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How far away is hydrogen? Its role in the medium and long-term decarbonisation of the European energy system☆

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ABSTRACT

Hydrogen is a promising avenue for decarbonising energy systems and providing flexibility. In this paper, the JRC-EU-TIMES model – a bottom-up, technology-rich model of the EU28 energy system – is used to assess the role of hydrogen in a future decarbonised Europe under two climate scenarios, current policy initiative (CPI) and long-term decarbonisation (CAP). Our results indicate that hydrogen could become a viable option already in 2030 – however, a long-term CO_2 cap is needed to sustain the transition. In the CAP scenario, the share of hydrogen in the final energy consumption of the transport and industry sectors reaches 5% and 6% by 2050. Low-carbon hydrogen production technologies dominate, and electrolysers provide flexibility by absorbing electricity at times of high availability of intermittent sources. Hydrogen could also play a significant role in the industrial and transport sectors, while the emergence of stationary hydrogen fuel cells for hydrogen-to-power would require significant cost improvements, over and above those projected by the experts.

"Oui, mes amis, je crois que l'eau sera un jour employée comme combustible, que l'hydrogène et l'oxygène, qui la constituent, utilisés isolément ou simultanément, fourniront une source de chaleur et de lumière inépuisables et d'une intensité que la houille ne saurait avoir."

(L'Île Mystérieuse, Jules Verne, 1874)

☆ The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.

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Introduction

Energy security, competitiveness and climate change are key policy drivers for the European Union. The conclusions on the 2030 Climate and Energy Policy Framework of the European Council [1] endorse a binding target for the EU of at least 40% domestic reduction in greenhouse gas (GHG) emissions by 2030 compared to 1990 levels, coupled with a minimum of 27% renewable energy and energy efficiency improvements. The challenge remains on identifying the best way to reduce GHG emissions, while at the same time improving competitiveness, growth, and security of supply.

This has rekindled interest in the "hydrogen economy", based on hydrogen as a promising clean energy carrier for decarbonised energy systems, if produced from renewable energy sources, or coupled with carbon capture and storage (CCS) or nuclear energy. Its penetration in the energy system could help to reduce GHG emissions, in particular in sectors where decarbonisation is the hardest [2]. Moreover, flexible hydrogen production technologies, coupled with hydrogen storage options, could provide added flexibility in the face of fluctuating energy demand.

The European Union (EU) has been actively pursuing advancements in hydrogen and fuel cells since the late 80s, supporting with over EUR 500M more than 200 research projects on hydrogen production, distribution, storage, end-use technologies, and best practices to promote the update of clean hydrogen technologies.[4] In 2002, the then-Commissioners for Energy and Transport and for Research established the High Level Group for Hydrogen and Fuel Cells Technologies, tasked with developing a vision on the potential contribution of hydrogen to sustainable energy [3]. In 2008, the European Council adopted Council Regulation 521/2008 [4], establishing the Fuel Cells and Hydrogen Joint Technology Initiative, which was renewed and strengthened in 2014 [5]. This represents an important public–private partnership, aimed at accelerating the development and deployment of hydrogen and fuel cells.[5] For transport, the new EU Directive on the "deployment of alternative fuels recharging and refuelling infrastructure" [6] aims amongst others "at ensuring a sufficient number of publicly accessible hydrogen refuelling points, with common standards, in the Member States who opt for hydrogen infrastructure, to be built by end-2025".[6]

Several European countries have developed national strategies to support the penetration of hydrogen and fuel cells in their energy systems. The German National Innovation Programme for Hydrogen and Fuel Cell Technology makes 1.4 billion € available over 10 years (2007–2016), with funding from public and private sources. It aims at advancing the deployment of hydrogen based technologies in all energy/transport sectors [7]. In France, various aspects of hydrogen energy pathways are covered within the 34 roadmaps of the "New Industrial France" [8]. Despite the renewed efforts in technological research and development for hydrogen and fuel cells, the hydrogen economy is not yet developed, and several technological and non-technical barriers persist. France Stratégie [9], for example, questions the role that hydrogen can play in the energy transition and argues that it is a too costly alternative.

Improving our understanding of the role that hydrogen could play in decarbonising the energy system in Europe is critical in informing better targeted policies in support of the sector. In doing so, it is important to realise that assessing the role of hydrogen in isolation from the rest of the energy system may lead to biased inferences, failing to capture interactions with other drivers of the energy system, as well as competition among sectors for primary energy.

Several authors address the opportunities and challenges of hydrogen. For an early review, see Ref. [10]. More recently, Ref. [2] reviews the barriers and opportunities for the deployment of hydrogen in the transport sector. They conclude that sustained high fossil fuel costs, large deployment of renewables and CCS, limited breakthrough in vehicle batteries, as well as stringent mitigation targets for the transport sector, are pre-conditions for the transition to a hydrogen-based mobility. Ref. [11] assesses the economic attractiveness of hydrogen production technologies, and concludes that coal and natural gas remain the most attractive processes from an economic perspective. The paper, however, focuses on the current situation, without considering technological improvements, competition with other sectors for fuels, nor climate change concerns.

Bottom-up energy system models, either in isolation or coupled with additional tools, have been used to assess the role of hydrogen in overall decarbonisation, addressing trade-offs within the wider energy system, at different levels of governance. For instance, Refs. [12–15] focus on the UK, while Ref. [16] on Germany, Ref. [17] on the US, and Ref. [18] on Japan. Some studies at the sub-national level have also been undertaken (for instance, Ref. [19] looks at hydrogen use in the transport sector in the region of Madrid). The focus on the European energy system can be found in Refs. [20] and [21–23]. Capros and co-authors [21–23] show that hydrogen is cost-effective in Europe in the long-term as a means to store excess power. At the global level, Ref. [24] finds that hydrogen production shifts towards renewable sources over time, in a carbon-constrained world, while Refs. [25,26] assess the key factors influencing the deployment of hydrogen fuel cell vehicles at the global scale.

Despite the different approaches and assumptions, these studies agree in considering investment costs in hydrogen production and consumption technologies a key obstacle. Moreover, they tend to identify a critical role of hydrogen for long-term decarbonisation, with a significant deployment starting usually around 2040 in a carbon-constrained world.[7] And, without a strong carbon price signal, the role of hydrogen remains limited.

[4] http://ec.europa.eu/research/energy/eu/index_en.cfm?pg=research-fch-support [last accessed on 21.05.15].

[5] http://www.fch-ju.eu/ [last accessed on 21.05.15].

[6] http://europa.eu/rapid/press-release_IP-14-1053_en.htm [last accessed on 21.05.15].

[7] Ref. [15] shows that, applying dynamic growth constraints to take into account of the time needed for the diffusion of new powertrains leads to a smoother transition, starting earlier, around 2030.