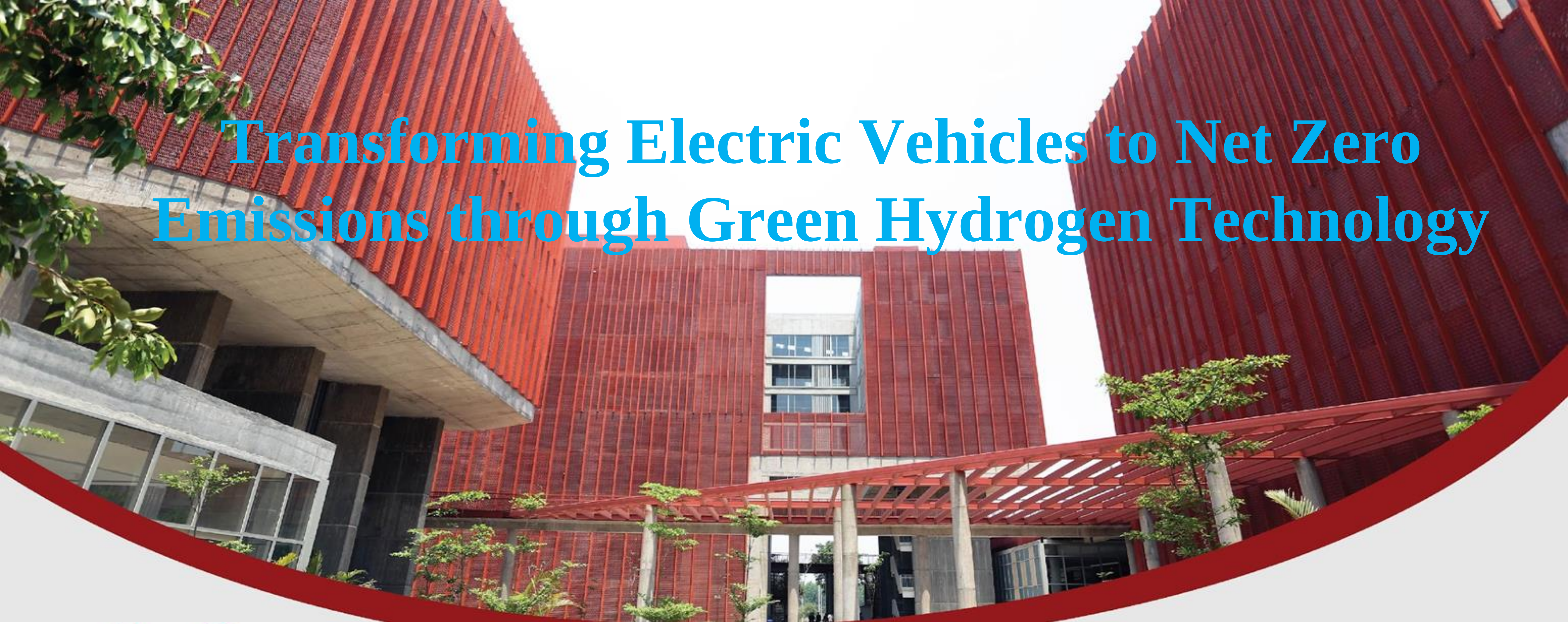
Transforming Electric Vehicles to Net Zero Emissions through Green Hydrogen Technology



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OF ENGINEERING & TECHNOLOGY
(Deemed to be Univerrsity)

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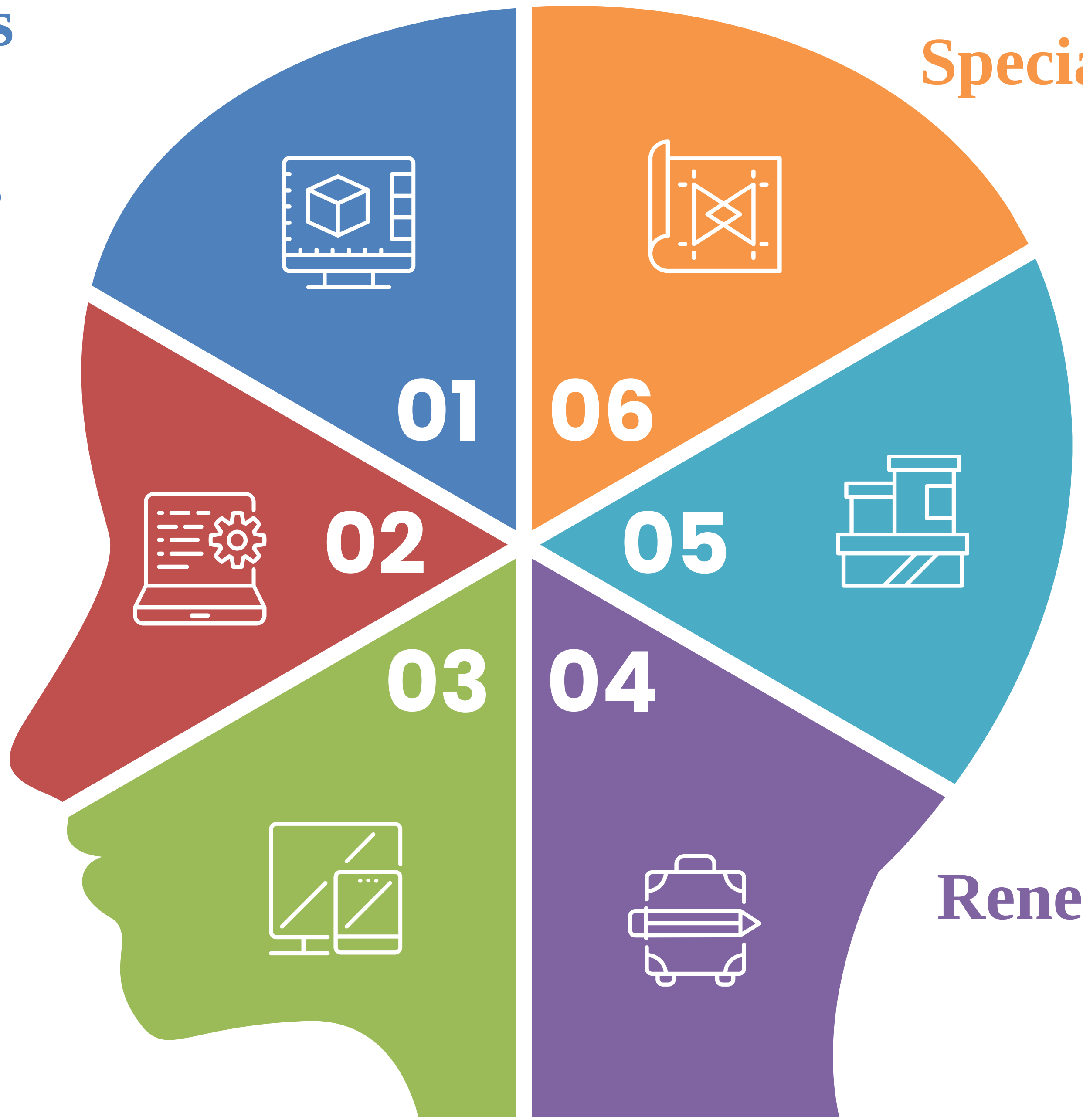
IEEE PES
Power & Energy Society®
Nepal Chapter

Research Domain

Power Electronics
&
Electrical Drives

Electric Vehicles (EVs),
Hybrid EVs
&
Green Hydrogen EVs

Acoustic Noise
&
Vibration of
Electric Machines



Special Electrical Motors
PMSM, BLDC
SRM, SynRM

Condition Monitoring
&
Fault Diagnosis

Renewable Energy Resources
Solar and Wind

Speaker Biodata

Dr. Rajesh M. Pindoriya (GM'14 - M'20 – SM'22) received a B. Tech degree in Electrical and Electronics Engineering from Rajasthan Technical University Kota, Rajasthan, India in 2012 and M. E. in Power Electronics and Electrical Drives from Gujarat Technological University, Ahmedabad, Gujarat, India in 2014. He received a Ph.D. degree in Power Electronics and Electrical Drives from the Indian Institute of Technology Mandi (IIT Mandi), India, in 2020. He worked as a Project Engineer at IIT Mandi, India from Aug. 2020 to Jun. 2022. He is currently working as an Assistant Professor in the Department of Electrical and Instrumentation Engineering at Thapar Institute of Engineering & Technology (TIET), Patiala, Punjab, India.

His present interests and expertise are being inclined (but not limited) to, controlling special electrical motors such as Permanent Magnet Synchronous Motor (PMSM), Brushless Direct Current (BLDC) motor, Switched Reluctance Motor (SRM) and Synchronous Reluctance Motor (SynRM) drives for the application in Electric Vehicles (EVs) and Green Hydrogen Vehicles. He is also working on the design of novel power electronics modulation techniques for the reduction of acoustic noise and vibration of special electrical motors.

Dr. Pindoriya is a Chapter Area Chair of Region 10, East and South Asia. He is a founding chairperson and advisor of IEEE PELS, SIGHT Student Branch chapter IIT Mandi and IEEE IAS-PES Student Branch Chapter Thapar Institute of Engineering and Technology, Patiala, respectively. He is a currently mentor of the IEEE Student Branch IIT Mandi. He is a member and executive at large member of the PELS Student Subcommittee and PELS YP, respectively. Dr. Pindoriya is a Senior Member of IEEE, a Member of the Institution of Electronics and Telecommunication Engineers (IETE) (AM'17-M'21), and a Member of the Institution of Engineering (IE) (AM'17-M'21).

Outlines

Introduction: Net Zero Emissions

What is the Green Hydrogen Technology

Green Hydrogen Production Mechanism

Simulation of DC-DC Converter with PMFC

Conclusions

What is an Electric Drives

Definition of electric drive

- “Systems employed for motion control are called **drives**”
- “Drives employing electric motors are known as **electrical drives**”

Why its required

- To control the speed and torque of the electric motors

Applications of electric drives


Electric Vehicles


Celling fan

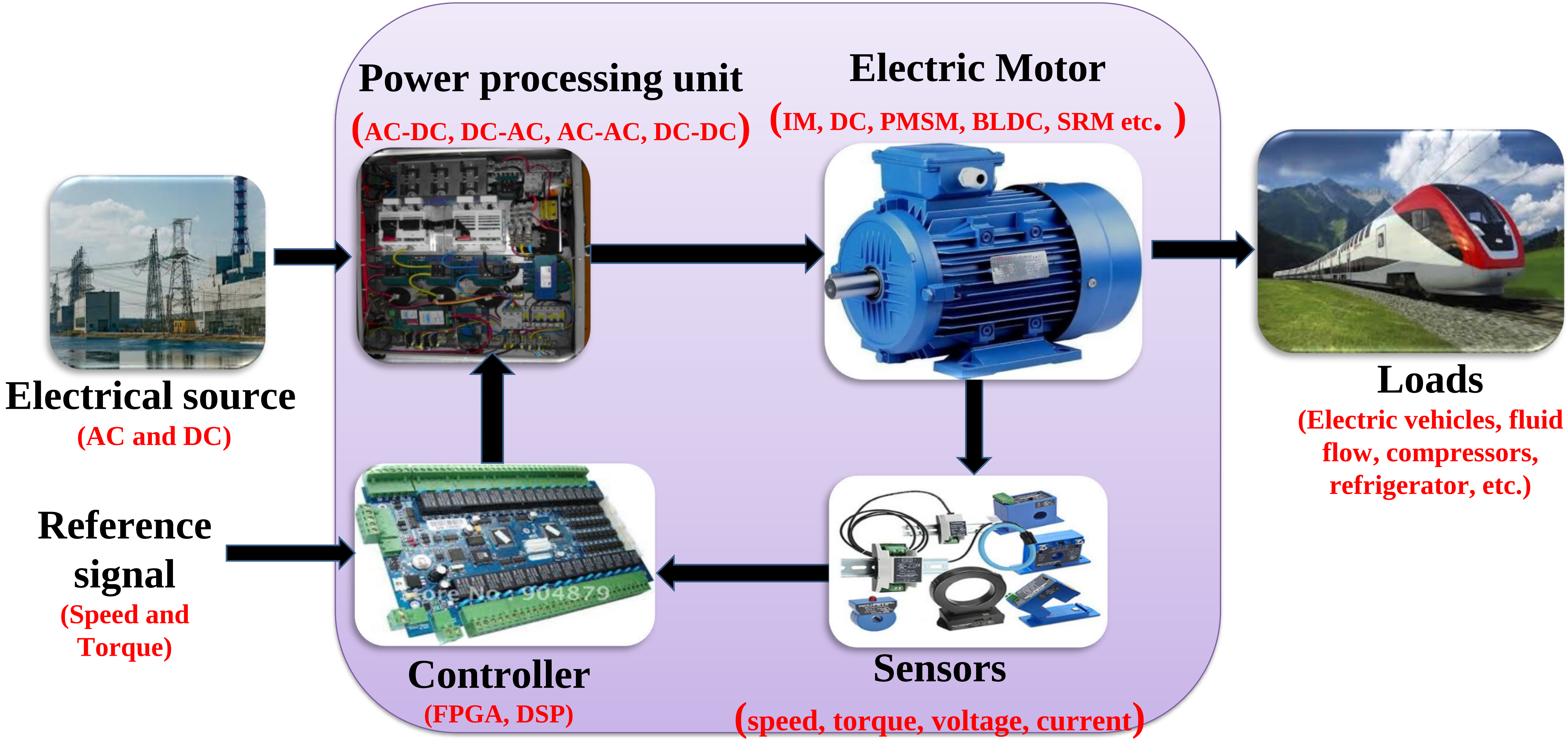

Refrigerator


Lift


Vacuumed cleaner


Ship

Introduction: Electric Drives



Net Zero Emissions

“Net zero emissions” refers to achieving an overall balance between greenhouse gas emissions produced and greenhouse gas emissions taken out of the atmosphere.

Think of it like a set of scales: producing greenhouse gas emissions tips the scales, and we want to get those scales back into balance, which means no more greenhouse gas can be added to the atmosphere in any given year than is taken out.

Introduction: Electric Vehicles

- Transport is a fundamental requirement of modern life, but **traditional Internal combustion (IC) engines are quickly becoming outdated.**

- Petrol or diesel vehicles are highly polluting and are being quickly replaced by fully Electric Vehicles (EVs) and Hybrid Electric Vehicles (HEVs) (see Fig. 1).

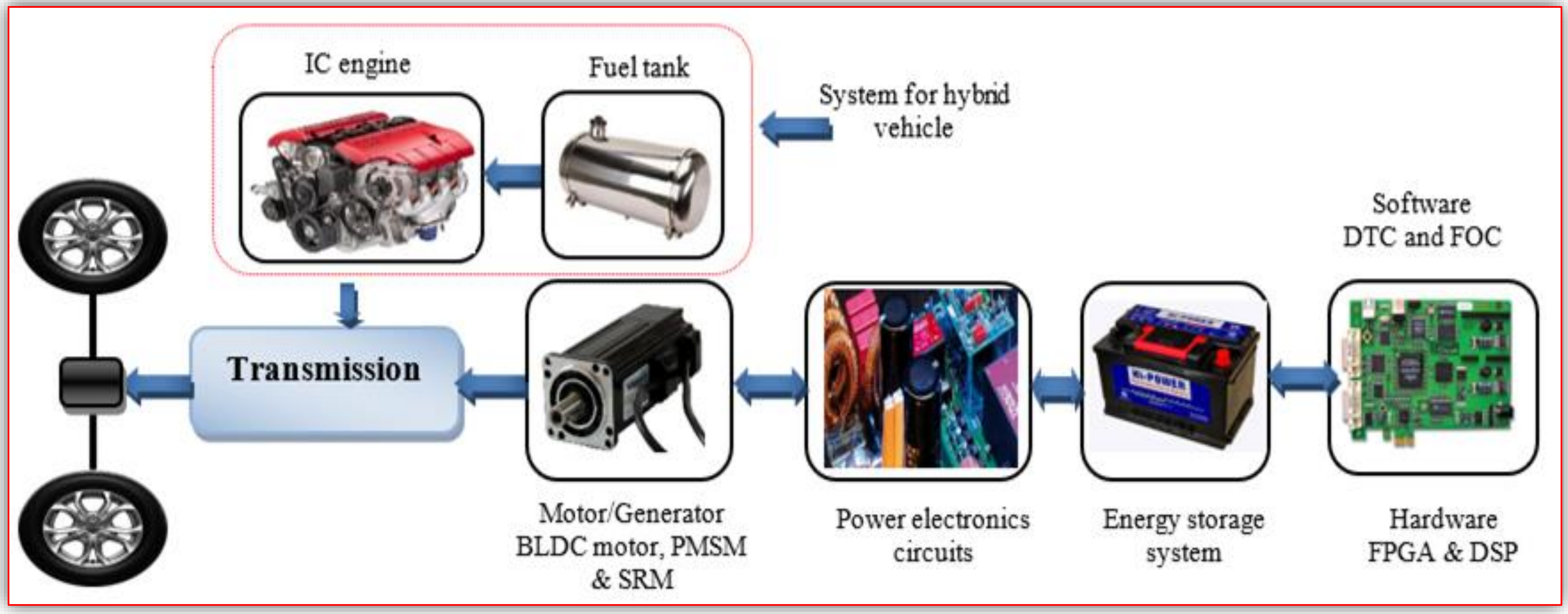
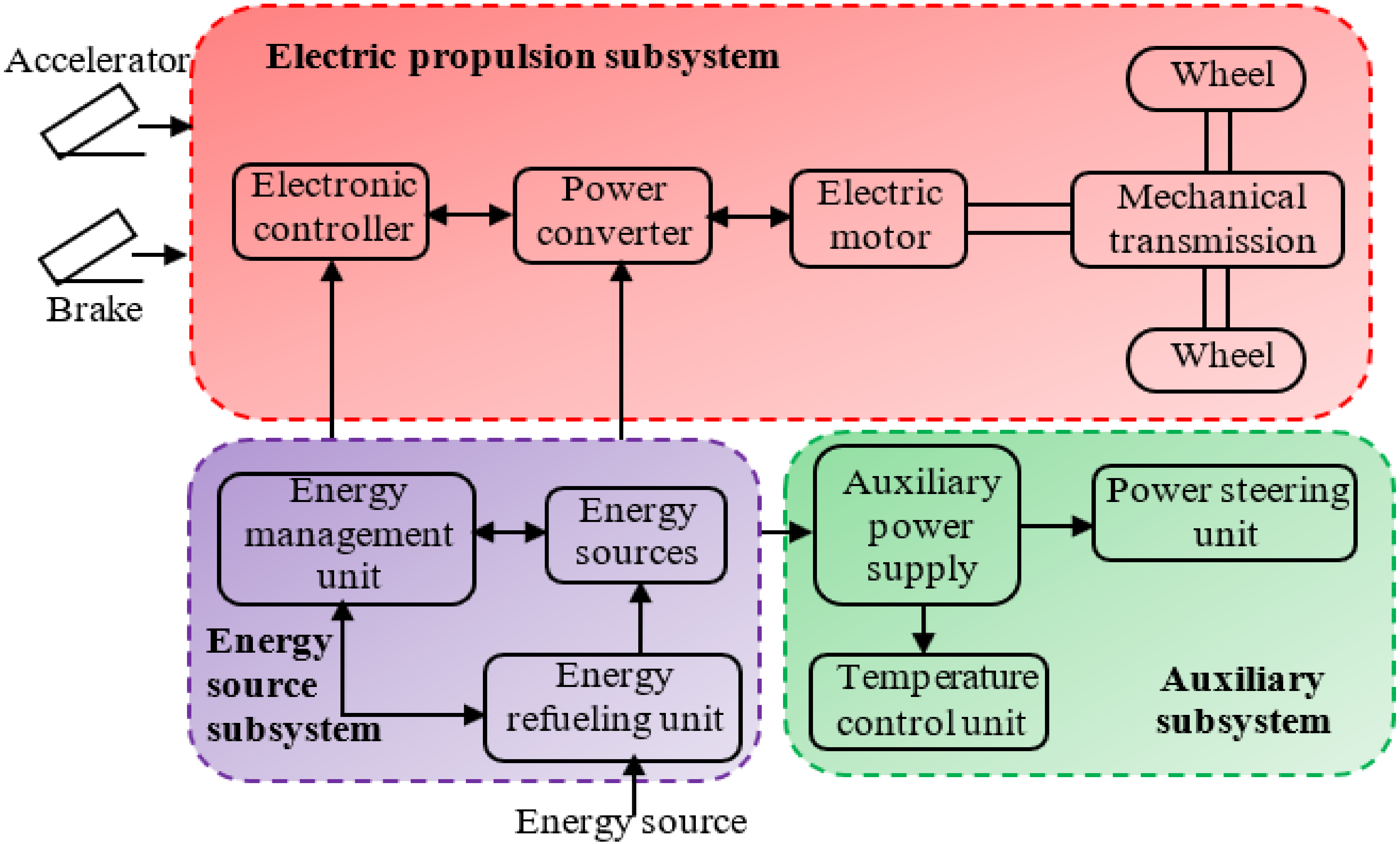


Fig. 1. A schematic layout of EVs and HEVs.

Components of Electric Vehicles



1. C. C. Chan, "The State of the Art of Electric and Hybrid Vehicles." Proc. IEEE 2002, 90, 247–275, 2002.

Benefits of Electric Vehicles

Lower running costs

Low maintenance cost

Petrol and diesel use is destroying our planet

Tax and financial benefits

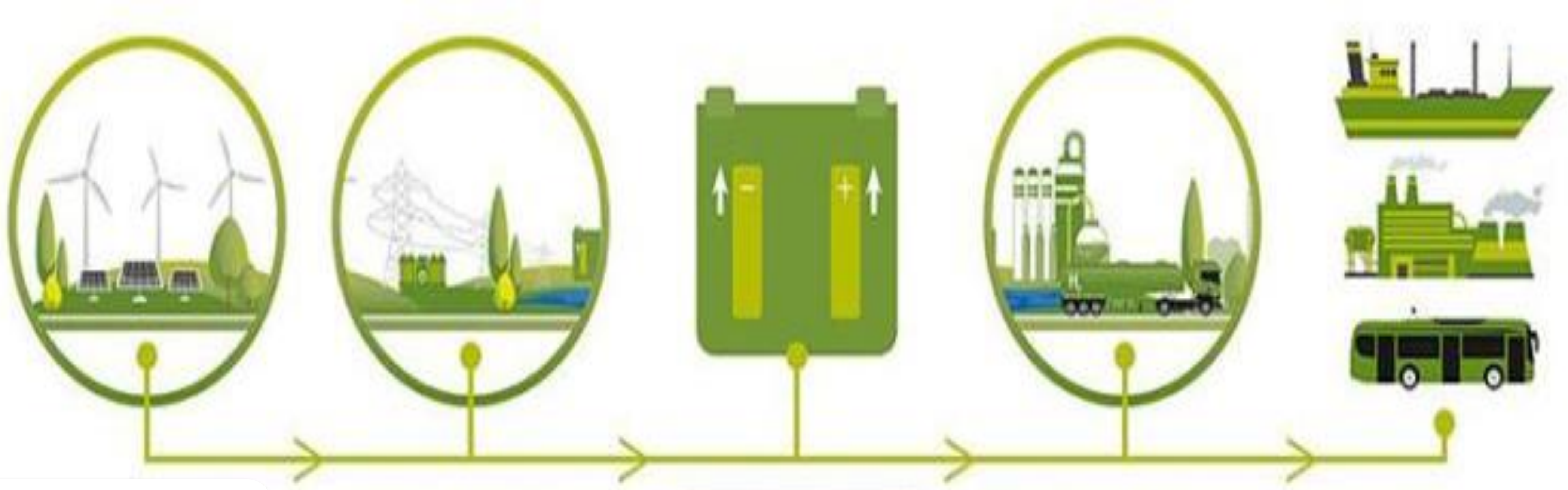
No noise pollution

Issues with Battery Operated Vehicles

1. Size of the Battery
2. Charging Time of the Battery
3. Not Possible to Long Drive

Introduction: Green Hydrogen Technology

- Green hydrogen is **hydrogen which is generated by renewable energy or from low-carbon power**.
- Green hydrogen has significantly lower carbon emissions than grey hydrogen, which is produced by steam reforming of natural gas, which makes up the bulk of the hydrogen market.



Renewable electricity generation

Getting electricity to an electrolyser

H_2 electrolyser

Distribution & storage of hydrogen

Net zero emissions

Source: https://www.sciencedirect.com/science/article/pii/S036031991732791X

Green Hydrogen Production

1. **Electrolysis:** Electricity is used in this process to split water into hydrogen and oxygen. This process has an efficiency of around 60-80% by calorific value.

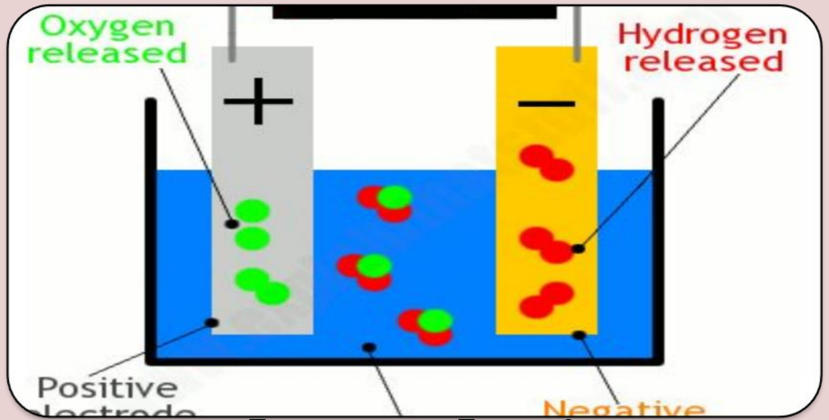
2. **Steam reforming:** Steam reforming can be used to convert methane, liquids derived from biomass resources, and biogas to hydrogen. This process provides the advantage of being a mature technology and easy transportation of input fuels with conversion on-site or at refueling stations.

3. **Fermentation:** In this process, sugar-rich feedstock from biomass is fermented to produce hydrogen using microbes either through direct hydrogen fermentation or microbial electrolysis cells (MECs).

A series of alternative production methods to split water is also under development. For example,

- **High-temperature water splitting,**
- **Photobiological water splitting,**
- **Photoelectrochemical water splitting,**

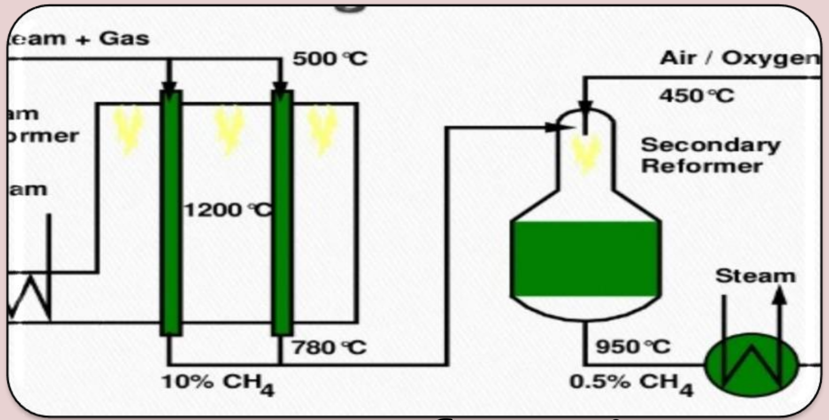
Green Hydrogen Production



Electrolysis

1.Need for improved overall energy efficiency.

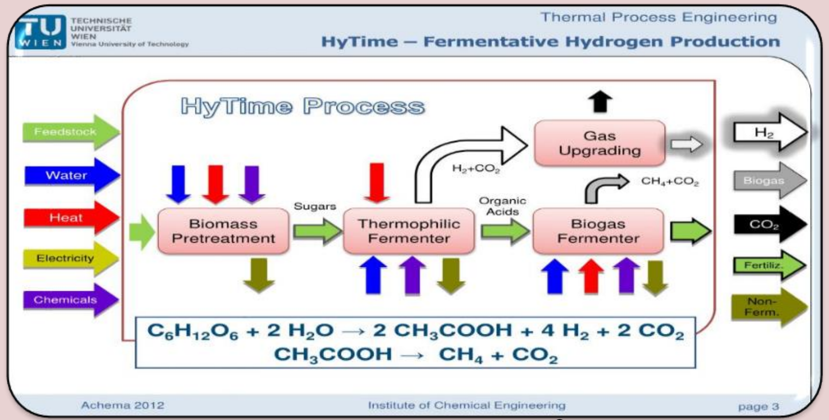
2.Need for additional onsite compressors.



Steam Reforming

1.High complexity of the reforming process.

2.Low overall efficiency of the process

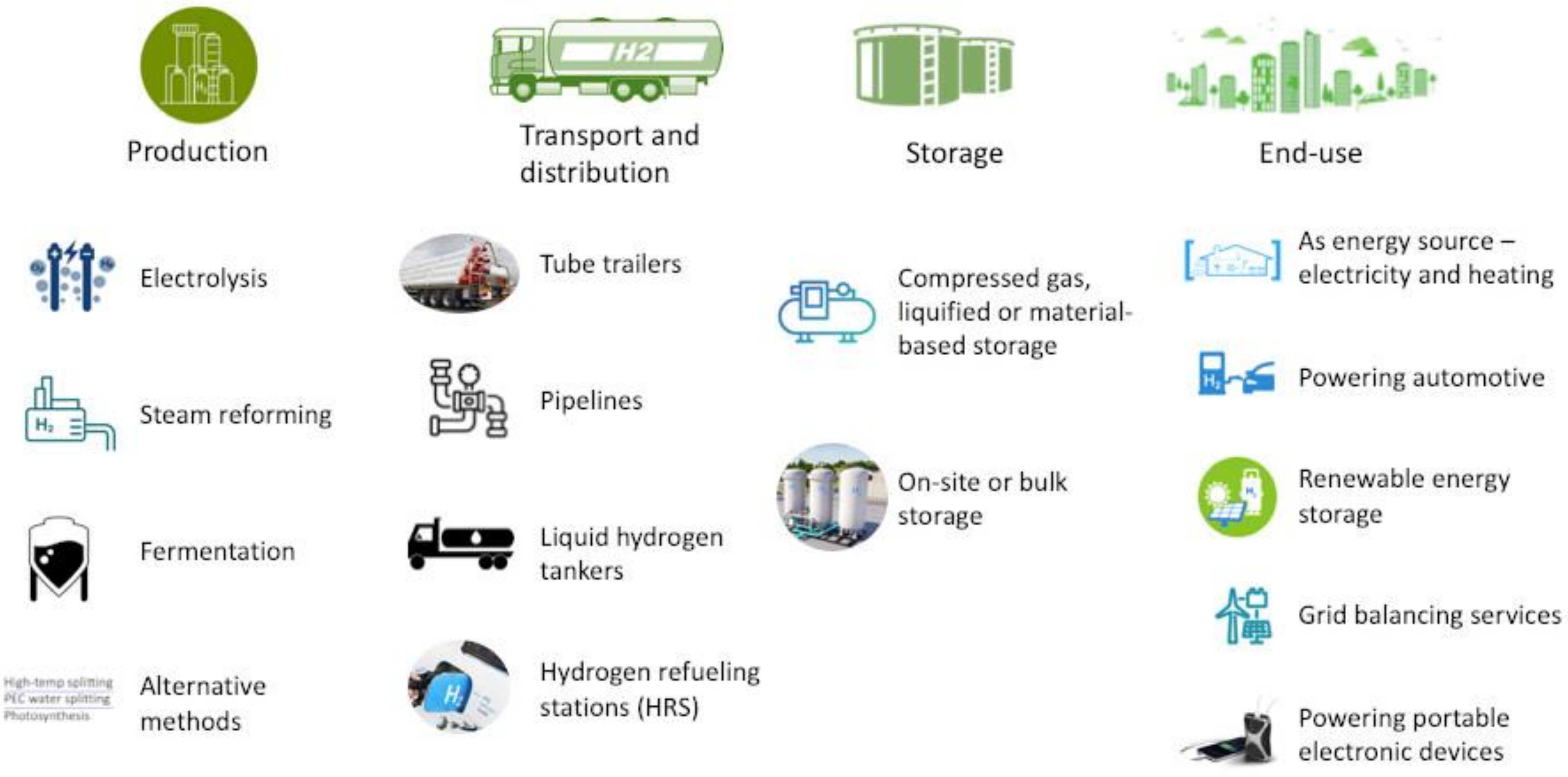


Fermentation

1. Low overall efficiency of the biogas reactor.

2.Low rates and yields of hydrogen production from fermentation.

Production to end use of Hydrogen



Source: “Hydrogen.” https://hydrogeneurope.eu/index.php/projects (accessed Dec. 30, 2020).

Classifications of Hydrogen

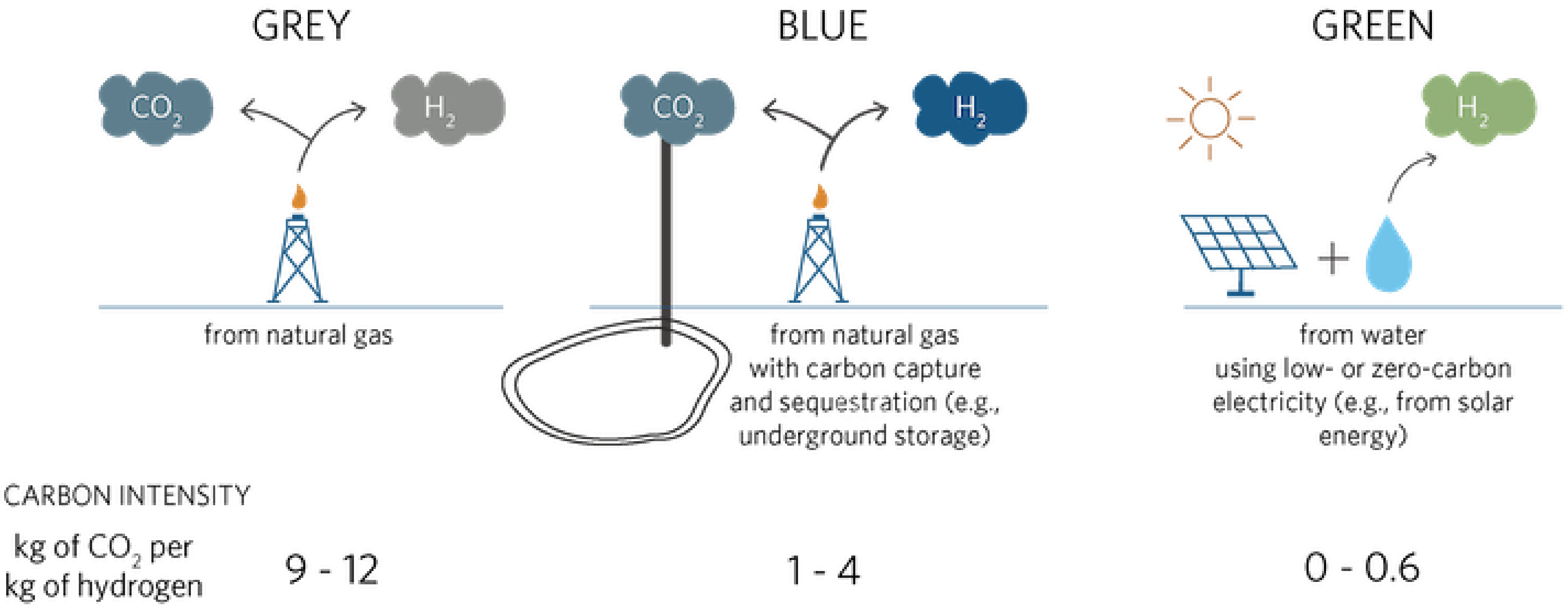
Brown Hydrogen	Grey Hydrogen	Blue Hydrogen	Green Hydrogen
Hydrogen is produced when ***coal*** is transformed under high-pressure conditions, and the resulting **carbon dioxide is released** back into the air	Hydrogen is produced when **natural gas** is transformed by burning methane and the resulting **carbon dioxide is released** back into the air	Hydrogen is produced from **natural gas**, but the output **carbon dioxide is captured and stored** thereby avoiding carbon emission	Hydrogen is **extracted from water** using a method called electrolysis that is **powered by renewable energy** such as wind, solar and etc.

Source: Green hydrogen to our rescue … – Lakes of India

Carbon Footprint of Hydrogen

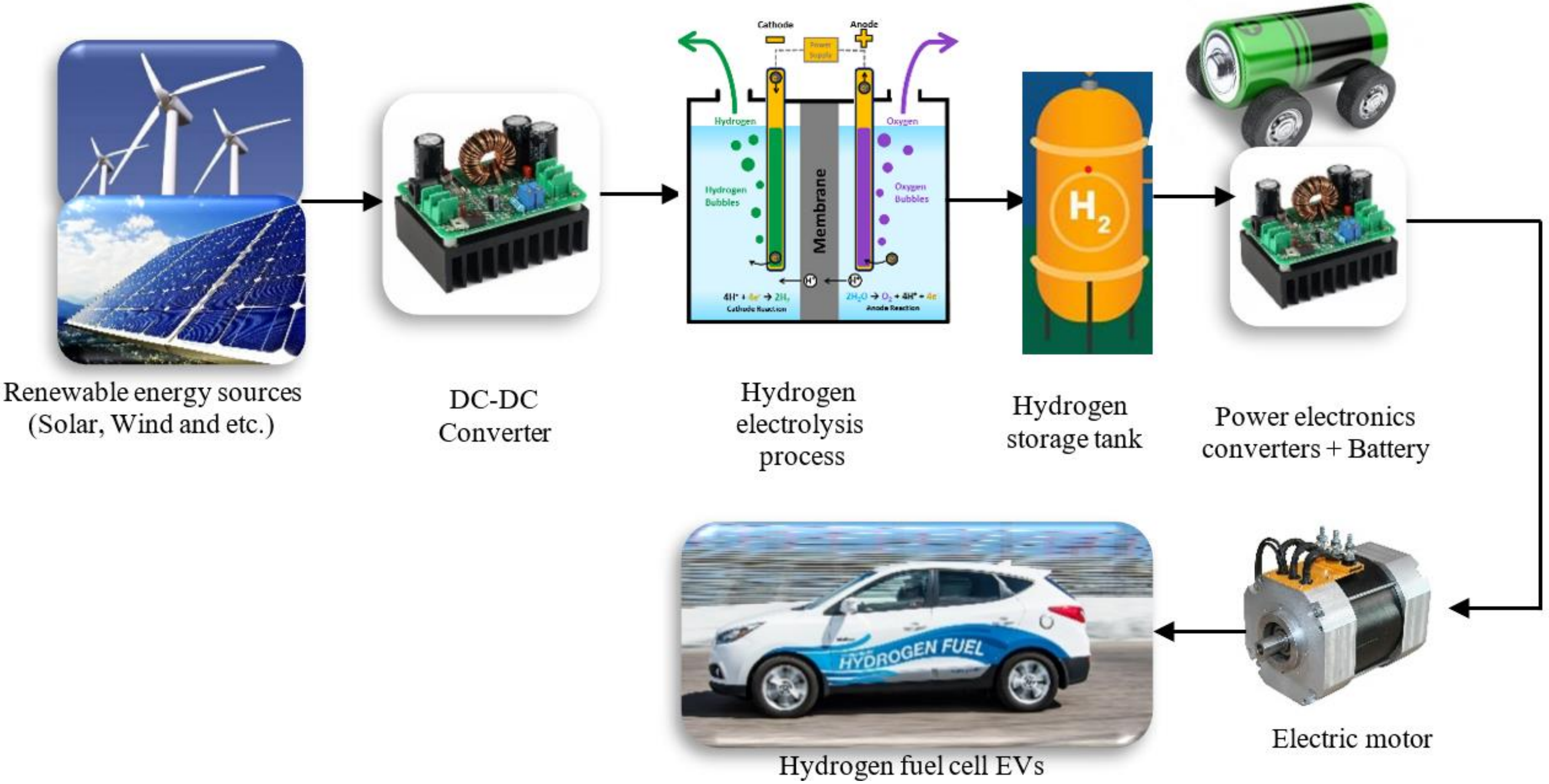
Hydrogen is a zero-carbon fuel, and it comes in three basic colors:

1. Grey
2. Blue
3. Green

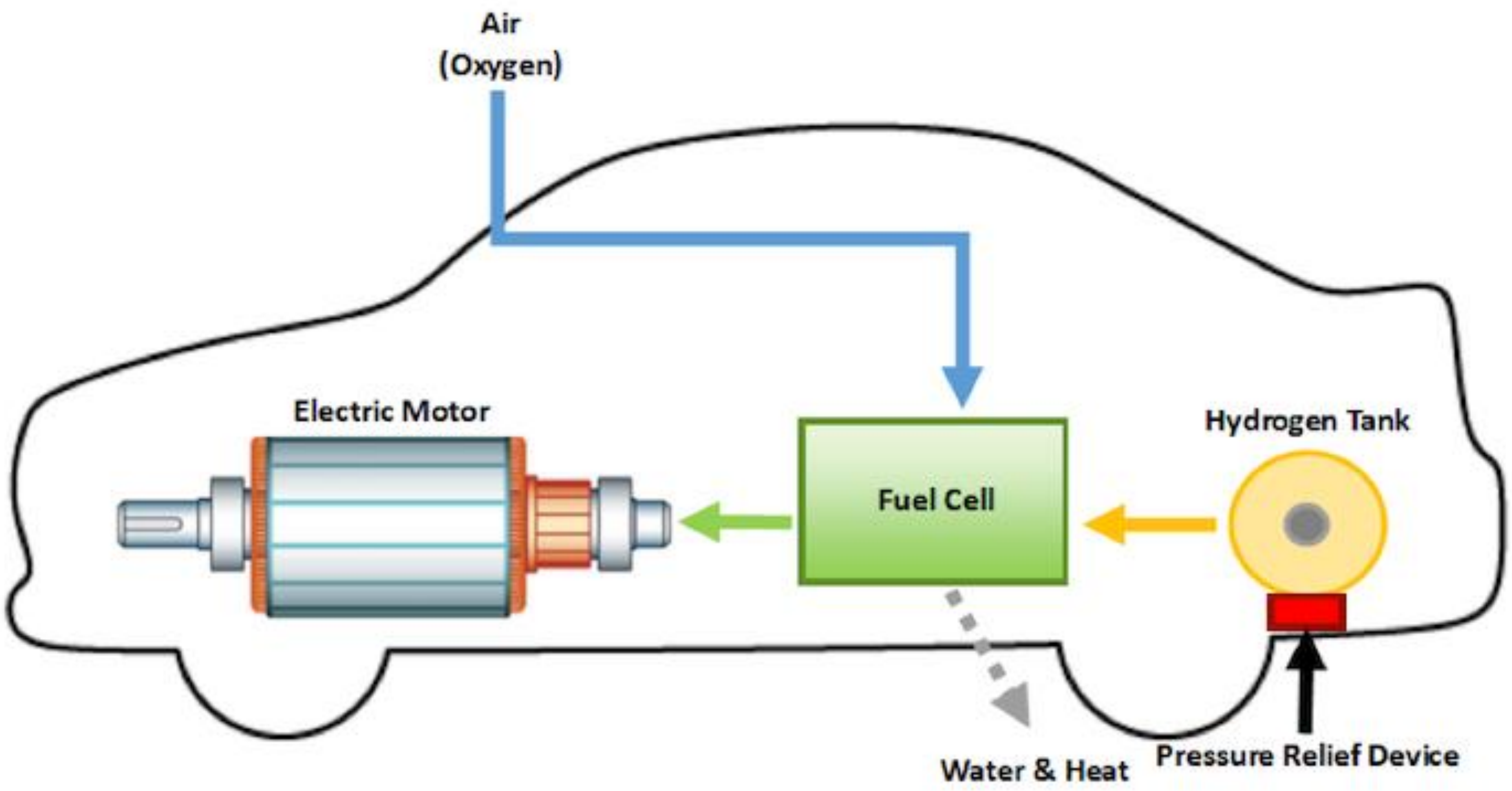


Source: [OPINION: Why green hydrogen — but not grey — could help solve climate change - Elliot Lake News (elliotlaketoday.com)]

Schematic Layout of Powered by Hydrogen FCEVs



Schematic Layout of Green Hydrogen Vehicles



Source: [Hydrogen Fuel Cell Vehicles—What First Responders Need to Know | Firehouse]

Working Principle of Green Hydrogen Vehicles

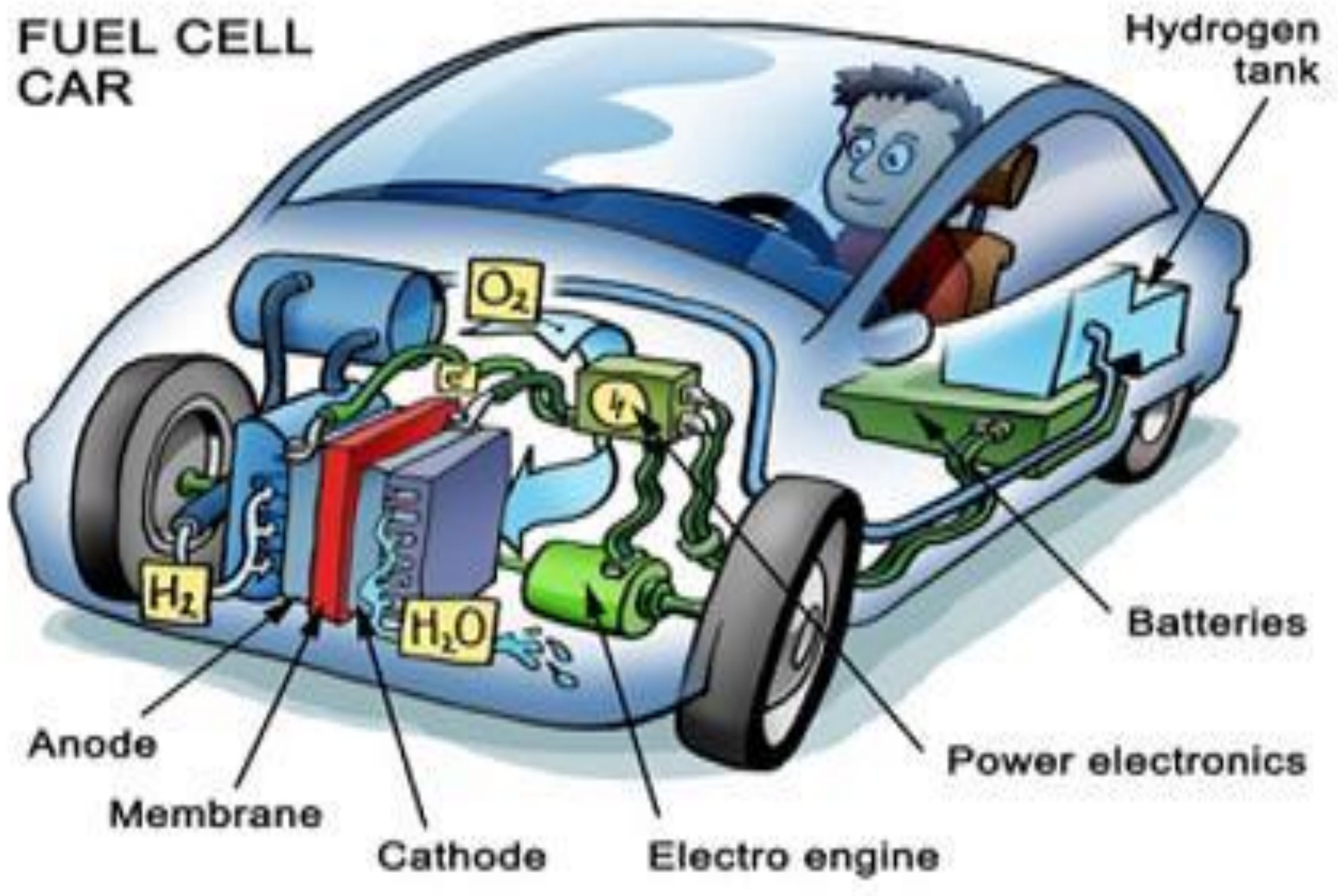
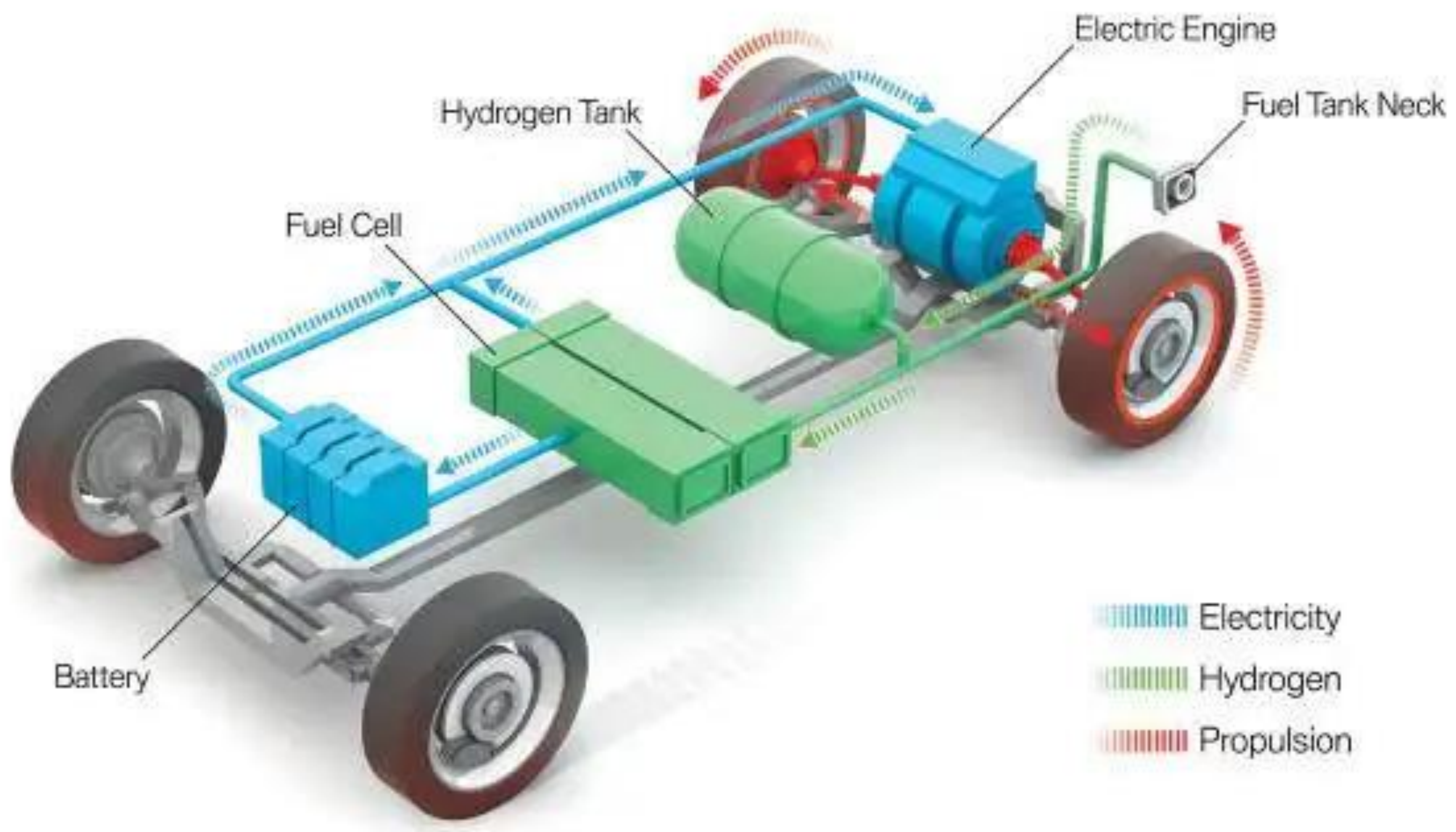


Fig. 2. Internal structural of Hydrogen vehicle.

- Hydrogen is passed into the fuel cell along with air as shown in Fig. 2.
- Inside the fuel cell, **the hydrogen atom is split into protons and electrons.**
- The electrons, and specifically the steady flow of electrons, **are the electricity used to operate the electric motor that drives the vehicle.**
- While the fuel cell is producing electricity, **the protons from the hydrogen combine with oxygen from the air to produce water.**
- **The only drain that Hydrogen EVs produce is water vapor.**

Source: Hydrogen Vehicle - Assignment Point

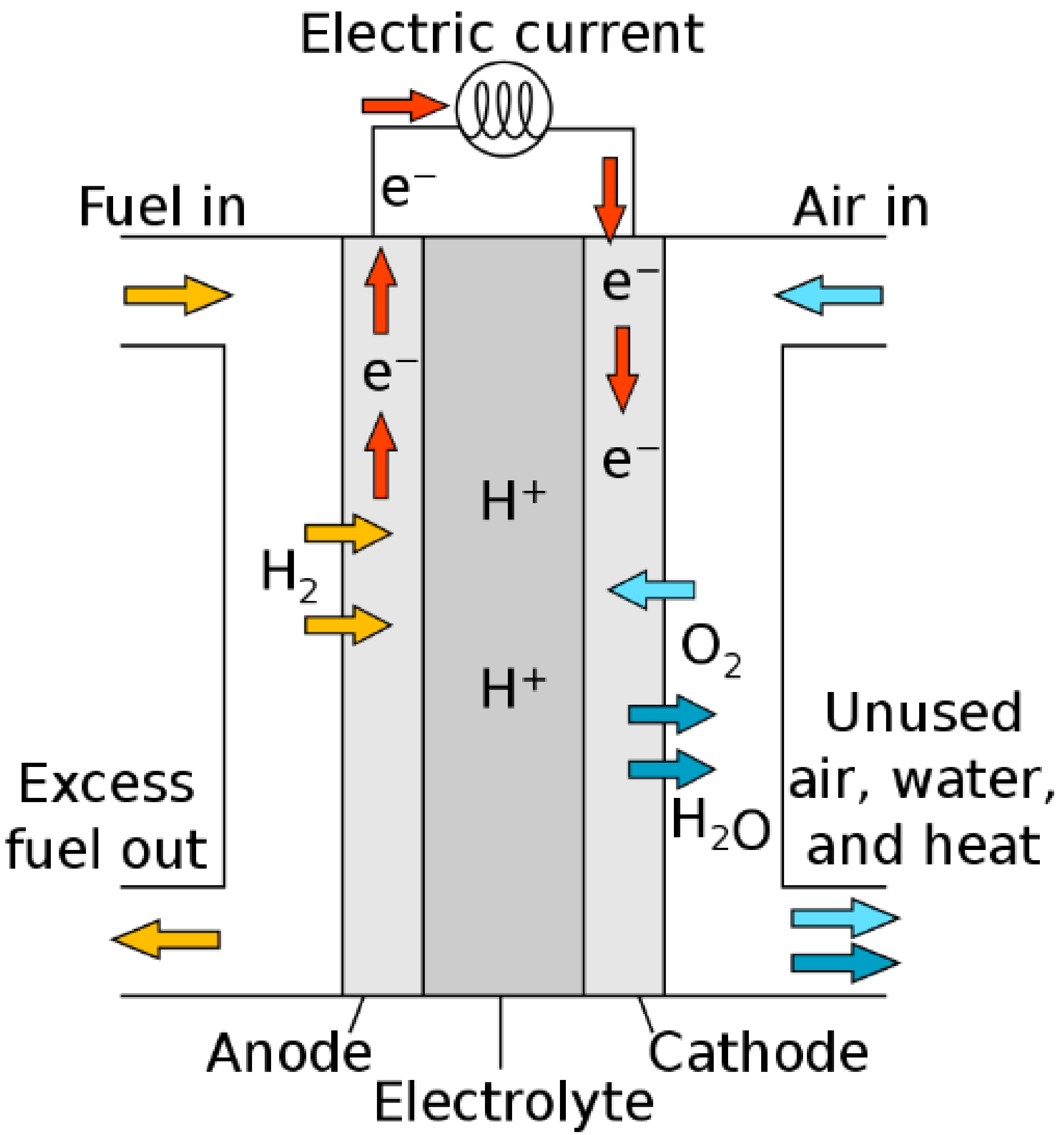
Internal Structural of Green Hydrogen Vehicles



Source: Hydrogen Fuel-Cell Vehicles - EEWeb

Internal Structural of Green Hydrogen Vehicles

Schematic Diagram of the PEM Electrolysis Process



Mathematical Formulations of PMFC

The chemical reactions that occur at the anode and cathode in a PEM electrolyzer are given in (1) and (2) [11]:

$$H_2O + Energy\ + Heat\ \rightarrow 2H^+\ + 2e^-\ + \frac{1}{2}O_2 \qquad (1)$$

$$2H^+\ + 2e^-\ \rightarrow H_2 \qquad (2)$$

A voltage of electrical operation can be expressed by (3) [11]:

$$V = E_{rev} + V_{diff} + V_{mem} \qquad (3)$$

V: Operating voltage of an electrolyzes,
E_{rev}: Reversible voltage or open circuit voltage,
V_{diff}: Concentration voltage or diffusion voltage,
V_{activ}: Activation voltage,
V_{mem}: Membrane voltage or ohmic voltage

Mathematical Formulations of PMFC

The reversible voltage can be written from the Nernst Equation as [11]:

$$E_{rev} = E_0 + \frac{RT}{2F}\left[\frac{ln\left(PH_2\sqrt{PO_2}\right)}{aH_2O}\right] \quad (4)$$

where H_2O is the water activity between the electrode and membrane and E_0 is the reversible voltage depending on the temperature, it can be given by (5):

$$E_0 = 1299 - 9.109.10^{-4}(T - 298) \quad (5)$$

Concentration voltage is given by (6)

$$V_{diff} = \frac{RT}{2F}\left[ln\left(1 - \frac{I}{I_{lim}}\right)\right] \quad (6)$$

Mathematical Formulations of PMFC

The activation voltage is described by the Tafel equation [11]:

$$V_{act} = \frac{RT}{anF} \ln(\frac{I}{I_0}) \tag{7}$$

$$V_{act} = V_{act}^{an} + V_{act}^{ac} \tag{8}$$

where, V_{act}^{an} and V_{act}^{ac} are anodic and cathodic activation voltages, respectively;

$$V_{act}^{an} = \frac{RT}{a_a nF} \ln(\frac{I}{I_{0a}}) \tag{9}$$

$$V_{act}^{ac} = \frac{RT}{a_c nF} \ln(\frac{I}{I_{0c}}) \tag{10}$$

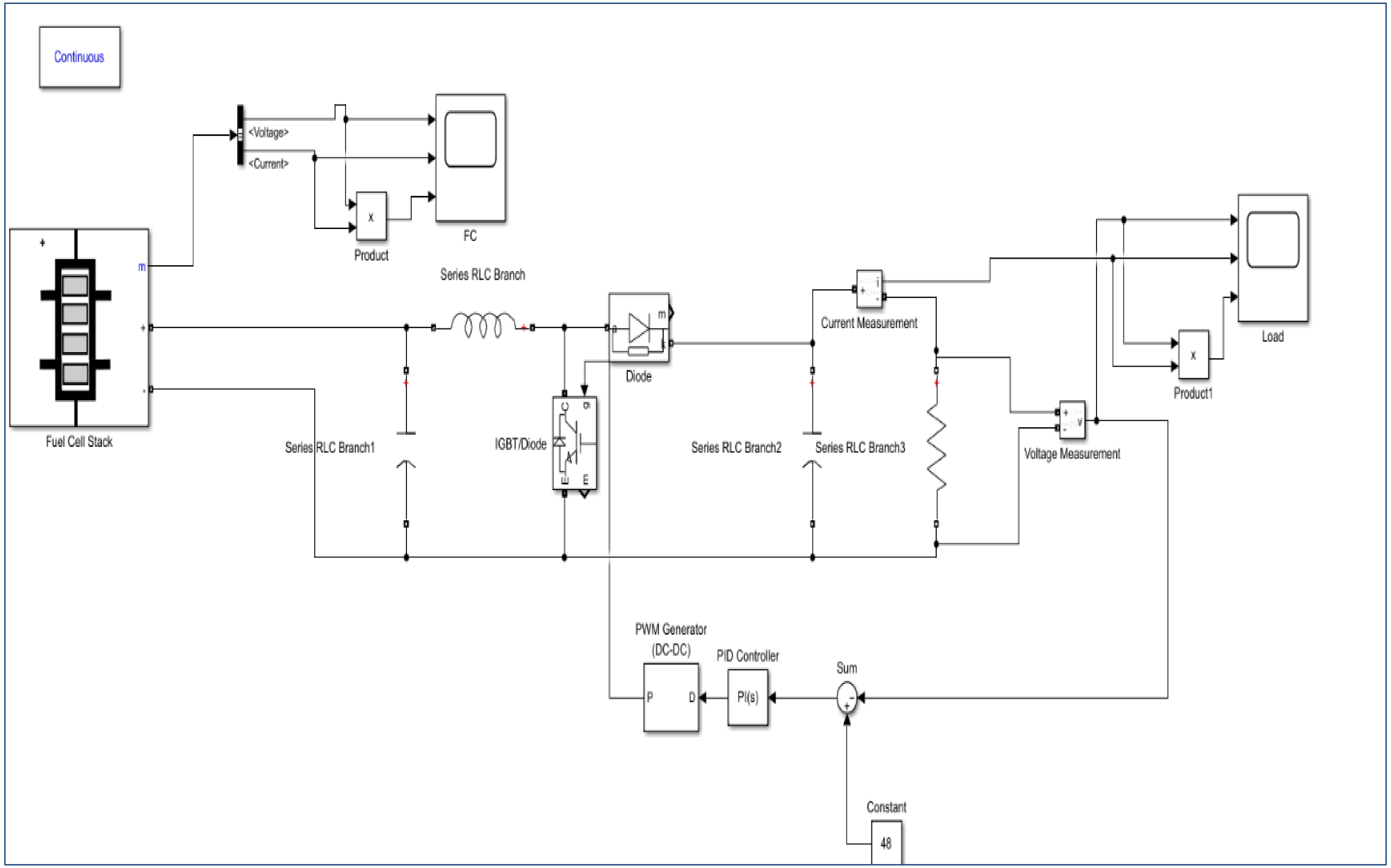
The membrane voltage is defined:

$$V_{mem} = R_{mem} \times I \tag{11}$$

Technical Parameters of Fuel Cell

Parameters	Values
Stack nominal power	1259 W
Stack maximum power	2000 W
Resistance	0.06187 ohms
Nerst voltage of one cell (En)	1.115 V
Nominal utilization of hydrogen	99.92%
Nominal utilization of oxidant	1.813%
Nominal consumption of fuel	15.22 slpm
Nominal consumption of air	36.22 slpm
Exchange current (io)	0.0273 A
Exchange coefficient (alpha)	0.308
Fuel composition	99.95%
Oxidant composition	21%
Fuel flow rate nominal	12.2 lpm
Fuel flow rate maximum	23.46 lpm
Air flow rate nominal	2400 lpm
Air flow rate maximum	4615 lpm
System temperature	328 K
Fuel supply pressure	1.5 bar
Air supply pressure	1 bar

Simulation of DC-DC Converter with Fuel Cell



Simulation of DC-DC Converter with Fuel Cell

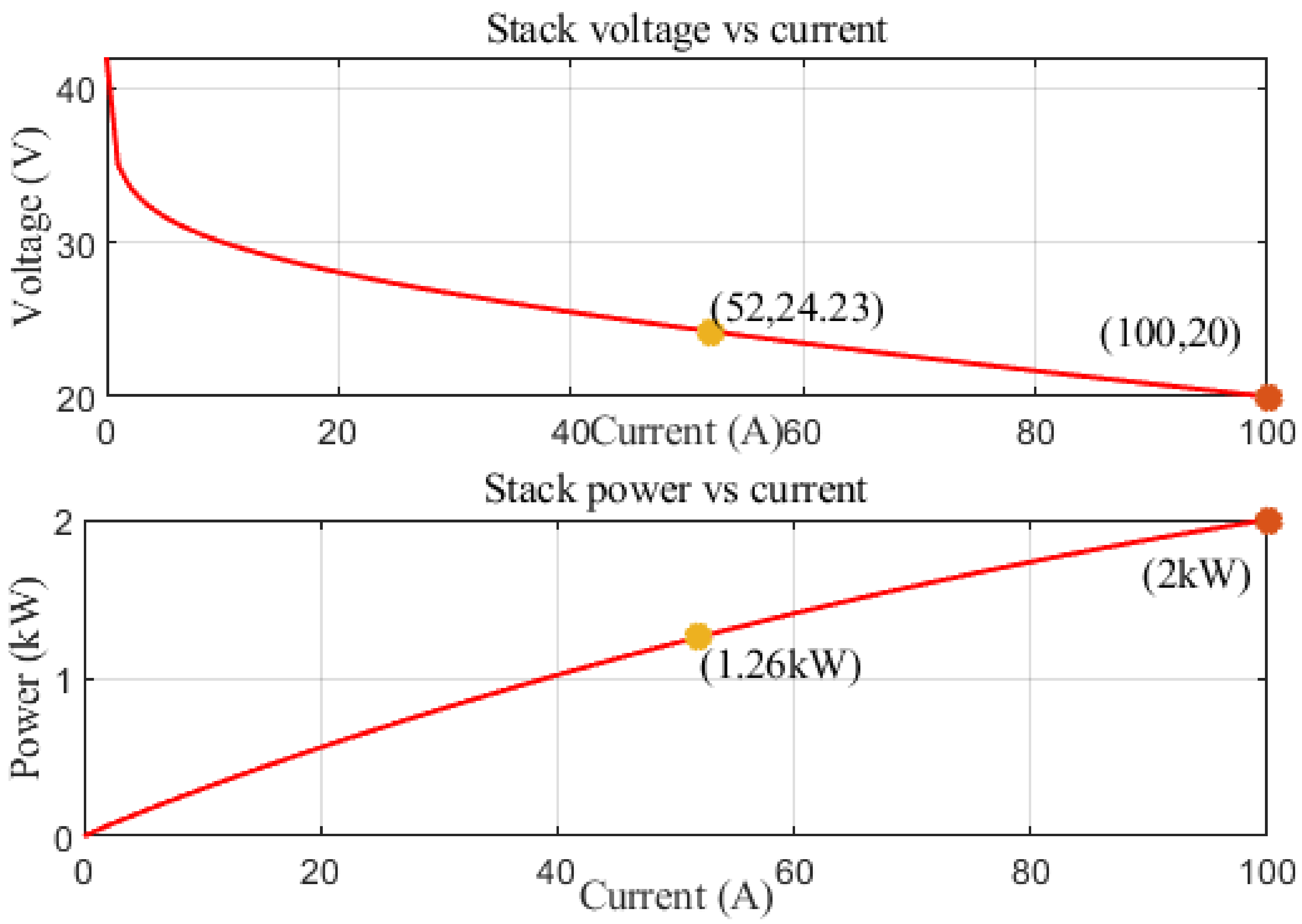


Fig. 3. Voltage vs current and power vs current characteristics of PMFC.

Simulation of DC-DC Converter with Fuel Cell

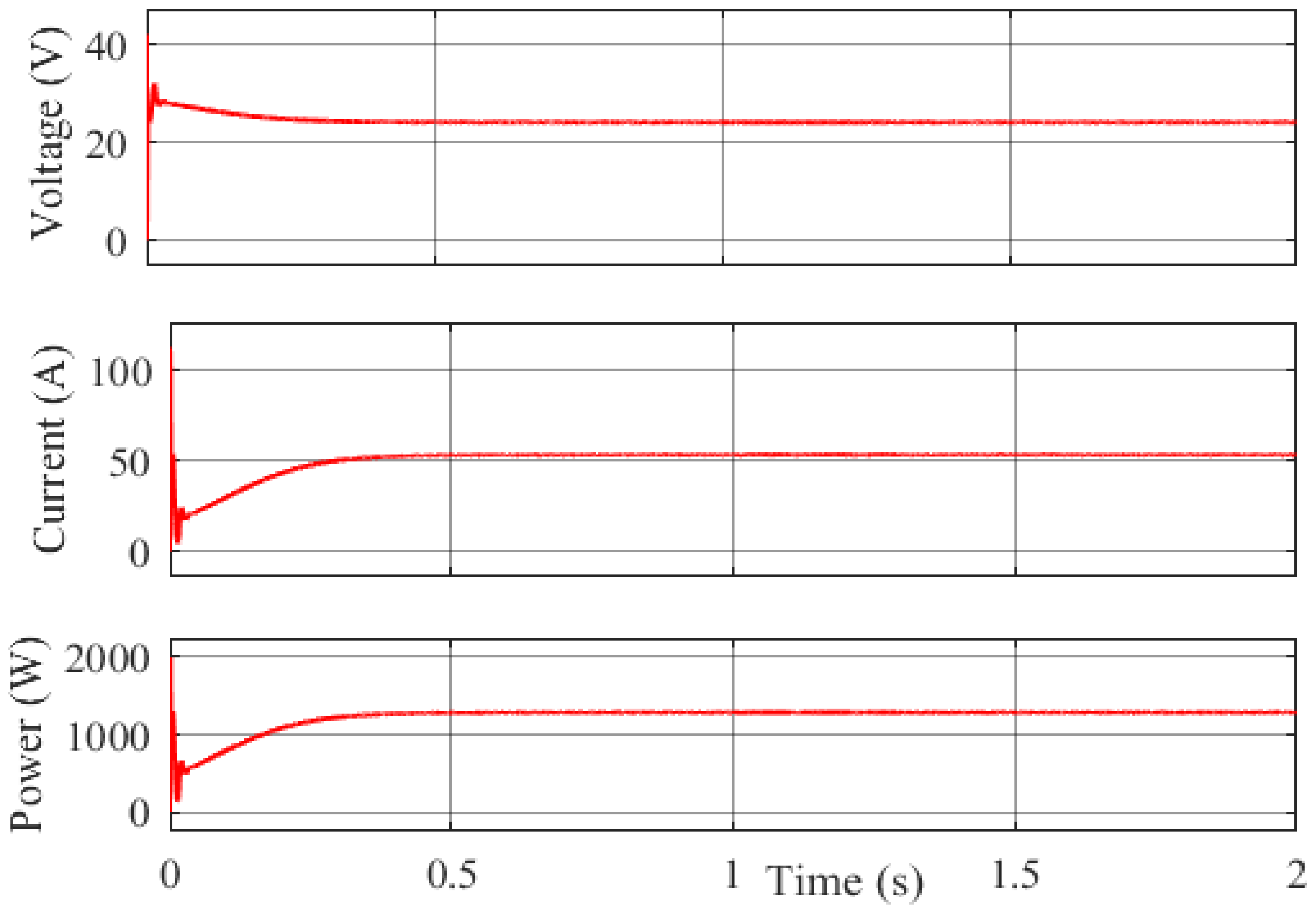


Fig. 4. Output voltage, current, and power of fuel cell.

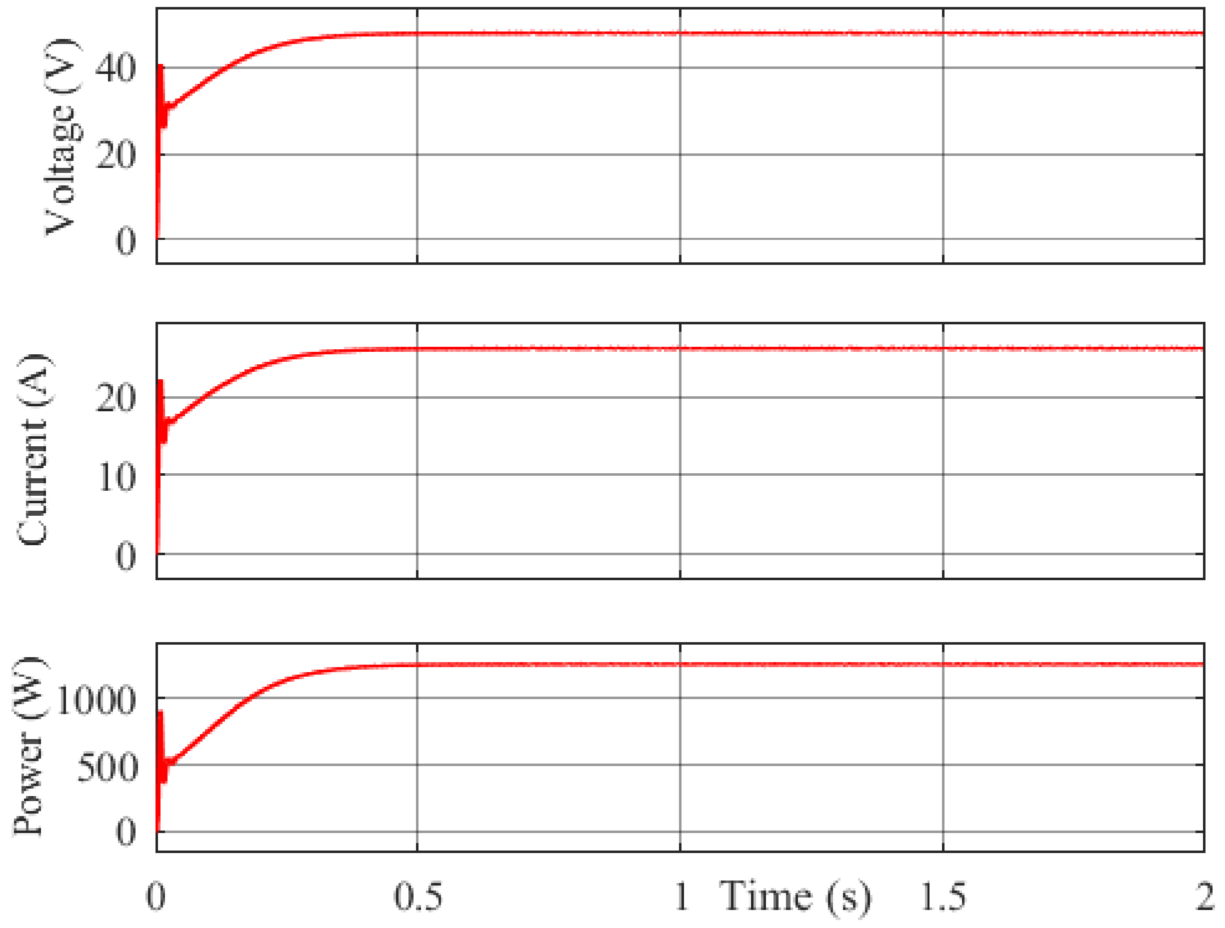
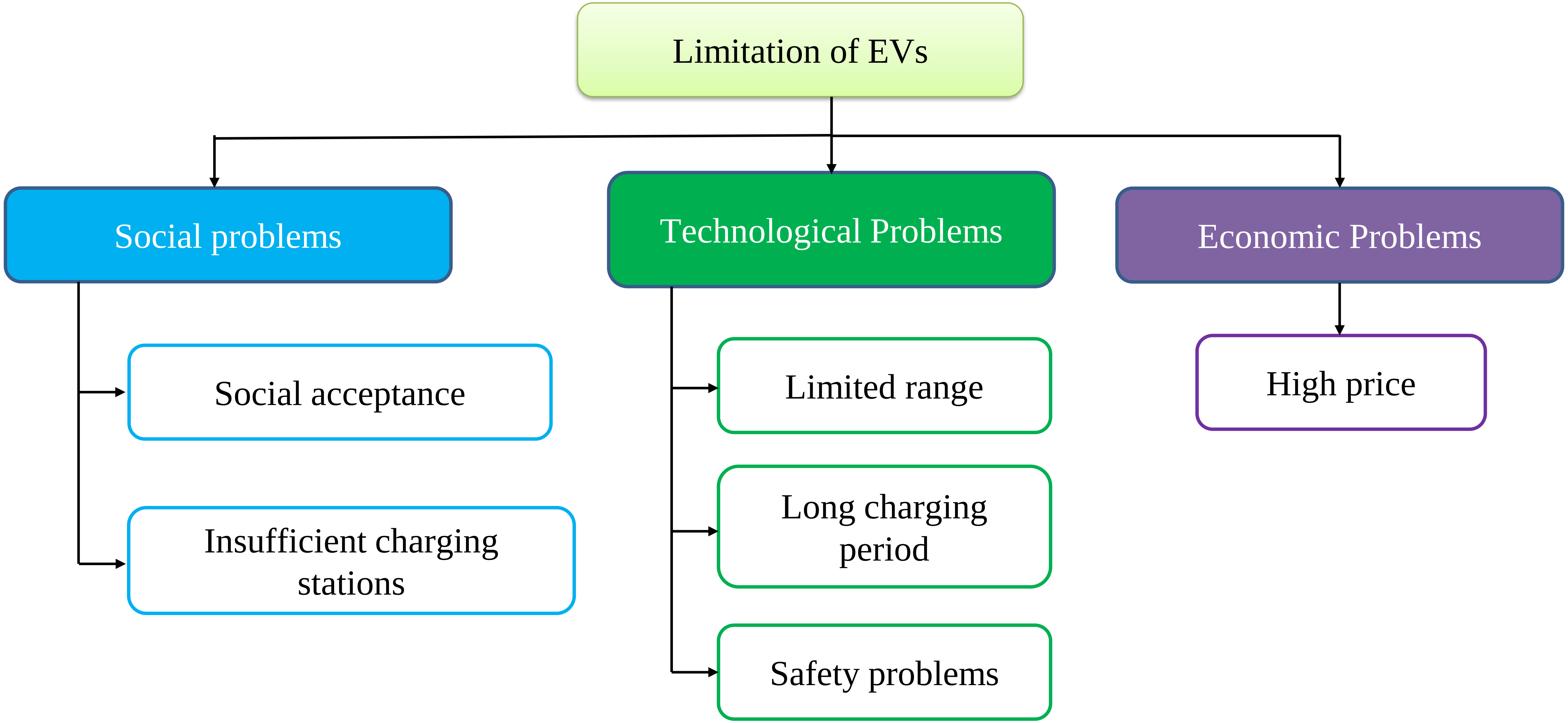


Fig. 5. Output voltage, current and power of boost converter.

Limitations of FCEVs



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Tentative Solutions of Current Limitations of FCEVs

Limitation	Probable solution
Limited range	Better energy source and energy management technology
Long charging period	Better charging technology
Safety problems	Advanced manufacturing scheme and build quality
Insufficient charging stations	Placement of sufficient stations capable of providing services to all kinds of vehicles
High price	Mass production, advanced technology, government incentives

Foot Race in Key FCEVs Factors

Factor	Foot Race
Recharging	Weight of charger, durability, cost, recycling, size, charging time
Hybrid EV	Battery, durability, weight and cost
Hydrogen fuel cell	Cost, hydrogen production, infrastructure, storage, durability and reliability
Auxiliary power unit	Size, cost, weight, durability, safety, reliability, cooling and efficiency

Major Trends and Future Developments

- Vehicles to Grid (V2G)
- Batter Charging Technologies
- Batter Battery Technologies
- Wireless Power Transfer
- Green Hydrogen Fuel

What are the Challenges Nowadays for Green Hydrogen Technology ?

The process of electrolysis is expensive

Storage of hydrogen is complex as its weight and volume are high

Costs about three times as much as natural gas

Current Areas of Research

- Reduce mass of overall vehicles
- Hydrogen production mechanism
- Improving the hardware
- Increase efficiency and life of battery

Summary

Production of green hydrogen

Battery Management System (BMS)

Design a net zero-emission EVs

Conclusions

- Net Zero Emission
- Battery Operated EVs
- Green Hydrogen Technology for EVs
- Green Hydrogen Production Mechanism
- Comparison of Battery Operated EVs and Green Hydrogen EVs
- Challenges of Green Hydrogen Technology for EVs

References

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Thank you for your attention

Queries

The future really is in our hands!