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Design of a new Hydrogen Fueled Hybrid Car Prototype

Abstract

The proposed project involves a new water-fueled hybrid car prototype that integrates various technologies, including photovoltaic (PV) panels, electrolysis, a fuel cell, a metal hydride tank, and a battery. The car is equipped with PV panels on its surface, such as the roof or hood, which convert solar energy into electricity. This electricity powers a DC motor that propels the vehicle. Excess electricity can be stored in a battery or used in an electrolysis system to split water into hydrogen and oxygen. The hydrogen is stored in a metal hydride tank for later use. Metal hydrides are materials capable of absorbing and releasing hydrogen gas, providing a safe and compact storage solution. The fuel cell converts hydrogen into electricity to power the DC motor when sunlight is not available. This hybrid system allows for direct solar-powered operation while also storing excess energy as hydrogen. Experimental tests were conducted on a prototype of this water-fueled car, with the fuel cell serving as a backup power source to ensure continuous operation even without solar energy. This concept offers several advantages, including the use of renewable solar energy, zero emissions during fuel cell operation, and the ability to store and utilize excess energy.

SECTION 1: INTRODUCTION

The current energy model, which relies heavily on non-renewable energy sources, is both economically and ecologically questionable. It has been the subject of discussions over the past few years. The escalating energy consumption and subsequent increase in pollutant emissions highlight the limitations of this energy model. It is evident that it cannot be sustained in the medium and long term without significant adverse effects on the environment and global development. Within this context, the transport sector, which accounts for a substantial portion of global energy consumption (27% [1]), has been actively exploring clean and sustainable solutions to diversify the energy mix in recent years.

The presence of hybrid, electric-powered and hydrogen-powered vehicles on the market automobile are successful examples of this research. Hydrogen as an energy vector for transport, and enhanced by fuel cells fuel, is increasingly highlighted as a promising solution due to its functional and performance characteristics (yield greater than 50%) and environmental (no emissions of pollutants from the vehicle) [2]. Using hydrogen as a fuel offers several advantages compared to gasoline or diesel: (i) Environmental Benefits, hydrogen is a clean and zero-emission fuel when used in fuel cell vehicles. The only by-product of hydrogen combustion in fuel cells is water vapor, making it an environmentally friendly option. It helps reduce greenhouse gas emissions and air pollutants, contributing to improved air quality and mitigating climate change. (ii) Energy Efficiency, Hydrogen fuel cells are more energy-efficient than internal combustion engines. Fuel cells convert the chemical energy in hydrogen directly into electricity, with higher efficiency compared to the process of converting chemical energy to mechanical energy in combustion engines. This higher efficiency translates into better fuel economy and reduced energy waste.

(iii) Renewable Energy Compatibility, Hydrogen can be produced from a variety of renewable energy sources, such as solar, wind, and hydroelectric power. This makes hydrogen an attractive option for storing and utilizing excess renewable energy generated during low-demand periods. It enables the integration of intermittent renewable energy sources into the energy grid and provides a way to store and utilize renewable energy for transportation. (iv) Fuel Diversity and Energy Security, Hydrogen offers diversification in fuel sources, reducing dependence on fossil fuels. It provides an alternative energy option that can help enhance energy security by reducing reliance on limited oil reserves and geopolitical tensions associated with fossil fuel supply [3-4]. (v) Metal hydrides have emerged as a promising solution for hydrogen storage in cars. These materials possess the ability to absorb and release hydrogen gas, making them ideal candidates for storing and transporting this clean fuel. Metal hydrides offer several advantages, including high hydrogen storage capacity, safety, and stability. They can store hydrogen in a compact and dense form, allowing for increased energy density compared to other storage methods. Additionally, metal hydrides exhibit excellent reversibility, enabling efficient release of hydrogen when needed.

A water-fueled hybrid car is a concept that proposes the use of water as a fuel source in combination with a hybrid propulsion system. However, it's important to note that currently, there is no commercially viable water-powered car available on the market. The concept of water as a fuel source for vehicles is often associated with claims of water-powered cars. Water itself cannot be used as a direct fuel source for combustion engines like gasoline or diesel. However, there are technologies that use water as a source of hydrogen, which can then be used as a fuel in certain types of fuel cells. Water can be electrolyzed to separate hydrogen and oxygen molecules. This process involves passing an electric current through water, causing it to split into hydrogen gas (H_2) and oxygen gas (O_2). The hydrogen gas can be collected and stored for later use as a fuel.

The car can operate in electric mode using the stored energy in the battery or fuel cell, and when additional power is required, the hydrogen fuel can be used from the metal hydride- hydrogen tank.

It's important to mention that the development of a practical and efficient water-fueled hybrid car faces significant challenges. These challenges include the energy-intensive process of hydrogen production, the storage of hydrogen, and the technical complexities of modifying the car to run on multiple power sources.

The idea of an electric vehicle is not new and has a history of more than 100 years. Since more than a decade ago, the searching for developments of Zero-Emission Vehicles (ZEV), Electric Vehicles (EV), and Hybrid Electric Vehicles (HEV) [1-3] has taken a new impulse. These technologies can be observed in the consecutive auto shows around the world in the shape of conceptual designs. An incipient presence in the market is appreciated in the last years, basically with hybrid technology combining two or more energy systems. In accordance with the use of new and clean energy sources, the trend is to supplant internal combustion engines by traction through electric motors, thus solving a problem related with greenhouse gas (GHG) emissions [4,5]. The need to research for achieving practical zero emission in the source and consumption in addition to the challenge of linking the scientific-technological knowledge to the global interests of a sustainable planet, by means of the promotion of the use of alternative energies, makes evident the aim to initially possess an experimental prototype of HEV. In this sense, photovoltaic solar energy plays an essential role in the implementation of clean energies as main electricity source for EVs. A zero-emission solar vehicle is powered by photovoltaic solar energy by means of solar panels, with storage of electric energy in batteries, and the traction is obtained by an electric motor, this is the basic idea [6]. Nevertheless, solar energy for vehicle applications is not an obvious issue because several critical points must be carefully analysed, e.g., a) the efficiency and costs of photovoltaic panels, b) how to maximize the solar radiation, and c) the energy management and control [7].

1.1. Fuel cell electric vehicles: State of the Art

Fuel cell vehicles (FCVs) have the potential to significantly reduce our dependence on foreign oil and lower harmful emissions that contribute to climate change. FCVs run on hydrogen gas rather than gasoline and emit no harmful tailpipe emissions. Several challenges must be overcome for them to be competitive with conventional vehicles, but their potential benefits are substantial.

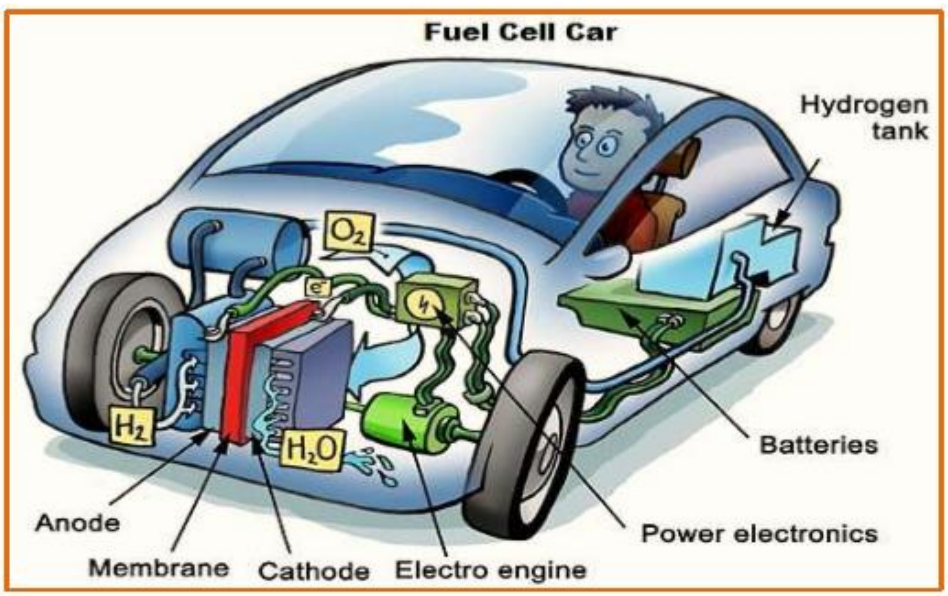


Fig. 1.1. Fuel cell car concept

As electric cars try to forge more than just a niche in the market, the automotive industry is already looking to another form of clean technology that could overtake today's battery powered vehicles. Commitments by automobile manufactures and various government agencies to develop hydrogen fuel-cell cars have surged in recent times. Applications in which these vehicles are involved include personal vehicles, fleet vehicles (for municipal and commercial use), transit buses, short-haul trucks (such as delivery trucks and drayage trucks for port facilities), and others [14]. In the case of light-duty vehicles auto makers like Ford, Hyundai, Daimler and others had already announced plans to build vehicles and prototypes that run on hydrogen. As an example, Ford, Daimler and the Renault-Nissan Alliance sign an agreement to accelerate the development of fuel-cell electric-vehicle technology with a goal of launching the world's first affordable mass-market FCEV.

Fig. 1.2. History of Fuel cell cars

1.2. Solar Car

The solar-powered vehicles, which utilize the sun's energy to run the automobile. A solar car is just like any other 4-wheeler except the powertrain of the former uses sunlight to power the electric motor, unlike in the case of latter, which solely depends on liquid fuel. As such vehicles make use of sun's energy, they are much more clean and mild in terms of emission and are not hazardous to the environment. Such eco-friendly cars are being designed and put into production by several auto giants of the world. Almost all the major auto brands have recognized the need to produce a green car, which not only provides zero emissions but also scores high on mileage scale. However, most of the general public is still unaware as to how a solar car works and what all are the procedures involved in it.

At present there are numerous solar vehicle projects around the world for multiple purposes. From the applied research point of view, interesting contributions have been presented in the last two years, e.g., in [5] a photovoltaic powered zero-emission electric vehicle is presented in the context of an educational project. In [8] a solar and wind powered HEV, with an internal combustion engine was proposed, and initially tested in a commercial product. A hybrid energy system for an EV is proposed in [9], including solar panel, battery and super-capacitor, jointly with the system configuration and control strategy analysis. A project involving battery powered electric vehicles charged by photovoltaic panels is being carried out for agricultural activities in remote hilly areas in the Southern Mediterranean region, with the aim to investigate the cleaner production of power hence reducing the use of diesel fuels in agriculture [10]. On the other hand, solar vehicles are built around the world to participate of different solar races with the aim to test and investigate new technological advancements and its potential application in zero-emission vehicles [11,12].

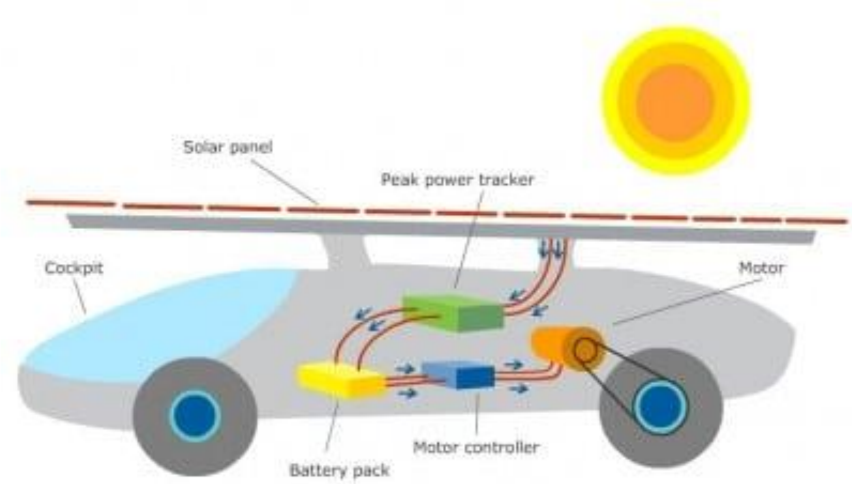


Fig. 1.3. solar car

1. These eco-friendly cars have solar panels mounted on their roof or exterior and these panels help in gathering the sunlight. The basic solar panel is made up of numerous Photovoltaic Cells (PVC), which efficiently transform the solar energy into electric energy.
2. The elements used in the making of PVC are most commonly Silicon, alloys of Nitrogen, Gallium and Indium. All of these elements have the capacity to retain light and then release it in the form of rapidly moving electrons, which help in generating flow of electricity.

3. This electricity is then stored in the batteries of a green car that are made up of special materials, such as lithium-ion, nickel-cadmium and nickel-metal hydride.

All of these elements help the battery in storing more amount of charge then the other conventional battery types.

4. When these eco-friendly cars are accelerated, the PV sends energy to drive the electric motor and in turn help the vehicle move. A solar car has the capacity to generally operate in voltage range of 80 – 170 V and can have a driving range of about 50-100 km.

5. When a green car is parked under sunlight, the PV attract the sun's energy and convert them to electric energy, which is then stored in the battery for further use.

However, most of such cars are not suitable for driving long distances, therefore, these are also being fitted with a standard engine under the hood. This engine comes to play when all the energy is drained from the battery and the driver has a considerable range to cover. While these cars run on the normal engine type, the solar cells help in retaining sunlight and use it to power the electric devices inside, such as radio, power windows and instrument cluster. Such types of clean and green vehicle are much needed in the modern world so as to conserve the pending non-renewable energy resources for future generation.

1.3. Advantages of Hydrogen Energy

<u>1- It’s a renewable energy source and bountiful in supply</u>

Hydrogen is a rich source of energy for many reasons; the main being that it’s bountiful in supply. While it may take a lot of resources to harness it, no other energy source is infinite as hydrogen. That, essentially, means there is no possibility of it running out like other sources of energy.

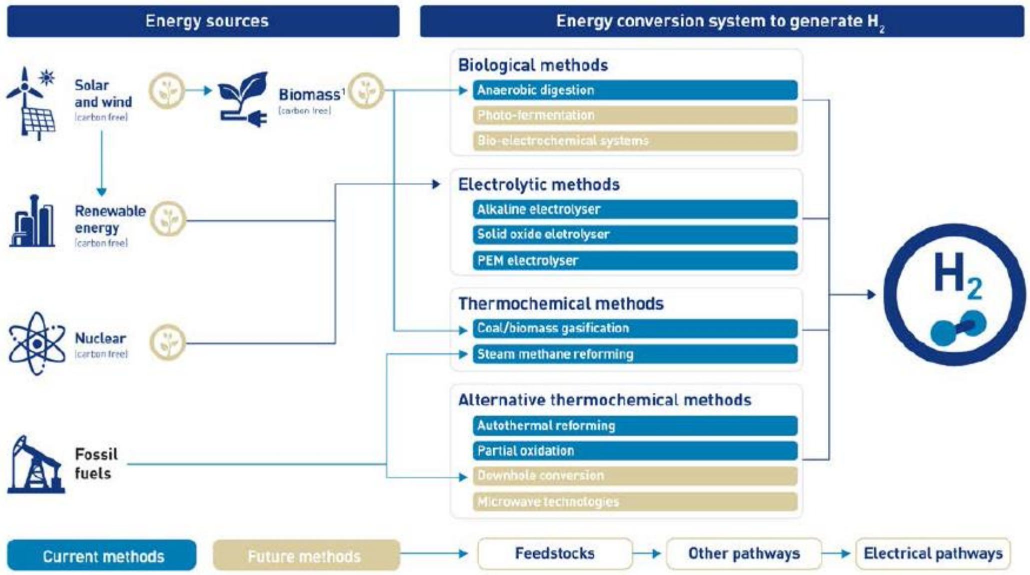


Fig. 1.4. Hydrogen can be 100% carbon-free when produced using renewable energy

2- It practically a clean energy source

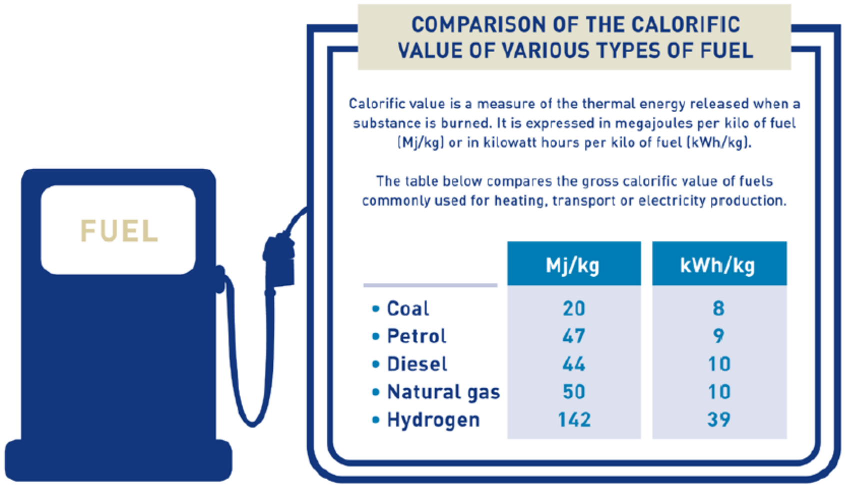
When hydrogen is burnt to produce fuel, the byproducts are totally safe, which means, they have no known side effects. Aeronautical companies actually use hydrogen as a source of drinking water. After hydrogen is utilized, it is normally converted to drinking water for astronauts on ship or space stations.

3- Hydrogen energy is non-toxic

This means that it does not cause any harm or destruction to human health. This aspect makes it preferred compared to other sources of fuel like nuclear energy, natural gas, which are extremely hazardous or daunting to harness safely. It also allows hydrogen to be used in places where other forms of fuel may not be allowed.

4- It's far more efficient than other sources of energy

Hydrogen is solidly efficient energy type since it has the ability to convey a lot of energy for every pound of fuel. This categorically means that an automobile that utilizes hydrogen energy will travel more miles than one with an equal amount of gasoline.



	Mj/kg	kWh/kg
• Coal	20	8
• Petrol	47	9
• Diesel	44	10
• Natural gas	50	10
• Hydrogen	142	39

Fig. 2.5. Comparison of the calorific value of various types of fuel.

Fuel cells can be thought of as alternative energy devices. They convert chemical energy into electrical energy. Hydrogen fuel cells do this very **cleanly**, with no toxic emissions, and very **efficiently**.

Fuel cells do not generate energy out of thin air. They use hydrogen. Hydrogen is an outstanding carrier of energy. Hydrogen is non-toxic, renewable, easily obtained, and packed with energy. When it is combusted with oxygen, it turns into water. This water can again be split into hydrogen and oxygen via electrolysis. The generated hydrogen can be combusted once again, thus undergoing a limitless cycle without toxic emissions. With a fuel cell, you can very efficiently convert hydrogen into electric current without combustion.

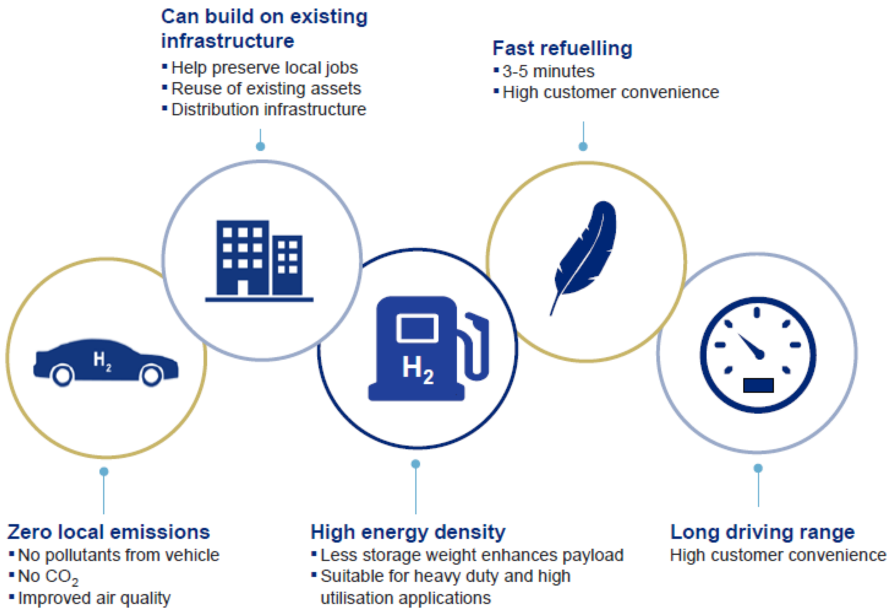


Fig. 1.6. Advantages of Hydrogen Energy

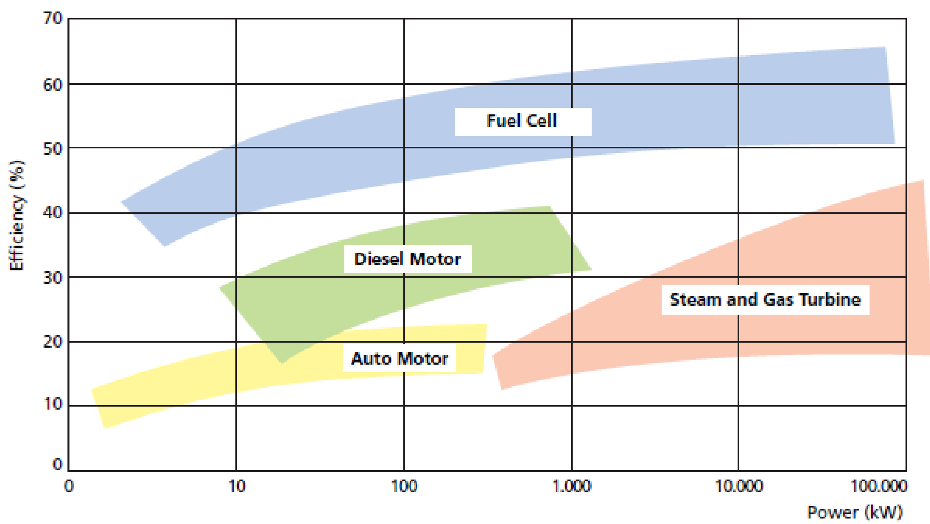


Fig. 1.7. Comparison of the efficiency for various types of energy systems.

SECTION 2: METHODOLOGY

2.1. Design and model development

In this project we have designed and developed a water-fuelled hybrid car prototype by implementing a fuel cell and PV panels as the sources of power to propel the prototype car. It has the capability to propel the electric motor by performing chemical reaction and converting chemical energy stored in hydrogen gas into useful electrical energy. In this fuel cell car prototype, the PEM fuel cell is used as the power source for the electric motor with the aid of a PV solar panels as other power source associated with it. An electrolyzer coupled to the PV array is employed for hydrogen production during excess of power from PV.

2.1.1. Car prototype selection

The first step in developing the product was determining the type of the car. In our case, we have chosen a small car model as our product. The components are: chassis, suspension, drive train, tyres, motors and bearings.

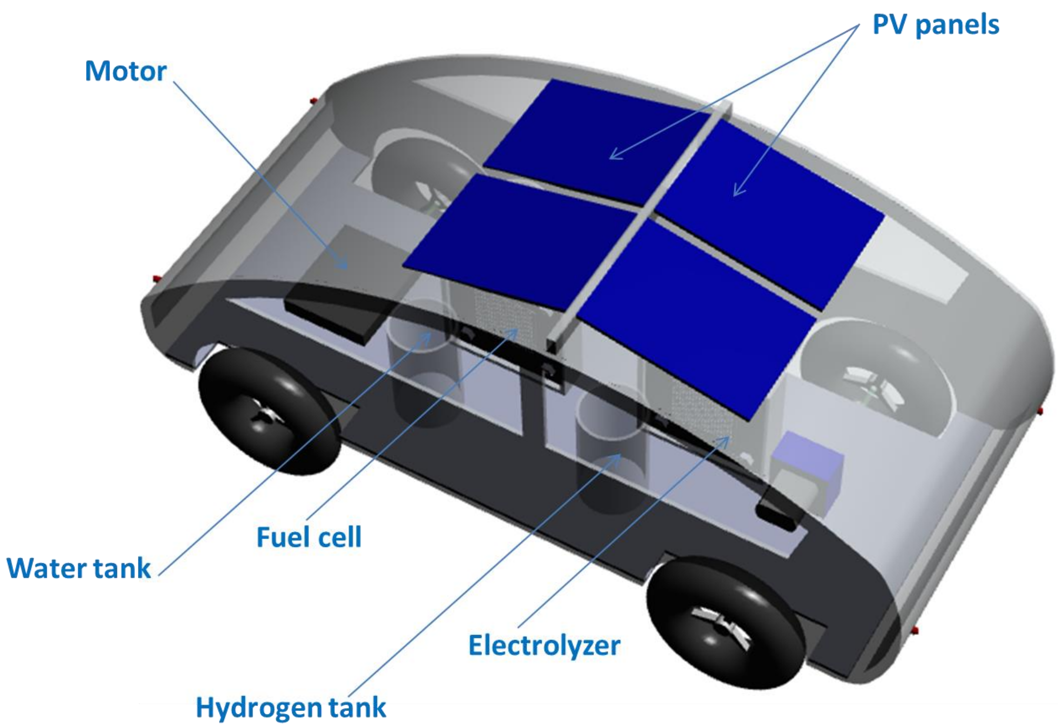


Fig. 2.1. The design of new Water Fueled hybrid car prototype

2.1.2. Electric motor selection

This is an important part in developing the fuel cell car. The electric motors act as an engine of the car substituting the internal combustion engine. There are several motors available in the market. To select the motor best suited for this car, it is important to know the size of the model and amount of cells planned to be used. Size of the vehicle will determine the size of motor needed to push the weight. For motors this is often best represented by the weight of the motor itself. Cell count will determine the winding or more specifically the KV of motor needed. It's also necessary to know the number of teeth for the gearing in the transmission. This will help to determine the exact motor cell count. In this project, the RS-540SH-6527 motor of capacity range 3 volts was chosen because it can propel the car with high speed and also can carry heavy load up to 1 kg.

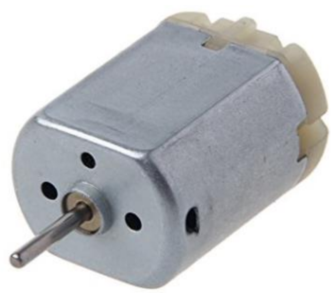


Fig. 2.2. The RS-540SH-6527 motor

2.1.3. Vehicle Dynamics

The electric power train block after all the signal processing generates a tractive force which is fed into the vehicle model block. The tractive force propels the vehicle forward overcoming the resistances it faces. The typical resistances a vehicle faces are rolling resistance, aerodynamic drag and grade resistance. For the analysis of energy consumption purposes, the vehicle may be considered through its longitudinal kinematics and dynamics [12]. The movement of the vehicle is obtained as a result of forces acting on it. Figure 2.3 shows the forces that act on a car while driving on the road.

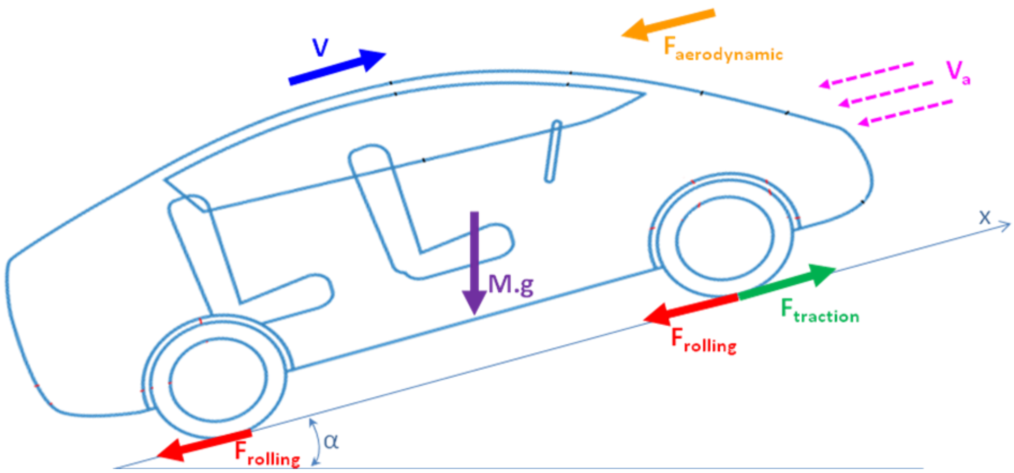


Fig.2.3. Forces Acting on the Car

$F_{traction}$ (t) is the traction force resulted from the torque imposed by the traction train ***$\Gamma_{wheel}(t)$*** through the wheels. Considering that the losses in slippering are negligible, this transformation is represented by the equation 2.1 (***R_{wheel}*** is the wheel radius). In terms of kinematic variables, equation 3.1 shows the transformation of the angular speed of the wheels ***$\omega_{wheel}(t)$*** in linear speed ***v(t)***.

$$F_{traction}(t) = \frac{\Gamma_{wheel}\,(t)}{R_{wheel}} \tag{3.1}$$

$$v(t) = \frac{\omega_{wheel}(t)}{R_{wheel}} \quad (3.2)$$

Performing the balance between traction force and the movement resistance resultant $F_{resistance}$, it is obtained the acceleration of the vehicle via the fundamental principle of dynamics (equation 3.3). Where M is the total mass of the vehicle.

$$\frac{dv}{dt} = \frac{F_{traction} - F_{resistance}}{M} \quad (3.3)$$

The resistive force $\boldsymbol{F_{resistance}}$ is mainly composed of three components (equation 3.4):

aerodynamic resistance $\boldsymbol{F_{aero}}$, rolling resistance $\mathbf{F_{roll}}$ and resistance due to the route profile $\boldsymbol{F_{slope}}$ (slope profile).

$$F_{resistance} = F_{aero} + F_{roll} + F_{slope} \quad (3.4)$$

<u>Aerodynamic resistance</u> $\boldsymbol{F_{aero}}$ It is the force exerted by the wind according to the vehicle axis of movement. It is dependent on air density, front surface S, air penetration coefficient of the vehicle C_x and the sum of the square of the speed of the vehicle v and the relative velocity of the air. The equation 3.5 defines $\boldsymbol{F_{aero}}$.

$$F_{aero} = \frac{1}{2}.\rho_{air}.S.C_x.\left(v + v_{air}\right)^2 \quad (3.5)$$

<u>Rolling resistance</u> $\boldsymbol{F_{roll}}$ It represents the resistant effort due to the contact between the tire and the surface bearings. It is proportional to the mass of the vehicle M, gravitational acceleration g, the rolling resistance coefficient μ and to the slope α Mathematically it is represented by the equation 3.6.

$$F_{roll} = M.g.\mu.cos\,(\alpha) \tag{3.6}$$

Slope profile resistance ***F_{slope}*** Represents the resistive effort to carry out a movement on a surface with inclination (equation 3.7).

$$F_{slope} = M.g.sin\,(\alpha) \tag{3.7}$$

The mathematical representation of the longitudinal dynamics of a vehicle is given by the equation 3.8.

$$\frac{dv}{dt} = \frac{\frac{\Gamma_{wheel}(t)}{R_{wheel}} - \left[\left(\frac{1}{2}.\rho_{air}.S.C_x.\left(v\,(t) + v_{air}\,(t)\right)^2\right) + M.g.\mu.cos\,(\alpha) + M.g.sin\,(\alpha)\right]}{M}$$

(3.8)

2.1.4 Drive train

Composed mainly by electric power train (electric machine) and gear reducer, the drive train provides the torque that will be applied to the wheels $\boldsymbol{\Gamma}_{\text{wheel}}$.

Gear reducer The reducer has the function of adjusting torque and speed of the electric machine to the wheels. Ideally, this element allows a total transmission of power.

However, due to losses such as friction losses, the gear reducer has an efficiency dependent on the turning speed.

Assuming a constant efficiency $\boldsymbol{\eta_{red}}$ and a transformation gain $\boldsymbol{k_{red}}$, the gear reducer is represented by the system of equations 3.9.

$$\begin{cases} \Gamma_{machine}(t) = \frac{\Gamma_{wheel}(t)}{\eta_{red} k_{red}} \\ \\ \Omega_{machine}(t) = \Omega_{wheel}(t)\, k_{red} \end{cases} \tag{3.9}$$

Table 2.1. shown below shows an assumption of the variables for the model of the vehicle.

Parameter	***Value***
Tire Radius, rd	*1.5 cm*
Vehicle Mass, M	*1.1 kg*
Gravitational Acceleration	*9.8 m/s2*
Air Density, δ	*1.29*
Frontal Area, Af	*98* cm^2
Aerodynamic Drag Coefficient, Cd	*0.416*

Table.2.1. Vehicle Parameters

2.1.5. Fuel cell selection

We selected the PEM fuel cell to power the car model for its earlier mentioned advantages. The range of voltage it produces must be equal to or lower than that of the electric motor chosen to make the motor work in optimum performance and also to avoid overheating. If the voltage produced by fuel cell is lower than that needed by the motor, the motor will run slowly and not uniformly.

A fuel cell is device that produces electricity from a chemical reaction. There are many different types of fuel cells that use different chemicals. The fuel cell in this kit converts hydrogen and oxygen into electricity and water, and vice versa. It is called a **reversible PEM fuel cell**. The abbreviation PEM refers to the membrane that separates the oxygen side from the hydrogen side of the cell. The letters PEM stand for **Proton Exchange Membrane**. A thin foil made of a polymer called **Nafion** serves as the membrane in your fuel cell.

Reversible means that all processes can run in both directions. In other words, the cell can operate both as a fuel cell to combine hydrogen and oxygen into water, or as an electrolysis agent to split water into hydrogen and oxygen.

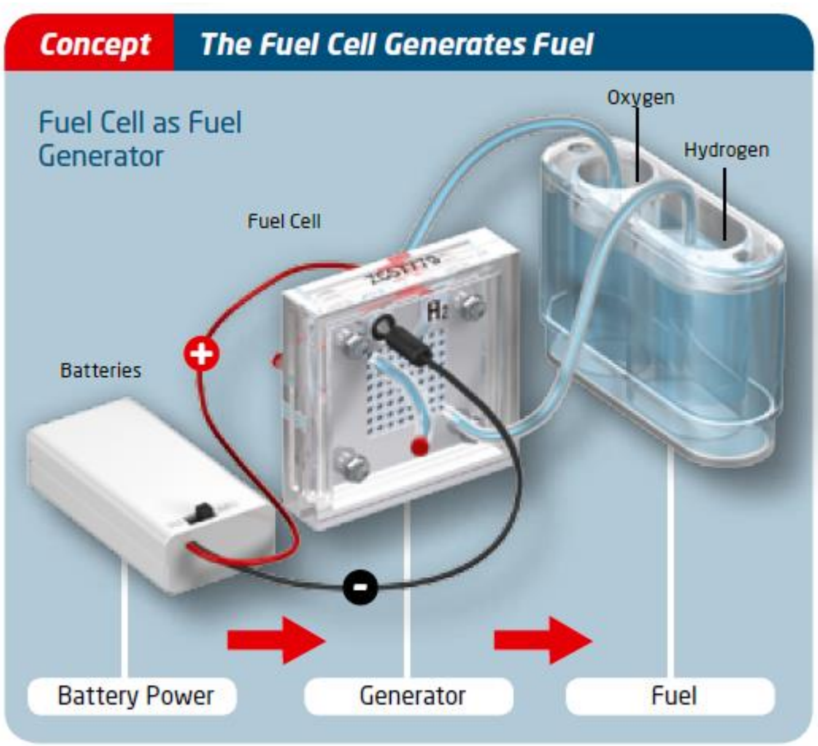


Fig.2.4. The Fuel Cell Generates Fuel

In addition to the PEM, the fuel cell contains two **electrodes** sandwiched together with gaskets in a clear plastic housing and held tightly together with eight bolts.

Electrodes are electrical contact plates. The two electrodes have different names since different things happen on them: the electrode on the hydrogen side is called the **anode**, and the electrode on the oxygen side is called the **cathode**. On the anode, electrically neutral hydrogen molecules (which come from the hydrogen tank) split into **electrons** and **hydrogen ions** with the help of a **catalyst**. A catalyst is a chemical that helps a reaction occur.

The positively charged hydrogen ions migrate through the polymer membrane towards the negatively charged cathode, while the electrons travel through a circuit with an electrical load (for example, the motor) from the anode to the cathode. The hydrogen ions, also known as **protons**, are small enough to pass through the membrane's small holes, but the larger oxygen ions cannot — hence the name Proton Exchange Membrane.

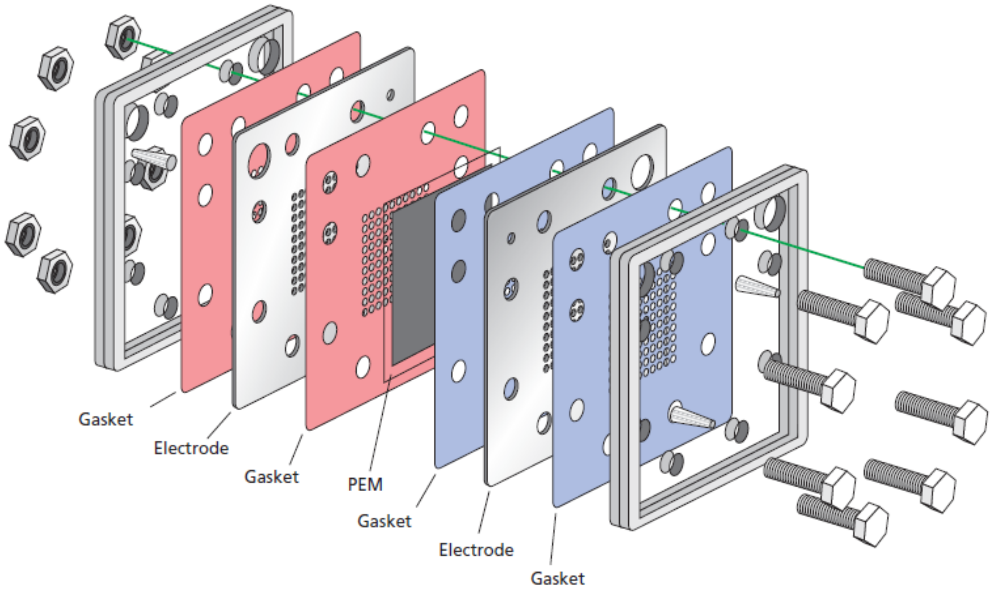


Fig. 2.5. An exploded view of the fuel cell

2.2. General Design

The elements that compose the new design:

1. Car body

2. Motor

3. Electrolyzer

4. Fuel cell system

5. PV panels

6. Hydrogen storage tank

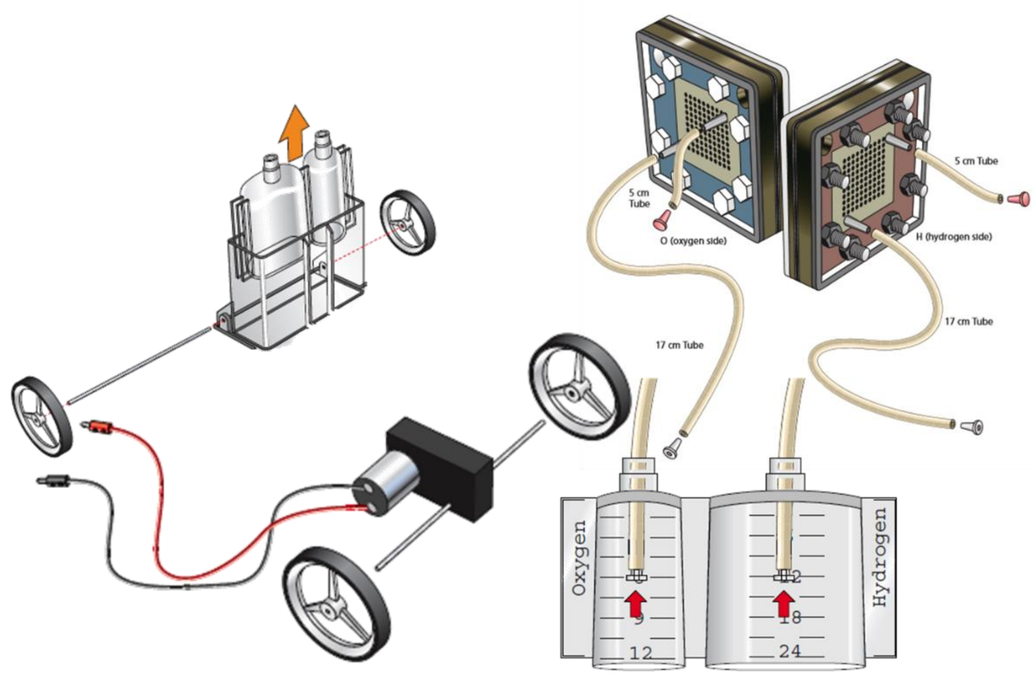


Fig.2.6. The elements that compose the new design.

2.2.1. Connecting solar panels

The solar modules constitute the main electricity source and are responsible for the energy generation used in the vehicle’s operation. The “solar roof” has a rectangular shape (16 x 14 cm), imposed by the solar race rules, and consists of an array of monocrystalline solar cells distributed in 4 solar panels.

There are three basic but very different ways of connecting solar panels together and each connection method is designed for a specific purpose. For example, to produce more output voltage or to produce more current. Solar panels can be wired in a series or parallel combination to increase the voltage or amperage respectively, or they can be wired together in both series and parallel to increase both the voltage and current output producing a higher wattage array.

Connecting Solar Panels in Series: The first method for connecting solar panels together is known as “series wiring “, commonly used to increase the total system voltage. To wire the panels in series, the negative terminal of each panel is connected to the positive terminal, as shown below. Solar panels in series add-up or sum the voltages produced by each individual panel, giving the total output voltage of the array.

Connecting Solar Panels in Parallel: The next method is known as “parallel wiring “, commonly used to increase the total system current (reverse of the series connection). To wire the solar panels in parallel the positive terminals are connected together (positive to positive) and the negative terminals are also connected together (negative to negative), as shown below. The single positive and negative connections are used to attach to a voltage regulator and batteries. In this wiring, the total voltage output remains the same as a single panel, but the end output current is the sum of the output of each panel.

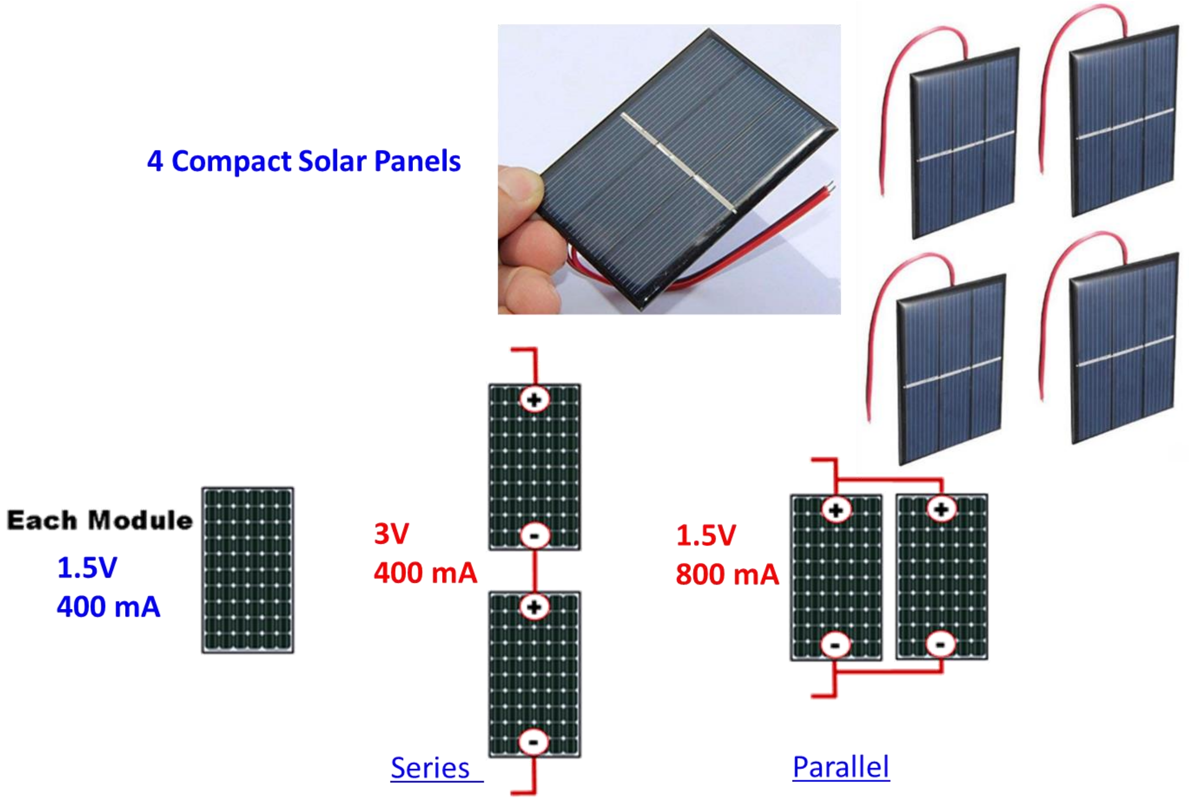


Fig.2.7. Connecting solar panels

2.2.2. Possible hybrid configuration of the PV/fuel cell car

This fuel cell has the capability to propel the electric motor by performing chemical reaction and converting chemical energy stored in hydrogen gas into useful electrical energy. In the developed fuel cell car prototype, the PEM fuel cell is used as the power source for the electric motor with the aid of a PV solar panels as other power source associated with it. An electrolyzer coupled to the PV array is employed for hydrogen production during excess of power from PV.

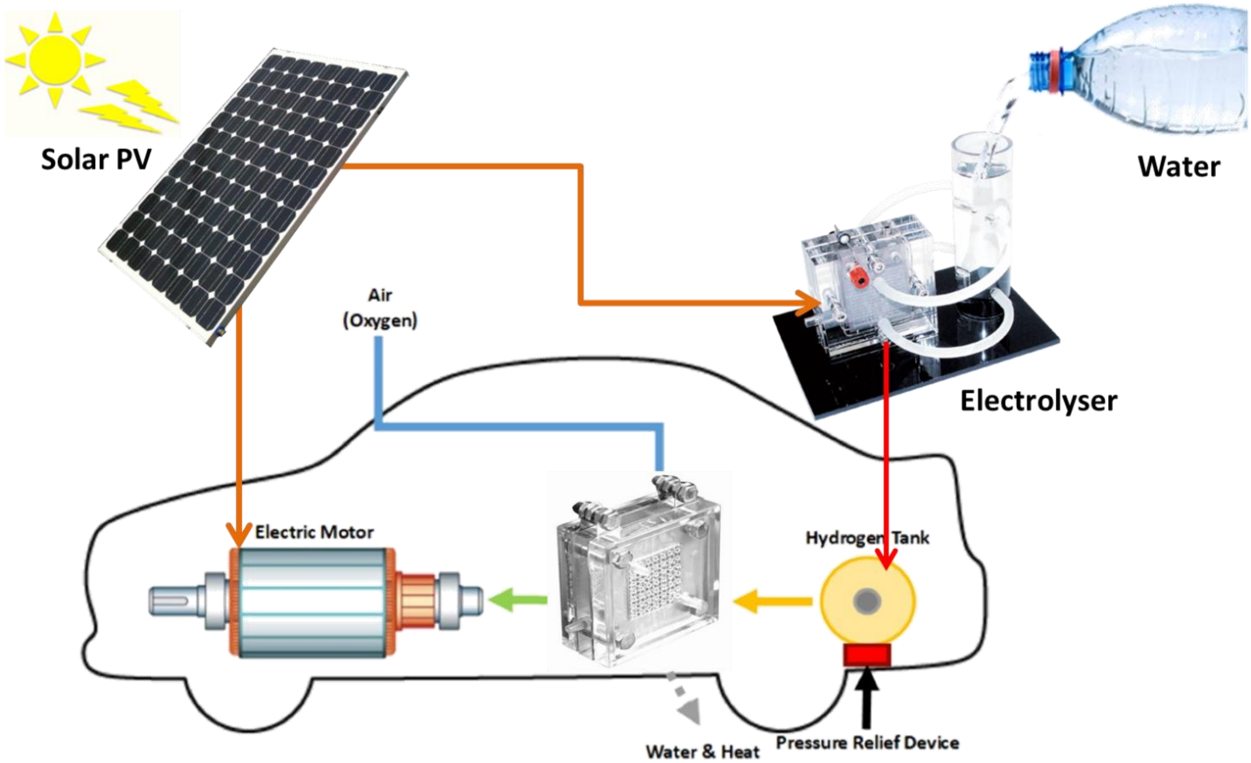


Fig. 2.8. The concept of the fuel cell car prototype

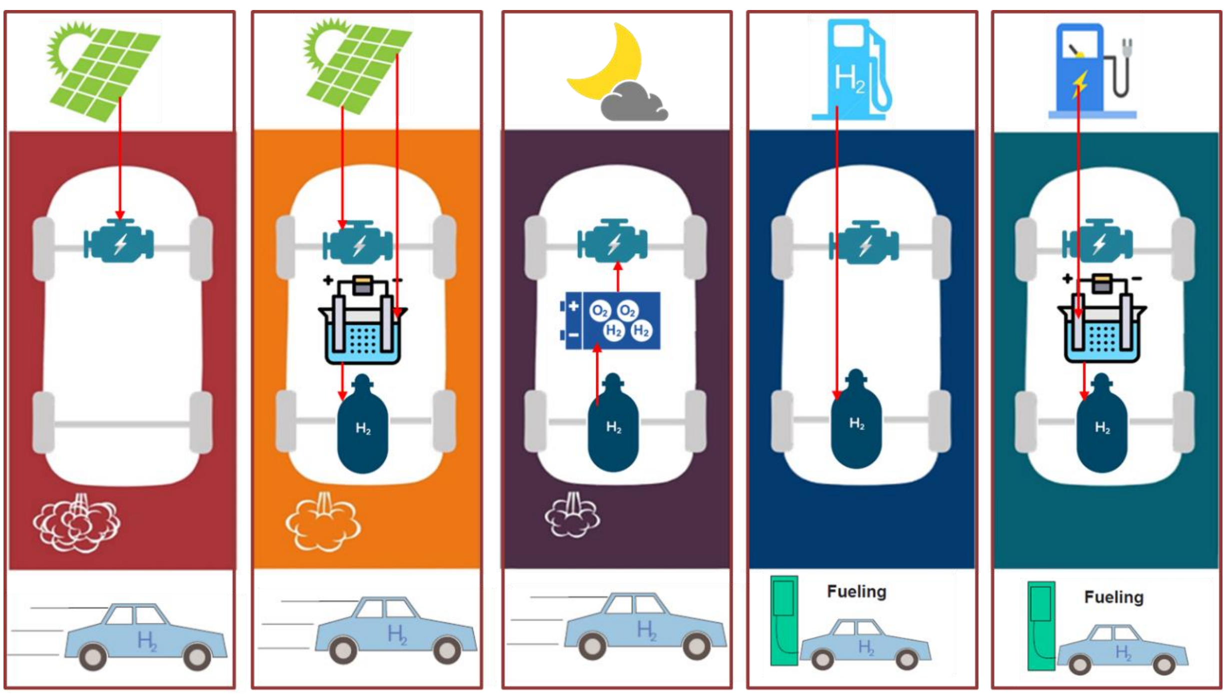


Fig. 3.9. Possible hybrid configuration of the PV/fuel cell car

SECTION 3: RESULTS

We made some test for the new water fueled hybrid car prototype, first test on the hydrogen production mode, second test on the fuel cell running mode.

3.1. Hydrogen production mode

In the first test we use a Stop Watch to determine the time required for the water electrolysis process to be completed. With optimum lighting, it will take 5-12 minutes to displace all the water into the upper hydrogen cylinder. Table 3.1 shows the time to complete water electrolysis process:

Table.4.1: Production Rate of Hydrogen and Oxygen

Time from start [minutes]	**Amount of hydrogen gas in cathode side [mL]**	**Amount of oxygen gas in anode side [mL]**
0	0	0
2	2.5	1
4	5	2
6	7	3.5
8	9.5	5
10	12	6

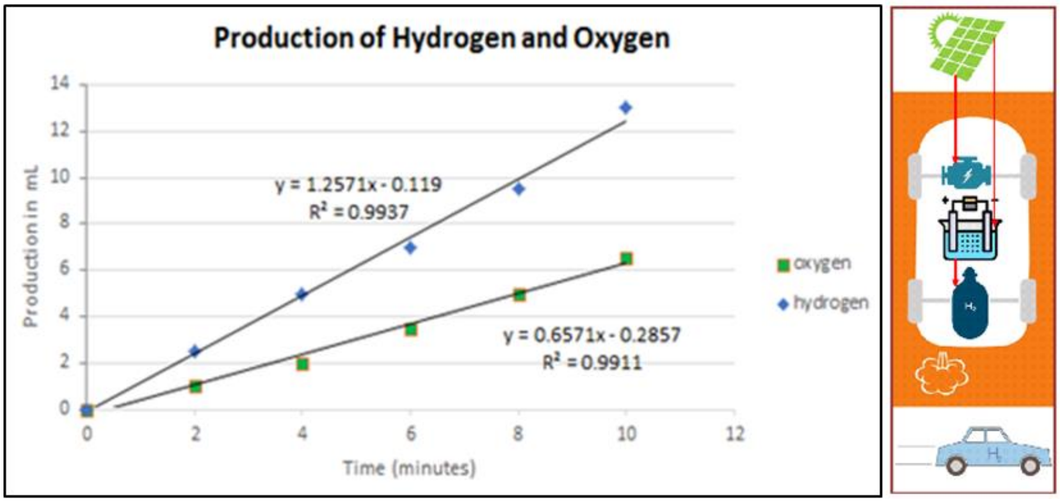


Fig.3.1. Hydrogen and oxygen production.

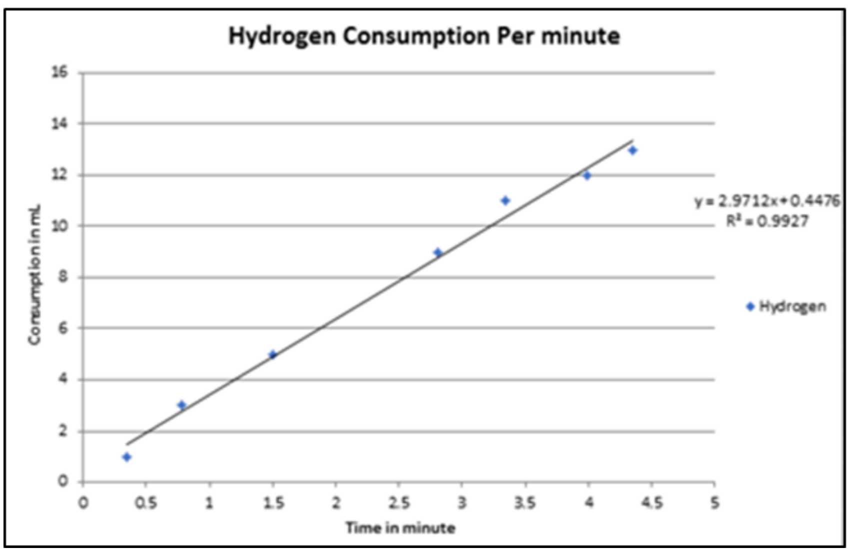
4. 2. Fuel Cell Test Mode

In this experiment, we calculate the hydrogen consumption rate in the PEMFC.

Fig.3.2. During the test experiment.

<u>Table.4.1: hydrogen consumption rate</u>

Time (min.)	*Consumption (mL)*
0.35	1
0.78	3
1.5	5
2.81	9
3.34	11
3.99	12
3.35	13



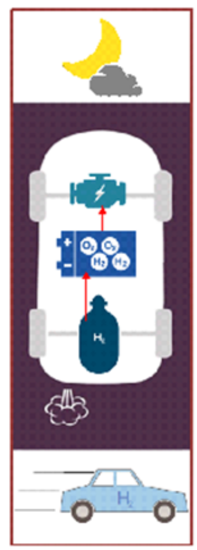


Fig.3.3: Hydrogen Consumption Per minute

A new water-fueled hybrid car prototype has been developed as part of this project, incorporating various technologies such as photovoltaic (PV) panels, electrolysis, a fuel cell, a metal hydride tank, and a battery. This innovative car aims to minimize environmental pollution and achieve the lowest possible operating costs by utilizing renewable resources. It achieves this by harnessing solar energy through PV panels and generating hydrogen gas through a fuel cell, which is then stored in a tank for use during evenings and cloudy weather conditions. During sunny weather, the car operates primarily on solar power, thereby contributing to the reduction of environmental pollution and offering cost savings in terms of operations. The most important solutions provided by the innovative car are:

- ✓ There is no pollution or consumption of conventional fuel sources in this hybrid car, as hydrogen is produced from water and reverts back to water through oxidation. Additionally, it does not emit any harmful exhaust gases that can negatively impact human health and the environment.
- ✓ The technology used in this hybrid car ensures high levels of safety, as it does not contain any elements that pose potential risks or dangers.
- ✓ The car operates with exceptional efficiency by directly converting solar and chemical energy into electrical energy, minimizing energy losses.
- ✓ This hybrid car has a longer lifespan and requires less maintenance compared to other vehicles.
- ✓ The volume of the car can be adjusted based on the required electric power for its operation.

SECTION 4: INTERPRETATION & CONCLUSIONS

The purpose of this work is to design and develop a new water-fuelled car prototype by implementing fuel cell and PV panels as the sources of power to propel the prototype car. This fuel cell has the capability to propel the electric motor by performing chemical reaction and converting chemical energy stored in hydrogen gas into useful electrical energy. In the developed fuel cell car prototype, the PEM fuel cell is used as the power source for the electric motor with the aid of a PV solar panels as other power source associated with it. An electrolyzer coupled to the PV array is employed for hydrogen production during excess of power from PV. Experimental investigations were carried out to test the water-fuelled car prototype.

1- The conception and assembly of a water-fuelled car prototype based on the combination of a hybrid PV-Fuel Cell car employing an electrolyzer for hydrogen generation is presented in this project.

2- The electrolyzer can be used to generate hydrogen during excess of power from PV.

3- The generated hydrogen can be stored in a tank for lower insolation levels or at night Fuel cell operation.

4- The car can incorporate a controller system to achieve permanent power supply to the motor via the PV array or the fuel cell, or both according to the power available from the sun.

5-A controller system is needed for this car.

SECTION 5: REFERENCES

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This project involves a water-fueled hybrid car prototype that integrates various techniques, including photovoltaic (PV) panels, electrolysis, a fuel cell, a metal hydride tank, and a battery. Experimental tests were conducted on a prototype of this water fueled car, with the fuel cell serving as a backup power source to ensure continuous operation even without solar energy.The report uses many fogures, presumably from other literatures,　and should make citations.