Successful Adoption of CNG and Emerging CNG-H_2 Program in India

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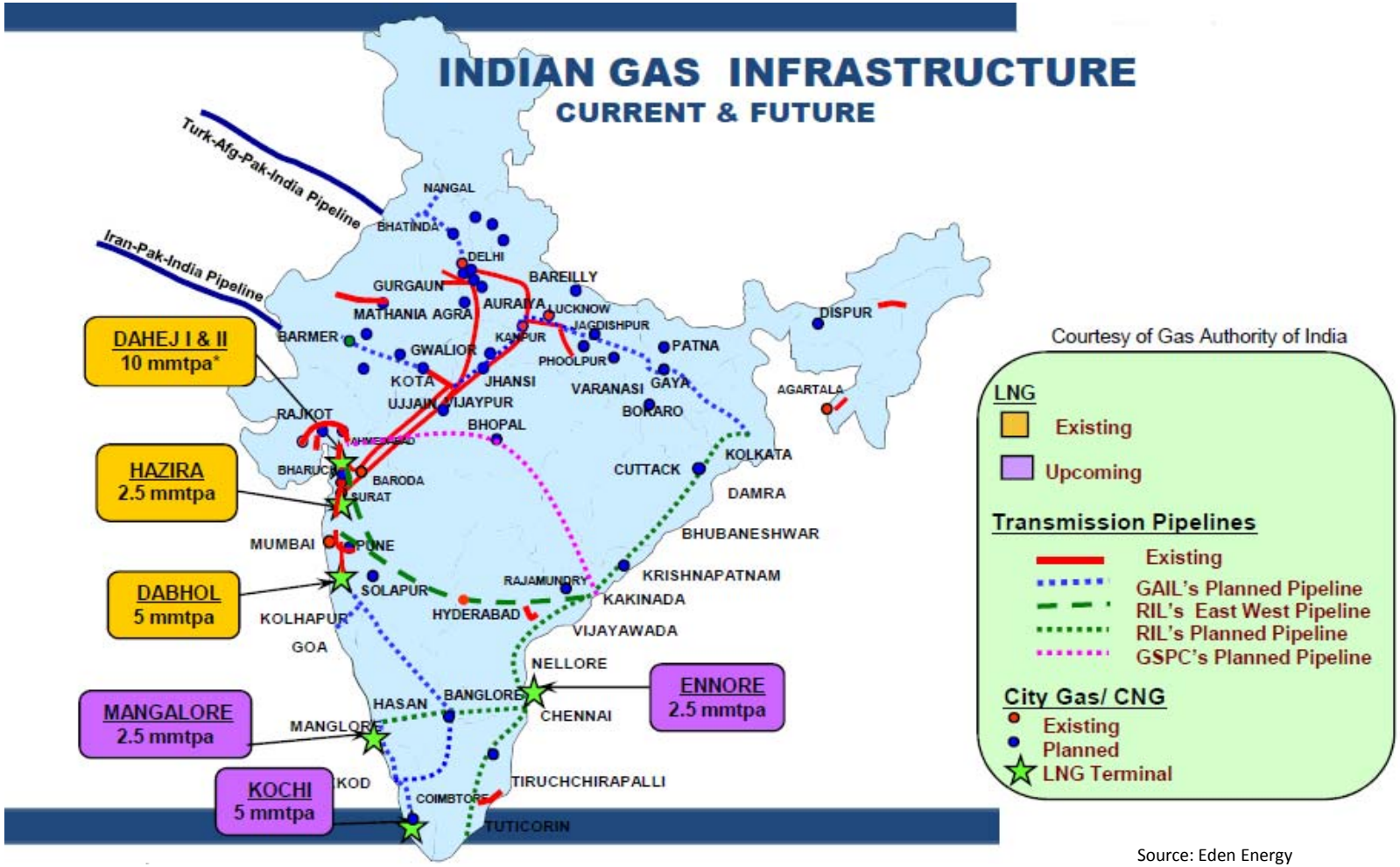
Background

1. CNG Program Implementation

- Started in 1991-92 as Pilot Project
- July 28, 1998 - Supreme Court of India orders the CNG program for Delhi
- Implemented largest ever CNG program – more than 100,000 CNG vehicles in one city within a span of 5 years
- Largest ever public transport bus fleet on clean fuels – > 10,000 CNG buses
- Enhancing the safety of CNG vehicles
  - Third party technical inspection for CNG buses
  - Intensive training of field staff on comprehensive inspection techniques for CNG vehicles
- CNG Program extended to other major polluted cities



Source: Eden Energy

Background

2. International Partnership for the Hydrogen Economy- *2003, Washington DC*

- The International Partnership for the Hydrogen Economy (IPHE) was established in 2003 as an international institution to accelerate the transition to a hydrogen economy. Each of the IPHE partner countries has committed to accelerate the development of hydrogen and fuel cell technologies to improve the security of their energy supply, environment, and economy.
- India after joining IPHE as founding member in 2003, seriously started exploring the possibilities of using hydrogen as an fuel for automotive and stationary applications.
- India could make progress in this direction because of steps taken by the Government after joining IPHE in 2003.

Background

3. The Planning Commission of India – July, 2003

- Deliberated on the Hydrogen Energy Status & Prospects in the 21st Century to address various aspects and develop guidelines for Hydrogen Energy in the country.

- Four sub-groups set up on different aspects of hydrogen for;
  - Hydrogen production;
  - Hydrogen storage & distribution;
  - Hydrogen applications;
  - Safety standards, security and related policy issues.

Background

4. Ministry of Petroleum & Natural Gas, Govt. of India

- International Workshop on Hydrogen Energy
- Creation of Corpus Fund of 20 million USD
- IOC R&D to act as nodal agency for H_2 research in Oil & Gas sector

5. National Hydrogen Energy Board

- Roadmap for country
- Funding of the projects

Hydrogen Corpus Fund

MoP&NG created corpus fund of $ 20 million for hydrogen research activities within Oil & Gas Sector in India with contribution from all Oil & Gas PSUs as per following distribution;

OIDB		$ 8 million
GAIL		$ 3.2 million
ONGC		$ 3.2 million
IOC		$ 3.2 million
HPC		$ 1.2 million
BPC		$ 1.2 million
Total	**=**	**$ 20 million**

Hydrogen Corpus Fund

The responsibility of overall co-ordination of Hydrogen Research activities within Oil & Gas Sector in India with Hydrogen Corpus Fund (HCF) had been given to **IndianOil**-R&D. While Hydrogen Corpus Fund being managed by OIDB, the projects undergo screening at 3 stages i.e.

i. Technical Committee (coordinated by IOC R&D)

ii. Scientific Advisory Committee of MoP&NG

iii. Steering Committee under chairmanship of Secretary, MoP&NG (CHT to act as secretariat for stage ii & iii)

Now, Centre for High Technology (CHT) is co-ordinating the Hydrogen Research activities under the HCF

National Hydrogen Energy Roadmap

- For accelerating development and commercialization of hydrogen energy and fuel cell technologies, a National Hydrogen Energy Board (NHEB) was set up in October 2003
- A National Hydrogen Energy Road Map (NHERM) was prepared under the guidance of NHEB in 2005 and was accepted by NHEB in 2006
- NHERM identifies paths for gradual introduction of hydrogen energy in the country and creation of hydrogen energy infrastructure
- Advocates total systems approach for developing hydrogen energy technologies
- Implementation through public-private partnerships
- Wide ranging R,D&D activities envisaged

National Hydrogen Energy Roadmap

Objectives

- Reduce India's dependence on import of petroleum products
- Promote the use of diverse, domestic, and sustainable new and renewable energy sources
- Provide electricity to remote, far-flung, rural and other electricity deficient areas
- Promote use of hydrogen as a fuel for transport and power generation
- Reduce carbon emissions from energy production and consumption
- Increase reliability and efficiency of electricity generation

National Hydrogen Energy Roadmap

- 1 Million Vehicles running on Hydrogen based IC Engines and fuel cells by 2020
- 1000 MW electricity generation using fuel cells by 2020.
- $ 5 billion estimated to be spent for whole Programme upto year 2020.

National Hydrogen Energy Roadmap

Green Initiative for Future Transport (GIFT) – *Vision 2020*

- Hydrogen cost at delivery point @ USD 1.2 – 1.5
- Hydrogen storage capacity to be 9 wt. %
- Adequate support infrastructure including a large number of dispensing stations to be in place
- Safety regulations, legislations, codes and standards to be fully in place
- 1,000,000 vehicles on road
  - 750,000 two / three wheelers
  - 150,000 cars / taxis etc.
  - 100,000 buses, vans etc.

National Hydrogen Energy Roadmap

Green Initiative for Power Generation (GIP) – *Vision 2020*

- Hydrogen cost at delivery point @ USD 1.2 – 1.5
- Hydrogen bulk storage methods and pipeline network to be in place
- Adequate support infrastructure including a large number of dispensing stations to be in place
- Safety regulations, legislations, codes and standards to be fully in place
- 1000 MW power generating Capacity to be set up
  - 50 MW capacity small IC engine stand alone generators
  - 50 MW capacity stand alone fuel cell power packs
  - 900 MW aggregate capacity centralized plants

Government Departments Engaged in Hydrogen Program in India

- Ministry of New & Renewable Energy (MNRE)
- Ministry of Petroleum & Natural Gas (MoP&NG)
- Department of Science & Technology (DST)
- Ministry of Road Transport & Highways (MoRT&H)
- Department of Atomic Energy (DAE)

Indian Oil's Initiatives

"International Workshop on Hydrogen" was organized by **IndianOil** R&D during December, 2003 in New Delhi.

- ⇨ 17 Eminent speakers from all over the world
- ⇨ Around 300 delegates
- ⇨ 9 Exhibitors from India & Abroad

Setting up of Fueling Infrastructure

- Setting up of H-CNG Dispensing Station at IndianOil R&D Centre, Faridabad- *2005*
  - H-CNG @ 250 bar
  - Hydrogen @ 350 bar (Disabled)
- Setting up of H-CNG Dispensing Station at IndianOil Retail Outlet, Dwarka, Delhi-*2009*
  - H-CNG @ 250 bar
  - Hydrogen @ 350 bar (Disabled)

Setting up of Fueling Infrastructure

Station Design Criteria

The Hydrogen Dispensing Stations had been designed keeping in mind the requirements of setting up a typical CNG station as per the **OISD-STD-179** standard. Area classification as per **IS 5572**.

H-CNG Dispensing Station at IndianOil R & D Centre at Faridabad

➡ India's First H-CNG Dispensing Station was set up in 2005 at **IndianOil** R&D Centre, Faridabad

- Hydrogen production – Electrolyser
- CNG brought from Delhi in Cascade mounted truck
- H2-CNG Dispensing - 250 bar
- H2 Dispensing - 350 bar (disabled)

H-CNG Dispensing Station at IndianOil's R&D Centre, Faridabad

H-CNG Dispensing Station at IndianOil's Retail Outlet at Dwarka, New Delhi

Broad Specification of Station

- Hydrogen Production
  - Electrolyser
  - Capacity - 5 Nm^3/hr ~ 10 kg / day if operated round the clock
- Hydrogen Storage
  - Buffer – 10 bar
  - High Pressure – 400 bar
- Hydrogen Compressor
  - Capacity - 5 Nm^3/hr
  - Pressure – 400 bar
- Hydrogen – CNG blender
  - Upto 20% Hydrogen in CNG
- H_2-CNG Dispenser
  - Upto 20% Hydrogen in CNG
  - Capable of dispensing 100% hydrogen also, but currently hydrogen line not connected as per the direction of PESO.

H-CNG Dispensing Station at IndianOil's Retail Outlet at Dwarka, New Delhi

Station Design Codes

- Indian Gas Cylinder Rules 2004
- NFPA 52 – Vehicular fueling system
- NFPA 55 – Storage use & handling of compressed gases
- NFPA 496 – Standard for purged & pressurized enclosures
- NFPA 497 / IS: 5572 – Hazardous electrical classification
- Electrical – IEC / NEC (NFPA 70)
- IS/IEC/60079/1/2007 supersedes IS: 2148 of 2004
- Dispenser – API/SAE
- Storage Tanks – ASME (Gas Cylinder Rules, 2004)
- Process Piping – ASME/ANSI
- Local Codes – building, fire, mechanical, environment etc.

H-CNG Dispensing Station at IndianOil's Retail Outlet at Dwarka, New Delhi

Safety Features

An emergency shutdown interface is provided to react to a contact closure from local or remote emergency shutdown switches. Other fueling shutdown input signals include:

- Over-pressure
- Drive-off
- Excessive flow
- Over-temperature
- Leak

Safety interlocks are installed to address:

- Vehicle check valve failure
- Fuel supply initiated alarms / trips
- Flame scanners
- Combustible gas sensors
- Excess fuel flow rate
- Excess fill time
- Minimum flow
- Loss of control power
- High supply pressure
- Fuel supply pressure failure

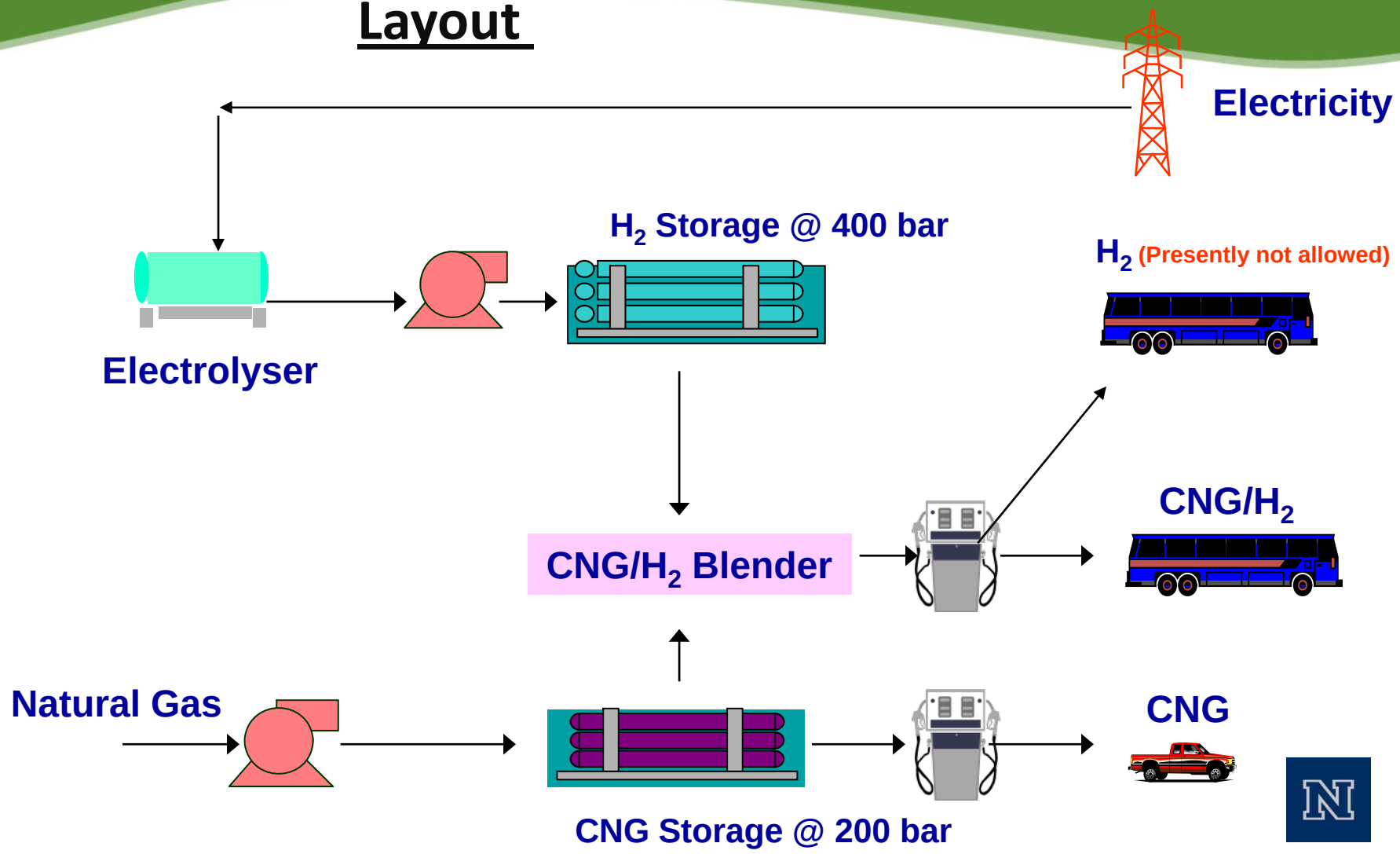
H-CNG Dispensing Station at IndianOil's Retail Outlet at Dwarka, New Delhi

Station Shut Down Summary

- Compressor High Outlet 450 bar
- Blender Level 2 Alarm
- Combustible Gas Detector at 40% LFL
- UV/IR Detects verified fire
- Emergency Shut Down (ESD)
- Smoke Alarm
- Rate of Rise Heat Detector
- Station Emergency Shut Down - Automatic
  - Shut down all equipment
  - Cut power to compressor motor
  - Cut Power to blender, dispenser, and PSP valves
  - Close all fail close valves
  - Sound horn
  - Illuminate flashing red lights

H-CNG Dispensing Station at IndianOil's Retail Outlet at Dwarka, New Delhi

Layout



H-CNG Dispensing Station at IndianOil's Retail Outlet at Dwarka, New Delhi

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H-CNG Dispensing Station at IndianOil's Retail Outlet at Dwarka, New Delhi

H_2-CNG Benefits for India

Hydrogen has a unique property of extremely lean burning:

- Extends lean misfire limit of CNG engines
- Lean burn results in lower combustion peak temperature which reduces NOx emissions (upto 50% with 20% HCNG)
- Improves thermal efficiency

Using H_2 as an additive to CNG provides:

- Lower risk due to very low energy content from H_2 -safety properties similar to CNG
- Nearly commercial technology to start using hydrogen-No major Engine modifications required
- Increased Nox emissions in Cities can be mitigated by supplementing CNG with hydrogen
- For lower blends existing CNG infrastructure can be utilized for using hydrogen without taking the risk of huge investment in creating the infrastructure

H_2-CNG Challenges

- Addition of Hydrogen with CNG results in reduction of net energy content of the mixed fuel - *20% H2 in CNG results in 14.4 % reduction in mixture energy content*
- For 20% H_2 in CNG, range is reduced by *10-15%* for 250 bar storage system
  - *Range can be taken care of with 350 bar storage system*
- H_2 is more expensive than CNG
  - *Can be mitigated by reduction in NOx emission or by calibration that favors thermal efficiency over NOx*
  - *Cost can be reduced by innovative hydrogen production technologies in future*

Why H_2-CNG in Transport Vehicles

- Options for use of Hydrogen in transport vehicles
  - *Internal combustion engines*
  - *Fuel Cell – Electric drive system*
- I.C. Engine technology-a matured technology, can be adapted for immediate use of hydrogen in the existing CNG engines with a very moderate expenditure on infrastructure development for H_2-CNG
- As a short term option, it is worthwhile for taking up H_2-CNG vehicle demonstration projects to take advantage of CNG vehicle experience as well as gaining experience for handling the new fuel
- Fuel cell technology is seen as ultimate solution for powering transport vehicles but currently it is not commercially viable.

Developmental / Demonstration Projects

- Development & Demonstration of Light-Duty vehicles operating with optimized H-CNG blended fuel
  - Passenger cars
  - School Buses
  - 3-Wheelers
- Development & Demonstration of Heavy-Duty vehicles operating with optimized H-CNG blended fuel –CNG
  - TATA
  - Ashok Leyland
- Development of Fuel-Injection based H-CNG passenger Car

Development & Demonstration of Light-Duty vehicles operating with optimized H_2-CNG blended fuel

- **Passenger cars**
- **School Buses**
- **3-Wheelers**

- Vehicles converted for H_2-CNG operation at IOC R&D
- Tests conducted with different H_2-CNG blends and 18% H_2-CNG blend selected for further optimization
- Vehicle performance and emission tests conducted with different spark timings
- Ignition timing retarded and *optimized for 18% H_2-CNG blend*
- Demonstrated in Progress

Development of Fuel injected H_2-CNG Passenger car

- Status:
  - Vehicle converted to CNG operation with gas injection fueling system installed first time in India
  - Vehicle optimized for CNG operation
  - Additional conversion done to enable H-CNG fueling
  - Emission, Performance and Field testing completed
  - Final Report prepared

- Outcome
  - Gas Injection based fueling system gives better results as compared open loop carbureted system
  - The optimized H-CNG blend found was 18% H_2- in CNG
- Way forward
  - Certain emissions needs to be optimized as due to non-availability of facilities for conducting modal analysis, these emissions could not be optimized.

Projects in Pipeline

- Setting up of Natural Gas Reformer based Hydrogen Dispensing station at Delhi during Commonwealth Games 2010 (Project Cost : $2.8 million) – ***Final Stage of approval***
  - Hydrogen Production Capacity – 200 kg / day
  - Hydrogen Dispensing @ 350 bar
  - HCNG Dispensing @ 200 bar
- Setting up of Solar powered Electrolyser based Hydrogen Dispensing station at Delhi during Commonwealth Games 2010 (Project Cost : $ 2.5 million) - ***Approved***
  - Hydrogen Production Capacity – 10 kg / day
  - Hydrogen Dispensing @ 350 bar
  - H2-CNG Dispensing @ 200 bar

Projects in Pipeline

❑ Setting up of Natural Gas Reformer based Hydrogen-CNG Dispensing station at Agra (Project Cost : ~ $ 2.8 million)

- Hydrogen Production Capacity – 200 kg / day
- H2-CNG Dispensing @ 200 bar
- Hydrogen Dispensing @ 350 bar

(Reforming is the most cost effective method for producing large quantity of Hydrogen)

❑ Setting up of Solar powered Electrolyser based Hydrogen-CNG Dispensing station at Jaipur /Jaipur-Delhi border (Project Cost : ~ $ 5 million)

- Hydrogen Production Capacity – 50 kg / day
- Hydrogen Dispensing @ 350 bar
- H2-CNG Dispensing @ 200 bar

(Abundant sunlight availability in the region makes solar route of H_2 production an ideal route)

Networking with National and International Organizations

- Organizing ***Annual Hydrogen Safety Workshops*** since 2007
- Indian Oil Corporation Ltd organized ***World Hydrogen Technology Convention*** 2009 (WHTC-2009) in association with SIAM, BHU and IIT Delhi
- Agreement signed with ***NEDO, Japan*** for information sharing on Hydrogen production, storage, transportation, safety codes and standards and Fuel Cell development
- IOC R&D signed an agreement with ***KOGAS, Korea*** in 2006 for information sharing on common interest projects related to H_2-CNG and LNG

Networking with National and International Organizations

- MOC signed with ***M/s SHELL India Market Pvt. Ltd.*** on 10th March 2009 for sharing information related to hydrogen safety codes & standards & assist OISD / PESO for formulation of standards in India (March, 2011)
- **IndianOil** R&D joined ***NHA, USA*** as Sustaining Member in 2009
- Formation of ***Hydrogen Association of India*** (HAI)
- **IndianOil** R&D joined ***Pathways to Hydrogen*** a consortium research program coordinated by University of California, Davis during 2003-06
- **IndianOil** R&D joined ***Sustainable Transportation Energy Pathways*** a consortium research program coordinated by University of California, Davis in 2007 through 2009

Sustainable Transportation Energy Pathways (STEPS)

Program Sponsors

MNRE’s Initiatives

H_2-CNG / Hydrogen Fuelled Vehicles

- Project sanctioned for demonstrating blending of hydrogen (up to 30%) with CNG in different types of vehicles (3 buses, 2 cars and 2 three wheelers) to SIAM in September 2007, for 2 years duration
- First project in public-private partnership mode
- SIAM, IOCL and 5 Auto Majors i.e. Tata Motors, Ashok Leyland, Eicher Motors, Mahindra and Mahindra and Bajaj Auto participating in project
- Project would help in optimization of engine performance and blend ratio of hydrogen with CNG

Hydrogen Research / Developmental / Demonstration Activities at other Organizations

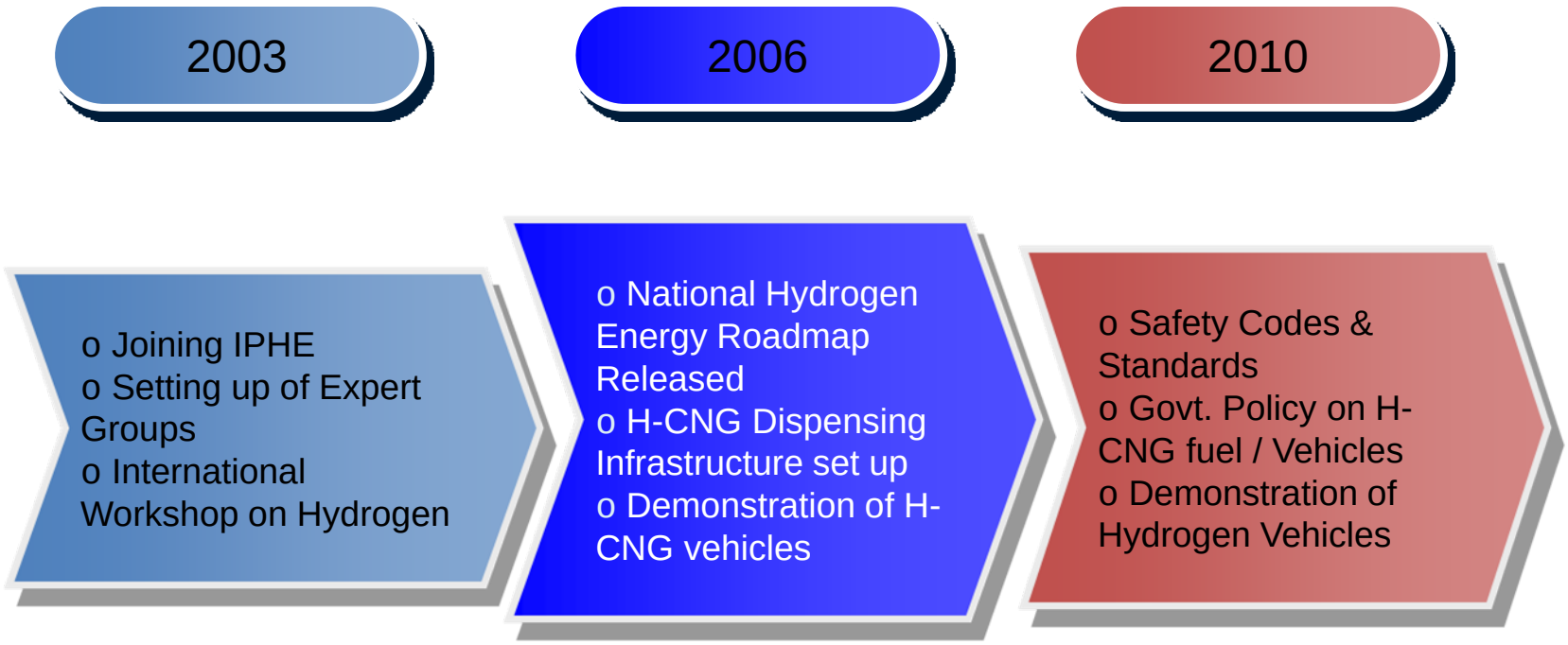
Activities on Hydrogen Infrastructure Development at BPCL R&D

- A three wheeler was developed for hydrogen use with an objective to gain experience of hydrogen storage and refueling on-board in a metal hydride canister system and performance of vehicle on hydrogen fuel..
- Hydrogen-CNG blend refueling of a standard CNG 3-wheeler was carried out with an objective to test the performance of small percentages of hydrogen blended CNG (from 10% vol. H2 in H-CNG blend to 40% vol. H2 in H-CNG blend) for safety, reliability, fuel efficiency, acceleration i.e. power performance and exhaust emissions.
- Research activities on development of advanced hydrogen storage materials are under progress.
- Initiated some projects on hydrogen production processes

Delhi Hy-ICE 3-wheeler Project

- **Objective**: To develop & demonstrate 15 nos. of H_2 IC Engine based 3-wheelers
- **Duration**: 24 Months
- **Partners**: IIT Delhi, Air Products, Mahindra & Mahindra, ITPO
- **Funding**: UNIDO
- **Demonstration site**: Pragati Maidan – venue hosting international trade fairs every year

Progress So far



Experience so far

- Have sufficient hands on experience in handling hydrogen as fuel – kind of confident in implementing large scale infrastructure projects
- Understanding the safety requirements and complying to the codes and standards
- Working with statuary agencies for understanding the safety perception and habits of public at large
- H-CNG route can be treated as best possible solution in the medium term which has many merits in terms of infrastructure requirements, and leverage factor for emission reduction potential.

Issues

- Safety Codes & Standards
  - In absence of clear-cut hydrogen safety codes & standards in the country, it becomes extremely difficult to convince statuary agencies for safety clearances. Now, hopefully, the codes & standards for H-CNG as well as Hydrogen will soon be finalized.
- Educating Local Administration Staff including Fire Deptt and Traffic Personnel
- Public Awareness
- Policy
  - Fiscal Measures
  - Regulatory
- Technical – Blending, Components, Tank Pressure etc.

Thank you

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