HYDROGEN ECONOMY

Promoted by UTM OTEC Solutions Sdn Bhd

With the Support of UTM Ocean Thermal Energy Centre (UTM OTEC)

Prepared and Presented by

Dato' Ir Dr A. Bakar Jaafar, FASc

Professor & Director of UTM OTEC

E-mail: bakar.jaafar@utm.my

Mobile: +60123207201

OUTLINE OF PRESENTATION

PREAMBLE

1.

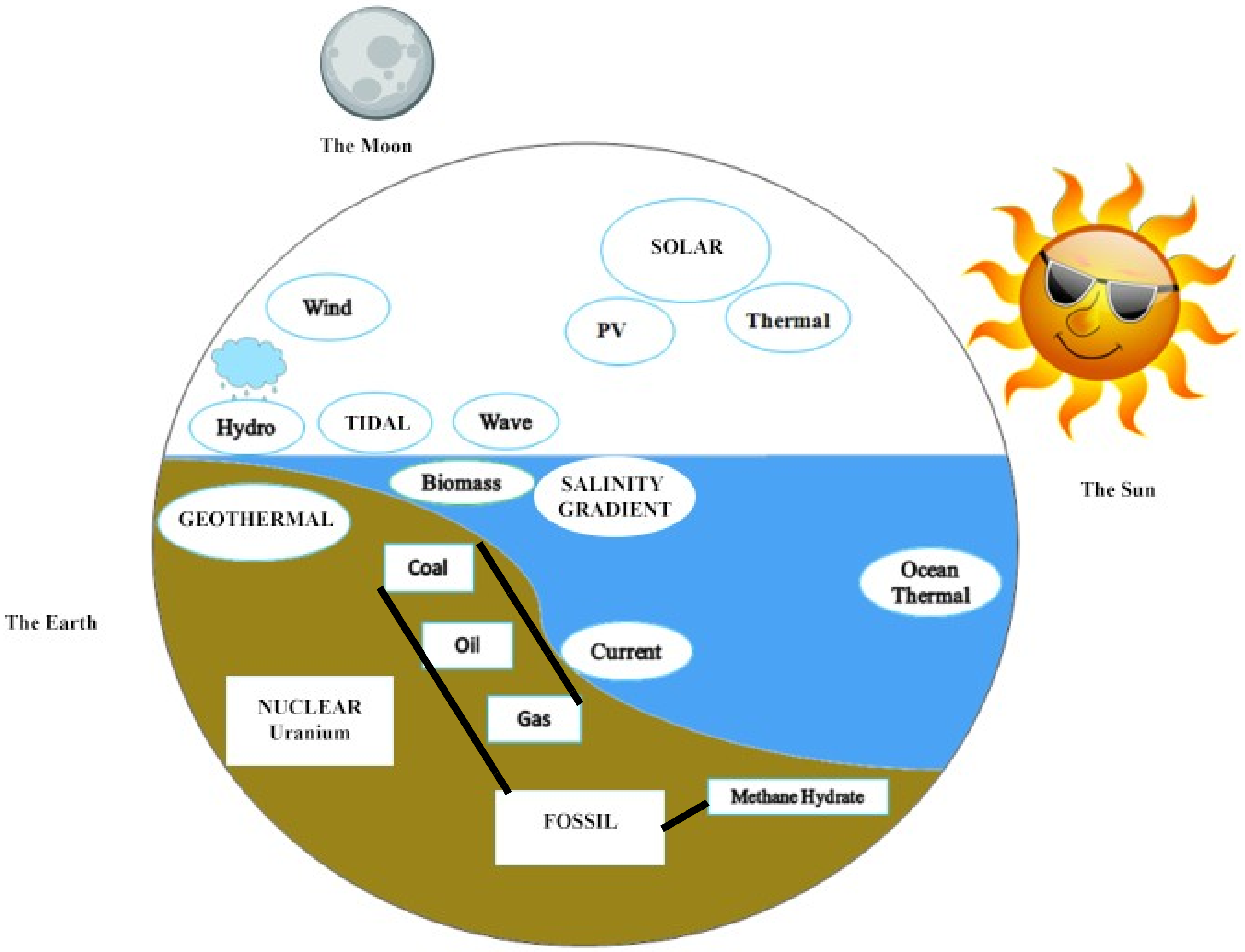
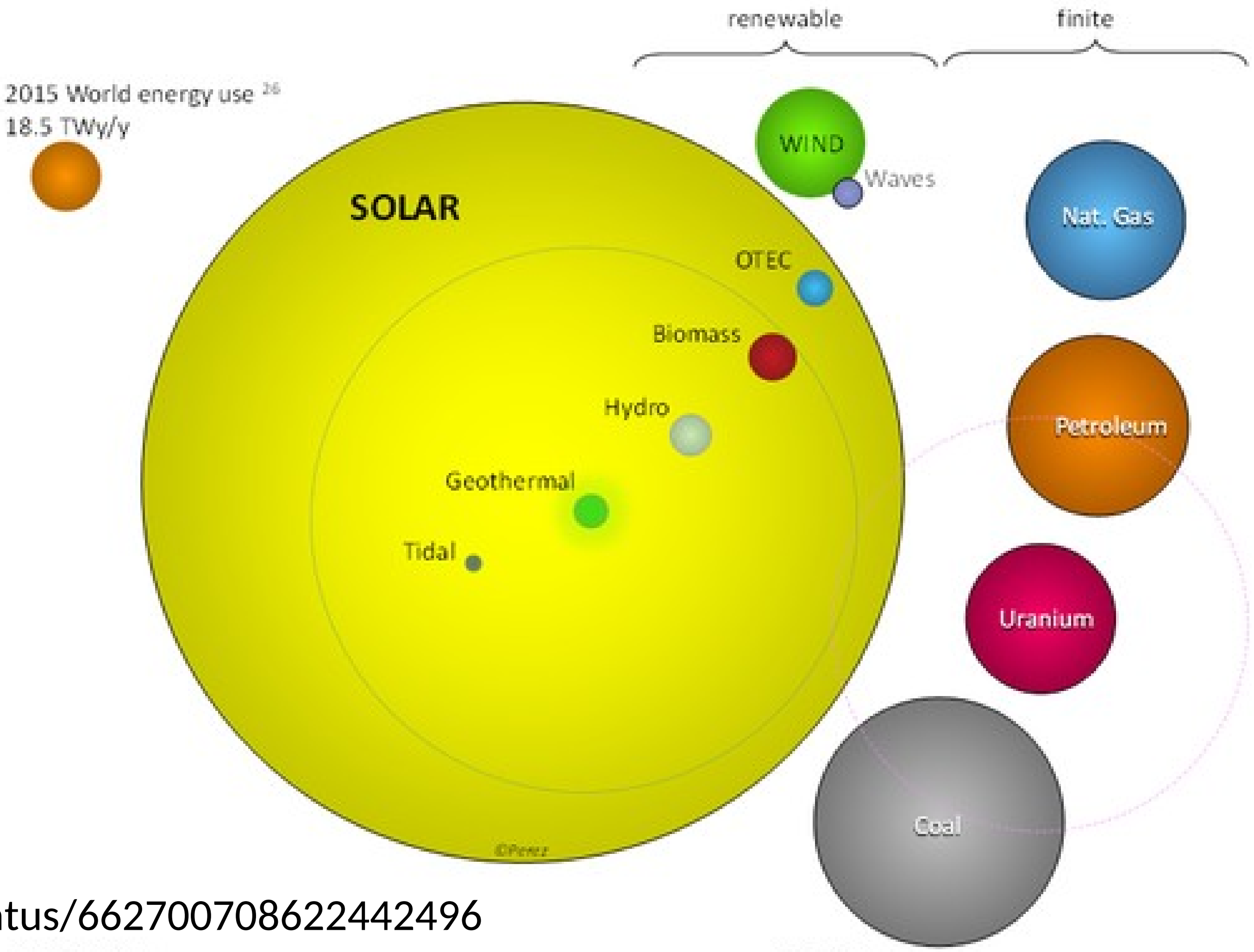


Figure 1 . Primary and Secondary Sources of Energy: Renewable & Non-Renewable



https://twitter.com/ieashc/status/662700708622442496

RENEWABLE				FINITE	
Solar [12]	23,000 TWy/y	Biomass [6]	2-6 TWy/y	Nat. Gas [9,21]	220 TWy
Wind [3]	75-130 TWy/y	Hydro [7]	3-4 TWy/y	Petroleum [9,21]	335 Twy
Waves [4]	0.2-2 TWy/y	Geotrm [8,22,23]	0.2-3++ TWy/y	Uranium [13 to 20]	185++ TWy
OTEC [5]	3-11 TWy/y	Tidal [2]	0.3 TWy/y	Coal [9,21]	830 TWy

HYDROGEN: THE MOST DOMINANT ENERGY CARRIER IN 21ST CENTURY

Ref: IbrahimDincer (2008)

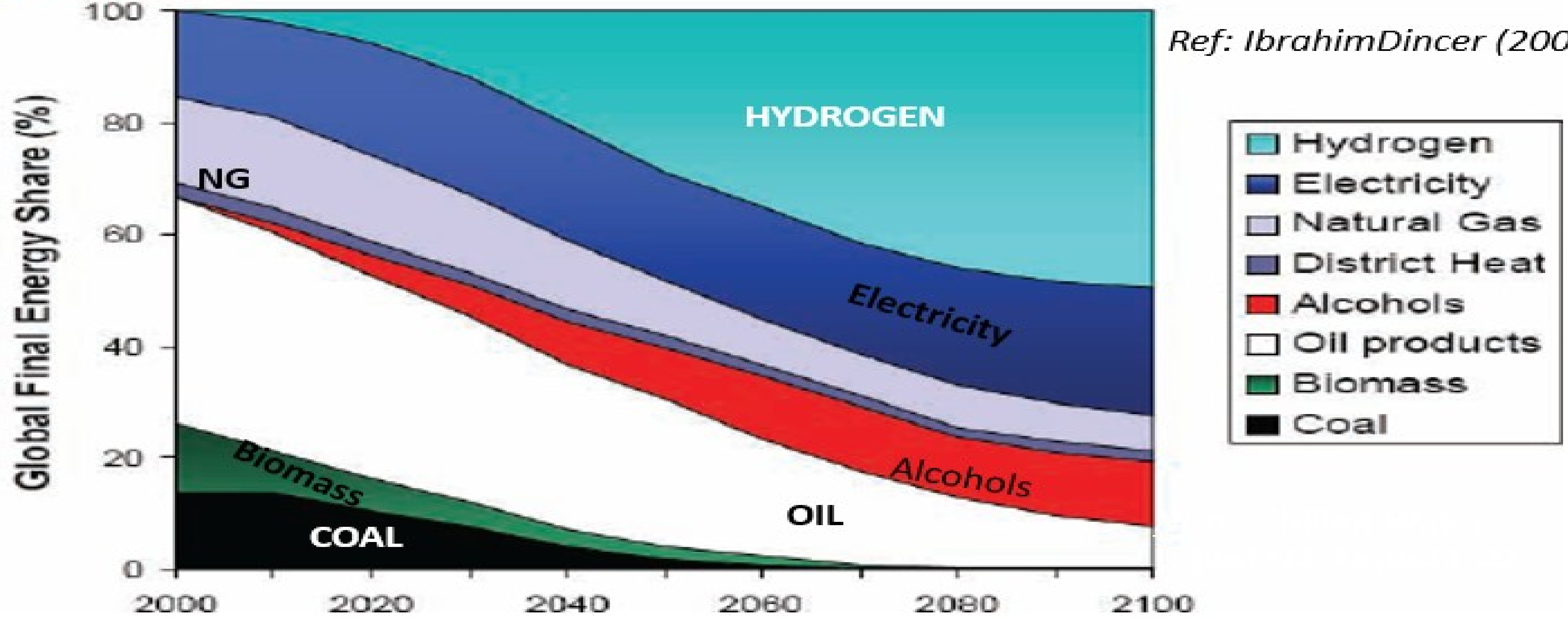
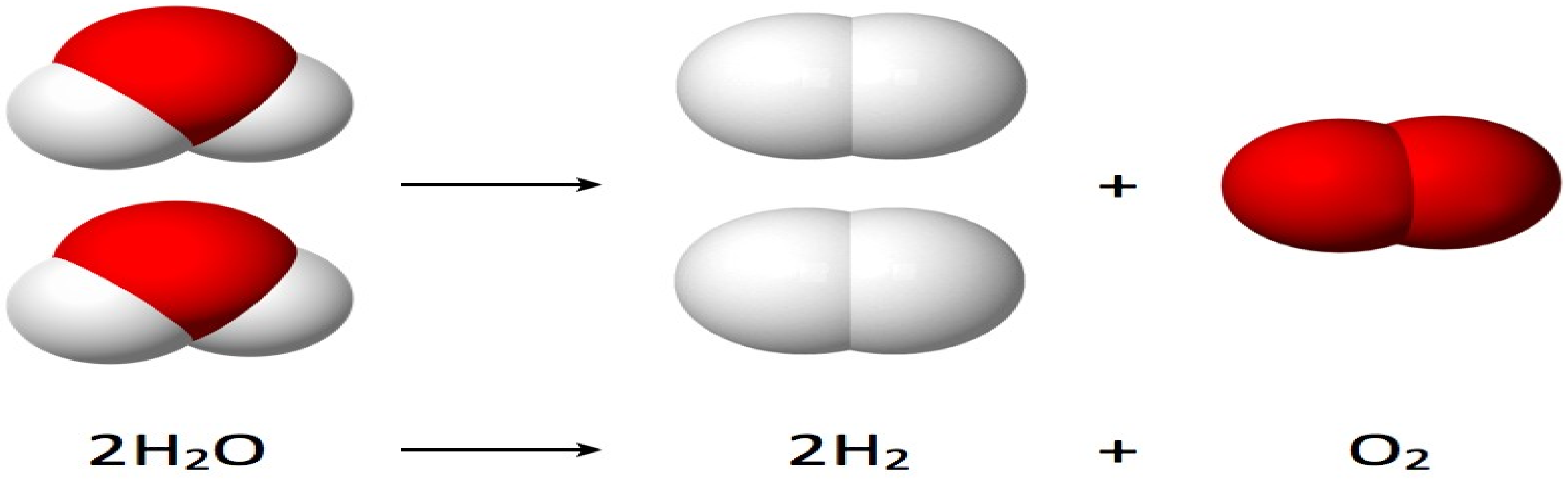
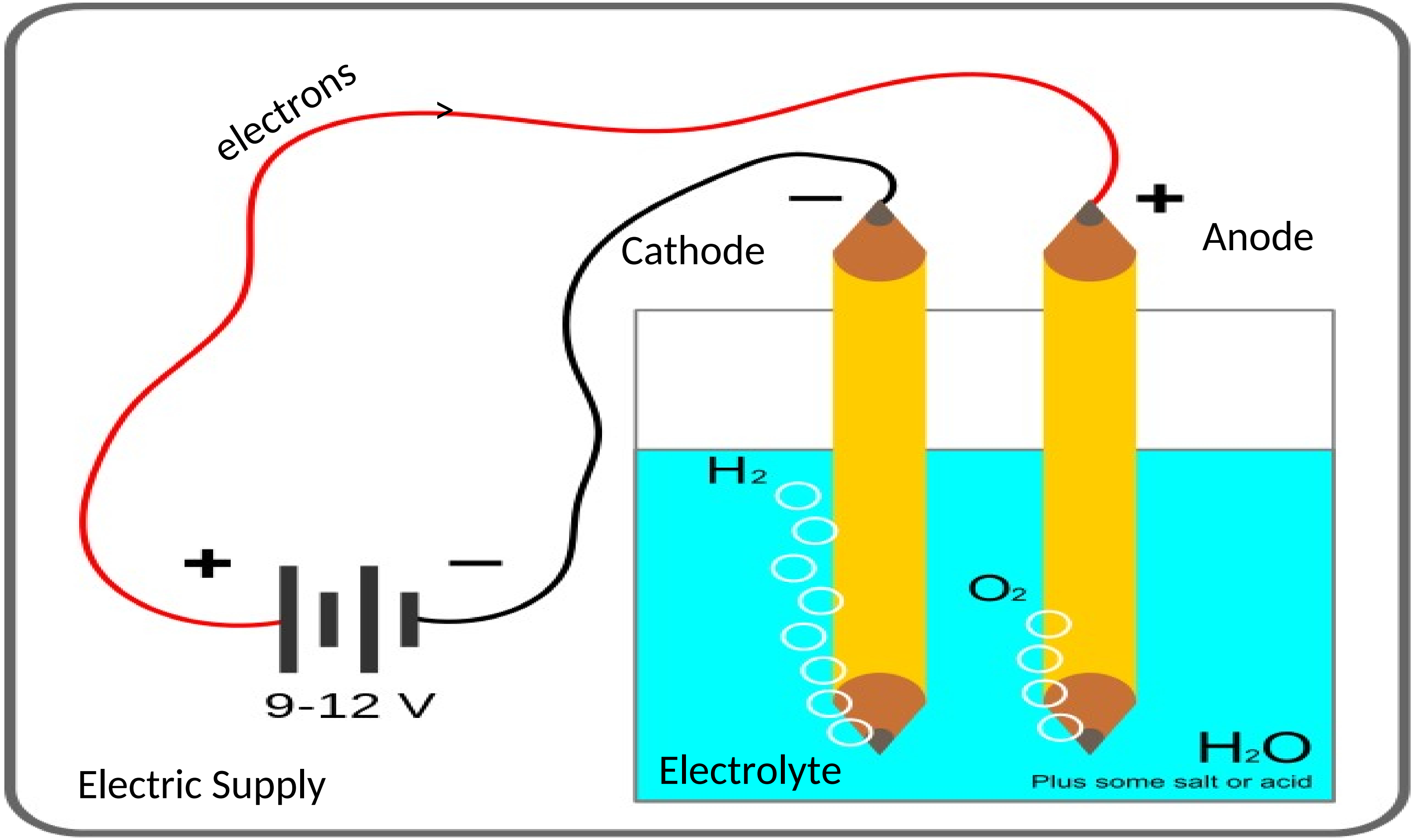


Figure 1. Evolution of global market shares of different final-energy carriers for the period 1990–2100 based on the scenario by Barreto et al. [4]. The alcohols category includes methanol and ethanol.

What is Electrolysis?



Basics in Electrolysis



REDUCTION REACTION IN ELECTROLYSIS

- In pure water at the negatively charged cathode, a reduction reaction takes place, with electrons (e^-) from the cathode being given to hydrogen cations to form hydrogen gas (the half reaction balanced with acid):
- Reduction at cathode: $2\,H^+(aq) + 2e^- \rightarrow H_2(g)$

OXIDATION REACTION IN ELECTROLYSIS

- At the positively charged anode, an oxidation reaction occurs, generating oxygen gas and giving electrons to the anode to complete the circuit:
- Oxidation at anode: $2\ H_2O(l) \rightarrow O_2(g) + 4\ H^+(aq) + 4e^-$

BALANCING BOTH REACTIONS IN ELECTROLYSIS

- Cathode (reduction):

  $2\,H_2O(l) + 2e^- \rightarrow H_2(g) + 2\,OH^-(aq)$

- Anode (oxidation): $4\,OH^-(aq) \rightarrow O_2(g) + 2\,H_2O(l) + 4\,e^-$
- Combining either half reaction pair yields the same overall decomposition of water into oxygen and hydrogen:
- Overall reaction: $2\,H_2O(l) \rightarrow 2\,H_2(g) + O_2(g)$

MINIMUM ENERGY REQUIRED TO SPLIT WATER INTO H2 & O2

- 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

CONVERSION

237 kJ/1 mole of H2

= 237 kJ/1.01 gm of H2

=237 kJ/(1.01 gm)(kg/kg)H2

=237 kJ/(1.01 gm)[(kg/kg)(kg/1000 gm) H2

= 234x1000 kJ/kg H2

= 234 x1000 kJ (hour/hour)/kg H2

= 234 x 1000 kJ (hour/3600 sec)/kg H2

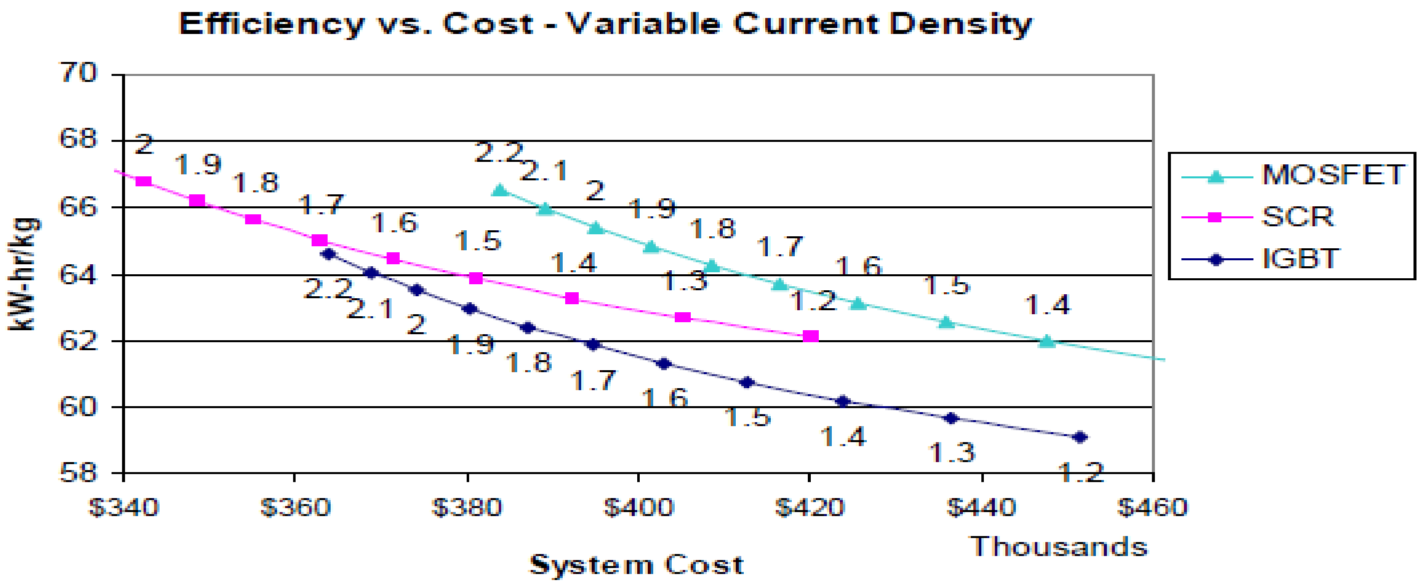
=234 x 1000 k (j/sec) hour/3600 kg H2

=234 x 1000 kWh/3600 kg H2

=65 kWh/kg H2

Results – Power Supply Trade Study

- IGBT Technology Power Supply Best Solution
  - System Cost and Net Efficiency Combination
  - Integration With Renewable Power Sources (AC/DC)



SPECIFICATIONS	Nel A-150	Nel A-300	Nel A-485
Capacity range per unit (Nm^3 H_2/hr)	50-150	150-300	300-485
Production capacity dynamic range	15 - 100% of flow range		
DC power consumption	3.8 - 4.4 kWh/Nm^3		
H_2 purity (%)	99.9 $\pm$ 0.1		
After purification			
O_2-content in H_2	< 2 ppm v		
H_2O-content in H_2	< 2 ppm v		
O_2 purity (%)	99.5 $\pm$ 0.2		
H_2 outlet pressure electrolyser	200 mm WG		
H_2 outlet pressure after compressor	Flexible range; 1 bar g - 200 bar g		
Dimensions/footprint	Flexible/ ~150m^2	Flexible/ ~200m^2	Flexible/ ~225m^2
Operating temperature	80^{0}C		
Electrolyte	25% KOH aqueous solution		
Feed water consumption	0.9 litre / Nm^3 H_2		

Note: 11.13 Nm^3/kg

Max. Production =1,046 kg/day
⇒**Supplying 1,000 city-urban H2FCVs** @105 km/day of travelling & @ 100 km/kg of H2

or equivalent to RM 30 of RON97 per 100 km

c.f. cost of H2 Fuel = RM15/kg

http://nelhydrogen.com/assets/uploads/2017/01/Nel_Electrolyser_brochure.pdf

Atmospheric Alkaline Electrolyser

CASE I:
THE ECONOMICS OF HFCV-vis-a-vis ICE for TRANSPORT

- 1 kg of H2 => 1 gallon of gasoline equivalent
- HFCV:ICE = 60 miles:25 miles
- Mileage: 35/25= 140%
- Conventional Cost: H2:Gasoline=100:70

  => 30 % more
- But to the consumer: HFCV more effective

Annual Sales of Hydrogen Fuel @ex-Production

4 MW per year

= 4,000 kW x 333 days per year x 24 hours/ day

= 32 million kWh

= (32/36) million kg of H2 per year @~36 kWh/kgH2

= USD ~ USD 2 million per year @USD 2.2/kgH2

How far will one gallon go and how much water will it produce?

Gasoline ICE Vehicle

➔ 25 miles per gallon (mpg)

1 gallon gasoline = 2.7 kg of fuel

(may be represented approximately as CH_2)

$CH_2 + 3/2\ O_2 \rightarrow CO_2 + H_2O$ *(water)*

2.7 kg + 9.3 kg ➔ 8.5 kg + 3.5 kg

3.5 kg water/25 miles = 0.14 kg water/mi

Hydrogen FCV

➔ 60 miles per gallon gasoline equivalent (mpgge)

1 gallon of gasoline equivalent of hydrogen very nearly equals 1.0 kg H_2

$H_2 + 1/2\ O_2 \rightarrow H_2O$ (water)

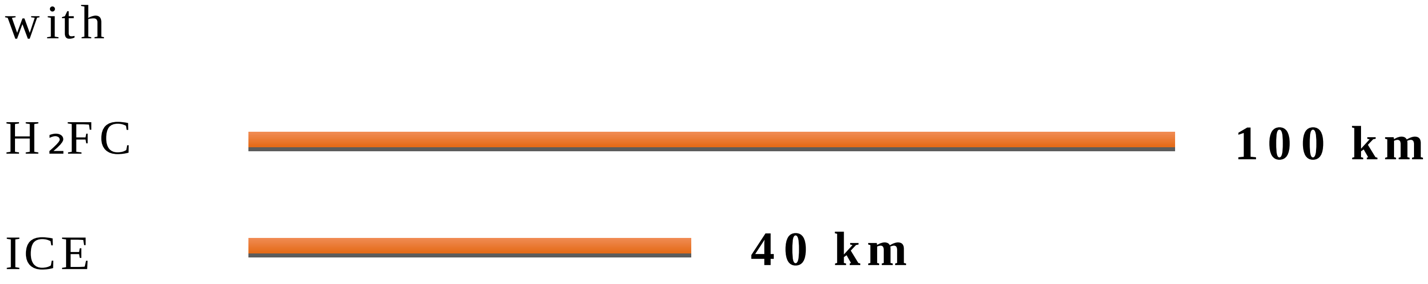
1.0 kg + 8.0 kg ➔ 9.0 kg

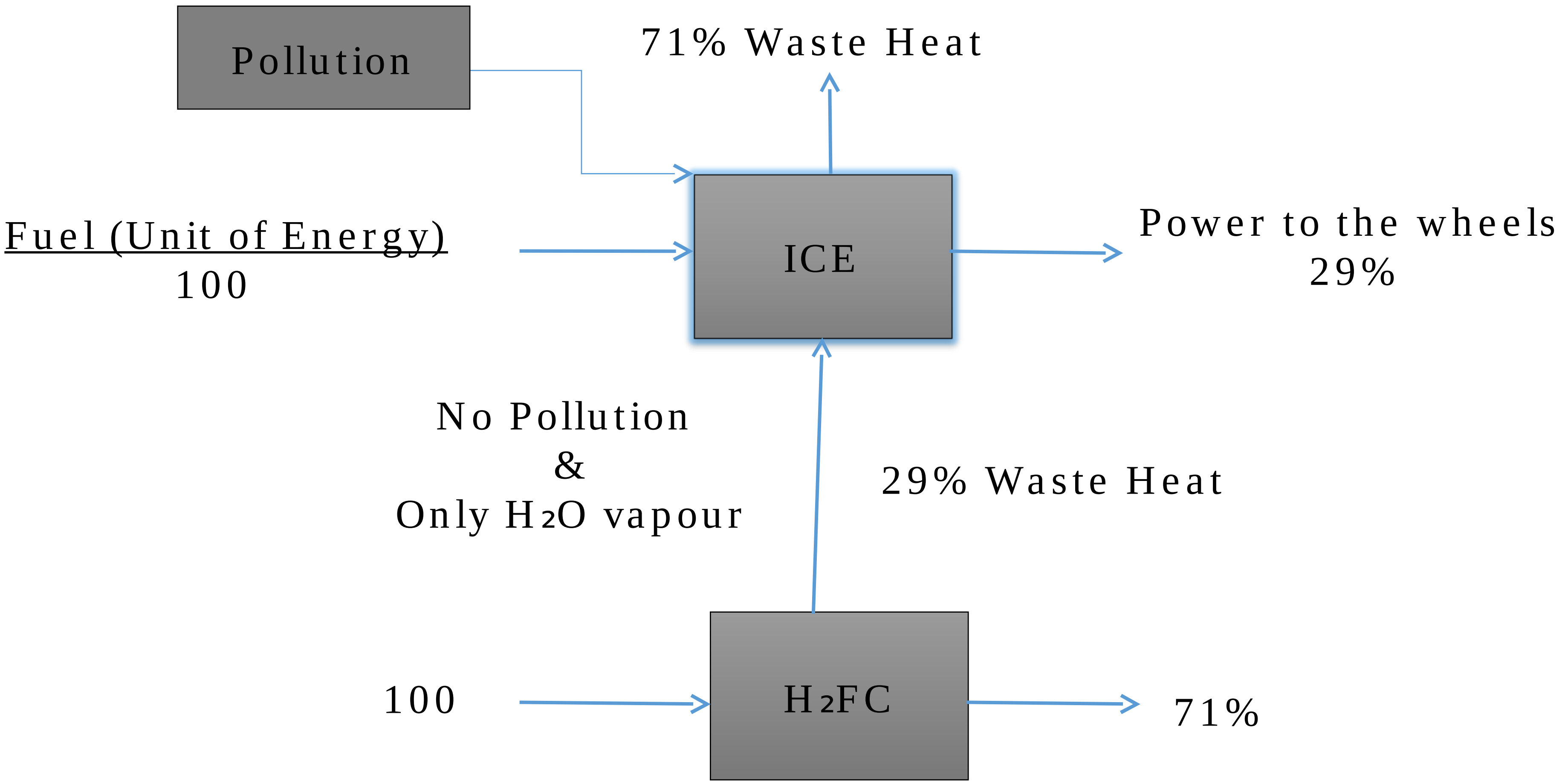
9.0 kg water/60 miles = 0.15 kg water/mi

Economics of H2FCV vs ICE-Petrol Car

RM	Fuel	Vehicle	Mileage(km)	Cost/km (RM)
10.00	Petrol	ICE	40 km	0.25
10.00	Hydrogen	H_2FC	100 km	0.10

LEXUS 250




Pollution
71% Waste Heat
Fuel (Unit of Energy)
100
ICE
Power to the wheels
29%
No Pollution
&
Only H2O vapour
29% Waste Heat
100
H2FC
71%

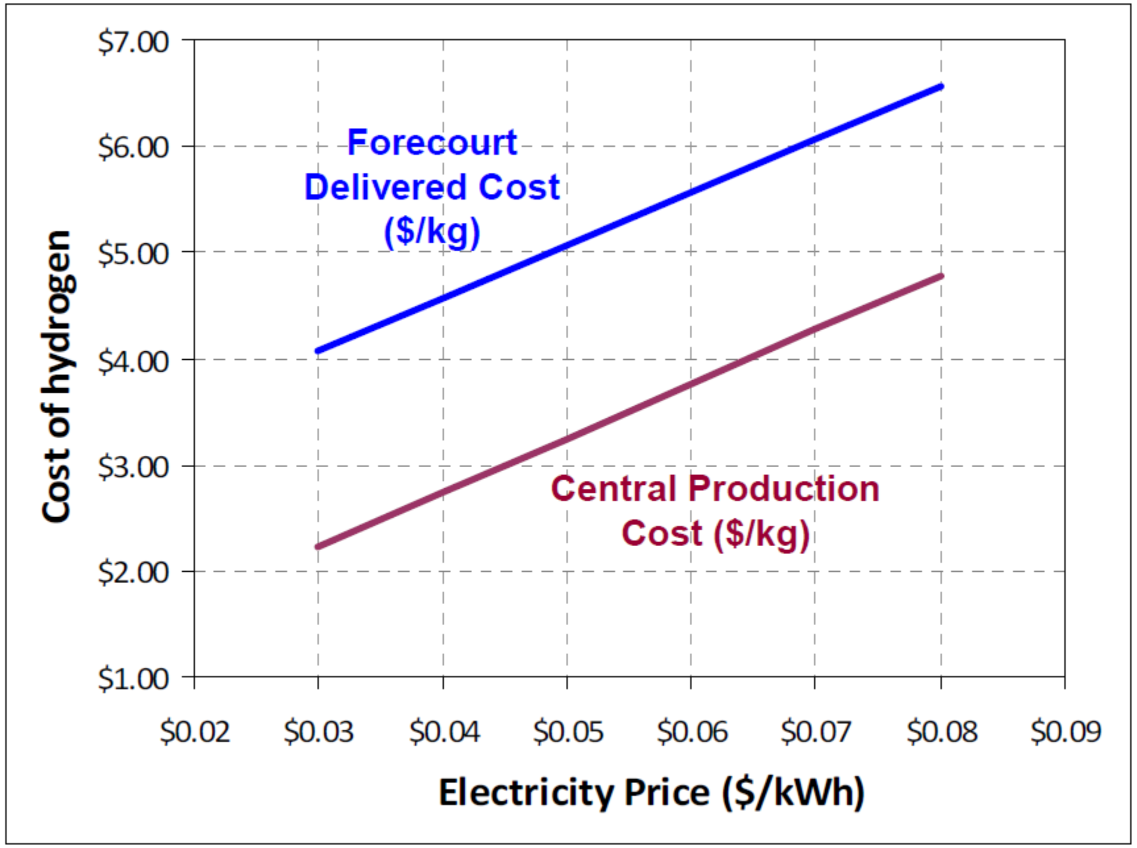
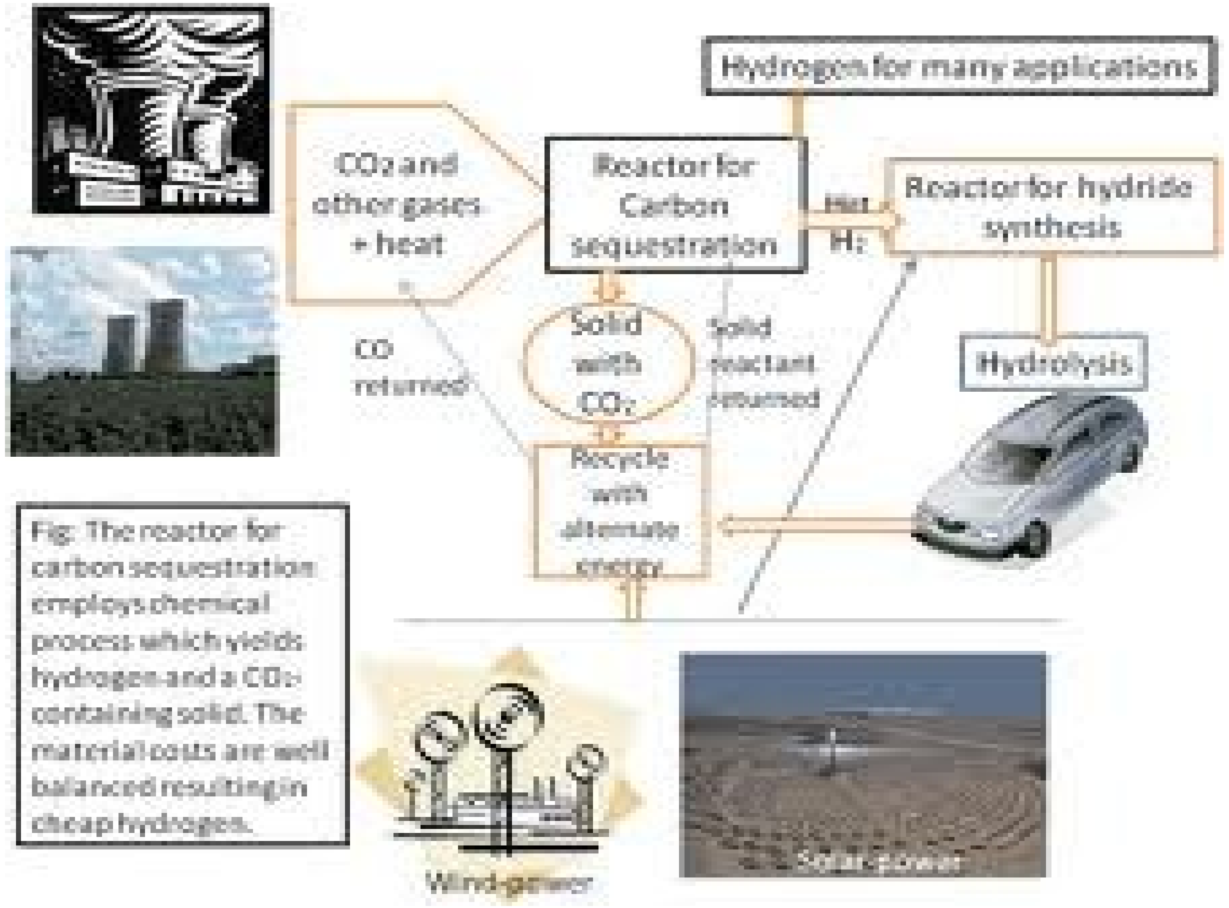


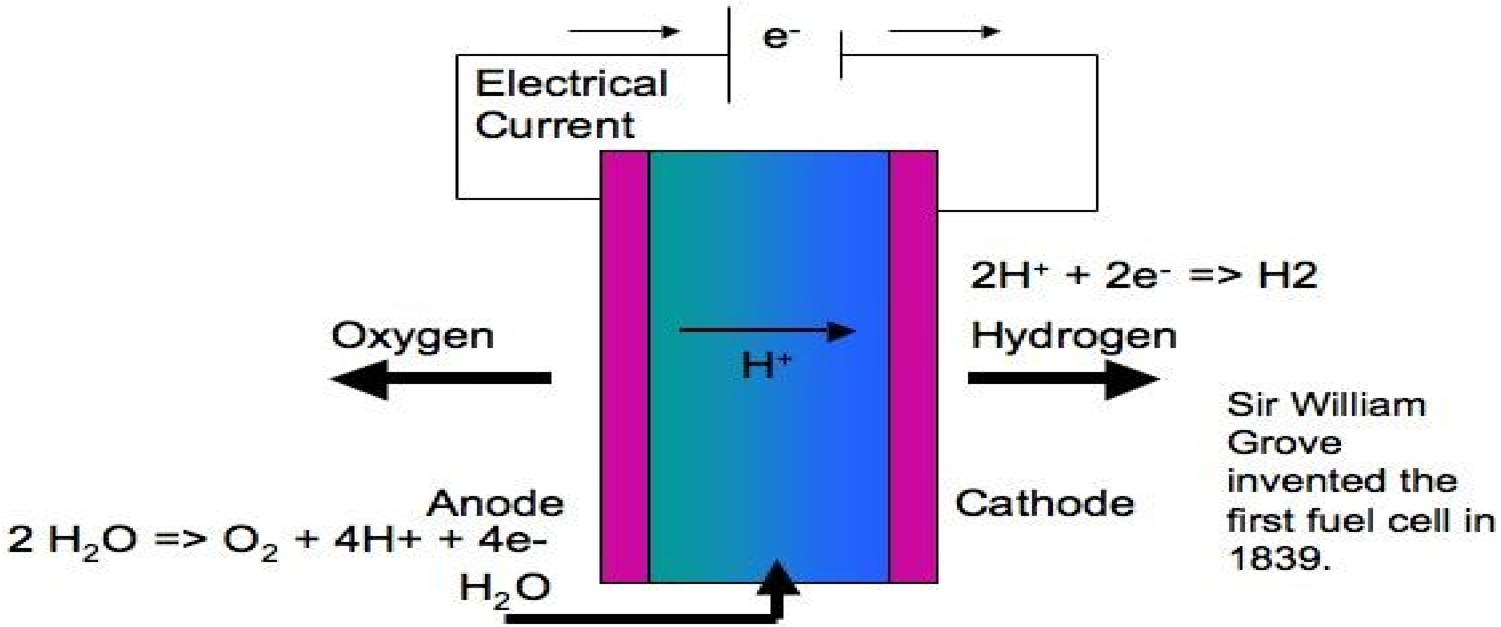
Figure 10. Base cases as a function of electricity price

Ref: http://energy.gov/sites/prod/files/2014/03/f10/46676.pdf
Accessed on 17 March 2016 by bakar.jaafar@gmail.com


DC1500
25-30%
FUEL ECONOMY
25-30%
ΟΙΚΟΝΟΜΙΑ
ΣΤΑ ΚΑΥΣΙΜΑ

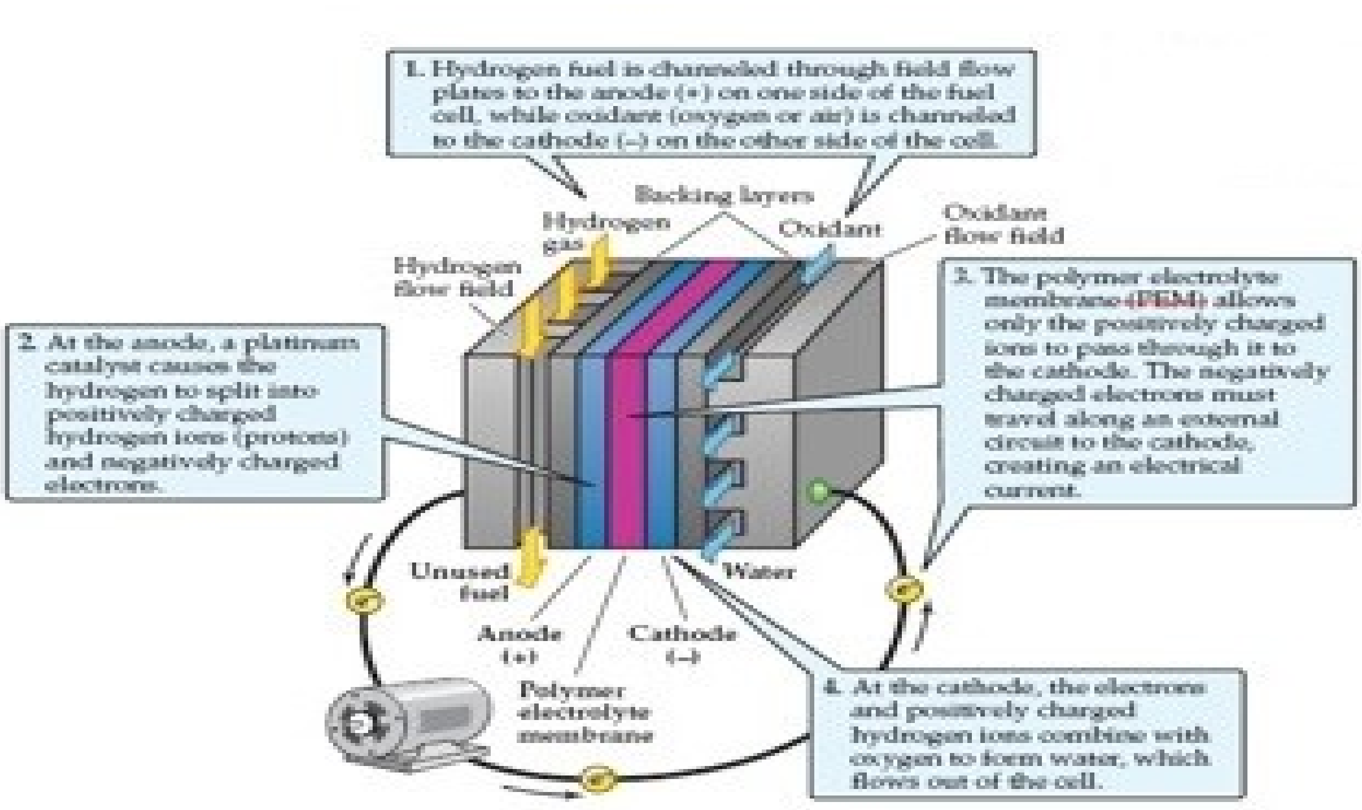

Hydrogen for many applications
CO2 and other gases + heat
Reactor for Carbon sequestration
Hot H2
Reactor for hydride synthesis
CO returned
Solid with CO2
Solid reactant returned
Hydrolysis
Recycle with alternate energy
Fig: The reactor for carbon sequestration employs chemical process which yields hydrogen and a CO2-containing solid. The material costs are well balanced resulting in cheap hydrogen.
Wind-power
Solar-power

Hydrogen Fuel Cells

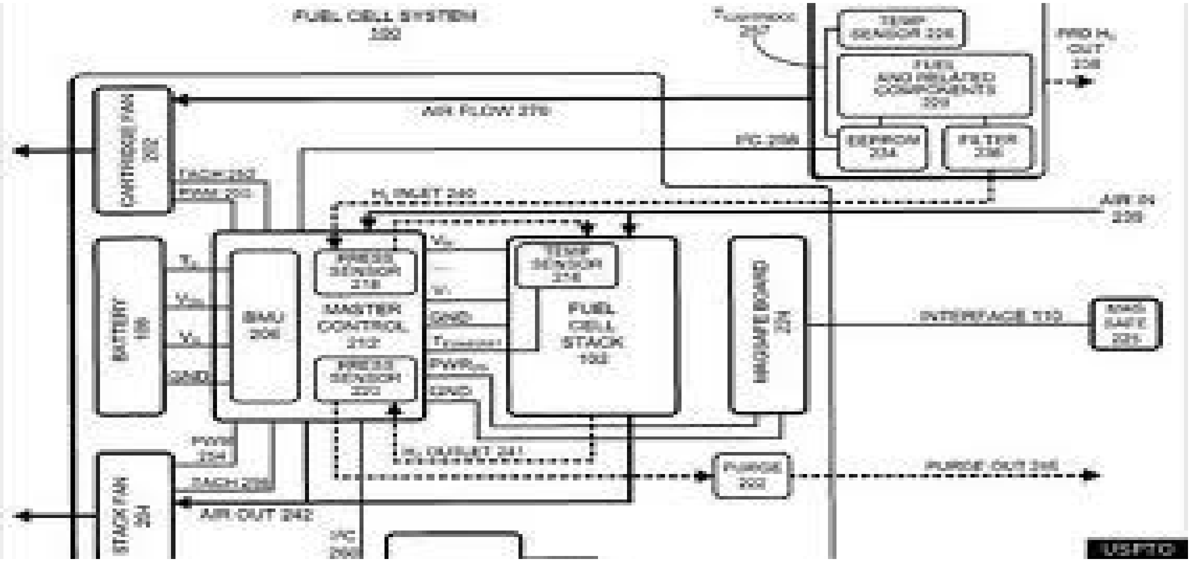


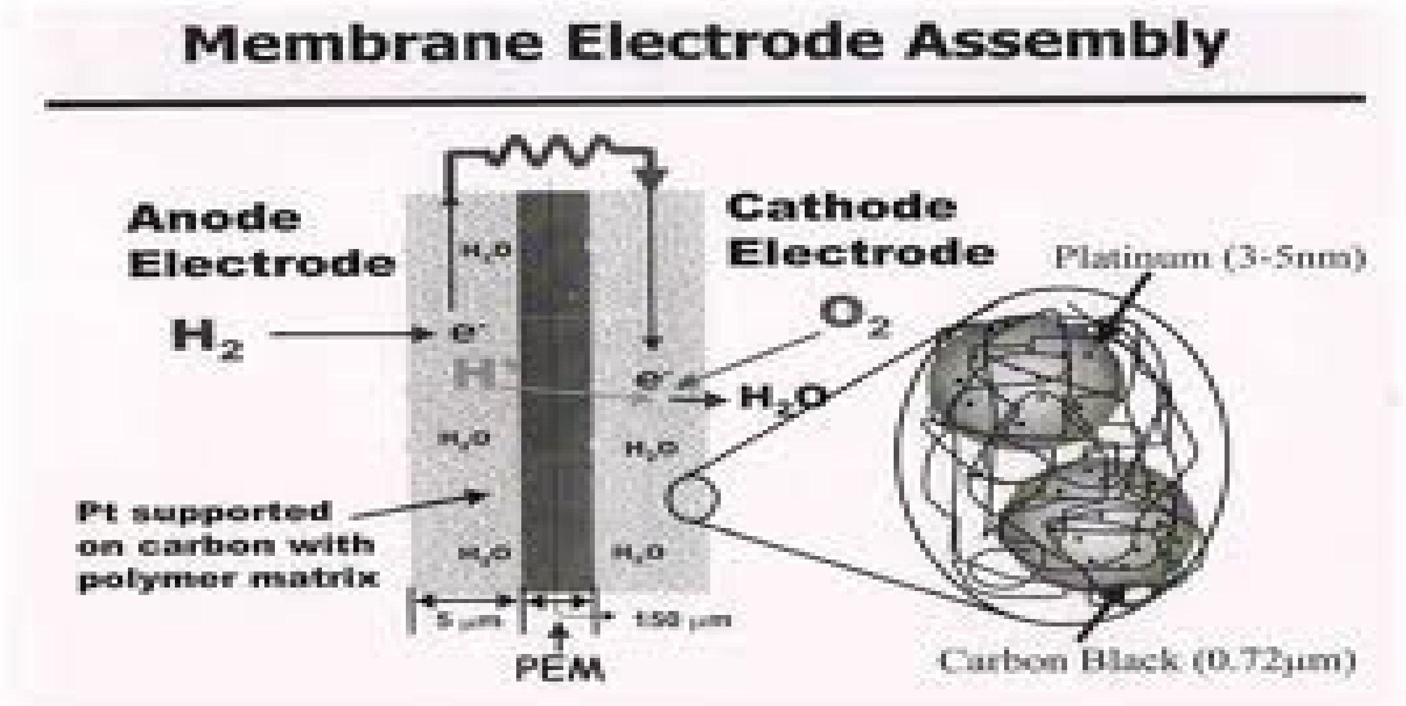
Source: Dept pf Energy http://www.sc.doe.gov/bes/hydrogen.pdf

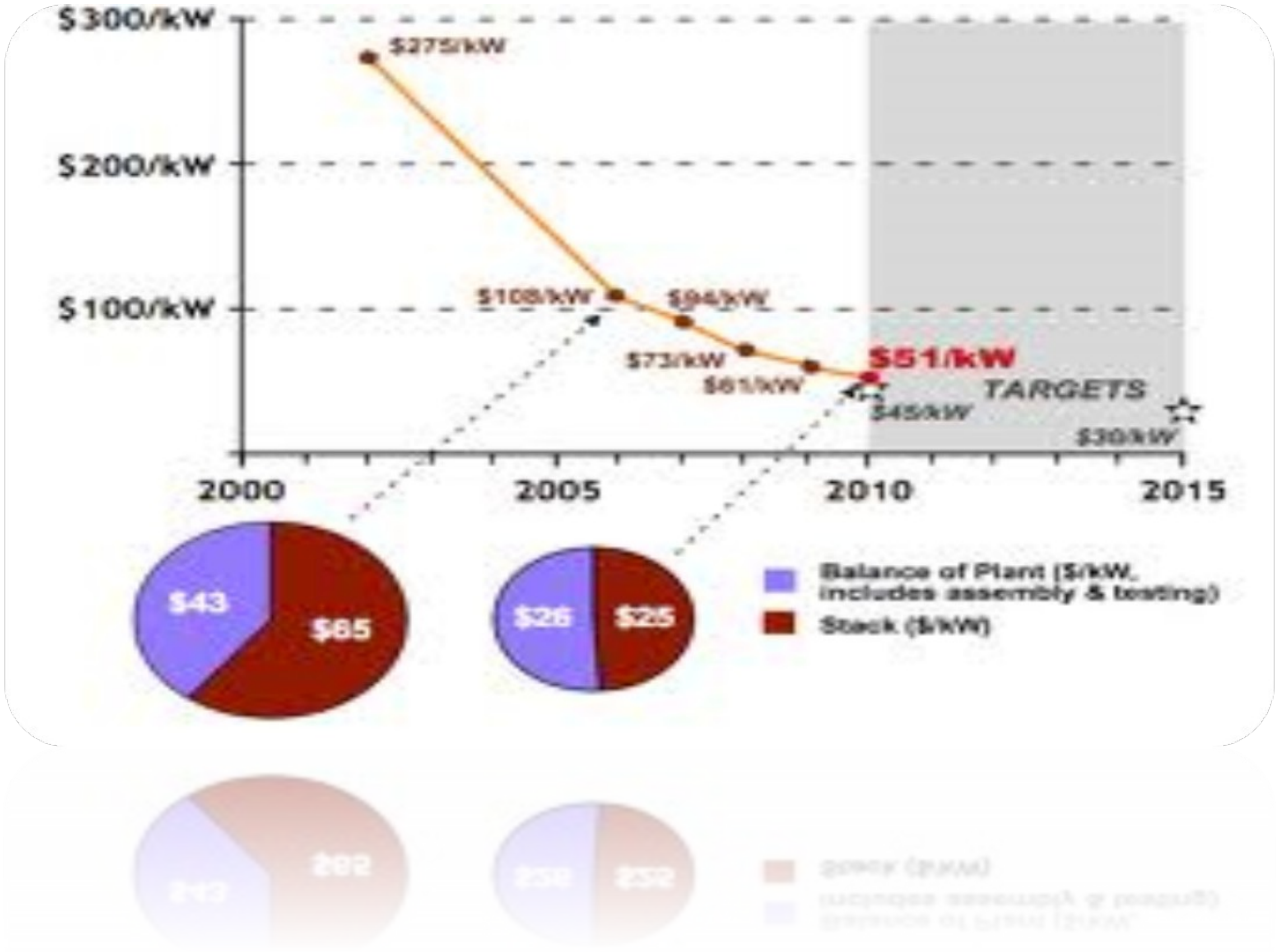

H2
HYDROGEN

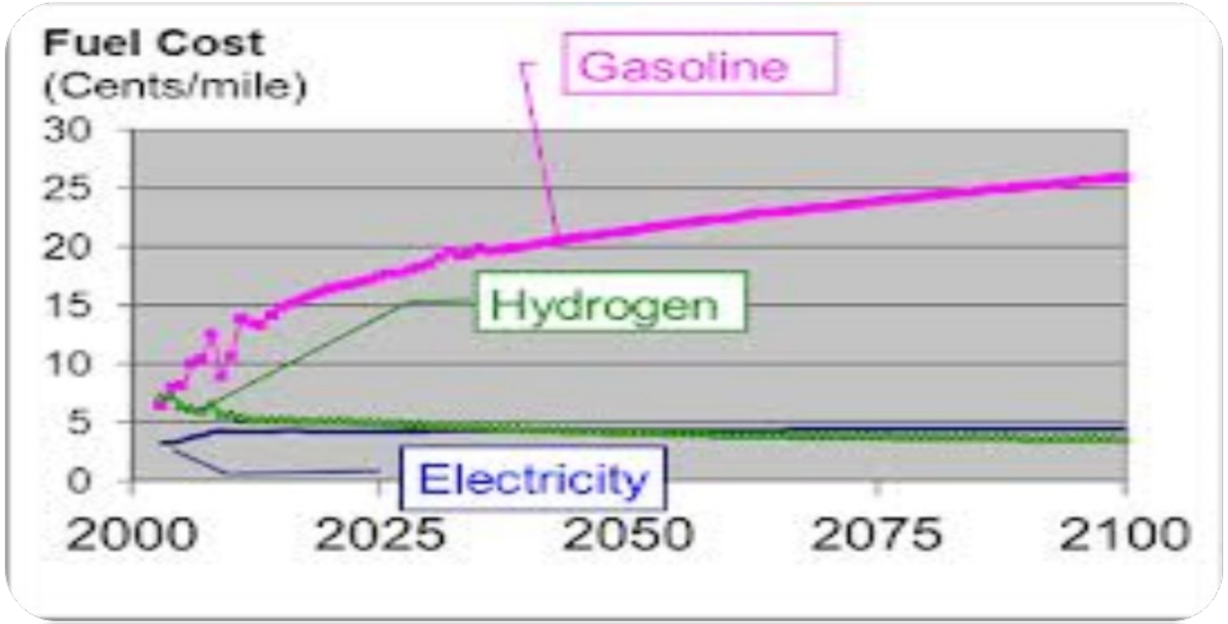

1. Hydrogen fuel is channeled through field flow plates to the anode (+) on one side of the fuel cell, while oxidant (oxygen or air) is channeled to the cathode (–) on the other side of the cell.
Backing layers
Hydrogen gas
Oxidant
Oxidant flow field
Hydrogen flow field
2. At the anode, a platinum catalyst causes the hydrogen to split into positively charged hydrogen ions (protons) and negatively charged electrons.
3. The polymer electrolyte membrane (PEM) allows only the positively charged ions to pass through it to the cathode. The negatively charged electrons must travel along an external circuit to the cathode, creating an electrical current.
Unused fuel
Water
Anode (+)
Cathode (–)
Polymer electrolyte membrane
4. At the cathode, the electrons and positively charged hydrogen ions combine with oxygen to form water, which flows out of the cell.


Hydrogen
Product: Shell hydrogen fuel

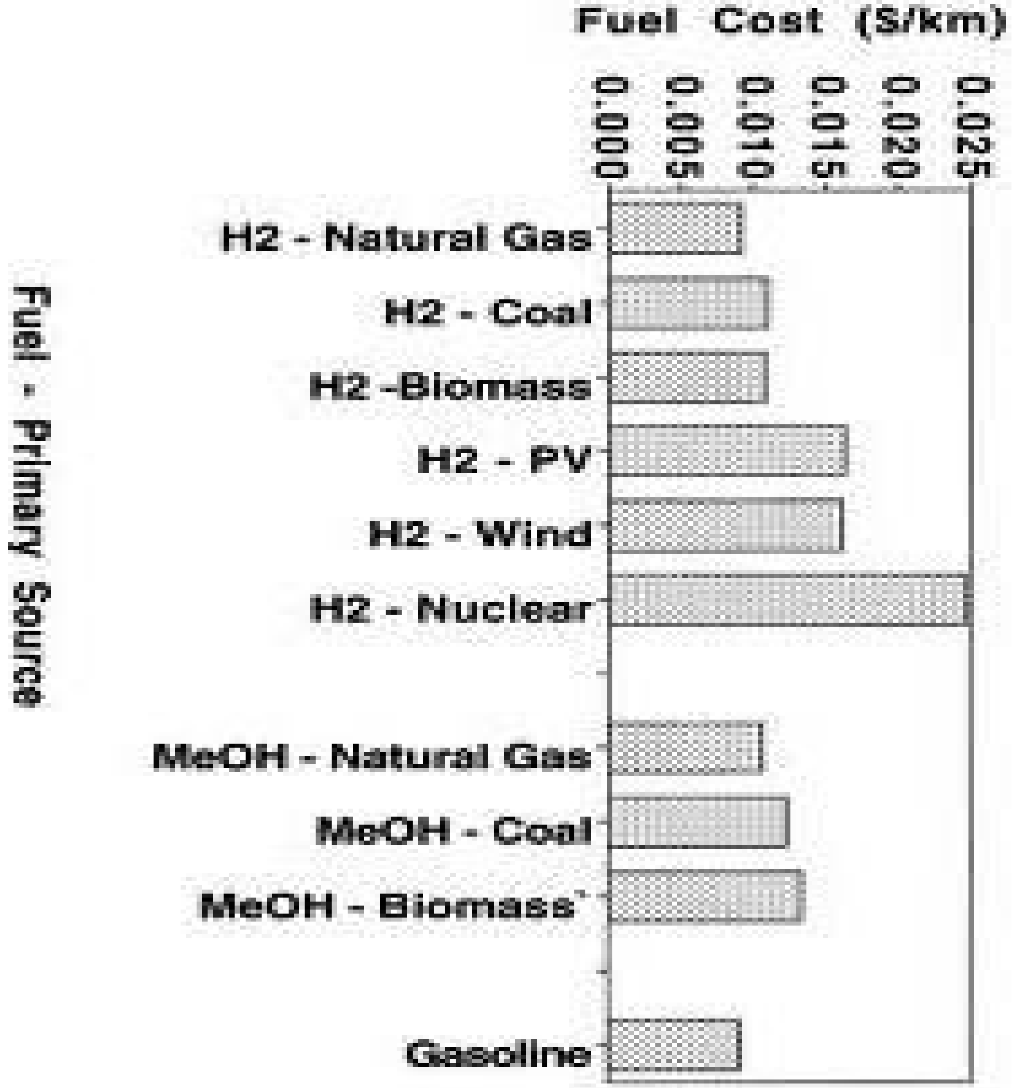

FUEL CELL SYSTEM
TEMP SENSOR
FUEL AND RELATED COMPONENTS
EEPROM
FILTER
AIR FLOW
CARTRIDGE FAN
AIR IN
BATTERY
MASTER CONTROL
PRESS SENSOR
FUEL CELL STACK
INTERFACE
PURGE
PURGE OUT
STACK FAN
AIR OUT
USPTO


Membrane Electrode Assembly
Anode Electrode
Cathode Electrode
H2
O2
H2O
Platinum (3-5nm)
Pt supported on carbon with polymer matrix
5 µm
150 µm
PEM
Carbon Black (0.72µm)

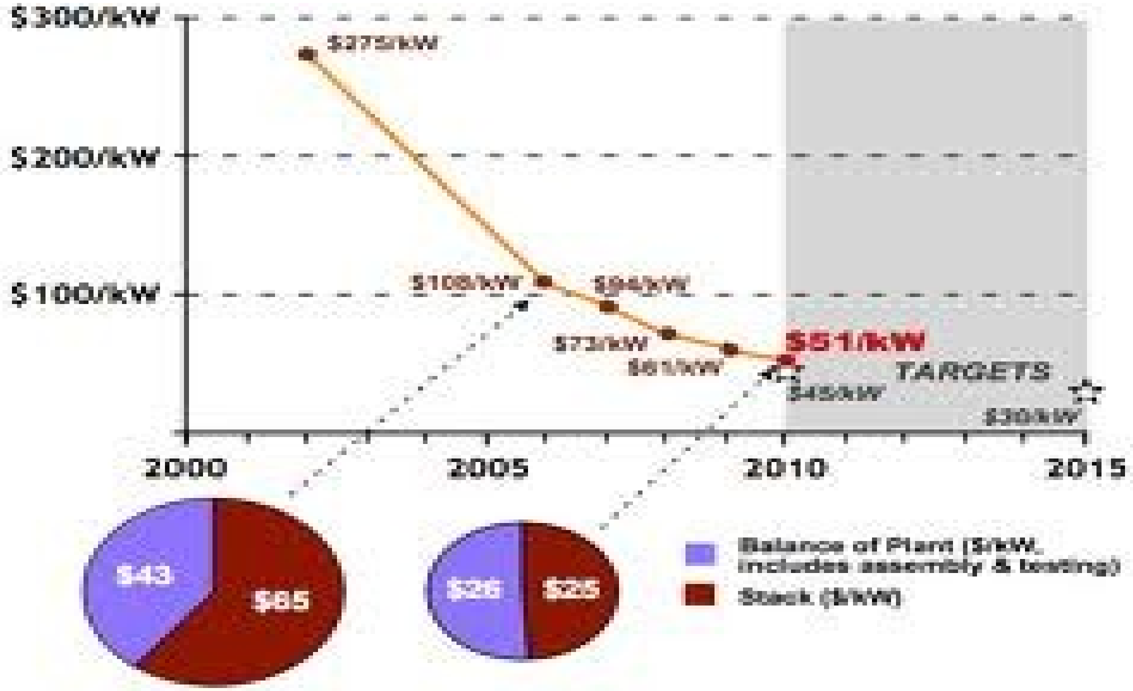

$300/kW
$200/kW
$100/kW
$275/kW
$108/kW
$94/kW
$73/kW
$61/kW
$51/kW
TARGETS
$45/kW
$30/kW
2000
2005
2010
2015
$43
$65
$26
$25
Balance of Plant ($/kW, includes assembly & testing)
Stack ($/kW)


Fuel Cost
(Cents/mile)
Gasoline
Hydrogen
Electricity
30
25
20
15
10
5
0
2000
2025
2050
2075
2100


OMV


Fuel Cost (S/km)
0.000
0.005
0.010
0.015
0.020
0.025
Fuel - Primary Source
H2 - Natural Gas
H2 - Coal
H2 -Biomass
H2 - PV
H2 - Wind
H2 - Nuclear
MeOH - Natural Gas
MeOH - Coal
MeOH - Biomass
Gasoline


www.KERETA.info


$300/kW
$200/kW
$100/kW
$275/kW
$108/kW
$94/kW
$73/kW
$61/kW
$51/kW
$45/kW
TARGETS
$30/kW
2000
2005
2010
2015
$43
$85
$26
$25
Balance of Plant ($/kW, includes assembly & testing)
Stack ($/kW)

		Reference			Advanced		
		2020	2050	2095	2020	2050	2095
Central station	Natural gas	2.96	2.55	2.04	2.96	2.20	1.76
	Coal	8.64	7.23	5.69	8.64	6.13	4.90
	Biomass	8.58	7.18	5.65	8.58	6.09	4.87
	Electrolysis	21.31	14.54	10.34	21.31	11.15	8.91
	Nuclear	20.16	20.16	11.02	20.16	11.87	9.49
	Wind	21.31	21.31	18.35	21.31	19.77	15.80
	Solar	21.31	21.31	18.35	21.31	19.77	15.80
T&D charge		17.49	15.49	12.55	17.49	13.52	10.80
Distributed	Natural Gas	18.62	14.48	11.00	18.62	11.85	9.47
	Electrolysis	21.31	21.31	18.35	21.31	19.77	15.80


HIGH PRESSURE
(410 BAR MAX)

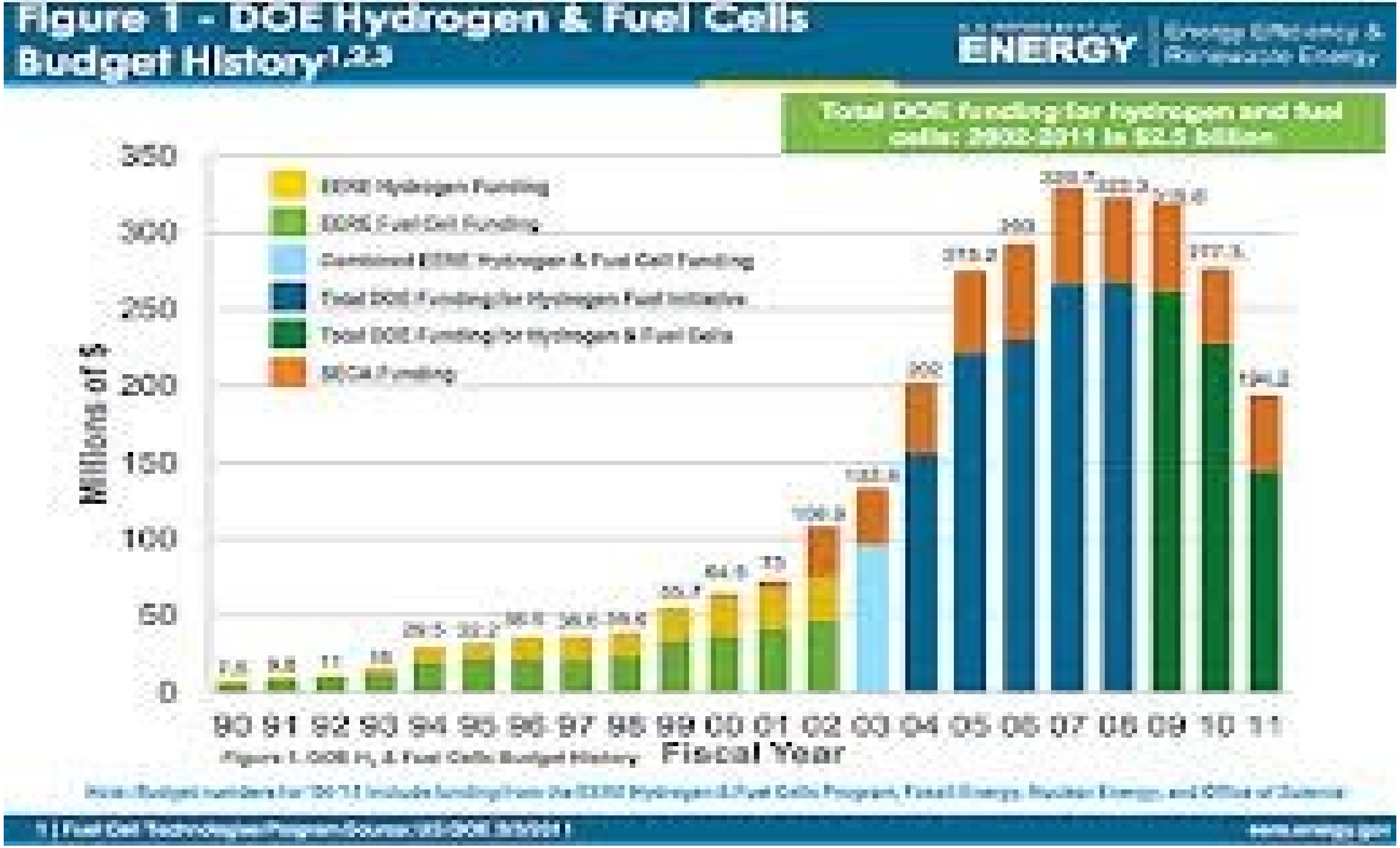
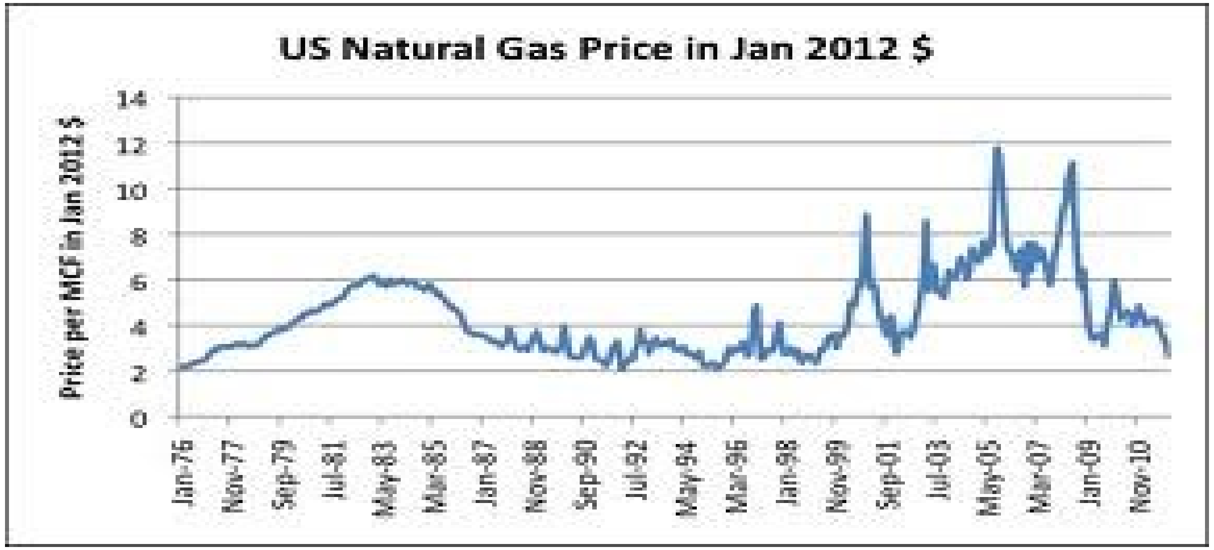
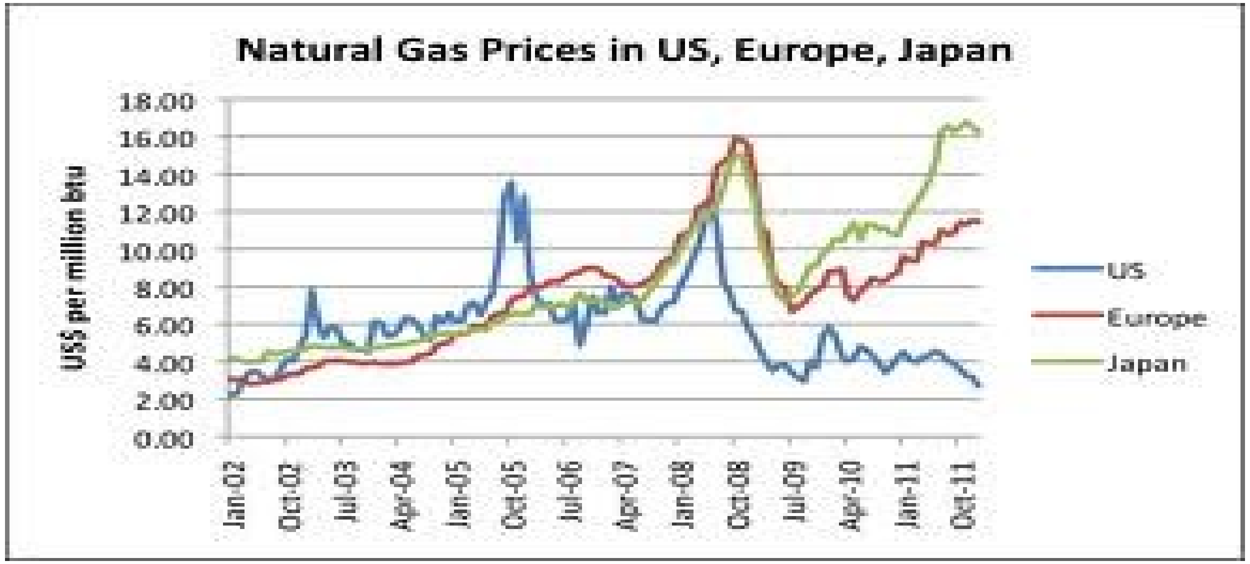
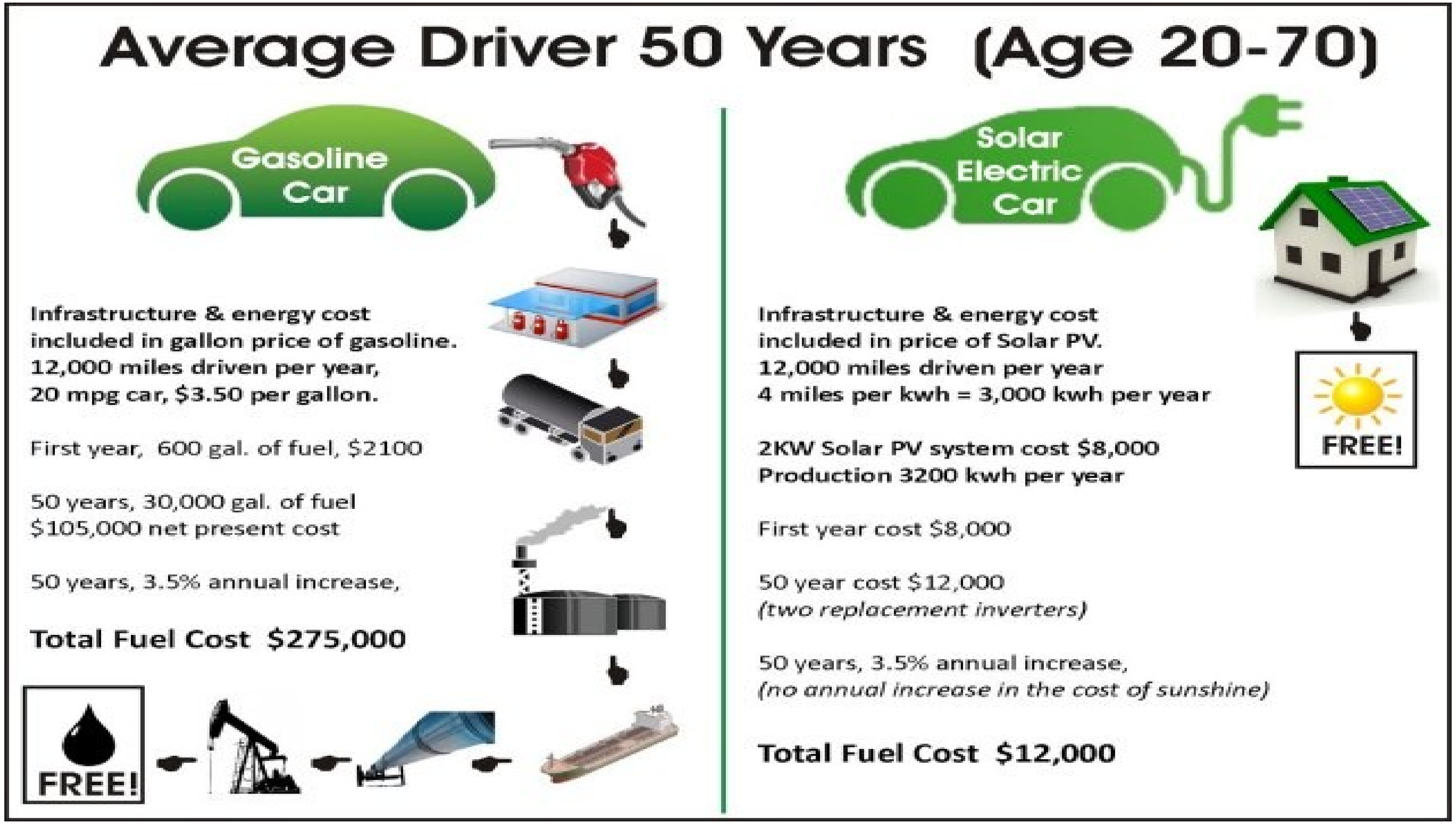


Figure 1 - DOE Hydrogen & Fuel Cells Budget History1,2,3
ENERGY
Millions of $
350
300
250
200
150
100
50
0
90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07 08 09 10 11
Fiscal Year

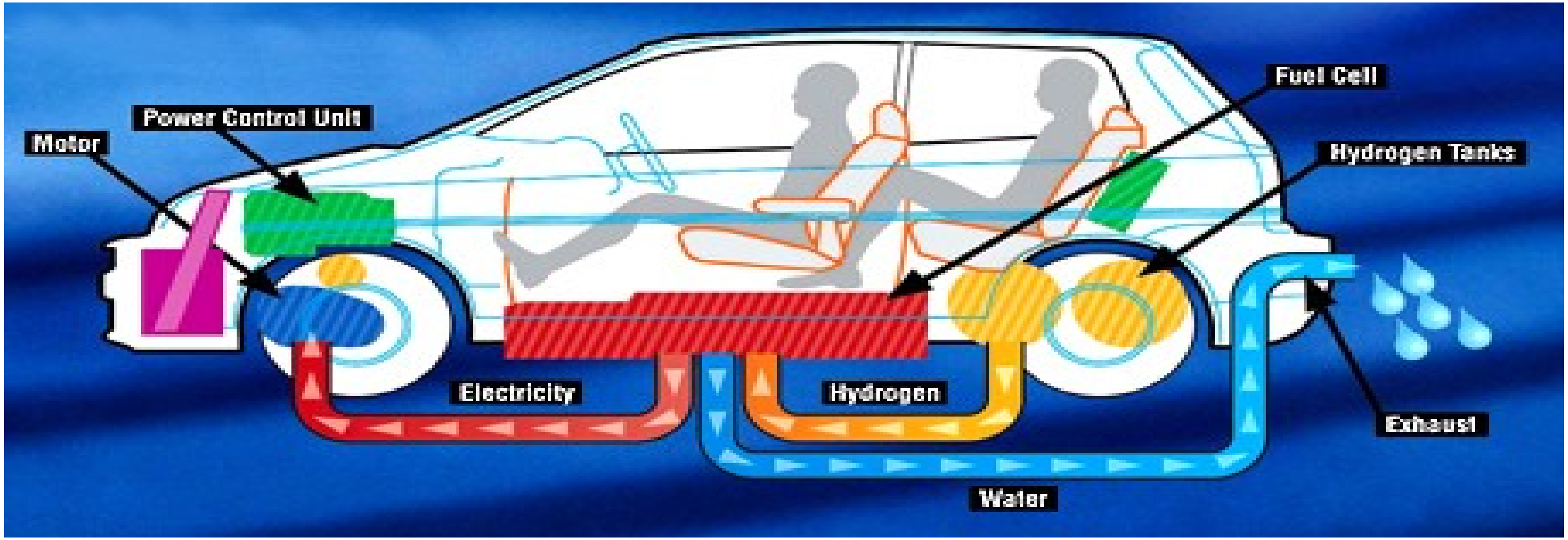

H2

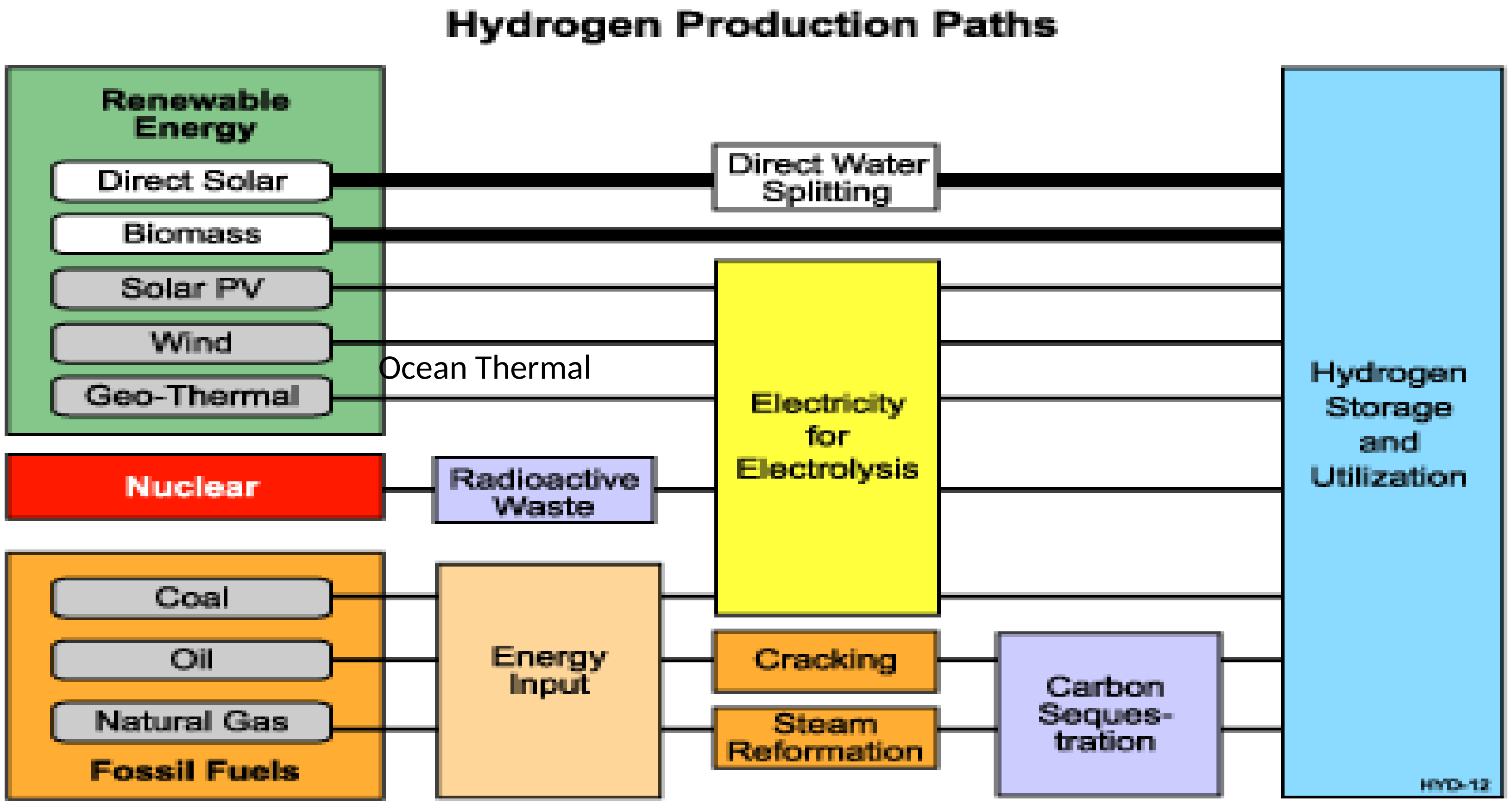

US Natural Gas Price in Jan 2012 $
Price per MCF in Jan 2012 $
0
2
4
6
8
10
12
14
Jan-76
Nov-77
Sep-79
Jul-81
May-83
Mar-85
Jan-87
Nov-88
Sep-90
Jul-92
May-94
Mar-96
Jan-98
Nov-99
Sep-01
Jul-03
May-05
Mar-07
Jan-09
Nov-10


Natural Gas Prices in US, Europe, Japan
US$ per million btu
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
Jan-02
Oct-02
Jul-03
Apr-04
Jan-05
Oct-05
Jul-06
Apr-07
Jan-08
Oct-08
Jul-09
Apr-10
Jan-11
Oct-11
US
Europe
Japan

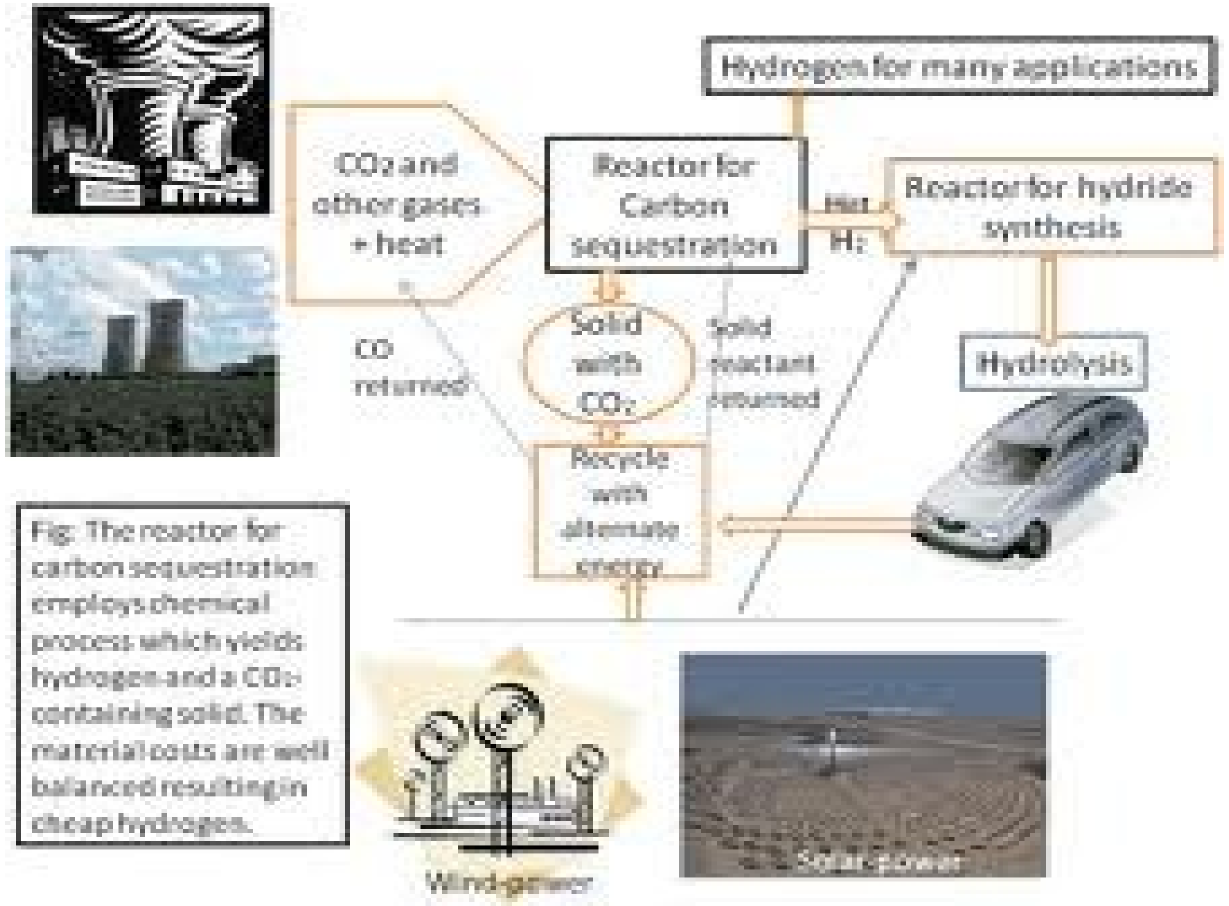

Average Driver 50 Years (Age 20-70)
Gasoline Car
Infrastructure & energy cost
included in gallon price of gasoline.
12,000 miles driven per year,
20 mpg car, $3.50 per gallon.
First year, 600 gal. of fuel, $2100
50 years, 30,000 gal. of fuel
$105,000 net present cost
50 years, 3.5% annual increase,
Total Fuel Cost $275,000
FREE!
Solar Electric Car
Infrastructure & energy cost
included in price of Solar PV.
12,000 miles driven per year
4 miles per kwh = 3,000 kwh per year
2KW Solar PV system cost $8,000
Production 3200 kwh per year
First year cost $8,000
50 year cost $12,000
(two replacement inverters)
50 years, 3.5% annual increase,
(no annual increase in the cost of sunshine)
Total Fuel Cost $12,000
FREE!


Gasoline
Regular
399 9/10
Plus
409 9/10
V-Power
419 9/10

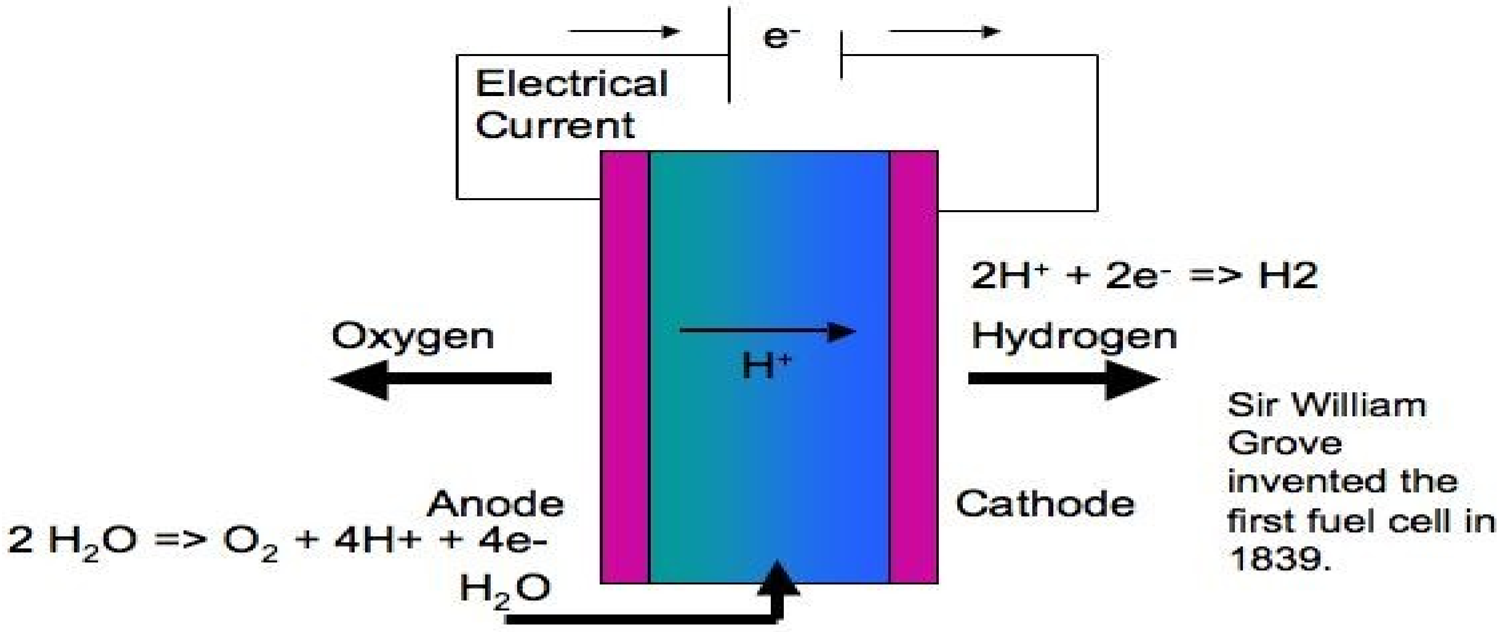

Motor
Power Control Unit
Fuel Cell
Hydrogen Tanks
Electricity
Hydrogen
Exhaust
Water


Hydrogen Production Paths
Renewable Energy
Direct Solar
Biomass
Solar PV
Wind
Ocean Thermal
Geo-Thermal
Nuclear
Radioactive Waste
Coal
Oil
Natural Gas
Fossil Fuels
Energy Input
Direct Water Splitting
Electricity for Electrolysis
Cracking
Steam Reformation
Carbon Seques-tration
Hydrogen Storage and Utilization
HYD-12


DC1500
25-30%
FUEL ECONOMY
25-30%
ΟΙΚΟΝΟΜΙΑ
ΣΤΑ ΚΑΥΣΙΜΑ

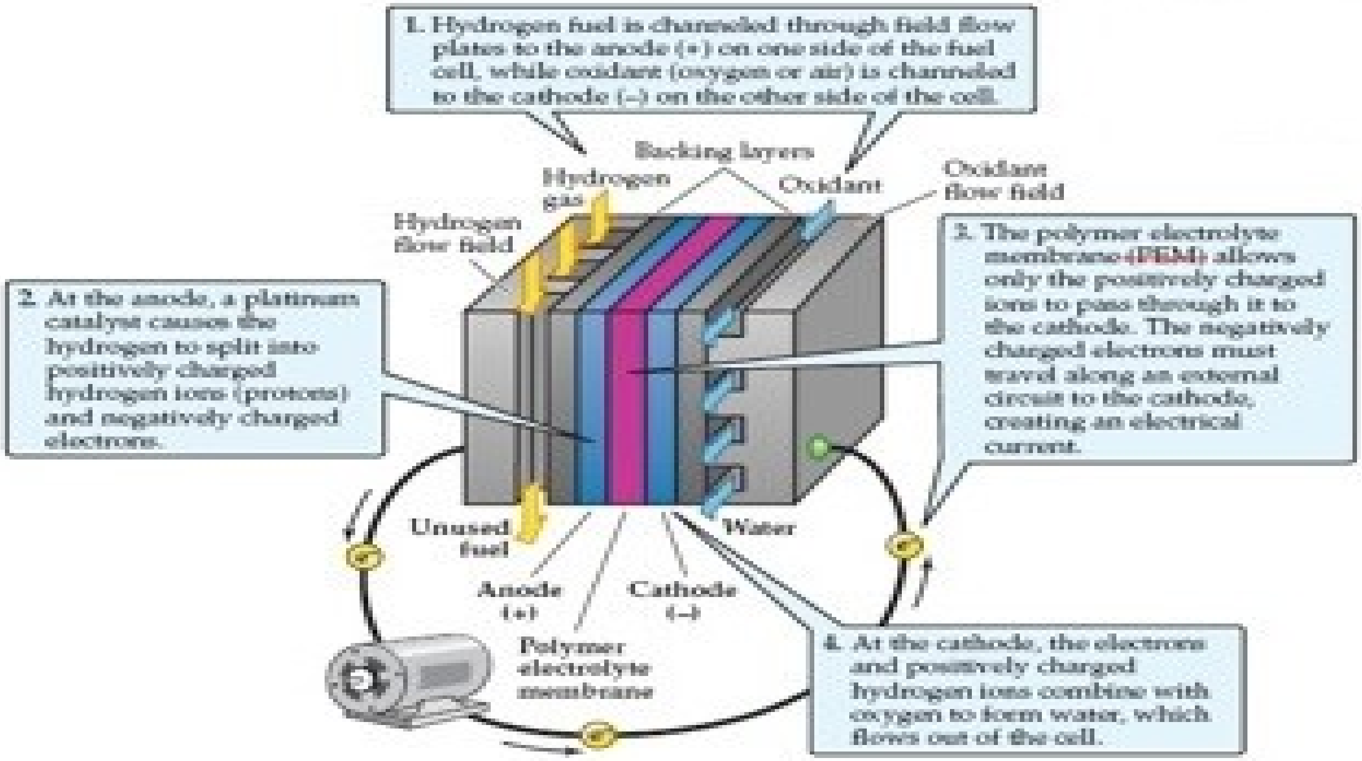

Hydrogen for many applications
CO2 and other gases + heat
Reactor for Carbon sequestration
Reactor for hydride synthesis
Hot H2
Solid with CO2
CO returned
Solid reactant returned
Hydrolysis
Recycle with alternate energy
Fig: The reactor for carbon sequestration employs chemical process which yields hydrogen and a CO2-containing solid. The material costs are well balanced resulting in cheap hydrogen.
Wind-power
Solar-power

Hydrogen Fuel Cells



Source: Dept pf Energy http://www.sc.doe.gov/bes/hydrogen.pdf


H2
HYDROGEN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Backing layers
Hydrogen gas
Oxidant
Oxidant flow field
Hydrogen flow field
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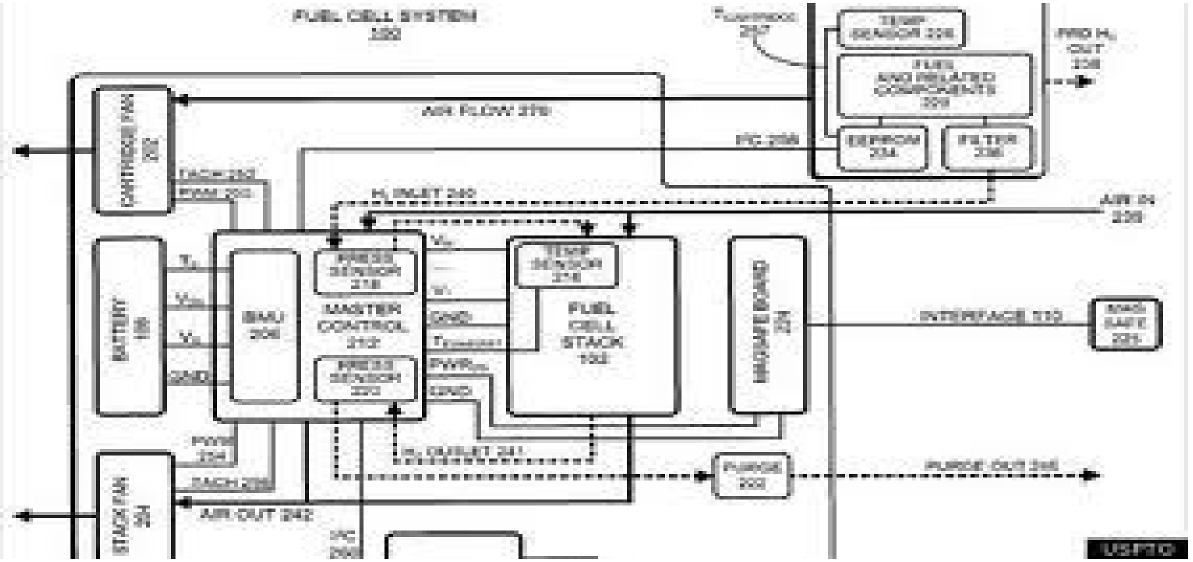
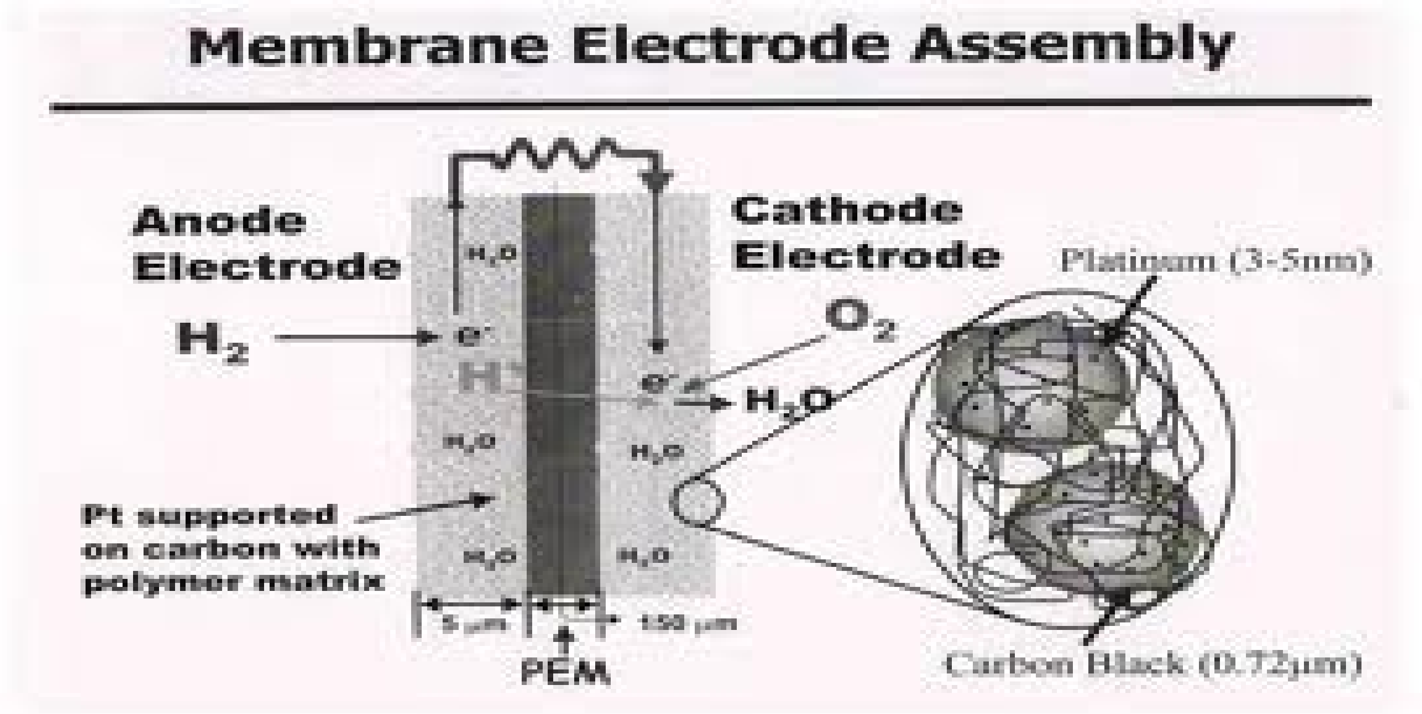
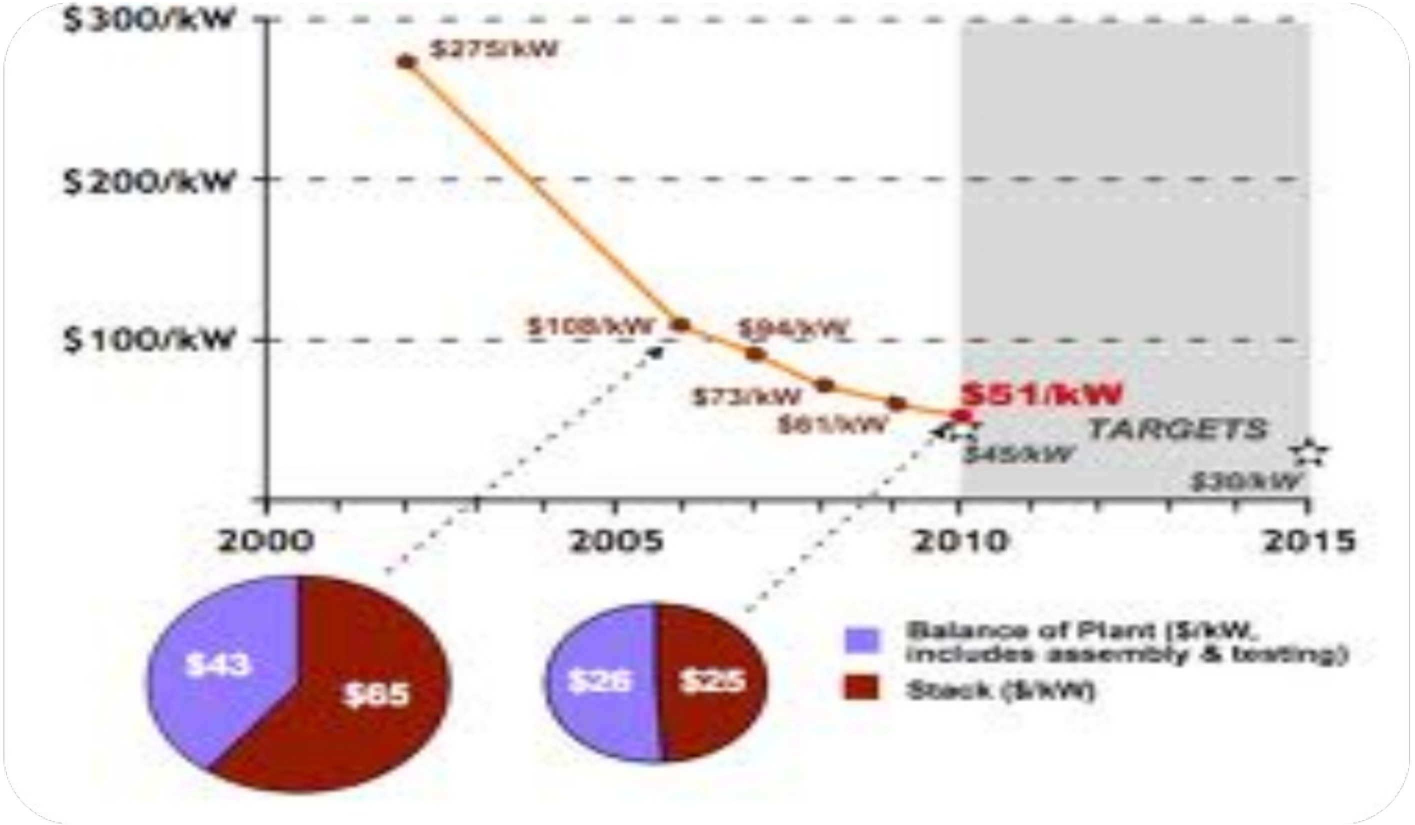
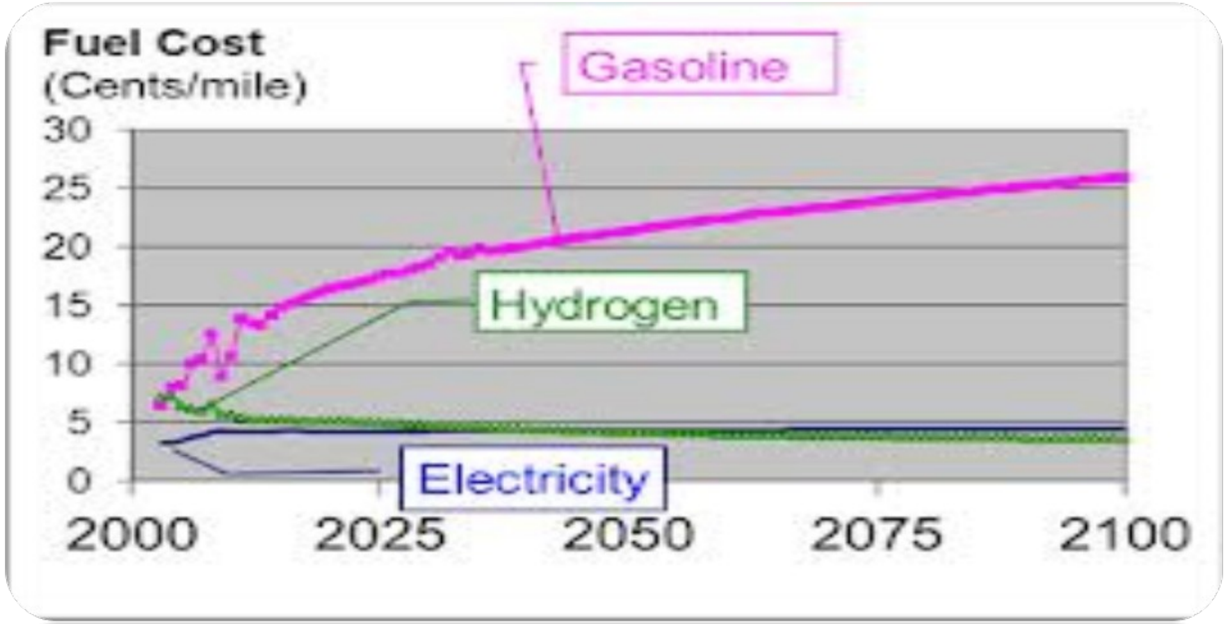
3. The polymer electrolyte membrane (PEM) allows only the positively charged ions to pass through it to the cathode. The negatively charged electrons must travel along an external circuit to the cathode, creating an electrical current.
Unused fuel
Water
Anode (+)
Cathode (–)
Polymer electrolyte membrane
4. At the cathode, the electrons and positively charged hydrogen ions combine with oxygen to form water, which flows out of the cell.


Hydrogen
Product: Shell hydrogen fuel

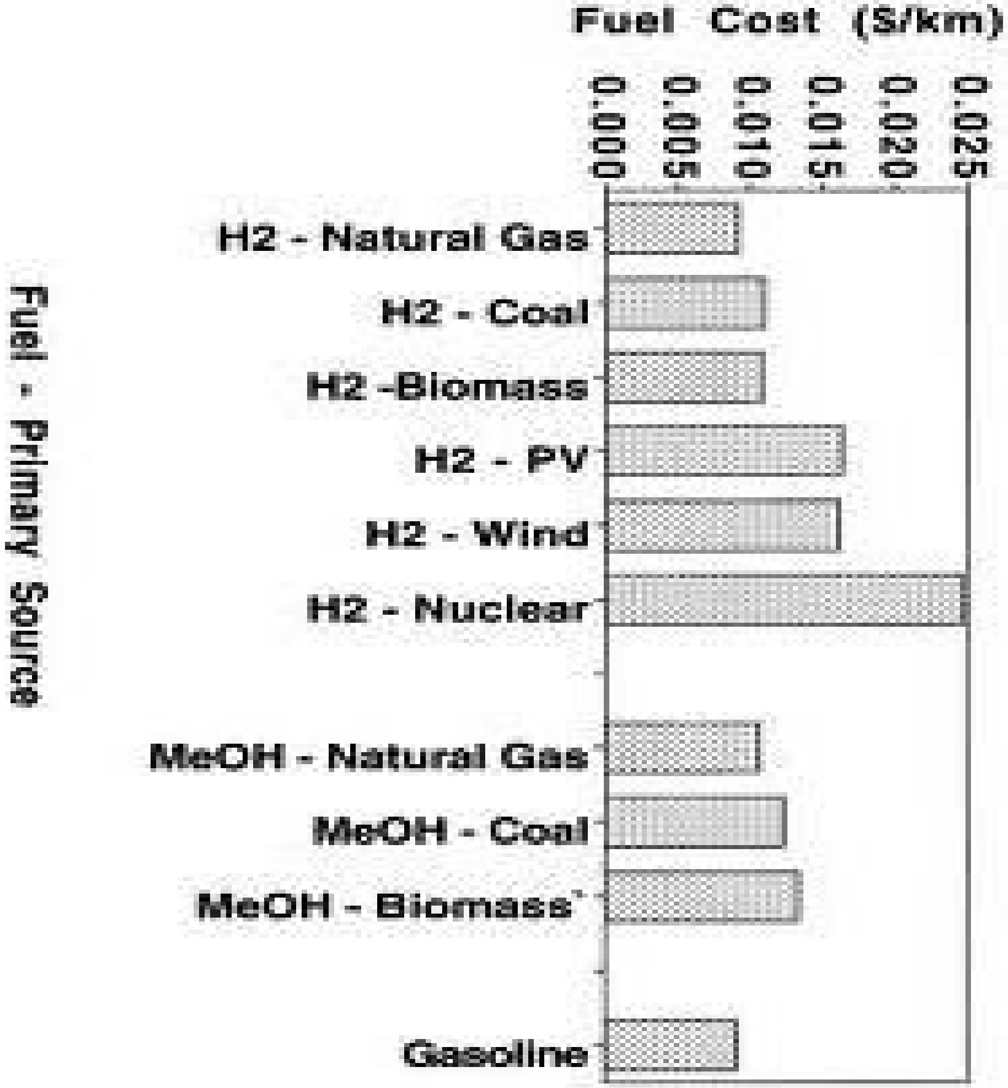

FUEL CELL SYSTEM
AIR FLOW
MASTER CONTROL
FUEL CELL STACK
BATTERY
INTERFACE
AIR IN
PURGE OUT
AIR OUT
USPTO


Membrane Electrode Assembly
Anode
Electrode
Cathode
Electrode
Platinum (3-5nm)
H_2
O_2
H_2O
Pt supported
on carbon with
polymer matrix
5 μm
150 μm
PEM
Carbon Black (0.72μm)

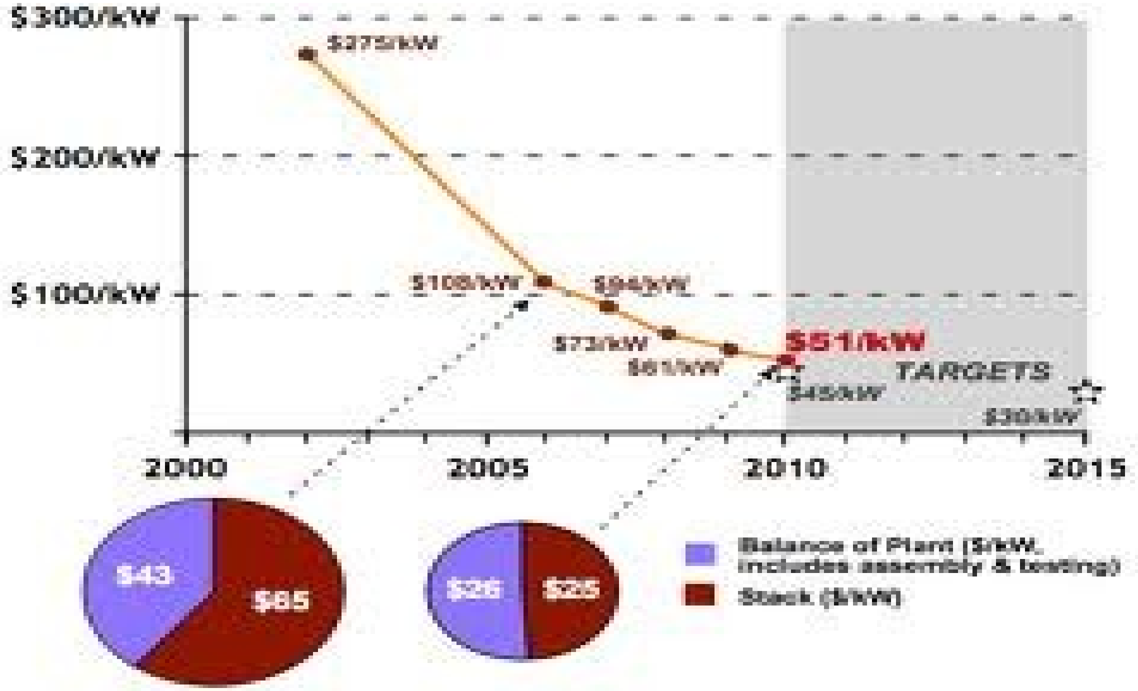

$300/kW
$200/kW
$100/kW
$275/kW
$108/kW
$94/kW
$73/kW
$61/kW
$51/kW
TARGETS
$45/kW
$30/kW
2000
2005
2010
2015
$43
$65
$26
$25
Balance of Plant ($/kW, includes assembly & testing)
Stack ($/kW)


Fuel Cost
(Cents/mile)
Gasoline
Hydrogen
Electricity
30
25
20
15
10
5
0
2000
2025
2050
2075
2100


OMV


Fuel Cost (S/km)
0.000
0.005
0.010
0.015
0.020
0.025
Fuel - Primary Source
H2 - Natural Gas
H2 - Coal
H2 -Biomass
H2 - PV
H2 - Wind
H2 - Nuclear
MeOH - Natural Gas
MeOH - Coal
MeOH - Biomass
Gasoline


e-gas
www.KERETA.info
Online Car Magazine


$300/kW
$200/kW
$100/kW
$275/kW
$108/kW
$94/kW
$73/kW
$61/kW
$51/kW
$45/kW
TARGETS
$30/kW
2000
2005
2010
2015
$43
$85
$26
$25
Balance of Plant ($/kW, includes assembly & testing)
Stack ($/kW)

		Reference			Advanced		
		2020	2050	2095	2020	2050	2095
Central station	Natural gas	2.96	2.55	2.04	2.96	2.20	1.76
	Coal	8.64	7.23	5.69	8.64	6.13	4.90
	Biomass	8.58	7.18	5.65	8.58	6.09	4.87
	Electrolysis	21.31	14.54	10.34	21.31	11.15	8.91
	Nuclear	20.16	20.16	11.02	20.16	11.87	9.49
	Wind	21.31	21.31	18.35	21.31	19.77	15.80
	Solar	21.31	21.31	18.35	21.31	19.77	15.80
T&D charge		17.49	15.49	12.55	17.49	13.52	10.80
Distributed	Natural Gas	18.62	14.48	11.00	18.62	11.85	9.47
	Electrolysis	21.31	21.31	18.35	21.31	19.77	15.80


HIGH PRESSURE STO
(410 BAR MAX)
DESIGNED AND MANUFACTUR
CHESTERFIELD SPECIAL CYLIND

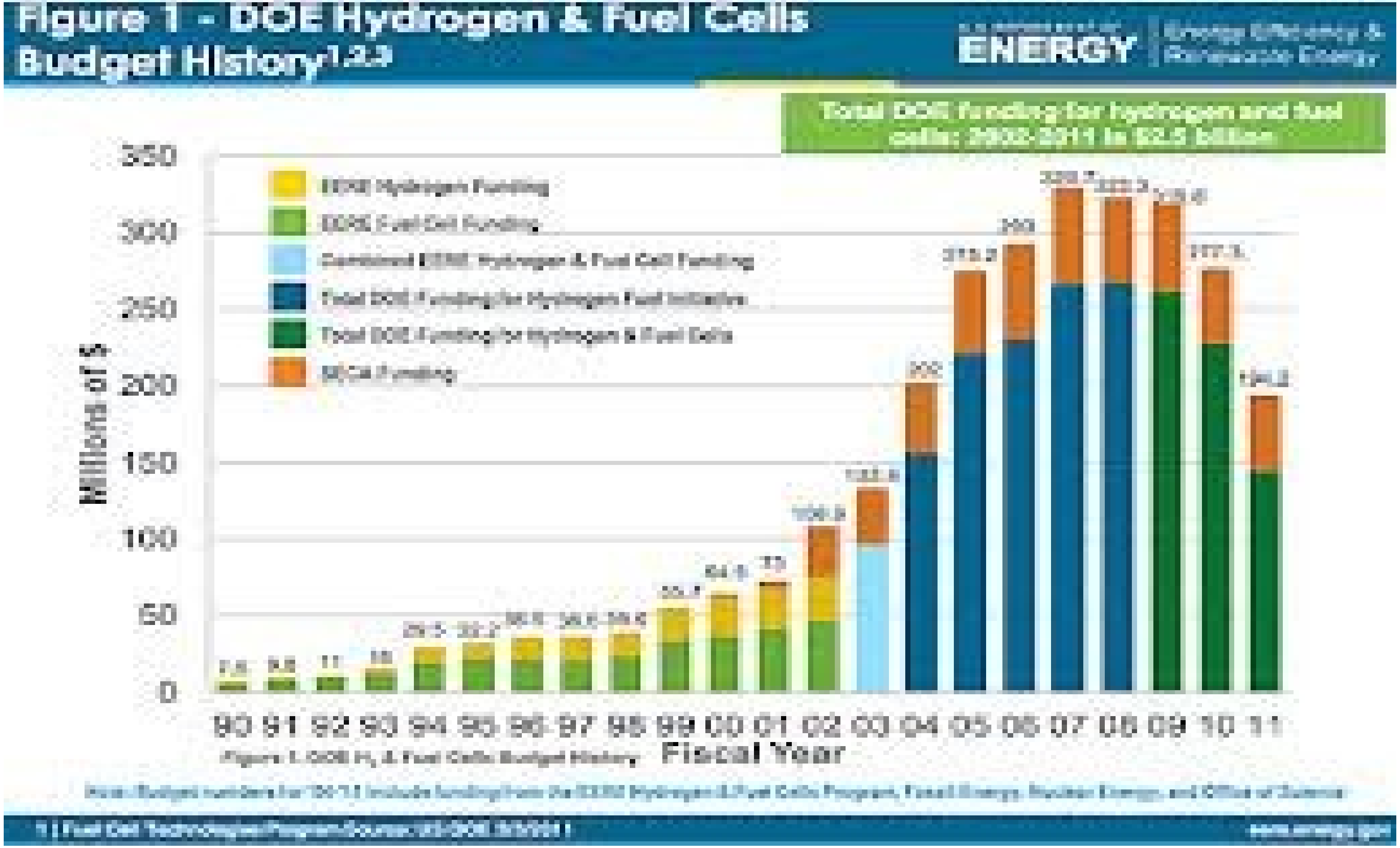
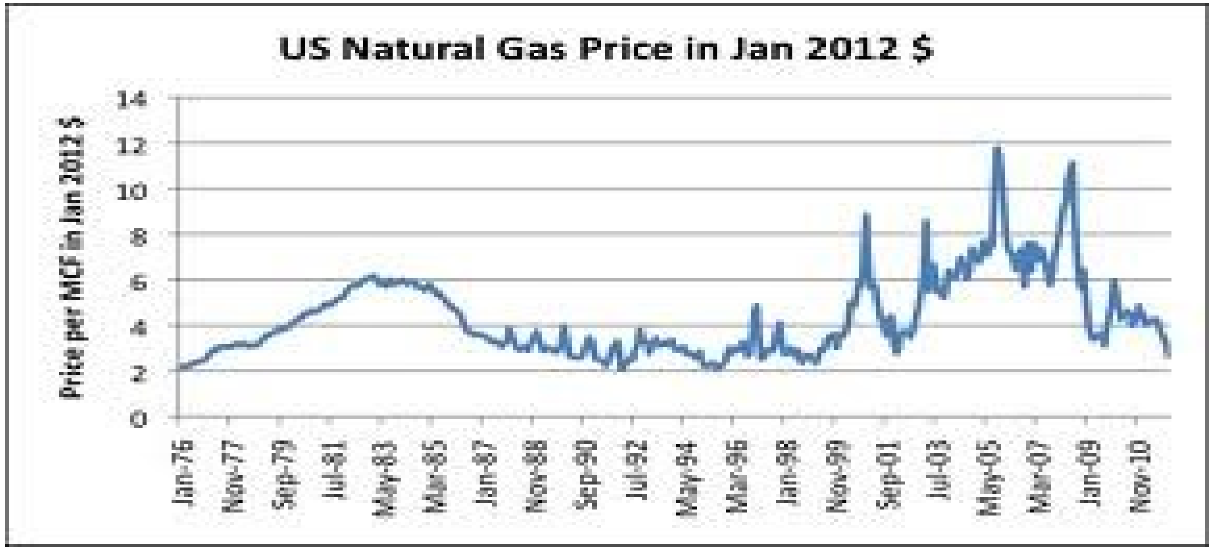
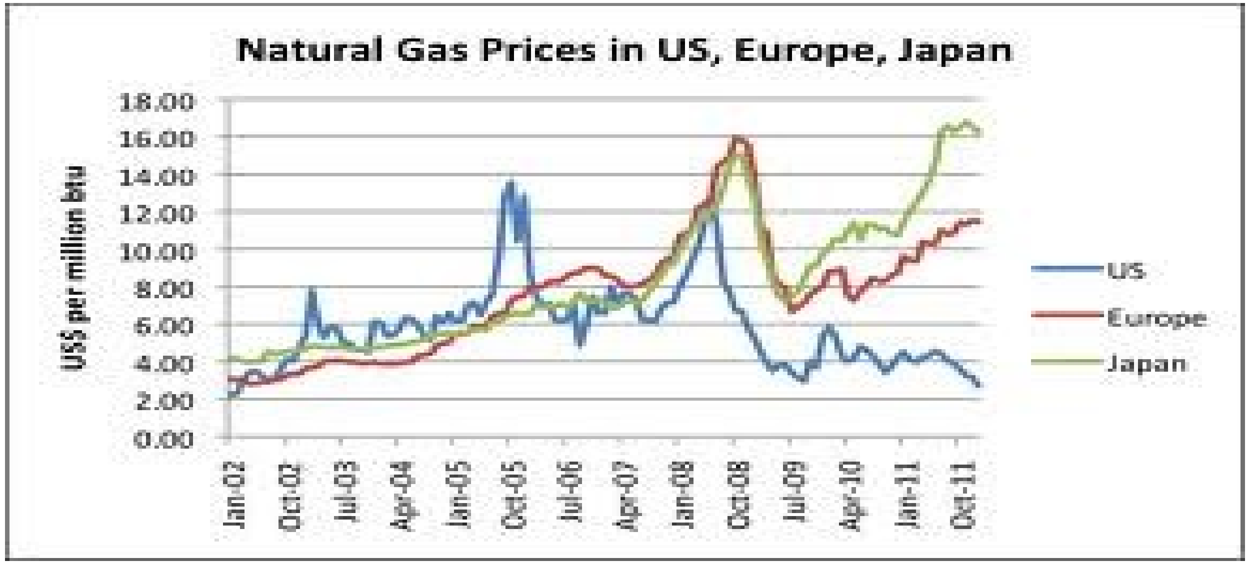
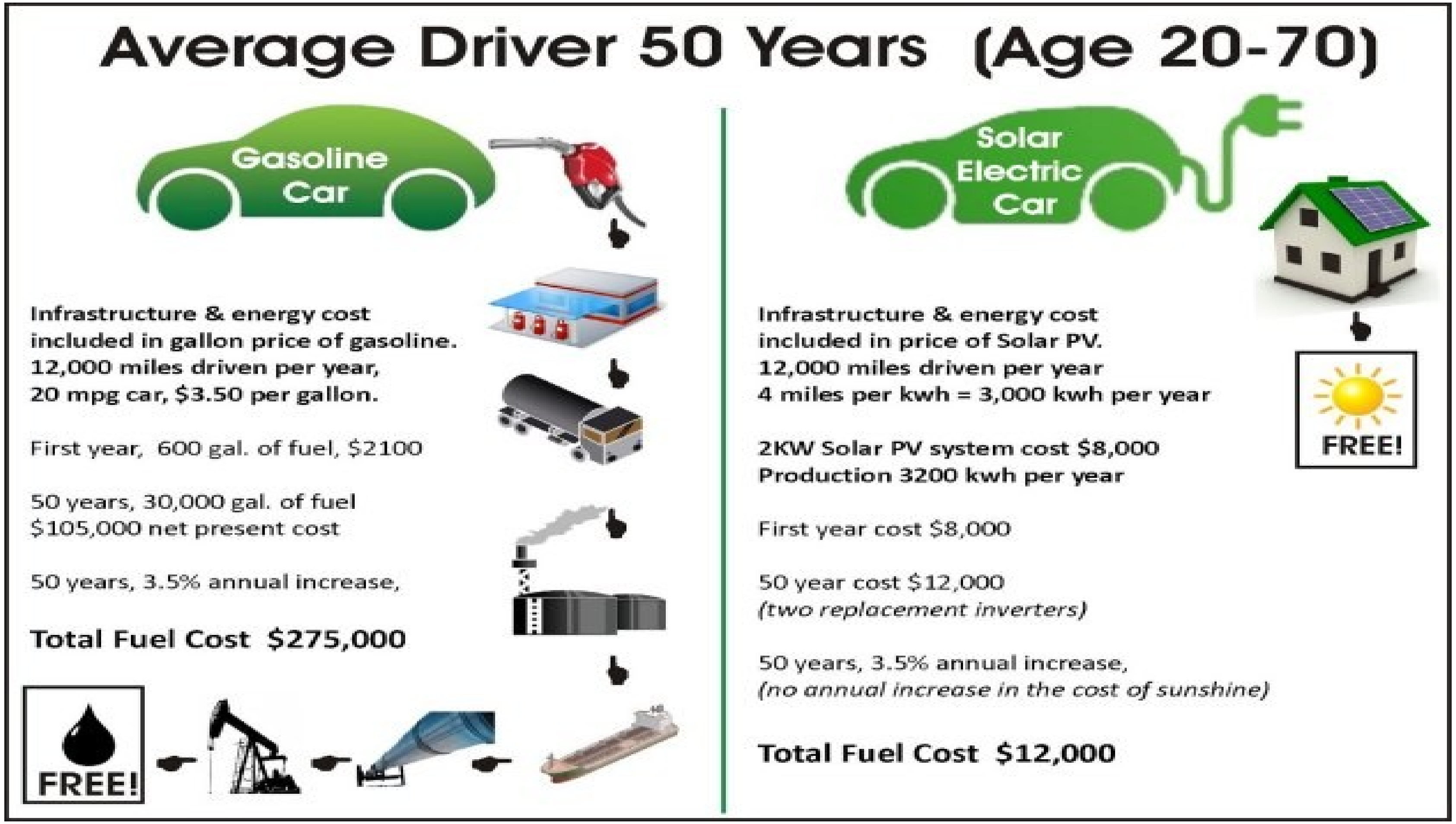


Figure 1 - DOE Hydrogen & Fuel Cells Budget History[1,2,3]
ENERGY
350
300
250
200
150
100
50
0
Millions of $
90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07 08 09 10 11
Fiscal Year


H2


US Natural Gas Price in Jan 2012 $
Price per MCF in Jan 2012 $
0
2
4
6
8
10
12
14
Jan-76
Nov-77
Sep-79
Jul-81
May-83
Mar-85
Jan-87
Nov-88
Sep-90
Jul-92
May-94
Mar-96
Jan-98
Nov-99
Sep-01
Jul-03
May-05
Mar-07
Jan-09
Nov-10


Natural Gas Prices in US, Europe, Japan
US$ per million btu
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
Jan-02
Oct-02
Jul-03
Apr-04
Jan-05
Oct-05
Jul-06
Apr-07
Jan-08
Oct-08
Jul-09
Apr-10
Jan-11
Oct-11
US
Europe
Japan


Average Driver 50 Years (Age 20-70)
Gasoline Car
Infrastructure & energy cost included in gallon price of gasoline.
12,000 miles driven per year,
20 mpg car, $3.50 per gallon.
First year, 600 gal. of fuel, $2100
50 years, 30,000 gal. of fuel
$105,000 net present cost
50 years, 3.5% annual increase,
Total Fuel Cost $275,000
FREE!
Solar Electric Car
Infrastructure & energy cost included in price of Solar PV.
12,000 miles driven per year
4 miles per kwh = 3,000 kwh per year
2KW Solar PV system cost $8,000
Production 3200 kwh per year
First year cost $8,000
50 year cost $12,000
(two replacement inverters)
50 years, 3.5% annual increase,
(no annual increase in the cost of sunshine)
Total Fuel Cost $12,000
FREE!


Gasoline
Regular
399 9/10
Plus
409 9/10
V-Power
419 9/10

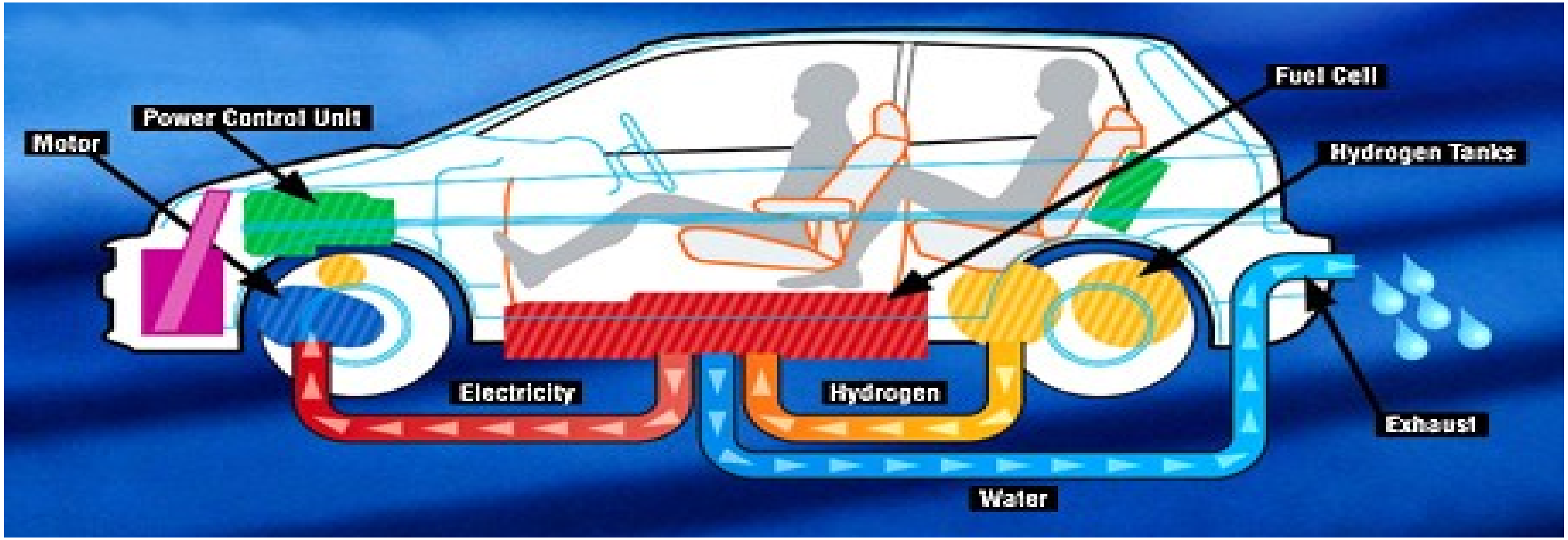
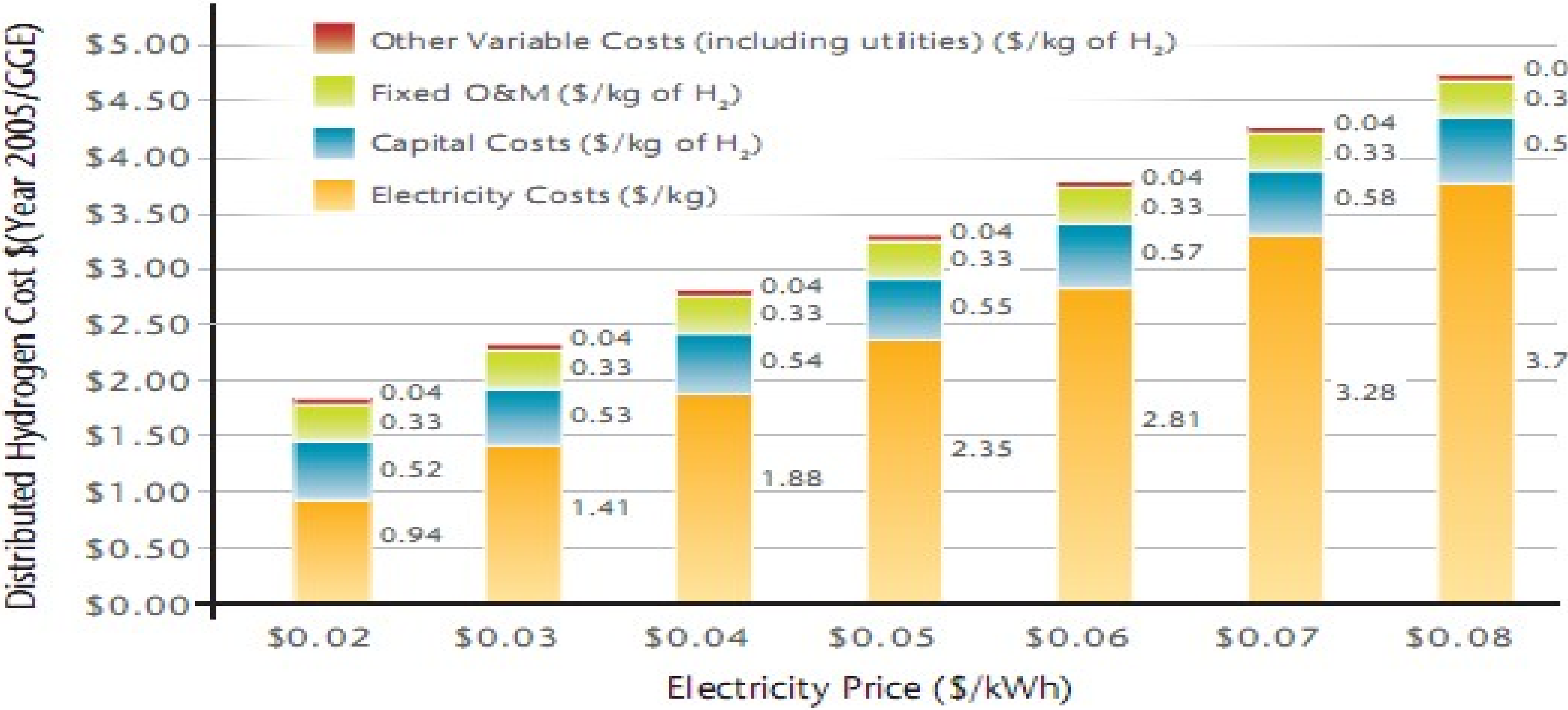

Power Control Unit
Motor
Fuel Cell
Hydrogen Tanks
Electricity
Hydrogen
Exhaust
Water

Figure 3. Effect of Electricity Price on Distributed Hydrogen Production Cost *(assumes 1,500 GGE/day, electrolyzer system at 76% efficiency, capital cost of $250/kW)*



How far will one gallon go and how much water will it produce?

Gasoline ICE Vehicle

→ 25 miles per gallon (mpg)

1 gallon gasoline = 2.7 kg of fuel

(may be represented approximately as CH_2)

$CH_2 + 3/2\ O_2 \rightarrow CO_2 + H_2O$ *(water)*

2.7 kg + 9.3 kg → 8.5 kg + 3.5 kg

3.5 kg water/25 miles = 0.14 kg water/mi

Hydrogen FCV

→ 60 miles per gallon gasoline equivalent (mpgge)

1 gallon of gasoline equivalent of hydrogen very nearly equals 1.0 kg H_2

$H_2 + 1/2\ O_2 \rightarrow H_2O$ (water)

1.0 kg + 8.0 kg → 9.0 kg

9.0 kg water/60 miles = 0.15 kg water/mi

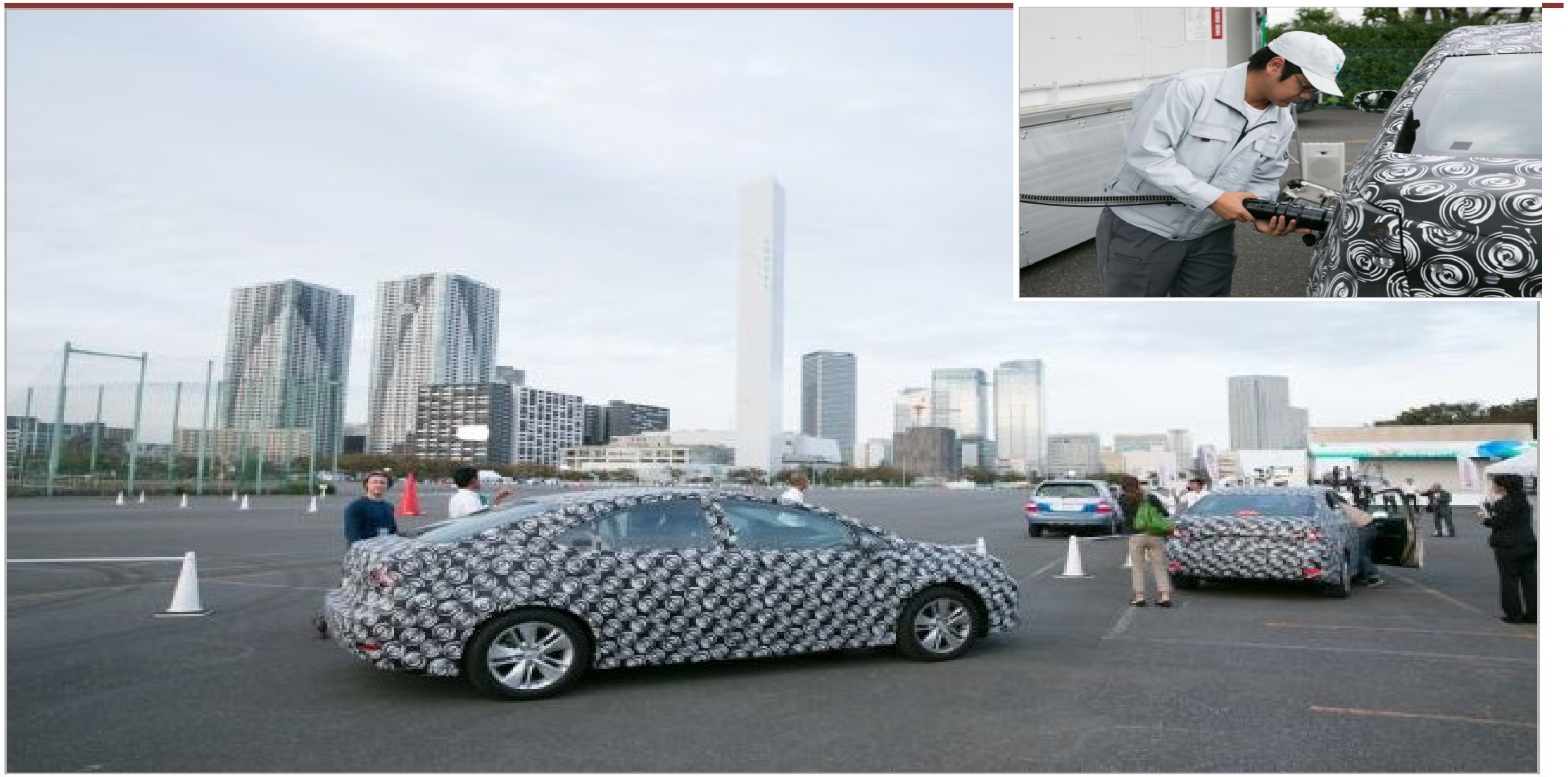
CONCLUSION

- The calculated power required to produce 1 kg of hydrogen by electrolysis does concur with the work of Porter (2008)

REFERENCE

Porter, Stephen (2008). Hydrogen Generation from Electrolysis: 100 kgH2/day . http://en.wikipedia.org/wiki/Electrolysis_of_water#History. Accessed on 6 April 2015

2015 Toyota Fuel Cell Electric Vehicle First Drive



http://www.motortrend.com/roadtests/alternative/1311_2015_toyota_fuel_cell_electric_vehicle_first_drive/#ixzz2nIDzPXoS

The reduced cost of the carbon-fiber-wound, 10,000-psi hydrogen storage tanks

5 kg of hydrogen (the energy equivalent of 5 gallons of gasoline

For over 300 miles (500km) ➔ fewer refill stations

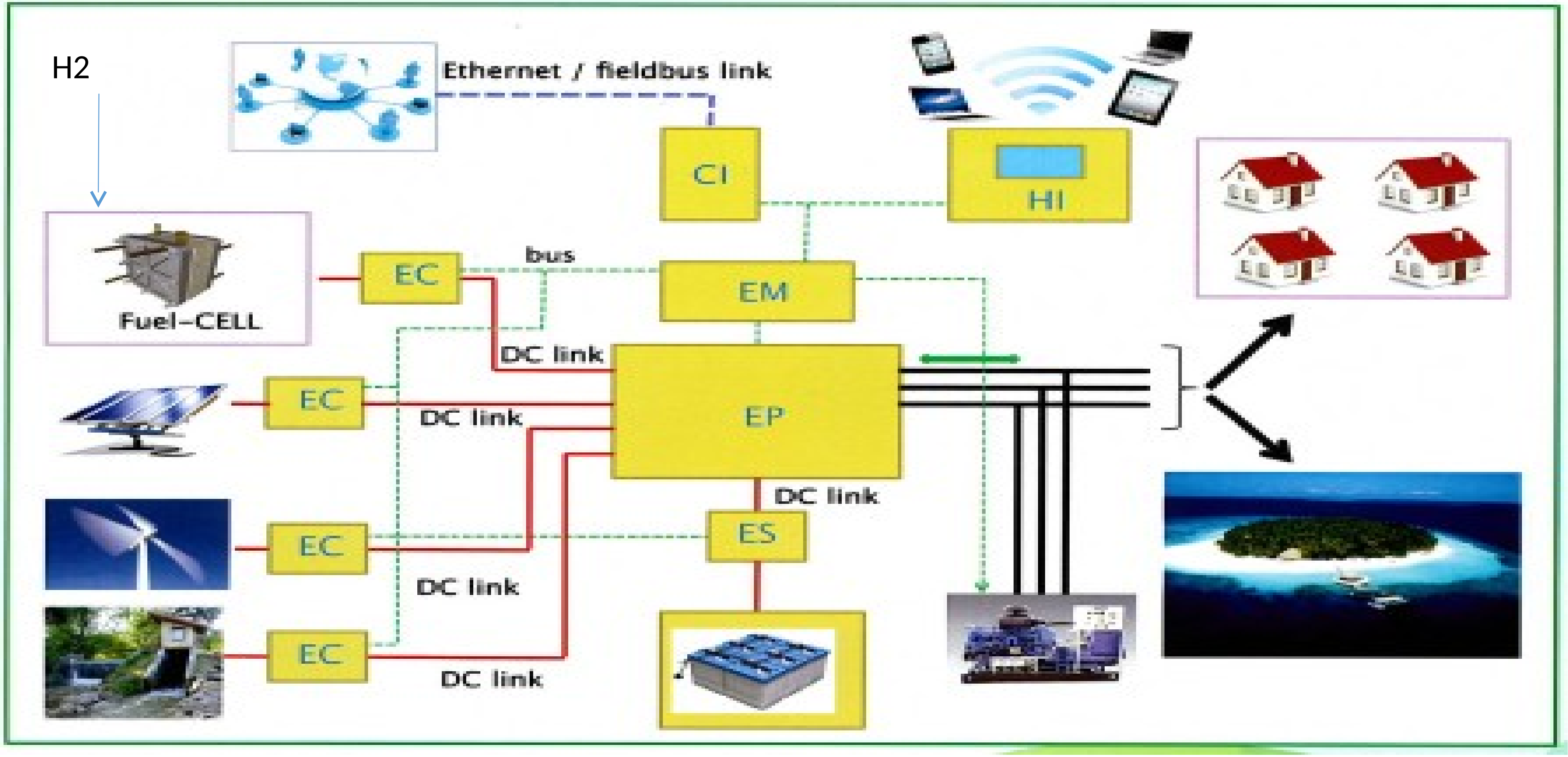
Refill time, 3-5 minutes

150 hp with instant torque

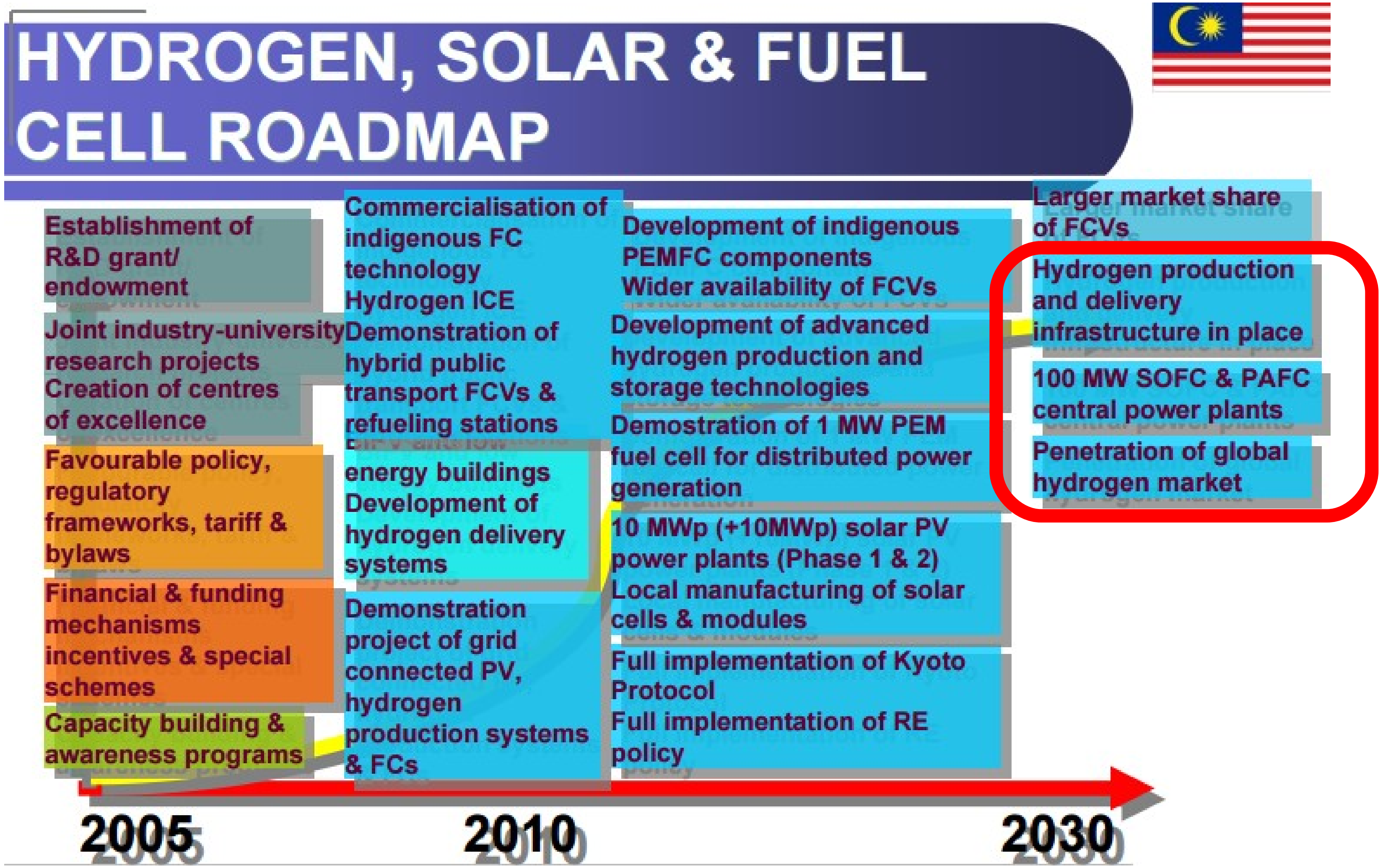
Model, the like of Lexus HS250h

Price: USD50,000

HYDROGEN FUEL-CELL SMART POWER GRID



HYDROGEN, FUEL CELLS & SOLAR :THE CASE FOR MALAYSIA



Prof. Wan Ramli Wan Daud
National Fuel Cell Research Program Malaysia
MALAYSIAN NATIONAL FUEL CELL RESEARCH & DEVELOPMENT PROGRAM

Market Trends & Drivers

Area/ Current	Short Term (2015-2019)	Medium (2020-2029)	Long (2030-2050)

Social

- Safety concerns
- Small start facilities (better evaluate)
- Better ad campaigns

Technological

- **Track and tracing**-real time shipment tracking
- **Intelligent infrastructures evolving**
- **Automation**- logistics & inventory automated planning
- **Intelligent transport systems**
- **Galileo** - a satellite navigation system
- **Alternative powering technologies**
- Cleaner Energy, Sustainable transport sector
- Improvisations in conversion technology favour H2 as energy carrier

Economic

- H2 market demand
- **Economic Growth – Demand** & Supply of Market
- Reliability of H2 supply
- Diesel
- **Oil/Bunker price**- 30% contribution of total logistics cost
- Crude
- IFO 180/IFO380
- **Market outlook –** Supply of carrier, Shift of market
- New build/demolition of vessel
- Logistics Market Trend

Environmental

- **Technological solutions**-Alternative fuels, reduced emissions and more efficient vehicles
- **HSE on Logistics & Distribution –** reduce violation on road/sea transportation,
- Loading / Discharging Facilities
- DG/non-DG

Political

- No policy on OTEC

- Political ownership
- OTEC Hydrogen logistics Hub in Asia the way forward- government solutions

Technology(Storage and Mode of Transportation)

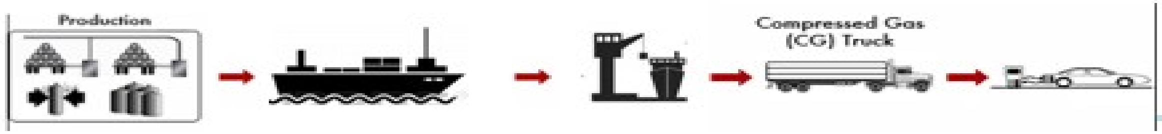
Area/ Current	Short Term (2015-2019)	Medium (2020-2029)	Long (2030-2050)

High Pressure Gas Cylinders

Storage at 200-350 bar (H_2=350 Kg/truck)

storage at 500 bar (H2=1,100 Kg/truck)

Light weight of storage with high storing capacity/ Lower Logistics Cost

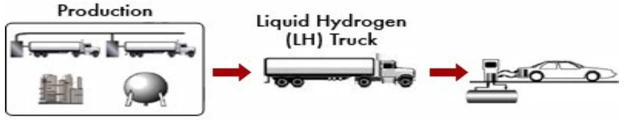


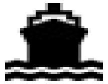
Liquid Hydrogen

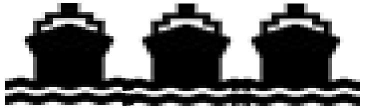
LH2 Container Truck

LH2 Vessel
FY2020 – Pilot vessel

LH2 Vessel
FY2025 – Commercial vessel







Chemical (LOHC)

Storage medium dibenzyltoluene – store in ambient pressure

Safety compliance

Solid Metal Hydride

- Safety compliance
- volume efficiencies

COST
Expensive material

Applications/ Product

Area/ Current	Short Term (2015-2019)	Medium (2020-2029)	Long (2030-2050)
Industrial	 	LPG tanks with H2 H2 boiler for industry uses 	Full industrial usage via centralized pipelines
Household			Supplying heat & electricity 
Transport	 	H2 produceD locally from various sources 	Hydrogen fuel cell vehicles widely adopted
(Wild Cards)		Hydrogen bomb	Hydrogen for; normal fusion, cold fusion (huge energy)

Programs/ Projects

Area/ Current	Short Term (2015-2019)	Medium (2020-2029)	Long (2030-2050)

Government Support

- Government **financial incentive** for Malaysia based Hydrogen logistic provider

- **Port & Terminal Authorities**

Research

- **UTM-OTEC Center**
- **Industrial Joint Research**
- **Port & Terminal Establishment**

Strategic Alliance

- Captive Production
- **Hydrogen Producer /OTEC**
- Merchant Production
- GasLog- Fleet solution
- **Logistics Service Provider**
- Clarksons- publication on Gas Vessel market forecast
- Contract Negotiation
- **Shipbroker/ship agent**
- Provide fleet /Market info
- Identifying potential ship owner

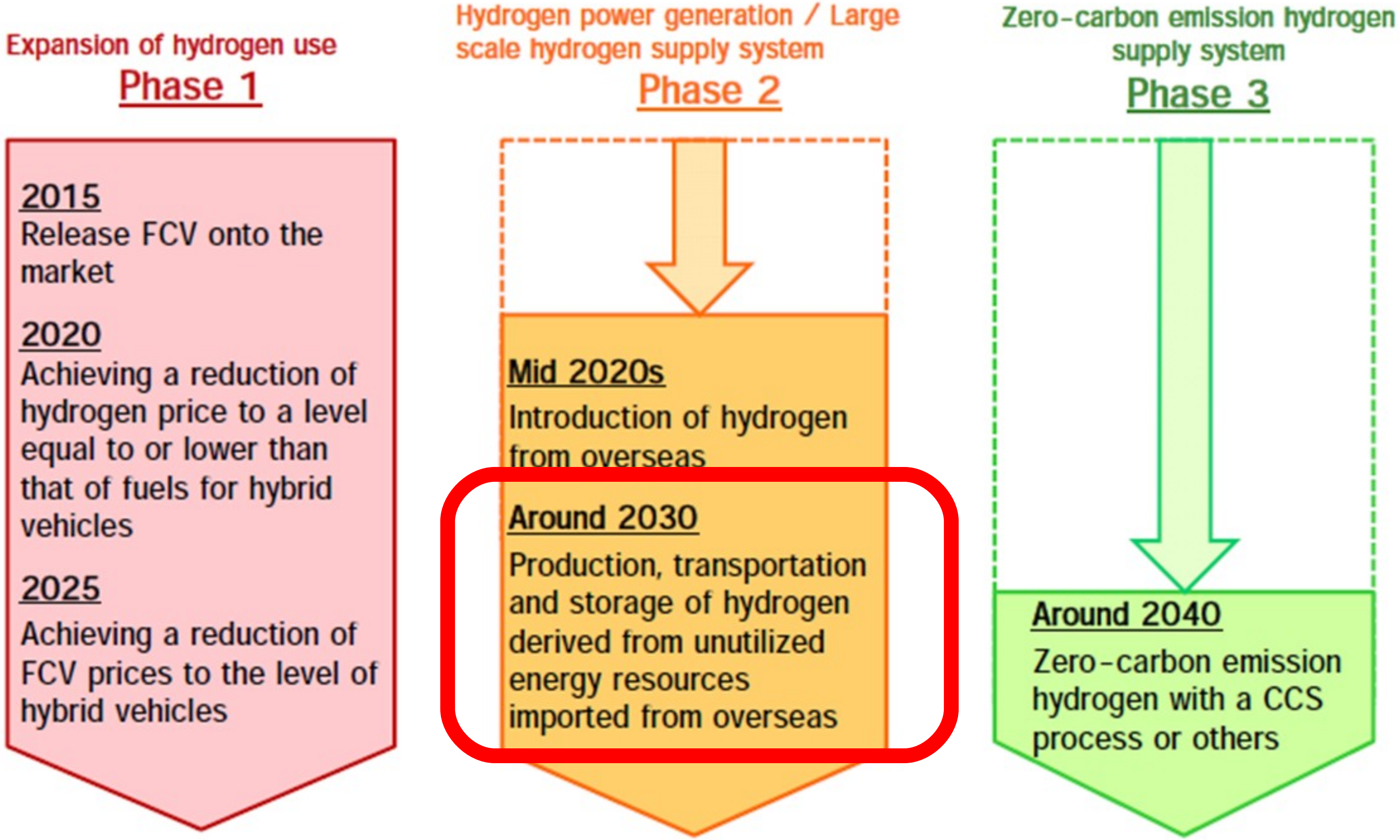
Advertisements/ Promotions

- Hydrogen Logistics Roadshow

- Industries Health Safety and Environment talk

- Potential Customer & Target Market

Japanese Government Energy Policy- Strategic Road Map for Hydrogen & Fuel Cell



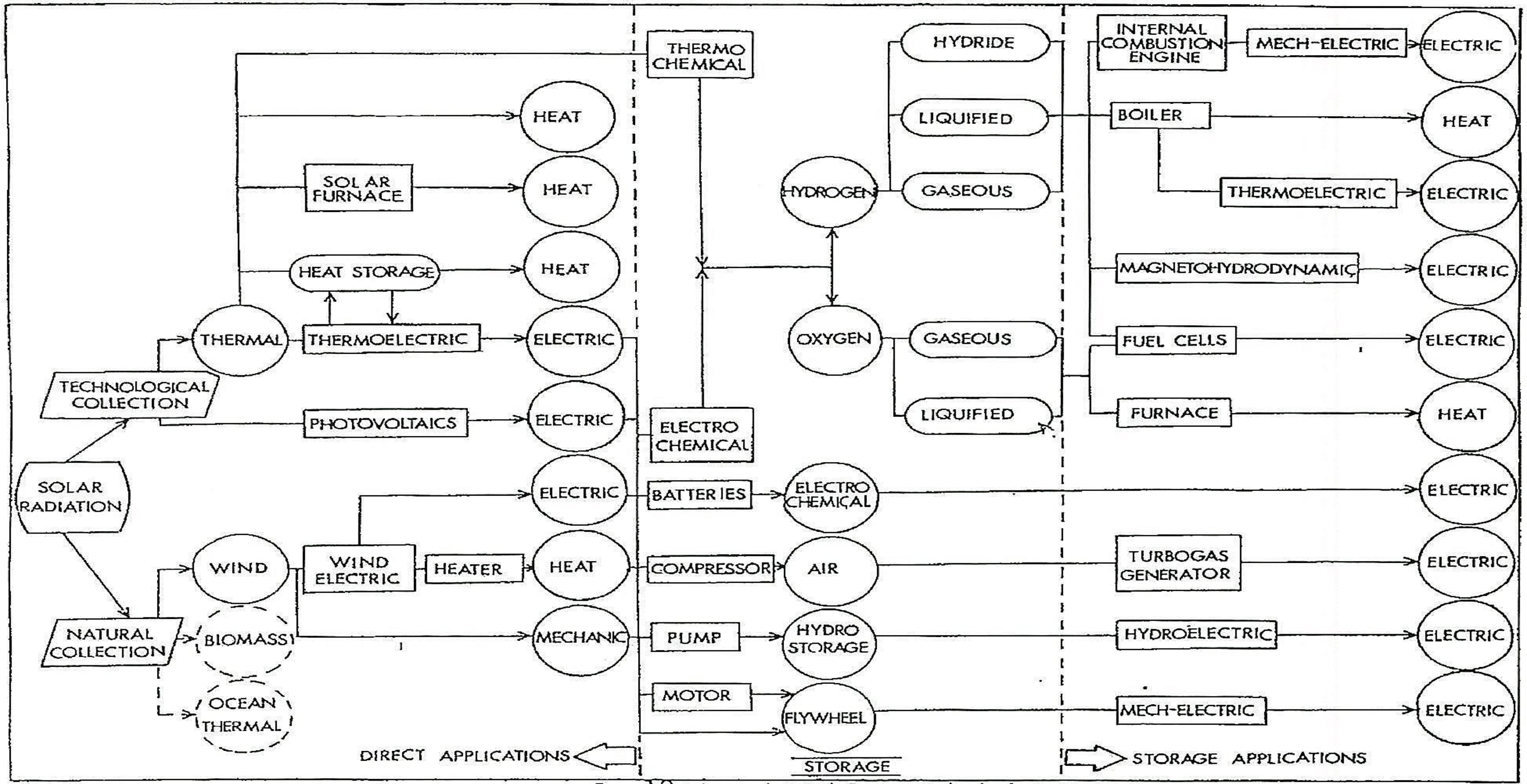


Figure 18 Solar and Wind Energy Technological Options

[Ref: Abu Bakar Jaafar (1976). "Applicability of Solar Energy Technology for Industrial Pollution Control and Production: The Case of the Primary Copper Smelting Industry". An Internship Report. Submitted to the Faculty of Miami University in par tial fulfillment of the requirements for the degree of Master of Environmental Science Institute of Environmental Sciences. Oxford, Ohio. P.82]

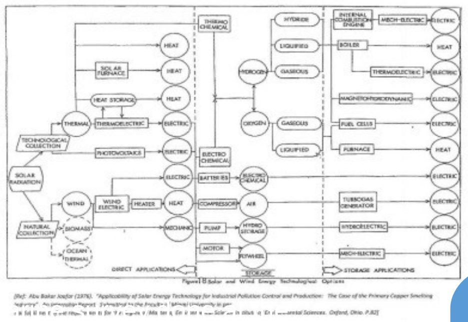
UTM Ocean Thermal Energy Centre
Universiti Teknologi Malaysia Kuala Lumpur,
Jalan Sultan Yahya Petra,
54100 Kuala Lumpur, MALAYSIA
+603 2615 4354 / 4883
utmotec@utm.my

Website: http://otec.utm.my

UTM OTEC Blue Energy
OCEAN THERMAL ENERGY CENTRE

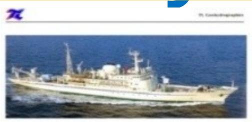
UTM
UNIVERSITI TEKNOLOGI MALAYSIA

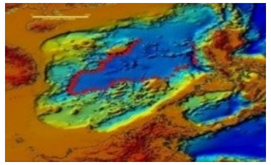
Key Milestones and Achievements



1976 — Master Thesis on applicability of solar energy technology

1981 — Prior study on OTEC potential in Malaysia by Prof. Dato Ir Dr. A Bakar Jaafar





2007 — Marine survey done at the South China Sea in 2008, has confirmed that Malaysia has a great potential to exploit OTEC technology

2012 — Malaysia Prime Minister approved the application of the Ocean Thermal Energy Corporation to conduct a study to generate electricity from the deep sea in Sabah


US companies ready to pump more money into Malaysia

PM happy with investors' feedback

2013 — The UTM Ocean Thermal Energy Centre established at Universiti Teknologi Malaysia.

UTM Blue Energy OTEC OCEAN THERMAL ENERGY CENTRE

2015 — Universiti Teknologi Malaysia (UTM) hosted the 3rd International OTEC UTM KL, 1-2 September 2015

2016 — The UTM Ocean Thermal Energy Centre joined the 4th International OTEC symposium demonstrates OTEC technology readiness and accelerated industry growth

2017 — Completion of UTM-DCNS / Naval Energies Pre-FS of OTEC Project at Pulau Layang-Layang under the MOF TDA-MoDefence Offset Programme

Partners

DCNS

IRENA
International Renewable Energy Agency

Bluerise
harnessing the ocean's power

OTEC foundation

INFRAKOMAS
Infrakomas Sdn. Bhd.

MAKAI
OCEAN ENGINEERING

IOES
INSTITUTE OF OCEAN ENERGY
SAGA UNIVERSITY JAPAN

KRISO
KOREA RESEARCH INSTITUTE OF
SHIPS & OCEAN ENGINEERING

Technip

HNEI

DCNS energies