PROJECT - I

SOLAR DRIVEN HYDROGEN PRODUCTION

Group 01

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OUTLINE

Project Description	Green hydrogen production by solar driven electrochemical water splitting
Project Objective	Design and create setup for the production of Green hydrogen even at small scale.
Methodology	Producing green hydrogen by electrolysis from renewable sources involves breaking down water molecules (H_2O) into oxygen (O_2) and hydrogen (H_2). 1. The water used in the electrolysis must contain salts and minerals to conduct the electricity. 2. Two electrodes are immersed in the water and connected to a power source and a direct current is applied. 3. The dissociation of hydrogen and oxygen occurs when the electrodes attractions with an opposite charge to them. 4. During the electrolysis, an oxidation-reduction reaction occurs due to the effect of the electricity.

INTRODUCTION

- Hydrogen is produced by splitting water into hydrogen and oxygen using renewable electricity. This is a very different pathway compared to both grey and blue hydrogen.

- Green hydrogen can contribute to a clean, carbon-neutral industry and can be a long-term option for energy storage on a large scale.

- Green hydrogen can help developing countries and emerging economies achieve energy transition, enhance their national energy security, and address climate mitigation objectives.

- Black / Brown / Grey hydrogen is produced via coal or lignite gasification (black or brown), or via a process called steam methane reformation (SMR) of natural gas or methane (grey). These tend to be mostly carbon-intensive processes.

- Blue hydrogen is produced via natural gas or coal gasification combined with carbon capture storage (CCS) or carbon capture use (CCU) technologies to reduce carbon emissions.

- Green hydrogen is produced using water electrolysis with electricity generated by renewable energy. The carbon intensity ultimately depends on the carbon neutrality of the source of electricity (i.e., the more renewable energy there is in the electricity fuel mix, the “greener” the hydrogen produced).

ADVANTAGES

- **Zero Emissions:** Green hydrogen production produces no greenhouse gas emissions, making it a key technology for reducing carbon emissions and achieving a sustainable energy future.

- **Renewable Energy Integration:** Green hydrogen production provides a way to integrate renewable energy sources into the energy grid and manage fluctuations in renewable energy supply.

- **Energy Storage:** Green hydrogen can be stored and used as a source of energy on demand, helping to balance the energy grid and providing energy security.

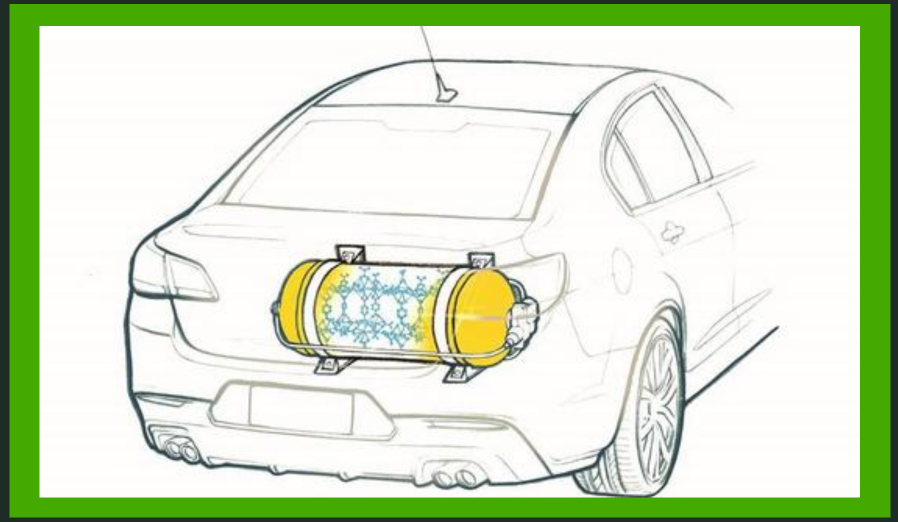
- **Versatility:** Green hydrogen can be used in a variety of applications, including transportation, power generation, industrial processes, heating, and agriculture.

- **Improved Energy Efficiency:** Green hydrogen production can improve energy efficiency compared to traditional hydrogen production methods, as the renewable energy used in the electrolysis process can be generated from highly efficient renewable energy technologies such as wind turbines and solar panels.

- **Improving Energy Security:** Green hydrogen can help to reduce dependence on fossil fuels and improve energy security by providing a domestic source of energy that is not subject to the geopolitical and economic uncertainties associated with oil and gas imports.

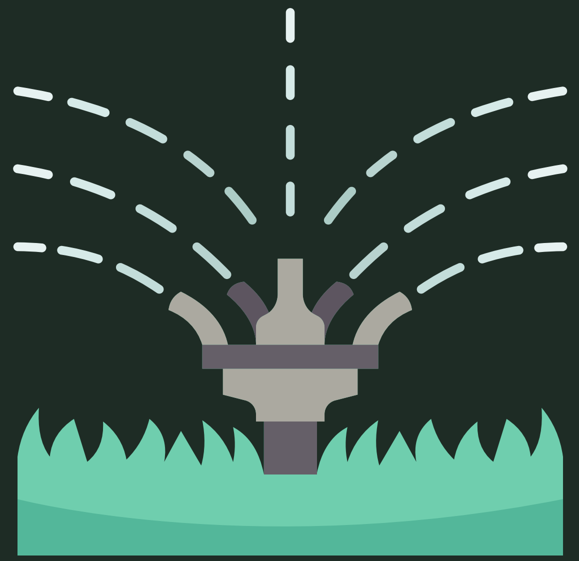
APPLICATIONS

- **Transportation:** Green hydrogen can be used as a fuel for vehicles, providing a zero-emissions alternative to gasoline and diesel. This includes the use of hydrogen fuel cell vehicles, which convert the hydrogen into electricity to power the vehicle's electric motor.



- **Industrial Processes:** Green hydrogen can be used in a variety of industrial processes, including refining and chemical production, where hydrogen is used as a feedstock or a fuel. This can help to reduce greenhouse gas emissions in these sectors.

- **Heating**: Green hydrogen can be used as a fuel for heating, providing a low-carbon alternative to natural gas and other fossil fuels.



- **Agriculture:** Green hydrogen can be used in agriculture as a source of energy for fertilization, irrigation, and other processes.

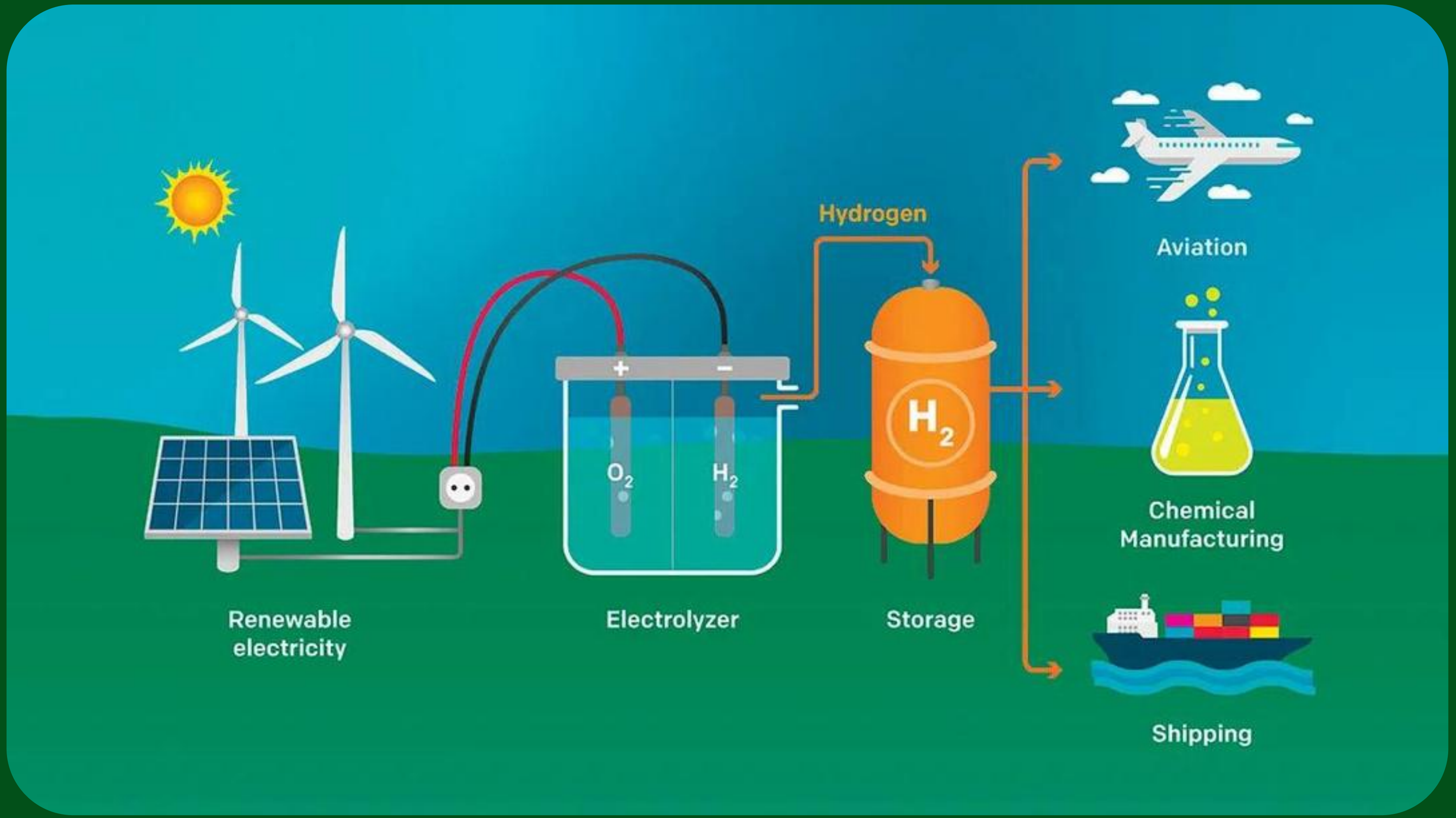
OBJECTIVE

GREEN HYDROGEN PRODUCTION BY SOLAR-DRIVEN ELECTROCHEMICAL WATER SPLITTING

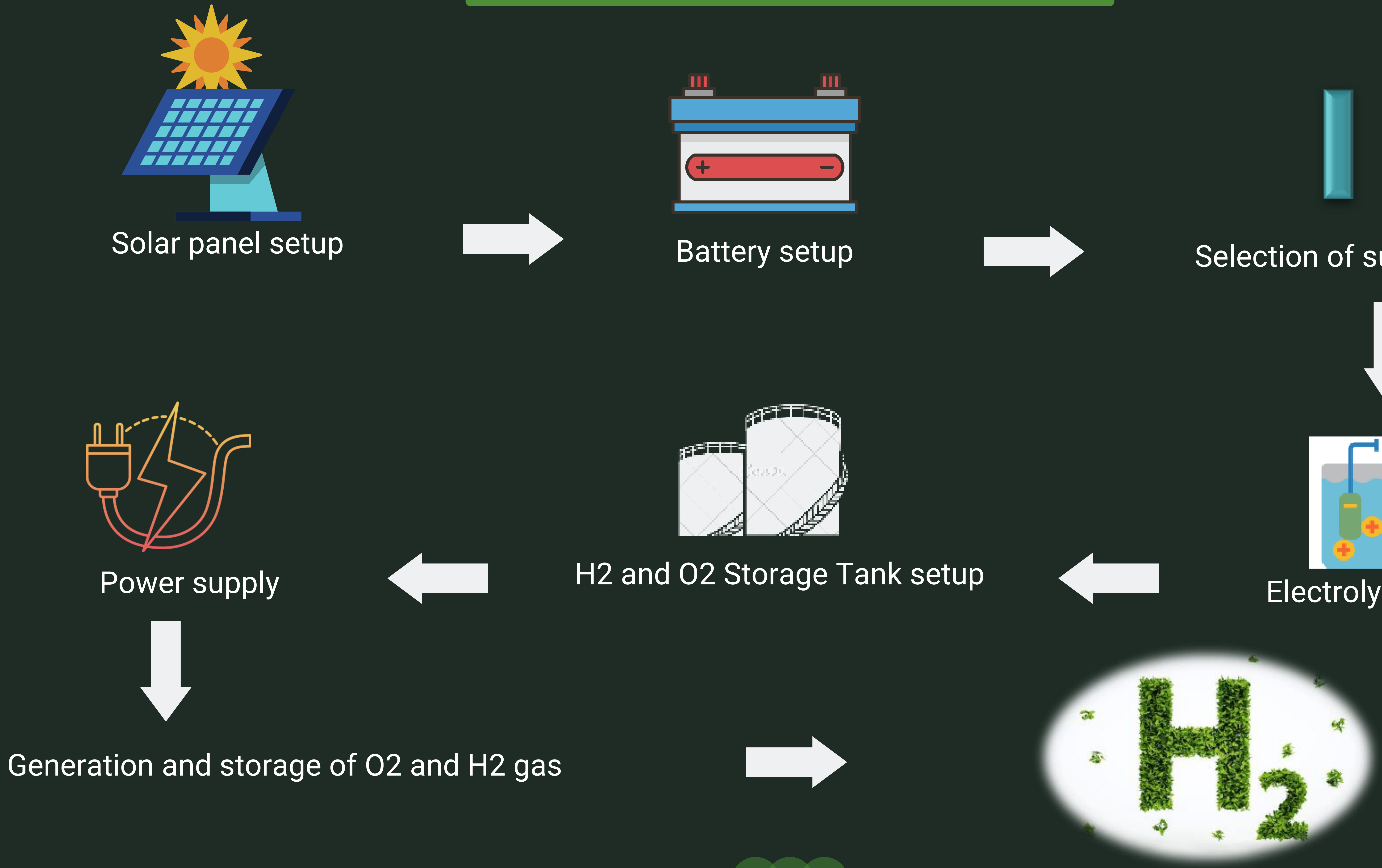
- The decreased cost of producing green hydrogen using renewable energies, together with a drive towards reducing greenhouse gas emissions, has given clean hydrogen an exceptional boost.

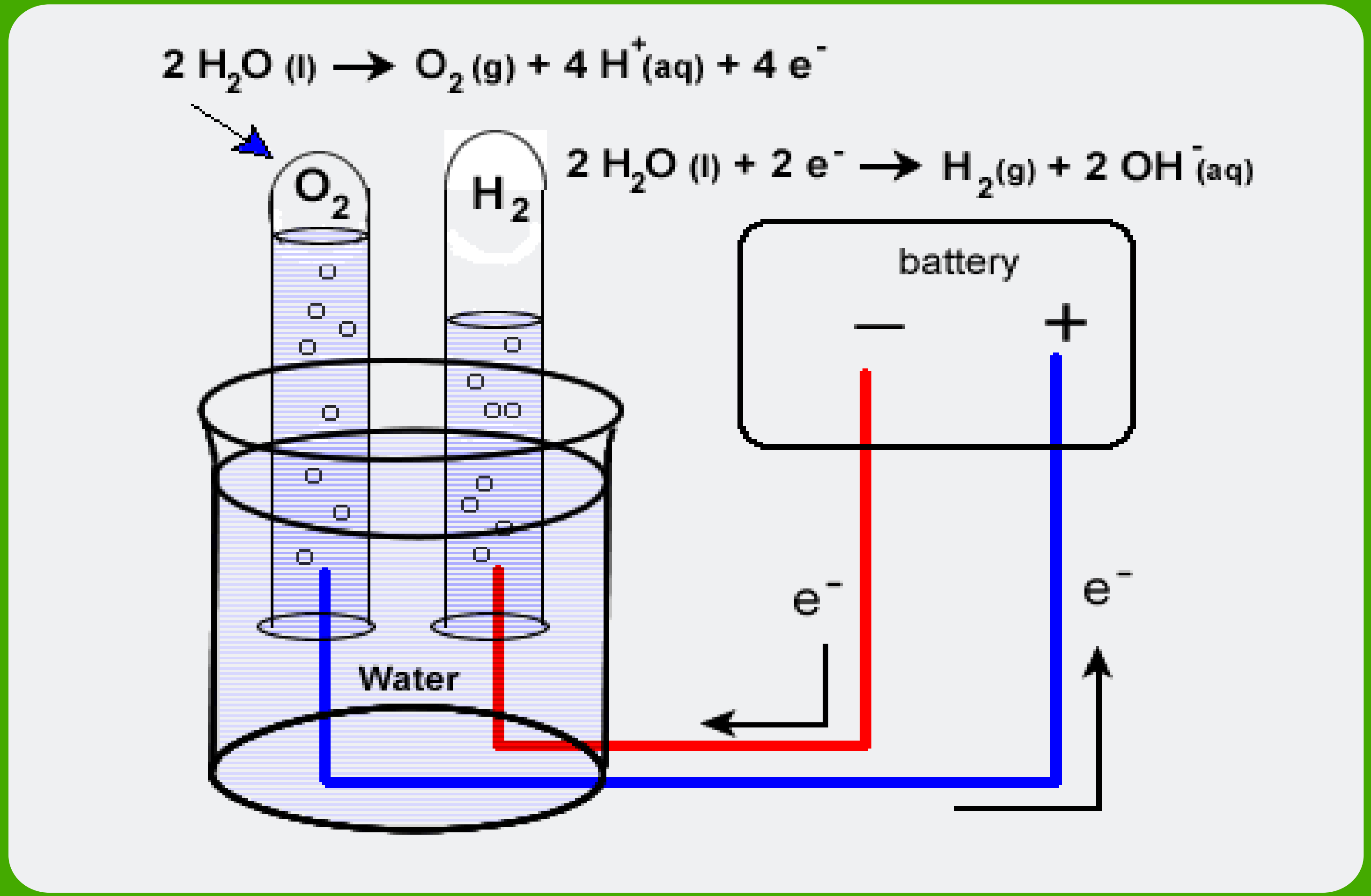
- Green hydrogen is becoming a key component in bringing about energy transition and ensuring a sustainable future.

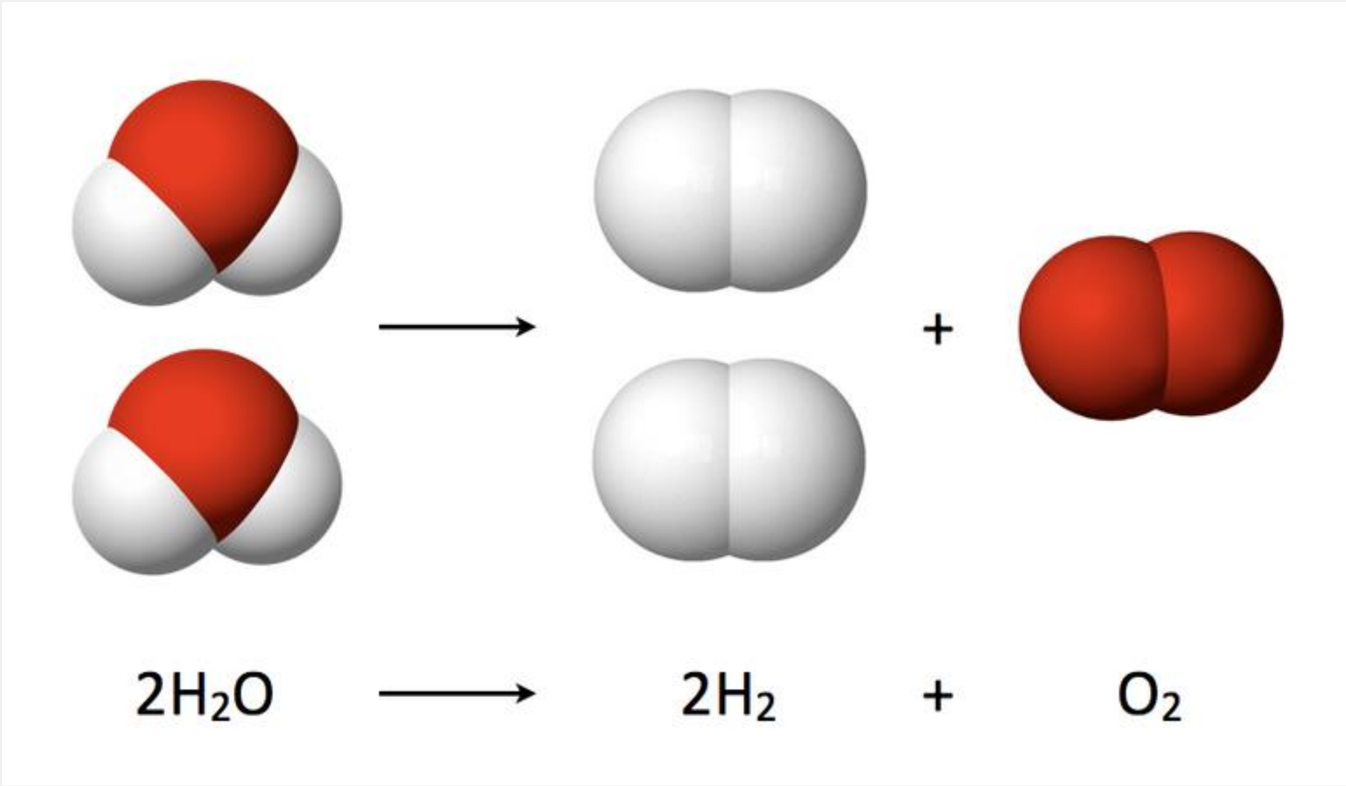
- Growing demand for green hydrogen as a sustainable future fuel, and there is a need to produce green hydrogen even at a small scale.



METHODOLOGY



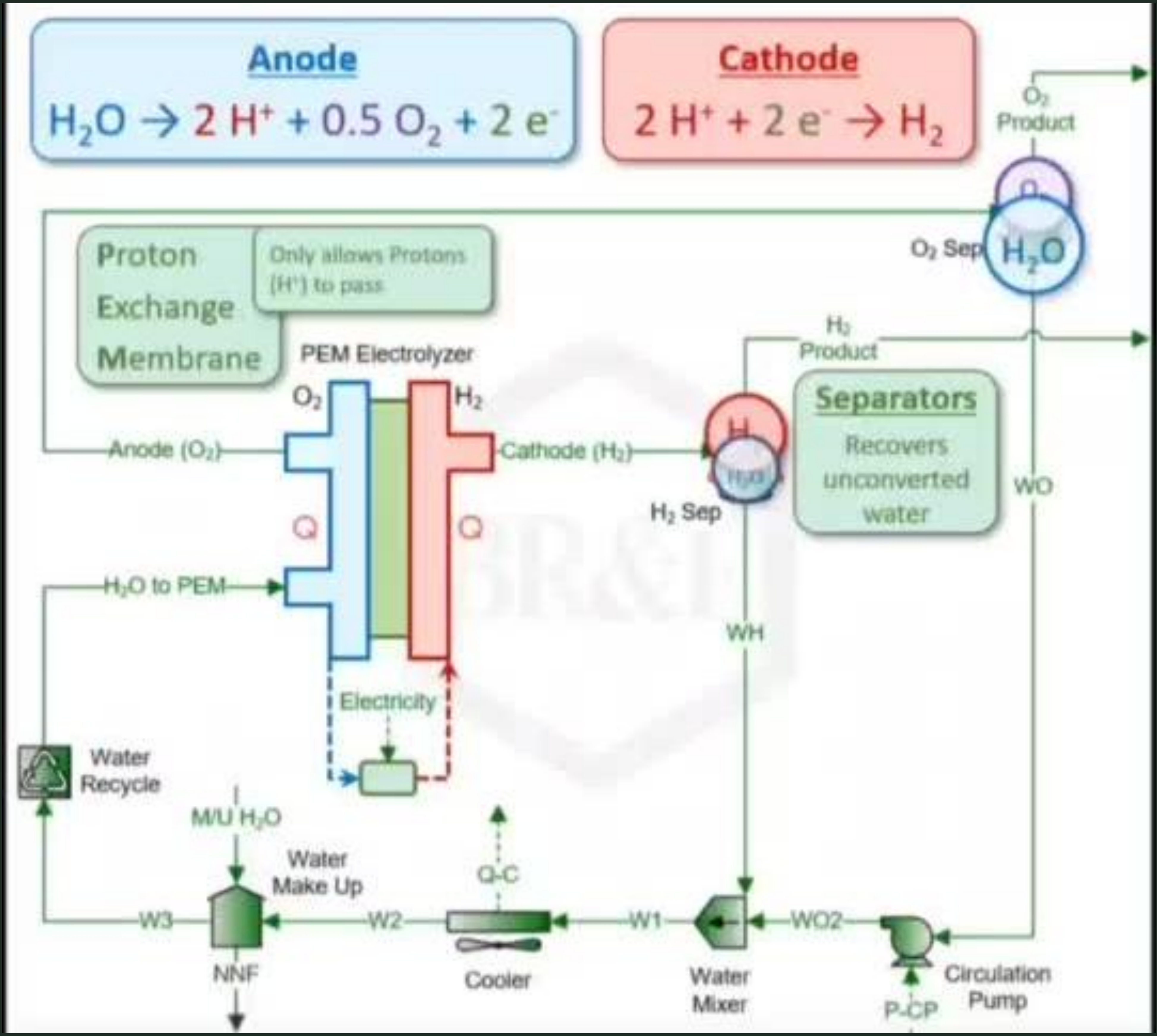




- The electrolysis of water in standard conditions requires a theoretical minimum of 237 kJ of electrical energy input to dissociate each mole of water, which is the standard Gibbs free energy of formation of water.

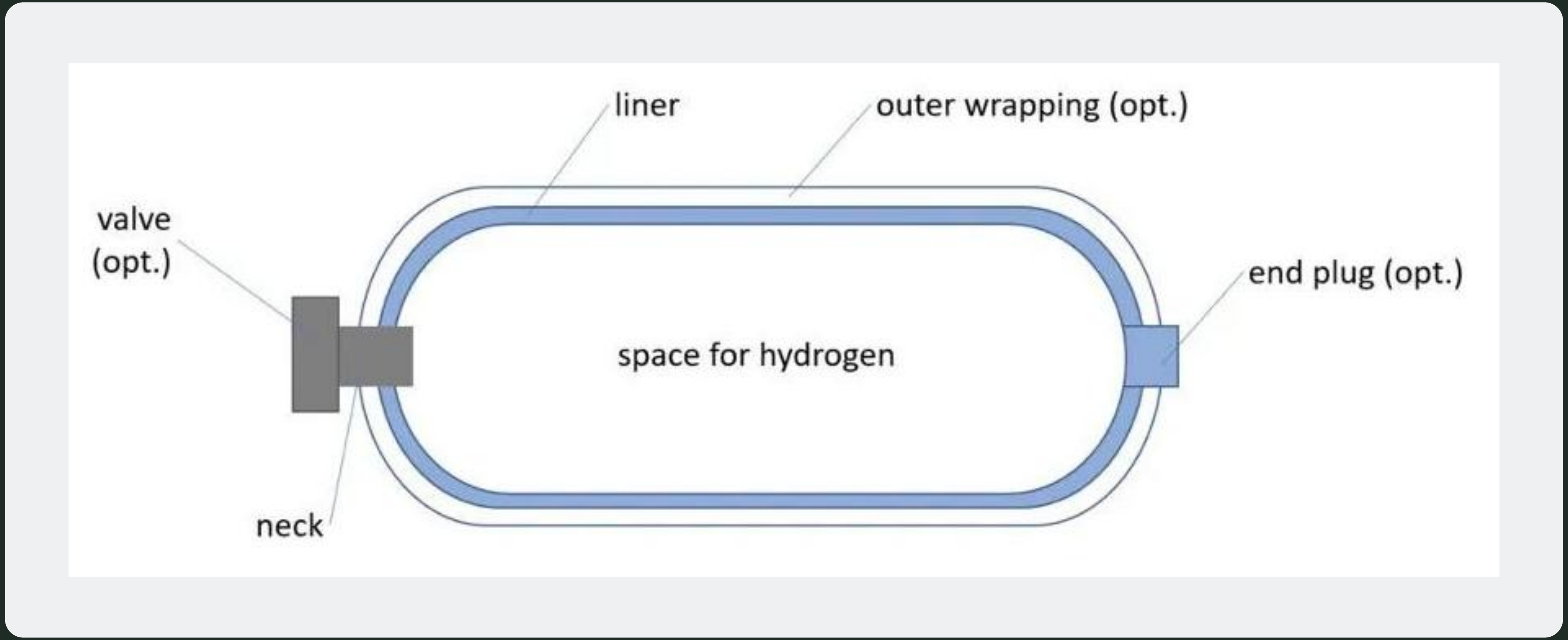
- It also requires energy to overcome the change in entropy of the reaction. Therefore, the process cannot proceed below 286 kJ per mol if no external heat/energy is added.

- A completely efficient electrolysis system would require 39 kWh of electricity to produce 1 kg of hydrogen. However, the devices commonly found in operation for this process are less efficient. A typical operational figure is about 48 kWh per kg of hydrogen.



- A short representation behind the concept of project to produce the green hydrogen by water electrolysis method.

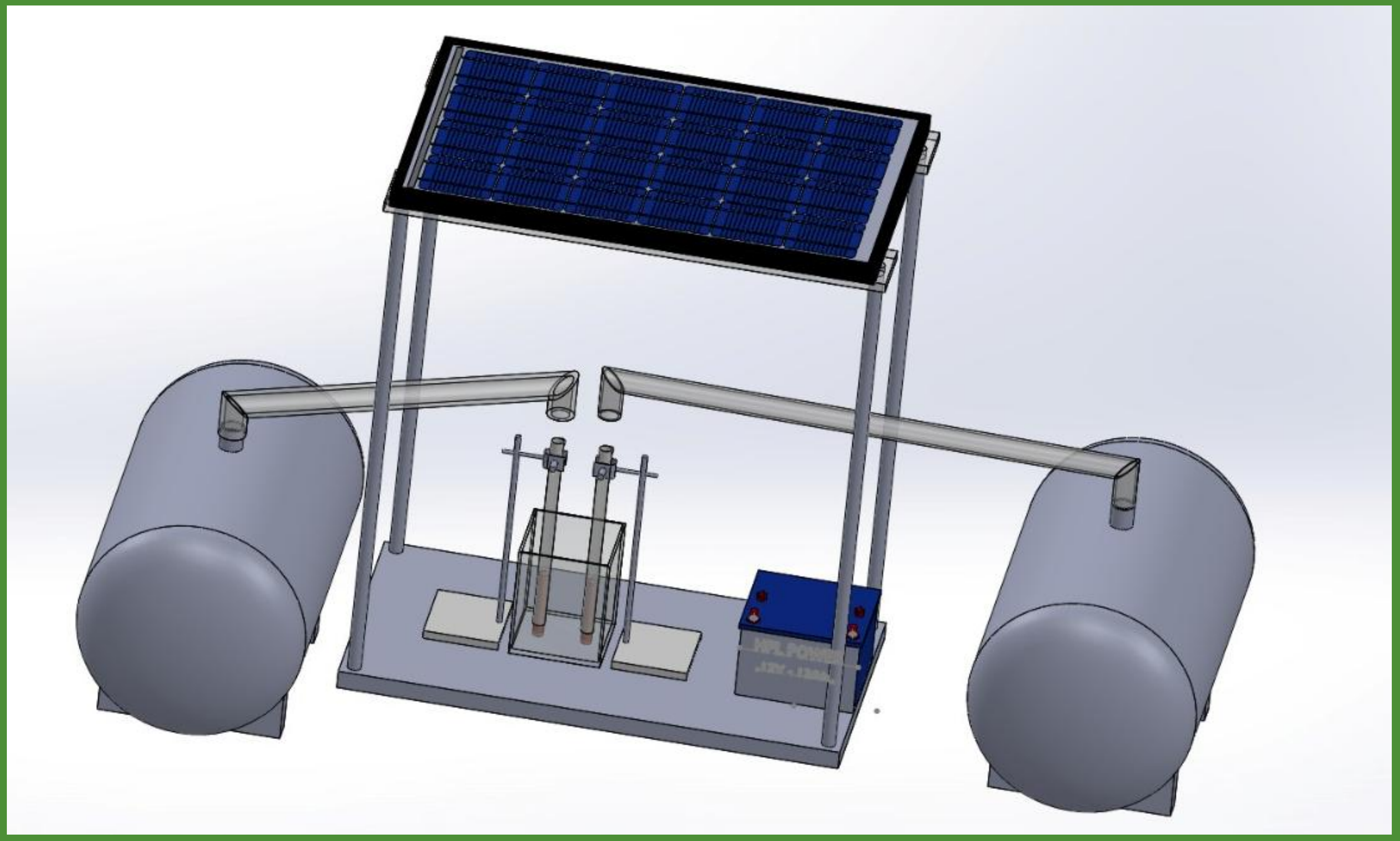
HYDROGEN STORAGE AND ELECTRODE MATERIAL



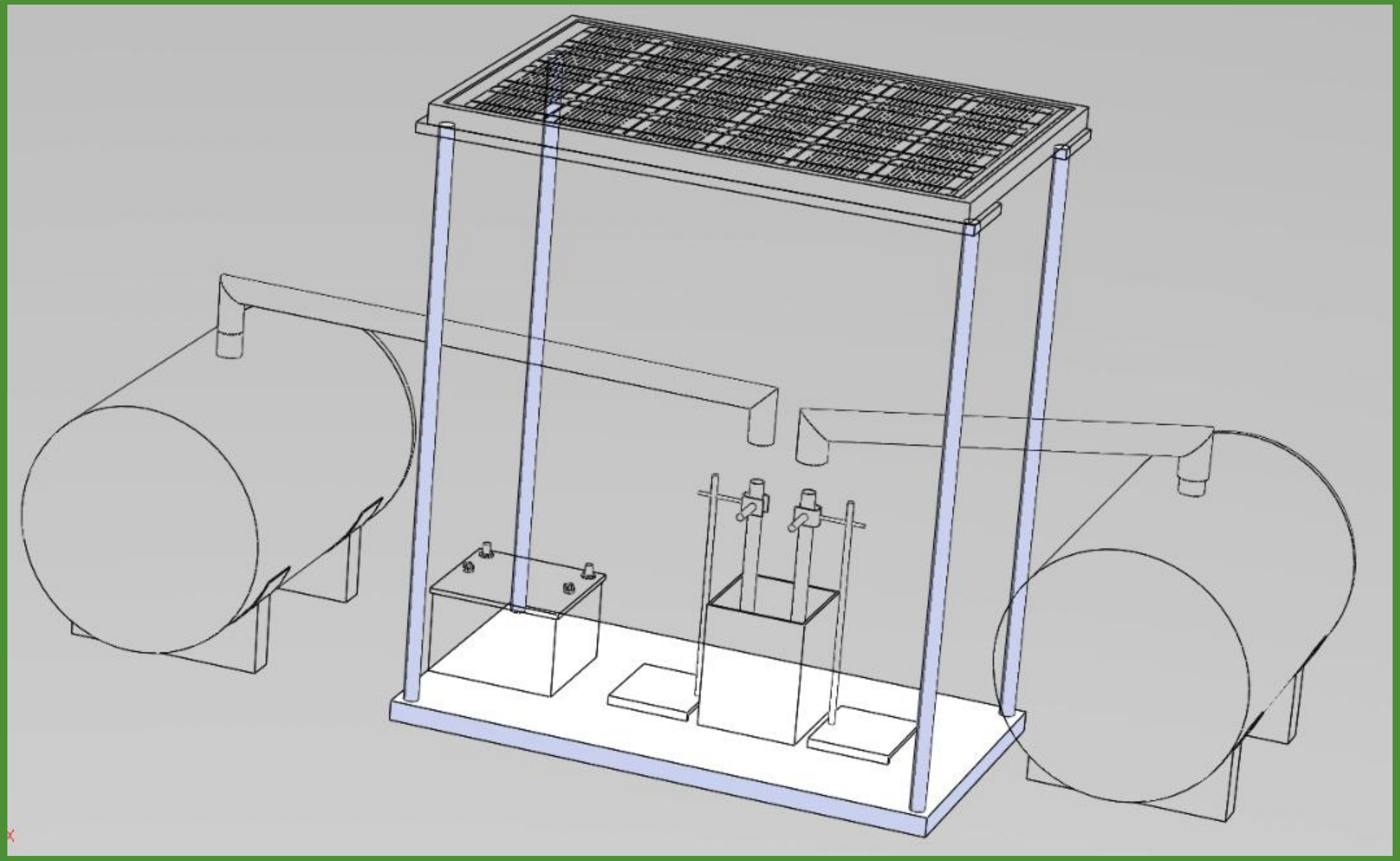
- Hydrogen tanks come in different shapes and forms Spherical forms are used for some liquid hydrogen tanks and any form is appropriate when storing hydrogen pressures near atmospheric pressure however a cylindrical container is the most common form of a hydrogen tank.

- Steel and iron are the most commonly used for electrolysis of water. These electrodes are used as anode and it is sacrificed in electrolysis, as the anode rusts (get oxidized) and the cathode de-rusts (get reduced).

SOLIDWORKS MODEL



These are basic model of our project, deigned in SolidWorks.



EQUIPMENT AND TOOLS

- Solar panel
- Battery
- Electrode
- Clamp stand
- Clamping base
- Wire
- Solder
- Switches
- Pipes
- Burette

EXPERIMENTAL SETUP

WE HAVE TRIED TO MAKE A SETUP AS PER OUR OBJECTIVE. BUT WE ARE FACING SOME CHALLENGES...

CHALLENGES

High Cost: Currently, green hydrogen production is still more expensive compared to other hydrogen production methods. This high cost is mainly due to the high capital costs associated with renewable energy generation and the cost of the electrolyzers used in the electrolysis process.

Energy Efficiency: Electrolysis is an energy-intensive process, and the efficiency of the process can be impacted by various factors such as the purity of the water, the temperature, and the cell design. Improving the efficiency of the electrolysis process is an important challenge for the green hydrogen industry.

Slow Production Rate: Production rate of hydrogen by electrolysis is very slow as compare to other method of production. Collection of produced gas is difficult because we are getting low amount of hydrogen.

Renewable Energy Integration: Green hydrogen production relies on the availability of renewable energy, and the intermittency of renewable energy sources such as wind and solar power can present challenges in terms of energy storage and grid integration.

Infrastructure Development: Developing the infrastructure required for the production, storage, and distribution of green hydrogen is a major challenge and requires significant investment in order to build the necessary pipelines, storage tanks, and distribution networks.

Regulatory Challenges: Green hydrogen production is a relatively new industry, and there are still many regulatory and policy challenges to overcome in order to facilitate its widespread adoption and commercialization.

EQUIPMENTS REQUIRED AND THEIR ESTIMATED PRICE

SERIAL NO.	EQUIPMENTS	ESTIMATED PRICE (Rs.)
1.	BATTERY	1350/-
2.	ELECTROLYZER	500/-
3.	SOLAR PANEL	1500/-
4	HYDROGEN AND OXYGEN STORAGE TANK	800/-
5	STAINLESS STEEL PIPE	500/-
6	PVC PIPE	500/-
7	A COUPLE OF HOSE CAMPS	500/-
8	OTHER EXPENSES	1000/-
9	TOTAL COST	**6650/-**

MODEL - 1

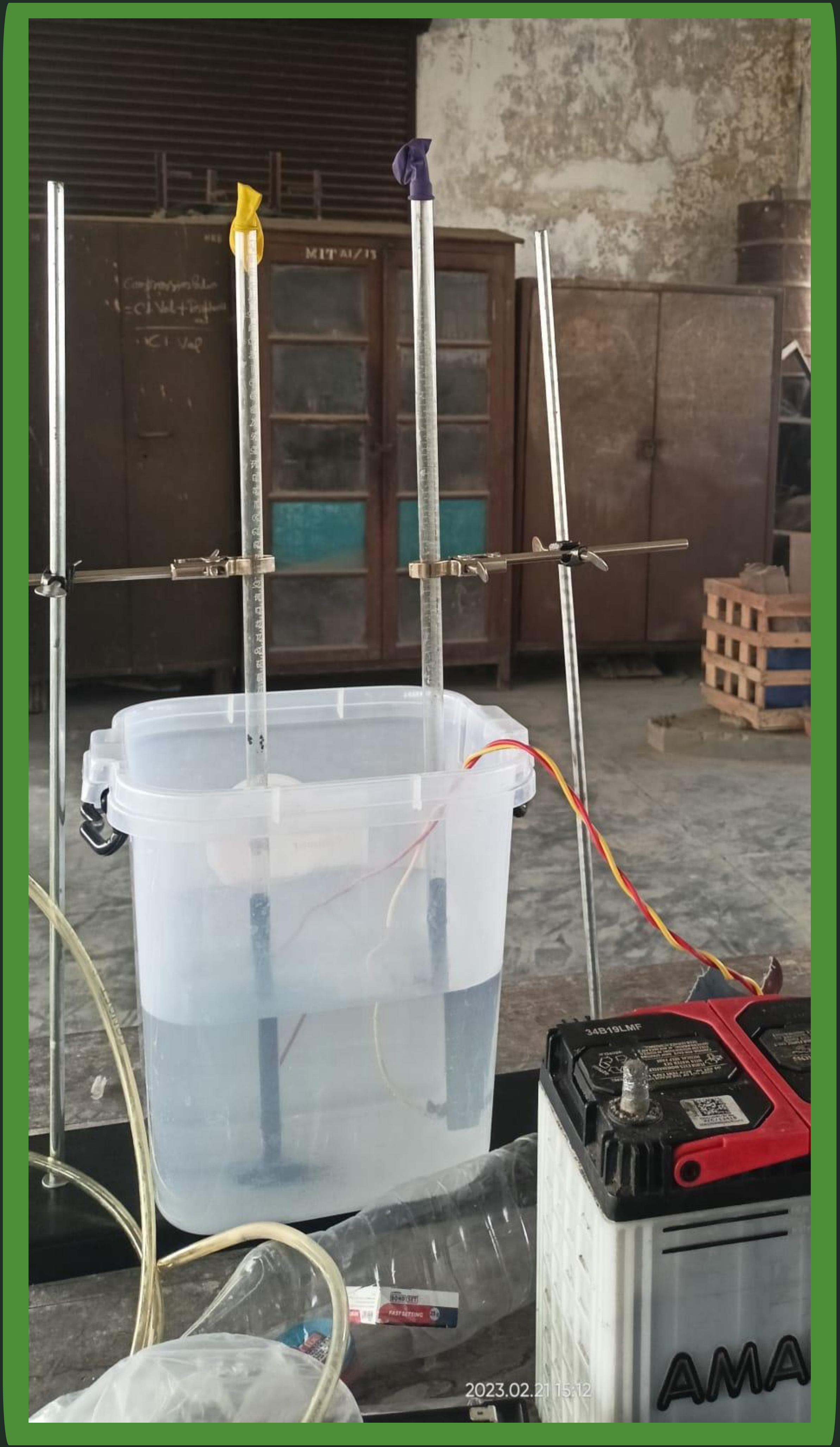
Electrolyte – Water
Catalyst – No catalyst used
Electrode – Graphite
Power supply – 12 V DC , 7 A attached with solar.

Observation :

1. Insignificant production rate.
2. Less current density.
3. Slow reaction rate.

Conclusion :

1. Electrical conductivity of water is low – suitable catalyst required.
2. Surface area of electrode has to be increased to improve rate of reaction.



MODEL - 2

Electrolyte – Water
Catalyst – NaCl and H_2SO_4
Electrode – Graphite
Power supply – 12 V DC , 7 A attached with solar.
Separate container for Cathode and anode.
Pipe connection for detection of O_2 and H_2 gas.

Observation :

1. Slow production rate but significant compare to Model -1.
2. Improved electrical conductivity as a catalyst was used.
3. Enhancement in reaction rate.
4. Pungent smell.

Conclusion :

1. Production rate of hydrogen gas was considerably low, hence a more suitable electrode with wide surface area has to be employed.
2. Also a better catalyst then NaCl and H_2SO_4 is required.

- Result observed in model 2 when H_2SO_4 is used as catalyst.

MODEL - 3

Electrolyte – Water
Catalyst – NaOH
Electrode – Graphite
Power supply – 12 V DC , 7 A attached with solar.
Separate container for Cathode and anode.
Pipe connection for detection of O_2 and H_2 gas.

Observation :

1. Slow production rate.
2. Improved electrical conductivity.
3. Enhancement in reaction rate.
4. Intense heating of container.

Conclusion :

1. Production rate of hydrogen gas was considerably low, hence a more suitable electrode with wide surface area has to be employed.

Result: we observed that rate of reaction has increased but due to some problem like leakage and unavailability of collection method of gas, we are not able collect the gas and calculate the other data.

MODEL - 4

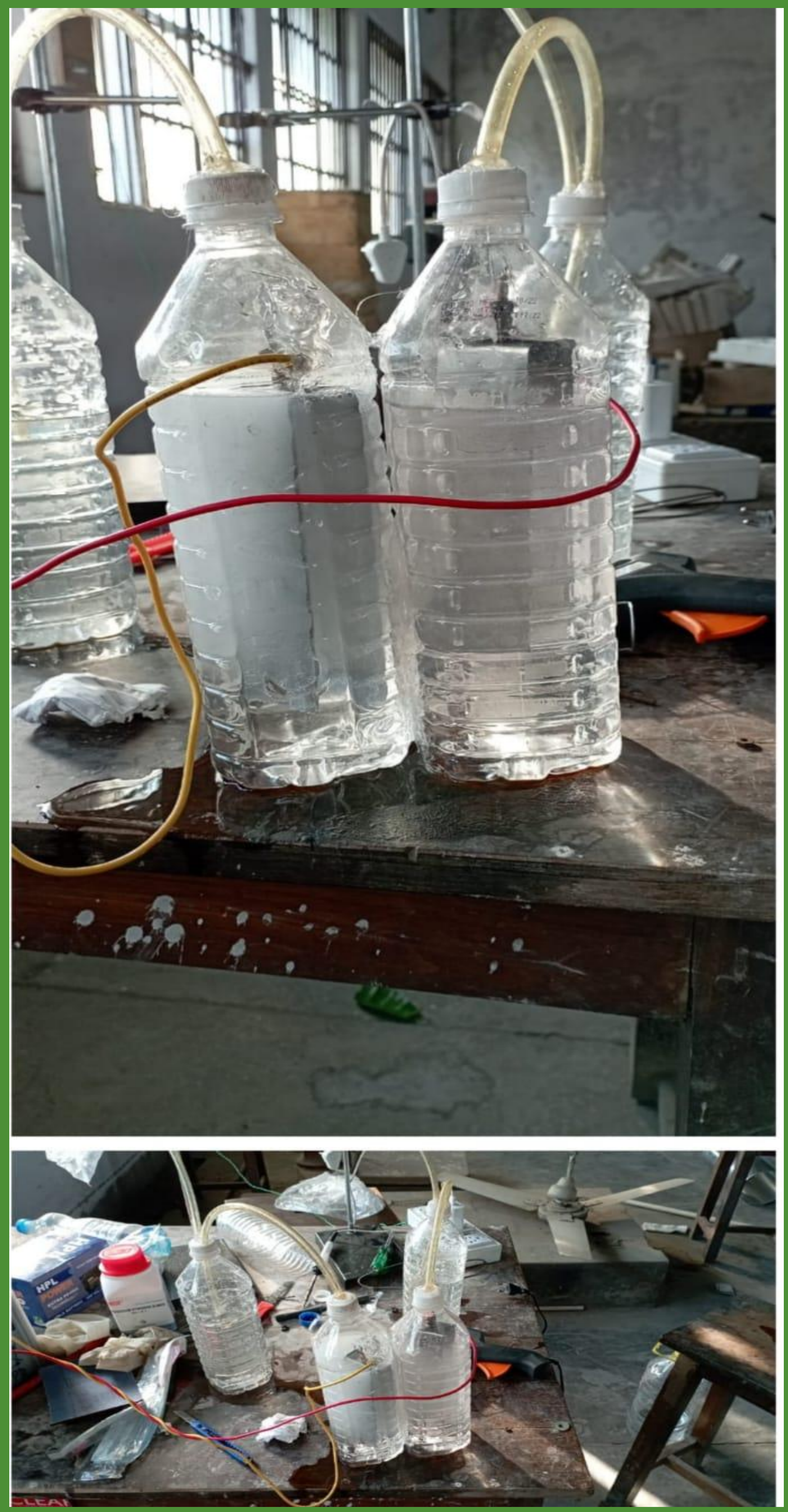
Electrolyte – Water
Catalyst – KOH
Electrode – Steel plates
Power supply – 12 V DC , 7 A attached with solar.
Separate container for Cathode and anode.
Pipe connection for detection of O_2 and H_2 gas.

Observation :

1. Significant production rate.
2. Rigorous reaction.
3. Fast chemical reaction.
4. KOH has a great effect on rate of chemical reaction.
5. Steel plate act as a suitable electrode.

Conclusion :

1. Production rate of hydrogen gas increased, but till facing problem of storage and prolonged period of accumulation.
2. Design of Electrolyzer is inferior i.e facing leakage problems and compactness



CALCULATION

The production of hydrogen gas by electrolysis can be calculated using Faraday's law.
Statement: Which states that the amount of substance produced at an electrode during electrolysis is proportional to the amount of electric charge passed through the electrode.

The equation for the production of hydrogen gas is:
$2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$

The reaction requires two moles of electrons for every mole of hydrogen gas produced.
The amount of charge required to produce 1 mole of hydrogen gas is given by the Faraday constant (F), which is equal to 96,485 coulombs per mole.
Therefore, the amount of charge required to produce 2 moles of hydrogen gas is:
$2 \times F = 2 \times 96{,}485 = 192{,}970$ coulombs

To produce 100 grams of hydrogen gas, we need to calculate the number of moles of hydrogen gas required using the ideal gas law:
$PV = nRT$
Where:
P = pressure (atm) V = volume (L) n = moles (mol) R = gas constant (0.08206 L.atm/mol.K) T = temperature (K)
Assuming standard temperature and pressure (STP), we have:
P = 1 atm, V = 22.4 L/mol (molar volume at STP), n = m/M (where m is mass and M is molar mass), R = 0.08206 L.atm/mol.K , T = 298 K

Substituting the values, we get:
1 x 22.4 = (m/M) x 0.08206 x 298

Solving for m/M, we get:
m/M = 0.08988 g/mol

Therefore, the number of moles of hydrogen gas required to produce 100 grams of hydrogen gas is:
n = m/M = 100/2.016 = 49.6 mol

The amount of charge required to produce 49.6 moles of hydrogen gas is:
q = n x 2 x F = 49.6 x 2 x 96,485 = 9,578,624 coulombs

The power (P) required to produce this amount of charge in a given time (t) is given by:
P = V x I = 12 x 7 = 84 watts

Assuming 100% efficiency, the time (t) required to produce 100 grams of hydrogen gas is:
t = q/P = 9,578,624/84 = 114,028 seconds

Therefore, the production of 100 grams of hydrogen gas by a DC power supply of 12V and 7A would take approximately 31.68 hours.

Reference: National renewable energy laboratory (Conference paper)
Link: [Hydrogen Production: Fundamentals and Case Study Summaries; Preprint (nrel.gov)]

NEW DESIGN OF ELECTROLYZER

- After performing many trials that we have mentioned in previous slide. We designed a new model of electrolyzer to avoid the maximum difficulties or limitation.

Advantages of new model of electrolyzer:

- Portable
- Leakproof
- Compact design
- Batter facilities for collection of gas
- More surface area of electrode
- Able to maintain high current density
- More efficient

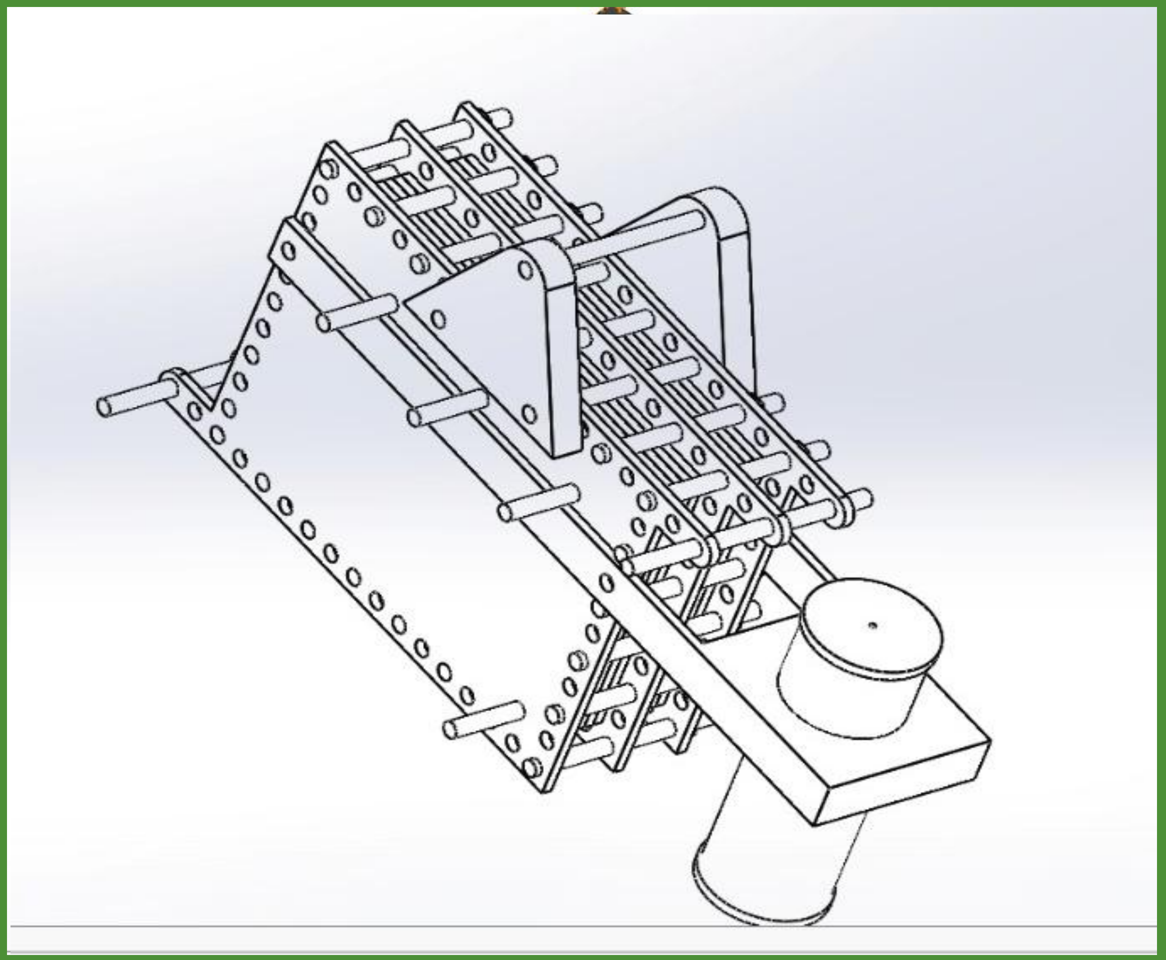


Fig: Old Model

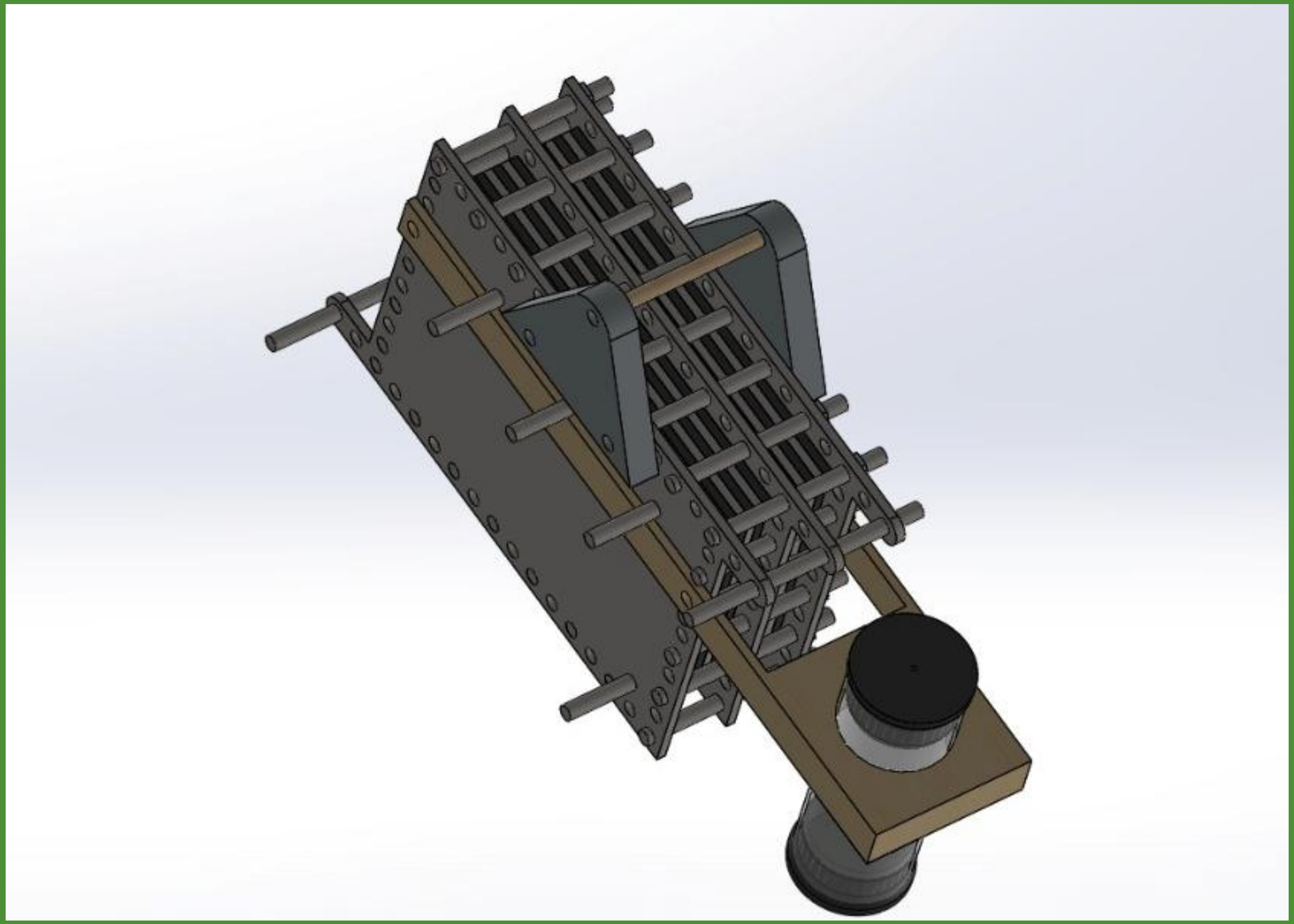


Fig: New Model

Thank You