Electrification of Buses in India
India’s experience in E-bus and its technology

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How it started?

- **FAME I**, initiated in 2015 set the path for introduction of Electric Vehicles in India.

- **Initially the target was set for 100% by 2030. However, looking to the challenges, the target was reduced to to 30% in 2018**

- **To increase the pace of adoption, FAME II refined the FAME I approach by linking the incentives to the size of the battery and mandated a TCO Based Business models**

- **In 2021, the Prime Minister set a target for CO2 reduction. The target at present is as follows: 1) India to get 50% of its energy from renewable resources by 2030 and 2) net-zero target by 2070**
What is FAME?

Faster Adoption and Manufacturing of Hybrid & Electric Vehicles (FAME) in India is the Initiative of the Government of India to Reduce the use of Diesel and Petrol Powered Vehicles in the country. The project is an integral part of the Government's National Electric Mobility Mission Plan (NEMMP).

### FAME I : 2015-2019

<table>
<thead>
<tr>
<th>FUNDS</th>
<th>Budget : Rs. 895 Cr to support 640 E Buses Utilized : Rs. 529 Cr</th>
</tr>
</thead>
</table>
| SUBSIDY | Based on Level of Localization  
Min 15% : 60% of Bus Cost (Max : Rs 85 lakh)  
Min 60% : 60% of Bus Cost (Max : Rs 1 Cr.) |

#### Types of Vehicles Supported

2W, 3W and 4W; Both Hybrid and Electric variants of all vehicles.

#### No. of E-Buses Supported

419 Buses

#### Business Model

Outright Purchase, GCC, NCC

### FAME II : 2019-2024

<table>
<thead>
<tr>
<th>FUNDS</th>
<th>Budget : Rs. 3545 Cr / 6265 E Buses Utilized : Rs. 1500 Cr / 3120 E Buses</th>
</tr>
</thead>
</table>
| SUBSIDY | Based on Bus Length and Battery Capacity  
9 /12 M Bus : Rs 45/55 lakh per Bus |

#### Types of Vehicles Supported

BEV for Buses, 2W and 3W; BEV and HEV for 4W

#### No. of E-Buses Supported

Approx. 4,000 buses

#### Business Model

GCC, Utility led variant of GCC
E-Bus Deployment in India

FAME I and FAME II

1.5 Lakh Buses
Total Number of Buses on Road in India

4647
Total Number of E-Buses in India

2/3rd are Midi 9m Buses

1/3rd are Standard 12m Buses

Source: DHI, STUs
**E-Bus Technologies**

### MOTOR

<table>
<thead>
<tr>
<th>1. Central Motor with Gearbox</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Voltage Battery</td>
</tr>
</tbody>
</table>

Motor is connected to rear axle through a shaft leads to transmission loss of energy. This lowers the acceleration and increases electricity consumption.

<table>
<thead>
<tr>
<th>2. Hub Motors</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Voltage Battery</td>
</tr>
</tbody>
</table>

Comparatively less transmission loss as the motors are connected directly to the real axle. (A variant of this model is the direct drive which has a common inverter and motor which connects to the rear axle)

### BATTERY

<table>
<thead>
<tr>
<th>1. Lithium Ion Phosphate (LFP) Battery</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Commonly used</td>
</tr>
<tr>
<td>• Usually paired with Plug-in Charging</td>
</tr>
<tr>
<td>• Heavy Batteries needed for Overnight Charging</td>
</tr>
<tr>
<td>• Overheating under fast charging</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2. Nickel Manganese and Cobalt (NMC) Battery</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Light weight</td>
</tr>
<tr>
<td>• High Energy Density per Kg.</td>
</tr>
<tr>
<td>• More likely to ignite/ burn under high charging rate</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3. Lithium Titanium Oxide (LTO) Battery</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Sustain faster rate of charging</td>
</tr>
<tr>
<td>• Can combine with Pantograph for faster charging</td>
</tr>
<tr>
<td>• Light batteries can be used</td>
</tr>
<tr>
<td>• Low fire risk</td>
</tr>
</tbody>
</table>

*Indigenous Indian manufacturers have tended to prefer central motor whereas Chinese suppliers have preferred hub motors.*
E-Bus Technologies

CHARGING TECHNOLOGY

1. Plug-in Charging  (Existing Model)
   - Commonly adopted model
   - Simple technology
   - Less Capital Cost compared to Pantograph
   - Fast and Slow Charging

2. Battery Swapping
   - Swapping a battery takes about 1-3 minutes
   - Reduces the Capex cost on the bus

3. Pantograph Charging  (Emerging Technology in India)
   - Charging time is very less when compared to Plug-in Charging (12-15 minutes for 0-100%)
   - In consideration for effective utilisation of the buses in terms of kilometres of operation
   - Automated and Less Maintenance

Battery and Charging Technology Comparison

<table>
<thead>
<tr>
<th></th>
<th>LFP (Fast + Slow Plug in Charging)</th>
<th>NMC (Plug-in Charging)</th>
<th>LTO (with Pantograph Charging)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost per KwH</td>
<td>Rs. 55,000</td>
<td>Rs. 60,000</td>
<td>Rs. 90,000</td>
</tr>
<tr>
<td>Maximum Charge (Kw)</td>
<td>150 Kw</td>
<td>300 Kw</td>
<td>800 Kw</td>
</tr>
<tr>
<td>Lifecycles (0-100% SOC)</td>
<td>5,000 + Cycles</td>
<td>4,000 + Cycles</td>
<td>20,000 + Cycles</td>
</tr>
<tr>
<td>Expected Lifespan (Years)</td>
<td>7-8 Years</td>
<td>5-6 Years</td>
<td>12-14 years</td>
</tr>
</tbody>
</table>
India’s Experience with E-buses

1. Bus Technology

Electric vehicles are broadly classified into 2 categories based on the type of technology.
- Hybrid Electric Vehicles (HEV)
- Battery Electric Vehicles (BEV)

Policies supported HEV and BEV. However, India prefers BEV.

<table>
<thead>
<tr>
<th>Bus Type</th>
<th>Bus Length</th>
<th>Battery Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predominant bus lengths in India are:</td>
<td></td>
<td>Most commonly used battery for EVs are</td>
</tr>
<tr>
<td>9m (Midi) buses and</td>
<td>• 9m (Midi) buses and</td>
<td>• Lithium Ion Phosphate (LFP)</td>
</tr>
<tr>
<td>12m (Standard) Buses.</td>
<td>• 12m (Standard) Buses.</td>
<td>• Nickel Manganese Cobalt (NMC)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Lithium Titanium Oxide (LTO)</td>
</tr>
<tr>
<td>Policies supported HEV and BEV. However, India prefers BEV.</td>
<td>LFP Batteries with a capacity of 150-180KwH are prevalent in India.</td>
<td>However, in case of Buses, it is difficult to achieve the daily operational kilometres with the available battery without opportunity charging during the day.</td>
</tr>
<tr>
<td></td>
<td>Many cities preferred 9m buses due to less CAPEX Cost and narrow streets. Few cities went for 12m buses as well.</td>
<td>To achieve operating efficiency without compromising on Service Levels, India is shall prefer LTO + Pantograph Charging.</td>
</tr>
</tbody>
</table>
India’s Experience with E-buses

2. Charging Technology

Charging Technology for Electric vehicles which are tried out in India are:
- Plug-in Charging
- Battery Swapping

**Battery Swapping**

Ahmedabad is the only city in India to try out Battery Swapping Model. The buses did not perform as expected due to the following reasons:
- Increased Range anxiety as the operational kms per swap was about 40 kms only.
- Number of swaps per day was high which reduced the operating efficiency (Time taken shall be about 3-5 minutes per swap). and service levels were compromised.

**Plug-In Charging**

Indian cities preferred Plug-in charging for electric buses as it is a well established system across the world.

The daily operational kilometres for a bus is high in major cities which had to be met with heavy batteries. This technology has a few disadvantages like:
- Time required for charging from 0-100% is about 6-8 hours for Slow Charging and 2-3 Hours for Fast Charging.
- Reduces Passenger Carrying Capacity
- Increased the Vehicle Weight
- Overnight charging alone is not enough to provide the required daily kms. This led to the need of opportunity charging during day time which reduces the operating efficiency.

At Present, E-Buses in India are using LFP + Plug-in Technology. But there is a scope for shifting to LTO + Pantograph Technology.
India’s Experience with E-buses

3. Business Model

Model 1: Outright Purchase Model
- Supplies Bus, Charger and Battery
- STU
- Bus, Battery and Chargers

Vehicle Manufacturer supplied the bus, battery and chargers to the STU which purchases them and carries out ownership, operation and maintenance using internal resources.

- Adopted by few cities like Kolkata, Indore, Jaipur, Guwahati and Jammu under FAME I.
- Many difficulties in deployment and operations.

Model 2: Gross Cost Contract
- Investors, OEMs, ESP
- VM / Operator
- Consortium
- Elec. Infra.
- Assured per km payment for O&M
- STU
- Bus, Battery and Chargers

Vehicle manufacturer owns, operates and maintains the buses, batteries and charging infrastructure and gets a fixed remuneration from the STUs based on assured km.

- Mandatory Model under FAME II.
- More than 3000 e-buses have been procured out of which 900 e-buses are operational.

Model 3: Utility Provider Led Model
- EU
- Elec. Infra
- Investors, VM, ESP

Energy Utility Company is the key stakeholder who owns the services and goes into an agreement with private parties for operation and maintenance.

- Experimented by NTPC in Andaman Nicobar. Not replicated further.

Predominant Model in India is Gross Cost Contract (GCC).
### 3. Business Model

**FAME I – allowed any business models - (419 Buses ordered)**

<table>
<thead>
<tr>
<th>47 PROPOSALS</th>
<th>44 CITIES</th>
<th>11 SELECTED</th>
<th>8 FINALISED TENDERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Himachal</td>
<td>Bengal</td>
<td>Mumbai</td>
<td>Indore</td>
</tr>
<tr>
<td>Only state with OPM and GCC</td>
<td>GCC Model</td>
<td>Navi Mumbai – Only OPM</td>
<td>Only GCC</td>
</tr>
</tbody>
</table>

In FAME I, buses were procured using all the models – i.e. Outright Purchase Model (OPM), Gross Cost Contract Model (GCC) and Net Cost Contract Model (NCC).

74% of the total bus order quantity was purchased through Outright Purchase Model / CAPEX Model.

**FAME II – Mandated GCC - (Approx. 4000 Buses till date)**

Many states participated in FAME II.

Andhra Pradesh, Assam, Bihar, Chhattisgarh, Delhi, Gujarat, Haryana, Himachal Pradesh, Karnataka, Jammu, Kerala, Maharashtra. Odisha etc.

However, few cities are still comfortable with Outright Purchase Model and have not gone for FAME II subsidy because of the mandate for GCC.

In April 2022, GoI under The Grand Challenge, procured 5450 buses for 5 metro cities on Gross Cost Contract Basis.
4. Involvement of Vehicle Manufacturers

- In Outright Purchase Model which was the most preferred in FAME I, the performance risk was very high as the Public Transport Agencies had limited knowledge on Operations and Maintenance of Buses.

- FAME II Mandated Gross Cost Contract which unbundled the responsibilities between different stakeholders and the Vehicle Manufacturers are completely involved in operation and maintenance of the vehicle for the entire contract period. This reduced the performance risk on the Public Transport Agencies.

5. Contract Period

<table>
<thead>
<tr>
<th>Contract Model 1 :</th>
<th>Contract Model 2 :</th>
<th>Contract Model 3:</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009 - 11</td>
<td>2014-17</td>
<td>2018-21</td>
</tr>
<tr>
<td>Bus Procured, Owned and Operated by <strong>Private Operator</strong></td>
<td>Bus Procured and Owned by <strong>Public Authority</strong> Operated by <strong>Private Operator</strong></td>
<td>Bus Procured, Owned and Operated by the <strong>Bus Manufacturer Led Consortium</strong> (For Electric Buses)</td>
</tr>
<tr>
<td>Contract Period : 7 years</td>
<td>8+1 years</td>
<td>10 years</td>
</tr>
</tbody>
</table>
India’s Experience with E-buses

6. Battery Size

- In Outright Purchase Model the Vehicle Manufacturers supplied buses with less battery capacity (about 120 – 130 KwH). This did not service the required daily operational kilometres and required more time during the day for opportunity charging. Here, the Vehicle Manufacturers were not involved in the O&M and cannot be held responsible for the same.

- However, in Gross Cost Contract Model, the buses were supplied with higher battery capacity (about 150 - 180KwH). Here the Vehicle Manufacturer was directly involved in O&M and the performance risk was on the manufacturer to provide the assured operating kilometres.

7. Total Cost of Ownership (TCO)

TCO depends on various factors like Capital Cost, Operational costs (like electricity prices and diesel buses), Maintenance cost (cost of spare parts and regular maintenance of the vehicles, battery cost etc.).

Studies show that the TCO for E-buses are economical than the conventional fuel buses under certain conditions like 200km of operation a day and if the buses are used for a period of more than 6 years.

<table>
<thead>
<tr>
<th>TCO for 12 m Buses</th>
<th>Rs. Per Km</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-Bus with 125 Kwh Battery</td>
<td>53.77</td>
</tr>
<tr>
<td>Diesel Bus (Low Cost Variant)</td>
<td>61.14</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TCO for 9 m Buses</th>
<th>Rs. Per Km</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-Bus with 102 Kwh Battery</td>
<td>49.44</td>
</tr>
<tr>
<td>Diesel Bus (Low Cost Variant)</td>
<td>50.09</td>
</tr>
</tbody>
</table>

Note: The values are without considering any financial subsidy.

Source: Procurement of Electric Buses: Insights from Total Cost of Ownership (TCO) Analysis, WRI
India - From 2017 – till date..

• India has about 4600 e-buses plying on roads at present when compared to no electric buses till 2017.

• From nil e-bus market to about 5 – 6 Manufacturers at present.

• From using buses with 120 KwH battery to 350 KwH battery

• Has experimented minimum 2 business models and is trying out other models.

• Has experimented 2 charging technologies (Battery Swapping and Plug-in Charging) with LFP Batteries and shall probably look into the combination of LTO Batteries with Pantograph Charging in the near future. Swap technology is emerging in 2-wheelers and 4-wheelers.

• The adoption drive started with the national policy and has spread across to have state specific policies which also focuses on supporting manufacturing and purchase of EVs in about 14 states.

• India has also framed specific policies which can impact the EV Adoption (*like Electric Charging Tariff Policy in about 10 states*).

• Captive charging depots for setting up of E-buses by accessing High Tension power in all major cities of the country.
India - From 2017 – till date...

- Data is being generated by GPS and GPRS to track the vehicle movement which helps in customising the battery combination based on the vehicle’s usage.

- And, the prices of EVs are falling. Shown below with an example of bidding prices of few Indian cities.

<table>
<thead>
<tr>
<th>FAME</th>
<th>City</th>
<th>Date</th>
<th>No. of Buses</th>
<th>Rate Rs/Km on GCC basis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>During FAME I (excluding subsidy and electrical consumption)</strong></td>
<td>Ahmedabad</td>
<td>June 2018</td>
<td>40</td>
<td>63.12</td>
</tr>
<tr>
<td></td>
<td>Ahmedabad</td>
<td>June 2018</td>
<td>10</td>
<td>40.80</td>
</tr>
<tr>
<td><strong>FAME II (Including subsidy and electrical consumption)</strong></td>
<td>Ahmedabad</td>
<td>Dec 2019</td>
<td>300</td>
<td>54.90</td>
</tr>
<tr>
<td></td>
<td>Surat</td>
<td>Dec 2019</td>
<td>150</td>
<td>55.26</td>
</tr>
<tr>
<td></td>
<td>Rajkot</td>
<td>Dec 2019</td>
<td>50</td>
<td>53.91</td>
</tr>
<tr>
<td></td>
<td>Surat</td>
<td>Dec 2021</td>
<td>150</td>
<td>48.87</td>
</tr>
<tr>
<td></td>
<td>Rajkot</td>
<td>Dec 2021</td>
<td>100</td>
<td>48.78</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td>800</td>
<td></td>
</tr>
</tbody>
</table>

Weighted Average of rates without taking impact of time value into consideration: **Rs.53.24/km.**

**Reduction in rates -8% on CAGR basis**

Comparing the rates under FAME II, we can see the decline in prices. (This is considering similar subsidies for the buses)

This indicates that India can have faster adoption with No Incentive in the near future.
Pooled Procurement of 5450 Buses in India

Convergence Energy Services Ltd. (CESL), a PSU under Ministry of Power has selected the operator for procurement, operation and maintenance of 5450 E-buses in 5 Indian cities – Availing the incentives available under FAME II.

**Why Pooled Procurement?**
To homogenise and aggregate demand

**Business Model Used**
Gross Cost Contract

**Contract Period**
12 Years (with 10 lakh assured km)

**Outcome of Pooled Procurement**
TATA Motors won the tender in all Categories

<table>
<thead>
<tr>
<th>Type of Bus</th>
<th>Rate (Rs/Km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 m Low Floor AC</td>
<td>47.49</td>
</tr>
<tr>
<td>12 m Low Floor Non-AC</td>
<td>43.49</td>
</tr>
<tr>
<td>12 m Std. Floor Non-AC</td>
<td>44.99</td>
</tr>
<tr>
<td>9 m Std. Floor AC</td>
<td>41.45</td>
</tr>
<tr>
<td>9 m Std. Floor Non-AC</td>
<td>39.21</td>
</tr>
</tbody>
</table>

**Advantages**

**Economies of Scale**

**Lowest Ever price was discovered**

Aggregation of demand and centralised procurement seems to have provided better economics. However, merits of common specification and service conditions are yet to be proven.
Factors that influence the range of the electric bus

- Vehicle weight
- Battery capacity
- Charger types
- Charging location
- Depot/opportunity charging time
- Operating schedules
- Route conditions
- Driver Behaviour

The range of the buses poses the biggest challenge in E-bus adoption
The vehicle performs with higher energy efficiency when its total weight is low.
## Vehicle Utilization by Battery Size – Total

<table>
<thead>
<tr>
<th>Battery Size (kWh)</th>
<th>21 - 140</th>
<th>141-150</th>
<th>151-160</th>
<th>161-170</th>
<th>171-180</th>
<th>181-90</th>
<th>191-200</th>
<th>201-210</th>
<th>211-220</th>
<th>221-230</th>
<th>231-240</th>
<th>241-250</th>
<th>251-276</th>
</tr>
</thead>
<tbody>
<tr>
<td>176 kWh</td>
<td>14.1%</td>
<td>5.6%</td>
<td>3.6%</td>
<td>13.7%</td>
<td>4.6%</td>
<td>11.9%</td>
<td>9.7%</td>
<td>14.4%</td>
<td>9.3%</td>
<td>5.3%</td>
<td>3.3%</td>
<td>3.9%</td>
<td>0.4%</td>
</tr>
<tr>
<td>347 kWh</td>
<td>3.5%</td>
<td>0.2%</td>
<td>1.1%</td>
<td>0.1%</td>
<td>0.7%</td>
<td>1.9%</td>
<td>25.9%</td>
<td>1.6%</td>
<td>6.4%</td>
<td>9.8%</td>
<td>16.7%</td>
<td>8.7%</td>
<td>23.1%</td>
</tr>
<tr>
<td>196 kWh</td>
<td>6.1%</td>
<td>0.7%</td>
<td>3.9%</td>
<td>12.2%</td>
<td>10.2%</td>
<td>19.9%</td>
<td>2.7%</td>
<td>7.4%</td>
<td>10%</td>
<td>18.3%</td>
<td>7.5%</td>
<td>0.7%</td>
<td>0.2%</td>
</tr>
</tbody>
</table>
Effect of Driving Condition on Energy Efficiency

60% of the drivers perform similarly everyday to obtain high energy efficiency

<table>
<thead>
<tr>
<th>Route</th>
<th>Avg EE</th>
<th>Max EE</th>
<th>Min EE</th>
<th>Avg CV</th>
<th>Max CV</th>
<th>Min CV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Route 12</td>
<td>0.88</td>
<td>0.96</td>
<td>0.79</td>
<td>0.13</td>
<td>0.18</td>
<td>0.05</td>
</tr>
<tr>
<td>Overall</td>
<td>0.91</td>
<td>1.11</td>
<td>0.76</td>
<td>0.13</td>
<td>0.18</td>
<td>0.02</td>
</tr>
</tbody>
</table>
India - Lessons

- E-buses are more attractive to customers
  - E-buses contribute to emission reductions, improvements in driving and riding comfort, and overall image of city buses

- Incentives to bring cost-parity
  - E-bus capital costs are high. State incentives are required to bring initial cost parity between e-buses and diesel/CNG buses.

- E-bus technology is evolving
  - Hence, gradual induction of buses may be preferred strategy
  - Downward trend in prices of E-buses is likely to continue because of technology improvements and declining battery prices - scale economies operate when the size is very large!

- Range constraints
  - Large batteries provide longer range but are expensive and heavy
  - Longer range possible with smaller batteries through network at charging at depots and terminals and smart scheduling
  - Technology standardisation required for inter-operability

- Capacity building
  - Performance vary by bus types, routes and drivers!
  - Capacity building activities (before and during operations) a necessary condition for success

- Technology Risks
  - Involving OEM as a stake-holder in the operations mitigate technology risks.

- Comprehensive Planning
  - Bus technology, battery size & range, charging strategy are critical elements in planning for transitioning to E-bus
  - Opportunity Charging at terminals, overnight at Depots.
  - Scaling up electrification would require interoperability among different makes and models through common charging and battery technology specifications
Thank You

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