Civil Aviation Technology College

Fuel Cell as a Green Energy Generator in Aerial Industry

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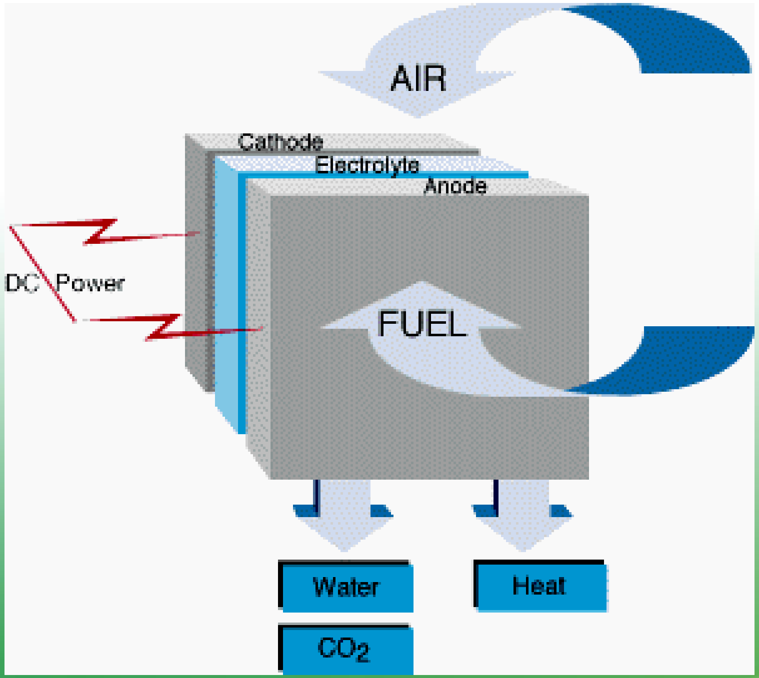
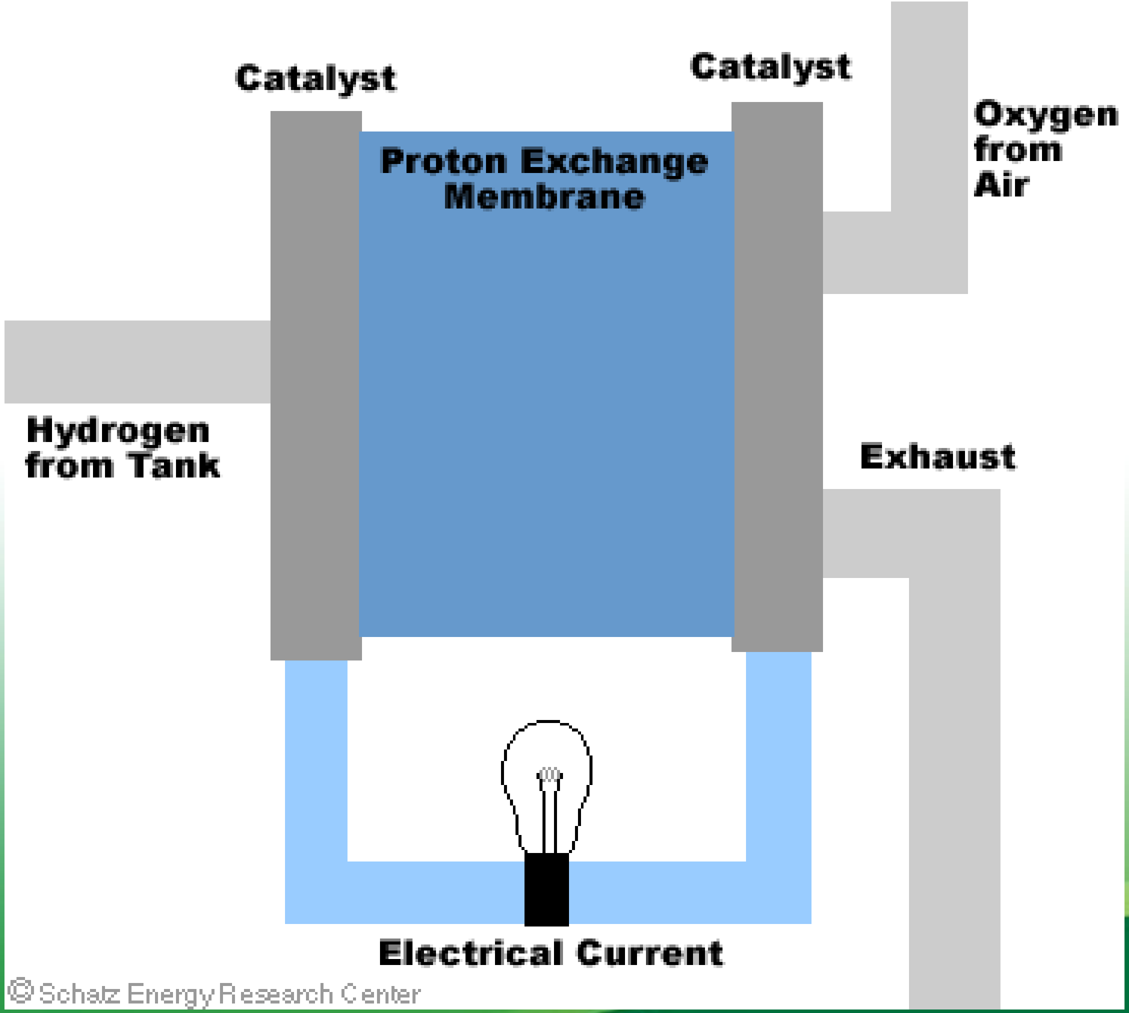
Fuel Cell Definition

an electrochemical energy conversion device

- To convert the chemicals hydrogen and oxygen into water, and in the process it produces electricity.

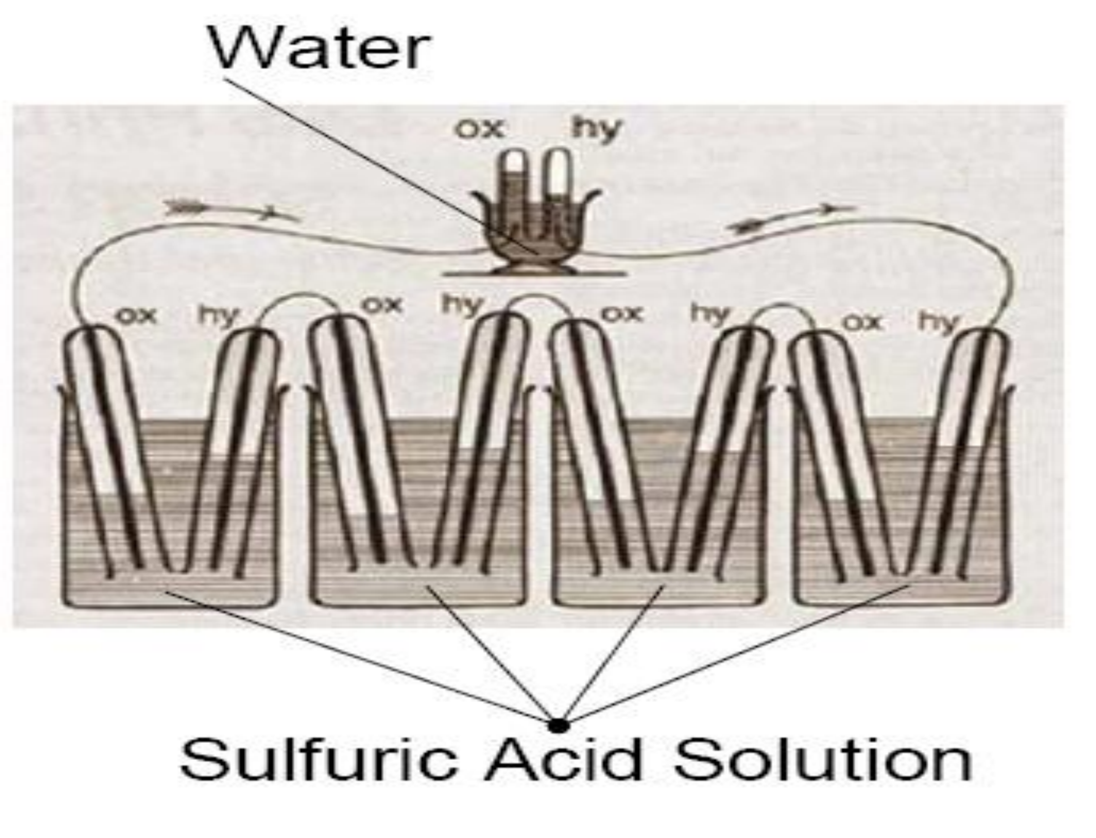


Principle of Operation



Fuel Cell History

1839: First Fuel Cell (Grove's "Gas Battery")

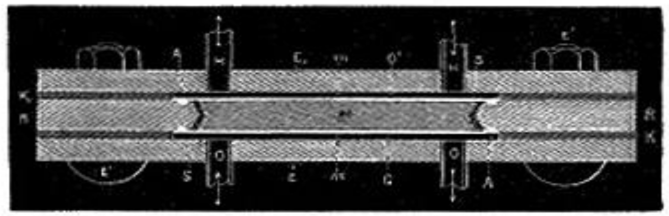


Sir William Grove

Fuel Cell History

1889: IMPROVED FUEL CELL

FIG. 1.



1959: THE ALKALI FUEL CELL

Francis Thomas Bacon with his Alkali Fuel cell.

1965: alkali fuel cell

A U.S. Army soldier operates a portable drill
powered by a n alkali fuel cell.

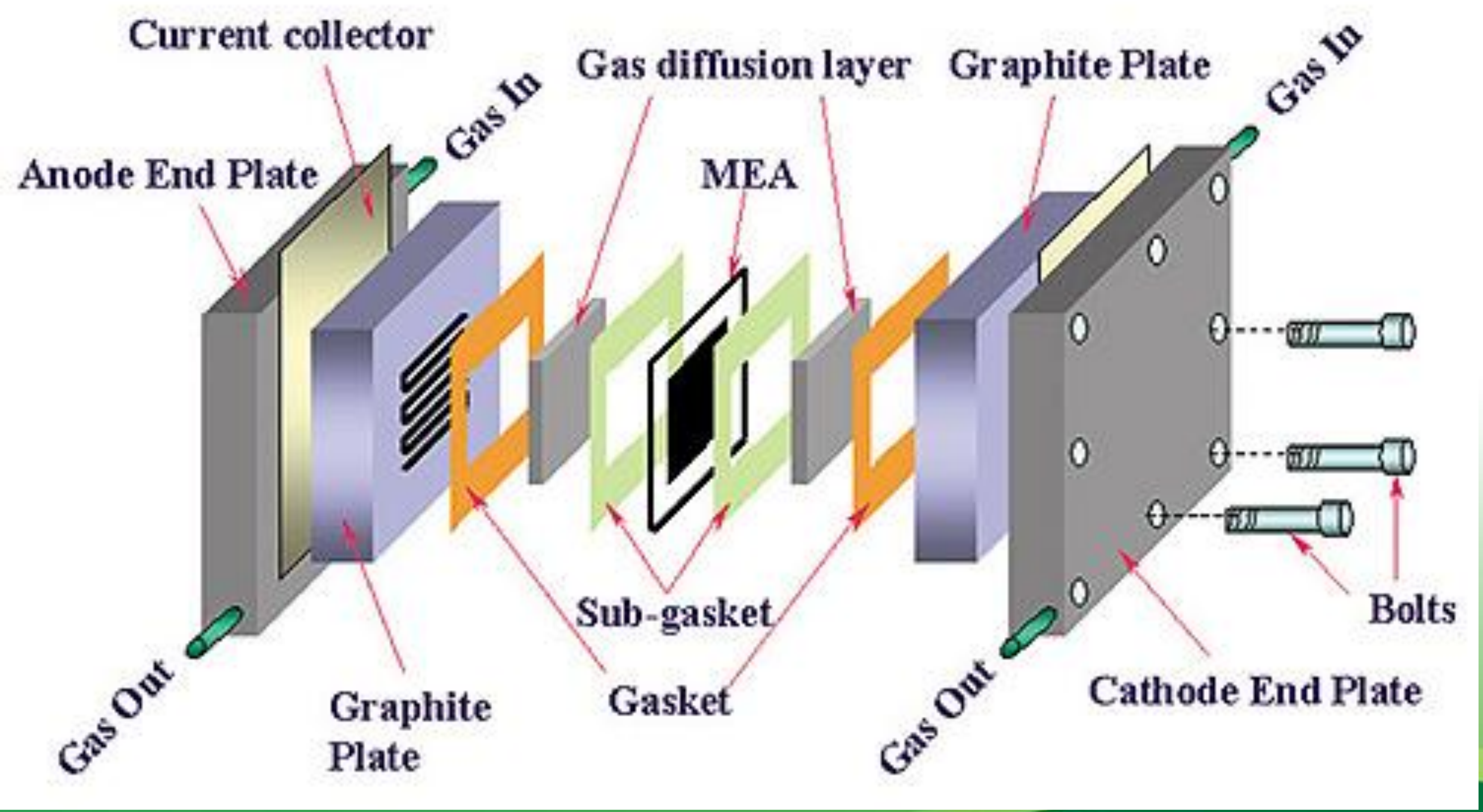
1967: FIRST FUEL CELL VEHICLE

Karl Kordesch rides his alkali fuel cell motorbike.

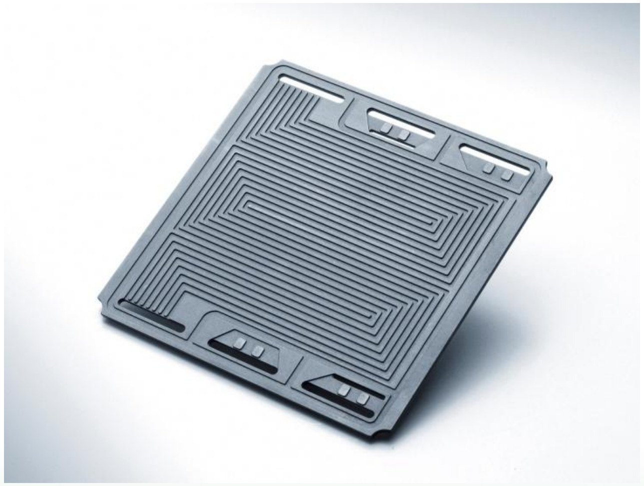
Fuel Cell Advantages

- High energy conversion efficiency
- Modular design- scale able to many sizes from 1 kW to 10's MW- offering a wide range of application
- Direct conversion avoids combustion process- allows for very low chemical and acoustical pollution(<60 dBA)
- Fuel flexibility
- Cogeneration capability- using waste heat
- Rapid load response
- High reliability- fewer moving parts
- Low Maintenance

Fuel Cell Component

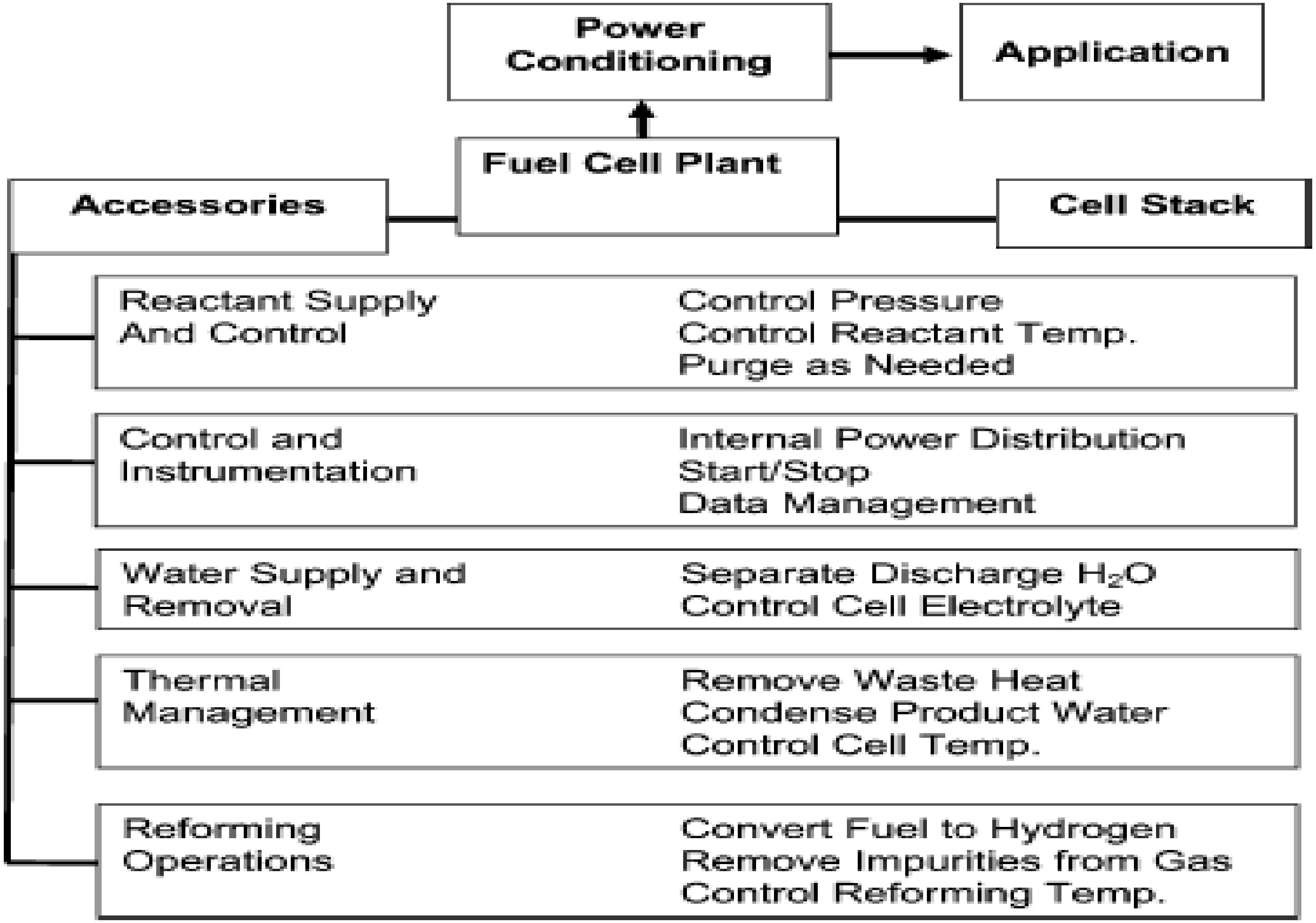


Fuel Cell Stack, Ballard Company

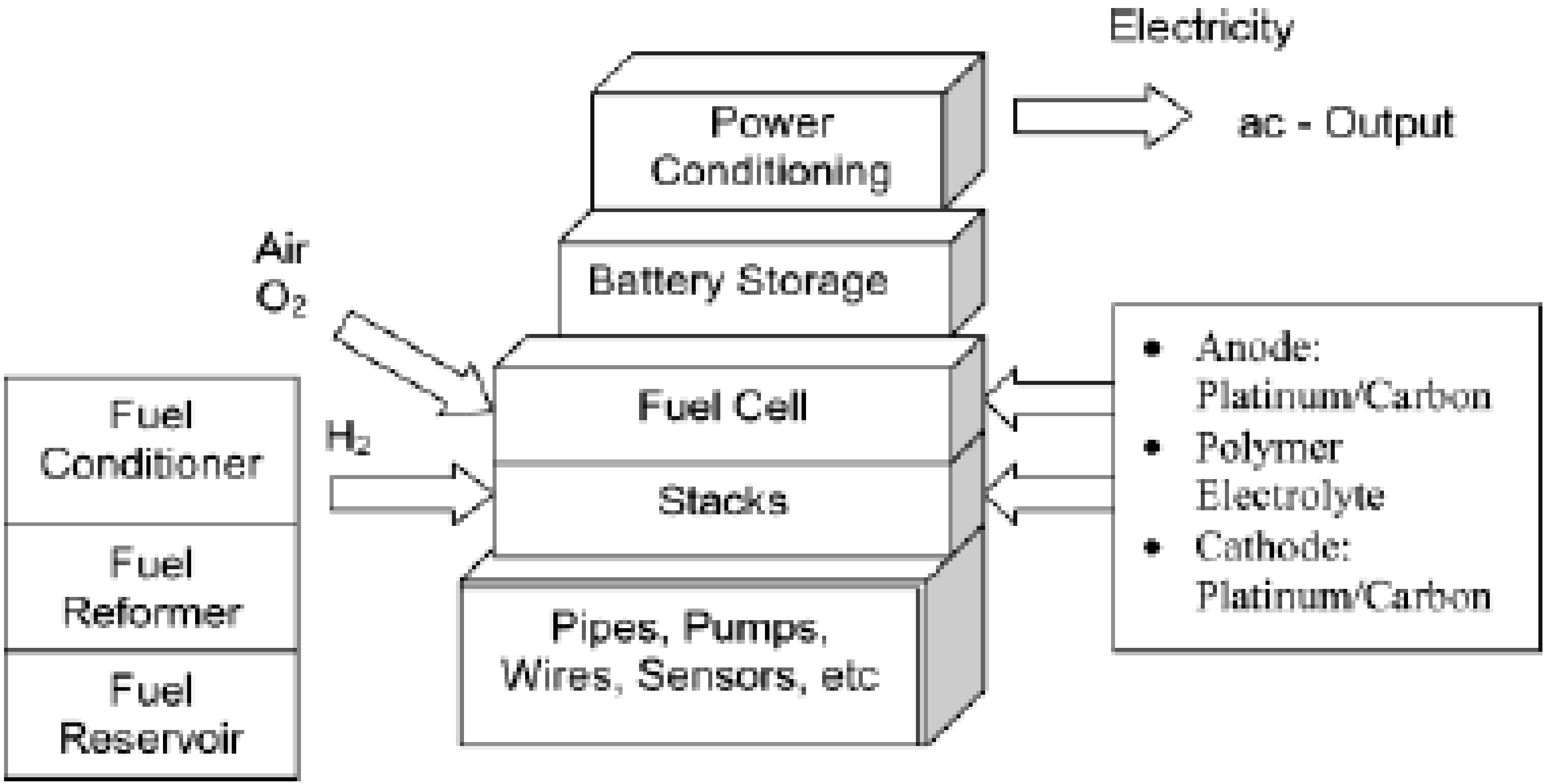


Graphite Plate

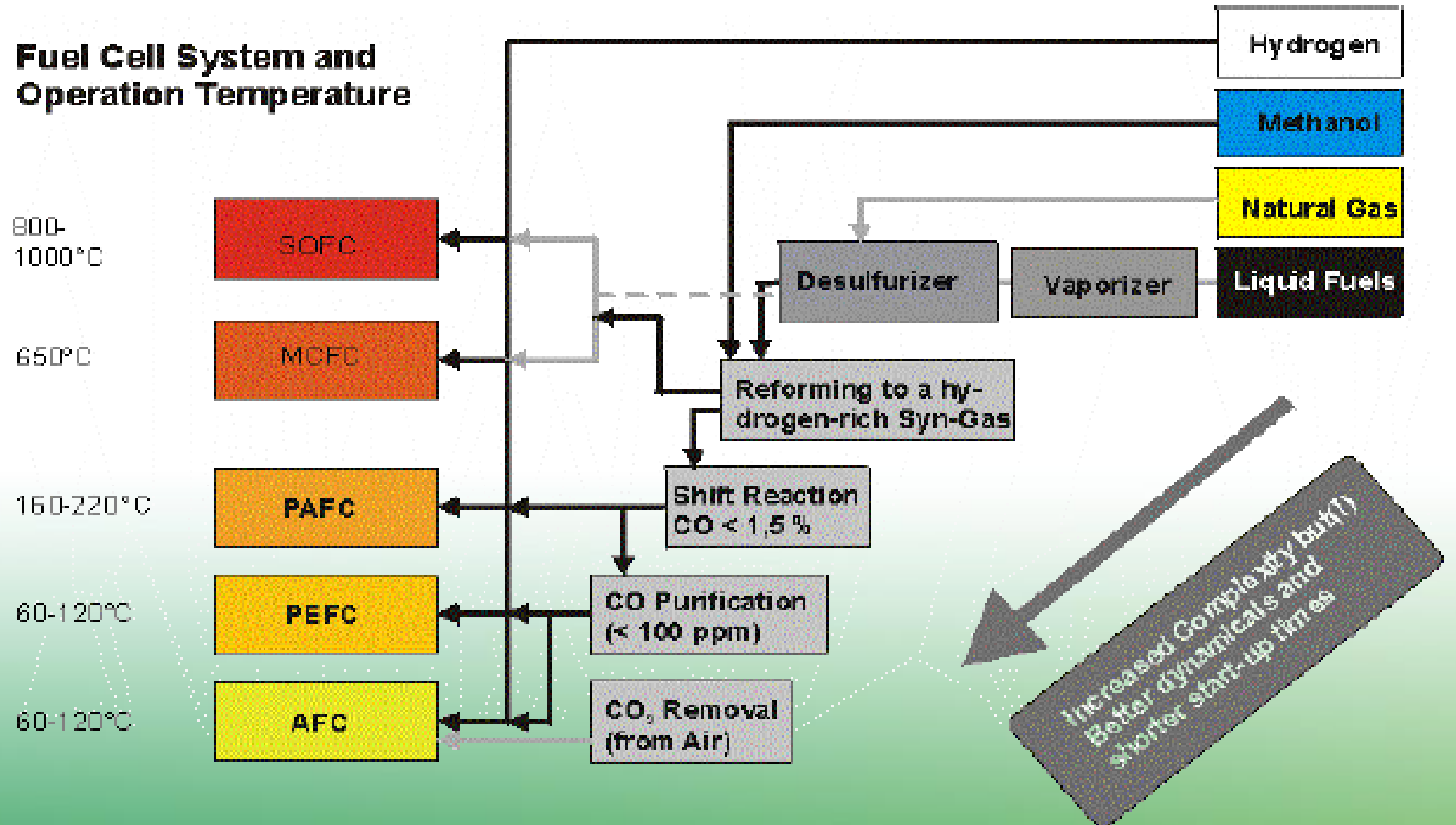
Fuel Cell System Block Diagram



Fuel Cell System



Fuel Cell Reforming Process



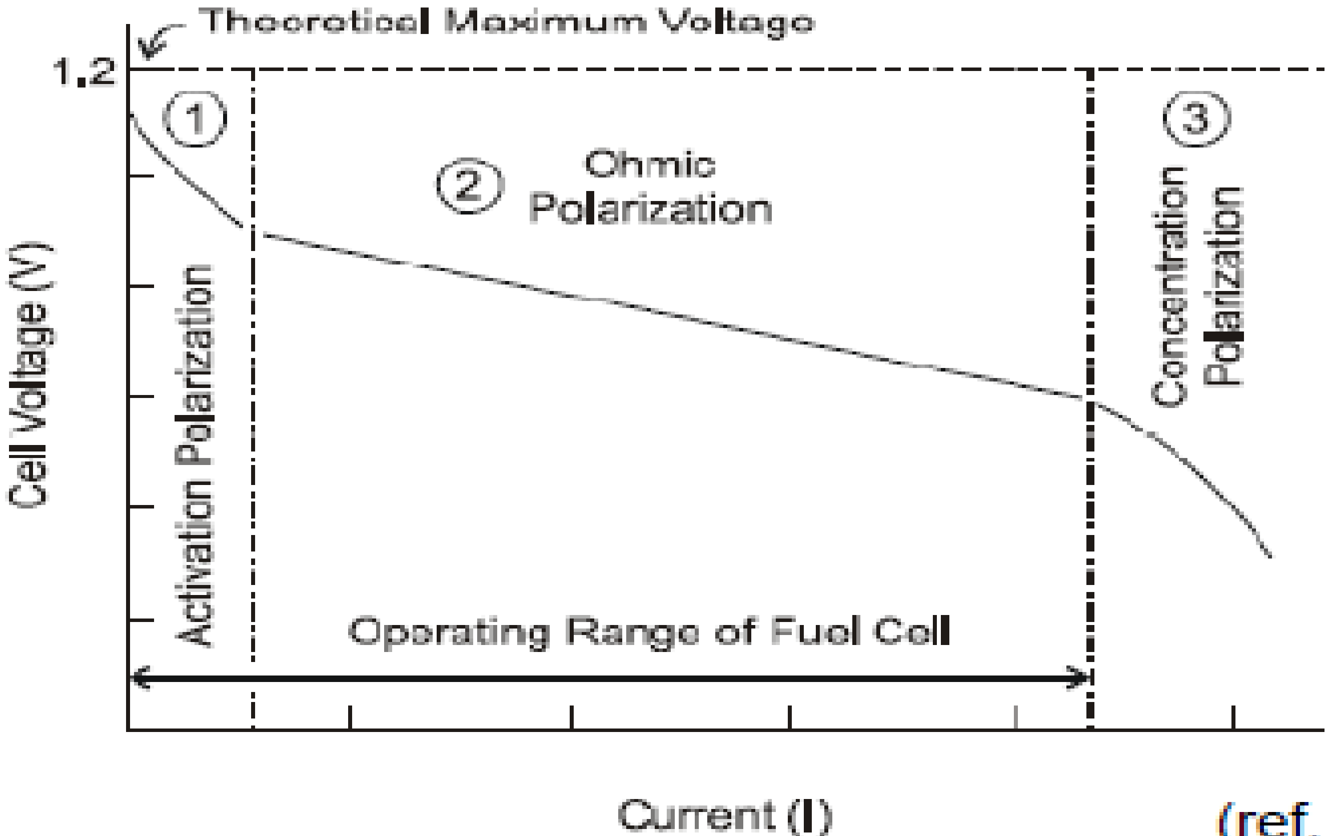
Reaction in the desulphurisation step: $ZnO + H_2S \rightarrow ZnS + H_2O$

Reaction in pre-reforming/reforming step: $CH_4 + H_2O \rightarrow 3\,H_2 + CO$

Reaction in the shift converter (HT and/or LT): $CO + H_2O \rightarrow CO_2 + H_2$

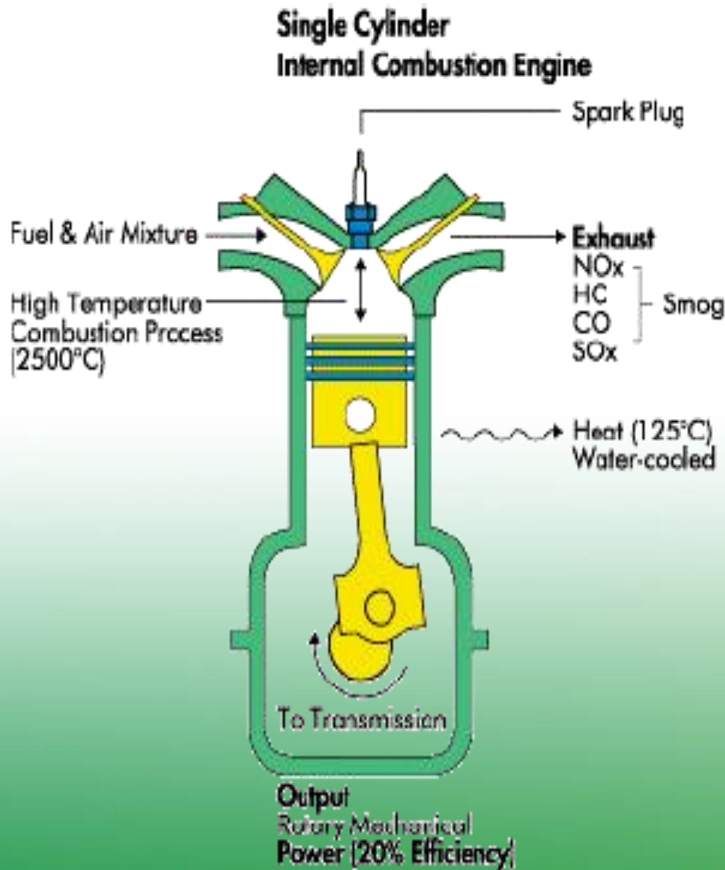
Reaction in PrOx-converter: $CO + \frac{1}{2}\,O_2 \rightarrow CO_2$

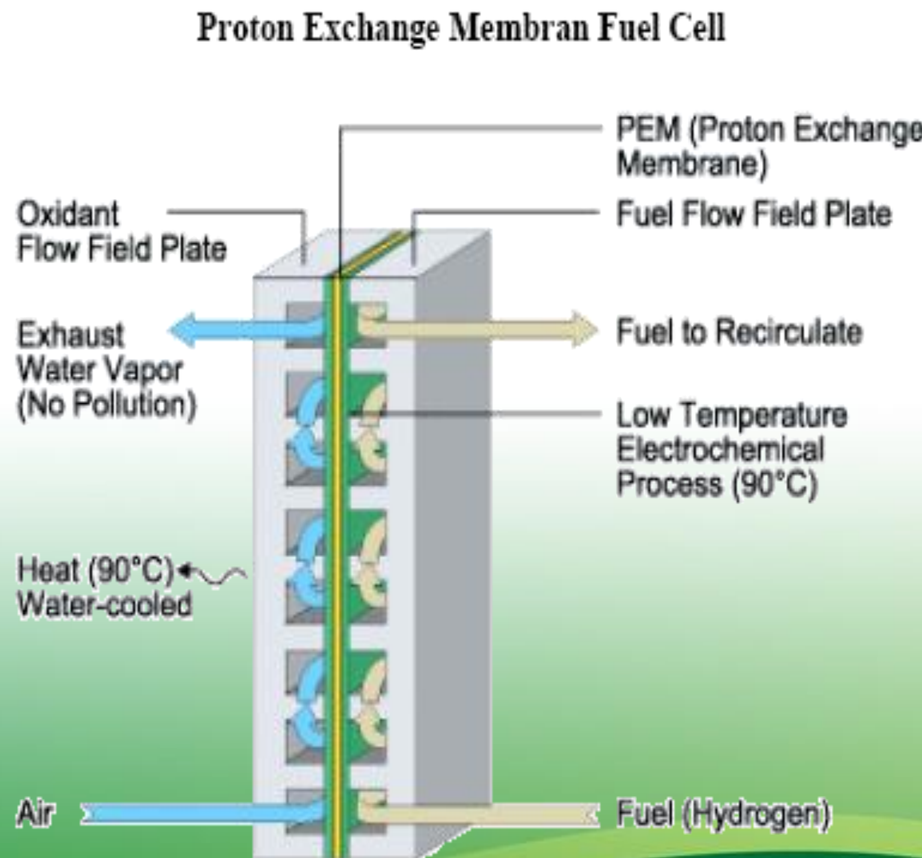
Fuel Cell Performance



(ref. 2)

Fuel Cell vs. Internal Combustion Engine

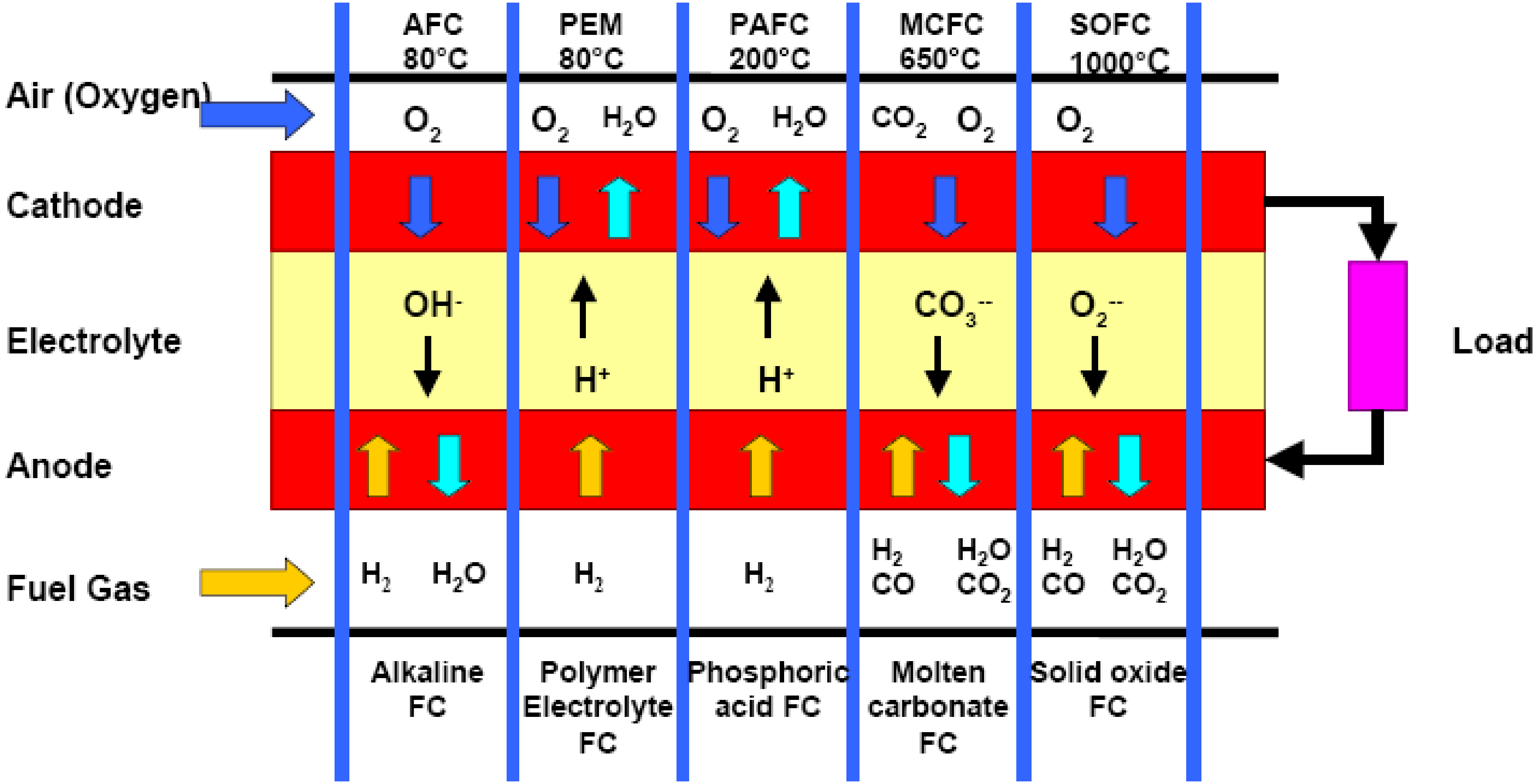




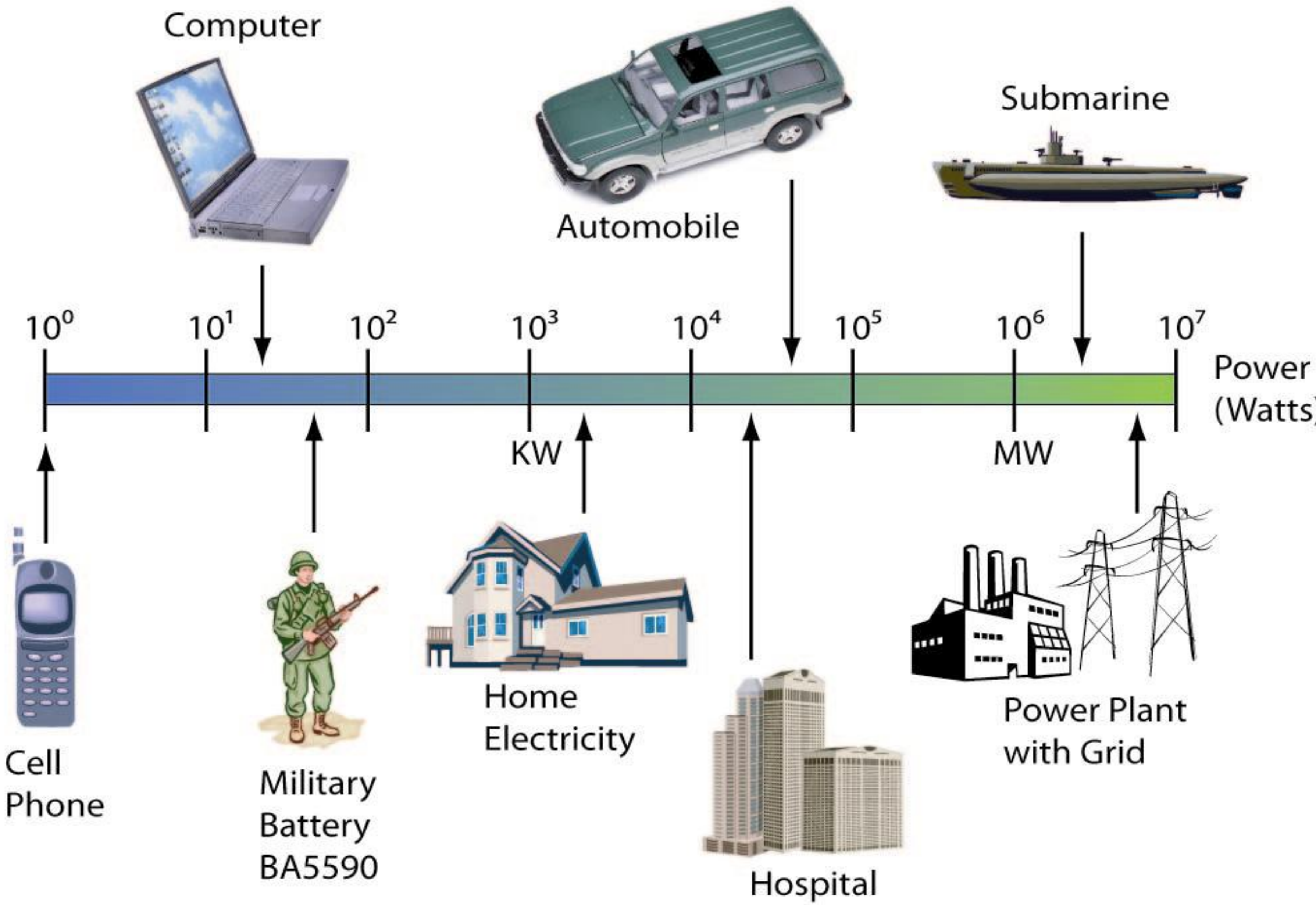
Types of Fuel Cell

Fuel Cell	Operating Conditions
Alkaline FC (AFC)	**Operates at room temp. to 80 ^{0}C** **Apollo fuel cell**
Proton Exchange Membrane FC (PEMFC)	**Operates best at 60-90 ^{0}C** **Hydrogen fuel** **Originally developed by GE for space**
Phosphoric Acid FC (PAFC)	**Operates best at ~200 ^{0}C** **Hydrogen fuel** **Stationary energy storage device**
Molten Carbonate FC (MCFC)	**Operates best at 550 ^{0}C** **Nickel catalysts, ceramic separator membrane** **Hydrocarbon fuels reformed in situ**
Solid Oxide FC (SOFC)	**Operates at 900 ^{0}C** **Conducting ceramic oxide electrodes** **Hydrocarbon fuels reformed in situ**
Direct Methanol Fuel Cell (DMFC)	**Operates best at 60-90 ^{0}C** **Methanol Fuel** **For portable electronic devices**

Types of Fuel Cell

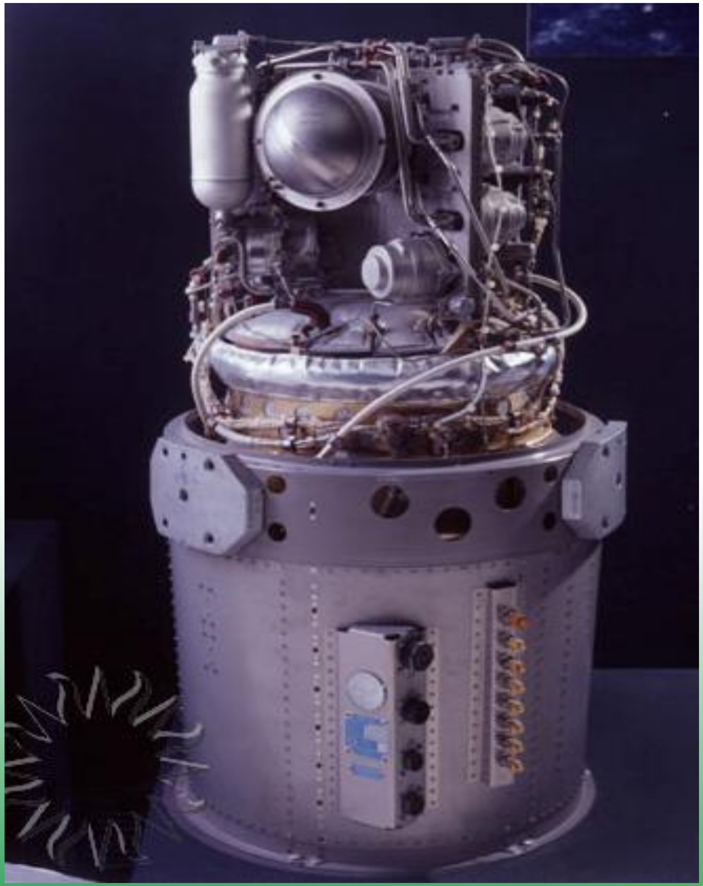


Fuel Cell Power Spectrum

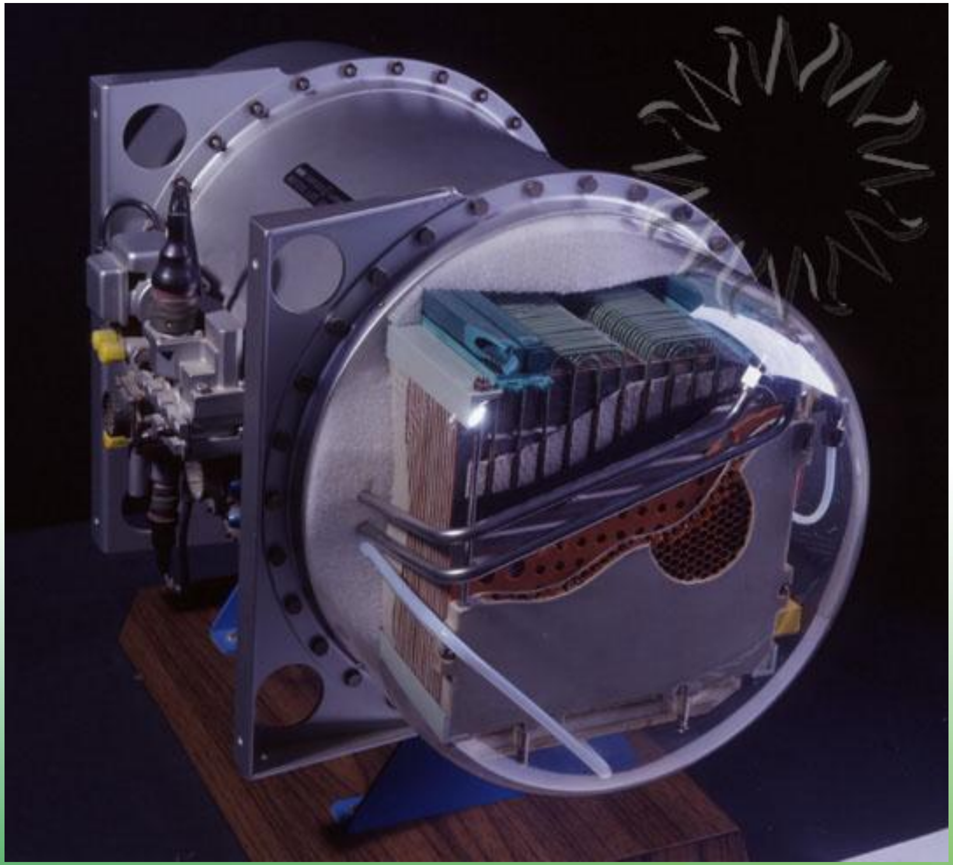


Space Application

Apollo Fuel Cell

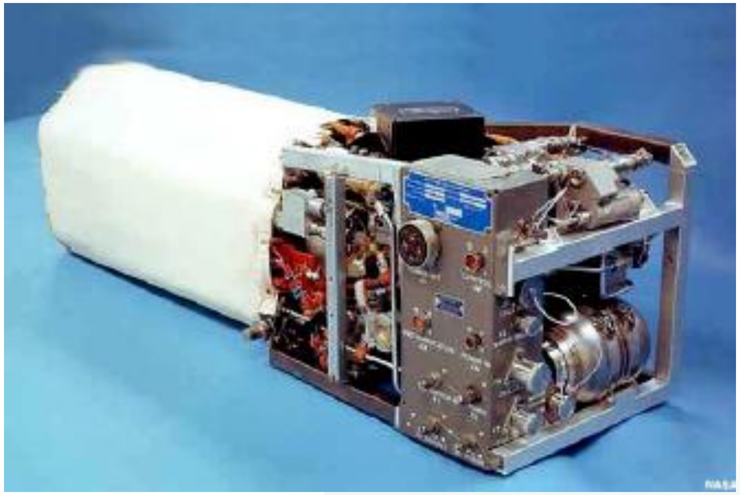


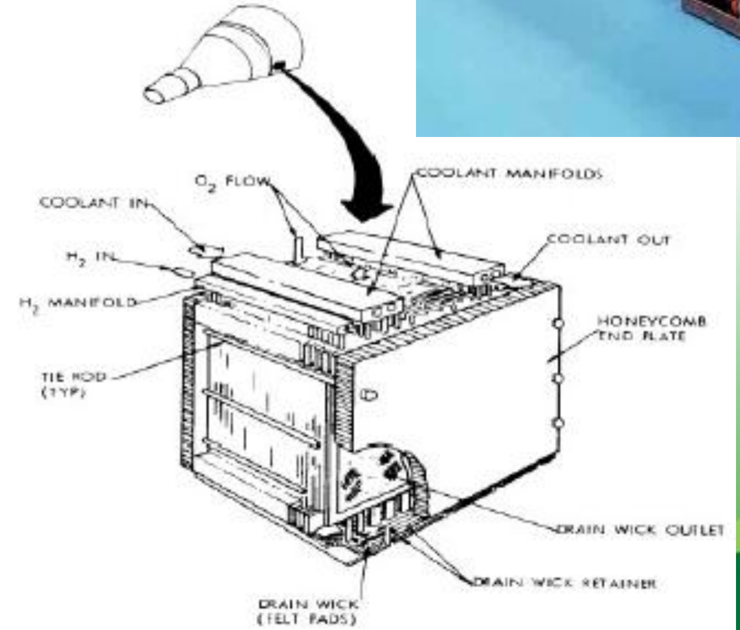
Gemini Fuel Cell



Space Application

Space Shuttle Fuel Cell

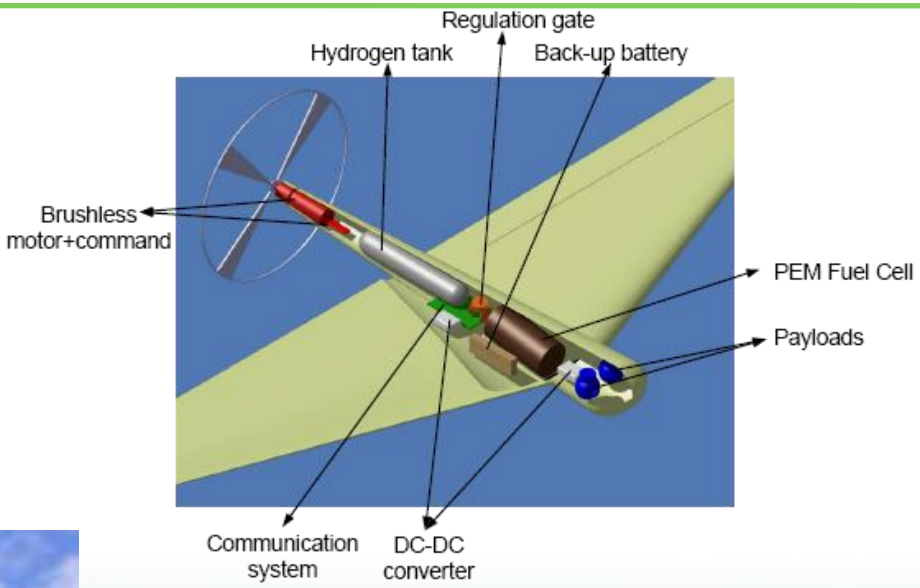




Gemini Fuel Cell Stack

Aerial Application

Icare II Airplane



Mini Fuel Cell UAV

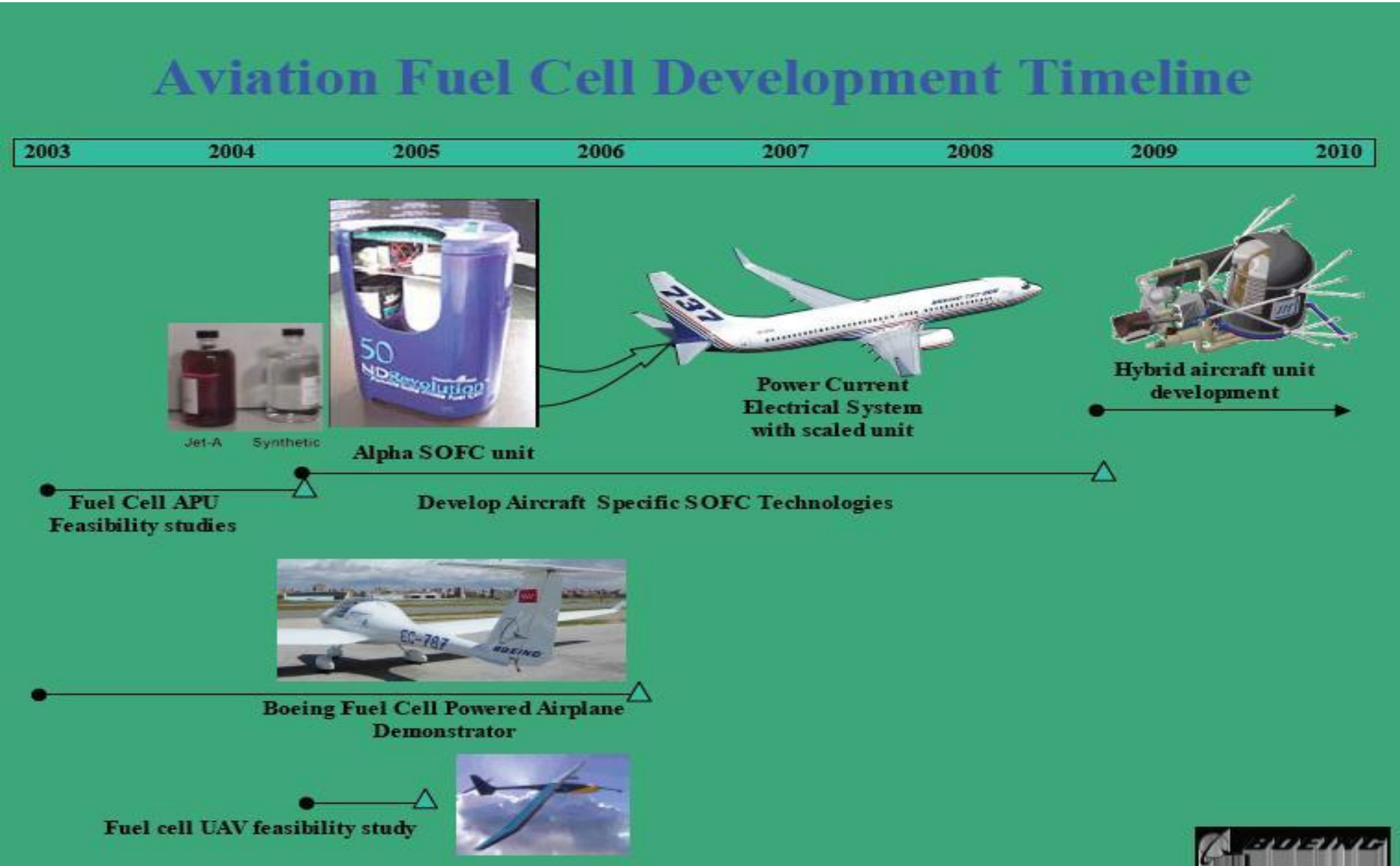
Helios

Aerial Application

Antares Airplane

Global Observer Airplane

Aerial Application



Aerial Application

Fuel Cell Powered Demonstrator Airplane

Batteries, H_2 system, motor/propeller and controllers being designed.

First flight in 2006

Diamond HK-36 airframe being modified

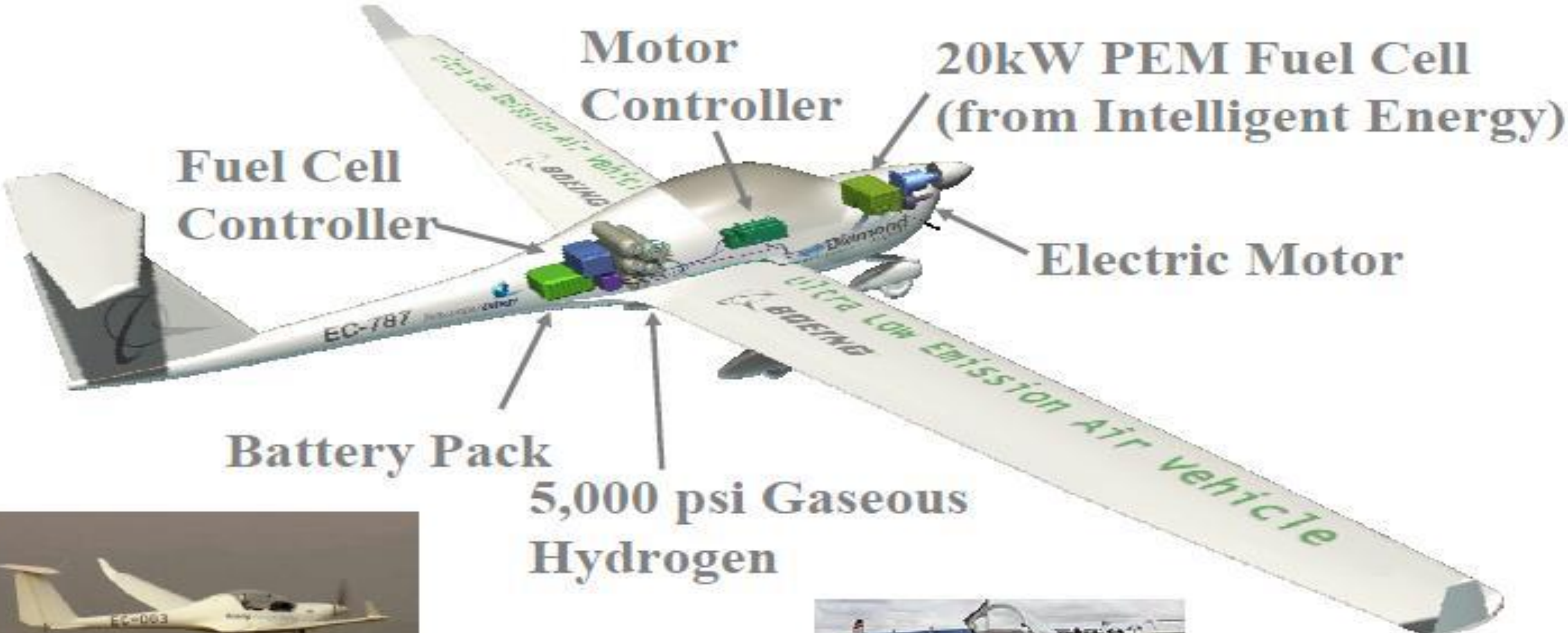
20kW Fuel cell unit built by Intelligent Energy (UK)

Integration in work

Aerial Application

Demonstrators are a means to get familiar with integration and operational issues

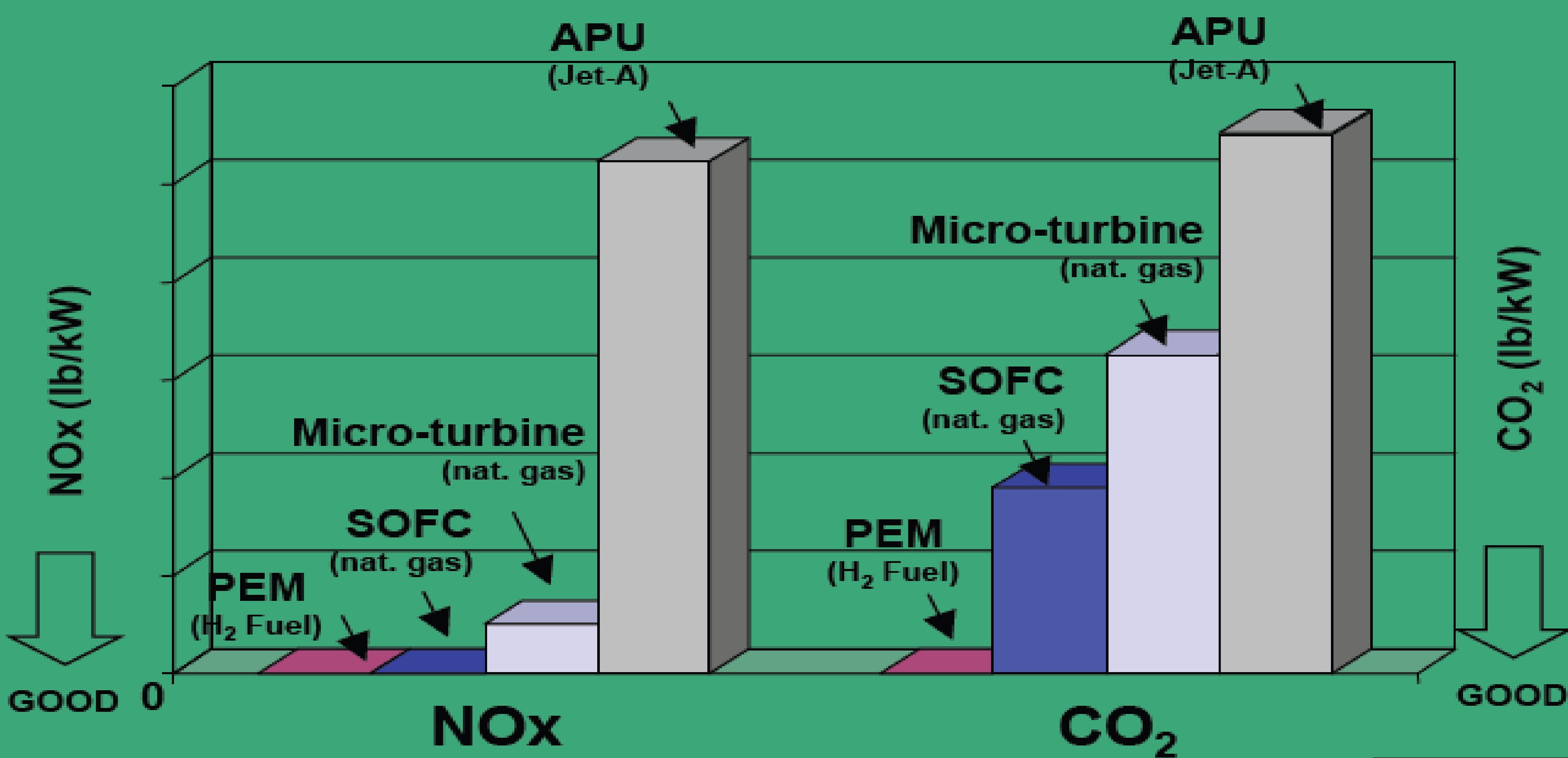
Boeing Fuel Cell Airplane Demonstrator – BR&T (Boeing Research and Technology) Europe



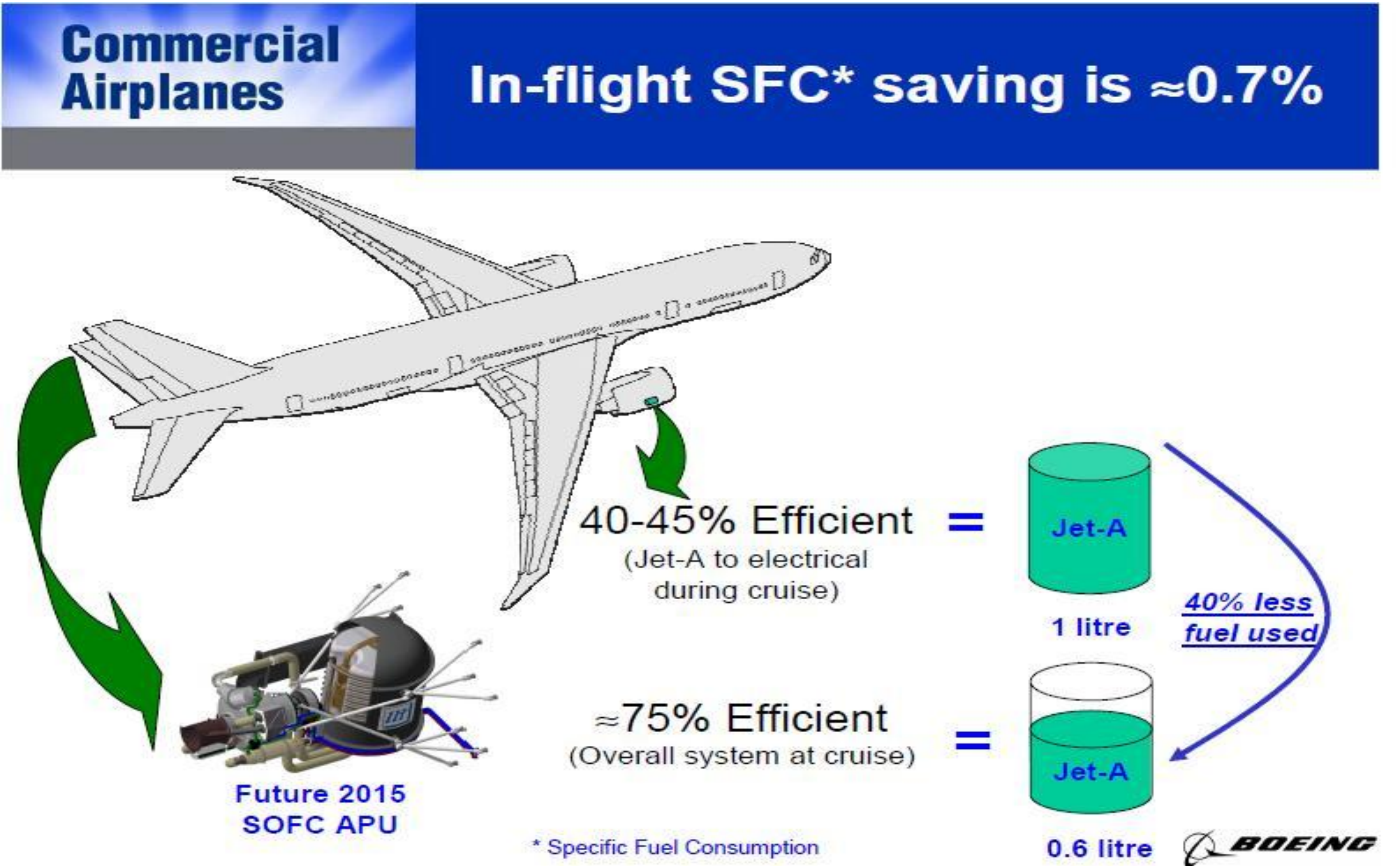
Aerial Application

Aerial Application

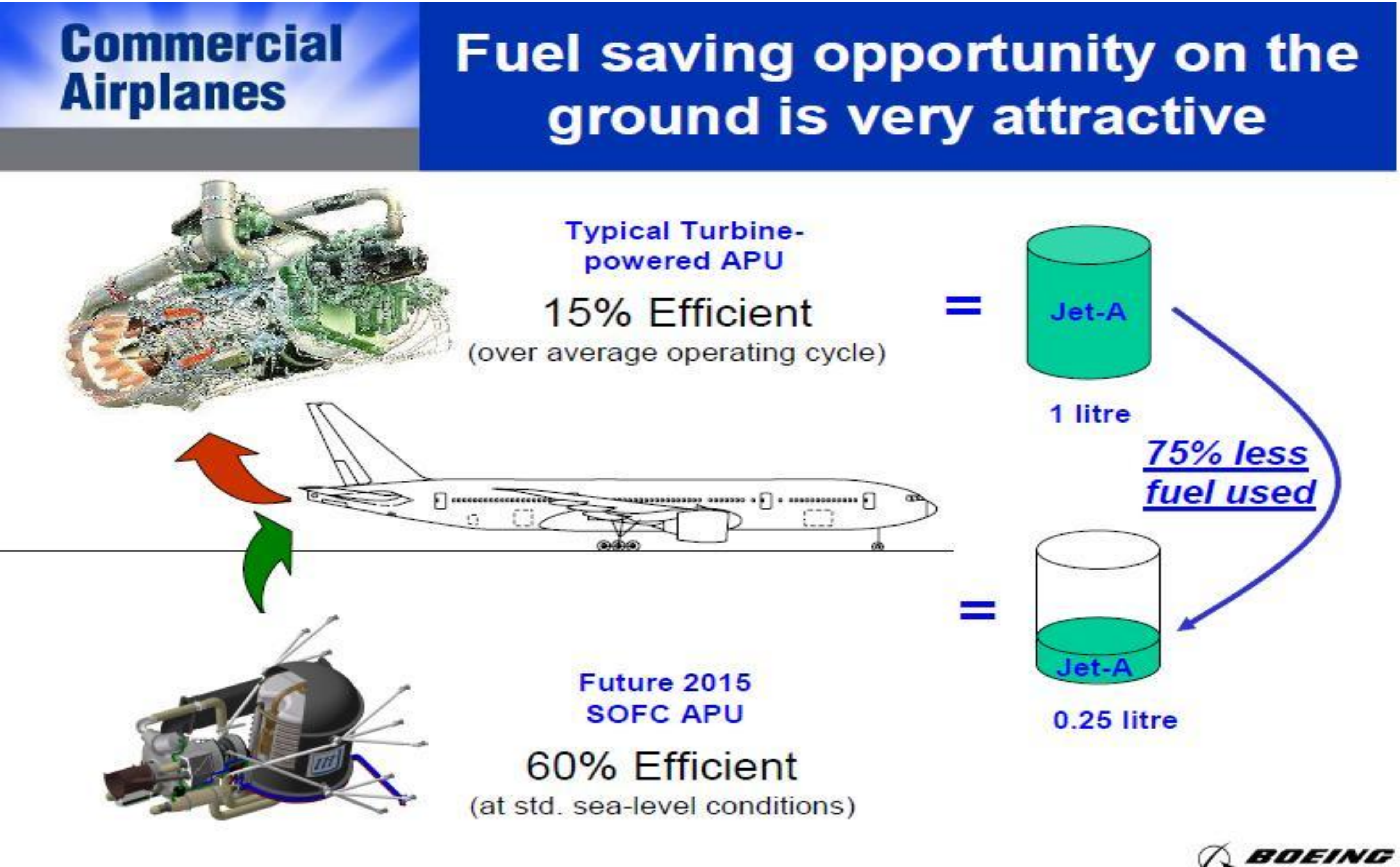
Fuel Cells Have Low Emissions



Aerial Application



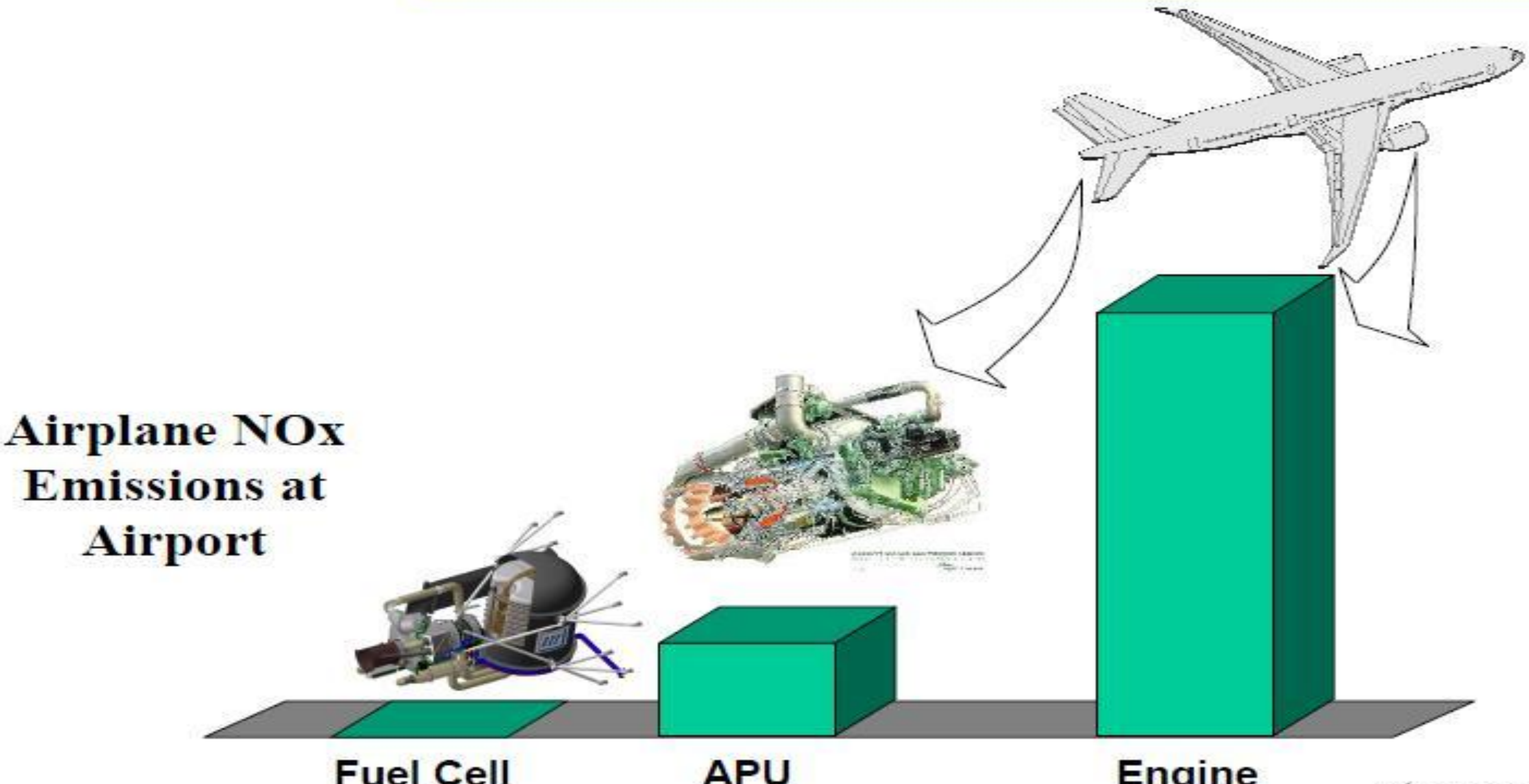
Aerial Application



Aerial Application

Commercial Airplanes

Fuel cell APU can cut airplane NOx emissions at the airport



BOEING

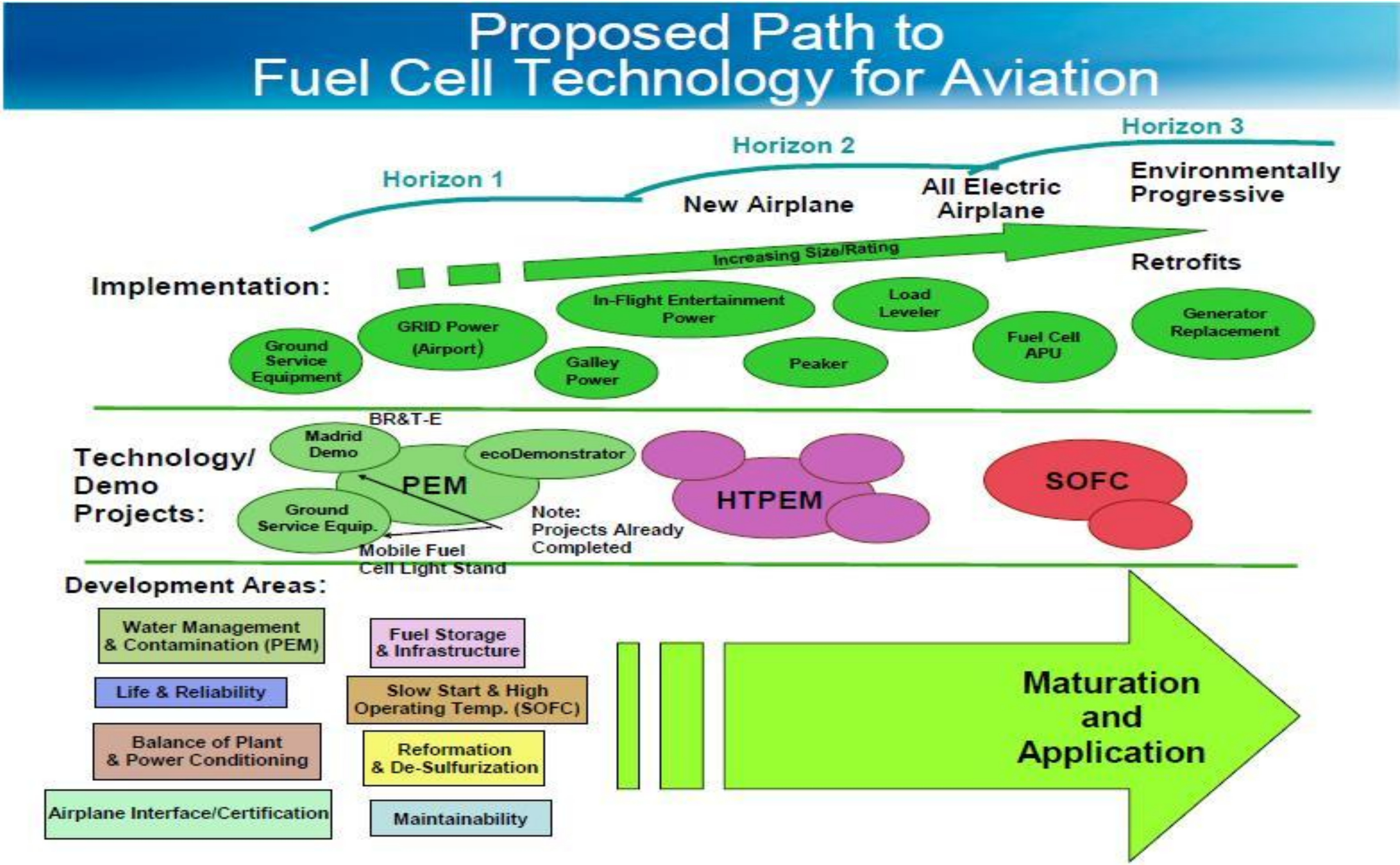
Aerial Application

More Electric Airplane (MEA) Background

- Efficiency changes in 787 due to:
  - Composite airframe
  - Efficient no-bleed engines
- Transition in power sources in the MEA
  - Increase in electric power to ~1.5 MW

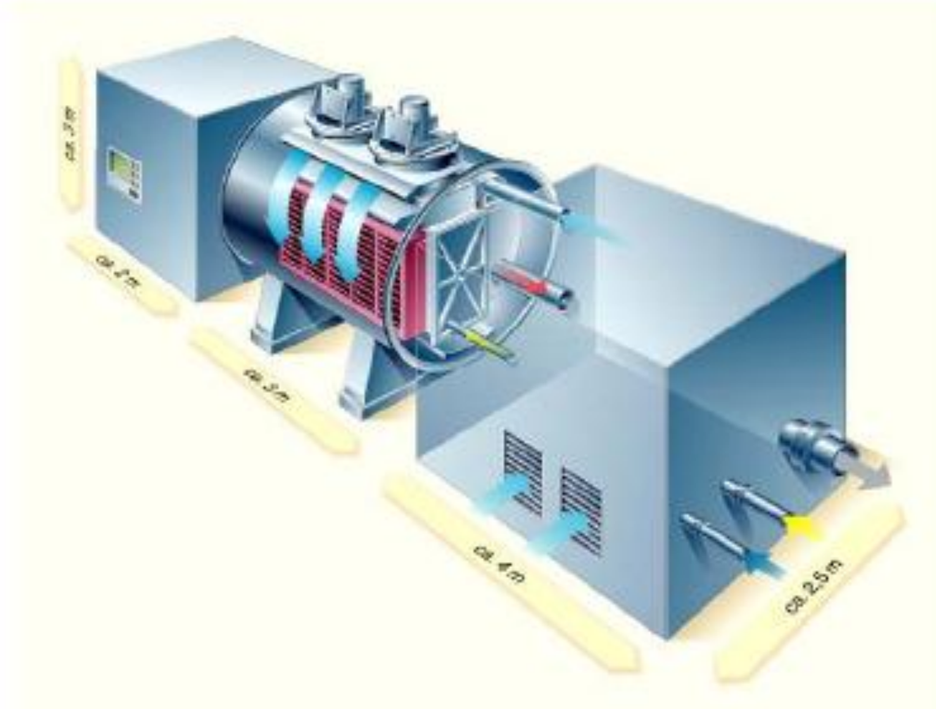
Power Source	Bleed	No Bleed + MEA
Electrical	Cabin Lighting Avionics, Fuel Pumps, etc.	Engine start, De-Ice ECS & Pressurization, Cabin Lighting, Avionics, Fuel Pumps, Brakes, Flight Controls, etc.
Hydraulic	Brakes, Flight Controls, Landing Gear, etc.	Flight Controls, Landing Gear
Pneumatic	Engine start, De-Ice ECS & Pressurization	Cowl De-Ice

Aerial Application



Power plant Application

Power plant Application



MTU's „Hot-Module" Development for CHP Power Plants

Courtesy of MTU

Power plant Application

Polymer Electrolyte Membrane (PEMFC)

- 1-10 kW
- 25-40 % efficiency LHV
- $ 5,000 /kW

Phosphoric Acid Fuel Cells (PAFC)

- 200-1000 kW
- 40 % efficiency LHV
- $ 3,500 / kW

Molten Carbonate Fuel Cells (MCFC)

- 250- 1,000 kW
- 45 % efficiency
- $ 3,000-4,000 / kW

Solid Oxide Fuel Cells (SOFC)

- 1-250 kW
- 45-48 % efficiency
- $10,000 - 20,000/kW

Power plant Application

Innovation and R&D Required for large Market

Efficiency, LHV

35-45

2005-2008

Early Markets
- Schools & Universities
- Government Buildings
- CHP; Free Fuel
- National Parks
- Military Bases
- State RPS Programs

2008-2010
- 5 kW – 75 kW PEMFC
- 250 – 1 MW MCFC, and SOFC
- 5- 40 kW SOFC
- $ 1,500-$2,000 / kW

55

65

2010-2020
- 75 kW – 250 kW PEMFC
- 250 – 3 MW MCFC, SOFC
- 2 – 50 kW SOFC
- 1MW + SOFC-CT
- <<$ 800 /kW

Transportation Application

Transportation Application

Transportation Application

Mercedes

Honda

GM

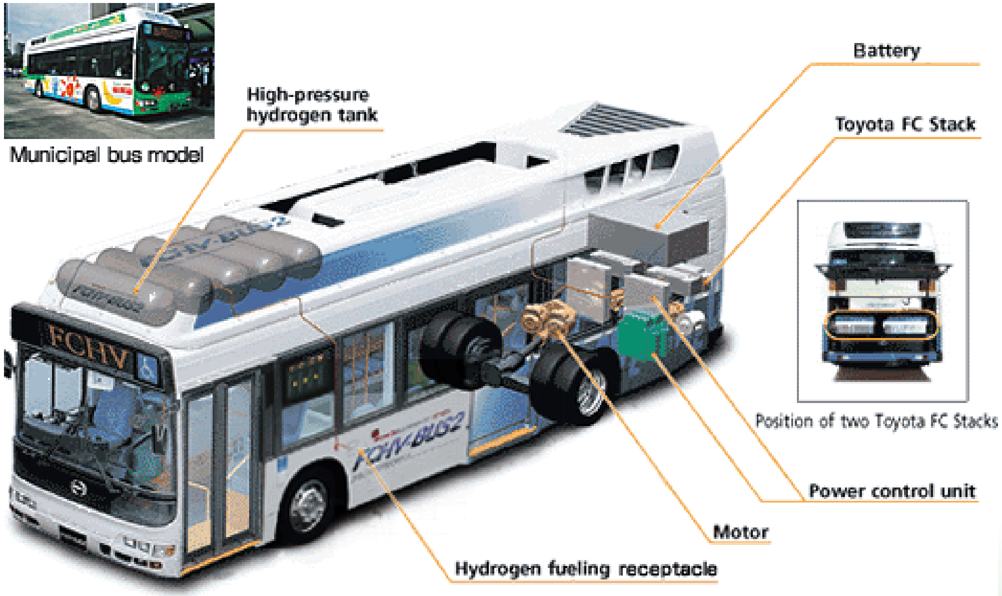
University of Delaware

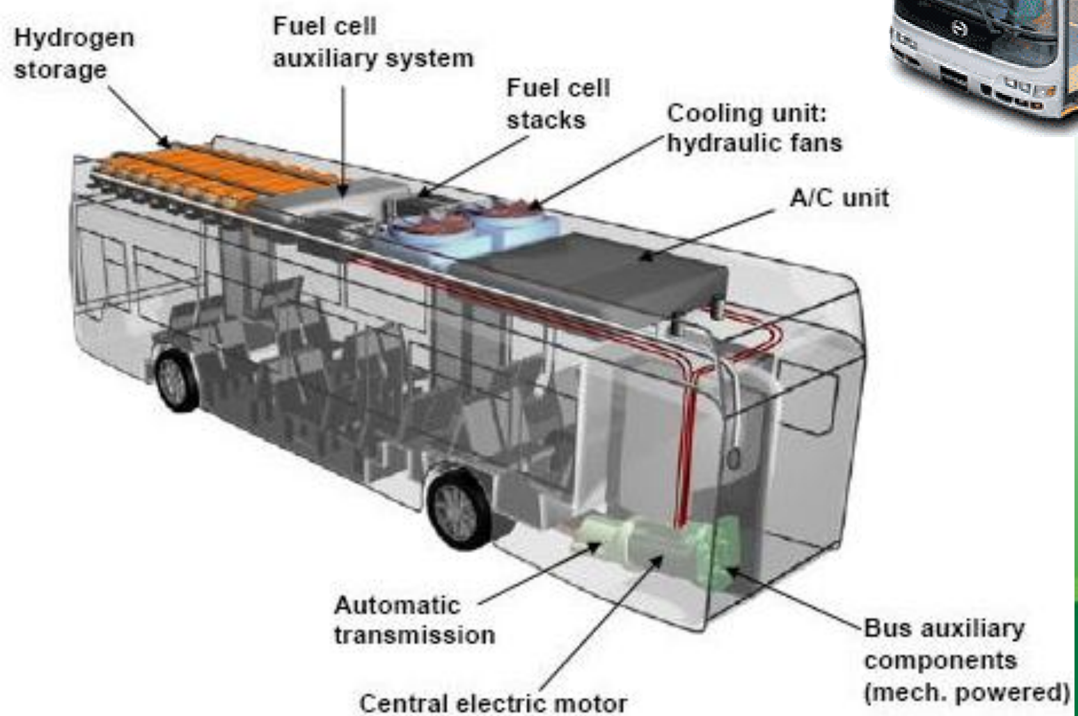
Europe

Transportation Application

Transportation Application

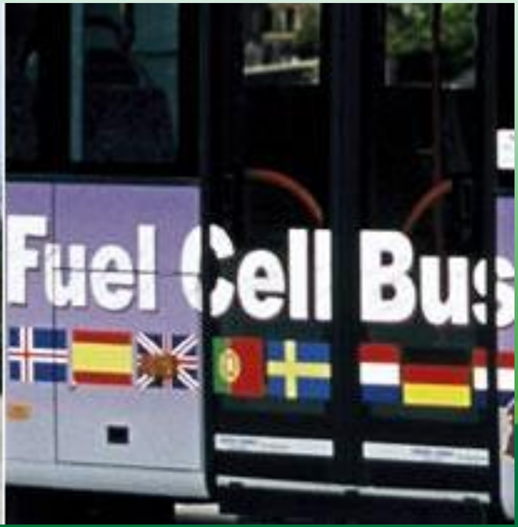
Toyota&Hino Bus



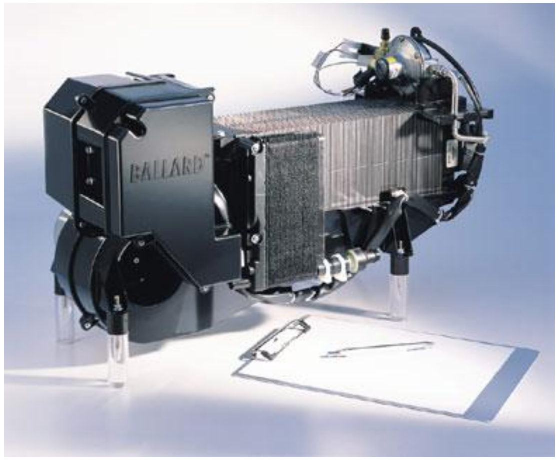


Citaro Bus, Mercedes Benz

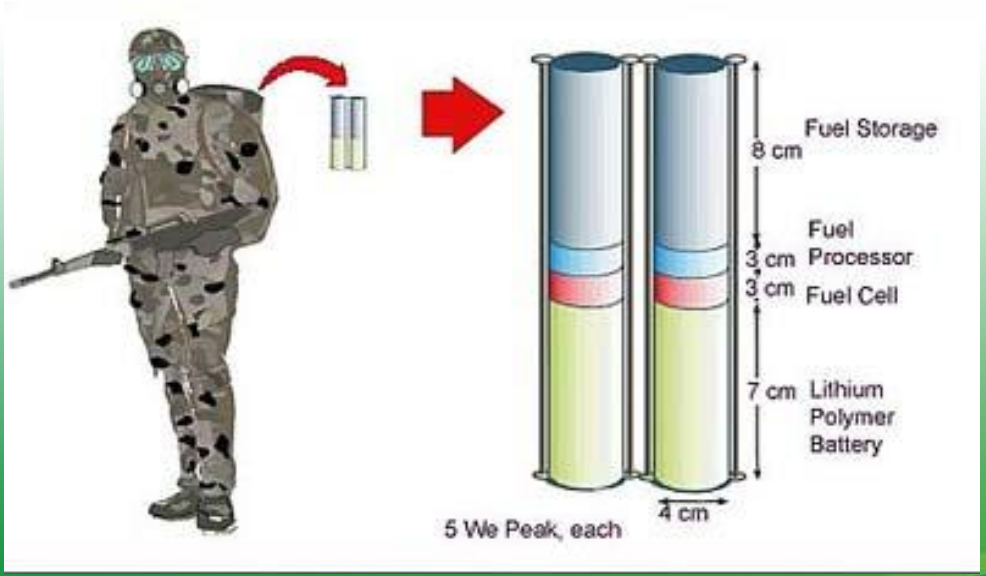
Transportation Application



Transportation Application



Portable Application



Fuel Cell R&D and Materials Research Needs

Key Areas of R&D(SOFC)

- Stable Interconnect under anode and cathode environments
- Advanced Electrodes
- Seals
- Low cost fabrication methods
- High power density
- Durability

Key Areas of R&D(PEMFC)

- Durable electrolyte
- High temperature electrolyte
- Lower Pt. Loadings
- Complex Fuel Processing

Fuel Cell in Iran, University & Research Center

- University

Amirkabir, Sharif, Tehran, Khajeh Nasir Tousi,

Tarbiat Modarres, Iran Science & Technology, …

- Research Center

Esfahan Engineering, SANA

Fuel Cell in Iran, Conference & Seminar

- Hydrogen & Fuel Cell Conference(second)
- Fuel cell Seminar (5th)

Thanks!

“Yes, My friends, I believe that water will one day be employed as fuel, that hydrogen and oxygen which constitute it … will furnish an inexhaustable source of heat and light … Water will be the coal of future”

Jules Verne, The Mysterious Island, 1874

Email: Micropropulsion@yahoo.com