

FUEL CELL TECHNOLOGY

STAV

VCE CONFERENCES

2004

Peter J Ball

Southern Biological



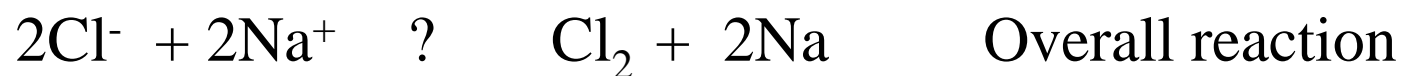
Fuel Cell History

- Michael Faraday, 1820, principle of electrolysis:
 - current can separate a conducting fluid into its components
- Sir William Grove, 1839, reverse electrolysis, ie principle of fuel cells
 - remove the current and the components spontaneously recombine

Demonstration of Fuel Cell Effect

- “Gas battery”
- Reverse electrolysis
- Electrolyse a solution of NaCl, then observe the reverse reaction as evolved gases react spontaneously on the surfaces of the Pt electrodes.

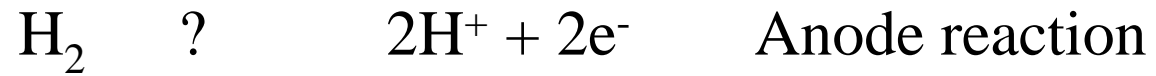
NaCl Electrolysis Reactions (1)



NaCl Electrolysis Reactions (2)



NaCl Fuel Cell Reactions



$$E_0 = 1.36\text{V}$$

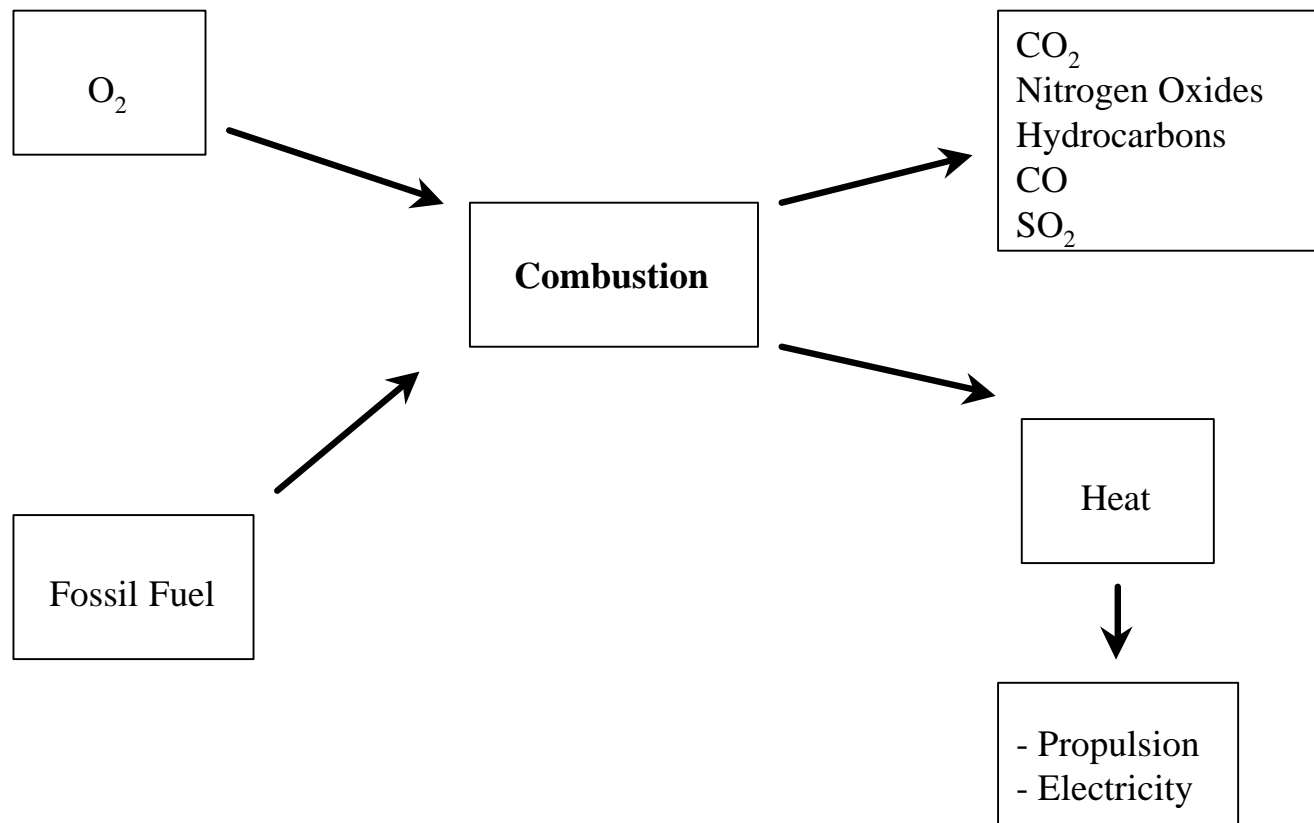
Reasons For Slow Development

- Ease of generation of electricity
- Development of internal combustion engines
- Technological barriers
 - Cost to overcome higher than alternative technologies

Renewed Interest Caused By:

- Dwindling fossil fuel reserves
- Increasing environmental concerns
- Limitations of alternative energy sources
- Solutions to technical problems

Environmental Concerns: Energy System Based On Fossil Fuel



Environmental Concerns: The Carbon Balance

Atmosphere

Oxidized carbon (CO, CO₂)

Surface of Earth

Carbon in organic systems
eg cellulose, plankton

Underground

Reduced carbon (C_nH_{2n+2})
i.e. hydrocarbons



Limitations of solar & wind energy

- Subject to vagaries of nature
- Objections from neighbours
- Remote locations
- Costly to transport electricity
- Inefficiencies in battery technology

Wind Farm Objections (1)

There are 80,800-tonne, 100-metre-tall wind turbines proposed in the area, with 46 of them directly adjacent to the Cape Liptrap Coastal Park. Where will we look then? Away?

Letter to *The Sunday Age*, 7th Dec 2002.

Wind Farm Objections (2)

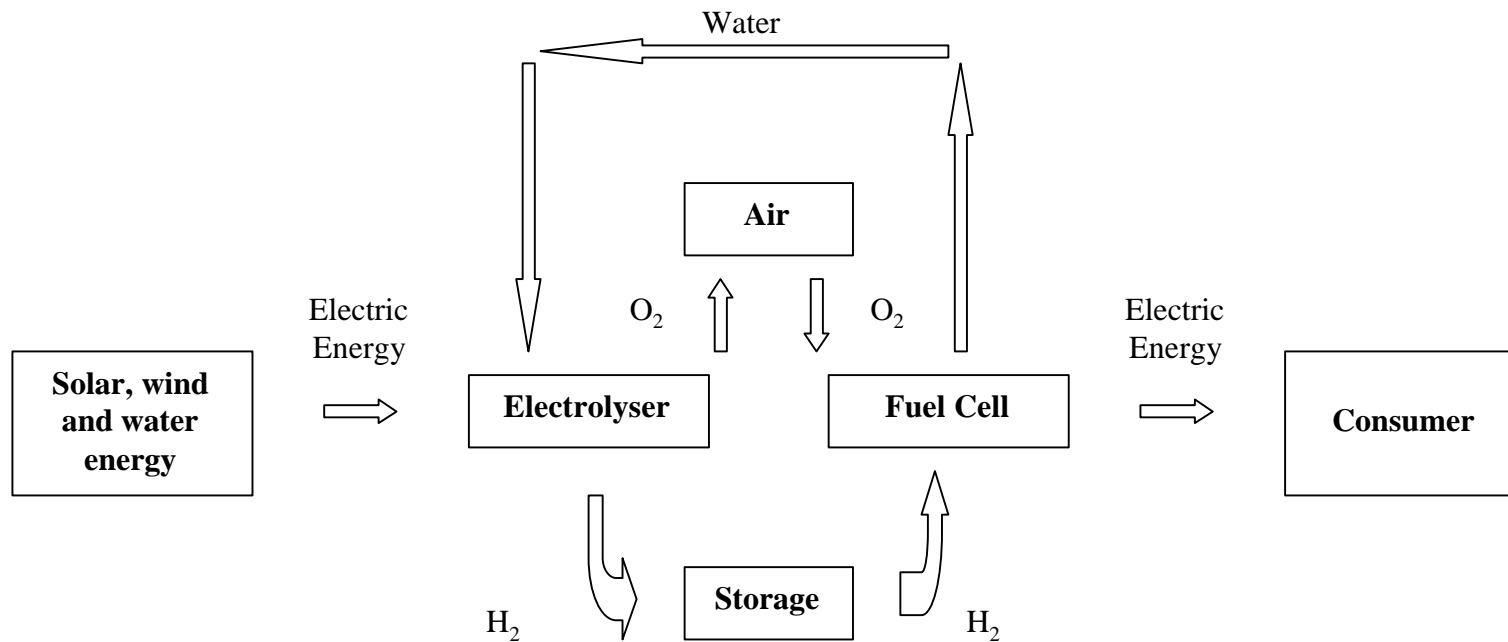
The State Government will require any future applicants for wind farms to undertake an assessment of landscape values in the first stage of seeking approval.

The Age, 22nd Nov 2003.

Overcoming Technical Hurdles

- New materials,
 - e.g. conductive polymers
- New production and manufacturing technologies,
 - e.g. catalytic converters
- Research and development,
 - e.g. NASA, the automotive industry

Energy System Based On Hydrogen



Advantages of Hydrogen Technology

- Highly efficient
- Clean
- Renewable

Advantages of Fuel Cells

- Continuous operation as long as fuel is available.
- Highly efficient due to direct conversion of chemical to electrical energy.
- Low (zero) emissions
- Quiet (silent) operation
- No mechanical wear since no moving parts

Challenges For Hydrogen Technology

Safe storage and transportation:

- Liquify at 200 atm & -253°C
- Transform into methane
- Absorb in metal hydrides
- Adsorb on carbon nanofibres

Twentieth Century Hydrogen disasters:

- The *Hindenburg* crash
- The *Challenger* explosion

Types Of Fuel Cell Technologies

Large Scale – High Temperature

- Phosphoric Acid
- Molten Carbonate
- Solid Oxide

Small Scale – Low Temperature

- Alkaline
- Direct Methanol Fuel Cells (DMFC)
- Proton Exchange Membrane (PEM)
 - Regenerative

Types Of Fuel Cell Technologies

Phosphoric Acid Fuel Cells

- Operating temperature 200°C
- Steam evolved can be used for cogeneration
- Suitable for large vehicles with long duty cycles (eg locomotives), or medium sized facilities such as hospitals, airports, large hotels.

Types Of Fuel Cell Technologies

Molten Carbonate Fuel Cells

- An emerging fuel cell technology that will use coal-based fuels, but with very high efficiency.
- Operating temperatures will be around 650°C.

Types Of Fuel Cell Technologies

Solid Oxide Fuel Cells

- This technology is advancing rapidly and is suited to large, high power applications such as regional electricity generation.
- Operating temperatures reach 980°C.

Types Of Fuel Cell Technologies

Alkaline Fuel Cells

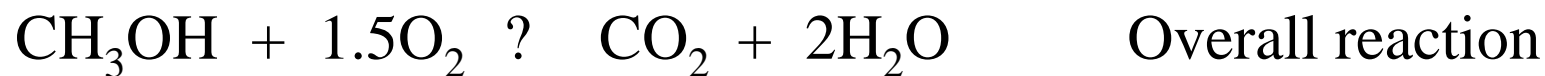
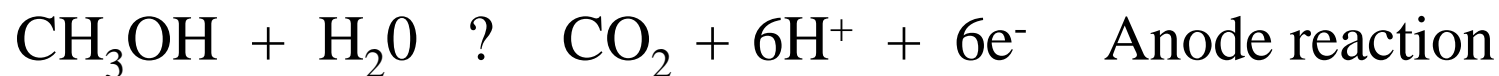
- KOH electrolyte
- Up to 70% efficient
- Very high cost
- Restricted to space applications

Types Of Fuel Cell Technologies

Direct Methanol Fuel Cells (DMFC)

- Use a polymer membrane as the electrolyte.
- The anode catalyst is able to extract hydrogen from methanol directly rather than requiring a reformer.
- Operating temperatures are low.

DMFC Redox Reactions

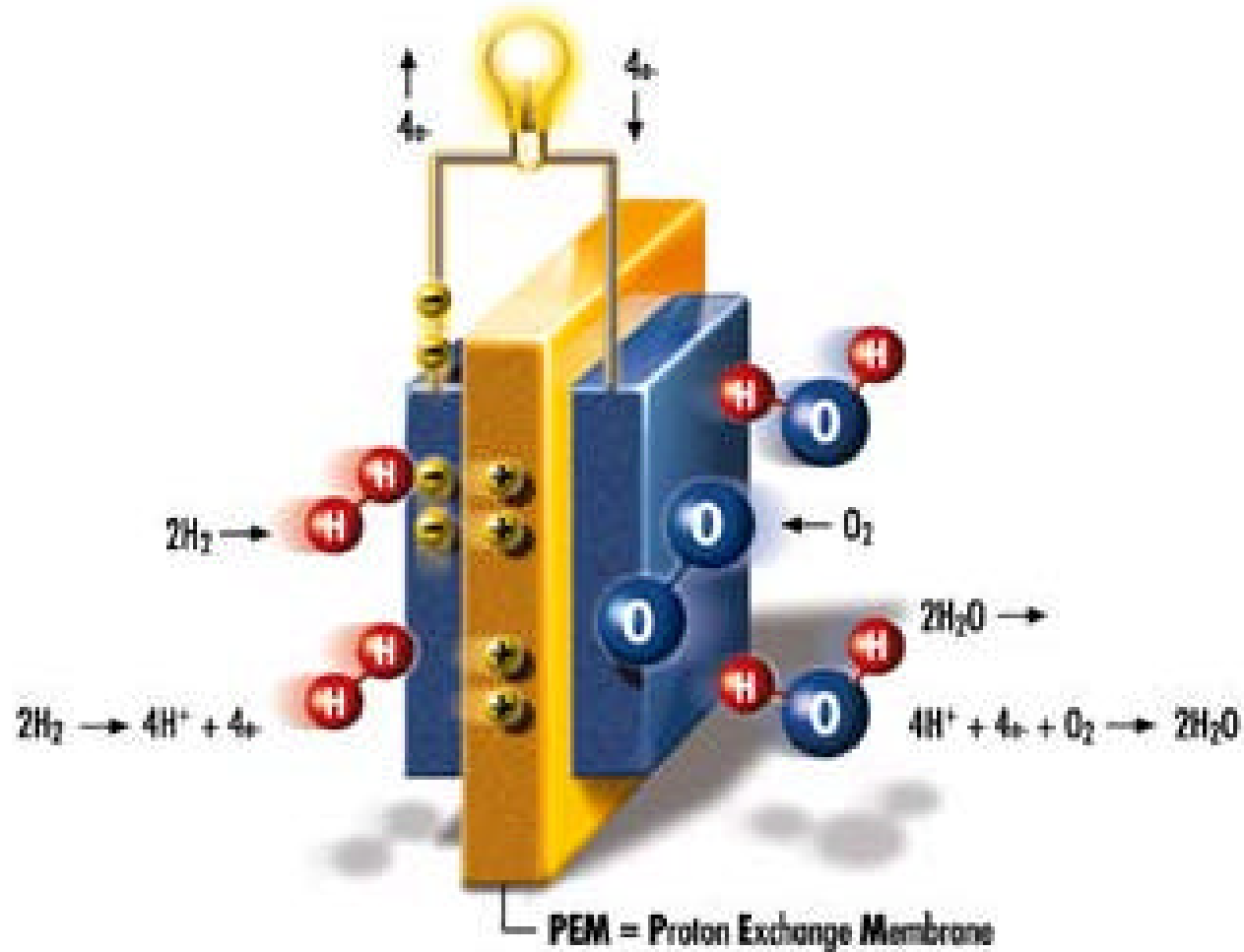


Types Of Fuel Cell Technologies

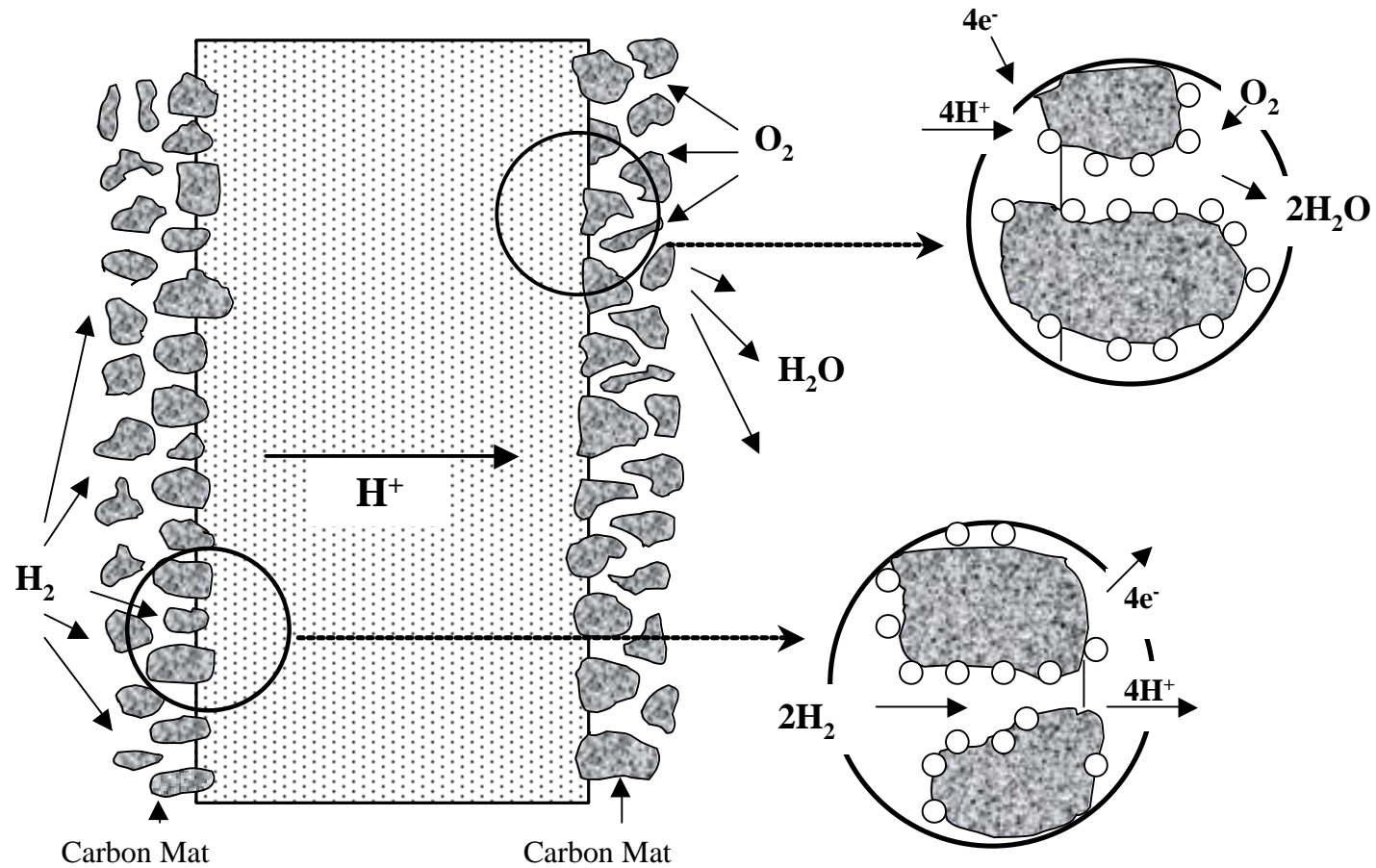
PEM Fuel Cells

- Suitable for applications like automotive vehicles where rapid shifts in power demand are required.
- Will eventually power small devices such as computers, mobile phones and cameras.
- Operate at low temperatures.

PEM Fuel Cell Schematic



PEM Electrode Assembly

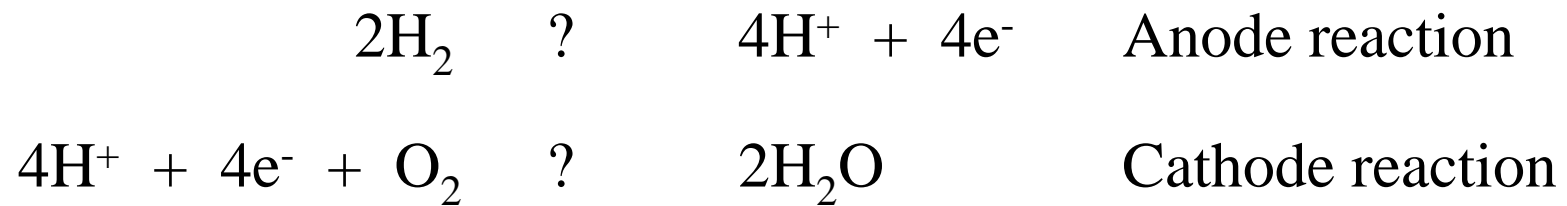


○ Platinum catalyst

Proton Exchange Membrane Structure

- Nafion[®] - developed by Dupont in the 1960s.
- Perfluorosulphonate Ionomer
 - PTFE with pendant SO₃H groups that form overlapping ionic clusters.

PEM Redox Reactions



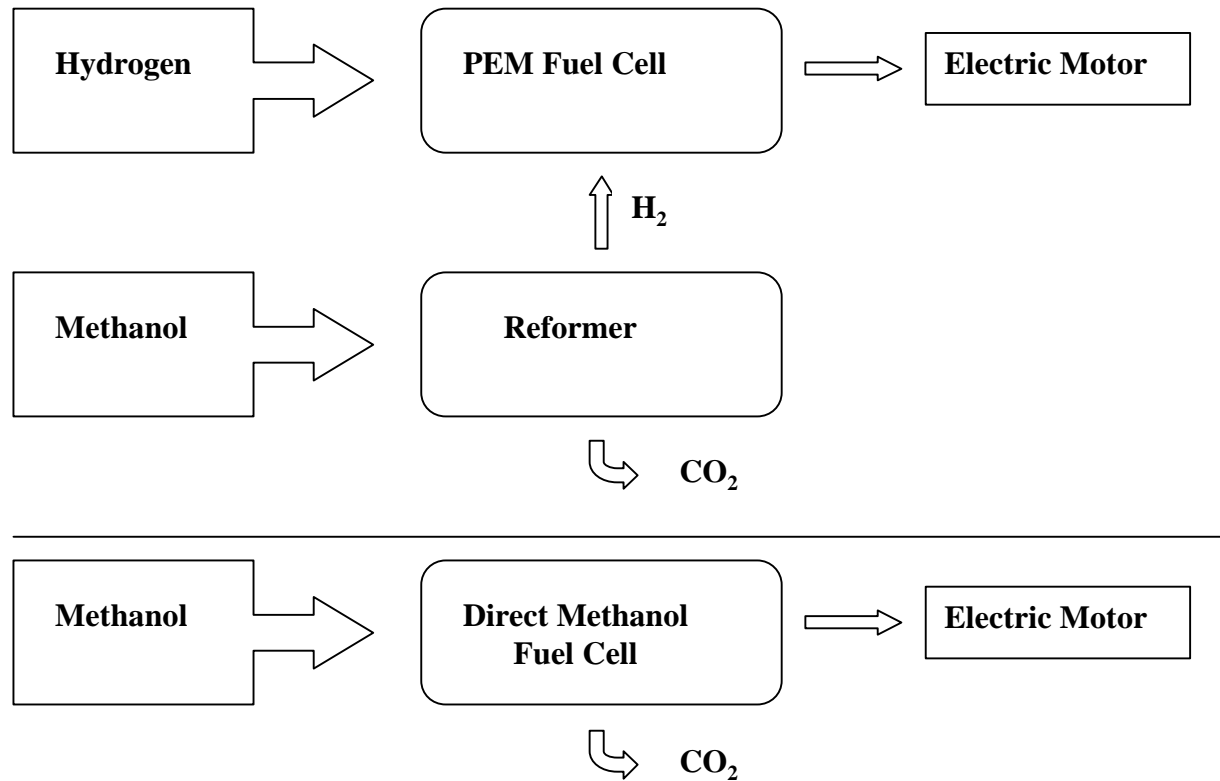
$$E_0 = 1.23\text{V}$$

Types Of Fuel Cell Technologies

Regenerative Fuel Cells

- A variation on PEM fuel cells where the water that is formed in the cell is recirculated back to the electrolyser where it can be used again.
- Research into this technology is being led by NASA.

Hydrogen Fuel Cell Possibilities



Implications Of Widespread Use: The Hydrogen Economy

- Reduction of Greenhouse Gases (CO₂)
- Alleviation of global warming
- Reduction in acid rain
- Reduced risk of oil spills
- Oil Companies become Energy Businesses
- Shifts in geo-political power
 - future of OPEC?

New Look of Energy Companies (1)

“Long before we decide to stop using fossil fuels, costs will have already made the decision for us. Not just the monetary cost, but the human cost, the cultural cost, the environmental cost.

We will, quite rightly, demand that our future energy is both sustainable and renewable. We will expect a lot from the likes of solar power, wind power, geothermal power and hydrogen fuel cells.”

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- advertisement for Shell, *National Geographic*, Nov 2003

New Look Of Energy Companies (2)

empower yourself

excellence

Solar Power is a modern reality which empowers you to generate your own clean, silent energy, wherever you might be.

BP Solar prides itself on meeting the solar power needs of a diverse world every single day.

solutions

Remote power for camping, marinas, homes and eco-tourism.

Urban power for grid connected homes and offices.

Industrial power for telecommunications, telemetry and monitoring.

choice

Contact us at
www.bpsolar.com
 or 1800 802 762



You grow bigger and stronger when you think long term.

Everyone is talking about it. But how much is really being done? As one of Australia's largest energy companies, we believe the corporate world can make a significant contribution towards environmental sustainability.

So much so that we've taken a leadership role and developed the Towards Leadership Code in partnership with The Barossa Environmental Foundation. The Code provides a simple and effective framework for businesses to address various environmental issues and progress towards an ecologically sustainable future.

This initiative, along with others such as our partnership with the native tree planting organisation, Greenfleet Australia, to offset the greenhouse gas emissions from our vehicle fleet by 2005, are just some of the ways we're looking positively to the future. Find out more by checking out our sustainability report at www.energex.com.au




“ a world of learning ”

Major Driver of Change: The Automotive Industry

Number of vehicles is increasing

- 1960 - 4% ownership
- 1980 - 9% ownership
- 2002 - 12% ownership (700 million cars)
- 2020 - 15% ownership (1.1 billion cars)

Major Driver of Change: The Automotive Industry

Vehicle distribution is widening

- Traditional concentration in:
 - North America, Europe, Japan
- Growing numbers in:
 - Brasil, China, India, Korea, Mexico, Russia and Eastern Europe, Thailand.

Fuel Cells In The Automotive Industry

- Daimler Chrysler
- Ford
- General Motors
- Honda
- Peugeot – Citroën
- Renault – Nissan
- Toyota

Fuel Cells In The Automotive Industry

Comparison of energy efficiency*:

- Internal combustion 20-30% max
- PEM fuel cells 55% plus

* Conversion of energy content of fuel to drive-wheel power

Fuel Cells In The Automotive Industry

New design possibilities:

- Improved safety due to lower centre of gravity
- More room
- “Drive by Wire” technology
- Modular construction – keep main chassis but replace upper body (docking station concept)
- Cars could power houses

Fuel Cells In The Automotive Industry



Fuel Cells In The Automotive Industry

If just one out of 25 vehicles in California had fuel cell technology, their combined generating capacity would exceed that of the state utility grid!

Curriculum Integration

Chemistry

- Redox
- Photochemistry
- Electrolysis
- Polymer Science
- Rates of Reaction
- Stoichiometry
- Catalysis
- Avogadro's Number
- Energy and Enthalpy

Physics

- Circuit Design
- Characteristics of DC circuits – current, voltage and resistance
- Connections in series and parallel
- Energy Transfer Efficiency
- Inverse Square Law

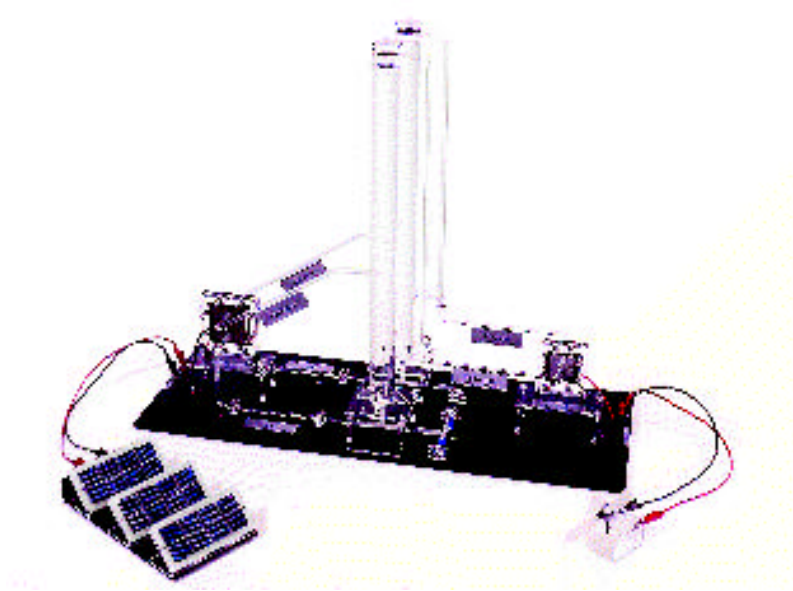
Environmental Science

- Solar Energy
- The Greenhouse Effect
- Renewable Energy
- Storage of Hydrogen
- The Carbon Balance
- Acid Rain and Oil Spills

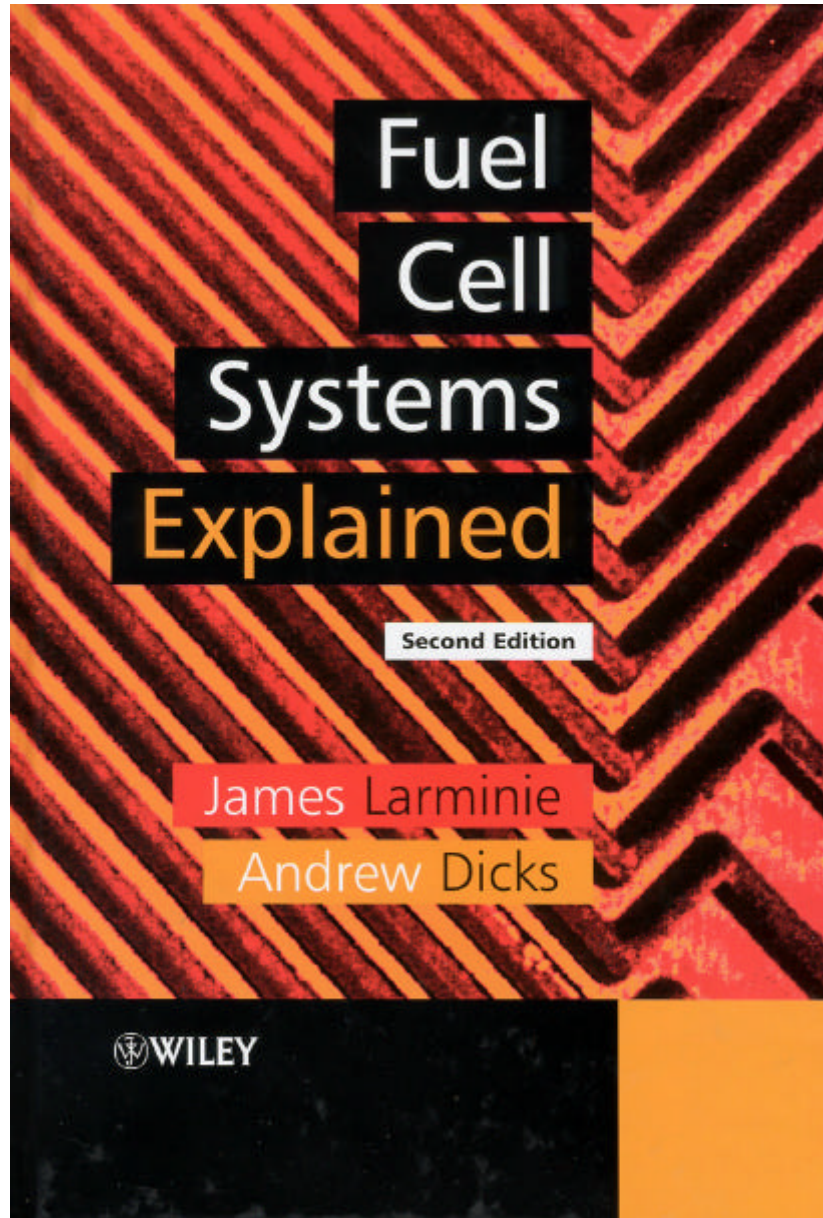
STUDY ASPECTS OF THE HYDROGEN ECONOMY

- Investigate the technical barriers that delayed the introduction of this technology for over 100 years.
- Research the implications for OPEC as global dependence on fossil fuels decreases.
- Examine the potential for a reduction in the Greenhouse Effect as the use of fuel cells becomes more widespread.
- Study other fuel cell technologies and compare them with Proton Exchange Membranes.
- Follow the transformation of the old economy “oil companies” into modern “energy businesses”.

Educational Fuel Cell Models



- Robust
- Reliable
- Stylish
- Experimental possibilities
- Self-contained
- Just add distilled water and light



Further Information

Further Reading Suggestions

- Australian Geographic, vol 67, Jul-Sep, 2002
- The Age, Drive Supplement, May 23rd, 2002
- Scientific American, Oct 2002
- New Scientist, August 16th, 2003
- The Economist, various issues

Going Further on the WWW

- www.aciltasman.com.au
- www.aie.org.au
- www.cfcl.com.au
- www.csiro.au
- www.howstuffworks.com/fuel-cell.htm
- www.h-tec.com
- www.southernbiological.com