



Light assisted solar fuel production by artificial CO₂ Reduction and water Oxidation

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Authors	Nana Gerstrøm Alsted Markus Zimakoff
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1. Executive summary

This report presents the findings of an investigation into societal perceptions on the LICROX technology and solar fuel technologies in general. With the current climate crisis demanding urgent action to phase out fossil fuels and transition to a sustainable energy system, the green transition in Europe is making progress, particularly in the electrification of society. However, it is evident that a sustainable energy system requires more than just electrification. The LICROX project aims to address all sectors of society but will have a special impact into those that cannot be electrified effectively, by developing a solar based fuel. As such a new technology stands to change the ways we operate as a society, citizens play a considerable role in defining the role for solar fuels.

The Danish Board of Technology conducted a citizen engagement process with over 300 European citizens from five countries during the spring of 2023, seeking to understand and integrate citizens' perceptions on emerging energy technologies, including LICROX. The EuropeSay methodology, utilizing small-scale workshops facilitated by private citizens and an interactive online platform, enabled deliberative discussions, providing both quantitative and qualitative insights.

The consultation reaffirms European citizens' strong commitment to reducing CO₂ emissions, emphasizing the role of technology advancements and lifestyle changes in achieving sustainability. Resource allocation considerations for LICROX, such as land use, reveal citizens' hesitation to prioritize local communities for facilities, with a preference for industrial areas over nature and forests.

Addressing freshwater scarcity in the LICROX process emerges as a key concern for citizens, aligned with global assessments highlighting the need for securing clean drinking water for all. Integrating sustainability across the production chain is vital, considering citizens' concern over plastic waste related to LICROX's end product, ethylene.

Citizens' support for CO₂-neutral production methods and interest in European sovereignty suggest potential for private-public partnerships in technology development. Furthermore, citizens' positive attitude towards investing in innovative technologies like LICROX aligns with their belief in technology's pivotal role in reducing CO₂ emissions.

The valuable insights gained from the engagement process inform the further development and implementation of LICROX and other emerging energy technologies, ensuring a more inclusive and sustainable green transition for Europe. These findings will guide policymakers and stakeholders in aligning technology design and implementation with citizens' needs and aspirations, fostering a collective effort towards a greener future.

Citizens perceptions on LICROX



Results from EuropeSay



Light assisted solar fuel production by artificial
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2. Introduction

The current climate crisis shows that we urgently need to phase out fossil fuels and transition to a sustainable energy system quickly. Fortunately, the green transition in Europe is progressing, and particularly the electrification of our society is developing rapidly. However, a sustainable energy system requires more than just electrification. This is the starting point for the LICROX project, which aims to produce solar fuels as the liquid renewable fuel of the future.

All technologies are dependent on economic factors as well as common resources. Because emerging technologies, like LICROX, hold the potential to be applied at a large scale, their design and implementation stand to greatly affect the lives of European citizens. Therefore, inclusion and foresight are essential to understand and integrate citizens' perceptions and factors that influence societal acceptability. To accommodate this, the Danish Board of Technology has conducted a citizen engagement process with over 300 European citizens in 5 different countries during the spring of 2023. The process has investigated citizens' ideas, hopes, and concerns on the future development of emerging energy technologies, like LICROX.

This report presents the results of a European-wide citizen consultation on the LICROX technology. The consultation has followed the EuropeSay methodology, developed by the Danish Board of Technology. The method functions as small-scale workshops consisting of 4-8 participants, which are arranged and facilitated by private citizens. The participants are guided through the process by an online platform which provides informative text, videos, pictures, and questions for shared discussion and then collects individual responses from each participant. What differentiates this method from survey-based methods is the interactive and reflexive element, which causes participants to deliberate on the given issues, rather than providing their immediate response. The method also provides information and understanding for citizens who are not well informed on the topic and therefore don't feel like they can contribute to the discussion or the decisions. Thereby, the EuropeSay methodology produces a quantitative as well as a qualitative output on the basis of a deliberative discussion.

2.1 About the LICROX project

The LICROX project is funded by the EU HORIZON program and brings together an interdisciplinary team of natural and social scientists from ICIQ, ICFO, EPFL, TUM, DBT, Avantama, and Hysytech.

Artificial photosynthesis mimics the natural process of converting sunlight to energy stored in chemical bonds. LICROX will fabricate and test a photoelectrochemical cell (PEC), an artificial photosynthesis device for converting sunlight, water and carbon dioxide (CO₂) into carbon-based molecules containing 1 carbon (C1) or 2 carbons (C2), capable of storing chemical energy.

The target is the formation of ethylene, a commodity chemical heavily used in the production of polymers and other materials and as a component in biofuel. The PEC will be constructed in a compact tandem structure consisting of a photoanode, a semi-transparent organic solar cell, and a photocathode for a broadband absorption of sunlight to achieve high current densities (above 5 mA/cm²). These photoelectrodes will be coupled to catalysts composed of nanoparticles (NPs) or molecular complexes of non-noble metals (Cu, Fe, Co) to drive the water oxidation and carbon dioxide reduction (CO₂R) reactions in an aqueous electrolyte at near-neutral pH.

2.2 About citizen perceptions – why it's needed.

Citizen engagement in the green transition has not shown to be an easy task, but nevertheless it is inevitable, as citizens have shown that they will mobilize and shut down projects and policies if they disagree or are not included in the decision making. Public support is a crucial aspect of any new green innovation. This issue that will profoundly affect the lives of all citizens should not only be discussed by experts, stakeholders and policymakers, but needs to have a broad public debate in order to gain legitimacy. A foundational aspect of democratic governance is that the citizens should be involved in deciding what technology can be considered to be societally beneficial and how these technologies should be applied. Further, if trust is to be created, it is necessary to know what the actual concerns are, what uses are seen as desirable and acceptable, and where the line should be drawn for what constitutes unethical, nefarious, or simply unacceptable use. Having this dialogue is essential to ensure that the full potential of the technology can be wielded for beneficial purposes while at the same time addressing and curtailing the negative potential inherent in the technology. The importance of having this discussion cannot be overstated, as avoiding it may instigate tech-lash against the green transition, which could ultimately lead to a severe backlash against fighting climate change.

Apprehension about asking citizens has often been based on a perception of citizens as having insufficient knowledge about technology or simply not being competent enough to provide useful output. But while not all citizens have technical expertise, this is only one point of view. Citizens have unique in-depth knowledge about how all parts of society function from their professional and private lives. Thus, the combined knowledge of citizens is vast and in no means inferior to that of experts. It is important to stress that the engineer, the social scientist, and the developer are all citizens. In addition, in contemporary societies citizens are historically well educated and, not just capable, but also willing to be engaged. There is plenty of evidence that suggests that when engaged through accessible and transparent methods, citizens can participate enthusiastically and insightfully in discussions on complex topics.

2.3 Method

2.3.1 EuropeSay

EuropeSay is a concept for distributed dialogue that is designed to engage citizens in deliberations about select topics. Citizens are engaged in micro-workshops of 4-8 participants which are organized by regular citizens volunteering to host the meetings. The meetings can take place wherever and whenever it is convenient for the participants, and instead of having a professional facilitator, the event is guided by an online platform. While a meeting was designed to last approximately 90 minutes, the actual duration could vary significantly; shorter if the discussion was sparse, and longer if the conversation was lively and more in-depth.

At the meetings, the participants gather at the chosen location, perhaps around a computer in the living room of the host, in the break room at the office, in the local library or wherever it is most convenient. The online platform will guide them through a predefined process during which they will engage in consecutive rounds of deliberation, alternating between presentation of information in the shape of short texts and video vignettes and deliberation on questions addressed by the videos. At the end of each round, they will be asked to provide answers to a range of questions with predefined answering options and be given the opportunity to write qualitative answers in an open textbox.

In short, the methodology enables anyone to invite friends, family, colleagues, etc. to join them for a face-to-face deliberation, wherever and whenever, using a digital platform to facilitate and inform the meetings

and to collect the results. Thus, the methodology provides the flexibility of online participation while ensuring that participants have had time to reflect over their answers and have had their preconceptions and values challenged in open face-to-face deliberation, thus producing informed and considered responses to the questions posed.

What this method seeks to achieve is a well-grounded picture of the tendencies in the European population, both at the national and transnational level. This picture can be very useful for getting a rough understanding of what the European population thinks about a given subject.

While the method is used for data collection it also provides the participants with a good experience of deliberating on an important topic, giving them food for thought and a chance to discuss and share ideas, values and presumptions with friends, colleagues and others. The deliberate element is crucial for the social acceptance of the green transition in Europe and whenever possible should be included in all parts of the process transitioning our society. Here are some citizens perspectives on the experience of participating in the EuropeSay workshops:

“What I found most interesting was to hear the perspectives of people who have very different experiences from each other and who emphasize different aspects of the new technology.” (Bulgarian participant)

“The most interesting thing for me during the discussion was to hear the opinions of the other participants, thanks to which I changed my initial skepticism about this innovative solution.” (Bulgarian participant)

“Learning about other participants' perspectives on climate problems and possible solutions.” (Polish participant)

“The arguments of my colleagues have seemed very interesting to me, since the topic we have discussed can have different points of view and learn what are the solutions depending on the point of view of each person.” (Spanish participant)

“That we agreed on our reflections. We had a good talk about “climate technologies” in general, and about innovation in the field of climate technology.” (Danish participant)

2.3.2 Demographic

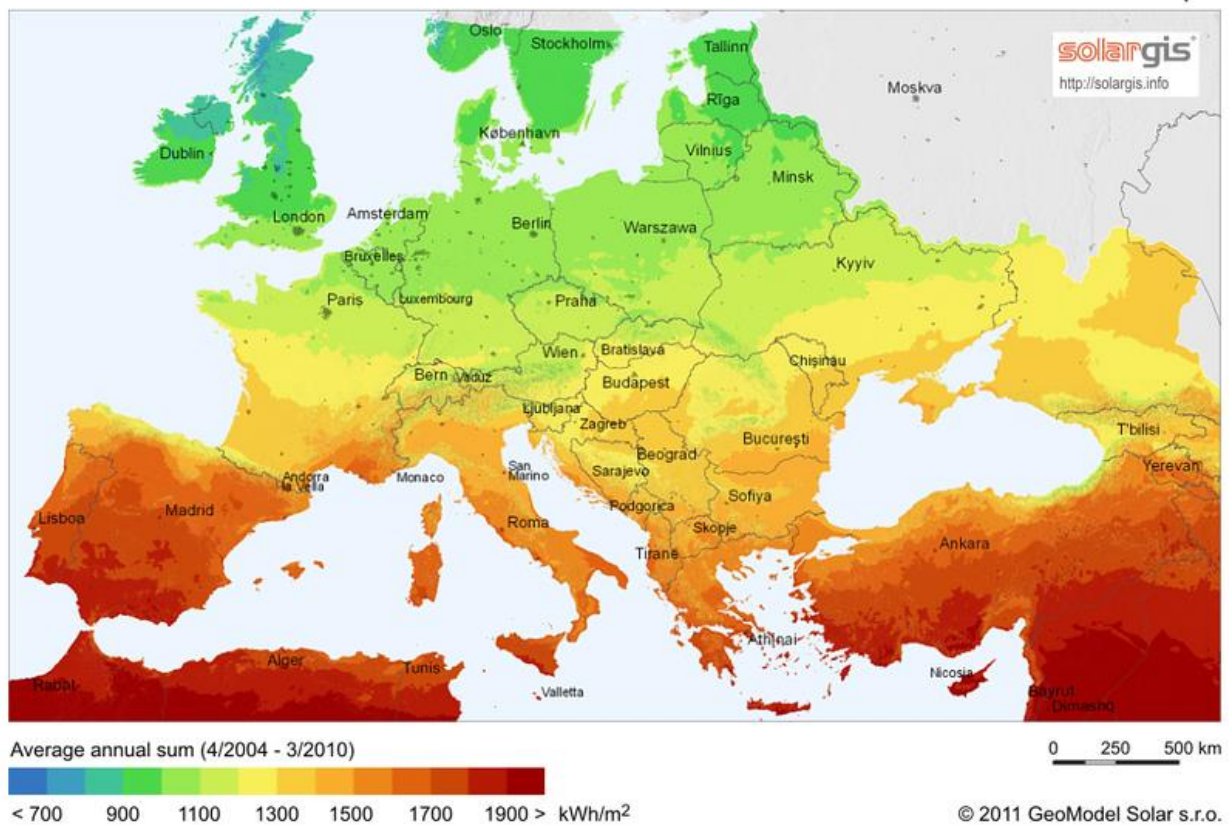
In the recruitment there has been a focus on getting a diversity in participants, several factors have been part of the recruitment strategy.

Nationalities

In the overall selection of countries for recruitment of participants there were different factors considered to get a diverse spread of participants. One factor was to get a geographical spread across Europe. We aimed to cover north/west, east and south. Besides, we chose countries that have different potential for solar installation according to the irradiation map seen below. There is a high probability of the final LICROX facilities primarily will be in the areas with the highest solar potential, which means that it is important for us to examine whether there are different attitudes and values at play in the the different zones.

Global horizontal irradiation

Europe



As the chart below illustrates, we cover both a geographic spread and the different zones of irradiation:

Country	Nr. of meetings	Nr. of participants
Denmark	10	61
Germany	3	15
Poland	10	57
Total green zone	23	133
Bulgaria	16	97
Spain	22	121
Total	61	351

Age and Gender

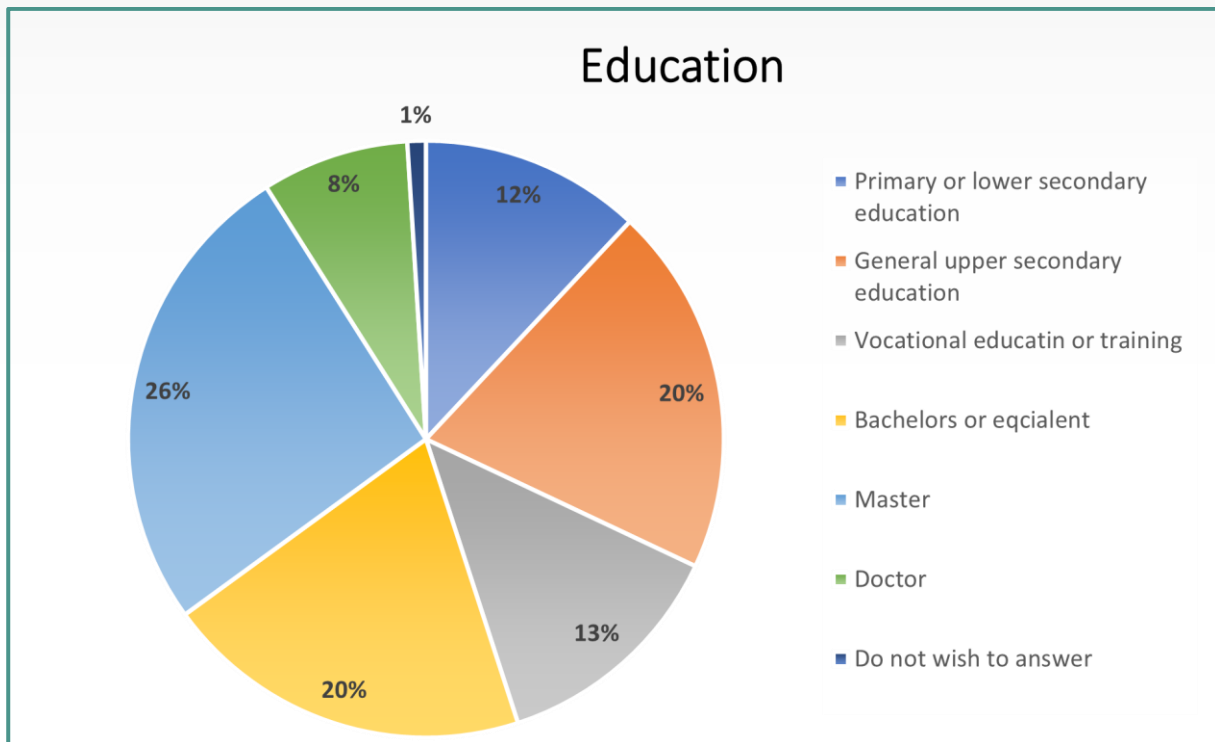
The age distribution was mixed, the oldest being born in 1939 and the youngest in 2008. There is a higher number of younger participants born between 1990-2008, as some of the recruitment partners worked through schools.

Year of birth	Nr. of participants
1930s	3
1940s	12
1950s	41
1960s	42
1970s	36
1980s	38
1990s	74
2000s	93

The gender distribution was fairly equal, with slightly more men (Male 54%, Female 41%, rest 5%)

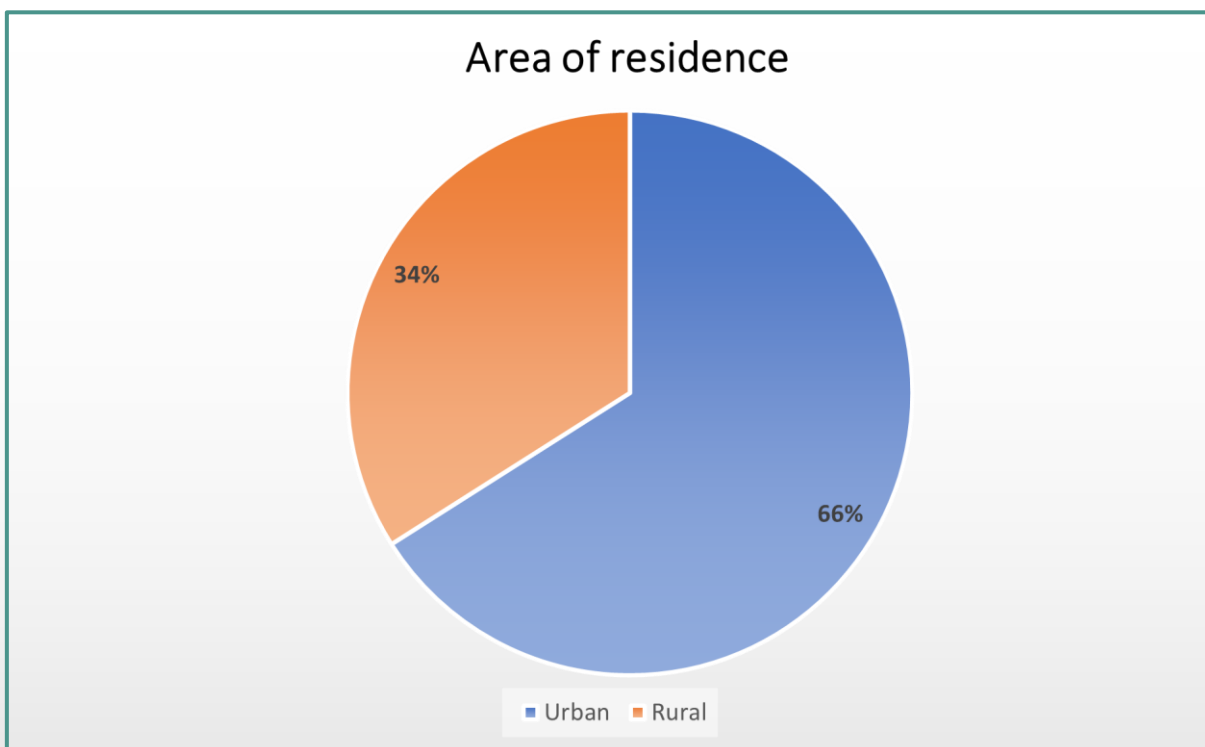
Education and area of residence

The education distribution also seems to be fairly equal, with a slight dominance of longer educations.



Area of residence

There is a slight over representation of citizens living in urban areas, which however corresponds with the main demographic tendency of urbanization.



2.3.3 Recruitment process

The recruitment of participants is based on a model, where a volunteer host is recruited, and the host then invites participants to the workshop. Our experience is that if we manage to have a demographic spread among the hosts, this is reflected in the total pool of participants.

In Denmark, DBT recruited and ensured a variety in Danish hosts. DBT reimbursed the hosts up to 40 Euro for snacks and refreshments during the meeting. The recruitment and demographical management of the hosts in other countries than Denmark, was managed by a local partner. The local partner also provided technical help in the local language and offered around 50 Euros per meeting, to cover snacks and refreshments. The rationale behind the economic incentive was to strike a balance: it should be sufficiently attractive for the hosts and participants, yet not so substantial as to become the sole motivation for participation.

Recruitment partners:

- Bulgaria: ARC foundation
- Spain: Science for Change
- Germany: Democratic Society
- Poland: Independent consultant Eva Daniella Mackevica

3. Results

Analytical approach

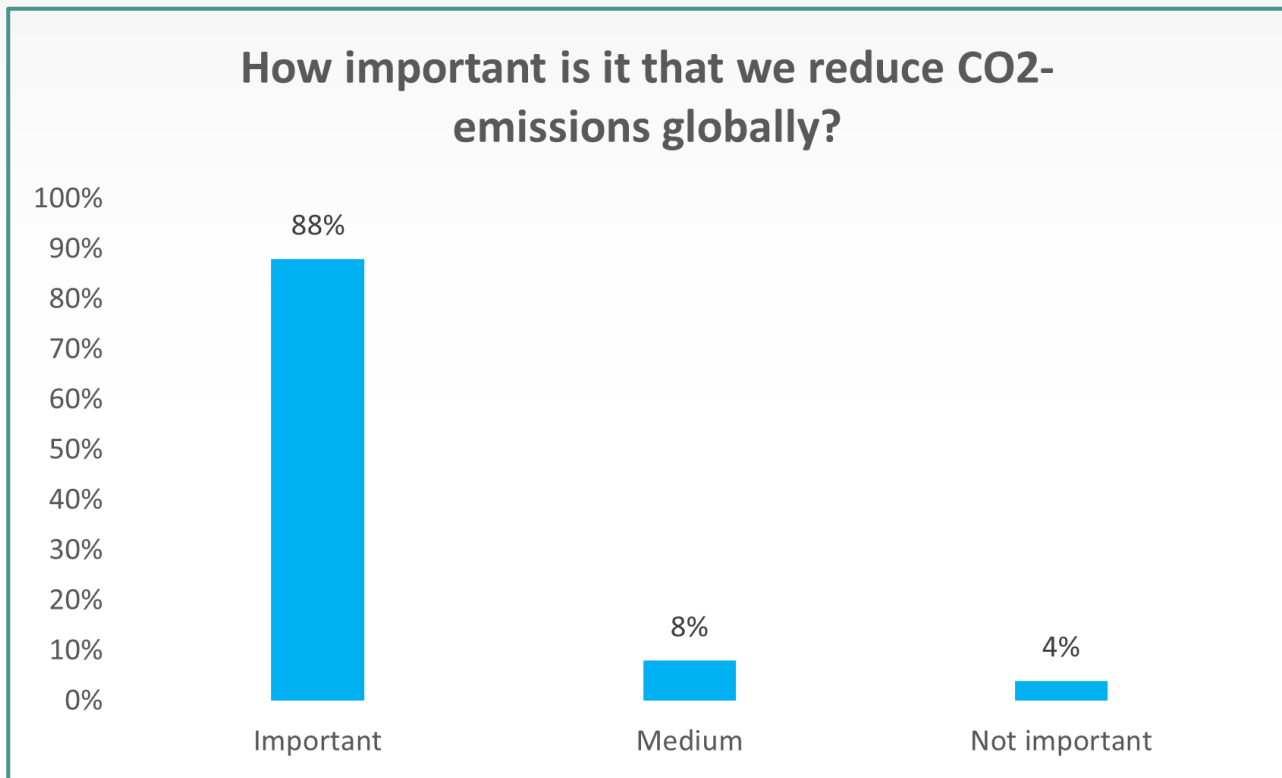
This chapter presents our findings from the EuropeSay. Reading the results, one should be aware of the following:

- Not all participants answered every question, therefore the total number of answers at different questions will not always match the total number of participants.
- In some of the questions, the participants were asked to give more than one answer, therefore the sum of answers are more than the sum of participants.
- Scales: The questions were asked on a scale from 1-5, we aggregated the answers 1+2 and 4+5, while kept the middle category 3. This gives a more easily readable table and a clearer indication of the tendency.
- We have crosschecked the demographics such as geography, age and area of residence, but only included these variations in the tables if they are significant.
- In our analysis of the tables, we've prioritized identifying broader tendencies, rather than focusing on areas with minimal percentage differences.

Section 1 – The citizens' perceptions on Climate Change and reducing CO₂ emissions.

The workshops started with an introduction, which provided contextual knowledge on our changing climate and the political agreements that aim to address climate action. The purpose of this session was to assess the general perceptions of European citizens on the sustainable transition and the need to minimize CO₂ emissions. Clearly, reducing CO₂ emissions is an important aim across Europe, with only minor deviations across geography and age.

How important is it to you that we reduce CO₂-emissions globally?

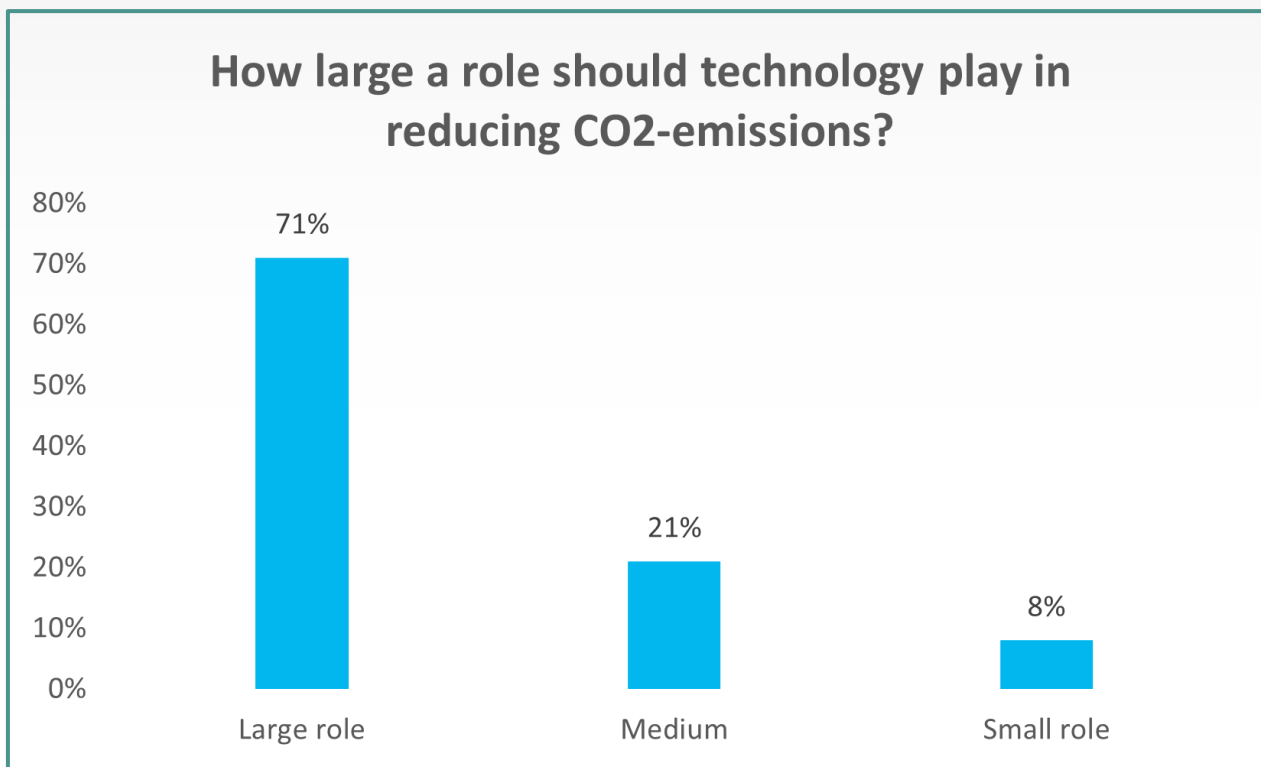


This result aligns with the results of the special EuroBarometer on ClimateChange from 2021:

Europeans consider climate change to be the single most serious problem facing the world. More than nine in ten Europeans (93%) believe that climate change is a serious problem, including 78% who say it is a very serious problem and 15% a fairly serious problem. These results are stable since 2019.¹

In many debates on CO₂ emission reduction, a dichotomy² between technological innovation and societal lifestyle changes is set up. In assessing the European perception of this dilemma, we asked to what degree citizens found each approach to be important in the reduction of CO₂ emissions. Because the two approaches are not mutually exclusive, we allowed citizens to assign each a large role, rather than having to choose between the two.

How large a role should technology play in reducing CO₂-emissions?



How large a role should consumption and lifestyle changes play in reducing CO₂-emissions?

As we can see from the answers the citizens find that both technology and lifestyle changes should play a large role, meaning that the participants find both lines of action important. As a participant from Bulgaria puts it here:

“A joint approach should be used - on the one hand, consumers should reduce their overall consumption, on the other, industries should use new technologies to reduce emissions.”

Or as a Danish participant puts it, stressing the urgency:

“We are already behind in reducing CO₂- emissions, so we should do everything we can.”

Unsurprisingly, we may conclude that European citizens are highly aware of the issues of climate change and the need to cut CO₂ emissions. The preferred combination of technological advances and lifestyle changes is interesting to the LICROX project, as an implementation of solar fuel technology plays into both pathways: While the technology advancement in itself holds the potential of CO₂ emissions reduction, a large-scale rollout of solar fuel technologies would impact people’s livelihoods and require changes in lifestyle and consumption such as land and resource use, as well as economic prioritization. The fact that European citizens see their own responsibility in the sustainable transition bodes well for emerging technologies.

Section 2 – The citizens perceptions on land use, plastic waste and fresh water

In connection with D6.3, a stakeholder workshop indicated that resource use in connection with the LICROX technology may become a point of contention for an eventual implementation. Specifically, area use, CO₂ as an input, freshwater use, and waste material were highlighted as potential barriers. To focus the discussion on tangible issues, citizens were presented with issues of area use, freshwater use and a hypothetical scenario of plastic production during the workshop. In this way, the consequences of the LICROX technology were made comprehensible, and our assessment of citizen perceptions to land use, freshwater use and plastic waste provides useful pointers for the project. Citizens were informed that the LICROX technology would require a considerable area and freshwater to be rolled out on a large scale. Additionally, the scenario using plastic production informed citizens how LICROX could help the plastics industry in reducing CO₂ emissions, while noting that plastic waste is a growing issue within the life cycle of all plastic products.

Land use

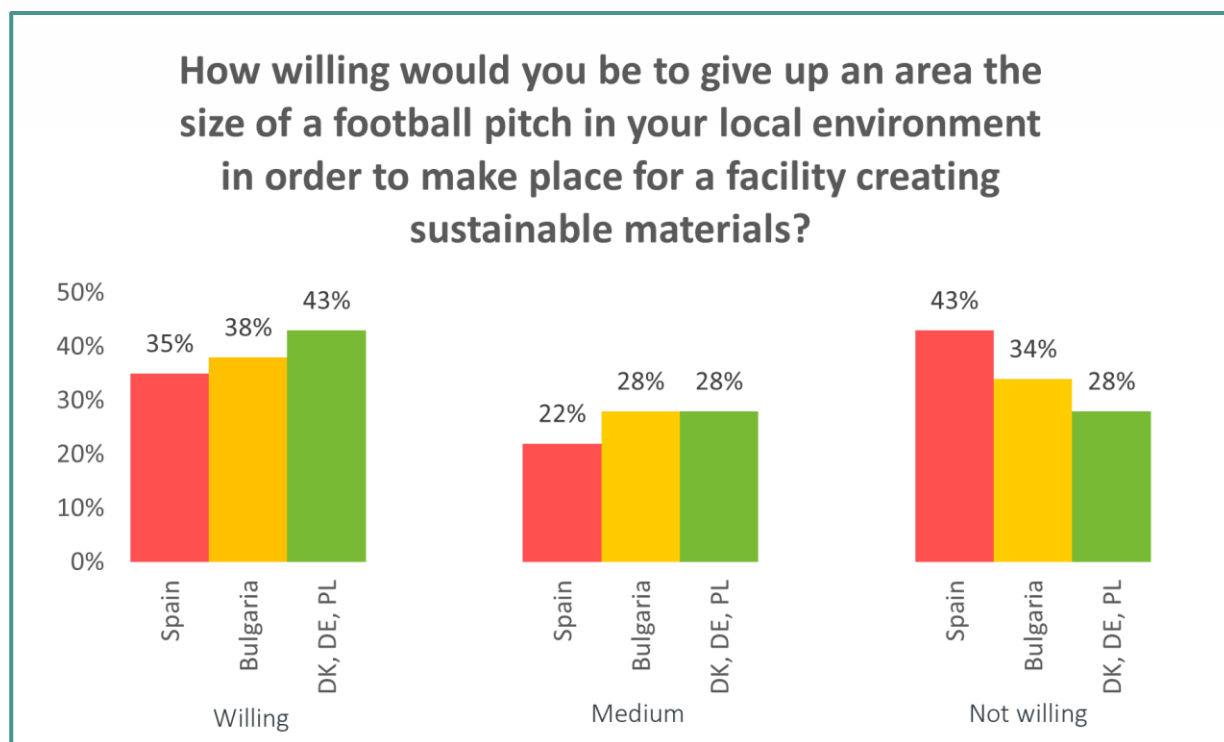
Land use is going to be a huge challenge in the process of the green transition, as we need to use vast areas of land for solar and wind power in the coming years. In popular as well as political discussions, the phenomenon known as NIMBY (Not In My Back Yard) is used to explain a growing local opposition against energy infrastructure projects. For this reason, the workshop aimed to investigate the nature of citizen's perceptions on infrastructure projects that would impact the spaces and areas they lived in.

The first assessment was made with a general focus of willingness to give up land area for sustainable production.

How willing would you be to give up an area the size of a football pitch in your local environment in order to make place for a facility creating sustainable materials?



The cross-European assessment indicates that citizens begin to hesitate when the implementation of infrastructure projects comes close to their environment and threaten their ways. It is important to note that a small majority is willing to use areas close to their home. More importantly, a considerable number of participants were undecided, indicating that the hypothetical scenario may be too vague to determine a position. Associating the question with giving up an area with the size of a local football pitch may impact responses, some participants, for example, might imagine sacrificing their football field to accommodate a sustainable production facility.



Another possibility is that our question does not provide enough context about the process. Recent research suggests that resistance towards large-scale sustainable energy infrastructure projects stems less from opposition to the facilities themselves, and more from perceptions of an unfair process.³

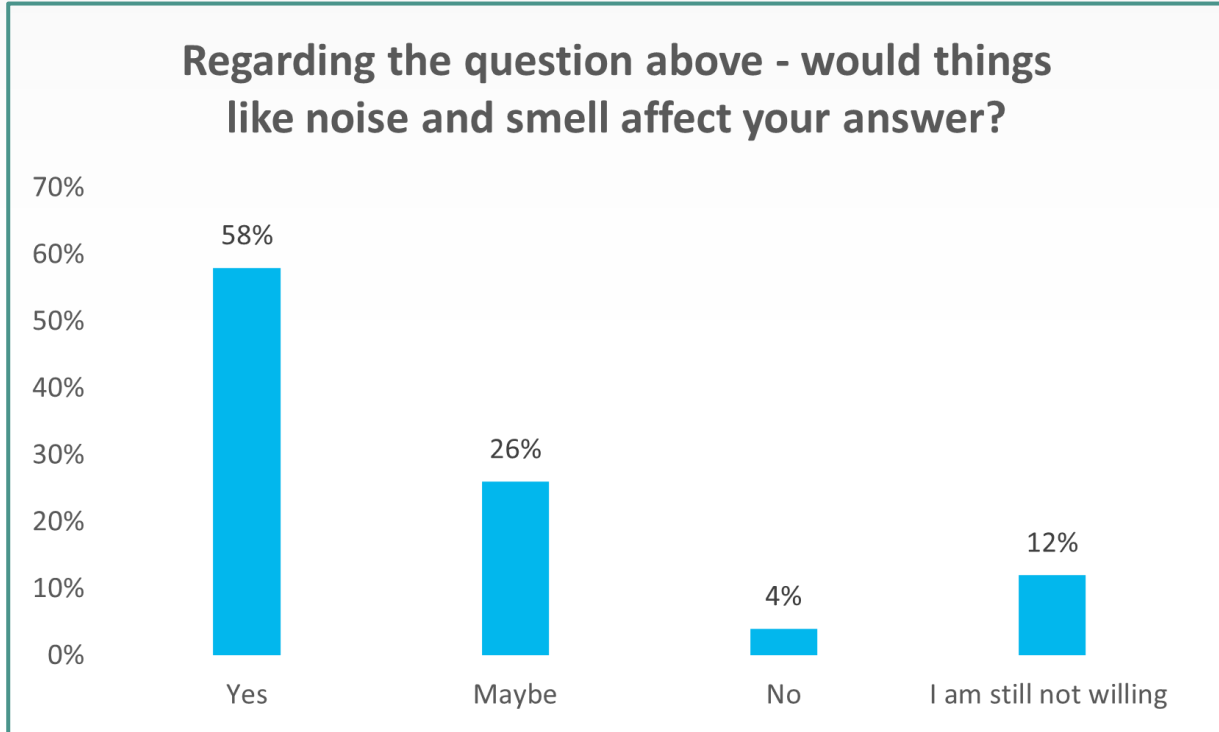
When we look at the differences between countries, a considerable difference is seen between Spain, and the countries in the green zone: Denmark, Poland and Germany. Spanish participants are generally hesitant in providing local areas for sustainable production, while the countries in the green zone are generally positive. Understanding this difference is of course a complex matter, however, the current Spanish rollout of solar energy has already resulted in protests and opposition among citizens.⁴ As the LICROX technology is associated with photovoltaics, citizens may be affected by this phenomenon. On the opposite side of the spectrum, countries in the green zone see more opposition to the implementation of wind energy projects.⁵

The wavering support for energy infrastructure in local vicinity should, however, not only be reduced to a question of NIMBY. Research indicates that the distance to infrastructure projects plays a considerably smaller role in social opposition than what popular discussions reflect. Local resistance in energy infrastructure may be explained as a result of three primary factors.⁶

1. Location: Distance to an energy infrastructure project is not the sole creator of local resistance. Rather, citizens hold affinity for an area, to which they assign value, identity, and meaning.⁷ Infrastructure projects that underestimate the emotional and symbolic meaning of areas risk igniting local opposition from citizens who perceive a lack of respect and a disregard for their sentiments.³
2. Justice: In line with the grievances related to location, citizens may oppose projects if they experience processual or distributive injustice. Processual injustice may be understood as project processes that undermine the voice, legitimacy, and value of citizens, for example in their valuation of local areas. Distributive justice relates to the distribution of value that is created from energy infrastructure projects, where citizens may feel at a disadvantage.⁸ Research indicates, however, that pay-offs not necessarily are an effective tool to uphold distributive justice, but rather influence and ownership.⁹
3. Values: While the implementation of new energy technologies may be seen as a necessary common good by some, citizens hold a great variety of values that may conflict with this view. What constitutes the 'common good' is not a given.¹⁰ For example, points of contention may be found between people that want a sustainable transition but prioritize differently between CO₂-emission reductions and biodiversity preservation. A more contemporary example is the conflict that has been seen in the Russian war on Ukraine, where the resulting energy crisis has put sustainable energy transitions under pressure. In short, disregarding the values of citizens with the explanation that an energy infrastructure project is for the common good may result in grievances and local resistance.

Continuing the assessment of citizen perceptions of area use, the workshop delved into a question of local nuisances:

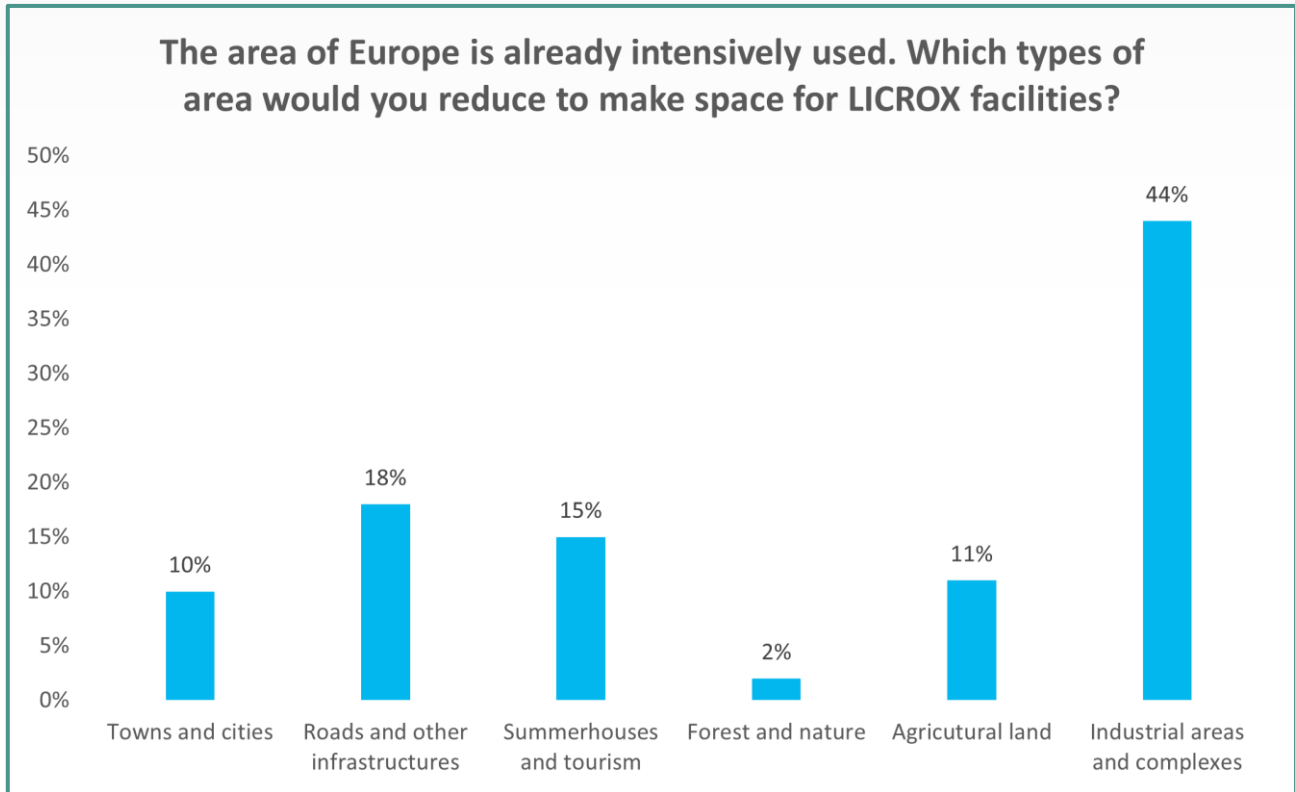
Regarding the question above - would things like noise and smell affect your answer?



This result may play into the normative understanding of the NIMBY-phenomenon, where proximity to nuisances may affect grievances of citizens. The design of the LICROX facilities clearly plays a role in reducing the NIMBY-phenomena, however it also affects the three previously mentioned factors of location, justice and values. The noise and smell from LICROX facilities could make citizens feel their beloved area is disrespected and it could also cause citizens to feel their voices and values are undermined and the process unfair.

Concluding the assessment of citizen’s perception of land use and placement of PtX technology, participants were asked to indicate areas they deemed suitable for LICROX facilities:

The area of Europe is already intensively used. Which types of area would you reduce to make space for LICROX facilities?



Interestingly, citizens perceive the suitable site to be industrial areas. This conflicts with current approaches to PV infrastructure, which primarily utilizes agricultural land. Of course, current production of ethylene is located at industrial facilities, potentially influencing citizen responses. Additionally, the need for CO₂ could be coupled with industrial point sources, allowing for a synergetic relationship. In this way, using industrial areas may seem viable both from an instrumental and societal perspective.

On the other end of the spectrum, only 2% percent believed forests and nature should be reduced. The citizens clearly do not want to see forests and nature substituted with energy infrastructure, pointing to the previous walkthrough of factors influencing local opposition.

“I am concerned about finding possible space to locate the production facilities.” (Bulgarian participant)

“Doesn't matter where, as long as nature is protected.” (German participant)

Plastic

Based on the stakeholder workshop in Copenhagen, plastic was used as an exemplary end-product stemming from a future implementation of the LICROX technology. This allowed citizens to deliberate on the potential life cycle of a product, where sustainable ethylene production is integrated. Citizens were prompted to discuss the merits and drawbacks of sustainable plastic production, noting that inherent issues with plastic waste are not addressed regardless of the sourcing of raw materials.

How much are you willing to pay for CO₂-neutral plastic products?

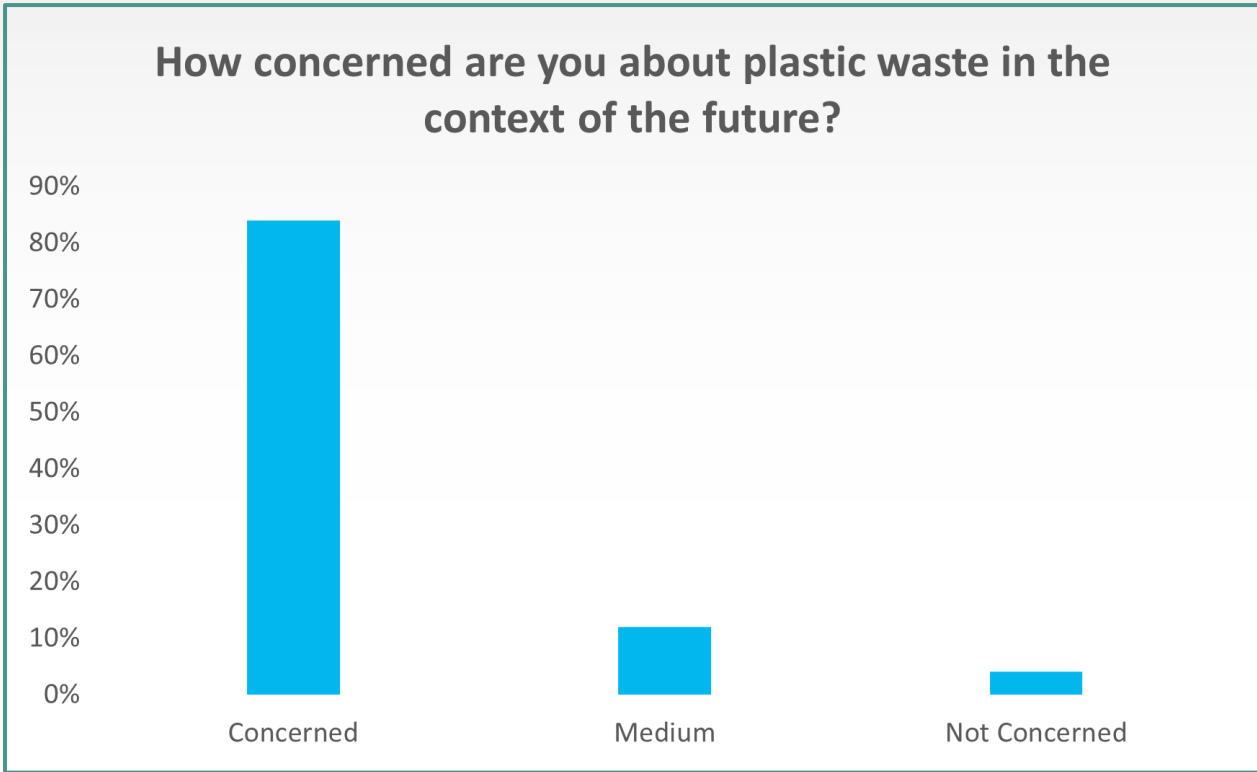
The assessment of citizen's perceptions to sustainable plastics production was done in economic terms. The assumption was that market-driven investments follow the potential willingness to pay for products.

When we then ask for the willingness to pay, around half of the citizens respond that they are willing to pay a little more. About 15% are willing to pay double or even more for CO₂-neutral products. This indicates a potential for more expensive production. However, cost-efficiency still determines the processes of the mainstream market. As was indicated during the stakeholder workshop in Copenhagen, there might be a niche for higher priced high-quality products e.g., in the biochemical industry, which could prompt an opening to the market.



How concerned are you about plastic waste in the context of the future?

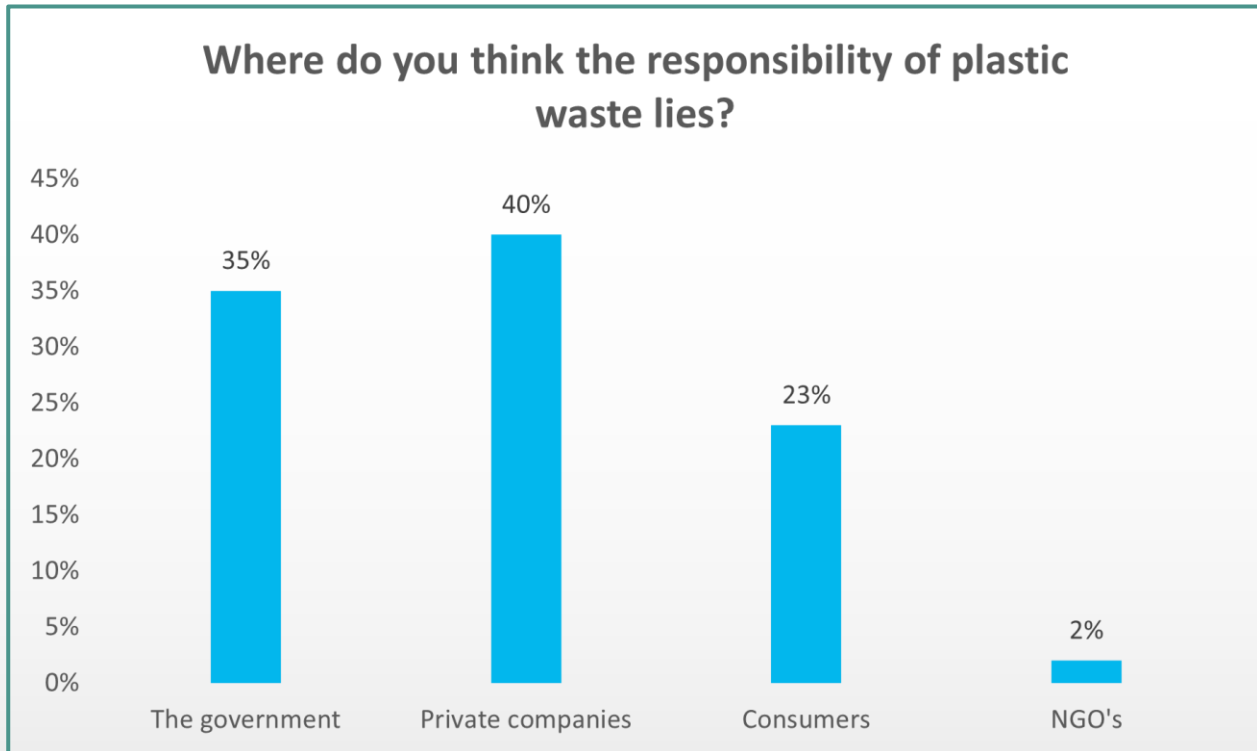
While the willingness to pay indicates a positive potential for the LICROX technology within the plastics industry, it is important to note how the technology would be linked with other environmental consequences, namely plastic waste. Assessing European concerns regarding plastic waste indicates how such a technological trajectory may lead to resistance.



As the graph clearly indicates, a massive majority of European citizens are concerned about issues of plastic waste. Addressing plastic waste may thus be of interest already at this stage in the value chain of plastic production.

Where do you think the responsibility of plastic waste lies?

As plastic waste is seen as a considerable concern for citizens, the citizen workshop explored perceptions of responsibility:



In the question of where the responsibility for the problem lies, the citizens answers points towards a tendency where they see it as a shared responsibility. This could mean that LICROX, as part of the production chain that leads to the plastic waste problem, will also be expected to take its part of the responsibility.

The citizens attitudes concerning the scenario of LICROX being part of the production chain of plastic, which could lead to plastic waste could be an important factor to take into consideration when seeking further funding and support for the LICROX technology, as it could lead to less social acceptability in the public if the technology is not seen as fully sustainable.

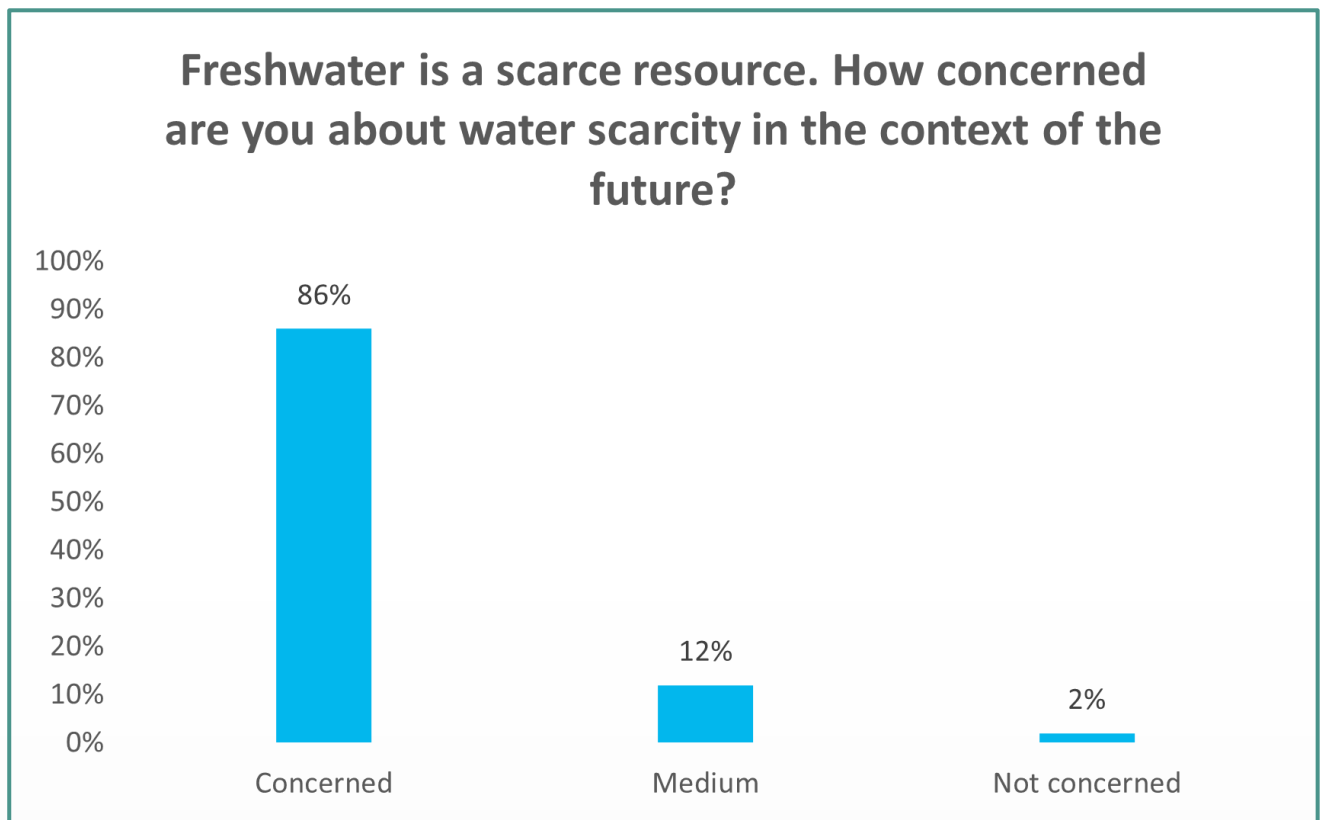
“The issue of plastic waste is key, we need to consider whether technology would have a neutral effect on this problem or make it worse - e.g. by increasing plastic consumption, influencing policies to limit plastic consumption.” (Bulgarian participant)

“The development of LICROX should take place with a simultaneous goal of reducing plastic use as much as possible - so that we do not use more water and land than necessary. So change in consumption has to be carried in parallel.” (Danish participant)

Freshwater

The current setup of the LICROX technology requires considerable amounts of freshwater. Freshwater is becoming an increasingly scarce commodity and according to the WHO, development needs speed up, for us to keep access to clean drinking water: *Historical rates of progress would need to double for the world to achieve universal coverage with basic drinking water services by 2030. To achieve universal safely managed services, rates would need to quadruple.*¹¹

The need for freshwater combined with the fact that LICROX is solar powered and therefore likely to be located in sunny and dry locations, suggests that freshwater could become an issue. Subsequently, it is interesting to explore citizens' attitudes concerning fresh water as this could affect the social acceptance of LICROX.



Freshwater is a scarce resource. How concerned are you about water scarcity in the context of the future?

The answers show quite clearly that fresh water is a big concern for the citizens as 86% of them answer they are concerned. It would therefore be highly recommended to take the fresh water use into consideration both in the further development work on LICROX and in the design of the facility. It is also something similar technologies should factor into their design.

“Water and the sun are the resources needed for this technology, but water is not an infinite resource and its overuse and depletion can be very scary and dangerous to human life.” (Bulgarian participant)

“A major problem for putting LICROX into production is the need for large amounts of drinking water, because this could mean even more people around the world not having access to clean water, leading to many health problems.” (Bulgarian participant)

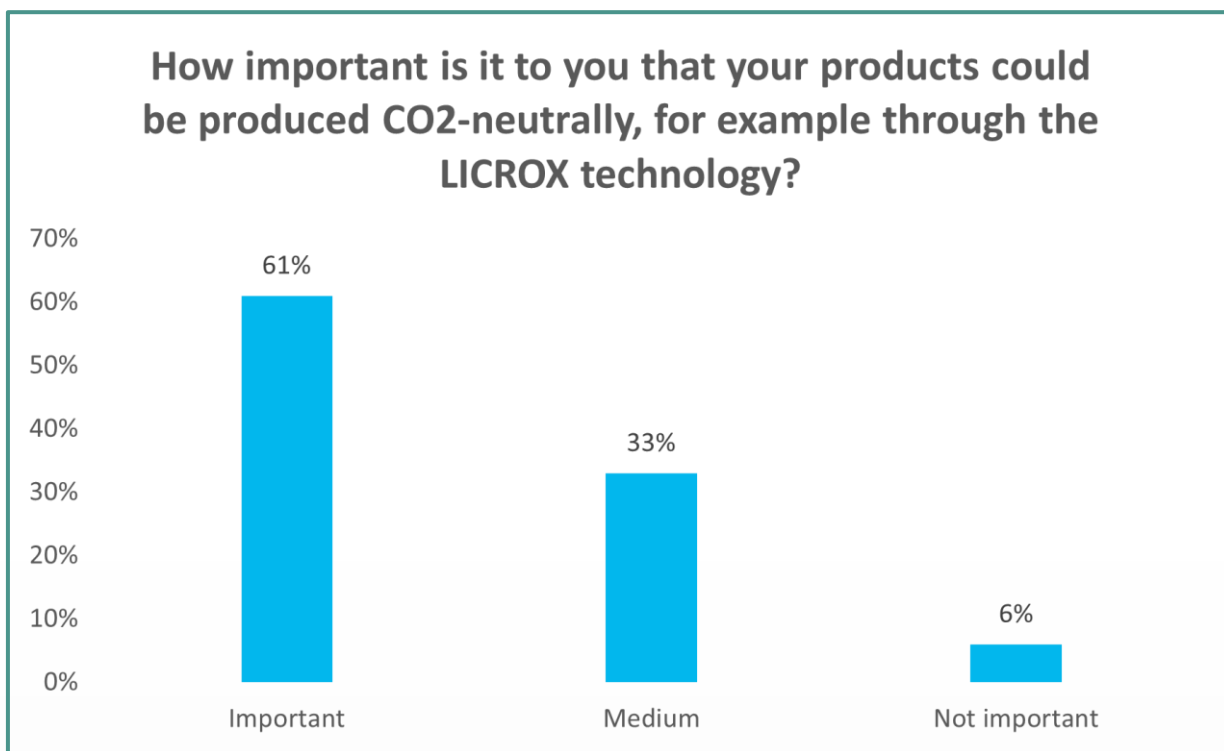
“We already have water shortages in some parts of the world, and it seems selfish that we here in the western world use even more water for our own benefit when there are water shortages in some parts of the world.” (Danish participant)

Section 3 – The citizens perceptions on resource allocation and economics

Emerging energy technologies require investment and consistent funding to penetrate the market and achieve widespread implementation. The stakeholder workshop in Copenhagen indicated that funding of technologies like LICROX is unstable, due to the low TRL and societal uncertainty on where to invest. Understanding citizen perceptions of public investment and economic resource allocation provides useful insights to the potential market for LICROX.

The starting point for this exploration was to assess the European willingness to prioritize the production of CO₂-neutral products:

How important is it to you that your products could be produced CO₂-neutrally, for example through the LICROX technology?



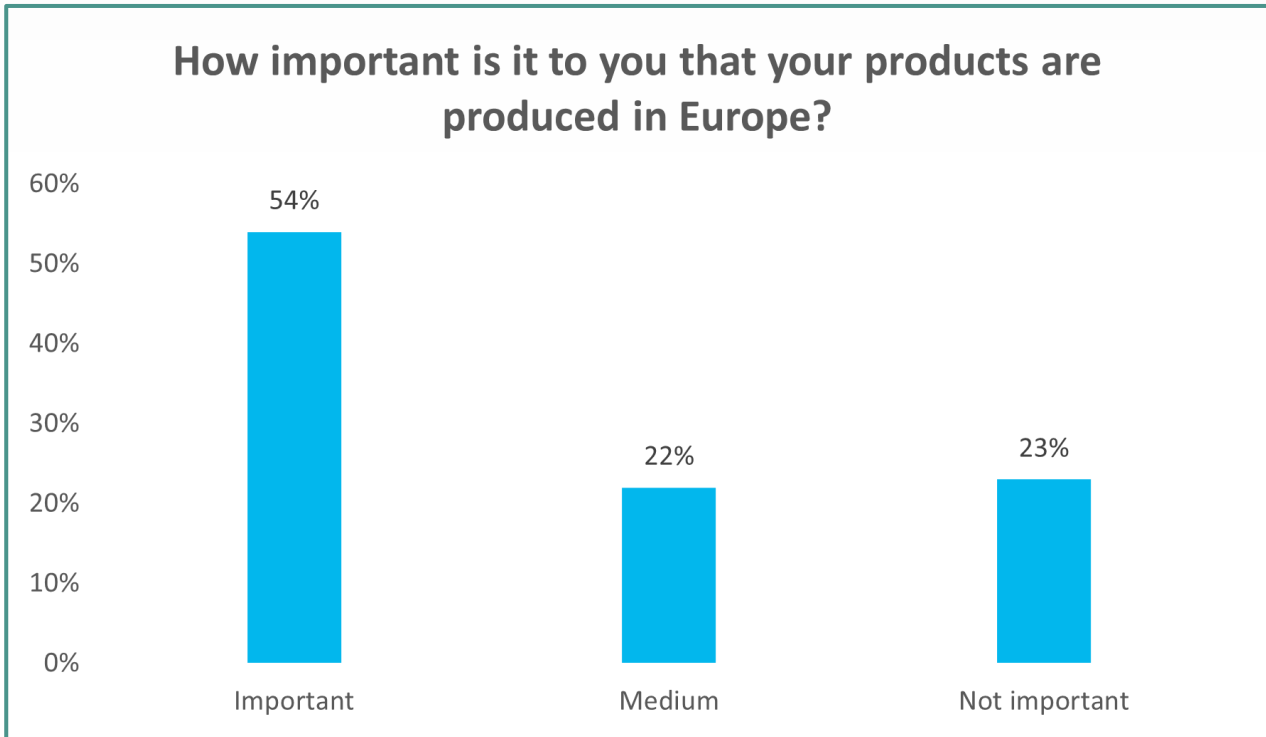
Reducing CO₂-emissions is clearly an important goal to Europeans, and citizens are interested in swapping products with more sustainable alternatives. This falls in line with research indicating a general willingness to choose and pay for products that emit less CO₂.¹²

Besides willingness to choose CO₂-neutral products, this assessment took into account recent developments in security concern. In the face of geopolitical changes, we are experiencing in these years, the need for a higher amount of self-sufficiency in energy production and raw materials is rising in Europe. Hence it is interesting to examine the citizens' attitudes towards this.

Regarding the ethylene produced by LICROX, it would not hold a lot of significance if it was produced in Europe only to be exported and made into clothes in India or China. Both the production of ethylene and the production of items would have to be in Europe for it to matter from the citizens' perspective.

As such, LICROX and similar technologies should consider whether they should aim for a European, geographically centralized production or whether the citizens are indifferent:

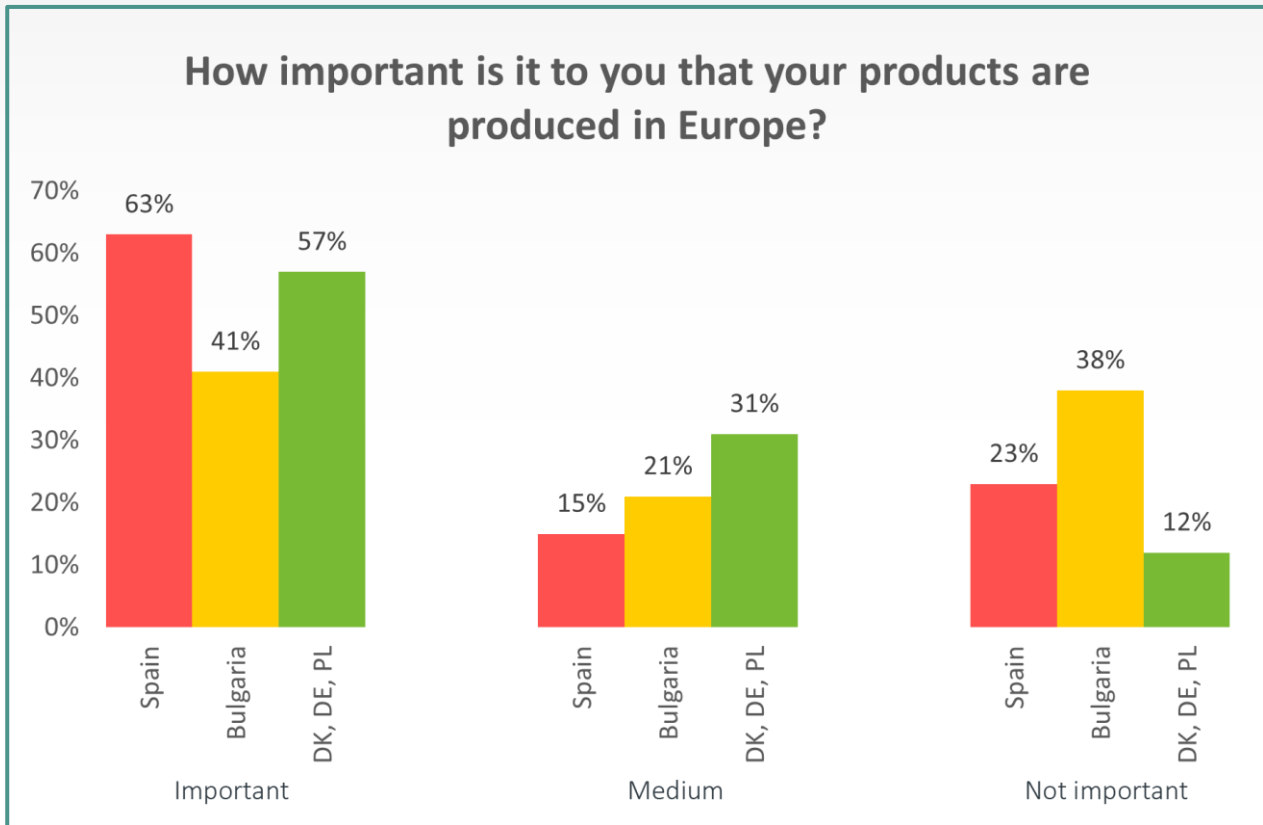
How important is it to you that your products are produced in Europe?



In general, European citizens are concerned about sovereignty and indicate an interest in self-sufficiency in the means of production. Importantly, this varies considerable between countries:

In Bulgaria the percentage of 'important' and 'not important' is comparable, indicating a greater willingness to have production facilities outside of Europe.

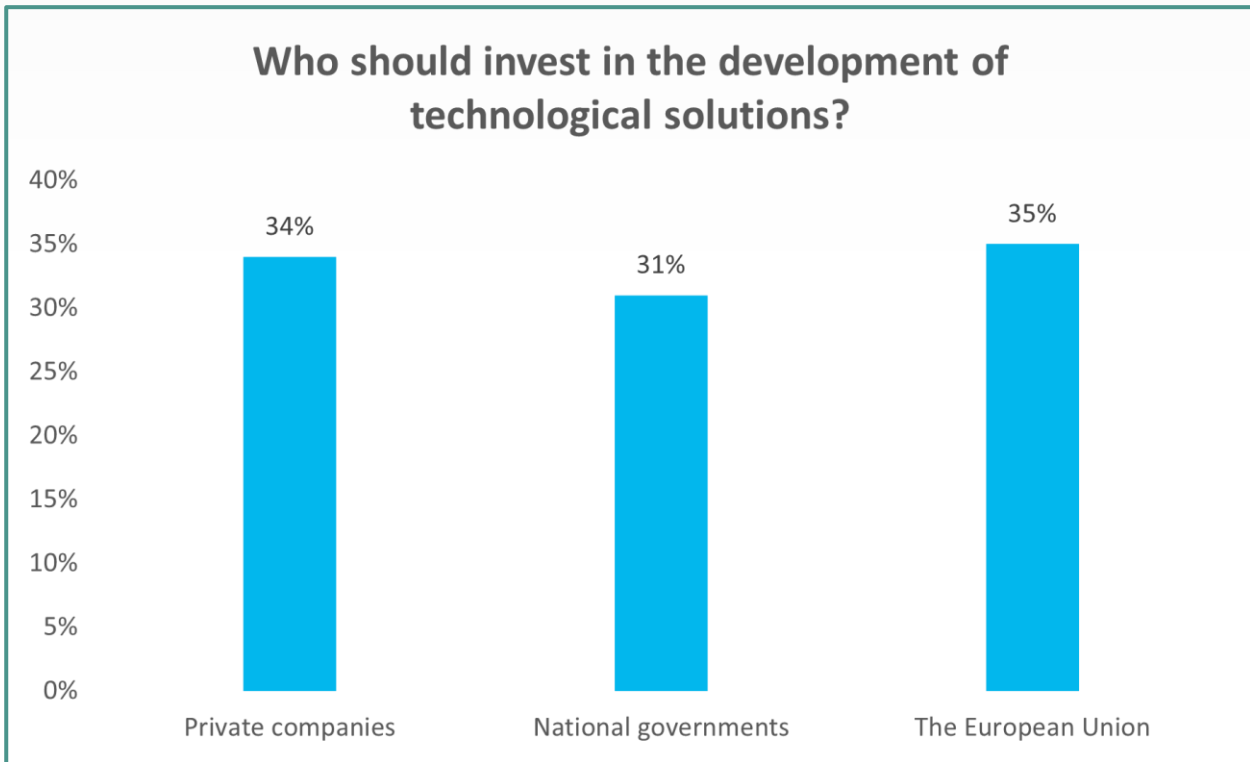
Countries in the green zone display a contrasting preference. Here, sovereignty and sell sufficiently in a European context seems to be valued considerable higher.



Similarly, Spain indicated a great importance being put on European production. At the same time, a greater number of participants indicated that European production was unimportant, compared to countries in the green zone. Division on this matter seems apparent and could be contributed to geographic differences within the country, or potentially differences in age.

The individual willingness to essentially invest in emerging technologies is not the sole contributing factor to an assessment of economic viability. To indicate some form of expected responsibility, we asked participants to reflect on the actors that should take the lead in investing in the development of energy technologies:

Who should invest in the development of technological solutions?

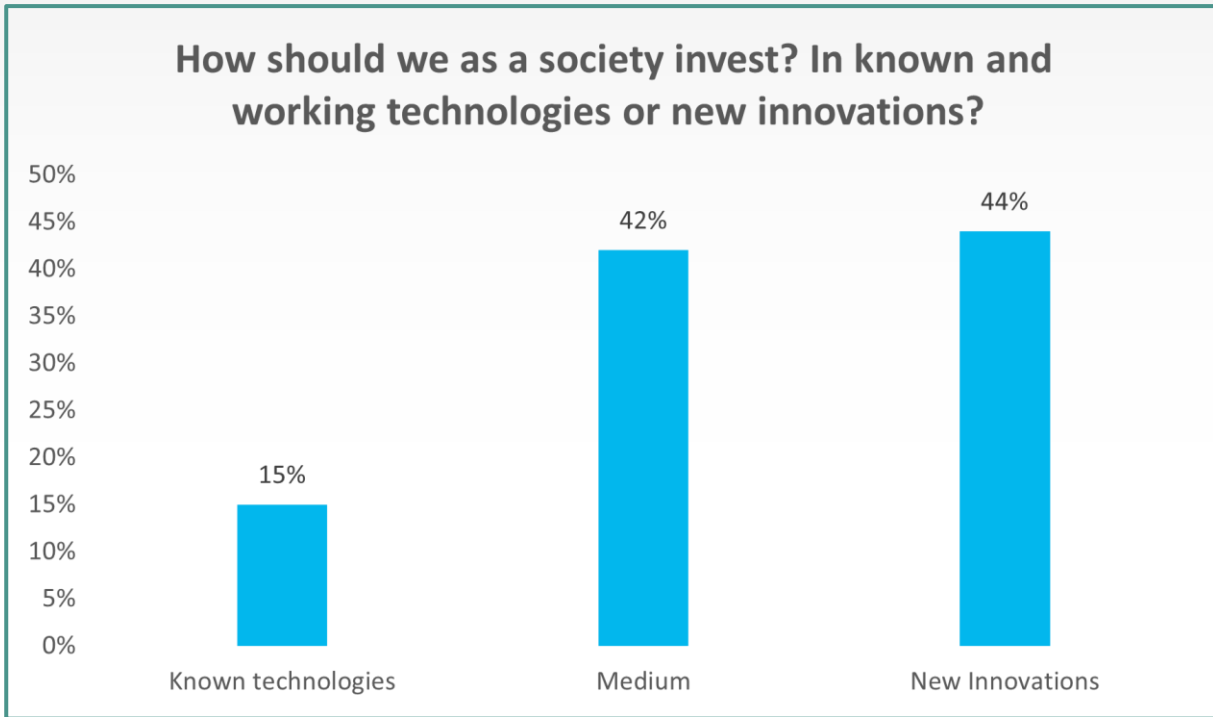


When asked about investment, the citizens points towards all levels: European Union, National Government and private companies. This could lead towards focusing on private-public partnerships and the citizens engagement in using public money for developing new technologies.

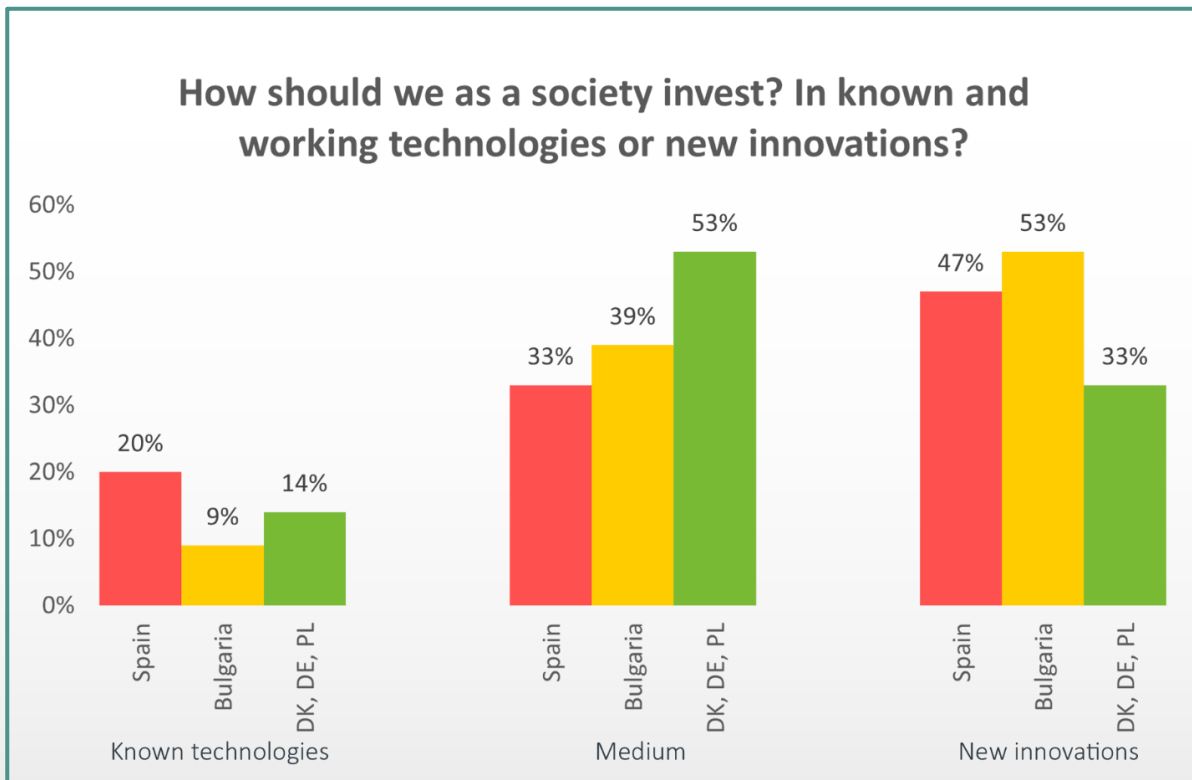
Alongside responsibility, the expected investment direction is important to consider. Whether citizens expect investments in known technologies or new research, may conflict with political ambitions.

In the effort towards reaching the climate goals, there is a dilemma of how to spend the limited resources we have as a society to invest. On one hand we can put our trust in known technologies, and invest in windmills and solar panels, that we already know or on the other hand, we can invest in new technologies, that will possible open new opportunities for reducing our CO₂ emissions in new arenas. This question gives insight into what citizens believe we should invest in.

How should we as a society invest? In known and working technologies or new innovations?



In general, the citizens are positive about investing in new innovations like LICROX and this also corresponds with their view of technology playing a large role in the effort to reduce CO₂ emissions. Technology optimism is still very much apparent among European citizens, providing fertile grounds for continued and strengthened research. Still, these results vary between countries:



While Bulgaria and Spain display a considerably higher interest in investments in new technologies, countries in the green zone indicate greater uncertainty.

“Economics is a huge issue if the sustainable transition is to be fair. Therefore, I also believe that we as a society have a great obligation to invest in the development of technological solutions and thereby reduce the investment risk for private individuals.” (Danish participant)

“It takes something from all of us to change consumption. Businesses, governments and the EU must take the lead, and those consumers who can take the lead must do so.” (Danish participant)

“Government, private companies and consumers need to engage with the problem. The responsibility is on everyone - consumers and producers.” (Bulgarian participant)

4. Conclusions and recommendations

From the results of the EuropeSay there are a number of interesting results, which can be included in the further development of the LICROX technology and as general input to the green transition.

Initially the results of our citizen engagement confirm that there is a strong commitment to reducing CO₂ emissions among European citizens, and hereby add to other surveys that show similar tendencies. The citizens find that in order to reach this goal both technology and changes in lifestyle and consumption patterns play a large role. The urgency of the climate crisis needs us as a society to use all means we have to meet the end goal.

When we ask further into how citizens would prioritize the use of resources such as land use, fresh water and plastic waste in the case of using the end product ethylene in plastic production, we get a deeper insight into the citizens perceptions of this.

In regard to land use, the citizens are in general hesitant to prioritize land in their local communities for a LICROX facility, however 39 % of the citizens are willing. As argued in the analysis there are several factors at play in getting public support or resistance when planning for larger infrastructure projects, which should be considered in the specific context. In general, when asked about where the citizens would prefer the facilities to be located, there is a clear preference for it to be located in industrial areas and a clear resistance for it to be located in nature and forest areas.

Fresh water is something that the citizens are highly concerned about, which aligns with the analysis of the WHO also pointing out that it will demand a huge international commitment to secure clean drink water for all in the future. For LICROX the reduction of clean water in the process needs to be given special attention in the further development of the technology as it holds potential to become a barrier for social acceptance.

Plastics were used as an exemplary end product stemming from a future implementation of the LICROX technology. This allowed citizens to deliberate on the potential life cycle of a product, where sustainable ethylene production is integrated. As to whether the citizens would be willing to pay a higher price for plastic products, there is a small majority who are willing to pay a little more and a niche of 15 % who are willing to pay double or even more. This could point towards focusing on marketing the Ethylene to production of high-end plastic products, targeting consumers of sustainable products. This being said, the citizens are also highly concerned about plastic waste and tend to hold the whole production chain responsible for this issue. This suggests that it would be important to think about sustainability into all aspects of the LICROX technology.

As funding of technologies like LICROX is unstable, due to the low TRL and societal uncertainty on where to invest it is interesting to understand the citizens perception on funding and willingness to prioritize CO₂ neutral production methods like LICROX. Here 61% of the citizens find it important that their products can be produced CO₂ neutral.

In regard to a new geopolitical situation, we also looked into the citizens' concerns about European sovereignty, as to the importance of products being produced in Europe. Here, the tendency leans towards an interest in self-sufficiency in the means of production, with some variations among countries.

When asked about where the responsibility for investment lies, they point towards all levels: European Union, National Government and private companies. This could lead towards focusing on private-public partnerships and the citizens engagement in using public money for developing new technologies.

When asked to prioritize between investments in well-known and new innovative technologies, the citizens are positive about investing in new innovations like LICROX and this also corresponds with their view of technology playing a large role in the effort to reduce CO₂ emissions.

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