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SOME ASPECTS OF HYDROGEN UTILIZATION IN AGRICULTURE

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Abstract

The pressure to produce more food and less pollution has led to the need for identification of applicable solutions, to solve, to improve the sustainability of production processes and accelerate innovation in the agriculture industry. These solutions based on the technical revolution can be characterized by the Farming 4.0 concept.

One of the main issues to be addressed for effective environmental protection and sustainable production is the abandonment of the use of fossil fuels. One possible solution is to use hydrogen through Hydrogen Fuel Cells (HFC).

This article gives a brief overview of the achievements based on the use of HFCs in agriculture and tries to synthesize the main future directions.

Key words: hydrogen, HFC, Farming 4.0.

INTRODUCTION

The Department of Economic and Social Affairs, Population Division, of the United Nations, (United Nations, 2019) has predicted that the global population will reach 8.55 billion people by 2030 and almost 10 billion people by 2050. In order to feed this growing population, according to FAO, food production must increase with 70 percent by 2050 and a 60 percent increase in demand for high quality protein such as milk, meat and eggs.

Agriculture is energy intensive and the pressure to produce more food requires more energy, an increasingly costly input to the production process. At the same time, the requirements for the use of sustainable methods and environmental protection for energy products have increased.

One of the projects that studies the solutions needed to achieve sustainable energy without pollution is RES4LIVE (https://res4live.eu/). This H2020 EU funded project, 2020-2024, with an overall budget € 5815206,88 have 17 partners from 8 countries. The strategic objective of RES4LIVE is to develop and bring into the market integrated, cost-effective and case-sensitive RES (Renewable Energy Systems) solutions towards achieving fossil-free livestock farming.

One of the many possible solutions is to use green hydrogen as an energy source. Green hydrogen is produced by electrolysis of water, using electricity from renewable sources like hydropower, wind, and solar. Zero carbon emissions produced. Turquoise hydrogen produced by the thermal splitting of methane (methane pyrolysis). Instead of $C0_2$, solid carbon produced. Pink (Purple / Red) hydrogen produced by electrolysis using nuclear power. Black (Grey) hydrogen extracted from natural gas using steam-methane reforming. Yellow hydrogen produced by electrolysis using grid electricity. Blue hydrogen is Grey or Brown hydrogen with its $C0_2$ sequestered or repurposed. White hydrogen produced as a by-product of industrial processes. Brown hydrogen extracted from fossil fuels, usually coal, using gasification.

The European Commission has foreseen the use of hydrogen since 2003 (European Commission, 2003).

MATERIAL AND METHOD

Hydrogen can be the sustainable energy source of the future, decrease the global dependence on fossil resources, and lower the pollutant emissions from the agriculture. Hydrogen can used as an energy source for both stationary and mobile equipment. In agriculture, the major interest is for use in self-propelled equipment.

Hydrogen can used as fuel in an internal combustion engines and as a fuel cell in vehicles.

Using hydrogen as a fuel of internal combustion engine can improve engine efficiency, power output and reduce NOx emissions. Has a heating value three times larger than petroleum, on a mass basis, and the emission is low compared to conventional vehicles but need additional space and weight to install the storage tank. This storage tank must comply with SAE J2579, the United Nations Global Technical Regulation No. 13 and the applicable standards for the country that the vehicle is deployed.

The first tractor converted to dual fuel was New Holland T5.140 Auto Command™, in the Netherlands (https://h2dualpower.com/en). The hydrogen is stored in five cylinders, placed above the tractor cab for increased safety without compromising functionality. Each cylinder contains 11.5kg of hydrogen pressurised at 350 bar. The engine is ideally suited for the use of HVO diesel. HVO (also sold as 'blue diesel') stands for "Hydrotreated Vegetable Oil" and is a new type of diesel fuel. It is made from waste vegetable oil together with other waste such as animal fat. HVO is thus a fossil-free, renewable fuel that offers huge sustainability benefits, such as an 89% reduction in CO_2 and lower emissions of harmful substances such as particulate matter, nitrogen and sulphur. HVO diesel is virtually odourless and easily biodegradable.

Hydrogen can be used in fuel cells for vehicular applications with several automotive manufacturers producing fuel cell vehicles currently. Fuel cells can achieve efficiencies of up to 60%, while the rest is lost as heat.

HFCs (Hydrogen Fuel Cells) are static energy conversion systems that generate electrical energy through an electro-chemical reaction of hydrogen and oxygen. The electrical energy will generated by HFCs as long as hydrogen and oxygen is conducted into the system. This electricity is used to charge the battery and to power the electric motors that drive the wheels. HFC system employs oxygen and hydrogen to generate electricity and water with no other pollutants.

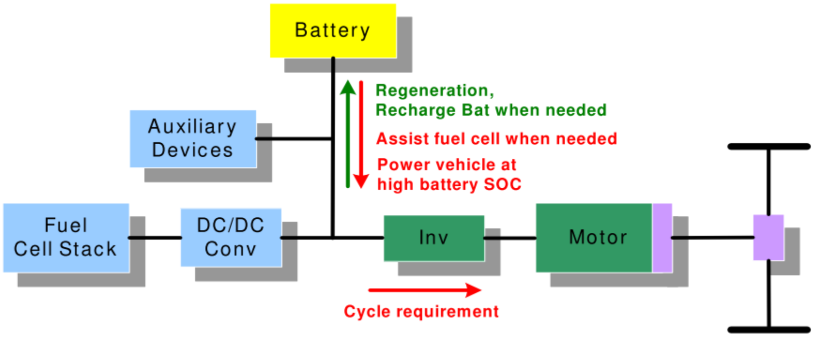

Fig. 1. Basic structure of fuel cell based electric tractor (Manoharan et al., 2019)

China's first 5G+ hydrogen fuel electric tractor officially launched in 2020 by the China National Agricultural Machinery Equipment Innovation Center and the Luoyang Advanced Manufacturing Industry R&D Base of Tianjin High-end Equipment Research Institute of Tsinghua University. The HFC operates when tractor is normal loaded and at overload is helped by a lithium battery.

In 2021, Volvo Group has opened a dedicated Hydrogen Fuel Cell Test Lab at the Volvo Construction Equipment Technical Center in Eskilstuna, Sweden.

Starting in 2023, a dedicated line at Toyota Motor Manufacturing Kentucky will begin assembling integrated dual fuel cell modules destined for use in hydrogen-powered, Class 8 heavy-duty segment.

Cummins laid out an aggressive strategy for hydrogen today, addressing both production of the low-carbon energy source as well as the fuel cell technology to convert it into power for customers. Cummins announced it will work with Navistar on the development of a class 8 truck powered by hydrogen fuel cells. The truck will be integrated into Werner Enterprises' fleet of more than 7700 tractors for local and regional service on a year-long trial basis out of Fontana, California.

Germany, for example, plans to spend $9 billion on hydrogen infrastructure this decade, with 5 Gigawatts of electrolyzer capacity by 2030. China and South Korea are developing fuel cell and hydrogen production targets. In the U.S., California expects to have spent about $230 million on hydrogen projects by the end of 2023.

RESULTS AND DISCUSSION

In October 1959 Allis-Chalmers demonstrated the first farm tractor with a fuel cell which powers an 20 horsepower DC electric motor.

The use of hydrogen as an energy source is not limited to agricultural tractors. Today, competitive solutions are being sought for its use in many applications such as commercial vehicles, trains, building heating, industrial heating etc.

As Leeuwen (Leeuwen, 2020) pointed out in the case of low-power tractors, at present, systems based on electric batteries are generally more advantageous than HFCs. Obviously, farm-level infrastructure can benefit from the use of HFCs.

On the other hand, Deloitte (Deloitte, Ballard, 2020) forecasts a strong advance in HFC technology and investment, so that in 5-6 years will be more profitable to use tractors, combines, high-power trucks equipped with HFC. The total cost of ownership will be smaller than battery-electric and traditional internal combustion engine vehicles. They also predict that in 9-10 years the technology will be extended to engines with lower powers.

The cost of hydrogen varies significantly across regions, as it depends heavily on the prices and availability of energy inputs. The cost of renewable hydrogen is expected to decline by about 60 percent in ten year. Since the costs of hydrogen production differ significantly between regions, long-distance transmission and international trade in hydrogen can be attractive. Even existing natural gas pipelines can transport hydrogen, often with only modest upgrades. Hydrogen refuelling stations are currently the highest cost element in the cost at the pump.

A solution to reduce costs, given the characteristics of agriculture, would be to produce hydrogen on farms. One of the applicable technologies is to obtain hydrogen from the air (Fasihi et al., 2019) but the most recommended, from my point of view, is the production of hydrogen from biomass (Binder et al., 2018).

There are two main methods of producing hydrogen from biomass: steam gasification and sorption enhanced reforming.

Although the initial investment is higher for the steam gasification method, the production costs are lower and the yields obtained are higher.

In Fig. 2. (Binder et al., 2018) is presented the concept of hydrogen production from biomass by steam gasification, DFB means dual fluidized bed, WGS means water gas shift and PSA means pressure swing adsorption.

It is necessary to modernize this process in order to accept as raw material all types of vegetable waste from the farm. Thus, the farm will not only provide its own hydrogen and energy needs, but will also be a supplier of hydrogen. When the production of hydrogen from fossil fuels is abandoned, these production units will be competitive.

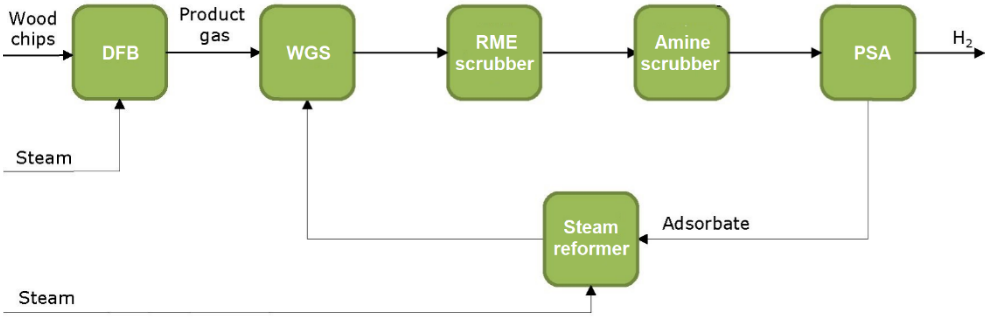

Fig. 2. Illustration of the DFB gasification based H_2 production (Binder et al., 2018)

CONCLUSIONS

As the agricultural industry faces pressure to achieve zero net emissions by 2040, the possibilities of alternative fuels in agriculture must applied.

Hydrogen is the most abundant element in the universe and is also a key element in the fossil fuels that have powered mankind since the first industrial revolution. Hydrogen as an energy carrier has two major advantages over fossil fuels for mobility applications. Its energy release through oxidation produces only water as an output, and it is renewable.

Urgent action needed to achieve net-zero targets quickly, and hydrogen is a necessary part of the answer. Hydrogen can become the most cost competitive solution for several specific use cases near-term, and it can quickly become so for many more.

In order to meet commitments on environmental protection and decarbonisation, it is absolutely necessary for governments to support investment and the development of the entire hydrogen chain.

Within this hydrogen chain, agricultural farms could have in addition to the role of important consumer of hydrogen for energy for self-propelled equipment, warehouses, buildings but also a zonal producer of hydrogen, thus being able to help distribute hydrogen to other consumers.

Governments should apply incentives such as tax breaks, subsidies or penalties on conventional alternatives to encourage the initial acceleration of hydrogen.

To support the development of this area, governments should support research, modernization and pilot projects in this area.

In this context, governments need to be made aware of the important role that agriculture can play in the field of hydrogen. This new role will not only help farm prosperity but also help grow and diversify crops and create new jobs in rural areas. Hydrogen Fuel Cells will be able to ensure, at competitive prices, the energy supply of all agricultural machines, warehouses and outbuildings.

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