A National Hydrogen Strategy is needed to develop Ireland's Hydrogen potential

UCD Energy Institute

Introduction

The energy sector is undergoing a massive transformation driven by the need to reduce carbon emissions while meeting growing demand for energy. Renewable technologies are leading to significant decarbonisation of the electricity sector, however decarbonisation is much more challenging in other energy sectors such as heat and transport where energy demand has a very high level of fluctuation. Hydrogen has the potential to replace fossil based fuels, as well as addressing challenges in the electricity system in relation to system stability and the mismatch between renewable energy availability and user demand. As we move to decarbonisation of all our energy, there is an increasing need for the major energy systems to become more integrated. At UCD Energy Institute our main area of research focus is the integration of energy systems through the Science Foundation Ireland (SFI) funded Energy Systems Integration Partnership Programme (ESIPP). This research is highlighting the important role hydrogen can play in the decarbonisation of the energy sector.

What is Hydrogen?
Hydrogen, in its pure form, is an invisible, odourless non-toxic gas that's lighter than air. However hydrogen is not naturally found in this state, so it has to be extracted before it can be used. There are several ways to do this, including steam reforming and gasification, however electrolysis, a process that has been used for over 100 years, does not require a fossil fuel source. This method involves passing an electric current through water, effectively releasing hydrogen as a gas. When we use electricity from renewable sources, we can make a clean fuel - known as green hydrogen. The only by-product is oxygen and there are no carbon emissions.

Uses of Hydrogen

Today hydrogen is used primarily as a chemical feedstock, in the production of ammonia or in the petrochemical industry where it has the highest value, but when used as a fuel source it is unique in that it has no harmful emissions at the point of use producing water. The figure below represents the current value chains for hydrogen.

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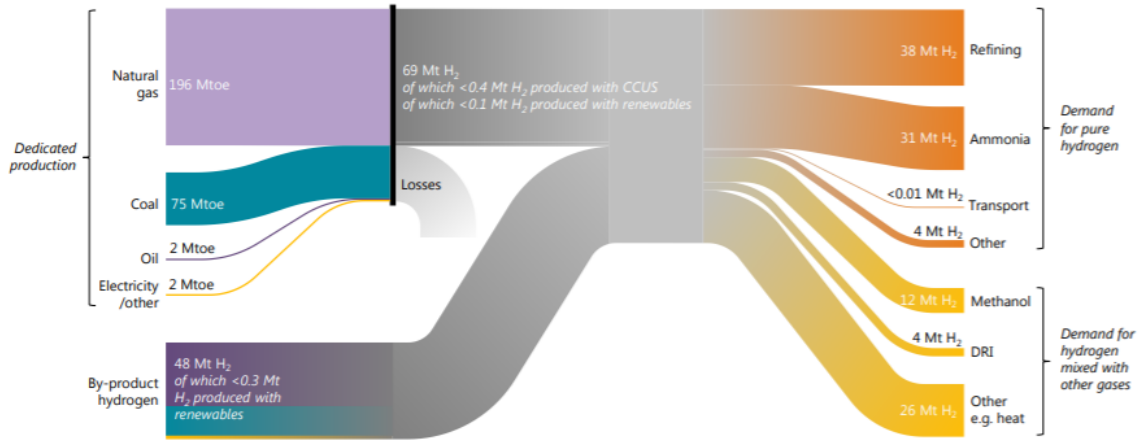
Figure 6. Today's hydrogen value chains



Notes: Other forms of pure hydrogen demand include the chemicals, metals, electronics and glass-making industries. Other forms of demand for hydrogen mixed with other gases (e.g. carbon monoxide) include the generation of heat from steel works arising gases and by-product gases from steam crackers. The shares of hydrogen production based on renewables are calculated using the share of renewable electricity in global electricity generation. The share of dedicated hydrogen produced with CCUS is estimated based on existing installations with permanent geological storage, assuming an 85% utilisation rate. Several estimates are made as to the shares of by-products and dedicated generation in various end uses, while input energy for by-product production is assumed equal to energy content of hydrogen produced without further allocation. All figures shown are estimates for 2018. The thickness of the lines in the Sankey diagram are sized according to energy contents of the flows depicted.

Hydrogen as a *fuel* has multiple uses:

- Hydrogen can be used to heat homes and industry, in a similar way to natural gas. Hydrogen can also be blended with natural gas. Delivery of hydrogen for these uses could use existing gas networks, which would reduce the amount of consumer disruption.
- Hydrogen can be used to decarbonise transport such as through powering fuel cell electric cars, trucks, buses and trains. This may have particular application for vehicles carrying larger loads and travelling longer distances, reducing the amount of time needed for refuelling compared to battery electric vehicles.
- Hydrogen can also be integrated with the electricity system. It can be used generate electricity (through fuel cells or being burned to drive turbines). At times of surplus renewable electricity, hydrogen can be made and stored and then used to produce electricity when there is insufficient supply available from other sources.

This wide range of uses is part of what makes it so appealing in our future energy portfolio. It provides an opportunity to decarbonise heat and transport at scale, while also enabling higher integration of renewables on the electricity system. Hydrogen can also be exported to supply fuel to other markets.

Sources of Hydrogen

The majority of hydrogen used in the world today is sourced from fossil fuels (Grey Hydrogen), which can be decarbonised through the use of carbon capture and storage (Blue Hydrogen). While this does add cost to hydrogen production, it eliminates the greenhouse gas emissions and allows hydrogen use at large scale. Hydrogen produced from renewable electricity through electrolysis of water (Green Hydrogen) does not produce any greenhouse gases and it additionally allows for otherwise lost renewable energy resources to be captured and stored for future use.

Challenges exist in transitioning from carbon based fuels to hydrogen. Storage and transport systems need to be modified and improved while new supply lines will need to be developed. Additional substantial challenges have to be overcome to develop green hydrogen at large (GW) scale. The basic challenge is the cost of production which has two elements: (1) the cost, efficiency and scale of electrolysers and (2) the price and availability of renewable electricity. In both cases progress is being made. Siemens recently claimed that their technology offering was competitive with existing production methods but this may depend on nature and extent of renewable electricity input. The price of offshore wind, which has the required scale in GW, has fallen substantially in recent European auctions. Beyond the basic cost challenge, deployment of green hydrogen production alongside a source of renewable electricity will lead to a series of interactions that will have to be dealt with, in particular the location of the hydrogen production facility (onshore or offshore) and the arrangements for the storage and transport of the hydrogen produced.

International Context

An increasing number of countries and agencies are recognising the need for and the potential of green hydrogen, and activity is gathering pace. Recent reports by international organisations such as the International Energy Agency (IEA)[1] and the International Renewable Energy Agency (IRENA)[2] point to the potential for hydrogen to support decarbonisation of energy. There will be a transition from grey hydrogen and blue hydrogen to green hydrogen over time. A number of countries have produced strategies to manage the hydrogen production and use issues. Japan produced a "Basic Hydrogen Strategy" in 2017. Australia has produced a number of documents on strategy and initial implementation, including identification of hubs. These countries are combining their efforts with regards to the development of hydrogen shipping building the world's first liquefied hydrogen ship[3]. In Europe, the Netherlands has been a leader in both strategy and developmental/ pilot projects and in developing international relationships. Germany has also recently produced a Hydrogen Strategy which outlines a number of aims and ambitions including the establishment of international hydrogen markets and cooperation because "Germany will have to import sizeable amounts of hydrogen in the medium and long term".

The European Commission has highlighted the role that Clean Hydrogen can play in making Europe climate-neutral by 2050 in the recently published "A New Industrial Strategy for Europe"[4], announcing plans to launch a European Clean Hydrogen Alliance in the coming months. The intention is to bring together EU member states, companies and research organisations to consider technology developments and infrastructure requirements to produce, transport and store the green hydrogen. According to a recent news report[5], the European Commission has raised the possibility of a carbon contracts-for-difference pilot scheme to pay the difference between the CO_2 strike price and the actual CO_2 price in the Emissions Trading Scheme (ETS) to bridge the cost gap between conventional (grey) and decarbonised (green) hydrogen. With other European countries such as the Netherlands and Germany preparing their own national strategies, it is essential that

[1] https://www.iea.org/reports/the-future-of-hydrogen
[2] https://www.irena.org/publications/2019/Sep/Hydrogen-A-renewable-energy-perspective
[3] http://global.kawasaki.com/en/corp/newsroom/news/detail/?f=20191211_3487
http://www.hystra.or.jp/en/
[4] https://ec.europa.eu/info/sites/info/files/communication-eu-industrial-strategy-march-2020_en.pdf
[5] https://www.greentechmedia.com/articles/read/a-green-hydrogen-cfd-and-eu-wide-renewables-tenders-leak-lifts-lid-on-eus-green-deal

Ireland is prepared to join in these discussions at a European level to ensure we can participate strongly in any discussions which will have implications for Ireland

Hydrogen Potential in Ireland

Given the international recognition of the potential for hydrogen in decarbonising our energy system, it is now time to assess the role it could play for Ireland and the role Ireland can play in the Global Hydrogen Economy. A recent report from SEAI[6] highlighted that Ireland is not on track to meet any of its 2020 renewable energy targets. In particular, the targets for heating and transport are proving to be difficult as changes in this area often require widespread actions from individuals, such as purchasing of electric vehicles or heat pumps. The target that we will come closest to reach is for renewable electricity where significant progress has been made in the integration of high levels of renewable generation onto the electricity system, with 33.3% of electricity coming from renewable sources in 2018[7]. Under the Climate Action Plan 2019[8] we have an ambitious target of 70% of electricity to come from renewables in 2030, with a view to having a net zero energy system by 2050. As we increase the penetration of renewable electricity, we see challenges associated with system stability and renewable energy curtailment. Integration with other energy systems such as the gas network and demand response opportunities will help deliver stability and flexibility.

Ireland has one of the best wind resources in Europe which can provide enough energy to meet Ireland's needs as well as potential for export. However, with increasing levels of renewable electricity we would expect to see increasing levels of constraint and curtailment. In Ireland the system operators regularly turn down the output from wind farms due to constraints on the system or to maintain security of supply. In 2019 this amounted to 7.7% of available wind[9]. As we continue to install more renewable energy, this may continue to increase if we don't find alternative uses of this energy, improve system operation tools and increase infrastructure development. This is a real challenge in terms of increasing our renewable energy supply. The production of hydrogen through electrolysis is an area that provides significant opportunity. The synergies of reducing renewable energy curtailment, providing alternative energy sources for transport and possibly heat, as well as decarbonising the gas network all point to hydrogen as being a real opportunity for the integration of energy systems. It also reduces the reliance on electricity network infrastructure as the hydrogen can be transported by different means.

The Gas Networks Ireland Vision for 2050[10] is for Ireland's gas network to be net zero carbon by 2050. This ambition is aligned with other European gas networks of which six have committed to net zero carbon by 2050. Biomethane has a role to play in achieving this goal, but cannot get all the way to a net zero carbon gas supply. Hydrogen, through both blue and green versions, can take us all the way there and beyond. The increased interest in hydrogen is reflected in the setting up of Hydrogen Ireland Association[11] in 2019.

Ireland has substantial renewable potential that can be developed over the years to 2050. In the Government Climate Action Plan Ireland has targeted renewable electricity of 8GW onshore wind and 3.5 GW offshore wind by 2030. Between 2030 and 2050 there is potential for a total of 10GW

[6] https://www.seai.ie/publications/2020-Renewable-Energy-in-Ireland-Report.pdf
[7] https://www.seai.ie/data-and-insights/seai-statistics/key-publications/renewable-energy-in-ireland/
[8] https://www.dccae.gov.ie/en-ie/climate-action/publications/Pages/Climate-Action-Plan.aspx
[9] http://www.eirgridgroup.com/site-files/library/EirGrid/2019-Qtrly-Wind-Dispatch-Down-Report.pdf
[10] https://www.gasnetworks.ie/vision-2050/future-of-gas/GNI_Vision_2050_Report_Final.pdf
[11] http://hydrogenireland.org/

offshore wind off the east coast, and of the order of 75 GW off the south and particularly the west coast. Delivery of Ireland's potential will require consideration of where to locate generation and how to use the electricity produced. According to the SEAI publication "Ireland's Energy Projections"[12], the total primary energy demand in Ireland by 2035 will be 18,000Ktoe. This is the equivalent of 8GW of wind power operating at a capacity factor of 30%. While some of the renewable electricity can be exported via interconnectors to Great Britain or France, both of these countries have their own plans to be self-sufficient in carbon free energy. Green Hydrogen can play an essential role in the process of capturing value from this renewable resource and making it available to all energy demand sectors throughout the world. Ireland has the potential to be a green energy exporter providing clean affordable energy for all humankind (UN Sustainable Development Goal 7). This is in line with the ambition in the June 2020 Draft Programme for Government[13] "We will also produce a longer term plan setting out how we will take advantage as a county of the massive potential of offshore energy on the Atlantic Coast."

Pathways to Green Hydrogen

Development of hydrogen as the green fuel of the future, underpinning an energy system with zero emissions, requires both a supply and a demand. Therefore initial steps need to be taken to help create a market for hydrogen as a fuel and energy vector. The highest value for hydrogen as a fuel can be obtained when it is used for transport[14], however this requires a network of refilling stations and a fleet of hydrogen powered vehicles. As has been observed for battery electric vehicles it can take a long time to put the infrastructure in place. Hydrogen can also be blended into natural gas networks at low concentrations <20% without the need to change any of the infrastructure or end use devices.

There are a number of approaches to integrating hydrogen into Ireland's future energy mix including:

1. Enabling the use of hydrogen within the Irish energy system irrespective of its origin to allow for the accelerated development of the market and end use technologies, followed by a transition to green hydrogen over time.
2. Utilising Ireland's existing and developing renewable energy facilities to produce green hydrogen which can be used to reduce the carbon emissions of all natural gas end users. With the focus being on green hydrogen from the outset, technical developments coupled with cost reductions will be required to ensure cost competitiveness and increased decarbonisation.

The approaches are not mutually exclusive and detailed analysis is required to assess at which scale and pace each approach will be best for Ireland from the perspectives of CO2 emissions, costs, jobs, the economy, public acceptance etc. This analysis requires investigation into the technical, economic and social aspects of transitioning to hydrogen as a primary fuel source.

[12] https://www.seai.ie/publications/Irelands_Energy_Projections.pdf
[13] https://static.rasset.ie/documents/news/2020/06/draft-programme-for-govt.pdf
[14] Work is already taking place in Ireland on this through GenComm: https://www.nweurope.eu/projects/project-search/gencomm-generating-energy-secure-communities/

Current Research Activities

Hydrogen research in Ireland spans all aspects of the hydrogen economy, from hydrogen generation, through storage transport and end use. The UCD Energy Institute is already leading many of the Irish research efforts on how to achieve our 2030 and 2050 energy goals. Through the SFI funded Energy Systems Integration Partnership Programme (ESIPP), all aspects of the energy transition are being investigated, including

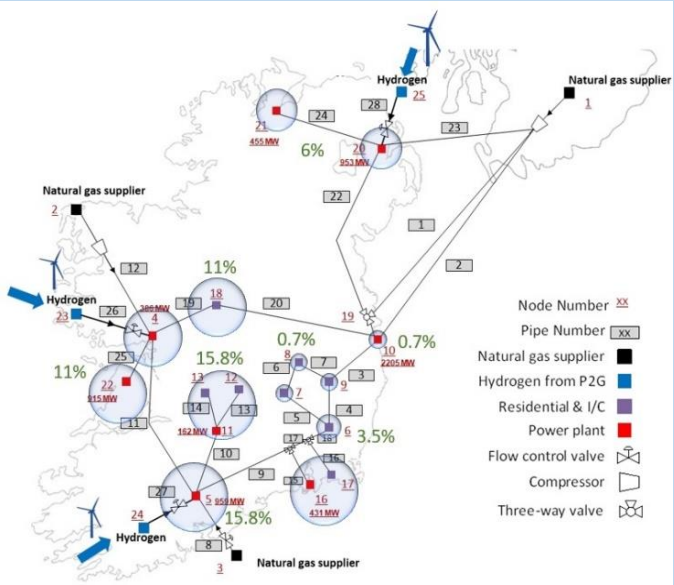
- Operation of electrical Transmission networks with 100% RES-E
- The integration and interaction of all aspects of the energy systems.
- Economic drivers for investment in green energy systems
- Decarbonisation of domestic and industrial heating, and transport
- The continued use of the Natural Gas Network to provide flexibility and resilience to a decarbonised energy system.

Ongoing research on ESIPP and in the UCD Energy Institute examines some of the technical and economic aspects of hydrogen within the Irish energy system, clearly identifying a strong opportunity for this technology to address some of our decarbonisation challenges. Modelling of green hydrogen in the gas network highlights how the gas network can provide support to the electricity network and how the gas network itself may need to change in the transition to a net-zero energy system.

ESIPP Research - Future Irish Gas Network

Research in the UCD Energy Institute is investigating the potential for the Irish Gas network to store and transport otherwise lost renewable electricity through the use of Power to Hydrogen. Modelling studies have shown that even with the current installed wind capacity, on windy day in Ireland, Hydrogen concentrations of up to 15% in the Natural gas network could be achieved if the available curtailed wind power was utilised.

REF Ekthiari, Flynn and Syron, Currently under Review.



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A Hydrogen Strategy for Ireland

In order for Ireland to address the challenges associated with decarbonising our entire energy system, it is essential that we examine the role that Green Hydrogen can play. Many countries have formed, or are now forming, their own Hydrogen Strategies, and we believe there is a need for Ireland to follow suit. As the European Commission is investigating opportunities for Europe it is essential that Ireland is prepared to participate in these discussions. The promotion of clean hydrogen as a fuel requires supply of hydrogen and demand for hydrogen to be developed in tandem, and a coordinated approach will be required. The development of a clear national strategy for hydrogen will:

- Identify the most appropriate pathway to Green Hydrogen for Ireland through assessment of multiple scenarios. This analysis requires investigation into the technical, economic and social aspects of transitioning to hydrogen as a primary fuel source.
- Enable Ireland to take advantage as a county of the massive potential of offshore energy on the Atlantic Coast.
- Outline a roadmap to a completely decarbonised energy system 2050.
- Assess current and future infrastructure requirements.
- Identify opportunities for hydrogen export (e.g. Germany) supported by our extensive renewable energy resources, including vast potential for offshore wind as technology matures and becomes more cost effective.
- Enhance Ireland's position as a world leader in integration of renewable energy technologies.
- Assist in delivering the market signals required to drive investment in a more economic manner.
- Identify the required changes to legislation and regulation.
- Focus and direct research and investment from both the public and private sectors.

We believe that Ireland requires a coordinated hydrogen strategy which can help support the significant opportunity Ireland has in this area and provide appropriate signals for investment. It is essential that Ireland is well positioned to take advantage of international developments in this area and is engaged in aspects such as the development of an international market for hydrogen at the outset. The development of a National Strategy will ensure we are in a stronger position in discussion with our international peers.

Next steps and recommendations

In order to develop a Hydrogen Strategy for Ireland we recommend the following next steps:

- The development of energy scenarios outlining the potential role of hydrogen in our future energy mix.
- An assessment of the different scenarios and pathways for the development of Green Hydrogen.
- Coordination of the relevant stakeholders through a Hydrogen Task Force.
- Identify opportunities for hydrogen within the next update of the Climate Action Plan.
- Promote R&D in hydrogen for Ireland.
- The development of testing facilities and demonstration sites to bring the research to higher Technology Readiness Levels (TRLs).

At UCD Energy Institute, and through our network of collaborators and industry partners, we are well placed to support these activities with rigorous research support. Our experience in the area of Energy Systems Integration through the ESIPP project ensures that this is examined within the context of the wider energy system. A coordinated strategy will ensure that this continues to be an important area of research focus, enabling increased capacity to be developed and maintained to support the decarbonisation of our energy future.

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