Transport

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Application possibilities of hydrogen technologies in vehicles

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Abstract: The goal within the EU is to transition to a green, circular, and low-carbon economy, reduce transport emissions, and increase the share of industrial production in the overall economies of EU countries. This shift has resulted in the massive development of electromobility. One potential drawback of battery-electric vehicles is their overall driving range, which, although significantly improved in recent years, still presents a major disadvantage on long-distance journeys. In addition to alternative fuels like hydrogen, climate-neutral e-fuels could be a solution, likely playing a key role in sectors where the use of battery-electric powertrains is inefficient. Given the efforts to fully ban internal combustion engines in passenger cars after 2035, many European automakers are focusing on battery-electric vehicles. However, for the future of the automotive industry in the EU, the adoption of an exemption for climate-neutral fuels is very positive news, as it provides a significant alternative to battery-electric vehicles in the form of internal combustion engines powered by e-fuels and hydrogen.

Keywords: hydrogen, technologies, vehicles;

Możliwości zastosowania technologii wodorowych w pojazdach

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Streszczenie: Celem Unii Europejskiej jest przejście na zieloną - niskoemisyjną gospodarkę, redukcja emisji spalin z transportu oraz zwiększenie udziału produkcji przemysłowej w gospodarkach krajów UE. Ta zmiana doprowadziła do masowego rozwoju elektromobilności. Jednym z potencjalnych mankamentów stosowania pojazdów elektrycznych jest zasięg jazdy. Chociaż w ostatnim czasie wykonano szereg prac projektowo – badawczych zwiększając dystans jazdy, jednak dalej występują problemy z podróżą na długim dystansie. Oprócz alternatywnych paliw, takich jak wodór, neutralne dla klimatu e-paliwa mogą być rozwiązaniem, które prawdopodobnie odegra kluczową rolę w sektorach, gdzie zastosowanie elektrycznych układów napędowych jest nieefektywne. Biorąc pod uwagę starania o całkowite zakazanie silników spalinowych w samochodach osobowych po 2035 roku, wielu europejskich producentów samochodów koncentruje się na pojazdach elektrycznych zasilanych akumulatorami. Jednak dla przyszłości przemysłu motoryzacyjnego w UE przyjęcie wyjątku dla paliw neutralnych dla klimatu jest bardzo pozytywną wiadomością, gdyż oferuje istotną alternatywę dla pojazdów elektrycznych w postaci silników spalinowych zasilanych e-paliwami i wodorem.

Słowa kluczowe: wodór, technologie, pojazdy;

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1. Introduction

The term "zero-emission propulsion" currently refers primarily to the emission-free operation of a vehicle (the driving phase). However, attention must also be directed towards the entire chain involved in the production and operation of the vehicle (its entire life cycle). This includes all stages of the supply chain, encompassing vehicle manufacturing, production of propulsion energy, the usage phase of the vehicle, and its recycling. A major issue may also be the lack of infrastructure for charging electric vehicles, as well as concerns about battery safety and the high cost of battery replacement. Reuters published some interesting information regarding the fate of damaged Tesla electric vehicles, where even relatively lightly damaged cars with low mileage are often not sent to repair shops but to scrap yards or auctions, where they may be sold for parts. This happens because insurance companies often deem the damage to be a "total loss," even for vehicles that, if they were not electric, would normally be repaired and covered under insurance. The reason lies in the high cost of repairs, primarily due to the batteries, the most expensive component of an electric vehicle. If the batteries are damaged in a collision, the repair costs become prohibitive. According to data from two of the largest auction houses in the U.S., of more than 120 Tesla vehicles involved in auctions following collisions in December 2022 and early January 2023, the vast majority had less than 16,000 kilometers on the odometer. Another potential weakness of battery-electric vehicles is their overall driving range, which, while significantly improved in recent years, still poses a significant disadvantage on long-distance trips. Solutions may include alternative fuels, such as hydrogen, and climate-neutral e-fuels, which are likely to play a key role, particularly in sectors where the use of battery-electric powertrains is inefficient.

2. Materials and Methods

The European emission standards were first introduced in 1992. Initially, they applied only to heavy-duty vehicles, but the increasing number of passenger cars shifted the focus to this sector as well. The aim of the European emission standards, known as EURO, was and remains to improve air quality. Emission standards have been revised and tightened approximately every four to five years. Since the adoption of the first EURO standards, harmful substances from vehicle exhausts were measured according to the New European Driving Cycle (NEDC) (Fig. 1). This cycle consists of a series of tests based on engine acceleration and deceleration on test benches. However, it later became apparent that emissions measured during laboratory tests differed significantly from those in real-world driving conditions. Therefore, since 2017, the Worldwide Harmonized Light-Duty Vehicles Test Procedure (WLTP) has been used. This procedure takes into account higher speeds and more realistic acceleration and deceleration patterns, thus providing a more accurate simulation of real-world conditions. The current EURO 6 standard has been revised over time, with each update denoted by an additional letter. Since January 2021, the Euro 6d standard has been in force. Given the ongoing need for greener transport, the Euro 7 standard could be introduced in the future. Figure 1 illustrates a roadmap depicting the historical development and planned goals for reducing the carbon footprint. Between 2025 and 2029, cars and vans will be required to emit 15% less CO_2. Additionally, by 2035, the goal is to achieve a 100% reduction in CO_2 emissions for new vehicles [1].

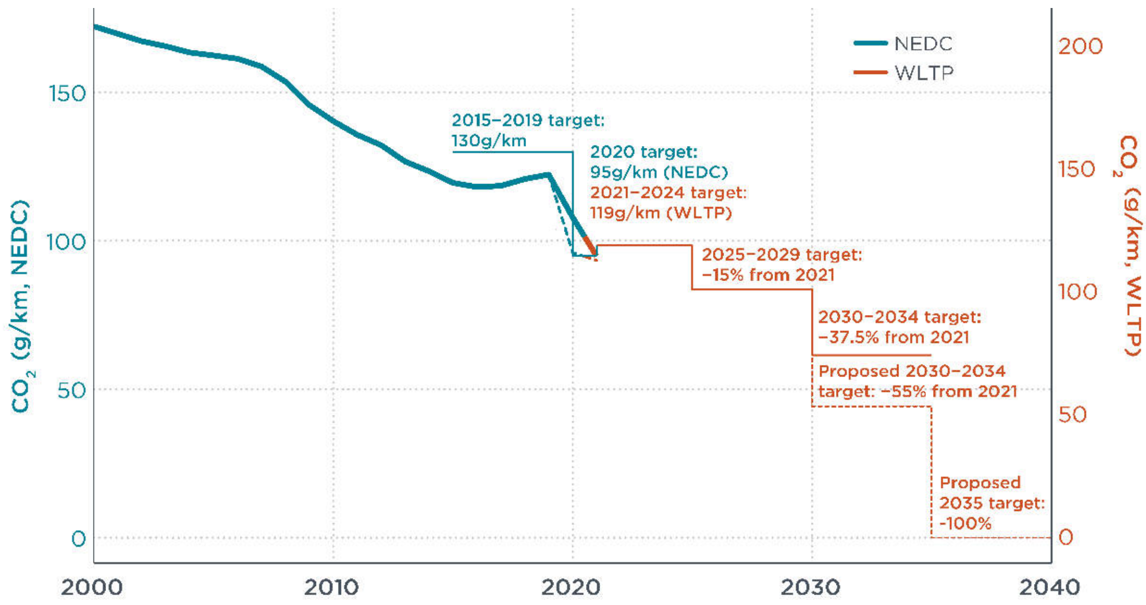

Figure 1. Development and proposed targets for average CO_2 emission values according to NEDC and WLTP [1]

Part of this plan is an agreement between Germany and the European Union that new vehicles with internal combustion engines may continue to be sold if they use climate-neutral fuel. The European Union's original draft law called for a complete ban on the sale of new vehicles equipped with internal combustion engines after 2035. However, Germany argues that vehicles burning e-fuels are carbon-neutral, as these fuels are produced using renewable energy and carbon captured from the air. The EU and Germany have agreed on specific procedural steps, and the process for granting an exemption for the use of e-fuels is expected to be completed by the end of 2024.

For electric vehicles, the largest CO_2 emissions occur during their production and recycling phases. At the same time, the potential for reducing CO_2 during the usage phase of an electric vehicle is very limited, especially when the charging electricity is not generated from renewable energy sources. Figure 2 shows global electricity production by the share of various energy sources in 2022 [2]. The analysis indicates that coal and fossil fuels in general remain the dominant sources for electricity generation worldwide.

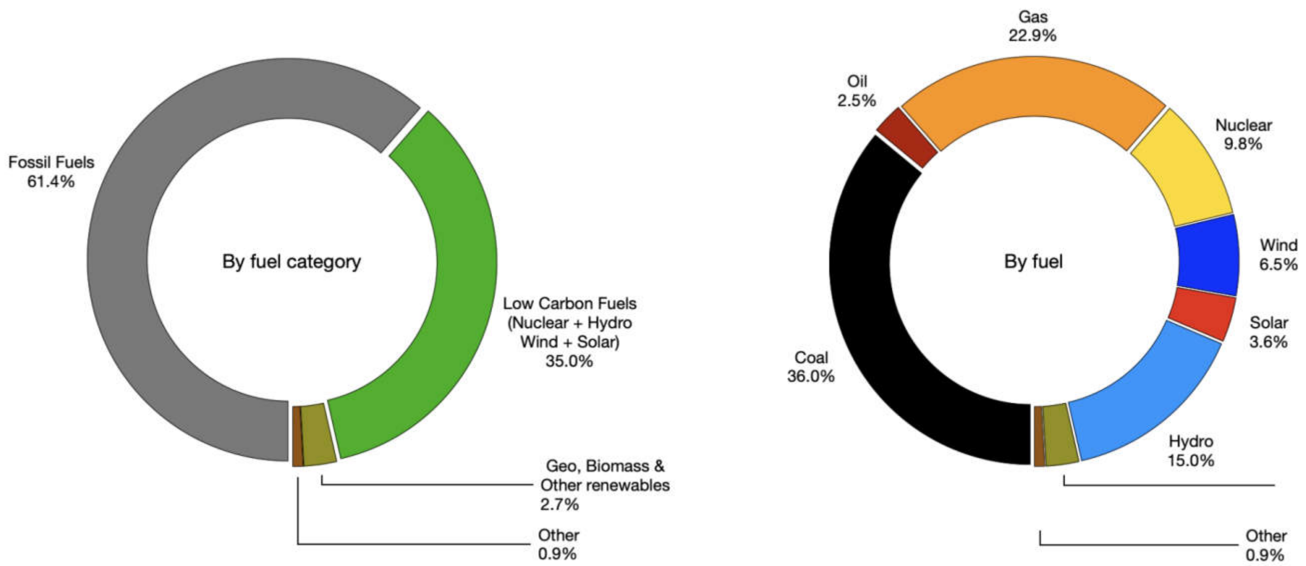

Figure 2. Global electricity production by share of energy sources [2]

The Annual World Energy Report provides an updated analysis of global coal production and consumption, assesses the future outlook for global coal supplies, and considers the implications of peak coal production on global economic growth. Figure 3 illustrates the historical and projected global coal production. It is expected that global coal production will peak before 2030 at over 8,000 million tons and decline to just above 6,000 million tons by 2050 [3].

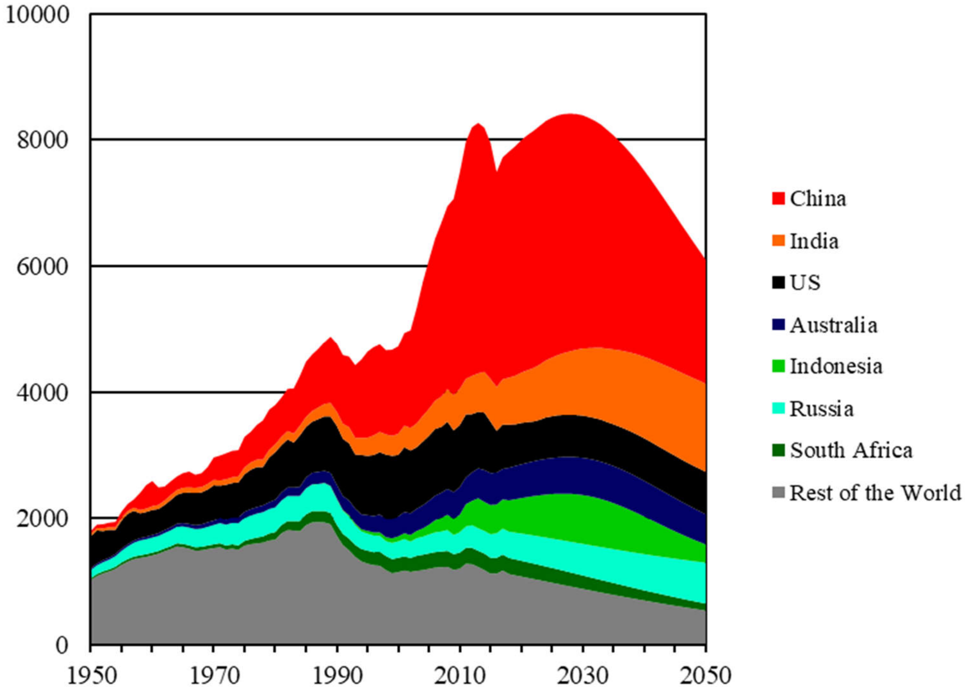

Figure 3. Historical and projected global coal production (in million tons) [3]

3. Results

In internal combustion engines, approximately 70% of CO_2 emissions over the entire vehicle lifecycle occur during the operation of the vehicle. The remaining 30% is distributed across the supply chain, which includes vehicle manufacturing, recycling, and fuel preparation. In the least favorable scenario, the share of emissions throughout the entire lifecycle of electric vehicles is nearly the same as that of conventional cars. Therefore, a shift to electric drives will only be effective if the entire lifecycle is optimized. Strategic areas of focus include battery production and the generation of electricity for charging electric vehicles. Currently, there is insufficient infrastructure in the form of a network of charging stations. Furthermore, the safety of high-capacity batteries has not yet been fully addressed. Internal combustion engine vehicles remain a popular choice among consumers. Thus, research and development in new engine technologies will continue to be crucial from an environmental perspective. Additionally, the internal combustion engine is a significant component of hybrid drives, and diesel engines have a notable advantage, particularly regarding performance parameters for SUVs.

The German Automotive Industry Association (VDA) is clear on this matter, stating that without sustainable fuels, the world and the EU will simply not manage after 2035: "CO_2 neutrality in the transport sector cannot be achieved solely through electric mobility. Even if we ideally have 15 million electric vehicles on the roads by 2030, the vast majority of the vehicle fleet will still be internal combustion engines. There are currently 280 million combustion engine cars in the EU and 1.5 billion worldwide. Climate-neutral transport cannot be achieved without considering the composition of the vehicle fleet and its decarbonization." The VDA also emphasizes that the only solution to reduce the carbon footprint of the existing fleet of internal combustion engine vehicles is the use of synthetic fuels and hydrogen. While 2035 is often mentioned as the end of the sale of cars with internal combustion engines, this does not automatically mean that the vehicle fleet will consist solely of electric cars thereafter. On the contrary, a new generation of fuels designed for existing internal combustion engine vehicles must be ensured by 2035.

Figure 4. Toyota Corolla with a hydrogen engine and Yamaha V8 hydrogen unit [4]

Toyota is experimenting with an alternative to direct hydrogen combustion as a form of propulsion, utilizing it in motorsport as well. In this endeavor, they are collaborating with Yamaha. „We are striving to achieve carbon neutrality by 2050," explains the president of Yamaha Motor. „At the same time, our company name includes the word motor, and in accordance with that, we support and engage with internal combustion engines in every possible way." They also introduced the V8 hydrogen engine developed by Yamaha for Toyota (fig.4).

These efforts indicate that the future of internal combustion engines is still viable. A realistic assessment of the benefits of different types of propulsion will be crucial. The mass production of synthetic fuels and hydrogen using "green" energy could facilitate the achievement of climate goals without the need for widespread charging infrastructure and the industry for battery manufacturing and processing. However, the final solution to these measures may ultimately take the form of a compromise between the development of electric mobility and the continued operation of internal combustion engines.

4. Conclusions

Hydrogen is a potentially sustainable alternative fuel for internal combustion engines. Furthermore, it is a clean gas, devoid of CO, CO_2, unburned hydrocarbons, and particulate matter, as it does not contain carbon atoms. Pure hydrogen spark-ignition (SI) engines emit only nitrogen oxides (NO_X) as harmful gases present in the exhaust system. Various methods are currently being employed to address this issue. Thus, hydrogen could serve as an effective fuel if produced from renewable sources. Among its key advantageous properties are a high combustion velocity, a wide range of flammability, and a low ignition energy. Renewable sources will play a crucial role in the transition towards clean and sustainable energy.

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