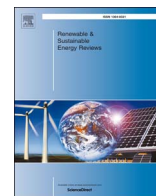




Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

The role of hydrogen in low carbon energy futures—A review of existing perspectives

Emma S. Hanley*, JP Deane, BP Ó Gallachóir

MaREI Centre, Environmental Research Institute, University College Cork, Ireland

ARTICLE INFO

Keywords:

Hydrogen pathways

Integrated energy system models

ABSTRACT

This study provides a review of the emergence of hydrogen within low-carbon pathways from different integrated energy system models. The objective is to understand the drivers and policy scenarios that lead to the emergence of hydrogen over other low-carbon technologies. The review is divided into global, multi-regional and national integrated energy system models with drivers, marginal abatement costs and timing of hydrogen emergence assessed. Hydrogen's use in energy systems is complex as a result of its relationship with other energy sources. It was found that bioenergy can act as both a competitor and driver for hydrogen energy, along with increased electrification and high renewable electricity scenarios. However, electric vehicles are a main competitor in the passenger vehicle sector. In reviewed results, hydrogen mainly emerges after 2030; although, some technologies emerge as early as 2020 and as late as 2050. The uncertainty and complexity surrounding hydrogen may be as a result of the difficulty of representing hydrogen technologies and systems in energy system models. This study can allow policy makers to assess the various options to be considered regarding hydrogen and make informed decisions for moving towards a decarbonised energy system.

1. Introduction

The global energy system must complete a transition to a decarbonised system to reduce greenhouse gas (GHG) emissions and mitigate climate change [1]. Furthermore, energy security and fuel affordability are important aspects to be considered [2–6]. Global GHG emissions continue to increase and after the 21st Conference of the Parties (COP21) the urgency of moving to a secure low-carbon energy supply is evident [1]. The future low-carbon pathway is uncertain and therefore so is the role of alternative fuels and technologies, that are envisioned to aid in the energy transition. This study reviews the role of hydrogen as one such alternative fuel in low-carbon pathways towards 2050 in various integrated energy system models. The potential of hydrogen as an energy carrier is well known; however, it has failed to

make a widespread impact on energy systems due to numerous barriers, including costs and availability of infrastructure. Hydrogen's versatility and its potential for emissions reductions can allow hydrogen to have an important role in future low-carbon pathways [7–9]. Hydrogen's role is reviewed in this paper to highlight hydrogen pathways emerging within different global, multi-regional and national models and scenarios. The purpose of this review is to highlight the complexity of the hydrogen energy system as a result of its synergies with other energy resources and analyse its emergence within different integrated energy system models. This study identifies the potential drivers and barriers of the hydrogen economy. Therefore, it can be used to allow policy makers to assess various options for moving towards a decarbonised energy system.

Hydrogen can be produced from a wide range of methods and

Abbreviations: AIM, Asian-Pacific Integrated Model; ACT, Accelerated Technology Scenario; BaU, Business as Usual Scenario; BEV, Battery Electric Vehicle; BIO, Bioenergy Scenario; CCS, Carbon Capture and Storage; CEA, Early Action Scenario; CCP, Least Cost Scenario; CCSP, Socially Acceptable Scenario; CGE, Computable General Equilibrium; CIM, Common Information Model; CFH, Faint Heart Scenario; CLC, Low-Carbon Scenario; CNG, Compressed Natural Gas; COP21, 21st Conference of the Parties; CO₂, Carbon Dioxide; CPI, Current Policy Incentive Scenario; CSAM, Super Ambition Scenario; DDPP, Deep Decarbonisation Pathways Project; DEC, Decarbonisation Scenario; DEM, Demand Scenario; D-EXP, Decarbonisation and Expand Scenario; DOM, Domestic Renewables Scenario; EFF, Efficiency Scenario; ETP, Energy Technology Perspectives; ETSAP, Energy Technology Systems Analysis Programme; EU, European Union; EV, Electric Vehicle; FCEV, Fuel Cell Electric Vehicle; GCAM, Global Change Assessment Model; GEA, Global Energy Assessment; GEEM, General Equilibrium Emissions Model; GHG, Greenhouse Gas; GMM, Global Multi-Regional MARKAL; HEV, Hybrid Electric Vehicle; HFO, Heavy Fuel Oil; HGV, Heavy Goods Vehicle; ICE, Internal Combustion Engine; IPCC, Intergovernmental Panel on Climate Change; JRC, Joint Research Centre; LC, Low Carbon; LDV, Light Duty Vehicle; LEAP, Long-Range Energy Alternatives Planning System; MAC, Marginal Abatement Cost; MARKAL, Market Allocation; MESSAGE, Model for Energy Supply Strategy Alternatives and their General Environmental Impact; PEC, Photoelectrochemical; PHEV, Plug-in Hybrid Electric Vehicles; PO, Partial Oxidation; R-DEM, Reduced Demand Scenario; RES, Renewable Energy System; SAGE, System for the Analysis of Global Energy Markets; SMR, Steam Methane Reforming; TIMES, The Integrated MARKAL-EFOM System; WEC, World Energy Council

* Corresponding author.

E-mail address: emma.hanley@ucc.ie (E.S. Hanley).<http://dx.doi.org/10.1016/j.rser.2017.10.034>

Received 18 January 2017; Received in revised form 11 July 2017; Accepted 26 October 2017

1364-0321/© 2017 Elsevier Ltd. All rights reserved.

energy sources with currently 96% generated from fossil fuels (48% natural gas, 30% oil/naphtha, 18% coal) and only 4% generated by electrolysis [10]. Steam methane reforming (SMR) is the main production method used; however, for hydrogen to be a low-carbon energy carrier the current generation methods must be adapted (integrated with carbon capture and storage (CCS)) or changed (renewable electrolysis). There are additional benefits arising from using renewable electrolysis such as storage that can aid increased renewable energy penetration [11–15]. The development of technologies for hydrogen generation including methods, such as the conversion of solar energy to hydrogen via photoelectrochemical (PEC) water-splitting process continues [16–19].

Currently, 50 million metric tons of hydrogen are produced globally per year. The main use is as a feedstock for ammonia production with 35% being used for oil refining. Considering its use in oil refining hydrogen is already contributing to emissions reduction. If hydrogen's role as a flexible energy carrier is realised, it may have future applications in passenger and freight transport (fuel cell vehicles, internal combustion engines (ICE)), thermal (solid oxide fuel cells, natural gas blending), storage (liquid and gaseous hydrogen) [20], power to gas generation and electricity generation [21–26], see Fig. 1 for pathways. The study considers the role of hydrogen in integrated energy systems across all sectors within the energy system.

Integrated energy system models are often used to provide different insights into low-carbon pathway scenarios and provide evidence for policy decisions [27]. This review aims to highlight the sectors hydrogen can emerge within integrated energy system models. This can indicate additional areas of policy development on hydrogen for policy makers. Different potential hydrogen pathways are shown in Fig. 1. The literature provides a review of both the production and delivery technologies used within integrated energy system models and reviews of national hydrogen futures [28,29]. However, this review will provide additional knowledge in relation to a comparison of hydrogen pathways

emerging within different global, multi-regional and national integrated energy system models. Furthermore, it will assess the drivers of hydrogen considering the entire energy system.

The paper layout is as follows:

- Section 2 briefly discusses different energy models and scenarios under which hydrogen is investigated.
- Section 2.1 presents a comparative review of hydrogen's role in eight global integrated energy system models.
- Section 2.2 discusses multi-regional European models.
- Section 2.3 compares 26 national integrated energy system models.
- Section 3 discusses the different hydrogen pathways emerging from the different models.
- Section 4 provides overall conclusions.

2. Integrated energy system models

Integrated energy system models consider the entire energy system with integration of the transport, thermal and electricity sectors. Energy system modelling allows insights to be provided for the assessment of suitable policies for the transition to a low-carbon economy [30].

A number of factors were considered when choosing the studies for the review. The methodology included only using integrated energy system models that considered the entire energy system (transport, heat, and electricity). Furthermore, as the time horizon considered in the review is to 2050 the following keywords were included in the search for literature “Low-carbon pathways to 2050”. In addition to this, reports and papers chosen required the inclusion of the final energy consumption breakdown of energy use. As there is a large quantity of studies and papers as well as models that include hydrogen as an option, only models and studies that have reports based on the above criteria were included. Many of the model scenarios for low-carbon pathways are for 2 °C scenarios They have at least a 70% reduction in

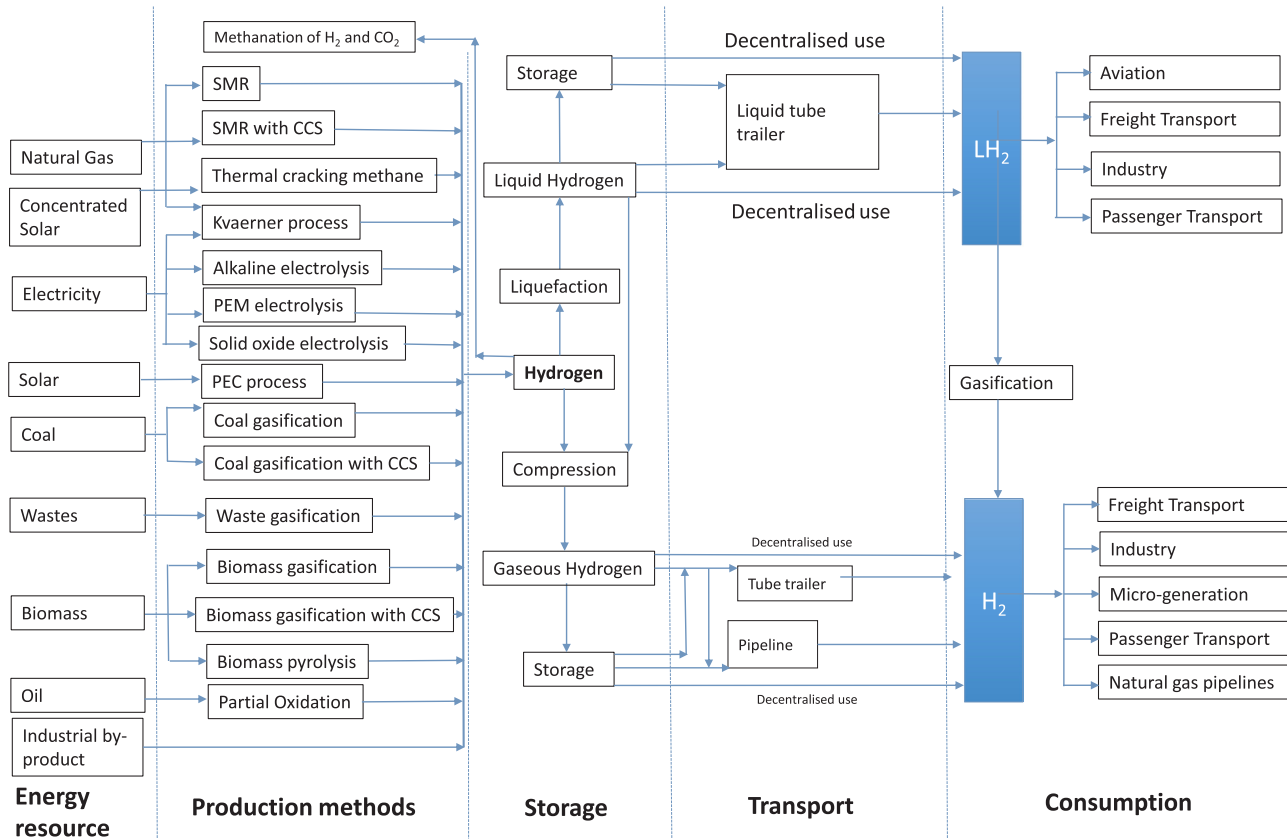


Fig. 1. Potential hydrogen pathways towards 2050.

Download English Version:

<https://daneshyari.com/en/article/8111999>

Download Persian Version:

<https://daneshyari.com/article/8111999>

[Daneshyari.com](https://daneshyari.com)