Air quality/environment
  - Climate Change
  - Transport infrastructure/mobility
  - Quality of life
  - Other (please specify)

Section 2 – Level of knowledge

- How much do you know about nuclear power?
  - Nothing
  - Not so much
  - A little A lot
- How much do you know about hydrogen production?
  - Nothing
  - Not so much
  - A little
  - A lot
    - For those who answered a little/a lot please list examples of hydrogen production technologies and/or sources
- How much do you know about what hydrogen can be used for?
  - Nothing
  - Not so much
  - A little
  - A lot
    - For those who answered a little/a lot please list examples of what hydrogen can be used for
- Did you know you can produce hydrogen from nuclear power?
  - Yes
  - No

Section 3 – Level of acceptance

- What is your level of support for nuclear power?
  - Strongly Support
  - Support
  - Neutral
  - Oppose
  - Strongly Oppose

- Why?
- What is your level of support for hydrogen?
  - Strongly Support
  - Support
  - Neutral
  - Oppose
  - Strongly Oppose
- Why?
- Do you think coupling a nuclear power plant with a hydrogen production facility can bring benefits in your country?
  - Yes
  - No
  - Don't know
- Why?
- Would you be willing to consider coupling a nuclear power plant with a hydrogen production facility in your community?
  - Yes
  - No
  - Don't know
- Why?

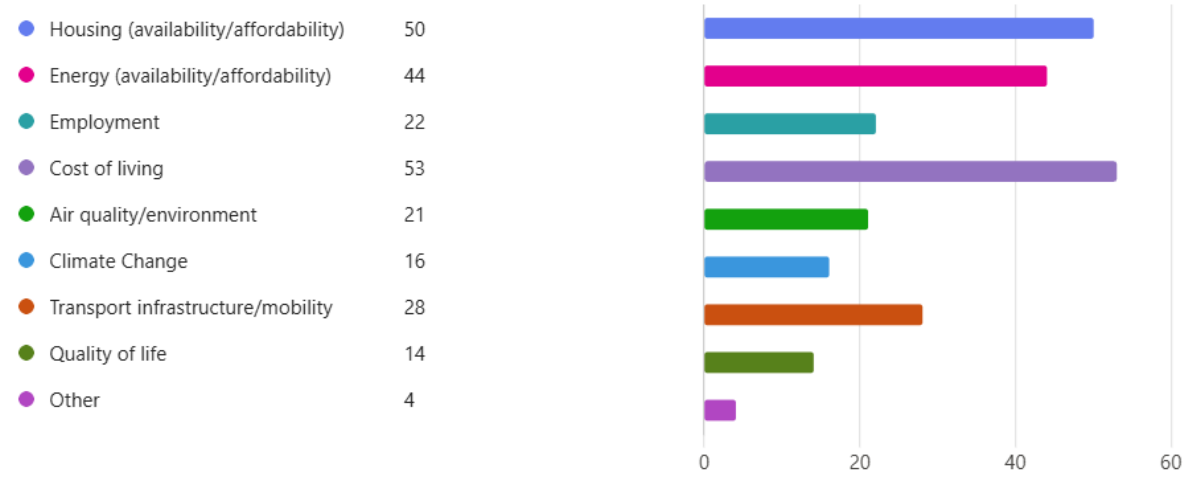
Section 4 – General information:

- Age group:
  - Under 18
  - 18-30
  - 31-40
  - 41-50
  - 51-60
  - Over 60
- Gender:
  - Female
  - Male
  - Non-binary
  - Prefer not to say
- Which sector are you active in?
  - Energy
  - Industry
  - Health
  - Economics/Finance/Banking
  - Public affairs/Communications
  - NGO
  - Education
  - Research
  - Agriculture/fisheries
  - Other (please specify)

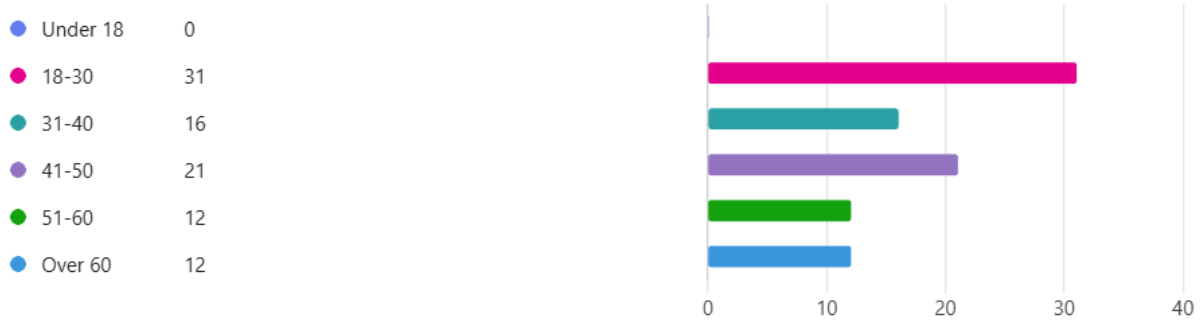
In order to reach out to a broader audience, promotion was extended to other social media accounts (eg facebook) and partners were encouraged to share it not just within their professional networks but also amongst family and friends. As a result, the number of people responding to the survey rose from just over 30 the first-time round, to just under 100 (92). Location wise, whilst the survey once again had many responses from Germany and the Netherlands, a lot more responses were received from other countries such as Spain, Belgium, Finland and the UK. There was also a shift in terms of what respondents believed to be the main concerns of their local community, with cost of living coming at the top of the list, followed by access to affordable housing and energy.

General Questions

What are the main concerns of your local community?



Age Group



Gender

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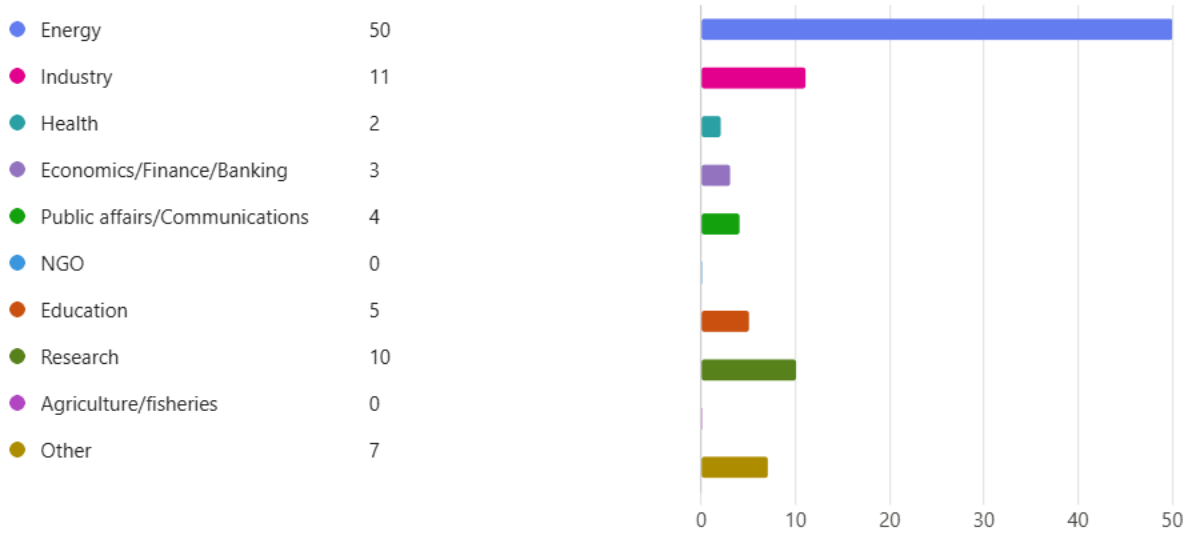
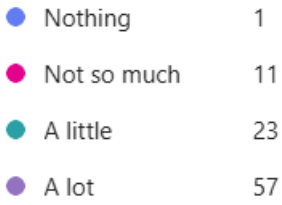
Sector which they are active in



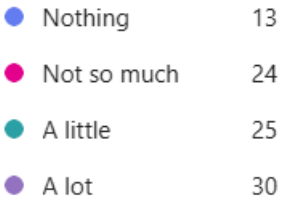
As highlighted in the responses, it was predominantly men who responded to the survey (76%), indicating that there is a potential lack of engagement on this topic with women (and that therefore efforts should be made to develop a communication strategy to at least encourage women to take part in the conversation). Interestingly, it was predominantly young people who responded to the survey (18-30 range), followed by the 41-50 age range and then 31-40. This shows that the younger generation is interested in the topic and want to be part of the conversation. In terms of sectors, an overwhelming majority said they worked in the energy sector, which would suggest that they already have some knowledge about this topic.

Level of knowledge

How much do you know about nuclear power?



How much do you know about hydrogen production?

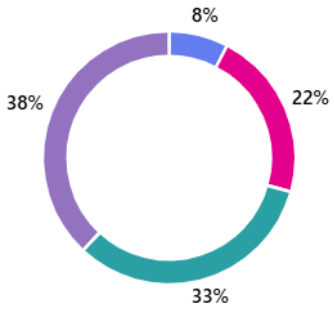


With the goal of obtaining more insights into the level of knowledge about hydrogen production, those respondents which answered 'a little' or 'a lot' to the previous question where then asked to list examples of hydrogen production technologies. The top answers received were the following:

- Electrolysis in general
- Steam Methane Reforming
- Alkaline electrolysis
- PEM electrolysis

The following question aimed to identify respondents' level of knowledge around what hydrogen can be used for. The following answers were received:

Nothing	7
Not so much	20
A little	30
A lot	35



As in the previous instances, those who answered 'a little' or 'a lot' to the previous question where then asked to list examples of what they believed hydrogen could be used for. The top answers received were the following:

- Fuel (transport, cars, synfuels)
- Industry (chemicals, metals)
- Ammonia
- Electricity
- Energy carrier
- Energy storage
- Heating

This section concluded by asking respondents whether they knew that hydrogen could be produced from nuclear power – an overwhelming majority (72%) answered yes.

Level of support

What Is your level of support for nuclear power?

Strongly Support	57
Support	22
Neutral	10
Oppose	2
Strongly Oppose	1

What Is your level of support for hydrogen?

Strongly Support	30
Support	35
Neutral	26
Oppose	1
Strongly Oppose	0

As shown in the responses to these two questions, a majority of respondents either 'support' or 'strongly support' both technologies, with nuclear seeing a slightly higher level of support over hydrogen (79 vs 65). The rest remained neutral with very few opposing either technology. In both these instances a follow-up question was asked to try and identify why respondents support/don't support nuclear and hydrogen.

For nuclear, a majority responded that they support this technology because it is clean, affordable and reliable. For those that opposed nuclear, the responses were related to safety, waste and perceived environmental impacts. In addition, some of those who said they were 'neutral' in terms of their

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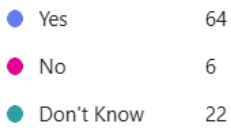
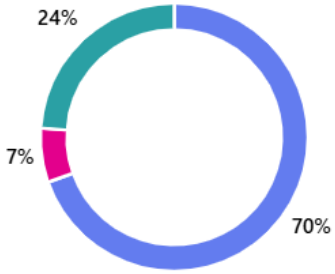
support for nuclear also indicated that they viewed it as expensive and did not believe it was flexible in terms of production.

For hydrogen, a majority responded that they support this technology because it is clean, flexible and a solution for hard-to-abate sectors. For the one respondent who indicated that they were opposed to hydrogen, they indicated that this because they do not believe it will bring the solutions being put forward (for example in the case of transport). Interestingly, many of those who said they were 'neutral' in terms of their support for hydrogen indicated 'don't know', suggesting that they are neutral to hydrogen because they do not have sufficient information to enable them to take a decision about hydrogen. Cost was also listed as a reason why they were neutral to hydrogen.

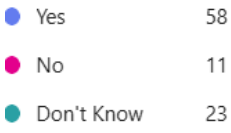
After establishing the level of support of respondents in relation to nuclear and hydrogen, the survey then went on to identify whether respondents believed that coupling a nuclear power plant with a hydrogen production facility could bring benefits to their country. A majority (70%) answered yes to this question, with only 7% answering no. Nearly a quarter were 'neutral'.

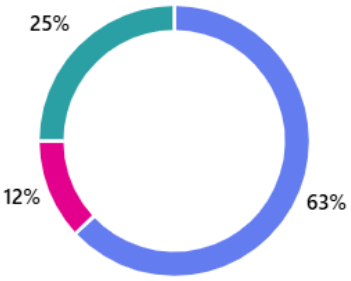




Here again a follow-up question was included to identify what benefits such coupling could bring to their country, with many indicating that would be an efficient way of producing energy, particularly in a grid where there is greater integration of intermittent renewables, it can help decarbonise industry and district heating and because it is viewed as a potentially affordable energy source. For those who answered 'don't know' to this question, they indicated that they simply did not know enough about this potential to take an informed decision. For those who were against, their reasoning was that there are other alternatives.

The question was then asked whether respondents would be in favour of such a coupling facility in their community (with the goal of identifying a potential NIMBY effect). Whilst the level of support fell, it remained quite high, with 63% supporting such a facility in their local community. The don't knows remained stable at 25%, whilst the percentage that were against rose to 12%.





The reasoning given by the 'don't knows' was as per the previous answer: they simply did not have enough information to make an informed decision. Those who answered 'no' indicated that this was due to concerns about waste, safety or because they lived in a city. For those who supported coupling

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in their community, many listed the benefits to their community (jobs, economic growth) and felt that both technologies implement high level of safety/are well regulated. In addition, the benefits included provision of cheap, clean and constant energy.

Conclusions

Based on the responses to the second survey – and taking into account the limited number of responses received – below are some recommendations on how to communicate around the benefits of coupling a nuclear power plant with a hydrogen production facility:

- Given the main concerns of the local communities where the respondents were based, communicating the benefits of such coupling in terms of access to affordable energy and its impact on the cost of living would be beneficial as it responds to the needs of the community. Employment opportunities would also help highlight the benefits of such coupling to the local community.
- Overall, the level of knowledge of respondents was quite high – which is to be expected given that a majority work in the field of energy. Nevertheless, simple communication around hydrogen (how it can be produced and what it could be used for) would be worthwhile.
- The level of support for both technologies was quite high, but for those who indicated 'don't know' to this series of questions because they simply did not have the information that would allow them to take an informed decision on this it would likely prove beneficial to explain why these technologies are clean, reliable and affordable.
- In terms of support for such a coupling project in their country, again the don't knows indicated that they simply did not have enough information to take a decision. So here communication around the benefits of nuclear with hydrogen would bring benefits. Based on the responses received by those who answered yes to this question, such messaging could centre around the efficiency which such coupling would bring to the energy system, particularly taking into account the increased penetration of intermittent renewables in the future. In addition, the benefits which it would bring in terms of support for industry in their efforts to decarbonise whilst maintaining their competitiveness is also worth considering in messaging.
- In relation to the NIMBY effect, again more simple information needs to be communicated to local communities, with the industry prepared to answer questions which may arise in relation to waste and safety.

2.2 Survey at national level: Ukraine

The questions used for the Ukrainian survey were the same as for the European one. The only difference between them was the location of the survey. It is also worth noting that the Ukrainian audience represent not only the country, but also the cities of the respondents, as the diagram below will show.

Section 1 – General information:

- In which city/town do you live?
- What are – in your opinion - the main concerns of your local community?
  - Housing (availability/affordability)
  - Energy (availability/affordability)
  - Employment
  - Cost of living
  - Air quality/environment
  - Climate Change

- Transport infrastructure/mobility
- Quality of life
- Other (please specify)

Section 2 – Level of knowledge

- How much do you know about nuclear power?
  - Nothing
  - Not so much
  - A little A lot
- How much do you know about hydrogen production?
  - Nothing
  - Not so much
  - A little
  - A lot
    - For those who answered a little/a lot please list examples of hydrogen production technologies and/or sources
- How much do you know about what hydrogen can be used for?
  - Nothing
  - Not so much
  - A little
  - A lot
    - For those who answered a little/a lot please list examples of what hydrogen can be used for
- Did you know you can produce hydrogen from nuclear power?
  - Yes
  - No

Section 3 – Level of acceptance

- What is your level of support for nuclear power?
  - Strongly Support
  - Support
  - Neutral
  - Oppose
  - Strongly Oppose
- Why?
- What is your level of support for hydrogen?
  - Strongly Support
  - Support
  - Neutral
  - Oppose
  - Strongly Oppose
- Why?
- Do you think coupling a nuclear power plant with a hydrogen production facility can bring benefits in your country?
  - Yes
  - No
  - Don’t know
- Why?
- Would you be willing to consider coupling a nuclear power plant with a hydrogen production facility in your community?
  - Yes

- No
- Don't know

- Why?

Section 4 – General information:

- Age group:
  - Under 18
  - 18-30
  - 31-40
  - 41-50
  - 51-60
  - Over 60
- Gender:
  - Female
  - Male
  - Non-binary
  - Prefer not to say
- Which sector are you active in?
  - Energy
  - Industry
  - Health
  - Economics/Finance/Banking
  - Public affairs/Communications
  - NGO
  - Education
  - Research
  - Agriculture/fisheries
  - Other (please specify)

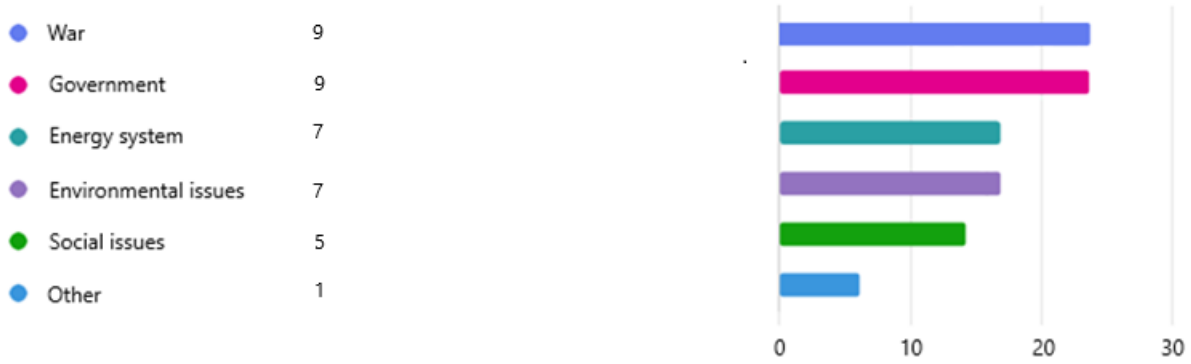
The survey was traditionally conducted through distribution on social networks. It is worth noting that in order to reach a larger circle of respondents, Ukrainian partners in the project involved specialised public organizations of Ukraine in conducting the survey. Thus, the survey was launched from several social media accounts.

The number of people who took part in the survey reached 38 respondents. The largest percentage among those surveyed were residents of satellite towns of Ukrainian nuclear power plants and the city of Kyiv.

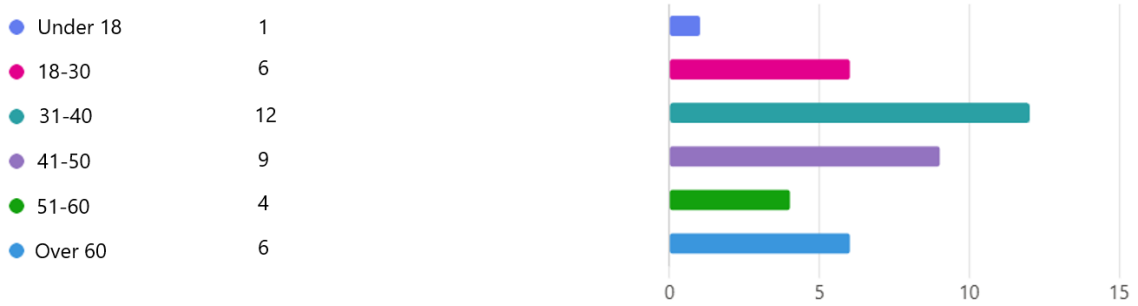
General Questions

What are the main concerns of your local community?

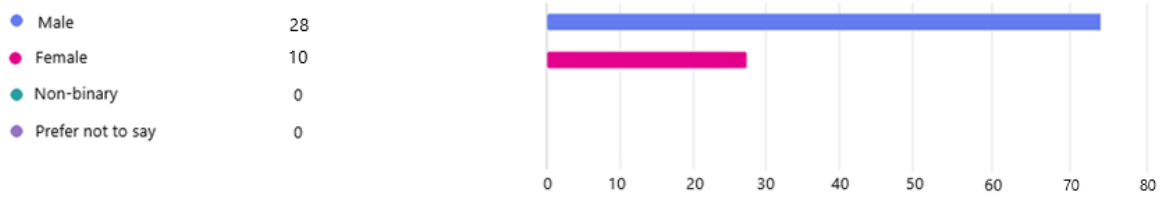
According to this open-ended question, the respondents' answers can be divided into several categories. It is worth noting that some of the answers relate to several categories at once, for example, most respondents noted that the problems of the energy system are associated with the war in the country, regular shelling of critical infrastructure and destruction of energy system facilities. In this case, the answer belonged to the category that is the root cause of the described problem. Below we can see the percentage:



Age Group

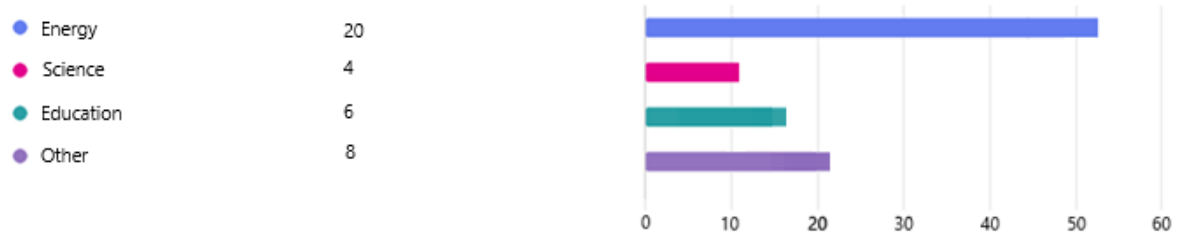


Gender



The survey of the Ukrainian audience was launched through the social media of highly specialised organizations, enterprises and public associations whose activities are focused on the field of nuclear energy. This influenced the fact that the professional circle of the audience is concentrated around the energy sector or related to it. We can see this in the diagram:

Sector which they are active in



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Level of knowledge

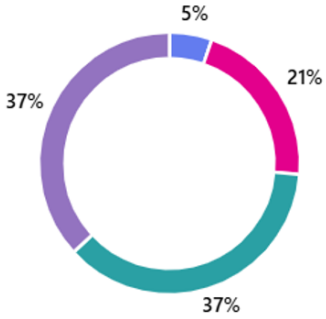
The knowledge block contains three questions. The purpose of this block is to determine the respondents' awareness of nuclear energy and hydrogen production. This block of questions precedes the block on the level of support, which directly depends on the level of knowledge.

How much do you know about nuclear power?

Nothing	0
Not so much	1
A little	2
A lot	35

How much do you know about hydrogen production?

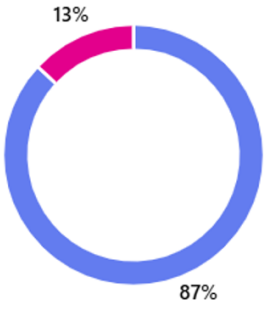
Nothing	2
Not so much	8
A little	14
A lot	14



Level of support

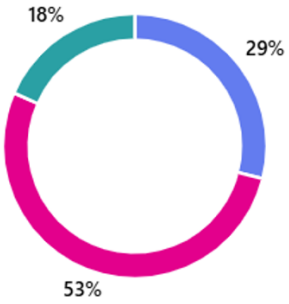
What Is your level of support for nuclear power?

Strongly Support	33
Support	5
Neutral	0
Oppose	0
Strongly Oppose	0



What Is your level of support for hydrogen?

Strongly Support	11
Support	20
Neutral	7
Oppose	0
Strongly Oppose	0



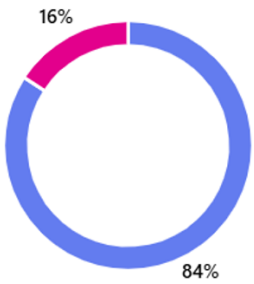
As we can see from the diagrams, both technologies have support, strong support or neutral attitude of respondents. None of the technologies causes categorical opposition. In percentage terms, nuclear energy receives greater support from respondents (100%), unlike hydrogen (82%), provided that we count the answers “support” and “strongly support” as support.

Respondents were asked to explain why they support nuclear power. The answers received included: reliability, stability, the ability to produce large amounts of energy, high safety standards and a high level of training of specialists in the field, environmental friendliness and minimal harm to the planet, and the lack of alternatives. No one among the respondents spoke out against.

Regarding hydrogen, the majority responded that they support this technology because of its safety, environmental friendliness and lack of harmful emissions, alternative nature, prospects and opportunities for the development of related industries, as well as through the development of new technologies and the creation of additional jobs and opportunities for the development of society. The respondents explained their neutral attitude towards hydrogen primarily by the lack of knowledge and misunderstanding of how reliable and safe it is, the complexity of production, and the lack of completed experimental results. The high cost was also cited as one of the reasons for neutrality towards hydrogen.

After determining the level of support for the nuclear and hydrogen industries, it is important to understand how much respondents like the idea of combining a nuclear power plant with a hydrogen production plant and how they think it could benefit their country. As can be seen from the graph, 84% of respondents believe that it could be beneficial.

Yes	32
Don`t Know	6
No	0



In support of hydrogen technology, respondents listed the fact that it is effective and can solve the issue of decarbonisation, optimise the use of nuclear energy, increase the profitability of nuclear power plants, and improve operational stability.

Supporters of combining a nuclear power plant with a hydrogen plant emphasised that nuclear energy is the cleanest source and its use is a successful solution for obtaining clean hydrogen. Hydrogen, in turn, can be used both for its own needs and for export, which will make a positive contribution to the country's economy. And in the future, hydrogen will play an important role as an energy carrier and as a fuel for vehicles.

In addition, the development of a new industry is undoubtedly an economic benefit from inventions, international interaction and cooperation, it is a contribution to the future, the creation of new jobs and the involvement of the intellectual potential of citizens.

Respondents who answered “don’t know” indicated that they were not aware of this issue and needed additional study of the topic to make a decision.

The next question we asked was whether you agree with the construction of hydrogen production in your community (in order to identify the potential NIMBY effect). The level of support remained quite high at 74%, among the reasons respondents cited technological development, economic benefits for the region, the emergence of new jobs, cheaper electricity and the availability of alternative fuels. “Don’t know” was answered by 21% of respondents, most of whom live in regions without operating nuclear power plants. 5% of respondents were categorically against such a decision due to the possibility of danger, due to war and due to the lack of completed research, geographical and economic complexity of implementing this idea.

Conclusions

After analysing the survey results, we can outline not only the level of support and opposition, but also understand their reasons, as well as outline further actions for interacting with society. Below are some reflections on the information obtained:

- Given that most respondents are nuclear energy specialists, the level of support for combining existing nuclear power plants with a hydrogen production facility was quite high. Respondents who were against or had doubts were not sufficiently informed, so educational activities are crucial in increasing the level of public trust.
- The listed problems of local communities can be partially or completely solved by building a hydrogen plant, and this must be discussed with society in order to gain their support.
- It is worth noting that some of the respondents who support a hydrogen project for the country were not ready for a hydrogen production facility to be located in their local community. And this is again a question of educational activities. Communication, clarification and sharing knowledge about hydrogen has a direct impact on the acceptance and support of hydrogen cogeneration by society at the local and national levels.

3 Communication recommendations for local outreach

The surveys above provide a snapshot of how the public could potentially view the coupling of an NPP with an HPP. They also provide a baseline from which future surveys could build to identify whether engagement with local communities is supporting public acceptance of such cogeneration or not.

In terms of recommendations for local outreach these can be summarised as follows:

- Focus on the issues which are of concern to local communities. This can help identify solutions which co-generation projects can bring to the table. For example, under the European survey, energy availability and affordability were listed as key issues of concern. By explaining how such cogeneration can help ensure security of energy supplies and more affordable energy, communications would be answering to a need of the local community. Another example is cost of living (which was the top issue), having a cogeneration facility in a local community will lead to job creation and economic growth both of which can help mitigate the impact of the rising cost of living. At the end of the day, the aim should be to answer the question: What's in it for me?
- The level of knowledge of citizens around a particular topic as it can help guide messaging – as indicated in the results of the survey, the vast majority of those who answered 'don't know' to questions around their level of support for the different technologies indicated that this was mainly due to the fact that they simply did not know enough about the topic to enable an informed answer. The goal should therefore be to provide them with information about the different technologies and enable them to come to operators with questions which they may have with the aim of increasing their level of knowledge. It is important to note that the focus should never be on 'educating', but rather on sharing information and **engaging in a conversation**.
- Understanding why citizens support – or don't support – nuclear, hydrogen or co-generation is also important. For those who support, it gives an idea as to why citizens might be interested in such technologies and can help develop communication activities promoting these perceived benefits for others (e.g energy security, affordability, jobs, growth). For those who are against, their reasoning can be used by operators to develop answers to questions should they arise (for example safety). In terms of communications, this means focusing on the positives (proactive communication) and answering questions on the 'negatives' (reactive communication).
- It is always interesting to identify whether citizens support a technology in general, and whether (or not) they would be willing to accept it in their local community (i.e. is there a NIMBY effect). If there is a risk of a NIMBY happening then demonstrating the benefits to the local community becomes even more important.
- It should be noted that it was mainly men who answered the surveys, which is often the case for nuclear in general. There is sometimes a misconception that women are more opposed to nuclear, when in actual factual fact it is that they are usually considered as 'neutral'. This is linked to the point made above: in most instances they remain neutral because they have not been engaged in the conversation – and so it important that efforts are made in order to reach out to women and engage with them.
- In order to obtain meaningful and measurable results that can help define communications and public engagement strategies going forward, it would be worthwhile to include at least some of the survey questions into existing national/local public acceptance surveys in order to keep track of how opinions are evolving.

4 Conclusions

Public acceptance will play a significant role in the deployment of a cogeneration project in the future. As such, it is important to have an understanding of how the local community could potentially view such a project and to engage in a conversation with them in order to outline the benefits which such a facility could bring, whilst being prepared to answer any questions which they may have.

As NPHyCo is a 'short-term' project, it has not been possible to obtain yearly data on public acceptance – nevertheless, the goal going forward is to encourage the industry to include elements of the survey in their own public acceptance survey and for nucleareurope to conduct the European survey on a yearly basis and publish the results.

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