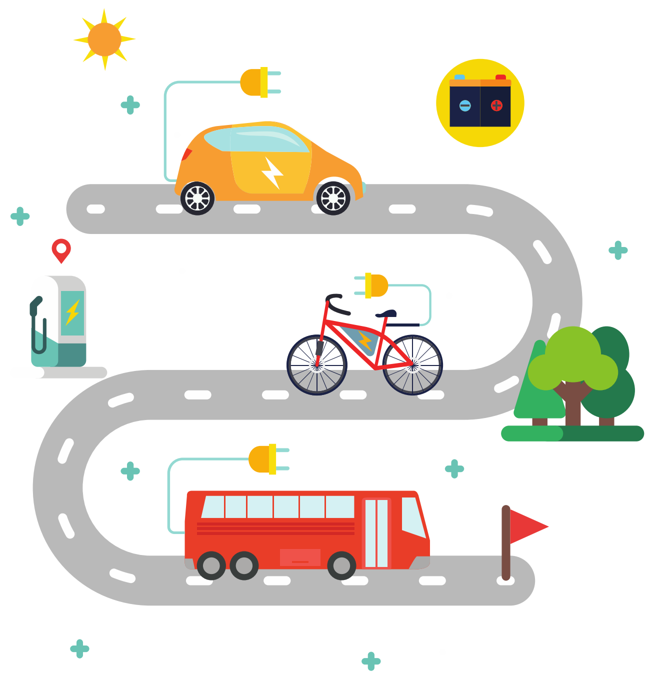

ELECTRIC MOBILITY FORUM

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Department of Science & Technology, Government of India

सत्यमेव जयते

Disruptive potential of fuel cell technology in transportation sector in India

March 24 , 2020
3:00 PM - 4:00 PM (IST)
WRI India Delhi

Speaker:
Prof Prakash Chandra Ghosh
Department of Energy Science and Engineering, IIT Bombay

Moderator:
Shravani Sharma
WRI India

WRI INDIA — ROSS CENTER

SHAKTI SUSTAINABLE ENERGY FOUNDATION

DISRUPTIVE POTENTIAL OF FUEL CELL TECHNOLOGY IN THE INDIAN TRANSPORTATION SECTOR

IIT Bombay

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Outline

- Introduction
- Overview of fuel cell technologies
- Fueling options for fuel cells
- Challenges for fuel cell vehicles
- Conclusions

About IITB and DESE

IIT Bombay

- Dept. of Energy Science and Engg was established in 2006
- Involved in energy related teaching and research
- Total of 23 faculties and > 400 students
- Offers Dual Degree (B.Tech-M.Tech and M.Sc.-Ph.D.), M. Tech and Ph.D. degrees

Introduction

Clean Environment
Clean water

Energy demand
Total: 43 kWh/day
Electricity: 6.65 kWh/day
Food: 67 Year @ 2500 kCal/day
Number: 6602 Million

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Threats and consequences

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THREAT

ON	BY
 	

CONSEQUENCES

- **Reserved fossil fuel is limited**
- **Depletion of fossil fuel**
  - Coal 300 Years
  - Petroleum 40 years
- **Future energy crisis**

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“The Stone Age did not end because we ran out of stones and the oil age will not end because we run out of oil”

Don Huberts

What is fuel cell

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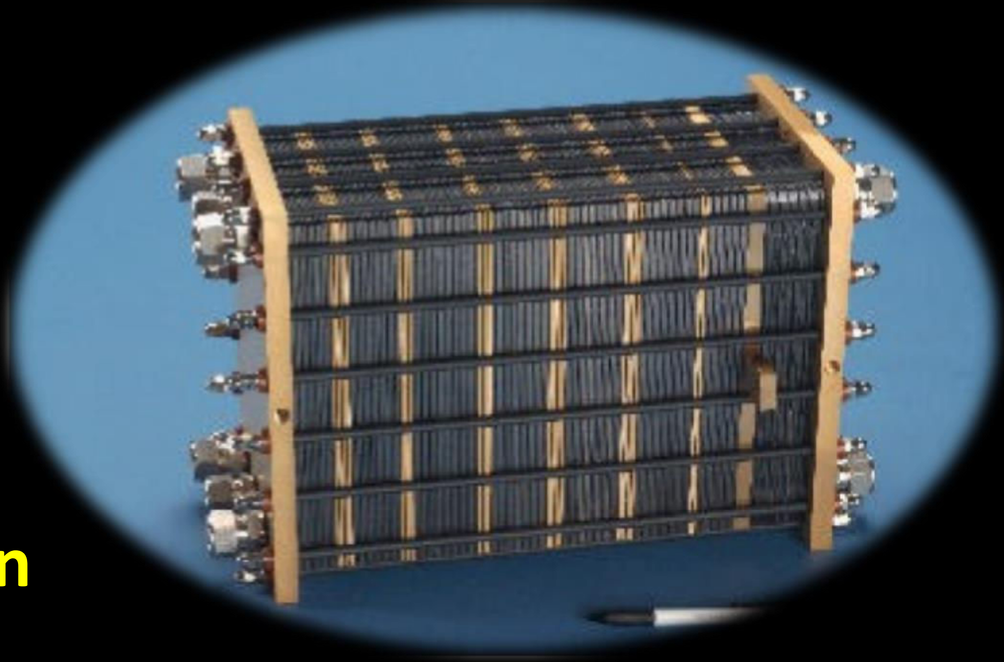
- Electrochemical devices which convert chemical energy directly to electrical energy
- Higher efficiency
- Higher lifetime
- No moving parts
- Extremely quite in operation
- Less emission



Efficiency

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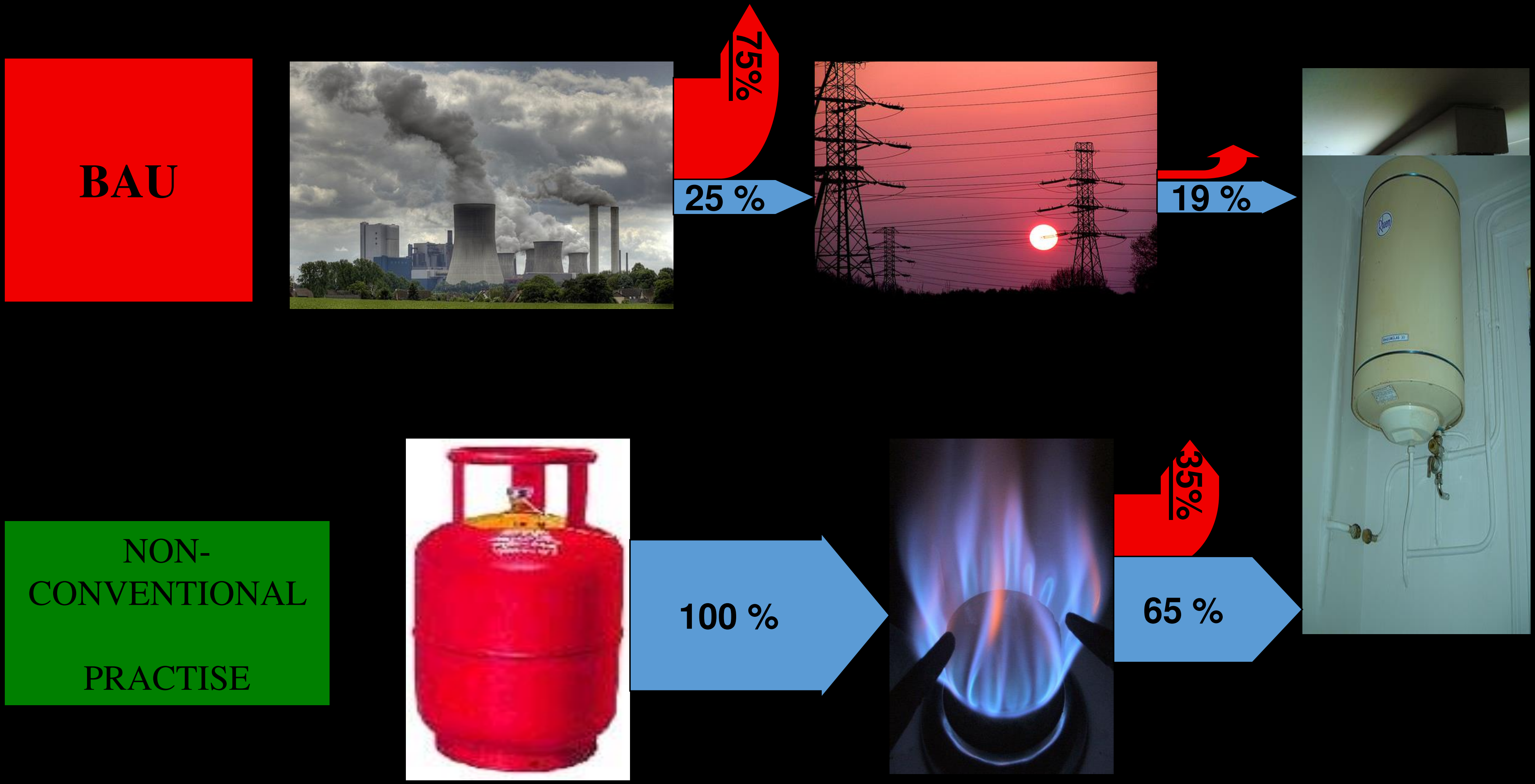

Efficiency comparison

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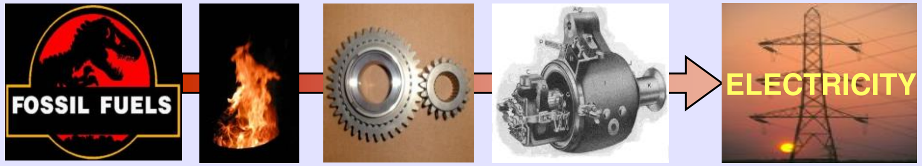
Conventional systems

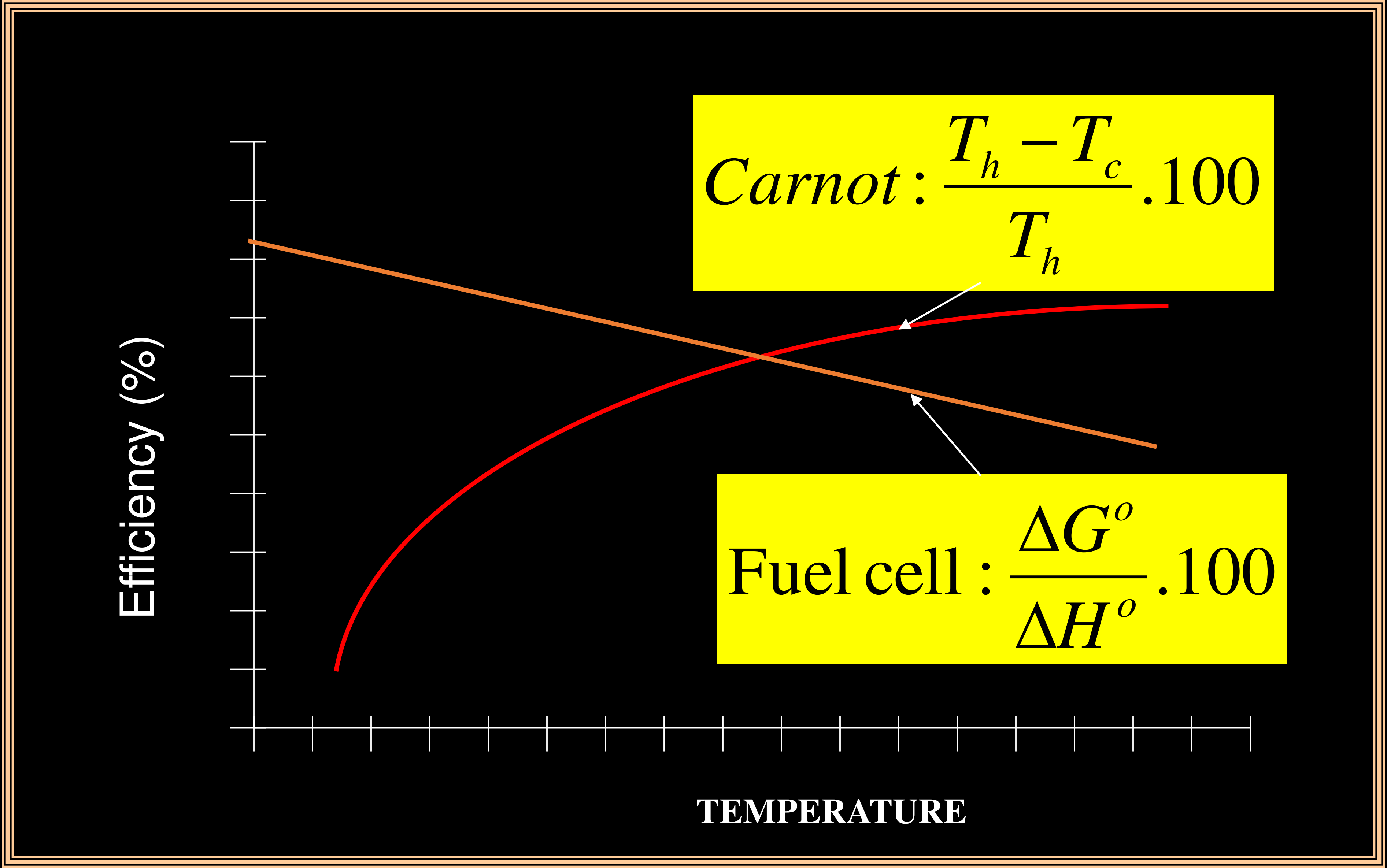


- Direct green house gas emission
- High temperature operation
- Lower efficiency
- Lower efficiency at partial load
- Loud operation
- Low investment cost
- Well established technology

Fuel cell based systems

- Indirect/lower emission
- High and low temp. operation
- Higher efficiency
- Higher efficiency at partial load
- Quiet operation
- High investment cost at present
- Under R&D

Efficiency comparison



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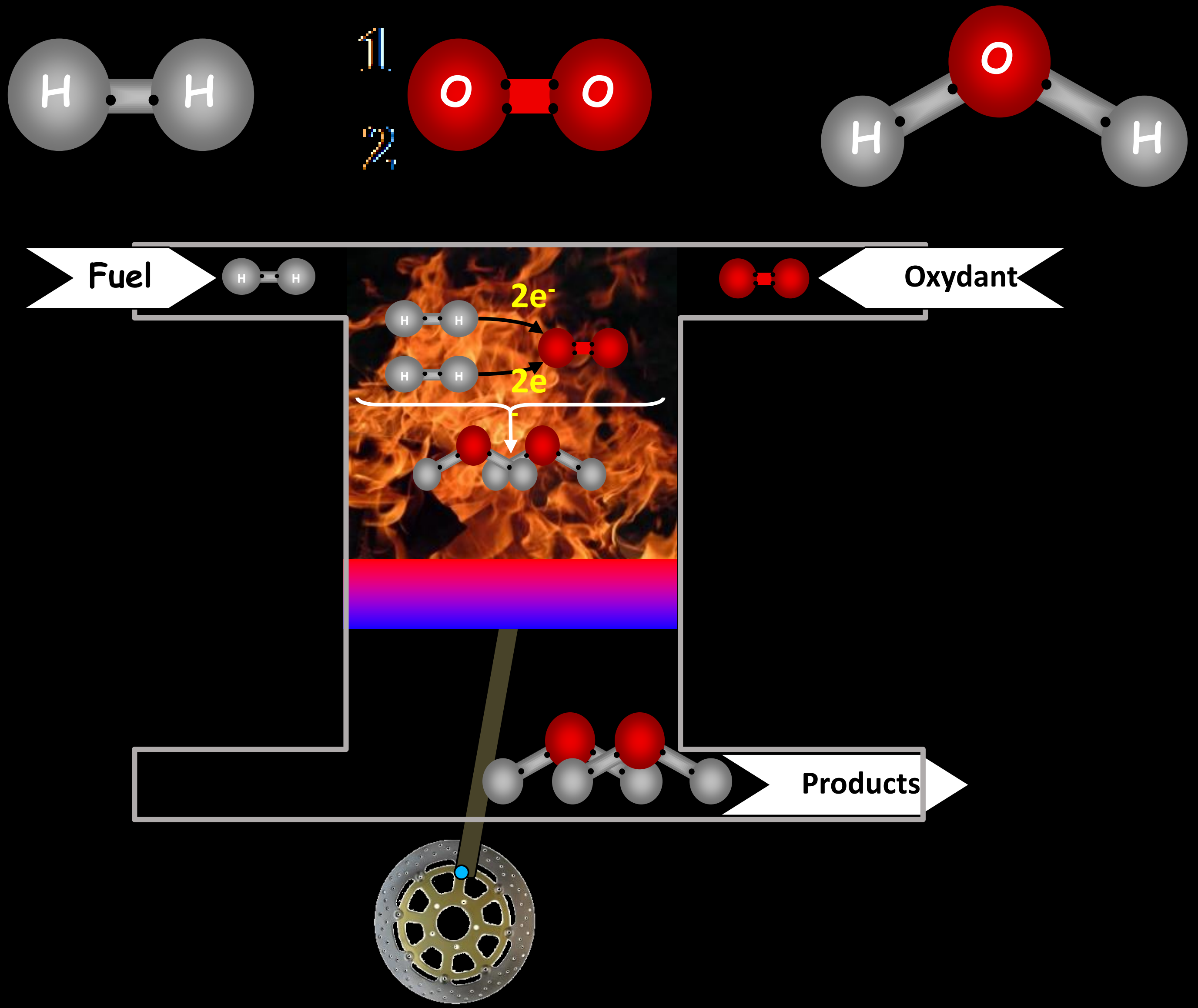
Fuel cells: Basics



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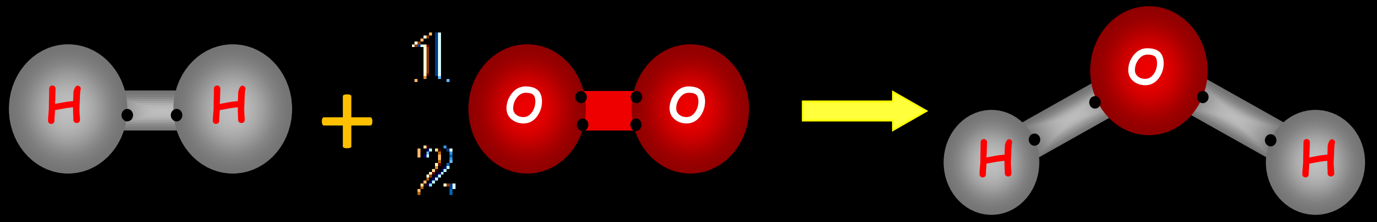
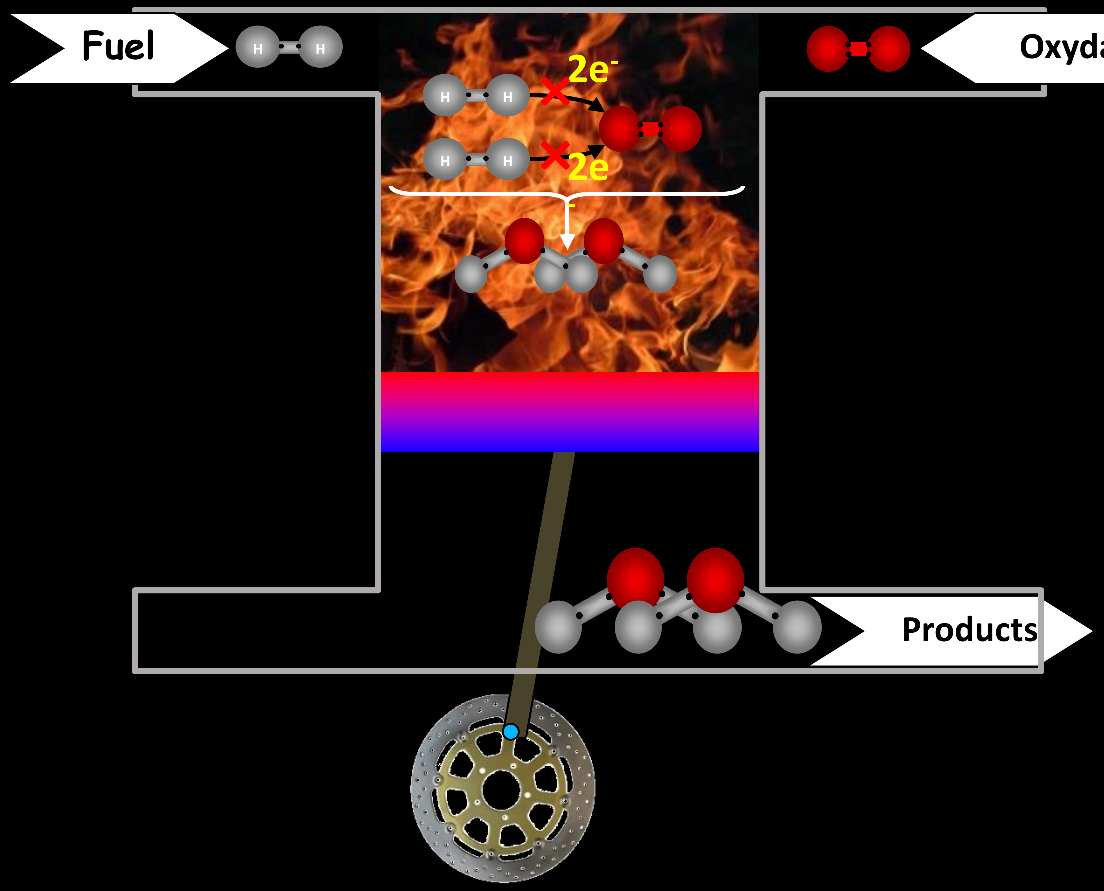
Fuel cells: Basics





Fuel cells: Basics

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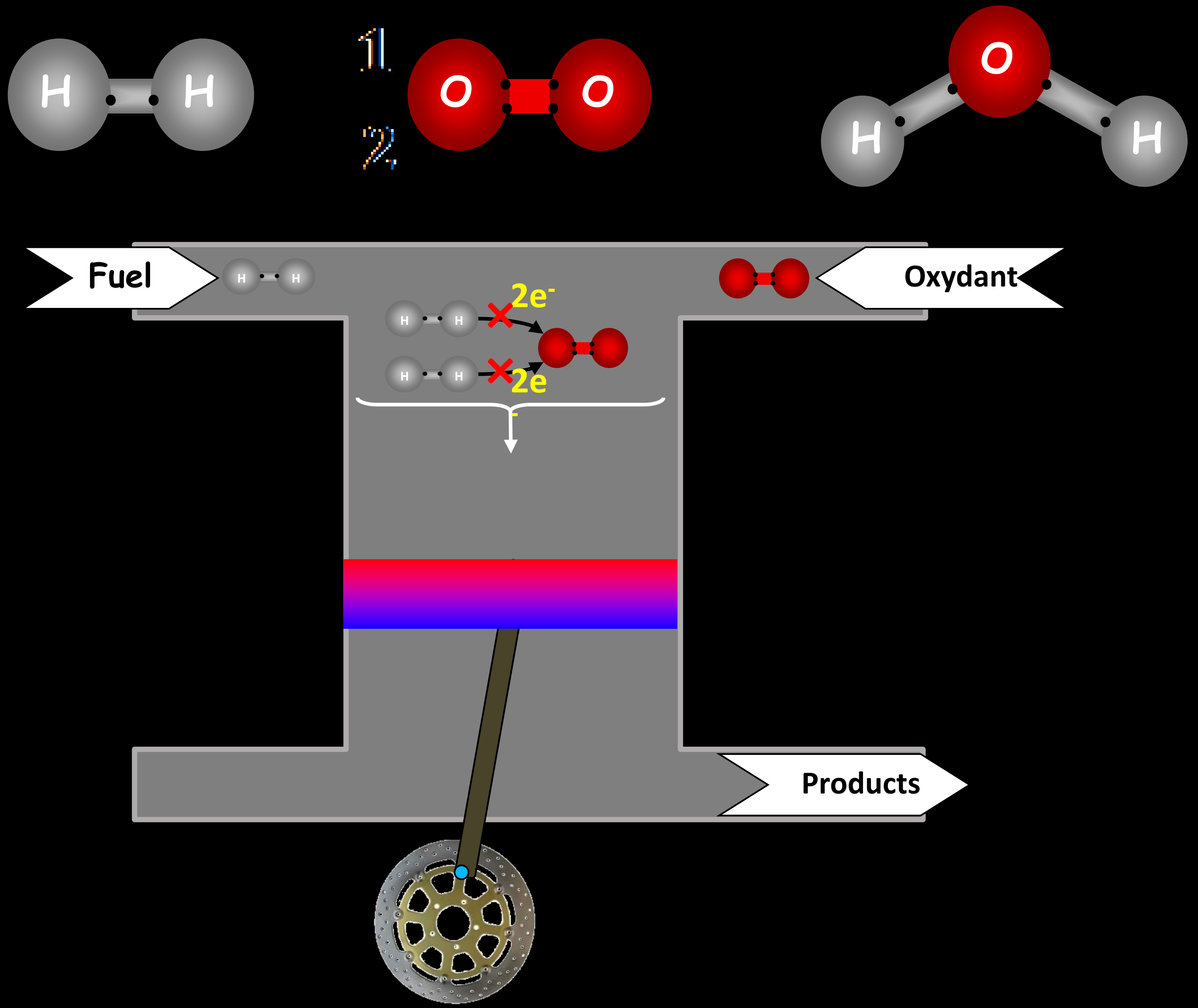

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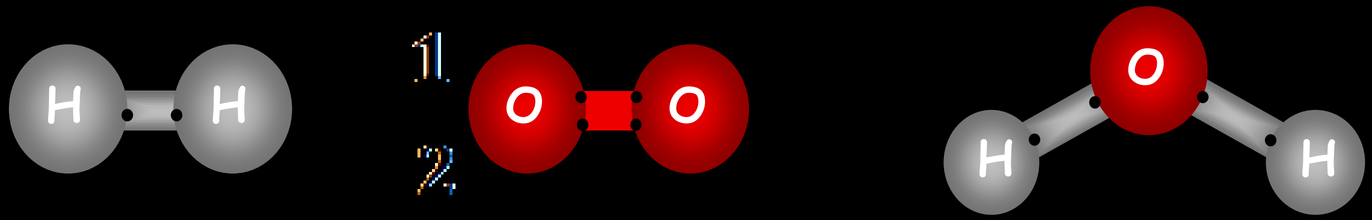

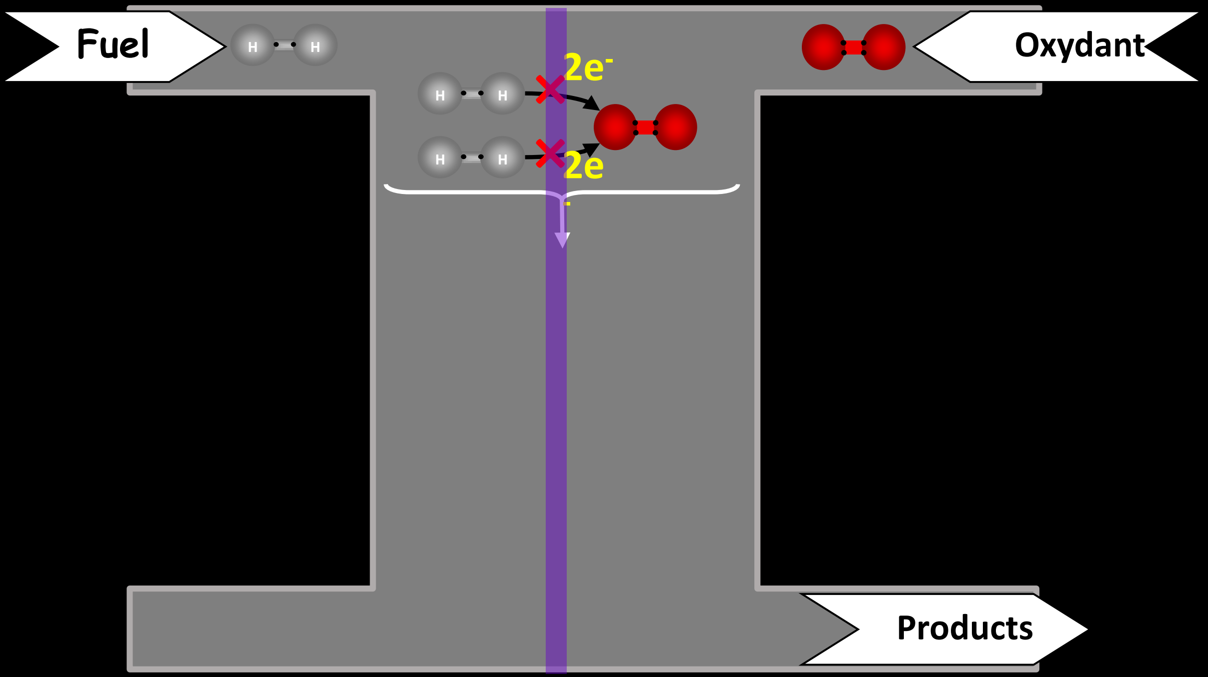

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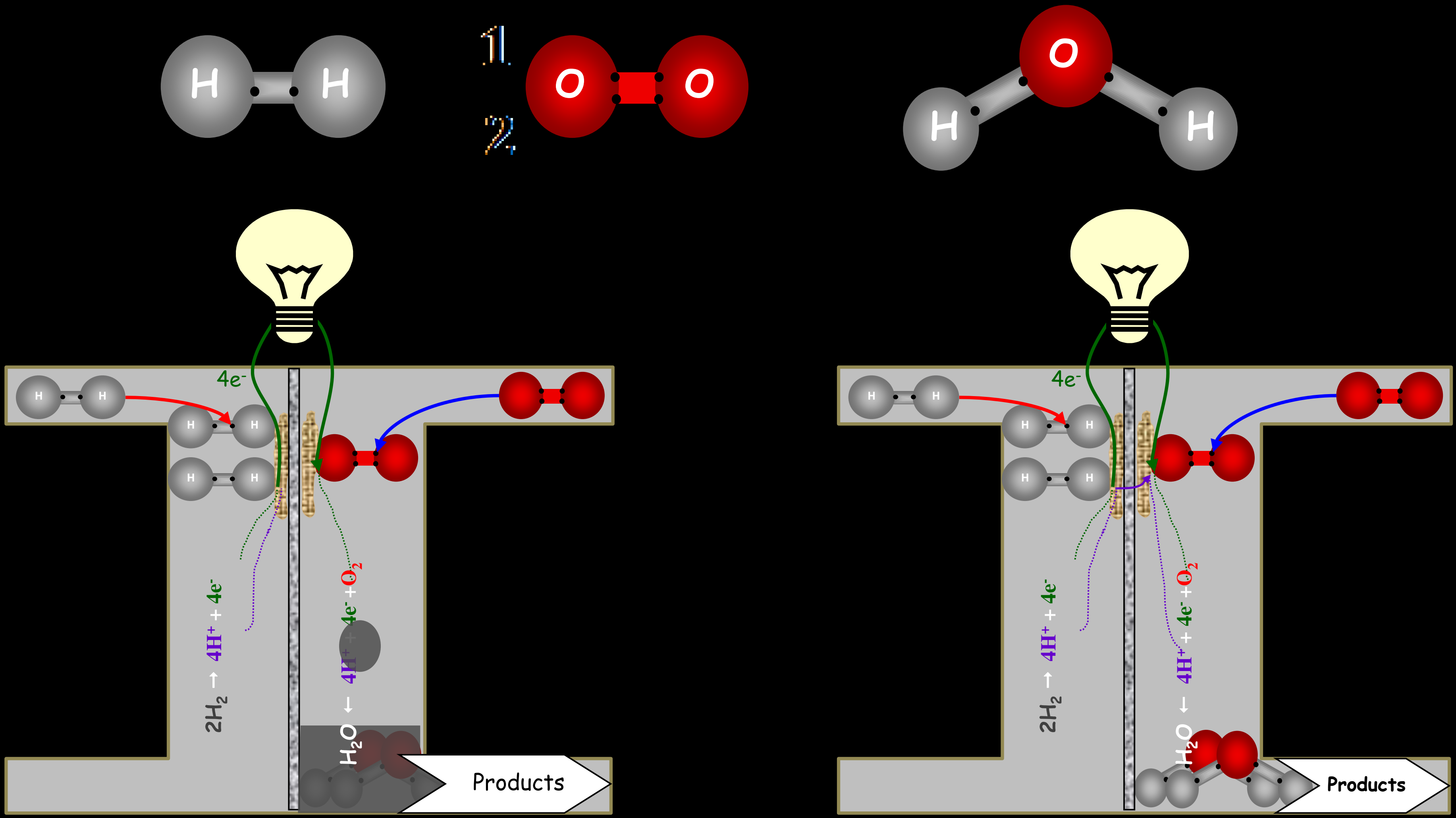
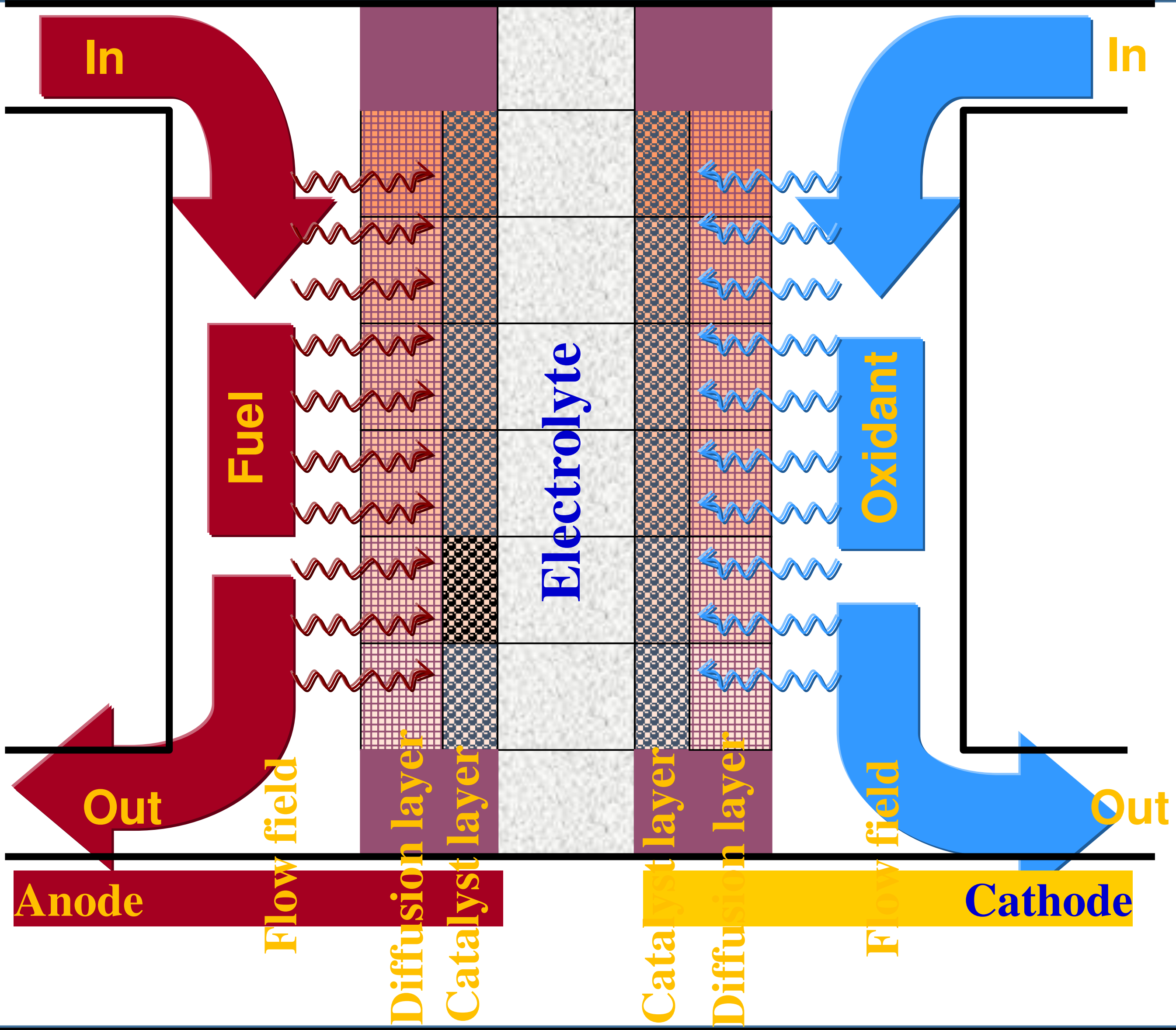


Fuel cells: Basic configurations



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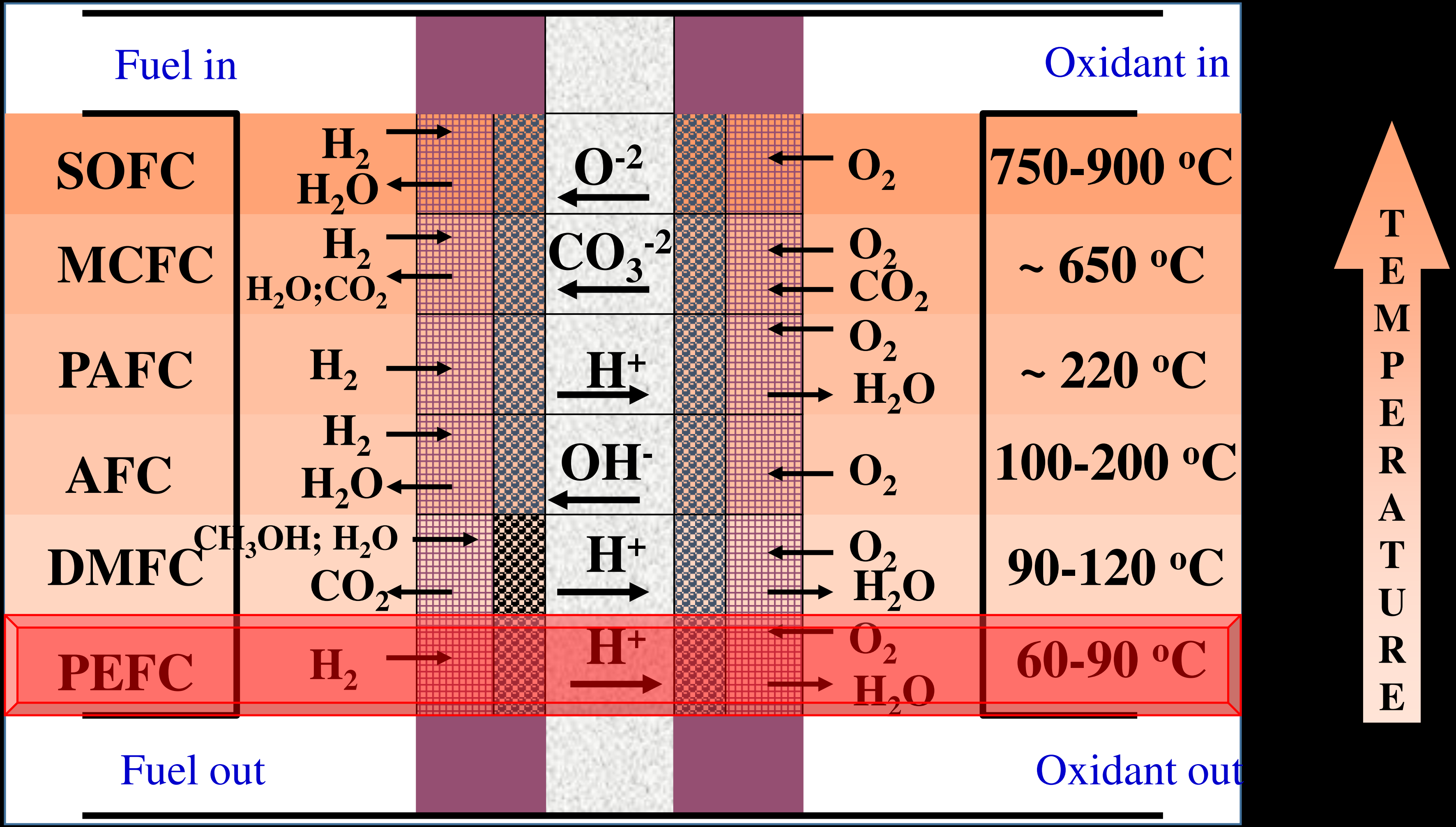
Fuel cells: types



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Fuel cells: types

Based on electrolyte

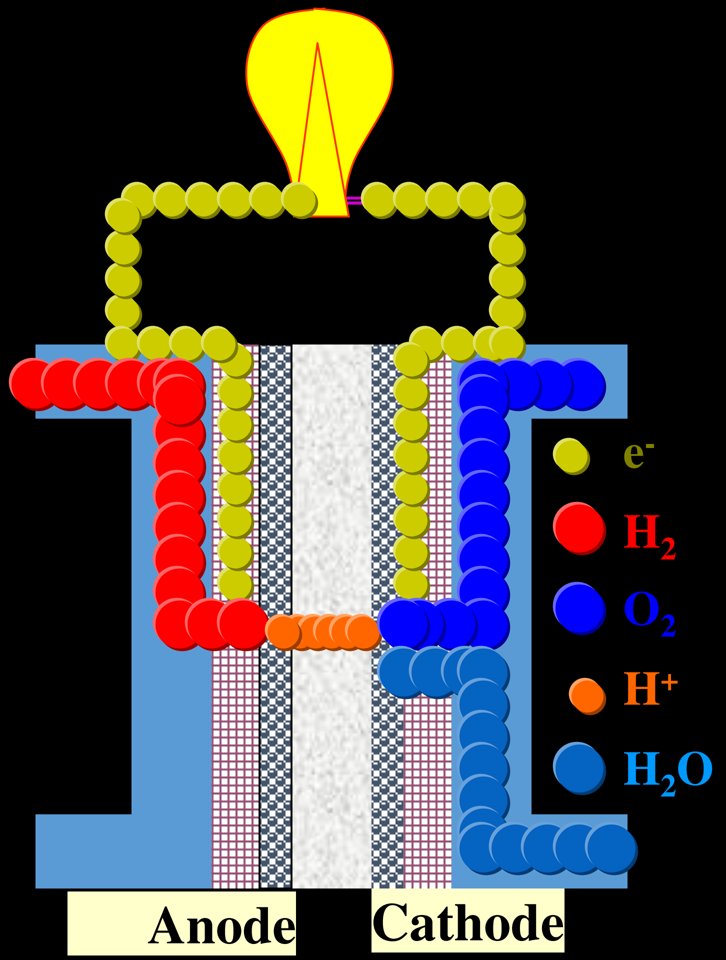
- Alkaline Fuel Cell (AFC)
- Polymer Electrolyte Fuel Cell (PEFC)
- Phosphoric Acid Fuel Cell (PAFC)
- Molten Carbonate Fuel Cell (MCFC)
- Solid Oxide Fuel Cell (SOFC)

Based on fuel

- Direct Alcohol Fuel Cell (DAFC)
  - Direct Methanol Fuel Cell
  - Direct Ethanol Fuel Cell
- Direct borohydride fuel cell (DBFC)
- Direct Carbon Fuel Cell (DCFC)
- Direct Formic Acid Fuel Cell (DFAFC)
- Microbial Fuel Cell (MFC)

Polymer Electrolyte Fuel Cells

- H_2 is oxidized on the anode side of the fuel cells in presence of platinum catalyst and produces H^+ and e^-
- Proton exchange membrane allows H^+ to move through it. However electron can not move through membrane
- Electron flows through external circuit and produces external work
- On the cathode side H^+, electron in presence of oxygen and produce water
- In this way the oxidation tendency of H_2 is used to convert the chemical energy of hydrogen directly into electricity



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Fuel cells: thermodynamics

Potential (v)= Energy/nF

Heating value (ΔH^0)

Free energy (ΔG^0)

Nernst energy (ΔG)

$$\Delta G^o = \Delta H^o - 298 \cdot \Delta S$$

$$\Delta G = \Delta G^o - \frac{RT}{nF} \ln Q$$

Energy (kJ/Mole)

Electrode kinetics & losses

Electrode Kinetics

- Overpotential
- Polarisation
- Irreversibility
- Losses
- Voltage drop

→ Activation losses

→ Internal losses

→ Ohomic losses

→ Concentration losses

Electrode kinetics & losses

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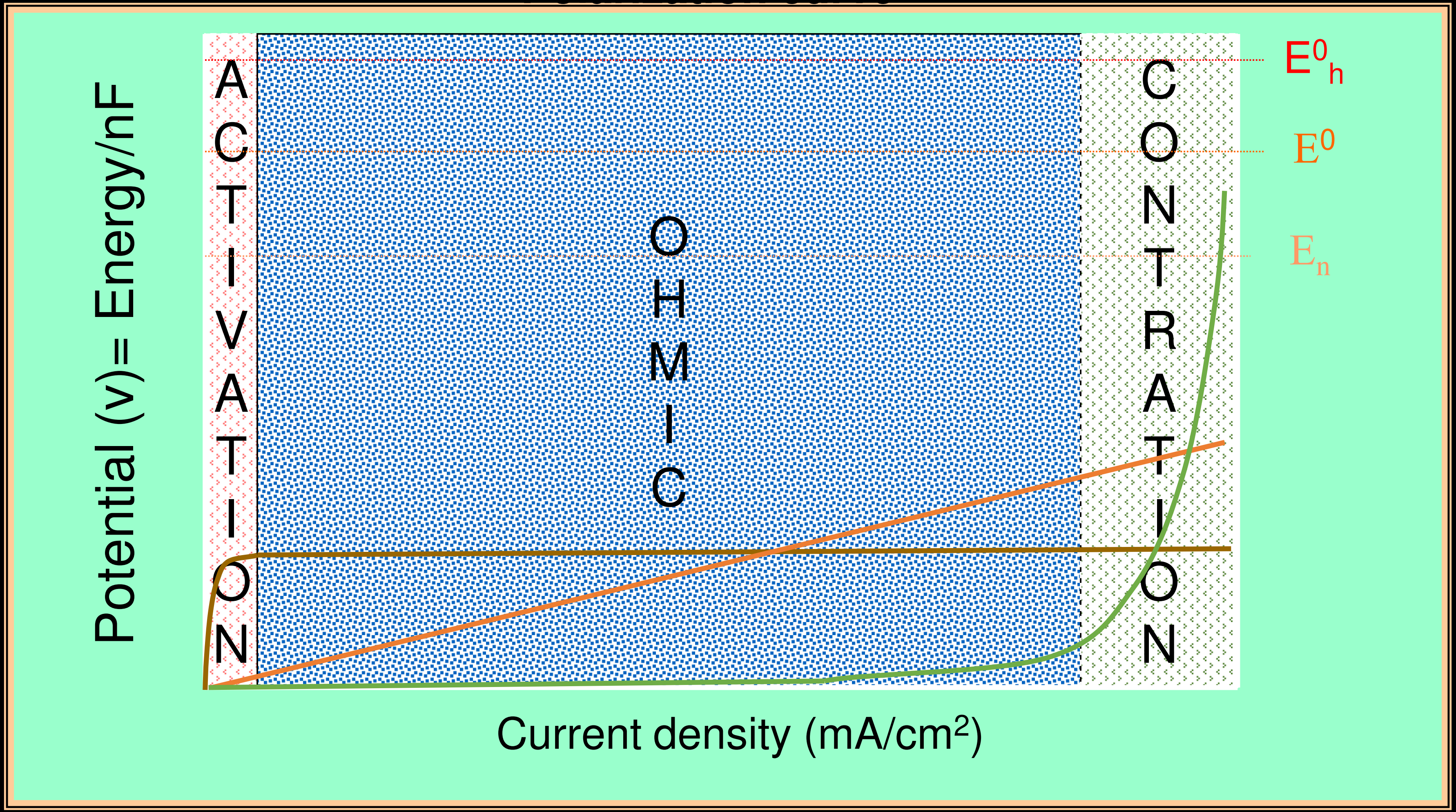
$$V_i = A\ln\left(\frac{i_n}{i_o}\right) \rightarrow V = E - V_i$$

$$V_{ohm} = IR = i.\rho.l \rightarrow V = E - V_{ohm}$$

$$V_{con} = -B\ln\left(1 - \frac{i}{i_l}\right) \rightarrow V = E - V_{con}$$

Characteristics: losses



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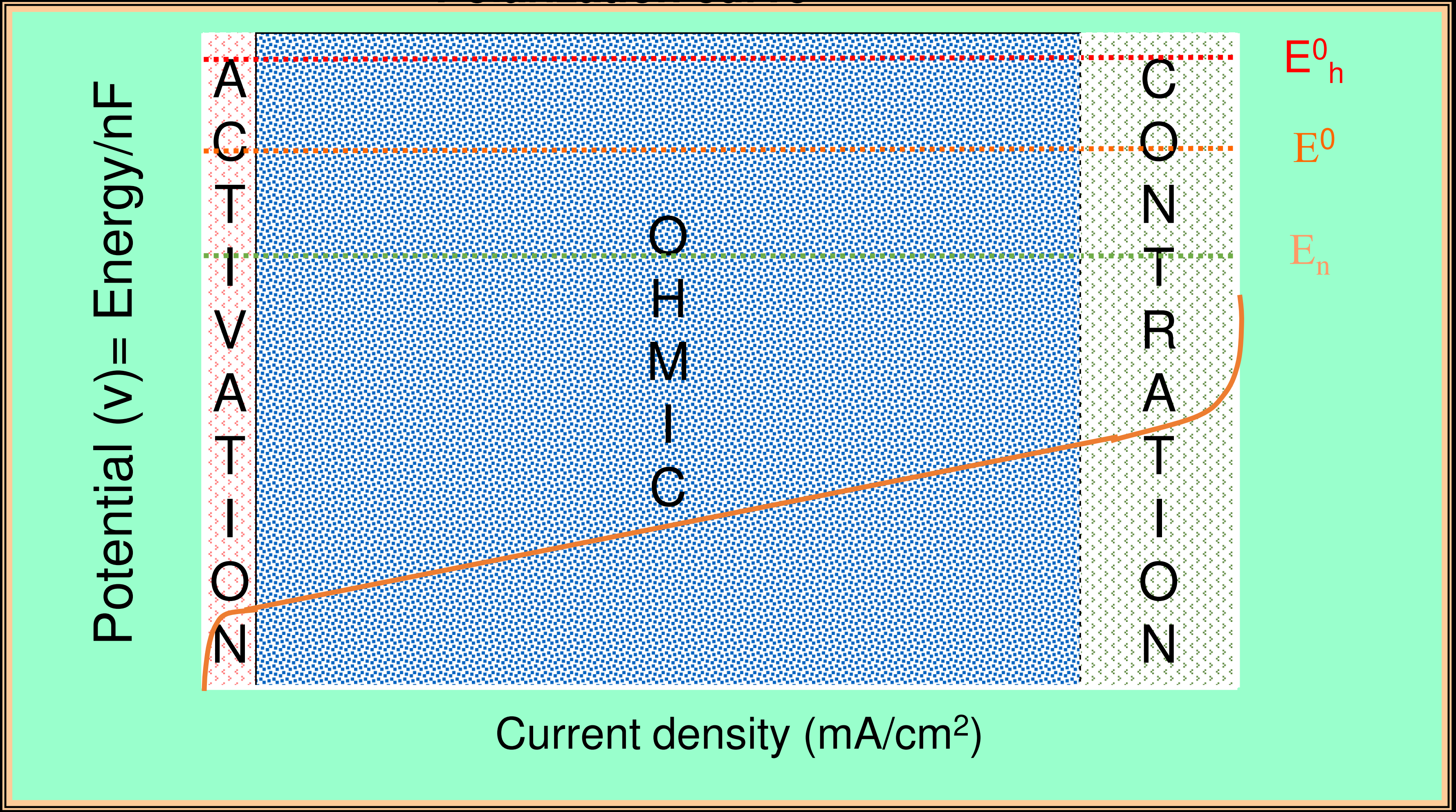
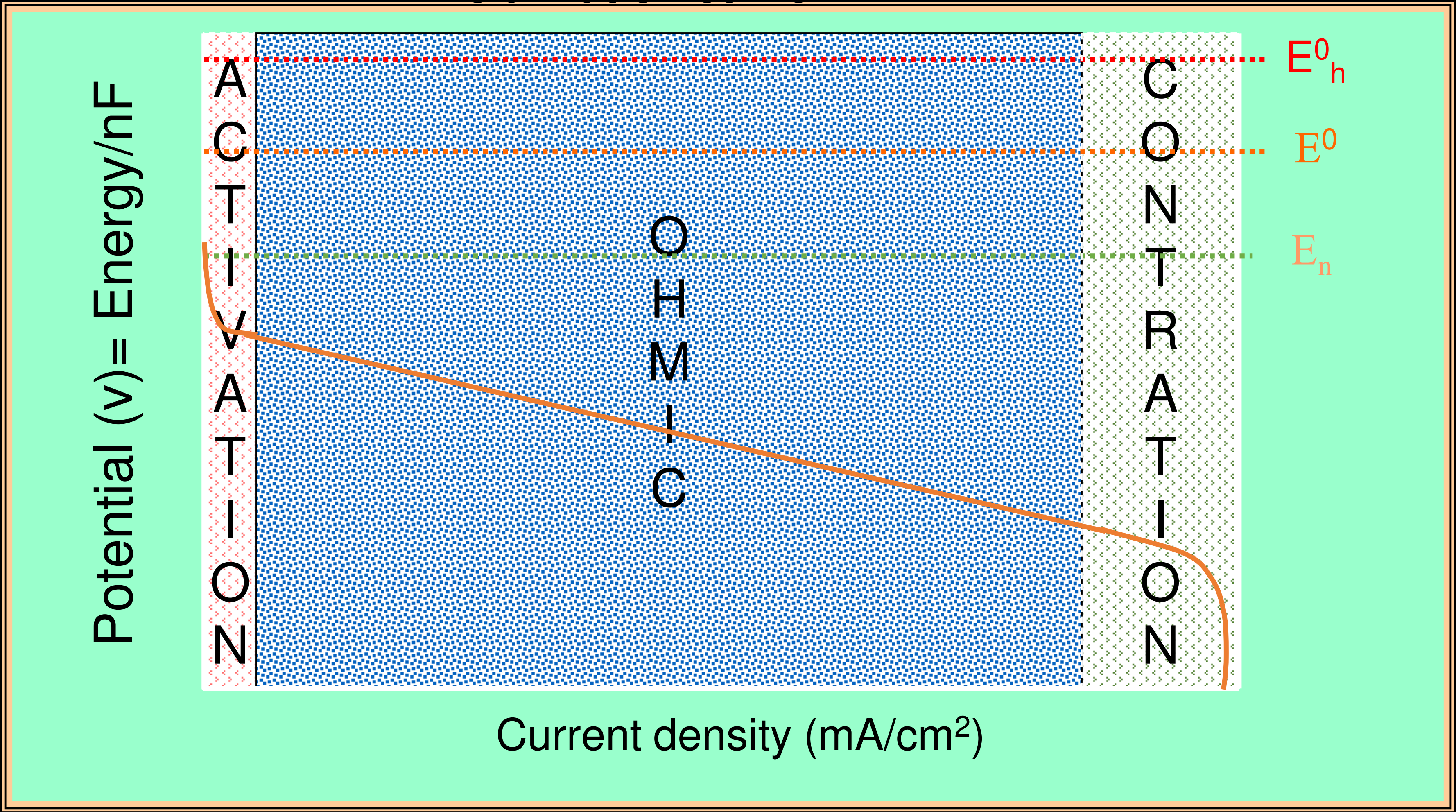
Characteristics: combined losses



Characteristics: I-V



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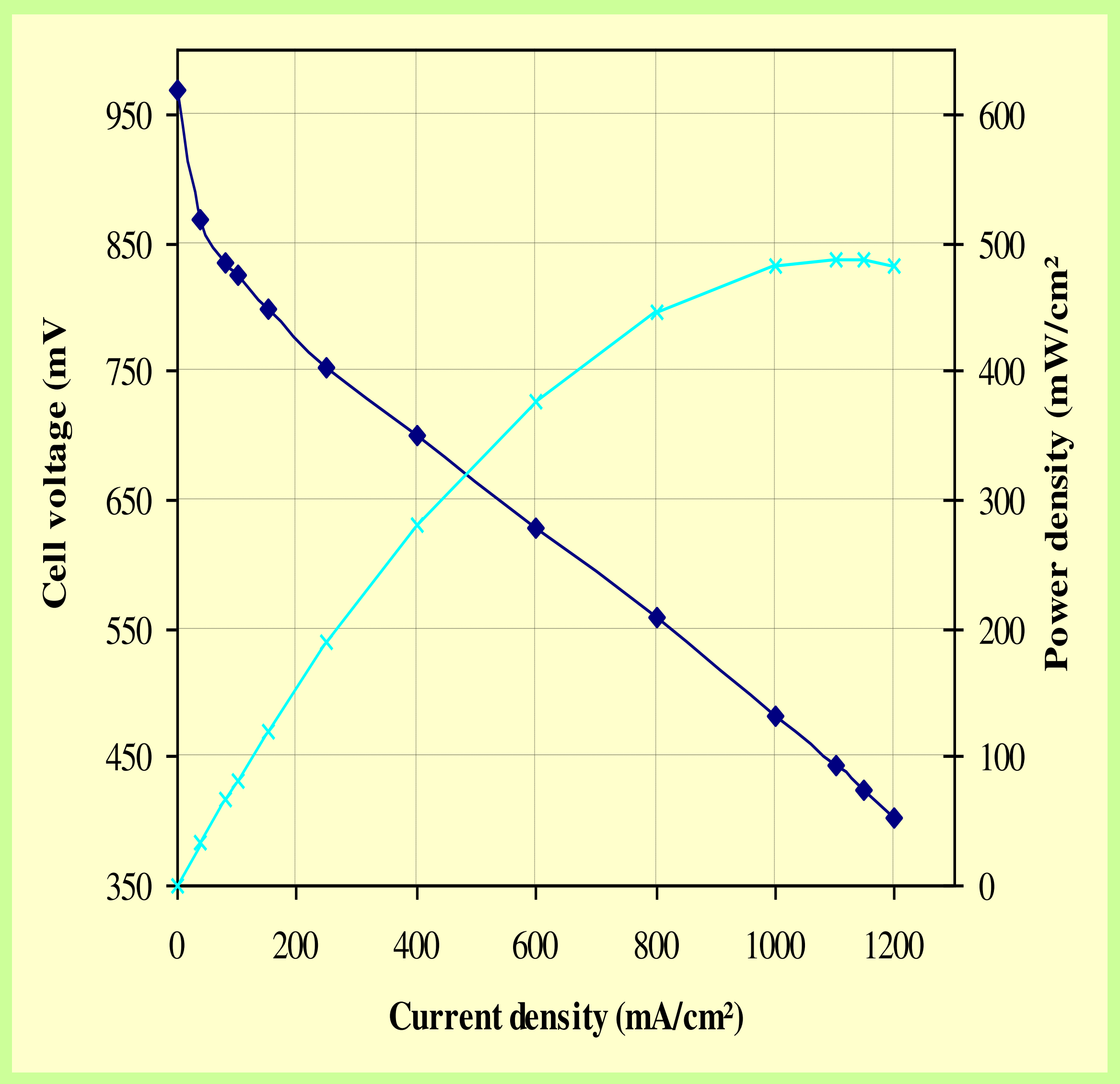
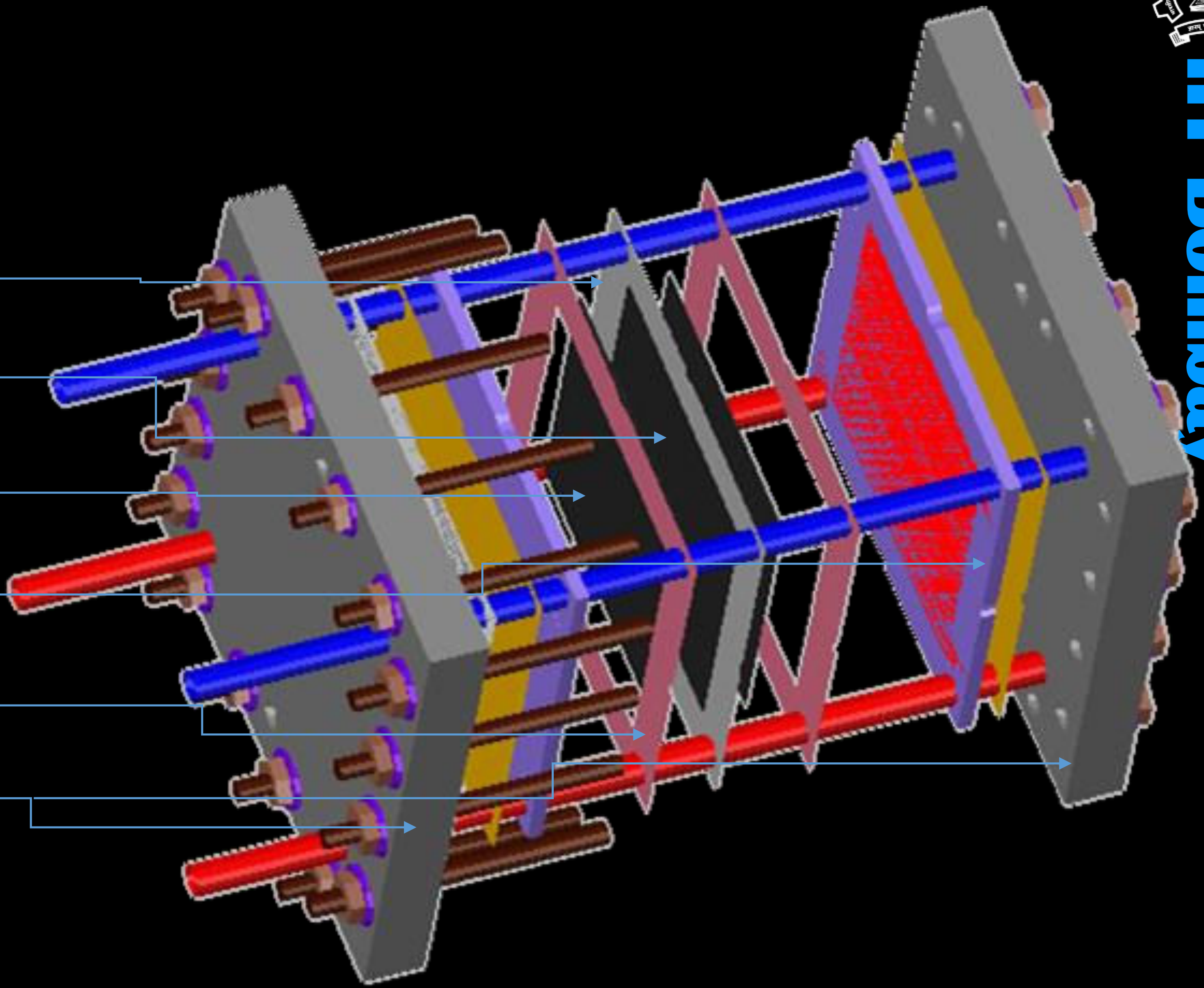
Typical I-V characteristics



Components

- Electrolyte
- Electrode
- Supporting layer
- Bipolar/interconnect plate
- Gasket/sealant
- Endplate



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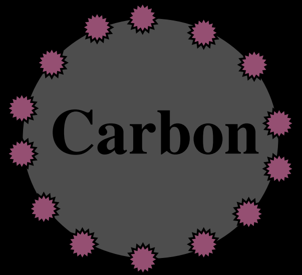
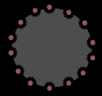
Electrode

- Electrodes are made of high surface area (235 m^2/gm)carbon and Platinum
- Carbon provides high surface to Pt catalyst
- Pt sizes are around 2-3 nm
- Carbon sizes are 20-40 nm

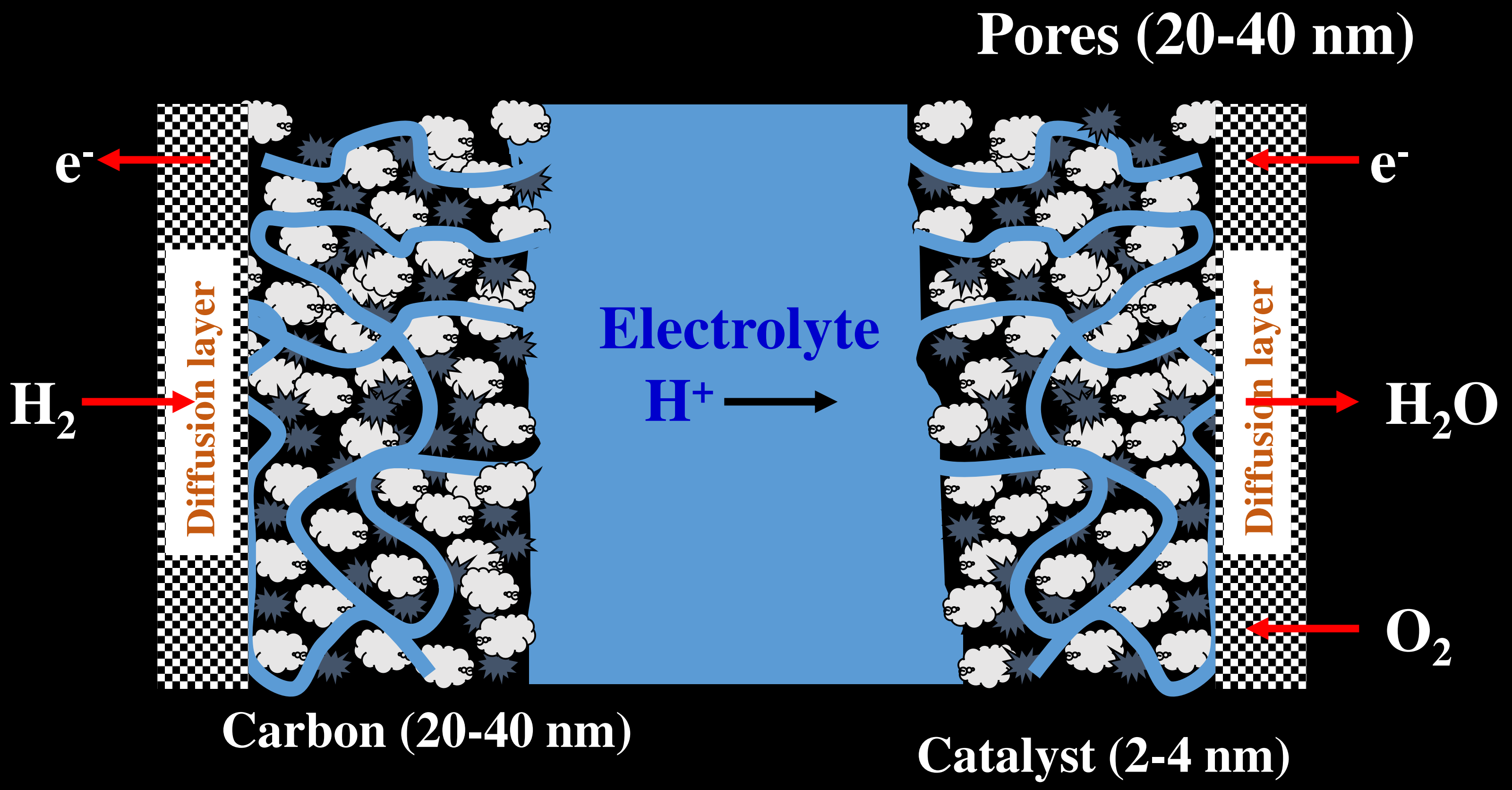


- Porous carbon electrodes on both side of membrane
  - provide the interface between reactant gases and the electrolyte
  - allow wet gases to diffuse and reach the electrolyte surface
  - allow electron to conduct from anode to cathode



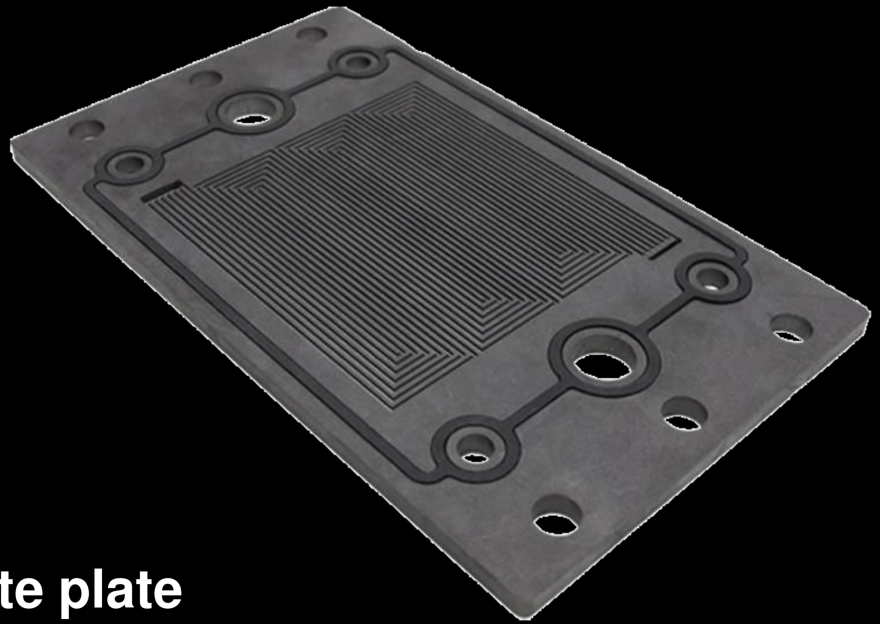
  - Platinum catalyst between membrane and electrode
    - used for high electrochemical activity, stability and electrical conductivity
    - loading is critical for cost (Typically: 0.4-0.6 mg/cm^2)
- MEA provides integral sealing

Electrode morphology

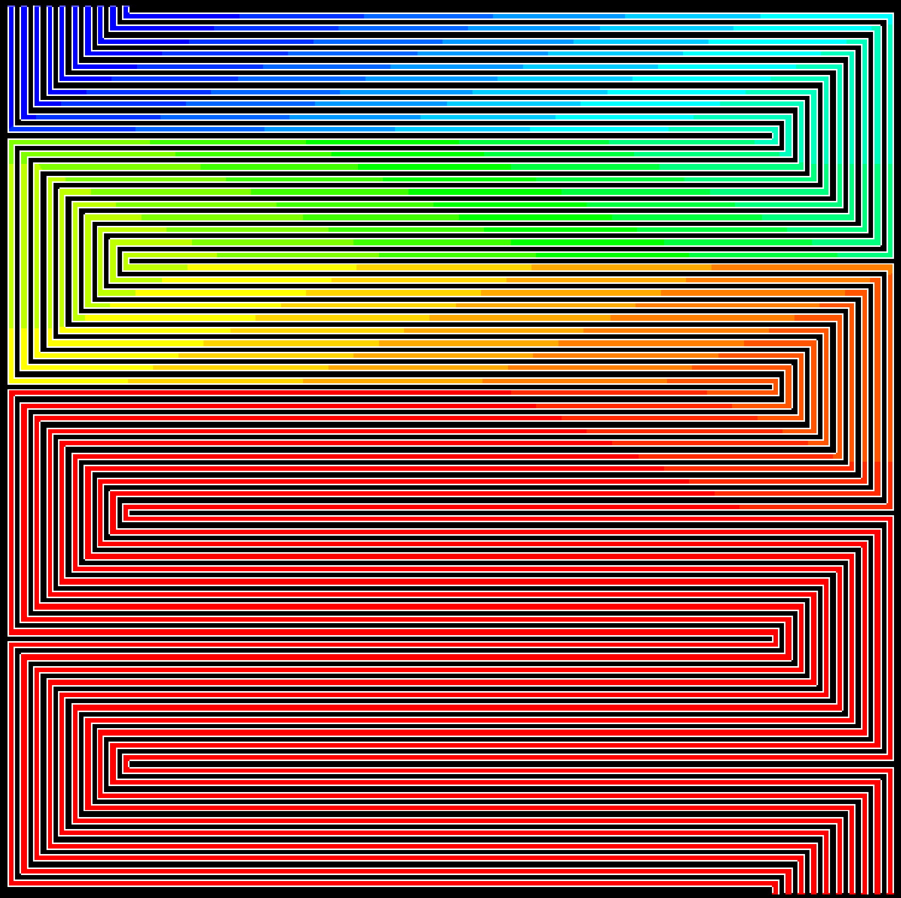


Reactant distributors: flow field and bipolar plate

- Reactant gases are supplied to the electrodes on both sides of MEA through flow field
- Flow field consists of single or multiple gas channels
- Design of flow field is very important for
  - uniform power generation
  - stable performance
  - water management
- Flow field material must be highly conductive
- Generally graphite is used for this purpose
- Flow field design is machined or pressed on graphite plate



Flow field: serpentine



- Commonly used in PEFC
- Water content in cathode reactant gases increases with length
- Causes water flooding at high current densities
- Degradation in performance

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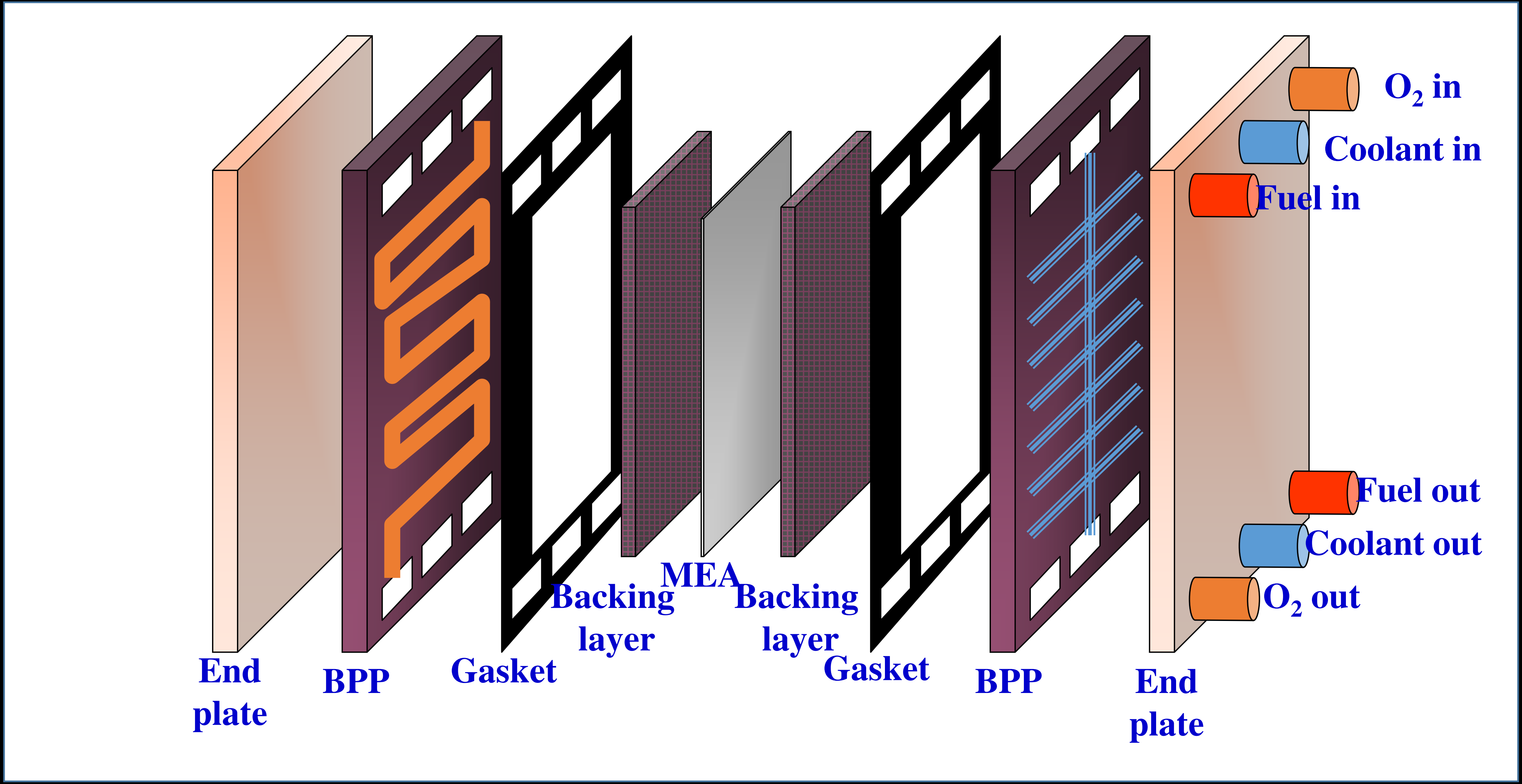
Unit cell assembly



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Multiple cell assembly

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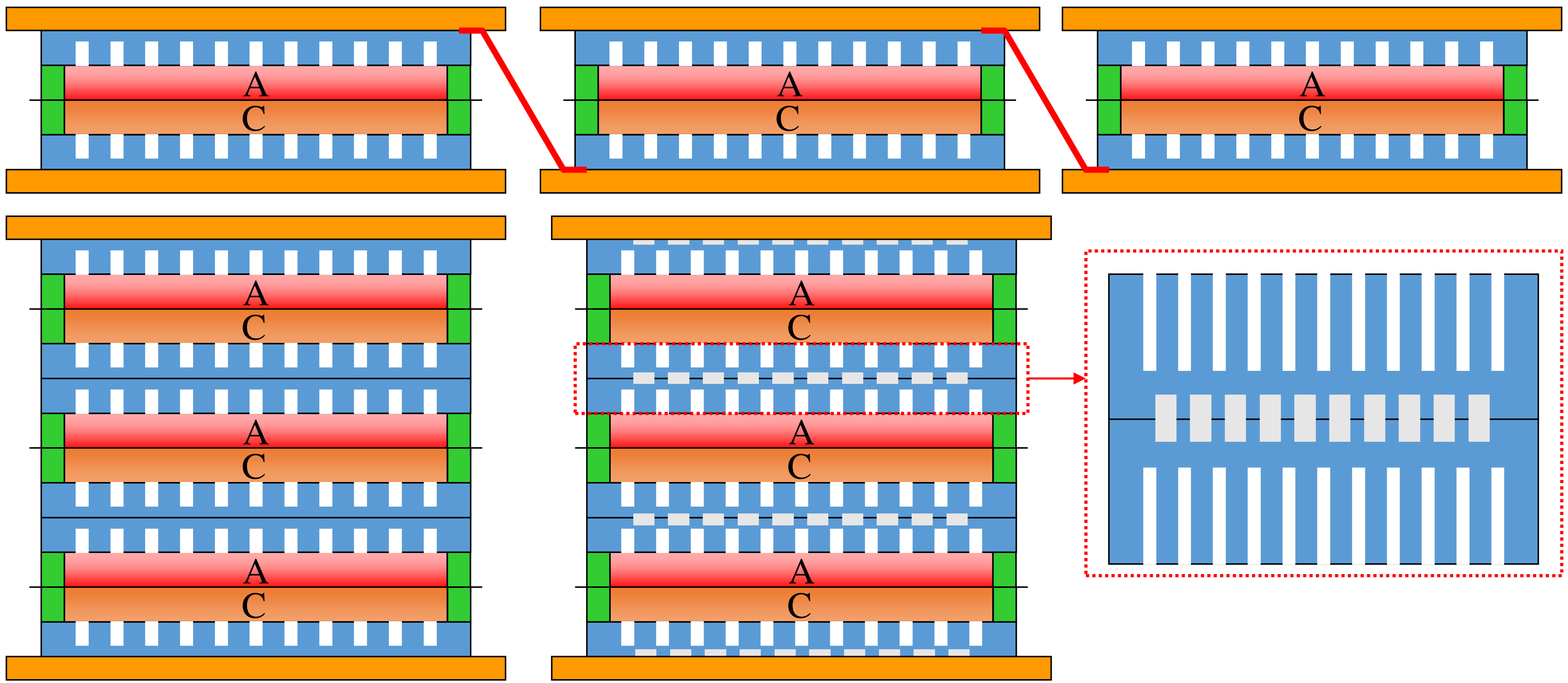
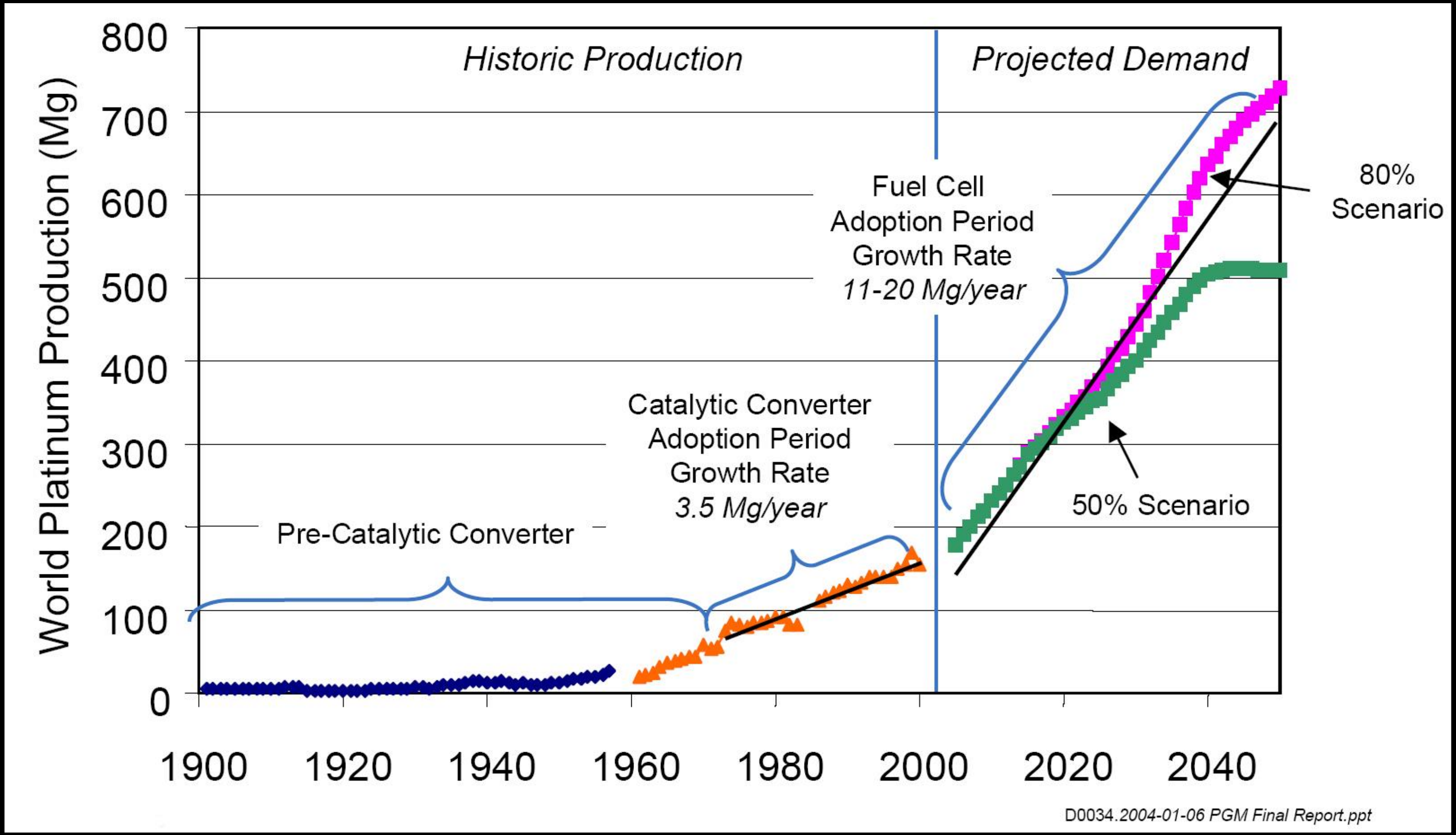


Historic Pt production and projected demand



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