Fuel Cell Electric 2-Wheeler Integrated with Indigenously developed Metal Hydride Based Hydrogen Storage Canisters

Nandlal Gupta*, Prof. Pratibha Sharma
Hydrogen Storage and Applications Laboratory
Department of Energy Science & Engineering
Indian Institute of Technology Bombay (IITB), India

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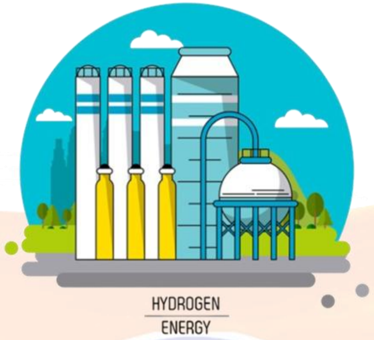
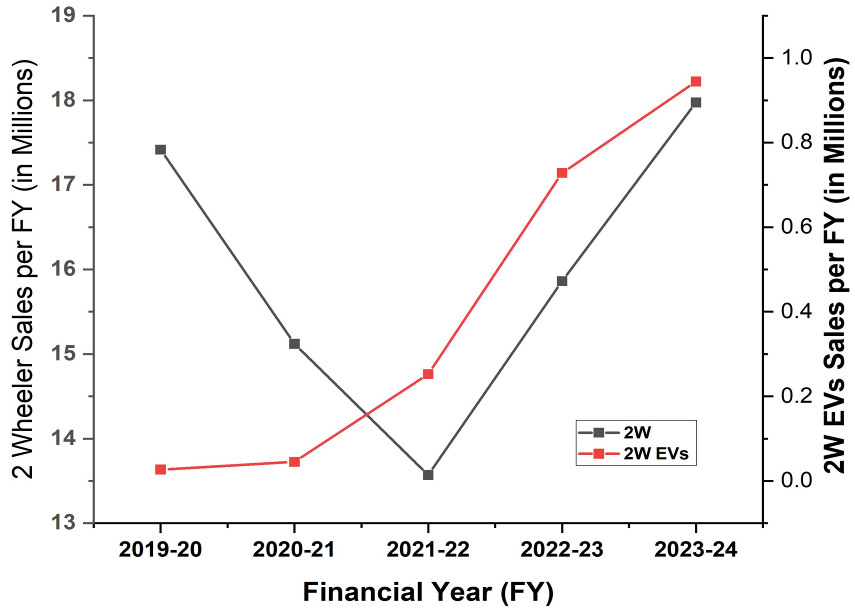


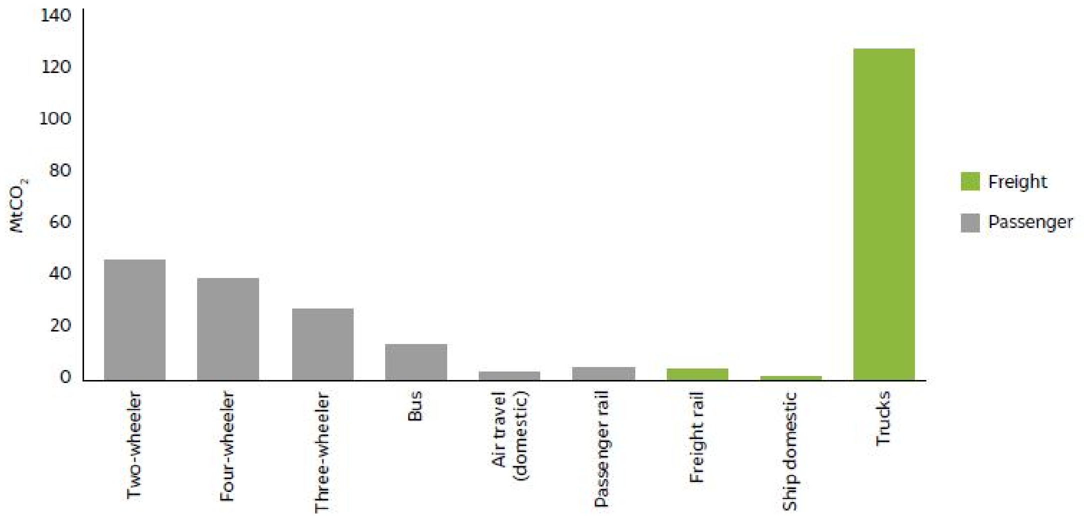
Hydrogen Storage and Application Laboratories

Department of Energy Science and Engineering, IIT Bombay

Problem Statement and Motivation

- **Decarbonization of Energy Sectors**
  - India: Energy Independent by 2047 and Net Zero by 2070
- **India's road transport sector contributes 14% of total CO_2 emissions**
  - 2Ws: Highest sales (17.9 million in FY23-24) and 2nd largest CO_2 emitter after heavy duty transport
  - Slower adoption of electric 2 wheelers (5.25% of total 2Ws sold in FY23-24)
- **H_2 as an energy carrier – potential medium towards decarbonization**
  - National Green Hydrogen Mission
- **Hydrogen Storage – Major Challenge**
  - CGH2: Type 4 tank; 350 to 700 bar standards; High Infrastructure Cost; Availability of HRS (2 in India)
  - LH2: -253°C H_2 storage in super insulated

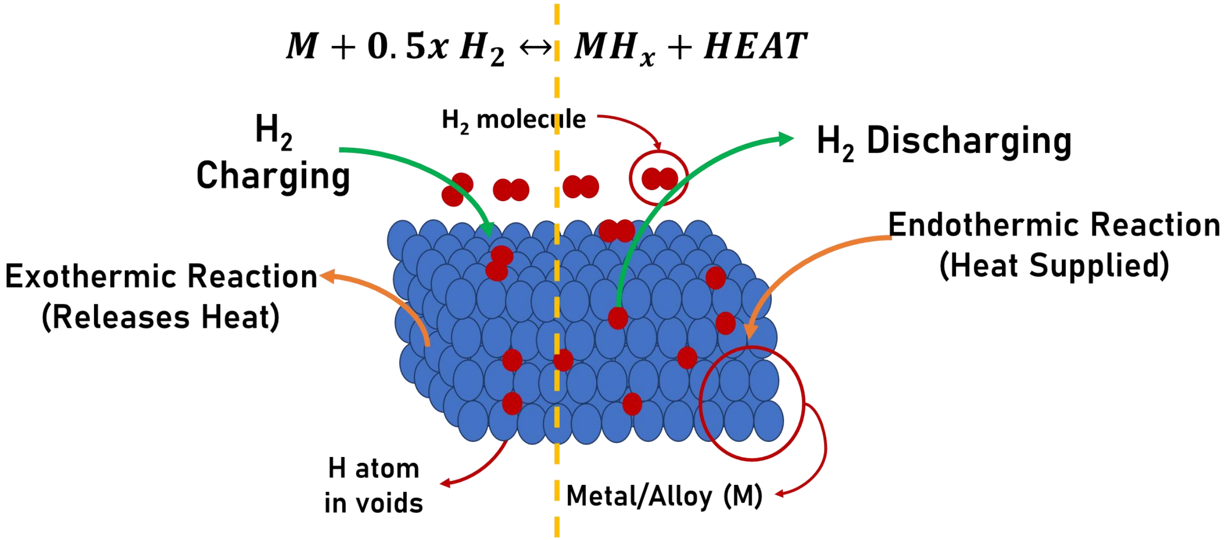




Source: Authors' analysis based on GCAM-CEEW

Metal Hydride (MH) based H_2 Storage

- **High Volumetric Density**
  - MH: 100 to 150 kg-H_2/m^3 vs 40 kg-H_2/m^3 – 700 bar Type 4 tank
- **Low Pressure H_2 Storage**
  - MH: 20 to 35 bar vs 350 to 700 bar in CGH2
- **High System Gravimetric Energy Density**
  - MH (>360 Wh/kg) vs Li-ion Battery (120-180 Wh/kg)
- **High Cyclic Life**
  - MH (>5 years) vs Li-ion battery (3 to 5

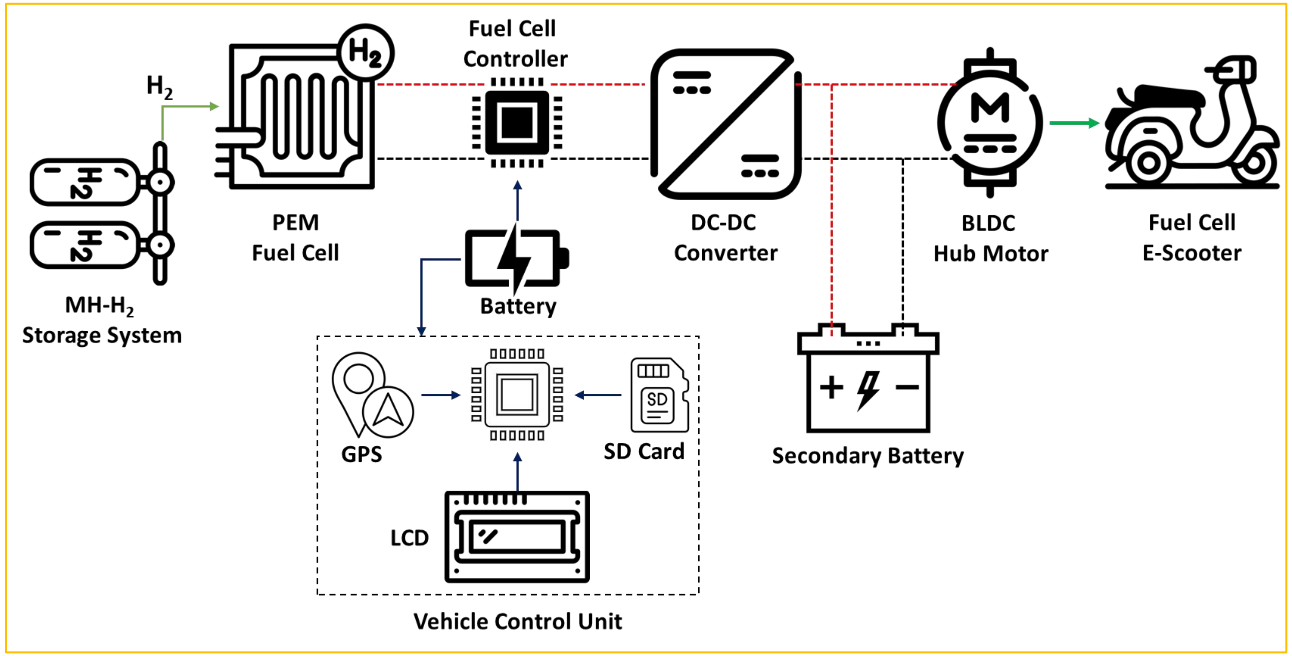


MH-H_2 System Applications

- Hydrogen Purification
- Compression
- Thermal Storage
- Refrigeration
- Back-up Power
- Vehicular

MH based H_2 powered Fuel Cell Electric 2-Wheeler

- **Indigenously developed Swappable MH storage Canisters** integrated with PEMFC to power FCEV
- **250 grams H_2** Storage (8.33 kWh Energy Storage)
- **MH Storage Vol. 5.33 liters** vs 8.8 liters (350 bar Type 4 tank)
- **Vol. Storage Density: 1.563 kWh/l**
- **Gravimetric Energy Density: 379 Wh/kg**
- Can be charged directly using **Green H_2** from electrolyzer at 20 to 35 bar pressure
- **Charging time: 15 minutes** (80% charging)
- **3.33 to 4.75 kWh** energy will be delivered
- Range: 120 km



Prototype: MH-H_2 powered Fuel Cell Hybrid Electric Scooter

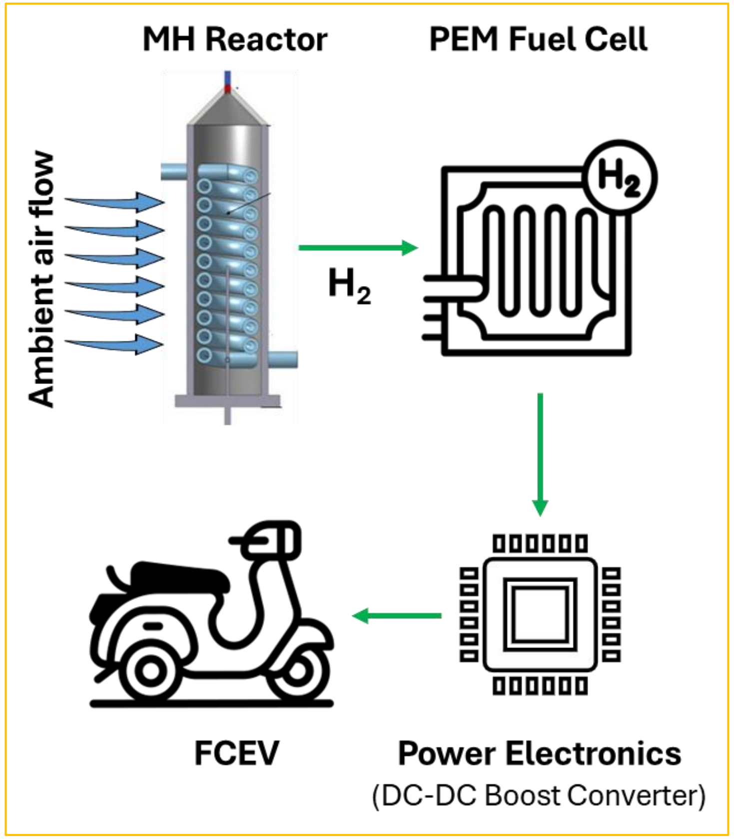
Powertrain:

Motor: 1.5 kW BLDC Hub motor ; MH H_2 Reactor: 34 g-H_2 ; 1 kW PEMFC ; 48 V,10 Ah Li-ion battery; DC-DC Boost Converter

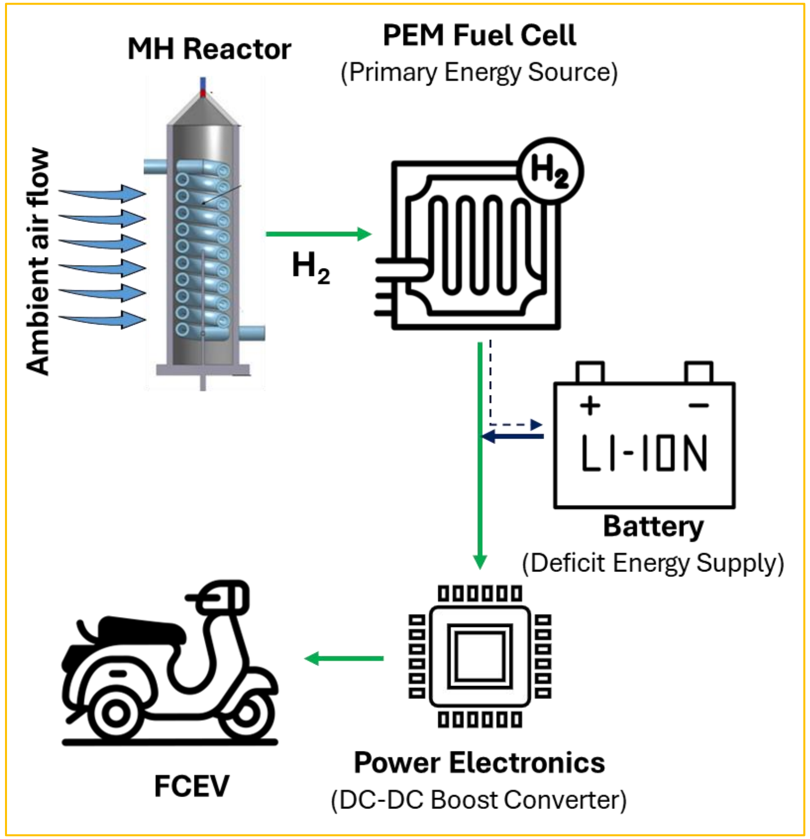
Fuel Cell – Primary Energy Demand; Battery – Deficit

Test Run Cases

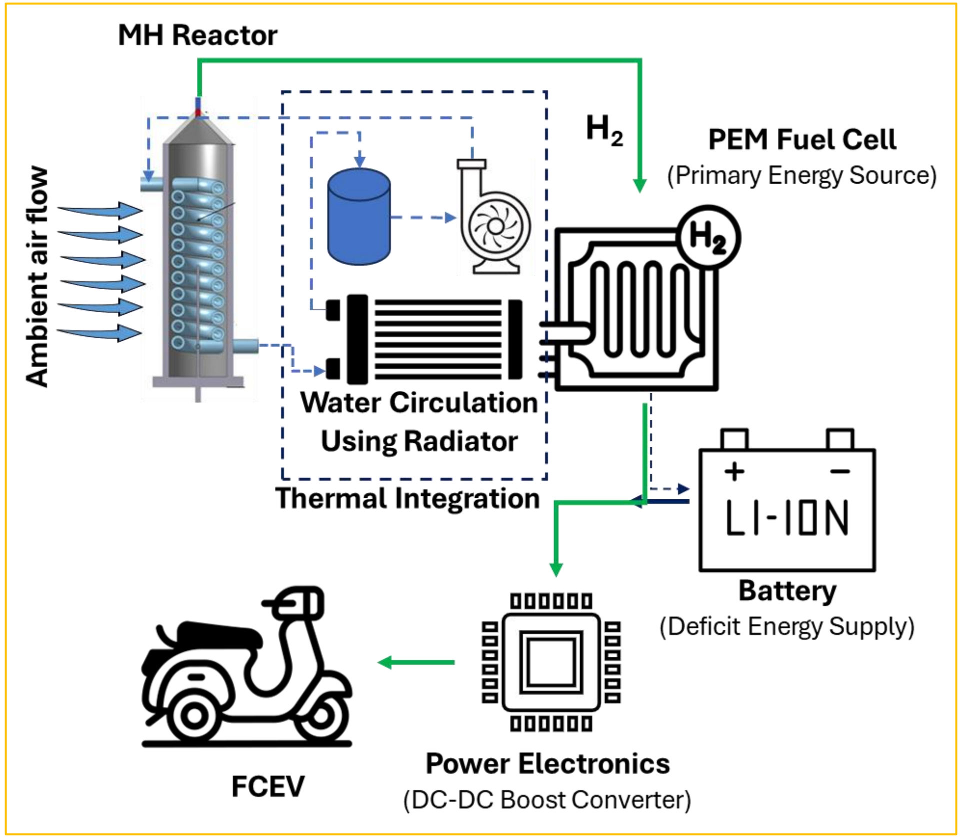
Aim: To understand the dynamic behaviour of onboard H_2 desorption from MH in real time driving performance analysis



(a) Test run 1: MH-FC

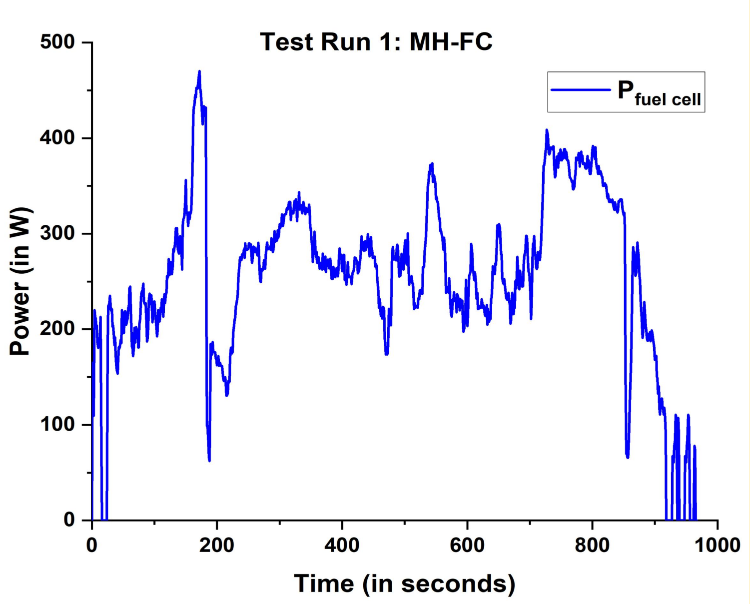


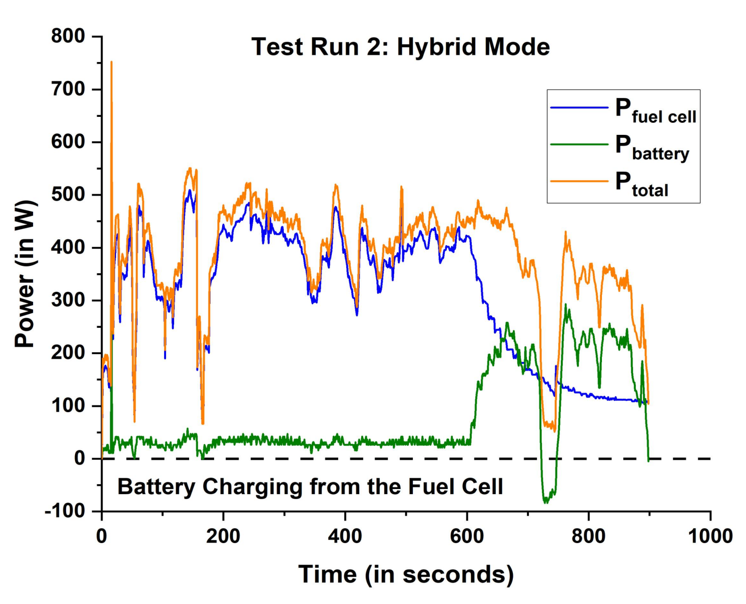
(b) Test run 2: Hybrid mode (MH-H_2 + Battery)

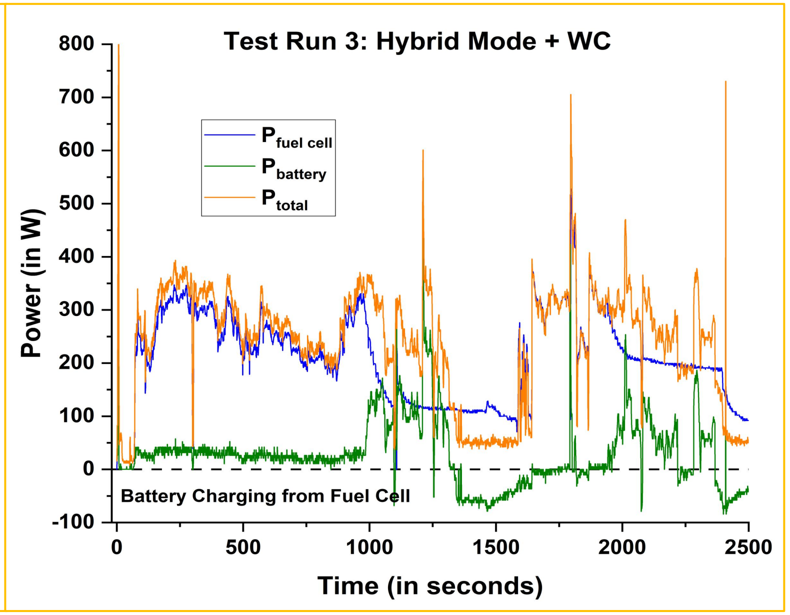


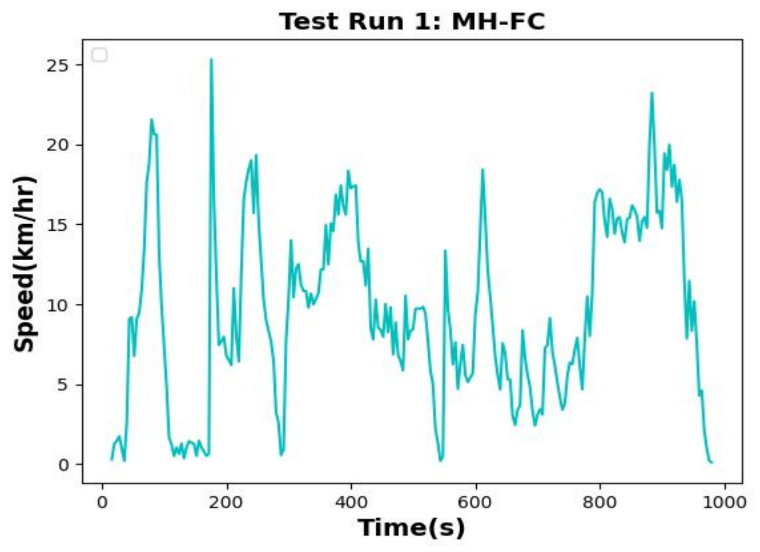
(c) Test run 3: Hybrid mode + Water circulation (WC)

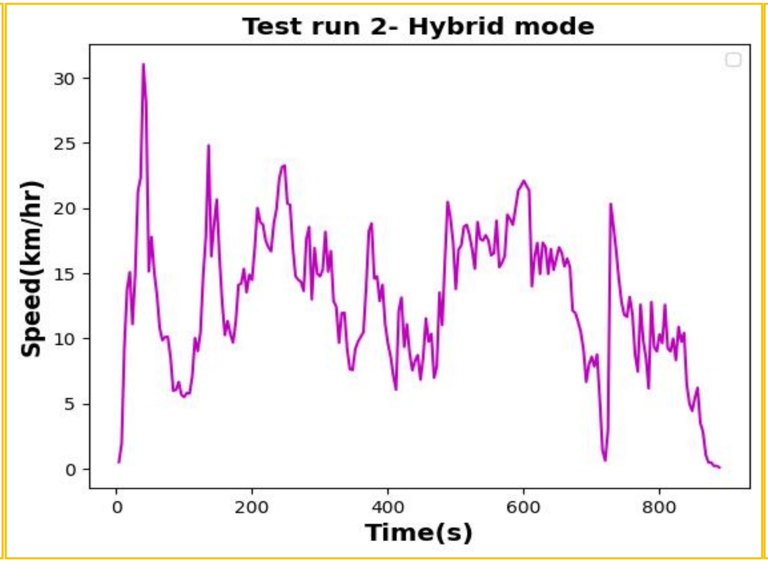
Drive Cycle Results

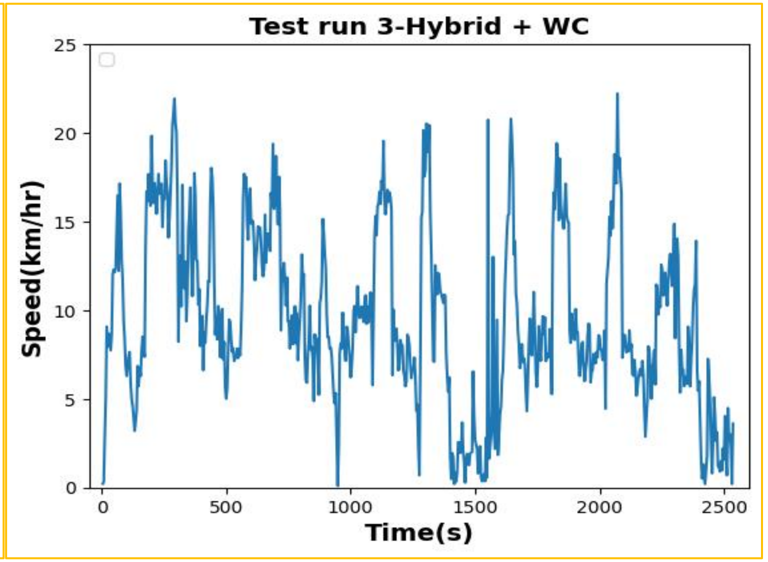




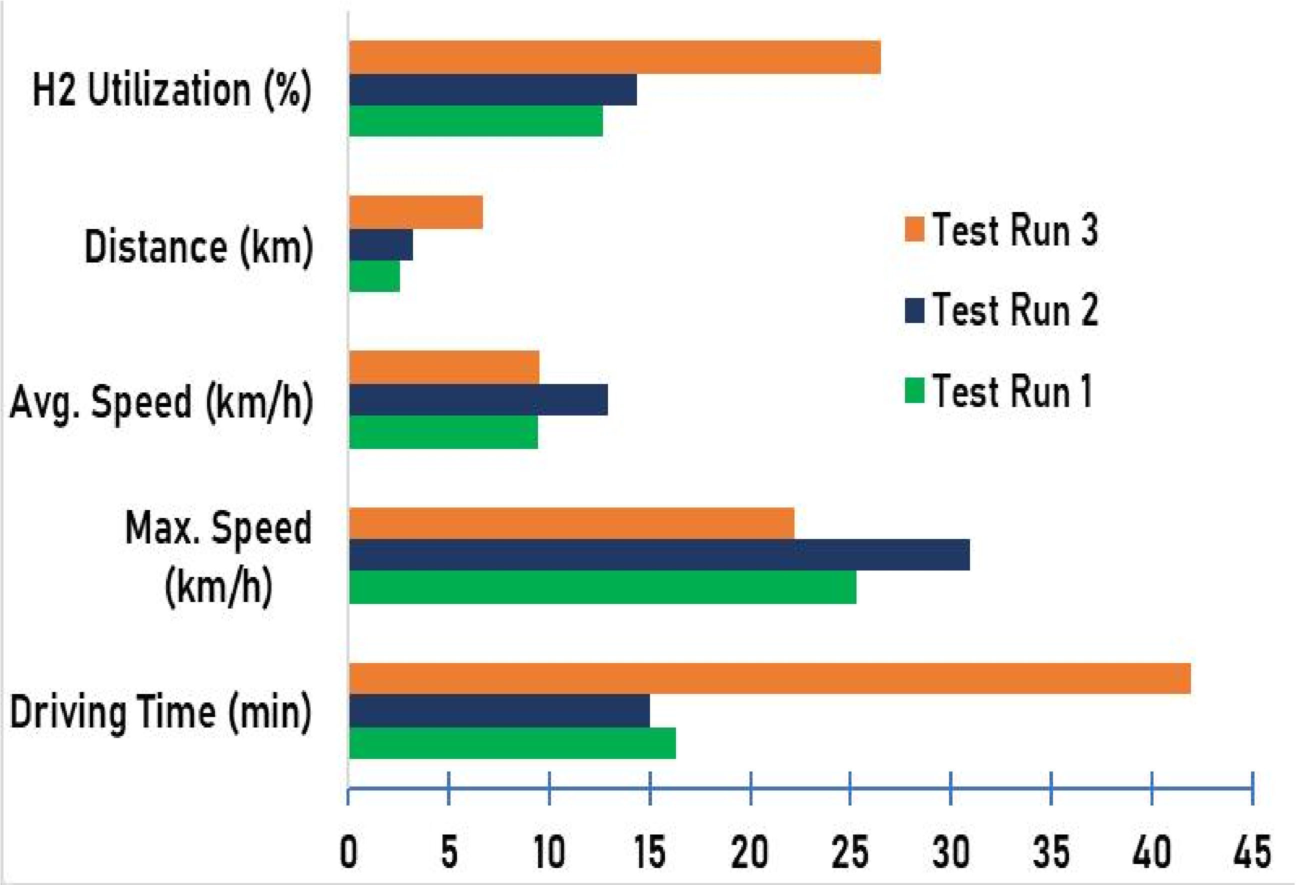


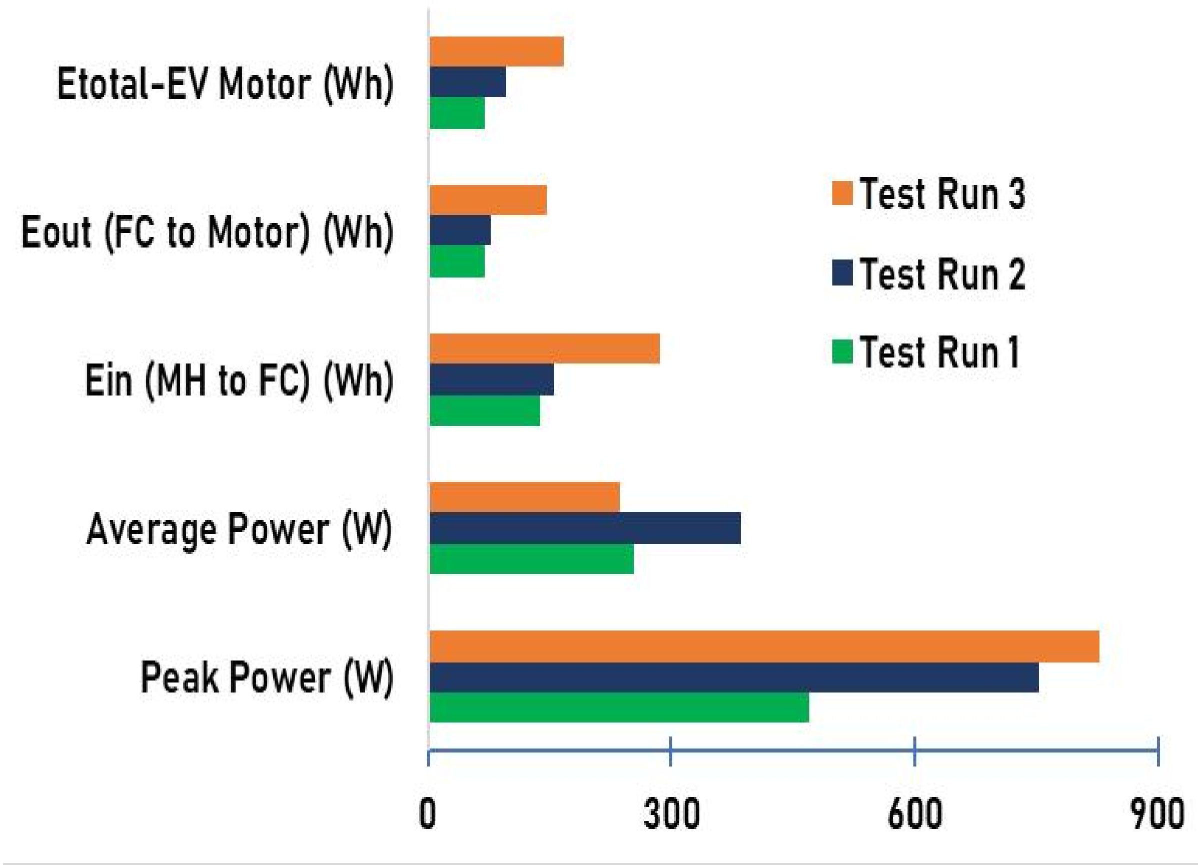






Techno-Economic Analysis



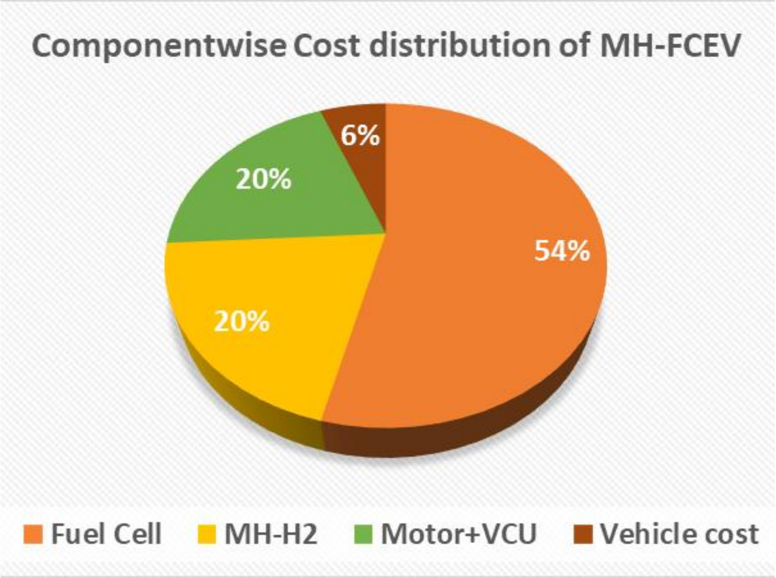


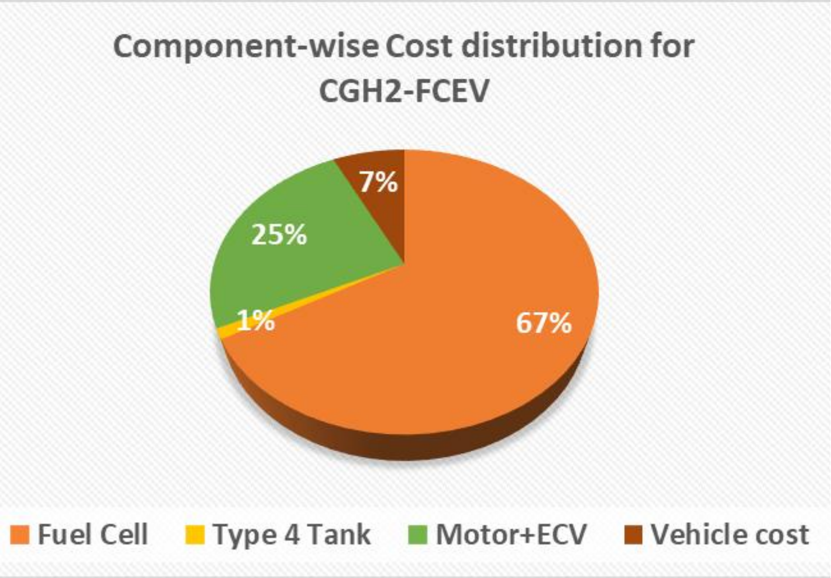
- *MH-FCEV consumes 2 g-H_2/km and able to deliver range of 15 km on charge in case of prototype*
- *80 to 85% of energy demand is met by Fuel Cell*
- *Conversion efficiency of system is 40 to 45%*
- *Effective and optimal thermal integration of MH and FC improves H2 utilization and Vehicle range b*

Techno-Economic Analysis

01 **Costs taken into account**
Initial capital cost, operational and maintenance cost (life 15 years)

02 **Component Cost taken into account for MH-FCEV**
MH Reactor, PEM Fuel Cell, Power Electronics, Electric Motor, Scooter cost, Instrumentation





Levelized Cost/km

FCEV Scooter + Metal Hydride-H_2
Rs. 11.24/km

FCEV Scooter + 350 bar Compressed H_2 Type IV tank
Rs. 11.56/km

*cost as per USDOE for 10000 Type 4 tanks/year

BEV Scooter
Rs. 4.53/km

High Levelized Cost on a laboratory scale development can be significantly reduced by indigenous manufacturing of MH alloy and

Scale-up Potential

- MH-FCEV Technology do not have high pressure infrastructure requirement and can be indigenously scaled on a larger scale in the present scenario
- Government policies/schemes such as NGHM, FAME, EV30@30 will be crucial in terms of scaling and public adoption of this technology
- Indigenous manufacturing of economic intensive component such as fuel cell will be promoted as demand rises
- HSAL, IIT Bombay as a research institute along with Government support will be instrumental to scale this technology along with technology partners and OEMs in line with nations target of becoming carbon neutral by 2070
- Manufacturing of solid state H_2 storage can reduce CO_2 emissions by approximately $1/4^{th}$ and $1/7^{th}$ contributed by manufacturing of BEVs and ICE Vehicles
- If entire Indian 2W fleet (sold in last 5 years) is replaced by MH-FCEV charged using green H_2 as proposed can avert atleast 26.73 Mt-CO_2/annum direct CO_2 emissions in

Thank you !