energies

MDPI

Review

Hydrogen or Electric Drive—Inconvenient (Omitted) Aspects

Jarosław Konieczny [1,*], Krzysztof Labisz [1], Szymon Surma [1], Jakub Młyńczak [1], Jerzy Łukasik [1], Renata Boris [2] and Michał Grzybowski [3]

1 Department of Railway Transport, Faculty of Transport and Aviation Engineering, Silesian University of Technology, Krasińskiego 8 Street, 40-019 Katowice, Poland; krzysztof.labisz@polsl.pl (K.L.); szymon.surma@polsl.pl (S.S.); jakub.mlynczak@polsl.pl (J.M.); jerzy.lukasik@polsl.pl (J.Ł.)
2 Laboratory of Composite Materials, Institute of Building Materials, Faculty of Civil Engineering, Vilnius Gediminas Technical University, Linkmenu Street 28, LT-08217 Vilnius, Lithuania; renata.boris@vgtu.lt
3 ALSTOM ZWUS sp. z o.o., Modelarska 12 Street, 40-142 Katowice, Poland; michal.grzybowski@alstomgroup.com
* Correspondence: jaroslaw.konieczny@polsl.pl

Abstract: Currently, hydrogen and electric drives used in various means of transport is a leading topic in many respects. This article discusses the most important aspects of the operation of vehicles with electric drives (passenger cars) and hydrogen drives. In both cases, the official reason for using both drives is the possibility of independence from fossil fuel supplies, especially oil. The desire for independence is mainly dictated by political considerations. This article discusses the acquisition of basic raw materials for the construction of lithium-ion batteries in electric cars, as well as methods for obtaining hydrogen as a fuel. The widespread use of electric passenger cars requires the construction of a network of charging stations. This article shows that, taking into account the entire production process of electric cars, including lithium-ion batteries, the argument that they are ecological cannot be used. Additionally, it was indicated that there is no concept for the use of used accumulator batteries. If hydrogen drives are used in trains, there is no need to build the traction network infrastructure and then continuously monitor its technical condition and perform the necessary repairs. Of course, the necessary hydrogen tanks must be built, but there must be similar tanks to store oil for diesel locomotives. This paper also deals with other possibilities of hydrogen application for transformational usage, e.g., the use of combustion engines driven with liquid hydrogen. Unfortunately, an optimistic approach to this issue does not allow for a critical view of the whole matter. In public discussion, there is no room for scientific arguments and emotions to dominate.

Keywords: energy transformation; energy consumption; climate policy; energy in transport; energy savings; climate policy

Citation: Konieczny, J.; Labisz, K.; Surma, S.; Młyńczak, J.; Łukasik, J.; Boris, R.; Grzybowski, M. Hydrogen or Electric Drive—Inconvenient (Omitted) Aspects. *Energies* **2023**, *16*, 4400. https://doi.org/10.3390/en16114400

Academic Editor: Wei-Hsin Chen

Received: 6 April 2023
Revised: 3 May 2023
Accepted: 12 May 2023
Published: 30 May 2023

1. Introduction

Drive Efficiency

Electric drives are used in various means of transport. The most common application is public transport, i.e., passenger cars [1], trams, trolleybuses [2], and buses, electric multiple units [3] or cycles [4]. Similarly, the aviation industry is considering the use of electrical technology and power electronics in cargo aircrafts [5]. Cars for the transport of goods (trucks) with electric drive did not go beyond the research area. However, passenger cars have entered the market quite recently. However, hydrogen-powered means of transport (FC) appeared about two decades ago. This drive is most often used in rail passenger transport, e.g., Siemens Mireo Plus H and Alstom Coradia iLint, and is currently used for passenger transport. Passenger cars equipped with fuel cells, although they are already in production (Toyota Mirai, Honda FCV Concept, Roewe 950 Fuel Cell, Audi Sportback A 7 h-tron Quottra, Hyundai Tucson Fuel Cell), are still not widely used.

In an internal combustion engine, the energy contained in the fuel (gasoline, oil, LPG) is converted into useful work [6]. Unfortunately, conversion of the form of energy into the engine is associated with a number of losses (Figure 1). First, an insignificant fraction of the fuel is not converted into ideal combustion products. In turn, the second law of thermodynamics states that only a small part of this energy can be converted into useful work. It is related to the thermodynamic efficiency and the change of heat in the work [7]. The energy of combustion is largely lost as a result of heat dissipation in conjunction with hot combustion gases, as well as thermal radiation and heat transfer [8] through the surfaces of the combustion chamber [9].

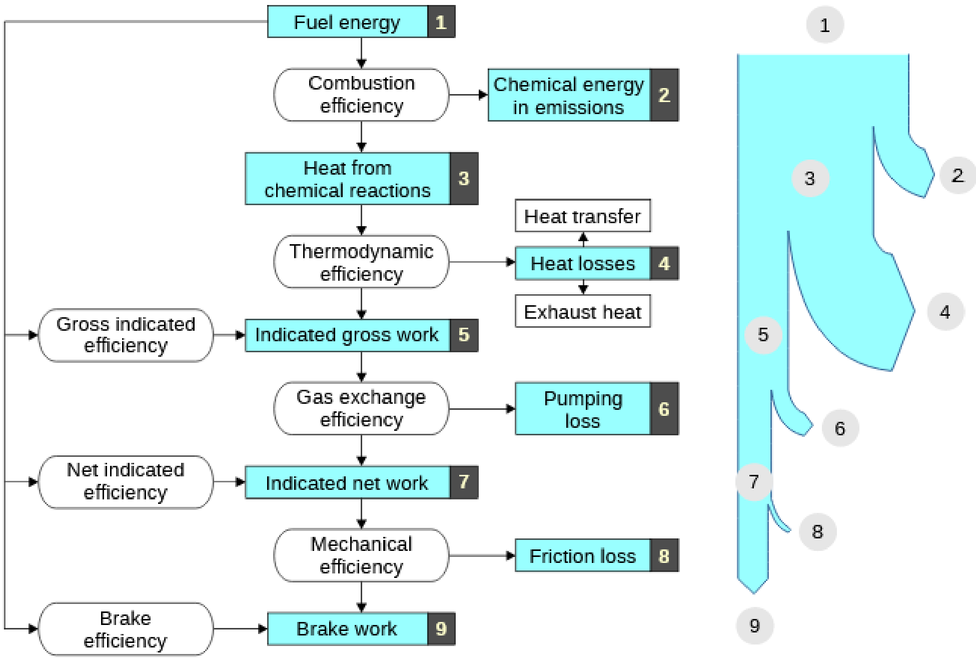

Figure 1. Overview of energy losses in a typical internal combustion engine [10].

In these devices, the chemical energy of the fuel is converted into electrical energy with a theoretical efficiency of 83% (Figure 2) [11]. Among the many advantages of fuel cells, it is worth highlighting the following [12]:

- unlike engines operating on the basis of the Carnot cycle, the maximum efficiency of energy conversion in fuel cells is at non-zero power;
- pure water is the product of conversion of chemical energy of hydrogen into electricity;
- electricity generation in applications with power ranging from milliwatts [mW] to megawatts [MW] is continuous, as long as substrates for electrochemical reactions are supplied.

According to an official of the European Commission, the whole world is in the process of producing electric cars. Europe has to massively produce batteries in massive amounts in Europe. In China, there should be 80 new electric car models by the end of 2023. The United States and India are building new production capacities. We in Europe build the best cars in the world, but we must not chain ourselves to the past. E-cars will be cheaper than combustion engines in the long run [13]. This transformation only makes sense if everyone is involved. Many people who are addicted to cars cannot afford expensive models. There will soon also be a market for used cars. It is our concern as social democrats that it becomes affordable for everyone. Change is inevitable, but we must make it socially just. Then, everything will be more expensive. The European government has to say where to go. That is the advantage of Europe, that we can provide long-term legislation [14].

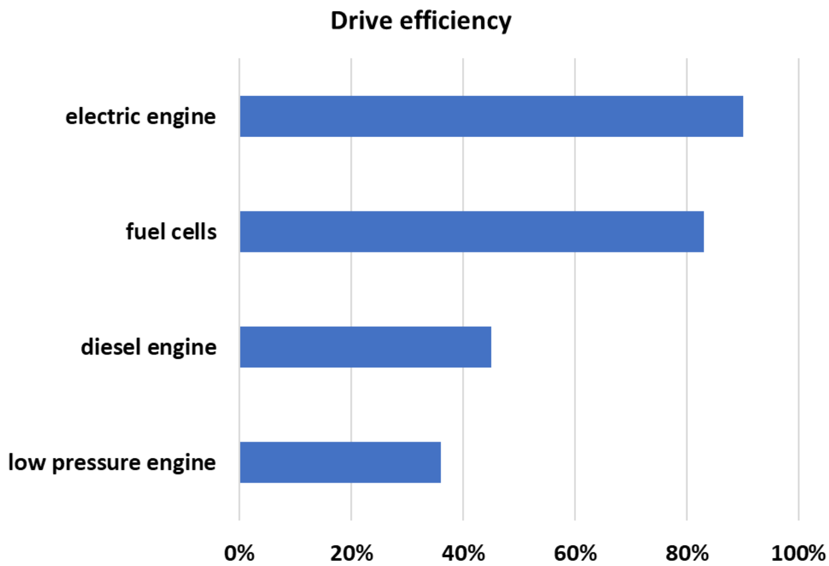

Figure 2. Efficiency of various types of drives (based on [11]).

According to the French Economy Minister Bruno Le Maire recently, all industrialised nations will return to nuclear power. The member states decide for themselves which energy sources they use. If the prices of renewables go down, you have to recalculate and compare the total costs for nuclear power plants. It takes a very, very long time to build nuclear power plants, and there are still risks related to waste, but also other environmental risks. This must also be taken into account. I am not at all ideological about this. I am disappointed that nuclear power is being made an ideological debate in Europe [14].

2. The Principle of Fuel Cell Operation

In hydrogen fuel cells, a chemical reaction of oxygen and hydrogen takes place, the effect of which is the energy generated during the reaction. Cells are made of an electrolyte Proton-Exchange Membrane—PEM [15] with a catalyst layer on both sides (Figure 3). Hydrogen atoms are led to a porous anode, where they are oxidised by giving up electrons, and hydrogen cations (protons) are formed [16]. However, in the cathode, oxygen reacts with electrons, reducing to the oxide anions O^{2-}. Then, protons (hydrogen cations) migrate through the semipermeable membrane to the second layer of the catalyst, the cathode [17]. After reaching the cathode, hydrogen cations react with oxide anions, resulting in water (in vapour or liquid form). During this time, electrons that cannot pass through the membrane reach the cathode through the electrical circuit, generating a current that allows the devices to be powered [18]. The efficiency of hydrogen cells is 94.5%, which is the highest among known and used drives [19].

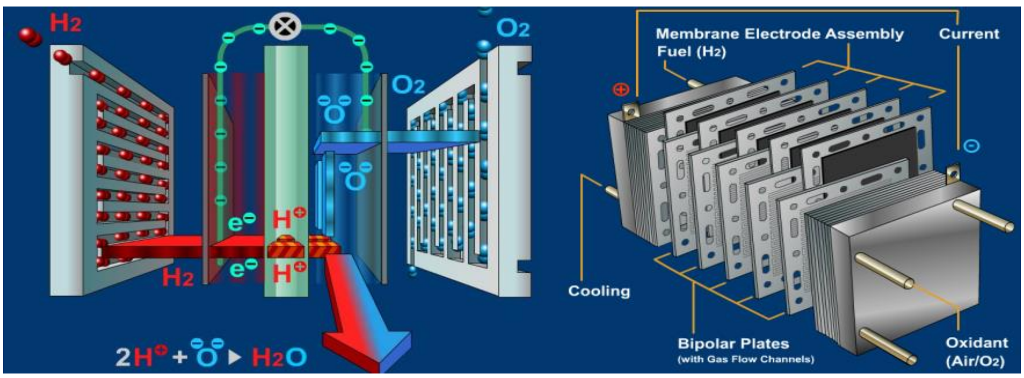

Figure 3. Diagram of a hydrogen fuel cell [18].

3. Application of Hydrogen Fuel

A chart that ranks the different uses of clean hydrogen according to their cost effectiveness is presented in Figure 4. The German government aims to make Germany greenhouse gas neutral by 2045. By 2030, CO_2 emissions will already fall by at least 65% compared to the base year 1990, and by at least 88% by 2040. These goals are laid down in the recently amended Climate Protection Act and require an acceleration of the energy transition. The key building blocks for this are the accelerated expansion of renewable energy and an increase in energy efficiency. In addition, so-called sector coupling is playing an increasingly important role, i.e., the direct or indirect use of electricity from renewable energies for previously unelectrified applications in transport, the heating sector and industry. According to Dr. Wolf-Peter Schill and Martin Kittel, hydrogen is going to become the saviour in the energy transition. It cannot be electrified directly or comfortably enough to be powered by hydrogen. Accordingly, the German government attributes an important role to hydrogen in the decarbonisation of the German economy. Our series of articles aims to take a closer look at the plans of the federal government and shed light on concrete areas of application, especially in the automotive sector. What is technically possible should also be tested for efficiency and scalability [20].

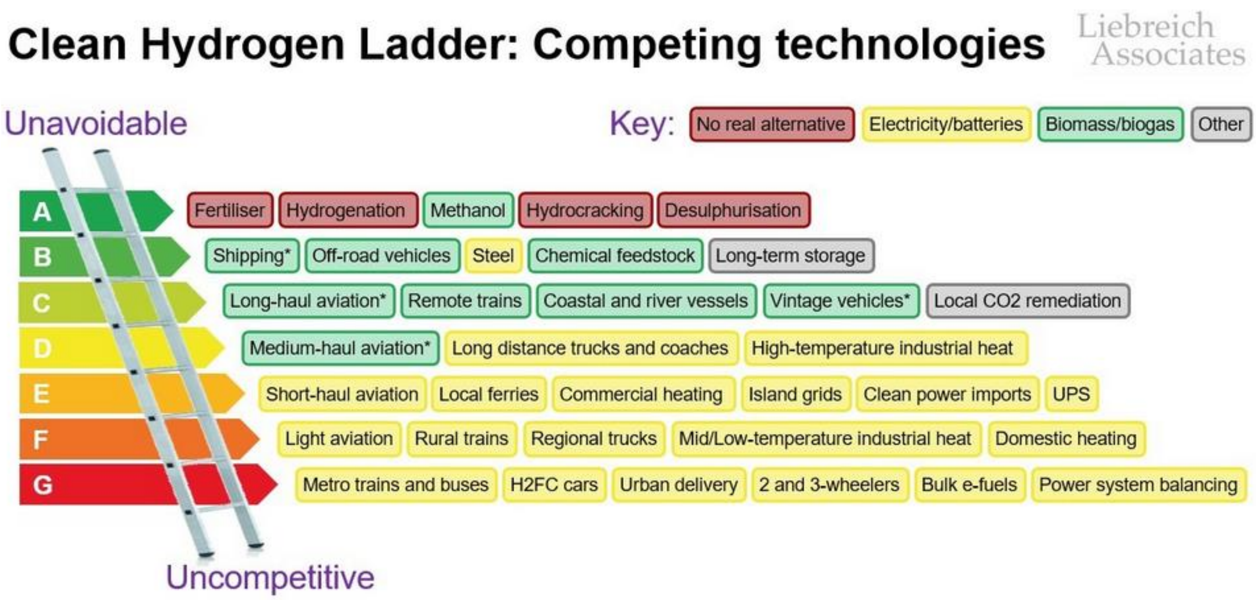

Figure 4. Different uses of clean hydrogen; A-B hydrogen cleanness scale—A-very clean, environmental neutral, G-potentially harmful to the environment; *—Via ammonia or e-fuel rather than H2 gas or liquid [21].

4. The Question, the Answer to Which Is the Foundation of Further Analysis: How Is Hydrogen Obtained?

4.1. Fundamentals of Hydrogen Technologies

Hydrogen can be produced by a variety of processes. Currently, thermochemical processes are used most often, in which hydrogen is released from organic materials (fossil fuels, biomass, water) [22]. Hydrogen gas can be produced from hydrocarbon fuels by three basic technologies [23]:

- steam reforming (SR);
- partial oxidation (POX);
- auto thermal reforming (ATR).

However, these technologies produce large amounts of carbon monoxide (CO), which is converted to carbon dioxide (CO_2) in the next step. This contradicts today's dominant argument about giving up cars equipped with internal combustion engines.

Currently, the dominant source of hydrogen production is natural gas (Figure 5) [23]. It accounts for around half of the annual global self-consumption hydrogen production of around 70 million tonnes. This is about 6% of the global consumption of natural gas [24,25]. The main hydrogen producers in the European Union are shown in Figure 6. Hydrogen can be obtained by decomposing water (H_2O) into hydrogen (H_2) and oxygen (O_2) using electrolysis or solar energy. Since 70% of electricity in the EU is generated by burning fossil fuels, converting one form of energy into another, taking into account the inevitable losses at each stage, defeats the purpose—it is senseless. So, the conviction of various institutions that currently opt for this solution is a lie (greenwashing again) or a lack of knowledge resulting from ignorance of basic scientific facts. There is also the possibility of obtaining hydrogen in biological processes, where it is produced by microorganisms, such as bacteria and algae. The idea of using microorganisms to produce energy appeared more than 100 years ago, and work on microbial fuel cells (MFCs) was intensified in the 1960s and 1970s [26–28].

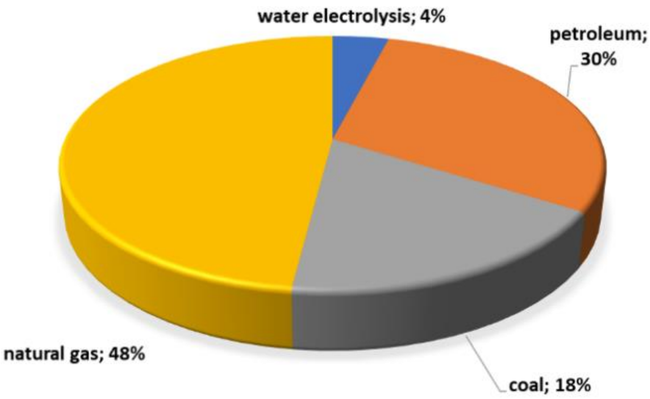

Figure 5. Production and use of hydrogen in the EU (2018) [25].

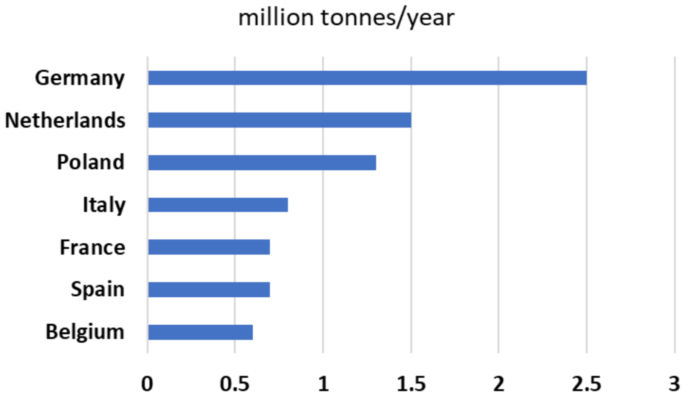

Figure 6. Mainly hydrogen producers in the European Union, 2018 [29].

Currently, 48% of the produced hydrogen is produced as a result of the reforming of methane using steam, 30% from crude oil (mainly in refineries), 18% from coal and the remaining 4% from water electrolysis. The majority of hydrogen produced today is the so-called "Gray hydrogen", which currently dominates the market. It is obtained from fossil fuels, primarily from natural gas and coal. Natural gas is converted into hydrogen and carbon dioxide under heat in what is known as steam reforming. CO_2 escapes unused into the atmosphere and, thus, increases the greenhouse effect. Depending on the source and the mix of electricity, the production of one tonne of hydrogen generates around ten tonnes of CO_2—a considerable amount [22,30].

The current efficiency of hydrogen production in the electrolysis process is approximately 75%, but it is expected to reach 90% in the future [31]. To produce 1 kg of hydrogen at a temperature of 25 °C and a pressure of 1 atmosphere, 39 kWh of electricity and 8.9 litres of water are needed [32].

A promising method for hydrogen production in the future may be the electrolysis of water. Electrolysis is a process in which a direct current flowing through two electrodes immersed in an electrolyte causes the disintegration of the chemical bonds of a water particle, resulting in its disintegration into oxygen and hydrogen atoms, and then their emission in the form of gases. Currently, this process produces about 4% of the hydrogen in the world [33]. The electrolysis of water, or its breakdown into hydrogen and oxygen, is a well-known method that began to be used commercially as early as 1890. It should be noted that the factor necessary to carry out electrolysis is the electric current. If we take into account the fact that in the EU, 80% of electricity is produced as a result of burning fossil fuels, in the current situation, the production of hydrogen as an ecological fuel, a substitute for, for example, petroleum products, is a lie, or it results from someone's ignorance—tertium non-datur.

4.2. Direct Solar Water Splitting Processes

Among the processes that remain in the stage of laboratory research and have not yet been implemented in industry is the splitting of a water molecule into hydrogen and oxygen atoms using solar energy. The advantage of this method is its very low environmental impact, as well as the long-term potential for sustainable hydrogen production.

4.3. Biological Processes

A method of low-emission hydrogen production may be the production of this gas as a result of biological reactions of bacteria and microalgae (Figure 7). Currently, these methods are in the research stage; however, they have the potential for sustainable hydrogen production with a low environmental impact. One of them is the photobiological decomposition of water, which takes place in a photobioreactor. Some algae produce hydrogen using sunlight [34,35]. The condition for this process is the removal of sulphur; then, the alga produces hydrogen in the photosynthesis process [36]. At the present time, methods of obtaining hydrogen in biochemical reactions are burdened with many problems, among which the most important are the achievement of economic competitiveness in relation to other methods of obtaining hydrogen and the achievement of high efficiency in the conversion of solar energy into chemical energy stored in hydrogen molecules.

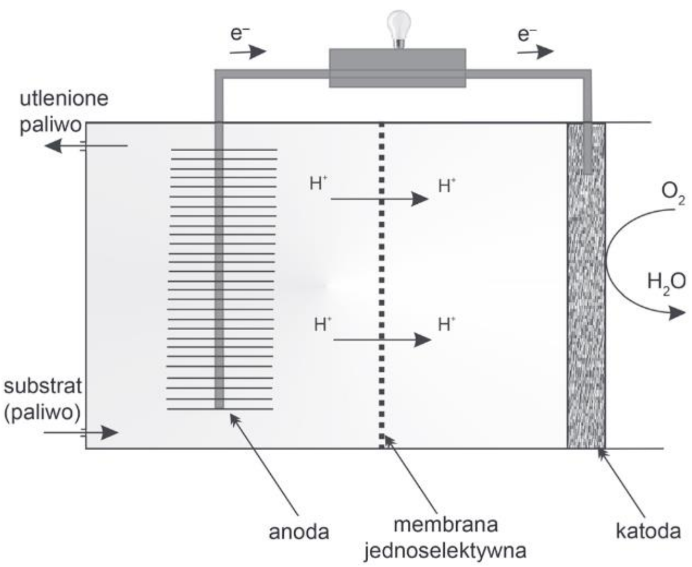

Figure 7. Diagram of a microbial fuel cell (MFC) containing an electrically conductive brush-shaped graphite anode (constituting a surface for the growth of microorganisms) and a flat passively oxygenated cathode; e^-—electrons, H^+—protons [36].

Some of the hydrogen is produced from salty water by evaporation. Most often, such reservoirs with large water surfaces are created artificially, and salt water is obtained from mines. However, the raw brine produced during the operation of lithium mines in salt lakes can change the physicochemical properties of the soil, leading to its salinisation. This time again there is interference in the natural environment.

It is worth looking at the methods of hydrogen production in light of ecology and economy combined. These two aspects cannot be considered separately. Currently, the production of green hydrogen is very expensive. If it is expensive, it means that in a market economy, the costs of this production are borne by the last link in the chain—that is, the consumer. Green hydrogen is produced from water using regenerative energies in an electrolysis process. The water molecule is divided into two elements: oxygen and hydrogen. If only electricity from renewable sources is used, hydrogen is considered CO_2-free—even if the production of a wind turbine, for example, is not completely climate-neutral [30].

Grey hydrogen does not make ecological sense (Figure 8). Blue hydrogen is produced mainly in the technology of steam reforming of natural gas, i.e., methane. The products of such a process are hydrogen, carbon monoxide or carbon dioxide (again, failure). With this technology, the energy consumption to produce a hydrogen unit is much lower than in the electrolysis process.

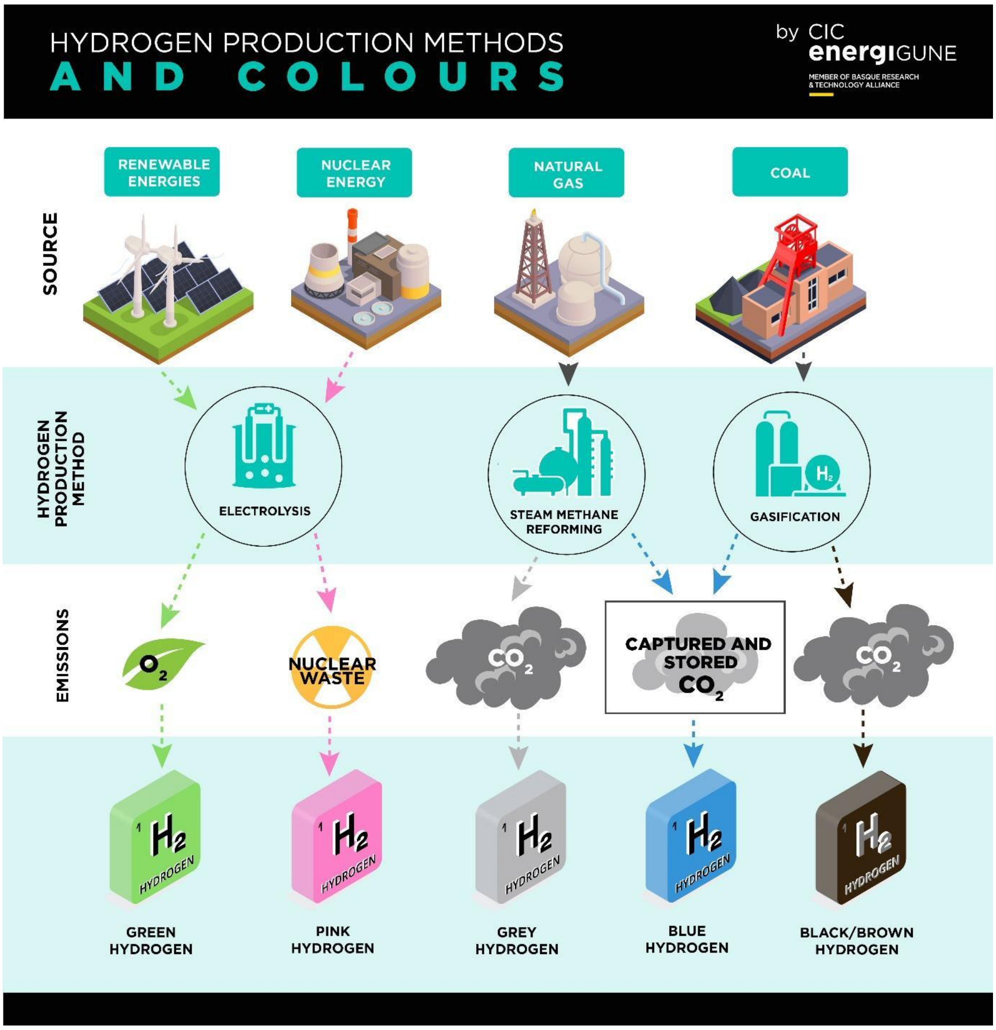

Figure 8. Hydrogen production methods and their colours [37].

4.4. Is Blue Hydrogen a Threat to the Climate? No One Listens to Scientists!

Decarbonizing the global economy is currently the goal of environmentalists and politicians. Unfortunately, neither the former nor the latter seem to be aware of the consequences of acting within the framework of modern possibilities. Scientific facts do not appeal to politicians.

According to the analysis of Robert W. Howarth and Mark Z. Jacobson, blue hydrogen means only a few percentage reductions in emissions compared to grey hydrogen [38]. Although its combustion is cleaner than burning coal or oil, it should be remembered that it is a greenhouse gas. A ton of methane released into the atmosphere warms the atmosphere twenty times more than a ton of carbon dioxide. Further, the carbon footprint caused by blue hydrogen is larger than that of burning methane, diesel or coal.

Blue hydrogen is actually grey hydrogen, so it is produced by fossil fuels (Figure 9). The key difference is the CO_2 produced is separated, collected and injected into suitable geological formations deep underground; therefore, it does not escape into the atmosphere. In English, one speaks of carbon capture and storage, or CCS for short. In balance, blue hydrogen is considered CO_2-neutral. Possible deposits are, for example, former oil or gas deposits and rock layers containing salt water. In Germany, the process has so far been used in pilot and test projects. Norway announced at the end of 2020 that it would invest 1.5 billion euros in the construction of a large CCS storage facility [30].

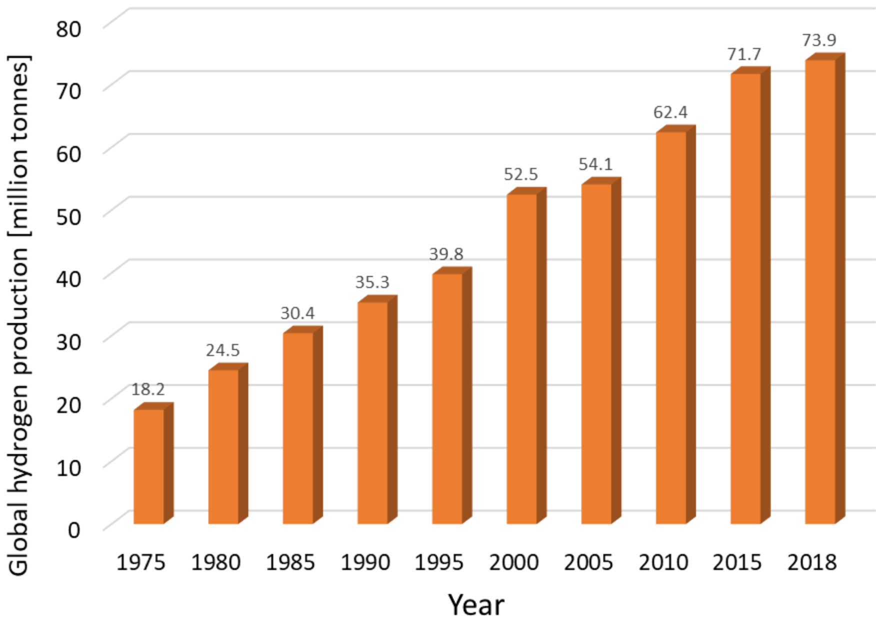

Figure 9. Global hydrogen production [source IEA]. Hydrogen production from fossil fuels 830 million tons of CO_2 [29].

It turns out that the reason for this is mainly methane leaks from mining and production installations (about 3.5%). Taking this factor into account, the carbon footprint of burning methane or hard coal for heating purposes is 20% less than the carbon footprint of blue hydrogen. On the other hand, diesel fuel consumption is up to 60% lower [38]. In summary, after thorough research and analysis, it turns out that new ecological solutions of hydrogen drives can be more harmful than those currently used [39].

There are, of course, many other productions ways, e.g., turquoise hydrogen is hydrogen that has been produced via the thermal cracking of methane—the so-called methane pyrolysis. Solid carbon is produced instead of CO_2. This process is CO_2-neutral if the high-temperature reactor is operated with renewable energy sources. Of course, the carbon produced must be permanently bound. One advantage of this process is that carbon is easier to store than CO_2 and could be used, for example, in the chemical and electronics industries or in road construction. Compared with the production of green hydrogen using electrolysis, methane pyrolysis is said to require only a fifth of the energy. However, so far, the process has only been tested on a laboratory scale. With funding from the Federal Ministry of Research, BASF has built a test facility in Ludwigshafen, which is scheduled to go into operation in the coming months after the test has been completed. Politically, green hydrogen is the focus of interest [30].

5. The Concept of a Modern Hydrogen Drive

Nowadays, the hydrogen drive in trains is implemented according to the scheme hydrogen cells—accumulator battery—electric motors (Figure 10).

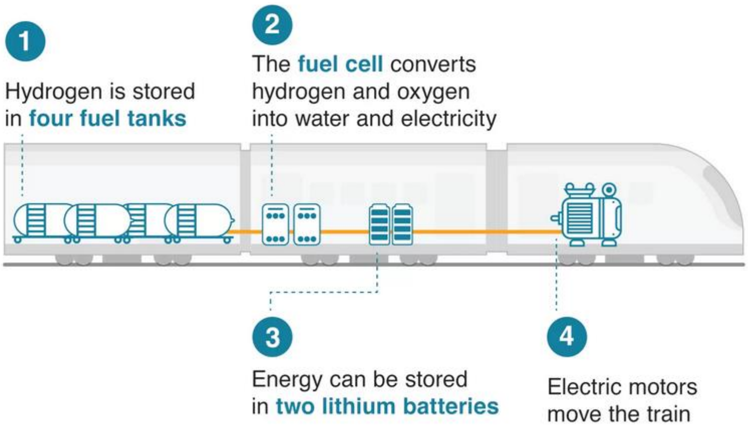

Figure 10. Diagram of the propulsion system in trains that use hydrogen [40].

Already today, such a solution brings about the desired effects of reducing CO_2 emissions to the atmosphere (Figure 11). However, a calculation that does not take into account the overall impact of a product on the environment is selective and, therefore, mendacious and erroneous (again, greenwashing).

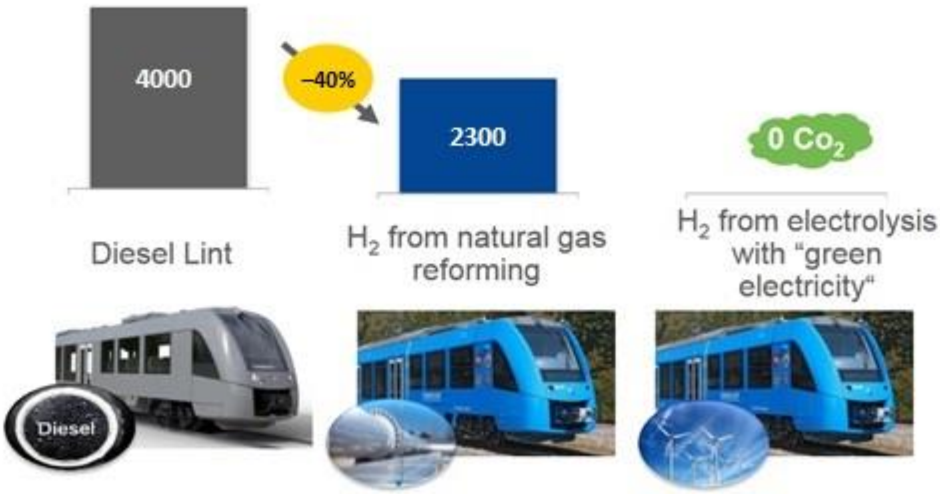

Figure 11. CO_2 emission depending on the drive used [41].

6. Lithium Production

An important element of the propulsion system, e.g., in electric trains and electric cars, is the batteries from which the current is drawn to drive electric motors. Currently, almost exclusively lithium-ion batteries are used. Lithium, as a rare earth element, is obtained in opencast mining (80%). For this reason, the use of these batteries has a very serious impact on the environment. Opencast mining causes devastation to the natural environment. The growing demand for lithium contributes to an increase in demand and, thus, to an increase in production.

Currently, the demand for lithium in the European Union is about 6000 t of lithium per year, but by 2030, it is expected to increase by 108,000 t (18 times), while in 2050, the demand for this element is expected to be 360,000 t, that is, 60 times the consumption in 2020 [42].

The processing of the lithium-rich ore that is mined generates pollution, which also has a very negative impact on the surrounding environment. Off-gases can be generated during the crushing, screening and unloading of the ore. On the wastewater other hand, that generated is the result of dewatering after flotation, sedimentation of waste and solid waste, such as processing slag.

Lithium is obtained through open-pit mining (spodumenes) and by evaporating brine from salty water reservoirs [43]. These are currently two main industrial ways of obtaining lithium [44]. From the mined ores, lithium is obtained by limestone calcination, the sulfuric acid method, the chloride method and the pressure brewing method.

The dominant method of lithium extraction is open-pit mining, but underground mines also occur. The extracted ore is subjected to traditional enrichment, which consists of grinding, the separation of lithium minerals and their concentration by the flotation of heavy liquids. The products are concentrates (spodumene or lepidolith) containing 6–7% Li_2O (75–87% spodumene) and are used for the production of lithium carbonate. Higher purity concentrates (7.6% Li_2O) are used in the ceramic industry [44].

The limestone calcination method has serious disadvantages, such as having a too low lithium content in the leach solution, very high energy consumption and a low lithium recovery rate. For this reason, and due to severe environmental pollution, the Chinese company CITIC Guoan stopped using this method. In turn, the sulfuric acid method requires the use of a large amount of sulphuric acid, forcing manufacturers to use expensive equipment with high anticorrosion properties. Of course, the sulfuric acid must be disposed of/neutralised after the lithium extraction process.

Another method of obtaining lithium from mined ore, chlorinated roasting, also has a number of disadvantages. These include, in the environmental aspect, the need to protect the equipment against corrosion in the roasting process and the use of sodium carbonate to precipitate lithium in one of the production stages. Sodium carbonate is a highly toxic agent and must also be disposed of. Another pressure cooking method is similar to the sulfuric acid method. It has shorter process times and lower costs, but it has more stringent requirements for process conditions.

The lithium extraction process uses a lot of fresh water, up to 1890 L per metric ton [45].

The lithium refining methods presented above result in the generation of impurities. The consequence of using the calcination and leaching method will be environmental pollution, because the spray drying process generates a large amount of acid mist and fluorine-containing gas [46].

Are there alternative methods of obtaining lithium? Such technologies are, for example, lithium extraction from salty waters, especially from natural brines, which have been developed very intensively in recent years. The basic method for obtaining lithium from brines is the ion exchange method, which is environmentally friendly. It is used to extract lithium from low-concentration brines and seawater [47]. Unfortunately, the process of producing adsorbents is complicated.

The cost of obtaining 1 t of lithium carbonate in the rock extraction process and subsequent extraction is approximately PLN 2.54 thousand, while the cost of obtaining 1 t of lithium carbonate from brines is on average PLN 5.58 thousand. USD [42].

And lithium prices are breaking records; currently (13 September 2022), the price of lithium carbonate in China has reached the level of 495.5 thousand yuan per tonne (PLN 325.85 per tonne). Just five years ago, a ton of lithium carbonate cost five times less than it does now (Figure 12). This is due to the fact that the supply has not been able to keep up with the growing demand for a long time, despite the economic slowdown. It is a nightmare for automotive companies. The need to build their own lithium production plants is being considered. Yet, it will not come from this deposit [48].

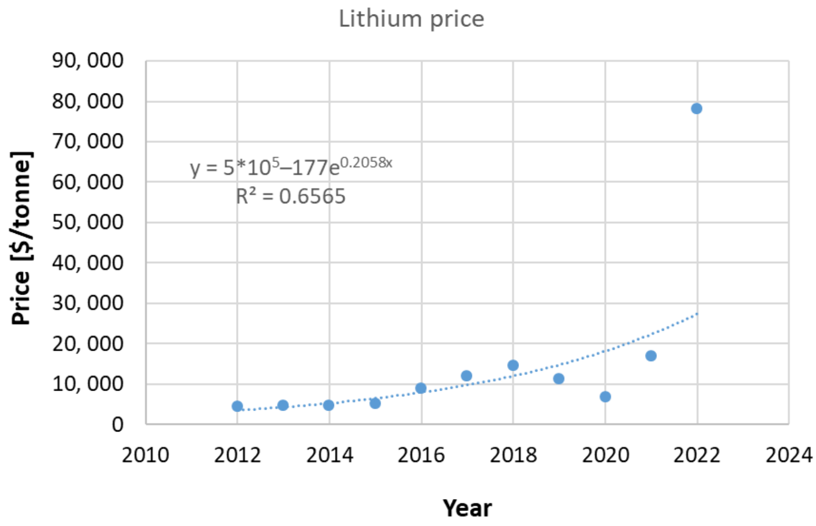

Figure 12. Lithi um prices per tonne, 2012–2022 (based on World of Statistics, [49]).

According to a tweet from the World of Statistics, lithium prices per ton were as follows:

The occurrence of lithium deposits is shown in Figure 13. The largest lithium producers in the world are Chemetall (USA/Chile), SQM (Chile), Admiralty Resources (Australia and South America) and CITIC Guoan Lithium (China).

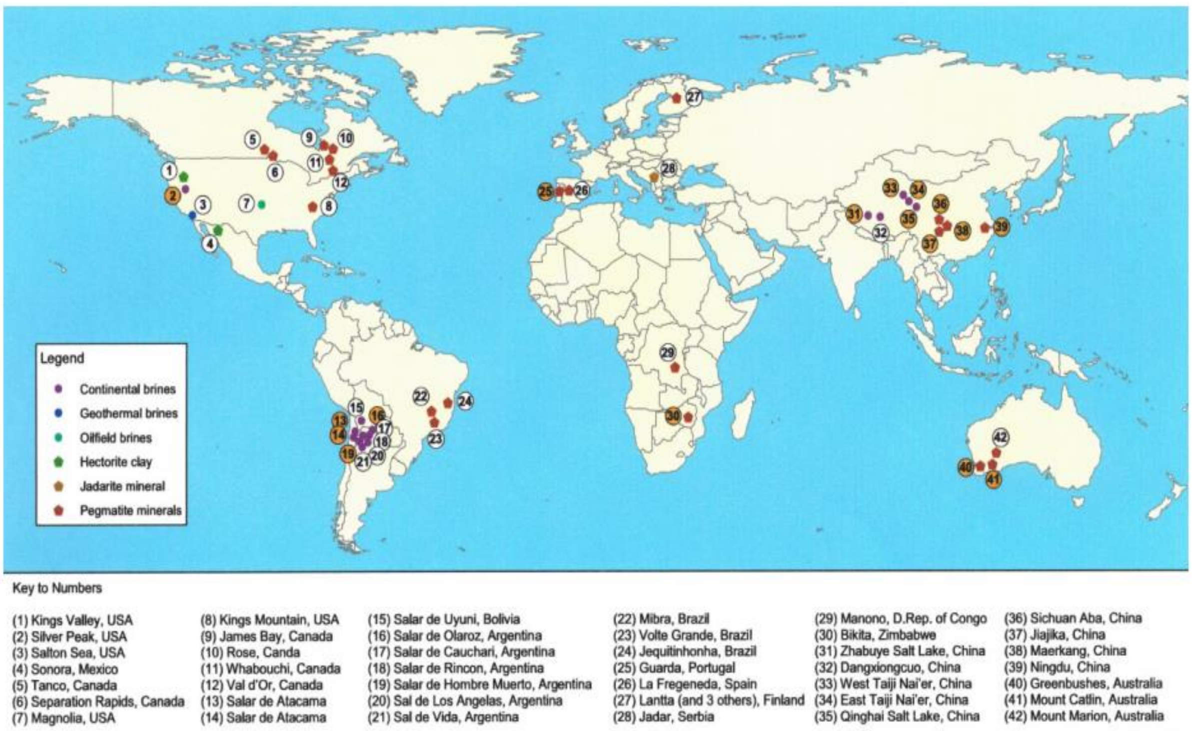

Figure 13. Distribution of the major lithium mineral deposits in the world [44,50].

According to Goldman Sachs, the battery used in the Tesla Model S car uses enough lithium to produce batteries for more than 10,000 smartphones [51].

In addition, the Taliban's takeover of Afghanistan, and thus the largest lithium deposit in the world, also means an increase in the cost of lithium-ion batteries. Analysts estimate that by 2040, the demand for lithium will increase 40 times, which means an increase in lithium prices and, consequently, an increase in the prices of electric vehicles (EVs) [45].

However, providing lithium for the production of lithium-ion batteries is not everything. Another element that is necessary for battery production is cobalt. For example, an

85 KWh battery is built using 8 kg of cobalt. The Bloomberg Intelligence report indicated that the current level of growth in sales of electric cars will increase the demand for this element by 9300% by 2040. According to preliminary data published by the US Geological Survey, in 2021, global cobalt production reached an all-time high thanks to electric car manufacturers. It is worth noting that about half of the cobalt used in the world comes from Katanga, where minors, among others, are employed to extract it—minors, including even seven-year-old children. In turn, in the Congo, about 35–40 thousand children work in its extraction. In the Democratic Republic of the Congo (DRC), which extracts almost 70% of the world's cobalt production used in lithium-ion batteries used in mobile phones, laptops and electric cars, adults and children mine cobalt with their bare hands, earning a dollar a day [52].

It is not widely known that in addition to lithium, rare earth metals, such as dysprosium, lanthanum, neodymium and praseodymium, are needed for the production of electric cars. The world leader in the extraction and production of these metals is the People's Republic of China [53]. Do European Union officials want to make us dependent on the Chinese economy?

Electric cars have been successfully sold for 10 years, and their life cycle is defined as a maximum of 20 years. These simple calculations show that even before 2030, electric cars will appear at scrapping points. However, there is currently no market for recycling lithium-ion batteries. Although there are no reliable calculations of scraping costs, processing techniques have not been developed so far, and it is not known what damage it will entail to the environment [53].

Although manufacturers of cars with combustion engines can guarantee buyers that these cars can reach a mileage of 300–400,000 km, producers of electric cars cannot guarantee the long-term operation of cars without a complete replacement of all batteries. What is more, current users of electric cars report that the range of their car depends very much on the temperature outside. The lower the temperature, the shorter the range of the car. If someone else would like to connect a trailer to their electricity car to transport something, then the range drops drastically. In addition, it is well known that the capacity of rechargeable batteries decreases with time.

The media is increasingly reporting on electric car fires. This is due to several reasons. First of all, these are new cars, so interest in them is very high. Second, there are more and more electric cars and hybrids every year, and each of these accidents causes a sensation, so there are more and more statistically similar accidents. At the same time, the risk of fire is much higher in the case of internal combustion engines than in electric cars. However, extinguishing a fire in an electric car involves much greater involvement of extinguishing agents and a much longer time of extinguishing operations. Most importantly, in an extinguished electric car, self-ignition can occur, which is initiated by the battery, in which the cells are still smouldering [54].

The factor that causes ignition is lithium or, more precisely, a gas that is released when the liquid (battery electrolyte) reacts with lithium. The problem with extinguishing it is that the batteries are sealed in housings so that no external medium enters the battery or flows out from inside the battery. For this reason, during an electric car firefighting operation, the main goal is to cool it down, which requires huge amounts of water. In some countries, special extinguishing containers are used during the firefighting operation of electric or hybrid vehicles (Figure 14) [55].

Of course, there is always a solution to this. So, Renault has patented a solution called Fireman Access: a special cover is built into the top cover of the battery, which melts under the influence of heat (e.g., flames) and reveals the inside of the battery. Due to this, during the firefighting operation, firefighters direct a stream of water through the side window directly to the cells. This action lasts five minutes [55].

Figure 14. A container for extinguishing electric vehicles, manufactured by Ekombud, belonging to JRG-5 Kraków [55].

There is also a new solution from Rosenbauer Polska Sp. z o.o. (Palmiry, Poland), in which a special nozzle is hammered into the accumulator (Figure 15). Then, through the nozzle, water is supplied to the accumulator, which fills its entire interior, cooling the accumulator [56].

Figure 15. Li-ion battery extinguishing system in Rosenbauer electric cars [56].

There is no getting away from the question of what to do with used lithium-ion batteries. Since the demand for them will increase in the near future in an almost exponential progress, the number of batteries used will also increase. One of the methods of managing this waste is the possibility of recovering the lithium and cobalt contained in the electrode powder of used lithium-ion batteries [57]. Unfortunately, this method is acid leaching with nitric, hydrochloric, phosphoric or sulphuric acids, which, depending on the reducer used, allows the recovery of 100–95% Li and 99–54% Co. Again, it has little to do with ecology. Of course, all the problems that arise from the use of these inorganic acids have prompted scientists to replace them in the leaching process with organic acids. However, work on the broad implementation of these changes is still ongoing.

It is also the question of the job market. The challenge will be to retrain the employees. The new automotive industry does not need fewer people, but new skills. We need people who can no longer handle cylinders, but can handle batteries and IT. The battery industry alone needs 800,000 people in Europe. Yes, we need all employees. We already have a skills shortage. I cannot accept that we only want to solve this with immigration. First of all, our people in Europe should get a new education, including those who are already 50 or 55 years old. I come from a coal region. When the pits where my grandfathers worked were closed, no thought was given to what people can do now. It was humiliating not to have any alternatives. Today, we have the ability to keep people in the industry. We must never repeat the mistake we made with solar cells. They were invented in Germany and adopted by the Chinese. We must shape and develop our industry with values and knowledge. We thought too long that we could do it only with combustion engines. We are now seeing e-mobility switching across the world. If we miss this development, then we lose our leadership role [14].

The last aspect related to the use of batteries in electric cars much larger than in cars with a classic drive is the increase in the weight of "electric cars" by about 300 ÷ 700 kg (in the electric SUV, Audi e-tron Sportback, the battery pack is up to 700 kg, while the battery of the Tesla Roadster 2 is about 0.8 ÷ 1.2 tons, depending on the source of information [58]). Scientists have detected particles of polymers and other materials, including metals and other materials derived from car tires, in the bodies of fish [59,60]. In cars with increased weight, the phenomenon of tire wear as a result of friction with the road surface will be even more intense. This will result in an increase in the emission of particles into the natural environment. These particles that enter the bodies of fish will be consumed by humans.

Considering the benefits of using hydrogen propulsion in trains, in addition to ecological factors, the possibility of reducing engine operating noise or its almost complete elimination by resigning from a noisy internal combustion engine should also be considered. In general, three different sources of railway noise have been identified [61]:

- engine noise;
- rolling noise;
- aerodynamic noise.

Engine noise is most significant at lower speeds of up to about 30 km/h, eye noise at speeds greater than 30 km/h and aerodynamic noise at speeds greater than 200 km/h.

Analysis of methods to minimise rail noise emission in an urban agglomeration in [62] showed that there is no method that would guarantee a 100% effect. Each method has certain advantages and disadvantages and limited effectiveness.

As can be seen from the quoted facts, for large population centres, e.g., in cities or large agglomerations, the benefits of using hybrid trains are almost imperceptible in this respect.

Perhaps the solution to some of the above-mentioned problems is the common use of FCVs (fuel cell vehicles), such as passenger cars and buses [15,16,63].

7. Economical Aspects

The financial world seems to confirm the future immense role of hydrogen; it is expected that it is the technology of the 21st century, and there is no way around it if the energy supply is to become climate neutral by 2050, one of the driving forces could be hydrogen.

The market has been awash with hydrogen stocks for the past time. Meanwhile, the hype surrounding many stocks has died down, and the wheat has been separated from the chaff. As a result, many hydrogen stocks have recently fallen sharply. That is exactly what now offers to the investors "THE" opportunity to invest in this lucrative sector. Because right now (2023), the courses offer interesting entry levels, and even more profit can be achieved. Despite the natural corrections on the share markets, the information for the entire hydrogen sector is excellent, because it is to be expected that ahead of us lies a historical megatrend that is just in its infancy. The potential is enormous because the entire industry will continue to grow strongly in the coming years and decades.

The sector is also receiving a powerful boost from politics. The national hydrogen strategy was already adopted under Angela Merkel's government. The current government is also massively investing in green energy sources and investing billions with the aim of establishing Germany as the global market leader in the field of hydrogen in the long term.

Further, according to politicians, it seems to be very clear: „Für uns ist klarer denn je: Die Zukunft gehört Windkraft, Solarenergie, und grünem Wasserstoff." (For us it is clearer than ever: the future belongs to wind power, solar energy, and green hydrogen)—Federal Chancellor Olaf Scholz [64].

If you can trust the forecasts of various experts, hydrogen is one of the next big boom sections in this world. According to the market research company QYResearch, the global sales volume in the industry is expected to increase eightfold over the next four years. The industry currently has sales of around USD 5 billion. According to market researchers, by 2026, sales should be around USD 40 billion. There is support from the Association of German Machine and Plant Builders. This assumes that in Europe alone in the field of car fuel cell components, sales of eleven billion euros could be possible by 2040. Not entirely unimportant: according to the VDMA, almost 70,000 new jobs could be created in Germany alone.

If investing directly in hydrogen shares is too risky for you, so-called ETFs are available. With these, investors can benefit from the performance of specially created hydrogen indices. The L&G Hydrogen Economy UCITS ETF has been a pure hydrogen share ETF since February 2021. This replicates the performance of the Solactive Hydrogen Economy Index. This hydrogen share ETF includes securities from Ballard Power, Daimler, Linde, Plug Power, Powercell Sweden and Weichai, among others. As an alternative to a pure hydrogen share ETF, there are also some alternative ETFs. These include, for example, ETFs for the Hydrogen Strategy Index, the World Hydrogen Index or the E-Mobility Hydrogen Index [65].

Finally, it is worth dealing with the crowning argument of part of the human population that human activity affects climate change in the world, especially those changes that we have observed over the last half century all over the world, e.g., the increase in average temperatures in Europe. A hundred years ago, the Serbian scientist Milutin Milankovitch hypothesised and then proved that the Earth's climate is influenced by the three most important cyclical factors [66]:

- the shape of the Earth's orbit, especially its eccentricity, because the Earth's orbit around the Sun does not follow a perfect circle;
- angle of inclination of the Earth's axis relative to the plane of the Earth's orbit around the sun;
- the change in the angle of inclination of the axis of rotation in which the Earth's axis is pointing is known as precession.

Milanković analysed and studied how variations in these three types of Earth's orbital motions affect the amount of solar radiation that reaches Earth's upper atmosphere. It turned out that cyclical orbital movements cause fluctuations of up to 25% of the amount of insolation on the Earth between $30 \div 60^{\circ}$ south and north latitude [67].

In addition, it is a scientific fact that the sun has the greatest impact on changes in the Earth's climate and, specifically, its activity in the so-called sun's corona. In the article "Climate and man", Professor Wolański states that even the complete cessation of CO_2 emissions into the atmosphere generated by humans will not affect the climate change on Earth. Of course, Professor Wolański states what most people agree with, namely, that care should be taken to protect the natural environment.

Many of the arguments used by uncritical supporters of electric cars are the so-called greenwashing. Let us remind you that greenwashing is "the act or practise of making a product, policy, activity, etc. appear to be more environmentally friendly or less environmentally damaging than it really is" [67] or "behavior or activities that make people believe that a company is doing more to protect the environment than it really is" [68]. In the case of electric cars, we deal with it when:

- ◦ companies provide incorrect information about the features relating to its environmental impact [69]—lithium-ion batteries (acquisition of lithium related to environmental degradation—open-cast mining);
- ◦ companies distort the actual impact of the product on the environment [70]—the ecological aspect is emphasised (electric cars do not emit exhaust fumes), but they do not mention that 80% of electricity in the EU is generated from burning fossil fuels, and no one can answer what will be done with used batteries in a few years;
- ◦ companies omit certain information, the disclosure of which could undermine the "ecological" nature of the product (nonecological aspects of the production of lithium-ion batteries, excessive wear of car tyres and releases into the natural environment).

8. Conclusions

The use of electric or hydrogen drives (fuel cell, hydrogen, batteries, electric motor) seems to be an ecological solution only at first glance. However, the results of a detailed and reliable analysis of the system's operation and its production, as well as the entire product life cycle, show that it is not an ecological solution, the operation of which would have a positive impact on the natural environment. According to the authors of this publication, the proposed solutions of alternative (to internal combustion engines) drives are at the stage of "infancy diseases", which automatically excludes them from being used on a mass scale.

The main factors that adversely affect the natural environment include:

1. Huge water consumption for the extraction of lithium from the ore, estimated at about 1890 litres per metric ton.
2. Danger of toxic chemicals entering post-mining excavations and groundwater (lithium mining and extraction).
3. Lithium mining (open-pit mining) can impact the environment, including fish that are human food up to 150 miles downstream.
4. Possible contamination of crops in the lithium mining area.
5. If hydrogen-based transportation should be applied globally, then it should be in the form of hydrogen internal combustion engine vehicles or using fuel cells. Pure hydrogen does not contain carbon; there are no carbon-based pollutants, such as carbon monoxide (CO), carbon dioxide (CO_2) and hydrocarbons (HC), in the exhaust, as well as no problems with batteries.

9. Advantages and Disadvantages of Hydrogen Trains

9.1. Benefits

Hydrogen-powered trains have many features that make them ideal for reducing carbon emissions:

- No emission of substances other than water vapour;
- Hydrogen is plentiful and can be produced from renewable energy;
- Short refuelling times;
- Their potential as a two-mode train, which means that they can run on both electrified and conventional lines;
- Better fuel consumption, more efficient? It is probably about engine efficiency;
- No engine noise or visual pollution;
- There are no disturbances in the entire network due to the lack of infrastructure for electricity transmission.

9.2. Disadvantages

The use of hydrogen fuel cells presents a number of challenges:

- The technology is currently expensive (investments required);
- Most of the energy used in the hydrogen extraction process currently comes from non-renewable sources;
- It requires storage of hydrogen under very high pressure on board (danger?);

- There are few places for refuelling, the need to expand the network;
- The hydrogen installation, which is currently located, for example, in the EMU, limits the number of people who can board the car;
- Currently, hydrogen trains are still dependent on virgin hydrogen and infrastructure.

To replace the current energy carriers with hydrogen, it is necessary to develop a cheap, fast and efficient method of its production [22].

Currently, research and development work on trains powered by hydrogen fuel cells is focused primarily on increasing the capacity (storage capacity) of hydrogen and developing new LTO (lithium-titanium-oxide) batteries with high energy density, the working time of which will be about 15 years. In addition, scientists are focusing on increasing the power density of fuel cells, extending their lifetime and lowering LCCs. An important aspect of the operation of hydrogen-powered trains is the DC/DC converters for fuel cells built using SiC technology. The use of this technology already allows reducing the weight and dimensions of the device and finally reducing energy consumption by 30%, also due to the use of supercapacitors [71].

The very beginning is already done; we will see how this development will be going on. The politician says that we do not need new highways. We need to expand the electricity grid and railway lines to have the right infrastructure for future mobility. There are major challenges with permits. I want to work with the federal government to speed up this. Yet, I do not think it is necessary to expand road networks. Mobility will change massively in the coming years. We will transport more through rivers and railways. We should rather invest massively in the railways. The hit of the Trako 2021. Pesa presented a hydrogen locomotive based on SM42 Figure 16.

Figure 16. The hit of Trako 2021. PESA presented a hydrogen locomotive based on the SM42 [photo by Jaroslaw Konieczny].

The common use of electric cars and the replacement of cars with combustion engines with them would have to be preceded by the preparation, i.e., the construction of a very dense current infrastructure necessary to charge the batteries. Of course, in addition to the charging station, this would require connecting each station to the power line and building new power plants that would continuously generate the electricity needed to power electric cars.

It is also important to answer the question of where and how electric cars will be charged by city dwellers who live in multistorey blocks of flats.

The currently functioning multi-storey car parks in city centres (but also in the vicinity of shopping centres located on the outskirts of cities) are not designed to carry such a mass of cars. The weight of the battery in an electric car is min. 700 kg (and, for example, that in a Tesla Roadster 2 is about 0.8–1.2 tons); then, parking the same number of cars in previously built car parks will result in a construction disaster.

The price of electric cars is so high that most people will not be able to afford a new electric car. Unlike cars with a combustion engine, electric cars that are already 5–6 years old are not interested in buyers, because every potential customer is aware that in a moment, the entire battery pack will have to be replaced, the cost of which is more than half the price of a new car. For example, Tesla Model 3 battery replacement in 2020 was USD 15,800. However, older electrics, such as the 2017–2018 VW e-Golf, will cost USD 23,443 (2021) to replace the battery pack and USD 20,000 for the 2014 Tesla Model S (December 2020) [72].

As reported by the media around the world, electric cars tend to self-ignite, although electric car fires are quite rare; according to statistics, they are only 0.03% of all car fires (1.5% of gas cars or 3.4% of hybrid cars) [73]. However, a car is difficult to extinguish, and the firefighting action may even last several hours (sometimes even more than 20 hours). Furthermore, even these extinguished cars have a tendency to self-ignite again. What will happen when one of them starts to burn in an underground parking lot full of electric cars? The result will probably be a disaster. The garage will be demolished after such a fire, but with luck, no people will be killed or injured.

Recently, the Norwegian ferry line Havila Kystruten announced that it will not allow electric, hybrid and hydrogen cars on board, although the Havila Capella ferry is equipped with a low-emission hybrid drive consisting of engines powered by LNG (liquefied natural gas), coupled with an electric drive powered by giant batteries weighing 86 tons and with a capacity of 6.1 megawatt hours, which allows for several hours of emission-free cruises. Perhaps concern for the safety of passengers is the reason for this decision [74].

The ban on the entry of electric cars into underground parking is related to the danger and risk of fire. This ban was issued by the administration of the Warszawianka swimming pool and applies not only to electric-powered cars, but also hybrid and gas-powered ones. The decision is conditional on the fact that "the underground garage is located directly under the sports swimming pool basin, and any potential fire caused by self-ignition of the traction battery in an electric or gas-powered vehicle will completely destroy the water supply and treatment system of the swimming pool made of PVC suspended from the ceiling of the garage. Additionally, the high combustion temperature can permanently damage the poles supporting the swimming pool basin and, as a result, suspend the activity of the swimming pool" [75].

Hydrogen-powered cars have the advantage that they do not need a battery, as electric cars do. The problems with obtaining lithium and cobalt (in such an increased amount) mentioned in this publication automatically disappear.

Certainly, replacing cars with internal combustion engines with cars with an electric or hydrogen engine will make the state independent from the supply of crude oil or its derivatives. The electricity needed for electric cars or electrolysis to obtain hydrogen will not come from the combustion of fossil fuels because dependence on fossil fuel suppliers will still remain, and thus, the argument about environmental protection by electric or hydrogen cars loses its raison d'etre.

Another possibility exists in the form of a hydrogen internal combustion engine vehicle (HICEV), which is a type of hydrogen vehicle that uses an internal combustion engine. Hydrogen internal combustion engine vehicles are different from hydrogen fuel cell vehicles (which use electrochemical use of hydrogen rather than combustion). Instead, the hydrogen internal combustion engine is simply a modified version of the traditional gasoline-powered internal combustion engine [11,12]. The absence of carbon means that no CO_2 is produced, eliminating the main greenhouse gas emission of a conventional petroleum engine.

Currently, the efficiency of FCS (Fuel Cell System) hydrogen cars in terms of usable electrical energy is lower (about 50%) than that of the lithium-ion battery (about 90%), although the range of the Hyundai Nexo equipped with 3 hydrogen fuel tanks is 666 km (in the WLTP cycle—Worldwide Harmonised Light vehicles Test Procedure). In addition, hydrogen is simple and much faster than charging electric vehicles. At the same time, FCVs are very safe, even in the event of a car accident—the Hyundai NEXO scored five stars in the Euro NCAP safety test. Of course, replacing cars with combustion engines with FCS cars also requires the construction of infrastructure, but in this case, it is enough to build the appropriate tanks for safe hydrogen storage in existing petrol stations [68].

Thanks to an appropriate economic strategy, the fuel cell (FC) can become a more advantageous alternative for use in cars, trucks and buses (electric cars). The hydrogen fuel cells will play an important role in the transport industry in the near future. In the near future, fuel cell prices should record a downward trend in terms of mass production and their widespread commercialisation [16].

The analysis of available literature data, taking into account all aspects and stages of production of electric cars and their most important components, such as lithium-ion batteries, shows that electric cars are not ecological. Obtaining lithium is associated with the degradation of the natural environment, the use of toxic chemicals that must be disposed of and the very high consumption of drinking water. The extraction of cobalt is often associated with the use of child labour. Finally, people currently do not have any idea how to manage used batteries. Therefore, the most important argument for their use, which is the protection of the natural environment, is a lie. Very often, it results from the ignorance of those who use this argument. Further, the hydrogen drive will be truly ecological if the hydrogen used is not a product of burning fossil fuels.

Author Contributions: Conceptualization, J.K. and K.L; methodology, J.K.; formal analysis, J.K. and K.L.; data curation, J.K. and K.L.; writing—original draft preparation, J.K. and K.L.; writing—review and editing, S.S. and J.M. and J.Ł.; supervision, J.K.; project administration, R.B. and M.G.; funding acquisition, J.K. and K.L. All authors have read and agreed to the published version of the manuscript.

Funding: Publication supported by the Rector's professor's grant. Silesian University of Technology, 12/060/RGP20/0067.

Data Availability Statement: Data available on request.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Wahid, M.R.; Budiman, B.A.; Joelianto, E.; Aziz, M. A Review on Drive Train Technologies for Passenger Electric Vehicles. *Energies* **2021**, *14*, 6742. [CrossRef]
2. Hurtová, I.; Sejkorová, M.; Verner, J.; Šarkan, B. Comparison of electricity and fossil fuel consumption in trolleybuses and bus. In Proceedings of the 17th International Scientific Conference Engineering for Rural Development, Jelgava, Latvia, 23–25 May 2018. [CrossRef]
3. Hata, H. *What Drives Electric Multiple Units? Railway Technology Today 4*; Wako, K., Ed.; Japan Railway & Transport Review 17; EJRCF: Tokyo, Japan, 1998; pp. 40–47.
4. Chinguwaa, S.; Nyembaa, W.R.; Ngondob, E.; Mbohwac, C. Development of an electric drive train for cycles as a sustainablemeans of transportation for a green environment. *Procedia Manuf.* **2019**, *33*, 91–98. [CrossRef]
5. Pornet, C. Electric drives for propulsion system of transport aircraft, Chapter 5 in New application of electric drives. *New Appl. Electr. Drives* **2015**, *9*, 115–141.
6. Favorsky, O.N. *Thermal to Mechanical Energy Conversion: Engines and Requirements*; Encyclopedia of Life Support Systems (EOLSS): Paris, France, 2009; ISBN 978-1-84826-021-4. Available online: http://www.eolss.net/sample-chapters/c08/e3-11.pdf (accessed on 5 April 2023).
7. Mauro, S.; Şener, R.; Gül, M.Z.; Lanzafame, R.; Messina, M.; Brusca, S. Internal combustion engine heat release calculation using single-zone and CFD 3D numerical models. *Int. J. Energy Environ. Eng.* **2018**, *9*, 215–226. [CrossRef]
8. Spitsov, O. Heat Transfer inside Internal Combustion Engine: Modelling and Comparison with Experimental Data. Master's Thesis, Faculty of Technology, Lappeenranta University of Technology, Lappeenranta, Finland, 2013.
9. Johansson, B. Path to High Efficiency Gasoline Engine. In Proceedings of the 2010 Directions in Engine-Efficiency and Emission Research (DEER), Detroit, Michigan, 27–30 September 2010.
10. Hannu Jääskeläinen, Engine Efficiency. Available online: https://dieselnet.com/tech/engine_efficiency.php (accessed on 4 October 2022).
11. Barbir, F. Pem Fuel Cells. In *Theory And Practice*, 2nd ed.; Elsevier Inc.: Amsterdam, The Netherlands, 2013.
12. Malinowski, A.M.; Iwan, G. Paściak, Właściwości elektryczne polimerowych ogniw paliwowych na bazie modyfikowanych elektrolitów. *Przegląd Elektrotechniczny* **2014**, *90*, 73–76.
13. Odenweller, A.; Ueckerdt, F.; Nemet, G.F.; Jensterle, M.; Luderer, G. Probabilistic feasibility space of scaling up green hydrogen supply. *Nat. Energy* **2022**, *7*, 854–865. [CrossRef]

14. Available online: https://www.ndr.de/der_ndr/presse/mitteilungen/Franzoesischer-Wirtschaftsminister-verbittet-sich-Kritik-an-franzoesischer-Atompolitik,pressemeldungndr23834.html (accessed on 5 April 2023).
15. Fan, L.; Tu, Z.; Chan, S.H. Siew Hwa Chan, Recent development of hydrogen and fuel cell technologies: A review. *Energy Rep.* **2021**, *7*, 8421–8446. [CrossRef]
16. Manoharan, Y.; Hosseini, S.E.; Butler, B.; Alzhahrani, H.; Senior, B.T.F.; Ashuri, T.; Krohn, J. Hydrogen Fuel Cell Vehicles; Current Status and Future Prospect. *Appl. Sci.* **2019**, *9*, 2296. [CrossRef]
17. Ryan, P. O'Hayre, Fuel cells for electrochemical energy conversion. *EPJ Web Conf.* **2017**, *148*, 00013. [CrossRef]
18. Sopena, D. Feve Hydrogen Tram. Presentation on I st Rail Technological Forum for Internationalization, 28 June 2011, Madrid, Spain. Available online: https://www.vialibre-ffe.com/pdf/Tranvia_hidrogeno_Feve.pdf (accessed on 5 April 2023).
19. Khotseng, L. *Fuel Cell Thermodynamics, Chapter in Thermodynamics and Energy Engineering*; IntechOpen: London, UK, 2019. [CrossRef]
20. Available online: https://www.heise.de/hintergrund/Gruener-Wasserstoff-in-der-Energiewende-Fokussierter-Einsatz-unverzichtbar-6193503.html?seite=all (accessed on 5 April 2023).
21. Michael Liebreich, Liebreich Associates, Clean Hydrogen Ladder, Version 4.1, Concept Credit: Adrian Hiel, Energy Cities, 15 August 2021. Available online: https://www.linkedin.com/pulse/clean-hydrogen-ladder-v40-michael-liebreich/ (accessed on 5 April 2023).
22. Wiącek, D. Wodór jako paliwo przyszłości. *Autobusy* **2011**, *10*, 446–452.
23. Kalamaras, C.M.; Efstathiou, A.M. *Hydrogen Production Technologies: Current State and Future Developments*; Hindawi Publishing Corporation: London, UK, 2013. [CrossRef]
24. Kozdra, D. Czy Polska ma Potencjał Wodorowy? Polskie Towarzystwo Studiów nad Przyszłością. Available online: https://ptsp.pl/czy-polska-ma-potencjal-wodorowy/ (accessed on 5 April 2023).
25. Holladay, J.D.; Hu, J.; King, D.L.; Wang, Y. An overview of hydrogen production technologies. *Catal. Today* **2009**, *139*, 244–260. [CrossRef]
26. Markowska, K.; Grudniak, A.M.; Wolska, K.I. Mikrobiologiczne ogniwa paliwowe: Podstawy technologii, jej ograniczenia i potencjalne zastosowania, POST. *Mikrobiol* **2013**, *52*, 29–40.
27. Davis, J.B.; Yarbrough, H.F., Jr. Preliminary experiments on a microbial fuel cell. *Science* **1962**, *137*, 615–616. [CrossRef]
28. Lovley, D.R. Microbial fuel cells: Novel microbial physiologies and engineering approaches. *Curr. Opin. Biotechnol.* **2006**, *17*, 327–332. [CrossRef]
29. Skłodowska, M. Europa chce mieć swoją „zieloną bombę wodorową", Wysokie Napięcie 21 May 2020. Available online: https://wysokienapiecie.pl/29265-czy-tania-zielona-energia-przyblizy-nam-zielony-wodor/ (accessed on 5 April 2023).
30. Available online: https://www.tuev-nord.de (accessed on 5 April 2023).
31. Spiegel, C.S. *Designing and Building Fuel Cells*, 1st ed.; McGraw-Hill: New York, NY, USA, 2007.
32. Rajeshwar, K.; McConnell, R.; Licht, S. *Solar Hydrogen Generation: Toward a Renewable Energy Future*, 1st ed.; Springer: New York, NY, USA, 2008.
33. Muradov, N.Z.; Veziroğlu, T.N. From hydrocarbon to hydrogen-carbon to hydrogen economy. *Int. J. Hydrogen Energy* **2005**, *30*, 225–237. [CrossRef]
34. Gimpel, J.A.; Specht, E.A.; Georgianna, D.R.; Mayfield, S.P. Advances in microalgae engineering and synthetic biology applications for biofuel production. *Curr. Opin. Chem. Biol.* **2013**, *17*, 489–495. [CrossRef]
35. Hemschemeier, A.; Melis, A.; Happ, T. Analytical approaches to photobiological hydrogen production in unicellular green algae. *Photosynth. Res.* **2009**, *102*, 23–540. [CrossRef]
36. Dudek, M.; Dębowski, M.; Grala, A.; Zieliński, M.; Rokicka, M.; Kupczyk, K. Produkcja wodoru w procesach biologicznych prowadzonych przez glony. *Interdyscyplinarne Zagadnienia W Inżynierii I Ochrronie Sr.* **2014**, *4*, 199–211.
37. Kilner, J. Hydrogen Production Methods and its Colours. Available online: https://cicenergigune.com/en/blog/hydrogen-production-methods-colours (accessed on 5 April 2023).
38. Howarth, R.W.; Jacobson, M.Z. How green is blue hydrogen? *Energy Sci. Eng.* **2021**, *9*, 1676–1687. [CrossRef]
39. Szypulski, P. Wodór "Brudniejszy" od Węgla? Alarmujący Raport Naukowców! 17 February 2022. Available online: https://www.auto-swiat.pl/wiadomosci/aktualnosci/wodor-brudniejszy-od-wegla-alarmujacy-raport-naukowcow/fpy3n3h (accessed on 5 April 2023).
40. Burridge, T. All Aboard Britain's First Hydrogen Train. BBC News. Available online: https://www.bbc.com/news/business-48698532 (accessed on 5 April 2023).
41. Ritter, M. Hydrogen for Regio Trains. Available online: https://www.fch.europa.eu/sites/default/files/default_images/8.%20Michael%20Ritter_170515_hydrogen%20for%20regio%20trains_v01%20%28ID%202902215%29.pdf (accessed on 5 April 2023).
42. Dąbrowski, K.M.; Zając, M.; Kozieł, K.A. *Koncepcja Pozyskania Litu ze Złóż wód Termalnych z Wykorzystaniem Technologii Membranowych, Nauka-Technika-Technologia*, 2nd ed.; Seria wydawnicza AGH: Kraków, Poland, 2021; pp. 31–44.
43. Flexer, V.; Baspineiro, C.F.; Galli, C. Lithium recovery from brines: A vital raw material for green energies with a potential environmental impact in its mining and processing. *Sci. Total Environ.* **2018**, *639*, 1188–1204. [CrossRef]
44. Szlugaj, J.; Radwanek-Bąk, B. Lithium sources and their current use. *Gospod. Surowcami Miner.* **2022**, *38*, 61–88.
45. Coburn, K. The True Costs of Lithium Extraction: A Grim Reality for EV Owners. Available online: https://www.industrial-innovation.com/true-costs-lithium-extraction-grim-reality-ev-owners/ (accessed on 23 November 2022).

46. Vertruyen, B.; Eshraghi, N.; Piffet, C.; Bodart, J.; Mahmoud, A.; Boschini, F. Spray-Drying of Electrode Materials for Lithium- and Sodium-Ion Batteries. *Materials* **2018**, *11*, 1076. [CrossRef] [PubMed]
47. Palagonia, M.S.; Brogioli, D.; La Mantia, F. Lithium recovery from diluted brine by means of electrochemical ion exchange in a flow-through-electrodes cell. *Desalination* **2020**, *475*, 114192. [CrossRef]
48. Malinowski, D. Wojna o Ten Metal już Trwa. Jego Ceny Biją Rekordy. Available online: https://www.wnp.pl/hutnictwo/wojna-o-ten-metal-juz-trwa-jego-ceny-bija-rekordy,621755.html (accessed on 9 November 2022).
49. Available online: https://twitter.com/stats_feed/status/1512445210097160195?ref_src=twsrc%5Etfw%7Ctwcamp%5Etweetembed%7Ctwterm%5E1512445210097160195%7Ctwgr%5E9c6df844da3c10467c1df29e5a05f0fa7df57cfa%7Ctwcon%5Es1_&ref_url=https%3A%2F%2Fpulsembed.eu%2Fp2em%2FYqFQGm5LO%2F (accessed on 15 November 2022).
50. Brown, T.; Walters, A.; Idoine, N.; Gunn, G.; Shaw, R.A. Lithium Profile. British Geol. Survey. 2016. Available online: https://www.bgs.ac.uk/news/mineral-profile-lithium/ (accessed on 12 November 2011).
51. Świderek, T. Electric Cars Drive the Price of Lithium. Available online: https://www.obserwatorfinansowy.pl/in-english/business/electric-cars-drive-the-price-of-lithium/ (accessed on 23 November 2022).
52. PolsatNews: Dzieci Wydobywają Kobalt Gołymi Rękami. Zarabiają Dolara Dziennie. 26 December 2020. Available online: https://www.polsatnews.pl/wiadomosc/2020-12-26/dzieci-wydobywaja-kobalt-golymi-rekami-zarabiaja-dolara-dziennie/ (accessed on 5 April 2023).
53. Gdzie Piękna TESLA, a Gdzie Ponura Katanga. Available online: https://mlodytechnik.pl/technika/29278-gdzie-piekna-tesla-a-gdzie-ponura-katanga (accessed on 5 April 2023).
54. Szypulski, P. Pożary aut Elektrycznych: Żeby Powstrzymać Ogień, Potrzeba Tysięcy Litrów Wody! Available online: https://www.auto-swiat.pl/ev/porady/pozary-aut-elektrycznych-jak-czesto-pala-sie-samochody-elektryczne-jak-ugasic-plonacy/t30mw5w (accessed on 24 November 2022).
55. Buliński, F. Pożar Elektryka to Spory Problem. Francuzi Mają Patent, jak go Ugasić w 5 Minut. Available online: https://e.autokult.pl/pozar-elektryka-to-spory-problem-francuzi-maja-patent-jak-go-ugasic-w-5-min,6807673940682369a (accessed on 24 November 2022).
56. Kamiński, M. Jak Ugasić Palące się auto Elektryczne? Nowe Sposoby Gaszenia Akumulatorów. Available online: https://www.auto-swiat.pl/ev/wiadomosci/jak-ugasic-palace-sie-auto-elektryczne-nowe-sposoby-gaszenia-akumulatorow/44x0dh6#slajd-1 (accessed on 24 November 2022).
57. Urbańska, W.; Osial, M. *Możliwości Odzyskiwania litu i Kobaltu Zawartych w Proszku Elektrodowym ze Zużytych Akumulatorów litowo-Jonowych MEtodą Kwaśnego Ługowania–stan Aktualny i Kierunki Rozwoju, Innowacyjna Zielona Gospodarka*; Główny Instytut Górnictwa: Katowice, Poland, 2021; p. 36.
58. Available online: https://elektrowoz.pl/auta/ile-wazy-bateria-tesla-roadster-2-okolo-08-12-tons-and-that'swhy-the-car-accelerates-in-19-seconds-to-60-mph/ (accessed on 5 April 2023).
59. Masset, T.; Ferrari, B.J.D.; Oldham, D.; Dudefoi, W.; Minghetti, M.; Schirmer, K.; Bergmann, A.; Vermeirssen, E.; Breider, F. In Vitro Digestion of Tire Particles in a Fish Model (*Oncorhynchus mykiss*): Solubilization Kinetics of Heavy Metals and Effects of Food Coingestion. *Environ. Sci. Technol.* **2021**, *55*, 15788–15796. [CrossRef]
60. Parker, B.W.; Beckingham, B.A.; Ingram, B.C.; Ballenger, J.C.; Weinstein, J.E.; Sancho, G. Microplastic and Tire Wear Particle Occurrence in Fishes from an Urban Estuary: Influence of Feeding Characteristics on Exposure Risk. *Mar. Pollut. Bull.* **2020**, *160*, 111539. [CrossRef] [PubMed]
61. Clausen, U.; Doll, C.; Franklin, F.J.; Franklin, G.V.; Heinrichmeyer, H.; Kochsiek, J.; Rothengatter, W.; Siebero, N. Graniczenie Hałasu Kolejowego; Dyrekcja Generalna Ds. Polityk Wewnętrznych Unii; PE 2012. Available online: https://www.europarl.europa.eu/RegData/etudes/etudes/join/2012/474533/IPOL-TRAN_ET(2012)474533(SUM01)_PL.pdf (accessed on 5 April 2023).
62. Polak, K. Sposoby minimalizacji emisji hałasu kolejowego w aglomeracji miejskiej. *Autobusy* **2018**, *6*, 221–225.
63. Bethoux, O. Hydrogen Fuel Cell Road Vehicles: State of the Art and Perspectives. *Energies* **2020**, *13*, 5843. [CrossRef]
64. Available online: https://www.aktien.investoren-wissen.de/megatrend-wasserstoff/?af=SEM_I_TD_GAW_OA_Megatrend-Wasserstoff_X-Suche-1&gclid=CjwKCAiA85efBhBbEiwAD7oLQMAJjaYU6N0DcwNjou8-RaBiC94ZMPmRTCl-MEQl4uTKUWGmZLjEixoCGFMQAvD_BwE (accessed on 5 April 2023).
65. Available online: https://www.freiepresse.de/erfahrungen/trading/aktien/wasserstoff/ (accessed on 5 April 2023).
66. Buis, A. Milankovitch (Orbital) Cycles and Their Role in Earth's Climate, 27 February 2020. Available online: https://climate.nasa.gov/news/2948/milankovitch-orbital-cycles-and-their-role-in-earths-climate/ (accessed on 5 April 2023).
67. Campis, C.J. Milankovitch Cycles, Paleoclimatic Change, and Hominin Evolution. *Nat. Educ. Knowl.* **2012**, *4*, 5.
68. Available online: https://dictionary.cambridge.org/dictionary/english/greenwashing (accessed on 5 April 2023).
69. Udrycka, K. Greenwashing. Zielone Pranie Mózgu. Available online: https://magazynpismo.pl/idee/katarzyna-udrycka-greenwashing-zielone-pranie-mozgu/?seo=pw;6.12.2022 (accessed on 23 March 2023).
70. Białas, K. Ekościema" w Marketingu, Czyli Czym jest Greenwashing. Available online: https://kaizenads.pl/marketing/ekosciema-w-marketingu-czyli-czym-jest-greenwashing/30.01.2023 (accessed on 23 March 2023).
71. *Innowacyjne Technologie dla Ekologicznego Transport*; Company Information Brochure Medcom Electrify; MEDCOM: Warszawa, Poland, 2022.
72. Updated: Electric Car Battery Replacement Costs. Available online: https://www.recurrentauto.com/research/costs-ev-battery-replacement (accessed on 26 March 2023).

73. National Transportation Safety Board. *Safety Risks to Emergency Responders from Lithium-Ion Battery Fires in Electric Vehicles*; Safety Report NTSB/SR-20/01; National Transportation Safety Board: Washington, DC, USA, 2020. Available online: https://www.ntsb.gov/safety/safety-studies/Documents/SR2001.pdf (accessed on 5 April 2023).
74. Szypulski, P. Elektrykiem i Hybrydą nie Wjedziesz na Prom? Pierwszy Armator Podjął Decyzję, Auta Świat, 19 January 2023. Available online: https://www.auto-swiat.pl/wiadomosci/aktualnosci/zakaz-wjazdu-autami-elektrycznymi-i-hybrydowymi-na-promy-pierwszy-przewoznik-zakazuje/y0dzqdg (accessed on 5 April 2023).
75. Michałowski, I. Wprowadzono Zakaz Parkowania dla Samochodów Elektrycznych w Garażu Podziemnym, 29 April 2023. Available online: https://legaartis.pl/blog/2023/04/29/wprowadzono-zakaz-parkowania-dla-samochodow-elektrycznych-w-garazu-podziemnym/ (accessed on 5 April 2023).