Submission to the Consultation on developing a Hydrogen Strategy for Ireland

Prepared by Codema - Dublin's Energy Agency

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Background

Codema - Dublin's Energy Agency is a not-for-profit company limited by guarantee and was founded in 1997. We are the energy agency to the four Local Authorities in Dublin, and **our mission is to accelerate Dublin's low-carbon transition through innovative, local-level energy and climate change research, planning, engagement, and project delivery**, in order to mitigate the effects of climate change and improve the lives of citizens. We are the Dublin Local Authority's one-stop-shop for developing pathways and projects to achieve their carbon reduction and climate targets. Examples of Codema's work include energy master planning, district heating system analysis, energy performance contracting, management of European projects, energy saving behavioural campaigns and detailed energy reviews. Codema is well networked in Europe and has been very successful in bringing European projects to Dublin with a local implementation for the Local Authorities.

Context

Codema welcomes the opportunity to make a submission to this consultation process. **Codema's interest in the Hydrogen Strategy stems from our current sector integration research involving hydrogen and district heating**, **our analysis of energy use and emissions from heating systems, and the development of cost-optimal heating technology pathways for the Dublin region**. Our research and practical experience of developing projects allows us to advise on local level low-carbon policies which aim to reduce energy, fossil fuel use and associated costs & emissions. We have more than 20 years' experience in the climate change and energy sector.

Codema's Experience in Heat Sector Debarbonisaion Pathway Analysis and Spatial Energy Planning

Codema are Ireland's leading experts in the area of spatial energy master-planning. As part of our work on the Dublin Region Energy Masterplan (DREM) we have assessed cost-optimal, technically feasible decarbonisation pathways for the heat, electricity and transport sectors in Dublin to 2030 and 2050. The masterplan addresses all energy sectors of electricity, heat and transport, and crucially has been modelled from a spatial perspective as well as from a technology perspective.

The analysis is at a granular spatial level called the 'small area' level[1]. This project also identifies and supports the use of low-carbon sources indigenous to Dublin, develops and harnesses new local level energy policy practices, and strengthens Ireland's integrated energy system modelling capabilities.

The pathways developed as part of the masterplan are based on detailed local-level, spatially driven energy scenario modelling, which has not been carried out before for any county in Ireland. This innovative local-level energy planning methodology builds upon leading international-class energy research in the area, and findings from the DREM have already been directly applied and demonstrated by the Dublin Local Authorities.

[1] Small Areas are areas of population generally comprising between 80 and 120 dwellings created by The National Institute of Regional and Spatial Analysis (NIRSA) on behalf of the Ordnance Survey Ireland (OSi) in consultation with CSO.

This work presents a set of clear, evidence-based pathways, which will enable the Dublin region to create effective, long-term energy policy in areas such as spatial planning, land-use, and public infrastructure. In addition to this the work also presents a geographic analysis of the current situation for energy use, along with additional spatial data layers to facilitate contextual analysis[2]. The results of the DREM will allow local authorities to effectively create evidence-based policies and actions to affect CO_2 emissions county-wide, by using the local authority's powers in spatial planning, land-use, planning policy and public infrastructure.

Codema's Experience in District Heating

Codema is Ireland's leading expert in District Heating research and project implementation. We have built the evidence-base to support the roll-out of DH in Dublin, developing the first heat demand and heat source maps in Ireland, based on European best practice methodologies. We have identified potential projects across Dublin and, working with Local Authority project champions, have **brought projects from idea to reality; from pre-feasibility, techno-economic analysis, business case through to securing funding, procurement, contracting and delivery**. We are the Dublin Local Authority's one-stop-shop for the roll-out of DH projects, and have supported South Dublin County Council in the development of the Tallaght District Heating, and Dublin City Council in the planning for the Dublin District Heating Scheme, centred in Poolbeg.

2 https://codema-dev.github.io/posts/

Executive Summary

Research & Development

There are several key areas in which hydrogen (H2) research and development should focus on in Ireland. These also align with Codema's vision for hydrogen end use and should be supported by spatial energy planning principles. Local-level **studies exploring sector integration opportunities** for H2 such as the 'Poolbeg sector integration project' [3] should be prioritised to maximise the carbon abatement potential of the technology. The **synergy between district heating (DH) and H2 production should be explored** based on the potential to recover waste heat from electrolysers. All H2 projects in the country should become integrated parts of local heat planning and this synergy could yield additional revenue for the H2 producer and low-cost green heat for the DH network.

H2 sector integration opportunities could also extend to transport and electricity. Further research should be undertaken into using H2 to decarbonise Ireland's **shipping** (passenger and freight) and **aviation** industries due to the improbability of electrifying these modes of transport. The co-location of H2 production near busy ports and airports is an important area to explore to reduce the infrastructure costs associated with H2 transport and storage. Applying spatial energy planning principles to create 'Hydrogen Hubs' is an important area which could also examine how green H2 can replace industrial products that currently utilise fossil / grey H2. Codema also supports research into using H2 for **certain industrial processes that require high temperature heat not suitable for electrification** (or as a feedstock), along with research into H2 for long term power storage.

Hydrogen Demand

Codema believes that the end use of green hydrogen should be based on maximising its potential for carbon abatement in difficult to decarbonise sectors. As a high-exergy fuel, **Hydrogen should not be used for low-exergy applications like space heating and hot water preparation where more efficient and lower-carbon alternatives exist** (e.g., heat pumps, district heating). Scenarios that come closest to carbon budget limits involve high deployment of district heat networks, and high levels of electrification of heat. Supporting this finding, recent analysis from Codema's Dublin Regional Energy Masterplan [4], shows that **district heat and heat pumps are the most effective technologies for decarbonisation of residential, commercial and public sector heat** in Dublin - approximately 87% of heat demand in the capital is suitable for district heating by 2050.

Codema considers that a 'multiplier' for green hydrogen (analogous to that used for some forms of biofuel under the EU Renewable Energy Directive, and as proposed in the 2021 Renewable Heat Obligation consultation) is not a suitable policy option for incentivisation of green hydrogen. Experience has shown that allocating multipliers to energy sources distorts the accounting processes for understanding renewable energy shares of these and other energy sources[5]. Codema considers that alternative policy options should be explored.

[3] https://www.codema.ie/projects/local-projects/integration-of-heat-electricity-and-transport-use-of-curtailed-renewable-en

[4] https://www.codema.ie/projects/local-projects/dublin-region-energy-master-plan/

[5] https://en.euractiv.eu/wp-content/uploads/sites/2/special-report/RED-III-Europes-reality-check-Special-Report-1.pdf

Hydrogen Supply, Transportation, Storage and Safety

Codema recognises a role for developing a future gas transmission network compatible with green hydrogen. This must include **planning for future decommissioning of the gas network where it currently serves space heating and hot water needs** in the residential, commercial, and public sectors, **while simultaneously examining the potential for dedicated hydrogen pipelines to serve hard to decarbonise end-uses**. This is an important route to investigate to minimise delayed climate action and risk of not aligning with carbon budgets, in comparison to research and investigation into raising blending thresholds in the gas network.

According to the SEAI National Heat Study [6], the most cost-effective, and lowest cumulative emission pathways for decarbonisation of the heat sector involve significant scaling back of the gas distribution network serving the residential, commercial, and public sectors on the path to 2050. Phase out dates for use of fossil fuel boilers are in the 2026 - 2035 time range to allow us to meet decarbonisation targets. Consequently, decommissioning of the fossil gas distribution network serving these sectors should also be planned in a comparable time frame.

Hydrogen is an **indirect greenhouse gas** with a global warming potential GWP of 11 over a 100-year time horizon [7]. A future hydrogen economy would therefore have greenhouse consequences and would not be free from climate perturbations. Burning hydrogen can also result in NOx emission up to six times higher than fossil gas boilers and burning hydrogen-based e-fuels produces similar emissions to fossil-based fuels [8]. The global warming potential (GWP) of NOx is estimated as GWP 30 - 33 and 7 - 10 for the respective time horizons of 20 and 100 years and is thereby comparable to that of methane. **NOx is also a main cause of poor air quality** which impacts people's health in dense urban areas. Careful planning for mitigation of these adverse effects, where possible, is required.

[6] https://www.seai.ie/data-and-insights/national-heat-study/
[7] https://www.gov.uk/government/publications/atmospheric-implications-of-increased-hydrogen-use
[8] https://www.google.com/url?q=https://www.transportenvironment.org/discover/in-tests-cars-powered-by-e-petrol-pollute-the-air-as-much-as-petrol/

Responses to Consultation Questions

6. Research & Development - Stakeholder views are sought on:

Which areas of hydrogen research require further examination?

- **Opportunities for the recovery of waste heat from hydrogen production**.
  Various literature sources suggest that the system efficiency of electrolyser plants can increase by 14 to 32% by recovering waste heat [9]. There are potential opportunities for co-location of hydrogen production and district heating, where hydrogen production is sited close to concentrations of heat demand, waste heat could supply heat to homes and businesses and offer increased decarbonisation for H2 technology.

- **Local-level studies exploring localised sector integration opportunities for Hydrogen**
  Research into the area of sector integration is essential for the deployment of hydrogen as technology. The Hydrogen valley / hub approach noted in the consultation document could benefit from specific studies into sector integration opportunities in these areas and how Hydrogen could integrate into the current and future energy landscape of these zones.
  As an example, Codema are currently involved in a project examining the potential for coupling and integrating separate aspects of the electricity, heat, and transport sectors[10]. The project will explore how district heat with thermal storage, and a separate hydrogen electrolyser, along with curtailed renewable electricity and hydrogen end-use applications, can provide an efficient, holistic, and integrated energy system solution. More projects of this type will benefit Hydrogen delivery planning.

What can an Irish hydrogen strategy do to drive innovation?

- A clear delivery framework and strategic direction for hydrogen development must include defined research priorities and directions. This is essential to guide and focus research, development and innovation into areas that will most support delivering Ireland's hydrogen vision. A hydrogen strategy will also help to remove demand uncertainty for investors and developers, facilitating research innovation to cascade into business innovation, and better project delivery.

- Codema also believes that a Hydrogen strategy could benefit from a space for citizen voice in the innovation and delivery process, to support delivery of solutions and infrastructure that work at a citizen level and have public acceptance.

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

- **Research into each hydrogen end-use should be supported by spatial energy planning principles.** This will support identification of how each hydrogen end-use fits into the local energy system context and what sector integration opportunities exist. This is important as sector integration is a key EU strategy, and hydrogen use is likely to be clustered in zones,

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[9] https://storbritannien.um.dk/en/-/media/country-sites/storbritannien-en/trade-council/main-report_heat-recovery-from-hydrogen-production.ashx

[10] https://www.codema.ie/projects/local-projects/integration-of-heat-electricity-and-transport-use-of-curtailed-renewable-en/

leading to strong potential for local-level synergies that further support hydrogen delivery in these strategic zones. An example to be built on is the recent SEAI funded sector integration study led by Codema, examining the sector integration opportunities for curtailed wind, green hydrogen, and district heat[11].

- **Research into inter-seasonal and long-term storage of Hydrogen.** Energy security is an increasingly important issue in today's energy climate. Ireland is quite reliant on fossil imports to meet its energy needs, a fact that has been highlighted during the ongoing invasion of Ukraine by Russia. The production of indigenous sources of energy is paramount to the security of supply and therefore, so too is research into the use of hydrogen as a long-term storage option and energy carrier in Ireland.

- **Research, demonstration, and planning for how green hydrogen can replace industrial products that currently utilise fossil / grey hydrogen.** There is currently only one significant domestic user of grey hydrogen in Ireland, the Whitegate refinery in Cork. This facility both produces and uses hydrogen in its refining process. Part of the facility's existing hydrogen demand is to produce hydrogenated vegetable oil (HVO) and Fatty Acid Methyl Ester (FAME), biofuels which can replace or be blended with fossil diesel. Green hydrogen could be used in this process to rapidly increase biofuel production from wastes at this location and directly compete with fossil fuels in the transport sector. The Whitegate facility is expected to be central to the early development of Ireland's green hydrogen economy so existing expertise and infrastructure must be leveraged.

- **Further research into opportunities and synergies for hydrogen or hydrogen products to decarbonise the shipping sector.** The decarbonisation of freight shipping could also offer potential as the electrolysers linked to offshore wind farms could be co-located with busy ports such as those in Dublin, Galway, and Cork. Current ships are often run on 'bunker fuel' which is a particular carbon intensive hydrocarbon. Global shipping also offers a method of transporting liquid hydrogen to mainland Europe which would be another benefit of co-locating electrolysers near shipping ports. The co-location of these 'installations' could also be connected to a local district heating scheme to improve the efficiency of the electrolyser along with providing low-carbon heat to nearby homes and businesses. This has added advantages as it is expected that by 2050, electrolysis could consume 20% of global electricity supply and the additional strain on the electricity grid could be avoided if electrolysers are located near wind farms.

- **Further research into opportunities for hydrogen to decarbonise the aviation sector.** The application of hydrogen in the aviation industry is another area which should be prioritised. Ireland has one of the largest European airlines in Ryanair whose headquarters are based here. Due to its high energy density (KWh/kg) relative to other carbon neutral options for aviation, H2 has significant potential to help the industry achieve its goal of carbon neutral commercial flights by 2050.

[11] https://www.codema.ie/projects/local-projects/integration-of-heat-electricity-and-transport-use-of-curtailed-renewable-en

7. Hydrogen Demand - Stakeholder views are sought on:

What end-uses are there for hydrogen in Ireland (i.e., where hydrogen will be used)?
Green hydrogen is most suitable for hard-to-decarbonise end-uses where other currently available decarbonisation options are not suitable. This includes:

- H2 for long term storage / security of energy supply
- H2 as a fuel for freight shipping / ferries
- H2 as a fuel for heavy goods vehicles and buses, pending development and suitability of electric options (where battery electric and 'electric road' options such as overhead catenary or induction are not feasible).
- H2 as a fuel for aviation
- H2 for HVO (Hydrotreated Vegetable Oil) and FAME (Fatty Acid Methyl Ester) biofuel production from wastes (3rd Generation Biofuels)
- H2 for certain industrial processes that require high temperature heat not suitable for electrification (or as a feedstock).

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

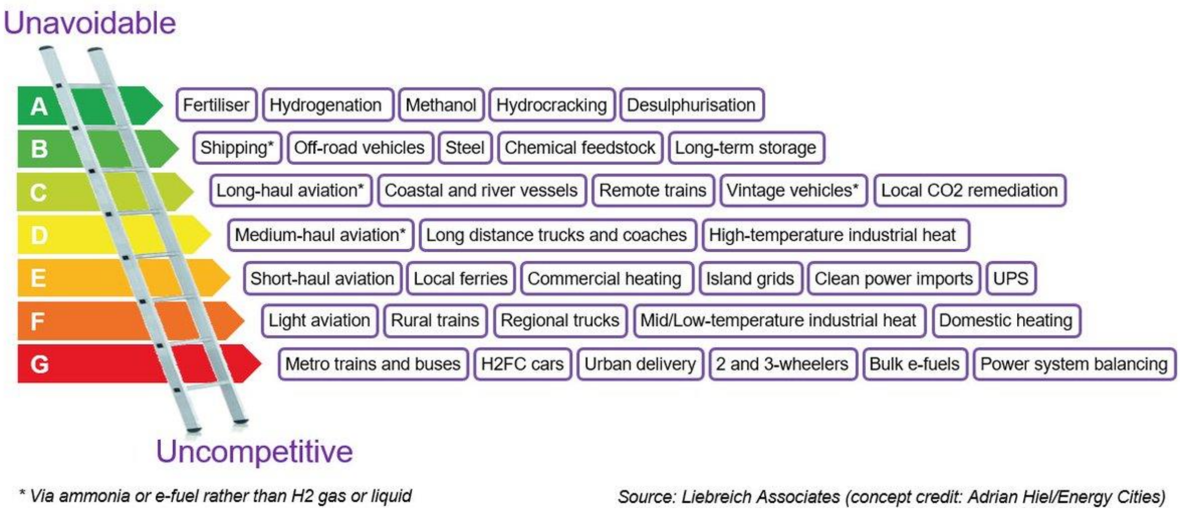

Figure 3: Hydrogen Ladder Ranking Potential Viable Uses of Green Hydrogen (Source: Liebrich Associates)

Codema supports the principle of identifying a prioritisation list for utilisation of green hydrogen in Ireland, in a similar manner to the figure above. The end use of green hydrogen should be based on maximising its potential for carbon abatement in difficult to decarbonise sectors. Higher priority areas for further investigation are suggested below:

- H2 for long term storage / security of energy supply
- Liquid H2 as a fuel for freight shipping / ferries
- Liquid H2 as a fuel for heavy goods vehicles and buses, pending development and suitability of electric options (where battery electric and 'electric road' options such as overhead catenary or induction are not feasible).
- Liquid H2 as a fuel for aviation
- H2 for HVO and FAME biofuel production from wastes (3rd Generation Biofuels)
- H2 for certain industrial processes that require high temperature heat not suitable for electrification (or as a feedstock).

Much recent evidence highlights that green hydrogen is not a suitable decarbonisation method for space heating or hot water in the residential, commercial, and public sectors, as other more cost-effective and lower carbon options exist.

According to the SEAI National Heat Study the most cost-effective, and lowest cumulative emission pathways for decarbonisation of the heat sector involve significant scaling back of the gas distribution network serving the residential, commercial, and public sectors on the path to 2050[12].

The study shows that decarbonisation pathways that rely on large scale decarbonised gases are more expensive, involve more cumulative emissions than alternative decarbonisation pathways, are not compatible with carbon budgets applied pro-rata to the heat sector, and see delayed action in comparison with other pathways.

Scenarios that come closest to carbon budget limits involve high deployment of district heat networks, and high levels of electrification of heat. Supporting this finding, recent analysis from Codema's Dublin Regional Energy Masterplan[13] shows that district heat and heat pumps are the most effective technologies for decarbonisation of heat in Dublin - approximately 87% of heat demand in the capital is suitable for district heating by 2050.

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

Codema considers that a 'multiplier' for green hydrogen (analogous to that used for some forms of biofuel under the EU Renewable Energy directive, and as proposed in the 2021 Renewable Heat Obligation consultation) is not a suitable policy option for incentivisation of green hydrogen. Experience has shown that allocating multipliers to energy sources distorts the accounting processes for understanding renewable energy shares of these and other energy sources. This makes it harder to understand and compare progress in implementation of renewables more broadly[14]. Codema considers that alternative policy options such as grants, and tariffs should be explored.

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

The application of hydrogen as a technology could be focused around "hydrogen hubs". These are areas where heavy industry, particularly chemicals, fertilizer, refineries, and other high temperature heat users come together with shipping, freight transport, pipeline, and power infrastructure. Examples of research into these synergies are the SEAI funded 'Poolbeg sector integration study[15]' led by Codema in partnership with Mullan Grid, and support from DCU. 'Poolbeg Integration Study' in Dublin and 'GH2' in Galway[16].

[12] https://www.seai.ie/data-and-insights/national-heat-study/
[13] https://www.codema.ie/projects/local-projects/dublin-region-energy-master-plan/
[14] https://en.euractiv.eu/wp-content/uploads/sites/2/special-report/RED-III-Europes-reality-check-Special-Report-1.pdf
[15] https://www.codema.ie/projects/local-projects/integration-of-heat-electricity-and-transport-use-of-curtailed-renewable-en
[16] https://impact.nuigalway.ie/news/finally-irelands-first-hydrogen-valley/

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

1. H2 for long term storage / security of energy supply - Replace existing 'Peaker plants' (oil / diesel), and thermal generation plants (gas / coal)
2. H2 as a fuel for shipping - Heavy fuel oil (bunker fuel)
3. H2 as a fuel for heavy goods vehicles and buses - Diesel / LNG /CNG
4. H2 as a fuel for aviation - Jet Fuel (Kerosene)
5. Liquid H2 for HVO and FAME biofuel production - Production of H2 using Steam Methane Reforming (CH4) replaced by electrolysis
6. H2 for certain industrial processes that require high temperature heat not suitable for electrification - fossil gas, coking coal.

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

As a high-exergy fuel, gas should not be used for low-exergy applications like space heating and hot water preparation (including natural gas, hydrogen etc.) where more efficient and lower-carbon alternatives exist (e.g., heat pumps, district heating). The reason for Codema's position on green hydrogen when it comes to lower temperature heating is that better alternatives already exist for providing heat at this temperature such as district heating, heat pumps, waste heat and direct electrification technologies, which are not subject to the same uncertainties around viability that green hydrogen is.

How should green hydrogen be incentivised in the electricity market?

Green H2 production requires green electricity to be supplied at a low price point. The two main factors which make H2 financially viable conflict with each other, these are (1) the low-cost green electricity (available during low demand times) and (2) high utilisation of the electrolyser which produces the green hydrogen to pay off its large upfront cost. Further research is required to determine whether the required levels of each can be achieved simultaneously to produce cost-effective green hydrogen.

8. Hydrogen Supply - Stakeholder views are sought on:

What are the most cost-effective ways of utilising potentially curtailed renewable electricity output for hydrogen production?
This is being examined in the context of a case study in the Poolbeg area as part of the SEAI funded 'Poolbeg sector integration study[17]' led by Codema in partnership with Mullan Grid, and support from DCU. This study will be completed in March 2023.

What is the expected minimum capacity factor of grid connected hydrogen electrolysers that would be financially viable?
This is being examined in the context of a case study in the Poolbeg area as part of the SEAI funded 'Poolbeg sector integration study[18]' led by Codema in partnership with Mullan Grid, and support from DCU. This study will be completed in March 2023.

What policy mechanisms could be used to avoid green hydrogen production competing with direct electrification?
On the demand-side green hydrogen policy support should only be applicable to high priority end-uses such as those identified in this consultation response, and further backed by additional research and evidence. Focusing support directly on end-uses unsuitable for direct electrification should reduce competition. Further work is required to understand options to avoid competition for renewable electricity on the supply side.

Where would it be best to locate hydrogen production? Should there be specific government policy to locate hydrogen production facilities where too much energy is being generated for the electricity grid to manage (i.e., grid constraints)? What spatial planning considerations should be factored into this? What role might ports play in the production and transportation of hydrogen?
A policy measure that is currently being investigated in Ireland to increase the deployment of district heating is 'heat network zoning'. A heat network zone is a designated area where district heating (DH) is the lowest cost low-carbon solution for decarbonizing heating (i.e., where DH represents the best opportunity for the long-term decarbonisation of an area's heat demand). Zones identified as suitable for district heating can then put certain requirements on buildings within the zone to connect in a set timeframe. The consideration of waste heat from hydrogen production, could be integrated into Irish heat policy to designate suitable electrolyser sites and encourage synergy between the two technologies to increase overall system efficiency.

Denmark has had recent success in attracting investment for hydrogen production based on the opportunity for these sites to sell waste heat to the country's well established district heating networks. Major new hydrogen projects in the country are integrated parts of local heat planning and this synergy yields additional revenue for the hydrogen producer and low-cost green heat for the DH network [19].

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[17] https://www.codema.ie/projects/local-projects/integration-of-heat-electricity-and-transport-use-of-curtailed-renewable-en

[18] https://www.codema.ie/projects/local-projects/integration-of-heat-electricity-and-transport-use-of-curtailed-renewable-en

[19] District Heating can help unlock the hydrogen economy in the UK - for the benefit of everyone involved - by Jacob Byskov Kristensen, Embassy of Denmark, UK

This is being examined in the context of a case study in the Poolbeg area as part of the SEAI funded 'Poolbeg sector integration study[20]' led by Codema in partnership with Mullan Grid, and support from DCU. This study will be completed in March 2023.

What minimum sustainability criteria should apply to hydrogen produced in Ireland?
Since hydrogen reacts with tropospheric hydroxyl radicals, emissions of hydrogen to the atmosphere perturbs the distributions of methane and ozone, the second and third most important greenhouse gases after carbon dioxide. Hydrogen is therefore indirect greenhouse gas with a global warming potential GWP of 11 over a 100-year time horizon [21]. A future hydrogen economy would therefore have greenhouse consequences and would not be free from climate perturbations. It should be noted however that the research on the GWP of H2 is limited but this early research indicates its influence on global warming will be small.

Assuming flame combustion rather than catalytic combustion, burning hydrogen can result in NOx emission up to six times higher than fossil gas boilers. NOx does not directly affect Earth's radiative balance, but they catalyse tropospheric O3 formation through a sequence of reactions. The global warming potential (GWP) of NOx is estimated as GWP 30 - 33 and 7 - 10 for the respective time horizons of 20 and 100 years and is thereby comparable to that of methane. NOx is also a main cause of poor air quality which impacts people's health in dense urban areas. Careful planning for mitigation of these adverse effects, where possible, is required.

9. Hydrogen Transportation and Storage - Stakeholder views are sought on:

What methods of transporting hydrogen are best suited to meet the needs of hydrogen end-use in each sector?
Codema recognises a role for developing a future gas transmission network compatible with green hydrogen, however green hydrogen should be reserved for specific high value use cases. Recent analysis from Codema's Dublin Regional Energy Masterplan [22] shows that district heat and heat pumps are the most effective technologies for decarbonisation of heat in Dublin - approximately 87% of heat demand in the capital is suitable for district heating by 2050.

Codema believes that green hydrogen should be primarily supported for use in certain applications where the heat supply cannot already be supplied more efficiently and more cost-effectively through renewable and waste heat sources and technologies currently available such as district heat, heat pumps, waste heat and direct electric technologies. The use cases where green hydrogen may be supported are likely to include Industry where it is used as a feedstock, shipping, long-haul aviation, seasonal power storage, and possibly power generation. This, along with the SEAI National Heat Study analysis that shows that in scenarios where we are most likely to meet our carbon budgets, grid connected gas use by 2050 declines around 60-75%, highlights that careful strategic consideration is given to the extent of any future hydrogen network.

[20] https://www.codema.ie/projects/local-projects/integration-of-heat-electricity-and-transport-use-of-curtailed-renewable-en

[21] https://www.geos.ed.ac.uk/~dstevens/Presentations/Papers/derwent_ijhr06.pdf
[22] https://www.codema.ie/projects/local-projects/dublin-region-energy-master-plan/

Whether hydrogen blends injected into the gas network is a good use of green hydrogen?

In addition to and supporting the findings of the SEAI National Heat Study, recent research, and guidance from IRENA (International Renewable Energy Agency) states: '*the blending of green hydrogen into existing natural gas networks should not be prioritised as it prolongs the use of high-carbon assets and displaces more efficient decarbonisation options for some applications.*[23]'

There is a need to avoid an emissions lock-in risk or investing in infrastructure that is based on polluting imported fossil fuels for which significant decarbonisation is extremely unlikely to occur in the short or medium term (gas network). Whilst existing infrastructure can accommodate small proportions of H2, the maximum proportion of H2 that can be accommodated without issues by volume is 20%. It is worth noting that the volume percentage differs significantly from the delivered energy proportion due to the difference in energy density between gas and H2 at the same pressure (i.e., in the same pipe). In the case where fossil gas has 20% of H2 blended in, this translates to a 13% reduction in energy capacity of the pipework with H2 only providing 7% of the energy delivered. To increase the proportion of H2 beyond 20%, replacement of pipework, compressors, valves and fittings, boilers, meters, and safety sensors would likely be required.

Planning for future decommissioning of the gas network where it currently serves space heating and hot water needs in the residential, commercial and public sectors, while simultaneously examining the potential for dedicated hydrogen pipelines to serve hard to decarbonise end-uses is an important route to investigate further to minimise delayed climate action and risk of not aligning with carbon budgets, as opposed to investigation of how to raise the blending thresholds in the gas network.

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

The most cost-effective, and lowest cumulative emission pathways for decarbonisation of the heat sector involve significant scaling back of the gas distribution network serving the residential, commercial, and public sectors on the path to 2050.

We cannot wait for decarbonisation of the gas network at scale to decarbonise residential, commercial, and public sector heat demands when we can act now with proven and currently available technologies and systems such as district heat and heat pumps [24]. Scenarios that rely on gas network decarbonisation do not meet pro-rata carbon budgets applied to the heat sector, have the highest cumulative emissions, and rely on big, delayed efforts in the 2040's to approach net zero emissions. Scenarios that come closest to carbon budget limits involve high deployment of district heat networks, and high levels of electrification of heat [25].

[23] https://www.irena.org/publications/2021/May/Decarbonising-end-use-sectors-green-hydrogen
[24] https://www.codema.ie/projects/local-projects/dublin-region-energy-master-plan/

[25] https://www.seai.ie/data-and-insights/national-heat-study/

Should there be a long-term plan for a transition of the natural gas network to 100% green hydrogen? How would this meet the needs of end-use sectors? What should be the timeline for this?
Planning for future decommissioning of the gas network where it currently serves space heating and hot water needs in the residential, commercial, and public sectors, while simultaneously examining the potential for dedicated hydrogen pipelines to serve hard to decarbonise end-uses is an important route to investigate further to minimise delayed climate action and risk of not aligning with carbon budgets, as opposed to investigation of how to raise the blending thresholds in the gas network.

In line with analysis conducted as part of the SEAI National Heat Study, phase out dates for use of fossil fuel boilers are in the 2026 - 2035 time range to allow us to meet decarbonisation targets. Consequently, decommissioning of the fossil gas distribution network serving the residential, commercial, and public sectors should also be complete in a comparable time frame.

How much of the network should be repurposed (should it be the transmission pipelines only or include some of the distribution network? Should the existing gas grid be broken up into smaller segregated sections to carry 100% hydrogen in some areas?
SEAI National Heat Study analysis that shows that in scenarios where we are most likely to meet our carbon budgets, grid connected gas use by declines around 60-75%, highlights that careful strategic consideration is given to the extent of any future hydrogen network. Due to emissions lock-in risks associated with hydrogen blending, scenarios where the gas grid is broken up into smaller segregated sections carrying 100% hydrogen to hard to decarbonise end-uses merits further investigation.

In recent times, the potential to use existing gas networks to transport green hydrogen (hydrogen produced by electrolysis using green electricity) has been discussed as a possible solution for decarbonising space heating and hot water preparation (<100°C). There are several factors that will not make this possible in the short to medium term and makes adopting in the long-term challenging. Some of these uncertainties which make green hydrogen adoption challenging include:

- Suitability of existing pipework for transporting H2: High pressure steel pipework (>7 bar 26) which represents approximately 4.5% of the gas grid in Dublin is vulnerable to Hydrogen embrittlement (where H2 diffuses into surface flaws in the pipework, reducing ductility 27) which causes cracking and failure of the pipe network, valves, and fittings (the location of all fittings may not always be apparent in infrastructure that is buried underground). High pressures are believed to increase the likelihood of these failures and hence high-pressure steel networks are not considered suitable for transporting H2. Older, lower pressure pipework may also be constructed from steel or iron and may also be prone to hydrogen embrittlement if the gas pressure is high enough; this likelihood is reduced somewhat if mild steel is used for the pipework.

[26] https://www.gasnetworks.ie/home/gas-meter/meter-services/Safety-Advice-for-Working-in-the-Vicinity-of-Natural-Gas-Pipeline.pdf

[27] https://www.policyconnect.org.uk/media/1042/download

- While hydrogen has more energy per weight than fossil gas, it has a lower energy per mole. This would result in the pressure in the gas network to be increased threefold to provide the same energy capacity and hence increase the likelihood of pipe failure caused by embrittlement. This required increase in compression also means that a threefold increase in compressors resulting in increased energy/electricity used to compress the gas would be required as well as ensuring pressure ratings of all pipework is not exceeded to avoid critical network failure.

- Suitability of Polyethylene pipework (used for pipelines less than 7bar pressure) for transporting H2: Polyethylene pipes are not prone to H2 embrittlement in the same way that steel pipes are, but PE pipes are more porous than steel pipes. These hydrogen-porous pipes represent 95% of the gas network in Dublin. The porosity of such pipes may also be exacerbated by the molecular size of hydrogen molecules - hydrogen is the smallest size molecule that exists, and hence is one which diffuses easily through materials. This can create problems in terms of safety particularly when it comes to elements within buildings but also creates another possible issue in that the Hydrogen itself has a global warming potential as discussed previously. A permeation coefficient of 2.10-17 Nm3.m-1.s-1.Pa-1 for PE membranes when transporting pure Hydrogen has been quoted in a report investigating Poly Pipes for Distributing Mixtures of H2 and CH4 [28].

- Safety is again a concern due to H2 being odourless and the difficulty in attaching an odour to a gas which cannot be detected with current sensors installed in boilers. This presents a significant safety issue as H2 is an explosive gas with a much higher flame rate than fossil gas. Converting electricity to H2 is about 60 - 70% efficient; converting H2 to heat is about 90% efficient giving an overall electricity-to-heat conversion efficiency of approximately 60% even when excluding leaks from the pipe network. Alternative heating methods have far higher efficiency. For example, the current large scale DH networks in Dublin have an average efficiency of 460% (almost eight times more efficient than using hydrogen boilers).

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

With the increased penetration of renewable electricity generation on our national grid, Ireland will see a rise in energy that cannot be accommodated by the system, also known as curtailment. This will be coupled with times where there is insufficient grid capacity to transport energy to where it is needed, also known as constraint. Mitigating curtailment and constraint on the electricity grid is critical to ensuring the viability of existing and future renewable energy projects and increasing the overall efficiency of Ireland's energy system.

Demand Side Management (DSM), increased interconnection and storage will allow a greater injection of renewables by effectively increasing demand. When supply exceeds demand, the excess electricity can also be converted to pressurised hydrogen, with electrolysis acting as a high-capacity storage option to supplement battery storage or interconnection. By changing the energy

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https://www.researchgate.net/publication/48693261_Polymer_Pipes_for_Distributing_Mixtures_of_Hydrogen_and_Natural_Gas_Evolution_of_their_Transport_and_Mechanical_Properties_after_an_Ageing_under_an_Hydrogen_Environment

vector, electrolysis also enables the decoupling of supply and demand, unlike electricity which requires that supply and demand be instantaneously matched. Using hydrogen in transport, for example, means that refuelling, and Variable Renewable Generation (VRG) can occur at different times. Several studies have shown that the presence of electrolysis both increases the feasibility and reduces the overall cost of decarbonising the energy systems it connects [29].

The increasing electrification of our society will increase the requirement for energy storage such as green hydrogen. VRG such as wind and solar will bring about renewable energy lulls, windless weeks in the summer combined with cloudy conditions. This coupled with sudden demand surges means we will rely quite heavily on interconnection, demand response, and storage during certain periods. Demand side response is the most effective measure to combat these peaks, and batteries can be a solution for a few a few hours, but hydrogen is a strong contender for a solution that can provide deep resilience for the electrified society proposed in our net zero future.

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29 https://iea.blob.core.windows.net/assets/deebef5d-0c34-4539-9d0c10b13d840027/NetZeroby2050-RoadmapfortheGlobalEnergySector_CORR.pdf.