A JÖVŐ KÖZLEKEDÉSI ÜZEMANYAGAINAK ÁTTEKINTÉSE

REVIEW OF FUTURE FUELS IN TRANSPORTATION

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ABSTRACT

The primary objective of this research is to investigate the impact of fossil fuel vehicles on greenhouse gas emissions. Given the potential for technological progress, the phase-out of fossil fuel vehicles is accelerating. The priority is to achieve greenhouse gas neutrality in transport as soon as possible. This study will present the impact of different powertrains on achieving greenhouse gas neutrality (with a particular focus on the impact of combined technologies) and the impact of battery electric vehicles on achieving greenhouse gas neutrality. The study will show, under different scenarios, that combining different technologies is more effective at reducing greenhouse gases than is using a completely clean technology.

1. INTRODUCTION

At 403 ppm, atmospheric carbon dioxide levels reached alarming levels. CO_2 generated from the oxidation of carbon during fuel combustion accounts for the majority of global anthropogenic greenhouse gas emissions [1]. As a result, the global mean surface temperature has risen by approximately 1 °C compared to preindustrial levels [2]. To slow or halt global warming, carbon emissions must be reduced by reducing our dependence on conventional fossil fuels and thereby encouraging the development of clean and sustainable fuels, especially from renewable sources. Biofuels are among the liquid fuels that are of growing importance for economic and environmental reasons.

Currently, all commercially viable methods of biofuel production involve photosynthetic capture of solar radiation and conversion of solar energy into chemical energy through chemical reduction of carbon [3]. Photosynthesis converts solar energy into chemical energy stored in plants, such as cucumbers or biowaste, which are later converted into biofuels. However, current biomass processing methods for biofuel production require large areas of land and sunlight.

Thus, when competing with food production for resources such as water and land, these methods are generally inefficient [4]. In 2009, the US Department of Energy (DOE) established the Electrofuels Program to study and develop new methods to advance transportation fuels and develop fuels using nonphotosynthetic methods [3].

Electrofuels can be considered an energy storage technique in which solar energy is converted into chemical energy by photovoltaic cells, and the energy is stored in the chemical bonds of the gas or energy carrier or in liquid fuels. Moreover, as a public transport fuel, electrofuels can take advantage of existing infrastructure, making transportation much easier and cheaper [6,7]. Recently, as a result of these factors, electrofuels have attracted the attention of several car manufacturers, such as Porsche and Mazda [8].

Hydrogen can also be used as an energy carrier but with a low volumetric energy density, which is much lower than that of petrol [9]; high pressure or low temperature are required to increase the volumetric energy density for transport, and hydrogen can be transported easily and safely [10].

A fuel can be defined as a reduced substance that can release chemical energy by oxidation, oxidation by combustion with pure oxygen or oxygen from the air, or oxidation reactions that result in the production of useful energy [11]. Unfortunately, in the literature, the terms electrofuels and synthetic fuels are sometimes used interchangeably, so that they refer to the same fuel. According to Ridjan et al., electrofuel refers to a fuel that uses CO_2 as the main source of fuel; however, this fuel can be produced by different methods. While the term synthetic fuel is used to denote fuels produced from coal, gas and biomass by thermochemical conversion to gaseous or liquid fuels [12], for example, synthetic paraffin kerosene (SPK), a type of aviation fuel, is produced from gas to liquid (GTL) by a process [13]. Electrofuels can be produced by two main methods: the first is the biological conversion of CO_2 into energy-dense fuel [14], and the second is a fuel produced by combining recycled CO_2 gas with hydrogen from the electrolysis of water [15].

Figure 1a shows the different energy conversion pathways from solar energy to biofuels and electrofuels [3], while Figure 1b shows the pathways from solar energy to biofuels and electrofuels. different sources and nutrients that can be fed into the bioreactor to produce biofuels. gas or liquid fuels [3].

In the literature, metal fuels are sometimes referred to as electrofuels, and metal is produced by electrochemical reduction reactions of metals to produce fuel oxides; if the energy source of the reaction is electricity, this type of fuel can be called electrofuels [16]. In the metal fuel cycle, the produced metal fuel is transported to the final point of use where it is indirectly burned (oxidized) in an atmospheric air combustor [17]. In a recent review paper [18], the predelivery costs of e-fuels were evaluated in

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different ways: first, through a literature review; second, through a more detailed literature review including pre-delivery and efficiency costs and efficiencies to separate e-fuels; and, finally, through a series of calculations to estimate and compare the costs with those found in the research literature. Masri [19] reviewed the literature on the challenges and difficulties facing the turbulent combustion of e-fuels.

He concluded that continued research in the field of turbulent combustion is needed to improve the prediction capabilities to a level that will enable them to become a reliable standard tool for the design and control of future combustion products. The purpose of this review is to address recent advances in the field of electrofuels, covering the chemistry of electrofuels and the reactants required for their production, and to summarize the various studies on the life cycle assessment and economic and technical evaluation of electrofuels. In addition, this review covers the combustion behaviour of electrofuels and discusses how this behaviour affects their performance and fuels for their integration into future energy systems.

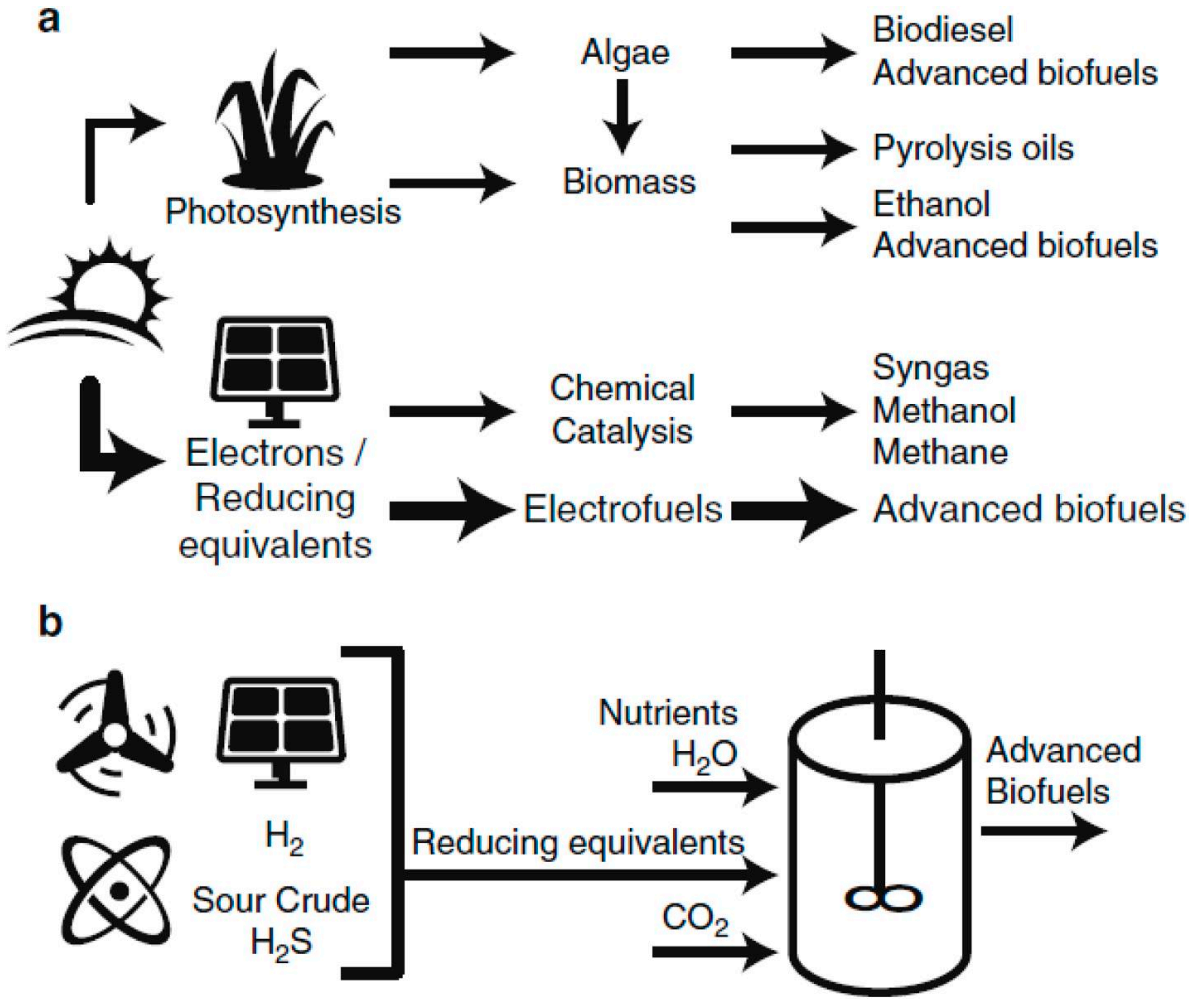

Figure 1 (a) Different energy conversion pathways from solar energy to biofuels and (b) different sources and nutrients that can be fed into a bioreactor for the production of gaseous or liquid fuels [3].

2. DECARBONIZING TRANSPORT

Germany, which is one of the largest emitters of greenhouse gases (GHGs), ratified the Paris Agreement in 2015 and committed to significantly reducing GHG emissions in October 2016 [20]. Efforts to reduce emissions in Germany have already led to reductions in GHG emissions in most sectors of its economy. Only the transport sector showed a slight increase in greenhouse gas emissions, not a reduction in its carbon footprint, from 163 Mt CO_2 equivalent in 1990 to 164 Mt CO_2 equivalent in 2014. The overall approaches to reducing GHG emissions during transport are fourfold: reducing the carbon intensity of fuels, increasing the energy efficiency of vehicles, shifting modes, and reducing overall demand [23].

The latter two are referred to as the mobility transition, and the first two refer to the energy transition of transport [24]. While the decarbonization effort is clear and a number of different technological solutions for the energy transition of road transport, such as electric vehicles, are available, there is still disagreement on the best option(s). Although uncertainty undoubtedly plays a major role in this disagreement, it is not clear how the different technological options relate to each other in terms of uncertainty.

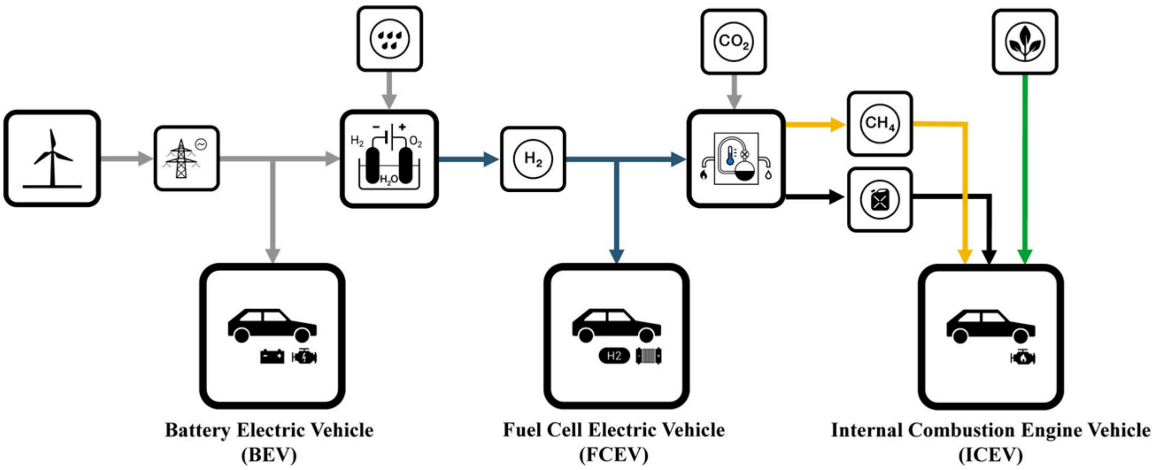

Figure 2 Key technological options for low-carbon road transport [25].

2.1. Comparison of technologies

In transport, three different technological options for achieving energy transition are commonly discussed: battery electric vehicles (BEVs), hydrogen fuel cell electric vehicles (FCEVs) and internal combustion engine vehicles (ICEVs), which run on either biofuels or synthetic fuels. Figure 2 illustrates these decarbonization options for road transport based on electricity from renewable energy sources.

BEVs are vehicles that run on electric energy provided by an on-board battery pack that powers an electric motor. Owing to the high efficiency of electric motors (up to 95%) and the possibility of partial recovery of mechanical energy, BEVs exhibit the highest (approximately 70%) well-to-wheel efficiency of all the technologies studied [26, 27].

FCEVs differ from BEVs in terms of electricity supply. An FCEV generates the necessary energy on board from hydrogen via a fuel cell unit. This electricity is subsequently used to power an electric motor. Compared with BEVs, the system has an additional step, as electricity is first used to produce an energy carrier (hydrogen) through electrolysis, which then allows it to be converted on-board into electricity. Accordingly, the overall well-to-wheel efficiency is relatively low (between 25 and 30%) [27, 28].

The third technology, the ICEV, is essentially a heat engine that produces mechanic energy from the combustion of fuel. From an energy conversion point of view, this fuel can be either synthetic fuel or biofuel, and both potentially enable carbon-neutral operation. The main sources of synthetic fuels are hydrogen and carbon dioxide. Due to the complexity of the conversion steps, the well-to-wheel efficiency is the lowest of all options (13-20%) [27, 28]. In contrast, biofuels produced from organic matter, such as crops or organic waste products, can theoretically be considered carbon neutral, as they only emit locally as much carbon as crops have previously absorbed (excluding the energy required for plowing and conversion processes) [29].

3. MEASUREMENT TASK

Fuel test investigations were carried out on a GUNT-built machine for training purposes (Fig. 3). The machine consists of a single-cylinder Hatz 1B20-6 diesel engine and a brake unit connected to it. To obtain a more comprehensive picture of the processes in the engine, it was also necessary to investigate the composition of the exhaust gas, for which a Testo 330-2 measuring device was used. This approach allowed us to document the effect of different fuels on the emission values.

3.1. The tested fuels

The effects of two different fuels on an experimental diesel engine are shown. The first is a commercially available standard diesel fuel (composition according to MSZ EN 590:2009), which contains 4.8% by volume of bio component fatty acid methyl ester as a standard. In contrast, the alternative fuel blend we tested was made with unesterified vegetable oil blended with the commercially available regular diesel fuel mentioned above. According to the international literature, in the production of alternative fuels, virgin oil is pretreated by a transesterification process [30].

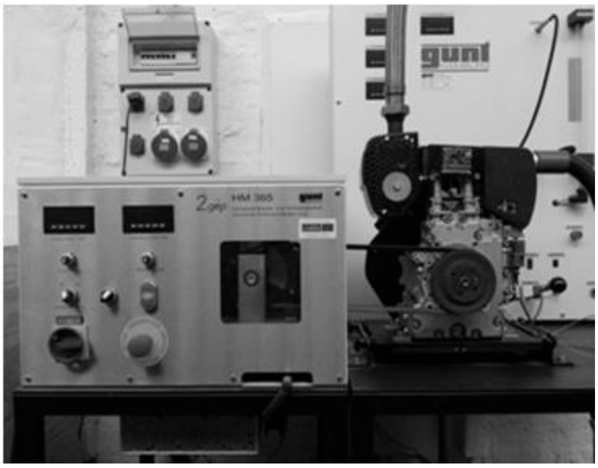

Figure 3. The experimental diesel engine and its brake unit.

In our research, we wanted to gather information on the effects of an alternative fuel blend on a diesel engine and its exhaust gas composition with the addition of a no esterified vegetable oil, which is also used in households. The alternative fuel thus formulated contained 2/3 by volume of normal diesel and 1/3 of sunflower vegetable oil.

4. RESULTS

In our tests, measurements were carried out using both fuels with the same operating parameters, i.e., running the engine at constant speed and increasing the load torque. The measurement started from the lowest achievable braking torque, which was 0.5 Nm. Subsequently, the subsequent measuring points were set up by increasing the load torque every 0.5 Nm to 5 Nm, taking care to ensure that the parameters to be measured were set to a constant value after the load was changed. A similar measurement method can be found in the publication by Wang et al. [31].

The fuel consumption data were evaluated and are shown in Figure 4. The graph clearly shows that, on average, 3.2% more fuel per unit mass per hour was consumed over the operating range when using the alternative fuel under the same operating conditions. There are several reasons for this additional consumption.

One reason is that the energy content of the alternative fuel blend is lower than that of normal diesel fuel; the other reason may be a change in combustion quality. The fuel that we produce contains vegetable oil used without transesterification, which increases the viscosity. As a result, the atomization and thus the combustion quality have deteriorated. The additional consumption measured is, however, dwarfed by the fact that a third of the fuel tested is not from fossil sources.

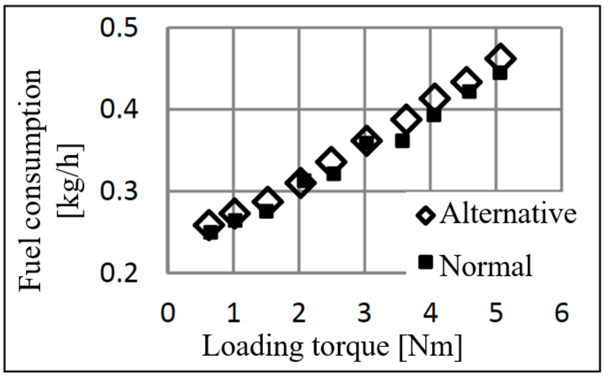

Figure 4. Fuel consumption [kg/h].

5. SUMMARY

It seems strategically useful, therefore, to keep all technological options open to adapt to unforeseen developments. In practice, this should not be a wait-and-see strategy but rather a parallel development of all options. This may entail higher initial costs, but it will increase the long-term resilience of the energy transition and help avoid snap decisions. Ultimately, the socioeconomic cost of building both BEV and FCEV infrastructure seems relatively low compared to that of other infrastructure budgets.

Our research experiments also show the potential of these materials for IBEV systems. Sub alternatives include the production of different no fossil fuels and blending them with existing fuels (or the production of fully synthetic fuels). We intend to continue our research under normal conditions on a brake test bench (high-performance diesel engine). Our results will be used to establish a new research collaboration with a large automotive company (testing new fuel types).

6. ACKNOWLEDGMENTS

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