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ENERGY FUTURE: ARE HYDROGEN SUPPLY CHAINS A SUSTAINABLE OPTION?

Keywords: *Hydrogen, Sustainability, Supply Chain Management*

Introduction. The Sustainable Development Goal 7 (SDG7) aims to ensure access to affordable, reliable, sustainable and modern energy for all[1]. The Russian invasion of Ukraine has accelerated the energy transition. Europe is facing a critical energy security problem just after the COVID pandemic. European plans to achieve climate neutrality by 2050 have been stated in the European Green Deal and its "Fit for 55" package, and the "REPowerEU" plan was launched in May 2022 with the specific objective to reduce European dependence on Russian fossil fuels[2]. The energy transition consists in reducing the use of fossil fuels and increasing the share of renewable sources in the energy mix. However, the transition is not easy for several reasons, one of them being the lack of infrastructure and investment costs for renewable energy sources (RES), another one is their intermittent nature which results in uncertainty about the power capacity to cover the electricity demand. To meet this challenge, hydrogen (H_2) represents a promising alternative to balance electricity generation and its consumption by recovering the electricity surplus creating greater flexibility in energy systems[3]. H_2 can be obtained from several energy sources, such as natural gas (grey H_2), coal (brown H_2), nuclear power (pink H_2), biomass, solar, wind, geothermal and hydro power (green H_2). If grey or brown H_2 processes are connected to carbon capture and storage (CCS), the final product is blue H_2. Each H_2 colour has a different cost and carbon footprint. Another advantage is the variety of the production processes (steam methane reforming, electrolysis, gasification) and the distribution options in a variety of forms using different technologies, gaseous hydrogen, liquefied hydrogen. Finally, it offers easy disposal of different H_2 products for industry or mobility applications (fuel cell electric vehicles). In industry, there is a big potential for hydrogen to be used in energy-intensive industry: iron-steel and cement sectors, partially motivated by more expensive CO_2 allowances[4]. In this sense, there is a need for the design and deployment of sustainable hydrogen supply chains (HSCs). Europe has been promoting the use of hydrogen technologies since the last two decades and in this paper, the approaches of Germany, France, UK, Hungary and Ukraine towards the implementation of HSCs, is analysed and discussed.

Purpose. The purpose of this research is to investigate if sustainability aspects are incorporated in the design of hydrogen supply chains in Europe. Specific goals are (a) to identify, the approaches and features of mathematical models used to optimise and design HSCs, (b) to describe the results of HSCs for different countries (centralisation level, type of technology, etc.),

and (c) to identify specific regional and economical caracteristics that can impact the use of sustanability metrics into the calculations, for this purpose European countries for different regions are part of the analysis.

Methodology. This paper investigates how the use of supply chain management (SCM) and optimisation tools allow the efficient and sustainable integration of suppliers, manufacturers, and distributors so that hydrogen can be produced and distributed at the right quantities, to the right locations and, at the right time, in order to minimize the total cost of the system under the satisfaction of demand requirements while taking into account other constraints, such as environmental ones. The management of supply chains is a complex task mainly due to large size of the physical supply network and inherent uncertainties and decisions[5]. In this paper, at least one scientific paper is selected per country based on expert opinion in order to: (1) search for the main features of the HSC, (2) the sustainability criteria (if available), and (3) the outcomes related to the cost and CO_2 emission per 1 kg of H_2. A quick literature review is also performed to capture the volume of scientific publications in English for HSCs optimisation per country.

Results. Many countries have developed energy transition roadmaps where hydrogen is mentioned as a valuable energy career. Each country and city face different opportunities and challenges based on their available energy sources, the local energy transition strategy, and the economic situation. It may be expected that West and Eastern Europe countries will have a different level of implementation, however, one important feature of the hydrogen fuel for mobility applications is that the vehicles travelling across Europe will need to find hydrogen refuelling stations. The results of the analysis for for Germany, France, UK, Hungary and Ukraine are given in Table 1. The majority of the selected papers use mathematical models to optimise the HSCs. These are labelled as "optimisation" papers. To study the level of centralisation, information linked to the actual number of refuelling stations and the level of transportation needed to move H_2 from production plants or storage units to the refuelling stations. R&D efforts can be aligned and connected among different countries. In this sense, some international agreements need to be implemented and information management regulated. Central and Eastern Europe countries have less mobility infrastructure installed but international efforts might accelerate the deployment of refuelling stations across the European corridors to fulfil hydrogen demand for buses and trucks by 2030. The implications of using hydrogen are not only linked to decrease on CO_2 emissions but also on the increase of electrification of several applications (e.g., mobility), and to decrease the energy dependency (for some countries). Today, electricity prices are highly dependent on natural gas prices, and this is a key issue because the surplus electricity generated from renewable sources might be used in a different manner in the future, and for this reason, the hydrogen transition needs to be carefully studied.

Conclusions. The consideration of sustainability metrics while designing hydrogen supply chains (e.g., multiobjective optimisation) is paramount. To succeed, hydrogen needs to be available at an affordable price, produced, stored, and distributed in a safe manner and have a positive impact for the environment. Today, the most used criterion is the cost optimisation, which can lead to unsustainable and non-resilient HSCs. The economic biased perspective can bring undesired effects for society but still is critical. In this sense, there is a need to include other environmental and social aspects into the picture when designing HSCs. Finally, it is recommended to have clear goals for the levelized cost of hydrogen, the maximum amount of carbon emissions, and the safety and quality standards. This will require implementation of policy and regulations for each country by considering international standards to make hydrogen a sustainable option.

Table 1. Comparison of hydrogen supply chains case studies – Germany, France, UK, Hungary, and Ukraine

Country	**Germany**	**France**	**UK**	**Hungary**	**Ukraine**
Number of H2 refuelling station 2021 ***	91	18	10	1	0
Number of scientific papers discussing HSC	more than 10	more than 10	more than 10	less than 3	less than 3
Reference papers	[6]	[7]	[8,9]	[10]	[11–13]
Market (mobility, industry, both)	Mobility	Mobility	Mobility	Mobility and industry	Mobility and industry
Type of paper	Optimisation	Optimisation	Optimisation	Optimisation	Calculation
Objective function for optimisation models	Cost, CO2	Cost, CO_2 and risk	Cost	Cost, CO_2, risk and social cost-benefit	-
H_2 colour	Grey and green	Grey, green and pink	Grey	Green	Green
Production technology	SMR, biomass and coal gasification	SMR and electrolysis	SMR, biomass and coal gasification	Electrolysis	Electrolysis
Expected cost	3-4*	6.1*	4.8*	4.8*	2.5-6.8*
Expected CO_2 emissions	1.6-18.8*	4.7*	15.4**	3.1*	3.1**
Supply chain centralisation level	Centralised	Decentralised	Centralised	Decentralised	Not reported
Comments *** https://www.statista.com/statistics/1026719/number-of-hydrogen-fuel-stations-by-country/	*in 2030	*in 2030	*in 2006 updated to 2013 values ** in 2006	*Average for 2030-50	*According to "Energy Efficient Cities of Ukraine" (2021)[5] ** Assumption based on (De-León Almaraz *et al*., 2022)

Source: formed by authors

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ICT AS DOMINANT IN MANAGEMENT

Abstract. *Education and literacy are very important to obtain ICT skills, which are necessary for modern management. Technology can make a difference in improving services and cutting costs, but it can do more than that. ICT makes a business more efficient, and effective and promptly responds to customers' needs.*
6.4 percent of enterprises introduced new or significantly improved goods on the market, while share of enterprises, that introduced new or significantly improved services. Innovations of goods and services in most cases were originally developed by the enterprises (accordingly 68.7 percent and 73.5 percent). In other cases, they received support from other enterprises or institutions. 60.6 percent of implemented innovations were new to enterprises, while 39.4 percent were new to the market.

As analyze shows Georgia has some experience to develop ICT as dominant role in management of enterprises.

Keywords *(ICT, Education, Statistics)*

Introduction

Education and literacy are very important to obtain ICT skills, which are necessary for modern management. Technology can make a difference in improving services and cutting costs, but it can do more than that. ICT makes a business more efficient, and effective and promptly responds to customers' needs. ICT can assist business activities including design, manufacturing, R&D, distribution, and sales and feedback[6].

Georgia is a country of universities[7], but we need more orientation to the modern program of Information technologies. Universities have been assigned a special role in the digital economy[8]. The increasing demand for ICT specialists stands an absolutely different situation for education

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