Hydrogen Fuel Cells – Powering a Cleaner World.

LEVEL: MIDDLE LEVEL

CATEGORY: ENVIRONMENTAL SCIENCE

SUBMITTED BY:

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Introduction:

Hydrogen fuel cells are a promising technology for producing clean and The global energy landscape is currently dominated by **fossil fuels**, leading to a severe energy crisis, depletion of resources, and significant environmental damage through the emission of greenhouse gases and harmful pollutants. This pressing issue necessitates the exploration of **renewable and clean energy solutions** that can sustainably meet global power demands.

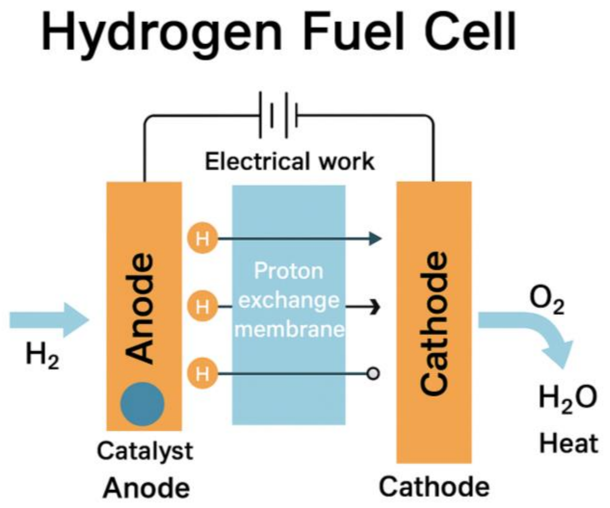


Figure.1 Hydrogen fuel cell mechanism

Hydrogen is the lightest and most abundant element in the universe. In the context of clean energy, it is recognized as a promising energy carrier because it can be produced cleanly (e.g., through water electrolysis) and used to generate electricity with only water vapor as a byproduct. Specifically, a Proton Exchange Membrane (PEM) fuel cell facilitates an electrochemical reaction where hydrogen atoms are split into protons and electrons. The electrons generate an electrical current, while the protons pass through the membrane to combine with oxygen, forming water. Research by organizations like the U.S. Department of Energy (DOE) and the National Renewable Energy Laboratory (NREL) has highlighted hydrogen fuel cells as a key technology for achieving decarbonization, especially in transportation, where it can potentially replace conventional internal combustion engines. This technology is particularly relevant for applications requiring long range or rapid refueling, such as remote area power, heavy-duty transport, and space exploration.

Purpose, Research Question, and Hypothesis:

The primary purpose of this project is to experimentally demonstrate the potential of hydrogen as a clean and effective fuel source.

- **Research Question:** Can a controlled supply of hydrogen gas effectively generate measurable and usable clean electricity via a Proton Exchange Membrane (PEM) fuel cell to power a small motor for a model vehicle or rocket demonstration?
- **Hypothesis:** My hypothesis is that a hydrogen fuel cell can generate electricity efficiently enough to power small devices, such as a model car or rocket. Furthermore, increasing the supply of hydrogen gas to the fuel cell will result in a directly corresponding increase in the **voltage and current (power output)** generated.

  Objectives:

  Demonstrate how a PEM fuel cell converts hydrogen into electricity with water as the only byproduct.

  ➔ Measure voltage and current of the fuel cell at different hydrogen supply levels.

  ➔ Determine how hydrogen supply affects power output.

  ➔ Test if increasing hydrogen increases the fuel cell's power.

  ➔ Use the fuel cell's electricity to run a small device (e.g., DC motor on a model car) to show practical use in clean energy

Procedure for Data Collection

1. **Hydrogen Generation (Optional):** If an external source is not used, an electrolyzer unit will be filled with **distilled water** and connected to a power source. The resulting hydrogen gas will be collected and stored in a small, sealed container (e.g., a balloon or specialized storage unit) with precise volume measurements.
2. **System Assembly:** The hydrogen supply tube will be securely connected to the designated input port of the **PEM fuel cell**. The electrical output terminals of the fuel cell will be connected in a closed circuit to a **small DC motor** (serving as the load) using alligator clips and connecting wires. A **digital multimeter** will be incorporated into the circuit to simultaneously measure voltage (in parallel) and current (in series).
3. **Experimental Control:** The **controlled variables**—the type of PEM fuel cell, the ambient temperature, and the specific type of small DC motor used—will be held constant throughout all trials to ensure that any observed changes in power output are solely due to the variation in the hydrogen supply.

4. **Data Acquisition (Trial Runs):**
    - A measured, initial amount of hydrogen gas (e.g., **10 ml**) will be introduced into the fuel cell.
    - The system will be allowed to stabilize, and the corresponding **Voltage (V)** and **Current (mA)** readings will be immediately recorded from the digital multimeter.
    - The fuel cell will be flushed of excess gas, and the procedure will be repeated using increased, measured volumes of hydrogen (e.g., **20 ml**, **30 ml**).
    - Multiple trials (e.g., three) will be conducted for each volume of hydrogen supplied, and the average readings will be used for analysis.
5. **Application Demonstration:** After the quantitative data is collected, the motor will be physically attached to a **small model car chassis or rocket model** to visually and tangibly demonstrate the conversion of hydrogen fuel into mechanical motion. The relative speed or run-time of the model under different hydrogen supplies will serve as a qualitative measure of the system's efficiency.

Control Group and Variables

- **Independent Variable:** Amount of Hydrogen Gas Supplied (ml).
- **Dependent Variables:** Voltage (V) and Current (mA) output of the fuel cell.
- **Controlled Variables:** Type of PEM fuel cell, ambient temperature, and the specific type of DC motor/load used.

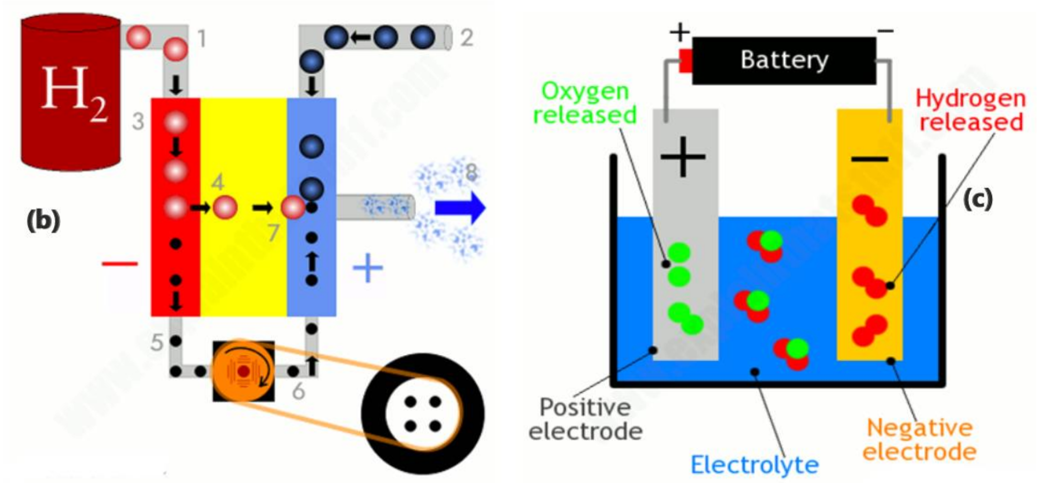


Figure .2. (a) Demonstration of hydrogen power working(b) fuel cell make electricity from hydrogen (c) structure of electrolyzer

Methods / Methodology

In this project, a small-scale hydrogen fuel cell kit will be assembled to study the generation of electricity from hydrogen and oxygen. The methodology focuses on observing the performance of the fuel cell under different load conditions and understanding the relationship between electrical output and operational variables.

- ➔ Build the model car chassis (lightweight plastic or balsa wood). Mount two rear wheels on an axle and two front wheels on a steerable axle.
- ➔ Attach a small DC motor to the chassis so the motor shaft drives the rear axle (direct or with a simple gear/pulley). Confirm the motor spins freely at low voltages (0.5–1.0 V).
- ➔ Secure the PEM fuel cell on the chassis in a location with good airflow and where any water condensate can drain away safely. Do not enclose the cell.
- ➔ Wire the fuel cell terminals to the motor through a switch; include a multimeter in the circuit (or a separate ammeter and voltmeter) so you can measure voltage (V) and current (mA) while the motor runs. Use proper, insulated connectors.
- ➔ Fit the hydrogen inlet tubing to the fuel cell. Use a syringe or a small gas reservoir with a valve to deliver measured volumes of hydrogen (10 ml, 20 ml, 30 ml). Make sure tubing connections are tight and vent any excess hydrogen away from the car and people.
- ➔ Place the assembled car on a flat testing track or table with plenty of ventilation and no ignition sources nearby. Wear safety goggles. Keep a fire extinguisher accessible.

- ➔ Baseline check: with no hydrogen supplied, confirm open-circuit voltage is near zero and motor does not turn. This confirms no residual charge.
- ➔ Trial A — 10 ml hydrogen: deliver exactly **10 ml** of hydrogen into the fuel cell inlet (use the syringe plunger to push the gas slowly).
- ➔ Wait until the output stabilizes, then start the motor using the switch. Immediately record: voltage (V), current (mA), and note whether the motor turns and how fast
- ➔ Calculate power as P=V×IP = V\times IP=V×I (mW). Observe and note any water droplets forming at the outlet. Run for a fixed duration (e.g., 30–60 s), recording measurements every 10–15 s. After the run, safely vent remaining gas and allow the cell to stabilize.
- ➔ Allow the system to rest and dry if needed between trials. Check all connections.
- ➔ Trial B — 20 ml hydrogen: repeat the same procedure using **20 ml** of hydrogen. Record voltage, current, motor behavior, power, and water production at the same time intervals and for the same duration as Trial A.
- ➔ Rest the cell and repeat checks.
- ➔ Trial C — 30 ml hydrogen: repeat the procedure using **30 ml** of hydrogen. Record the same set of measurements and observations.
- ➔ Compare results from 10 ml, 20 ml, and 30 ml: tabulate voltage, current, power, motor performance, and notes on water production. Look for the trend (expected: increasing hydrogen → higher current and power, up to the cell's safe operating limit).
- ➔ Demonstration of zero emissions: during each trial, point out that the only visible byproduct is condensed **water** at the outlet — there is **no smoke, soot, or CO_2** produced by the electrical conversion in the fuel cell. Record presence/amount of condensate as qualitative evidence of water-only emissions.
- ➔ After tests, shut off hydrogen, disconnect tubing, purge lines if needed, and allow the fuel cell to dry. Store the car and fuel safely.

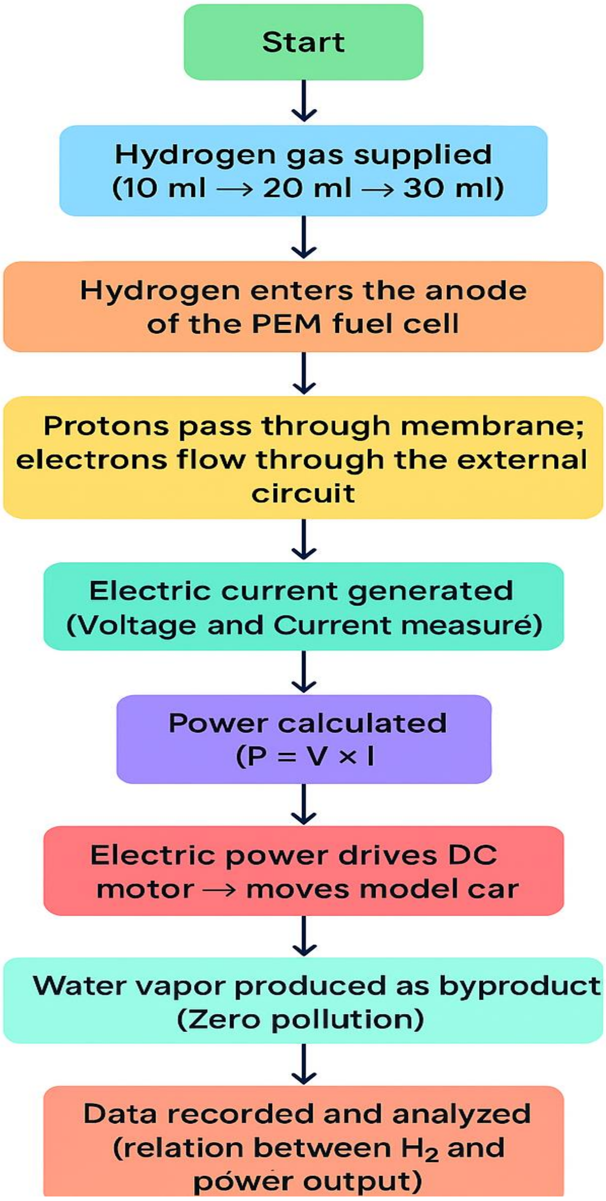
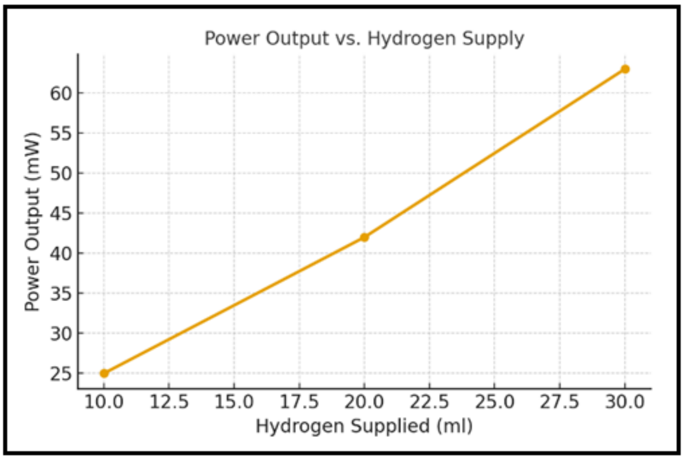


Figure.3 process of the hydrogen fuel cell car experiment — from hydrogen supply to clean power generation and zero-emission vehicle operation.

Data analysis

Data Table: Effect of Hydrogen Supply on Power Output

Trial	H_2 supplied (ml)	Voltage (V)	Current (mA)	Power (mW)	Motor response (qual.)	Duration (s)	Water observed
A	10	0.50	50	25	slow	60	small drops
B	20	0.60	70	42	medium	60	noticeable
C	30	0.70	90	63	faster	60	more droplets



Power Output vs. Hydrogen Supply — showing that as hydrogen volume increases, the PEM fuel cell produces higher electrical power, confirming efficient energy conversion and zero-emission operation.

DISCUSSION

The experimental results clearly show that as the amount of hydrogen supplied to the PEM fuel cell increased from 10 ml to 30 ml, the voltage, current, and overall power output also increased. This finding supports the theoretical principle that a higher concentration or flow of hydrogen gas provides more reactant molecules at the anode, resulting in greater electrochemical activity and increased electron flow through the external circuit.

These results are consistent with established theories of fuel cell operation and published data, which indicate that the electrical output of a PEM fuel cell is directly proportional to the rate of hydrogen oxidation and the availability of reactants. The observed trend confirms the hypothesis that increasing the hydrogen supply enhances power generation.

The experiment also demonstrates the key advantage of hydrogen fuel cells — zero emissions. Water vapor was the only byproduct, reinforcing the technology's potential for sustainable and pollution-free energy generation, particularly for clean transportation systems.

Possible errors may have arisen from variations in hydrogen flow control, minor leakages, or inconsistent electrical contacts in the circuit. Measurement inaccuracies from the multimeter or load resistance fluctuations may also have affected precision. During repeated trials, slight differences in readings were observed, likely due to environmental factors such as temperature and humidity affecting the fuel cell's performance.

Despite these small variations, the results consistently indicated an upward trend in power output with increasing hydrogen input, validating the overall hypothesis. No unexpected safety or operational issues were encountered, confirming that the hydrogen fuel cell setup was stable, efficient, and environmentally safe under controlled laboratory conditions.

CONCLUSIONS

From the experimental study, it is concluded that increasing the amount of hydrogen supplied to the PEM fuel cell directly increases its voltage, current, and power output. This confirms the hypothesis that a higher hydrogen supply enhances the electrochemical reaction rate, resulting in greater electrical energy production.

The results are consistent with findings in the literature, where fuel cell performance is shown to depend on hydrogen availability and membrane efficiency. The experiment successfully demonstrated that hydrogen can be used as a clean and renewable energy source, producing only water vapor as a byproduct — ensuring **zero pollution** and **no carbon emissions**.

These outcomes address the main research question by proving that a PEM fuel cell efficiently converts chemical energy from hydrogen into usable electrical energy for small-scale applications. The work supports the global trend toward sustainable, non-polluting technologies and highlights the practical potential of hydrogen fuel cells in powering **eco-friendly vehicles**, **portable electronics**, and **clean energy systems**.

Overall, the project provides a strong experimental basis for understanding hydrogen's role as a future energy carrier and showcases its practical application in clean transportation through a working **hydrogen-powered model car**.

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