E-BUS TECHNOLOGY OPTIONS & CHARGING INFRASTRUCTURE

ANAND DESHPANDE
SR. DEPUTY DIRECTOR
ARAI (PUNE)

WRI Workshop on Electrification of Public Transport

23 September 2019
Venue: Hotel Fortune Landmark, Ahmedabad
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)
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
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...
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.
Driving Forces

- Paris Climate Change Agreement
- Ambient Air Quality Concerns
- Import of Oil (Energy Security)
- Thrust on Solar Power Generation & Storage

Electric Mobility
National Electric Mobility Mission Plan (NEMMP)

**Faster Adoption and Manufacturing of Electric (\& 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:

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Component</th>
<th>2019-20</th>
<th>2020-21</th>
<th>2021-22</th>
<th>Total Fund requirement in crores</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Demand Incentives</td>
<td>822</td>
<td>4587</td>
<td>3187</td>
<td>8596</td>
</tr>
<tr>
<td>2</td>
<td>Charging Infrastructure</td>
<td>300</td>
<td>400</td>
<td>300</td>
<td>1000</td>
</tr>
<tr>
<td>3</td>
<td>Administrative Expenditure including Publicity, ICE activities</td>
<td>12</td>
<td>13</td>
<td>13</td>
<td>38</td>
</tr>
<tr>
<td>4</td>
<td>Committed expenditure of Phase –I</td>
<td>366</td>
<td>0</td>
<td>0</td>
<td>366</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1500</td>
<td>5000</td>
<td>3500</td>
<td>10000</td>
</tr>
</tbody>
</table>

(All amounts are in Rs. Crore)

- 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.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Vehicle Segment</th>
<th>Maximum Number of vehicles to be supported</th>
<th>Approximate Size of battery in KWH</th>
<th>Maximum Ex-factory price to avail incentive</th>
<th>Total Fund support from DHL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Registered e-2 Wheelers</td>
<td>1000000</td>
<td>2 KWH</td>
<td>Rs. 1.5 Lakhs</td>
<td>Rs. 2000 Cr</td>
</tr>
<tr>
<td>2</td>
<td>Registered e-3 Wheelers (including eRikshaws)</td>
<td>500000</td>
<td>5 KWH</td>
<td>Rs. 5 Lakhs</td>
<td>Rs.2500 Cr</td>
</tr>
<tr>
<td>3</td>
<td>e-4 Wheelers</td>
<td>35000</td>
<td>15 KWH</td>
<td>Rs. 15 Lakhs</td>
<td>Rs. 525 Cr</td>
</tr>
<tr>
<td>4</td>
<td>4W Strong Hybrid Vehicle</td>
<td>20000</td>
<td>1.3 KWH</td>
<td>Rs. 15 Lakhs</td>
<td>Rs. 26 Cr</td>
</tr>
<tr>
<td>5</td>
<td>e-Bus</td>
<td>7090</td>
<td>250 KWH</td>
<td>Rs. 2 Crores</td>
<td>Rs. 3545 Cr</td>
</tr>
<tr>
<td></td>
<td><strong>Total Demand Incentive</strong></td>
<td></td>
<td></td>
<td><strong>Rs. 8596 Crores</strong></td>
<td></td>
</tr>
</tbody>
</table>

## 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

<table>
<thead>
<tr>
<th>Vehicle Category</th>
<th>Approx. Incentive</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Wheelers</td>
<td>Rs. 20,000 (~USD 300)</td>
</tr>
<tr>
<td>3 Wheelers</td>
<td>Rs. 50,000 (~USD 700)</td>
</tr>
<tr>
<td>Passenger Cars &amp; LCVs (commercial taxi, goods transport)</td>
<td>Rs. 1,50,000 (~USD 2,000)</td>
</tr>
<tr>
<td>Buses (public transport by STUs)</td>
<td>Rs. 50,00,000 (~USD 70,000) on Opex model</td>
</tr>
</tbody>
</table>

- 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
## Workshop on Electrification of Public Transport
### Phase Manufacturing Program (PMP) Guidelines

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Category</th>
<th>Item Description</th>
<th>e-2W</th>
<th>e-3W</th>
<th>e-3W</th>
<th>e-4W</th>
<th>e-4W</th>
<th>e-Bus</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>L1 &amp; L2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>e-Rickshaw</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>e-Cart</td>
<td>L5</td>
<td>M1</td>
<td>N1</td>
</tr>
<tr>
<td>6</td>
<td>AC charging inlet Type 2</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>1-Apr-2020</td>
<td>1-Apr-2020</td>
<td>1-Apr-2020</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>DC charging inlet BEVC DC 001</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>1-Oct 2020</td>
<td>1-Oct 2020</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Electronic throttle</td>
<td>1-Apr-2020</td>
<td>1-Apr-2020</td>
<td>1-Apr-2020</td>
<td>1-Apr-2020</td>
<td>1-Apr-2020</td>
<td>1-Apr-2020</td>
<td></td>
</tr>
</tbody>
</table>
# Phase Manufacturing Program (PMP) Guidelines

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Description</th>
<th>e-2W</th>
<th>e-3W</th>
<th>e-3W</th>
<th>e-4W</th>
<th>e-4W</th>
<th>e-Bus</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>w.e.f. 1 Apr 2019</td>
<td>w.e.f. 1 Jul 2019</td>
<td>w.e.f. 1 Oct 2019</td>
<td>w.e.f. 1 Apr 2020</td>
<td>w.e.f. 1 Oct 2020</td>
<td>w.e.f. 1 Apr 2021</td>
</tr>
<tr>
<td>16</td>
<td>Integrated rear axle including motor, motor controller, transmission system &amp; rear braking system</td>
<td>NA</td>
<td>1-Oct-2019</td>
<td>1-Apr-2020</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

**ARAI**

Progress through Research
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**

- **Battery Safety AIS 048**
- **E-rickshaw/ E-cart GSR 709 (E)/GSR 2590(E)**
- **Low Speed 2 Wheeler GSR 291(E)**
- **Small Series AIS 131**
- **EV AIS 038, 039, 040, 041, 049**
- **HEV AIS 102 Part 1 & 2**
- **Retrofitment AIS 123 Part 1, 2 and 3**
- **Charging Stations AIS 138 Part 1 & 2**
## EV Regulations

<table>
<thead>
<tr>
<th>Indian Standard</th>
<th>Ref. Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AIS 038 Rev 1</strong>: Requirements for Construction and Functional Safety</td>
<td>ECE R 100</td>
</tr>
<tr>
<td><strong>AIS 039 Rev 1</strong>: Measurement of Electrical Energy Consumption (Wh/km)</td>
<td>ECE R 101</td>
</tr>
<tr>
<td><strong>AIS 040 Rev 1</strong>: Method of Measuring the Range (km)</td>
<td>ECE R 101</td>
</tr>
<tr>
<td><strong>AIS 041 Rev 1</strong>: Measurement of Net Power &amp; Maximum 30 minute power</td>
<td>ECE R 85</td>
</tr>
<tr>
<td><strong>AIS 049 Rev 1</strong>: CMVR Type Approval for EV</td>
<td>-</td>
</tr>
<tr>
<td><strong>AIS 048</strong>: Safety Requirements for Traction Batteries</td>
<td>USABC, ISO/IEC Standards</td>
</tr>
</tbody>
</table>
Workshop on Electrification of Public Transport

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

- Unintended Vehicle Movement
- Low Energy "Stranding"
- Shock Protection
- REESS Rupture Resistance & Toxic Gas Management
- REESS Installation Integrity/Protection
- Elimination/Mitigation of Potential Thermal/Explosive Events
EVS GTR 20 – Phase 1: Requirements

- Protection/Warning from single cell thermal runaway propagation
- Management of gases emitted from battery
- BMS functionality (in-use) at vehicle and pack levels: Protection from external short circuit, overcharge, overdischarge, overtemperature, low temperature, and overcurrent.

- Warnings in the case of:
  1. BMS failure
  2. Thermal event in REESS
  3. Low Energy

- Post-crash (vehicle level):
  - Electric shock prevention
  - Battery retention
  - Electrolyte spillage
  - Battery integrity and fire safety

- REESS Safety component level (In-use):
  - Vibration; thermal shock and cycling; and fire resistance

- In use (Vehicle Level):
  - Prevention of electric shock during drive, park, charging, and under water exposure
  - Warning for loss of isolation.
  - Functional safety at start-up exiting vehicle and charging

**Notes:** requirements apply to light duty vehicles. Option to apply to heavy trucks and buses.
## HEV Regulations

<table>
<thead>
<tr>
<th>Indian Standard</th>
<th>Ref. Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AIS 102 (Part 1)</strong>: CMVR Type Approval for Hybrid Electric Vehicles with GVW &lt; 3500 kg</td>
<td>ECE R100</td>
</tr>
<tr>
<td></td>
<td>ECE R 101</td>
</tr>
<tr>
<td></td>
<td>ECE R 83</td>
</tr>
<tr>
<td></td>
<td>ECE R 85</td>
</tr>
<tr>
<td><strong>AIS 102 (Part 2)</strong>: CMVR Type Approval for Hybrid Electric Vehicles of M and N Category with GVW &gt; 3500 kg</td>
<td></td>
</tr>
</tbody>
</table>
### Indian Standard

<table>
<thead>
<tr>
<th>Indian Standard</th>
<th>Ref. Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AIS 123 (Part 1):</strong> CMVR Type Approval of Hybrid Electric System Intended for Retro-fitment on Vehicles of M &amp; N Category having GVW &lt;= 3500kg</td>
<td>Nil</td>
</tr>
<tr>
<td><strong>AIS 123 (Part 2):</strong> CMVR Type Approval of Hybrid Electric System Intended for Retro-fitment on Vehicles of M &amp; N Category having GVW &gt; 3500kg</td>
<td>Nil</td>
</tr>
<tr>
<td><strong>AIS 123 (Part 3):</strong> CMVR Type Approval of Electric Propulsion kit Intended for Conversion of Vehicles for Pure Electric Operation</td>
<td></td>
</tr>
</tbody>
</table>
EV Charging Regulations

- AC Conductive Charging
- DC Conductive Charging
## Charging Type

<table>
<thead>
<tr>
<th>Charging Type</th>
<th>Ref. Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC Low Power Slow Charging (Mains 230 VAC, 15 A, 3.3 kW)</td>
<td>IEC 60309 (BEVC AC001)</td>
</tr>
<tr>
<td>DC Low Power Fast Charging (48/72 VDC, 200 A, 10/15 kW)</td>
<td>IEC 61851-24 System B (BEVC DC001)</td>
</tr>
<tr>
<td>AC High Power Fast Charging</td>
<td>IEC 62196-2 (Type 2)</td>
</tr>
<tr>
<td>DC High Power Fast Charging</td>
<td>IEC 61851-24 System C (CCS)</td>
</tr>
<tr>
<td></td>
<td>IEC 62196-3</td>
</tr>
<tr>
<td></td>
<td>IEC 61851-24 System A (CHAdMeMO)</td>
</tr>
</tbody>
</table>
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
- Chassis Dyno. calibration
- Vehicle Parameterization
  - Configuration Design
  - Component Layout
  - Harness Design
  - Packaging
- Component Sizing and specification
- Control System Development
- System Integration
- Vehicle Calibration

ARAI
Progress through Research
Workshop on Electrification of Public Transport

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
Workshop on Electrification of Public Transport

EV Safety

Electrical Safety

EMC

Crash / Frontal Impact
Workshop on Electrification of Public Transport

EV Components Development

Electric Motor
• High efficiency
• Performance
• Durability

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

Charging Stations
• Safety / Weatherproof
• Communication
• Interoperability
• Rollout
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
Workshop on Electrification of Public Transport

ARAI’s Centre of Excellence on E-Mobility

Cell Level Lithium Ion Battery Test System

Pack Level Lithium Ion Battery Test System

Battery Emulator, 100kW, 160 kW, 250 kW

E-motor Test Bed 150kW and 250 kW

Environmental Chamber To Test Lithium-ion Cells Of Traction Battery
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.
Workshop on Electrification of Public Transport

EV Charger – Technology Available for Transfer

- In-house development
- Simulator
- Developed in partnership with an Indian power electronics manufacturer
- Communication & Charge Control Software
- Coupler
- Bought out
- AC & DC Public Charging Station
- Power Electronics
- General Electrical / Electronics

ARAII®
Progress through Research
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
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...