# E-BUS TECHNOLOGY OPTIONS & CHARGING INFRASTRUCTURE

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**WRI Workshop on Electrification of Public Transport**

**23 September 2019**

**Venue : Hotel Fortune Landmark, Ahmedabad**

# Clean Disruption of Energy & Transportation

**Tony Seba, Author & Stanford University Economist Professor**

With convergence of technologies (solar PV panels, lithium-ion batteries) accelerated by business model innovations (ride sharing services), the author forecasts that by 2030:

- **All new energy will be provided by solar and wind**
- **All new cars will be EVs**
- **All of these cars will be autonomous (self-driving)**
- **Individual car ownership model will be obsolete; new car market will shrink by 80% (Mobility as Service)**

# EV Global Scenario & Outlook

- Global electric car stock surpassed 5 million vehicles in 2018
- Various countries such as Norway, Netherlands, Germany, France, UK have set targets for migrating to total electric transportation by 2030 – 2040
- India has focused on electrification of transportation
- Various vehicle manufacturers such as Volvo, Daimler, Volkswagen, have announced plans to go for only electric powertrain for future models
- As per forecast by International Energy Agency (IEA) in its Global Outlook 2017 report, electric car stock will be ~ 70 million by 2025
- World Bank announced that it will stop financing upstream oil and gas projects after 2019 to raise funds to finance a shift towards clean energy

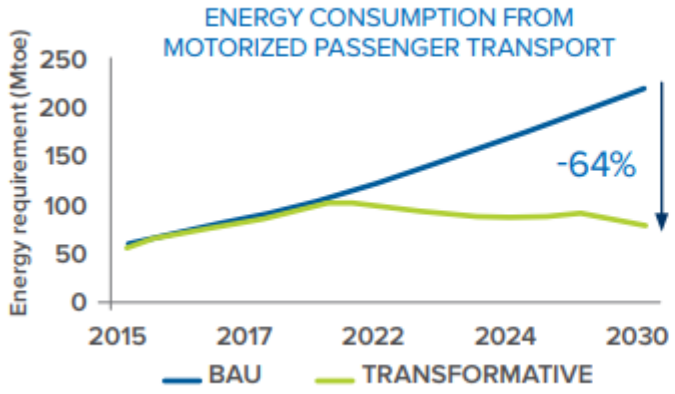
# EV Global Scenario – Electric Buses

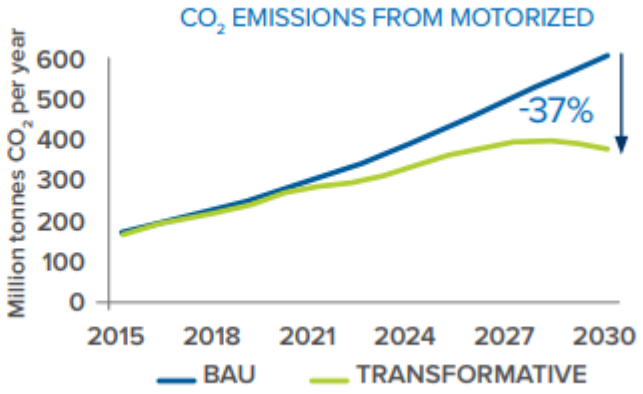
- Global electric bus stock reached 4,60,000 vehicles in 2018
- China accounts for 99% of global market for electric buses
- Shenzhen city operates largest fleet of 16,000 electric buses
- Other countries include Europe, Latin America, USA and India
- Schiphol Airport operates 100 electric buses
- In India 390 buses operate in 11 cities with funding under FAME-I Scheme
- DHI has approved 5595 electric buses to 64 cities / State Govt entities / STUs for intr-city and inter city operation under FAME-II Scheme

# Government of India Initiatives…

# NITI Aayog Report - Approach to Mobility Transformation


India can save 64% of anticipated road based mobility related energy demand and 37% of carbon emissions in 2030 by pursuing a shared, electric and connected mobility resulting in a net savings of roughly Rs 3.9 lakh crore (approximately 60 billion USD) in 2030




FIGURES ES-1 - ES-2: MODELED ENERGY REQUIREMENT FOR PASSENGER MOBILITY (LEFT) AND RESULTANT $CO_2$ EMISSIONS (RIGHT) FOR "BUSINESS-AS-USUAL" (BAU) AND "TRANSFORMATIVE" SCENARIOS, 2015–2030

# Driving Forces

Ambient Air Quality Concerns

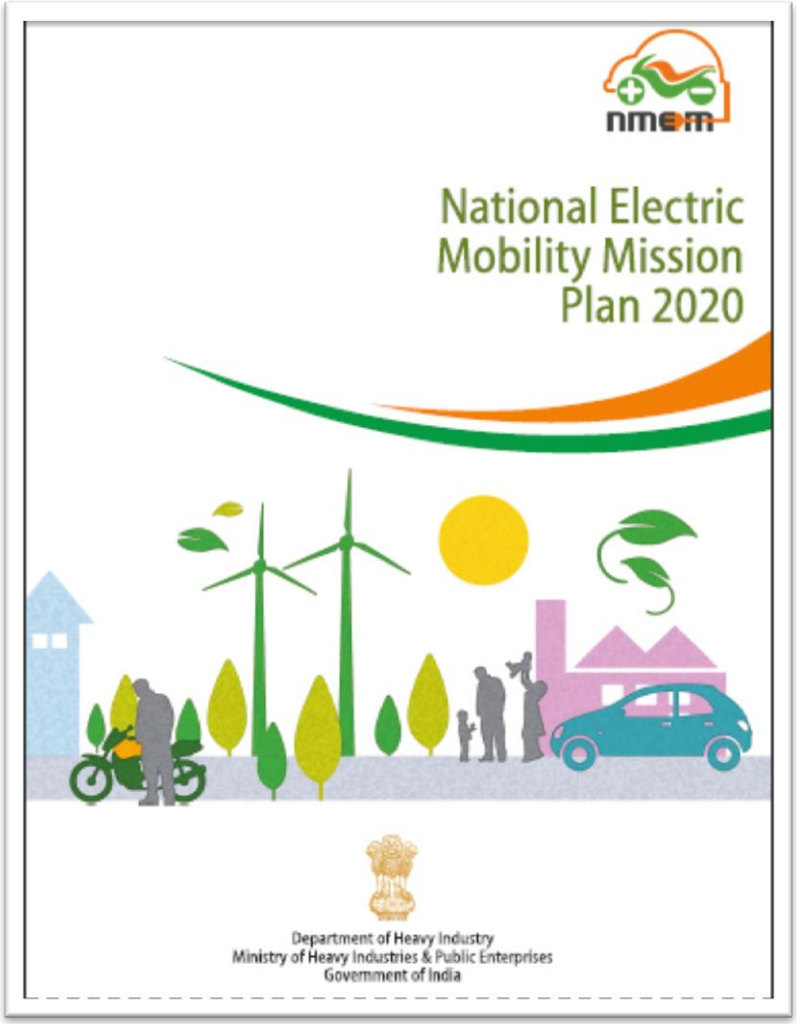
Import of Oil (Energy Security)

Paris Climate Change Agreement

Thrust on Solar Power Generation & Storage

**Electric Mobility**


# National Electric Mobility Mission Plan (NEMMP)




**F**aster **A**doption and **M**anufacturing of **E**lectric (& Hybrid) Vehicles in India

FAME-India Scheme

The scheme has 4 focus areas:

- Technology development
- Demand creation
- Pilot projects
- Charging infrastructure

# Background of FAME India Scheme

- Phase I of FAME (Faster Adaption of Manufacturing of Hybrid and Electric Vehicles) launched in Mar-15 with outlay of INR795 crore
- FAME-I initially approved for 2 years starting from Apr-15 was further extended up to 31-Mar-19
- Allocation of outlay of Rs. 795 crore further enhanced to Rs. 895 crore
- Based on experience of FAME-I and inputs from stakeholders DHI formulated Phase II of FAME (FAME-II)

# FAME-II: Overview

- Implementation over a period of 3 years starting from 1-Apr-19
- Verticals/Components:
  - Demand Incentives
  - Establishment of network of charging stations
  - Administration of Scheme including publicity
- Breakup:

*(All amounts are in Rs. Crore)*

| Sr. No. | Component | 2019-20 | 2020-21 | 2021-22 | Total Fund requirement in crores |
|---|---|---|---|---|---|
| 1 | Demand Incentives | 822 | 4587 | 3187 | 8596 |
| 2 | Charging Infrastructure | 300 | 400 | 300 | 1000 |
| 3 | Administrative Expenditure including Publicity, ICE activities | 12 | 13 | 13 | 38 |
| Total for FAME-II | | 1134 | 5000 | 3500 | 9634 |
| 4 | Committed expenditure of Phase –I | 366 | 0 | 0 | 366 |
| Total | | 1500 | 5000 | 3500 | 10000 |

- Flexibility in fund allocation among themselves

# Demand Incentive: Introduction

- Intended to help in demand generation of EVs by reducing acquisition cost
- Vehicle fitted with '**advanced batteries**' are eligible
- Demand incentive is **based on the battery capacity in kWh**
- With the emphasis of environment friendly **public transport**, scheme is mainly for
  - Public transport or commercial purpose in 3 wheeler, 4 wheeler and bus
  - Privately owned 2 wheelers as a mass segment
- Applicable categories of the vehicles:
  - Bus (EV)
  - Four wheelers (EV, SHEV, PHEV)
  - Three Wheeler (EV)
  - Two wheeler (EV)
- Demand Incentives are based on energy content of the battery
  - INR 10,000/kwh for all vehicles except buses
  - **INR 20,000/kwh for buses**

# Demand Incentive: Details

**Vehicle segment-wise Incentives, Maximum Number of vehicles to be supported and other details.**

| Sr. No. | Vehicle Segment | ##Maximum Number of vehicles to be supported | Approximate Size of battery in KWH | ##Total Approximate Incentive @ 10000/KWh for all vehicles and 20000/KWh for Buses and Trucks | Maximum Ex-factory price to avail incentive. | Total Fund support from DHI. |
|---|---|---|---|---|---|---|
| 1 | Registered e-2 Wheelers | 1000000 | 2 KWH | Rs. 20000/- | Rs. 1.5 Lakhs | Rs. 2000 Cr |
| 2 | Registered e-3 Wheelers (including eRikshaws) | 500000 | 5 KWH | Rs. 50000/- | Rs. 5 Lakhs | Rs.2500 Cr |
| 3 | e- 4 Wheelers | 35000 | 15 KWH | Rs. 150000/- | Rs. 15 Lakhs | Rs. 525 Cr |
| 4 | 4W Strong Hybrid Vehicle | 20000 | 1.3 KWH | Rs. 13000 | Rs. 15 Lakhs | Rs. 26 Cr |
| 5 | e-Bus | 7090 | 250 KWH | Rs. 50 Lakhs/- | Rs. 2 Crores | Rs. 3545 Cr |
| Total Demand Incentive | | | | | | Rs. 8596 Crores |

*## The proposed amount of incentives per KWH are, however, subject to review as per the reduction in battery costs & thereby reduction in vehicle cost and would be notified accordingly from time to time. It is to be noted that the number of vehicles and fund support among the sub components as above is fungible with the approval of PISC.*

# EV Incentives FAME-II

- Demand incentive to purchaser

| Vehicle Category | Approx. Incentive |
|---|---|
| 2 Wheelers | Rs. 20,000 (~USD 300) |
| 3 Wheelers | Rs. 50,000 (~USD 700) |
| Passenger Cars & LCVs (commercial taxi, goods transport) | Rs. 1,50,000 (~USD 2,000) |
| Buses (public transport by STUs) | Rs. 50,00,000 (~USD 70,000) on Opex model |

- GST at discounted rate of 5%
- Income tax deduction up to Rs. 1.5 lakhs on interest component of electric vehicle loan by purchaser
- State Govts providing waiver of registration tax, road tax and additional incentives etc.
- State Govts are formulating State EV Policies e.g. Maharashtra, Karnataka, Telangana, Andhra Pradesh

# Charging Infrastructure

- Adequate public charging infrastructure to instil confidence among EV users
- Charging infrastructure to be established as per **MoP notification** vide no.12/2/2018-EV dated 14-Dec-2018 subject "Charging Infrastructure for Electrical Vehicles – Guidelines and Standards"
- **DHI EoI for establishment of 1000 public charging stations**
- **Funding to the extent of 100 % of the cost depending upon the project proposal**
- Consideration of pantograph charging, flash charging
- Encourage interlinking of renewable energy sources

# Phase Manufacturing Program (PMP) Guidelines

| Sr. No. | | e-2W | e-3W | e-3W | e-4W | e-4W | e-Bus |
|---|---|---|---|---|---|---|---|
| | | L1 & L2 | e-Rickshaw / e-Cart | L5 | M1 | N1 | M2/M3 |
| 1 | HVAC | NA | NA | NA | 1-Oct-2019 | 1-Oct-2019 | 1-Apr-2020 |
| 2 | Electric compressor | NA | NA | NA | 1-Oct 2020 | 1-Oct 2020 | 1-Oct 2020 |
| 3 | Wheel rim | 1-Jul-2019 | 1-Jul-2019 | 1-Jul-2019 | 1-Jul-2019 | 1-Jul-2019 | 1-Apr-2019 |
| 4 | Power & control wiring harness along with connectors | 1-Apr-2019 | 1-Apr-2019 | 1-Apr-2019 | 1-Oct-2019 | 1-Oct-2019 | 1-Oct-2019 |
| 5 | MCB/circuit breakers/electric safety device | 1-Apr-2019 | 1-Apr-2019 | 1-Apr-2019 | 1-Apr-2020 | 1-Apr-2020 | 1-Apr-2020 |
| 6 | AC charging inlet Type 2 | NA | NA | NA | 1-Apr-2020 | 1-Apr-2020 | 1-Apr-2020 |
| 7 | DC charging inlet CCS 2 / CHAdeMO | NA | NA | NA | 1-Oct 2020 | 1-Oct 2020 | 1-Oct 2020 |
| 8 | DC charging inlet BEVC DC 001 | NA | NA | NA | 1-Oct 2020 | 1-Oct 2020 | NA |
| 9 | Traction battery pack | 1-Jul-2019 | 1-Jul-2019 | 1-Jul-2019 | 1-Jul-2019 | 1-Jul-2019 | 1-Apr-2020 |
| 10 | Wheel rim integrated with hub motor | 1-Oct-2019 | 1-Oct-2019 | 1-Oct-2019 | 1-Oct-2019 | 1-Oct-2019 | 1-Oct-2019 |
| 11 | DC-DC converter | 1-Oct-2019 | 1-Oct-2019 | 1-Oct-2019 | 1-Apr-2020 | 1-Apr-2020 | 1-Apr-2020 |
| 12 | Electronic throttle | 1-Apr-2020 | 1-Apr-2020 | 1-Apr-2020 | 1-Apr-2020 | 1-Apr-2020 | 1-Apr-2020 |
| 13 | Vehicle control unit | 1-Apr-2020 | 1-Oct-2019 | 1-Apr-2020 | 1-Apr-2020 | 1-Apr-2020 | 1-Apr-2020 |

# Phase Manufacturing Program (PMP) Guidelines

| Sr. No. | | e-2W | e-3W | e-3W | e-4W | e-4W | e-Bus |
|---|---|---|---|---|---|---|---|
| | | L1 & L2 | e-Rickshaw<br>e-Cart | L5 | M1 | N1 | M2/M3 |
| 14 | On board charger | 1-Apr-2020 | 1-Oct-2019 | 1-Apr-2020 | 1-Apr-2020 | 1-Apr-2020 | 1-Apr-2020 |
| 15 | Traction motor | 1-Apr-2020 | 1-Oct-2019 | 1-Apr-2020 | 1-Apr-2021 | 1-Apr-2021 | 1-Apr-2021 |
| 16 | Integrated rear axle including motor, motor controller, transmission system & rear braking system | NA | 1-Oct-2019 | 1-Apr-2020 | NA | NA | NA |
| 17 | Traction motor controller / inverter | 1-Apr-2020 | 1-Oct-2019 | 1-Apr-2020 | 1-Apr-2021 | 1-Apr-2021 | 1-Apr-2021 |
| 18 | Instrument panel | 1-Jul-2019 | 1-Jul-2019 | 1-Jul-2019 | 1-Jul-2019 | 1-Jul-2019 | 1-Apr-2019 |
| 19 | Windscreen wiping system | NA | 1-Jul-2019 | 1-Jul-2019 | 1-Apr-2019 | 1-Apr-2019 | 1-Apr-2019 |
| 20 | Chassis (For e-2W & e-3W – Allowable import content @ 20%) | 1-Oct-2019 | 1-Jul-2019 | 1-Jul-2019 | 1-Apr-2019 | 1-Apr-2019 | 1-Apr-2019 |
| 21 | Body Panels | 1-Jul-2019 | 1-Jul-2019 | 1-Jul-2019 | NA | NA | NA |

| Code | Effective Date of Indigenisation of Parts |
|---|---|
| | w.e.f. 1 Apr 2019 |
| | w.e.f. 1 Jul 2019 |
| | w.e.f. 1 Oct 2019 |

| Code | Effective Date of Indigenisation of Parts |
|---|---|
| | w.e.f. 1 Apr 2020 |
| | w.e.f. 1 Oct 2020 |
| | w.e.f. 1 Apr 2021 |

# India New EV Program

- Govt. focus on electrification of transportation
- Early EV penetration in public transport

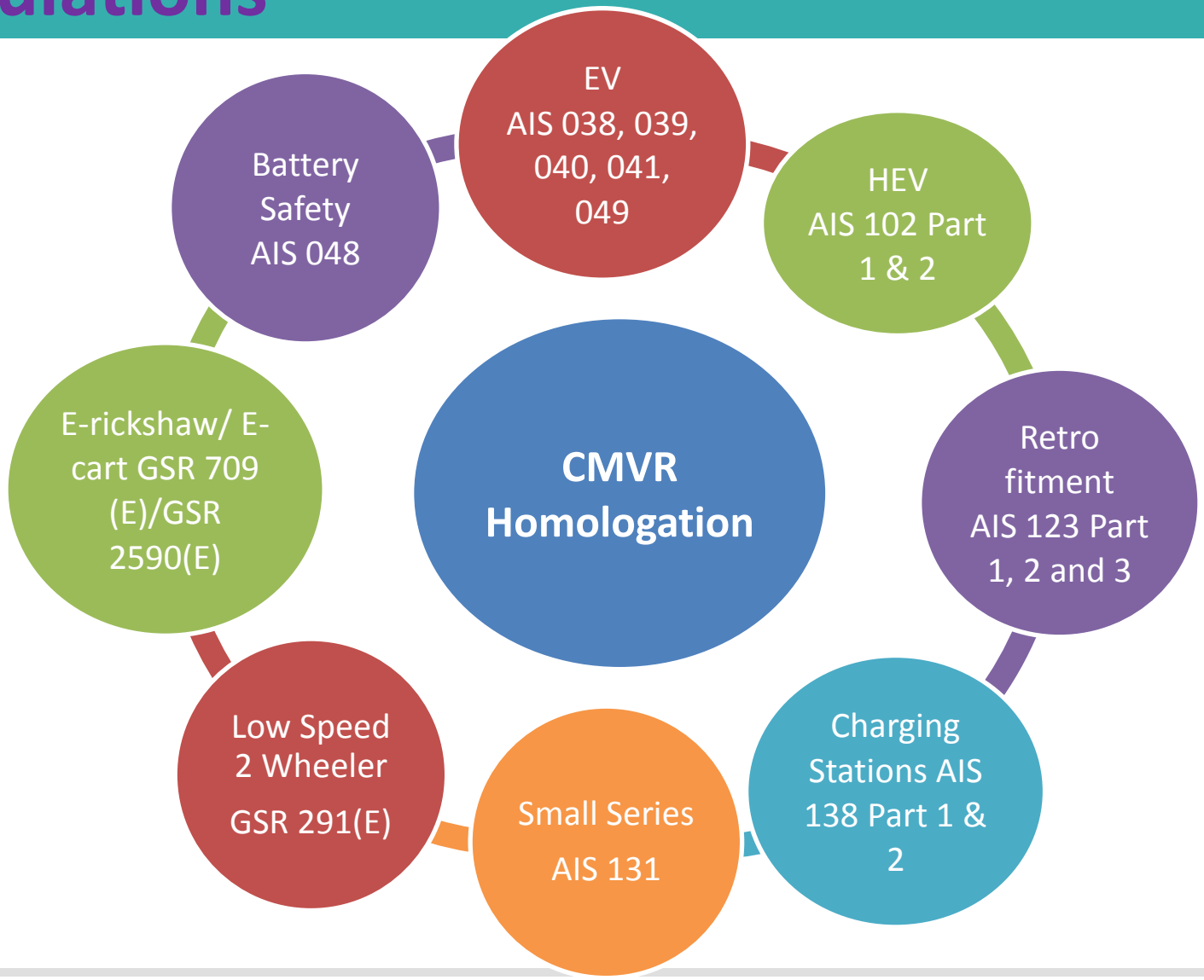
  E-rickshaw, E-auto, Taxis, Buses
- Strategy – Aggregation of demand (by EESL)
- EESL tender for 10,000 EV sedan cars and 2000 Bharat EV Chargers
- DHI EoI for STUs for electric bus operation and public charging stations
- Standardisation of tender specifications for electric buses by DHI
- Model Concession Agreement for Opex model by Niti Aayog for electric bus fleet operation

# Innovative Business Models

- Swappable battery vs fixed battery (separate vehicle and energy business)
- City electric bus fleet on Opex model
- Multi-modal electric transportation solution in cities (auto, taxi, bus, metro)
- Electric shared fleet (Ola, Uber)
- Electric fleet for delivery, e-commerce services
- Electric retro-fitment solutions for in-use vehicles

# Electric Vehicle Standardization In India

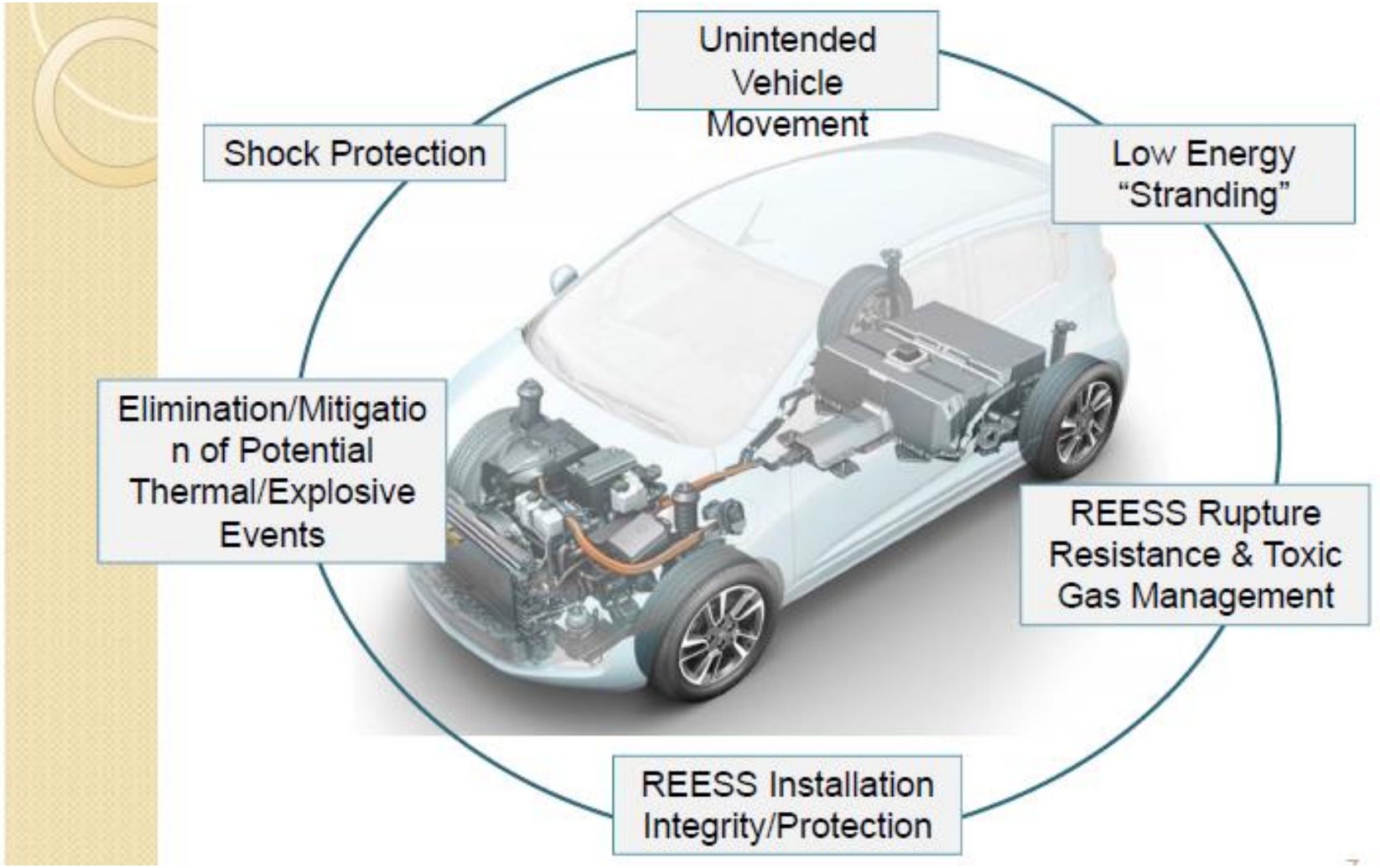
# EV Regulations



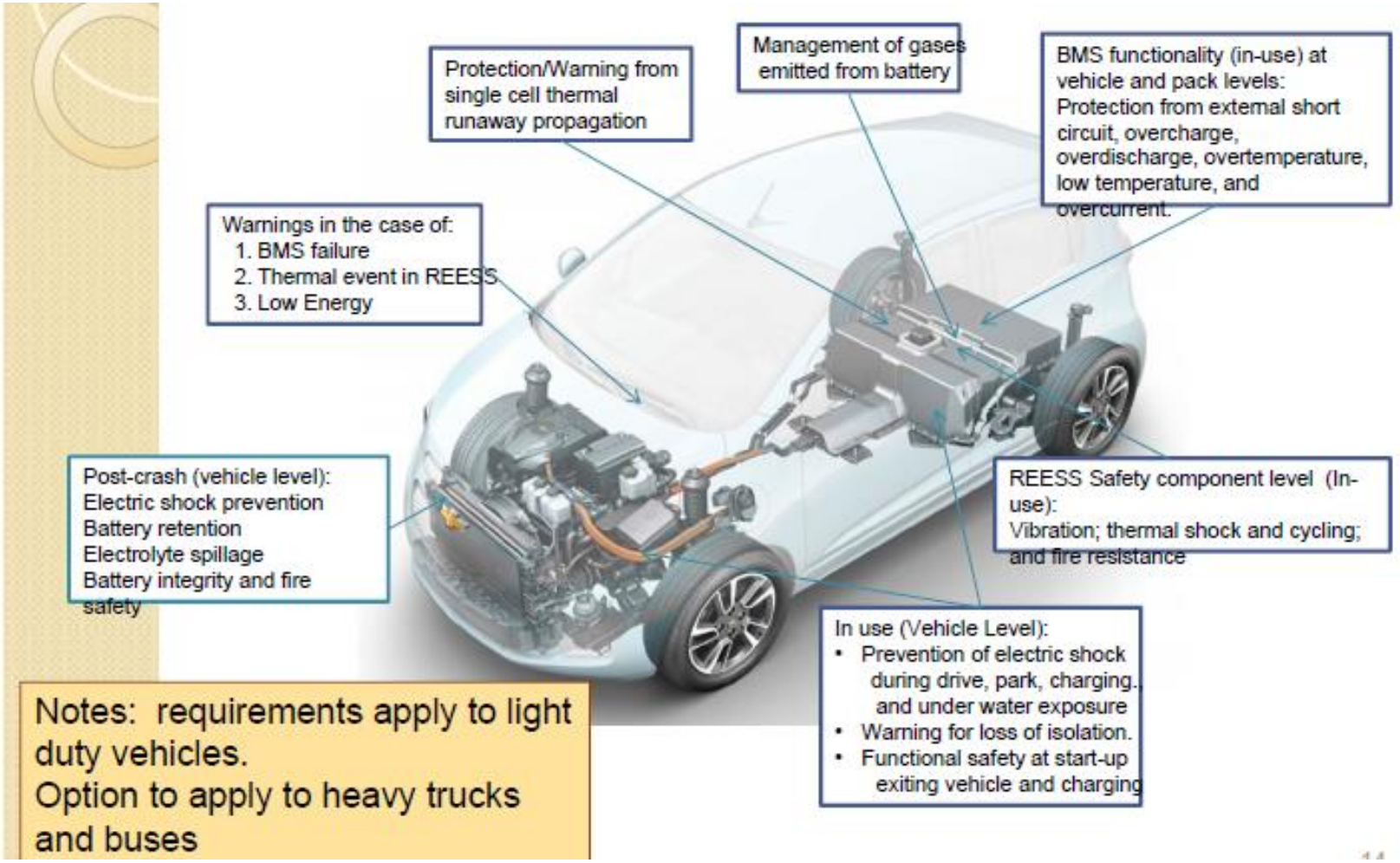
# EV Regulations

| Indian Standard | Ref. Standard |
|---|---|
| **AIS 038 Rev 1 :**Requirements for Construction and Functional Safety | ECE R 100 |
| **AIS 039 Rev 1:** Measurement of Electrical Energy Consumption (Wh/km) | ECE R 101 |
| **AIS 040 Rev 1:** Method of Measuring the Range (km) | ECE R 101 |
| **AIS 041 Rev 1:** Measurement of Net Power & Maximum 30 minute power | ECE R 85 |
| **AIS 049 Rev 1:** CMVR Type Approval for EV | - |
| **AIS 048:** Safety Requirements for Traction Batteries | USABC, ISO/IEC Standards |

# EV Safety (EVS) GTR 20 – Phase 1: Circle of Safety



# EVS GTR 20 – Phase 1 : Requirements



# HEV Regulations

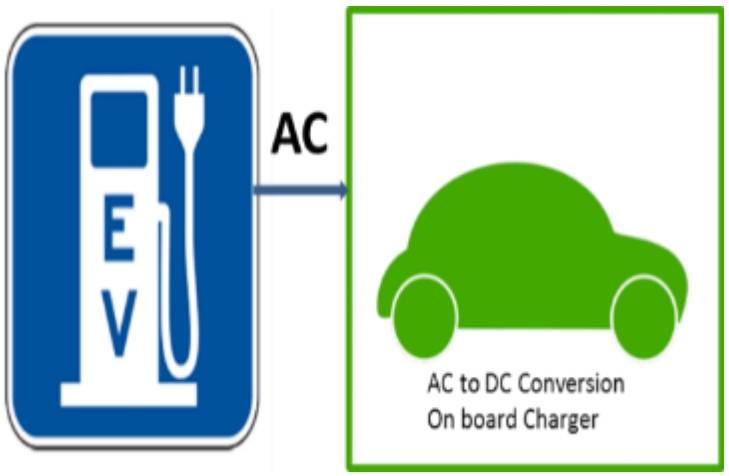
| Indian Standard | Ref. Standard |
|---|---|
| **AIS 102 (Part 1) :** CMVR Type Approval for Hybrid Electric Vehicles with GVW < 3500 kg | ECE R100<br>ECE R 101<br>ECE R 83<br>ECE R 85 |
| **AIS 102 (Part 2) :** CMVR Type Approval for Hybrid Electric Vehicles of M and N Category with GVW > 3500 kg | |

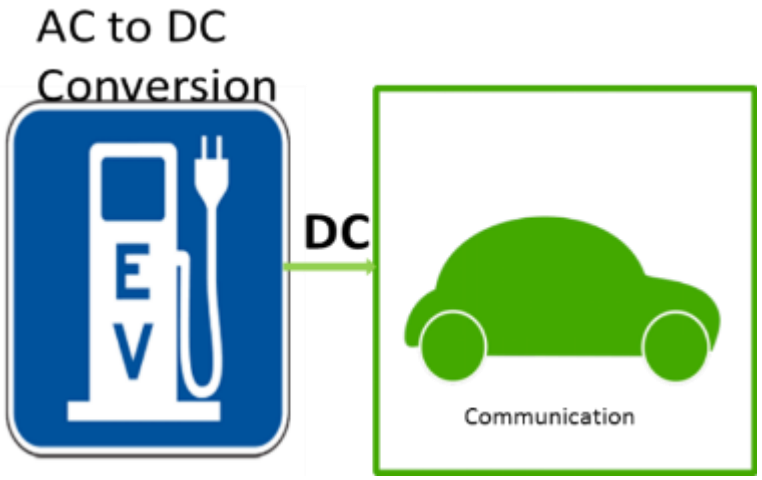
# EV / HEV Retro-fitment Regulations

| Indian Standard | Ref. Standard |
|---|---|
| **AIS 123 (Part 1) :** CMVR Type Approval of Hybrid Electric System Intended for Retro-fitment on Vehicles of M & N Category having GVW <= 3500kg | Nil |
| **AIS 123 (Part 2):** CMVR Type Approval of Hybrid Electric System Intended for Retro-fitment on Vehicles of M & N Category having GVW > 3500kg | |
| **AIS 123 (Part 3):** CMVR Type Approval of Electric Propulsion kit Intended for Conversion of Vehicles for Pure Electric Operation | |

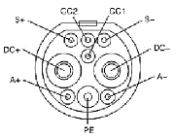
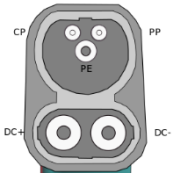
# EV Charging Regulations

- **AC Conductive Charging**
- **DC Conductive Charging**



# EV Charging Coupler, Protocol Standardisation (MoP Guidelines)

| Charging Type | Ref. Standard |
|---|---|
| AC Low Power Slow Charging (Mains 230 VAC, 15 A, 3.3 kW) | IEC 60309 (BEVC AC001)  |
| DC Low Power Fast Charging (48/72 VDC, 200 A, 10/15 kW) | IEC 61851-24 System B (BEVC DC001)  |
| AC High Power Fast Charging | IEC 62196-2 (Type 2)  |
| DC High Power Fast Charging | IEC 61851-24 System C (CCS)<br>IEC 62196-3<br>IEC 61851-24 System A (CHAdeMO)  |

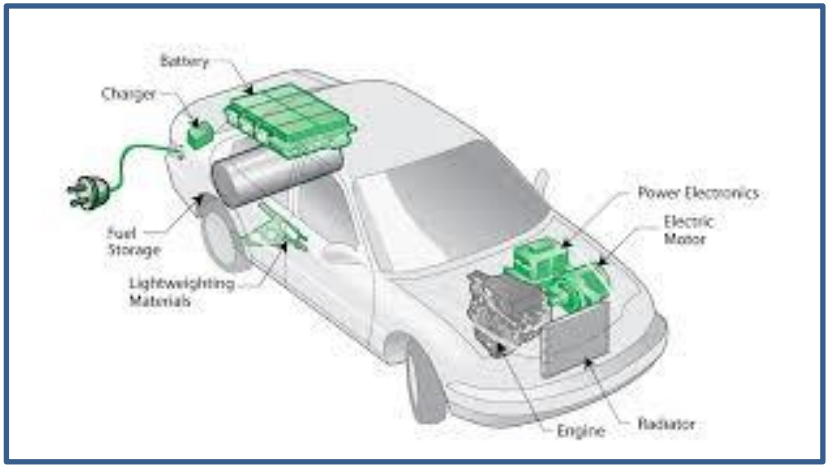
# Charging Options – Electric Buses

**Plug-in Charging**
**Depot / Terminal**
**50 to 200 kW**

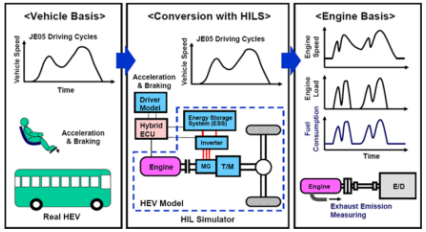
**Pantograph**
**En-route Charging**
**Up to 450 kW**


**Induction**
**Up to 200 kW**

# Electric Vehicle Development Challenges

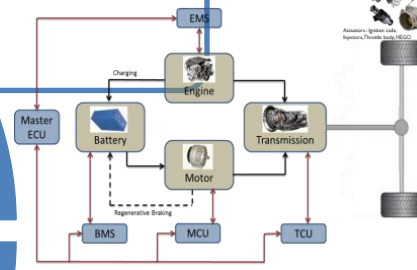


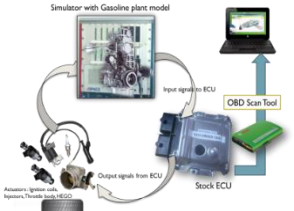
# EV Powertrain Development




- Domain Expertise
- Simulation and Modeling Tool Chain

- MBD Tool Chain
- V – Model Process




Component Sizing and specification

Control System Development

Vehicle Calibration

System Integration

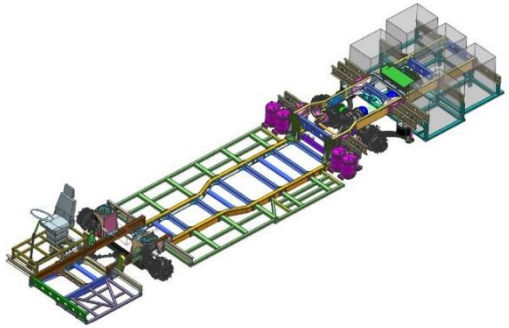
- Chassis Dyno. calibration
- Vehicle Parameterization

Configuration Design
Component Layout

- Harness Design
- Packaging

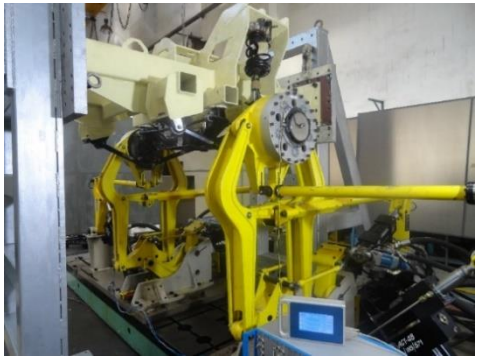
# EV Chassis Development

## Lightweight Chassis Design




## Structural Adequacy Evaluation

**Suspension Evaluation of Multi axis Technique**

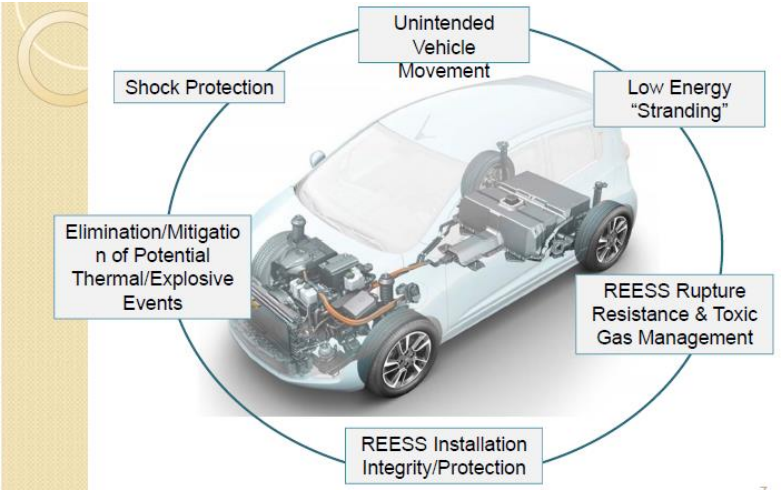


**Evaluation of Battery Structure and supports using Multi-axis Shaker table "MAST".**


**Four Poster durability of EV for structural adequacy**

# EV Safety

## Electrical Safety



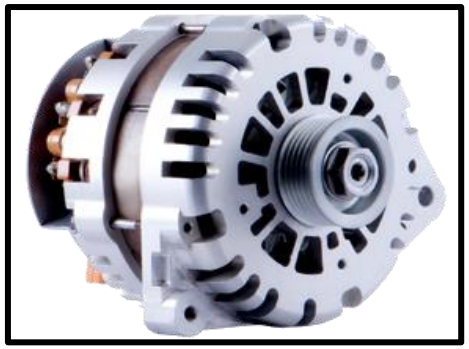

## EMC

## Crash / Frontal Impact

# EV Components Development

## Electric Motor

- High efficiency
- Performance
- Durability

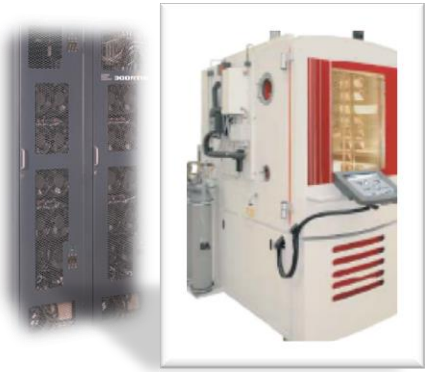


## Charging Stations


- Safety / Weatherproof
- Communication
- Interoperability
- Rollout

## Battery

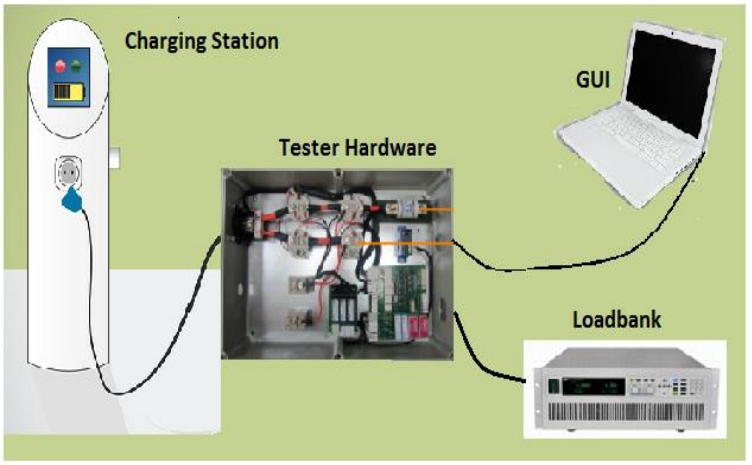
- Safety (Mechanical, Thermal & Electrical Abuse)
- BMS
- Cycle Life

# EV – Charger Interoperability

**Charger Tester:**

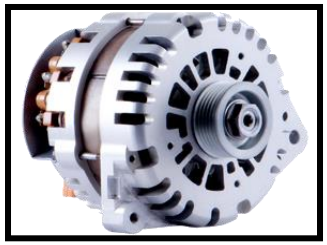
- Simulates Electric Vehicle environment for offline testing of Charging Station.
- Load bank is charged by charger.
- Automated testing, Fault simulation and Data logging.
- Useful for testing Charging Stations according to AIS138.




**Load simulator for design validation and certification testing of Charging Station functions:**

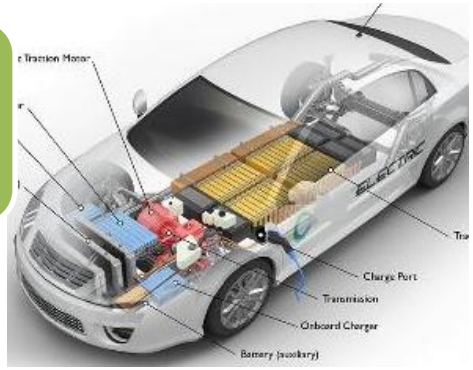
- System inspections, verification and validation.
- System verification (Protocol validation)
- EVSE power ready recognition
- EVSE connected to vehicle function (Locking mechanism check)
- EVSE charge delivery function
- EVSE Control Pilot Signal communication test
- Power Failure Check.
- Automatic data logging and Report generation

# ARAI's Center of Excellence (CoE) on E-Mobility



Power Train

Performance Evaluation




Chassis


Component

Safety

# ARAI's Centre of Excellence on E-Mobility

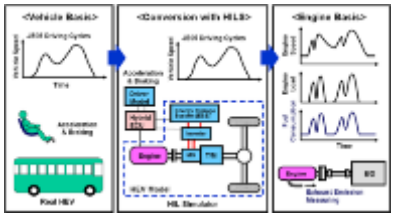
Cell Level Lithium Ion Battery Test System

Environmental Chamber To Test Lithium-ion Cells Of Traction Battery

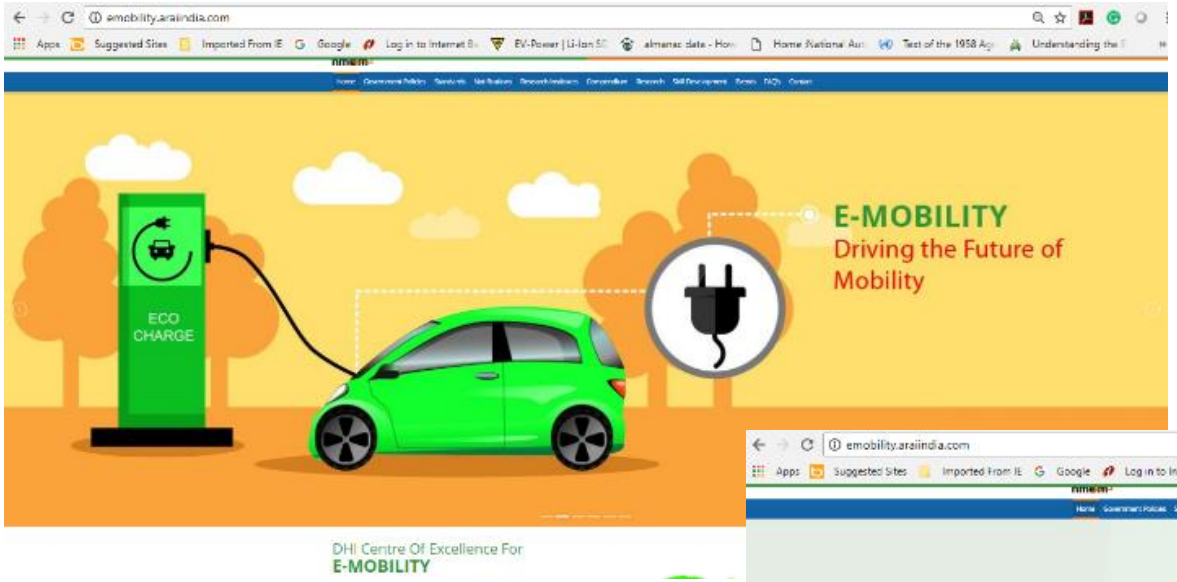
Pack Level Lithium Ion Battery Test System

E-motor Test Bed 150kW and 250 kW

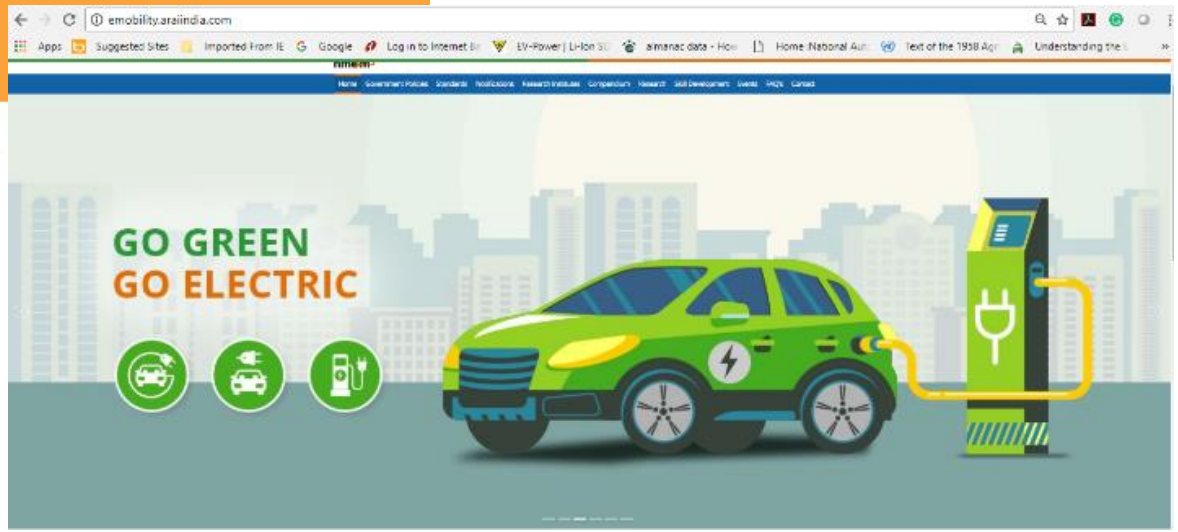
Battery Emulator, 100kW, 160 kW, 250 kW



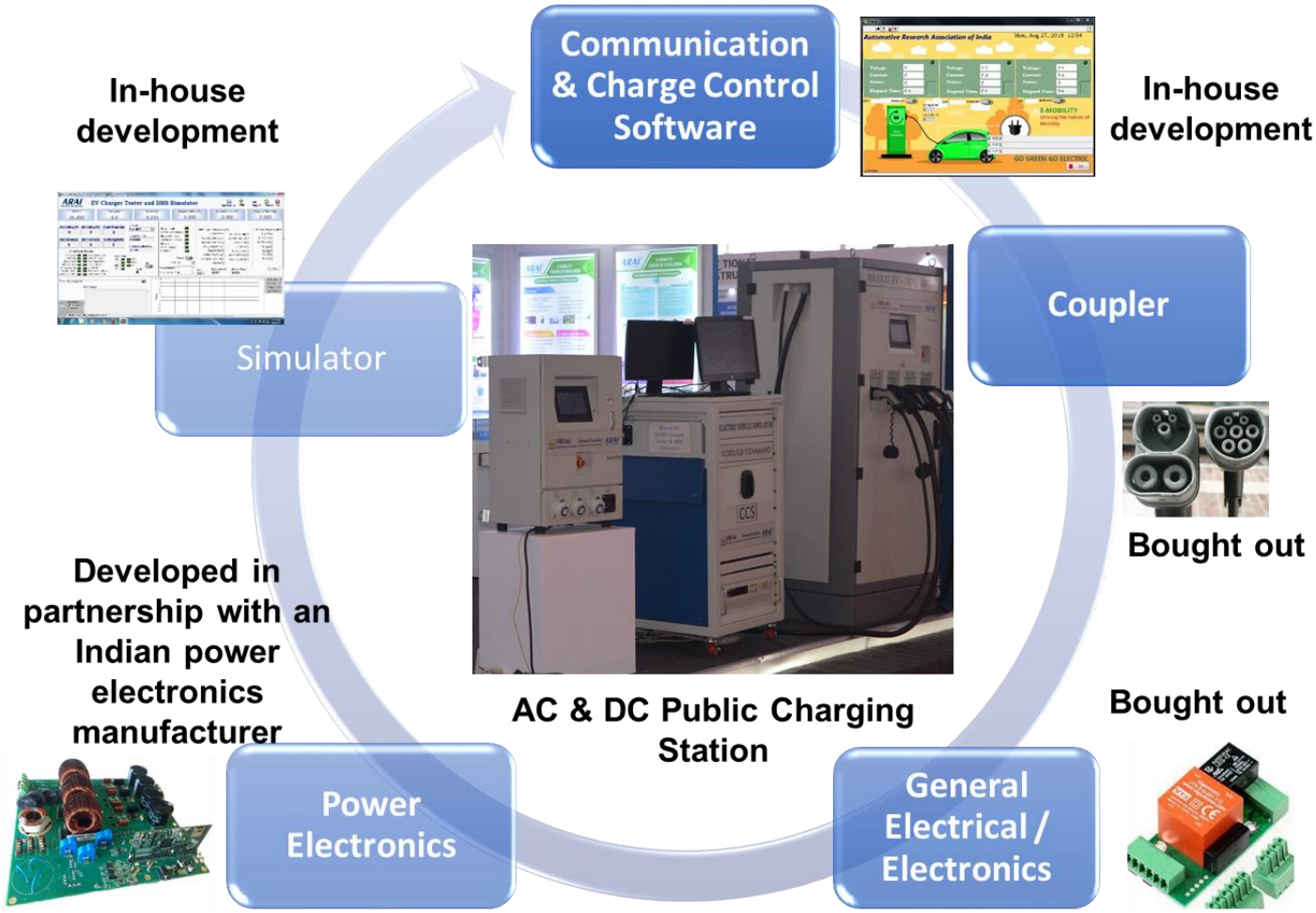
# Web Portal for E-mobility (emobility.araiindia.com)




With support of DHI, ARAI launched dedicated portal for Electric Mobility and Centre of Excellence with sole objective of dissemination of information at one click



# EV Charger – Technology Available for Transfer

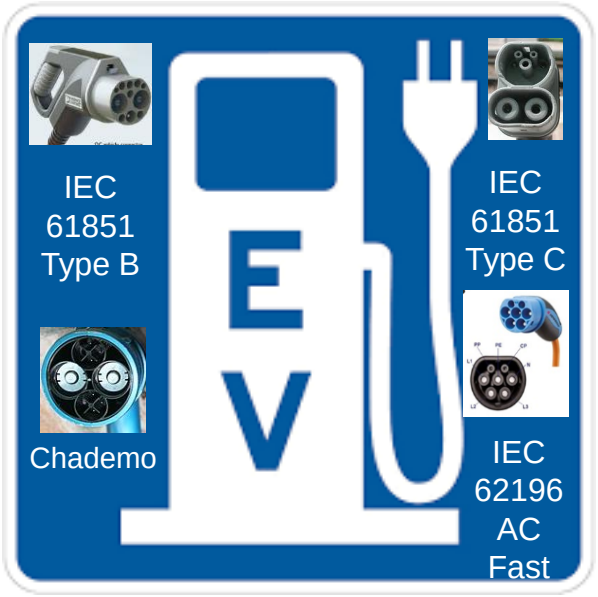


# EV Charger – Technology Available for Transfer

## AC Charging Station Prototype 1 & 2


- AC-3Ø Industrial Connector 3.3 kW each
- AC-1 Type 2, 22 kW

## DC Charging Station Prototype 3 & 4




- DC-001, 40-100 V, 200A
- DC-CHAdeMO, 200-500 V 140A
- DC-CCS 2 , 200-500 V 140A
- AC-1 Type 2, 22 kW

## DC Charging Station Prototype 5


- DC-CCS, 400-800V 125A
- AC-1 Type 2, 43 kW

# BMS – Technology Available for Transfer

**Main Features**

- ☐Monitoring of every cell Voltage
- ☐Intelligent cell balancing (efficient passive balancing)
- ☐Monitors State-of-Charge
- ☐Monitors State-of-Health
- ☐Active De-rating and Monitoring
- ☐Thermal Management
- ☐Failure and Diagnostics
- ☐Temperature Monitoring (NTC)

# Thank You…