STUDY ON HYDROGEN'S ROLE IN THE TRANSITION TO A CLIMATE NEUTRAL EUROPE

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Abstract. *The phase-out of coal, oil, and gas and switching to environmentally friendly fuels will increase the demand for electricity compared to today. The corresponding amounts of electricity can be covered mainly by solar and wind energy in Europe, and if we follow the costs of energy produced from these renewable sources, we see that they are decreasing. Hydrogen will play a key role in hard-to-decarbonize sectors (such as maritime and air transport), with it expected to contribute more than a third of road sector decarbonization. Hydrogen participates in creating products and applications necessary for a modern and sustainable society. It is an important pawn in climate neutrality but is limited for economic and technical reasons. In the paper, a study was carried out on obtaining hydrogen. We differentiated the hydrogen produced from renewable energy from the hydrogen produced from oil or gas. As a methodology, we used the Sankey diagram to visualize the energy flow in Romania. The paper includes data taken from specialized literature and is designed to provide an overview of the role that hydrogen plays in the energy system, the reduction of greenhouse gas emissions, and the global economy.*

Keywords: *climate neutrality, CO2 emissions, hydrogen, renewable resources, the transport sector*

Introduction - The challenge

The European Union has set itself the goal of being climate neutral by 2050. The commitment to climate neutrality requires that applications and products with greenhouse gas emissions be replaced by emission-free alternatives.

Mark &, Delucchi (2009, p.60) explains that the maximum power consumed worldwide in 2009 was approximately 12.5 trillion watts (terawatts or TW), with an estimated 16.9 TW of energy power needed globally in 2030.

Figure 1 shows us, on the left side, four scenarios for the decarbonization of the energy system between the years (2015-2050) and on the right side the resources available at the European level to realize these scenarios. If we look to the future, most of the energy system will be renewable, so it will have to deal with seasonal imbalances and, simultaneously, satisfy consumer preferences and be friendly to the environment.

In this context, industry, commercial and residential buildings, and transport will have to transition to energy with low carbon emissions. We have renewable energy in various forms, but these present a smaller and smaller percentage untapped, so it will be necessary to consider the role of hydrogen in the energy mix. According to the 2020

Energy Technologies Perspectives report of the International Energy Agency (p.25), in the sustainable development scenario, electricity, hydrogen, renewable resources, and synthetic fuels could provide more than 70% of total energy, with a share like that of fossil fuels.

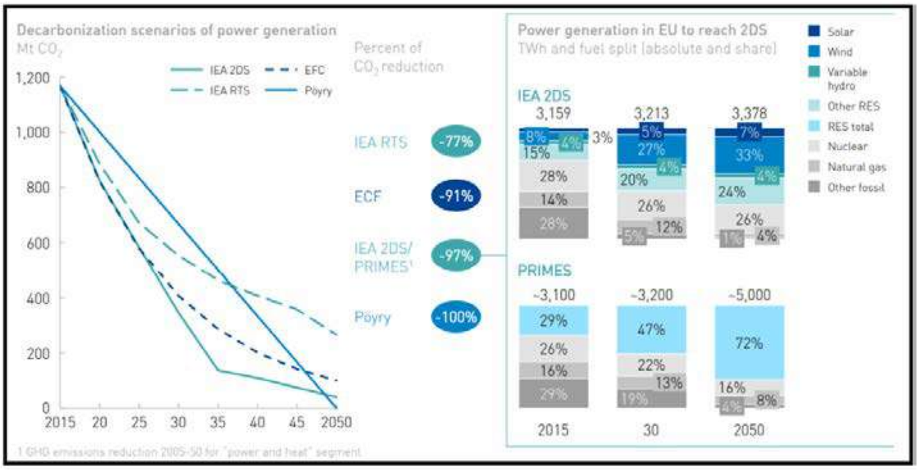

Figure 1. Decarbonization targets and power mix
(Fuel Cells and Hydrogen, 2019, p.20)

Hydrogen can be used in different forms. It can represent the raw material, act as fuel, or participate in energy transport and storage processes. This variety of roles that hydrogen can fulfill can be used in sectors that are more difficult to decarbonize such as industry, transport, and construction. Figure 2 shows the most important functions that hydrogen can have in the energy mix.

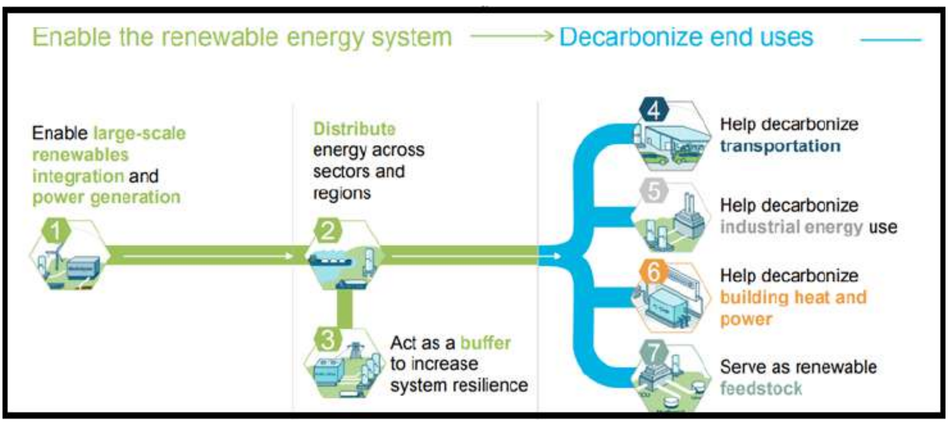

Figure 2. Functions of hydrogen in the energy transition
(Hydrogen Council, 2017, p.17)

The most important aspect of hydrogen could be considered to provide the clean raw material for the economy by acting as a buffer in increasing the resilience of the energy system. Therefore, meeting the climate neutrality objective in 2050 of the European Green Deal can only be achieved by considering the role of hydrogen. Failure to fulfill this pact would have a major impact on the climate, expressed through extreme temperatures, continued flooding from rising sea levels, and significant biodiversity loss.

Methodology

The aim of this paper is to provide an overview of the functions that hydrogen has in the process of moving towards climate neutrality, highlighting, at the same time, its technical and economic limits. An analysis of the final use of energy in Europe carried out by Eurostat (Database European Commission) in 2018 shows "three dominant categories: transport (30.5%), households (26.1%) and industry (25.8%)". At the European level, transport is the largest energy consumer produced from fossil fuels and the most difficult to decarbonize. At the level of Romania, if we look at the diagram in figure 3, we notice that transport is the second main consumer with 6461 KTOE/year, after households with a consumption of 8008 KTOE/year of energy.

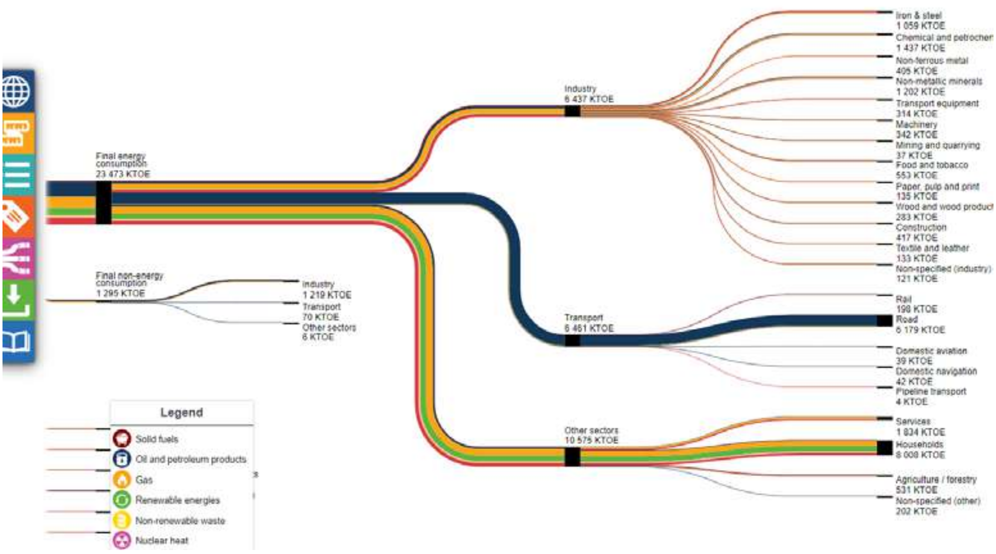

Figure 3. Energy balance of Romania with Sankey Diagram (Eurostat Database, 2020)

The energy flow presented in figure 3 shows us that transport in Romania is mostly based on petroleum products. The shift from petroleum products to renewable resources for transportation is not just about changes to cars, but at the same time, it is about a paradigm shift in addressing this challenge. When we refer to this transition, two aspects will be pursued: the storage of a large amount of energy, with low weight in a small space, and the modification of the infrastructure for fueling vehicles.

“In terms of road transport, in June 2022 the European Parliament backed a proposal to reach zero emissions from new cars and vans in the EU by 2035.” (EU responses to climate change, 2022)

In the report presented by the Hydrogen Council (2017, p.8) it is specified “that in the transport sector, hydrogen-fueled vehicles are commercially available and that in the next five years medium and large cars of the type: buses, trucks, vans to be powered by hydrogen.”

In this context, I studied from the specialized literature, the main methods of obtaining hydrogen. Hydrogen is a chemical element with many abilities. It rarely occurs in pure form; it must be extracted from compounds with other elements. This is an energy-consuming process.

In figure 4, the primary energy sources of hydrogen production processes can be grouped into 3 categories: fossil fuels, nuclear energy, and renewable energy. Renewable energies are derived directly (solar energy) and indirectly (biomass and wind) from the Sun. Similarly, hydrogen feedstock comes from 3 categories: fossil fuels, water, and biomass. While fossil fuels and biomass can serve as both an energy source and a raw material, water is only used as a raw material and another energy source is required to power the process.

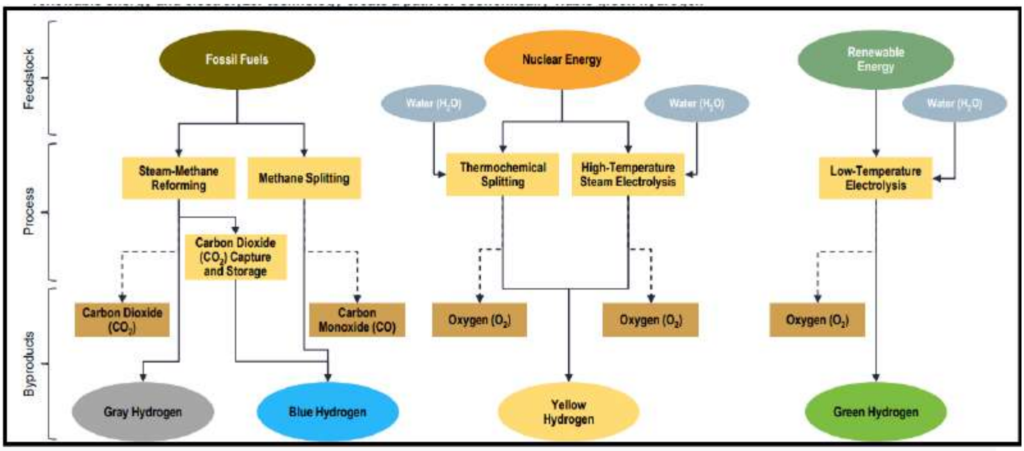

Figure 4. Hydrogen production technologies
(LAZARD, 2021)

In figure 4 we observe five fundamental chemical and biological processes to produce hydrogen: thermo-chemical processes of fossil fuels, biomass and biofuels, electrolysis, thermal water splitting, photo-electrochemical processes, and biological processes. The hydrogen produced is divided into 4 large categories: gray hydrogen, blue hydrogen, green hydrogen, and yellow hydrogen.

“Hydrogen itself is colorless. “(Groll, 2021) The different colors of hydrogen depend on the source from which it is obtained and the impact they have on the environment.

Green hydrogen is hydrogen produced by the electrolysis of water (in electrolysis, with electricity) and electricity produced from renewable sources. The greenhouse gas emissions generated by hydrogen production from renewable sources over the entire life cycle are close to zero. Even if this resource is limited, as shown (Howarth & Jacobson, 2021, p.1677) in their paper, green hydrogen is an important pawn in the transition to zero CO2 emissions.

Blue hydrogen, a relatively new concept, is based on the gasification of natural gas or fossil fuels with carbon capture, but here the greenhouse gases emitted in the process are captured and stored. Multiple studies have demonstrated that the gas emissions resulting from obtaining hydrogen with fossil fuels as raw material are higher when the carbon capture process is not used, but the capture process presents multiple variables that lead to an efficiency of a maximum of 90 %. Regarding the production of blue hydrogen from natural gas, using renewable sources, the methane emissions associated with producing natural gas to obtain hydrogen are not considered. “Methane is a powerful greenhouse gas; it is estimated that 25% of global warming is due to methane”. (Howarth & Jacobson, 2021, p.1677)

Currently, most hydrogen is produced from fossil fuels called gray hydrogen. Greenhouse gas emissions generated by the production of hydrogen from fossil fuels throughout the entire life cycle are high and are eliminated directly into the atmosphere. Yellow hydrogen is obtained through the electrolysis process carried out at high temperatures.

Results and discussion

Transport and aviation have limited resources for using low-carbon fuels. In Romania transport is the second main consumer with 6461 KTOE/year, after households that consume 8008 KTOE/year of energy.
Green hydrogen is used as a fuel for various modes of transport; being a natural substitute for several existing fossil fuels (eg. natural gas, petrol, diesel, coal and oil). As a result of its versatility, it represents a potential solution for reducing carbon emissions in traditional "hard to reduce" sectors such as transport/mobility, heating, oil refining, ammonia and methanol production and power generation.

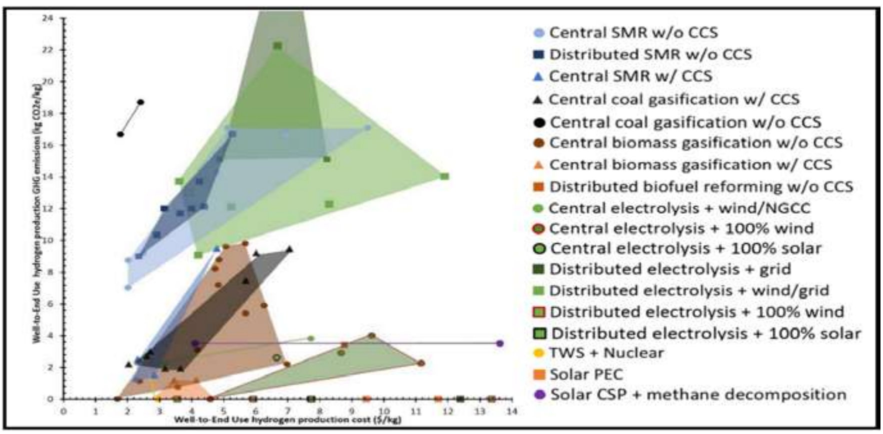

Figure 5. Estimates of production costs and gas emissions of hydrogen production methods (Tong et al, 2017, p2)

What is the principle behind these performances?
“Hydrogen contains more energy per unit mass than natural gas or gasoline, which makes it attractive as a transportation fuel.” (IEA, 2021, p.34)

The process of transforming hydrogen into electricity is as follows: The electrolyze contains an anode and a cathode separated by an electrolyte. This water decomposition process removes oxygen (a non-polluting element), and hydrogen is captured and stored in special tanks. Through electrolysis, oxygen (O2) is formed at the anode, and hydrogen (H2) at the cathode.

The process of transforming H2 hydrogen into electricity uses the "hydrogen fuel cell" principle. This process is done with the help of electrochemical cells that produce energy, water, and heat in contact with hydrogen. The current obtained is continuous and can be controlled with the help of converters.

The vision presented regarding the inclusion of hydrogen in the energy mix to decarbonize various sectors seems attractive, but what are the costs to make it a reality?

Figure 5, is the graphical representation of the estimates, from the specialized literature, regarding the production cost and greenhouse gas emissions for 1 kg of high-purity hydrogen delivered to the end use.

Both direct and indirect emissions related to the delivery of hydrogen to fuel pumps are included in the calculations. The cost of production comprises the cost of purchasing equipment and the costs of replacement, operation, and maintenance. From the graph, we can see that there are methods with gas emissions close to zero and low production costs (ex-central biomass gasification) but they are not sustainable in the medium and long term. In each situation shown in figure 5, hydrogen production costs remain high, or the technology is still in the early stages of being implemented on a large scale.

Conclusions

The phase-out of coal, oil, and gas and switching to environmentally friendly fuels will increase the demand for electricity compared to today. The corresponding amounts of electricity can be covered mainly by solar and wind energy in Europe, and if we follow the costs of energy produced from these renewable sources, we see that they are decreasing. Hydrogen participates in creating products and applications necessary for a modern and sustainable society. It is an important resource in climate neutrality, but it is limited for economic and technical reasons.

Hydrogen could be produced in areas with high-capacity factors for both wind and solar energy because it needs electricity to be obtained.

The basics of hydrogen synthesis “have been known for decades; hydrogen technology is not new. The world already produces and consumes more than 55 Mt of hydrogen annually in a wide range of industrial processes”. (Hydrogen Council, 2017, p.18)

On the climate protection side, the process has gained momentum in recent decades and numerous demonstration applications have been built.

Nuclear reactors are ideal for hydrogen production, but in the last two decades, there has been no significant progress in their research and development. Biological methods are still in their scientific infancy. To become viable pathways at scale, these technologies must demonstrate long-term hydrogen production and increase the production rate to an acceptable threshold.

These sustainable transport options are developing in countries with a high standard of living. The change is less visible in developing and poor countries. To avoid this gap between countries on the decarbonization of the transport sector, financing, affordable technologies, and decarbonization strategies that also extend to countries with a low standard of living are needed. Local authorities are crucial in decarbonizing the transport sector by providing incentives, and encouraging public transport and active travel.

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