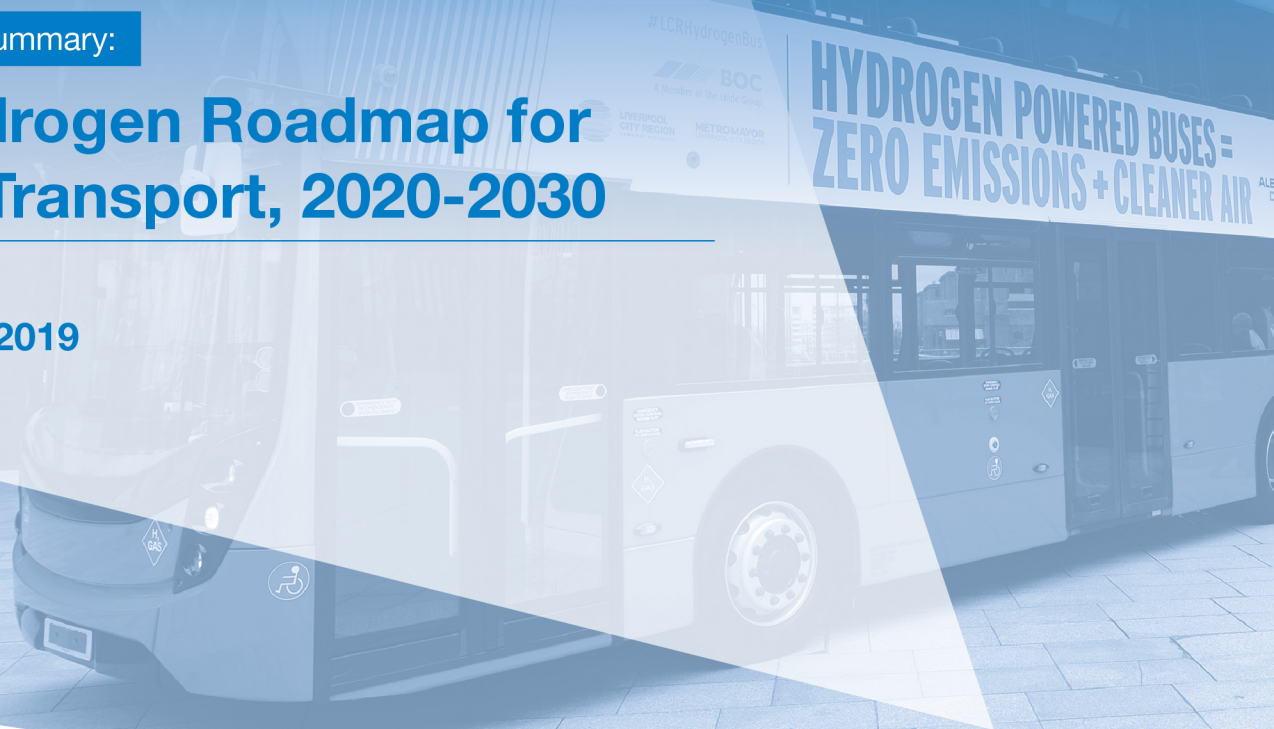


Narrative Summary:

A Hydrogen Roadmap for Irish Transport, 2020-2030

Date:
October 2019



Zero Carbon Transportation - A Hydrogen Mobility Strategy for Ireland

Introduction

Hydrogen has gained significant interest as a fuel for the future because using hydrogen to power vehicles results in no direct emissions of greenhouse gases or any local pollutant emissions. Hydrogen can also be produced from a wide range of low and zero carbon energy sources and can be used as a fuel by most vehicle types from small cars through to ferries and trains. This means hydrogen represents one of very few options for the complete decarbonisation of the road transport sector.

Hydrogen Mobility Ireland is a group of Irish stakeholders looking to develop the use of hydrogen for transport in Ireland to help meet the challenge of decarbonising transport whilst keeping transport practical and affordable. Hydrogen Mobility Ireland includes industry members from across the transport and energy industries and has been informed by input from a range of policy stakeholders from the Republic of Ireland and Northern Ireland (for a complete membership list see the last page).

A Hydrogen Strategy for Ireland

The first action of Hydrogen Mobility Ireland has been to develop a hydrogen mobility strategy for Ireland, setting out a pathway for the introduction of hydrogen production sites, hydrogen stations and hydrogen vehicles between now and 2030. The strategy provides a clear picture of what hydrogen mobility can achieve in Ireland over the next ten years and demonstrates that this vision is clearly achievable at levels of commitment that industry and government can support.

By 2030 the strategy can deliver many benefits for Ireland, including:

- **Hydrogen as a mass market fully zero carbon fuel:** Hydrogen can be produced in a number of ways which ensure essentially zero carbon emissions in its entire production chain. This means the use of hydrogen as a fuel for transport can be a key part of achieving the Republic of Ireland's plans for decarbonisation of society.
- **Cost competitive clean transport:** The hydrogen mobility sector is gaining momentum which means the cost of hydrogen vehicles and infrastructure is falling quickly and the number and type of vehicles available is increasing. Data from our partners suggest that this will lead to the total cost of ownership of hydrogen vehicles matching that of conventional vehicles in most vehicle segments by the mid to late 2020s.
- **No local pollutant emissions:** an added benefit of the use of hydrogen as a fuel is the removal of all local pollutant emissions (the only emission is water), meaning the switching of vehicles to hydrogen leads to cleaner towns and cities.
- **A solution for heavy use transport:** whilst we have seen considerable progress in the use of plug-in battery vehicles for light duty vehicles, these solutions do not appear viable for high use (long range) and heavy vehicle types. Hydrogen offers a solution for decarbonising vehicles such as trains, ships and trucks, for which very few other zero emission solutions exist.
- **Direct benefits for the Irish economy:** Currently, Irish transport fuel is imported from oil producing nations, meaning much of the value of transport fuel does not benefit Ireland. Hydrogen by contrast will be produced domestically, which means the economic activity associated with the production of hydrogen will be kept within Ireland.
- **Catalysing other hydrogen energy applications:** there are other potential applications for hydrogen in the energy sector, including as a fuel for heating buildings and an input to a range of industrial processes, where hydrogen could be produced at large scale and distributed using the existing Irish gas system. These are longer term applications, which could be supported through the experience gained during an early move into hydrogen for transport.

Hydrogen Vehicles – A zero emission option for all segments

Hydrogen Mobility Ireland sees now as an excellent time for Ireland to develop a hydrogen strategy as the momentum behind hydrogen mobility is growing worldwide. There are already 1,000's of hydrogen cars, trucks and buses operating in regions such as California, Japan, Korea and parts of China. These large vehicle markets have committed to growing their hydrogen vehicle share. For example, China has committed major investment towards hydrogen vehicle production, hydrogen vehicle sales and hydrogen infrastructure rollout with a targeted rollout of 1 million hydrogen vehicles and 1,000 refuelling stations by 2030. A similar level of ambition in Japan and USA will drive up fuel cell production volumes and bring down the price. This will result in the total cost of ownership of hydrogen vehicles matching those of conventional vehicles in the 2020s.

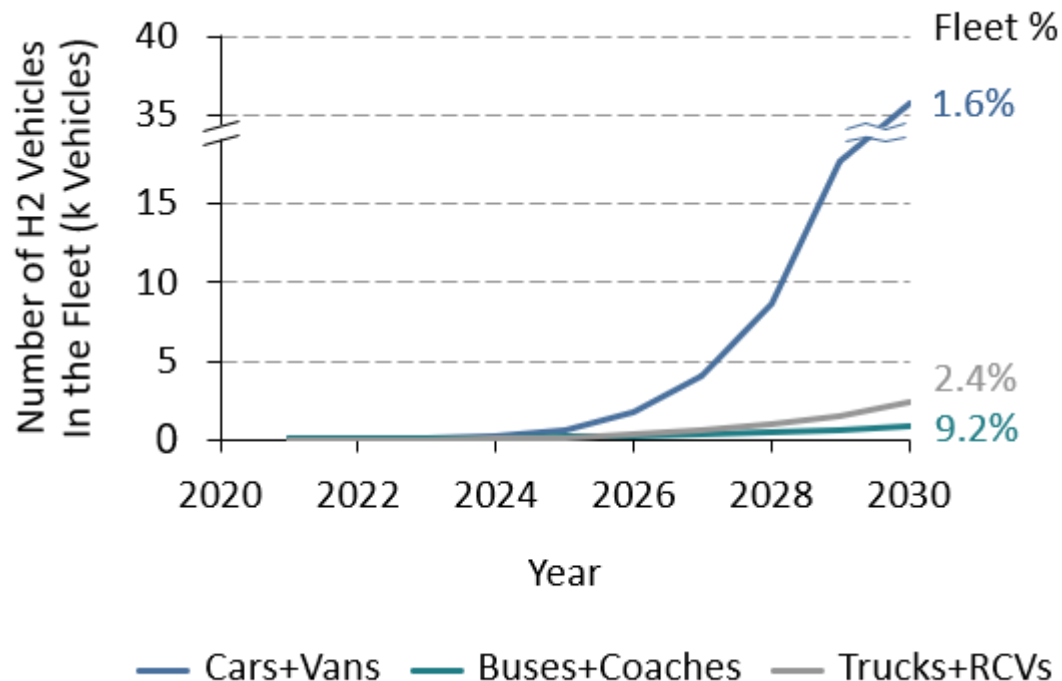


Following these larger vehicle markets allows Ireland to learn from their experiences and to benefit from cost reductions in vehicles and infrastructure caused by the increasing scale of the hydrogen industry. Vehicles are already available to Ireland in a range of vehicle classes. For example, hydrogen vehicles are already available in the car (Toyota and Hyundai) and bus markets (WrightBus and Alexander Dennis) with vans (LDV), trucks (Hyundai, Nikola), RCV (FAUN), coaches (CaetanoBus), trains (Alstom) and ferries (Ferguson Marine) expected in the early 2020s.

Our strategy starts by focusing on “captive” heavy-use fleets with a specific focus on buses, vans and taxis. Captive fleets operate in a constrained geographic area, which means they can be served by a small number of refueling stations. The heavy-use also helps to guarantee demand for fuel, which improves the economics for these early stations. The partners will target the development of first clusters of hydrogen demand in Dublin and then Belfast as these have the largest concentration of users.

From this initial start, the range of vehicles and the types of user will grow. We expect demand for vehicles to grow alongside the roll-out of refueling infrastructure during the 2020s so that by 2030 hydrogen vehicles are operating in all vehicles segments and represent a growing share of the Irish

fleet bus/coach (9% of the fleet, 900 vehicles), car/van (2% of the fleet, 36,000 vehicles), truck (2% of the fleet, 2,400 vehicles) and train (1% of the fleet).



Hydrogen Production – Making a low carbon fuel for Ireland

The hydrogen for these vehicles will be produced in Ireland, mainly from indigenous energy sources. Hydrogen can be produced using a range of methods, the strategy focuses on three methods which are available today, which fit with the Irish energy system and can deliver ultra-low carbon emissions.

1. Electrolysers co-located with renewable generators, particularly wind – these guarantee 100% carbon free hydrogen production
2. Electrolysers co-located with energy from waste plants – which provides a useful and affordable source of low carbon power for the early years
3. Large scale reformation of natural gas – which produces CO₂ from the input fossil natural gas, but will only be implemented alongside a plan to capture and dispose of the CO₂ (CCS)

The majority of hydrogen produced is expected to come from renewables. The study considered three options for the Irish production mix which lead to between 50% and 100% of hydrogen being produced from electrolysers co-located with renewable electricity generators, a process that leads to a very green fuel.

Summary of the Hydrogen Production Pathways

Scenario 1: Follow BEV Emissions

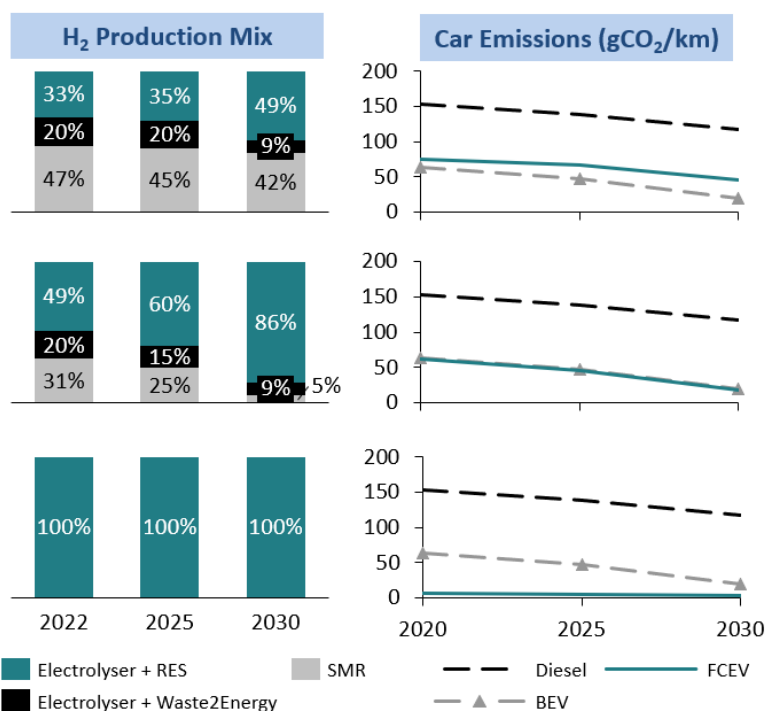
In recognition that BEV were supported before the decarbonisation of the grid, with the expectation that emissions would come down, this pathway follows the BEV pathway 5 years behind

Scenario 2: Match BEV Emissions

From the first introduction of hydrogen the Well to Wheel emissions match those of a battery electric vehicle using grid electricity

Scenario 3: Going Green

Enough wind/solar capacity is available, and hydrogen is produced purely from electrolyzers co-located with renewable generators



The actual mix of hydrogen production in Ireland will be dictated by policy-makers through the implementation of the currently planned update to the Biofuels Obligation Scheme (BOS). A BOS that rewards producers for producing green hydrogen will skew the economics of hydrogen production in favour of the greenest production routes and could lead to the development of 30 electrolyzers being installed at renewable generator sites in the 2020s producing 100% green hydrogen for distribution to refuelling stations across Ireland.

Hydrogen Stations – Making hydrogen available to all

A network of hydrogen stations needs to be built across the island of Ireland to allow hydrogen vehicle users to move freely without limitations. This cannot happen overnight and the strategy needs to ensure stations are rolled-out in concert with the increase in demand, which means the operators of the refueling stations can create a business case even in the early years of the roll-out.

Our strategy, as shown in the figure below, starts in Dublin with an initial cluster of three stations and expands to close to 80 stations providing a basic national coverage of Ireland, so that by 2030 all major towns and cities have a cluster of hydrogen stations and stations are also deployed along all the connecting routes.

We propose starting the station rollout with three stations in Dublin designed to demonstrate the technology at scale. These will refuel a fleet of buses, taxis and vans. This will ensure drivers in Dublin have options for their refuelling, enabling first take-up in the city.

This is quickly followed by Phase 2.1 where clusters of stations are built in the major cities and along connecting motorways to provide for the large population centres and fleets that move between them (e.g. coaches, trucks). Phase 2.2 introduces stations in the smaller cities and at ports to allow distribution companies to start to use hydrogen. Then in Phase 2.3 stations are installed in commuter towns to allow hydrogen to spread beyond fleets to high mileage private users and the mass market. Finally, in Phase 3, which could occur just before or after 2030 depending on the speed of hydrogen

vehicle uptake, stations are installed in more rural locations to give access to hydrogen refuelling in all regions.

Motorway Service Refuelling Stations



City Centre Refuelling Station Clusters



★ Phase 1 ★ Phase 2.1 ★ Phase 2.2 ★ Phase 2.3 ★ Phase 3

For hydrogen vehicles to be competitive they require a Total Cost of Ownership (TCO) that matches conventional vehicles. The cost of owning and operating hydrogen vehicles will come down very quickly over the next decade (thanks to economies of scale in both hydrogen production and also global vehicle manufacturing vehicles) to the point that in the 2025 to 2030 period, the vehicles can compete with conventional and other zero emission options on an unsubsidised basis.

However, the early hydrogen vehicles will be more expensive than conventional vehicles. The higher costs can be balanced by policies (purchase grants, tax exemptions etc.) and support for the production of green hydrogen fuel. In this study, we assume that the current suite of policies in place in the Republic of Ireland to support battery electric vehicles are extended to hydrogen vehicles. With these policies in place, hydrogen needs to be sold to the consumer at close to €5.00/kg for HDV and €9.00/kg for LDV in Phase 1 and €6.50/kg for HDV and €11.00/kg for LDV by 2030, to make hydrogen vehicles cost competitive. To achieve these hydrogen sale price targets with the expected volumes in the report, we suggest including hydrogen in the upcoming revision of the BOS. This scheme will need to be adapted to be consistent with the Renewable Energy Directive II, which encourages the inclusion of green hydrogen. BOS credits for green hydrogen of €4.00/kg in Phase 1 and €1.50/kg towards 2030 are needed to make the hydrogen infrastructure investment viable.

To deliver hydrogen as a mass market fuel in Ireland in 2030 the strategy sets out a clear pathway (summarised in the timeline below) of actions required by government, industry and consumers to install infrastructure and rollout vehicles. To begin this process, the strategy starts with Phase 1 (2022 to 2023), a large scale first deployment project that demonstrates the potential of hydrogen for mobility in Ireland and helps to de-risk future investment in hydrogen mobility by Irish investors. The Phase 1 project proposes the installation of a cluster of 3 hydrogen refuelling stations in the greater

Dublin area and two electrolytic hydrogen production sites to support several heavy and light-duty captive fleets. The strategy envisions this will entail the introduction of 30 buses, 50 cars and 10 vans, however, interest from fleets could expand this to include more vehicles or a wider range of vehicle types such as refuse collection vehicles. First budget estimates suggest the proposed Phase 1 project will cost €34m and will require support from an Irish and/or European funding programme for energy innovations to provide a capital grant of €14m to help match fund the programme and government support for the inclusion of green hydrogen in the BOS.

Summary of the Phase 1 Project

Vehicles: The proposed Phase 1 involves 30 buses, 50 cars and 10 vans, representing a total investment of €17.5m that is supported by the government through €6m of grant funding

30 Buses



50 Cars



10 Vans



Production and dispensing infrastructure: A €16.5m investment will also be required for the infrastructure to refuel these vehicles which will require €8m grant funding from the government

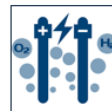
3 refueling stations



2 production sites



Electrolyser

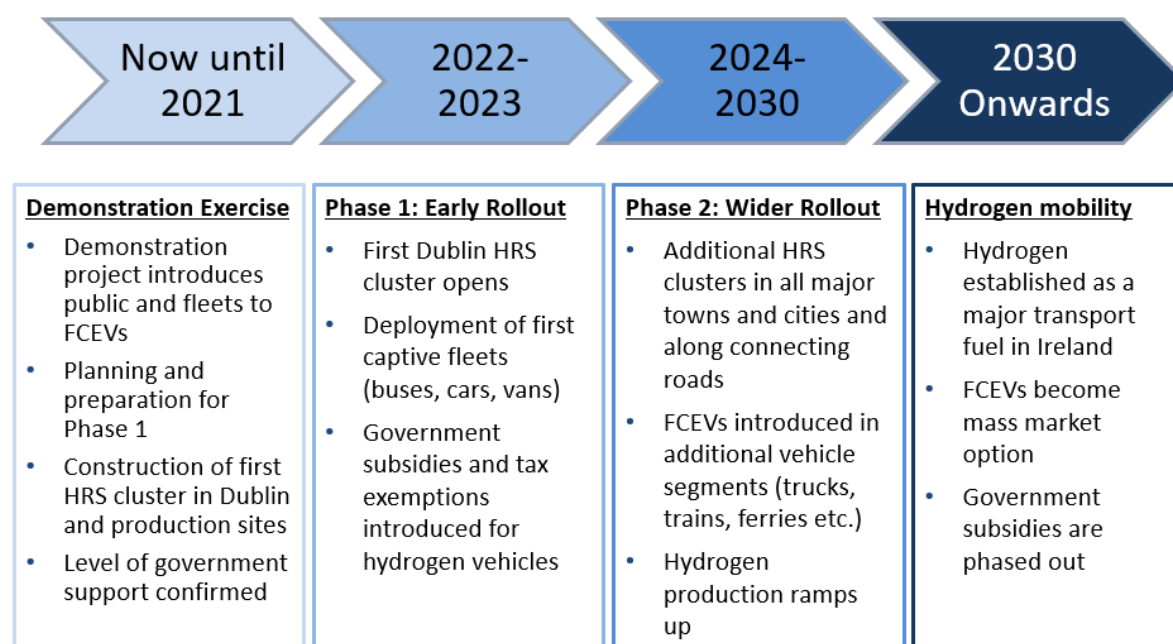


Electrolyser

The successful growth of the hydrogen mobility sector beyond Phase 1 will be supported by the continued work for Hydrogen Mobility Ireland who will monitor the Phase 1 project and publish a clear strategy on the detailed actions required to deliver Phase 2 in a follow up to this study. To help a smooth transition from large scale demonstration project to rapidly growing industry hydrogen mobility in the Republic of Ireland will require political support and certainty. The policy support needed to meet the 2030 goals include:

1. Extending current battery electric policies such as grants and tax exemptions to hydrogen vehicles
2. Introduce new grants to support the purchase of zero emission trucks, as has been done in other regions such as Switzerland and the UK
3. Ensure the update to the BOS provides adequate support for low emission hydrogen production

Strategy Summary and Timeline



A Key Part of Achieving a Zero Carbon Economy

This strategy has been developed through detailed discussions between the industry members of Hydrogen Mobility Ireland, with valuable feedback from policy stakeholders in the group and the Low Emission Vehicle Taskforce. The conclusion of the study, from the stakeholders involved, is that the ambition set out is achievable, the size of the policy request is in-line with the investment made by the government to support the introduction of other low emission fuels and the investment required and returns available make the hydrogen industry investable in for industry.

The successful introduction of hydrogen as a decarbonisation fuel across Ireland will support both government's efforts to achieve deep decarbonisation of the economy by offering a more cost effective option to totally decarbonise sectors such as industry and heavy-duty transport than is possible in a future reliant only on electricity as a low carbon fuel. The development of hydrogen will also have many economic benefits for Ireland by:

- supporting the further growth of the renewable energy industry;
- kick starting the use of hydrogen for heating which can provide a long term role for the Irish gas network as a hydrogen network and thus avoiding costly electricity grid upgrades associated with a shift to all-electric heating;
- and increase national income through the production of a valuable fuel in Ireland using indigenous energy resources rather than buying fuels from other countries as is predominantly the case today.

Members of Hydrogen Mobility Ireland



This report has been compiled by Element Energy for Hydrogen Mobility Ireland. Element Energy is a specialist low carbon energy consultancy with offices in the UK and in France. They have been centrally involved in Hydrogen related projects across Europe and coordinate many pan European hydrogen programmes such as JIVE and JIVE2 as well as the H2ME project.

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