A Joint Hydrogen Strategy Framework for the North Sea Region

Recommendations by the HyTrEc project partnership to support the deployment of hydrogen-fuelled transport
Hydrogen in the North Sea Region

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A Joint Strategy Framework for advancing the adoption of hydrogen as an alternative energy carrier in the North Sea Region

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A Hydrogen Transport Energy Economy in 2020
1 Hydrogen in the North Sea Region

1.1 Introduction

The outputs of the HyTrEc project will improve access to and advance the adoption of hydrogen as an alternative energy vector across the North Sea Region.

HyTrEc focuses on:
- Facilitating transnational co-operation and learning
- Enhancing the competitiveness of the North Sea Region
- Providing a platform for joined-up working towards a strategy for supporting the deployment of hydrogen-fuelled transport across the North Sea Region.

Seven European countries have come together to share their variety of experiences in the hydrogen sector and input to the development of this set of strategic recommendations, which will contribute to strengthening and stimulating the hydrogen industry in the North Sea Region. The main activities carried out by the partnership include a Skills Development Programme, Policy Development and Demonstration and Evaluating and Building In Sustainability.

HyTrEc project partners represent the following regions:

<table>
<thead>
<tr>
<th>Partner Region</th>
<th>Member State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aberdeen City Council</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>Gateshead College</td>
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<td>European Institute for Innovation</td>
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<td>SP Technical Research Institute</td>
<td>Sweden</td>
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<tr>
<td>Nvrvik University College</td>
<td>Norway</td>
</tr>
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</table>

1.2 Why Hydrogen?

1.2.1 Drivers for the implementation of a hydrogen transport economy

The implementation of hydrogen as an energy carrier for a more sustainable energy system is based on the following key drivers:

- Zero or low emission transport technology - hydrogen fuelled vehicles contribute to air quality targets
- Energy storage - hydrogen will help maximize the share of renewable electricity in the energy system, addressing the problem of intermittent energy production from wind and solar through conversion of excess renewable electricity to hydrogen, i.e. as a "power to gas" or "power to fuel" solution

1.2.2 European Policy Drivers

1.2.2.1 European energy targets for 2020 and 2030

Energy policy objectives in Europe for 2020 are known as the "20-20-20" targets:

- 20% reduction in EU greenhouse gas emissions from 1990 levels;
- Raising the share of EU energy consumption produced from renewable resources to 20%;
- 20% improvement in the EU's energy efficiency.

The 20-20-20 targets represent an integrated approach to climate and energy policy that aims to combat climate change, increase the EU's energy security and strengthen its competitiveness.

In October 2014, national governments came together to agree a new EU energy and climate change package which will now include the following three targets for 2030:

- reduce the EU's greenhouse gas emissions by 40% by 2030 from 1990 levels;
- increase the share of renewables in energy consumption by 27%;
- increase energy efficiency by at least 27%.

1.2.2 Low-carbon transport within the European energy targets

Low carbon technologies in transport applications will play a crucial role in helping to achieve the overall energy targets. 96% of transport in Europe is oil-based, 84% of it being imported, at a cost of up to EUR 1 billion per day, with increasing costs to the environment.

1.2.3 Energy policy framework for the North Sea Region

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1.2.7 Low-carbon transport within the European energy targets

Low carbon technologies in transport applications will play a crucial role in helping to achieve the overall energy targets. 96% of transport in Europe is oil-based, 84% of it being imported, at a cost of up to EUR 1 billion per day, with increasing costs to the environment.
The decarbonisation of the transport sector offers a range of benefits, which are in themselves strong drivers for deploying low carbon transport technologies, including:

- **Energy security:** Through reduced demand for fossil fuels, reliance on foreign oil imports is reduced, thereby reducing the geo-political risks associated with often unpredictable parts of the world.

- **Long-term affordability:** By reducing oil imports to fuel the transport sector, significant improvements to the balance of payments can be achieved. This is particularly relevant for alternative fuels instead of locally produced, e.g. renewable electricity, hydrogen and carbon fuels.

- **Expansion of renewable capacities:** Widespread deployment of alternative fuelled vehicles that use electricity as their main feedstock (e.g. electric vehicles, hydrogen fuel cell vehicles), rather than fossil fuels, creates significant additional demand on the electricity grid, which can be used to reduce peaks in grid energy, thereby enabling the deployment of additional renewables - a key policy goal for Europe and the North Sea Region's member states.

- **Energy storage:** With increasing development of intermittent renewable electricity generators to the grid (e.g. wind), unpredictable production patterns can lead to grid balancing issues in supplying electricity at times of low demand, or an inability to supply sufficient electricity at times of high demand. This can restrict the potential share of renewable electricity in the energy mix, and mean that fossil fuels are relied upon to give a reliable base level of power supply. Low carbon transport technologies such as batteries and hydrogen are able to contribute towards grid balancing through allowing options for energy storage at times of low demand, and re-generation at times of high demand.

- **Air Quality:** Significant local and national air quality benefits can be derived from the deployment of low and zero carbon vehicles offering zero exhaust emissions, reducing harmful pollutants such as nitrogen oxides (NOx) and particulate matter (PM10). Hydrogen fuelled vehicles have a key role to play in decarbonising the transport sector since hydrogen fuelled transport applications, as well as the hydrogen refuelling infrastructure required to support these vehicles.

- **Widespread use of renewable energy:** Fuel cells offer the opportunity to use renewable energy sources, including fuel cell electric vehicles (FCEVs) as well as non-road, train, maritime and aviation applications, including hydrogen production, storage and re-electrification systems. The initial focus will be on the role hydrogen can play in supporting the integration of renewable energy into the electricity grid.

- **Public-private EU Programme: Fuel Cells and Hydrogen Joint Undertaking**

The EU’s directive 2014/94/EU on the deployment of alternative fuels infrastructure aims to facilitate the development of a single market for alternative fuels for transport in Europe, focusing on electricity, compressed natural gas (CNG), liquid natural gas (LNG) and hydrogen. The FCH 2 JU programme of research and innovation is structured around two research and innovation pillars dedicated to ‘Transportation’ and ‘Energy Systems’. Complementing these two pillars are four cross-cutting research activities, as well as the hydrogen refuelling infrastructure required to support these vehicles.

- **Energy policie:** The FCH 2 JU programme of research and innovation aims to create a strong, sustainable and globally competitive fuel cell and hydrogen sector in the European Union with an overall budget of more than EUR 1.2 billion, to be invested between 2014 - 2020, with half coming from the European Commission, complemented by at least an equivalent level of investment by industry and research partners.

- **Air Quality:** The FCH 2 JU will support projects such as hydrogen production for energy storage and grid balancing from renewable electricity. This could include large scale green hydrogen production, storage and re-electrification systems. The initial focus will be on the role hydrogen can play in supporting the integration of renewable energy into the electricity grid.

- **Widespread use of renewable energy:** Besides these topics the FCH 2 JU will specifically focus on realising large demonstration projects, facilitating a large scale implementation of low-carbon technology in the form of hydrogen fuelled transport applications.
1.2.2.5 EU and national hydrogen-fuelled transport programmes
The Trans European Network for Transport (TEN-T) programme is supporting the development of a European network of hydrogen infrastructure for long distance travel by hydrogen fuel cell car. In addition, most North Sea Region Member States have developed national programmes for the development of hydrogen refuelling infrastructure and deployment of hydrogen vehicles. These are known as H2 Mobility Programmes.

1.3 Status of hydrogen in the North Sea Region
To establish the status of hydrogen in the North Sea Region the HyTrEc partnership developed:
- A diagram summarising hydrogen activities within the partners’ areas using a map of the North Sea Region (Figure 1 and Figure 2)
- A SWOT analysis of a hydrogen transport economy in the North Sea Region, summarising the strengths, weaknesses, opportunities and threats within the area (Figure 3).

These exercises were influenced by the experience that the project partners have in the hydrogen sector or from the introduction of other alternative fuels, renewable energy and low carbon sectors. Other activities undertaken throughout the project period are also taken into account, such as demonstration activities carried out by some partners, as well as the development of the HyTrEc education programmes and a journey by hydrogen car around the North Sea Region. Further information on these can be found in the project website at www.hytrec.eu.

1.3.1 Hydrogen activities of the HyTrEc partners in the North Sea Region
Figure 1 shows that in the North Sea Region hydrogen fuelled transport is demonstrated in terms of:
- Hydrogen refuelling infrastructure (green hydrogen production on-site from electrolysis and also utilising by-product hydrogen)
- Fuel cell electric vehicles (provided directly by OEMs and storing hydrogen on board at 700 bar pressure)
- Electric vehicles with retrofitted fuel cell range extenders, storing hydrogen at 350 bar pressure
- Internal combustion engines converted to burn hydrogen in addition to conventional fuel like petrol or diesel for applications including vans and trucks, both in 350 bar hydrogen
- Material handling devices running on hydrogen stored at 350 bar pressure.

Aberdeen, UK:
- Two refuelling stations with on-site electrolyser - one at 350 bar, one at both 350 and 700 bar
- Ten Van Hool fuel cell buses, with Ballard and Siemens technology
- Hydrogen – diesel hybrid vans (ULEMCo)
- Plug-in Hybrid Fuel Cell Electric Van (Symbio FCell)

Southwest Sweden:
- Refuelling station – Malmo
- Hyundai fuel cell ix35 x 3

Gateshead:
- Petrol / hydrogen hybrid car
- Hydrogen range extender fitted to electric car

Belgium:
- Refuelling station using by-product hydrogen for 5 buses in Antwerp
- Refuelling station using on-site electrolyser at 350 bar for fueling material handling equipment near Brussels
- Refuelling station using on-site electrolyser at 350bar for the fueling buses, refuse trucks
- Hyundai fuel cell ix35 car x 1

Denmark:
- Refuelling station – 700bar
- Hyundai fuel cell x 2 or 3

Figure 1: Hydrogen activities of the HyTrEc partners in the North Sea Region

Figure 1: Hydrogen activities of the HyTrEc partners in the North Sea Region
Hydrogen Vehicle and Refuelling Infrastructure Programmes (2014)

Scandinavia
An initial well distributed network provides coverage across the region for Fuel Cell Electric Vehicles (FCEVs).

UK
A consortium of industry leaders and Government developed a strategy for a network of 65 hydrogen refuelling stations (HRS) by 2020. Full range of storage, production and distribution demonstrations (salt caverns, pipelines, CCS, electrolysis, power-to-gas) are in place.

Germany
A large private consortia has agreed a strategy based on early deployment of captive fleets and associated infrastructure. This will migrate to a nationwide infrastructure for FCEVs by 2025.

France

Belgium
Developing H2 Mobility programme together with industry and government for 2015-2025. Large number of uniform codes and standards. Lack of mainstream / public knowledge. Lack of incentive mechanisms.不足

Netherlands
Developing H2 Mobility programme together with industry and government for 2015-2025. Limited number of uniform codes and standards. Lack of mainstream / public knowledge. Lack of incentive mechanisms.不足

1.3.2 SWOT analysis for hydrogen in the North Sea Region

The following figure shows the SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis of hydrogen transport economy in the North Sea Region, undertaken by the H2iE partnership.

Figure 3: SWOT Analysis for hydrogen in the North Sea Region

Natural resources for renewable energy production
Most member states have H2 Mobility programmes
Lack of mainstream / public knowledge
Limited number of uniform codes and standards

Weaknesses
Competition from other global locations
Emerging interest in zero emission zones in cities
Competition from other energy storage / zero emission transport technologies
Lack of strong incentive mechanisms

Opportunities
Supporting market for renewable energy production
Unique hydrogen demonstration projects
Combating climate change

Threats
Market for renewable energy production
Limited number of uniform codes and standards
Lack of mainstream / public knowledge
Lack of incentive mechanisms

Figure 2: North Sea Region Member States and National Hydrogen Policies and Programmes

Figure 3: SWOT Analysis for hydrogen in the North Sea Region

The following figure shows the SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis of hydrogen transport economy in the North Sea Region, undertaken by the H2iE partnership.
In summary, the HyTrEc partnership believes the North Sea Region can play a key role in the following main areas:

a) Technology supplier
b) Early market for hydrogen vehicles
c) Exporter of ‘green’ hydrogen
d) Exporter of skills and hydrogen training expertise
e) Lead for the rest of Europe

1.3.3 Themes of a strategy framework for hydrogen in the North Sea Region

In order to develop a strategy framework for improving access to and advancing the adoption of hydrogen as an alternative energy vector across the North Sea Region, the HyTrEc partnership identified key barriers or challenges to be overcome.

These key challenges and barriers are grouped under the following four themes:

- Infrastructure and applications
- Finance and economics
- Policy and regulation
- Communication and education

These themes then form the basis for this strategy for hydrogen in the North Sea Region.

1.3.4 Challenges to further take-up of hydrogen technologies

The key barriers or challenges identified are listed below, grouped under the relevant theme and explained further on the following page.

Figure 4: Themes of a joint strategy on hydrogen fuelled transport in the North Sea Region

Figure 5: Key challenges for hydrogen transport roll-out in the North Sea Region
Communication and education

A lack of mainstream knowledge and understanding of hydrogen in transport and the opportunities it presents can restrict the buy-in of decision makers and policy makers. There is also a lack of hydrogen education opportunities at certain levels within the education system, such as in further education and in some cases schools.

Infrastructure and Applications

Although a number of regions have introduced hydrogen vehicles, which have a driving range comparable to conventional fuelled vehicles, the use of these vehicles for longer distance trips is still limited due to a lack of refuelling infrastructure throughout the North Sea Region. Costs are a barrier at this point in time as they are still well above those of incumbent technologies.

A lack of clear ownership for joint strategies and roadmaps is a challenge in some areas because hydrogen transport fits several key policy agendas and government departments, for example energy and transport, with often no one department taking a lead. The development of infrastructure and the deployment of vehicles need to be implemented in parallel and based on realistic expectations.

Finance and economics

With the sector still being in a demonstration stage and pre-commercial, the need for public funding matched with industry and local funds can be a barrier, not least because of the complexity of setting up and managing funding partnerships. The lack of a competitive supply chain is another challenge, which also impacts costs. With projects having high start-up costs and time-limited grant funding, the longer term economics can be a challenge.

Local circumstances around potential for use of residual heat and oxygen from electrolysis, as well as electricity grid balancing should be considered in order to enhance the business case for refuelling facilities.

Policy and regulation

In some areas a lack of one clear lead policy driver can cause a challenge, when the topic cuts across many agendas. Where this should be an advantage, it can be restrictive where no one department takes a clear lead in driving a roll out strategy forward. The Hydrogen Journey undertaken by the HyTrEc partnership identified disparities in regulations and knowledge of regulations throughout different member states. Having clear policies will support investment and encourage well-planned and co-ordinated deployment, maximising potential benefits.

HyTrEc’s Hypothetical Journey exercise concluded that the EU policy/ regulatory framework tends to be translated differently by member states, making it difficult to coordinate a joined up, cross border hydrogen refuelling infrastructure network. This challenge is reinforced by the fact that although most North Sea Region member states have H2 Mobility programmes, there is little or no mechanism to ensure the national programmes are co-ordinated with each other and to ensure cross border issues are tackled.

Communication and education

A lack of mainstream knowledge and understanding of hydrogen in transport and the opportunities it presents can restrict the buy-in of decision makers and policy makers. There is also a lack of hydrogen education opportunities at certain levels within the education system, such as in further education and in some cases schools.
2 A Joint Strategy Framework for advancing the adoption of hydrogen as an alternative energy carrier in the North Sea Region

Following consideration of the DOST analysis for hydrogen transport in the North Sea Region, the HyTrEc partnership proposes the following vision for 2020. This Strategy Framework then goes on to explain how the key barriers standing in the way of achieving this vision can be overcome.

2.1 Vision

In 2020 the North Sea Region is leading Europe on the production and use of green hydrogen as an energy carrier, using excess renewable electricity for zero-emission transport. Hydrogen is a widely accepted, commonly used low emission transport fuel helping to maximise the sustainable use of the North Sea Region’s natural resources.

2.2 Recommended actions 2015 - 2020

Actions that could overcome the key barriers (1.3.4) to achieving this vision for 2020 were:

- Zero-emission transport applications (cars, buses, vans, forklifts, refuse trucks, water-based vessels, etc.)
  - operational existing fleets in order to have optimal utilisation of fuelling stations
  - transferring existing knowledge and experience to other areas within the North Sea Region

Based upon the experiences and strengths of the North Sea Region the demonstration projects should be focused on:

- Hydrogen fueling stations utilising green hydrogen - hydrogen produced from excess renewable electricity (especially wind)
  - hydrogen produced as a by-product from chemical industries
- Zero-emission transport applications (buses, vans, forklifts, refuse trucks, water-based vessels, etc.)
- Exchanging applications (buses, cars, forklifts, etc) between regions will be a cost-efficient way of learning best practice.

2.2.1 International demonstration / lighthouse projects

Aim: Enlarging existing and realising new DEMONSTRATION PROJECTS highlighting below. These broadly fit under the four themes explained in section 1.3.3.

2.2.2 Policy Support measures for early implementation

Aim: Transnational ANALYSIS OF INCENTIVES that can compensate in a sustainable way for the additional costs of zero-emission hydrogen technologies.

The aim of this action is to inventory and analyse incentives (their definition, advantages and disadvantages and lessons learnt) regarding the implementation of hydrogen (fuelling stations, transport and energy storage) in all North Sea Region member states and beyond. With the involvement of governments, industry and other key stakeholders, this will provide recommendations on the most effective incentives for each member state, within current legislation. It is also important to learn from experiences of other clean transport fuels.

2.2.3 Education programmes

Aim: Developing a well-coordinated, transnational EDUCATION PROGRAMME on hydrogen for transport and energy storage, based upon the knowledge and experience gained in demonstration projects. This will support large-scale demonstration of hydrogen technology to the sectoral situation and give confidence.

2.2.4 Communication

Aim: Active, structured and regular transnational COMMUNICATION of the status of hydrogen development in the North Sea Region, including the North Sea Commission Thematic Group and North Sea Power to Gas Platform.

This should be based upon results, experiences, barriers encountered and overcome, with the involvement of governments, industry and other key stakeholders, and published as a communication tool.

Tasks within this action include:

- Mapping and reporting every six months to discuss:
  - Technical / economic results from existing projects: fuelling stations and vehicle applications - closing the infrastructure gaps around the North Sea Region (taking forward recommendations from HyTrEc’s Hydrogen Journey)
  - Discussion of policy measures
  - Regulations and codes - raising awareness of key disparities among member states
  - Incentives - identifying and recommending the most effective approaches
- Outlining future joint actions and projects that will be delivered in collaboration with the previously identified four key actions around Demonstration, Policy Support Measures, Education and Communication.

2.2.5 Structural cooperation

Aim: Create a structural cooperation platform “Hydrogen in the North Sea Region” for co-ordinated knowledge exchange and taking forward the steps necessary to realise the vision.

With the strong and ambitious renewable energy targets of the North Sea Region, large scale demonstration projects should take place with hydrogen used as an energy storage medium.

Regional large scale demonstration projects should be in line with the European vision, as stated in the second Fuel Cells and Hydrogen Joint Undertaking (FCH 2 JU) and will be co-funded by industry, by FCH 2 JU and by structural funds.

Of the key targets are defined:

- Cooperation and aligning of activities with other North Sea Region organisations, including the North Sea Commission Thematic Group and North Sea Power to Gas Platform.

In new technology the key is to communicate results and expectations as clearly as possible and avoid “overpromising / underperforming”. It is important to communicate results rather than expectations.
In 2020 the North Sea Region is leading Europe on the production and use of green hydrogen as an energy carrier, with excess renewable electricity for zero-emission transport. Hydrogen is a widely accepted, commonly used low-emission transport fuel helping to maximise the sustainable use of the North Sea Region’s natural resources.

In order to be a leader in the sector in Europe, the Interreg North Sea Region, with about 60 million inhabitants and an area of about 664,000 km², will focus on applications that are closest to commercial production so as to support existing refuelling infrastructure and the development of new facilities that will close current gaps. This increased volume will lower costs through targeted supply chain development. While other, currently more niche and innovative applications will also be important, the highest priority applications for large scale roll-out are:

- **Hydrogen Fuel Cell Cars (refuelling at 700 bar)**
  - In 2015 hundreds of cars are running on hydrogen around the world and major OEM’s have clear ambitions for further roll out. Based on current plans and programmes, in 2020 it is realistic to expect that there will be 5,000 hydrogen fuel cell cars operating in the North Sea Region.

- **Hydrogen Fuel Cell Buses (refuelling at 350 bar)**
  - In 2015 about 100 buses are running on hydrogen around the world and European OEM’s have defined a target of 500-1,000 buses in Europe in the short term. Based on current plans and programmes, it is realistic to expect that in 2020 there will be 500 hydrogen fuel cell buses operating in the North Sea Region.

- **Hydrogen Fuel Cell Forklifts (refuelling at 350 bar)**
  - In 2015 around 5,000 forklifts are running on hydrogen around the world and some major end-users are starting demonstration projects. The North Sea Region is a major logistics centre for Europe. Based on current plans and programmes, it is realistic to expect that in 2020 there will be 3,000 hydrogen fuel cell forklifts operating in the region.

Based on current plans it is expected that in 2020 these vehicles will be supported by 145 hydrogen refuelling stations (100 at 700 bar and 45 at 350 bar).

The North Sea Region, with the largest installed wind capacity in Europe, will focus hydrogen production on renewable electricity. By estimating the annual total hydrogen use of the vehicles expected to be operating in the North Sea Region in 2020, the HyTrEc partnership concludes that 185MW of electricity is required per year to produce this fuel (appendix 1). Total wind energy capacity in the HyTrEc partners’ countries totalled almost 69,000MW in 2014 (Source: European Wind Energy Association), and most of these countries are in need of a method for storing energy, to assist with the difficulties of matching supply and demand.

It is therefore concluded that by working together as one region, it is possible to achieve the vision for 2020 and be a leader in Europe on the production and use of green hydrogen as an energy carrier, using excess renewable electricity for zero-emission transport.

### Appendix 1

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<tr>
<th>Application</th>
<th># Hydrogen Refuelling stations</th>
<th># Vehicles per station</th>
<th># Total vehicles</th>
<th>Annual Hydrogen use (tonne/year)</th>
<th>Equivalent Wind capacity (MW)</th>
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<td>500</td>
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<td>Forklifts</td>
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<td>10⁴</td>
<td>3000</td>
<td>2700</td>
<td>65</td>
</tr>
</tbody>
</table>

1. Average hydrogen production efficiency: 60-60 kWh/kg, average wind turbine: 2500 equivalent full-load hours
2. Annual range 30,000 km/year, specific hydrogen consumption: 1 kg/100 km
3. Annual range 70,000 km/year, specific hydrogen consumption: 10 kg/100 km
4. 3 shifts/day, 300 days/year, specific hydrogen consumption: 1 kg/shift
For further information
www.hytrec.eu
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