Overview of Indian Hydrogen Programme &
Key Safety Issues on Hydrogen Fuel

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Overview of Indian Hydrogen Programme &
Key Safety Issues on Hydrogen Fuel

• National Hydrogen Energy Road Map
  – Initiatives
  – Target 2020 : GIFT
  – Programme in India
  – CNG – H₂ Programme
  – Partnership
  – Technology Development
  – Concerns & Challenges

• Key Safety Issues
  – CNG Lessons
  – Material compatibility
  – Dispensing Stations
  – Vehicular applications
    • IC Engines
    • Fuel Cells
    • Crash Test
  – Post incident procedures

• Ideas for cooperation
## Proposed Time Frame for Alternative Fuel Strategy

<table>
<thead>
<tr>
<th>Time Frame</th>
<th>Alt Fuel Tech</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short term</td>
<td>Ethanol, CNG, LPG</td>
</tr>
<tr>
<td>Medium term</td>
<td>Bio-Diesel, Hybrid, Electric</td>
</tr>
<tr>
<td>Long term</td>
<td>Hydrogen ICE / Fuel Cell</td>
</tr>
</tbody>
</table>
National Hydrogen Energy Road Map in India (NHERM)

• Based on Public-Private Partnership
• Roadmap is an Industry driven Planning Process
• Support by Government and other stakeholders viz. Research Organizations, Academia, NGOs
• Development of sustainable and cost effective hydrogen energy technologies & infrastructure
• Issues relating to Production, Storage, Delivery / Transport, Applications, Safety and Awareness, capacity building being addressed
National Hydrogen Energy Road Map (Contd…)

- Provides long term solution to meet growing energy needs of India while ensuring energy security
- Identifies paths for gradual introduction of hydrogen energy in the country
- Accelerate commercialization efforts
- Facilitate creation of hydrogen energy infrastructure
- Total systems approach for developing hydrogen energy technologies
Indian NHERM: Two Major Initiatives

• Green Initiative for Future Transport (GIFT)
  – Demonstrate One Million Hydrogen Vehicles
    • 700,000 two wheelers
    • 50,000 three wheelers
    • 50,000 cars and taxis
    • 100,000 buses and vans

• Green Initiative for Power Generation (GIP)
  – Set up 1,000 MW Hydrogen Based Power Generation Capacity
    • 50 MW small IC engine stand alone generators
    • 50 MW stand alone fuel cell power packs
    • 400 MW Gas Turbine Based Power Plants
    • 500 MW Central Fuel Cell Power Plants

• Targets up to 2020
Programs in India

• Prototypes
  • IC Engine based devices
  • Hydrogen fuelled motorcycles, three wheeler & Small Cars

• Ongoing Projects
  • Hydrogen fueling station by Indian Oil Corporation
  • SIAM Demonstration Project on Hydrogen-CNG vehicles in partnership with five auto majors
  • Near Future - Dedicated Hydrogen IC Engine Projects

Designation of Hydrogen and Hydrogen blends as automotive fuel
The CNG-H$_2$ Programme

• Three Light Commercial Vehicles
• One car,
• One utility vehicle
• Two three wheelers

Use up to 20% blend in existing CNG engines
Optimize engines for power & NO$_x$
Retrofit in existing fleet

Goal: Introduce Hydrogen in the fleet, Environment impact, & Energy Security
Technology Development

Suggested Mission Mode Projects

- Clean Coal Gasification Technologies for Hydrogen Production
- Hydrogen Production through Biological Routes / Nuclear/Thermo-chemical routes
- Hydrogen Storage in Hydrides / Carbon Nanostructures
- Development of IC Engine for Hydrogen fuel
- Development of PEM and SOFC Fuel Cell Technologies
Concerns & Challenges

• Higher cost of hydrogen
• Need to improve production rates from different methods.
• Development of compact & inexpensive storage capacity
• Development of high pressure cylinders (~700 bars)
• Capacity of hydrogen storage system to give a range of 150-500 km per charge
• Development of hydrogen fuelled IC engines with higher life and costs comparable to IC engines.
• Efficiency improvement for different types of Fuel Cell systems

• Regulations and codes
• Vehicles leading regulation.
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• Ideas for cooperation
CNG: Lessons - 1

• Education and Training
  – Manufacturers / Kit suppliers
  – Testing Authorities
  – Transport officials
  – Inspection & Maintenance officials
  – Fueling Station
  – Mechanics
  – Fleet operators
  – Converters
  – Users
  – Drivers
  – Police & Fire Department
  – Policy makers ……..
CNG : Lessons - 2

- Dispensing Stations
- Filling procedure
- Nozzle and Receptacle
- Conversion kits & type approval
- Safety audits
- Inspection and maintenance
  - High Temperatures / Exhaust Temperatures
  - Wiring Harness
  - Sparking
  - Valves and components
  - Catalytic converters
- Accident investigation
- No CNG Two wheeler yet !
Hydrogen Safety, Codes and Standards

New Codes and Standards Need to be Developed or by adopting world-wide standards in the areas of:

- natural gas fuel processors/electrolysers and renewable energy based on-site generation
- compressed cylinders/metal hydride canisters
- liquid hydrogen/gaseous hydrogen tanks or pipelines
- Hydrogen energy devices/systems including fuel cells/internal combustion engines & turbines
- Setting up of Hydrogen Dispensing Stations within the premises of normal fuel station. .......

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Safety for Infrastructure

Critical Work Areas

Maintenance:
Leak Detection Systems, Emergency Response Plan For Hydrogen Leaks, Fire Detection Systems

Fueling Facility:

Emergency Response Plan For Hydrogen Fires

- Electrical Classification For Hazardous Locations
- Positive Ventilation
- Emergency Stop Equipment
- Designated Parking and Storage

Public Perception : Education
## Safety Issues for Hydrogen IC Engines

<table>
<thead>
<tr>
<th>Item</th>
<th>Critical Technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Storage</strong></td>
<td>High pressure (up to 700 bar) tank technology (Metal or metal composite)</td>
</tr>
<tr>
<td></td>
<td>Hydrogen storage efficiency (wt%) in metal-hydrides</td>
</tr>
<tr>
<td></td>
<td>Controlled heat exchanging in metal-hydride storage</td>
</tr>
<tr>
<td></td>
<td>Substitution of critical rare earth materials</td>
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<tr>
<td><strong>SI IC Engines</strong></td>
<td>Engine refinement with e.g. high compression ratio, reliable engine cranking</td>
</tr>
<tr>
<td></td>
<td>EMS optimization</td>
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<tr>
<td></td>
<td>Development of suitable engine and fuel line components</td>
</tr>
<tr>
<td><strong>Vehicle</strong></td>
<td>High pressure fuelling system (Compressed hydrogen)</td>
</tr>
<tr>
<td></td>
<td>Safety (fuel handling and crash worthiness)</td>
</tr>
<tr>
<td></td>
<td>Ventilation in crank case area</td>
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<tr>
<td></td>
<td>Valve material</td>
</tr>
<tr>
<td></td>
<td>Leak detection</td>
</tr>
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Crash Test Conditions

• Crash test conditions (speeds, impact points, impact directions)
• Statistically most likely to be encountered in crashes being studied
• To avoid the risk of hydrogen leakage essential to include both
  • Performance requirement standards - Crash test procedures
  • Installation requirements standards - main shut off valve, container check valve, pressure relief device, etc.
• Eq.: Japanese Study

Two / Three Wheeler?
Post Incident Procedures 5 – R’s

• Response
• Rescue
  – Vehicle Access
  – Securing the vehicle (Safety)
• Removal
• Repair
• Reintroduction in the fleet. Recertification?

Codes, Manuals, Education, Training

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Material Compatibility

- Accelerated exposure tests
- Material specifications
- Mandatory marking of key components
- Regular inspection and certification
- Two mixtures proposed to be tested
  - 20%
  - 30%

Challenge to regulate after market
Label for HCNG fueled vehicles

Label shall be coloured ‘white’ and sized 80 mm x 80 mm square. Label shall have
on them the text “HCNG” in a central position not less than 20 mm high, coloured
‘Blue’. The label shall have a ‘Black’ border 1 mm wide and 5 mm inside the outer
edge and running parallel to it. The 80 mm dimension is measured from the outer
edge.
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• Ideas for cooperation
Partnerships are the Enablers

- Vehicle & other equipment manufacturers
- End consumers
- Hydrogen producers
- Hydrogen infrastructure: logistics and retail sites
- Scientific & research organisations
- Government
  - Commitment
  - Targets
  - Incentives
- International cooperation
International Cooperation: Ideas -1

• Collate and Communicate:
  – Issues and Concerns
  – Best Practices
  – Standard formulation efforts & results
  – Progress in Code development
  – Training & Education: Material & methodology
  – Public out reach programmes
  – Fueling & fleet operations
International Cooperation: Ideas -2

• Cooperate and Collaborate
  – Standard making, ISO, WP 29, Harmonization
  – Code and best practices
  – Development of Testing methodology & centers
  – Accident investigation & analysis
  – In use vehicle monitoring
  – R & D
    • High temperature behaviour
    • Two & Three wheelers
  – Pilot programmes
  – Training & Development
International Cooperation: Ideas -3

• Continue Dialogue
  – Evolution of Standards, codes & practices
  – End of life regulation
  – Enforcement
  – Education & Training
  – 5th EFV Conference US is host
Thank you for your attention
For further details please write to:
dchenoy@siam.in
Key Safety Issues

• Production Challenges
• Setting up of Testing Facilities
• Need to develop and notify appropriate Codes & Standards for H-CNG & H₂
  – Onsite Hydrogen Production
  – Transportation from source of Production to Dispensing Outlets
  – Fueling Stations : Multi fuel
  – Vehicles
  – Retrofit, aftermarket material compatibility
  – Inspection & Certification
  – In Service Compliance
• Education & Training of personnel
Hydrogen Transportation & Delivery

OVERVIEW
Most common method: pressurized tanks (150-400 bar) by road or rail
Compact forms of hydrogen storage are easier to transport
Transporting liquid hydrogen is more efficient in the case of large quantities

OPTIONS
• Road
• Rail
• Air
• Sea
• Pipelines
Hydrogen Storage

- Compressed Hydrogen
- Solid State Storage
  - Intermetallic hydrides/complex hydrides
  - Carbon nanotubes & nanofibres
  - Metal Organic Complexes & more
- Storage in Chemicals
  - Ammonia
  - Methanol
- Bulk storage
Fuel Cells

- Phosphoric Acid Fuel Cell (PAFC)
- Proton Exchange Membrane (PEMFC)
- Solid Oxide Fuel Cell (SOFC)
- Direct Methanol (DMFC)
- Molten Carbonate Fuel Cell (MCFC)
- Alkaline Fuel Cell (AFC)
Challenges for Fuel Cell Applications

- Proper conversion of chemical energy (hydrogen) to electrical energy
- Integration of Fuel tank, fuel processor, fuel cell stack, power converter into a vehicle
- Need for pure hydrogen
- Development of FCs for auxiliary power unit to support heating, A/C, lighting etc in existing system could enable applications in bigger vehicles in short term
Hydrogen Industry in India

• Indian industry is producing hydrogen commercially for use in:
  – Oil refineries, fertilizer plants, and chemical industry
  – Chlor-alkali industry produces hydrogen as a by-product
• Over 3 MMT per annum of hydrogen is currently produced in petroleum refineries and fertilizer plants
• Hydrogen Storage in pressurized cylinders is the most common method of commercial supply
Pressure Relief Device in Common

- In the case of multiple containers linked together,
- To avoid risks, the installation requirement “main shut off valve, PRD and container non-return valve shall be mounted directly on each container”
- Other Performance Test
  - Hydraulic test with extreme temperature
    - to validate the safety at end of life
  - Target vehicle lifetime range
    - 360,000 mile ~ 15 years