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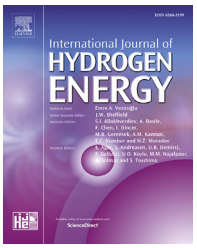

Smart energy solutions with hydrogen options

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ABSTRACT

We are in an era where everything is now requested to be smart. Here are some examples, such as smart materials smart devices, smartphones, smart grid, and smart metering. In regard to energy portfolio, we need to make it in line with these under smart energy solutions. With the developed cutting-edge technologies and artificial intelligence applications, we need to change the course of action in dealing with energy matters by covering the entire energy spectrum under five categories, namely, energy fundamentals and concepts, energy materials, energy production, energy conversion, and energy management. It is important to highlight the importance of a recent event. On 17 January 2017 a total of thirteen leading energy, transport and industry companies in the World Economic Forum in Davos (Switzerland) have launched a global initiative, so-called: Hydrogen Council, to voice a united vision and long-term ambition for hydrogen to foster the energy transition. It has aimed to join the global efforts in promoting hydrogen to help meet climate goals. This is a clear indication that smart solutions are not possible without hydrogen options. This study focuses on introducing and highlighting smart energy solutions under the portfolio pertaining to exergization, greenization, renewabilization, hydrogenization, integration, multigeneration, storagization, and intelligization. Each one of these plays a critical role within the smart energy portfolio and becomes key for a more sustainable future. This study also focuses on the newly developed smart energy systems by combining both renewable energy sources and hydrogen energy systems to provide more efficient, more cost-effective, more environmentally benign and more sustainable solutions for implementation. Furthermore, a wide range of integrated systems is presented to illustrate the feasibility and importance such a coupling to overcome several technical issues. Moreover, numerous studies from the recent literature are presented to highlight the importance of sustainable hydrogen production methods for a carbon-free economy.

Introduction

As the world faces unprecedented energy challenges, many countries are looking to include smart energy solutions as an effort to reach a sustainable future. Hydrogen energy systems have the potential to become a part of a clean, reliable, affordable, safe, and sustainable portfolio of smart energy solutions. A key advantage of hydrogen is that it can be

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produced from a variety of sources, including fossil fuels, nuclear power, biomass, and renewable energy.

Smart energy systems and role of hydrogen in such systems have been sparking interest, which can be seen in the recent literature. For instance, Dincer [1] has introduced and highlighted smart energy solutions under the portfolio pertaining to exergization, greenization, renewabilization, hydrogenization, integration, multigeneration, storagization, and intelligization in a sequentially meaningful form for implementation (Fig. 1). Dincer and Acar [2] have investigated and comparatively assessed smart energy systems for a sustainable future. The authors have stated that smart and sustainable energy systems should use technologies and resources that are adequate, affordable, clean, and reliable. Therefore, they have evaluated several smart energy systems based on their efficiencies, environmental performance, and energy and material sources. Lund et al. [3] have reviewed the scientific literature within the fields of smart energy and smart energy systems. The authors have also discussed the term smart energy systems regarding the issues of definition, identification of solutions, modeling, and integration of storage. The authors have concluded that smart energy systems represent a scientific shift in paradigms away from single-sector thinking to a coherent energy system understanding on how to benefit from the integration of all sectors and infrastructures. Ponce-Jara et al. [4] have comprehensively studied the Smart Grid power system by comparing experiences and success stories from around the world. Dincer and Acar [5] have discussed critical challenges related to increasing global energy demand and drawbacks of traditional fuels along with some potential resolutions including smart energy solutions with hydrogen options. Herrero et al. [6] have interrogated the contribution of residential smart energy systems to the ambitious carbon emissions reduction efforts required under the 1.5 °C mitigation pathway set by the Paris Agreement and their suitability for energy poverty alleviation goals.

Hydrogen and hydrogen-rich fuels such as natural gas and biogas can be used in fuel cells to provide power and heat cleanly and efficiently in a wide range of transportation, stationary, and portable power applications. Widespread deployment of hydrogen and fuel cell technologies offers a broad range of benefits for the environment, for our energy security, for our domestic economy, and for end-users. Hydrogen is a smart solution for the sustainability of future energy systems. Hydrogen offers many sustainable end use options for small scale, large scale, and mobile and stationary energy requirements. The end use options of hydrogen vary

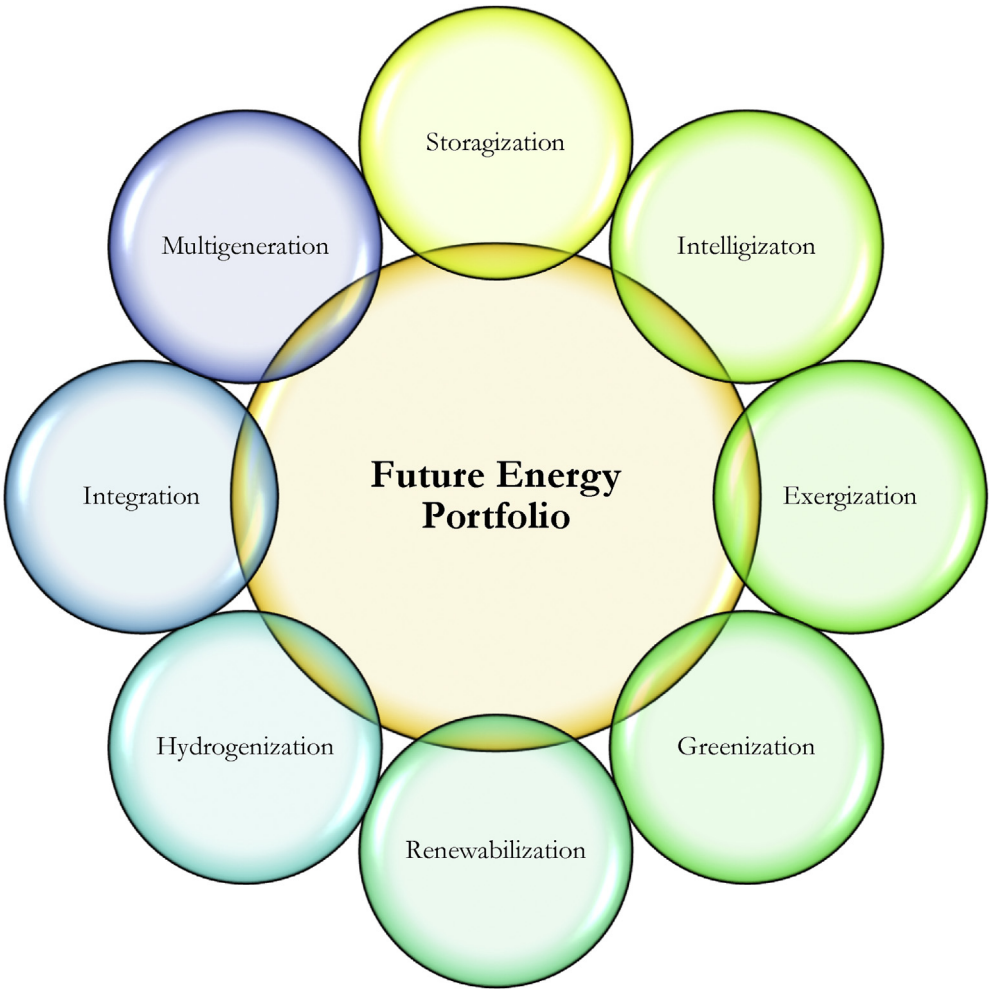

Fig. 1 – Eight branches of future energy portfolio (Dincer [1]).

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