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The ecological car the foundation of the sustainable development of the modern road transport system

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Abstract. The scientific paper presents in a concrete and elegant manner a comparative study of two existing propulsion sistems on ecological automobiles. It is made by the author with the aim of implementing some concepts in wich technical aspects are presented, carried out through SWOT analyses, wich highlight the qualities of propulsion systems that use hydrogen fuel cells and electric accumulators. In this way, those interested can learn about the advantages offered by these propulsion systems of current automobiles, wich are defined by the source that electrical energy necessary to drive the electric motor (motors) existing in their propulsion systems. Finally, the conclusions in the addressed field are presented.
Keywords: *automobile, fuel cell propulsion, hydrogen, electric propulsion, strenghts, weaknesses, opportunities, threats.*

1. Introduction

Transport is responsable for almost a quarter of greenhouse gas emissions, so it must be decarbonised through a systematic approach. In this sense, it is necessary to switch all transport systems to electromobility, through the use of vehicles with limited or zero emissions, wich are equipped with efficient alternative propulsion systems, for all modes of transport [1]. On a different note, carbon based fuels are becoming more limited in quantity and more expensive every year, the liquid ones being mainly concentrated in the Middle East area, wich at this time is quite unstable from a political point of view. The specialists estimate that these resources are still available to humanity for a maximum of 35-40 years. Other areas, such as Eastern Europe and China, can be defined as areas in transition, in their case the exploitation of oil resources may even be limited to 20 years. For this reason, the ecological, environmentally friendly car that uses green energy for propulsion is high on the agenda of automotive engineers and researchers. Among the solutions, ideas related to the use of hydrogen, an extremely widespread gas in nature and wich does not produce polluting emissions when burned. Hydrogen is also found in the composition of the seas or oceans on Earth, one km^3 of water containing 113,108 tons of hydrogen [2]. In this sense, humanity wil have to find viable and ecological solutions to ensure its travel needs and those necessary for daily living. Fossil fuels will be replaced by alternative ones (e.g. electricity, wind, water, etc). On a global level, ecological vehicles, vehicles powered by renewable energy (hydrogen fuel cells, electric and others) are gaining momentum. Engines that use this type of energy are emerging with small steps, but they are catching up and will be, in addition to other types of ecological propulsions, the alternative for the propulsion of automobiles in the future, thus ensuring the sustainable and sustainable development of modern transport systems.

2. Presentation of the car with hydrogen fuel cells

The hydrogen can be used in two ways to propel vehicles:

a) in conventional engines (internal combustion engines);
b) in fuel cells.

To be used as fuel in the engines of high-powered vehicles, hydrogen must meet two conditions:

- to have a level of maneuverability equivalent to that of the fuels used for conventional car propulsion;
- have a range and safety similar to theirs.

Research into the use of hydrogen as a fuel was also done by the famous german inventor of the internal combustion engine, Nikolaus Augustus Otto, who used a synthetic fuel containing 50% hydrogen in this engine. When the carburateur was invented, wich marked the decline of the use of alternative fuels, including hydrogen.

After Augustus Otto's death, all the research he had done up to that date was taken over and continued by the German engineer Wilhelm Maybach. Then German engineer Rudolf Erren also did research and made innovations, patenting the engine that burned hydrogen in its cylinders in the UK in 1930. Research also continued in the USA in 1939, where Erren anticipated that hydrogen could eventually be used to power cars and submarines.

After this period, research into the use of hydrogen as a fuel stagnates for over 30 years. In the 1970s, Ricardo, Broustell and Erren made further attempts to adapt the spark ignition engine to hydrogen operation. Knowledge at that time was sufficient to clarify almost entirely the various aspects of using hydrogen as a fuel, with some reservations about storage and distribution.

The most efficient way to use hydrogen as a fuel is by using it in fuel cells. This is the way to achieve maximum efficiency and effectiveness. In this case, through oxidation-reduction reactions at the anode and cathode respectively, hydrogen is converted into electricity, which powers the electric propulsion engines of cars, and only water is left in the exhaust. The efficiency of hydrogen fuel cells decreases only after 250,000 km of driving, when it is necessary and appropriate to replace it. A fuel cell is more expensive than an electric battery. This means that where there is state of the art technology, there will also be a price to pay for a new car powered by hydrogen converted to electricity via fuel cells.

3. Presentation of the electrically powered car

The electric car first appeared in the world in the late 1800s. By the early 1900s it held sovereignty. On the American continent at that time there were more than four thousand cars, according to research, where less than 30% had electric motors. The smell of gasoline or steam and the vibrations produced by the conventional automobile were unbearable, and mankind was at that time becoming increasingly interested in the alternative opportunities of polluting cars. Another key reason for electric propulsion was the ease of operation of this type of car, since the conventional car was cranked manually and its driveability and manoeuvrability required special attention when changing gears. Cars powered by steam power did not require manual gear changes, but had disadvantages in terms of the long time it took to start them.

Wood's Queen Victoria Electric Car, a model produced in the USA in 1906, was a much more interesting and viable option for the time. Electric car manufacturing reached its peak in 1912, eight years later, with electric car manufacturers achieving fantastic results with them. However, at that time, car technology was quite expensive; as now, not everyone could afford it, and interest in the niche declined. There was then a total abstinence of the public from this type of car.

It was not until the 1960s and 1970s that the electric car became interesting again, after the policies of world environmental organisations (e.g. the Clean Air Act), which called on the world's governments to take action and set standards for air and environmental quality, demanded clear deadlines for the implementation of legislation. All these issues were amplified by the 1973 OPEC oil embargo, which caused oil prices to rise substantially.

Here are two reasons why mankind has had to look for alternatives to transport. In 1976, the US Congress authorised the Department of Energy to support researchers in developing hybrid and electric vehicle technology. Many ideas were put into action, which were subsequently developed and implemented. All over the world, brand manufacturers invest substantial funds to create and develop models, and the major German car manufacturer BMW presents the prototype of an electric car at the Olympic Games in Munich in the summer of 1972.

The 1970s were quite creative in this respect, so many such cars appeared on the market, but they remained unbuilt because they were limited in terms of speed, the range of the electric batteries that powered them and their comfort, which left something to be desired. By 1989, their popularity was at a low ebb, but since 1990, emissions legislation has made a temporary comeback for electric cars. In the US, General Motors produces over a thousand EV1s. The model had a range of 100 miles and was only available for lease to residents of California, Arizona and Georgia.

However, it seems that the public was not too impressed this time either, and when the leases expired, the company decided to scrap the vehicles, keeping only 40 examples that were donated to institutions and museums. However, over the next few years, electric models developed by General Motors, Nissan and Volkswagen were produced in impressive numbers, in the order of millions, and the trend is upwards. Since 2016 they have launched six new electric car models on the market.

Coming back to the present moment, Tesla is proposing new high-tech, reliable and powerful electric motors to be fitted to the "Faraday Future" prototype, as well as electric batteries for propulsion with a high range, which have been put into service as early as 2020. However, even today, in full development, it seems that the stability of the electric car on the market is uncertain. This is due to the multitude of indicators that determine quality in electromobility (range, cost price of electricity, dependence on charging stations, purchase price), each of which acts in its own way and has something to say.

4. Comparative study on the two types of propulsion

International bodies and institutions are constantly calling on transport organisations and car manufacturers to take all measures to reduce pollutant emissions and to use zero emission vehicles (ZEV). In this direction, in order to highlight the advantages and disadvantages of a propulsion system with a conventional engine (thermal engine), compared to those of a hybrid propulsion system, we propose in the following to carry out a SWOT analysis in order to present their strengths, weaknesses, opportunities and threats. These analyses will show the advantages and disadvantages of the two propulsion systems analysed, as well as the efficiency and effectiveness of one compared to the other.

4.1 SWOT analysis for the hydrogen fuel cell car

In addition to the electric car, the hydrogen fuel cell vehicle is another efficient and clean source of human travel. By using hydrogen as a fuel source in fuel cells, the oxidation-reduction process converts its energy into energy that powers the electric motors that drive this type of car. Hydrogen is a cheap, efficient, clean but dangerous fuel. Sophisticated, sophisticated and therefore expensive technologies are used to store it. Nevertheless, hydrogen is considered to be the energy source that will provide for mankind's future mobility needs. Hydrogen fuel cells can only prove their efficiency if the hydrogen used for combustion is obtained from renewable sources (e.g. electrolysis of water) [3].

Table 1. SWOT analysis of the hydrogen fuel cell vehicle. Strengths (S)

S. Strenghts	**Development/ consolidation proposals**
S_1. They are environmentally friendly - *carbon emissions, solid particles and unburned hydrocarbons are completely eliminated. Only water vapour is released into the atmosphere.*	Use of modern, clean manufacturing technologies; use of environmentally friendly raw materials and manufacturing materials (plastics, light metals, etc.); public information and education.
S_2. Quiet operation - *hydrogen fuel cells and electric motors produce no noise in operation.*	Conduct research to improve the performance of hydrogen fuel cells and electric motors.

S. Strenghts	Development/ consolidation proposals
S_3. Hydrogen fuel cells are maintenance-free - *they have a maximum service life of 250,000 km.*	Increasing the lifetime of fuel cells; informing users with a view to popularisation.
S_4. High reliability - *low failure rate, low number of parts under friction forces.*	Increasing the deadlines/times for carrying out overhauls and technical maintenance and other maintenance work; extending the warranty period.
S_5. Fast hydrogen refuelling at filling stations - *refuels much faster compared to an electric car.*	Increased safety in the use and handling of hydrogen used as fuel; use of ready-charged tanks (containers) and their interchange in the car with unloaded ones; development of the service infrastructure for replacing ready-charged tanks with empty ones in the car; public information and education.
S_6. Hydrogen fuel cells produce constant energy in all seasons - *compared to electric batteries, fuel cells are stable even at low temperatures (their capacity does not drop).*	Research to continuously improve the technical performance of hydrogen fuel cells to increase their lifetime.

Table 2. SWOT analysis of the hydrogen fuel cell vehicle. Weaknesses (W)

W. Weaknesses	Disposal measures
W_1. Hydrogen is a very dangerous fuel, being explosive - *it creates problems in terms of transportation, storage and storage.*	Additional safety and security measures; continuous training of staff, the public and users of vehicles using hydrogen fuel; well-defined, precise and well-developed logistics, well-sealed storage tanks; use of high-precision working tools; appropriate protective equipment for hydrogen handlers; protection of tanks with anti-explosion materials and devices.
W_2. Poor hydrogen refuelling infrastructure - *in some countries the refuelling infrastructure is non-existent.*	Locate and develop hydrogen refuelling/charging infrastructure similar to conventional fuels outside settlements, away from habitable areas.
W_3. High purchase price - *the equipment and sophisticated technology involved are more expensive than electric or hybrid cars.*	European countries' authorities to maintain incentives for the population (eco-bonuses) when purchasing a new hydrogen fuel cell vehicle; lower purchase price.
W_4. They are complex - *they are made up of highly complex technology and systems.*	Simplified diagnosis; simplified maintenance work.
W_5. Higher car weight - *the specific equipment fitted increases the weight of these cars, which has a direct impact on weight and therefore on energy consumption.*	Use of lightweight construction elements (carbon, plastic, aluminium, light alloys).
W_6. Lack of service units - *the existence of service units and specialists is deficient.*	Development of service units dedicated to this type of vehicle, equipping them with specific logistics, training and instruction of service staff.

Table 3. SWOT analysis of the hydrogen fuel cell vehicle. Opportunities (O)

O. Opportunities	Development measures/ fructification
O_1. Global warming - *the release of noxious gases into the atmosphere by conventional vehicles damages the ozone layer.*	Lower the minimum chemical noxious emissions threshold for the pollution standard for cars with internal combustion engines; tighten environmental legislation.

O. Opportunities	Development measures/ fructification
O_2. Technology evolution - *benefit from the latest technological developments.*	Development of new technologies in electromobility, safety, ergonomics and comfort of hydrogen fuel cell powered cars.
O_3. It is the product of research - *substantial funds invested in research.*	Further research into the development of technologies in the field of electromobility, safety, ergonomics and comfort of hydrogen fuel cell cars; allocate the necessary resources to research in this area.
O_4. Environmental legislation - *environmental legislation prohibits the use of polluting vehicles.*	Strengthening environmental protection legislation.
O_5. Zero taxes and charges - *local authorities provide incentives to encourage people to buy this type of car.*	Exemption from paying annual taxes to local authorities; substantial eco-bonuses when buying a new car; free and dedicated parking spaces with refuelling stations on motorways, expressways and national roads.
O_6. They can drive in areas or cities where conventional motor vehicles are banned - they do not pollute the environment.	Prohibiting the entry and circulation of cars with internal combustion engines below a certain pollution standard (e.g. Euro 4) in the central area of large cities or urban metropolises.
O_7. Sustainable development - *ensures the sustainable development of the road transport system.*	Extensive research into the development of hydrogen fuel cell vehicles; public education and information.

Table 4. SWOT analysis of the hydrogen fuel cell vehicle. Threats (T)

T. Threats	Mitigation/ reduction/ countermeasures
T_1. The financial crisis is creating public disinterest in purchasing these vehicles - *high purchase prices compared to conventional and even electric vehicles, low living standards, authorities not granting substantial eco-bonuses.*	GDP growth; increase in living standards and purchasing power of the population; advantageous leu/currency ratio; measures to curb currency growth on the interbank market; development of alternative energies from renewable sources.
T_2. Rising raw material prices - *emergence of new, cheaper propulsion technologies (e.g. electric cars).*	Obtain raw materials at low, advantageous prices.

4.2 SWOT analysis for the electric car

The electrically powered car is now the most efficient and cleanest way of meeting the mobility needs of the population. Electric propulsion has been a long-standing concern of automotive specialists and researchers [4, pp. 81-94].

Two of the basic advantages of electric motors are that they provide maximum torque at all engine speeds and are quiet in operation. However, in the world, the problem of range is far from solved. At the moment, electric cars are only proving their worth in urban environments. In order to be efficient in non-urban environments, the range of electric traction batteries must be developed and extended. Its short range is one of its biggest drawbacks. In the following, a SWOT analysis has been carried out, showing other advantages and disadvantages of the electric car.

Table 5. SWOT analysis of the electrically powered vehicle. Strengths (S)

S. Strengths	Development/ consolidation proposals
S_1. They are environmentally friendly - *zero emissions in terms of noxious emissions into the atmosphere.*	More efficient electric batteries and recharging only from renewable sources; use of modern, clean manufacturing technologies; use of environmentally friendly raw

S. Strengths	Development/ consolidation proposals
	materials and materials; comprehensive information/advertising on electro-mobility.
S_2. Simple power supply - *can also be powered from the mains (if a power supply is purchased).*	Power anywhere, at any charging station.
S_3. Low operating costs - *does not use conventional fuels for propulsion, it is fully electric.*	Infrastructure/ battery development and smart charging.
S_4. High reliability - *low failure rate, low number of parts under friction forces.*	Reduced drop rate; extended warranty period.
S_5. Energy recovery - *electric motors go into generator mode when decelerating or going downhill.*	Increased storage capacity of electric batteries; more powerful and efficient electric motors/ generators.
S_6. Attractive incentives when buying a new car - *the authorities grant eco-bonuses.*	Allocation of dedicated lanes, specified city areas and free parking spaces; maintaining support for the population when purchasing a new electric vehicle and informing/educating them; rental contracts for certain periods with a specified number of km/year included on electric cars or batteries.
S_7. High power - *electric motors produce maximum torque at any speed.*	Improving the technical performance of electric motors.
S_8. Simplified maintenance - *electric motors do not require regular maintenance.*	Development of the network of service units; training of maintenance specialists; continuous training of maintenance specialists.
S_9. They are extremely quiet - *electric motors produce no noise in operation.*	Requires installation of sound generators; public information/ education.
S_{10}. Fast payback - *cheap renewable electricity.*	Informing, stimulating and educating the population; maintaining or lowering the price of electricity.
S_{11}. Simplified transmission - *from a design point of view, eliminates components from the transmission (clutch and clutch operating mechanism).*	Increased battery capacity, power and autonomy; increased power and reduced size of the electric motor.

Table 6. SWOT analysis of the electrically powered vehicle. Weaknesses (W)

W. Weaknesses	Elimination measures
W_1. They have a low driving range on the electric module (480-600 km) - *the electric battery that provides the energy needed for traction is consumed quickly depending on the load, season and the way the vehicle is used (aggressive driving).*	Design and development of cheaper, high capacity, low weight and low size electric batteries; Development and design of dedicated, efficient tyres to increase the range of electric batteries.
W_2. They are dependent on specialised energy supply infrastructure - *in some countries the infrastructure is deficient.*	Placement and development of electricity charging infrastructure in all car parks, on all motorways and European roads; placement and development of power supply infrastructure in block car parks and large shops.

W. Weaknesses	Elimination measures
W_3. Slow charging of batteries - *traction batteries reach full charge capacity within [30 min.-12 hours], depending on the power of the charging station. The long charging time causes syncope in the transport operation.*	Equip all charging points with powerful power stations (over 100 kW; 400-500 Vdc).
W_4. High cost price of traction batteries at replacement - *traction battery made of expensive materials and technologies.*	Lower price per kWh for electric batteries; use of cheaper and higher quality materials in the manufacture of electric batteries; development of new technologies for electric batteries.
W_5. High purchase price - *complex and expensive state-of-the-art electrical technology.*	European countries' authorities to maintain incentives for people to buy an electric car (eco-bonuses); lower prices per kWh for electric batteries.
W_6. Poor infrastructure and service - *the number of power supply stations and service units for carrying out maintenance work in Romania is currently insufficient.*	Allocation by the authorities of the financial funds needed to develop the refuelling infrastructure; gradual transition from traditional refuelling points to electricity refuelling stations; development of service units dedicated to this type of vehicle, equipping them with specific logistics, training and instruction of service staff.
W_7. Low battery capacity at low temperatures - *cold affects the capacity of electric batteries.*	Manufacture of heated battery packs with improved energy storage and charging capacity; avoid vehicle overcharging, hard acceleration and aggressive (sporty) driving.

Table 7. SWOT analysis of the electrically powered vehicle. Opportunities (O)

O. Opportunities	Development measures/ fructification
O_1. Global warming - *the release of noxious gases into the atmosphere by conventional cars has destroyed the ozone layer.*	Not granting (eliminating) financial incentives for conventional motor vehicles.
O_2. Evolution of technology - *benefit from the latest technological developments.*	Development of new technologies in electromobility, safety, ergonomics and comfort of electric cars.
O_3. It is the product of research - *substantial funds invested in research;*	Continue research into electromobility technologies, safety, ergonomics and comfort of electric cars; allocate resources for research in this area.
O_4. Environmental legislation - *environmental legislation prohibits the use of polluting, environmentally unfriendly vehicles*	Strengthening environmental protection legislation.
O_5. Taxes, charges, incentives - *local public authorities provide incentives to encourage people to buy this type of car.*	Exemption from paying annual taxes to local authorities; substantial eco-bonuses on the purchase of a new car; free and dedicated parking spaces with refuelling stations in car parks.
O6. Easy access in urban areas - *no environmental pollution.*	Facilitating traffic in central areas of large cities at the expense of thermal engine vehicles.
O_7. Sustainable development - *ensures the sustainable development of the road transport system.*	Extensive research into the development of electric vehicles; educating and informing the public.

Table 8. SWOT analysis of the electrically powered vehicle. Threats (T)

T. Threats	Mitigation/ reduction/ countermeasures
T_1. Energy crisis - *the rising cost of electricity will make this type of vehicle inefficient.*	Maintaining or lowering the cost price of electricity; developing alternative, renewable energies.
T_2. The financial crisis is creating a disincentive for customers to buy these vehicles - *high purchase price, low living standards, authorities not granting substantial eco-bonuses.*	GDP growth; rising living standards and purchasing power of the population; advantageous leu/currency ratio; measures to curb currency growth on the interbank market.

5. Discussions and interpretations

The SWOT analyses of the two types of propulsion were based on information from the literature, the online environment and the experience of the author, and the comments that follow are personal views as follows:

a) The electric car has a high purchase price. This price is imposed by the technology used. If the authorities of the European countries no longer grant eco-bonuses for country-specific purchase programmes (e.g. in Romania, EUR 10,000 for the Rebate Plus Programme), the price of an electric car will increase by 40-50%, and those who want such vehicles will no longer be able to afford the total purchase price, which has become unattractive (EUR 20,000-35,000) compared to a car with an internal combustion engine. It should be noted that we are talking exclusively about the purchase of a new electric vehicle. The eco-bonus solution is necessary and should be maintained;

b) If the price of electricity rises to 1.95 lei/Kwh, this type of vehicle is no longer efficient and becomes unattractive. In this case, according to some calculations, driving 100 km with an electric vehicle becomes equivalent to driving the same distance with an internal combustion engine vehicle. The situation remains favourable to the electric car consumer as long as the price/kWh remains unchanged;

c) A major problem for electric vehicle owners is the electric battery supply infrastructure, which in some countries is deficient. Also, the low range of existing electric batteries in current electric cars still does not allow them to be driven over long distances (electric cars are only efficient in urban areas). This is also where the time lost at the charging station comes in. For the electric car, work still needs to be done on efficiency, in particular on the ability of batteries to ensure maximum range regardless of internal factors (consumers in the car) or external factors (air temperature, terrain, driving style, etc). A viable solution to this problem is to replace the discharged battery with a charged one. Research carried out by a Chinese electric car manufacturer (Nio Inc. together with the state-owned BAIC - Beijing Automotive Incorporation China) is proposing a technical solution by developing networks (robotic technical stations) to replace electric accumulators. The proposed technical variant can only be applicable in the context where the battery is not part of the car's strength structure and if there is a logistical structure to carry out such actions. They have been accepted only in urban areas, with the possibility of experimentation in the field of electric taxis. This option could also be accepted in Romania, even in extra-urban areas, by developing electric battery replacement stations on motorways, expressways or national roads. For a subscription to a specific company, it would be possible to replace the car's battery in a maximum of 5-7 minutes. This is much less time than charging at an electric station. It is thought that this could be a reasonable solution to the autonomy of electric accumulators, which at the moment are a major problem for electric cars travelling outside the city. But what also needs to be considered is the multitude of brands of electric cars;

d) Then there is the question of maintenance. The skilled repair workforce is, like their market, in training and development. Specialists in electric car repair, at least at national level, are few. This makes skilled labour in the field expensive, leading to high maintenance costs after the warranty expires. Current research shows that some electric vehicle owners in Romania are going across the border to neighbours to repair their electric vehicles (especially Tesla models). This is because the electric car is in its infancy on the sales market and an electromobility specialist is training hard. He trains, acquires the knowledge, expertise and skills needed to diagnose specific complex systems in a few years;

e) It is assumed that local authorities will no longer grant tax rebates. At the moment, in some counties in Romania, taxes and charges are halved or even zero for hybrid vehicles and zero for electric vehicles. These are set at county level by local councils, precisely to encourage people to move towards electro-mobility. If these incentives are no longer granted on the purchase of a new hybrid/electric car, then it will once again become unattractive;

f) Replacing the propulsion battery, if it fails or at the end of its life, is relatively expensive. The price of a traction battery can sometimes exceed the market value of an old electric car. Research has shown that when buying a new battery, the cost price per kWh of battery capacity is € 300 with VAT. A new, large capacity battery can cost over € 2,000 with VAT. Not everyone will be able to afford to replace their car battery.

Of course, the likelihood of all these things happening at once is extremely low. At the moment, in Europe and in our country, from 2015 until now, the electric car is proving its efficiency. It is believed that when the electric car becomes the main player in the national vehicle fleet, it is likely that some of the issues outlined above will be triggered and we will see the imposition of local taxes and charges that will target all electric car owners. Facilities for citizens who love electromobility are now available from the authorities of all European countries. With the evolution of technology in the field of electromobility, the complexity, safety and price of electric cars has increased.

There are other objections to the electric car. These include:

a) the manufacturing technology of electric traction batteries is carried out by processing rare metals (e.g. lithium, which is the most widely used). As the number of electric cars increases, rare metals will run out relatively quickly and again mankind will probably come to a standstill until solutions are found;

b) electricity is produced in some countries from non-environmentally friendly sources, by burning fossil fuels (fuel oil, coal or diesel) in thermal power stations which are major environmental polluters. If the energy needed to power it does not come from renewable sources, then the electric car itself becomes a pollutant.

Fortunately, our country has plenty of hydropower sources due to its relief. There are plains where the wind blows strongly, as well as a small stretch with an opening to the sea. All these are benefits that should be exploited.

As far as the hydrogen-powered car is concerned, the biggest problem with this type of car is still the use of hydrogen as a fuel. Although it is a very common chemical element, hydrogen is not found in the free state, but only in compounds. From these compounds it can be extracted in three ways:

- ✓ from natural gas - by thermochemical method;
- ✓ from biogas obtained by decomposing waste - by thermolysis;
- ✓ from water - by electrolysis.

All three methods are expensive. The whole system for generating electricity in a hydrogen car is extremely expensive and the installation involves certain risks.

Pure hydrogen is known to be particularly dangerous because hydrogen in its gaseous state (molecular hydrogen or dihydrogen) [5] is highly flammable, which is also evident from the relationship:

$$2H_2(g) + O_2(g) \rightarrow 2\ H_2O(l)\ (572\ kJ/2\ mol) = 286\ kJ/mol = 141{,}865\ MJ/kg, \quad (1)$$

where: 286 kJ/mol, represents the energy per mole of combustible material (in the case of molecular hydrogen) i.e. the enthalpy of combustion which has exactly this value [6].

The explosion hazard of hydrogen gas derives from its combination with air (O2) in concentrations of 4 to 74% and chlorine (Cl_2) in concentrations of 5 to 95% [7]. The source of hydrogen ignition in the two concentrations can be initiated by heat or strong sunlight, sparks or other ignition sources, and the spontaneous self-ignition temperature in air is 932º F (500ºC) [8, p. 402]. Therefore, its separation/extraction, transportation and storage methods require impressive logistics and a large amount of fossil fuels to be produced in industrial quantities.

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Taking into account the industrial manufacturing process, 48% of hydrogen worldwide is obtained from natural gas by catalytic reforming [9], 30% from various oil fractions, 18% from coal by gasification [10], [11]. But according to researchers such as [10], the main source of hydrogen remains fossil fuels. The reaction to make hydrogen results in carbon dioxide. This leads to the same situation we see with electric cars: we don't pollute when we use them, but we pollute when we manufacture them. That still leaves 4% of the total hydrogen produced that could be environmentally friendly: the industrial process of manufacturing it by electrolysis of water [12]. Water is plenty. Green hydrogen can also be obtained from renewable energy or biomass [13]. But electricity is needed for electrolysis. If this is not from renewable sources, we are back to the problem of environmental pollution.

5.1 The state of sales of environmentally friendly vehicles in Europe

According to the data presented in figure 1, in October 2023 there is a significant increase for electrically powered vehicles, with a market share of 14.2% compared to 12% in October 2022 (Figure 1) [14].

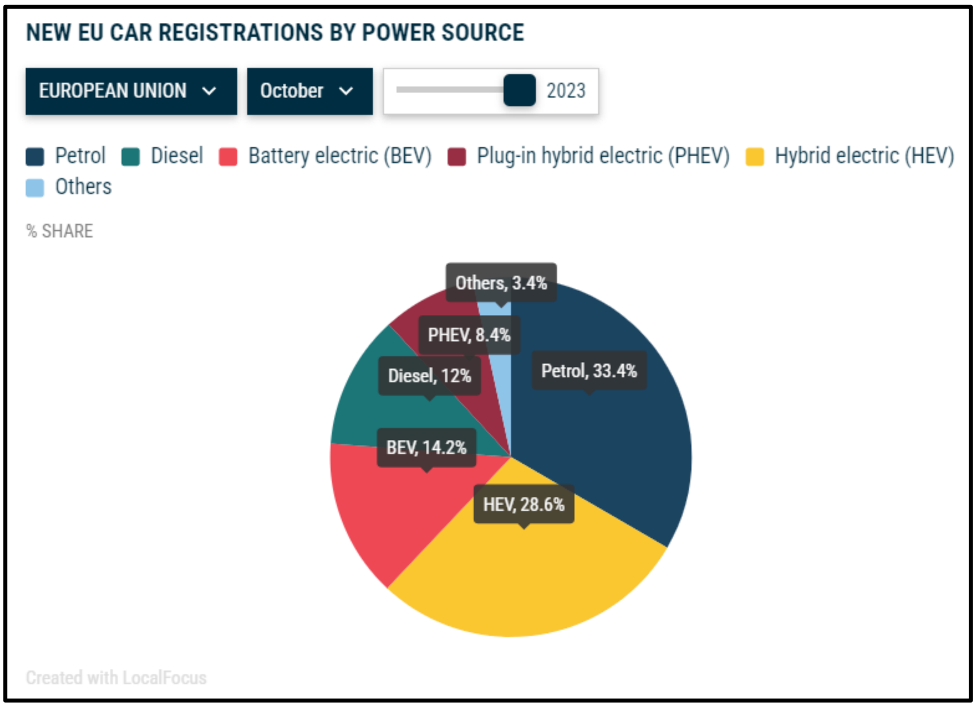

Figure 1. The situation of motor vehicle registration, by power sources on October 31.2023 [14].

The increase exceeds for the first time in the history of car sales for the first nine months of 2023 by 14% the cumulative share of diesel cars. In the Romanian car market, sales increased by 9.9% in October 2023 for electrically powered vehicles. In the first ten months of 2023, the market share of electric cars in Romania increased by +10.6% [14]. As far as the hydrogen fuel cell car is concerned, it seems that things are not so good at European level. The hydrogen fuel cell car can be charged in five minutes and has a range of 650-1.000 km on a full tank, but the expensive, polluting production of this gas, which is considered efficient and clean after consumption, and the energy losses to get to the refuelling site (station) prevent mass production of this type of car. As a fuel for fuel cell vehicles, hydrogen is perceived by vehicle users as a dangerous gas because of its high volatility and flammability, it can cause devastating explosions. In the midst of the transition to electromobility, the green vehicle industry is conducting painstaking research to find an alternative to the battery-electric car. Although major manufacturers such as Toyota, Honda, BMW and others are interested in powering their vehicles with this type of fuel, they are running up against a deficient supply infrastructure, including in European countries with highly developed industries. The fact that hydrogen is not a solution for cars in Europe can be seen from the following conclusion: there are more than 1,000,000 electric cars (including plug-in hybrids and full electric vehicles) on the streets of Germany, where there is a much higher standard of living, a highly developed economy and a cult of clean, expensive, powerful and technologically advanced cars, and only a maximum of 600 hydrogen fuel cell vehicles. A closer look at the data presented in the graph in Figure 1 shows that the hydrogen car is not taken into account in a distinctive way, which shows a lack of interest in this type of propulsion by the European authorities. However, it is possible to interpret the percentage of 3.4% noted with "others" of which these vehicles are considered to be a part as being low.

Dietmar Voggenreiter, lead researcher behind the Horvath & Partners study, said: *"No country that claims to be developing a sustainable economy can afford to consume twice as much renewable energy for a hydrogen-powered car to travel the same distance as a battery-powered car"* [15].

But hydrogen may offer promising prospects in other areas of transport. The researchers behind the Horvath & Partners study believe that investment in hydrogen fuel cells should focus on developing in other areas of transport, such as aviation and shipping, not cars.

Despite these impediments, by this date, the EU has set itself an ambitious programme to equip its infrastructure with 300 dedicated hydrogen refuelling stations suitable for trucks by 2025 and at least 1,000 by 2030. At the same time, the European authorities plan to have every hydrogen refuelling station every 200 km along the European transport network (TEN-T) by 2030. The capacity of a hydrogen refuelling station for trucks will be six tonnes per day for two dispensers per station. The situation of hydrogen refuelling stations in 2030 in Europe is shown in Figure 2.

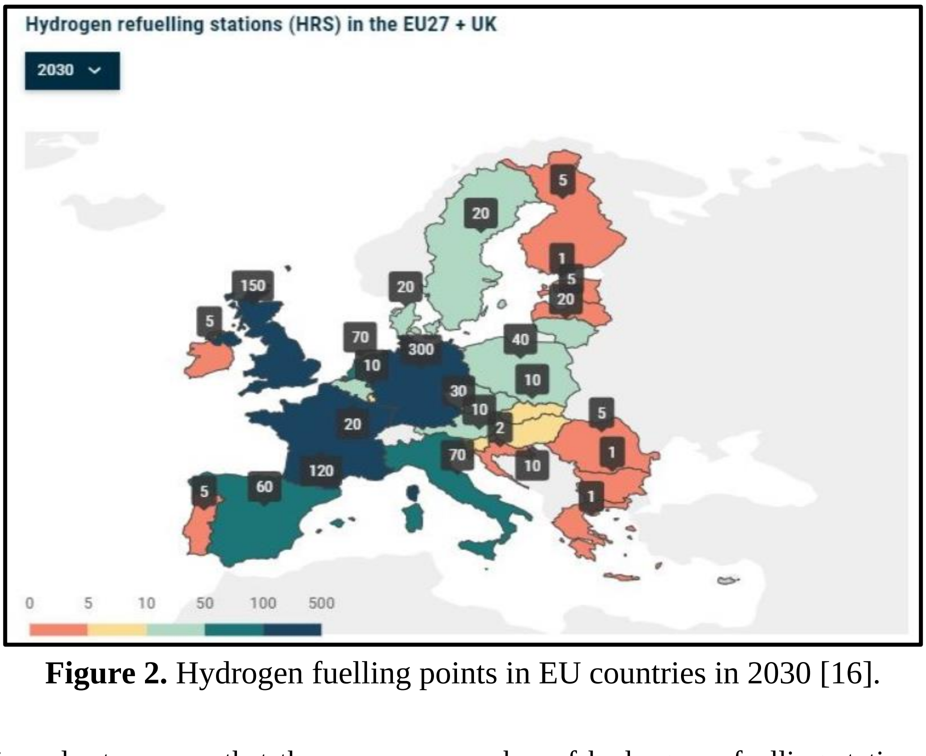

Figure 2. Hydrogen fuelling points in EU countries in 2030 [16].

However, in order to ensure that the necessary number of hydrogen refuelling stations will be available in all EU countries, binding targets should be set for each Member State by 2025 and 2030. Our research shows that action to achieve this is rather weak.

According to the document (ACEA position paper on truck infrastructure requirements), Romania should have two stations by 2025 and five operational hydrogen refuelling stations by 2030.

6. Conclusions

The electric car has the opportunity to grow and is on the rise. This will only happen if technology evolves rapidly and other methods of ensuring human mobility are discovered.

The hybrid, electric or hydrogen fuel cell vehicle, compared to the internal combustion engine vehicle, is currently considered the most viable form of environmentally friendly transport.

Both electric and hydrogen fuel cell cars are only efficient as long as their direct energy source (electricity or hydrogen) is obtained from clean, green, renewable sources.

Due to the low range of the battery that provides the energy needed to power the propulsion system, the electric car is now only efficient in urban environments. This also makes these cars unattractive to the population. There are also electric cars with a longer range (500 - 600 km), which could be more efficient for extra-urban travel, but their cost price is high (€ 50,000 - 60,000). Even if the European authorities offer a substantial eco-bonus (€ 10,000) for the purchase of a new electric car, not everyone will have access to one.

The danger of hydrogen in use (transfer, transport, storage) and the lack of infrastructure for its production and distribution makes the hydrogen fuel cell car unattractive both in Europe and Romania.

I believe that hydrogen will still be the energy source that will meet mankind's mobility needs in the future. The hydrogen fuel cell car will gain the upper hand at the expense of the electric car. I justify this statement with the following: At the moment, the range aspects of electric batteries are slow to evolve, and if factors such as low winter temperatures (significantly reduce the capacity of an electric battery), high-speed driving, sudden accelerations of the car and climbing ramps (rapidly consumes the energy in the battery) are also taken into account, use of the air conditioning system in winter and air conditioning in summer (substantial energy consumption), and finally the physical wear and tear of the electric battery over time (similar to the electric battery in a mobile phone which, due to wear and tear, loses capacity over time) make the electric car unattractive. Added to all this is the dependence on electric charging stations (in our country, few in number, located in the car parks of large shops in urban areas and almost non-existent on motorways, expressways or national roads). I, like any other user, find it easier and more comfortable to fill up my tank with petrol or diesel and cover a 1,000 - 1,200 km route without stress and without worrying about refuelling.

At the moment, the hybrid car provides the greatest comfort in this respect, but it is important to bear in mind that carbon-based fuels will soon run out. Research into the hydrogen fuel cell car will have to be stepped up. Hydrogen safety involves technology, and that costs more than research into developing the autonomy of electric batteries at this time. A hydrogen fuel cell is more reliable, has a longer lifespan, but is more expensive compared to an electric traction battery. The cost prices of raw materials to make electric batteries, such as lithium, cobalt and nickel, and the cost price of electric battery components, have pushed the value of energy packs up to $ 151/kWh. This means a 7% increase in 2022 compared to 2021. Their prices are expected to rise in the years to come (152 USD/kWh in 2023 and so on). The electric car industry claims that the price of 100 USD/kWh for an electric traction battery is the benchmark at which the electric car becomes competitive with the conventional, internal combustion engine car. Since the beginning of 2021, the price of the raw materials from which electric batteries are made have increased enormously (lithium has increased by about tenfold, nickel has increased by more than 74%, and the price of cobalt has doubled since 2020). All these increases are becoming a big problem for the green car market. It is believed that these increases would have been even higher if the Chinese market had not stepped in with cheaper lithium iron phosphate (LFP) battery packs, which have a shorter range. By 2022, the demand for electric car manufacturing energy on the world market has doubled to 603 kWh for Li-ion materials. For this reason, an acute shortage of semiconductors was observed in 2022, and some electric vehicle manufacturers had to reduce their production. The cost price of electric battery packs on the world market varies significantly, so that in China the price is USD 127/kWh, while in the US the price has reached USD 157/kWh and in Europe the price has even reached USD 169/kWh.

In Romania, the electric car is currently making its debut. Soon, its electric batteries will wear out and will have to be replaced. The problem of dismantling (scrapping) them arises, and specialists are thinking and looking for solutions to the problem. Urgent investments will have to be made.

In Romania, it is not possible to develop a hydrogen fueling network for cars because there has been a legislative vacuum since 2008.

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