Hydrogen: the missing link for the energy transition

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Nicolas Kraus discusses hydrogen technology and how it can contribute to meeting the climate goals set for Europe

Hydrogen is becoming one of the major energy carriers of the 21st century. With renewable energies, it provides a solid foundation for the development of the energy economy of the future. Thanks to its particular characteristics, hydrogen technology is able to contribute to achieving the climate goals set for Europe by 2050, and to translate them into economic activities.

Hydrogen is indeed a key component of the future of energy systems that will accelerate the transition to 100% decarbonised systems, in particular to solve the problem of the intermittency of renewable energies and the rapid decarbonisation towards 'zero emission' transportation and energy systems. It presents opportunities in terms of job creation, technological leadership, and environmental protection for Europe.

The hydrogen economy is already a hundred billion-dollar market worldwide. It is today mainly used for the production of fuels (50% of the market), fertilizers (43%) and various industrial processes (6%) such as the production of glass, iron, as well as various food products such as margarine.

Other uses of hydrogen exist but are still marginal on a global scale with 1% of the market: the propulsion of vehicles - cars, buses, trains, boats, the production of electricity and heat for commercial use and residential, renewable energy storage in the form of hydrogen, or substitution of natural gas with hydrogen in industrial and domestic applications. Indeed, hydrogen enables sectoral integration.

The ability of power-to-hydrogen to access and integrate each sector of the energy system opens up the opportunity for deploying and utilising renewables to a much greater extent. Power-to-hydrogen systems can be implemented within the electricity grid utilising long-term power purchase, guarantees of origin, in accordance with providing energy storage ancillary services for managing renewables in electricity grids and in direct combination with renewable power sources.

Whereas electricity derived from renewables provides the power sector with a profound decarbonisation pathway, the heat and mobility sectors as well as industry do not yet have decarbonisation pathways of equivalent significance. The versatility of hydrogen enables these sectors to be integrated and to contribute to Europe's energy transition.

These uses are, therefore, likely to grow for four reasons, as they offer:

1. A solution for seasonal storage of renewable energy in large quantities to promote the development of local energy in Europe and limit energy dependence:

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Renewable power generation is characterised by variability and intermittency. As the renewables' penetration increases, the problem of balancing supply and demand for operators of electricity networks also rises. Periods of non-consumption-oriented production of renewable energy are usually managed by curtailing renewable power sources because the electricity cannot be sold at the time of generation.

For example, in 2015 Germany curtailed 4.7TWh of renewable electricity and re-dispatching costs for Germany and the UK were €1 billion in 2016. It has been estimated that curtailment could amount to 30% of Germany's electricity consumption by 2050 unless methods for storing and making use of this energy are implemented.

Power-to-hydrogen technologies in a power system integrating high penetration of Renewable Energy Sources (RES) can operate throughout long periods of non-consumption-oriented production of renewable energy by feeding hydrogen into one or more energy sinks (eg. the gas grid, the storage tanks of hydrogen refuelling stations, and salt caverns). Stored hydrogen can be used on various timescales for satisfying demands for heat, transport, power or industry achieving high utilisation and absorption of energy.

Production of hydrogen (or synthetic natural gas derived from hydrogen and carbon dioxide (SNG)) for injection into the natural gas grid is usually referred to as power-to-gas (P2G). It is currently being demonstrated at approximately 15 sites across Europe. As a major energy conveyor, the gas grid offers an extant energy sink for renewables and, unlike the power system, has a large inherent storage capacity in the TWh scale. Therefore, power from the electricity grid can be transferred readily to the gas grid via P2G.

Hydrogen can also be easily produced by replacing natural gas by biomethane in Steam Methane Reformers (SMR): when using hydrogen produced from biomethane, ie. from wastes, it will boost the circular economy by giving other market opportunities to biogas.

2. An electro-mobility solution. Fuel Cell Electric Vehicles (FCEVs) have a fast fefuelling time (maximum 5 minutes for 500 km) and are particularly well-suited for heavy-duty or frequent rotation vehicles such as taxis, utility vehicles, trucks, buses, trams, trains. Zero-emission maritime applications are also emerging.

This hydrogen-based electromobility also has great potential for employment and innovation leadership in Europe (in fact, nearly 1,400 units are assembled for a fuel cell vehicle compared to only 200 for electric battery vehicles). Green hydrogen offers a higher energy density than green electrons stored in today's batteries and therefore provides greater autonomy for transport and energy applications than purely battery electric systems.

Hydrogen refuelling stations (HRS) incorporating on-site electrolysers are producing, storing and dispensing hydrogen to FCEVs in accordance with grid balancing requirements (eg. as part of the dynamic Firm Frequency Response service in the UK). The essential hydrogen storage capacity at each station enables production to be decoupled in time phase from demand for refuelling FCEV. In other words, hydrogen can be produced at the HRS when it contributes to stabilising the power grid.

Furthermore, the required electrolyser capacities, and the need to implement significant numbers of HRS in a geographical distribution matches well with the power sector's requirements for balancing increasing amounts of renewable generation in distribution networks. In the coming years, as the numbers of FCEVs (cars, buses, vans and other vehicles) increase, the aggregate electrical load of electrolyser-HRS will become significant for grid balancing at a national level.

This approach is advantageous for further decarbonising both the mobility and power sectors. It facilitates the use of much higher efficiency road vehicles, so reducing the energy requirement for road travel while shifting it to a sustainable energy resource.

Additionally, the use of hydrogen in the mobility sector reduces direct (CO_2) and indirect (eg. NO_x and SO_2) GHG emissions so contributing to a decrease in health concerns. Progressive utilisation of such vehicles will foster zero emission transport in urban zones, hydrogen eco-systems and corridors between cities/countries so solving the infrastructure development situation.

Moreover, grid-connected long-term power purchase with renewable energy sources, guarantees of origin, and direct connections offer pathways that certify the renewable character of the hydrogen and enable increasing its share at European and national level.

3. A decarbonisation solution for industrial processes through the use of green hydrogen (produced from renewable energy), particularly in the chemical and iron and steel industry.

Hydrogen is today widely used in industry and almost entirely produced by fossil fuels, with a related CO_2 footprint. Using green hydrogen produced from renewables will increase the share of renewable energy sources in industrial processes. As the industry is cost sensitive, green hydrogen needs to serve applications where it offers most benefits.

Steel manufacturing processes offer one such application. One process to produce steel is to use hydrogen for the reduction of ore. Several initiatives are on the way in Sweden, Austria, and Germany; partly supported by European funding.

Refineries could also utilise green hydrogen to decarbonise their refining processes. Today, global hydrogen production is at 55 million metric tons annually. Out of this, ±40% is consumed at refineries. Utilising Power-to-Hydrogen could therefore have a significant beneficial effect on the overall system decarbonisation.

Fuel producers are obliged to reduce CO_2 in their supply chain. This CO_2 reduction can be achieved by using green hydrogen in the refinery process. Although the costlier green hydrogen doesn't compete yet economically with hydrogen produced from fossil hydrocarbons, it does compete with biofuels.

To achieve this, regulations should provide non-discriminating rules that allow the use of hydrogen in the upstream fuel processes in a fair competition (both in price and GHG mitigation potential) with biofuels to fulfil the obligations for the renewable share in liquid fuels, therefore helping to reduce the dependency of the European Union on natural gas whilst contributing to the reduction of palm oil consumption.

Hydrogen can also be used as a green synthetic substitute for many different applications in the fuel and chemical sectors. Methanol, for example, is a liquid chemical with many different possibilities of application.

4. A decarbonising pathway for the heating sector through either a fuel switch or technology update. Hydrogen and hydrogen admixtures can be used as an alternative to natural gas for space heating, water heating and gas cooking. Hydrogen admixtures or hydrogen can be distributed via the existing gas grid, thus making use of the large available infrastructure asset.

Because heat is by far the largest energy demand and has the greatest seasonal variation (disparity between high demand in winter, in times of low RES generation, and high RES generation in the summer), P2G can be applied to decarbonise gas networks and ultimately store excess renewable energy produced in the summer for release in the winter. Therefore, P2G can make a major contribution to decarbonising the heating sector and decreasing our dependency on natural gas imports.

The natural gas infrastructure is progressively decarbonising through the introduction, in the short-term, of biomethane and, hydrogen with low concentration admixture or as SNG without requiring any changes to the infrastructure or gas appliances.

Long-term objectives of full decarbonisation should therefore focus on enabling increasing shares of hydrogen, SNG and biomethane with needed standardisations. In order to maximise efficiency in the energy system, combined heat & power (CHP) should be utilised. Fuel Cell CHP has been deployed for commercial and district heat at scale for several decades. Micro-CHP fuel cells are today being deployed in Japan with 190,000 units expected to be installed. Meanwhile the largest European project (PACE) is aiming at 2,650 units.

Hydrogen and fuel cell technologies offer much-needed solutions as governments work to deliver on their ambitious decarbonisation targets and commitments set forth by the Paris Agreement. A study of the Hydrogen Council, *Hydrogen, scaling up* released at the COP23, shows that worldwide, hydrogen could help reduce the annual CO_2 emissions by 6 gigatons - 20% of the abatement need required to limit global warming to 2 degrees Celsius - by enabling higher share of renewable energy in the energy mix and by decarbonising applications in transport, industry energy, heating and power.

Hydrogen also serves as a feedstock using captured carbon, while generating a €2 trillion global market and creating high added value jobs for 30 million people (with up to €52 billion market and 800K new jobs by 2030 potential in Europe).

It is now a question of knowing where Europe's position will be with regard to the use of this new energy vector. Are we going to import the technologies or are we going to create a new export industry? So far, the European Union (EU) has taken the lead, with companies exporting their technologies to the US, Korea and Japan, but for how long

will the EU remain a pioneer in this sector, which requires support at European, but also national, regional and local level.

In order to accelerate the deployment of hydrogen and fuel cell technologies in Europe as well as at regional and local levels, Hydrogen Europe, together with the European Public-Private Partnership for Hydrogen and Fuel Cells (FCH JU), has created a new initiative to help regions/cities to develop projects in the hydrogen and fuel cell sectors - and to bring them together with European industry.

The initiative aims to:

- Support regions to evaluate hydrogen and fuel cell applications in business cases and assess their potential
- Identify and optimize the use of different financing options by sharing information on financing/financing options for hydrogen projects and public-private fuel cells
- Gather public funding at European level (FCH JU, European Investment Bank EIB, EFSI, EIF, ERDF), national (eg. Caisse des Dépôts Group) and regional
- Put forward private financing, eg. industrial self-financing (jointly supported by users and manufacturers or other industrial players) or private finance (private equity players, venture capital funds, high-tech funds)
- Support regions/cities in the promotion of technology - for example in the context of their 'smart specialization strategies'
- Develop roadmaps and concepts to prepare and implement deployment projects from 2018

Among the many regions that establish a hydrogen roadmap, we are proud to have a French champion region namely the Auvergne Rhône Alpes region which has just received confirmation from the EU that €10.1 million will contribute to the installation of 20 hydrogen charging points and 1000 vehicles equipped with hydrogen fuel cells.

That's excellent news! And we look forward to more such projects in the coming years, but that will have to go hand in hand with legislative decisions that allow the industry to thrive.

However, many of the opportunities offered by hydrogen have not been exploited, particularly because of regulatory or legislative barriers.

An adaptation of the Renewable Energy Directive is currently being discussed at European level. It is essential that the text puts the different technologies on an equal footing, insofar as they allow both the integration of renewable energies in the transport sector, as well as the decarbonisation of mobility and further, to push for the creation of a green industry in the European regions. ■

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Hydrogen Europe is the leading organisation that brings together many companies - from SMEs to multinationals - and European research institutes that are mobilising to promote the wider use of hydrogen as a new energy carrier in the economy, and fuel alternative and low-carbon raw material in the mobility and industry sectors. Hydrogen Europe represents more than 115 industrial companies 65 research organizations and 10 national associations. The association is partnering with the European Commission in the public-private partnership Fuel Cells and Hydrogen Joint Undertaking (FCH JU) to accelerate the market introduction of clean technologies in the energy and transport sectors.

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