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Review of Hydrogen Consultation Responses

Client	**DECC**
Document Ref.	22159-R-006
Project Title	Technical Support Instrument REPowerEU
Date	07/04/2023

Technical Note

Project title:	Technical Support Instrument REPowerEU		
Subject:	Review of Hydrogen Consultation Responses		
To:	Department of the Environment, Climate, and Communications (DECC)		
Project number:	22159	Document ref.:	22159-R-006
Prepared by:	Dr. Shane McDonagh	Revision:	06
Checked by:	Dr. Paul Bonar	Date of issue:	07/04/2023
Approved by:	Dr. Cian Desmond		

Project Title:	Technical Support Instrument REPowerEU
Report Title:	Review of Hydrogen Consultation Responses
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Client:	DECC
Ultimate Client:	European Commission
Confidentiality	Client Confidential

Revision History

Rev	Date	Reason for Issue	Originator	Checker	Reviewer	Approver
01	16/12/2022	Client review	SMD	PB	CD	CD
02	27/01/2023	Formatting. Addressing comments from DECC.	SMD	PB	JD	CD
03	07/02/2023	Addressing comments from DECC	PB	PB	CD	CD
04	16/03/2023	Addressing comments from external reviewer	SMD	SMD	CD	CD
05	27/03/2023	Anonymising responses	PB	PB	CD	CD
06	07/04/2023	Formatting. Addressing comments from DECC.	PB	PB	CD	CD

DISCLAIMER

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EXECUTIVE SUMMARY

The Department of the Environment, Climate, and Communications (DECC) published a request for submissions to its "Consultation on Developing a Hydrogen Strategy for Ireland" in July 2022. The consultation documentation contained a substantial volume of reference and introductory material along with a list of 49 specific questions targeted to inform and support the development of a National Hydrogen Strategy. A total of 126 submissions were received. Gavin and Doherty Geosolutions (GDG) was tasked with reviewing and summarising these responses under the framework of the REPowerEU Technical Support Instrument (TSI).

Respondents engaged with the survey in such a manner that quantitative analysis, which might provide data on whether respondents replied positively or negatively to specific questions, was not feasible. Instead, the lengthy and often didactic responses required the use of methods generally used for the analysis of data generated through semi-structured interviews. As such, for the purposes of analysis and reporting, responses have been grouped into themes. Within each theme, a summary of views derived from responses across multiple questions is provided along with a brief response providing the view of the authors of this report. The following themes are discussed:

- Where hydrogen will be used,
- How and where will hydrogen be produced,
- Incentivisation and policy support,
- Hydrogen storage and transportation,
- Regulation and safety,
- Export potential,
- Integration with the electricity market / wider system integration, and
- Questions requiring further research.

1 Introduction

On the 12th of July 2022, the Department of the Environment, Climate, and Communications published the "Consultation on Developing a Hydrogen Strategy for Ireland". The stated purpose was to "gather the views of stakeholders and interested parties" through responses to a set of questions which were included in the consultation documentation. Submissions were accepted until the 2nd of September.

This concise report provides a summary of those responses with the objective of extracting information which will assist with the development of Ireland's National Hydrogen Strategy.

Section 2 (*The Survey*) of this report reviews the questions provided in the consultation document, the composition of the respondents is analysed, and the level of engagement is assessed. A methodology for summarising the responses is also presented.

Section 3 (*Summarising Responses*) summarises the responses under several themes and concisely presents the suggestions, commentary, and other relevant information provided by respondents. Included in the summary of responses to each theme is "the GDG view" which provides some additional context to responses received.

Section 4 (*Developing a Hydrogen Strategy*) provides a summary of overall lessons learned through the consultation process.

In the Appendix, a longer summary report of non-confidential consultation responses can be found, arranged in a sequential order by question.

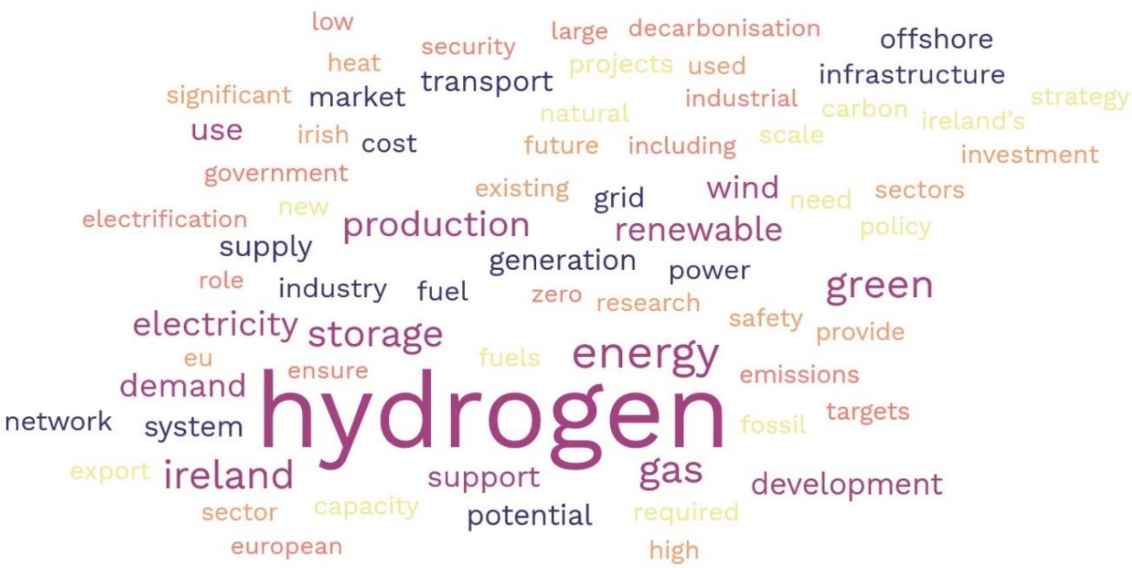

Figure 1 - Word cloud generated from responses to the consultation

2 THE SURVEY

2.1 SURVEY DESIGN

A list of 49[1] questions, herein referred to as "the survey", formed the basis of the consultation and were included on pages 31 to 34 of the original document. The survey was divided into sections as follows, with the numbers in brackets denoting the number of questions per section:

- Research and development (3),
- Hydrogen demand (7),
- Hydrogen supply (11),
- Hydrogen transportation and storage (13),
- Export opportunity (4),
- Safety and regulation (3),
- Supports and targets (6), and
- Energy security (2).

The questions ranged from those seeking high-level opinion to those seeking detailed answers. Several questions also contained sub- or follow-on questions. The responses sought varied between objective, subjective, qualitative, and quantitative.

2.2 WHO RESPONDED?

The survey received 126 responses in total. As expected, the majority of these were from the energy industry and included developers, suppliers, and service providers. Of note was the relatively high share of individual responses (12%) which included members of the public and political figures. Advocacy groups (11%) were also well represented.

Among the energy industry responses were elements of repetition suggesting that some respondents utilised elements of a prepared industry response for their own individual responses.

It should be noted that there is a certain degree of unavoidable overlap between the categories used to classify respondents, such as between energy providers and energy developers and between advocacy groups and professional bodies. The variety in responses clearly demonstrates the growing interest in and cross-cutting nature of hydrogen.

[1] *Questions 19 and 48 are the same but appear in different sections of the original survey meaning that there are 48 unique questions.*

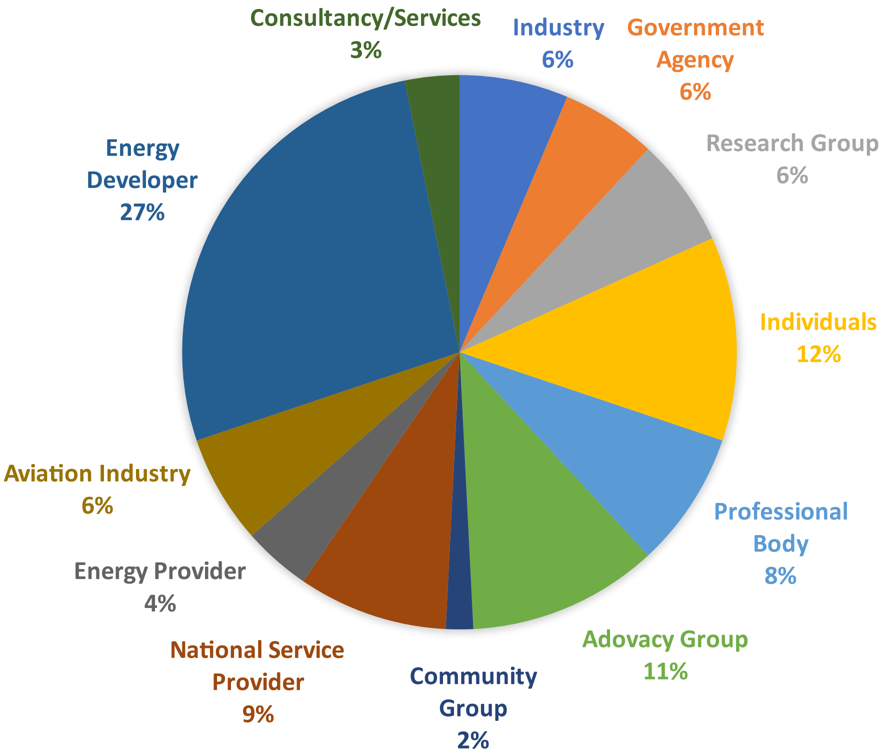

Figure 2 - Categorisation of the respondents

2.3 Level of Engagement

Across the survey, questions received an average of 35 responses, with a minimum of 15 and a maximum of 63.

The responses largely contained positive feedback and general support for developing a hydrogen strategy, but many submissions also lacked specific proposals that could be used to shape policy, and often did not engage with the substance of the questions. However, many respondents included referenced material showing that they spent significant time curating their responses. Across all categories, the responses displayed a mixed understanding of hydrogen technology, but it was also clear that there is a good level of awareness among companies hoping to operate in this space.

Although there was clear enthusiasm for the subject, both the length of the survey and the overlap in questions had a negative effect on the level of engagement. This is demonstrated by the fact that the average number of respondents almost halves between the first and final sections: reducing quite consistently from 42 responses per question in the first section to 23 per question in the final section. Towards the end of the survey, rather than engaging with each question or section, many responses simply pointed the reader to information provided in earlier sections.

2.4 METHODOLOGY FOR SUMMARISING RESPONSES

The long-form responses received to the consultation meant that a quantitative / objective review of responses was not appropriate. Instead, questions were regrouped into several themes to allow a concise and effective summary of responses. This approach addresses the fact that respondents engaged with questions to varying degrees and that information pertinent to one section was often contained in a response to another. This approach also reduces duplication in the production of this report whilst allowing for the effective summary of responses received and the anticipated next steps.

2.5 RE-GROUPING QUESTIONS

Groupings are based on key themes which emerged in the responses and to group similar or directly related questions from the original survey. Some themes received particular attention and required the definition of sub-themes.

For reference, the re-grouped questions are provided at the start of each section in this report.

Table 1 - Selected metrics from before and after the questions were regrouped

Metric	Before re-grouping			After re-grouping		
	Max.	Avg.	Min.	Max.	Avg.	Min.
Average number of responses per question within a section	42	34	23	41	36	28
Total responses to questions within a section	437	241	84	319	217	138

Regrouping allowed the number of responses per question in each section to be distributed more evenly. The effect is most noticeable with respect to the total responses, where both the maximum and minimum move much closer to the average. Essentially, the responses, which were previously concentrated around the earlier questions, can now contribute to much more of the survey.

2.6 ANALYSIS

In the style of a semi-structured interview, or qualitative analysis, the following sections summarise the views of respondents as solicited through the survey. Each section contains an overview, sub-themes under which responses are collated, and “the GDG view”, where a brief commentary on the summary of each sub-theme is provided. Section 3.8 has a different format and instead summarises the areas in which additional research may, in the view of GDG, be beneficial.

3 Summary of Responses

3.1 Where hydrogen will be used

3.1.1 Original survey questions covered in this theme

Q4. *What end-uses are there for hydrogen in Ireland (i.e. where hydrogen will be used)?*

Q5. *How much hydrogen would be anticipated for use in each (in low, medium and high demand scenarios)? At what rate might that increase? What current evidence supports these projections?*

Q6. *What specific end-uses should be high, medium and low priority for green hydrogen use?*

Q8. *How does hydrogen compare to competing technologies (direct electrification and other decarbonisation options) for each of these end-uses?*

Q9. *What are the competing fossil fuels that are sought to be displaced?*

3.1.2 Overview

On average, each question received 41 responses. Respondents provided many examples of potential end-uses. The questions on the scale of the opportunity (low, medium, high) did not yield meaningful results. However, this is something that can be objectively calculated once potential uses have been identified. In terms of judging the relative support for each use, the sections below provide a synopsis of opinions on a selection of the technologies. Please note that more uses were identified and are explored under other themes (e.g., energy storage, export).

3.1.3 Transport

3.1.3.1 Buses

Many responses noted that buses, especially the nationally owned fleet, could constitute a suitable use case for hydrogen. However, many also noted that a cost comparison with battery electric buses was needed. Of particular interest was CIE's response, "…the current strategy to transition our fleets relies primarily on Battery Electric Vehicle (BEV) technology" though they also note that hydrogen is a "feasible option in combination with BEVs".

3.1.3.2 Trucks

Fuel Cell Electric Vehicles (FCEV) heavy duty trucks was the most common suggested use of hydrogen in transport. However, many respondents cautioned than BEV could offer lower costs than FCEVs and the Freight Transport Association of Ireland (FTAI) suggests that BEVs can "do the bulk of journeys today". Hydrogen Ireland cautioned that after accounting for grid upgrades, secondary storage, and more, the potential efficiency of FCEVs is "understated".

3.1.3.3 Aviation

This was another popular suggestion, though the actual form in which hydrogen would be consumed was not often stated. Respondents recognised aviation as a hard-to-abate sector with a large and long-term need for low-carbon fuels. It was variously suggested that hydrogen-derived fuels are a short- to medium-term option, before direct hydrogen use appears in the future, though Zeroavia, a hydrogen plane producer, highlights that Ireland's regional airports could be well suited before long. The total scale of this demand was noted as especially large.

3.1.3.4 SHIPPING

Like aviation the scale of the potential demand from shipping is seen as especially large. As well as hydrogen-derived hydrocarbons, compressed and liquified hydrogen, ammonia, and methanol were suggested. A notable response came from Killybegs Fisherman's Organisation who supported the idea of hydrogen as a marine transport fuel for its fleet.

3.1.3.5 RAIL

Rail received less support, and while CIÉ recognised the ability to convert diesel trains to hydrogen, "Iarnród Éireann currently plans to prioritise electrification of the network via overhead catenary and electrical train sets".

3.1.3.6 NON-ROAD MOBILE MACHINERY

Handling equipment, construction machinery, and other more niche applications are noted as use cases where hydrogen could be well suited, especially considering their duty cycles. Hydrogen Mobility Ireland succinctly addressed this point, calling hydrogen a "strong contender for decarbonising non-road mobile machinery", pointing to forklifts as a common use case today, and highlighting the increasing availability of hydrogen-powered construction equipment.

3.1.3.7 THE GDG VIEW ON HYDROGEN USE IN TRANSPORT

Buses: Where the range and charging patterns of a battery electric vehicle can be accommodated, they generally offer a lower total cost of ownership than fuel cell hydrogen options[2], especially if the cost of refuelling infrastructure is included. It is therefore likely that only a share of intercity and long-distance private services are suited to hydrogen, with the feasibility of such an option largely dependent on demand from the trucking sector and the ability of the grid to provide adequate charging.

Trucks: Battery options are likely to be preferred in many applications due to lower costs. However, there may be applications to which hydrogen is better suited, namely longer and time-sensitive haulage. Ireland is also obliged to provide a minimum coverage of compressed and liquid hydrogen refuelling stations under EU regulations. A study is required to quantify potential usership (including buses) and therefore assess if this minimum coverage would be sufficient.

Aviation: There is a certain and long-term need for sustainable aviation fuels at scale. How these will be produced and traded is not yet certain but given that renewable electricity is our primary sustainable resource, sustainable aviation fuels could constitute a large green hydrogen demand into the future.

Shipping: Replacing fossil fuels in shipping is vital and currently options beyond synthetic fuels are limited, thus green hydrogen based synthetic fuels could constitute a large and long-term demand. The costs, demand, and international competitiveness of these two options (aviation and shipping) should be quantified.

Rail: The role for hydrogen in rail is uncertain, as with trucks, a battery electric option is likely to prove more cost effective, especially over the distances covered by the Irish rail network.

Non-road mobile machinery: Hydrogen is commonly used in forklifts and can offer off-road equipment with little access to charging, the opportunity for low-carbon fuel. There may be few alternatives to hydrogen, therefore the debate focuses on whether it will be used directly or as a hydrogen-based fuel.

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[2] A report from Transport & Environment as well as another from the International Council on Clean Transportation both find this result.

It is clear from the responses, and GDG agrees, that there is no significant role for hydrogen in the passenger car fleet. Battery electric passenger cars are at a much higher technology readiness level, with the advantages of hydrogen less applicable to this segment.

The cross-cutting nature of green hydrogen is also such that providing green hydrogen as an option for some of the options above could provide benefits beyond the transport and into the electricity sector; this too should be quantified to inform any decision.

3.1.4 Industry

Industry was commonly identified as a sector that will require the use of hydrogen. Examples given were refineries, chemical production, distilleries, and data centres. Many respondents noted hydrogen's suitability to satisfy demand for high temperature heat.

3.1.4.1 The GDG view on industrial uses of hydrogen

Existing and continued demand for hydrogen should be transitioned to low-carbon sources. However, alternatives should be explored and costed and interactions with other policies such as the EU Emissions Trading Scheme must be accounted for. The interactions and potential benefit to the electricity grid is also an important factor here. Novel applications such as back-up power for data centres may also find a place for hydrogen as a replacement for diesel or natural gas.

3.1.5 Residential

Respondents noted the greater suitability of electrification to home heating and cooking. In particular, the superior efficiency of a heat pump was recognised as the more suitable solution to space heating, respondents appear to have based this on an understanding of the economics. Friends of the Earth (FOTE) were very strong in their response and said it is "imperative that hydrogen is not used in home heating". Some responses cautioned against fully ruling hydrogen out for residential heating purposes, with Bord Gáis citing suitable scenarios such as "where heat pumps are not technically or economically feasible".

3.1.5.1 The GDG view on residential uses of hydrogen

As with the responses, GDG does not see a significant role for hydrogen in home heating or cooking. The costs and as yet unresolved safety issues mean that heat pumps and/or induction hobs will likely be the preferred solutions. Building hydrogen infrastructure to accommodate the likely very small number of homes unsuited to the combination of improved insulation and electrification would likely have an unfavourable abatement cost.

3.2 How and where hydrogen will be produced

3.2.1 Original survey questions covered in this theme

Q11. *What is the renewable electricity potential that does not have a route to market from conventional grid connections? Could this be used for green hydrogen production?*

Q12. *What are the most cost-effective ways of utilising potentially curtailed renewable electricity output for hydrogen production?*

Q14. *What is the expected minimum capacity factor of grid connected hydrogen electrolysers that would be financially viable?*

Q16. *Where would it be best to locate hydrogen production? Should there be specific government policy to locate hydrogen production facilities where too much energy being generated for the electricity grid to manage (i.e. grid constraints)? What spatial planning considerations should be factored into this? What role might ports play in the production and transportation of hydrogen?*

Q42. *What scale of ambition is right for Ireland regarding hydrogen production targets? What timelines should set for these targets?*

3.2.2 Overview

On average, each question received 39 responses though many of these were not as constructive as in other sections. This is presumably as the questions themselves asked for a level of detail beyond the knowledge of most respondents. This section also provided significant scope for advocacy-type responses as opposed to engaging with the question objectively.

3.2.3 Converting constrained renewable electricity into hydrogen

3.2.3.1 Required electrolysis capacity factor

The few respondents who answered provided estimates of between ca. 30 – 70%, with all recognising that higher capacity factors are needed for more economic operation of electrolysers. Responses to other questions did not seem to recognise this point. Bord na Móna's point that this "fundamentally depends on the value of the hydrogen produced which is uncertain" is apt.

3.2.3.2 How much constrained capacity will there be

This question invited speculation from a variety of sources, with estimates varying wildly but largely based on offshore wind farm potential, especially that on the west coast. Estimates as high as 2GW in 2030 and up to 20GW+ in 2050 were provided.

3.2.3.3 The GDG view on generation of hydrogen from curtailed renewables

Hydrogen production from electrolysis is one way to supply energy from renewable electricity generators that may not otherwise have a route to market. Though the required capacity factor is undoubtedly high (above 40%)[3], the exact figures for this, and especially for the volume of constrained renewable capacity should be part of a wider study as they depend on many factors.

3.2.4 Physical location and hydrogen valleys/clusters

3.2.4.1 Choosing a location

Several valid points were raised such as locating hydrogen production close to demand to minimise transport requirements. dCarbonX suggested the involvement of the Transmission System Operator in evaluating the best location for any large-scale projects. As is explored in Section 3.4, geological storage could be a major factor in locating hydrogen projects.

3.2.4.2 Suitable demand centres and candidate locations

These questions were related to the concept of a hydrogen valley where multiple demands are located close to production. Suggested locations included Galway harbour, along the Atlantic Economic Corridor, Bremore port, adjacent to Cork's industrial heartlands, and Rhode Green energy park. These suggestions were typically based on the local knowledge of the respondents rather than a critical assessment of the options, but the responses demonstrate a desire for many business communities

[3] A report from the International Energy Agency shows that at capacity factors of less than ca. 40%, or 3,500 hours per year, the cost per unit of hydrogen produced is much greater.

to attract hydrogen investment. Gas-fired power stations, airports, shipping ports, and large industry were all noted as existing demands centres for co-location or inclusion in hydrogen valleys.

3.2.4.3 The GDG view on locating hydrogen infrastructure

The concept of a hydrogen valley is extremely relevant as minimising transport and storage, expensive components of the overall cost of green hydrogen production, is key to economic viability. GDG is of the opinion that existing industrial centres are suitable candidates in the short to medium term, as well as ports and airports amongst others in the longer term.

3.3 Incentivisation and policy support

3.3.1 Original survey questions covered in this theme

Q13. *What should government do to de-risk efficient investment in green hydrogen production to supply Ireland's demand?*

Q15. *What policy mechanisms could be used to avoid green hydrogen production competing with direct electrification?*

Q18. *What policy mechanisms could be used to ensure that competition between green hydrogen production and other direct uses of renewable electricity is managed such that there are no negative impacts on emissions reductions or consumer costs?*

Q43. *How should the deployment of hydrogen in Ireland be funded / supported?*

Q44. *What are the potential policy options for incentivising for hydrogen end - uses?*

Q45. *How should green hydrogen be incentivised in the electricity market?*

Q46. *What policies should be put in place to develop further hydrogen-based enterprises?*

Q47. *How could supports and targets account for cross sectoral deployment of hydrogen?*

3.3.2 Overview

On average, each question received 37 responses. This section invited a wide variety of suggestions on how hydrogen should be supported but the specifics of any scheme should be linked to detailed goals and aligned with EU policy. Ireland has a significant second mover advantage in the production of a National Hydrogen Strategy and many respondents suggested that we take the opportunity to reflect upon what worked and did not work in other national strategies. It is the view of both the respondents and GDG that without policy or financial support, hydrogen is unlikely to enter the energy mix in time to contribute towards the realisation of our climate ambitions.

3.3.3 Schemes which may represent a cost to the exchequer

3.3.3.1 Tax-based incentives

The majority of respondents noted that hydrogen will benefit from exemption from taxes such as VAT, duties, and levies. ECI among others noted that not applying various taxes increases the competitiveness of hydrogen. Mayo Energy Group among others suggested that a tax benefit/rebate on investments in hydrogen production and transport related assets would be beneficial.

3.3.3.2 European matched funding

Enterprise Ireland, Bremore port, and others encouraged the leveraging of EU funding mechanisms, matched with national investment. Many of the examples given have now ended but have been replaced by schemes such as the European Climate, Infrastructure, and Environment Executive Agency (CINEA), other ongoing calls may include the Clean Hydrogen Partnership. Hydrogen Mobility Ireland and the German Irish Hydrogen Council suggested that Ireland was the only EU country not to join/submit a proposal to the hydrogen Important Project of Common European Interest (IPCEI) funding call.

3.3.3.3 Pilot projects

All respondents who mention pilot/pathfinder projects do so to emphasise the importance of building commercial experience, developing business models, and supporting demand creation. Competitive calls are the most suggested means of supporting these. Ongoing pilots such as the Galway Hydrogen Hub and that in Irving Oil's Whitegate refinery should also be supported. Those in favour of pilot projects include Hydrogen Ireland, Gas Networks Ireland, EirGrid, Nephin Energy, ESB, SSE, and Indaver.

3.3.3.4 Carbon Contracts for Difference

As well as many of the aforementioned organisations, EIH2, DLA Piper, and others specifically spoke about Carbon Contracts for Difference (CCfDs) as a suitable means of supporting sustainable hydrogen consumption. The advantages stated were targeted support for hard-to-abate sectors, de-risking effect, support at an EU level, technology neutrality, and the ability to learn from others who have implemented similar policies. SSE's response also mentions the Dutch SDE++ scheme and is particularly relevant to this theme.

3.3.3.5 The GDG view on exchequer supports for hydrogen

There is no one size fits all solution. Ireland has a history of encouraging investment via tax incentives which should be extended to hydrogen projects. Not applying for EU funding calls would be highly regrettable and all avenues should be exploited, particularly as they apply to pilot projects which are required to pave the way for further development. Finally, we see carbon contracts for difference as a potentially suitable support scheme which should be investigated and applied.

3.3.4 Schemes that do not require exchequer funding

3.3.4.1 Mandates

Applying EU policy on blending of low-carbon fuels in hard-to-abate sectors such as aviation was recognised by respondents as inherently promoting hydrogen and its competing solutions. The largest benefit was seen to be demand generation within the free market.

3.3.4.2 De-risking investments

Many of the previously suggested supports substantially de-risk further investment (pilots, tax breaks, financial supports) but additional measures were also proposed. Mercury Renewables, Energia, and others suggest that private wire legislation is required for clarity and to allow for the acceleration of the delivery of supporting infrastructure independent of the electricity grid. Furthermore, according to many respondents committing more resources to the planning agencies and streamlining processes will reduce risk. Establishing an offtaker of last resort was suggested by Shane Heffernan, Hydrogen Utopia Ireland, and RWE. Finally, leadership from state-owned entities in adopting hydrogen was suggested by Hydrogen Mobility Ireland.

3.3.4.3 THE GDG VIEW ON NON-EXCHEQUER SUPPORTS FOR HYDROGEN

Obliging industry to increase its share of renewables creates a market for hydrogen while also allowing competition between various solutions. With sufficient oversight as provided by the Renewable Energy Directive and the associated acts this appears to be a promising solution that GDG would endorse, subject to additional investigation. A suite of solutions from the suggestions above would prove to de-risk projects but the exact nature of the risk and more targeted measures would likely be needed. De-risking is therefore likely best approached separately for different project types. If an offtake of last resort were created, care to avoid consenting projects without a long-term economically viable future must be taken.

3.4 HYDROGEN STORAGE AND TRANSPORTATION

3.4.1 ORIGINAL SURVEY QUESTIONS COVERED IN THIS THEME

Q22. *What methods of transporting hydrogen are best suited to meet the needs of hydrogen end-use in each sector?*

Q27. *What level of hydrogen storage should Ireland have? Where would it be best to locate hydrogen storage?*

Q31. *Are there any predefined geographical areas of interest in relation to potential hydrogen storage?*

Q32. *What types of technologies, including any existing infrastructure, could be put in place to facilitate hydrogen storage?*

Q33.[4] *What would be the major challenges and opportunities presented by the possibility of storing hydrogen underground for the long term, particularly so to be able to effectively balance consumer demand and supply during peak periods and to address seasonal demand?*

Q23. *Whether hydrogen blends injected into the gas network is considered to be a good use of green hydrogen?*

Q24. *Would hydrogen blends in the gas network be a viable way to underpin investment and ensure lack of demand risk is mitigated in the event that hydrogen demand fails to adequately materialise in end-use sectors?*

Q25. *Should there be a long-term plan for a transition of the natural gas network to 100% green hydrogen? How much of the network should be repurposed (should it be the transmission pipelines only or include some of the distribution network? Should the existing gas grid will be broken up into smaller segregated sections to carry 100% hydrogen in some areas? How would this meet needs of end-use sectors? What should be the timeline for this?*

3.4.2 OVERVIEW

On average, each question received 35 responses. The responses provide some insight into relative support for various pathways and recognition of their weaknesses. As with other sections, specific studies are required to address some of the objective questions raised in the consultation, especially regarding the volume of storage required.

This section is divided into responses related to the natural gas grid and those related to other forms of storage and transportation. Questions about which methods best suit the various use cases are

[4] *This question also appears in Section 3.7*

found throughout as the questions did not garner responses that would generally contribute to a Hydrogen Strategy beyond the fact that storage and transport should be use case appropriate and minimised.

3.4.3 The Natural Gas Grid

3.4.3.1 Arguments for Blending in the Gas Grid

The network being "hydrogen-ready" was mentioned in several responses. Many respondents conclude it could therefore offer a potential low-resistance path to stimulate hydrogen consumption, with the associated benefits of reducing project risk, particularly if used to enable the offtaker of last resort facility. In response to Action 169 of the Climate Action Plan 2921, Gas Networks Ireland (GNI) submitted a report titled "Injecting green hydrogen blends into Ireland's gas network" to DECC in December 2022. The report provides an initial high-level technical assessment of the readiness of the national network to carry hydrogen blends of 20 – 100%. The report concludes that whilst there are no major technical barriers to blending within the distribution network, materials testing will be required for 50% of pipelines within the transmission network for blends of over 10% to avoid reductions in operating pressures.

Blending would reduce demand for natural gas and was supported by some respondents who state that blending hydrogen may be an option to quickly connect initial hydrogen supply with demand.

3.4.3.2 Arguments Against Blending in the Grid

Arguments against hydrogen injection into the gas grid included the risk of fossil fuel infrastructure lock-in, the potential of hydrogen leakage and associated global warming impact, the potential for increased NO_x emissions, and concerns about the degree of incompatibility with the steel gas transmission network which transports gas regionally and to the largest end-users (as opposed to the polyethylene distribution network which primarily transports gas locally to domestic, commercial, and some smaller industrial demand). Most commonly it was seen as having limited emissions reduction potential due to the lower energy content and low blend limits of hydrogen. The round-trip efficiency of such a configuration was also viewed as difficult to justify. A notable response to this effect came from several respondents who quoted the European commission warning that blending requires "careful consideration" due to the risk of increased costs and lower efficiency.

3.4.3.3 100% Hydrogen Pipelines

Responses showed a preference for full conversion to hydrogen over blending, however the implied timeframe over which this could be achieved could not be derived from responses. This option was also noted to have strong overlap with the concept of a hydrogen valley. The scale of ambition varied substantially from small, isolated parts of the grid being converted, to the grid at large, to becoming part of the proposed EU Hydrogen Backbone.

3.4.3.4 The GDG View on Gas Pipeline Injection

The natural gas grid represents a large potential store for hydrogen and could be used to solve the initial issue of a temporal mismatch between developing a hydrogen production industry and waiting for demand to evolve. In December 2022, Gas Networks Ireland (GNI) produced "Injecting green hydrogen blends into Ireland's gas network", a report which provides an initial high-level technical assessment of the readiness of the national network to carry hydrogen blends of 20 – 100%. The report concludes that whilst there are no major technical barriers to blending within the distribution network, materials testing will be required for 50% of pipelines within the transmission network for blends of over 10% to avoid reductions in operating pressures.

It is the view of GDG that beyond catalysing an indigenous green hydrogen industry through the generation of demand, non-targeted blending of natural gas with hydrogen is not an efficient use of resources especially considering the limited emissions reductions potential. Repurposing parts of the natural gas grid to supply pure hydrogen to new industrial demand or power generation clusters as they develop in line with the hydrogen market evolution is the logical long-term use case for existing pipeline infrastructure.

3.4.4 NON-GAS GRID SOLUTIONS

3.4.4.1 DISTRIBUTED PRODUCTION AND USE AS A FORM OF STORAGE

For mobile-handling equipment and other relatively small-scale solutions, this has the potential to have a lower overall cost than centrally produced and transported hydrogen. Though the actual distinction is unclear, it is proposed as also potentially suited to trucking as opposed to resupplying hydrogen refuelling stations via tube trailer or similar.

3.4.4.2 GEOLOGICAL STORAGE

Depleted oil and gas fields, salt caverns, and aquifers were all suggested in the responses. With respect to oil and gas fields, one respondent noted that existing gas connections and proximity to port infrastructure could be advantageous. In terms of salt caverns, Engineers Ireland and others point out that suitable onshore geology in the Republic of Ireland is lacking, and opportunities in Northern Ireland may prove better suited. To this end, Islandmagee Energy has proposed such a project near Larne, Co. Antrim. Finally, with respect to aquifers much study is required to ascertain the potential of this storage method as demonstrated by the relatively vague way in which it is presented in the responses.

3.4.4.3 HYDROGEN-BASED FUELS OR PRODUCTS

Synthetic hydrocarbons such as kerosene and methanol, as well as useful products such as ammonia, have been suggested as alternative means of what is essentially hydrogen storage. Suggestions to this effect came from a wide range of stakeholders including the University of Galway, Aergaz, and BOC. This strategy was also noted as aligning well with EU policy and the need to decarbonise hard to abate sectors such as heavy-duty transport (see Section 3.1.3).

3.4.4.4 THE GDG VIEW ON NON-PIPELINE BASED STORAGE

Distributed production and storage are indeed suited to smaller-scale applications. Distribution has the advantage of increasing the potential benefits to the electricity grid as it does not significantly exacerbate pressure in one location. With respect to trucking, the feasibility of the distributed solution is less clear, and the choice will be a balance between technical considerations, costs, and grid impacts.

Geological storage has the potential to be of a larger scale and lower cost than other solutions but, being extremely location-specific, the feasibility of any project will also be a function of costs and technical considerations: the ideal being the discovery of a suitable site coincident with a proposed hydrogen valley, or indeed their co-location. Ultimately, the variety of responses with respect to geological storage demonstrate that this opportunity is not very well understood in Ireland.

Storage requirements can be greatly reduced, and transport issues largely resolved with immediate conversion into more easily handled liquids/gases with existing and mature supply chains. Many of these options also have existing and long-term markets as discussed in Section 3.1.

3.5 REGULATION AND SAFETY

3.5.1 ORIGINAL SURVEY QUESTIONS COVERED IN THIS THEME

Q17. *What minimum sustainability criteria should apply to hydrogen produced in Ireland?*

Q29. *What regulatory and statutory framework should be put in place to allow for geoscientific investigation of the potential for geological storage of hydrogen in the future?*

Q34. *What new environmental considerations should be considered in relation to hydrogen storage?*

Q39. *What is the appropriate safety framework for the future hydrogen economy?*

Q40. *What state body should be nominated as the hydrogen safety regulator, charged with responsibility for the development, implementation and oversight of the hydrogen safety framework for the various elements of the future hydrogen economy?*

Q41. *What international standards will be necessary for products and processes used in the hydrogen industry, particularly in regard to safety? What standards should be adopted in Ireland and why?*

3.5.2 OVERVIEW

On average, each question received 28 responses, this represents poor engagement with the questions in this theme relative to others. However, the responses were also more focused and provided a greater consensus than in other sections. There was a sense that uncertainty here must be resolved quickly to reduce risk to developers / investors and provide guidance when it comes to designing projects.

3.5.3 SUSTAINABILITY CRITERIA

There was a clear focus on green hydrogen produced from renewable electricity and how it matches national ambitions in solar and in particular wind. Several respondents were cautious about the inclusion of blue hydrogen (from fossil fuels with carbon capture) pointing to studies that question the emissions savings. Some respondents were against the inclusion of blue hydrogen in any plans, with others being more agnostic but still recognising the need for sustainability criteria and differentiating the source of the hydrogen.

EU directives and delegated acts were seen as suitable guiding documents with specific policies like additionality[5], temporal matching, and PPAs noted as potentially preventing unsustainable production. However, strict adherence to Directives before an industry has a chance to become established was discouraged by Engineers Ireland for fears it would stifle "early deployment, hindering the sector potential long-term". Similar comments came from several respondents.

There was also a recognition that hydrogen has a greater global warming potential than often accounted for and that leakage from infrastructure should be well understood and factored into plans for a hydrogen rollout.

3.5.4 OWNERSHIP AND LAND RIGHTS

It is worth including an extract from Dr. Yvonne Scannell's (School of Law, Trinity College Dublin) submission which states that "rights to store gas underneath the ground under lands owned by persons other than the promoters of the hydrogen project should be resolved, otherwise such storage

[5] The proposed delegated act on additionality has not passed and green hydrogen production will not be subject to such additional rules. The updated rules are expected in mid-December 2022.

will be legally impossible in a jurisdiction with very fragmented landholding like Ireland. Matters such as the right to lay pipes and the planning issues related to this (particularly for the private sector) should be resolved. A commitment to provide resources and upskill regulators who ought to know what they are doing when dealing with the industry should be given and honoured". This issue also needs to be resolved to reduce risk with respect to geological storage.

3.5.5 Safety and who is the regulating authority

Most respondents recognise the CRU as the appropriate authority, with a potential supporting role from GNI and possibly the HSA. Harmonisation with other countries is also noted as important, especially with respect to the potential export opportunity. Existing regulations such as Control of Major Accident Hazards Regulations (COMAH) and multiple ISO standards are seen to cover hydrogen though as recommended in Section 3.8, a detailed review is required to provide certainty to stakeholders. Engineers Ireland specifically note that in the case of 100% hydrogen, ATEX gas group IIC regulations are required, which may have "significant implications for equipment retrofit in this area".

3.5.6 Planning

With respect to planning, respondents suggest that "Ireland's government should resource the public sector to address spatial planning needs and facilitate spatial planning relationships between hydrogen production facilities, industry clusters, safety, and end-user locations". Several others also highlighted the importance of this point including Aergaz, Galway Harbour Company, and the DAA. Wind Energy Ireland's response contains detailed analysis of the issues facing the planning system.

3.5.7 The GDG view on regulation and safety

Reducing leakage is difficult. Regulations, material selection, and quality installation are required. Strategies such as minimising transport will help in this respect.

In the face of pressure to accelerate progress, likely compounded by the war in Ukraine, the delegated act on additionality is being reconsidered. However, it was always unlikely that the pace of electrolysis development could keep up with renewable generation capacity deployment. Regardless, the focus should be firmly placed on green hydrogen from renewable electricity rather that other forms of hydrogen generation.

In terms of the regulations applicable to hydrogen, the issue requires a full review with the participation of all relevant stakeholders. A clear set of guidelines should be published, removing any ambiguity.

3.6 Export potential

3.6.1 Original survey questions covered in this theme

Q35. *What is Ireland's potential opportunity to export green hydrogen? What are the impacts of this on consumers and the economy?*

Q36. *How does export of green hydrogen compare with the direct export of renewable electricity through electricity HVDC interconnection?*

Q37. *What methods and volumes of exportation are likely to be viable by 2030 and in the period to 2035?*

Q38. *How should Ireland support the development of green hydrogen exports?*

3.6.2 Overview

On average, each question received 35 responses. Responses to these questions were not short on ambition, with many references to the potential scale of demand in other regions as well as our potential offshore wind resources. Others were far more tempered on what could be achieved. This section appeared to have the greatest divergence of opinion across responses.

3.6.3 Responses that suggested export will play a small role

Those who believe it will be difficult to build an export market point towards our high costs and lack of relative experience. The potential is also dependent on the fast rollout of offshore wind. Respondents also noted the high level of cooperation and targeted cost reductions required which would therefore favour direct electrification.

Respondents suggests there will be "sufficient domestic demand to absorb all hydrogen produced" both to 2030 and to 2035. The focus on fuel production for domestic use and targeting export by acting as an international refuelling station was considered a realistic option according to many respondents.

Exporting our resources as electricity may be preferable, says Ray Cunningham (Local Area Representative, Green Party), citing the greater efficiency, and this is echoed by ESB and the University of Galway. Chamber Ireland were pragmatic in pointing out that without a terminal, export potential is undermined, and that moving the hydrogen to the terminal would itself be a complex task. An alternative idea, converting large sections of the natural gas network, in line with the EU hydrogen backbone concept, would have a large effect on consumers here.

Several responses also warn of the potential to lose focus on decarbonisation and warn not to "subsidise hydrogen production that is then exported for use in other countries".

3.6.4 Responses that suggested export represents a major opportunity

The German Irish Hydrogen Council say that the potential is "limited by Ireland's ambition", this type of enthusiastic comment is common in responses, particularly those from business groups. Bord na Móna, in addition to recognising the challenges, also speaks about the "huge potential to produce green hydrogen beyond our domestic needs" and the synergy between first building a domestic industry and potentially later exporting. EirGrid states that renewable generation will be greater than our need and capacity to manage, leading to a potential export opportunity, with Constant Energy noting this is particularly applicable to the west of Ireland. Export in the forms of hydrogen derivatives such as shipping of ammonia, is seen as a potential avenue with the example of the Canadian and German agreement being presented by AEC and SCC.

3.6.5 The GDG view on hydrogen export potential

Despite our vast potential resources, Ireland remains a high-cost region for renewable electricity generation. Beyond our interconnectors, we also lack experience in natural gas and other related infrastructure that could be leveraged against building an export facing industry. Though there are many enthusiastic stakeholders, it would require extraordinary development and cost reductions for

Ireland to become a competitive hydrogen producer and exporter. It is most likely that unless Ireland attracts massive foreign investment and skilled labour, and other regions fail to execute plans, Ireland will not export significant amounts of hydrogen. Capitalising on the potential would require cooperation across a wide range of actors at a pace not seen before and demand much greater than what is currently anticipated. It is the view of GDG that the focus instead should be on domestic demand, and this is a no-regret means of building capacity. Such capacity could be later geared towards export if suitable market conditions arise.

3.7 INTEGRATION WITH THE ELECTRICITY MARKET

3.7.1 ORIGINAL SURVEY QUESTIONS COVERED IN THIS THEME

Q19. *What contribution could domestic green hydrogen supply make towards Ireland's energy security?*

Q26. *What role could hydrogen storage play in Ireland's energy system?*

Q33.[6] *What would be the major challenges and opportunities presented by the possibility of storing hydrogen underground for the long term, particularly so to be able to effectively balance consumer demand and supply during peak periods and to address seasonal demand?*

Q49. *What role could hydrogen storage play regarding security of supply?*

3.7.2 OVERVIEW

On average each question in this theme received 35 responses. It proved difficult to group responses received to questions in this theme. This is perhaps due to respondents misunderstanding the focus of the questions but is also likely due to the fact that many of these questions appeared further down the survey, and as such, received less engagement as discussed in Section 2.3. The issues of electricity market integration and energy security as also highly cross-cutting meaning that many respondents may have felt that they had provided text elsewhere that addresses these issues. How and where hydrogen will be produced (Section 3.2) and hydrogen storage and transportation (Section 3.4) both contain responses relevant to this section.

3.7.3 CONSTRAINT AND CURTAILMENT

3.7.3.1 HYDROGEN'S ROLE AS PART OF A NET ZERO EMISSIONS ELECTRICITY SYSTEM

Green hydrogen has the potential to provide system services to the grid through flexible consumption, a point made by Scottish Power and others. HyLight noted that hydrogen-based demand-side management, load shedding and following, is another function electrolysis could provide. Most respondents who replied to this section spoke about hydrogen's ability to provide dispatchable generation via thermal plants. The response from Hexicon was notable as they state that hydrogen "should not be incentivised in the electricity market due to System and Pathway Loss which will increase costs".

[6] *This question also appears in Section 3.4.*

3.7.3.2 CONSUME OTHERWISE DIFFICULT TO MANAGE ELECTRICITY

Producing hydrogen solely by using curtailed or constrained electricity does not make commercial sense according to IBEC. The view of H Wind and others is that consuming curtailed electricity is beneficial but is only part of the solution.

3.7.3.3 THE GDG VIEW ON CURTAILMENT AND CAPACITY

It is true that relying on curtailment or constraint alone will mean that the hydrogen produced is very expensive with higher capacity factors needed. Similarly "oversizing", or building more electrolysis capacity to capture more difficult to manage electricity, is unlikely to emerge due to the cost implications[7]. Instead, curtailed energy should form part, but not all, of an electrolyser's energy demand.

The value of dispatchable low-carbon electricity will increase over time, at what point this becomes viable will be a function of how the electricity mix develops and the cost of carbon emissions.

3.7.4 CONTRIBUTION TO ENERGY STORAGE AND SECURITY

Energia highlighted the "need for systems level thinking and energy system optimisation in planning for net zero". This was reflected in a number of other answers that highlighted the interdependency of various plans and targets. Also, commonly noted, was that including hydrogen in the energy mix could offset natural gas imports and increase the overall share of energy served by Irish resources.

Defining the actual contribution to energy storage and security proved difficult. Instead responses commonly quote figures from existing reports[8]. Repeated many times across responses was the ability of hydrogen and hydrogen-based fuels to act as highly flexible electricity storage which will be required if we are to achieve our wind and solar targets.

3.7.4.1 THE GDG VIEW ON HYDROGEN AND ENERGY SECURITY

We need to differentiate between long- and short-term energy security. In the short-term, flexible demand from hydrogen can balance variable renewables and maintain a stable electricity grid. It could also provide generation via thermal plants (with the benefit of inertia) or via fuels cell (faster acting, more efficient, but no inertia). However, long-term security will be entirely dependent on the scale and cost of storage. Thus, the contribution to energy security may be limited to grid stability unless much more ambitious projects are developed.

Further assessment of the availability, costs, benefits, and business cases for different forms of hydrogen storage and hydrogen derivates will be required to determine the most appropriate solutions to support Ireland's security of supply and resilience needs. Ultimately though, a flexible and large-scale store of hydrogen / hydrogen-based energy carriers is a very useful tool to have when moving towards net zero.

3.8 QUESTIONS REQUIRING FURTHER RESEARCH

3.8.1 ORIGINAL SURVEY QUESTIONS COVERED IN THIS THEME

Q1. *Which areas of hydrogen research require further examination?*

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[7] *Oversizing and relaying on curtailment/constraint alone is costly as it leads to low capacity factors, as discussed previously and as found in this report from the International Energy Agency.*

[8] *For example the GreenTech Skillnet, Wind Energy Ireland, and GDG report on Hydrogen and Wind Energy.*

Q2. *What can an Irish hydrogen strategy could do to drive innovation?*

Q3. *What are the research priorities for the development of each hydrogen end-use (demand) in Ireland?*

Q7. *How might the combined deployment of green hydrogen across multiple sectors synergies facilitate the development of hydrogen in Ireland?*

Q10. *How can Ireland avoid hydrogen use that increase the overall level of energy used in the economy versus other decarbonisation pathways?*

Q20. *What strengths does Ireland have in hydrogen supply chains?*

Q21. *What potential uses are there for the oxygen by-product of hydrogen production?*

Q25. *Should there be a long-term plan for a transition of the natural gas network to 100% green hydrogen? How much of the network should be repurposed (should it be the transmission pipelines only or include some of the distribution network? Should the existing gas grid will be broken up into smaller segregated sections to carry 100% hydrogen in some areas? How would this meet needs of end-use sectors? What should be the timeline for this?*

Q30. *What is the potential acceptance of or resistance to hydrogen storage facilities in communities? What public engagement might be required?*

Q32. *What specific aspects would be needed for any research and development to test the feasibility of storing hydrogen underground, particularly in respect of depleted gas fields?*

3.8.2 Overview

On average, each question received 35 responses. Below is a selection of questions which GDG believes are either critical to an informed National Hydrogen Strategy, warrant further investigation in the Irish context, or where we should closely observe international research and contribute where possible. The required level of analysis to answer each question varies substantially, but each should at a minimum be considered in the Irish context in advance of producing a Hydrogen Strategy.

There was significant room for interpretation within this theme and some interesting research questions arose from the responses. It was also clear that many of the questions posed are better answered through objective research rather than through further subjective consultation.

3.8.3 Questions critical to an informed Irish Hydrogen Strategy

1. ***Stranded asset analysis***: Identify investments that do not have a long-term role in the energy system, or which will be competitive for too short a time to payback the required investment. This analysis should include the following:
    - Futureproofing and/or de-risking fossil fuel infrastructure investment,
    - Assessing the long-term utility of the natural gas network and capacity to retrofit, and
    - Long-term assessment of hydrogen transport infrastructure.
2. ***Technological comparative assessments to inform policy making***: Informed technology-neutral policy is generally preferable. Ireland should be cautious to only invest in solutions where more economic options are not available. Useful to this is:
    - Total cost of ownership analysis on competing solutions (e.g., in transport and heat),
    - Whole system modelling to identify long-term end use cases, and

- Holistic assessment of electricity storage solutions.

3. ***Export potential versus other countries***: A realistic assessment of Ireland's competitive position is required before making investments that could distract from domestic utilisation and should cover:
    - Ireland's competitive position and potential customer analysis,
    - Lead time analysis in terms of costs and timelines and available infrastructure (e.g., ports), and
    - Ireland's readiness to produce hydrogen and attractiveness to investors.
4. ***Geological storage of hydrogen***: A discreet project that brings together government and industry stakeholders to identify potential issues throughout the supply chain is needed and would:
    - Assess current regulations and their suitability to the specifics of hydrogen,
    - Identify responsibilities throughout the process and in the long-term, and
    - Map areas suitable for storage and make the data publicly available.
5. ***International hydrogen policy reviews***: Many countries are further ahead in their hydrogen journeys and Ireland should review international best practice and apply the lessons here including:
    - Suitable funding/incentive schemes that offer best value,
    - Best means of integrating EU schemes such as Guarantees of Origin, and
    - How best to guide the use of hydrogen towards hard-to-abate sectors.
6. ***Skills gap and job creation***: Ireland does not currently have the skills or labour required to build hydrogen-related infrastructure, and so in determining who will build it and how we support job creation it is vital to assess:
    - The potential scale of the shortfall, where and when it may materialise,
    - The skills requirements and lead time on acquiring them, and
    - The implications for the pace and cost of any potential rollout.

3.8.4 QUESTIONS WHICH WARRANT FURTHER INVESTIGATION IN THE IRISH CONTEXT

1. ***Islands as hydrogen incubation sites***: There is an opportunity for islands to increase their energy independence through hydrogen and act as testbeds for the technology, though full and informed consent is required.
2. ***Continued academic research***: Where research in Irish institutions is ongoing it should continue to be funded, this includes research into practical engineering issues (e.g., compression, storage of hydrogen), energy systems research (e.g. ideal scale and location of electrolysis), and the social implications (e.g. perception, dividends, acceptance).
3. ***Global warming potential of hydrogen***: Fugitive hydrogen is a greenhouse gas whose impact must be accounted for. The leakage figures need to be well understood and quantified with an eye on choosing the consumption and distribution methods that minimise leakage here. The importance of minimising leaks should also form part of any training courses.

4. ***Valorising the oxygen produced***: By weight, eight times as much oxygen as hydrogen is produced using electrolysis. Means of utilising this to either reduces emissions or increase economic viability should be investigated such as wastewater treatment, medical applications, or oxycombustion.

3.8.5 QUESTIONS WHERE WE SHOULD OBSERVE AND POTENTIALLY CONTRIBUTE TO INTERNATIONAL RESEARCH

Several other potential research questions were raised in the responses. Though certainly worthwhile, some such as electrolysis/fuel cell cost reductions and performance improvements, would not be able to contribute to a Hydrogen Strategy in the timeframe imagined. Ongoing research should continue but developing new research in this area would take many years. As would developing liquified hydrogen storage technologies and applications, methods of reducing NOx emissions from hydrogen combustion, or other innovations with applicability to Ireland.

Others are better evaluated on a project-by-project basis, including sustainable water consumption, potential for waste heat recovery, and district heating.

4 General Lessons

To provide some conclusions and look towards the development of the Hydrogen Strategy, this section reiterates some key take-home messages. These are based on arguments commonly found throughout the responses, which we feel are worthy of focused attention.

4.1 Respondents were supportive of green hydrogen

Though there is an obvious risk of selection bias, the general mood was very supportive of green hydrogen. Support for fossil hydrogen was low. Respondents were both strongly for hydrogen's use in certain cases such as in meeting blending targets for aviation and shipping fuels, and strongly against it in others such as passenger cars and home heating. Though not always consistent, the responses showed that there was a clear appetite to decarbonise the economy, and that green hydrogen had a role to play.

4.2 Contents of a Hydrogen Strategy

The respondents are strongly of the opinion that the strategy should contain specific and objective goals in place of statements of ambition. Ireland has the advantage of being able to take learnings from other regions and should therefore be able to be more ambitious in characterising what we hope to achieve, and how we will enable it.

4.3 Competition is encouraged

There was a consensus on the need for support for pilot projects and hydrogen-related research and development. However, electrification was seen as the most suitable solution to many sectors and thus technology neutral as opposed to hydrogen-specific decarbonisation policy was heavily favoured. Policy intervention that curtails competition was not supported by the respondents. Similarly, where possible, policy should be based upon long-term cost benefit analysis. Many responses noted that Carbon Contracts for Difference (CCfDs) appeared to meet these goals.

4.4 Reducing costs is key

The transition at large requires that Ireland's high-cost environment is tackled, this is a far-reaching multifaceted policy consideration beyond the scope of this consultation. Pilot projects and other forms of investment can reduce the cost of hydrogen infrastructure. However, as the main input, reducing the high cost of wind and solar will also be required. This was the point most often raised where respondents were pessimistic about Ireland's export potential.

5 APPENDIX

A summary of the hydrogen consultation responses by question has been submitted as a separate document alongside this report.

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