Public Consultation on developing a hydrogen strategy for Ireland

Response from: Hydrogen Ireland Association

"Hydrogen Ireland" is an all-island association composed of industry, academics, individuals, and NGO's, from the island of Ireland and internationally. Hydrogen Ireland is an all-Island Association, but not limited by the island. "Hydrogen Ireland Association" aims to:

- *Promote the role of hydrogen as a clean fuel and energy vector and related technologies in the energy, mobility, heat, domestic, industrial, and agricultural systems* to enable them to become key components of our future low carbon economy *on the island of Ireland (Northern Ireland and the Republic of Ireland)*
- *Contribute to the introduction of sustainable clean technologies and processes for the benefit of citizens and of all sectors of the economy through the promotion, use and development of safe hydrogen technology.*

"Hydrogen Ireland" achieves this by:

- Hydrogen Ireland Association facilitates public and business awareness of the potential of hydrogen via informing, showcasing and demonstration of the latest scientific data & technology.
- Hydrogen Ireland Association provides clear, informed, and current view on best practice for hydrogen technologies.
- Hydrogen Ireland Association engages with government on both sides of the border to develop policy and support for the inclusion of hydrogen, and its related equipment, within this energy transition.
- Hydrogen Ireland Association expects to create new high-tech jobs and skill sets in all areas of society to enable the green economy.

Hydrogen Ireland welcomes the opportunity to respond to the Public Consultation on developing a hydrogen strategy for Ireland.

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Executive Summary

Net zero Targets

Ireland's hydrogen strategy requires a focus on Net Zero targets

Not all of Ireland's energy needs can be met through electricity, including heavy goods transport, shipping, aviation, industrial heating, and thermal generation to complement intermittent renewables. Net Zero 2050 will see renewable electricity and carbon free molecules powering an integrated energy system. To achieve this, Ireland's hydrogen strategy must plan out to 2050 with short-, medium- and long-term actions identified to develop the green hydrogen supply chain in parallel with decarbonising our electricity system.

Energy Security

Today Ireland's energy security relies on fossils fuels including imports from UK (not a EU country) and the soon to be exhausted Corrib gas reserve. While Ireland is rightly focussing on the short-term measures to address concerns for Winter 2022, medium term action is imperative & necessary to avert further crises in the coming years.

Green hydrogen created from Irish renewable energy, stored, and transported on this island as a complement to renewable electricity means Ireland can achieve energy security that is sustainable and affordable.

TWhr Energy Storage

Ireland requires a solution to TWhr Energy Storage through Green hydrogen

Due to the intermittent nature of renewables, we need to be able to store energy for long periods of time when the sun isn't shining nor the wind blowing for electricity production. Storage is also needed when there is more sunshine and wind than we need at that instant. 90 days primary energy storage (best practice in EU) is equivalent to ~30TWh storage. This is equivalent to the storage capacity of >15,000 Turlough Hill pumped storage units). Whilst other renewable and short-term storage initiatives (such as short cycle batteries, etc.) can and will play an assisting role, to meet this scale, Ireland's energy system will require much larger scale storage solutions which could be achieved using Green Hydrogen

Export Capability

Irelands wind resources means we can become a net exporter of energy as Green Hydrogen

In Ireland, there is a high potential to convert energy from our abundant wind resources, both onshore and offshore, into renewable hydrogen to provide clean, reliable, and storable energy to achieve our net zero ambition and for export to EU Member States who are already forecasting shortfalls between their indigenous hydrogen production capacity and their hydrogen requirements in a net zero economy. Furthermore by creating a route to market proportionate to the available energy, Ireland becomes very attractive to foreign direct investment energy by large energy companies due to economies of scale.

Stable energy prices for customers

Green hydrogen will support stable energy prices for customers

The War in Ukraine has focused Europe's approach to where and from whom and what fuel is necessary for Europe. The war has escalated fossil gas prices to unprecedented levels, affecting every customer including Ireland. The gas price at its current level may be a new normal or it may reduce to a lower level but in 2022 & expected 2023 the prices are expected to remain very high.

Green Hydrogen will enable energy system integration in Ireland meaning we can meet our energy needs from our renewable resources. This independence will enable an affordable, secure, and sustainable Energy Future for Ireland

Jobs and economic growth of a new sector

Green Hydrogen supply chain will create jobs and enable economic growth

Exploiting our offshore wind resources and encouraging the synergies between floating offshore wind and hydrogen can create thousands of jobs by 2050, through staging, installation and the operations and maintenance of wind farms and hydrogen plants, thus enabling companies to fully develop infrastructure. Moreover, the social licence needed to build out the infrastructure for the energy transition will be enhanced through a sense of ownership by the additional citizens benefitting from the economic uplift of the new sector.

Green Hydrogen Strategy can come to life through climate action plan.

While Hydrogen Ireland welcomes this consultation process, we strongly believe it needs to be actioned through Climate Action Plan 2023 as well as Ireland's National Energy and Climate Plan. Additional resources both in terms of funding and increasing capacity in key state bodies as well as collaboration between previously silo-ed parts of the energy sector. We in Hydrogen Ireland look forward to supporting the implementation of the Hydrogen Strategy for Ireland.

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1. Hydrogen Research

1.1 Which areas of hydrogen research require further examination?

- Need net zero 2050 study to quantify Hydrogen needed to complement role of electrification and hence set targets for minimum renewables needed
- Hydrogen subsidy support development must be actioned and released so businesses & investors can start to develop economic hydrogen projects.
- Electrolyser scale up & manufacture & feasibility to locate electrolyser giga factories in Ireland.
- Hydrogen Hub/Valley development in locations such as Dublin, Galway, Cork, Shannon, Wexford, etc.
- Hydrogen storage at large scale, e.g. in Saline Aquifers offshore Cork as well as Salt Caverns offshore Dublin, Clare and in Northern Ireland and re-electrification.
- Explore the best routes to produce e-kerosene or e-methanol manufacture from green hydrogen & biogenic carbon for aviation fuel
- Explore the viability of Ammonia production in Ireland for domestic and / or export
- Ireland must understand its position and capability and economics on exporting hydrogen or hydrogen efuels or other energy carriers - The REPowerEU plan's ambition is to produce 10 million tonnes and import 10 million tonnes of renewable hydrogen in the EU by 2030 – a substantial increase from the 5.6 million tonnes foreseen within the revised Renewable Energy Directive[1], published in July 2021.

1.2 What could an Irish hydrogen strategy do to drive innovation?

As discussed above & in section 1.3 Ireland must compliment the EU activities in the Hydrogen Research and Innovation priority areas (Detailed list above & section 1.3)

The Commission will establish a new open innovation test bed in renewable hydrogen in 2023 under Horizon Europe to provide access to physical facilities, capabilities and services. As part of the open innovation test bed, the implementing parties will seek guidance on compliance with the European legal and regulatory frameworks and on increasing life cycle assessment, to support the development of a vibrant hydrogen economy across the entire value chain. Insights from the 22 open innovation test beds supporting the industrial uptake of technological innovations in the areas of nanotechnology and advanced materials will inform the future applicability of this approach. This will be complemented with advice from high-level groups such as a "New Mobility Tech Group" on facilitating testing and trials of emerging mobility technologies and solutions in the EU (European mobility test bed)[2]. *Ireland* must engage with this hydrogen innovation test bed activities and other EU hydrogen activities.

Important Projects of Common European Interest (IPCEIs) in the hydrogen sector have been initiated, and the European Clean Hydrogen Alliance (ECH2A) has been set up. European-level action is vital,

[1] http://ec.europa.eu/commission/presscorner/detail/en/ip_21_6682

[2] See https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/659455/EPRS_BRI(2021)659455_EN.pdf

however national policies also play a key role to support local national Research and Innovation. *Ireland* must engage with and support hydrogen IPCEI submissions and other EU hydrogen activities.

The revised State Aid Framework for Research and Development and Innovation will include, upon adoption, a new rule allowing Member States to grant aid for the construction and upgrade of testing and experimentation infrastructures. This will ensure that the Research and Development and Innovation framework together with the General Block Exemption Regulation (GBER) can help Member States support the delivery of the European Green Deal[3] and the Commission's Industrial strategies. *Ireland* must engage with and support hydrogen submissions and other EU hydrogen activities.

1.3 What are the research priorities for the development of ~~each~~ hydrogen end-use (demand) in Ireland?

With the European Green Deal & RePowerEU, the European Union is driving forward the energy transition to become climate neutral by 2050 and green Hydrogen has become an important driver for energy related research, business collaborations and inward investment in most European countries.

In the Staff Working Document[4] accompanying the REPowerEU plan, the Commission outlines a 'hydrogen accelerator' concept to scale up the deployment of renewable hydrogen, which will contribute to accelerating the EU's energy transition and decarbonising the EU's energy system.

Innovation is essential to drive *Ireland's* competitiveness and requires significant levels of investment
alongside well-functioning ecosystems to mobilise relevant stakeholders and take forward a systemic approach that can deliver essential economic and societal transformations. The energy transition & Hydrogen will require deep technology & software solutions. *Ireland* has a recent history in innovation and is optimally positioned to lead this wave of deep hydrogen energy & technology innovation for the underlying reasons:

- steep business & workforce competition
- beneficial tax environment
- beneficial regulatory & policy environment,
- vibrant start-up ecosystem with a strong supply of Science, Technology, Engineering and Mathematics (STEM) and entrepreneurial skills
- educated workforce, and associated capabilities that adhere to the highest research and development values and principles as well as some of the highest standards of ethics and integrity.

Ireland also has some of the best higher education institutions (HEIs) and research organisations in the world leading to the fact that 40% of the Irish workforce is Highly Skilled.

Ireland, from a national strategic Hydrogen Research and Innovation perspective, is best placed to align with existing EU hydrogen research activities and engage heavily in partnership with our national Universities & National Funders and National Research Centres on the most suitable hydrogen Research and Innovation priorities for our national economic, resources and energy strategic position.

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[3] See https://ec.europa.eu/clima/eu-action/european-green-deal_en

[4] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=SWD%3A2022%3A230%3AFIN&qid=1653033922121

In Europe, it has become clear that the many EU Commission coordinated Hydrogen Research and Innovation activities (of which *Ireland* has representation on most) are beginning to strategically align (see below).

Ireland must compliment the EU activities in the following Hydrogen Research and Innovation priority areas:

- Support Innovative high end electrolyser Manufacturing; including Electrolyser Gigafactory &/or complementary high end hydrogen technology manufacture in Ireland (like Ireland's Pharmaceutical & Medical device Industry of today, drawing top global companies & inward investment[5*])
- Support, Develop & Scale of Hydrogen Hubs/Valleys & Renewable hydrogen production, storage, transmission, and distribution
- Support, Develop & Scale Demand for renewable hydrogen, e.g.:
  - Industry heat - Alumina & cement production using hydrogen as a heat source in place of fossil gas
  - Industry electricity – datacentres using hydrogen as a source for onsite generation in place of fossil gas
  - Energy - Large scale storage (TWhr) of renewable hydrogen and regeneration to electricity at grid scale plus smaller step-down hydrogen storage in areas not connected to the grid
  - Drop in efuel – e-kerosene or e-methanol manufacture from green hydrogen & biogenic carbon for aviation fuel & for export
  - Decarbonised Transport – hydrogen directly for road freight & Rail
- Develop a supportive hydrogen regulatory & policy environment
- Facilitate public acceptance, training & education

<u>Existing EU Commission coordinated Hydrogen Research and Innovation activities that Ireland can align with:</u>

- **Strategic Research and Innovation Agenda - Agenda Process for the European Research and Innovation Initiative on Green Hydrogen**: During the German EU Council Presidency in 2020, research ministers agreed on a member state led Research and Innovation initiative to build a European hydrogen economy. 25 interested member states, including *Ireland*, and five third countries have come together under the auspices of the German Federal Ministry of Education and Research (BMBF) to form a task force to jointly launch a pilot agenda process on green hydrogen, in close collaboration with the European Commission. All participants were given the chance to express their perspectives on research and innovation issues and to name the priority research needs along the entire hydrogen value chain. A report was published in March 2022[6].

  Research priorities highlighted include:
  - Supply, demand, markets & certification for green hydrogen
  - Hydrogen Hubs, repurposing pipes to hydrogen, regulation & safety

[5*] Ireland has successfully grew the pharmaceutical and medical technology bases in Ireland to over €70Bn annually.

[6] https://www.bmbf.de/bmbf/shareddocs/downloads/files/SRIA_green_hydrogen.pdf?__blob=publicationFile&v=3

- Research to enable scaling up of electrolyser technology & increase installed capacity
  - Offshore renewable hydrogen production
  - Large scale storage of renewable hydrogen
- **The Joint Research Centre** (JRC) - is the EU Commission's science and knowledge service. The JRC employs scientists to carry out research in order to provide independent scientific advice and support to EU policy.[7] The JRC is supporting these efforts, providing scientific insights and evidence to help Europe grasp the opportunity to be a world leader in this new and exciting technology. Research priorities highlighted include:
  - Increase hydrogen demand – Industry & Energy & efuels
  - Innovative Hydrogen Electrolyser Manufacturing
  - Innovative logistics solutions – Transport road freight & Rail
  - Regulation frameworks & standardisation – hydrogen quality, technology, pipes valves, etc
  - Digital ecosystem where hydrogen data and services can be made available, collected, and shared in a trusted manner.
- **Hydrogen Europe** – Hydrogen Europe have detailed a Strategic Research & Innovation Agenda[8] (Hydrogen *Ireland* Association is a full member).
  Research priorities highlighted include:
  - Hydrogen production & scaling up of electrolyser technology
  - Large scale storage of renewable hydrogen & efuels
  - Hydrogen Hubs; Heavy Duty Vehicles, Hydrogen turbines for electricity
- **Clean Aviation** – In the clean Aviation Agenda[9], Hydrogen presents several key advantages when considering aviation application: it allows for the elimination of CO_2 emissions in flight and along the entire life cycle if produced carbon-free. Its usage in fuel cells allows for zero-emission propulsion (including NOx and particles). When burnt in a turbine engine, very low particle emissions can be expected, as well as reduced NOx emissions, provided that the combustion system is optimised.
  Research priorities highlighted include:
  - Ultra-high efficiency propulsive system development and integration
    - Drop in fuel – efuels including e-kerosene & e-methanol
    - Electric propulsion including fuel cells
    - Other fuels - liquid hydrogen (LH_2) based propulsion systems
- **The European Clean Hydrogen Alliance** – is part of the EU Commissions New Industrial Strategy for Europe, aiming to build its global leadership in the hydrogen domain, to support the EU's commitment to reach carbon neutrality by 2050, echoing the European Green Deal and Europe's clean energy transition require. By bringing together industry, public authorities and civil society, the European Clean Hydrogen Alliance will play a crucial role in facilitating the implementation of the European Hydrogen Strategy vision. Some of Hydrogen Ireland Association's members are direct members of The European Hydrogen Alliance.
  - Scale up of low-carbon hydrogen production, transmission, and distribution
  - Hydrogen demand in industry & mobility
  - Manufacturing hydrogen related technologies

[7] See https://ec.europa.eu/info/departments/joint-research-centre_en
[8] https://hydrogeneurope.eu/wp-content/uploads/2021/11/Hydrogen-Europe_EU-Recovery-Plan-Analysis_FINAL.pdf
[9] https://clean-aviation.eu/sites/default/files/2022-01/CAJU-GB-2021-12-16-SRIA_en.pdf

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- **UN-ECE** – The United Nations Economic Commission for Europe - **Task Force on Hydrogen**[10], of which Ireland has a representative on this group of experts, was initiated by the UNECE Group of Experts on Gas, the Group of Experts on Renewable Energy, and the Group of Experts on Cleaner Electricity Systems. This community of experts developed a technology brief on hydrogen that assessed the whole hydrogen value chain and assessed various technology production pathways[11].

  The following focus areas were identified:
  - Develop standards & certification for hydrogen
  - Facilitate public acceptance
- **Clean Hydrogen Partnership**[12] **-** Funded through Horizon Europe – the Framework Programme for Research and Innovation Clean Hydrogen Partnership has a matching budget of €300million, the main objective is to contribute to EU Green Deal and Hydrogen Strategy through optimised funding of R&I activities. As an EU member Ireland can leverage this funding and support for Research and Innovation[13].

  Main topics include:
  - Hydrogen production, distributing and storage
  - Decarbonising energy intensive industries and heavy-duty transport
  - The development and scale up of Hydrogen Hubs/Valleys

[10] https://unece.org/task-force-hydrogen
[11] https://unece.org/sites/default/files/2020-12/Hydrogen_at_UNECE.pdf
[12] https://www.clean-hydrogen.europa.eu/index_en
[13] https://www.clean-hydrogen.europa.eu/apply-funding/call-proposals-2022/call-proposals-2022_en

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2. Hydrogen Demand

The objective of this section of the Response to Consultation on Developing a Hydrogen Strategy for Ireland by Hydrogen Ireland is to consider the role of Green Hydrogen as a vector in the "least burden and most opportunity pathways to decarbonisation". The responses to the consultation questions relating to hydrogen demand are framed in the context of the challenging decarbonisation targets required by Ireland's contribution to climate change mitigation and adaptation nationally, within the EU, and globally.

The Climate Action and Low Carbon Development Amendment Act (2021) sets Ireland on a pathway consistent with a sustainable economy and society where greenhouse gas emissions are balanced or exceeded by the removal of greenhouse gases by 2050. Under the legislation, the proposed carbon budgets for the periods 2021-2025 and 2026-2030 must provide for a reduction of 51% in the total amount of those greenhouse gas emissions (specified by the regulations) by 2030, relative to 2018. Emissions ceilings for each of the Group 1 sectors of the Irish economy were announced by the Government of Ireland in July 2022[14], and are shown in Table 1 below.

Table 1. Total greenhouse gas emissions, measured in million tonnes of CO2 equivalent[15], recorded in 2018, and the percentage reductions and emissions ceiling to be achieved in 2030

Group 1 Sector	Reduction	2018 *	2030 ceiling *
Electricity	75%	10.5 MtCO2eq	3 MtCO2eq
Transport	50%	12 MtCO2eq	6 MtCO2eq
Buildings (Commercial and Public)	45%	2 MtCO2eq	1 MtCO2eq
Buildings (Residential)	40%	7 MtCO2eq	4 MtCO2eq
Industry	35%	7 MtCO2eq	4 MtCO2eq
Agriculture	25%	23 MtCO2eq	17.25 MtCO2eq
Other**	50%	2 MtCO2eq	1 MtCO2eq

Notes: Source: Government of Ireland

* = Figures for MtCO2eq for 2018 and 2030 have been rounded. This may lead to some discrepancies

** = F-gases, Petroleum Refining and Waste

Finalising the Sectoral Emissions Ceiling for the Group 2 sector Land-Use, Land-Use Change, and the Group 3 sector Forestry (LULUCF) sector has been deferred for 18 months to allow for the completion of the Land-Use Strategy.

In addition, the agreement announced by the Government in July 2022 under the Climate Action and Low Carbon Development Amendment Act (2021), commits additional resources for solar (more than doubling the target to 5,500 MW), off-shore wind (moving from a target of 5,000 MW to 7,000 MW),

[14] https://www.gov.ie/en/press-release/dab6d-government-announces-sectoral-emissions-ceilings-setting-ireland-on-a-pathway-to-turn-the-tide-on-climate-change/

[15] **CO2 Equivalent:** greenhouse gases other than CO2 (i.e. methane, nitrous oxide and F-gases) may be converted to CO2 equivalent using their global warming potentials (GWPs).

green hydrogen (an additional 2,000 MW), agro-forestry and anaerobic digestion (up to 5.7 TWh of biomethane) – to further accelerate the reduction of overall economy-wide emissions.

The recently published EPA report on Ireland's Provisional Greenhouse Gas Emissions 1990-2021[16] estimated that 2021 total Group 1 sector national greenhouse gas emissions increased by 4.7% on 2020 levels to 61.53 million tonnes carbon dioxide equivalent (Mt CO_2eq, total figure excluding Group 2 sector Land-Use, Land-Use Change, and the Group 3 sector Forestry (LULUCF)). This increase in total emissions in 2021 compared with 2020 was driven by increased use of coal and oil for electricity generation, and by increases in both the Agriculture and Transport sectors. It highlights that further, transformative measures will be needed to meet National Climate ambitions (EPA, 2022). This view has been supported by the Climate Change Advisory Council[17].

The total Group 1 sector greenhouse gas emissions in 2018 that are relevant to the recently announced sectoral emission ceilings for 2030 were 63.37 Mt CO2eq in 2018 (Table 1, and EPA, 2022). The percentage contribution of each component sector to greenhouse gas emissions is shown in Figure 1. In 2021, total Group 1 sector greenhouse gas emissions of 61.53 Mt CO_2eq had declined by 2.9% in comparison with the 2018 Group 1 sector emissions.

[16] EPA (2022) Ireland's Provisional Greenhouse Gas Emissions 1990-2021
https://www.epa.ie/publications/monitoring--assessment/climate-change/air-emissions/EPA-Ireland's-Provisional-GHG-Emissions-1990-2021_July-2022v2.pdf

[17] https://www.climatecouncil.ie/media/climatechangeadvisorycouncil/contentassets/publications/letters/Chair%20CCAC%20%20Statement%20re%20Provisional%20estimates%20of%20Irelands%20Greenhouse%20Gas%20Emissions%201990-2021.pdf

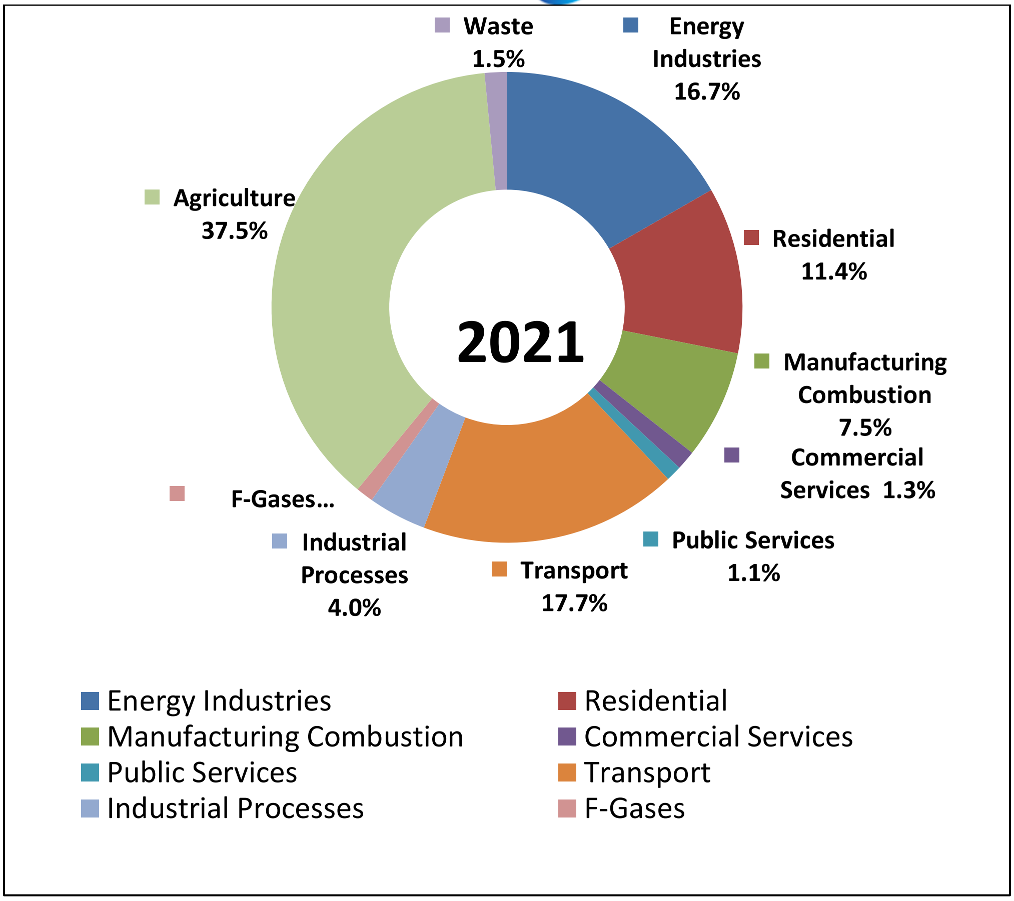


Figure 1. Percentage contribution to greenhouse gas emissions (CO2eq) by different components of the Group 1 sectors of the Irish economy in 2021.

Source: EPA (2022) Ireland's Provisional Greenhouse Gas Emissions 1990-2021

The greenhouse gas emission inventory for 2021 is the first of ten years over which compliance with targets set in the European Union's Effort Sharing Regulation (ESR; EU 2018/842) will be assessed. Ireland's ESR emissions annual limit for 2021 is 43.48 Mt CO2eq. Ireland's provisional 2021 greenhouse gas ESR emissions are 46.19 Mt CO2eq, this is 2.71 Mt CO2eq more than the annual limit for 2021 (EPA, 2022).

The percentage contribution of each component Group 1 sector to Carbon dioxide (CO2) emissions is shown in Figure 2. Carbon dioxide emissions are more generally representative of current fossil fuel use in the Group 1 sectors; most of the greenhouse gas emissions in the agriculture sector arise from methane (CH4) and nitrogen dioxide (NO2), and these account for c. 94% of the emissions of these two greenhouse gases in Ireland.

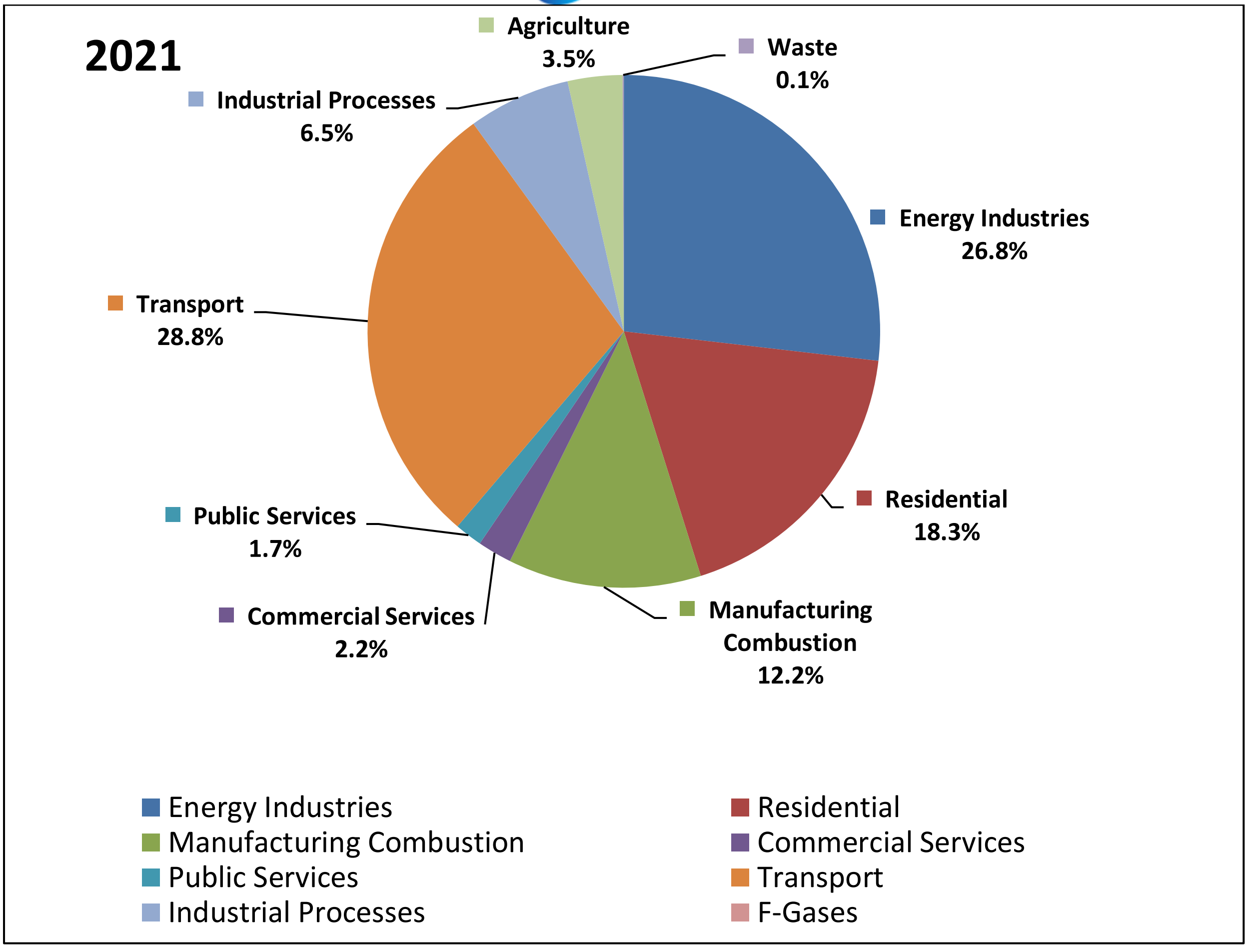


Figure 2. Percentage contribution to Carbon dioxide emissions (CO2) by different components of the Group 1 sectors of the Irish economy in 2021.

Source: EPA (2022) Ireland's Provisional Greenhouse Gas Emissions 1990-2021

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

Potential use of green hydrogen to replace fossil fuels

Currently, fossil fuels provide 90% of the energy used across all sectors of the economy in Ireland. In the electricity generating sector, 36% of the electricity generated is renewable (wind, hydro, and solar power), and 64% is generated in thermal power stations using coal, oil, and natural gas. There is a potential for green hydrogen to be used to replace fossil fuels in all Group 1 Sectors, to assist in decarbonisation and in meeting greenhouse gas emission ceilings. Table 2 shows an overview of existing fossil fuel uses in Group 1 Sectors, and the associated greenhouse gas emissions in 2021.

Table 2. Fossil fuel uses and total greenhouse gas emissions, measured in kilo tonnes of CO2 equivalent

Group 1 Sector	**Current fossil fuel use**	**Greenhouse gas emissions kt CO2eq in 2021**
Electricity	Thermal power generation Coal, oil, natural gas	9795.45
Transport	Internal combustion engines Petrol, diesel	10911.55
Buildings (Commercial and Public)	Space heating, dispatchable generation Gasoil, kerosene, natural gas	1479.84
Buildings (Residential)	Space heating, water heating, cooking Solid fuels including coal, gasoil, kerosene, natural gas	7039.63
Industry	High temperature heat Feedstock for industrial processes, space heating Gasoil, kerosene, natural gas	4593.45 2459.84 Total 7052.93
Agriculture including horticulture	Agricultural machinery, dispatchable generation, water heating, space heating mainly for horticulture Diesel	589.69
Other** F-gases, and Waste	Mix	938.40
Other ** Petroleum Refining	Natural Gas	294.37
Total Greenhouse gas emissions (kt CO2eq) in 2021 in all Group 1 sectors		38,101.86

Source: EPA (2022) Ireland's Provisional Greenhouse Gas Emissions 1990-2021

Notes: Natural gas including CNG & LNG. Dispatchable generation refers to back-up generators typically provided to supply electricity in the event of a power outage (e.g. hospitals and other public services, shops and other commercial premises) or where no electricity grid power supply is available

For agriculture, the greenhouse gas emissions cited are for CO2 and relate to the use of fossil fuels in agriculture

Green hydrogen can also be used to store energy, for use in the electricity sector 'when the wind does not blow and the sun does not shine'. Because of our geographical location in the north-east Atlantic, some of the available onshore and offshore wind energy resource in Ireland can be used to produce green hydrogen to replace fossil fuels in all sectors of the economy, and to provide storage for energy security in all sectors of the economy. The updated target of 5,500 MW for onshore solar power provides some seasonal balancing of renewable power for electricity and for green hydrogen production, in that solar power will have the greatest output during the summer months of longer daylight, when wind resource is typically reduced relative to winter months.

Green hydrogen export opportunities are discussed in the responses to the Consultation Questions on Export Opportunities.

Potential use of green hydrogen to replace grey or blue hydrogen

Grey hydrogen is currently used in Ireland in industry and in refining. Whitegate produces grey hydrogen (hydrogen from a fossil fuel source, with no carbon abatement) and is listed by the Fuel Cells and Hydrogen Observatory[18] as SMR (steam methane reformer) with a production capacity of 26.2 Mt/Day. It is understood that use of Carbon Capture and Storage (blue hydrogen) is under consideration at Whitegate.

The Fuel Cells and Hydrogen Observatory[19] (FCHO) is one of the resources provided by the Clean Hydrogen Partnership[20], a Joint Undertaking of the European Commission. Table 3 shows the existing hydrogen demand in Ireland, total demand for hydrogen in 2020 was 7662 metric tonnes (Mt). Oil refining at Whitegate is the primary producer and consumer of grey hydrogen for use on site. Industrial uses of hydrogen in Ireland currently include Intel (manufacturing computer chips), pharmaceuticals, food (hydrogenation of vegetable oils to make margarine, chocolate), and fertiliser production. It is understood that the 7662 metric tonnes (Mt) of hydrogen in use in Ireland in 2020 is grey hydrogen (Table 3). The carbon footprint of grey hydrogen arises during production of the fuel by steam methane reforming (SMR), and not during use of the fuel.

Biofuels produced in Ireland currently use grey hydrogen as part of the production process. Hydrogen demand in this sector will increase as a result of current EU and national policies. Current production of biofuels in Ireland is in the order of 10TWhours. Green hydrogen requirements by 2030 are expected to require several 100s MW of onshore wind equivalent to produce the required volumes to meet EU RTFO targets.

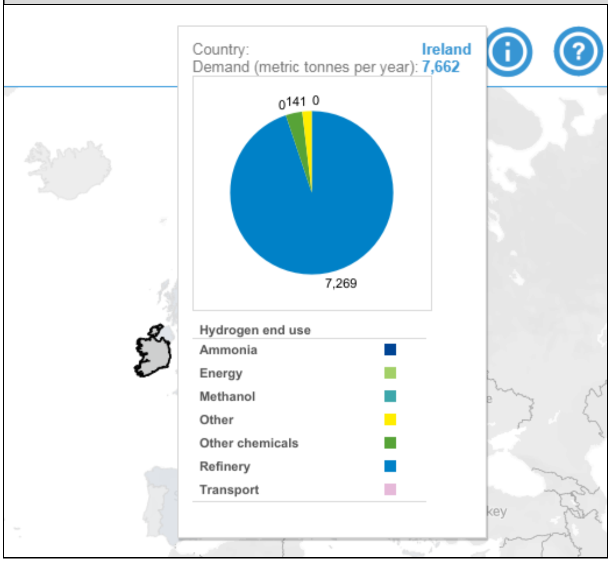
[18] https://www.clean-hydrogen.europa.eu/media/news/completion-first-phase-fuel-cells-hydrogen-observatory-fcho-2022-07-25_en

[19] https://www.fchobservatory.eu/

[20] https://www.clean-hydrogen.europa.eu/index_en

Table 3. Existing grey hydrogen demand in Ireland

Existing grey hydrogen demand in Ireland, 2020 - Metric tonnes per year



Ammonia	0
Energy	0
Methanol	0
Other	141
Other chemicals	251
Refinery	7,269
Transport	0

Data source: https://www.fchobservatory.eu/observatory/technology-and-market/hydrogen-demand

Current production of green hydrogen in Ireland

FCH Observatory currently records Ireland as having a single water electrolysis plant producing 0.09 Mt/day green hydrogen in 2020, for industrial use and also this is the electrolyser operated by BOC in Dublin that provides certified green hydrogen for use in three Bus Eireann hydrogen buses currently operating in Dublin.

In comparison, Denmark had 4 water electrolysis plants producing 1.13 Mt/day green hydrogen, and Germany had 33 water electrolysis plants producing 19.09 Mt/day green hydrogen in 2020. These data are based on research conducted by Hydrogen Europe in March 2022 and refer to the end of 2020. The database will be updated annually.

Existing technologies and equipment that can use green hydrogen to replace fossil fuels

Table 4. Existing hydrogen technologies and applications that can use green hydrogen to replace fossil fuels in all Group 1 Sectors

Group 1 Sector	Existing technologies that can use green hydrogen to replace fossil fuels
Electricity	• Thermal combustion of green hydrogen in hydrogen ready gas turbines, open or combined cycle systems • Thermal combustion of green hydrogen in hydrogen ready boilers or CHP units for heat or heat and power generation • Stationary green hydrogen fuel cells for power generation • Switching to green hydrogen for generator cooling – minor demand
Transport	Green hydrogen (a Renewable Fuel of Non-Biological Origin (RFNBO) can be used as a fuel – • in fuel cell electric vehicles (FCEVs); the range of FCEV vehicle types now available are: trucks and heavy goods vehicles, refuse collection trucks, buses and coaches, light commercial vehicles including mini-buses, vans, and passenger cars. • in a hydrogen internal combustion engines[21] e.g. construction vehicles • indirectly when renewable hydrogen is used to synthesise other more complex synthetic fuels, e.g. shipping, aviation
Buildings (Commercial and Public)	Hydrogen ready boilers or CHP units for heat or heat and power generation, Hydrogen ready boilers, water heaters, cookers Stationary green hydrogen fuel cells for power generation
Buildings (Residential)	Hydrogen ready boilers, water heaters, cookers, room heaters[22] Stationary green hydrogen fuel cells for power generation
Industry	Hydrogen ready boilers or CHP units for heat or heat and power generation Stationary green hydrogen fuel cells for power generation Replacing - grey hydrogen e.g. (Intel manufacturing computer chips), pharmaceuticals, food (hydrogenation of vegetable oils to make margarine, chocolate)
Agriculture	Stationary green hydrogen fuel cells for power generation Hydrogen fuelled agricultural machinery in development
Other** F-gases, and Waste	Potential production of low carbon hydrogen?
Other ** Petroleum Refining	Substitution of existing grey hydrogen for blue or green hydrogen

[21] https://en.wikipedia.org/wiki/Hydrogen_internal_combustion_engine_vehicle#:~:text=A%20hydrogen%20internal%20combustion%20engine,of%20hydrogen%20rather%20than%20combustion).

[22] https://www.hy4heat.info/
https://www.baxiheating.co.uk/the-future-of-heat
www.worcester-bosch.co.uk/hydrogen

2.2 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?

Ireland's existing and future hydrogen demand should be met entirely by green hydrogen produced by electrolysis using renewable energy (wind, hydro, solar). Certification of Green Hydrogen origin will be required.

Hydrogen demand projections are discussed in the context of:

- The greenhouse gas emissions ceilings for each of the Group 1 sectors of the Irish economy (see Table 1 above)
- 2020 hydrogen production and demand reporting by FCH Observatory[23]
- Wind Energy Ireland (July 2022[24]) survey of its members which indicates that there is more than 10GW of projects in the onshore wind pipeline, and already up to 28GW of projects in the offshore wind pipeline seeking to compete to deliver by 2030. Allowing for competition at auction stage, and attrition at planning stage, there would appear to be a potential to deliver more than 2GW of green hydrogen from offshore wind before 2030
- According to WEI approximately 7.5GW of the projects in the onshore wind pipeline will not have an electricity grid connection before 2030. These projects would have a significant combined potential for direct production of green hydrogen (Power-to-X, PtX) in the short term[25].
- In addition, the agreement announced by the Government in July 2022 under the Climate Action and Low Carbon Development Amendment Act (2021), commits additional resources for solar (more than doubling the target to 5,500 MW).

Under the 2012 Directive on Energy Efficiency, amended in 2018, the EU set an energy efficiency target for reducing energy consumption in 2030 by at least 32.5% compared to 2007 consumption projections for 2030. An EU Commission proposal of July 2021[26] seeks to recast the whole directive. It seeks to introduce a higher target for reducing primary (39%) and final (36%) energy consumption by 2030 now binding at EU level, in line with the Climate Target Plan, up from the current target of 32.5% (for both primary and final consumption). Higher targets for renewables and energy efficiency incorporated the EU Commission proposals in June 2022[27]. The Council and the Parliament will now enter interinstitutional negotiations to agree on the final text of the Directive on Energy Efficiency and of the Directive on Renewable Energy[28].

[23] https://www.fchobservatory.eu/sites/default/files/reports/Chapter%202%20-%20FCHO%20Market%20-%202022%20Final.pdf

[24] https://windenergyireland.com/images/files/wei-position-paper-on-repowereufinaljuly2022.pdf

[25] PtX is a blanket term for a number of technologies that are all based on using renewable electricity directly to produce hydrogen. This hydrogen can subsequently be used directly to replace fossil fuels, to replace grey hydrogen, or further converted into other renewable fuels of non-biological origin (RFNBOs), chemicals and materials.

[26] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021PC0558

[27] https://www.consilium.europa.eu/en/press/press-releases/2022/06/27/fit-for-55-council-agrees-on-higher-targets-for-renewables-and-energy-efficiency/

[28] https://www.consilium.europa.eu/en/press/press-releases/2022/06/27/fit-for-55-council-agrees-on-higher-targets-for-renewables-and-energy-efficiency/

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The 2021 Climate Action Plan[29] is informed by the 2012 Directive on Energy Efficiency, amended in 2018. The Climate Action Plan identifies direct electrification, an increased proportion of renewable electricity, and reductions in energy demand that depend on measures including retrofit of buildings, targets for Battery Electric Vehicles (BEVs), and promoting active travel and the use of public transport, among the key actions to be taken to decarbonise our economy and reduce dependence of imported fossil fuels.

The Climate Action Plan considers Green Hydrogen as a renewable fuel of non-biological origin, which has been identified as having potential to support decarbonisation of energy production, across home heating, industry and transport. The development of green hydrogen supply and demand is identified as a cross-cutting Policy issue. This Response to the Consultation on Developing a Hydrogen Strategy for Ireland is informed by issues arising with regard to policy coherence and Just Transition in the implementation of Climate Mitigation and Adaptation Actions. Green hydrogen demand for the electricity sector

The green hydrogen demand for the electricity sector presented in Table 5 is informed by the analyses included in Our Climate Neutral Future – Zero by 50, prepared by MaREI for Wind Energy Ireland[30] in March 2021. However, Table 5 brings 75% of the 2021 greenhouse gas emissions for the electricity sector forward for decarbonisation with green hydrogen by 2030, giving a hydrogen demand of 215 kilo tonnes of green hydrogen (H2kt), to provide 11.9 TWhr of dispatchable generation in each year. Provision of another 97 to 385 H2kt to provide full decarbonisation of the 2021 electricity sector is recommended by 2035 (Table 5). It is acknowledged that renewable electricity provision (arising from increased wind and solar power) is expected to increase to 75% of total generation by 2030.

However, this anticipated freeboard by 2030 in green hydrogen supply relative to anticipated demand for dispatchable generation in the electricity sector can be allocated to hydrogen storage for energy security. In this context, it should be noted that studies of wind energy and storm tracks over Ireland have shown significant projected decreases in the energy content of the wind for the spring, summer and autumn seasons, with the projected decreases largest for summer and no significant trend in winter[31]. The overall number of North Atlantic cyclones is projected to decrease by approximately 10 %. Results also indicate that the paths of extreme storms will extend further south, bringing an increase in extreme storm activity over Ireland, although the number of individual storms is projected to be quite small. Met Éireann also notes that as extreme storm events are rare, the storm-tracking research needs to be extended. Future work will focus on analysing a larger ensemble, thus allowing a robust statistical analysis of extreme storm track projections.

The Eirgrid Annual Report (2021[32]) covers the period from 1 October 2020 through to 30 September 2021. It identifies a need for the continued development and retention of low carbon dispatchable generation, most likely low carbon new gas generation of 2.6GW capacity in the island of Ireland by 2030 (2GW in Ireland, 0.6GW in Northern Ireland), to ensure security of supply when renewables are

[29] https://www.gov.ie/en/publication/6223e-climate-action-plan-2021/

[30] https://www.met.ie/climate/climate-change
https://windenergyireland.com/images/files/our-climate-neutral-future-0by50-final-report.pdf

[31] https://www.met.ie/climate/climate-change#Reference2

[32] https://www.eirgridgroup.com/site-files/library/EirGrid/Annual-Report-2021.pdf

not performing for climatic reasons, and critically will allow the closure of coal, peat and oil thermal generation plants. Low carbon gas is not defined in the report, and no reference to green hydrogen is included in the 2021 Annual Report.

Green hydrogen demand projections for the Group 1 sectors Transport, Buildings, Industry and Agriculture

The green hydrogen demand projections for the Group 1 sectors Transport, Buildings, Industry and Agriculture follow the same approach: calculating the green hydrogen demand required to replace current fossil fuel emissions in each sector (Table 5) gives a combined demand in the order of H2 700 kilotonnes. The green hydrogen demand for all Group 1 sectors including electricity indicate that an overall green hydrogen demand of 1 Megatonne, as presented in Table 5, will be sufficient to meet the 2030 greenhouse gas emissions ceilings that arise from the use of fossil fuels. 2 GW of offshore wind energy equivalent (as proposed by Government in July 2022 under the Climate Action and Low Carbon Development Amendment Act (2021) would provide H2 250kt. This would be sufficient to comply with the required 2030 emissions ceiling for the electricity sector if electricity demand does not increase above current peak demand. However, current policy is to decarbonise the group 1 sectors Transport and Buildings largely by direct electrification. This policy risks giving rise to a potential transfer of greenhouse gas emissions between Group 1 sectors, rather than an providing the required overall decrease in greenhouse gas emissions across all group 1 Sectors, if insufficient zero carbon fuel in the form of green hydrogen is produced to replace current fossil fuel use in all sectors.

Eight Gigawatts (8 GW) of offshore wind equivalent would provide 1 Megatonne of green hydrogen by 2030. It is anticipated that a further green hydrogen demand of 0.5 Megatonne (= H2 500kt) of offshore wind energy equivalent, to be provided by 2035-2040, will be required to completely decarbonise Group 1 sectors including bringing the electricity sector to zero greenhouse gas emissions, produced by offshore wind and onshore wind and solar renewable energy (Table 5).

It is recommended that green hydrogen production commences onshore, with a target of at least 250 MW (stated elsewhere in this response as 500MW) electrolyser capacity operational by 2025. It is anticipated that onshore green hydrogen production can be approved and operational quickly, if the appropriate supporting policies and incentives are included in the Hydrogen Strategy for Ireland. There is already a project stream of >100MW capacity of onshore green hydrogen production at proposal stage. These, together with further onshore solar and wind energy can provide sufficient green hydrogen to build demand for the use of hydrogen fuel cell electric vehicles (FCEVs) in public transport and other public service vehicles, heavy goods vehicles (HGVs), light commercial vehicles including mini-buses, and passenger vehicles including taxis together with infrastructure for hydrogen refuelling (see Figure 3). Other early hydrogen demand in space and water heating and cooking in buildings (Commercial and Public, and Residential), and fuel cell dispatchable generation in several Group 1 sectors including agriculture / horticulture, can start to provide decarbonised energy security.

Table 5. 2021 greenhouse gas emissions in kt CO2eq for each Group 1 sector, the emission ceiling and reduction required by 2030, and the green hydrogen (H2kt) required to comply with the 2030 ceiling for that Group 1 sector

Group 1 Sector	Current fossil fuel use	Greenhouse gas emissions kt CO2eq in 2021	Greenhouse gas emissions ceiling 2030 (kt CO2eq)	Kt CO2eq reduction required by 2030	TWhr (H2) required to meet emissions ceiling 2030	H2 kt required to meet emissions ceiling 2030	Technology
Electricity (Scenario calculation for zero GHG emissions)	Thermal power generation Coal, oil, natural gas	9795.45	9795.45	0	17	312-600	wind, solar & combined cycle / open cycle gas turbines
Electricity	Thermal power generation Coal, oil, natural gas	9795.45	3000	6795.45	11.9	215	wind, solar & combined cycle / open cycle gas turbines
Transport	Internal combustion engines Petrol, diesel	10911.55	6000	4911.55	10	c. 200	Fuel Cell Heavy Duty Vehicles
Buildings (Commercial and Public)	Space heating, dispatchable generation Gasoil, kerosene, natural gas	1479.84	1000	479.84		c. 50	Hydrogen ready gas boiler
Buildings (Residential)	Space heating, water heating, cooking Modal share c. solid fuels including coal 15%, gasoil / kerosene 50%, natural gas 25%, renewables 3%	7039.63	4000	3038.63	10	c. 200	Hydrogen ready gas boiler

Industry	High temperature heat, feedstock for industrial processes, space heating Gasoil, kerosene, natural gas	7052.93	4000	3052.93	10	c. 200	Green Hydrogen feedstock & hydrogen ready gas boiler & open cycle gas turbines
Agriculture including horticulture*	Agricultural machinery, dispatchable generation, water heating, space heating mainly for horticulture Diesel	589.69				c. 50	Fuel Cell & hydrogen ICE Heavy Duty Vehicles
Other** F-gases, and Waste		938.40	470	-	-	-	-
Other ** Petroleum Refining		294.37	150			7.3 (replace grey hydrogen)	Green hydrogen feedstock

Notes: Emission ceilings refer to cumulative greenhouse gas emissions including CO2, CH4, N2O.
*The relevant emissions for agriculture with a potential to be replaced by green hydrogen cited here are CO2
Electricity modal share 2021 (EPA 2022): renewables 34.7%, natural gas 49.8%, oil and coal c. 15%, imports almost 1,600 GWh
Transport modal share 2020 (EPA 2022): passenger cars 54% of road transport emissions in 2020, Heavy Goods Vehicles 20%, Light Goods Vehicles for 18% and Buses 7%.

Hydrogen Ireland

Larger scale offshore wind projects, together with onshore wind and solar projects, will be required to include green hydrogen production to meet the demand shown in Table 5. Green hydrogen demand across all Group 1 sectors requires annual production of c.1 Megatonne of green hydrogen by 2030, with production increasing annually during the 2026 to 2030 carbon budget period to assist in decarbonising the Irish economy. A further annual green hydrogen demand of 0.5 Megatonne (= H2 500kt) after 2030 will contribute to Net Zero by 2050, with 1.5MT required annually for use and storage for national energy security. An additional 25% of green hydrogen annual demand (c.250kt hydrogen) would representing c90 days energy storage.Green hydrogen production for export is considered separately, in the responses to the consultation questions on Export Opportunity.

Current evidence of accelerating green hydrogen demand in Europe

It should be noted that EU Member States that are already implementing their National Hydrogen Strategies are increasing their targets for green hydrogen production and use before and by 2030. The report on the Third European Hydrogen Forum 30 November 2021 provides a recent overview. Key observations from the overview are that 87% of hydrogen production projects are electrolysers producing green hydrogen and that the estimated hydrogen production (electrolysis capacity) is around 52.4 GW by 2030, which exceeds the 40 GW target set out in the Hydrogen Strategy by 31%[33].

In this context, the modest green hydrogen demand proposed for Ireland in the Baringa[34] report is focussed on energy efficiencies, interconnectors, and storage, and would seem to have little or no buffer against predicted climate change reductions in seasonal wind energy levels that could affect onshore and offshore wind generation. The demand indicated in Table 5 takes the precautionary principle in this regard.

The **Intergovernmental Panel on Climate Change (IPCC, 2021)** notes that because of the complex interactions of the phenomenon of climate change, it is essential to decarbonise quickly, and that emissions reductions over the next ten years (to 2030/31) will be far more impactful than those over the following ten. Atmospheric carbon dioxide levels need to stop rising, and to decline. Ireland must contribute to this process.

Set up in July 2020, the European Clean Hydrogen Alliance is part of EU efforts to ensure industrial leadership and accelerate the decarbonisation of industry in line with its climate change objectives. The Alliance brings together industry, public authorities, civil society and other stakeholders. Six roundtables provide sector specific inputs: Hydrogen production, clean hydrogen transmission and distribution, clean hydrogen in industrial applications, clean hydrogen for mobility, clean hydrogen in the energy sector, and clean hydrogen for residential applications[35]. The European Clean Hydrogen Alliance (October 2021) report Executive Summary[36] concludes as follows:

[33] https://ec.europa.eu/docsroom/documents/47802

[34] Endgame - A zero-carbon electricity plan for Ireland (baringa.com)

[35] https://ec.europa.eu/growth/industry/strategy/industrial-alliances/european-clean-hydrogen-alliance/roundtables-european-clean-hydrogen-alliance_en

[36] https://ec.europa.eu/growth/industry/strategy/industrial-alliances/european-clean-hydrogen-alliance/roundtables-european-clean-hydrogen-alliance_en

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"The current policy framework offers limited technological openness. While the direct use of (green) electricity-based technologies has advantages, the large majority of the Roundtable members believe that an "electrification only" approach does not seem feasible neither at system nor at consumer level in the time frame required by the EU climate targets, as mentioned in the EU Commission scenarios for a climate-neutral 2050."

2.3 What specific end-uses should be high, medium and low priorities for green hydrogen use?

In the interests of achieving:

- rapid decarbonisation in line with IPCC recommendations
- policy coherence
- confidence to investors
- equal access to decarbonising fuels and technologies by industry, public and commercial sectors, and citizens
- climate change mitigation and resilience benefit and decarbonisation supports to communities that live in areas with higher wind and solar energy resources that host renewable energy installations and infrastructure, in the interests of achieving Just Transition

It is recommended that green hydrogen should be prioritised in all end uses in which hydrogen technology is available currently, with on-going rapid scaling up of existing and new technologies to replace fossil fuels. End uses for green hydrogen include:

- dispatchable generation by combustion (thermal electricity generation)
- dispatchable generation in hydrogen fuel cells in Group 1 sectors Electricity, Buildings (Commercial and Public), Industry, and Agriculture
- transport FCEV vehicles
- buildings hydrogen cookers, boilers, water heaters, hydrogen gas space heaters
- high temperature heat in industry
- feedstock in industry
- replacement of grey hydrogen in oil refining and industry, and as a feedstock in the production of biofuels.

Maintaining a diverse energy system including green hydrogen as a key vector in the "least burden and most opportunity pathways to decarbonisation" will also support our energy resilience.

An objective of the Climate Action Plan (2021) in relation to citizen engagement is as follows: "We must ensure we bring people with us and that the transition is fair. The National Dialogue on Climate Action will give everyone in society the opportunity to play their part. We will engage with people, ensuring that they are empowered to take the actions needed".

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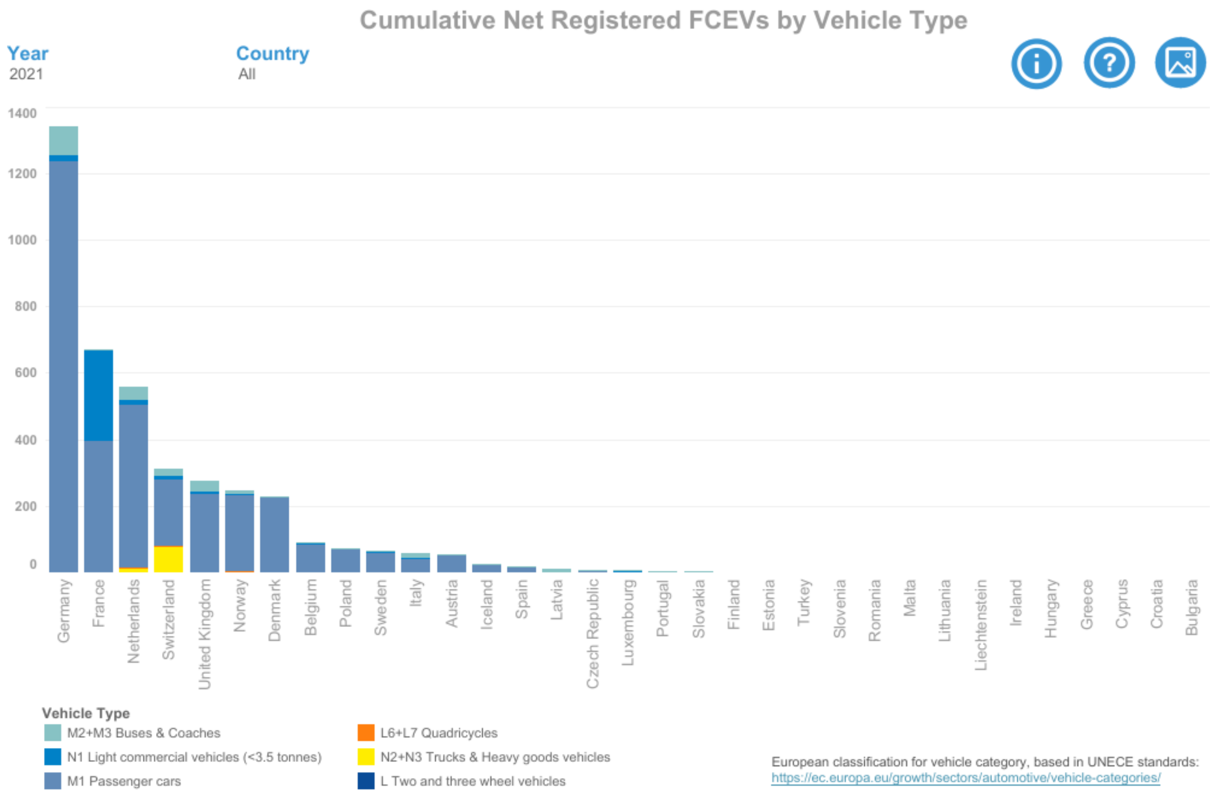

Figure 3. Cumulative registered hydrogen fuel cell electric vehicles (FCEVs) in Europe[37].

Data source: Fuel Cells and Hydrogen Observatory

[37] https://www.fchobservatory.eu/observatory/technology-and-market/net-number-of-fcev-net

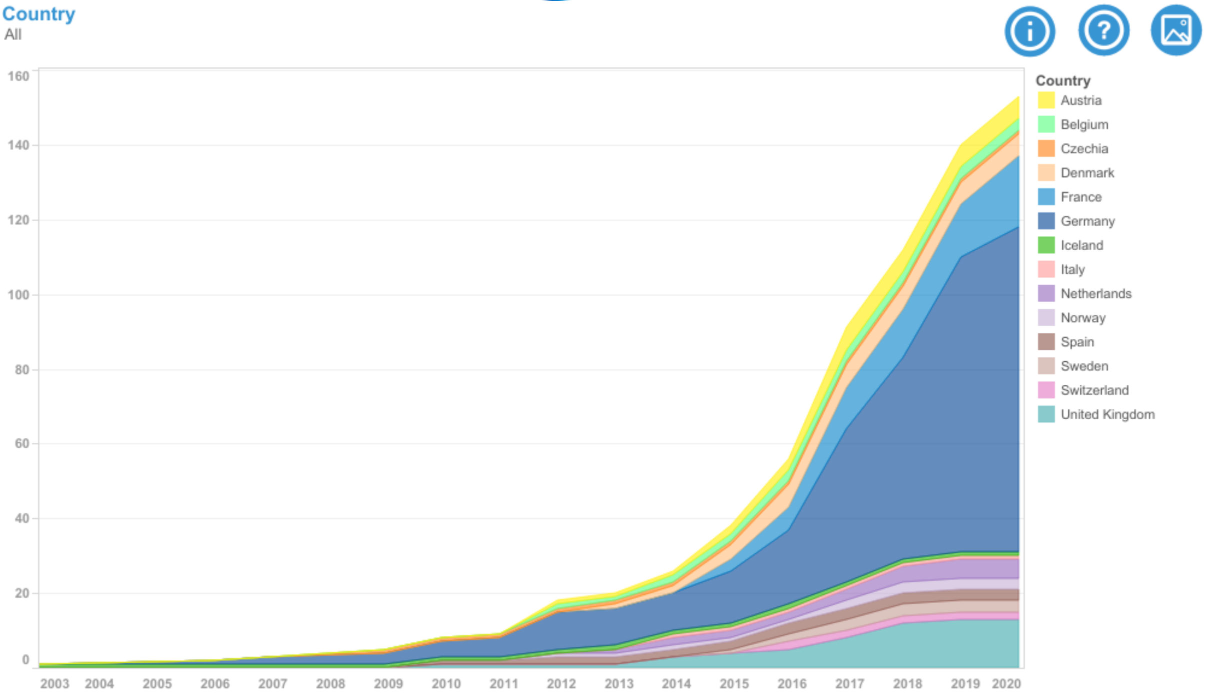

Figure 3. Deployment of Hydrogen Refuelling Stations by Country and by year in Europe

Data source: Fuel Cells and Hydrogen Observatory

What are the potential policy options for incentivising for each of these end-uses?

Incentivising all end uses of green hydrogen in Ireland needs to be facilitated within the framework of the Hydrogen Strategy for Ireland. Five key policy and governance measures are listed in Table 6.

Table 6. Measures recommended by Hydrogen Ireland to establish a market for green hydrogen, create the right environment for investment, and enable the development of dedicated infrastructure, including for trade with third countries, within the new EU Framework and Hydrogen Strategy for a climate-neutral Europe.

Measure 1. Hydrogen Strategy Policy Statement
It is recommended that Ireland's existing and future hydrogen demand will be met entirely by electrolysis using renewable energy (wind, hydro, solar, and other renewables), producing clean green hydrogen to replace fossil fuels, facilitate participation in decarbonisation effort nationally, and producing additional green hydrogen for export
Measure 2. Governance
Ireland should develop a flexible, integrated, and results-based governance structure to implement the Hydrogen Strategy for Ireland, including roles and responsibilities in ensuring policy coherence, strategic management, plan and project implementation, co-ordination and support for research

and advisory functions, and in the provision of accessible information for citizens and all stakeholders in public-private partnership endeavour for a climate-neutral Europe
Measure 3. Regulatory Measures
1. Transposing of EU Legislative, regulatory and standardisation measures into national legislation 2. Continuous review of interactions of Hydrogen Strategy with Climate Action Planning and implementation of measures 3. Annual audit of decarbonising actions in relation to carbon budgets, Climate Action Plan update including update of 4. Identifying all relevant Government Departments, State and Semi-state Agencies including planning, regulation and certification agencies relevant to governance of the Hydrogen Strategy, and other stakeholders in a public-private partnership endeavour 5. Defining and reviewing governance roles in the context of new and emerging EU legislative and regulatory measures and guidelines; ensuring that agencies are adequately resourced to carry out all required actions and functions
Measure 4. Certification and Guarantees of Origin for hydrogen
Measure 4.1. Identify and resource the Competent Authority and all relevant agencies in Ireland that will have a role in the certification and provision of Guarantees of Origin for hydrogen
Measure 4.2. Establish the National Hydrogen Registry for Ireland Identify, resource and advertise the agencies to be responsible for operating and maintaining the National Hydrogen Registry for Ireland. These agencies will need to be adequately resourced to undertake a new work package required to implement in important part of the Hydrogen Strategy in Ireland, to establish, operate and maintain the National Hydrogen Registry, to interface with the CertifHy European issuing body and registry, and to ensure continuous alignment with the regulatory and standardisation environment for green hydrogen production in Ireland within the EU regulatory framework and Hydrogen Strategy
Measure 4.3. Certification and Guarantee of Origin of green clean hydrogen produced in Ireland in compliance with the CertifHy™ GO scheme: 1. Identify, resource and advertise the agency/agencies to be responsible for operating and maintaining the *Guarantee of Origin for green and low carbon hydrogen produced in Ireland* 2. **Auditors** will ensure that the hydrogen producers (production devices) comply with the CertifHy™ GO Scheme requirements. The auditors are part of a **Certification body**, which has a relevant accreditation to perform this activity 3. The **Accreditation body** (a member of the International Accreditation Forum) controls the quality assurance system of the Certification body. It increases trust in conformity assessment by ensuring that certification bodies have the technical capacity to perform their duties.
Measure 4.4. Hydrogen Certification and Guarantee of Origin - Hydrogen import Policy Coherence Actions:

It is recommended that Ireland's existing and future hydrogen demand will be met entirely by electrolysis using renewable energy (wind, hydro, solar, and other renewables), producing clean green hydrogen. Currently, Ireland imports non-renewable fossil fuel based hydrogen for use in industry, including oil refining and pharmaceuticals. Hydrogen is a raw material for ammonia production in fertilisers for use in the agriculture sector. Non-renewable hydrogen plays a key role in the production of low carbon liquid biofuels used primarily in the transport sector. Ensure that the update to the Biofuels Obligation Scheme (BOS) provides adequate support for green hydrogen production. It is recommended that all non-renewable hydrogen imports to Ireland are recorded as such in the National Hydrogen Registry, and that the Hydrogen Strategy and Climate Action Plan both develop and implement actions to eliminate use of non-renewable hydrogen in all sectors of the economy in Ireland, and replace it with Certified GO green hydrogen produced in Ireland, with full audit and traceability of actions in the National Hydrogen Registry and it's interactions with the CertifHy Registry.
Measure 4.5. Hydrogen Certification and Guarantee of Origin – accounting for potential future hydrogen blending in the natural gas interconnector between Ireland and the UK It will be necessary to develop an agreed methodology for registering and accounting for the greenhouse gas (GHG) intensity of gas transmission in the gas interconnector between Ireland and the UK, including reference to the origin of any hydrogen blended into natural gas.
Measure 5. Interaction of Hydrogen Strategy with Climate Action Plan
Measure 5.1 Update the Terms of Reference of the Climate Change Advisory Council to include analysis of the implementation of the Hydrogen Strategy in Ireland in its annual reporting, and include recommendations on measures to further promote and support the production, transmission and use of green hydrogen to assist in meeting progressing decarbonisation, and re-adjust or refocus actions to ensure that decarbonisation targets are achieved

With regard to the electricity sector, a key policy is to require all new dispatchable generation to be hydrogen ready.

Transport:

Transport accounts for over 40 per cent of our energy related CO2 emissions in Ireland. HGVs currently account for 15 per cent of transport energy demand.

The Department of Transport Renewable Fuels for Transport Policy Statement November 2021:

Green hydrogen produced through electrolysis using renewable electricity will be supported through quadruple credits, as set out in Sections 13 and 14 of the Transport Policy Statement.

Section 13 of the Transport Policy Statement: Inclusion of Renewable Fuels of Non-Biological Origin, Fuels such as green hydrogen (produced using renewable electricity) and synthetic fuels produced from green hydrogen will be eligible for credits. Subject to enabling legislation, RFNBOs will become eligible for credit under the scheme from 1 January 2023.

Section 14 of the Transport Policy Statement: Treatment of Development Renewable Fuels refers to a category for certain renewable fuels called 'Development Renewable Fuels' will be added to the scheme and multiple credit will be awarded to incentivise their deployment. Subject to enabling legislation, the highest level of credit proposed among the fuels in question applies to Green Hydrogen, and the credit multiplier to apply from 1 January 2023 is x4.

While the credit level to which the multiplier will apply remains to be determined, this Transport Policy initiative is welcomed by Hydrogen Ireland as indicating an important commitment to facilitating and supporting the production and use of green hydrogen in Ireland. It is noted that the proposed credits would usefully be considered about the production, fuelling infrastructure and end users of green hydrogen, not only in public, commercial, and private transport, but also in other Group 1 sectors of the economy including Electricity, Buildings, Industry/Enterprise, and Agriculture.

It is requested that recommendations on the profile, sustainability, and supply of green hydrogen as a renewable ultra-low carbon transport fuel are also brought forward for implementation on 1 January 2023.

Recently announced supports for taxis[38] apply to grants will enable owners of small public service vehicles (SPSV), such as taxis and hackneys, to buy electric vehicles (EVs). It is recommended that supports for EVs should be extended to Hydrogen fuel cell EVs (FCEVs), as FCEVs are increasingly becoming available as detailed in the IERC paper Hydrogen in the Irish Energy Transition: Opportunities and Challenges,

Against the backdrop of the requirement to meet RED II obligations, the need for hydrogen refuelling infrastructure is bolstered by the European Commission's proposal on a Regulation for Alternative Fuels Infrastructure. Part of the Fit for 55 package, Article 6 contains provisions for Member States to ensure minimum coverage of publicly accessible refuelling points for hydrogen

[38] https://www.gov.ie/en/press-release/f1623-up-to-25000-for-taxi-drivers-to-buy-electric-vehicles/

dedicated to heavy and light-duty vehicles on the TEN-T core and comprehensive network. Subject to agreement at EU level, these refuelling points are to be in place by 31 December 2030. Member States will therefore have a mandatory obligation to provide this refuelling infrastructure.

Agriculture

Approved community gain project types for new onshore wind and solar farm developments should be extended to include green hydrogen projects, to support and supply local community needs for transport and heating.

Supports for the use of green hydrogen in farm machinery and energy supply should be considered and implemented in the agriculture and horticulture sectors and should include supports for renewable energy coupled with green hydrogen production at individual farm, rural community and agricultural co-operative level.

Policy and grant support for decarbonised domestic and commercial heating should target zero emission technology, and should include supports for green hydrogen compatible central heating boilers for use in domestic and commercial heating, and supports for the early provision of a guaranteed green hydrogen fuel supply. Pilot projects should be advertised, promoted, and initiated throughout Ireland.

Pricing

Develop green hydrogen fuel pricing structures, ensuring that zero carbon fuel production and use is supported and uptake encouraged, in conjunction with implementing carbon floor pricing of fossil fuels with increasing carbon pricing towards 2030.

Electricity

The Eirgrid Annual Report (2021) covers the period from 1 October 2020 through to 30 September 2021. It identifies a need for the continued development and retention of low carbon dispatchable generation, most likely low carbon new gas generation of 2.6GW capacity in the island of Ireland by 2030 (2GW in Ireland, 0.6GW in Northern Ireland), to ensure security of supply when renewables are not performing for climatic reasons, and critically will allow the closure of coal, peat and oil thermal generation plants. Low carbon gas is not defined in the report, and no reference to green hydrogen is included. Eight battery storage projects across the island of Ireland were energised with a total capacity of just over 335MW. Eirgrid (2021) identifies electricity demand side flexibility as critical to ensuring the transition to the 2030 targets and facilitate electrification of the heat and transport sectors while maintaining power system security. This is a key consideration in the Shaping Our Electricity Future Roadmap[39].

[39] **https://www.eirgridgroup.com/site-files/library/EirGrid/Annual-Report-2021.pdf**

2.4 How might the combined development of green hydrogen across multiple sectors synergies facilitate the development of hydrogen in Ireland?

The measures recommended by Hydrogen Ireland to establish a market for green hydrogen, create the right environment for investment, and enable the development of dedicated infrastructure, including for trade with third countries, within the new EU Framework and Hydrogen Strategy for a climate-neutral Europe (see Table 6), demonstrate a commitment to the development of green hydrogen in Ireland. The hydrogen demand required to comply with the 2030 greenhouse gas emission ceilings for each Group 1 Sector is calculated at 1 Megatonne (see Table 5). Additional storage of 0.25 Megatonne (250kt) of green hydrogen is recommended to provide energy security. This creates a target Power to X requirement of 10GW offshore equivalent in Ireland, to be operational before 2030, and facilitates the development of a Hydrogen Strategy for Ireland that includes a clear and unambiguous statement of intent to decarbonise the Irish economy.

H2 valleys [40] A Hydrogen Valley is a defined geographical area where hydrogen serves more than one end sector or application in mobility, industry and energy. They typically comprise a multi-million euro investment and cover all necessary steps in the hydrogen value chain, from production (and sometimes with dedicated renewable electricity production) to subsequent storage and its transport & distribution to various off-takers. Ireland has the capacity for a number of clusters at coastal locations where offshore wind can be used to produce renewable H2 at scale for use by local industry, heavy transport, local dispatchable power generation and , if sufficient scale, can be exported. Cluster model can be used to promote potential end uses of H2 and H2 products as well as expansion to new user via pilot projects and ultimately scale and strengthen H2 demand.

Examples: https://h2v.eu/hydrogen-valleys/

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

Carbon intensity of different fuels

In responding to this question, it is important to consider the carbon intensity of different fuels. Carbon emissions arise during the production of a fuel, and also during its use, as shown in Table 5. Hydrogen and electricity are both zero carbon fuels when in use. Currently, the production emissions of electricity are high, arising from the use of fossil fuels for thermal generation when the wind is not blowing. Green hydrogen is low to ultra-low carbon to produce and has a much greater decarbonisation potential than direct electrification in meeting 2025 carbon budgets and 2030 emission ceilings.

Table 5. Comparison of carbon dioxide emission factors during use of fuels.

[40] https://h2v.eu/

In the case of green hydrogen, and electricity, CO_2 emissions that arise during the production of the fuel are also tabulated

Fuel Type – EU Taxonomy Low carbon Hydrogen (Source: Hydrogen Council[41])	**Hydrogen production emissions $kgCO_2eq/kgH_2$**	**Fuel use emissions (gCO_2/kWh) (NCV)**
Hydrogen (electrolysis using hydropower, wind or solar)	< 3	0.0
Hydrogen (electrolysis using hydropower)	0.3 - 0.45	0.0
Hydrogen (electrolysis using wind)	0.5 - 0.70	0.0
Hydrogen (electrolysis using solar)	1.0 – 2.58	0.0
Fossil fuel; solid, liquid, gas (Source: SEAI, accessed 2.02.2022[42])	**Fuel production emissions**	
Coal	+	340.6
Milled peat	+	420.0
Sod peat	+	374.4
Peat briquettes	+	355.9
Liquid fossil fuel	+	
Gasoline / Petrol	+	251.9
Kerosene	+	257.0
Gasoil / Diesel	+	263.9
Residual Oil / Fuel Oil	+	273.6
LPG	+	229.3
Bottled LPG (Propane or Butane)	+	232.0
Natural Gas	+	204.7
Electricity generation in Ireland (Sources: SEAI, accessed 2.02.2022, and EPA July 2022)	**Electricity production emissions (gCO_2/kWh) (NCV)**	
Electricity 2018	375.40	0.0
Electricity 2019	324.50	0.0
Electricity 2020	295.80	0.0
Electricity 2021	331.00	0.0

Green hydrogen produced by electrolysis using hydropower, wind energy and solar energy is all classifiable as low carbon, defined in the current EU taxonomy as <$3kgCO_2/kgH_2$. Hydrogen produced by electrolysis using hydropower and wind energy is classified as ultra-low carbon <$1kgCO_2/kgH_2$.

41 https://hydrogencouncil.com/en/

42 https://www.seai.ie/data-and-insights/seai-statistics/conversion-factors/

Emissions from electricity production were higher in 2021 at 331.00 gCO_2/kWh, than in 2020. This increase in emissions in 2021 compared with 2020 was driven by increased use of coal and oil for electricity generation (EPA, 2022).

Fuel production carbon emissions are not readily available for fossil fuels and peat but are noted as arising; carbon emissions arising from the use of these fuels is listed in Table 5. Data on carbon emissions arising from the production and use of different biofuels are not listed by SEAI currently.

Green hydrogen is now regarded as a mature technology in the **International Energy Agency (IEA) Global Hydrogen Review 2021** (October 2021[43]). The IEA Global Hydrogen Review 2021 lays out a series of recommendations for near term-action beyond just mobilising investment in research, production, and infrastructure. It highlights that governments could stimulate demand and reduce price differences through carbon pricing, mandates, quotas and hydrogen requirements in public procurement. Both electricity and green hydrogen can be used to replace fossil fuels in our economy. Availability of both electricity and green hydrogen provides options, allows consumer choice in switching away from fossil fuels, and increases economic and social resilience.

In Ireland, it will take time to fully decarbonise electricity generation. We have only just begun to replace fossil fuels with green hydrogen (3 hydrogen FCEVs buses in Dublin) to start to decarbonise other sectors of our economy and to meet our carbon budgets. We need to accelerate this process with new ambition and commitment confirmed in a Hydrogen Strategy for Ireland that includes regulatory measures, supports and incentives, and infrastructure.

Several studies show that an EU energy system having a significant proportion of hydrogen and renewable gases would be more cost effective than one relying on extensive electrification[44]. These include studies reported in the European Clean Hydrogen Alliance Newsletter for May 2022[45], and in the fourth Hydrogen Forum of the European Clean Hydrogen Alliance, which took place on 16 June 2022[46] . A value chain analysis of the national costs by the Netherlands Environmental Assessment Agency shows that at a cost of 3,60 €/kg a large part of the homes are most cost effectively heated with hydrogen. A benefit of the use of green hydrogen in decarbonising Transport, Buildings, and Industry in Ireland is the reduced pressure on the electricity system while it decarbonises and builds capacity. The electricity sector in Ireland currently is not seen as being able to supply existing demand through the winter of 2022-23. Increasing electricity demand and tightening margins around electricity supply means we are having more System Alerts. Pressure on supply has been heightened by increased electricity demand; a delay in new generators coming onto the grid; the withdrawal of

[43] https://www.iea.org/reports/global-hydrogen-review-2021
[44] https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/689332/EPRS_BRI(2021)689332_EN.pdf

[45] https://ec.europa.eu/docsroom/documents/50320
[46] https://ec.europa.eu/docsroom/documents/50574
https://ec.europa.eu/docsroom/documents/50554

some planned generators by developers; decreased availability of existing generators as they age, and; the need for essential maintenance on other generators[47].

Regarding direct electrification of transport, most car manufacturers seem to be announcing that they intend to increase FCEV production. Some see a declining role for EVs (e.g. BMW[48]: "As long as the network of hydrogen filling stations is so thin, the low demand from customers will not enable profitable series production of fuel cell cars. And if there are hardly any hydrogen cars on the roads, operators will be reluctant to expand their refuelling network".

Supply chains for battery manufacture are starting to become an issue, about the global resource availability, supply, and ethical issues with regard to supply chains for rare earth and other metals required for battery manufacture. Forovia[49] suggests that "We are going to move from a dependence on oil to an even stronger dependence on the metals of electrification". FCEVs might become seen as more resilient than BEVs in this regard. For Patrick Koller of Ferovia, the hydrogen car will compensate for the shortcomings of the battery-powered electric car. According to him, they are of two kinds. The first is an issue of sovereignty related to metal supplies.

For Patrick Koller, there is another major issue with the hydrogen car. According to him, this technology effectively solves the infrastructural problem posed by the electric battery.

Motorway areas will have to be massively equipped with fast charging stations, up to 80 per service station according to him. But the cost of this infrastructure will not be borne by any economic model.

"The investments required on the major axes are colossal to meet the needs of a few days a year", says Patrick Kohler.

Speaking of the economic model, the boss of Forvia estimates that he will be able to offer a complete hydrogen traction chain for a 100 kWh car (high range of electric cars currently on the market) between 7,000 and 8,000 euros in 2030. "I don't think battery technology will reach that price" he judged.

A study prepared for Hydrogen Mobility Ireland, concludes that the relative efficiency of hydrogen fuel cell vehicles greatly understated[50]. The Total Resource Requirement—is more important than citing Energy Conversion Efficiency**.** Analysis demonstrates that hydrogen fuel cell trucks need LESS renewable energy capacity than battery trucks, based on a real world 2050 scenario. Battery vehicles need considerable additional resources, such as grid storage, secondary production, secondary storage, and secondary generation, while fuel cells need electrolysers and hydrogen storage.

[47] https://www.eirgridgroup.com/the-grid/gridalerts/
[48] https://hydrogen-central.com/goodbye-e-cars-bmw-wants-mass-produce-hydrogen-cars/
[49] https://hydrogen-central.com/automotive-forvia-faurecia-promises-hydrogen-cheaper-battery-cars-2030/
[50] https://h2mi.ie/wp-content/uploads/2022/04/Eliminate-Not-Abate-hydrogen-efficiency-advantages.pdf

Biofuels

Geo-political events are causing global fossil fuel and food price spikes, shortages, and supply chain disruption. Biofuel feedstock supply chains are becoming constrained, as the need to secure vegetable oils for human food consumption becomes increasingly apparent. Drought conditions currently affect some 66% of Europe, in what is becoming described as a 500-year drought. Crop yields in 2022 are being affected by drought, and it currently seems unlikely that the use of crops to produce biofuels will be sustainable in the short, medium, or long term.

Denmark[51] has already made decisions in this regard:
"Biofuels can lead to significant CO_2 emissions in the value chain: Indirect Land Use Change (ILUC) and impacts the climate through the removal of areas that store large amounts of carbon. New land being claimed for cultivation also comes with a high risk of negatively impacting biodiversity. A political decision has been made to incorporate ILUC values (or similar values) into the national fuel regulation by 2025 at the latest".

2.6 What are the competing fossil fuels that are sought to be displaced?

Coal, oil, kerosene, gasoil / diesel, petrol, natural gas and liquefied natural gas (LNG), as shown in Table 2 and in the response to hydrogen demand Q1 above.

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

The Climate Change Advisory Council, in its response to the announcement of Group 1 emission ceilings[52], noted that "There is concern that the current timelines for delivery of core measures within the Climate Action Plan are too long and the procedures to facilitate the delivery of these measures are not progressing quickly enough. The most impactful measures must urgently be prioritised and accelerated at a rate not previously foreseen. "Emissions from electricity production were higher in 2021 at 331.00 gCO_2/kWh, than in 2020. This increase in emissions in 2021 compared with 2020 was driven by increased use of coal and oil for electricity generation (EPA, 2022). Until electricity production is fully decarbonised, using green hydrogen to decarbonise the other Group 1 Sectors of the economy should not be avoided.

As the Climate Change Advisory Council has noted, energy efficiency measures are not progressing quickly enough.

[51] https://ens.dk/sites/ens.dk/files/ptx/strategy_ptx.pdf

[52] https://www.climatecouncil.ie/media/climatechangeadvisorycouncil/contentassets/documents/news/Chairs%20statement%20on%20sectoral%20emission%20targets.pdf

Given the current evidence of accelerating climate change, direct use of green hydrogen as a fuel that is low or ultra-low carbon to produce, and zero carbon in use, should be viewed as a priority.

If implemented correctly in Ireland, Hydrogen should not increase the overall level of energy used in the economy in the short term. In the short-term utilising hydrogen produced from renewable sources makes the entire system more efficient as the amount of dispatch down electricity can be greatly reduced and redirected to other areas of the economy.

In the long term an electrified energy system using hydrogen as an energy buffer will be more efficient (and therefore require less energy than the equivalent energy system using fossil fuels). The sector coupling of a highly electrified energy system which means the scale up of renewable wind (onshore & offshore) and solar (domestic & industrial), electric passenger vehicles, heat pumps for domestic heating, etc, will still require energy storage, in the form of batteries, interconnection and the use of hydrogen and its electrofuels.

A separate point is that the total amount of energy used in the economy is expected to increase, due to the buildout of large datacentres and to a lesser extent domestic economic growth which require more energy than not having them.

Suggest that policy mechanisms should incentivise (and fund) the most efficient decarbonisation solutions for each end user seeking to move away from fossil fuel.

How should green hydrogen be incentivised in the electricity market?

Regarding the electricity sector, a key policy is to require all new dispatchable generation to be hydrogen ready. Existing natural gas fired thermal generating plant should where possible be retrofitted to run on 100% hydrogen.

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Hydrogen Ireland

3. Hydrogen Supply

3.1 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?

- There are 7GW of fixed bottom offshore wind looking to get an electricity grid connection on the east and southeast of Ireland, Arklow Bank, Dublin Bay & Carensore has a limit of the amount of GW even after interconnection[53]. Therefore, in the existing pipeline of project GWs of wind does not have a route to market from conventional grid connections that could benefit from options to produce green hydrogen rather than building congested electrical cables.
- To fully decarbonise via electricity and renewable hydrogen we need circa 30GW+ of "offshore equivalent renewables", this will require floating offshore wind in the main.
- Ireland's renewable resources, according to SEAI are 70GWelectricity and others estimate over 500GWe. If harnessed, are multiples of our energy requirements for decarbonised economy (which is about 5GWe).
- Ireland needs to accelerate the planned trajectory for development of Irish renewables, particularly offshore wind. This requires:
    - Exploiting the full potential of existing electricity grid infrastructure and specifically the utilisation of hybrid grid connections and interconnectors.
    - Setting development targets in line with climate action and energy security needs and develop infrastructure to deliver this rather than limiting development to the current available infrastructure.
    - Enable development of renewable projects for hydrogen production as well as electricity.
- There is significant renewable capacity that could be harnessed for offgrid production of Hydrogen, however, optimal strategy for a SECURE integrated energy system is:
    1. Holistic design of power system with large scale grid connected renewables producing electricity for direct use as well as for Hydrogen production
    2. Grid connected electrolysers which provide smart, fast acting flexible demand
    3. Hydrogen storage at scale (TWhr)
    4. Zero carbon dispatchable power generation.

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

In the short term utilising hydrogen produced from renewable sources makes the entire system more efficient as the amount of dispatch down electricity can be greatly reduced and redirected to other areas of the economy.

While curtailed renewable electricity could be used to power an electrolyser, the business case for such an investment would require 'guaranteed energy supply'. It would not be commercially viable to operate an electrolyser solely at times when curtailed energy is available. The offtaker or customer will have defined the required volume which must be

[53] https://www.4coffshore.com/windfarms/ireland/arklow-bank---phase-1-ireland-ie01.html

delivered. The value of curtailed electricity is more so related to reducing the overall cost of electricity for the plant i.e. reducing the cost when curtailed electricity is available.

Put simply, green hydrogen production is an opportunity for Ireland to develop a form of long duration storage in the form of stored hydrogen or to decarbonise other sectors like transport, aviation, power generation etc. Using curtailed electricity to produce it can reduce the overall cost to the energy system, and consumers.

3.3 What should governments do to de-risk efficient investment in green hydrogen production to supply Ireland's demand?

- Integrated approach to design secure zero carbon energy system with large scale renewables producing electricity for direct use and for H2 production
- There were conflicting views among the members around the blending of renewable H2 with methane in the gas network.
    - Members are calling for government support, for example in the form of gas injection into the gas network, to remove demand risk until the industry is established. Investment of the scale needed will not be found if demand risk exists.[54]
    - Members also recognise the EU Commission [55] "reiterates its position that blending hydrogen into the natural gas grid requires careful consideration as it diminishes methane gas quality, can increases overall system costs and the costs of heating for the residential sector (if not certified for specific use in thermal plants or industry), and it is in most applications a less efficient alternative to direct electrification. ".
    - Members support EU prioritisation of " .. hydrogen valleys that bring together – in a limited geographical area - all the elements of renewable hydrogen production, storage and end-use into an integrated ecosystem. Hydrogen valleys can vary in size and scope thus proving to be very flexible in adapting to local energy needs."[56]

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

- Increase scale and reduce cost of renewables
    - Step up offshore wind targets to allow for attrition.
    - Accelerate deployment of offshore wind projects.
    - Fast track renewables via allowing hybrid connections.
    - Enable MAC (Marine Area Consent) for hydrogen projects.

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[54] Hydrogen Science Coalition | Principles - Hydrogen Science Coalition (h2sciencecoalition.com) " Before blending our valuable renewable hydrogen into the natural gas grid, the priority needs to be areas where we can have significant and immediate emissions reductions"

[55] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52022SC0230&from=EN

[56] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52022SC0230&from=EN footnote 44

- Mandate only Green Renewable Hydrogen – restrict investment in fossil fuel based derived alternatives
- Leverage the smart flexible demand associated with electrolysers to support the power system.
- De-risk and incentivise efficient green Hydrogen production.
    - Incentivise green Hydrogen production at point of use.
    - Reduce planning obstacles.
    - Efficient and effective capex and opex support for H2 production.
    - Support creation of demand for efficient use of H2. Set ambitious targets for renewable H2 to complement the role of electricity in achieving a secure net zero electricity system by 2040, and secure net zero energy by 2050.
- The European Commission's draft delegated act for RFBNOs proposes criteria necessary for green hydrogen categorisation. While this is focused on hydrogen use in transport, it is expected to form the basis for other end uses. However, the criteria for demonstrating additionality are overly restrictive. [57] The delegated act proposed a derogation on the additionality criteria until January 2027, after which, it will be permissible to use only electricity from newly constructed, unsubsidised wind and solar plants to generate renewable hydrogen. The timeframe of the derogation in the European Commission's draft delegated regulation on RFNBOs must be considered. Whilst the derogation for electrolysers commissioned before 1 January 2027 is welcome, the proposed transitional period and grandfathering period should be extended until at least 2030. There may be some challenges in meeting the requirements on reporting avoided curtailment. Discussions are currently ongoing between Hydrogen Ireland and EirGrid, and it is hoped that a meeting with the Commission for the Regulation of Utilities will take place in September 2022.
- Support lighthouse projects (capex support for H2 production infrastructure, per kg H2 support, switching support for H2 user (see Targets and Support section).

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

- Electrolyser capacity factor will have direct impact on price and, consequently, on the support mechanism required.
- In Ireland, according to research available, electrolysers should operate over 50% capacity factor for best commercial economics of the produced hydrogen fuel, weather the electrolyser is electricity grid connected or operating independent to the electricity grid (directly connected to a renewable source) or in a hybrid mode of both scenarios[58] [59].
- It can be challenging for a hydrogen production plant to match a customer need/supply of hydrogen produced by intermittent renewable energy with the steady demand from a

[57] Production of renewable transport fuels – share of renewable electricity (requirements) (europa.eu)
[58] https://www.sciencedirect.com/science/article/pii/S1364032122002258

[59] https://www.mdpi.com/1996-1073/13/7/1798

Hydrogen user such as a bus operator/ industrial heat customer. A low-capacity factor electrolyser necessitates investment in high capex, low capacity hydrogen storage to ensure a secure & resilient supply of Hydrogen for customers, thereby further increasing Hydrogen costs.

- However Electrolysers could be commercially operated below 50% capacity in certain circumstances that would not be based on pure economics of the produced hydrogen fuel;
  - This is based on the capability of electrolysers to operate efficiently during a load shedding event (load shedding is used to relieve stress on a primary energy source when demand for electricity is greater than the primary power source can supply.)
  - The electrolyser would be strategically located at a congested node of the electricity grid to allow for intermittent electricity load management for Demand side response reasons or for electrical grid frequency balancing or load shedding events to avoid blackouts or over supply of un-demanded electricity.
  - Electrolyser size would be designed to match the site and the commercial benefit would be from local & national energy security and grid stability, with the added benefit of hydrogen gas produced onsite and moved offsite to demand.
  - Incentivise grid connected electrolysers backed by renewable energy contracts, can be smartly dispatched to support the power system.
  - This would be location specific and limited in scale but could be strategically important for the electricity grid and reduce the need or defer the need for investment to reinforce the electricity grid at specific locations.
  - It is probable that these electrolysis facilities would be managed by state TSO.

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

- RESS supported renewables, paid for by the electricity customer under PSO, are already obliged to export all available MWh to the grid and are not permitted to set up PPA with any commercial customer, including h2 producers.
- Ambitious targets for renewables to produce H2 to complement the role of electrification for a secure, decarbonized energy system should be set.
- Existing out-of-support renewables should be permitted to enter PPA with any 3rd party including H2 producer- this will help retain wind capacity on the system who may otherwise close.
- Allow for oversizing (supported) projects to maximise MWs developed and allow for excess use in electrolysers.
- Price differential between green electricity and green hydrogen will always remain. Direct electrification will be more cost effective, where possible. Policy supports for electrification and supply chains (I.e. heat pumps + SEAI grants, EV cars) are in place.
- Hydrogen Ireland Do not see that policy intervention is needed to avoid green hydrogen production competing with direct electrification. The economics of the options will mean green hydrogen cannot compete with direct electrification in the medium term.

3.6 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 (ie grid constraints)? What spatial planning considerations should be factored into this? What role might ports play in the production and transportation of hydrogen?

- See answer to 3.4:
- Electrolysers could be commercially operated below 50% capacity in certain circumstances that would not be based on pure economics of the produced hydrogen fuel;
  - This is based on the capability of electrolysers to operate efficiently during a load shedding event (load shedding is used to relieve stress on a primary energy source when demand for electricity is greater than the primary power source can supply.)
  - The electrolyser would be strategically located at a congested node of the electricity grid to allow for intermittent electricity load management for Demand side response reasons or for electrical grid frequency balancing or load shedding events to avoid blackouts or over supply of undemanded electricity.
  - Electrolyser size would be designed to match the site and the commercial benefit would be from local & national energy security and grid stability, with the added benefit of hydrogen gas produced onsite and moved offsite to demand.
  - Incentivise grid connected electrolysers backed by renewable energy contracts, can be smartly dispatched to support the power system.
  - This would be location specific and limited in scale but could be strategically important for the electricity grid and reduce the need or defer the need for investment to reinforce the electricity grid at specific locations.
  - It is probable that these electrolysis facilities would be managed by state TSO.
- If the government wants to develop a spatial strategy for hydrogen development, the decisions need to focus on what best supports the development of a green hydrogen industry. Resolving unrelated grid constraint issues should be a secondary concern.
- Hydrogen is challenging to transport/ distribute and is best produced at point of use. [60]
  - There will be a role for small-scale local production of hydrogen at point of use e.g. Hydrogen refuelling Stations (HRS) where the renewable energy is efficiently transported via wires.
  - Hydrogen clusters / Hubs / Valleys: An integrated energy system approach can be delivered by a cross-sector clustered model of offshore wind, H2 production, H2 storage, distribution to H2 customers and zero carbon dispatchable generation. This should be based around coastal generation sites to leverage infrastructure for export. This can achieve economies of scale and efficiencies with shared high cost H2 infrastructure.

[60] Members who support hydrogen blending with methane in gas network also advocate locating hydrogen production at point of injection on the grid

3.7 What minimum sustainability criteria should apply to hydrogen produced in Ireland?

- Green hydrogen (produced from renewable energy generators) should be prioritised
- Applying the Certify[61] sustainable criteria
- Large scale hydrogen production, independent to the electricity grid (directly connected to a renewable source) should be considered where electric grid infrastructure is unavailable or cost prohibitive
- Incentivise renewable electricity-based hydrogen only.
- Hydrogen use prioritised for local demand
- Hydrogen produced from electricity grid connected electricity should be limited in size and application & time & site specific depending on local/regional electricity and hydrogen demand - 'grid hydrogen' has as high carbon footprint as the electricity grid
- Allow similar arrangements such as Purchase Price Agreements (PPA) with unsupported renewable generators, include temporal matching monthly/ annual until 2030.

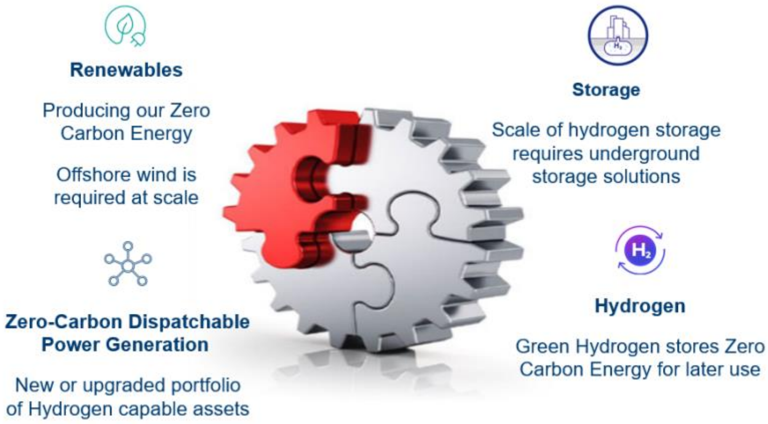
3.8 What policy mechanisms could be used to ensure that competition between green hydrogen production and other direct uses of renewable electricity is managed such that there are no negative impacts on emissions reductions or consumer costs?

- Efficient mechanisms should be introduced to incentivise the optimal decarbonisation choice that is aligned with net zero target. As per EU ESI strategy, electrification is preferable if it is feasible.
- Focus on sector coupling and the complementary roles of renewable electrons and renewable hydrogen
- Consumers should not receive subsidies for use of green hydrogen where they have a viable decarbonisation route via electrification.
- Priority should be given to 'no regrets' option which ensure best value for taxpayer in terms of €/ kg CO2 abated
- Price differential between green electricity and green hydrogen will always remain. Direct electrification will be more cost effective, where possible. Policy supports for electrification and supply chains (I.e. heat pumps + SEAI grants, EV cars) are in place. Do not see that policy intervention is needed to avoid green hydrogen production competing with direct electrification. The economics of the options will mean green hydrogen cannot compete with direct electrification in the medium term.

[61] https://www.certifhy.eu/

3.9 What contribution could domestic green hydrogen supply make towards Ireland's energy security? (see also under Energy Security tab)

- **Develop** 4 key infrastructure elements in parallel for **secure, integrated net zero Irish energy system 2050**



[62]

- **Set ambitious targets** for each infrastructure element

	Govt 2030	recommended 2030	net zero electricity	net zero energy
Offshore Wind	7GW	9GW	15GW	30GW
H2 Production		2GW	>8GW	15GW
Zero-Carbon Power Generation		2GW	8GW	>10GW
Storage		2TWh	10TWh	>20TWh

[63]

[62] Presented at Energy Ireland by ESB
[63] Wind Energy Ireland Report 0by50

3.10 What strengths does Ireland have in hydrogen supply chains?

In the absence of a clear hydrogen strategy with strong policy and funding commitment to underpin its delivery, it will be difficult to secure access to supply chains for hydrogen and renewables projects as Ireland will be competing with GB and other EU member states who have ambitious renewables and hydrogen targets and have already committed huge investment in next decades.

The key components of the **green hydrogen supply chain** are **production, storage, transport,** and **consumption.** Considering Ireland in that context, our strengths lie in the production and storage components. Ireland's significant renewable energy resources mean we have a distinct advantage in renewable electricity production, the primary resource input in green hydrogen production. Given the current onshore wind development pipeline a constant renewable electricity supply will be readily available for electrolysers in the mid 2020s. In addition, the Government recently announced an increased offshore wind target of 7GW by 2030 which has sent a clear signal to offshore wind developers. Delivering this capacity alongside the onshore pipeline would mean sufficient RES-E to power 2GW of hydrogen [64].

Depending on the demand in Ireland for green hydrogen by 2030, Ireland may well be in a position to export large quantities of green hydrogen to mainland Europe.

Storage:

Considering the storage aspect of the supply chains, traditional trailer storage already exists here. Companies like dCarbonX[65] are partnering with companies like ESB in Ireland investigating subsurface and subsea storage to provide storage solutions for green hydrogen. These solutions especially subsea storage will allow Ireland to develop strategic stores of green hydrogen to mitigate price spike and security of supply challenges in future.

As noted by DECC in the consultation paper, Energia and BOC gases are already transporting hydrogen by road in Ireland, this is a key element of the supply chain for which we have established expertise.

As noted earlier, there are divergent views among Hydrogen Ireland members on the role of injecting renewable hydrogen into the gas grid. Those who support this use would like to call out this newer element for green hydrogen transport via injection into the natural gas network operated by GNI. Providing for blended hydrogen in the gas network will be an important step in distributing the fuel quickly to customers located all over the Island.

An alternative viewpoint by other members would like to prioritise 'no regrets' investments to ensure best value for taxpayer in terms of €/kg CO2 abatement. In that context, they suggest the need for distinction to be made between "the transport of pure & clean hydrogen by gas network for decarbonisation purposes – i.e. to supply only the hard-to-electrify sectors

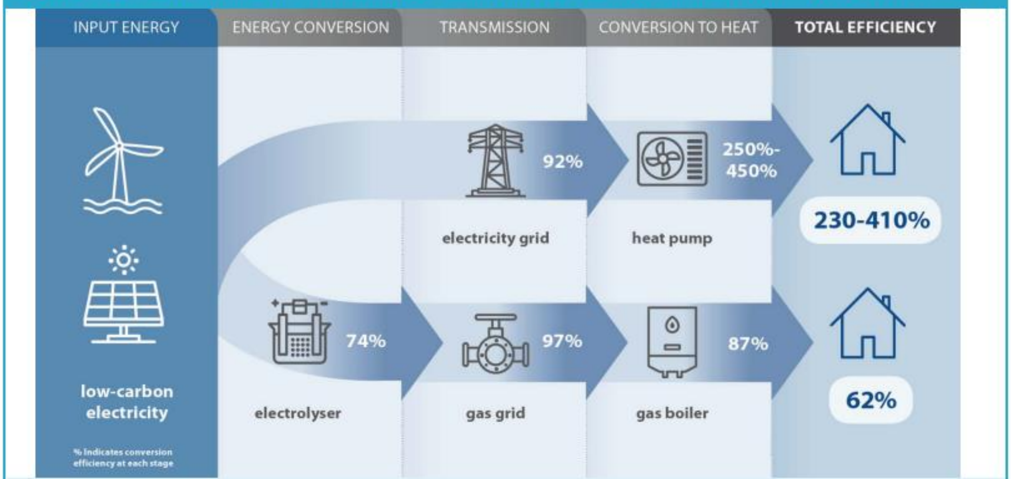
[64] https://www.irishexaminer.com/opinion/commentanalysis/arid-40930463.html

[65] https://hydrogen-central.com/esb-dcarbonx-green-hydrogen-storage-development-ireland/

relying on hydrogen -versus blending which could be both cost and energy inefficient. " [66] These members would like to draw attention to credible independent studies which do not see a major role for heating buildings with renewable hydrogen. "There are also unresolved questions over the implications for nitrogen oxide (NOx) emissions from burning hydrogen in boilers. Blending a premium fuel with a fossil fuel to serve residential customers is not a 'no regrets' option."[67]

Ireland also has access to the European single market meaning that surplus green hydrogen can be exported to meet demand on the continent while avoiding any additional tariffs or restrictions. Installing green hydrogen refuelling/storage hubs at ports would make it easy to export and/or refuel. In time the development of subsea pipelines to EU could provide an addition route for green hydrogen transportation.

Figure 1.2. Relative efficiency of heating: electricity in heat pumps vs. electrolytic hydrogen in boilers



Source: CCC analysis.
Notes: The diagram shows the indicative efficiency of using a given amount of zero-carbon electricity in delivering heat for buildings. Whilst in practice each of the efficiency numbers could vary, this would not be sufficient to change the conclusion that heat pumps provide a much more efficient solution for providing heat from zero-carbon electricity than use of electrolytic hydrogen in a boiler.

[68]

[66] https://www.iee.fraunhofer.de/content/dam/iee/energiesystemtechnik/en/documents/Studies-Reports/FINAL_FraunhoferIEE_ShortStudy_H2_Blending_EU_ECF_Jan22.pdf

[67] 18 independent studies challenging the use of H2 for heating buildings

[68] Hydrogen in a low-carbon economy - Climate Change Committee (theccc.org.uk)

3.11 What potential uses are there for the oxygen by-product of hydrogen production?

The worldwide oxygen market is valued at approximately $40 billion with an annual growth of over 6%.

Medical use of oxygen is well known; however, the steel industry is by far the largest consumer, other industrial users include semiconductors, plastic industry, food & beverage, pulp & paper industry, wastewater treatment, plastics industry, metals & metalworking.

Modern water treatment systems require air (oxygen) to promote the growth of bacteria to treat the effluent. The collocation of electrolysis systems and wastewater treatment facilities could be very beneficial and provide additional benefits such as land use efficiency and utilisation of the electrolysers plants as seen in Belfast [69].

As part of the initiative to decarbonise electricity production the combustion of hydrogen fuel in an oxygen environment is being researched (by Siemens Energy), this may lead to synergy between hydrogen & oxygen production in an electrolyser, and consumption of both gases in an electricity generation plant.

Largest industrial & medical gases producer Air Liquide[70] has in 2022 formed a joint venture with Siemens Energy to develop large scale hydrogen electrolyser manufacture. This and similar ventures establish a direct link between green hydrogen production, and a route to market for the oxygen by-product.

[69] http://www.belfastp2x.co.uk/power-2-x/

[70] https://hydrogennews.airliquide.com/press-release-news/2022-06-23/air-liquide-and-siemens-energy-form-joint-venture-european-production-large-scale-renewable-hydrogen

4. Transport and Storage

It is essential to transform Ireland's energy system to achieve its goal of a climate-neutral economy by 2050. Hydrogen can play a pivotal role in the country's decarbonisation efforts and be at the centre of its energy system integration. It can support the transport of renewable energy over long distances and facilitate seasonal energy storage whilst also providing Ireland with essential security of supply of green energy. However, successfully developing a hydrogen energy system requires focusing on the critical aspects of hydrogen transport and storage.

For a better understanding of the transport and storage of hydrogen, we refer you to a report prepared by Gas Infrastructure Europe (GIE)[71], The European Network of Transmission System Operators for Gas (ENTSOG)[72] and Hydrogen Europe[73]. This report, entitled "How to transport and store hydrogen? Facts and figures"[74], addresses a number of fundamental questions about gaseous and liquid hydrogen transport and storage. The report, and the supporting referenced reports and analysis[75] in this document, provide key information on hydrogen transportation and storage, which are applicable to Ireland. This report should be read in conjunction with the Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Region on "A Hydrogen Strategy for a climate neutral Europe"[76]

Transport

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

Methods of transporting hydrogen need to consider various aspects, such as volumes (produced/consumed), distances between production and consumption centres, actual or potential possibility to link transport and storage assets, quality requirements (infrastructure assets and final customers' needs).

The main methods for transporting hydrogen include:

- Pipelines - 0-5000km - K-Mtonnes H2- regional distribution to industry or electricity generation demand, export to UK
- Shipping by water/sea/ocean - 1000-10,000km - Ktonnes H2 - export to UK or Europe , etc
- Trucking - 0-200km - Tonnes H2 - local industry or transport applications
- Rail - 0-400km - Tonnes H2 - national industry or transport applications

Technologies available to allow for the transport (and storage) of hydrogen, include:

- Pressurised hydrogen
- Liquified hydrogen (LH2)
- Liquid organic hydrogen carriers (LOHC)

71 www.gie.eu

72 www.entsog.eu

73 www.hydrogeneurope.eu

74 How to transport and store hydrogen – facts and figures (gie.eu)

75 Appendix A

76 hydrogen_strategy.pdf (europa.eu)

- eKerosene
- Ammonia
- Methanol
- Synthetic eMethane

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

As stated in the "Technical and economic conditions for injecting hydrogen into natural gas networks report"[77], the ability to generalise and scale up the injection of hydrogen into the networks depends on the tolerance of the gas infrastructures and downstream users' equipment, with customers (in particular diffuse customers and domestic customers), taken as a whole, representing a significant and complex, including financial, challenge.

Blending green hydrogen with natural gas may represent an effective solution in the short term, applicable to exploit hydrogen production where pure hydrogen consumption centres do not yet exist and/or to scale-up hydrogen where users cannot be efficiently connected to electrolysers.

Better solutions include early segregation of the pipe infrastructure where sections of the grid are dedicated to 100% hydrogen pipelines and related supply, storage & industrial demand.

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

Blending represents a viable way to underpin hydrogen developments because it can promote market ramp-up, making it available at affordable conditions when demand materialises in end-use sectors (e.g. industrial heating & electricity generation).

In the very short term, blending to c. 5% threshold (as proposed by EU in the new gas package[78]) would not require major investment into the networks, nor would it have implications in terms of safety that cannot be appropriately addressed.

De-blending solutions[79] (e.g. membranes) can provide further upside, shielding natural gas users from hydrogen blends that cannot be accepted (e.g. CNG filling stations) or, conversely, providing hydrogen to dedicated, pure hydrogen users.

References to technical and economically sustainable blending percentages are included in the aforementioned reports, "How to transport and store hydrogen? Facts and figures" [80] and the "Technical and economic conditions for injecting hydrogen into natural gas networks report"[81], as well

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[77] https://www.elengy.com/images/Technical-economic-conditions-for-injecting-hydrogen-into-natural-gas-networks-report2019.pdf

[78] https://energy.ec.europa.eu/topics/markets-and-consumers/market-legislation/hydrogen-and-decarbonised-gas-market-package_en

[79] https://smarter.energynetworks.org/projects/nia_nggt0177/

[80] How to transport and store hydrogen – facts and figures (gie.eu)

[81] https://www.elengy.com/images/Technical-economic-conditions-for-injecting-hydrogen-into-natural-gas-networks-report2019.pdf

as the MarcoGaz report[82] "Overview of available test results and regulatory limits for hydrogen admission into existing natural gas infrastructure and end use".

Ireland's TSO, Gas Networks Ireland[83], is already actively evaluating the role of hydrogen within their system and as stated in their recent engagement document, *"*Hydrogen and Ireland's National Gas Network*"*[84]***: "****Gas Networks Ireland believes hydrogen will play a critical role in decarbonising the gas network and is supportive of projects, which aim to deliver hydrogen to energy customers, for end-uses such as space heating, transport, industry and dispatchable electricity generation, in a safe and secure manner."*

While acknowledging that "*currently the Code of Operations by which the gas network is operated in Ireland does not allow for the injection of hydrogen into the gas network*", their engagement document adds that "*Gas Networks Ireland believes that the re-use and re-purposing of existing gas network infrastructure is a cost-effective gas transportation model*". Accordingly, Gas Networks Ireland is engaging with stakeholders "*to outline the main areas that will need to be addressed and actions required in order to facilitate the injection, transportation and storage of hydrogen on the gas network in Ireland*."

In line with hierarchy of use in H2 demand section, ESB suggest that renewable H2 should be distributed in 100% H2 pipework and targeted for use in sectors which cannot be electrified. It is accepted that GNI work cited above is essential to prepare for imports of methane blended with H2 from GB. The power sector consumes ~50% of the gas in Ireland and there will be challenges, yet to be quantified, dealing with fluctuating %H2 in the gas supplied to gas turbines.

4.4 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 pipeline only or include some of the distribution network? Should the existing gas grid 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?

Fossil fuels, including "Natural gas" (methane) must be transitioned to 100% renewable alternatives. Methane when combusted produces CO2 while methane leakage & fugitive methane emissions are an issue for many biogases and biomethane plants & processes as methane is many times worse greenhouse gas as compared to CO2.

Therefore, the gas infrastructure must transition to either fully 100% green hydrogen, a mix of sustainable biomethane & 100% green hydrogen or a segregated grid with most of the infrastructure operating on 100% green hydrogen.

[82] https://www.marcogaz.org/wp-content/uploads/2019/09/H2-Infographic.pdf
[83] https://www.gasnetworks.ie/corporate/news/active-news-articles/hydrogen-ready/
[84] Hydrogen and Irelands National Gas Network.pdf

However, the transition of the natural gas network to a 100% (full) hydrogen network must take into consideration also the possibility to:

- keep (a small part) of the gas network operative to be able to transport methane, to which potential future Carbon Capture & Storage (CCS) facilities might crack the methane to hydrogen for use in the gas grid infrastructure and the CO2 exported. This could also be applied (making imported fossil natural gas potentially compatible with net zero in the medium-long term, however this depends on energy security concerns and facilitating the use of imported fossil fuels)
- develop other green gases such as biomethane, which is already fully compatible with the methane gas network and its economics, environmentally sustainable criteria, and cross-sectoral economic advantages (agriculture, waste industry, etc.)

The repurposing of the transmission & distribution network should proceed aligned with the repurposing of the distribution assets once the DSOs have fully identified and assessed the potential and the possibilities as to where hydrogen would be utilised. In this regard, it is recommended to refer to studies/projects developed by DSO UE association[85] and THUGA[86], a German DSO which is very active in developing their networks for hydrogen.

An appropriate way to identify these possibilities could be represented by the DSO's involvement (e.g. via dedicated sessions or consultations) in the TSO's network development plans drafting (e.g. gathering data on DSO's envisaged hydrogen switching programme and thus coordinating upward/downward grids developments). The segregation of the existing gas grid into fully dedicated hydrogen branches could represent an evolution to serve dedicated areas (e.g. hydrogen valleys or clusters).

This process should be carefully evaluated and implemented to take care not only of the prospective hydrogen customers' needs, but also of the actual/ongoing natural gas users (e.g. via appropriate re-connections plans).

In summary, the needs of both end-use sectors (hydrogen and natural gas) should be duly reflected when planning segregation/repurposing strategies (including compatible timelines, ensuring no customers would remain without energy). The ongoing assessment and interaction by Gas Networks Ireland with various stakeholders on the future blending of hydrogen within its network is a vital step towards realising Ireland's future hydrogen economy.

[85] https://gd4s.eu/

[86] https://www.thuega.de/stadtwerke-der-zukunft/unsere-wasserstoff-initiative/.

Storage

Gas Infrastructure Europe's commissioned report "Picturing the value of underground gas storage to the European hydrogen system"[87] highlights the vital need for underground storage in Europe. This report, published in June 2021, predates the Russian invasion of Ukraine, which further highlights the need for energy security in terms of strategic storage for both methane gas today, as well as the evolution to hydrogen storage in the future.

Key points from the executive summary, which was written from a total EU perspective, have direct read across implications for the development of the Irish hydrogen market, are transcribed below:

- *"Large-scale, underground hydrogen storage is indispensable to the development of the European hydrogen market and will become an important part of the future decarbonised energy system*."
- "*As in today's energy system, supply and demand balancing will be required on all timescales (hourly, daily, weekly, and seasonal)*."
- *"The overall energy system (electricity, gases) designed to meet the ultimate objective of the energy transition—net zero emissions by 2050 at the lowest cost to society—will also have to be optimised and secure."*
- *"Underground gas storage will be a key enabler for all these objectives, as it already provides these benefits to the energy system."*
- "*Compared to its current use, the role of underground gas storage will be even more pronounced to ensure the resilience of the energy system as a whole.*
    - *On the supply side, this is mostly due to higher (green) hydrogen supply variability driven by intermittent renewable electricity production from the sun and wind.*
    - *On the demand side, this is because of the sheer volumes (especially for industrial use) and demand variability from increasing electrification and the related need to meet higher electricity demand peaks created by residual load*."
- "*If hydrogen is to be deployed at scale, a substantial deployment of storage will be needed as well, requiring a better understanding of the specific storage needs. These hydrogen storage needs will be determined by an overall sector coupling equation. Developments in hydrogen supply and demand as well as interrelations with other sectors (power, transport, heating, cooling) and the sectors' ability to use other flexibility tools (batteries, heat and cold storage, pumped hydropower, etc.) will determine the specific hydrogen storage requirements*."
- "*When hydrogen production is expected to follow intermittent renewable sources, highly flexible storage is required in addition to the large scale seasonal volumes. Similarly, if hydrogen is used for power system balancing (short term and seasonal) and heating (directly or indirectly), substantial storage capacities with high flexibility will be required. A whole system adequacy exercise should be performed for electrical and gas systems to allow for the efficient use of energy networks, including storage. Both storage capacities and operating profiles need to be investigated."*

[87] Picturing the value of gas storage to the European hydrogen system_FINAL_140621.pdf

- “*In the early stages of hydrogen market development (up to 2030), demand will likely be concentrated around cluster areas (hydrogen valleys) that will initially mostly manage their supply locally. Underground hydrogen storage will be an integral part of these valleys, helping to significantly improve the economics of the emerging hydrogen infrastructure. In some places, underground storage sites for hydrogen might be repurposed or new ones developed even before the arrival of the European Hydrogen Backbone (EHB)*.”
- “*Alternatively, hydrogen blending in storage assets is an option. This option comes with the need to either de-blend the two gases upon withdrawal or to accept a different gas purity standard. By 2030, the EHB could start to interconnect the first valleys into hydrogen regions, both intra-country and cross-border. These developments can also support the large-scale integration of renewables in these regions, particularly offshore wind, with hydrogen storage as a critical component. As the transition continues and hydrogen supply and demand grow, the hydrogen valleys will evolve into an interconnected hydrogen network, as shown by the EHB initiative (after 2030).*”
- *“More natural gas storage will be repurposed for hydrogen, and the interconnectivity of the network will enable storage further away from hydrogen supply and demand to be used. Hydrogen might also begin to be used in heating (directly or indirectly) and to help meet peaks in electricity demand, beyond the mostly industrial (and transport) uses in the early transition. These uses would alter the demand profile for hydrogen. Peaking would require flexible storage to balance the variation in renewable electricity production, and heating would emphasise the larger need for seasonal storage. The overall hydrogen infrastructure, including storage, will enable a better hydrogen price convergence between the interconnected regions and the already established hydrogen valleys.”*
- *“Our first-order estimation of hydrogen storage capacity requirements for the 21 countries covered by the EHB shows the need for around 70 TWh of hydrogen storage in 2030, growing to around 450 TWh of hydrogen storage in 2050.”*
- *“All underground storage types will need to be utilised, both for capacity and geographical reasons. Repurposing and developing new storage sites will be required going forward. The decision for repurposed versus new development will be driven by a variety of factors including the development of hydrogen and natural gas storage needs over time, the availability of the storage, and the individual suitability of the storage site.”*
- *“From a physical point of view, hydrogen, due to its lower energy density compared to natural gas, needs about four times higher storage volumes to store an equivalent energy amount.”*
- *“Hydrogen storage in salt caverns is a low-hanging fruit and current research shows that porous structures (depleted gas fields, aquifers) are showing fair potential to cover further storage needs for pure and blended hydrogen. Given the geographical availability and expected capacities required, we will need all types of underground storage for hydrogen.”*
- *“Salt caverns are suitable for large scale pure hydrogen storage but are limited by their geographical availability across Europe. Depleted gas fields and aquifers are likely to be usable for hydrogen and are present more widely across Europe, so these will need to be utilised as well. Salt caverns (for natural gas storage) are operational in six EU member states and the UK with an estimated working gas capacity of 50 TWh of hydrogen after repurposing. Depleted gas fields and*

aquifers are used as gas storage in 16 EU member states and the UK with an estimated working gas capacity of 215 TWh of hydrogen after repurposing."

- *"To be ready for substantial hydrogen demand and regional pipeline networks by 2030, we need to start on the storage now. Repurposing can take anywhere between 1 and 7 years and developing new storage assets takes between 3 and 10 years from pre-feasibility to operation. Each existing site must be investigated for its suitability to store pure and blended hydrogen. Storage system operators have a key role—their experience will be needed. Many of these operators have started to investigate the feasibility of repurposing their assets. Several pilots are testing or planning to test storing hydrogen pure and in various blends in salt caverns, depleted gas fields, aquifers, and hard rock caverns. More field testing and R&D is needed, however."*
- *"Certain repurposing actions could be standardised to streamline the procedure. Some storage operators have also taken commercial role in the planning of new hydrogen projects. A clear business case and an enabling regulatory environment need to be present to enable decisions to repurpose or develop large-scale, underground hydrogen storage. Collaboration between supply, demand, infrastructure operators, and regulators will be key. Integrated infrastructure planning including hydrogen storage is necessary for a cost-efficient and timely energy transition in Europe."*

4.5 What role could hydrogen storage play in Ireland's energy system?

SEAI's Energy in Ireland 2021 report[88] provided a summary of Ireland's TPER. As detailed in this report, the predominant sources of energy were carbon-based. Whilst the expansion of renewable electrification has made great strides over the past 2 decades, it must be noted that this still only represents c.27% of TPER in 2020.

Future plans to increase renewable penetration (primarily by floating offshore wind) will create the need for further baseload green energy to support the electricity system. As detailed elsewhere in this submission, the production of green hydrogen can provide such baseload green energy, which can be used for power generation support. Surplus green hydrogen can also be re-profiled and utilised for decarbonising hard-to-abate areas, supplying green energy to those sectors not directly served through the electricity market, as well as underpinning security of energy supply and supporting future export opportunities.

As Wind Energy Ireland point out in their report "Seizing our Green Hydrogen Opportunity[89], green hydrogen can be central to creating a clean, decarbonised Irish economy by providing long-term energy storage for the decarbonising electricity market for when the wind isn't blowing, and the sun isn't shining.

Energy storage in the form of green hydrogen can also provide the assurance that Ireland can guarantee a secure energy supply for its citizens and importantly, with even more ambitious wind energy resource targets being set, green hydrogen production and its storage can provide further market support against curtailment, thereby assisting in the economics of wind deployment. The successful acceleration of decarbonising the Irish electricity sector, will create a requirement to ensure that there is suitable "renewable" or "decarbonised" energy storage.

4.6 What level of hydrogen storage play in Ireland's energy system?

As Ireland moves forward with its decarbonisation plans, Ireland's energy system will have to rely on a number of decarbonised energy storage mediums - such as batteries, flywheels, hydro-power, etc – but an analysis of the TPER shows that as Ireland decarbonises, and with corresponding renewable energy penetration increases, it will require a significant level of decarbonised storage at scale – and that is where large scale hydrogen storage comes in.

In the past, Ireland has relied largely on "carbon-based" energy storage, including storage of coal at Moneypoint, peat at various Bord na Mona facilities, methane gas at Kinsale Head and NORA's strategic oil reserve, which is set at a 90-day minimum storage level. In 2020, it is noteworthy that whilst 86% of TPER was fossil based (oil/gas/coal/peat), 96% of primary energy storage was fossil based.

Currently, it is common practice in mainland Europe to have c. 90 days (heating season) of annual gas consumption stored in underground geological formations – today, Ireland has none. Ireland's only underground gas storage facility (at Kinsale Head) was closed in 2017 and its physical infrastructure is currently in the final stages of decommissioning and removal.

[88] https://www.seai.ie/publications/Energy-in-Ireland-2021_Final.pdf

[89] **20220127-greenhydrogenactionreport-002.pdf (windenergyireland.com)**

Post-Brexit, Ireland also has its only gas inter-connection to a non-EU state (UK) which itself currently has only 5 days storage. In response to this storage crisis, the UK have recently sanctioned the rehabilitation of the offshore North Sea Rough Gas Storage Facility, with the UK government intervening to assist in the purchase of the cushion gas required to make it operational.

To ensure that the future Irish energy system is secure, reliable & resilient, Ireland needs to put in place significant amounts of energy storage. There are a range of potential TPER scenarios for 2030, net zero electricity, net zero energy - all which generate substantial storage requirements.

One such analysis, carried out recently by ESB[90], projects that Ireland will need at least 21 TWh of "decarbonised" energy storage to ultimately replace fossil fuels over the next 3 decades. WEI 0 by 50 report[91], identifies ~120TWh primary energy in 2050. 90 days primary energy storage (best practice in EU) is equivalent to ~30TWh storage. This is equivalent to the storage capacity of >15,000 Turlough Hill pumped storage units). Whilst other renewable and short-term storage initiatives (such as short cycle batteries, etc.) can and will play an assisting role, to meet this scale, Ireland's energy system will require much larger scale storage solutions to address the intermittency of renewable power, as well as the plans for significant green hydrogen that will be produced as a result of material increases in offshore wind power over the coming decades. Such large scale storage should take the form of underground natural gas storage, which will migrate via blending to green hydrogen as green hydrogen production increases.

Additionally, looking at the more recent initiatives within the EU on security of supply, REPowerEU recommends that members states carry at least 90 days of storage. Ireland already does this for oil reserves (through NORA) but to adhere to EU guidelines, 90 days of molecular storage (gas and hydrogen) should be implemented. Based on forecast TEPR, this would represent upwards of 30 Twh of energy storage in the short term.

4.7 Where would it be best to locate hydrogen storage?

Generally, energy storage should be located proximate to the end user market to minimise costs. However, as discussed above, Ireland's energy system will require large scale hydrogen storage, and due to geological, societal and planning considerations, the most appropriate location for such large scale storage is offshore, sub-sea. This provides societal, safety and consenting benefits as the storage infrastructure is unseen, is off-shore and is subsea.

In Ireland, extensive evaluation of geological formations confirms suitable locations for large scale hydrogen subsurface storage offshore Dublin (in salt caverns), offshore Shannon (again in salt caverns) and offshore Cork (in the decommissioned Kinsale gas fields, which previously hosted a 2.3 TWh methane gas storage facility which can readily be repurposed for molecular gas storage.) These three identified areas, adjacent to existing onshore infrastructure, can provide suitable storage capacity for 21 TWh.

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[90] ESB TPER ANALYSIS – (NEED TO GET APPROVAL)

[91] https://windenergyireland.com/images/files/our-climate-neutral-future-0by50-final-report.pdf

On the island, in Northern Ireland at Larne[92] [93], there is in the range of 10-20TWhr storage capability with a first stage 2.5TWhrs currently being developed for hydrogen storage.

In addition to large-scale, offshore sub-sea storage, as is common practice in the gas industry worldwide, there are opportunities to deploy "step-down" storage facilities (either sub-surface silos or in surface dewars) for smaller quantities of hydrogen storage (tens to hundreds of tonnes). These "step-down" storage facilities can be located adjacent to hydrogen producing or consuming locations, that may not be connected through pipeline infrastructure (off grid).

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

The benefit of developing offshore sub-sea hydrogen storage facilities is that they are not immediately adjacent to communities, thereby minimising societal and environmental impacts. Obviously, to access these storage facilities, pipeline infrastructure would be required to link up with onshore facilities for the processing and forward transport of hydrogen. Here, there would obviously be a requirement for public engagement.

Once hydrogen storage plans have been planned, the acceptance or resistance in communities could be anticipated to follow similar dynamics as for natural gas storage facility and its associated infrastructure. Any potential resistance can be responsibly addressed through:

- transparent and public engagement of (local or adjacent) communities, explaining the test results and sharing evidence about the ability to safely store hydrogen; It should be noted that the storage of hydrogen in the sub-surface is not a new development and indeed, sub-surface hydrogen storage has been utilised worldwide for over 40 years;
- the economic benefits that will accrue to the involved territories/communities (e.g. support to local public facilities or activities; creation of jobs);
- explanation/exploitation of the "green value" of the initiative, as substantial and concrete contribution to climate change;
- the ability to repurpose existing carbon based infrastructure (such as power stations) to future hydrogen usage.
- Detailing the waste management of brine water in a safe and ecological sustainable manner

4.9 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?

The regulatory framework should promote R&D and ensure that innovation enabling players cover their costs related to any tests and/or innovative projects. In addition to EU directives and EU

[92] https://www.bbc.com/news/uk-northern-ireland-58896311

[93] https://www.islandmageeenergy.com/

sponsored initiatives for underground molecular storage, other valid examples in this direction can be referenced to UK regulatory framework tools aimed at spurring innovation, such as:

- the Network Innovation Allowance - NIA, which ensures several resources that network operators are entitled to receive as part of their allowed revenues for innovation projects.
- the Strategic Innovation Fund - SIF (as replacement for the former Network Innovation Competition -NIC), that according to the strategic direction using innovation challenges set by Ofgem, intends to support innovative activities that contribute to the achievement of environmental benefits with positive returns both for network companies and for the overall society.

Importantly, due to the long lead times required and the significant expenditure requirements, the statutory and safety framework should ensure that all the pre-conditions are in place to allow for the geo-scientific investigations and development of storage, including:

- the carrying out of all geological investigations, including a clear process for obtaining all operational and environmental authorisations for site investigations, drilling operations and salt cavern excavation.
- the carrying out of all sub-sea operations, including a clear process for obtaining all operational and environmental authorisations for the production, the injection and/or the withdrawal of gases from offshore reservoirs.
- providing visibility and certainty to investors (e.g. the set-up of a stable and long term regime of licensing concessions).

As stated above, the CRU should be given jurisdiction and control over all licensing and safety aspects relating to hydrogen transportation and storage.

4.10 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?

Depleted gas field in Ireland may not be viable for hydrogen storage, but it should be investigated and researched with university partners.

4.11 Are there any predefined geographical areas of interest in relation to potential hydrogen storage?

As discussed in 4.7 above, predefined geographical areas of interest for potential hydrogen include offshore Cork (in saline reservoirs) and offshore Dublin, Clare and Northern Ireland through the development of salt caverns. The key element is that these areas are offshore and sub-sea, thereby minimising potential societal impacts.

4.12 What type of technologies, including any existing infrastructure, could be put in place to facilitate hydrogen storage?

Technology already exists for hydrogen storage so the main impetus should be put on regulatory and planning measures to facilitate the development of suitable storage facilities. Please refer to "How to transport and store hydrogen? Facts and figures" [94]

Release a hydrogen auction for electricity generation & backup to fund such developments.

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

The main opportunity for storage of energy in gaseous molecular form (including future hydrogen developments) is linked to the distinctive features and advantages compared to batteries and other forms of electrons storage, as shown in this Frontier Economics report: The Value of Gas Infrastructure in a Climate-Neutral Europe[95]

To cope with peaks period, storage facilities should be appropriately oversized, so as technically be able to address seasonal/annual storage needs required by the energy systems to address demands swings between e.g. summer/winter or across different years. The major challenge is to ensure that there are measures in place to support innovative activities (lab tests, pilot projects, scaling-up initiatives, technologies adaptations or evolutions) required to get to the actual commissioning of hydrogen underground storages done as quickly as possible.

4.14 What new environmental considerations should be considered in relation to hydrogen storage?

In considering environmental consideration in relation to hydrogen storage, your attention is drawn to the EU's position for the storage of hydrogen. In July 2020, the European Parliament agreed a resolution[96] in July 2020 on a comprehensive European approach to energy storage, which identifies the workflows for structural, environmental and safety matters pertaining to energy storage.

[94] How to transport and store hydrogen – facts and figures (gie.eu)

[95] *https://www.frontier-economics.com/media/3120/value-of-gas-infrastructure-report.pdf*

[96] Texts adopted - A comprehensive European approach to energy storage - Friday, 10 July 2020 (europa.eu)

5. Export opportunity

5.1 What is Irelands potential opportunity to export green hydrogen? What are the impacts of this on consumers and the economy?

The report "The Dawn of Green Hydrogen"[97] produced by PwC's Strategy& estimates that global demand for "green hydrogen" could reach about 530 million tons (Mt) by 2050, displacing roughly 10.4 billion barrels of oil equivalent (around 37 percent of pre-pandemic global oil production). It also estimates that the green hydrogen export market could be worth US$300 billion yearly by 2050, creating 400,000 jobs globally in renewable energy and hydrogen production. In addition, a new study from Indian/US firm Transparency Market Research (TMR) calculates that the global green hydrogen market will expand from $2.14bn last year to $135.73bn by 2031 — a "phenomenal" compound annual growth rate (CAGR) of 51.6% [107].

In general, green hydrogen represents an opportunity for countries like Ireland, who can produce green hydrogen to boost domestic industries and for export. Although countries such as China and the U.S. are seeking to invest in green hydrogen, their export prospects are limited by large domestic demand that will probably consume most of their production. By contrast, Ireland can export much of their green hydrogen and still have ample, low-cost renewable energy.

As stated in the previous section on hydrogen demand, a domestic opportunity that has been identified in the report issued by Wind Energy Ireland on "Hydrogen and Wind Energy"[98] is hydrogen injection into existing natural gas pipelines where a blend of up to 20% is considered technically achievable. Pipeline injection also presents a long-term opportunity considering that the Irish gas network features over 14,000 km of pipeline spread across the country which is connected to the wider markets, in the UK and Europe, via Scotland[99]. Moreover, with the European Commission (EC) REPowerEU action plan[100] expecting to see 1.3 million tonnes (mt) of green hydrogen to be blended into the natural gas network by 2030, injecting hydrogen into this grid brings an opportunity to use existing and new infrastructure to help the distribution of clean gas whilst also supporting potential partnerships such as one between Ireland and Scotland and the possibility to have a pipeline to The Netherlands.

An additional positive step taken towards hydrogen exporting opportunities was the recently announced Government agreement that commits additional resources for solar (more than doubling the target to 5,500 MW), offshore wind (moving from a target of 5,000 MW to 7,000 MW), green hydrogen (an additional 2,000 MW)[101], – to accelerate the reduction of overall economy-wide emissions. This is a significant contribution to increasing our ambition for using offshore wind to create green hydrogen giving Ireland and the electricity industry new options to find new ways to meet the

[97] https://www.strategyand.pwc.com/m1/en/reports/2020/the-dawn-of-green-hydrogen/the-dawn-of-green-hydrogen.pdf
107 https://www.rechargenews.com/energy-transition/global-green-hydrogen-market-to-grow-by-more-than-6-000-by-2031-says-new-study/2-1-1271676
[98] https://windenergyireland.com/images/files/final-hydrogen-and-wind-energy-report.pdf
[99] https://www.gasnetworks.ie/corporate/company/our-network/
[100] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52022SC0230&from=EN
[101] https://www.gov.ie/en/press-release/dab6d-government-announces-sectoral-emissions-ceilings-setting-ireland-on-a-pathway-to-turn-the-tide-on-climate-change/

increasing need for energy without relying mainly on burning fossil fuels as the EIRGRID and SONI's All-Island Generation Capacity Statement 2021 – 2030[102] indicates.

Green Hydrogen and e-fuels such as eKerosene or eAmmonia, produced from green hydrogen present a massive export opportunity for Ireland. For example, it is predicted that Germany will have to import 68 per cent of its 2050 hydrogen demand[103]. JCB in the UK recently signed a multibillion-pound memorandum of understanding to import green hydrogen from Australia[104]. Belgium is looking to import green hydrogen from Chile[105].

Europe is a major energy user aiming for an increased renewable energy share across most of its member countries, with limited renewable capacities. The primary goal for using clean hydrogen in Europe is to decarbonise industry although transport is also being targeted. In Germany, the emphasis is on chemical, petrochemicals and steelmaking industries together with a focus on heavy-duty vehicles such as military vehicles, haulage trucks and buses. France is focusing on replacing carbon-based hydrogen in existing industrial sectors (e.g., refining, chemistry, agribusiness) while also looking to pilot projects in the maritime and aviation sectors and seeking to be a key producer of electrolysers. In the Netherlands, the government is considering the development of a hydrogen infrastructure to connect the different users. Norway is cautious about significant clean hydrogen production due to the notable infrastructure costs but is exploring potential solutions, such as producing hydrogen close to customers and transporting the CO2 back to Norway for storage. Elsewhere, Spain and Portugal are focusing on the production and domestic consumption of renewable hydrogen, with longer term export aims[106].

As countries build partnerships to import and export green hydrogen, Ireland must show that we can deliver to realise this opportunity and follow the model of potential partners like Germany who are setting hydrogen diplomacy offices to increase dialogue with strategic partner countries, covering areas such as the development of the international hydrogen market and ways to enhance cooperation in order to harness the opportunities that this market creates. Because promoting hydrogen and its downstream products also generates competitive advantages. The offices are therefore tasked with providing expertise as well as analyses of the local and regional impact of the transformation. Another key part of their role is to build ties between decision-makers, experts, and companies from two or more countries[107] and the signing of formal commitments such as memorandum of understanding.

[102] https://www.eirgridgroup.com/site-files/library/EirGrid/208281-All-Island-Generation-Capacity-Statement-LR13A.pdf

[103] https://static.agora-energiewende.de/fileadmin/Projekte/2020/2020_10_KNDE/A-EW_193_KNDE_Executive-Summary_EN_WEB_V111.pdf

[104] https://www.thetimes.co.uk/article/equipment-company-jcb-buys-up-supplies-of-green-hydrogen-

[105] https://www.euractiv.com/section/energy-environment/news/hydrogen-trade-belgium-signs-deal-with-chile-germany-woos-uae/

[106] World Energy Council Working Paper on National Hydrogen Strategies, September 2021. https://www.worldenergy.org/assets/downloads/Working_Paper_-_National_Hydrogen_Strategies_-_September_2021.pdf

[107] https://www.auswaertiges-amt.de/en/aussenpolitik/themen/hydrogen-diplomacy-office/2513802

As green hydrogen continues to build momentum, Wind Energy Ireland report "Revolution"[108] also states that green hydrogen brings an enormous chance for Ireland. Exploiting our offshore wind resources and encouraging the synergies between floating offshore wind and hydrogen can create thousands of jobs by 2050, through staging, installation and the operations and maintenance of wind farms and hydrogen plants, thus enabling companies to fully develop infrastructure. Such is the case of Denmark, who recently established the political agreement named PtX.[109] Under this agreement, two partners (Energinet and Evida) will be given the opportunity to establish and operate hydrogen infrastructure in Denmark and explore the possibility of connecting a hydrogen grid in Jutland with the German system. It is also expected to include the possibility for Energinet to establish and operate a hydrogen storage facility.

5.2 How does export of green hydrogen compare with the direct export of renewable electricity through electricity HVDC interconnections?

HVDC interconnections are limited by their physical electrical capacity and will be fully utilised in balancing electricity from renewable electricity as well as trading electricity on the open electricity energy market. Hydrogen export is an additional mechanism to **manage excess capacity** of building out large scale renewable energy in Ireland. It is limited only by the limit we choose to place on it. It would interact on different timescales, allowing energy buffering, energy stockpiling and on different markets allowing security of supply and security of price for customers.

An additional argument of exporting green hydrogen in comparison to the direct export of renewable electricity through electricity HVDC interconnections, **is that green hydrogen is versatile**[110]**.** Technologies already available today enable hydrogen to produce, store, move and use energy in different ways. As stated, it can be transported as a gas by pipelines or in liquid by ships, much like liquefied natural gas (LNG). It can be transformed into electricity and methane to power homes and feed industry, and into efuels to power ships and planes and for export.

Moreover, the ability to store electricity using green hydrogen could make wind and solar power a secure energy source, freeing Europe from its dependency on imported fossil fuels[111]

Renewables give us clean and sustainable electrical energy, but the intermittency is something which is difficult and expensive to manage. The main problem is the insufficient buffering or storage capacity. If we direct all the electricity immediately into the electricity grid, we may encounter situations with either too much electricity, which can stress the entire electrical network, or we rely too much on renewables we can at times not have any electricity. This would also cripple the network unless there is a buffer or storage allowing excess electrical energy to be absorbed or re-directed into the electricity network when supply is limited. That buffer or storage can be green hydrogen produced through electrolysis.

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[108] https://windenergyireland.com/images/files/revolution-final-report-july-2021-revised.pdf
[109] https://denmark.dlapiper.com/en/news/new-political-agreement-develop-and-promote-power-x
[110] https://iea.blob.core.windows.net/assets/9e3a3493-b9a6-4b7d-b499-7ca48e357561/The_Future_of_Hydrogen.pdf
[111] https://ec.europa.eu/research-and-innovation/en/horizon-magazine/hydrogen-could-help-secure-europes-energy-supply-bert-de-colvenaer

This challenge has been identified by EIRGRID's 2021 Annual Innovation Report[112] stating "our future energy needs will be met increasingly by renewable electricity; however, some energy end uses are hard to electrify via the grid or with batteries, especially in transport but also in other sectors. In many sectors, direct electrification is, and will remain, technologically challenging or uneconomical, even at very high CO2 prices. Hydrogen represents a possible overall solution for long-term, carbon-free seasonal or day to day energy storage. While batteries, super-capacitors and compressed air can also support balancing, they lack either the power capacity or the storage timespan needed to address >day imbalances let alone seasonal imbalances. As we transition towards net zero emissions, these secondary fuel requirements will need to be reviewed and hydrogen could play a key role".

Therefore, green hydrogen would absorb electricity in surplus situations. And then later, once hydrogen has been made, it can be used as a clean transport fuel, convert it back to electricity using fuel cell technology or inject it into the natural gas grid.

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

Hydrogen export from Ireland could be viable and at scale between 2030 & 2035. This leaves between 7 & 12years for Ireland to develop the international agreements, secure funding, & infrastructure planning and develop infrastructure and the capability to be able to export and compete with other countries globally, like what Ireland has achieved in the Agri industry or pharma industry over the past 2 decades.

The European Hydrogen Backbone (EHB)[113] initiative is a promising solution to accelerate hydrogen adoption for greater energy security and meet renewable targets. To achieve this, the EHB has accelerated its program from 2035 to 2030 with the aim to meet the REPowerEU targets, which include a 10 MT target of domestic EU hydrogen supply, as well as a 10 MT target of hydrogen imports from outside the EU[114].

To deliver the 2030 hydrogen demand targets set by the RePowerEU plan, five large-scale pipeline corridors are envisaged and are included in the EHB's most recent report "Five hydrogen supply corridors for Europe in 2030"[115]. The corridors will initially connect local supply and demand in different parts of Europe, before expanding and connecting Europe with neighbouring regions with export potential.

The planned hydrogen backbone network will largely be based on repurposing existing natural gas infrastructure. Therefore, Gas Networks Ireland is a key participant in Corridor C. Corridor C would meet demand from industrial clusters and ports in the UK, the Netherlands, Belgium and Germany enabling European partnerships that include Ireland[116]. For this purpose, collaborative research has begun between Gas Networks Ireland and University College Dublin's (UCD's) Energy Institute to

112 https://www.eirgridgroup.com/about/innovation-and-research/2021-Innovation-Report.pdf
113 https://ehb.eu/
114 https://ec.europa.eu/commission/presscorner/detail/en/IP_22_3131
115 https://ehb.eu/files/downloads/EHB-Supply-corridors-presentation-ExecSum.pdf
116 https://www.agriland.ie/farming-news/gas-networks-ireland-joins-major-european-hydrogen-project/

www.hydrogenireland.org info@hydrogenireland.org

ensure the safety and operability of Irish Gas Network when transporting a blend of hydrogen and methane.

An alternative to consider is exporting hydrogen by ship, as Australia is planning, where work is already underway in Australia to produce renewable hydrogen for Japanese consumption with the Australian and Victorian governments partnering on the Hydrogen Energy Supply Chain Pilot Project (HESC) which aims to be fully operational in 2030. The HESC involves the construction of a liquefied hydrogen export facility in Hastings, Victoria to export hydrogen to Kobe, Japan.

Development of hydrogen shipping

To support the development of Irelands hydrogen export potential, there must be a roadmap specifically designed for the transport of hydrogen for both the domestic and export markets. The cost of hydrogen delivery depends on the amount of hydrogen transported, the transport distance, the transport means used and the state in which hydrogen is transported (the 'packaging' mode). In this brief, 'packaging' is used when referring to the form in which hydrogen is being delivered. 'Packing' refers to the compression or liquefaction of hydrogen or its conversion to a chemical carrier. 'Unpacking' means reversing that process to have purified, gaseous hydrogen at a defined pressure and purity at the use site.

When constructing a national framework for the transport of hydrogen, the emissions polluted because of means of transport should be considered the top priority and next should be the cost competitiveness and efficiencies. Therefore, ideally hydrogen would be transported via pipelines due to the reduced emissions levels. However, due to Irelands geographical position the most cost-effective method of transport would be shipping.

The 2019 IEA's "Future of Hydrogen Report"[117] estimated that green hydrogen in 2030 in Japan would be approximately $6/kg compared to $3.8/kg in Australia where it would be produced. Indicating a significant transport cost that would add around $3 per kg of hydrogen. As production cost continue to fall significantly, we must ensure that transport cost have a similar trajectory to ensure that potential importers choose clean hydrogen rather than alternative energy sources. Thus, ensuring the stability and sustainable development of Irelands hydrogen export potential rather than short term gains that have negative long-term consequences. There are numerous forms or methods of shipping hydrogen with varying advantages and disadvantages. Below is a simple table that illustrates these various methods.

Method	Description	Advantages	Disadvantages	Status
Shipping: ammonia	By combining hydrogen with nitrogen to create ammonia (NH3) and then liquifying (-33oC),	High density means low cost to ship. If ammonia can be used directly, conversion losses	Round trip conversion losses if a pure form of hydrogen is required (such as for fuel cell	Potentially suitable, particularly over longer distances and where re-

[117] https://iea.blob.core.windows.net/assets/9e3a3493-b9a6-4b7d-b499-7ca48e357561/The_Future_of_Hydrogen.pdf

	density can be significantly increased	are only 7–18%. Some transmission infrastructure already established	vehicles) are 14–36%. Toxic	conversion is not needed.
Shipping: other LOHCs	Hydrogen density can be significantly increased by combining with a 'carrier' molecule such as toluene	Can be transported as liquids without any cooling and therefore very low shipping costs. Could use adapted existing oil tankers	High conversion losses currently (35–40%). Potentially toxic. Multiple solutions still being trialled	Potentially suitable but technology still in its early stages
Shipping: liquid hydrogen	Hydrogen liquifies at -253oC, increasing its density by 800 times	Liquefaction significantly reduces transport costs/unit. Could use a similar technology to existing LNG vessels. Delivers pure hydrogen	Liquefaction and maintaining a low temperature consume significant amounts of energy (25–35%) & a certain proportion is lost as boil-off	Potentially suitable but highly capital intensive. First liquid hydrogen ships expected in 2022
Shipping: compressed hydrogen	Compressing hydrogen to 250 bar significantly increases the volume of hydrogen that can be stored	No conversion losses and only modest technical challenges to store compressed hydrogen. Delivers pure hydrogen	Relatively high shipping costs per unit reduces cost efficiency with distance	Potentially suitable. Type approval in principle from the American Bureau of Shipping. Construction of pilot ship expected to begin shortly

There is no single optimal hydrogen delivery solution across every transport scenario. The most cost-effective way to deliver renewable hydrogen depends on distance, amount, final use, and whether there is infrastructure already available.

5.4 How should Ireland support the development of green hydrogen exports?

In Ireland, there is a high potential to convert energy from our abundant wind resources, both onshore and offshore, into renewable hydrogen to provide clean, reliable, and storable energy to achieve our net zero ambition and for export to EU Member States who are already forecasting shortfalls between their indigenous hydrogen production capacity and their hydrogen requirements in a net zero economy.

To stimulate the supply and demand of hydrogen, Ireland should align with proposals at EU level, to not apply additionality conditions until 2027. In fact, Ireland is a particular case within the European Union and the government should urge the European Commission to push the additionality conditions to 2030 considering the diversity on geography, capacities, national targets, and resources amongst each of its member states.

Moreover, and once again taking the example of Australia, Ireland should carry pilot projects. Australia, like Ireland, is exceptionally well placed to deliver green hydrogen, with world-beating renewable resources and ports and the government of Australia aims to create a major green hydrogen export industry, particularly to Japan, for which Australia signed an export deal in January. Under the agreement, Japan will participate in the first round of the $150 million Australian Clean Hydrogen Trade Program (ACHTP). The ACHTP aims to advance Australian-based hydrogen supply chain projects that catalyse international investment and contribute to the development of export markets for Australian hydrogen products, including liquefied hydrogen and ammonia[118].

Ireland also needs to act boldly and develop the right policies and regulations to support the domestic market, define the governance and institutional framework, and develop the funding model in parallel to build the export infrastructure and secure supply agreements with key export markets.

When looking at Hydrogen Europe's [119] report on other member states' national hydrogen strategies we observe that the policy and legislative measures are:

- Fiscal incentives: exemption of surcharges; public – private partnerships; tax exemptions; direct funding.
- Standards: European and International support; infrastructure; refuelling stations; end-use.
- Support for Research and Development: entire hydrogen value-chain; skills and competences for the hydrogen future.
- Administration: removal of administrative barriers; simplification of procedures for hydrogen; civil servants preparation.
- Guarantees of Origin: International and European; green hydrogen; carbon footprint.

Therefore, a similar approach and supports should be taken into consideration for a Hydrogen Strategy for Ireland.

As for funding, Hydrogen Europe reported €20.9 bn of public funds dedicated to hydrogen by nine countries as shown in the following image:

[118] https://arena.gov.au/blog/australia-signs-hydrogen-export-deal-with-japan/

[119] Hydrogen Europe - National Hydrogen Strategies Tracker & Analysis. 27.07.2022

Nine countries have committed €20.9bn of public funds towards H2

Data as of 28/07/2022

Country	National Funding Committed (€)	Details
Austria	**0.545bn**	Non-exclusive for R&D, IPCEI and subsidies for electrolysers/biomethanation
Belgium	**0.15bn**	Energy Transition Fund (non-exclusive) & Recovery & Resilience Plan (exclusive)
Czech Republic	**0.522bn**	Non-exclusive, available through 3 funds and operative programmes
Denmark	**0.176bn**	Exclusive, PtX subsidies based on tender and PtX task-force
France	**5bn**	Priorities: Industry & heavy duty transport decarbonisation and R&D
Germany	**11.11bn**	Non-exclusive, spread among 6 funds/programmes
Poland	**0.446bn**	Non-exclusive, available through 4 programmes and funds
Portugal	**0.525bn**	Exclusive for H2 production in the form of a variable feed-in-premium until 2030
United Kingdom	**2.35bn**	Non-exclusive funds through 13 funds, competitions and programmes

When the committed funds are a range, the median value of that range was used.

Hydrogen Europe

Thus, Ireland should commit dedicated funding to strategic hydrogen projects through Enterprise Ireland or SEAI or through the Climate Action Fund and the creation of a specific funding scheme to develop hydrogen markets and through a dedicated scheme similar to ORESS for floating offshore wind energy and hydrogen production.

Likewise, the support should be extended to action at European level where the participation of Irish stakeholders in European funding programmes is encouraged such as the Innovation Fund, the Clean Hydrogen Partnership programme and IPCEI.

For this, and in line with the recommendation on incentivizing the development of hydrogen valleys, political backing and buy-in of the general public for smooth and continuous project development is key, consequently, breaking down project barriers such as: securing public funding, securing off-take commitments, securing private funding and mitigating technological readiness and technological performance[120].

Hydrogen export from Ireland could be viable and at scale between 2030 & 2035. This leaves between 7 & 12years for Ireland to develop the international agreements, secure funding, & infrastructure planning and develop infrastructure and the capability to be able to export and compete with other countries globally.

[120] https://www.fch.europa.eu/sites/default/files/documents/20210527_Hydrogen_Valleys_final_ONLINE.pdf

6. Safety and Regulation

6.1 What is the appropriate safety framework for the future hydrogen economy?

Safety regulation should be considered holistically along the entire hydrogen value chain to ensure that interfaces are minimised, standards and requirements are both appropriate to the level of risk involved, but also consistent. The UK Hydrogen Strategy acknowledges the need to provide assurance on quality and safety in the early years. As with any nascent technology, rules and regulations will be required to facilitate the expansion of the hydrogen market up to 2030.

The final approach adopted should demonstrate that the level of personal and societal risk is as low as reasonably practicable that is explicitly accepted by the appropriate safety regulator. Although hydrogen has different characteristics compared to natural gas, they are closer in behaviour and risk than they are different.

Several key objectives must be considered in the design and implementation of a safety framework for a hydrogen economy, these include:

1. Timetable of policy and legislative changes needed to implement the safety framework and its regulation in line with forthcoming EU mandated obligations. There is merit is following the format of other national hydrogen strategies and including pre-2025 and post 2025 objectives.

2. The safety framework for hydrogen should be like the current natural gas safety framework and European Union COMAH Regulations (Control of Major Hazards involving Dangerous Substances), based on a goal setting, safety-case approach, and major accident prevention policy.

3. Given the broad range of sectors that will be considered in the introduction of hydrogen safety framework, the work programme for introducing legislation for an appropriate safety framework should be prioritised according to the projected hierarchy of demand.

4. The designation of a single authority for the regulation, implementation, and monitoring of the safety framework.

5. Many organisations involved in the production, distribution, transmission, storage, and use of hydrogen will likely come under the scope of the EU's Corporate Sustainability Reporting Directive. Obligated entities will need to report on an agreed set of EU standards, which will include safety metrics and providing assurance that safety standards are applied.

Against the backdrop of developing a **hierarchy of demand** for hydrogen, the safety framework must consider Ireland's projected demand profile in tandem with timeframes included in proposals for EU legislation. In terms of demand, further context regarding the EU's expected demand profile was provided in the European Commission's Hydrogen Strategy, highlighting hydrogen's important role in overall EU strategy for energy system integration.[121] It foresees the creation of new lead markets

[121] European Commission, A hydrogen strategy for a climate-neutral Europe, (COM(2020) 301 final)

concurrently with scaling up of the production of hydrogen. These include industrial applications and mobility, which can be gradually developed to use the potential of hydrogen cost-effectively.

Other national hydrogen strategies, including the German Hydrogen Strategy, point to sectors such as air and maritime transport or industries in which process-related emissions are unavoidable will be impossible or very difficult to electrify, even in the long term. This applies in particular to aviation, parts of heavy-duty transport and maritime transport. This is why the fossil input and fossil fuels need to be replaced by renewables-based alternatives, for example jet fuel produced through Power-to-X.[122]

With respect to Ireland's EU mandated obligations, a number of draft proposals are currently subject to discussion by EU legislators. These include the deployment of alternative fuels infrastructure, the so-called Alternative Fuels Infrastructure Regulation (AFIR)[123] and the Gas Package[124]. For example, AFIR will introduce new mandatory national targets for the deployment of sufficient alternative fuels infrastructure in the EU, for road vehicles, vessels and stationary aircraft. The Gas Package (when agreed at EU level) will establish the legislative basis for the decarbonisation of gas markets, including a common framework for establishing a hydrogen market. As was noted in the explanatory memorandum for the proposed Gas Regulation, barriers exist for the development of a cost-effective, cross-border hydrogen infrastructure and competitive hydrogen market. Facilitating a common approach in the applicability of a safety framework for hydrogen will be crucial in facilitating the uptake of hydrogen production and consumption.

Notwithstanding differences in existing gas infrastructure in various Member States, the safety framework must be based on robust analysis. In the UK, the Department of Business, Energy and Industrial Strategy (BEIS) is working with Health and Safety Executive (HSE) and industry to assess the potential for 20 per cent hydrogen blending into the gas network, and supporting the development of prototype 'hydrogen-ready' appliances such as boilers and cookers.[125] It points out that potential users must be able to purchase hydrogen-using equipment, with proper assurances about safety and reliability.[126] Under the UK Gas Safety (Management) Regulations 1996, hydrogen content in the gas networks is limited to 0.1 per cent by volume. The UK Hydrogen Strategy cites that any deliberate effort to safely blend new gases into the existing gas network therefore requires evidence gathering and HSE approval, prior to any live deployment.[127] In the Irish case, the consistent application of the safety parameters should apply to any entity along the hydrogen value chain, from production, transportation, storage etc., although there may need to be thresholds below which some requirements do not apply as is currently the case for COMAH sites.

Action 169 (*Develop Ireland's Gas Grid*) in Ireland's Climate Action Plan 2021 has been so important in building the foundations upon which to build the safety framework for hydrogen use. The requirement to test the technical feasibility of safely injecting green hydrogen blends in the gas grid and to assess

[122] German Hydrogen Strategy, 2020.

[123] European Commission, Deployment of alternative fuels infrastructure

[124] The Gas Package includes a Proposal for a Directive on common rules for the internal markets in renewable and natural gases and in hydrogen (COM/2021/803 final) and Proposal of the revised gas markets and hydrogen Regulation (COM/2021/804 final).

[125] BEIS, *UK Hydrogen Strategy,* August 2021.

[126] BEIS, *UK Hydrogen Strategy,* August 2021.

[127] BEIS, *UK Hydrogen Strategy,* August 2021.

the potential for energy system integration between the electricity and gas networks including the production, storage and use of green hydrogen will form the basis of working towards future obligations, such as the requirement for harmonised approach on blending hydrogen into the natural gas system (requirement for TSOs to accept blends of 5% hydrogen at Interconnection Points by 2025).

In looking to the German experience, its hydrogen strategy includes a commitment by the Federal Government to revisit and develop the regulatory framework and the technical requirements for the gas infrastructure. For example, it will examine whether natural gas pipelines which are no longer needed to transport natural gas can be converted into hydrogen infrastructure and investigate whether the compatibility of existing or upgraded gas infrastructure with hydrogen can be ensured.[128]

In the UK, a variety of joint government and industry research, development and testing projects are underway, designed to help determine the safety, feasibility, costs and benefits of converting the existing gas grid to carry 100 per cent hydrogen.[129] The German Hydrogen Strategy aims to its existing transport and distribution infrastructure and continue to ensure that the use of hydrogen applications is safe. This includes building and expanding a dedicated hydrogen network.[130]

With respect to hydrogen **storage**, notwithstanding the differences in gas storage infrastructure between Ireland and Great Britain, the UK government is promoting further research and innovation to increase the efficiency for hydrogen storage, develop the viability of more energy dense options at a variety of scales, and understand the safety and environmental impacts of different storage options.[131]

With respect to the development of a safety framework for a hydrogen economy, efforts to integrate electricity, heat, and gas infrastructure must be considered. For example, the Germany Hydrogen Strategy includes the aim is to shape the planning, financing, and the regulatory framework in a way that makes it possible to coordinate these different parts of the infrastructure and develop them as required in line with the needs of the energy transition and in a cost-efficient way.[132] The safety framework should also develop along these lines.

To date, Clean Hydrogen Joint Undertaking (formerly the Fuel Cells and Hydrogen Joint Undertaking – FCH JU) established the European Hydrogen Safety Panel (EHSP) in 2017. It has two main objectives: to address hydrogen safety as well as disseminating knowledge and a safety culture in the hydrogen value chain. This group could have important learnings for developing early stage safety frameworks.

[128] German Hydrogen Strategy, 2020.
[129] BEIS, *UK Hydrogen Strategy,* August 2021.
[130] German Hydrogen Strategy, 2020.
[131] BEIS, *UK Hydrogen Strategy,* August 2021.
[132] German Hydrogen Strategy, 2020.

Supporting policy and activity: what needs to be in place to deliver?

	Early 2020s (2021-2024)	Mid-2020s (2025-2027)
Regulatory frameworks	- Networks delivered through existing regulatory and legal framework - Regulatory signals (e.g. H2 readiness) in place - Wider standards (e,g. safety and purity) updated/in place - Critical first-of-a-kind deployment barriers addressed - Planning and permitting regimes in place - Necessary regulations, codes and standards addressed and in place	- Initial network regulatory and legal framework in place including potentially blending - Initial system operation in place - Further deployment barriers addressed – purity, installation, equipment - Gas billing methodology in place - Framework in place enabling cross-border pipeline/ shipping trade - Regulatory framework adapted as market matures

The UK Hydrogen Strategy includes a clear timeline of activities, including an update to safety standards as necessary in the early 2020s.

Through the Commissioner for Regulation of Utilities (CRU), Ireland already has put in place appropriate licensing, safety and environmental frameworks for the handling, transport and storage of molecular energy (gas). As the CRU[133] is Ireland's independent energy and water regulator, it has a wide range of economic, customer protection and safety responsibilities in energy and water. Specifically, u*nder the Gas Safety Framework,* the CRU has the statutory function to:

- Regulate the activities of gas undertakings with respect to safety. This includes gas network operators and gas suppliers;
- Regulate gas installers with respect to safety; and,
- Promote the safety of gas customers and the general public with regards to the shipping, supply, storage, transmission, distribution and use of natural gas.

With this comprehensive experience in all aspects of molecular energy licensing, transport and storage, including safety, it would be wholly appropriate that the remit of the CRU is properly expanded such that it is nominated by the Irish government as hydrogen safety regulator, charged with responsibility for the development, implementation and oversight of the hydrogen safety framework, including certification.

[133] CRU Gas Safety Framework for Professionals in the Energy Sector

6.2 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?

As outlined above, all functions relating to the development, implementation, and oversight of the hydrogen safety framework for the various elements of the future hydrogen economy should be carried out by one state entity nominated as the hydrogen safety regulator.

Recital 47 in the proposed Gas Directive introduces time limits for consenting and authorisation to allow the deployment of hydrogen production facilities and infrastructure at an adequate pace. While it specifically relates to consenting, it includes useful guidance as to expected development timelines. The suggestion that Member States report on its ability to meet these timelines, and the appointment of an administrative contact point (intended to reduce complexity for developers and increase efficiency and transparency) will also assist in securing finance for investment for the deployment of hydrogen and the associated infrastructure (recital 48). Article 7 of the revised Directive suggests an authorisation period of **no longer than two years** for projects to progress through all relevant procedures. Paragraph 3 permits an extension of up to one year, to be justified on the grounds of "extraordinary circumstances". Article 7 introduces a number of obligations on Member States to ensure that the existing authorisations under national law for the construction and operation of natural gas pipelines and other network assets also apply to pipelines and network assets for transport of hydrogen. Therefore, the safety framework must complement the objectives as set out in this section of the proposed Gas Package.

If different elements of the safety framework were to sit with different entities, this inevitably creates boundaries and differences in approach that would be to the detriment of both the hydrogen industry, but also to the general public. A single regulator is a far more attractive proposition for all stakeholders.

As the hydrogen economy is predicted to develop quickly over the coming decade and beyond, the hydrogen safety regulator should be sufficiently resourced to enable timely decision making.

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

The National Standards Authority of Ireland (NSAI) and the European Committee for Standardisation (CEN) are actively engaged in a standardisation programme related to necessary safety and technical standards required for hydrogen.

As referenced in the response to the first question in this section, Article 20 of the draft Directive in the proposed Gas Package states "Transmission system operators shall accept gas flows with a hydrogen content of up to 5% by volume at interconnection points between Union Member States in the natural gas system from 1 October 2025, subject to the procedure described in Article 19 of this Regulation."

- While Ireland is not directly connected to a Union Member State, it is connected indirectly via the UK (which in any case has confirmed that it will align with this ambition), so this timeframe provides a clear view of the European ambition to have blended hydrogen on existing gas networks.
- All the enabling legislative requirements, safety regulatory framework(s), standards, market arrangements, etc should be completed well in advance of the aforementioned date so that all regulatory approvals can be in place by then. These frameworks will enable (i) hydrogen blends to flow across the interconnector from the UK and (ii) indigenous renewable hydrogen to be injected into the national gas network in Ireland.
- European and Irish gas infrastructure technical standards will need to be updated to provide for blends of natural gas and hydrogen and for 100% hydrogen.

The German Hydrogen Strategy points to the need to avoid misallocated investments, whereby the transformation process that is required to enhance the hydrogen economy should be oriented to the demand that can be expected in view of the 2050 carbon neutrality goal.[134] The development of safety standards should also facilitate the export potential of hydrogen, to prevent unintended barriers to export.

[134] German Hydrogen Strategy, 2020.

7. Supports and Targets

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

- Important to consider what a future net zero energy system looks like, the scale of renewables and Hydrogen needed to achieve this and start building towards it now. To date Ireland have focused on delivering renewable electricity generation. Electrification has been identified as a key pathway to decarbonisation. Today [36%] of our electricity and c. 10% of our total energy is zero carbon.
- Delivering a secure Net Zero Energy system by 2050 requires Ireland to establish 4 critical pieces of infrastructure developed in tandem. All four are required for decarbonisation and a secure energy system
    - Build sufficient Renewables to deliver Ireland's total energy requirements. This requires significant development of offshore wind – more than 30 GW.
    - Build a H2 production capability of [15 GW] to convert zero carbon electricity into zero carbon green hydrogen. Green hydrogen can be used for energy requirements that cannot be electrified or stored for later use
    - Build seasonal hydrogen storage of c. 22 TWh to ensure that energy supply is secure in all seasons and when Ireland has a wind drought.
    - Develop or convert dispatchable generation capacity that can utilise green hydrogen as a fuel to produce electricity when wind is not available.
- Hydrogen must reach GW scale by the end of this decade, so it can make a material contribution to decarbonisation in the 2030s and beyond.
- The challenge is to ramp up a new industry from infancy to maturity.
- Transport fuel projects around 1MW are difficult to scale up. The key to growing an industry is 10-20MW scale projects in green hydrogen hubs or valleys or Clusters, followed by 50-100MW scale and then GW scale. Projects whose timing match this ramp up are the most valuable for the country. We may go on building small projects for many years, but they will not amount to an industry.
- **Set ambitious targets**[135] for each infrastructure element

[135] Denmark has a power system of similar size to Ireland: The government has pledged 4-6GW installed electrolyser capacity by 2030, with 7GW of announced projects in the pipeline for that timeframe.

	Govt 2030	recommended 2030	net zero electricity	net zero energy
Offshore Wind	7GW	9GW	15GW	30GW
H2 Production		2GW	>8GW	15GW
Zero-Carbon Power Generation		2GW	8GW	>10GW
Storage		2TWh	10TWh	>20TWh

*this graphic was used by ESB in presentation at Energy Ireland.

7.2 How should the deployment of hydrogen in Ireland be funded/supported?

- The task is to ramp up a new industry from infancy to maturity. That means policy needs to be agile and learn and change as the industry grows. The most appropriate support will change as the industry grows.
- We should expect a deployment / cost reduction curve similar to wind, batteries and solar. As costs come down new uses will become economic and the scale of the industry will grow and the mix of uses will change.
- In the early days every project needs an end to end package – production, logistics and end use, otherwise it may not be bankable.
- Eventually there will be a 'market price' for hydrogen. Until then price depends on when, where and what quantity is needed.
- Support for Green Hydrogen production
  - Create a flexible environment for delivery of 'first mover' projects to kick start the industry including:
    - Defer 'additionality' requirement until industry reaches scale
    - Defer rigorous temporal matching until industry reaches scale
  - Develop scheme for capital funding for renewable green Hydrogen production[136]
  - Contractual, producer focused CfD business model like GB[137]. (Whole life costs of hydrogen production is dominated by the cost of energy. A revenue subsidy per kg produced is more useful than a capital grant.)
    - The simplest subsidy is a fixed €/kg top up, awarded to a specific production plant for a 10+ year period. This should be awarded in a competitive process to ensure value for taxpayers.

[136] https://www.gov.uk/government/publications/net-zero-hydrogen-fund-strand-1-and-strand-2

[137] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1092369/hbm-nzhf-electrolytic-round-application-guidance.pdf

  - Every project is different and will experience price and volume risk in a unique way. Better to let developers and investors manage that for themselves and build it into the fixed rate subsidy they need, rather than complicate the subsidy mechanism.
  - Early adopters of hydrogen are not competing with the price of fossil fuels. However they are competing with later adopters who 'lock in' to a lower cost of production at a later date. This means a subsidy is required to overcome first mover dis-advantage.
  - Demand creation is critical to de-risk investment by Hydrogen producers
    - Set ambitious zero emission targets in transport starting with public transport and public sector
    - Set ambitious target for industry decarbonisation
    - Se a target for hydrogen storage
    - Set target date for net zero electricity system

- <u>Support for Green Hydrogen users</u>
  - Introduce a switching support for end users to allow for associated up-front costs for transitions switching to hydrogen where there is no alternative, more efficient decarbonisation solution.[138]
  - Transport end-user Switching Support
    - CAPEX funding for vehicles - differential between FCEV and fossil equivalent
    - In the absence of public HRS network, some fleet operators will require support (CAPEX) to modify their depots to facilitate storage and dispensing of hydrogen for FCEV.
    - CAPEX will be needed to support development of public network of Hydrogen Refuelling Station (HRS) as required under Alternative Fuels Infrastructure Regulation
  - Industry End-user Switching Support
    - Provide DEVEX funding (development expenditure) for Front End Engineering Design (FEED) studies and post FEED costs.
    - Provide CAPEX for plant modifications including associated OPEX
    - Incentivise grid connected, Zero Carbon back up generation including Data centres
  - Rapid scaling and lower costs can be realised by an agreement or partnership at Governmental level with other EU nations for Hydrogen exports, if this does not compromise achievement of national renewable targets/ carbon budgets
- <u>Support for green hydrogen storage</u>
  - Accelerate leasing and licensing for hydrogen and ammonia storage
  - Create a RAB model for the provision of geological sub-sea gas storage.
- <u>Support for green hydrogen power generation</u>

[138] https://www.gov.uk/government/publications/industrial-fuel-switching-competition

    - Create a new market mechanism for the delivery of a zero-carbon dispatchable generation
    - Incentivise existing gas power plant to transition to Hydrogen
    - Existing Plant Switching Support
        - Further 10yr Zero Carbon capacity contracts with allowances for CAPEX investment for plant modification to safely operate with H2/ H2 blend
        - Energy market mechanism should reward low carbon dispatchable generators
    - New Entrants
        - Create targets and a ring-fenced capacity market allocation for new zero-carbon dispatchable generation
        - Rigorously define Hydrogen Capable/Ready for all new generation assets
        - Create a mechanism to incentivise incremental investment in Hydrogen Readiness that will not disadvantage auction competitiveness
        - All new industry backup power generation should be grid connected and zero carbon

7.3 What are the potential policy options for incentivising for hydrogen end-uses?

- Demand creation is critical to de-risk investment by Hydrogen producers
    - Set ambitious zero emission targets in transport starting with public transport and public sector
    - Set ambitious target for industry decarbonisation
    - Set target date for net zero electricity system
- Develop a hierarchy of use of renewable Hydrogen, based on identification of high value/ efficient applications, focussing on sectors without alternative options for decarbonisation
    - Heavy Transport
    - Industry – Cement/Alumina/Glass/Fertilizer
    - Power Generation – Dispatchable backup
    - Export - Build scale in Hydrogen/Renewables
- Set Zero-Emissions targets of 2030 for ALL public vehicles in our urban centres including the bus/train fleet (to stimulate battery electric vehicles & green hydrogen fuel cell electric vehicles)
- Promote demand in a clustered or hub approach with three Hydrogen Valleys based around specific areas (e.g. Galway, Dublin, Cork, Shannon Estuary) dedicated to industrial processes capable of decarbonising with a dedicated Hydrogen fuel and new industries such as e-fuels/ fertiliser based on renewable Hydrogen from offshore wind energy.

Pricing

1. *Develop green hydrogen fuel pricing structures, ensuring that zero carbon fuel production and use is supported, and uptake encouraged, in conjunction with implementing carbon floor pricing of fossil fuels with increasing carbon pricing towards 2030.*

Transport

Transport accounts for over 40 per cent of our energy related CO2 emissions in Ireland. HGVs currently account for 15 per cent of transport energy demand.

The Department of Transport Renewable Fuels for Transport Policy Statement November 2021:

Green hydrogen produced through electrolysis using renewable electricity will be supported through quadruple credits, as set out in Sections 13 and 14 of the Transport Policy Statement.

Section 13 of the Transport Policy Statement: Inclusion of Renewable Fuels of Non-Biological Origin, Fuels such as green hydrogen (produced using renewable electricity) and synthetic fuels produced from green hydrogen will be eligible for credits. Subject to enabling legislation, RFNBOs will become eligible for credit under the scheme from 1 January 2023.

Section 14 of the Transport Policy Statement: Treatment of Development Renewable Fuels refers to a category for certain renewable fuels called 'Development Renewable Fuels' will be added to the scheme and multiple credit will be awarded to incentivise their deployment. Subject to enabling legislation, the highest level of credit proposed among the fuels in question applies to Green Hydrogen, and the credit multiplier to apply from 1 January 2023 is x4.

While the credit level to which the multiplier will apply remains to be determined, this Transport Policy initiative is welcomed by Hydrogen Ireland as indicating an important commitment to facilitating and supporting the production and use of green hydrogen in Ireland. It is noted that the proposed credits would usefully be considered about the production, fuelling infrastructure and end users of green hydrogen, not only in public, commercial, and private transport, but also in other Group 1 sectors of the economy including Electricity, Buildings, Industry/Enterprise, and Agriculture.

It is requested that recommendations on the profile, sustainability, and supply of green hydrogen as a renewable ultra-low carbon transport fuel are also brought forward for implementation on 1 January 2023.

Recently announced supports for taxis[139] apply to grants will enable owners of small public service vehicles (SPSV), such as taxis and hackneys, to buy electric vehicles (EVs). It is recommended that supports for EVs should be extended to Hydrogen fuel cell EVs (FCEVs), as FCEVs are increasingly becoming available as detailed in the IERC paper Hydrogen in the Irish Energy Transition: Opportunities and Challenges,

Against the backdrop of the requirement to meet RED II obligations, the need for hydrogen refuelling infrastructure is bolstered by the European Commission's proposal on a Regulation for

[139] https://www.gov.ie/en/press-release/f1623-up-to-25000-for-taxi-drivers-to-buy-electric-vehicles/

Alternative Fuels Infrastructure. Part of the Fit for 55 package, Article 6 contains provisions for Member States to ensure minimum coverage of publicly accessible refuelling points for hydrogen dedicated to heavy and light-duty vehicles on the TEN-T core and comprehensive network. Subject to agreement at EU level, these refuelling points are to be in place by 31 December 2030. Member States will therefore have a mandatory obligation to provide this refuelling infrastructure.

Agriculture

- *Approved community gain project types for new onshore wind and solar farm developments should be extended to include green hydrogen projects, to support and supply local community needs for transport and heating.*
- *Supports for the use of green hydrogen in farm machinery and energy supply should be considered and implemented in the agriculture and horticulture sectors and should include supports for renewable energy coupled with green hydrogen production at individual farm, rural community, and agricultural co-operative level.*
- *Policy and grant support for decarbonised domestic and commercial heating should target zero emission technology and should include supports for green hydrogen compatible central heating boilers for use in domestic and commercial heating and supports for the early provision of a guaranteed green hydrogen fuel supply. Pilot projects should be advertised, promoted, and initiated throughout Ireland.*

7.4 How should green hydrogen be incentivised in the electricity market?

- A secure, resilient, reliable Net-Zero energy system is not possible without a backup Power Generation fleet that is fuelled by a Zero-Carbon source (Hydrogen)
- Implement ambitious targets for CO2 grid intensity to create demand for dispatchable Hydrogen power generation
- Create a new market mechanism for the delivery of a zero-carbon dispatchable generation
- Incentivise existing gas power plant to transition to Hydrogen
- Promote zero-carbon dispatchable power generation at three Hydrogen Valleys based around Dublin, Cork, Shannon Estuary dedicated to large scale production, storage and use of renewable H2 from offshore wind energy

7.5 What policies should be put in place to develop further hydrogen-based enterprises?

As discussed in section 1, Ireland must support Research & development and innovation at every level of the economy, and this will support renewable business growth and a green hydrogen industry growth:

Ireland must compliment the EU activities in the following Hydrogen Research and Innovation priority areas:

- Support Innovative high end electrolyser Manufacturing; including Electrolyser Gigafactory &/or complementary high end hydrogen technology manufacture in Ireland (similar to Ireland's Pharmaceutical & Medical device Industry of today, drawing top global companies & inward investment[140*])
- Support, Develop & Scale of Hydrogen Hubs/Valleys & Renewable hydrogen production, storage, transmission, and distribution
- Support, Develop & Scale Demand for renewable hydrogen, e.g.:
    - Industry heat - Alumina & cement production using hydrogen as a heat source in place of fossil gas
    - Industry electricity – datacentres using hydrogen as a source for onsite generation in place of fossil gas
    - Energy - Large scale storage (TWhr) of renewable hydrogen and regeneration to electricity at grid scale plus smaller step-down hydrogen storage in areas not connected to the grid
    - Drop in efuel – e-kerosene or e-methanol manufacture from green hydrogen & biogenic carbon for aviation fuel & for export
    - Decarbonised Transport – hydrogen directly for road freight & Rail
- Develop a supportive hydrogen regulatory & policy environment
- Facilitate public acceptance, training & education

[140*] Ireland has successfully grown the pharmaceutical and medical technology bases in Ireland to over €70Bn annually.

Support Hydrogen Education & Training Programmes to support jobs and innovation in Ireland's hydrogen industry

The hydrogen sector, being a key component of the clean energy transition, faces challenges of its own pertaining to the need for qualified professionals. Global management consulting firm McKinsey & Company[141] foresees the creation of 5 million jobs related to hydrogen by 2050 worldwide, while Navigant's Gas for Climate analysis[142] forecasts up to 2.4 million new positions in the EU by the same year because of scaling up "renewable gases. The European Commission estimates that, for every €1 billion invested in hydrogen, 10,300 direct and indirect jobs could be created. This future workforce needs to be prepared, competent and capable of working with hydrogen technologies in a safe and efficient way. Some of the jobs which will be critical to help the EU achieve the ambitious targets set in its Hydrogen Strategy will relate to areas such as: the installation, operation, and maintenance of hydrogen technologies such as electrolysers, fuel cells and hydrogen combustion systems; hydrogen compression and storage; transportation and delivery of hydrogen; the manufacturing and use of hydrogen sensors and detectors to enable safe operations; amongst others. In addition, research and high-level education on hydrogen will continue to prove essential for the support, dissemination, and innovation of this future hydrogen infrastructure. The following is a brief compilation of institutions across Ireland / NIUK that offer hydrogen education and training courses and programmes. For further information, relevant links and websites are provided.

- **Belfast Metropolitan College**

Belfast Met through its international project work in GenComm, SMART H2, HAZEL and other hydrogen initiatives have developed a suite of training and upskilling modules for curriculum development and industry. The college is also developing H2 CAT – the catalyst for supporting and empowering industry to capture the full economic, social, and environmental benefits of renewable energy systems and drive sustainable economic development.

https://www.nweurope.eu/projects/project-search/gencomm-generating-energy-secure-communities/

141 https://www.mckinsey.com/business-functions/sustainability/our-insights/the-economic-transformation-what-would-change-in-the-net-zero-transition

142 https://gasforclimate2050.eu/wp-content/uploads/2020/03/Navigant-Gas-for-Climate-Job-creation-by-scaling-up-renewable-gas-in-Europe.pdf

- **Dublin City University**

DCU is a major centre of hydrogen research in Ireland and a founding organisation of Hydrogen Ireland. It offers a Graduate Diploma in Sustainable Energy Systems, which prepares graduates to meet the challenges of transitioning to net-zero carbon and explores energy vectors such as hydrogen. https://springboardcourses.ie/details/10000

- **University of Galway**

The University of Galway is a major centre of hydrogen research in Ireland and a founding organisation of Hydrogen Ireland. It offers Level 8 Bachelors and Level 9 master's degrees in Energy Systems Engineering. These are highly interdisciplinary programmes of study and are accredited by Engineers Ireland.

https://www.nuigalway.ie/courses/undergraduate-courses/energy-systems-engineering.html

- **The Hydrogen Training Academy**

Led by Mid & East Antrim Council, based in Ballymena, Northern Ireland, the recently launched Academy aims to deliver hydrogen training in partnership with Belfast Met, Northern Regional College and the University of Birmingham helping industry pivot to the new green economy.

https://investmideastantrim.com/economic-drivers/hydrogen-training-academy/

- **Queen's University Belfast**

QUB has a PGCert in Hydrogen Energy Systems, which provides learners with essential skills needed to support the growth of the hydrogen economy. https://www.qub.ac.uk/Study/skill-up-flexible-skills-fund/green-technologies/hydrogen-energy-systems-pgcert/

- **Ulster University**

The Northern Irish university established its Hydrogen Safety Engineering and Research Centre (HySAFER) in 2008 and currently offers two postgraduate courses focused on hydrogen safety.

https://www.ulster.ac.uk/research/topic/built-environment/hydrogen-safety-engineering

- **The HySkills programme**

A collaborative Erasmus+ project working towards the creation of critically safe technical training for the hydrogen workforce. Open-source materials developed by institutions such as DCU, including an 8-module course, will be available from 2023. https://twitter.com/hy_skills

- **The GreenTECH Skill Net programme**

Run in conjunction with WEI & GDG presents an introductory course on hydrogen https://www.greentechskillnet.com/introduction-to-green-hydrogen1

7.6 How could supports and targets account for cross sectoral deployment of hydrogen?

- Hydrogen Hubs or Clusters or Valleys are “bottom-up “creators of local acceptance and awareness of the importance of hydrogen for the clean energy transition. Through local value creation, additional job creation, the improvement in air quality and the resulting visibility, Hydrogen Valleys can pave the way for the full roll-out of a global market by showcasing its potential on an increasing scale.
- In Ireland, promote demand in a clustered approach with three Hydrogen Valley dedicated to industrial processes capable of decarbonising with a dedicated Hydrogen fuel and new industries such as e-fuels/ fertiliser based on renewable hydrogen from offshore wind energy
- Learn from others about effective policy recommendations for developing Hydrogen valleys[143]
    - Create a clear vision of the Ireland’s future hydrogen economy in a national hydrogen strategy that sets the framework for Hydrogen Valley development
    - Create a regulatory environment conducive to the development of Hydrogen Valleys by creating business certainty as well as adequate incentive and support schemes
    - Close the gaps in (or amending) permitting procedures for Hydrogen Valleys

[143] https://www.clean-hydrogen.europa.eu/system/files/2021-06/20210527_Hydrogen_Valleys_final_ONLINE.pdf

8. Energy Security

8.1 What contribution could domestic green hydrogen supply make towards Irelands energy security?

The War in Ukraine has focused Europe's approach to where and from whom and what fuel is necessary for Europe. The war has escalated fossil gas prices to unprecedented levels, affecting every customer including Ireland. The gas price at its current level may be a new normal or it may reduce to a lower level but in 2022 & expected 2023 the prices are expected to remain very high[144].

Fossil gas presently backs up Ireland's electricity system 40% are renewable where 60% comes from fossil gas, imported from UK (not a EU country). Irelands only gas reserve, Corrib is on a downward trajectory and will be exhausted c.2030.

Minister Eamon Ryan highlighted the concerns of entering winter2022 and the short-term measures that will be enacted[145]. However medium-term action is imperative & necessary to avert further crises in the coming years. This action must secure low cost & low carbon indigenous electricity (renewables), it must also build more electrical infrastructure to allow the efficient use of electricity when it is available; but it also must replace the backup (when the wind does not blow) currently 60% gas need, reliant on imported fossil gas, with green electricity and heat backup; green hydrogen is a complimentary for Ireland and as mentioned in previous sections not only serves one sector of the energy system but multiple energy sectors and industrial sectors.

8.2 What role could hydrogen storage play regarding security of supply?

Ireland's energy system will require large scale storage, multi TWhr, solutions to address the intermittency of renewable power, as well as the plans for significant green hydrogen utilisation over the coming decade.

Geological hydrogen storage on the island and in the republic of Ireland (as mentioned & referenced in the storage section above) is viable and at lower cost than other forms, including importing fuel from outside the state.

The capability of national geological hydrogen storage scaled to between 10-22TWhrs would enable >90days of electricity backup (when the wind does not blow) and enable industry & transport to use it.

This would ensure Ireland can have the necessary capability to achieve net zero emissions reductions, ensure stable energy prices for customers but also be capable to effectively plan and enable national secure capability in any crisis or if any unprecedented circumstance arises.

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[144] https://www.bnnbloomberg.ca/natural-gas-soars-700-becoming-driving-force-in-the-new-cold-war-1.1787721

[145] https://data.oireachtas.ie/ie/oireachtas/committee/dail/33/joint_committee_on_environment_and_climate_action/submissions/2022/2022-08-30_opening-statement-eamon-ryan-t-d-minister-for-the-environment-climate-and-communications_en.pdf

Appendix A

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