Futuristic Fuels for Transport Sector

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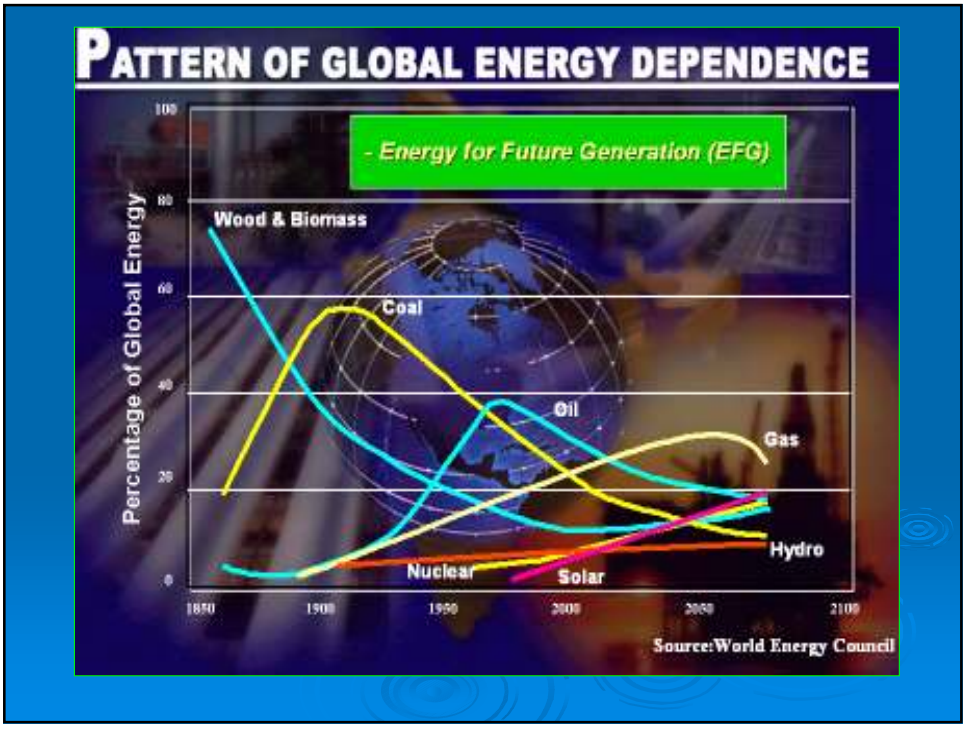
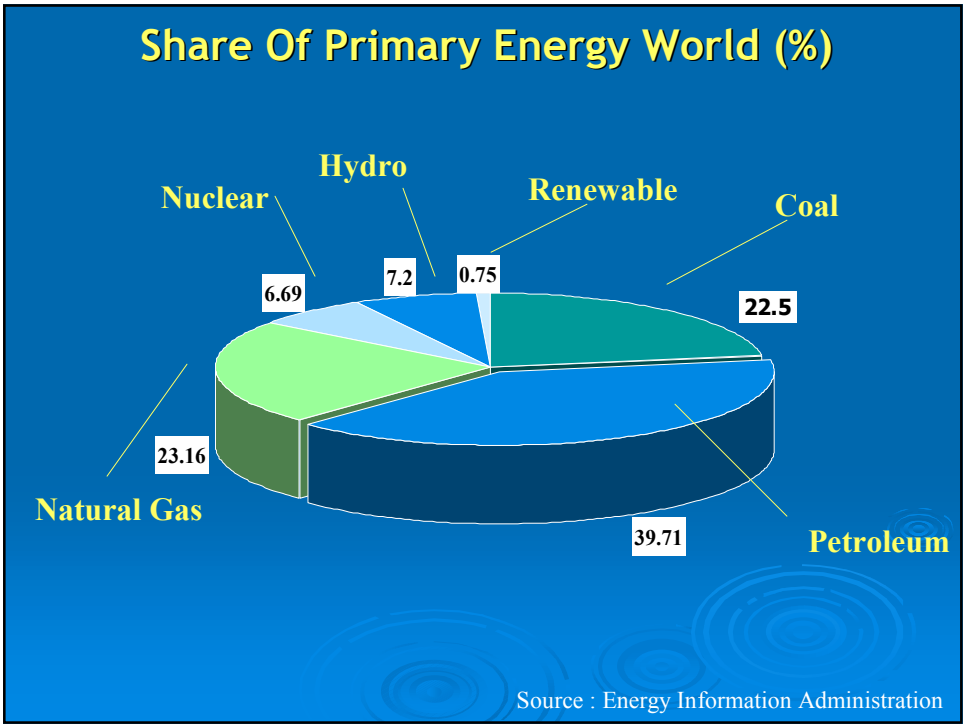
The future is unfolding before our eyes. India see it in floods, Canada see it in disappearing Arctic ice and permafrost. Australians see it in fatal heat-waves and extended droughts. Scientists see it in tree rings, ancient coral and bubbles trapped in icicles. All of these things reveal that the world has not been as it has been for a millennium or more, and that the last years have been the hottest on record.

Peter Garrett
Environmentalist and Politician, Australia


PATTERN OF GLOBAL ENERGY DEPENDENCE
- Energy for Future Generation (EFG)
Percentage of Global Energy
Wood & Biomass
Coal
Oil
Gas
Hydro
Nuclear
Solar
Source:World Energy Council


Share Of Primary Energy World (%)
Nuclear
Hydro
Renewable
Coal
6.69
7.2
0.75
22.5
23.16
Natural Gas
39.71
Petroleum
Source : Energy Information Administration

ENERGY CONSUMPTION BY SOURCE

BIOMASS 2.9%
renewable
Heating, electricity, transportation

HYDROPOWER 2.7%
renewable
Electricity

GEOTHERMAL 0.3%
renewable
Heating, electricity

WIND 0.1%
renewable
Electricity

SOLAR & OTHER 0.1%
renewable
Light, heating, electricity

PETROLEUM 38.1%
nonrenewable
Transportation, manufacturing

NATURAL GAS 22.9%
nonrenewable
Heating, manufacturing, electricity

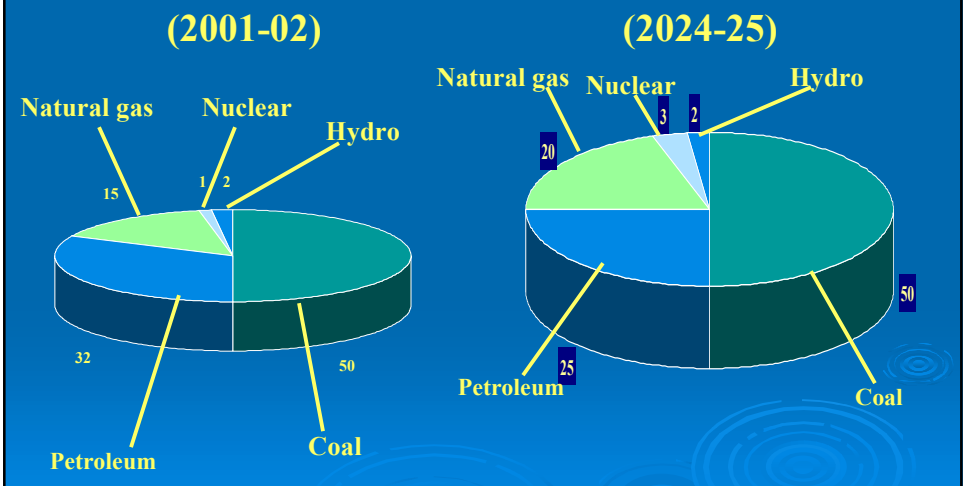
COAL 23.2%
nonrenewable
Electricity, manufacturing

URANIUM 8.1%
nonrenewable
Electricity

PROPANE 1.7%
nonrenewable
Manufacturing, heating

Source: US Department. of Energy

SHARE OF PRIMARY ENERGY - INDIA (%)



Source : India Hydrocarbon Vision 2025

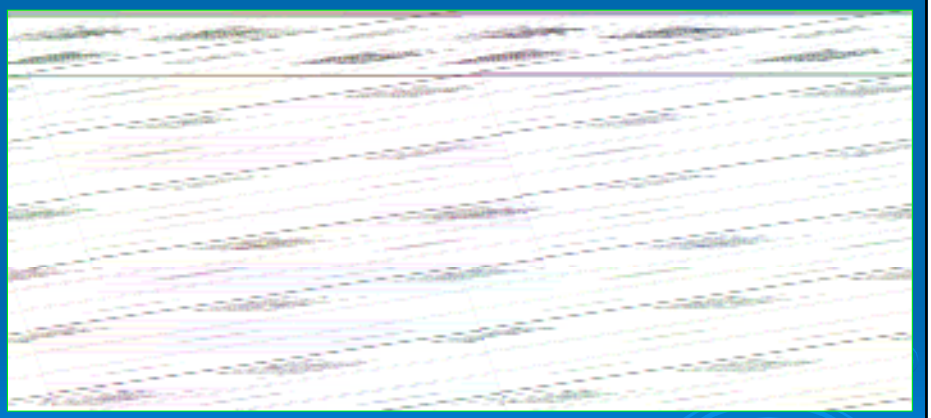
Alternative Energy Sources as Future Options in Transport Sector

- Increasing energy requirement
- Thrust on Resources Conservation
- Soaring crude oil prices and reduced availability
- Energy security
- Stringent environmental regulations

Alternate energy sources which are renewable in nature and environmentally safe could be a solution

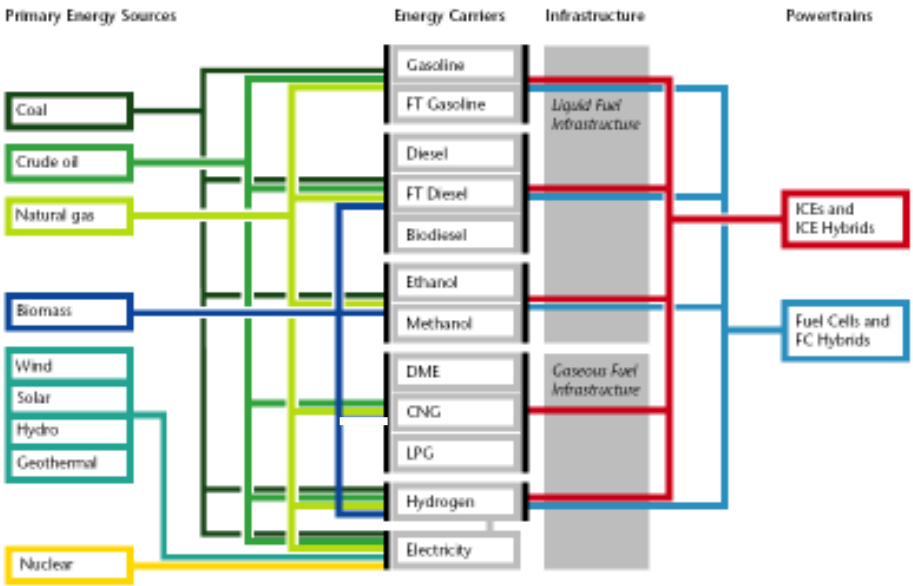
Energy Resources, Possible Future Fuels and Engine Technologies

MATRIX OF POSSIBLE FUEL/PROPULSION SYSTEM COMBINATIONS



Source: Frost & Sullivan 2002

Possible Transport Fuel Pathways



Source: Sustainable Mobility Project, E4tech, 2003

Alternative Energy and Technology Options for Transportation

- Gaseous Fuels (CNG, LPG, Biogas)
- Bio-fuels
  - Ethanol
  - Biodiesel
- Electric vehicles
- Hydrogen fueled Cars
- Fuel cell Vehicles

Major thrust is currently on Bio-fuels and Hydrogen

Bio-fuels

International Experience on use of Ethanol

- *Brazil*- Ethanol as automotive fuel in 1989 as neat hydrated ethanol and 24% ethanol -gasoline blend
- *US*- Clean Air Act of 1990 made use of oxygenates mandatory in 41 most polluted cities during winter months to reduce emissions
- In 2001, US made it mandatory to increase the Renewable content of gasoline and diesel fuel 1.6 % by 2005 & 3% by 2010
- *Europe-* Mandated biofuels use up to 2% in 2005, which will go up to 5.75 % in 2010

Indian Experience- Ethanol

- Several trials conducted in India with 5-20% ethanol in gasoline
- While some manufacturers accept 10% ethanol without modifications, others agree only upto 5%
- BIS allow 5% at present, examining 10% issue

Currently 5% ethanol blending in gasoline is mandatory through out the country.

Properties of Ethanol Gasoline Blends

Properties	BIS Spec.	Com. Gasoline	Gasoline + 5% Ethanol	Gasoline + 10 % Ethanol
Distillation E70	10-45	30	36.5	45
RON	88	89.2	90.5	92.6
Potential Gum, g/m^3	50	40	140	180
RVP, kPa	35-60	55.9	63.3	63.0
VLI	750 / 950	769	885	945

Observation on Physico- chemical Properties

- Octane number of gasoline increases with ethanol blending - offer opportunities to refineries for reducing benzene and MTBE
- Copper impurity in the anhydrous ethanol acts as precursor for oxidation of the blends
- Additional dosage of anti-oxidants required to meet potential gum specification and prevent engine deposit formation
- Addition of corrosion inhibitor required as blends have been reported to cause problems on carburetor needles of two wheelers

Issues for Ethanol - Diesel Blend

- BIS specification does not permit blending of ethanol in diesel
- Flash Point of the blend is less than 15°C and need to be addressed by BIS
- OEMs are concerned about Lubricity of the blend and its effect on injector wear
- Approvals of OEMs and FIP manufactures required

Biodiesel *is monoalkyl ester of long chain fatty acids produced from the Trans-esterification reaction of vegetable oil with alcohol in the presence of catalyst & can be used as fuel*

Raw Materials for Biodiesel Production

- Rapeseed oil (Europe)
- Sunflower oil (Italy and Southern France)
- Soybean oil (USA & Brazil)
- Palm oil (Malaysia)
- Linseed, olive oils (Spain)
- Cottonseed oil (Greece)
- Jatropha (Nicaragua & South America)
- Jatropha and Pongamia (Karanjia) in India

Jatropha & Karanjia
Material of choice for India

Impacts of Biodiesel Blending on Diesel Fuel Properties

- **Cetane number increases** – Better combustion, lower emission
- **Lubricity improves** – Protection to fuel injection equipment
- **Lower Flash point** – More safety
- **Kinematic Viscosity** – Higher but within range, better protection to fuel injection equipment
- **Low Sulphur content** – Lower SO2 and Particulate emission
- Poor Oxidation Stability & cold flow properties

WIDE GLOBAL ACCEPTANCE OF BIODIESEL

- By leading automobile manufacturers :

  Audi, BMW, Kubota, Massey-Ferguson, Mercedes-Benz, Nissan, Peugeot, Renault, Skoda, Volkswagen, Volvo etc.
- By the fuel trade : Chevron -Texaco, Shell, TOTAL,Exxon-Mobil, BP etc.
- By the end-user – Bus companies, taxi fleets, forestry enterprises, railroad, boat owners etc.

Complete Value Chain study of Biodiesel by IOC R&D

Plantation of Jatropha

- 1,75, 000 saplings of Jatropha have already been planted on 70 Ha of Railway land in Surendra Nagar, Gujarat

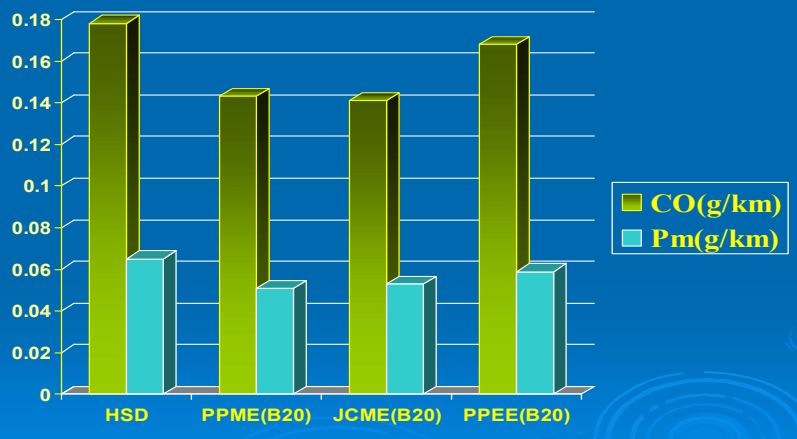
Biodiesel Production Technology

- Biodiesel Pilot Plant set up at IOC R&D Centre with a capacity of 60l Biodiesel in a Batch Process
- Trans-esterification process optimization, patenting and commercialization.
- Know How Transferred to M/s Venus Ethoxyethers, Goa on Technology Fee and Royalty basis

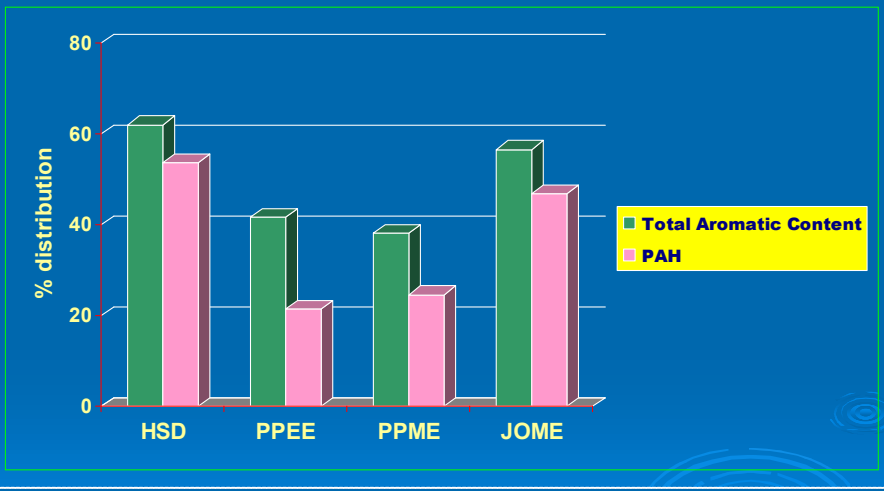
Study of Biodiesel by IOC R&D
- Performance & Emissions Studies

- Testing of LOCO engine with Biodiesel and diesel blends jointly with **RDSO**
- Vehicle performance and Emission studies jointly with **Escorts & Tata motors**
- Field trials on buses jointly with **Haryana Roadways, Rajasthan Roadways & Tata Motors**

Mass Emissions using Bio-diesel Blends



PAH Distribution in Particulate Matter



Lower PAH content with Biodiesel indicate lesser carcinogenicity of Particulates

POTENTIAL BIODIESEL DEMAND & AREA OF PLANTATION IN INDIA

Year	% Blend	Bio-diesel Requirement (Mill Tonnes)	Area of Plantation (Mill Ha)
2006-07	5.00	2.62	2.19
2011-12	5.00	3.35	2.79
2011-12	20.00	13.38	11.19

Total availability of land for plantation is 148 million hectares, however only 11.19 million hectares is required for sustaining 20% blend

Source:Planning Commission Report

R&D Needs for Biodiesel

- Development of anti-oxidants for enhancing the shelf life
- Exploring the possibility of other resources for biodiesel production like Indian Mustard, Palm Waste, Acid Oils and Algae
- Development of enzymatic processes (lipase catalyzed) for biodiesel production
- Continuous process development for Biodiesel production from different feedstocks
- Study of co-relation of biodiesel chemistry and NOx emissions
- Utilization of end products : Glycerol
- Life cycle analysis of biodiesel

2nd Generation Biofuels

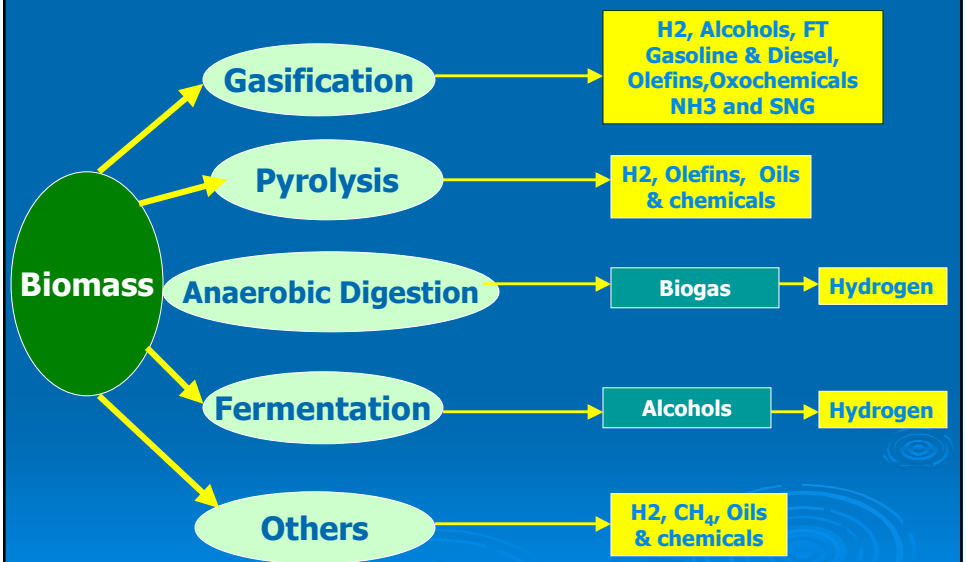
2nd Generation Biofuels

- 2nd Generation Biofuels have high emission reduction potential
- Biomass to be used include woody crops and grasses (not competitive with food crops)
- High yields /Hectare as compared to 1st Generation Biofuels (BTL >3100 L/Hc of HSD Equivalent)
- BTL results in designer fuels compatible with new technologies

Technology options for 2nd Gen Fuels

- Pretreatment/ fermentation/ hydrolysis of lignocellulosic material to ethanol production
- Conversion technology for syngas to liquid fuels available
- The other technologies for Power and fuels generation from Biomass include;
  - Direct Fired Combustion
  - Gasification
  - Pyrolysis
  - Cofiring

Various Biomass Conversion Technologies



Biorefinery Concept : Threshold of a New Era

Source: NREL

A Comparison of Petro & Biodiesel Vs Green Diesel

	Petroleum Diesel (ULSD)	Biodiesel (FAME)	Green Diesel
% Oxygen	0	11	0
Density g/ml	0.83-0.85	0.883	0.78
Sulfur content	<10ppm	<10ppm	<10ppm
Heating Value (lower) MJ/kg	43	38	44
% change in NOx emission	baseline	+10	0 to -10
Polyaromatic content (wt%)	4	0	0
Cloud Point ºC	-5	-5 to +15	-10 to -5
Distillation 10-90% pt, ºC	200-300	340-355	265-320
Cetane	40-55	50-65	70-90
ASTM	D 975-06	D 6751-06a	D 975-06

Source: UOP

Emerging Route for Biodiesel Production

Biodiesel from Algae

- Algae are photosynthetic efficient organisms with rapid growth and can double biomass in a day
- Algae Can Play that Role in biodiesel production and can be grown on non-arable land in saline water.
- The estimated yield for biodiesel production from algae is very high as compared to other sources and require less land.

Estimated Yield per acre

Crop	Gal/Acre/yr Of Oil
Soybean	48
Peanuts	113
Rapeseed	124
Coconut	287
Palm Oil	635
Algae	15,000

Source: UC Berkley

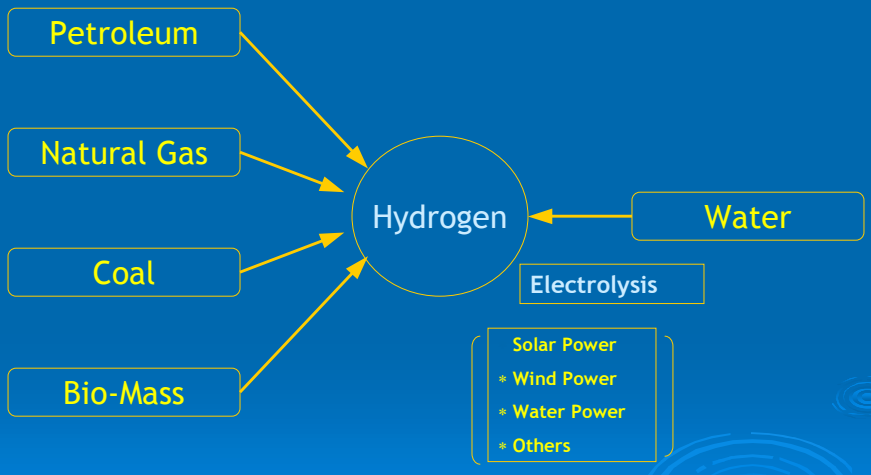
Feasibility of algae farming proven, however the scale up for biofuel will be a challenge.

HYDROGEN
Cleanest of the Clean Fuels

….“ I believe that water will one day be employed as fuel, that hydrogen and oxygen which constitute it, used singly or together will furnish an inexhaustible source of heat and light of an intensity of which coal is not capable……water will be coal of the future”

JULES VERNE- Mysterious Island (1876)

WHERE WILL THE HYDROGEN COME FROM ?



Hydrogen can be produced from variety of sources, therefore hydrogen economy at one area will be different from other depending upon the regional source of hydrogen production.

Hydrogen Availability / Production

- Nearly all H_2 production is based on fossil fuels at present.
- Hydrogen can also be produced from renewable sources such as bio-mass, wind / solar energy.

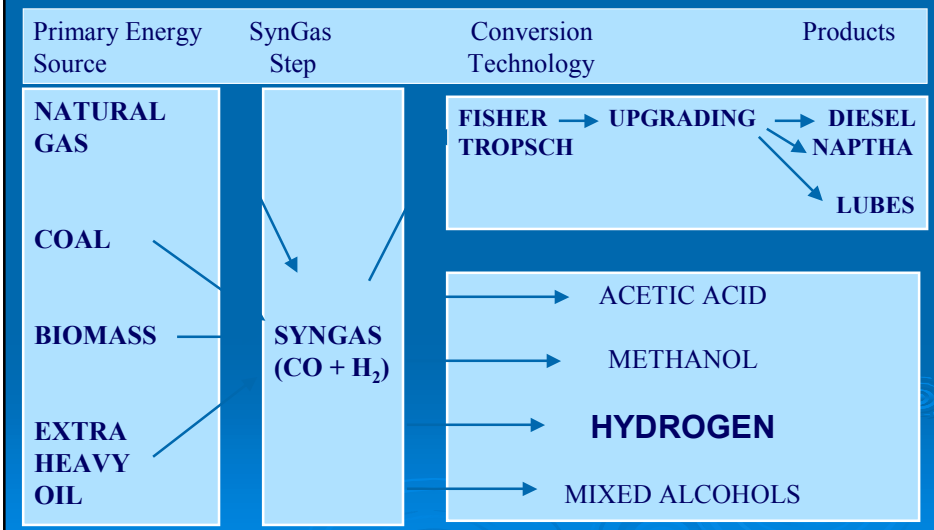
World wide production

- From Natural gas (mostly steam reforming) - 48%
- Oil (mostly consumed in refineries) – 30%
- Coal – 18%
- Electrolysis –4%
- In India possibilities of producing hydrogen in sugar mills from Bagasse cogen power- electolytic exist. Cloro-alkali units also have surplus hydrogen.

CURRENT & FUTURE HYDROGEN PRODUCTION OPTIONS

- **THERMAL PROCESSES**
  - Reforming of Natural Gas / Naptha
  - Gasification of Extra Heavy Oil / Coal / Biomass
  - High-temperature Water Splitting
- **ELECTROLYTIC PROCESSES**
  - Electricity from renewable sources like wind, solar, hydel etc.
- **PHOTOLYTIC PROCESSES**
  - Photobiological Water Splitting
  - Photoelectrochemical Water Splitting
- **OTHER OPTIONS**
  - Chlor-Alkali Plants
  - Co-generation electricity from Bagasse at sugar mills

H_2 PRODUCTION – GASIFICATION OPTION



Source: BP Corporation

HYDROGEN PRODUCTION COST

- As on Today SMR is the most economic route for H_2
  - Central plant large : $ 0.8 /kg
  - Central plant small : $ 1.3 /kg
  - Onsite ~ 100 Nm^3/hr : $ 3.6 /kg
- H_2 production cost in India (SNR /SMR big size): Rs 70 /kg
- Electrolysis (Small Scale) : Rs. 150-250 /kg
- Transportation from Chlor-Alkali Industry: Rs. 55-65/kg (Rs. 40/kg for Hydrogen + Rs. 15 transportation + Rs.10 for SupplyH2 banks)

In future H_2 from renewables including Biomass may come down

R&D AREAS FOR HYDROGEN PRODUCTION

- Reforming (small Reformers)
- Electrolysis of water(Use of Solar or Wind Energy or Photo Voltaic)
- Water Splitting by use of Solar/Nuclear Heat
- Coal /Biomass Gasification / Pyrolysis
- Direct from biomass to H_2

For sustainable hydrogen production in long term – We need to focus on various renewable energy based technologies or biomass conversion processes

R&D AREAS FOR STORAGE SYSTEMS

- Development of high pressure storage systems
  - Composite materials
  - Testing facilities to be created for high pressure storage system
- Development of metal hydride storage systems
  - To increase the hydrogen density requiring materials research
  - To improve hydrogen absorption and release characterstics
  - Durability of metal hydride systems
- Nano-technology based hydrogen storage system development

HYDROGEN TRANSPORTATION COSTS

- In the early stages of hydrogen infrastructure, when compressed gas trucks serve small stations, storage costs account for approximately 30% of the delivery cost or about 15% of the total hydrogen cost to the vehicle.

- Higher pressure operation appears to be an effective way to reduce compressed gas truck delivery costs.
- For liquid hydrogen pathways, costs are dominated by storage-related costs, primarily for liquefaction.
  - Storage accounts for 70-80% of the delivery cost or 35-40% of the total delivery cost to the vehicle
- With on-site production from natural gas, gas storage and compression account for ~ 30% of the hydrogen cost
- In long term, pipeline systems will probably give the lowest delivery costs in densely populated cities, and will be preferred in terms of emissions and energy used

R&D Areas for Hydrogen Applications

- **COMBUSTION FUEL IN IC ENGINES**

  - Hydrogen in mixture with CNG (H2 - CNG)

  Can Use Existing CNG infrastructure

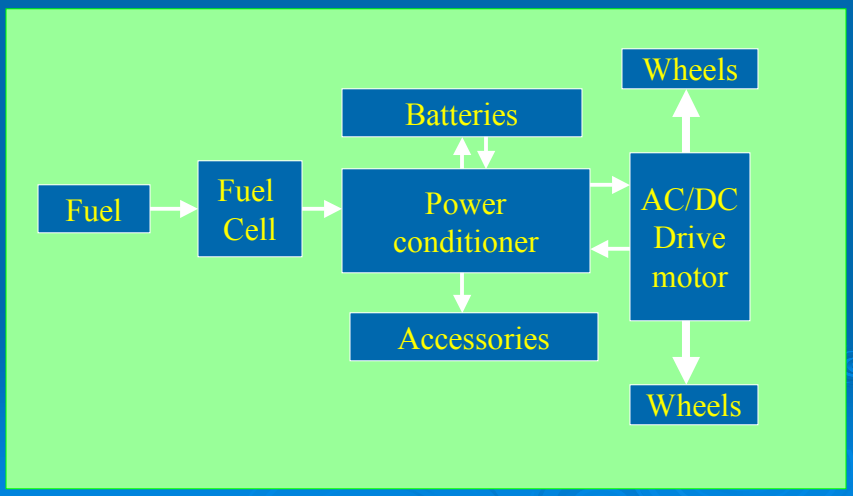
  Can Provide Useful experience with Hydrogen

  - As a neat hydrogen fuel in IC Engines

- **FUEL CELLS**

  -More Efficient way of using hydrogen

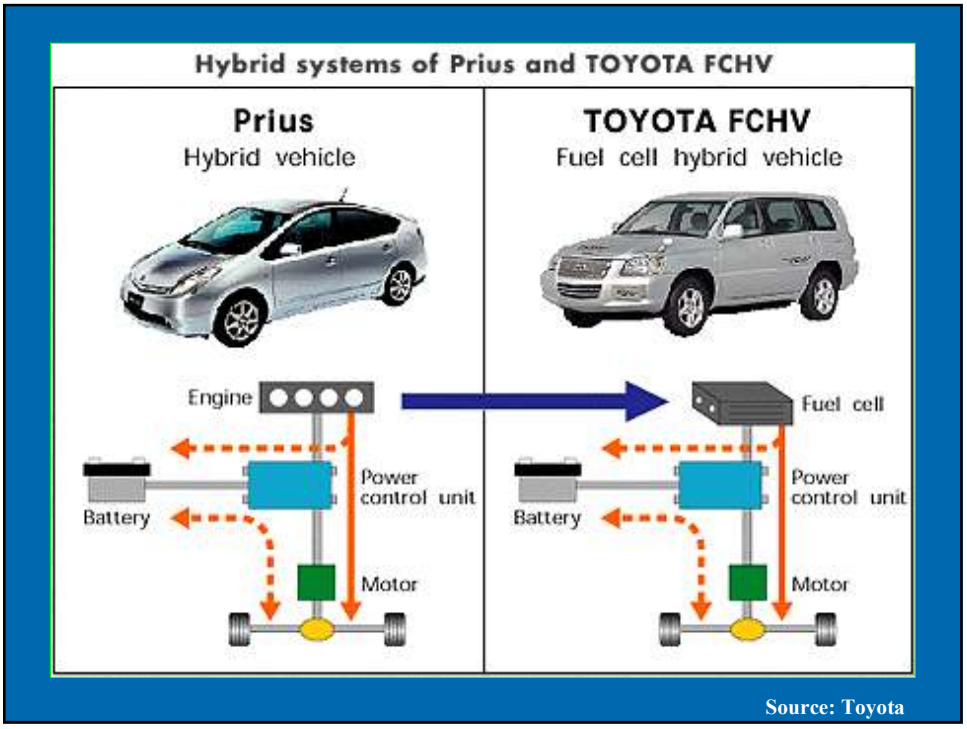
FUEL CELL VEHICLE CONFIGURATION



Status - Hydrogen Activities of IOC

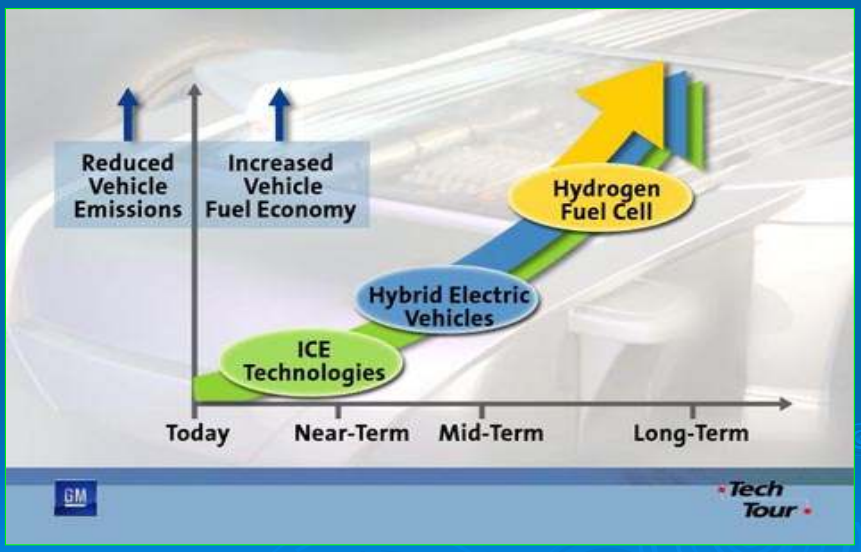
- IOC set up India's first Hydrogen Dispensing Station at IOC R&D Centre, Faridabad in Oct, 2005
- Second similar station is being set up at Delhi, which will be operational by 2008.

- **Hydrogen production - Electrolyser**
- **Hydrogen Dispensing - 350 bar**
- **H_2-CNG Dispensing - 250 bar**

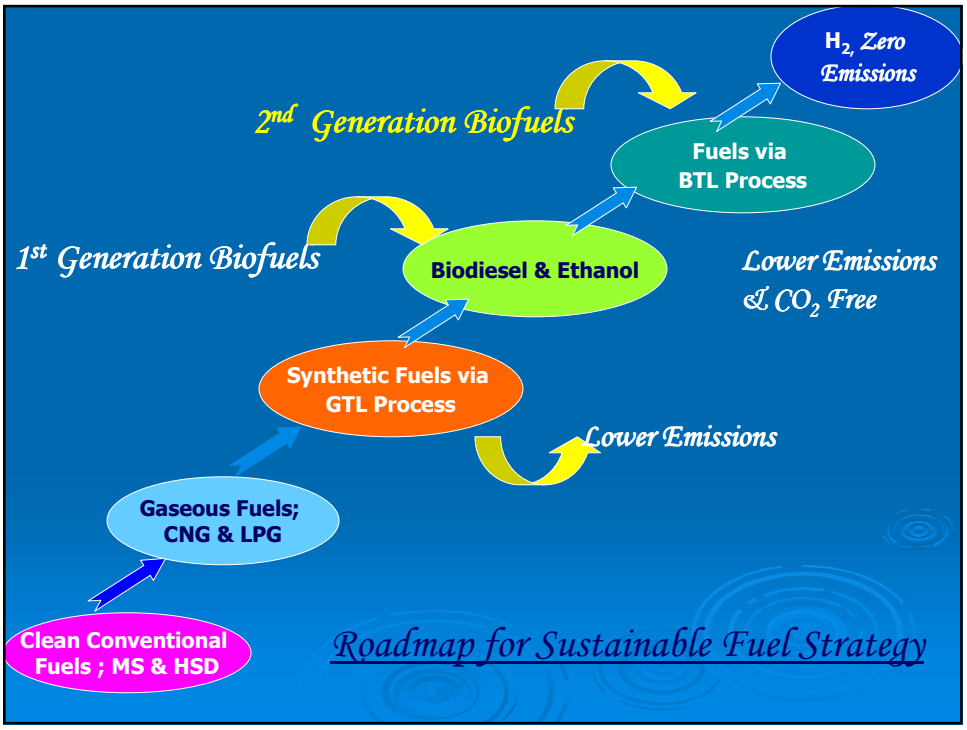


Source: Toyota

Road to Hydrogen Fuelled Automobiles



Source : General Motors


H_2, Zero Emissions
2nd Generation Biofuels
Fuels via BTL Process
1st Generation Biofuels
Biodiesel & Ethanol
Lower Emissions & CO_2 Free
Synthetic Fuels via GTL Process
Lower Emissions
Gaseous Fuels; CNG & LPG
Clean Conventional Fuels ; MS & HSD
Roadmap for Sustainable Fuel Strategy

Thank You