Society of Automobile Manufacturers,
National Hybrid/Electric Mobility Study
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iii. SUMMARY

India has potential to reach an overall annual sales figure of 6 to 7 million xEVs by 2020. Battery electric 2 wheelers are expected to drive xEV sales, contributing to 4.8 million annual sales in 2020. 4 wheeler xEVs could also reach 1.3 – 1.6 million unit sales in 2020, contributing significantly to xEV penetration. Striving towards reaching this potential should be a priority for India, given the substantial benefits of xEV adoption. The projected xEV sales of 6 to 7 million units would lead to annual liquid fuel savings of 2.2 to 2.5 million tonnes, amounting to ₹13000 - ₹14000 crore in 2020. Majority of this will come from large scale electrification of 2 wheelers, accounting for 1.4 million tonnes of liquid fuel savings (~₹8500 crore). In addition, carbon dioxide emissions are expected to decrease by 1.3% to 1.5% overall. Additional 60,000 – 65,000 jobs are expected to be created in the manufacturing segment by 2020 due to advent of xEVs in the Indian market. Additional service jobs in operation and maintenance are expected to be 3 times the manufacturing jobs. However, it is impossible to reach this potential without a clear roadmap. In order to induce acceptance of xEVs among consumers and producers as well as localize production, investments in infrastructure and incentives are required. An estimated ₹12500 - ₹13500 crore investments on the demand and supply side and ₹8000 - ₹9000 crore on R&D and infrastructure across all vehicle segments, clubbed with mandates for xEVs in various central and state government fleets could help India reach the estimated potential. xEV 2 wheelers and 4 wheelers require the majority of these investments. However, the returns on these investments are big enough to justify them. While electric 2 wheelers are expected to yield ROI worth ₹28000 crore, xEV cars can yield ₹4800 – 7100 crore. Overall return across all vehicle segments is expected to range between ₹39000 crore to ₹43000 crore.

While government could take up investments in demand incentives, power infrastructure and electricity generation, OEMs could partner with the government to develop the charging infrastructure. Investments in manufacturing facilities would be required from OEMs to ensure supply. As an example, 4 wheeler OEMs would need to invest ₹41000 - ₹45000 crore\(^1\) over the next 9 years to sustain 2020 potential. Significant payback will be available to OEMs with price evolution and scale effect kicking in.

\(^1\) Assuming investment of ₹5000 crore is required for 5.2 lakh xEV 4 wheelers.
<table>
<thead>
<tr>
<th></th>
<th>2W</th>
<th>3W</th>
<th>4W</th>
<th>Bus</th>
<th>LCV</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Incremental sales of xEVs²</strong> (’000)</td>
<td>4800</td>
<td>20 - 30</td>
<td>1300 - 1600</td>
<td>2.3 - 2.7</td>
<td>150 - 170</td>
<td>6000 - 7000</td>
</tr>
<tr>
<td><strong>Liquid Fuel Savings³</strong></td>
<td>MT</td>
<td>1.4</td>
<td>0.06 - 0.09</td>
<td>0.4 - 0.65</td>
<td>0.16 - 0.19</td>
<td>0.09 - 0.16</td>
</tr>
<tr>
<td></td>
<td>₹Crore</td>
<td>8500</td>
<td>350-500</td>
<td>2600 - 3600</td>
<td>950 - 1050</td>
<td>550 - 900</td>
</tr>
<tr>
<td><strong>CO₂ Reduction (%)⁴</strong></td>
<td>2.7%</td>
<td>- 0.9%</td>
<td>0.6% - 1%</td>
<td>1.8% - 2.1%</td>
<td>1.5%</td>
<td>1.3% - 1.5%</td>
</tr>
<tr>
<td><strong>Jobs Created</strong></td>
<td>Manufact uring</td>
<td>22500</td>
<td>1400 - 1600</td>
<td>26700 - 30200</td>
<td>1500 - 1600</td>
<td>8500 - 9200</td>
</tr>
<tr>
<td></td>
<td>Service</td>
<td>180000 - 200000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Investment (₹Crore )</strong></td>
<td>Demand /Supply</td>
<td>5200</td>
<td>430 - 710</td>
<td>5000 - 5650</td>
<td>500 - 550</td>
<td>1300 - 1500</td>
</tr>
<tr>
<td></td>
<td>Others</td>
<td>5000</td>
<td>110 - 180</td>
<td>2250 - 3050</td>
<td>600 - 630</td>
<td>150 - 250</td>
</tr>
<tr>
<td><strong>Return on Investment⁵</strong></td>
<td>28000</td>
<td>1200 - 1700</td>
<td>4800 - 7100</td>
<td>3300 - 3700</td>
<td>1500 - 2700</td>
<td>39000 - 43000</td>
</tr>
</tbody>
</table>

---

² Excluding retrofit solutions  
³ These are well to wheel savings  
⁴ Carbon emission benefits have not been quantified in monetary terms  
⁵ ROI calculated using a hurdle rate of 12% and terminal multiple of 10
I. INTRODUCTION

The National Hybrid / Electric Mobility Study was conducted on the behalf of the Ministry of Heavy Industries and Public Enterprises and the Society of Indian Automobile Manufacturers (SIAM) by Booz & Company. The overall objective of the study is to:

“Develop a mission plan and roadmap for promoting the adoption of a range of electric mobility solutions for India, which can enhance national fuel security, provide affordable and environmentally friendly transportation and enable the Indian automotive industry to achieve global manufacturing leadership.”

Environmental degradation and depletion of fuel are global concerns today and India is no alien to it. With automobiles accounting for the bulk of petrol and diesel consumption, countries across the world are looking at alternative vehicle technologies - fuel cells, hybrid / electric vehicles, alternate fuels such as CNG etc. Hybrid and electric vehicles have emerged as a viable technology, and several OEMs have launched commercial models. However, in most cases, the price premium over conventional technologies, make these vehicles less affordable. A holistic plan to promote hybrid and electric vehicles also needs to include domestic technology development, as well as local production. The scope of the study was to develop a mission plan for India integrating all these concerns.

Recognising the national importance of hybrid and electric mobility, a three-tier leadership structure has been set up under the overall leadership of Ministry of Heavy Industries to develop the National Hybrid/Electric Mobility plan. It consists of the National Council for Electric Mobility (NCEM), comprising of ministers, leaders from industry and academia and the National Board of Electric mobility (NBEM), comprising of secretary level officials and all stakeholders in the mission. The NBEM and NCEM are ably supported by the National Automotive Board (NAB), which is a body of experts. This study will provide a fact-base for the NBEM and NCEM towards formulating the National Hybrid/ Electric Mobility Plan for the next ten years.
II. PROJECT METHODOLOGY

The project approach focused on understanding all the key aspects related to hybrid / electric vehicle technologies (xEVs), as depicted in Exhibit 1.

The first phase of the study involved understanding of global HEV / BEV vehicle market in terms of global demand and policy levers used by governments to promote xEVs, specifically in two wheeler, three wheeler, four wheeler, buses and light commercial vehicle segments. Also, detailed understanding of the global technology evolution in critical areas such as ICE technology development, developments in start-stop technology, as well as all xEV components (batteries, power electronics, electric motors etc.) was obtained. As battery is the most critical component of xEVs, more emphasis was placed on understanding the cost and price evolution of batteries. This phase provided an extensive knowledge base to benchmark the global market and identify existing and potential issues.

The second phase focused on understanding the Indian HEV / BEV market, supported by extensive primary research across various stakeholders.

These stakeholders can be broadly classified into four categories (Exhibit 2)

- Consumers/Customers
- Institutions which support the requirements of consumer/customer – e.g. vehicle dealers and testing institutions
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- Organizations which develop strategy to meet consumer demands and make necessary investments to develop the end product and infrastructure for it – e.g. – OEMs, component manufacturers, power boards etc.
- Organizations which frame policies for the product – e.g. – Government bodies, industry associations etc.

Exhibit 2 - Stakeholders in the HEV/EV policy

To understand the preference of the consumers, 12 focus group discussions for all vehicle segments were held in the north, east and west zones of the country (Table 2).

Table 2 - Focus Groups Conducted

<table>
<thead>
<tr>
<th>Region</th>
<th>Location</th>
<th>2W</th>
<th>3W</th>
<th>4W</th>
<th>Buses</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>Delhi</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lucknow</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>West</td>
<td>Mumbai</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pune</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>South</td>
<td>Bangalore</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Coimbatore</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>East</td>
<td>Kolkata</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Patna</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

This was followed by a nation-wide survey covering ~7000 consumers across 16 cities (Table 3). 4 tiers of cities were identified based on population and for each tier, the survey was
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conducted in 4 cities. The survey captured various important aspects like - technology awareness and preference, preferred attribute levels (price, mileage, top speed etc.), perception of alternative technology compared to conventional technology, major drivers and barriers to adoption etc. Additionally, a conjoint questionnaire was floated with the survey and analysis performed to capture the sensitivity of consumer preference to parameters like price, running cost, recharge time and range, to obtain true insights into consumer preferences for these attributes.

Table 3 - Consumer Interviews

<table>
<thead>
<tr>
<th>Segment</th>
<th>Tier 1</th>
<th>Tier 2</th>
<th>Tier 3</th>
<th>Tier 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scooter</td>
<td>109</td>
<td>188</td>
<td>97</td>
<td>143</td>
</tr>
<tr>
<td>Bike</td>
<td>444</td>
<td>362</td>
<td>300</td>
<td>249</td>
</tr>
<tr>
<td>3 Wheeler</td>
<td>402</td>
<td>401</td>
<td>402</td>
<td>407</td>
</tr>
<tr>
<td>4 Wheeler</td>
<td>591</td>
<td>712</td>
<td>584</td>
<td>669</td>
</tr>
<tr>
<td>Bus</td>
<td>201</td>
<td>108</td>
<td>63</td>
<td>59</td>
</tr>
<tr>
<td>LCV</td>
<td>96</td>
<td>124</td>
<td>104</td>
<td>107</td>
</tr>
</tbody>
</table>

Note: Tier 1 (Delhi, Mumbai, Kolkata, Chennai), Tier 2 (Lucknow, Ahmedabad, Hyderabad, Guwahati), Tier 3 (Jalandhar, Ranchi, Ajmer, Trivandrum) and Tier 4 (Rohtak, Ujjain, Cuttack and Mangalore)

Source: Nielsen Field Research, Booz & Company analysis

To capture the agenda of the stakeholders on the supply and regulatory side, about 200 interviews were conducted with strategic personnel in the industry and government (Table 4). Apart from this, perspectives of Booz & Company global experts on automotive industry were taken into account. Significant insights into the opportunities and challenges for India were gathered from these interviews.

The stakeholder feedback helped to shape the understanding of consumer acceptability of xEV technologies in India. Consumer preference was captured through conjoint analysis. The sensitivity of consumers to different parameters like price, running cost, range and recharge time was evaluated. Preference and sensitivity variation with demographic parameters like age, occupation, education etc. was also considered. The industry interviews also helped understand the production capability, price-performance evolution of xEVs, and technology capability within the country, along with the potential for xEVs.
# Table 4 - Interview Summary

<table>
<thead>
<tr>
<th>Segment</th>
<th>Interviewee Region/Affiliation</th>
<th>Sample Titles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Booz Experts</td>
<td>• Brazil</td>
<td>• Partner</td>
</tr>
<tr>
<td></td>
<td>• China</td>
<td>• Principal</td>
</tr>
<tr>
<td></td>
<td>• UK</td>
<td>• Senior Executive Advisor</td>
</tr>
<tr>
<td></td>
<td>• France</td>
<td>• Senior Associate</td>
</tr>
<tr>
<td></td>
<td>• Japan</td>
<td>• Director</td>
</tr>
<tr>
<td></td>
<td>• United States</td>
<td>• Chairman</td>
</tr>
<tr>
<td></td>
<td>• Netherlands</td>
<td></td>
</tr>
<tr>
<td>Central Govt.</td>
<td>• Ministry of Heavy Industries and Public Enterprises</td>
<td>• Special Secretary</td>
</tr>
<tr>
<td></td>
<td>• Ministry of Urban Development</td>
<td>• Joint Secretary</td>
</tr>
<tr>
<td></td>
<td>• Ministry of Road Transport &amp; Highways</td>
<td>• Director</td>
</tr>
<tr>
<td></td>
<td>• Ministry of New &amp; Renewable Energy</td>
<td>• Chairman</td>
</tr>
<tr>
<td></td>
<td>• Ministry of Finance</td>
<td></td>
</tr>
<tr>
<td>State &amp; City Governments</td>
<td>• State Gov. of Maharashtra</td>
<td>• Chairman</td>
</tr>
<tr>
<td></td>
<td>• State Gov. of Karnataka</td>
<td>• Principal</td>
</tr>
<tr>
<td></td>
<td>• Karnataka State Road Transport Corporation</td>
<td>• Secretary</td>
</tr>
<tr>
<td></td>
<td>• Govt. of Delhi</td>
<td>• Commissioner</td>
</tr>
<tr>
<td></td>
<td>• Kolkata Municipal Corporation</td>
<td>• Deputy Commissioner</td>
</tr>
<tr>
<td></td>
<td>• Bangalore Metropolitan Transport Corporation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Brihanmumbai Electricity Supply and Transport</td>
<td></td>
</tr>
<tr>
<td>Research Institutions</td>
<td>• Automobile Research Association of India</td>
<td>• President</td>
</tr>
<tr>
<td>and Associations</td>
<td>• Society of Manufacturers of Electric Vehicles</td>
<td>• Chairman</td>
</tr>
<tr>
<td></td>
<td>• Bureau of International Standards</td>
<td>• Director</td>
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<tr>
<td></td>
<td>• The Energy Resources institute</td>
<td>• Executive Director</td>
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<td></td>
<td>• IndianOil Corporation - R&amp;D</td>
<td>• Secretary</td>
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<td></td>
<td>• Bureau of Energy Efficiency</td>
<td>• General</td>
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<tr>
<td></td>
<td>• India Semiconductor Association</td>
<td>• Managing Director</td>
</tr>
<tr>
<td>State Power Boards</td>
<td>• North Delhi Power Limited</td>
<td>• Chairman</td>
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<tr>
<td></td>
<td>• Tamil Nadu Electricity Board</td>
<td>• Managing Director</td>
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<tr>
<td></td>
<td>• Karnataka Power Corporation</td>
<td>• Director</td>
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<tr>
<td>OEMs</td>
<td>• Ashok Leyland</td>
<td>• Managing Director</td>
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<td></td>
<td>• Bajaj Auto</td>
<td>• President</td>
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<td></td>
<td>• General Motors</td>
<td>• Chief Technology Officer</td>
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<td></td>
<td>• Hero Motocorp</td>
<td>• Vice-President</td>
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<td></td>
<td>• Maruti Suzuki</td>
<td>• General Manager</td>
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<td></td>
<td>• TVS</td>
<td>• Manager</td>
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<td></td>
<td>• Electrotherm</td>
<td>• Assistant Manager</td>
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<tr>
<td></td>
<td>• Hero Electric</td>
<td>• Deputy</td>
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<td></td>
<td>• Hyundai Motors</td>
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<td>• Mahindra and Mahindra</td>
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<td>• Mahindra Reva</td>
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<td>• Tata Motors</td>
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<td>• Toyota Kirloskar Motor</td>
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<td>• KPIT Cummins</td>
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<td>• Daimler</td>
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<td>• Kinetic Engineering</td>
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</table>
The third phase involved extensive analysis to develop policy recommendations including demand incentives, supply incentives, R&D investments and infrastructure investments required by each vehicle segment. Along with this, net benefit analysis for each vehicle segment was done to understand the relative potential returns achievable for the country. This was followed by detailing of overall potential benefits achievable through adoption of xEVs, in terms of fuel security, carbon dioxide emissions and employment creation.

Numerous analytical models were used in course of the study. The fuel savings from xEVs was calculated by obtaining inputs on expected vehicle segment sales by 2020, penetration of different technologies in vehicle sales, vehicle miles travelled by each segment and its future evolution, vehicle mileage by each segment and its future evolution (Exhibit 3).
The total cost of ownership model was used to arrive at relative economics of all powertrains, and likely penetration of each (Exhibit 4). In order to arrive at the total cost of ownership of a specific vehicle (2w, 4w etc.) of a specific drivetrain (HEV/PHEV/BEV etc.), the acquisition cost comprising of vehicle and powertrain cost, running cost, maintenance cost and incentives were considered. From the total cost of ownership, the least cost drivetrain for each mobility segment (based on miles travelled) was identified. Based on the assumption that consumers will make the most economic choice, the distribution of drivetrains in incremental sales was calculated leading to total market size for automobiles and penetration per drivetrain.
Exhibit 4 - Total Cost of Ownership Analysis

Note: Price in 2011 refers to expected price if OEMs bring the commercial product to the market based on current price and performance
2) VMT refers to the Total Vehicles Miles Travelled (annual distance travelled in km)
3) The Market penetration is adjusted with a market inertia factor to reflect consumer hesitance while shifting to new xEV technologies
Source: EIA, SIAM, Global Insight, Argonne National Lab, OEMs, expert, dealer interviews, Booz & Company analysis

A carbon dioxide emissions model was developed to calculate the emissions from each power train, and future evolution of emissions (Exhibit 5). Total CO$_2$ emission calculations involved the calculation of emission per vehicle per kilometre by vehicle technology. This has 3 components – the tank to wheel emission which depends on the fuel efficiency of the drivetrain; the well to tank emission which is a function of battery size in addition to fuel efficiency; and the material emissions which are dependent on the vehicle weight. The total emission is the combination of these three components. The three components were individually computed and the total emission per vehicle per kilometre was multiplied with annual average vehicle kilometre driven and total parc to get total emissions. Comparison of emissions of the high gas/HEV scenario and high gas/HEV/BEV scenario with status-quos gave the emission reduction.
III. EXECUTIVE SUMMARY

III.1. RATIONALE FOR ALTERNATIVE POWERTRAIN TECHNOLOGIES: FUEL SECURITY

As per India’s Integrated Energy Policy and TERI, with an expected 8% GDP growth, India’s total primary energy requirements are expected to grow from 650-700 MToE\(^6\) in 2010 to about 1100 – 1200 MToE by 2020. On the other hand, the crude oil production in the country is unlikely to change significantly. Consequently, the deficit between crude oil demand and supply is expected to increase to 4- 5 times the domestic production, leading to increasing imports. This poses a serious challenge to India’s fuel security. The transportation sector, specifically road transportation, accounts for a bulk of the total crude oil consumption. Hence technologies with improved fuel efficiency and alternative fuel can contribute significantly in enhancing fuel security.

III.2. ALTERNATIVE TECHNOLOGIES

Various alternate powertrain technologies are available today with a majority being in the electric vehicle space. Come of the important variants are Hybrid Electric Vehicle (HEV), Plug-In Hybrid Electric Vehicle (PHEV), Extended-Range Electric Vehicle (EREV) and Battery Electric Vehicle (BEV). Collectively, they are referred as xEVs in the document. Hybrid electric vehicles have both an IC engine and an electric drive (powered by a battery), which work in tandem leading to higher fuel efficiency. If the battery is used only when vehicle is started or stopped, along with features such as regenerative braking and limited motor assist, it is classified as mild hybrid. In full hybrids, a battery assists the engine while starting and there is a provision for electric motor drive. These vehicles also have start-stop and regenerative braking capabilities. Plug-in hybrid and extended range electric vehicles have an extended range and an IC engine backup. Plug-in hybrids / extended range electric vehicles may or may not have pure electric range based on future developments in technology. These vehicles require external charging of the battery (through AC mains). Battery electric vehicles run solely on batteries and need to be charged externally. Their driving range is limited by the battery size and capability.

III.3. xEV: GLOBAL TECHNOLOGY EVOLUTION

Sustained R&D efforts have led to significant technological innovations in both the conventional and alternative vehicle space. However, with increasing focus on xEV research

\(^6\) Million Tons of Oil Equivalent
due to their potential environmental and fuel benefits, promising developments across all dimensions of powertrain have been registered. xEV powertrains have become more efficient with developments in engine downsizing (HEV/PHEV) and adaptive cruise control. Also, significant development activity has been carried out in space of non-rare earth material motors. Multi-dimensional research in battery and battery management systems around chemistry, stability, performance, smart charging etc. is being carried out and continued efforts are likely to lead to a favourable cost evolution. In the space of controllers too, better cooling and power management techniques have been developed and a higher level of control integration is being envisaged. These cumulative efforts have led to significant performance improvement and cost reduction in xEVs.

**III.4. Battery Cost Evolution**

Lithium-ion batteries are the current preferred choice for usage in xEVs. They have high energy density and low discharge rates, and hence are able to deliver sustained high performance. The battery maintenance cost is negligible and the lifespan is long as well. However, high price is the issue limits widespread usage.

Technology innovation and scale are important levers that together impact almost 90% of the lithium-ion battery cost. From the technology standpoint, cost could be reduced by identifying cheaper raw materials and safe chemistries for automotive usage. Furthermore, manufacturing processes could be automated and streamlined to improve quality and yield. Scale would impact the production cost by distributing overhead and fixed costs over larger volumes. For instance, the percentage of labour and R&D costs per unit would decrease with increasing production.
SIAM: National Hybrid/Electric Mobility Study

Exhibit 6 - Lithium-ion Battery Price Evolution

Note: Assume technology impacts cost of active materials and other parts like electronics reducing cost by ~50% by 2020; scale effects impact equipment (depreciation), labor, R&D costs; scale based on estimated global uptake of respective powertrain systems and market share of lead battery manufacturer; 2011 costs based on JRC/Duke estimates

Source: MIT Technology Review, JRC, JD Power, Argonne National Lab, Deutsche Bank, Expert Interviews, Booz & Company analysis

Favourable developments in the aforementioned levers could bring down Lithium ion battery costs from the current levels of $500-800/kWh to $325-430/kWh by 2020 (Exhibit 6). In the BEV segment, this would tantamount to a 5% y-o-y decrease, while for HEV and PHEV, the decrease could be up to 7%. With favourable battery cost evolution, there could be significant global sales penetration of xEVs.

III.5. xEV: Global Demand Evolution

Continued innovation efforts could bring xEVs within the ambit of affordability, from where market demand could take off. xEVs could have significant global demand in all vehicle segments by 2020 (Exhibit 7). Riding on existing widespread demand in China, the global penetration of electric 2 wheelers is expected to be about 35% by 2020. In cars and buses too, the xEV penetration levels are expected rise significantly reaching 10-20% by 2020.
III.6. GLOBAL POLICIES

To promote xEVs, global economies have made different choices across policy levers to align with their strategic objectives (Exhibit 8). While US has been focusing on both demand and supply side incentives, with the government directly subsidizing private initiatives, Japan and France have focused on creating charging infrastructure for plug-in hybrid and battery-operated electric vehicles, with limited support to demand- and supply-side incentives.
### Exhibit 8 - E-mobility Models-Comparison of Select Countries

<table>
<thead>
<tr>
<th>Lever</th>
<th>US</th>
<th>China</th>
<th>Japan</th>
<th>France</th>
</tr>
</thead>
<tbody>
<tr>
<td>R&amp;D</td>
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<tr>
<td>Supply Side</td>
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<tr>
<td>Demand-side Incentives</td>
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<tr>
<td>Infrastructure</td>
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</tr>
</tbody>
</table>
| HEV / PHEV / BEV Incentives| • Incentives for HEVs phased out  
• Incentives for PHEVs and BEVs based on battery size | • Only road tax deduction for HEVs  
• Maximum subsidy for BEVs, lesser for PHEVs | • Equal incentives for all xEV technologies  
• Incentives for HEVs <50% compared to PHEVs / BEVs | |
| Proposed Investment        | >$5 B    | >$20 B  | >$1.7 B | >3.5 B  |

**Note:** Japan’s investment is from 1998-2014  
**Source:** Literature Research, Booz & Company analysis

In contrast, China has a comprehensive and large scale program for adoption of e-mobility and plans to spend tens of billions of dollars over the next decade, primarily to support plug-in hybrid and battery electric vehicles (lately, there is talk to support hybrid electric vehicles also).

#### III.7. Stakeholder View

The Indian government is willing to support xEVs with research grants and tax exceptions. The import duty on critical xEV components have already been reduced to a modest level. However, to ensure a progressing degree of localization of the industry, CBU (completely built units) imports are discouraged with a high duty structure. The government is also willing to support xEV with cash subsidies. However, implementation issues make it contentious.

OEMs are broadly aligned with the government on the incentive structure and methodology (Exhibit 9). However, they stress on the importance of cash subsidies to support the fledgling xEV industry.
III.8. CONSUMER RESEARCH

Numerous insights have been generated into the expected buying behaviour in xEV market from the extensive consumer research in India. While, consumers have expressed a high preference for HEVs; PHEV and BEV preference is moderate to low. This is especially due to lack of charging requirement and battery replacement for HEVs. Limited preference for PHEV and BEV is due to low electric range and high battery replacement cost. However, the most important factor affecting buying decision seems to be acquisition price which is reflected by the highest sensitivity of consumer preference on this parameter. For all three technologies, there is significant latent demand at lower price points. This indicates demand incentives are likely to be effective in developing a market for xEVs. Significant sensitivity has been registered around running cost as well, which is an indicator of a strong market for fuel efficient cars. Charging time, however, seems to be a less important issue. Sensitivity around charging time was insignificant. Thus, pilots for public rapid/fast charging terminals should be conducted to monitor adoption before full rollout.

Highest preference for 2 wheeler and 4 wheeler xEVs was expressed in Tier 1 and Tier 2 cities. Low maintenance cost and high mileage were cited as the major drivers for adoption by consumers in these cities. Cash subsidies and battery replacement discounts were the incentives preferred by consumers.
III.9. xEV FORECAST

The future potential for India was arrived at by considering 5 major inputs (Exhibit 10):

- **Fuel Security Impact**: The potential was developed, so as to have a tangible impact on the fuel security objective of the country.
- **Stakeholder inputs**: The potential was developed keeping in mind the current state of industry. Industry’s technological readiness for xEV, the scale required to reach self-sustainability and external support required for the same were evaluated and tied in with government’s views on policies and interventions.

Exhibit 10 - xEV Potential in India: Inputs and Projections

- **Consumer Research**: Significant insights regarding consumer preference and buying patterns were factored in.
- **Price-Performance Evolution**: Price evolution due to technology, inflation etc. were factored and a total cost of ownership analysis was performed to arrive at a latent demand for various powertrains
- **Global Perspective**: Global benchmarks were used to investigate industry and market potential and the expected global penetration was considered.

Based on extensive analysis of the aforementioned parameters, the cumulative potential of xEVs in 2020 appears to be 5-7 million units. The battery operated 2 wheeler segment has

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7 The cited numbers are xEV sales projections (over and above CNG) for 2020 including assumptions for ICE technology improvement and scale effects and represent a steady state. Subsequently similar annual sales are expected. No incentive support is factored beyond 2020
the highest potential with an expected 3.5 – 5 million units in 2020. Hybrid cars, buses and LCVs are expected to penetrate the market reaching 1.3- 1.4 million units. Other battery operated vehicles are expected to reach 0.2 – 0.4 million unit sales in 2020.

However, the market is unlikely to reach the potential on its own owing to several barriers hindering adoption. Government and industry need to support a clear long term roadmap in order to realize this potential for India (Exhibit 11)

Exhibit 11 - Illustrative Roadmap for Electrification

Currently, the solutions available in the market don't meet consumer expectations, and hence the market is at the “infeasible” stage (specifically for xEV 4Ws, buses, 3Ws and LCVs). To achieve the tipping point for the market, the first step is to bridge this price-performance gap for consumers, and bring acceptable products into the market through demand side and supply side interventions. In parallel, the industry also needs to invest in building manufacturing and technology development capabilities. Along with this, power and charging infrastructure investments need to be made to facilitate adoption. This will lead to development of viable solutions in the market for consumers at acceptable price-points. OEMs should be incentivized for local manufacturing. Self-sustainability can be achieved with increasing market penetration beyond which incentives shall not be required.
III.10. Policy Levers

The interventions required to support the growth of the hybrid / electric market can be classified into five areas—fuel efficiency regulations, demand and supply related interventions, research and development support, and infrastructure investments.

At this stage, given the level of maturity of the xEV market, modifying fuel efficiency norms to support xEV growth is not recommended. Once the market has further matured, fuel efficiency norms can be re-examined with xEVs as a new reference point. Segment specific interventions can be made vis-à-vis demand, supply, R&D and infrastructure. Demand side interventions could incentivize xEV sales through cash subsidies to consumers. Also, demand assurance can be created by mandating xEVs in government fleets and public transportation.

On the supply side, the idea is to provide incentives to strengthen the local manufacturing capabilities. Accelerated depreciation and tax holidays could be provided to encourage local assembly and manufacturing. Moreover, the current low import duty structure on critical components could be increased overtime to ensure greater degree of localization. It is essential to invest in R&D to develop India specific solution at a cost advantage to cater to the Indian consumers. This will require efforts from both the government and the automobile industry. Consortium or direct grant models could be examined to ensure a strong local R&D base yielding tangible results.

Moreover, xEV adoption shall depend largely on the existing infrastructural support. Pilots could be conducted to support xEVs and test effectiveness. Investments in charging infrastructure would be required particularly for buses.

With regards to charging infrastructure, the government can play the role of an enabler by providing access to land for setting up charging infrastructure, cheap electricity for xEV recharge, speedy clearances etc. Although commercial investment will be the responsibility of private companies, the government may fund some of these projects on an “equal pain, equal gain” basis, i.e., revenue from joint public-private investments could be split between the two parties reflecting the share of each party’s investment.

Globally, two charging infrastructure models have been deployed with significant success – EV charging stations and battery swapping stations. At EV charging stations batteries can be plugged in to recharge. These charging stations can be set up in communities, apartment complexes, parking garages, workplaces, etc. Coulomb Technology, an electric vehicle
infrastructure company, has deployed several of these charging stations in the USA. At the battery swapping stations the depleted battery can be replaced by a fully charged battery. This swapping process is automated. In this model, the swapping station owns the battery. Better Place has deployed a switchable battery electric taxi project in Tokyo.

Finally, creating awareness about xEV technology among the consumers is a responsibility of the automobile industry. However, government can facilitate this process by providing some incentives at an industry level.

In the following section, the consumer preference and interventions customized to each vehicle segment have been described.

**III.11. FOUR WHEELERS**

**Demand Side**

A field survey of 1800+ consumers across 16 cities in India indicates that ~25-30% of consumers surveyed would prefer xEVs to traditional ICEs if the price-performance expectations are met. Preference for HEVs is the highest whereas BEVs have the lowest preference. Further, xEV uptake is higher in Tier-1 and Tier-2 cities relative to Tier-3 and Tier-4 cities.

Projections based on the total cost of ownership indicate that with suitable incentives four-wheeler xEVs can have significant latent demand by 2020. Demand is forecasted to increase from negligible number of units today to ~1.6-1.7 M units in 2020 with HEVs being the most popular.

Sensitivity across the four key parameters (price, running cost, recharge time and range) was studied as part of conjoint analysis on 1800+ consumers across 16 cities. For typical variations, consumers are highly sensitive to price and running cost of HEV cars. Doubling the price of the HEV car, nearly halves the demand. For PHEVs, among the key parameters, price strongly impacts adoption. Following a similar trend, BEV uptake is largely driven by price (Exhibit 12). Hence, lowering acquisition cost with incentives can be effective in stimulating demand. Incentives can be structured by battery size, technology and minimum performance criteria and can be given to a specific number of vehicles each year.
Exhibit 12 – Latent Demand for BEV Cars (Conjoint Analysis)

Note: Base Price for BEV Car = 8 Lakhs, running cost = 75 paise per km, Charging time = 7 hours, Range = 90 km
Source: Nielsen field research, Booz & Company analysis

On the demand incentive side, the following incentive structure is proposed:

- Mild HEV – ₹25k
- Full HEV – ₹50k
- PHEV - ₹1 lakh
- Low performance BEV – ₹1 lakh
- High performance BEV – ₹1.5 lakh

Subject to localization and quality, incentives could be provided to a total of two lakh vehicles per year for five years and tapered off in the sixth year. Unused incentives could be carried over to the next year.

Demand generation by government can go a long way towards promoting xEVs in 4Ws. Government owns a large fleet of 4 wheelers and demand assurance can be created by mandating procurement of hybrid and electric cars at the central and state level. This will encourage OEMs to venture into xEV manufacturing with a minimum demand assurance being in place.

Supply Side

Addressing the local demand calls for a strong development and manufacturing base. Currently domestic capabilities in powertrain and component development and manufacturing are low. Only a few OEMs are investing in building manufacturing capabilities for xEVs. The local xEV component manufacturing capability in India is also very limited. Interviews with OEMs reveal that battery technology is nascent with no manufacturing capabilities in the country for lithium-ion battery cells.
SIAM: National Hybrid/Electric Mobility Study

A four-phased approach spread over next ten years can be followed to build the manufacturing capability for 4W xEVs in India (Exhibit 13). Investments need to span the entire value chain from research and product development to sourcing and manufacturing.

**Exhibit 13 - Manufacturing Strategy for xEV 4 Wheeler OEMs and Suppliers**

<table>
<thead>
<tr>
<th>Stage 1</th>
<th>Domestic Assembly</th>
<th>1 - 4 yrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research</td>
<td>Product Development</td>
<td>Sourcing</td>
</tr>
<tr>
<td>Initiate investments in R&amp;D and PD centres</td>
<td>Increasing local sourcing</td>
<td>Local assembly of xEVs using imported / local components</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stage 2</th>
<th>Indigenized Products</th>
<th>5 - 8 yrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research</td>
<td>Product Development</td>
<td>Sourcing</td>
</tr>
<tr>
<td>Indigenized components (BMS, transmission system, electric motors etc.)</td>
<td>52-70% local sourcing of xEV components</td>
<td>Custom duty exemptions phased out</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stage 3</th>
<th>Locally Developed Technologies for India</th>
<th>~8 -10 yrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research</td>
<td>Product Development</td>
<td>Sourcing</td>
</tr>
<tr>
<td>Indigenized components (BMS, transmission system, electric motors etc.)</td>
<td>Nearly 100% local sourcing</td>
<td>Local manufacturing of battery cells</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stage 4</th>
<th>Exports</th>
<th>~10 yrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research</td>
<td>Product Development</td>
<td>Sourcing</td>
</tr>
<tr>
<td>Enhance capability of R&amp;D and PD centres, and production plants for exports</td>
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</table>

Source: Industry interviews, Booz & Company analysis

This first stage of development from 2012 to 2016 should strive to strengthen domestic assembly (this assumes that the appropriate policies and incentives are in place by 2012). This can be improved by increasing local sourcing and local assembly of xEVs using imported or local components. Domestic assembly can be promoted by reducing import duty for xEV Completely Knocked Down (CKD) kits. The duty can be tiered depending on the degree of localization, with lower import duties for high localization. The import duty reduction could apply to CKD kits used in xEVs except battery, motor chargers etc. (which currently attract very low import duty). Since this duty reduction does not apply to the entire 4W industry, this structure could be considered as an exception to WTO guidelines (which prevent lower duties tied to localization). However, this is an issue that needs to be debated by the NBEM and NCEM.

The second stage spanning the next 5-8 years calls for developing indigenized products. R&D and product development centers should have attained moderate capabilities by this point with the ability to develop indigenized components (BMS, transmission system, electric motors etc.) leveraging global technology. The third phase, ~8-10 years from now, needs to focus on development of technologies to suit Indian conditions and usage. In this period, industry should look to have high capabilities across the value chain from research to manufacturing and assembly. The fourth stage requires suitable investments to enhance capability of R&D, product development centers and production plans for exports. It needs
to be noted however, that to achieve this vision, timely and concerted efforts by policy makers, OEMs and suppliers are required.

On the manufacturing side, domestic production can be promoted by linking incentives to localization of xEV components. Starting from present state of 0-5% localized (locally manufactured) components, incentives could be modelled to benefit the manufacturers achieving a minimum 5% incremental localization over the next 5 years. Also the current low import duty structure should be phased out over the next 5 years. This will provide an incentive to the OEMs and suppliers to start localizing xEVs.

Domestic assembly can be promoted by reducing import duty for xEV Completely Knocked Down (CKD) kits. The duty can be tiered depending on the degree of localization, with lower import duties for high localization. The import duty reduction could apply to CKD kits used in xEVs except battery, motor chargers etc. which currently attract 5-10% import duty. This reduction can be phased out after five years, to promote local manufacturing of xEV components.

Incentives can be suitably designed to promote local manufacturing as well. Potential incentives include:

- 3-5 year tax holidays to OEMs and component manufacturers for xEV greenfield or brownfield investments
- Greenfield plants for xEVs can be part of National Manufacturing and Investment Zone proposed by the National Manufacturing Policy with:
  - Low cost funding for land as well as power, water and road connectivity
  - Complete import duty exemption for all parts and equipment
  - Exemption from Central Sales tax etc.
- Customs duty and excise exemption for capital equipment used by OEMs for assembly of xEVs
- Accelerated depreciation of capital equipment used by such manufacturers
- Soft loans / grants (1:3 or 1:4 ratio) to OEMs to promote full xEV development

**Research and Development**

Analogous to current manufacturing capabilities, Indian component manufacturers and OEMs have limited R&D capabilities across all the key components. To attain global standards, India can employ a range of technology strategies based on priorities, internal capabilities, competitive intensity and investment needs. R&D capability can be built via
multiple routes including licensing/alliances, acquisitions, joint ventures, and organic development. Interviews indicate that high priority areas for India include technologies like battery cells which will drive affordability and adoption (Exhibit 14). Battery cells and battery management systems form the highest priority areas as they have a great impact on cost and performance. Localized battery systems customized for Indian weather and traffic duty cycles will yield better performance. The next priority is accorded to power electronics (especially for HEVs/ PHEVs) and electric motors. Localized power electronics will yield better performance at a lower cost. Low cost motors can be developed by the use of non-rare earth magnets.

Exhibit 14 - R&D Priorities for India

<table>
<thead>
<tr>
<th>xEV Components</th>
<th>Potential Areas for Research</th>
<th>Priority for India</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery Cell</td>
<td>• Develop low-cost batteries through new chemistries</td>
<td>High affordability</td>
<td>High performance batteries available globally</td>
</tr>
<tr>
<td></td>
<td>• Increase performance of batteries through increased cycles, power density, energy density</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Battery Management System</td>
<td>• Customize for Indian weather and traffic duty cycles</td>
<td>High performance</td>
<td></td>
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<tr>
<td>Power Electronics (Hybrid)</td>
<td>• Develop low-cost and localized power electronics for HEV / PHEV (motor speed controllers, more efficient regenerative braking etc.)</td>
<td></td>
<td>Localized power electronics will yield better performance at lower cost</td>
</tr>
<tr>
<td>Electric Motor</td>
<td>• Develop low-cost motors by use of non rare earth magnets</td>
<td>Increasing cost &amp; availability of rare earth magnets</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Increase energy density of induction based motors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transmission System (Hybrid)</td>
<td>• Develop low-cost technologies e.g. double clutch systems, better integration of components</td>
<td></td>
<td>Lower cost of drivetrain</td>
</tr>
<tr>
<td></td>
<td>• Achieve fuel efficiency and cost competitiveness in advanced automatic transmission</td>
<td></td>
<td>Lack of automatic transmission systems in India</td>
</tr>
</tbody>
</table>

Source: Industry interviews, Booz & Company analysis

While the priorities have been established, the right to win is determined by evaluating current capabilities, investments required and global competitive intensity. Combining the priorities and the right-to-win evaluation yields different technology strategies for various xEV components (Exhibit 15). High priority but hard-to-develop systems like battery cells can be developed by acquiring technologies and partnering with global players. Medium priority and easier to develop technologies like battery management systems, power electronics and electric motor can be developed by organic investment and local consortia. OEMs can strive to improvise on global product development activities in transmission systems or acquire companies on reaching scale.

Joint investments by industry and government of a magnitude of ₹500 crore are required over the next 5 years to build capabilities in battery cell and electric motors. A minimum of
two component validation and testing units are also required leading to additional investment to the tune of ₹50 crore. These test centres can be used by all the OEMs and suppliers to test their xEVs and components.

Hence, implementing these strategies calls for an estimated investment of ~₹550 crores in the next five years. They could be implemented through OEMs, universities and national labs. Universities and national labs could take the lead on nascent technologies like battery cells and electric motors. For more mature systems like BMS, power electronics and transmission systems, component manufacturers and OEMs can take the lead. Government funding for national laboratories and industry can be through multiple routes including consortia and direct R&D grants. These issues should be discussed and finalized during the future meetings of the NBEM and NCEM.

**Infrastructure**

Adequate charging facilities are required to support xEV demand and uptake (Exhibit 16). It is estimated that by 2020, 150-225 MW of extra power generation capacity and investment of ₹750-1000 crore for charging infrastructure may be required to support the xEV potential.
Exhibit 16 - Estimate of Required Power and Charging Infrastructure

### High Gas / HEV Scenario – 4W

- **Extra Generation Required (MW)**: 150
- **Charging Infrastructure Investment (Rs. Crores)**: 750
- **Rapid Chargers**
  - 35
- **Fast Chargers**
  - 122
- **Level 1 Chargers**
  - 175

**Note:** Price per charging station – ₹2,25,000 ($5,000) for fast charging (10% of stations), ₹36,000 ($800) for level 2 charging (20% of stations), ₹18,000 ($400) for level 1 charging (70% of stations). Charging station efficiency = 18 hours per day.

**Source:** Booz & Company analysis

### Summary of Interventions

**Table 5 - Summary of Proposed Interventions - 4W**

<table>
<thead>
<tr>
<th>Lever</th>
<th>Suggested Intervention</th>
<th>Key Agencies Involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand Side</td>
<td>Demand Assurance – Procurement of xEVs for government fleets</td>
<td>Ministry of Heavy Industries, Planning Commission</td>
</tr>
<tr>
<td></td>
<td>Demand Incentives -</td>
<td>Ministry of Heavy Industries, Ministry of Urban Development, Ministry of Finance, Planning Commission</td>
</tr>
<tr>
<td></td>
<td>• Mild HEV – ₹25k</td>
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</tr>
<tr>
<td></td>
<td>• Full HEV – ₹50k</td>
<td></td>
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<tr>
<td></td>
<td>• PHEV - ₹1 lakh</td>
<td></td>
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<tr>
<td></td>
<td>• Low performance BEV – ₹1 lakh</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• High performance BEV – ₹1.5 lakh</td>
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<tr>
<td></td>
<td>to 2 lakh xEV per year for 5 years tapering it off in the 6th year</td>
<td></td>
</tr>
<tr>
<td>Supply Side</td>
<td>• Link incentives to localization of xEV components. Starting with current 0-5% localization, incentives could be modeled to benefit the manufacturers achieving a minimum 5% incremental localization over the next 5 years.</td>
<td>Ministry of Heavy Industries, NMCC, DIPP</td>
</tr>
<tr>
<td></td>
<td>• To promote local manufacturing, benefits similar to NMIZ in the National Manufacturing policy, as well as 3-5 year tax holidays can be provided.</td>
<td></td>
</tr>
</tbody>
</table>
• Other benefits like accelerated depreciation of capital equipment for xEV manufacture, soft loans etc. can also be considered

<table>
<thead>
<tr>
<th>Research &amp; Development</th>
<th>Investments to the tune of 500 crore for battery and motor research and 50 crore for two component validation and testing centers</th>
<th>OEMs and Ministry of Heavy Industries, Department of Science and Technology, MNRE, Ministry of Finance, Planning Commission</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrastructure</td>
<td>150-225 MW additional power generation ₹750 – 1,000 crore for charging infrastructure</td>
<td>Ministry of Power, Ministry of Urban development, Ministry of Road Transport, Ministry of Heavy Industries, Ministry of Finance, Planning Commission</td>
</tr>
</tbody>
</table>

### III.12. Two Wheelers

**Demand Side**

Although there is significant preference for battery operated two-wheelers in India, consumers are highly sensitive to acquisition cost. Sensitivity with respect to four key parameters (price, recharge time, running cost, range) was studied as part of a conjoint analysis across 1800+ consumers in 16 cities (Exhibit 17). Both scooter and bike consumers are most sensitive to changes in price and recharge time. While running cost and range seem to be important parameters in decision making, consumers seemed to be less sensitive to changes within the given range.

**Exhibit 17 - Latent Demand for BEV Scooters (Conjoint Analysis)**

![Preference Indicated % vs Price](image1)

**Price Sensitivity : BEV Scooter**

- Expected attribute level
- Preference indicated %
- Price (Rupees) 50000, 63000, 80000
- Preference Indicated %: 65, 60, 55, 50, 0%

![Preference Indicated % vs Running Cost](image2)

**Running Cost Sensitivity : BEV Scooter**

- Preference indicated %
- Running Cost (Rupees/km) 0.5, 0.6, 0.7, 0.8, 0.9, 1.0
- Preference Indicated %: 57, 56, 55, 54, 53, 52, 51%

![Preference Indicated % vs Recharge Time](image3)

**Recharge Time Sensitivity : BEV Scooter**

- Preference indicated %
- Recharge Time (Hours) 0, 3.0, 7.0
- Preference Indicated %: 66, 59, 56%

![Preference Indicated % vs Range](image4)

**Range Sensitivity : BEV Scooter**

- Preference indicated %
- Range (km) 120, 100, 80, 65, 50
- Preference Indicated %: 57, 57, 56, 56, 55%

**Note:** Base characteristics of BEV scooter: Price ₹63000, Running Cost ₹0.54/km. Charging Time – 7 hrs. Range – 65km. 1355 interviews for scooters across 16 cities; Battery replacement cost factored in running cost.
Source: Nielsen field research, Booz & Company analysis

With acquisition cost strongly impacting customer decision, incentives are required to stimulate initial adoption and develop scale. The acquisition cost needs to be sufficiently low to aid initial adoption to an extent whereby OEMs have sufficient scale to make this self-sustainable. Apart from the overall acquisition cost, subsidies on battery replacement would also be an effective tool to increase adoption as the high cost of battery replacement is a key concern.

The demand incentives for xEV 2 wheelers could be linked to battery size and durability in addition to technology. The following incentive structure has been arrived at:

- Scooters
  - HEV / Low Speed BEV Scooter (0.5 - 1.5 kwh battery) - ₹5k – 7.5k
  - High Speed Low Durability BEV Scooter (1.5 - 2.5 kwh battery) - ₹5k – 7.5k
  - High Speed High Durability BEV Scooter (1.5 - 2.5 kwh battery) - ₹10k – 12.5k
- BEV Motorbikes (>2.5 kwh battery) - ₹15k

Subject to localization and quality, incentives could be provided to a total of 1 million vehicles per year for 5 years and tapered off in the sixth year. Any unused incentive in a year could be rolled over to the subsequent years.

To promote good quality xEVs in two-wheelers and localization, demand incentives should be subject to the OEMs meeting specified conditions. The minimum qualifying quality conditions should include:

- Local assembly of vehicles (no incentives for completely built imported vehicles)
- Adhering to safety and quality standards of an approved institution like ARAI
- Minimum comprehensive warranty on vehicles including batteries

Supply Side

Catering to the domestic demand necessitates strengthening the local manufacturing and supply base. A phased approach (Exhibit 18) could be followed in India for building the manufacturing capability for two-wheeler xEVs.
Manufacturing Strategy for xEV 2 wheelers OEMs and Suppliers

Development across the value chain can be envisaged as a three stage process. In the first stage, local assembly of xEVs using imported or locally manufactured components can be fully strengthened. During second stage, industry should aim to develop indigenized products. Subsequently, the industry needs to enhance capabilities to be globally competitive and further develop R&D, Product Development and production plants for exports.

On the manufacturing side, domestic production can be promoted by linking incentives to localization of xEV components. The Bill of Material can serve as the basis to evaluate the value and degree of localization of xEV components in the vehicle. Localization of lead-acid based BEVs should be relatively easy given that India already has capabilities in lead-acid battery cell. Hence, more stringent criteria for localization should be laid out for supply side incentives. Starting from present state of 30-35% localization, incentives could be modelled to benefit the manufacturers achieving a minimum 5% incremental localization over the next 5 years, thereby reaching 60% local production. Also the current low import duty structure should be phased out over the next 5 years.

As in the case of 4 wheeler xEVs, other incentives like tax holidays to OEMs and component manufacturers, central support for greenfield xEV plants, duty exemption for capital equipment used by OEMs for xEV assembly, soft loans and grants could be extended to xEV 2 wheelers to facilitate production (III.11. Four Wheelers).

R&D

To successfully implement the localization strategy, government and industry need to make investments in R&D, product development and testing infrastructure. Total potential funding required for implementing these strategies is estimated to be ~₹550 crores in the
next five years, similar to 4Ws. Investments should span all the major xEV components – battery cell, battery management system, power electronics, electric motor and transmission system. Periodic reviews of these programs can be conducted to adapt to changing requirements. Beyond investments, collaboration between government and industry on this front forms the keystone for successful indigenization of two-wheeler xEVs.

**Infrastructure Requirements**

Infrastructural support is essential to drive the two wheeler xEV potential to fruition. Compared to other segments, the ease of implementation in two wheelers is relatively higher given the fact that charging infrastructure rollout is not essential. Two wheelers could be charged entirely at home. To support battery recharging of two-wheeler BEVs, given the expected uptake, an estimated 600MW of additional power generation capacity is required.

**Summary of Interventions**

<table>
<thead>
<tr>
<th>Lever</th>
<th>Suggested Intervention</th>
<th>Key Agencies Involved</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demand Side</strong></td>
<td><strong>Demand Incentives</strong> -</td>
<td>Ministry of Heavy Industries, Ministry of Urban Development, Ministry of Finance, Planning Commission</td>
</tr>
<tr>
<td></td>
<td>• Scooters</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- HEV / Low Speed BEV Scooter (0.5 – 1.5 kwh battery) - ₹5k – 7.5k</td>
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</tr>
<tr>
<td></td>
<td>- High Speed Low Durability BEV Scooter (1.5 – 2.5 kwh battery) - ₹5k – 7.5k</td>
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<td>- High Speed High Durability BEV Scooter (1.5 – 2.5 kwh battery) - ₹10k – 12.5k</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- BEV Motorbikes (&gt;2.5 kwh battery) - ₹15k</td>
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<tr>
<td></td>
<td>to 10 lakh xEV per year for 5 years tapering it off in the 6th year</td>
<td></td>
</tr>
<tr>
<td><strong>Supply Side</strong></td>
<td><strong>Link incentives to localization of xEV components. Starting with current 30-35% localization, incentives could be modeled to benefit the manufacturers achieving a minimum 5% incremental localization over the next 5 years</strong></td>
<td>Ministry of Heavy Industries, NMCC, DIPP</td>
</tr>
<tr>
<td></td>
<td><strong>To promote local manufacturing, benefits similar to NMIZ in the National Manufacturing policy, as well as 3-5 year tax holidays can be provided.</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Other benefits like accelerated depreciation of capital equipment for xEV manufacture, soft loans etc. can also be considered</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Research &amp;</strong></td>
<td><strong>Investments to the tune of 500 crore for battery and motor research and 50 crore for two component validation and testing centers</strong></td>
<td>OEMs and Ministry of Heavy Industries, Department of Science and Technology, MNRE,</td>
</tr>
</tbody>
</table>
III.13. BUSES

Demand Side

Demand generation for hybrid/ electric buses would entail mandating a share of new sales in the public intra-city buses and metro feeders to xEVs. The initial demand for xEVs can be built by government bodies such as JNNSURM funding the purchase of the buses.

~170 interviews of bus fleet owners were conducted across 11 cities to understand consumer preferences for premium xEV buses (priced above ₹20 Lakhs). Substantial latent demand exists for xEVs in various cities. Maintenance cost, pick-up and running cost were cited as the top factors considered by consumers while buying xEV buses.

Based on the consumer interviews and a subsequent conjoint analysis, sensitivity was tested for various parameters such as price, running cost, range and recharge time. For xEV buses, consumers were found to be very sensitive to price/ acquisition cost. Hence, incentives on price are essential to generate demand. Moderate sensitivity to running cost was observed for HEV and BEV buses (Exhibit 19).

Exhibit 19 - Latent Demand for HEV Bus (Conjoint Analysis)

![Graph showing preference indicated vs price and running cost sensitivity for HEV buses]

Note: Base Price = 1.0 Crore, Running cost = ₹12.9 per km, Range = 400 km
Source: Nielsen Field Survey, Booz & Company

Cash subsidies (for intra and inter city buses) and toll discounts (for inter-city buses) could prove effective in pushing up xEV bus sales. The incentive structure could be front-loaded to drive adoption. Since there is significant scale effect for xEV buses, the incentives could...
decline over a period of 5-6 years. The following incentive structure per unit has been arrived at:

- HEV - ₹20 lakh at beginning, tapering down to ₹5 lakh
- PHEV - ₹34 lakh at beginning, tapering down to ₹18 lakh
- BEV - ₹37 lakh at beginning, tapering down to ₹20 lakh

Subject to localization and quality, incentives could be given to first 3,000 buses starting 2013. To ensure quality and localization, certain qualifying conditions should be laid out to the OEMs which includes:

- Local assembly of vehicles - Incentives could be handed out based on a minimum level of localization of vehicle and component manufacturing. Completely built imported vehicles should not be incentivized.
- Safety standards - Ensuring that the vehicle meets minimum safety and quality standards. These standards could be set by an agency like ARAI.
- Minimum warranty on vehicles, including batteries.

**Supply Side**

The demand-side incentives should be matched with a robust manufacturing strategy by bus OEMs and suppliers. For building manufacturing capabilities of xEV buses, a 3-stage approach (Exhibit 20) spanning ~8-10 years could help in building a strong supply-side and bridging the current gaps. The focus in the first stage, in the initial 1-4 years, should be on developing high capabilities in local assembly of xEVs using imported or locally manufactured components. The second stage ~5-8 years from now, should focus on developing indigenized components. Focus in the third stage should be on enhancing capabilities of Research and Development and Product Development centres and production plants to supply in the Indian market as well as for exports.
On the manufacturing side, domestic production can be promoted by linking incentives to localization of xEV components. Starting from present state of 0-5% localized components, incentives could be modelled to benefit the manufacturers achieving a minimum 5% incremental localization over the next 5 years, reaching 25-30% by 2018. Also the current low import duty structure for xEV components should be phased out over the next 5 years.

As in the case of 4 wheeler xEVs, other incentives like tax holidays to OEMs and component manufacturers, central support for greenfield xEV plants, duty exemption for capital equipment used by OEMs for xEV assembly, soft loans and grants could be extended to buses to facilitate production (refer to section III.11. Four Wheelers for details).

**Research and Development**

To successfully implement the localization strategy, government and industry need to make investments in Research and Development, Product Development and testing infrastructure. Technology development incentives are essential for battery cells (to decrease their cost), which can also be facilitated by acquisition and alliances. Investments in new product development are essential for battery management system, power electronics and electric motors. Investment in new product research and development of electric motors is expected to be ~₹500 crores over the next five years, which could be split equally between government and industry. Further, ₹80 crores needs to be invested in component and vehicle testing infrastructure (which can be shared by all OEMs and suppliers). The success of the investments would be based on the collaboration between government and industry.

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Infrastructure

Supporting the demand-side incentives and supply capabilities, a sustainable infrastructure is critical. Based on various scenarios an estimated 2-4 MW of extra generation would be required. Charging infrastructure would entail an investment of ₹10-20 crores to build 300-500 charging terminals (Exhibit 21, Exhibit 22).

Exhibit 21 - Infrastructure Requirement - Bus (High Gas/HEV)

Exhibit 22 - Infrastructure Requirement - Bus (High Gas/HEV)

Note: Price per charging station - ₹10,00,000 ($22,000) for fast charging (10% of stations), ₹4,50,000 ($10,000) for level 2 charging (20% of stations), ₹2,00,000 ($4,400) for level 1 charging (70% of stations). Charging station efficiency -18 hours/day; majority of xEV charging is expected to occur in off-peak hours.

Source: Booz & Company analysis

Summary of Interventions

Table 7 - Summary of Proposed Interventions - Buses

<table>
<thead>
<tr>
<th>Lever</th>
<th>Suggested Intervention</th>
<th>Key Agencies Involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand Side</td>
<td>Demand Assurance – Procurement of xEVs for intra-city bus fleets, metro feeders etc.</td>
<td>Ministry of Heavy Industries, Planning Commission</td>
</tr>
<tr>
<td>Demand Incentives</td>
<td>• HEV – ₹20 lakh – 5 lakh</td>
<td>Ministry of Heavy Industries, Ministry of Urban Development, Ministry of Finance, Planning Commission</td>
</tr>
<tr>
<td></td>
<td>• PHEV – ₹34 lakh – 18 lakh</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• BEV - ₹37 lakh – 20 lakh</td>
<td></td>
</tr>
<tr>
<td>Supply Side</td>
<td>Link incentives to localization of xEV components. Starting with current 0-5% localization, incentives could be modeled to benefit the manufacturers achieving a minimum 5% incremental localization over the next 5 years reaching 25-30% by 2018</td>
<td>Ministry of Heavy Industries, NMCC, DIPP</td>
</tr>
</tbody>
</table>
| Research & Development | • Investments to the tune of 500 crore for battery and motor research and 80 crore for two component validation and testing centers  
• To promote local manufacturing, benefits similar to NMIZ in the National Manufacturing policy, as well as 3-5 year tax holidays can be provided.  
• Other benefits like accelerated depreciation of capital equipment for xEV manufacture, soft loans etc. can also be considered | OEMs and Ministry of Heavy Industries, Department of Science and Technology, MNRE, Ministry of Finance, Planning Commission |
| Infrastructure | 2-4 MW additional power generation  
₹10-20 crore for charging infrastructure | Ministry of Power, Ministry of Urban development, Ministry of Road Transport, Ministry of Heavy Industries, Ministry of Finance, Planning Commission |

### III.14. THREE WHEELERS

**Demand Side**

On the demand side, consumer perceptions were captured along several dimensions to understand the adoption preferences for xEV three wheelers. Interviews of over 1600 consumers were conducted to understand their preferences. Maintenance cost, range and running cost were indicated as top factors considered while buying three wheeler xEVs. Consumers have indicated high preference for incentives such as tax reduction and reduced permit. Higher sensitivity to acquisition cost was exhibited in the subsequent conjoint analysis results as compared to running cost and range (kilometres travelled by the vehicle after charging) for BEV three wheelers (Exhibit 23). Three wheeler demand incentives could be given in two ways - free permits and cash subsidies. Subject to localization and quality, first 20,000 BEV three wheelers could be provided with free permits and incentive of ₹10,000 for 5 years, starting 2012.

To ensure quality and localization, certain guidelines/ qualifying conditions should be laid out to the OEMs which includes:

- Local assembly of vehicles
SIAM: National Hybrid/Electric Mobility Study

- Ensuring that the xEV 3-wheeler meets minimum safety and quality standards of vehicles which should be approved by an agency such as ARAI
- Minimum performance guidelines to be met e.g., >80 km range, top speed >30 kmph
- Minimum warranty on vehicles including batteries

Exhibit 23 - Latent Demand for BEV 3 wheeler (Conjoint Analysis)

Note: BEV 3W Base Price = 1.5 Lakh, running cost = ₹1.4 per km, Charging time = 7 hours, Range = 80 km
Source: Nielsen Field Survey, Booz & Company

Supply Side

On the supply side, domestic production can be promoted by linking incentives to localization of xEV components. Supply side incentives could be modelled similar to xEV 2 wheelers and LCVs. Starting from present state of 30-35% localization, incentives could be modelled to benefit the manufacturers achieving a minimum 5% incremental localization over the next 5 years, thereby reaching 60% local production. Also the current low import duty structure should be phased out over the next 5 years.

As in the case of 4 wheeler xEVs, other incentives like tax holidays to OEMs and component manufacturers, central support for greenfield xEV plants, duty exemption for capital equipment used by OEMs for xEV assembly, soft loans and grants could be extended to three wheelers to facilitate production (refer to section III.11. Four Wheelers for details).
Infrastructure

Electricity generation requirements would be 10-15MW, based on scenarios of High Gas/HEV/BEV 3 wheelers. However, it would entail investments of ₹50-75 crore for charging infrastructure (Exhibit 24, Exhibit 25).

**Exhibit 24 - Infrastructure Requirement - 3 wheeler (High Gas/HEV)**

Extra Generation Required (MW) | Charging Infrastructure Investment (Rs. Crores) | # Charging Terminals (in ’000)
--- | --- | ---
10 | 50 | 11

Majority of xEV charging is expected to occur in off-peak hours

2020 - With 20% Peak Charging

**Exhibit 25 - Infrastructure Requirement - 3 wheeler (High Gas/HEV/BEV)**

Extra Generation Required (MW) | Charging Infrastructure Investment (Rs. Crores) | # Charging Terminals (in ’000)
--- | --- | ---
15 | 75 | 18

Rapid Chargers
Fast Chargers
Level 1 Chargers

2020 - With 20% Peak Charging

Note: Price per charging station – ₹2,25,000 ($5,000) for fast charging (10% of stations), ₹36,000 ($800) for level 2 charging (20% of stations), ₹18,000 ($400) for level 1 charging (70% of stations). Charging station efficiency = 18 hours per day.

Source: OEM Interviews, Booz & Company analysis

### Summary of Interventions

**Table 8 - Summary of Proposed Interventions - 3W**

<table>
<thead>
<tr>
<th>Lever</th>
<th>Suggested Intervention</th>
<th>Key Agencies Involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand Side</td>
<td>Demand Incentives -</td>
<td>Ministry of Heavy Industries, Ministry of Urban Development, Ministry of Finance, Planning Commission</td>
</tr>
<tr>
<td></td>
<td>• Free permits</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Cash incentives – ₹10,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>to 20000 BEV 3 wheeler per year for 5 years starting 2012</td>
<td></td>
</tr>
<tr>
<td>Supply Side</td>
<td>• Link incentives to localization of xEV components. Starting with current 30-35% localization, incentives could be modeled to benefit the manufacturers achieving a minimum 5% incremental localization over the next 5 years</td>
<td>Ministry of Heavy Industries, NMCC, DIPP</td>
</tr>
<tr>
<td></td>
<td>• To promote local manufacturing, benefits similar to NMIZ in the National Manufacturing policy, as well as 3-</td>
<td></td>
</tr>
</tbody>
</table>
III.15. Light Commercial Vehicles

Demand Side

Interviews of ~430 consumers were conducted to capture their perceptions and preferences for LCVs. A subsequent conjoint analysis was performed to test sensitivity along various parameters such as price, running cost and range. While high consumer sensitivity to price and running cost was observed for xEV LCVs, recharge time and range sensitivities were low (Exhibit 26). Consequently, incentive on price is likely to be effective in generating demand. The following incentive structure per unit has been arrived at:

- HEV - ₹50k
- BEV - ₹1 lakh

Also, improving fuel efficiency could push up hybrid LCV sales. To ensure quality and localization, certain guidelines/ qualifying conditions should be laid out to the OEMs which include:

- Local assembly of vehicles
- Ensuring that the LCVs meet minimum safety and quality standards of vehicles which should be approved by an agency such as ARAI
- Minimum warranty on vehicles including batteries
SIAM: National Hybrid/Electric Mobility Study

Exhibit 26 – Latent Demand of Battery Electric LCV (Conjoint Analysis)

Note: Base Price = 5.23 Lakh, Running cost = ₹2.18 per km, Charging time = 7 hours, Range = 55 km
Source: Nielsen Field Survey, Booz & Company analysis

To ensure quality and localization, certain guidelines/ qualifying conditions should be laid out to the OEMs which include:

- Local assembly of vehicles
- Ensuring that the LCVs meet minimum safety and quality standards of vehicles which should be approved by an agency such as ARAI
- Minimum warranty on vehicles including batteries

Supply Side

Along with the demand-side incentives discussed, a robust supply-side strategy is essential. For building manufacturing capability for xEV LCVs, a phased approach could be followed in India (Exhibit 27). While the current capabilities are limited, a 3-stage process spanning ~8-10 years can help in bridging the current gaps.

The focus in the first stage, in the initial 1-4 years, should be on developing high capabilities in local assembly of xEVs using imported or locally manufactured components. The second stage ~5-8 years from now, could focus on developing indigenized products. The third and the final stage, ~8-10 years from start, should locally develop technologies for India and exports. These timelines assume that appropriate policies are in place within a year and the Government and OEMs/Suppliers are working actively towards implementing a roadmap for hybridization / electrification.
On the manufacturing side, domestic production can be promoted by linking incentives to localization of xEV components. LCVs will mostly be lead-acid battery based, which makes localization relatively easier. Hence supply side incentives could be modelled similar to xEV 2 wheelers. Starting from present state of 30-35% localization, incentives could be modelled to benefit the manufacturers achieving a minimum 5% incremental localization over the next 5 years, thereby reaching 60% local production. Also the current low import duty structure should be phased out over the next 5 years.

As in the case of 4 wheeler xEVs, other incentives like tax holidays to OEMs and component manufacturers, central support for greenfield xEV plants, duty exemption for capital equipment used by OEMs for xEV assembly, soft loans and grants could be extended to LCVs to facilitate production (refer to section III.11. Four Wheelersfor details).

**Infrastructure**

For supporting the demand-side incentives and supply capabilities, sustainable infrastructure is critical. Based on the two scenarios of adoption – high gas/HEV and high gas/HEV/BEV, an estimated 10-20 MW of extra generation would be required. Charging infrastructure would entail an investment of ₹75-120 crores to build 18,000-27,000 charging terminals (Exhibit 28, Exhibit 29).
SIAM: National Hybrid/Electric Mobility Study

Exhibit 28 - Infrastructure Requirement - LCV (High Gas/HEV)

Extra Generation Required (MW) | Charging Infrastructure Investment (Rs. Crores) | # Charging Terminals (in '000)
--- | --- | ---
10 (2020 - With 20% Peak Charging) | 75 (2020) | 18

Majority of xEV charging is expected to occur in off-peak hours.

Exhibit 29 - Infrastructure Requirement - LCV (High Gas/HEV/BEV)

Extra Generation Required (MW) | Charging Infrastructure Investment (Rs. Crores) | # Charging Terminals (in '000)
--- | --- | ---
20 (2020 - With 20% Peak Charging) | 120 (2020) | 27

Note: Price per charging station – ₹2,25,000 ($5,000) for fast charging (10% of stations), ₹36,000 ($800) for level 2 charging (20% of stations), ₹18,000 ($400) for level 1 charging (70% of stations). Charging station efficiency = 18 hours per day.

Source: Booz & Company analysis

Summary of Interventions

Table 9 - Summary of Proposed Interventions - LCV

<table>
<thead>
<tr>
<th>Lever</th>
<th>Suggested Intervention</th>
<th>Key Agencies Involved</th>
</tr>
</thead>
</table>
| Demand Side | Demand Incentives -  
  - HEV – ₹50,000  
  - BEV – ₹1,00,000  
  to 50000 units per year for 5 years starting 2013 | Ministry of Heavy Industries, Ministry of Urban Development, Ministry of Finance, Planning Commission |
| Supply Side | Link incentives to localization of xEV components. Starting with current 30-35% localization, incentives could be modeled to benefit the manufacturers achieving a minimum 5% incremental localization over the next 5 years  
  - To promote local manufacturing, benefits similar to NMIIZ in the National Manufacturing policy, as well as 3-5 year tax holidays can be provided.  
  - Other benefits like accelerated depreciation of capital equipment for xEV manufacture, soft loans etc. can also be considered | Ministry of Heavy Industries, NMCC, DIPP |
### III.16. Demand Generation

Cash incentives alone may not be effective in promoting localization of xEV production as component suppliers would not invest in setting up infrastructure for local production unless there is sufficient demand volume. Subsequently cash incentives, being linked to localization of components, would not be disbursed. This chicken-and-egg situation will continue unless sufficient upfront demand is created for xEVs, encouraging component manufacturers to localize production.

Demand assurance could be generated by mandating xEVs in government fleets. Procurement of xEVs for central and state government car fleets would create an estimated demand assurance of 90000 units annually. A share of new sales in the public intra-city buses and metro feeders could also be mandated to xEVs. State Transport Utilities (STUs) purchase ~22,000 buses per annum of which 50% are intra-city, a share of 10-20% can be allocated to xEV buses. Government LCV fleets in niche applications like airports etc. could be completely electrified. The cumulative demand assurance across all vehicle segments through government procurement mandates will lead to significant scale for component suppliers to invest in setting up local infrastructure for manufacturing.

Government mandates have been effective in the past in promoting CNG adoption in local transport. Initial demand was created by a mandate to convert all public road transport (buses and 3 wheelers) in Delhi to CNG technology and today India, with 1.1 million vehicles, has the fifth largest CNG vehicle fleet in the world. New Delhi is home to the largest fleet of CNG public transportation vehicles in the world. A combination of incentives and mandates could drive India towards a strong status in xEV technology as well.
### III.17. Impact

Achieving the potential laid out will result in significant benefits for India. Annual liquid fuel (petrol/diesel) savings of 2.2-2.5 million tons worth ₹13,000 – 14,000 crore can be achieved by targeting the sales figure of 7 million units in 2020\(^8\). Bulk of these fuel savings (>50%) could come from battery electric two wheelers. Four wheelers are also expected to account for 20-25% of these fuel savings, followed by buses, light commercial vehicles and three wheelers in decreasing order of fuel savings. CNG and xEV adoption will also help achieve potential reduction of 1.3% - 1.5% in CO\(_2\) emissions\(^9\).

Local manufacturing capabilities could be developed through supply side incentives which would lead to incremental 60k – 65k in manufacturing employment opportunities by 2020. Assuming each manufacturing job creates an additional 3 service jobs, an additional ~180K to 200K jobs are feasible. These service jobs will be focussed on operation and maintenance of electronic equipment, and hence will be over and above the jobs due to ICE technology rather than being a replacement. Demand incentives, along with support for R&D and local manufacturing can facilitate creation of affordable xEV solutions which can meet consumer expectations and build a self-sustainable industry. Thus the return on investment is reasonably high. With total investments of ₹20,000 – 23,000 crore, net benefits of ₹39,000 – ₹43,000 crore can be achieved.

Adoption of battery 2 wheelers seems to have the highest return across all segments (Table 11) and given the current capabilities in the country, unlocking the potential for electric 2 wheelers would be less challenging.

---

\(^8\) Fuel savings due to xEVs is well to wheel and captures the fuel efficiency improvement of ICE

\(^9\) A monetary number to carbon emission reduction has not been assigned
### Table 11 - Summary of Benefits

<table>
<thead>
<tr>
<th>Vehicle Segment</th>
<th>2W</th>
<th>3W</th>
<th>4W</th>
<th>Bus</th>
<th>LCV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario</td>
<td>High HEV</td>
<td>High HEV</td>
<td>High HEV</td>
<td>High HEV</td>
<td>High HEV</td>
</tr>
<tr>
<td></td>
<td>High HEV/BEV</td>
<td>High HEV/BEV</td>
<td>High HEV/BEV</td>
<td>High HEV/BEV</td>
<td>High HEV/BEV</td>
</tr>
<tr>
<td>NPV (₹Crore)</td>
<td>28000</td>
<td>1200</td>
<td>1700</td>
<td>4800</td>
<td>7100</td>
</tr>
<tr>
<td></td>
<td>3300</td>
<td>3700</td>
<td>1500</td>
<td>2700</td>
<td></td>
</tr>
<tr>
<td>Cumulative liquid fuel savings ('11-'20)</td>
<td>4.9 MT</td>
<td>0.2 MT</td>
<td>0.3 MT</td>
<td>1.1 MT</td>
<td>1.6 MT</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.5 MT</td>
<td>0.6 MT</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.3 MT</td>
<td>0.5 MT</td>
</tr>
<tr>
<td>Ease of Implementation</td>
<td>Moderate - High</td>
<td>Moderate</td>
<td>Low - Moderate</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td>₹Demand incentives</td>
<td>5200</td>
<td>430</td>
<td>710</td>
<td>5000</td>
<td>5650</td>
</tr>
<tr>
<td></td>
<td>500</td>
<td>550</td>
<td>1300</td>
<td>1500</td>
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</tr>
<tr>
<td>Other Investments</td>
<td>5000</td>
<td>110</td>
<td>180</td>
<td>2250</td>
<td>3050</td>
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<tr>
<td></td>
<td>600</td>
<td>630</td>
<td>150</td>
<td>250</td>
<td></td>
</tr>
</tbody>
</table>

10 Other investments include investments in R&D, power infrastructure, charging infrastructure (wherever applicable) and electricity generation.
IV. CASE FOR CHANGE

The primary objective for adoption of alternative technologies in general and xEVs in particular is to decrease oil consumption. There is serious deficit between the domestic demand and production and the country largely depends on crude oil imports.

Considering an 8% GDP growth rate, the total primary energy requirements are expected to rise from 650-700 MToE in 2010 to 1100-1200 MToE in 2020 (Exhibit 30). This would mean that the crude oil requirements shall increase from 160-170 MMT in 2010 to 220-230 MMT in 2020, while the expected production level is not expected to change much. Consequently, the deficit between production and consumption would be about 4-5 times the production. It is therefore an urgent requirement to look at ways to bridge this deficit.

Exhibit 30 - Energy Requirements and Crude Deficit

In order to meet the fuel security goals, concerted efforts are required across the range of solutions available (Exhibit 31). There is a need to increase access to liquid fuel reserves and to utilize the available liquid fuel resources more efficiently. Acquiring overseas assets and tapping deep water reserves could be the potential steps in this direction. Fuel substitution could be another alternative. Natural gas and bio-fuel based technologies could be developed to substitute them for liquid fuel in various operations. Utilization of existing resources can be made more efficient by using intelligent systems in applications like road...
transport. Improving public transport would encourage people to use it over personal vehicles which can be an important step in efficient fuel utilization.

Exhibit 31 - Possible Fuel Security Initiatives

Exploring alternative mobility solutions could be an important way to reduce excessive dependence on liquid fuels. The automobile sector, specifically the road transport sector, is the largest liquid fuel user. Hence any tangible fuel saving initiative would require a review of the usage patterns and explore ways to reduce consumption in the road transport industry. CNG and bio-fuel based transportation solutions have been identified as possible alternatives. However, the thrust globally is on electric alternatives. Broadly the electric mobility solutions can be classified into hybrids (HEV), plug-in hybrids (PHEV) and battery electric vehicles (BEV). The focus of this study is to develop a roadmap for these electric solutions in India, focussing on solutions tailored for the country. There are significant benefits in terms of liquid fuel savings and emission reductions as will be explained in the following chapters.

It is essential to customize the xEV solutions to the local consumer and conditions. India is a unique market with its own set of complexities. Affordability and value for money are important parameters on which consumers base their choice. This is evident from the higher sale of 2 wheelers compared to other segments and high penetration of small cars. Mini and compact cars form ~75% of total passenger car sales.

The driving conditions are difficult in India due to lack of sufficient road infrastructure, high traffic, congestion etc. Coupling the price sensitivity and condition requirements, we are
looking at solutions that are cheap and sturdy. On top of it, India has 8-10% power deficit on an average. The bottom-line is – it is not easy to replicate solutions from other markets in India. The products have to be developed specifically keeping in mind the consumer preference and infrastructural realities. However, a study of global markets and products shall give a good starting point to the Indian vision, setting up appropriate benchmarks in different dimensions of electric mobility.
V. GLOBAL MARKET AND TECHNOLOGY PERSPECTIVES

V.1. GLOBAL DEMAND

Significant activities in research and development combined with increasing awareness of benefits have developed a growing market around the world. Cost and technology evolution are expected to lead to enhanced penetration in the next 10 years. In the following sections, the global demand trends and their drivers for xEV 2 wheelers, 4 wheelers and buses are discussed.

V.1.1. 4 wheelers

Global demand for 4 wheeler xEVs has a high degree of uncertainty - based on different technology scenarios, the range can vary between 5 million and 13 million units in 2020. There is a high degree of market uncertainty, primarily because both demand and supply sides are immature. xEV technology is relatively immature and is available at a significant premium to the conventional technology. Also, the future technology and price evolution is not clear, hence forecasting a relatively tight sales range is difficult. 4 wheeler xEVs are typically expected to use lithium-ion batteries which have a very high current cost. The price evolution of Lithium batteries are going to affect the xEV acquisition and running price significantly and therefore their demand as well. However, there is great uncertainty in Lithium battery price evolution which makes the entire picture somewhat hazy.

There is an expectation of significant penetration of xEVs in the passenger 4 wheeler vehicle space owing to their multiple benefits. The global demand is expected to grow at a CAGR of 18-30% in the next 10 years (Exhibit 32). xEVs are expected to capture 7-19% of global 4W incremental sales by 2020.

SIAM: National Hybrid/Electric Mobility Study

Exhibit 32 - Global Demand Projection - 4 wheelers

Note: 4Ws are comprised of passenger vehicles in the above analysis. Passenger vehicles include all passenger cars, SUV/CUVs, and minivans. In the United States, pickup trucks are also considered passenger vehicles

1) Upper range calculations based on Deutsche Bank data

Source: JD Power - Drive Green 2020, JD Power - Global Engine and Transmission Forecast, Deutsche Bank - Electric Cars Plugged In 2, Booz & Company analysis

US and Europe are expected to have the greatest penetration of 4 wheeler xEVs given their strong focus on emission control and liquid fuel savings. Japan has made significant technological breakthroughs with Toyota leading the way in hybrid and plug-in hybrid technologies and is expected to have a significant number of xEV units by 2020. China seems an uncertain market. Although, China has capabilities in electric 2 wheeler space, these are focussed on lead-acid battery based solutions. In the xEV four wheeler market lead-acid solutions may not be sustainable as the volume and size of battery required to power the vehicle would be too large. There is significant uncertainty over whether China will choose to focus on investments related to lithium battery technology for four wheelers.

V.1.2. 2 wheelers

This segment is at an advantage compared to others because there is already a significant adoption of two-wheelers in China, pushing the global xEV penetration to ~40%. Moreover, significant improvement in xEV 2 wheeler penetration is expected over the next 10 years (Exhibit 33).

---

12 China has significantly revised its xEV targets from 10 million units to 1.8 million units (2020) with OEMs like BYD not meeting their targets. Since most components are imported, cars are expensive even after subsidies.
The current demand projection of 17 million units is expected to rise to 27 million units in 2020, maintaining a 5% CAGR. The majority of demand is expected to arise from Asia Pacific. China is expected to have maximum demand, accounting for about two-thirds of the total global demand. 95% of the total demand is expected to come from Asia-Pacific.

While the current penetration of electric 2 wheelers in China is close to 75%, it is expected to decline over time reaching 68% by 2020. This is attributed mainly to safety concerns and change in licencing rules.

**V.1.3. Buses**

There are expectations of significant achievements in the domain of electric buses by 2020 (Exhibit 34). The xEV bus sales are expected to grow at 22% CAGR reaching ~1.1 – 1.2 lakh units in 2020. The penetration is also expected to rise from the current 5% to 20% in 2020.
China is expected to lead the global electrification efforts in buses by developing a strong electric bus national market driven by pollution reduction and an export market, commanding 45% of the total sales share in 2020. Penetration of electric bus in China is expected to rise from the current 4% to about 24% in 2020.

V.2. POLICY

In order to promote electric mobility, several policy levers have been tried by countries across the world. While some have chosen to focus on demand side incentives, others have chosen to create a demand assurance to encourage xEV manufacturing. Mostly, a careful mix of various policy measures has been implemented. In the following section, the various levers are introduced followed by case studies of policy measures of a few representative countries.

V.2.1. Key Policy Levers

There are five key policy levers that have been employed by governments to drive xEV demand globally:

**Fuel efficiency and emission regulations:** Various regulations have already been put in place to ensure higher standards in fuel efficiency thereby driving OEMs towards production of more fuel efficient vehicles. At this stage, given the level of maturity of the xEV market, modifying fuel efficiency norms to support xEV growth is not recommended.
Once the market has further matured, fuel efficiency norms can be re-examined with xEVs as a new reference point.

**Research and Development:** Large investments in xEV Research and Development activities have either been executed or are planned. National laboratories have been set up to focus on xEV research and testing in partnership with leading automotive and battery manufacturers, and they are doing pioneering work in US and China. Educational institutes are encouraged to carry out research in alternative technology space. Specialized courses in xEV technologies are being taught in US and Chinese universities.

**Supply side incentives:** Supply side incentives are meant to support the OEM or component suppliers of xEVs. They have been disseminated in various ways. Demand assurance has been created in some countries through government fleet procurements. Substantial research grants have been provided to industry to carry out R&D in battery cells and electric motors through consortiums and direct grants. Cash subsidies based on quality assurance are another form of supply side incentives. One of the common ways in which supply incentives are given is tax incentive. Several countries follow a policy of administering low import duty and sales tax on critical xEV components like battery, BMS, motor, controller etc.

**Demand side incentives:** Demand side incentives are meant to support the end customer to drive demand for xEVs. The most common way is to provide cash subsidies on acquisition price of the vehicle to make it more affordable. Subsidies could be handed out to customers for battery replacement as well. Tax holidays are other ways to provide demand incentives. In some countries, the customer is spared of sales and road taxes or has to pay much less taxes compared to conventional vehicles. Other ways could be to provide concessions on daily operation - like toll tax reduction, parking charge concession, dedicated lanes, preferential parking, free electricity for charging etc.

**Infrastructure support:** Infrastructural support is essential to develop a strong xEV market. Realising its importance, several countries around the world have started providing subsidies to strengthen the infrastructure. Direct subsidies for charging station and battery swapping stations are being provided at several places globally.

A strong partnership model is required to efficiently regulate the policy levers mentioned above. Public – Private – Partnership models and Joint Ventures are the preferred ways
globally. In the following sections, various initiatives across different policy levers by US, China, Japan and France have been presented.

V.2.2. United States

The United States has been focussing on both demand and supply side incentives to promote the local xEV market. The government is directly subsidizing the private initiatives to encourage the production and usage of xEVs.

On the supply side, the federal government aims to buy only alternative-fuel vehicles for its fleets by 2015. This will create significant demand assurance for OEMs to venture into production at a sustainable scale. Moreover, the US Department of Energy has provided more than $ 2.4 billion as loans to OEMs like Ford, Nissan etc. to facilitate production of xEVs.

Research and Developmental work in alternative technology is a big focus area for US. More than $2.5 billion have been disbursed through Department of Energy as research grants. These grants are awarded through a process of competitive bidding of projects in key focus areas and are disbursed on a payback basis i.e. the progress is monitored by the government periodically and the spend in that particular period is reimbursed. This ensures that the best proposals are supported and progress is monitored regularly.

In addition to providing research grants, the US government is focussing on R&D through national labs. Argonne National Laboratory is a premier research institution doing pioneering research in EV technology. It has also set up a testing base to evaluate performance of emerging xEV technologies on various parameters.

On the demand side, the government has provides tax credits of upto $ 7.5k for purchase of xEVs. In addition to direct cash subsidies, income tax credits and sales tax exemptions have been administered in various states. Free access to high occupancy vehicle lanes in several states and free parking for EVs are other policy measures used to incentivize demand of xEVs.

There is substantial investment to develop infrastructural support as well. Around $ 400 million have been assigned to set up 15,000 charging stations in 15 cities across US, including cities like Chicago and LA.

Besides xEV specific measures, fuel efficiency and emission norms have been made more stringent in general. Federal standards are being implemented to push OEMs to improve fleet performance by 2020. The Corporate Average Fuel Economy (CAFE) is a federal
This information is confidential and was prepared by Booz & Company solely for the use of our client; it is not to be relied on by any third party without Booz's prior written consent.
Exhibit 36 depicts the partnership model that is followed in US between the government and other stakeholders. The government directly subsidizes private initiatives for research and development, manufacturing and infrastructure through grants. Consortium and direct grant models are supported for R&D activities. In addition it directly reaches out to consumers through cash and tax subsidies. Joint ventures between OEMs, infrastructure developers and utilities have been developed to deploy charging networks. In essence, US has a strong participation from all segments of the value chain and regulatory bodies.

**Exhibit 36 - Collaboration Model - US**

Source: ICCT, Literature Research, Booz & Company analysis

**V.2.3. China**

China has a comprehensive and large scale program for adoption of electric mobility and aims to have 5 million xEVs by 2020. It also aims to add 1 million xEVs every year following 2020 and reach xEV penetration level of 20-30% by 2030. And in order to achieve this target, large scale investments have been planned.

Around $15 billion is earmarked over the next 3 years for research and development activities. The research grants are disbursed phase wise through the 863 program. The projects are evaluated over a period and only the more successful ones qualify for grants in the next phase. Government adopts a project management system and evaluates budgets and cost accounts.

On the supply side, the regulations come as both incentives and penalties. There are progressive taxes on vehicle manufacturers based on engine size. The tax rate on small
vehicles was cut from 5% to 3% in 2005, while the tax rate on vehicles with large engine size was raised from 8% to 20%. In order to facilitate xEV production, $7 – 9k is directly paid to OEMs by the government.

Similarly on the demand side there are penalties in the form of progressive sales tax on vehicles by engine sizes. In addition there are subsidies to private purchase of xEVs of $440/kwh up to $8800 for BEVs and $7400 for PHEVs. Acquisition taxes on BEVs and PHEVs have been removed.

$4.4 billion has been allocated for conducting pilot projects over the next 10 years. Moreover, 5 billion has been earmarked for deployment of more than 500,000 public chargers. State utilities have been investing in charging infrastructure deployment to support electric mobility.

In addition to the technology specific incentives and penalties, fuel efficiency and emission norms have been made even more stringent to discourage polluting vehicles. Only Europe and Japan have more stringent regulations than China. With the deployment of its third phase of fuel economy regulations in 2010, the fuel efficiency standards for passenger vehicles in 2015 have been announced to be 7L/100 km along with CO2 emissions of 167 g/km. The new standards are designed to take volume-weight average (mpg) from 37 in 2010 to 42.2 in 2015.

Exhibit 37 - Collaboration Model - China

Source: ICCT, Literature Research, Booz & Company analysis

Government collaborates with most stakeholders to deploy these policy initiatives. R&D investments are mostly in the form of government grants. China follows a public-private-
partnership model for infrastructural development. Joint ventures exist between State electricity companies and battery manufacturers for deployment of charging infrastructure. Exhibit 37 depicts the Chinese collaboration model.

However, in spite of extensive investments in xEVs, China’s policies have not been effective in transforming the market. Most xEV components are imported, due to which there is significant price premium over conventional vehicles. Indigenous technology development could reduce prices by about 75%. However, China seems to be weak at basic R&D. Moreover, power for xEVs is obtained from highly polluting coal-fired stations, and hence there is lack of any substantial improvement in the environment. Due to all these reasons, China has started re-evaluating its BEV-focused strategy.

V.2.4. Japan

Japan aims at having 2 million xEV vehicles by 2025. In order to achieve this, significant investments in infrastructure development are being made in addition to moderate R&D support and incentives. Government has plans to set up 15,000 charging stations in Japan by 2015. There is also provision of mobile charging stations in areas where there is no charging station.

On the demand side, subsidies to the tune of $2,700 are provided for new xEVs when the old car is scrapped and ~$1,100 is provided without scrapping. New xEVs are exempt from acquisition and road taxes, while old xEVs have to pay reduced acquisition taxes. On the supply side, there are progressive taxes on vehicle manufacturers based on engine size.

$250 million is earmarked for research and development activity over the next 3 years for R&D on vehicles and components in Japan. Subsidy for the establishment of Clean Energy Vehicles refueling facilities is provided. In addition, the government is funding demonstration projects for low-pollution vehicles including car-sharing and station car. However, a significant chunk of R&D activity is carried out by OEMs like Toyota themselves. They have collaboration with research and academic institutes to conduct joint R&D.

Japan has the most stringent fuel efficiency norms. The 2015 targets for passenger cars is 16.8 kmpl. For light trucks and small buses, it is 15.2 kmpl and 8.9 kmpl respectively. This amounts to a near 24% increase over the 2004 performance parameters.
The Japanese collaboration model is mostly public-private partnership (Exhibit 38). Government is collaborating with US and PPPs for Okinawa smart-grid pilot. Moreover, there are collaborative experiments in the area of battery swapping, e.g. Better Place has started setting up battery swapping stations for electric taxis.

**V.2.5. France**

France is aiming at a cumulative adoption of 2 million xEVs by 2020. To achieve this target the government is providing customer incentives in addition to developing public charging infrastructure.

The National Electric Vehicle Plan launched in 2009 has set aside € 400 million for R&D on batteries. Besides, € 125 million has been earmarked for developing lithium ion battery manufacturing facility. On the supply side, through a consortium of major industries and government agencies, purchase of 1,00,000 EVs are planned.

On the demand side, xEVs are eligible for rebates upto $8000. xEVs are also exempted of registration, company car tax, congestion charges, inner-city parking etc. Moreover, no tax is levied on electricity used for charging xEVs.

Extensive investments are planned for developing charging infrastructure to support xEVs. $2 billion investment plans have been chalked out for establishment of a recharging network of 1 million charging points by 2015.
In addition to these direct and indirect policy levers, the new EU emission norms are expected to increase adoption of electric and hybrid technologies. With the adoption of Euro 5 standards, the particulate matter emissions and NOx emissions by diesel engines have to be reduced by 80% and 28% respectively. Euro 6 standards will mandate an additional 50% reduction in NOx levels over Euro 5. The technology independent greenhouse gas emission laws with 26% lesser CO₂ levels by 2020, are also expected to drive usage of alternative fuel technology. In the first phase, the fleet wide average GHG emission standard has been fixed as 130 g/km. Vehicles with emissions less than 50 g/km have been proposed to receive credits and eco-innovation credits are planned for innovative GHG reducing technologies. The long term goal is to achieve 95 g/km emission standard by 2020.

The collaboration model followed in France is that of a PPP for infrastructural development (Exhibit 39). In addition, the state utilities, OEMs and battery suppliers collaborate through joint ventures. Furthermore there are JVs between foreign electric companies and local investment firms.

Source: ICCT, Literature Research, Booz & Company analysis
V.3. TECHNOLOGIES

V.3.1. Overview
Together with regulations and incentives, technology innovation is expected to drive xEV emergence. Globally, lot of promising research is going on to improve the performance levels of conventional technology as well as to explore alternative options.

In conventional technology, efforts are focused in two areas to yield higher fuel efficiency and lesser emissions - the drivetrain and the vehicle body. Direct injection methods are being evaluated to increase energy efficiency and engine power. Dual clutch manual transmission is expected to improve the powertrain efficiency. Additionally downsizing operations in engines, structural weight reduction and resistance optimization are expected to reduce fuel consumption.

In the alternative mobility space, research and development is being conducted across the powertrain components to lead to commercially viable solutions. The biggest concern for xEVs is the battery technology. High energy density requirements coupled with stability and reliability concerns have triggered extensive research in basic battery chemistry. Additionally possibility of smart charging and improved battery life are also being evaluated. Battery management systems are being developed to achieve higher level of integration and reliability. A lot of work is being done in the areas of acceleration assist optimization for downsizing engines and regenerative energy optimization to improve efficiency of xEV powertrains. Controllers are being designed to provide for better cooling and power management, in addition to providing higher level of control integration.

With these extensive research efforts spanning almost every part of the powertrain, significant ground can be gained in bridging the price-performance gap. Coupled with the obvious running cost and environmental advantages, bringing the xEVs within the ambit of affordability will give a fillip to their global demand.

In the following section, the technology innovation in both the conventional and alternative technology space is described in more detail.

V.3.2. ICE innovation
Widespread technology innovation driven by tighter fuel efficiency and emission norms are expected to result in significant fuel efficiency gains in ICE vehicles by 2025. Exhibit 40 depicts the focus areas of research, the expected timeline and potential benefits.
Direct chamber injection of high pressurized fuels for enhanced combustion, leading to better, balanced energy efficiency and power.

Smaller but higher performance engines
0.8-1.4 L engines perform equivalent to & more efficiently than larger engines

Every 10% of weight reduced cuts fuel consumption by 5%

2-pedal manual transmission with seamless gear shifting mechanisms for increased drivetrain efficiency

Reduce resistances in tire rolling and wheel bearing friction through material, tribology advances

Replace, re-engineer structurals with light weight materials (Al, Mg, CFRP, etc.)
Every 10% of weight reduced cuts fuel consumption by 5-10%

Expected Fuel Efficiency Improvements by 2020

<table>
<thead>
<tr>
<th>ICE</th>
<th>Downsizing Optimization</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Smaller but higher performance engines</td>
</tr>
<tr>
<td></td>
<td>0.8-1.4 L engines perform equivalent to &amp; more efficiently than larger engines</td>
</tr>
<tr>
<td></td>
<td>Direct injection</td>
</tr>
<tr>
<td></td>
<td>Direct chamber injection of high pressurized fuels for enhanced combustion, leading to better, balanced energy efficiency and power</td>
</tr>
<tr>
<td></td>
<td>Dual Clutch Manual Transmission</td>
</tr>
<tr>
<td></td>
<td>2-pedal manual transmission with seamless gear shifting mechanisms for increased drivetrain efficiency</td>
</tr>
<tr>
<td></td>
<td>Rolling Resistance Optimization</td>
</tr>
<tr>
<td></td>
<td>Reduce resistances in tire rolling and wheel bearing friction through material, tribology advances</td>
</tr>
<tr>
<td></td>
<td>Weight Reduction</td>
</tr>
<tr>
<td></td>
<td>Replace, re-engineer structurals with light weight materials (Al, Mg, CFRP, etc.)</td>
</tr>
<tr>
<td></td>
<td>Every 10% of weight reduced cuts fuel consumption by 5-10%</td>
</tr>
</tbody>
</table>

Source: Argonne National Laboratory, Automotive OEM press releases, Booz Allen Hamilton Technology Center, Booz & Company analysis

The most important tool to reduce emissions among powertrain technologies is engine downsizing. Downsizing optimization typically means developing smaller engines while maintaining or even enhancing the performance levels. Moreover, it is an effective technique for improving fuel efficiency: 10-15% improvement in fuel efficiency is expected by engine downsizing by 2020.

Direct fuel injection is a fuel-delivery technology that allows gasoline engines to burn fuel more efficiently, resulting in more power, cleaner emissions, and increased fuel economy. The fuel is highly pressurized, and injected via a common fuel line directly into the combustion chamber of each cylinder, as opposed to conventional multi-point fuel injection. This provides precise control over the amount of fuel and injection timings, which can be varied according to the load conditions. The major advantage is increased fuel efficiency and higher power output.

Dual clutch transmission provides a seamless gear-shifting mechanism providing increased drivetrain efficiency. This prevents the torque transmission loss between engine and wheels during gear shifts and makes gear shifts smooth. A ~10% improvement is expected in fuel efficiency by 2020 due to further evolution of dual clutch manual transmission.

Furthermore, reducing resistance in tire rolling and wheel bearing friction through use of better materials and surface designs are being studied. Structural weight reduction by using light weight sturdy materials are also being evaluated and exercised. About 5-10% fuel efficiency improvements are expected with 10% weight reduction.
V.3.3. xEV innovation

As discussed earlier, multi-dimensional R&D is being conducted in the xEV space. Broadly they can be classified into four areas as discussed below

Areas

Battery unit: Battery is the most important part of the xEV powertrain, both by function and by value. About 40-50% of total manufacturing cost is the cost of battery for BEV cars. Such high battery cost is the primary reason for high price premium of xEVs. Therefore, significant research and development is focussed around developing cost effective battery solutions. Primarily, battery research is focussed around cell chemistry seeking improved power density, thermal management, lifespan and stability at a reasonable price. Technology compatibility for second-life application of spent batteries is also being evaluated.

Battery Management System (BMS): Battery management system refers to the electronics which binds the cells together into a battery pack. It manages the rechargeable battery by monitoring its state, protecting the battery, controlling its environment, and balancing it. BMS development focus is largely concentrated on providing flexible compatibility with a range of cell chemistries and battery architectures.

Power Electronics: Power Electronics refers to the control system that provides energy to the motor from batteries. It is also referred to as motor controller. Controller research is typically focussed on providing a greater level of integration. Other significant areas are enhancing thermal control and eliminating external signal conditioning.

xEV Powertrain: Multiple research initiatives are focussed towards developing a more efficient xEV powertrain. Applications of dual operation mode of motor-generator module in hybrids and plug-in hybrids like providing acceleration assist etc. are being looked into. Downsizing the IC engine and optimizing regenerative energy by adaptive cruise control in HEV is another dimension. On the motor front, the challenge is to develop products which are not based on rare earth materials.

Battery Technology and Cost Evolution

Batteries for xEVs are the most studied components and ironically, remain the most enigmatic as well. Widespread research on battery chemistry compatible with mobility solutions is underway. Four types of chemistries have been widely studied – Lead Acid, Nickel-Cadmium, Nickel Metal Hydride and Lithium-ion (Exhibit 41).
SIAM: National Hybrid/Electric Mobility Study

Lead Acid battery provides moderate power density and has low discharge rates. It doesn’t suffer from memory effect and is inexpensive. However, the energy density is low which means the battery size required to provide energy to automobiles would be substantially higher. It has a short lifespan which translates to additional running cost due to frequent battery replacement. Moreover, slow charging makes it unattractive. Lead-Acid batteries therefor, could be used only for specific segments like scooters, 3 wheelers etc. which don’t have high energy requirements.

Nickel Cadmium battery has high power density, small recharge time and long lifespan. Moreover, the cost is not significant. However, low capacity and memory effect limit the usage of nickel-cadmium batteries. The storage capacity deteriorates over time and there is high self-discharge. Clubbed with these are the environmental issues which make it unfit for use in electric mobility solutions.

Exhibit 41 - Battery Chemistries

<table>
<thead>
<tr>
<th>Battery Type</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lithium ion (Li-ion)</td>
<td>• High energy density • Low discharge • No maintenance • Long lifespan</td>
<td>• Safety issues • Low stability • Expensive</td>
<td>• xEVs • Consumer electronics</td>
</tr>
<tr>
<td>Nickel Metal Hydride (NMB)</td>
<td>• Good energy density • Low memory effect • Good safety • Good lifespan</td>
<td>• Overheating • High self discharge • Low utility at low temp • Expensive</td>
<td>• Earlier xEVs • Consumer electronics</td>
</tr>
<tr>
<td>Nickel Cadmium</td>
<td>• High power density • Fast recharge • Inexpensive • Long lifespan</td>
<td>• Memory effect • Low capacity • High self discharge • Environmental issues</td>
<td>• Consumer goods • Back-up power</td>
</tr>
<tr>
<td>Lead Acid</td>
<td>• Good power density • No memory effect • Low discharge • Inexpensive</td>
<td>• Low energy density • Slow charging • Short lifespan • Environmental issues</td>
<td>• Conventional car • Back-up power</td>
</tr>
</tbody>
</table>

Source: HSBC Hybrids and Electric vehicles, Booz & Company analysis
Nickel metal hydride has been used in earlier variants of xEVs owing to moderate energy density and good lifespan. It also meets the required safety standards and maintains a fairly uniform storage capacity over its lifetime. However, it suffers from high-self discharge and overheating. Additionally, the cost is high.

Lithium-ion chemistry is the current preferential choice for usage in xEVs. They have high energy density and low discharge rates and hence is able to deliver sustained high performance. The battery maintenance cost is negligible and the lifespan is large as well. Low stability and high price are issues limiting its viability.

With Lithium-ion chemistry being the most apt technology for automobiles, the industry is exploring a range of chemistries within it for xEV applications (Exhibit 42). A trade-off has to be made with most available technologies as far as price and performance is concerned. Research is underway on Lithium titanante and Lithium air configurations which are thought to be promising solutions, but are quite expensive or infeasible currently.

1) Modified Li ion battery with Lithium titanate on anode
2) Lithium anode with air (Oxygen) cathode
Source: Market reports, Expert interviews, Booz & Company analysis

The cost of the battery pack is a major roadblock in adoption of xEVs. The breakup of cost-structure\(^{13}\) of a Li-ion battery pack (Exhibit 43) reflects two important levers that could be

\[\text{Assuming battery capacity of 15kwh, annual production of 50,000 modules and 500 batteries, scrap assumptions of 10\% in cell and 2\% in module}\]
instrumental in reducing battery cost – technology innovation and scale. While about 48% of battery pack cost is technology dependent, scale affects about 40% of it. Hence, almost 90% of the battery cost can be impacted by these two parameters combined.

Exhibit 43 - Cost Structure of Li-ion Battery Pack

From the technology standpoint, cost could be reduced by identifying cheaper raw materials and safe chemistries for automotive usage. Furthermore, manufacturing processes could be automated and streamlined to improve quality and yield. Collaborative models across countries for research and development of Lithium-ion chemistries could reduce the IP barriers and lead to low cost batteries in much lesser time than organic activities. Scale would impact the production cost by distributing overhead and fixed costs over larger volumes. Full capacity utilization of manufacturing units would decrease cost per unit. For instance, the percentage of labour and R&D costs per unit would decrease with increasing production. Hence, with increasing demands and greater R&D, favourable cost evolution is expected in the next 10-15 years, leading to cheaper batteries.

Favourable technological developments and greater scale could bring down Lithium ion battery costs from the current levels of $ 500-800 /kWh to $325-430 /kWh (Exhibit 44). Scale effects impacting R&D and manufacturing manifest at a manufacturer level. Volumes

Source: Bloomberg, Nicholas School of the Environment (Duke University), MIT Energy Initiative Symposium, Argonne National Library, Booz & Company

This information is confidential and was prepared by Booz & Company solely for the use of our client; it is not to be relied on by any third party without Booz's prior written consent.
have been estimated assuming overall growth for the segment and penetration for a leading manufacturer (Nissan for BEVs and Toyota for HEV, PHEV segment). Technology largely impacts the price of active material and purchased parts. Based on interviews, this price is estimated to fall at an annual rate of 8% until 2015 and 4% from 2016-2020. Consequently, the price of a 24kWh BEV battery is expected to decline from ~$12,250 in 2011 to ~$7,850 in 2020, translating to annual 5% decline. PHEV and HEV battery prices are also expected to reduce more, touching 7% decline year on year.

**Exhibit 44 - Lithium-ion Battery Cost Evolution Estimate**

<table>
<thead>
<tr>
<th>Battery Type</th>
<th>2011</th>
<th>2015</th>
<th>2020</th>
<th>CAGR</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEV 24 kWh</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2,244</td>
<td>3,688</td>
<td>7,645</td>
<td>-5%</td>
</tr>
<tr>
<td>PHEV 5.2 kWh</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>693</td>
<td>495</td>
<td>429</td>
<td>-7%</td>
</tr>
<tr>
<td>HEV 1 kWh</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>88</td>
<td>88</td>
<td>86</td>
<td>-7%</td>
</tr>
</tbody>
</table>

**Note:** Assume technology impacts cost of active materials and other parts like electronics reducing cost by ~50% by 2020; scale effects impact equipment (depreciation), labor, R&D costs; scale based on estimated global uptake of respective powertrain systems and market share of lead battery manufacturer; 2011 costs based on JRC/ Duke estimates

**Source:** MIT Technology Review, JRC, JD Power, Argonne National Lab, Deutsche Bank, Expert Interviews, Booz & Company analysis

In spite of global favourable cost-evolution, the battery costs shall remain higher than the expectations of the Indian consumer (Exhibit 45). Considering a 15% price premium being acceptable to Indian consumers clubbed with inflationary effects, the equivalent battery price expectation would be somewhere between $210-275 per kWh. Even if an aggressive estimate of 7% CAGR reduction is assumed from the current price levels, the lithium-ion battery price is expected to hover between $300 and $400 per kWh.
Exhibit 45 - Lithium-ion Battery Cost Evolution and Consumer Expectations

**Note:** Consumer expectation for lithium ion battery price based on their willingness to pay premium for xEVs without any scale effect on xEV cost

**Source:** MIT Technology Review, JRC, JD Power, Argonne National Lab, Deutsche Bank, Expert Interviews, Booz & Company analysis

**Global Research Efforts**

**United States:**

In the United States, while battery cell research is the primary focus amongst component suppliers, OEMs have focussed on xEV transmission system research (Exhibit 46). Additionally, national labs and academic institutions are also conducting research at various levels of the xEV powertrain. Argonne National Laboratory is a pioneer institution conducting research in metal oxide and composite electrodes. National Renewable Energy Laboratory has patents on integrated BMS, xEV control systems etc. Valence, Greatbatch, A123 systems and 3M are major battery suppliers holding significant intellectual property in Lithium ion batteries. Research is focussed mostly around cell chemistry.
OEMs like GM and Ford have significant patents on transmission systems. Tesla Motors has many patents on BMS and chargers.

**Japan:**

Japan has heavily focussed on battery cells and has achieved the world leader status in Lithium ion battery research and development (Exhibit 47). In Japan, research is mostly driven by OEMs and suppliers. Battery suppliers like Sanyo, GS Yuasa, NEC etc. have extensive intellectual properties in lithium ion chemistry around electrolytes, electrode material, charging/discharging methods etc. OEMs like Toyota and Nissan also hold numerous battery and BMS patents.

---

**Exhibit 46 - United States - xEV Patents**

<table>
<thead>
<tr>
<th>Battery</th>
<th>BMS</th>
<th>Power Electronics</th>
<th>Electric Motor</th>
<th>Transmission System</th>
<th>Areas of focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>Metal Oxide electrode, Composite electrode</td>
</tr>
<tr>
<td>9</td>
<td>✗</td>
<td>✗</td>
<td></td>
<td></td>
<td>Metal Oxide electrode</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>✗</td>
<td>✗</td>
<td>11</td>
<td>Integrated BMS, Control system, powertrain</td>
</tr>
<tr>
<td>81</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td>Electrodes, circuits</td>
</tr>
<tr>
<td>105</td>
<td>15</td>
<td>5</td>
<td></td>
<td></td>
<td>Electrodes, over-voltage protection</td>
</tr>
<tr>
<td>35</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Electrodes</td>
</tr>
<tr>
<td>9</td>
<td>5</td>
<td>5</td>
<td>12</td>
<td>69</td>
<td>Powertrain, Predictive BMS, Control system, Inverters</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>8</td>
<td>5</td>
<td>152</td>
<td>Powertrain, control system, Dual rotor motor; PE cooling unit</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td></td>
<td>5</td>
<td>7</td>
<td>Traction control, chargers</td>
</tr>
</tbody>
</table>

Source: ESpaceNet, US Patents, Booz & Company analysis
Motor and transmission system are the other areas where Japanese OEMs hold significant patents. Honda, Toyota and Nissan combined hold more than 350 patents on alternate transmission systems and more than 220 patents in electric motors.

**South Korea:**

South Korea’s focus is also largely around battery and BMS research (Exhibit 48). LG Chem and SBLiMotive (JV between Samsung and Bosch) are leading research and manufacturing efforts of Lithium ion batteries in Korea. Efforts are directed towards developing customized battery packs for different xEVs. Among OEMs, Hyundai-Kia is interested in alternative technology and holds intellectual property in xEV powertrains in areas like dual clutch transmission and 4-wheel drive. Some academic institutions like Korea Advanced Institute of Science and Technology holds some patents on Lithium battery anode materials.
China:

China has recently started focusing on basic research in the xEV space and has acquired significant IC in lithium-ion batteries (Exhibit 49). Academic institutions like Jia Tong University and Tsinghua University have patents around cathode materials, hydraulic brake regeneration, fault simulation systems etc. Chery has worked on high capacity lithium-ion batteries and high voltage power management. BYD holds a large number of patents in lithium-ion batteries.

SAIC and Chery hold significant patents in BMS both individually, and through their collaborative venture. Torque management and power distribution controller are areas where Chery has worked in electric motors. IC in transmission system is held by SAIC, Chery and BYD.
**Exhibit 49 - China - xEV Patents**

<table>
<thead>
<tr>
<th>Battery</th>
<th>BMS</th>
<th>Power Electronics</th>
<th>Electric Motor</th>
<th>Transmission System</th>
<th>Area of Focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>35</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>8</td>
<td>- Communication Protocol, hydraulic brake regeneration, electric eddy speed damper</td>
</tr>
<tr>
<td>50</td>
<td>8</td>
<td>4</td>
<td>4</td>
<td>10</td>
<td>- Driving anti-skid control, high rate cathode material, fault simulation system, integrated vehicle with mobile power system</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td></td>
<td>1</td>
<td>2</td>
<td>- Double motor controller, mechanic and hydraulic transmission system</td>
</tr>
</tbody>
</table>

Source: ESpaceNet, US Patents, Booz & Company analysis

**Start-Stop Technology**

As a stepping stone in migration towards hybrid, the start-stop technology could be introduced in the market. Its introduction would be easier given the fact that it is based on lead-acid batteries and is quite affordable. Start-stop battery provides support to IC engine only when the vehicle is being started or stopped. In other words, motor assist is not provided. Within start-stops, there could be two grades – with and without regenerative braking. Start-stops could provide 5-10% fuel efficiency benefits over conventional technologies. For higher improvements, mild hybrid and full hybrid technologies should be considered. Table 12 compares the various grades of hybrids based on features.

**Table 12 - Hybrid Classification**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Pure Start Stop</th>
<th>Mild Hybrid</th>
<th>Full Hybrid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine Start Stop</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Auxiliary Functions (lights, wipers, electronics, AC etc.)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Regenerative Braking</td>
<td>Limited</td>
<td>Active</td>
<td>Active</td>
</tr>
</tbody>
</table>
As mentioned earlier, start-stop could be looked at as cost-effective technology with advantages of a hybrid solution. Both variants of micro-hybrid solutions use valve regulated lead-acid batteries (VRLA) which cost between $100 and $250 (Table 13).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Vehicle</td>
<td>~12 V</td>
<td>TBO</td>
<td>500-700 Wh</td>
<td>FLA</td>
<td>FLA</td>
<td>$50-$100</td>
<td>N/A</td>
<td>Proven and lowest cost technology</td>
</tr>
<tr>
<td>Micro-Hybrid 1</td>
<td>12-14 V</td>
<td>2-5 KW</td>
<td>600-1000 Wh</td>
<td>FLA, Advanced FLA, VRLA</td>
<td>VRLA</td>
<td>$100-$200</td>
<td>~$300</td>
<td>FLA and advanced FLA have higher acid stratification issues</td>
</tr>
<tr>
<td>Micro-Hybrid 2</td>
<td>14+ V</td>
<td>2.5 KW</td>
<td>0.7-1.3 kWh</td>
<td>VRLA, VRLA +UCAP</td>
<td>VRLA +UCAP</td>
<td>Battery : $150-$250 UltraCap: $40 - $60</td>
<td>~$500</td>
<td>Ultracapacitors have superior charge acceptance compared to lead-acid batteries Low power (&lt;1kW) events would still be handled by the battery</td>
</tr>
<tr>
<td>Mild Hybrid</td>
<td>42 V</td>
<td>15-20 KW</td>
<td>1-2 kWh</td>
<td>NiMH, Li-ion</td>
<td>Li-ion</td>
<td>$600-$1000</td>
<td>~$1000</td>
<td>Additional energy requirements require higher power and energy, for which Li-Ion is likely to be the dominant technology due to high energy density</td>
</tr>
<tr>
<td>Full Hybrid</td>
<td>200+ V</td>
<td>30-50 KW</td>
<td>1.5-3.5 kWh</td>
<td>NiMH, Li-ion</td>
<td>Li-ion</td>
<td>$800 - $2000</td>
<td>~$3000</td>
<td></td>
</tr>
</tbody>
</table>

The micro hybrid 2 solution has to be augmented by an ultracapacitor, which has a superior charge acceptance compared to a lead acid battery. This would cost another $50. Still the battery cost is highly reasonable compared to $1,000 - $3,000 for a full hybrid solution.
Lithium Supply

Lithium-ion is perceived as the future for automobile batteries. With a view to develop long-term battery solutions, it is essential that the supply base of raw materials is maintained over a long period in future and global projections strengthen the case for lithium based technologies.

With discovery of new reserves, lithium supply is expected to meet the additional demand created due to Li-ion automobile batteries (Exhibit 50).

Exhibit 50 - Lithium Demand and Supply Projections

Source: Tahil, BNAmericas, Booz & Company analysis

A major portion of world lithium supply comes from South America. Chile is the leading producer followed by Argentina. Without any significant expansion in the lithium supplies, the demand for xEV and non-xEV applications combined is expected to be met till 2019. However, there are large untapped lithium reserves which can be harnessed to substantially increase production. The Sentient group is expected to begin mining in Argentina by 2016 which would heavily increase global lithium supplies. Moreover, half the world’s known reserves are in Bolivia and they remain largely untapped. China can also emerge as a significant producer of Lithium recovered from brine.

Recycling battery is another way to maintain sustainable future supply. In addition to slowing down resource depletion, recycling has many other benefits. Lithium and Cobalt are the major materials obtained from recycling batteries and these have a high market price. Moreover the environmental hazards arising out of battery scrappage can be done away
with. However, recycling costs are high. Currently, lithium-ion battery recycling costs $1500 per ton. Energy requirements for recycling are about 6 to 10 times those of manufacturing equivalent new batteries. Additionally, logistics of collection have to be established.

Recycling costs are expected to come down to $300 per ton with increasing scale, following which, it could be an attractive proposition. The bottom-line is that lithium based technologies could be aptly looked at as future of xEV batteries given their favourable characteristics and supply assurance.
VI. STAKEHOLDER FEEDBACK

To develop a holistic view of the hybrid and electric vehicle market, numerous industry stakeholders and government entities were engaged to gather feedback on the future evolution of this industry. Along with this, several focus group discussions (FGDs) were conducted among potential consumers, to obtain their views about hybrid and electric vehicles within each vehicle segment. The insights collected from these interviews and discussions have been detailed in this section.

VI.1. CONSUMER FOCUS GROUP DISCUSSION FINDINGS

Several FGDs were conducted among consumers to obtain qualitative inputs into consumer preferences, barriers to adoption, major drivers for adoption of hybrid and electric vehicles. These interviews were conducted across major metros such as Delhi, Mumbai, Bangalore, Kolkata; as well as other large cities such as Lucknow, Pune, Coimbatore and Patna. Following are the major insights obtained from these discussions:

VI.1.1. Lack of Awareness

There is a limited understanding of xEV technologies currently; this needs to be addressed through a concerted marketing and education effort by the Government and OEMs.

VI.1.2. Willingness to Pay Premium for xEVs

Consumers are open to paying a premium of 10-20% for HEVs justified by lower operating costs; however, this premium should be recoverable within 2-3 years.

In a focus group discussion conducted for two wheeler segment in Lucknow, a consumer highlighted that with lower running costs, a 20% premium would be possible. Similarly, in an FGD conducted in Delhi, a three wheeler owner highlighted that he could pay up to ₹2 – 2.25 Lakh for a hybrid three wheeler if it was cheaper to run than a CNG-operated three wheeler. Similarly, a three wheeler owner in Coimbatore commented that he would be willing to pay ₹30,000 more (~20% premium) if the running cost of hybrid three wheeler was lower. In four wheelers as well, consumers seemed to be willing to pay a premium of 20% on hybrid four wheelers if the total cost of ownership was lower, performance was similar to petrol / diesel vehicles, and the premium could be recovered in 2-3 years. The willingness of consumers to pay a premium for hybrid and electric vehicles has been captured in Exhibit 51.
**VI.1.3. Preference for HEVs**

Consumers across all vehicle segments seemed to prefer HEVs due to the familiarity of an IC engine as a backup to the electric drive.

Though hybrid 2W and 3W don’t exist in the market, the preferred choice among the respondents seemed to be a hybrid vehicle. Consumers in 3W segment preferred the hybrid option as the frequent braking recharged the battery, and the IC engine would allow longer trips (Delhi FGD). The CNG hybrid option was preferred as it would have the lowest operating cost.

For 4W and buses, HEVs were the most preferred followed by PHEVs due to dual powertrain. In 4W segment, a consumer commented that automatic recharge through braking in hybrid vehicle would save him the hassle of manually recharging the battery. In the Kolkata bus FGD, a bus owner commented that twin engines would enable better performance of the vehicle as there would be lesser strain on one. Consumer preference for various types of xEVs has been highlighted in Exhibit 52.
VI.1.4. Preference for Range, Charging Infrastructure

Consumers appear to be more receptive to PHEVs and BEVs if the battery gives them an acceptable range and the necessary charging infrastructure is available.

Respondents in the three and four wheeler segments specifically were unwilling to adopt BEVs unless they were assured satisfactory battery range. This was primarily due to anxiety around the battery range not being sufficient, and the fear of a depleted battery. In the FGD conducted in Delhi, a three wheeler owner remarked that the battery should give at least a 250 km range on one charge; otherwise he may get stuck on the road without a battery. Similarly, a three wheeler owner in Bangalore wanted a mileage of at least 100 km on one charge. Even four wheeler owners expressed preference for BEVs which can give range of 100 km on a single charge. These concerns have been highlighted in Exhibit 53.

Source: Consumer Focus Group Discussions

Exhibit 52 – Alternative Drivetrains that Respondents were most Comfortable with (% of Total Respondents)

Source: Consumer Focus Group Discussions

Exhibit 53 – Consumer Response to “What is the minimum distance that a battery should cover” (% of Total Respondents)

Source: Consumer Focus Group Discussions
Charging infrastructure was also important for respondents, as most seemed to prefer public charging facilities. A 6-8 hour recharge time was considered too long and respondents expressed that they would prefer to shift to a PHEV or BEV if this was lower (< 2 hours). Charging time anxiety was specifically higher for two wheeler and three wheeler owners.

Also, respondents preferred to use public charging infrastructure rather than setting up their own charging points at home. A three wheeler fleet owner in Coimbatore expressed anxiety around finding a safe place to charge multiple vehicles for 7-8 hours. In the FGD conducted in Bangalore, consumers highlighted that most of them lived in apartments, and due to lack of parking they had to park their vehicles far from their home, where it would not be safe to keep the personal charging stations. Consumer’s preference for public charging stations has been depicted in Exhibit 54.

Exhibit 54 – Consumer Response to “Would you prefer charging at home or use public charging infrastructure” (% of Total Respondents)

![Bar chart showing consumer preference]

Source: Consumer Focus Group Discussions

VI.1.5. Environmental Benefits

Environmental benefits of xEVs do not appear to be an important buying criterion for consumers, though most seemed aware of the health benefits of reduced emissions.

These insights were explored further in the quantitative face-to-face interviews conducted across 7,000 respondents in 16 cities. Some of the additional questions covered in these interviews included the parameters which triggered and shaped the consumer purchase, the factors considered while buying a vehicle, the usage pattern of vehicles, level of awareness of alternate fuel / hybrid / electric mobility technology and consumer perception towards these technologies, factors which influence the purchase of these technologies, and trade-offs which the consumer was willing to make for the adoption of these solutions.
VI.2. INDUSTRY AND GOVERNMENT FEEDBACK

Numerous interviews were conducted with major OEMs (17), component manufacturers (8), industry associations (13), dealers (8); as well as central, state and city governments (18) and state electricity boards (5). The discussions involved their views around future potential for xEVs in India, industry readiness, key barriers which had to be overcome to unlock the potential for xEVs and potential solutions. Key insights from these interviews have been detailed below.

Most major OEMs supported / were open to promoting xEVs in India. The degree of support for these vehicle technologies has been detailed in Exhibit 55.

![Exhibit 55 - Overall Response of OEMs Interviewed](graph).

Source: Industry Interviews

OEMs which supported xEVs strongly believed that these are important for supporting India’s fuel security. They further believed that hybrid electric vehicles are viable in short to medium term, and with technological advances and establishment of infrastructure, demand for BEVs could also pick up.

OEMs which offered moderate support to xEVs or were open to these technologies, opined that they could look at xEVs in future subject to supply side incentives / demand assurance from the government. They would also require the government to proactively start building the charging infrastructure to support electric vehicles, before any large investments were made in this space.

OEMs which did not have any plans to introduce xEVs in future believed that government should not favour one vehicle technology over another, and Indian market was not yet ripe
for xEVs – as there is no demand (as price-performance gap has not been bridged, and no supporting infrastructure exists)

VI.2.1. Demand for xEVs
OEMs believe that the demand for xEVs is low in the Indian market due to high price, performance anxiety, lack of infrastructure and low awareness. Further, they believe that HEVs seem to be preferred by consumers due to higher range and no charging requirement compared to PHEV / BEVs.

- **Buses** – OEMs believe that there is an opportunity for adoption of hybrid / electric buses, specifically among state transport units (STUs). The STUs desired clear operational and environmental benefits to justify the price premium for xEVs.

- **2W** – The industry believes that the demand for E2Ws, specifically battery electric scooters could be significant as price performance gap is not high, however durability needs to be improved.

- **4W** – While the industry believes that there could be demand for HEVs in this segment, a key constraint is pricing; PHEV / BEV demand is expected to increase if public charging infrastructure investments are made, and sufficient incentives are provided.

- **3W** – There could be some demand for battery electric 3Ws, if supported through free permits, demand incentives etc.

VI.2.2. Battery Technologies
The automotive industry strongly believes that battery technologies should be researched and developed locally to customize for the Indian weather and driving conditions – for all vehicle segments. Most OEMs believed that lithium ion batteries are most promising for xEVs, an OEM commented that while they used lead acid batteries to start with, they were shifting to lithium ion batteries as these were much lighter and could give a much higher range. However, high price for lithium ion batteries are considered a major barrier for adoption for xEVs.

In the four wheeler segment, OEMs opined that focused R&D efforts are required for A2 vehicles (3.4 to 4M in length with engine size <1.2L) which is the highest selling segment in India; as globally, OEMs have focused on larger vehicles.
VI.2.3. Incentives and Investments

The automotive industry believes that strong support is required from the government in the form of consumer and production incentives, as well as investments in R&D and building appropriate charging and power infrastructure.

Consumer incentives suggested by the industry include cash subsidies on vehicles and battery (for BEVs), tax breaks (road tax, VAT, income tax), and other peripheral incentives such as parking and toll rebates. As production incentives, majority of suppliers would want the government to assure demand, provide capital subsidies, and other benefits such as exemption of customs duty on xEV components for a few years, lower duty on CKD imports etc.

In terms of investments, most OEMs felt that the government should lead the way by forming consortiums for R&D or giving direct grant to OEMs to support research and product development. While some OEMs and component manufacturers are willing to form consortium with joint contributions in funding and resources, the IP sharing model needs to be worked out. OEMs also felt that the government needs to invest in creating charging infrastructure, however this should be rolled out by conducting pilots first, to test consumer acceptability. Also, some OEMs pointed out that the requirement for widespread availability of charging points can be mitigated through utilization of cheap manpower for charging, or pursuing the battery bank model.

The government also had strong views about supporting R&D in this field. The consortium model involving the OEMs and the government for each vehicle segment was suggested for joint collaboration, which could be led by Indian OEMs. For charging infrastructure, it was felt that this could be rolled out by the private players, or through PPP mode. Also, decentralized renewable power plants could be considered for charging xEVs to positively impact the carbon dioxide emissions from xEVs. While the government did not express strong support for cash incentives, other form of incentives such as accelerated depreciation, exemption of customs duty for xEV components, and income tax exemptions were supported.
VII. POTENTIAL FOR xEVs IN INDIA

Based on a comprehensive set of inputs, the future potential for India was arrived at. These inputs can be grouped into 5 major areas (Exhibit 56):

- **Fuel Security Impact:** The potential was developed in such a manner, so as to have a tangible impact on the fuel security objective of the country.

- **Stakeholder inputs:** The potential was developed keeping in mind the current state of automobile industry and its readiness for xEV adoption. Extensive industry and expert interviews were conducted to capture the industry’s response to alternative technologies. Sustainability and scalability of xEV manufacturing keeping in mind the price-premium over conventional vehicles were examined. External support required for the industry to develop a strong xEV base was evaluated and tied with government’s views on policies and interventions.

- **Consumer Research:** As mentioned earlier, consumer preference was captured through extensive interviews across India. Nearly 7000 interviews were conducted across 16 cities segmented into 4 tiers (based on population). The interviews were used to identify buying criteria, major barriers to adoption, technology preference etc. In addition, conjoint analysis was performed to measure consumer sensitivity around parameters like acquisition price, running cost, recharge time and range. Insights from all these were factored in developing the future potential for India.
- **Price-Performance Evolution:** The total cost of ownership of different powertrains was evaluated based on annual distance travelled. This includes various costs over the vehicle lifecycle like acquisition cost, maintenance and servicing cost, cost of fuel/electricity, battery replacement cost etc. Additionally price evolution due to technology, inflation etc. were also factored into the analysis. Subsequently, an algorithm was used to convert total cost of ownership of power train to market penetration. Results from this economy based lens were useful inputs to develop xEV demand potential.

- **Global Perspective:** Global benchmarks were used to investigate industry and market potential for India. This included examining R&D and manufacturing capability, government policies etc. The expected global penetration was considered to derive a reasonable estimate for India.

Based on an extensive analysis of the aforementioned parameters, the cumulative potential of xEVs in 2020 appears to be 5-7 million units. The battery electric 2 wheeler segment has the highest potential with expected sales of 3.5 - 5 million units in 2020. Hybrid cars, buses and LCVs can reach 1.3- 1.4 million in unit sales by 2020. Other battery electric vehicles could reach 0.2 – 0.4 million unit sales in 2020.

Based on future goals and consumer acceptability, three most likely strategic transportation scenarios have been considered to arrive at this potential.

- **Status-quo:** - There is no effort to change the fuel mix from the current state. Consequently, the penetration patterns of the respective vehicle segments shall remain similar to the current pattern i.e. - high ICE penetration and marginal CNG penetration. ICE sales penetration in 2020 is assumed to be greater than 95% in all vehicle sub-categories.

- **High Gas and High HEV:** - This is a potential scenario, if government focuses on CNG and xEV through investments and incentives. This underlines a strong HEV focus to substitute IC engine technology. In this scenario, CNG penetration will be substantial, reaching about 30-35% in 2020. Hybrids will have significant penetration in sales as well, reaching 10-15% in 2020. BEV penetration is expected to be low, reaching about 2% in 2020. However, given the ease of deployment of

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14 The cited numbers are xEV sales projections (over and above CNG) for 2020 including assumptions for ICE technology improvement, scale effects and represent a steady state. Post 2020 similar annual sales are expected. No incentive support is factored beyond 2020.
BEV technology in 2 wheelers, 15% penetration in sales is possible in 2020 in this segment.

- **High Gas, High HEV and High BEV**: This is one step ahead of the high gas/HEV scenario and underlines a strong focus on BEVs in addition to CNG and HEV. In addition to high CNG and HEV penetration, significant penetration of BEV is expected. BEV penetration is expected to increase to 5% in 2020 (by sales) across most vehicle segments, while capturing 15% of 2-wheeler market.

Considering these scenarios, estimate of sales have been made in the High Gas/High HEV and High Gas/High HEV/High BEV scenarios. BEV 2 wheeler seems to have the least roadblocks to adoption. Considering the current capabilities, these are expected to have high sales. Table 14 summarizes the expected unit sales by segment in order to reach the 5-7 million potential in 2020. Additionally, the liquid fuel benefit over status-quo is described.

<table>
<thead>
<tr>
<th>Vehicle Sales in 2020 (’000 units)</th>
<th>2W</th>
<th>4W</th>
<th>Bus</th>
<th>LCV</th>
<th>3W</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEV/PHEV</td>
<td>-</td>
<td>1,275</td>
<td>2</td>
<td>120</td>
<td>-</td>
</tr>
<tr>
<td>BEV</td>
<td>4,800</td>
<td>170-320</td>
<td>0.3-0.7</td>
<td>30-50</td>
<td>20-30</td>
</tr>
<tr>
<td>Fuel Savings due to xEVs (Million Tonnes of Liquid Fuel)</td>
<td>1.4</td>
<td>0.4-0.65</td>
<td>0.16-0.19</td>
<td>0.09-0.16</td>
<td>0.06-0.09</td>
</tr>
</tbody>
</table>

These total annual fuel (petrol / diesel) savings of 2.2 – 2.5 MT in 2020 translates to crude oil savings worth ₹13,000 crore (High gas/High HEV scenario) to ₹14,000 crore (High Gas/High HEV/BEV). Additionally, the CO₂ emissions are expected to decline by 1.3% - 1.5% due to high xEV penetration.

However, the market is unlikely to reach the potential on its own owing to several barriers hindering adoption. Government and industry need to support a clear long term roadmap in order to realize this potential for India. Potential interventions have been identified towards developing this OEM-government collaboration roadmap.
VIII. UNLOCKING THE POTENTIAL FOR xEVs

VIII.1. CURRENT GOVERNMENT SCHEMES

Realizing the possible impact of hybridization/electrification, the government of India has come up with a set of initiatives to facilitate xEV penetration in the country. Alternate Fuels for Surface Transportation Program by the Ministry of New and Renewable Energy (MNRE) has given a jumpstart to the Indian EV industry. Following this initiative, a number of other government entities have also started incentivizing xEVs. The Alternate Fuels for Surface Transportation Program guarantees demand incentives for all xEVs, amounting to a total of ₹95 crore between 2010 and 2012. This is however subject to OEMs giving at least 1 year warranty and setting up 15 service stations across India. Table 15 summarizes the proposed incentives for each vehicle segment.

### Table 15: Alternative Fuels for Surface Transportation Program – Targets and Central Financial Assistance

<table>
<thead>
<tr>
<th>Segment</th>
<th>Type of Vehicle</th>
<th>Physical units</th>
<th>Assistance per vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>FY11</td>
<td>FY12</td>
</tr>
<tr>
<td>2W</td>
<td>Low Speed</td>
<td>20,000</td>
<td>80,000</td>
</tr>
<tr>
<td></td>
<td>High Speed</td>
<td>10,000</td>
<td>20,000</td>
</tr>
<tr>
<td>3W</td>
<td>7 seater</td>
<td>100</td>
<td>166</td>
</tr>
<tr>
<td>Passenger Car</td>
<td>4 seater</td>
<td>140</td>
<td>700</td>
</tr>
<tr>
<td>Bus/MiniBus</td>
<td>&gt;10 seater</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**Source:** MNRE AFSTP Annexures, MNRE RDD&D Guidelines, Web search, Booz & Company analysis

The program also provides support for research, design, development and demonstration projects on a partnership basis with the stakeholder involved. Pilot projects involving partnership with industry / civil organizations are eligible for 50% funding. 100% funding is provided for universities and government research institutions. Research projects for advanced high energy density batteries, Ultra-capacitors, Control Systems etc. are being funded.
SIAM: National Hybrid/Electric Mobility Study

It also lays down the IPR and Technology Transfer protocols for projects under this program. If research is jointly done by research institution, MNRE and industrial player (which contributes at least 1/3rd of the cost) then industry has the first right for its IP. However, if grantee can’t file the patent then MNRE would file it and 20% of earnings would accrue to industrial player. Owing to the several benefits provided by this program, xEV 2 wheelers have witnessed a growth of 20%. Also, Reva recorded a three-fold rise in average monthly sales.

Following the MNRE initiative, other government bodies have also started to bring in programs incentivizing xEVs. The Department of Science and Technology (DST), Govt. of India, has a funding scheme for all industries, including automotive industry. The key requirement to claim this grant is creation of a prototype. Loans upto 50% of the project investments are provided under this program. Reva has availed loans worth ₹4.65 crore under this scheme.

Council for Scientific and Industrial Research (CSIR) sponsored a national seminar by Department of Automobile Engineering that has developed 2W, 3W and a 4W prototype. Furthermore, R&D on lithium-battery technology for xEVs has been started at the Central Electrochemical Research Institute, Karaikudi. Additionally, about 50 electric rickshaws were launched by CSIR in Kolkata.

In an attempt to modernize the bus fleet, about ₹4590 crore have been earmarked under JNNURM for procurement of buses for urban transport. Electric trolleybuses will be introduced in Mysore and Bengaluru under the same scheme. Certain state governments like the Delhi govt. are providing demand side subsidies in addition to VAT and road tax waiver.

As is evident, most of these initiatives are largely fragmented and short-term. In order to achieve the potential laid out, a more systematic and collaborative approach is required from the Government and industry need to support a clear long term roadmap (Exhibit 57).
Currently, the solutions available in the market don’t meet consumer expectations, and hence the market is at the “infeasible” stage (specifically for xEV 3W, 4W, buses and LCVs). To achieve the tipping point for the market, the first step is to bridge this price-performance gap for consumers, and bring acceptable products into the market through demand side and supply side interventions. In parallel, the industry also needs to invest in building manufacturing and technology development capabilities. Along with this, power and charging infrastructure investments need to be made to facilitate adoption. This will lead to development of viable solutions in the market for consumers at acceptable price-points. OEMs should be incentivized for local manufacturing. Self-sustainability shall be achieved with increasing penetration beyond which incentives shall not be required.

All these interventions required to promote xEVs for each vehicle segment have been detailed in the following sub-sections.
VIII.2. FOUR-WHEELERS

VIII.2.1. Consumer Demand and Related Incentives

While four-wheeler xEVs have relatively low penetration in the Indian market, there is a significant latent demand across the country.

Field survey of 1800+ consumers across 16 cities pan India indicates that ~25-30% of consumers surveyed would prefer xEVs to traditional ICEs if preferences are suitably met. Among the possible xEV four-wheelers (HEV, PHEV, BEV), HEVs have the highest demand whereas BEVs have lower demand (~5-6%) (Exhibit 58). Further, xEV uptake is higher in Tier-1 and Tier-2 cities relative to Tier-3 and Tier-4 cities. Consumers in Tier-1 and Tier-2 cities have quoted low maintenance and high mileage as the major benefit driving adoption. However, Tier-1 city consumers are concerned about high PHEV car prices leading to a strong preference for HEVs over PHEVs. Similarly, there is low potential uptake of BEVs in Tier-3 cities as consumers have voiced concern about high battery replacement cost. OEMs can initiate development of charging infrastructure in cities like Ahmedabad, Mumbai and Kolkata where consumers have a high preference for xEVs.

Exhibit 58 - Preference by City Tier: xEV Cars

![Preference by City Tier: xEV Cars](image)

**Note:** Based on 1857 interviews across 16 cities.
**Source:** Nielsen field research, Booz & Company analysis

Projections based on the total cost of ownership indicate that with suitable incentives four-wheeler xEVs have significant latent demand by 2020. Demand is forecasted to increase to ~1.6-1.7 M units in 2020 with HEVs being the most popular (Exhibit 59). Scale effects also
come into play in 2020 and it is assumed that this has a 10% reduction in price due to scale is possible. Mild hybrid and full hybrid EVs can have a latent demand of ~20% by 2020 due to lower acquisition and operating costs. PHEVs may have ~4% latent demand by 2020. In contrast, demand for BEVs can vary from ~2.5% to 5% depending on the acquisition cost. In the low cost scenario A2 BEV base price is reckoned at ~₹8 lakhs in 2011 whereas in the high cost scenario the price is ~₹10 lakhs. These will evolve with time due to technology changes, cost evolution and inflation.

**Exhibit 59 - Four-Wheeler xEV Latent Demand**
(Total Units, % of Annual 4W sale, 2011, 2015, 2020)

Note: Mild HEV is considered for the analysis. Mild HEV costs ₹90,000 more than conventional ICE vehicle. A3 BEV base price is ₹13 lakhs in 2011, 2020 latent demand assumes 10% impact due to scale effect.

Source: SIAM, OEM and expert interviews, Argonne National Laboratory, Booz & Company analysis

Addressing this latent demand implies catering to consumer expectations. A study of consumer preferences reveals that in addition to technological and infrastructural improvements, demand side incentives would be highly effective in meeting needs.

1800+ face to face interviews were conducted across 16 cities in India to understand consumer preferences. In the population surveyed, four-wheeler xEVs are perceived as worse than their ICE counterparts on attributes such as pick-up, maintenance cost and passenger carrying capacity. An overwhelming 55% of respondents believed that xEVs fare worse in their pick-up speed and monthly maintenance costs (Exhibit 60). This perception impedes acceptance of xEVs and pick-up speed and battery replacement cost figure among
the top factors inhibiting the purchase of xEVs (Exhibit 61). xEV top speed, range, sturdiness, charging time and price constitute other key technological and economic factors inhibiting widespread acceptance of xEVs.

**Exhibit 60 - Perception of xEV compared to ICE**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Worse compared to ICE</th>
<th>Same as ICE</th>
<th>Better than ICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mileage</td>
<td>31%</td>
<td>42%</td>
<td>24%</td>
</tr>
<tr>
<td>Top Speed</td>
<td>38%</td>
<td>45%</td>
<td>14%</td>
</tr>
<tr>
<td>Pick Up</td>
<td>38%</td>
<td>53%</td>
<td>16%</td>
</tr>
<tr>
<td>Sturdiness</td>
<td>45%</td>
<td>43%</td>
<td>15%</td>
</tr>
<tr>
<td>Range</td>
<td>46%</td>
<td>43%</td>
<td>15%</td>
</tr>
<tr>
<td>Carrying Capacity</td>
<td>40%</td>
<td>46%</td>
<td>19%</td>
</tr>
<tr>
<td>Price</td>
<td>47%</td>
<td>46%</td>
<td>10%</td>
</tr>
<tr>
<td>Maintenance/month</td>
<td>55%</td>
<td>39%</td>
<td>18%</td>
</tr>
<tr>
<td>Availability of Spares</td>
<td>57%</td>
<td>30%</td>
<td>10%</td>
</tr>
<tr>
<td>Looks</td>
<td>62%</td>
<td>20%</td>
<td>15%</td>
</tr>
</tbody>
</table>

**Note:** Based on 1857 interviews across 16 cities.

**Source:** Nielsen field research, Booz & Company analysis

**Exhibit 61 - Key Barriers Inhibiting Adoption of Four-Wheeler xEVs**

Source: Nielsen field research, Booz & Company analysis

Sensitivity across four key parameters (price, running cost, recharge time and range) was studied as part of conjoint study on 1800+ consumers across 16 cities.
For typical variations, consumers are highly sensitive to price and running cost of HEV cars (Exhibit 62). Doubling the price of the HEV car, nearly halves the demand. Decreasing the running cost from the current expected level of ₹3.5/km to ₹2.5/km can increase latent demand from ~15% to ~17%. This high sensitivity implies that cash incentives and fuel efficiency can serve as effective levers to increase adoption of HEVs. OEMs should focus on improving fuel efficiency and spreading awareness about the same.

Exhibit 62 - Latent Demand for HEV Four-Wheelers (Conjoint Analysis)

Note: Base Price for Mild Hybrid = 5.14 Lakhs, running cost = ₹3.5 per km, Range = 500 km. Based on 1857 interviews across 16 cities
Source: Nielsen field research, Booz & Company analysis

For PHEVs, among the key parameters, price strongly impacts adoption. Given the higher expected price of a PHEV (~₹8.5 lakh) in comparison to a HEV (~₹5.14 lakh), consumers opting for this segment are relatively less sensitive to price variations- 65% increase in price translates to ~33% drop in demand. However, relative to other parameters for PHEVs, price still appears to swing the preference needle considerably (Exhibit 63). Hence, lowering acquisition cost with incentives can be effective in stimulating demand. In addition, running cost can be addressed by increased fuel efficiency and battery performance and recharge time can be reduced with better infrastructure. Pilots can be conducted for public rapid/ fast charging terminals to monitor adoption of xEVs before complete roll out.
Exhibit 63 - Latent Demand for PHEV Four-Wheelers (Conjoint Analysis)

Price Sensitivity: PHEV Car

Running Cost Sensitivity: PHEV Car

Recharge Time Sensitivity: PHEV Car

Note: Base Price for PHEV 4W - 8.5 Lakhs, running cost: ₹1.9 per km, Charging time: 7 hours, Range: 500 km
Based on 1857 interviews across 16 cities.
Source: Nielsen field research, Booz & Company analysis

Following a similar trend, BEV uptake is largely driven by price (Exhibit 64). Decrease in price from ₹8lakh to ₹6.5lakh can increase preference from 5.7% to 7%. Demand incentives reducing the acquisition cost would be effective in this case as well.

Exhibit 64 - Latent Demand for BEV Four-Wheelers (Conjoint Analysis)

Price Sensitivity: BEV Car

Running Cost Sensitivity: BEV Car

Note: Base Price for BEV Car = 8 Lakhs, running cost = 75 paise per km, Charging time = 7 hours, Range = 90 km.
Based on 1857 interviews across 16 cities.
Source: Nielsen field research, Booz & Company analysis

Face-to-face consumer interviews have validated the potential efficacy of acquisition cost based incentives and battery subsidies. 58% of the respondents indicated cash/tax subsidies as the preferred incentive for the adoption of four-wheeler xEVs (Exhibit 65). A subsidy on batteries emerged as the second most favoured route and was elected by 56% of those
surveyed. However, battery subsidies may not be required in the near term as the advent of lithium-ion batteries in cars delays the replacement of batteries to 7-10 years after purchase. Lower preference has been indicated for other peripheral benefits such as dedicated toll lanes, toll discounts etc. xEV retrofit kits at low cost can be a viable solution as well. Retrofit kits could qualify for incentives if they pass minimum safety and durability standards (for instance, set by ARAI). This solution can be examined as the technology matures.

Exhibit 65 - Incentives Required for Adoption of Four-Wheeler xEVs

Source: Nielsen field research, Booz & Company analysis

The proposed demand side incentives can be tiered on the basis of vehicle parameters (battery size, technology, and performance), time/volume and degree of localization.

- **Vehicle Parameters:** Incentives can be structured by battery size, technology and minimum performance criteria. Given the larger battery size, higher incentives can be provided for BEVs in comparison to PHEVs and HEVs (Exhibit 66). Higher incentives for PHEVs and BEVs would also aid in stimulating the weak demand for these vehicle types. Incentives can be awarded to vehicles that meet minimum quality and durability criteria set by an accredited agency like ARAI. Mild HEV would include vehicles with start-stop technology, regenerative braking and limited motor assist. A Full HEV has a motor drive (where vehicles travel on battery alone for short distance) in addition to start-stop and regenerative braking. PHEV and Range Extender EVs have higher pure electric range or extended range with the support of an IC engine and external charging through AC mains. OEMs would need to provide minimum warranty on vehicles including batteries.
Incentives can be structured based on performance as well. Higher incentive of ~₹1.5 lakh can be provided to high performance BEVs with top speed greater than 120 kmph, pick-up of 0-60 kmph in less than 9s and electric range of ~90 km with AC charging. Lower incentive of ~₹1 lakh can be awarded to low performance BEVs with top speed between 90 – 120 kmph, pick-up of 0-60 kmph in less than 9s and electric range of ~60 km with AC charging. These performance criteria should be finalized during the NBEM and NCEM meetings.

Exhibit 66 - Proposed Demand Incentives for Four-Wheelers (In ₹000 based on battery size)

Source: OEM, Expert interviews, Secondary research, Booz & Company analysis

- **Time / Volume:** To generate competition and scale, the first 200,000 vehicles per year can be incentivized from 2012 with the incentives phased out later (Exhibit 67). Incentives can be gradually phased out from the sixth year with 100,000 units supported in the first half and 50,000 units in the second half. Following this the incentives can be withdrawn. The government can consider providing the option of carrying forward unused incentives. To bolster BEV demand and prevent domination from other types, 75-90% of the annual incentives can be reserved for mild/full HEVs and PHEVs and the remaining 10-25% can be reserved for BEVs. Same incentives can be applied to retrofit solutions if these meet all the quality and safety standards.
Localization: To promote local manufacturing and sourcing, demand incentives can be subject to minimum level of localization of xEV components in the vehicle. The Bill of Material can serve as the basis for evaluation. A minimum threshold percentage of localized value can be specified for each technology. Further, a minimum annual increase can be specified (at least 5%). No incentives may be provided for completely built imported vehicles encouraging local manufacturing and assembly. In addition, current import duty benefits may be phased out over a period of time (for instance, 5 years) to promote indigenous products.

Various options are available for channelizing demand incentives:

- **Cash Incentive to OEM:** A direct cash incentive can be given to the OEM. This can also be extended to any exports.
- **Tax Incentive to OEM:** Involves a tax exemption provided to OEM
- **Cash Incentive to Consumer:** A direct cash incentive can be given to the consumer. However, to streamline the process, this can be routed via the OEMs with the registration copy being a proof of sale.
- **Tax Incentive to Consumer:** Involves a tax exemption provided to consumer.

Incentives provided to OEMs are easier to implement as they could have centralized processes with easy monitoring of sales. Incentives provided directly to consumers are decentralized and consequently, a burden to administer and monitor. However, these ensure that consumers enjoy full benefit of the incentive. By providing cash or tax incentives to OEMs, the government needs to monitor whether the incentive is translated to tangible...
benefits for the consumer. Cash incentives are preferred over tax breaks, as the latter have at least a one year time lag between sales and reimbursement.

After weighing the pros and cons of each method, it appears that providing a cash incentive to the consumer but routed via the OEM would be the best option. Not only is a direct benefit being passed on to the consumers, but also administration is streamlined with the OEMs submitting claims on behalf of the consumers. For successful implementation, the government should ensure that the entire process is expedited.

Apart from incentives, demand assurance from public and private sector can provide scale and lower prices. Assuming each Central and State Government gazetted officer is entitled to a car and a replacement age of 7 years, it is estimated that an annual demand assurance of upto ~90000 xEV cars can be provided by Central and State Governments alone (Exhibit 68). This can also be supported by private companies. For instance, FedEx and UPS have started emphasizing on hybrid/electric vehicles in the US as part of their fleet.

Exhibit 68 - Annual Demand Assurance Possibility

Government Fleet Procurement

<table>
<thead>
<tr>
<th>Central Govt. Officials</th>
<th>State Govt. Officials</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>69,000</td>
<td>21,000</td>
<td>90,000</td>
</tr>
</tbody>
</table>

Note: Assume # of gazetted officers in a state is proportion to state population. Assume there exists similar proportion of gazette officers in Central and State government.
Source: CMIE, Census 2011, Census of government officials 2008, NMCC, Booz & Company analysis

VIII.2.2. Supply-side Strategy

Addressing the local demand calls for a strong development and manufacturing base. The importance of R&D and production is underscored by the fact that almost two-thirds of the xEV value is created in R&D and production (Exhibit 69). This is similar to gasoline vehicles where ~60% of the value arises from component production and assembly and ~7-8% from research and development.
Within R&D and production of different components, powertrain constitutes majority of the costs for xEVs (Exhibit 70). Unlike traditional ICE vehicles where chassis and powertrain each contribute to 33% of the costs, chassis only contributes to 16% of BEV cost and powertrain to ~67% of the cost. Within the powertrain, the battery pack and power electronics dominate, contributing to ~55-70% and ~10-15% of the cost respectively. Consequently, these assume paramount importance while determining areas of focus for R&D and production.

**Exhibit 69 - Vehicle Lifecycle Cost for Industry – Breakup by Supply Chain Elements (% of Total Cost)**

**Note:** Analysis for sub-compact battery electric vehicle

**Source:** Argonne National Laboratory, Booz & Company analysis

**Exhibit 70 - Cost of Manufacturing for ICE and Battery Electric Vehicles**

**Note:** Analysis for sub-compact battery electric vehicle

**Source:** Nomura, Argonne National Laboratory, Booz & Company analysis
Currently domestic capabilities in powertrain and component development and manufacturing are low. Few OEMs are investing in building manufacturing capabilities for xEVs (Exhibit 71). While firms like Mahindra (Reva) and Maruti Suzuki have made progress in the four-wheeler xEV space, much of the technology and products are still imported. The local component manufacturing capability in India across major sub-systems is also very limited (Exhibit 72). Interviews with OEMs reveal that battery technology is nascent with no manufacturing capabilities in the country for lithium-ion cells.

Exhibit 71 - OEM Development Activities on Various Powertrains in India

Source: Literature search, OEM Interviews, Booz & Company analysis
Exhibit 72 - xEV Component Supplier Activities in India

<table>
<thead>
<tr>
<th>Battery</th>
<th>BMS</th>
<th>Transmission System</th>
<th>Electric Motors</th>
<th>Power Electronics</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓</td>
<td>✓</td>
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Source: Internet research, Supplier interviews, Booz & Company analysis

Absence of current initiatives entails supply side investments. A four-phased approach spread over next ten years can be followed to build the manufacturing capability for xEVs in India. Investments need to span the entire value chain from research and product development to sourcing and manufacturing.

This first stage of development from 2012 to 2016 should strive to strengthen domestic assembly. It should be noted however, this timeline assumes that the appropriate policy structure is in place and the Government and Industry collaborate as necessary to achieve the vision. Industry should look to build high capability in manufacturing with local assembly of xEVs using imported or local components. Simultaneously, local sourcing can be increased translating to moderate capabilities on this front. Since research and product development capabilities are currently low, industry and government can look to initiate investments in R&D and product development centers.

The second stage spanning the next 5-8 years calls for developing indigenized products. R&D and product development centers should have attained moderate capabilities by this point with the ability to develop indigenized components (BMS, transmission system, electric motors etc.) leveraging global technology. ~25-30% of xEV components need to be sourced locally with the customs duty exemptions phased out completely. These local components (except battery cells) would be assembled locally using the strong manufacturing capabilities developed by this time.

The third phase, ~8-10 years from now, needs to focus on developing technologies to suit Indian conditions and usage. In this period, industry should target having high capabilities across the value chain from research to manufacturing and assembly. Nearly 100% of the
components should be locally sourced with local manufacturing of complex components like battery cells. All components need to be indigenously developed to target the Indian market.

The final stage of evolution will target the export market. This requires suitable investments to enhance capability of R&D, product development centers and production plans for exports.

Domestic assembly can be promoted by reducing import duty for xEV Completely Knocked Down (CKD) kits. The duty can be tiered depending on the degree of localization, with lower import duties for high localization (Exhibit 73). The import duty reduction could apply to CKD kits used in xEVs except battery, motor chargers etc. which currently attract 5-10% import duty. This reduction can be phased out after five years, to promote local manufacturing of xEV components.

Incentives can be suitably designed to promote local manufacturing as well. Potential incentives include:

- 3-5 year tax holidays to OEMs and component manufacturers for xEV greenfield or brownfield investments
- Greenfield plants for xEVs can be part of National Manufacturing and Investment Zone proposed by the National Manufacturing Policy with:
  - Low cost funding for land as well as power, water and road connectivity
  - Complete import duty exemption for all parts and equipment
  - Exemption from Central Sales tax etc.
- Customs duty and excise exemption for capital equipment used by OEMs for assembly of xEVs
- Accelerated depreciation of capital equipment used by such manufacturers
- Soft loans / grants (1:3 or 1:4 ratio) to OEMs to promote full xEV development

Exhibit 73 - Suggested Import Duty for xEV CKD Kits
(For different share of localized xEVs as % of total xEV sales)

Source: DIPP, SIAM, Booz & Company analysis
VIII.2.3. Research and Development Investment

Analogous to current manufacturing capabilities, Indian component manufacturers and OEMs have limited R&D capabilities across all key components. OEMs like TVS (with 5-7 patents) and Mahindra Reva (with 10 patents) have made some progress on key components like Battery, power electronics and electric motor (Exhibit 74). However, this is far behind global standards where countries like US have registered 2000+ patents. Indian component manufacturers have no patents as yet and foreign OEMs and manufacturers carry out most of the R&D in the home country.

Attaining global competitiveness dictates reaching capability levels comparable to US, Japan, China and Korea. Globally, Japan, United States and Korea have strong capabilities in lithium batteries. Japan leads with ~5500 patents for battery cells and BMS and Korea and US follow suit with ~2500 and ~2000 patents respectively (Exhibit 75). Japan and United States are also strong in transmission systems with the major players applying for ~373 patents in Japan and ~239 patents in US. These patents are spread across local and international universities, national labs, OEMs and suppliers.

Exhibit 74 - Number of Patents Granted to Component Suppliers and OEMs in India

<table>
<thead>
<tr>
<th>Areas of focus</th>
<th>Battery</th>
<th>BMS</th>
<th>Power Electronics</th>
<th>Electric Motor</th>
<th>Transmission System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indian OEMs</td>
<td><img src="hero.png" alt="HERO" /></td>
<td><img src="reva.png" alt="REVA" /></td>
<td><img src="tvs.png" alt="TVS" /></td>
<td><img src="reva.png" alt="REVA" /></td>
<td><img src="tata.png" alt="TATA" /></td>
</tr>
<tr>
<td>- Hero Electric – 1 patent. Automatic connector for battery terminal</td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>- Reva – 10 patents. Modulating regenerative braking and reserved energy in a battery</td>
<td></td>
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</tr>
<tr>
<td>- TVS – 5-7 patents on battery, motor controllers, more efficient transmission systems</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- TATA – 1 patent on regenerative braking</td>
<td></td>
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<td>Foreign OEMs</td>
<td><img src="x.png" alt="X" /></td>
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<tr>
<td>- Manufacturing plants are present</td>
<td></td>
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</tr>
<tr>
<td>- R&amp;D in home country</td>
<td></td>
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</tr>
<tr>
<td>Indian Component Manufacturers</td>
<td><img src="x.png" alt="X" /></td>
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<tr>
<td>- No patents yet</td>
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<tr>
<td>- Exide conducting research on lead acid battery for electric 2 wheeler</td>
<td></td>
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<tr>
<td>- Kirloskar supplying e-motors to Reva</td>
<td></td>
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<tr>
<td>Foreign Component Manufacturers</td>
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<tr>
<td>- &quot;We are lagging far behind other countries in xEV R&amp;D&quot; – Indiag 4W OEM</td>
<td></td>
<td></td>
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</tbody>
</table>

Source: Espacenet, Patent search, Booz & Company analysis
Within batteries, cell materials and electronics are the most research intensive areas. The electrodes and the electrolyte within the cell together constitute one of the largest cost buckets for lithium ion batteries leading to considerable research in these areas. For instance, Sanyo has been granted 134 patents on optimizing lithium ion battery performance. This includes 84 patents on electrolytes, 26 on electrodes and 15 related to the electronics (Exhibit 76).

Source: Deutsche Bank, Booz & Company analysis
SIAM: National Hybrid/Electric Mobility Study

To attain global standards, India can employ a range of technology strategies based on priorities, internal capabilities, competitive intensity and investment needs. R&D capability can be built via multiple routes including licensing/ alliances, acquisitions, joint ventures, and organic development (Exhibit 77). Licensing technologies from other entities and forging alliances is the least complex route with much less investment in terms of time and money. This is typically industry led. For instance, Toyota has licensed hybrid technology to several global OEMs including Ford, Nissan and Mazda. At the other end of the spectrum, organic in-house development calls for significant time and monetary investment. This is typically led by academia and smaller groups within large industrial houses.

Exhibit 77 - Options for Building R&D Capability

- Toyota providing hybrid technology to other OEMs
- Nissan: Using complete hybrid systems
- Ford: Using 20 patents
- Mazda: Using transmissions, power electronics and battery
- Tata acquired equity in Norway’s Miljo Grenland (producer of super polymer lithium batteries)
- Launching Indica EV in European market
- Reva: JV b/w Maini (designs and manufactures) and AEV LLC (auto part manufacturer)
- Mahindra acquired 55% equity in 2010
- Independent research on batteries etc.

Examples:

Source: Green Autoblog, Booz & Company analysis

Interviews indicate that high priority areas for India include technologies like battery cells which will drive affordability and adoption (Exhibit 78). Battery cells and battery management systems form the highest priority areas as they have a great impact on cost and performance. Localized battery systems customized for Indian weather and traffic duty cycles will yield better performance. The next priority is accorded to power electronics (especially for HEVs/ PHEVs) and electric motors. Localized power electronics will yield better performance at a lower cost. Low cost motors can be developed by the use of non-rare earth magnets.
While the priorities have been established, the right to win is determined by evaluating current capabilities, investments required and global competitive intensity. From a comparative analysis, it emerges that India has a right to win only in battery management systems, power electronics and electric motors for xEVs (Exhibit 79). While battery cell is a high priority area, high investments and global competitive intensity translate to a lower right to win for India. BMS, power electronics and electric motors are highly attractive areas as current expertise in technology and manufacturing is high and investments required are also low- to moderate.

Source: Industry interviews, Booz & Company analysis

Exhibit 79 - Evaluation of India’s Right to Win for Prioritized Research Areas
Meshing the priorities and the right-to-win evaluation yields different technology strategies for various xEV components (Exhibit 80). High priority but hard-to-develop components like battery cells can be developed by acquiring technologies and partnering with global players. Moderate priority and easier areas like battery management systems, power electronics and electric motor technologies can be developed by organic investment and local consortia. OEMs can work towards improvising on global product development activities in transmission systems or acquiring companies on reaching scale.

Implementing these strategies calls for an estimated investment of ~₹550 crores in the next five years. Organic in-house product development of battery management systems and power electronics and improvising transmission technologies requires targeted investment from OEMs and manufacturers. However, electric motor and battery cell technologies are more nascent, requiring government assistance. Expert interviews and secondary research suggest that the government needs to invest ~₹200 crores with a matching investment from OEMs to support battery cell alliances and technology acquisition including infrastructure for battery recycling. Similarly, funding to the tune ~₹50 crores over next five years is required for new product research and development of electric motors. Further, the government should invest ~₹50 crores to develop component validation and vehicle testing facilities. Periodic review of these programs can be conducted to suggest modifications or expansions.
These strategies can be implemented through OEMs, universities and national labs (Exhibit 81). Universities and national labs can take the lead on nascent technologies like battery cells and electric motors. For more mature components like BMS, power electronics and transmission systems, component manufacturers and OEMs can take the lead.

**Exhibit 81 - R&D Value Chain**

**Source:** DST, Booz & Company analysis

Government funding for national laboratories and industry can be through multiple routes including consortia and direct R&D grants. To develop xEV technologies, India could leverage a consortium model, which has been successful in other parts of the world. A consortium entails a partnership with shared goals and liabilities. Collaborative research promotes standardization of technologies resulting in scale efficiencies and lower cost. It is a risk-reward sharing model with collaboration leading to efficient utilization of resources. Strong industry and government leadership, with a well-defined organization structure, role and accountability, forms the cornerstone for the consortium’s success. Research needs to have adequate funding with clear definitions of Intellectual Property ownership. The United States Advanced Battery Consortium (USABC) is an example of a successful consortium comprising government national labs, OEMs and component manufacturers (Exhibit 82). Clear demarcation of roles and responsibilities and IP ownership has led to the success of this consortium.
Direct R&D grants coupled with competitive bidding and effective monitoring could also prove to be successful. Direct grants refer to the partial or total funding of a research proposal. Implementation is simplified as there is a clear accountability and any Intellectual Property developed rests with grantee. However, competitive bidding for award of grants and effective monitoring are required for the program to be a success. Government can consider co-funding the program instead of full funding. Grants need to be allocated for all components of the eco-system. United States government’s grant of $249Mn to A123 systems is one success story. A competitive bidding process was followed with final award based on multiple criteria including benefits in terms of localization and job creation. The government effectively monitored the project with investments reimbursed only on presentation of status report. A123 used the grant to set-up the largest lithium-ion automotive battery manufacturing plant in Michigan (Exhibit 83). In another example, China awarded a direct grant to a battery manufacturer (BAK). Successfully implementation has resulted in research and commercialization of high power lithium phosphate cell technology.
Exhibit 83 - Direct Grant Model – Success Stories

<table>
<thead>
<tr>
<th>Source</th>
<th>Dept. of Energy, A123 Systems, Green Congress 2011, BAK China Battery, Booz &amp; Company analysis</th>
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</table>

### VIII.2.4. Infrastructure

Adequate charging facilities are required to support xEV demand and uptake. It is estimated that by 2020, 150-225 MW of extra power generation capacity and investment of ₹750-1000 crores for charging infrastructure may be required to support the xEV potential (Exhibit 84).

In a scenario assuming high uptake of CNG and HEVs, 150MW of extra power generation may be required in 2020 assuming 20% peak charging. This translates to ~175,000 charging stations including fast chargers, level 1 chargers and rapid chargers. In the alternate scenario assuming high CNG, HEV and BEV uptake, the 2020 power requirement rises to ~225MW. High proliferation of BEVs calls for ~227,000 charging stations to be established by 2020.

Exhibit 84 - Infrastructure Requirement for xEV Four-Wheelers

**High Gas / HEV Scenario – 4W**
- Extra Generation Required (MW): 150
- Charging Infrastructure Investment (Rs. Crores): 750
- # Charging Terminals (in '000): 175
  - Rapid Chargers
  - Fast Chargers
  - Level 1 Chargers

**High Gas / HEV / BEV Scenario – 4W**
- Extra Generation Required (MW): 225
- Charging Infrastructure Investment (Rs. Crores): 1,000
- # Charging Terminals (in '000): 227
  - Rapid Chargers
  - Fast Chargers
  - Level 1 Chargers

**Note:** Price per charging station - ₹2,25,000 ($5,000) for fast charging (10% of stations), ₹36,000 ($800) for level 2 charging (20% of stations), ₹18,000 ($400) for level 1 charging (70% of stations). Charging station efficiency = 18 hours per day.

**Source:** Booz & Company analysis

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This information is confidential and was prepared by Booz & Company solely for the use of our client; it is not to be relied on by any third party without Booz's prior written consent. 115
To facilitate development of adequate charging infrastructure, government can consider building laws, subsidies for equipment and concessions for real estate.

- **Building Laws**: Guidelines and specifications may mandate charging infrastructure for all new construction including residential, commercial and retail space. International cities like London and San Francisco have taken a step in this direction with charging infrastructure required in all new buildings. Government can also streamline the charger installation permit process. For instance, Los Angeles plans to make it easier to obtain EV charger installation permits. City departments will prioritize processing of necessary permits and schedule inspections to facilitate installation of at-home chargers within 7 days.

- **Equipment Subsidies**: Subsidies can be provided for installation of EV chargers at homes, super markets and communities. For instance, Los Angeles is offering upto $2000 subsidy on home EV charging stations for the first 1000 applicants. Investment and production tax credit can be accorded to private operators for laying out charging infrastructure.

- **Real Estate Concessions**: Land concessions can be provided to operators for setting up charging infrastructure. Singapore is planning to provide land at concessional rate for charging infrastructure at all public properties.

Government needs to mandate technical standards for charging infrastructure, so that OEMs and infrastructure providers can cater to a standardized plug design and voltage rating specification.

Charging infrastructure should be created per requirements of the location (Table 16: Charging Terminals by Location). A few public charging points can be established on a pilot basis to evaluate consumption. As indicated by the conjoint analysis, four-wheelers are not likely to require large investments in rapid charging infrastructure.

<table>
<thead>
<tr>
<th>Area</th>
<th>Suitable Charging Terminals</th>
<th>Typical Time taken for Charging</th>
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<tbody>
<tr>
<td>Residential / Office Buildings/ Parking Lots</td>
<td>Level 1 terminals</td>
<td>6-8 Hours</td>
</tr>
<tr>
<td>Commercial areas (shopping malls), airport / railway stations</td>
<td>Level 2 terminals (fast chargers)</td>
<td>3-4 Hours</td>
</tr>
<tr>
<td>Convenient locations in cities (e.g. near petrol pumps)</td>
<td>Level 3 terminals (rapid chargers)</td>
<td>&lt;30 minutes</td>
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</table>

**Source**: Innovations (Harvard University), Booz & Company Analysis
VIII.2.5. Summary: Potential Investments for xEV Four Wheelers

An analysis of the demand and supply side markets indicates that catering to the latent demand while strengthening local manufacturing and supply necessitates multiple forms of interventions from the government and industry.

- **Demand Side:** While latent demand for four-wheeler xEVs exists, industry lacks scale due to high acquisition and running costs that impede uptake. Government can assist in creating demand assurance by mandating xEVs in government fleet, public transportation and encouraging private fleets to adopt the same. Tiered demand incentives can be provided depending on vehicle parameters like technology, time/ volume and degree of localization. In the base case, mild HEVs can be provided ~₹25000, full HEVs: ~₹50000, PHEVs: ~₹100000, low performance BEVs: ₹100000 and high performance BEVs: ₹150000. The first 200,000 vehicles can be incentivized annually subject to localization and quality.

- **Manufacturing:** Domestic manufacturing can be incentivized by linking demand side incentives with localization of xEV components (0-5% to 25-30% in 5 years for BEVs). Further, xEV greenfield and brownfield plants can be supported via tax holidays, creation of special manufacturing zones, accelerated depreciation etc. Import duty on xEV CKD components can be reduced providing an impetus to local assembly.

- **Research and Development:** High capabilities need to be developed in research and product development across key technologies including battery cells, battery management systems, power electronics, electric motor and transmission systems. The technology strategy for each is determined by the need to develop the technology and India’s right-to-win. Potential options include licensing/alliances, acquisition, joint venture and organic growth. Battery cell and electric motor research call for ~₹500 crores of joint investment by government and industry over the next five years. Government needs to invest an additional ₹50 crores to develop infrastructure for component validation and testing.

- **Infrastructure Support:** Developing requisite infrastructure for charging is vital for ensuring widespread acceptance of xEV technology. By 2020, 150-225 MW of extra power and an investment of ₹750-1000 crores for charging infrastructure may be required to support xEV potential. Charging terminals would include Level 1 chargers, fast chargers and rapid chargers. To facilitate development of
adequate charging infrastructure, government can consider building laws, subsidies for equipment and concessions for real estate.

It is estimated that total investment of ₹7000-9000 crores will be required to promote four-wheeler xEVs over next 10 years (Exhibit 85). Around 60% needs to be directed towards providing demand-side incentives. The other large cost accounts include development of power infrastructure and charging stations. With a higher uptake of CNG and HEVs, the estimated investment is at the lower end of ₹7200 - ₹7300 crores. However, in a scenario with a high uptake of BEVs as well, ₹8700 - ₹8800 crores may be required. This arises from additional demand side incentives, power and charging infrastructure required by BEVs.

Exhibit 85 - Total Investments for supporting Four-Wheeler xEV potential

Note: Fuel procurement for power generation includes cost of coal = ₹2.4 / kWh
Source: Booz & Company Analysis

VIII.2.6. Benefits

Adoption of xEV four-wheelers results in manifold benefits including reduction in CO₂ emissions, liquid fuel savings and creation of jobs.

In the aggressive scenario, adoption of four-wheeler xEVs results in a ~1% decrease in CO₂ emissions (Exhibit 86). With evolution of technology, PHEVs are expected to have ~35+% lower well-to-wheel emissions compared to contemporary gasoline engines in 2020 and BEVs are expected to have ~45+% lower emissions. Cleaner electricity generation with improved fuel mix will help lower CO₂ emissions further.
Exhibit 86 - Estimated CO₂ emissions from xEV Four-Wheelers

**Note:**
1. Tank to wheel emissions from Gasoline, Diesel, HEV were matching from SIAM A₃ emissions data
2. Total emissions include material, well to tank and tank to wheel as its further segments
3: Refer Appendix for assumptions

**Source:** MIT research, Argonne National Lab research, expert interviews, Booz & Company analysis

Adoption of xEVs will help achieve liquid fuel savings in the range of ~1.1 MT – 1.6 MT from 2011-2020. In a conservative scenario with high gas and HEV uptake, fuel savings are estimated to be ~1.1 MT, whereas an aggressive scenario with high BEV adoption in addition to CNG and HEVs results in fuel savings of ~1.6 MT.

~26000-30000 additional jobs are forecast to be created in the next 10 years. Cumulative net benefits are estimated to have NPV of ~₹4800-7100 crores (Exhibit 87). While initial investments translate to negative returns in the near term, positive benefits are expected from 2018 onwards.
VIII.2.7. Challenges and Ease of Implementation

Initiating xEV adoption and ensuring widespread acceptance is fairly challenging.

Current supply side capabilities are low with only Reva having a commercially available product manufactured in India. However, the ease of implementation is moderate as many MNCs can setup assembly plants with growing demand. Price-performance gap is high at present with low premium for mild HEVs but a high premium for BEVs.

A catch-22 situation prevails where consumer uptake is low at the current price points and with the absence of necessary infrastructure. On the other hand, lower price points warrant scale and technological advancements. Significant investments need to be made in manufacturing, research and product development. However, OEMs are wary in making these investments and would like to see "real demand". With suitably designed demand and supply side incentives, the government can help break this impasse.
VIII.3. TWO-WHEELERS

VIII.3.1. Consumer Demand and Related Incentives

Despite their low penetration today, battery electric two-wheelers have high latent consumer demand (Exhibit 88). Consumers in Tier 2 cities such as Ahmedabad, Lucknow etc. indicate the highest preference to adopt two-wheeler xEVs, followed by those in Tier 1 cities. For the initial roll-out, OEMs can target cities like Ujjain, Mumbai, Ahmedabad and Guwahati, where consumers have shown high xEV preference across segments. Environmental benefits arising from BEV scooters drive their popularity in Tier-1 and Tier-2 cities. High BEV prices and low electric range are key barriers for their adoption in Tier-3 cities.

Exhibit 88 - Preference by City Tier – xEV Two-Wheelers

Note: 1892 interviews across 16 cities
Source: Nielsen field research, Booz & Company analysis

Demand projections based on the total cost of ownership also indicate significant latent demand (Exhibit 89). Demand for BEVs is forecast to rise from 2% in 2011 to 16% in 2020 due to comparable total cost of ownership. In the base case, with petrol prices increasing from ₹63/l to ₹126/l, demand could reach ~20% for BEV scooters and ~15% for BEV bikes by 2020. In the aggressive case, if petrol prices increase from ₹63/l to ₹185/l in 2020, latent BEV demand could be as high as 21%.
Note: High speed scooter BEVs are assumed to have lead acid batteries whereas BEV bike are expected to evolve using advanced lead acid based batteries; prices based on OEM discussions; average annual vehicle kilometer travelled (VKT) is taken to be 8985 kms decreasing to 8280 kms by 2020; Petrol prices increase from 63 Rs/l to 126 Rs/l in 2020; in high petrol price case, gasoline prices increase from 63 Rs/l to 185 Rs/l in 2020

Source: Interviews with OEM, Argonne National Lab, Experts, Secondary research, Booz & Company analysis

While the latent demand is high, meeting consumer preferences is fundamental to increasing adoption of BEV two-wheelers. A study of consumer needs reveals that in addition to supply side technological and infrastructural improvements demand side incentives would be highly effective in increasing two-wheeler BEV adoption.

1800+ face-to-face interviews were conducted to understand consumer needs. Consumers perceive two-wheeler xEVs as being worse than their ICE counterparts particularly in speed, pick-up and maintenance costs. Around 55% - 60% of the respondents indicated BEVs as worse than ICE in their top-speed, pick-up and monthly maintenance costs (Exhibit 90). Majority of the respondents picked the same factors as top barriers inhibiting xEV purchase (Exhibit 91).
## Exhibit 90 - Perception of xEV 2W compared to ICE

<table>
<thead>
<tr>
<th>Parameter</th>
<th>2W - Scooters</th>
<th>2W - Bikes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mileage</td>
<td>31% 27% 42%</td>
<td>25% 23% 51%</td>
</tr>
<tr>
<td>Top Speed</td>
<td>33% 35% 55%</td>
<td>25% 23% 62%</td>
</tr>
<tr>
<td>Pick Up</td>
<td>40% 45% 55%</td>
<td>35% 27% 48%</td>
</tr>
<tr>
<td>Sturdiness</td>
<td>8% 49% 57%</td>
<td>10% 40% 48%</td>
</tr>
<tr>
<td>Range</td>
<td>35% 46% 67%</td>
<td>25% 37% 41%</td>
</tr>
<tr>
<td>Carrying Capacity</td>
<td>15% 44% 67%</td>
<td>16% 40% 41%</td>
</tr>
<tr>
<td>Price</td>
<td>27% 39% 35%</td>
<td>24% 35% 55%</td>
</tr>
<tr>
<td>Maintenance / month</td>
<td>31% 35% 55%</td>
<td>12% 33% 55%</td>
</tr>
<tr>
<td>Availability of Spares</td>
<td>3% 61% 30%</td>
<td>9% 54% 37%</td>
</tr>
<tr>
<td>Looks</td>
<td>15% 65% 20%</td>
<td>16% 58% 26%</td>
</tr>
</tbody>
</table>

Note: 1892 interviews across 16 cities
Source: Nielsen field research, Booz & Company analysis

## Exhibit 91 - Key Barriers Inhibiting Adoption of BEV Two-Wheelers

Source: Nielsen field research, Booz & Company analysis

Sensitivity with respect to four key parameters (Price, Recharge time, Running cost, Range) was studied as part of a conjoint analysis across 1800+ consumers in 16 cities. Both scooter and bike consumers are most sensitive to changes in price and recharge time. While running cost and range seem to be important parameters in decision making, consumers seemed to be less sensitive to changes within the given range.
SIAM: National Hybrid/Electric Mobility Study

Exhibit 92 and Exhibit 93 indicate that typical changes in price and recharge time translate to significant variations in consumer preference for BEV bikes and scooters. However, consumers are relatively agnostic to changes in running cost and electric range. This implies that an incentive on BEV scooter/ bike purchase is likely to be effective in boosting demand. Adoption of fast / quick chargers could also help generate demand.

**Exhibit 92 - Latent Demand for BEV Scooters (Conjoint Analysis)**

**Exhibit 93 - Latent Demand for BEV Bikes (Conjoint Analysis)**

**Note:** Base characteristics of BEV scooter: Price - ₹63000, Running Cost - ₹0.54/ km. Charging Time - 7 hrs. Range - 65km. Analysis based on 537 interviews for scooters across 16 cities; Battery replacement cost factored in running cost

**Source:** Nielsen field research, Booz & Company analysis

**Note:** Base characteristics of BEV bike: Price - ₹65000, Running Cost - ₹0.13/ km. Charging Time - 7 hrs. Range - 100km. 1355 interviews for scooters across 16 cities; Battery replacement cost factored in running cost

**Source:** Nielsen field research, Booz & Company analysis

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With acquisition cost strongly impacting customer decision, incentives are required to stimulate initial adoption and develop scale. The acquisition cost needs to be sufficiently low to aid initial adoption to an extent whereby OEMs have sufficient scale to make this self-sustainable. This will also help generate competition in the industry. Further, incentives should be given to consumers and claimed by OEMs only after registration. These can also be split across first purchase and purchase of replacement batteries and other spare parts.

Differential incentives can be provided varying with type of vehicle, time and volume sold. Apart from high speed high durability vehicles, incentives can also be provided to low speed xEV two-wheelers to promote their use for neighbourhood transportation (Exhibit 94). However, all xEVs under this scheme need to adhere to minimum performance, safety and durability standards as defined by ARAI.

### Exhibit 94 - Proposed Demand Incentives for Two-Wheelers

(₹, based on battery size)

<table>
<thead>
<tr>
<th>Battery Size</th>
<th>2012-2014</th>
<th>2014-2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5-1.5 kWh</td>
<td>7,500</td>
<td>7,500</td>
</tr>
<tr>
<td>HEVs / low</td>
<td></td>
<td></td>
</tr>
<tr>
<td>speed BEVs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.5-2.5 kWh</td>
<td>5,000</td>
<td>15,000</td>
</tr>
<tr>
<td>High speed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>low durability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BEV scooters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.5-2.5 kWh</td>
<td>7,500</td>
<td>12,500</td>
</tr>
<tr>
<td>High speed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>high durability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BEV scooters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5+ kWh</td>
<td>5,000</td>
<td>15,000</td>
</tr>
<tr>
<td>(High speed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>high speed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BEV bikes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Can be awarded to the first one Million units annually starting 2012*

### Source:
Interviews with OEM, Experts, Secondary research, Booz & Company analysis

High incentives ranging from ₹7500- ₹15000 (depending on vehicle type) can be phased in from 2012-2014. This may be followed by lower incentives from 2014-2017. To achieve scale, incentives can be a function of the sales volume as well (Exhibit 95). They can be started in 2012 and full incentive can be awarded to the first million units. In the 6th year, incentives can be given to 500,000 units in the first half and 250,000 units in the second half, after which they may be withdrawn. The option of carrying forward unused incentives to future years...
can be considered. If the industry becomes self-sustaining within five years, the incentives can be withdrawn earlier.

Exhibit 95 - Incentive Phase-Out – Example
(xEV Units eligible for incentives, 2012-2017)

Apart from the overall acquisition cost, subsidies on battery replacement would also be an effective tool to increase adoption as the high cost of battery replacement is a key concern. An analysis of consumer preference indicates that respondents would view reduction in battery costs as an incentive to move towards xEVs (Exhibit 96). Suitable subsidies can be formulated with variations based on battery size, technology, durability, recyclability and volumes.

Exhibit 96 - Motivators for Adoption of xEV Two-Wheelers

Source: Nielsen field research, Booz & Company analysis

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To promote good quality xEVs in two-wheelers and localization, demand incentives should be subject to the OEMs meeting specified conditions. The minimum qualifying quality conditions should include:

- Local assembly of vehicles (no incentives for completely built imported vehicles)
- Adhering to safety and quality standards of an approved institution like ARAI
- Minimum comprehensive warranty on vehicles including batteries

The Bill of Material can serve as the basis to evaluate the value and degree of localization of xEV components in the vehicle. Demand incentives can be based on a minimum localization threshold for each technology supplemented by a minimum annual increase in localization (at least 5%). Current import duty benefits can be phased out over a period (for example over 5 years) to encourage localization.

**VIII.3.2. Supply-side Strategy**

Catering to the domestic demand necessitates strengthening the local manufacturing and supply base. A phased approach could be followed in India for building the manufacturing capability for two-wheeler xEVs (Exhibit 97). Currently, low-moderate capabilities exist across the entire value chain with local assembly being slightly more mature. Development across the value chain can be envisaged as a three stage process.

In the first stage, spanning next 1-4 years, local assembly of xEVs using imported or locally manufactured components can be fully strengthened. Direct and indirect incentives to increase local sources will help this segment mature. Investments in Research and Development and Product Development can be initiated as well.

During the second stage, 5-7 years from now, industry should aim to develop indigenized products. By this time, the industry will have high capabilities across the value chain. Research and product development focus needs to be on indigenized components including battery, transmission system, electric motor etc. Moving down the value chain, the target should be to source >60% of the xEV components locally with the customs duty exemption completely phased out. Most components will be indigenously manufactured with vehicles localized to suit the Indian market.

The plan for the third stage, ~7-10 years from present, should focus on designing products for the export market. At this point, the industry needs to enhance capabilities to be globally competitive and equip R&D, Product Development and production plants for exports.
Other incentives like tax holidays to OEMs and component manufacturers, central support for greenfield xEV plants, duty exemption for capital equipment used by OEMs for xEV assembly, soft loans and grants could be extended to all vehicle segments to facilitate production. These have been detailed in the 4 wheeler segment (VIII.2.2. Supply-side Strategy)

VIII.3.3. Research and Development Investment

To successfully implement the localization strategy, government and industry need to make investments in R&D, Product Development and testing infrastructure. Total potential funding required for implementing these strategies is estimated to be ~₹550 crores in the next five years (Exhibit 98).

Investments should span all the major xEV components – battery cell, battery management system, power electronics, electric motor and transmission system. Given high battery costs, cell technology warrants investment in basic research facilitated by acquisition and alliances. Industry experts estimate required investment to be ~₹200 crores, with the industry matching government funding. Similarly, current indigenous capabilities in electric motor development are low and ~₹50 crores funding is estimated to be required over the next five years to strengthen these capabilities.

However, Indian IT, Engineering Services companies and OEM captive centres have attained proficiency in developing battery management systems and power electronics for global vehicles. OEMs and individual companies can invest in extending these capabilities to develop products tailored to Indian conditions. OEMs and manufacturers need to invest to achieve minimum standards for transmission systems, improvise on existing technology and
attain scale. Government can support these industry initiatives by developing centralized component validation and vehicle testing centres with an investment of ~₹50 crores.

Periodic reviews of these programs can be conducted to adapt to changing requirements. Beyond investments, collaboration between government and industry on this front forms the keystone for successful indigenization and large scale local sourcing of two-wheeler xEVs.

Exhibit 98 - Research Investment for Two Wheelers

<table>
<thead>
<tr>
<th>Component</th>
<th>Technology Strategy</th>
<th>Component Research</th>
<th>Component Development</th>
<th>Component and Vehicle Testing Infrastructure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery Cell</td>
<td>Technology development, acquisition and alliances</td>
<td>200 Crores&lt;sup&gt;1&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Battery Management System</td>
<td>Invest in new product development</td>
<td></td>
<td>OEM / Mfr. investment</td>
<td></td>
</tr>
<tr>
<td>Power Electronics</td>
<td>Invest in new product development</td>
<td>OEM / Mfr. investment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electric Motor</td>
<td>Invest in new product R&amp;D</td>
<td>~₹50 Crores over 5 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transmission System</td>
<td>Adopt minimum standards and improvise</td>
<td></td>
<td>OEM / Mfr. investment</td>
<td></td>
</tr>
</tbody>
</table>

Note: 1: Infrastructure for battery recycling should also be developed with these funds
Source: Industry interviews, Booz & Company analysis

VIII.3.4. Infrastructure

Infrastructural support in terms of additional electricity generation would be required. Additional 600 MW power requirement is estimated. However, investment in public charging may not be required.

The battery size and capacity used in 2 wheelers is small. Hence they can be charged at home. Hence significant investments in public charging infrastructure may not be required.

VIII.3.5. Summary: Potential Interventions for Two-Wheeler xEVs

An analysis of the demand side and supply side reveals that in order to achieve the national mission of high xEV penetration together with local manufacturing and technology development, multi-dimensional incentives and initiatives are warranted.

- **Demand-Side Incentives**: The consumer is incentivized to adopt xEVs by lowering the initial acquisition cost as well as major (battery) replacement cost. Acquisition cost based
incentives may vary with vehicle type/technology, time and volume sold. Initial incentives can range from ₹7500- ₹15000 and gradually phased out by 2017. Incentives can be provided to the first million vehicles sold each year subject to localization and quality. Battery cost subsidies to be based on battery size, technology, durability, recyclability and volumes.

- **Manufacturing:** Sourcing and manufacturing incentives can be devised as a function of the degree of localization of xEV components (e.g. 35% to 60% for lead acid based BEVs). Gradually, the customs duty exemption on xEV components can be phased out.

- **Research and Development:** The aim is to develop R&D and Product Development capabilities across major xEV components. This requires joint funding of basic research in battery cells and electric motors by OEMs and Government totaling ~₹500 crores for next five years. Industry investments will help develop battery management systems, power electronics and transmission systems. Government should look to invest ~₹50 crores in component validation and testing infrastructure.

- **Infrastructure Support:** To support battery recharging and power the two-wheeler BEVs, given the expected uptake, an estimated 600MW of additional power generation capacity is required. However, additional charging infrastructure is not required assuming all two-wheeler owners have access to charging points at home.

Total investment of ~₹10000-10500 crores will be required to promote two-wheeler xEVs over the next ten years (Exhibit 99). Given the impetus required to create an initial demand and achieve sufficient scale for self-sustainability, nearly 50% of the investment will constitute demand-side incentives. Although R&D and product development investments constitute a smaller fraction (~5%), they are fundamental to the long term success. Remaining ~45% needs to be dedicated to developing the power infrastructure and financing the fuel costs.
VIII.3.6. Benefits

Adoption of battery operated two-wheelers translates to manifold benefits including reduction in CO₂ emissions, fuel savings and creation of jobs in product development and manufacturing.

In the aggressive scenario, adoption of two-wheeler BEVs can potentially reduce two-wheeler CO₂ emissions by ~3% in 2020. With ~2% annual improvement in gasoline engine efficiencies, WTW emissions are estimated to decrease to 45gCO₂/km/vehicle in 2020. However, decrease in transmission losses and technological improvements result in BEVs with emissions of only ~29gCO₂/km/vehicle in 2020 (Exhibit 100).

Note: Fuel procurement for power generation includes cost of coal at ₹2.4/kWh
Source: Booz & Company analysis
Note: Total emissions include material, well to tank, and tank to wheel emissions. Refer appendix for all assumptions.

Source: Booz & Company analysis

Uptake of ~4.8Mn BEV two-wheelers is estimated to result in fuel savings of 4.9MT till 2020 with ~22000 additional jobs created by 2020. High performance scooters have been assumed to grow and constitute 35% of BEV scooter sale by 2017, from 0% in 2011 and motorcycle sales have been assumed to grow from 2014 onwards. Implementation of xEV strategy across two-wheeler segment translates to net benefits with NPV of ₹28000 crores from 2011 to 2020 (Exhibit 101).

Exhibit 101 - Net Benefits from Adoption of xEV Two-Wheelers (in '000 crores)

Note: Assume terminal multiple: 10. Hurdle rate for NPV calculation: 12%

Source: Booz & Company analysis

VIII.3.7. Challenges & Ease of Implementation

Two-wheeler BEV uptake appears highly promising with a moderate to high ease of implementation. Capability development is moderate as some OEMs like Electrotherm and Hero Honda have commercial electric scooters but no prototype exists for bikes and this could take time to develop. The price-performance gap is low to moderate. While current solutions are acceptable in the market, their durability and performance needs to be improved. In summary, BEV two-wheelers hold great promise for the future as the potential volumes are large and the benefits are clear, bolstered by a strong customer preference.
VIII.4. BUSES

VIII.4.1. Consumer Demand and Related Incentives

Extensive consumer research has shown significant latent demand for xEV buses. About 430 bus fleet owners were interviewed across 16 cities to understand consumer preferences for xEV buses. Out of these, about 171 owned premium bus fleets. A tier wise breakup reflected that HEVs have the high preference in Tier 2 and 4 cities while PHEV technology is preferred mostly in Tier 4 cities. Consumers in Tier 2 cities have indicated low running cost and no requirement of charging as major reasons for their HEV preference. In the case of BEV technology, preference is highest for Tier 4 followed by Tier 1 cities (Exhibit 102).

Exhibit 102 - Preference by City Tiers – xEV Buses

Source: Nielsen Field Survey, Booz & Company analysis

The face to face interviews also indicated that xEV buses were perceived worse on maintenance cost and similar on other attributes as compared to the ICE counterparts, as seen in Exhibit 103.

Exhibit 103 – Perception of xEV Buses compared to ICE

Source: Nielsen Field Survey, Booz & Company analysis

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Key barriers inhibiting adoption of xEV technologies included pickup, battery replacement cost and charging time (Exhibit 104).

Exhibit 104 – Key Barriers Inhibiting Adoption of xEV Buses

Source: Nielsen Field Survey, Booz & Company analysis

Maintenance cost, pick-up and running cost are important to more than 60% consumers in making a choice for a xEV bus purchase (Exhibit 105).

Exhibit 105 – Top Factors Considered while Buying xEV Buses

Source: Nielsen Field Survey, Booz & Company analysis

To build the initial momentum for xEV buses, it is critical to provide incentives to consumers. Preference for subsidies and toll discounts can be provided to bus fleet owners to push up the sales for xEV buses (Exhibit 106). With use of lithium ion batteries in buses, battery replacement will be required in 5-7 years. Hence the replacement cost of batteries is
SIAM: National Hybrid/Electric Mobility Study

not expected to be a barrier in future however, upfront acquisition cost needs to be subsidized.

**Exhibit 106 – Preferences for Incentives for Adoption of xEV Buses**

Source: Nielsen Field Survey, Booz & Company

Based on the consumer interviews and a subsequent conjoint analysis, sensitivity was tested for various parameters such as price, running cost, range and recharge time (Exhibit 107, Exhibit 108, Exhibit 109). For xEV buses, consumers were found to be very sensitive to acquisition cost. Hence, incentives on price are essential to generate demand. Moderate sensitivity to running cost was observed for HEV and BEV buses, which can be addressed by OEMs by improving the fuel efficiency. Moderate sensitivity was also observed for recharge time for PHEV and BEV buses, indicating the need to set-up rapid and fast charging stations.

**Exhibit 107 – Latent Demand for HEV Buses (Conjoint Analysis)**

Note: Base Price = 1.0 Crore, Running cost = `12.9 per km, Range = 400 km
Source: Nielsen Field Survey, Booz & Company
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Exhibit 108 – Latent Demand for PHEV Buses (Conjoint Analysis)

Note: Base Price = 1.2 Crores, Running cost = ₹7.9 per km, charging time = 7 hours, Range = 400 km
Source: Nielsen Field Survey, Booz & Company

Exhibit 109 – Latent Demand for BEV Buses (Conjoint Analysis)

Note: Base Price = 1.25 Crores, Running cost = ₹4.5 per km, Charging time = 7 hours, Range = 100 km
Source: Nielsen Field Survey, Booz & Company

In order to harness the existing latent market potential leading to increased xEV adoption, a strategy to incentivize both consumers and producers would be required. Demand side incentives for xEV buses will help push demand by making them affordable. Consequently, OEMs can achieve scale through increased demand. Scale would reduce production cost thereby making the product more affordable.

Cash incentives could be provided to consumers to decrease the price-premium of xEVs buses. It would be preferable to front-load the incentives to drive early adoption and then phase it out. For the HEVs, incentives can start from ₹20 lakhs for the first 900 buses and reduced to ₹15 lakh for the next 750 units. Next 600 units could have ₹11 lakh incentives. In the subsequent 450 units, the incentive could be reduced to ₹7 lakh and lastly 300 units could be given a subsidy of ₹5 lakh. For PHEVs a similar phase-out strategy of incentives

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from ₹34 to 18 lakhs can be followed and similarly for BEVs the levels could vary from ₹37 to 20 lakhs, over the first 3,000 buses starting from 2013 (Exhibit 110). 75-90% of these demand incentives can be reserved for HEVs/ PHEVs and 10-25% for BEVs.

Exhibit 110 – Proposed Demand Incentives for xEV Buses
(From 2013 Onwards)

Note: Incentive given to 3000 buses to be used for niche applications such as intra-city low distance feeder buses; low/ semi-low floor, air conditioned, ~12 mt long buses are considered for the analysis; commercial electricity rates are considered at ₹8/unit which is increased at 5% p.a; vehicle prices are based on OEM discussions

Source: OEM and Expert Interviews, Booz & Company analysis

Similar incentives can be considered for the 7m buses as well provided that the OEMs can develop viable solutions. Currently the price premium of xEV solutions in this segment is too high for them to be considered, even with reasonable incentives. Also, retrofit solutions can be provided with the same incentives as OEM solutions, given that they meet quality and safety standards.

To ensure quality and localization, certain qualifying conditions should be laid out to the OEMs which includes:

- Local assembly of vehicles - Incentives could be handed out based on a minimum level of localization of vehicle and component manufacturing. Completely built imported vehicles should not be incentivized.
- Safety standards - Ensuring that the vehicle meets minimum safety and quality standards. These standards could be set by an agency like ARAI.
- Minimum warranty on vehicles, including batteries.

The demand incentives can be subject to a minimum level of localization of xEV component value of the vehicle, based on the bill of material. Starting from present state of <5% localization of xEV components, there can be a minimum 5% incremental localization over the next 5 years, thereby reaching 25-30% local production for the xEVs. Moreover, current
import duty benefits on xEV components can be phased out over a period of 5 years to encourage localization.

Another lever in encouraging OEMs to look at manufacturing alternative powertrains could be demand assurance. This could be materialized by mandating a share of new sales in the public intra-city buses and metro feeders to xEVs. State Transport Utilities (STUs) purchase ~22,000 buses per annum of which 50% are intra-city, a share of 10-20% can be allocated to xEV buses. The price points for premium buses are comparable to low floor ICE buses (₹1-1.3 crores for xEVs compared to ₹60-70 lakhs for ICE buses). However, the price points for xEV high floor buses are very high compared to ICEs (~₹70-80 lakhs compared to ₹25-30 lakhs for ICEs). Therefore, a fixed share of xEVs could be mandated in the low floor bus purchase. Government plans like JNURM could be instrumental in funding the purchase of xEVs bus fleets.

Before full-scale commercialization, pilots can be conducted for hybrid/ electric buses in cities such as Bangalore, Delhi, Mumbai and Hyderabad. Benefits such as increase in fuel efficiency, reduction in CO₂ emissions should be monitored closely. To prevent any major technical issues, adoption of xEVs should also be monitored and rectified as required. Consumer awareness on the benefits of hybrid/ electric buses can be increased by campaigns through radio, outdoor advertisements etc. Also, ticket prices of buses can be increased, specifically in BRTS corridors, to recover the investments and make the use of xEV buses feasible.

VIII.4.2. Supply-side Strategy
The demand-side incentives should be matched with a robust manufacturing strategy by bus OEMs and suppliers. For building manufacturing capabilities of xEV buses, a 3-stage approach spanning ~8-10 years could help in building a strong supply-side and bridging the current gaps (Exhibit 111).

The focus in the first stage, in the initial 1-4 years, should be on developing capabilities in local assembly of xEVs using imported or locally manufactured components. Investments in research and development and product development can be initiated to build capabilities in indigenized components.

Having developed the local assembly of xEVs, the second stage which is ~5-8 years from now, should focus on developing indigenized components. Research and Development should focus on indigenized components such as BMS, transmission system, electric motors.
At least 25-30% xEV components should be locally sourced and the custom duty exemptions should be phased out, to increase localization.

The third and the final stage, ~8-10 years from start, should focus on locally developing technologies for India and exports. Focus should be on enhancing capabilities of research and development and product development centres and production plants to supply in the Indian market as well as for exports. Capabilities should be also developed across the value chain with indigenously developed components, local manufacturing of battery cells and nearly 100% local sourcing.

Exhibit 111 – Manufacturing Strategy for Bus OEMs and Suppliers

Source: Booz & Company analysis

Other incentives like tax holidays to OEMs and component manufacturers, central support for greenfield xEV plants, duty exemption for capital equipment used by OEMs for xEV assembly, soft loans and grants could be extended to all vehicle segments to facilitate production. These have been detailed in the 4 wheeler segment (VIII.2.2. Supply-side Strategy)

VIII.4.3. Research and Development Investment

To successfully implement the localization strategy, government and industry need to make investments in research and development, product development and testing infrastructure. A total of ₹580 crores investment is expected which includes ₹250 crores investment by government, matched by an equal amount by the OEMs and ₹80 crores for testing infrastructure (Exhibit 112).
SIAM: National Hybrid/Electric Mobility Study

Exhibit 112 – Research Investment for Buses

1) Infrastructure for battery recycling should also be set up with these funds

Source: Industry Interviews, Booz & Company analysis

Technology development incentives are essential for battery cells, to decrease their cost, which can be facilitated by acquisition and alliances. An estimated investment of ~₹200 crores is expected by the industry equally matched by the government bodies. Investments in new product development are essential for battery management system, power electronics and electric motors. Investment in new product research and development of electric motors is expected to be ~₹50 crores over the next five years. Further, ₹80 crores need to be invested in component and vehicle testing infrastructure.

Periodic reviews of these programs can be conducted to adapt to suggest modification or expansions. The success of the investments would be based on the collaboration between the government and the industry.

VIII.4.4. Infrastructure

For supporting the demand-side incentives and supply capabilities, sustainable infrastructure is critical. Based on the scenarios, an estimated 2-4 MW of extra generation would be required. Charging infrastructure would entail an investment of ₹10-20 crores to build 300-500 charging terminals (Exhibit 113, Exhibit 114). State Transport Utilities (STUs) can establish charging stations at bus stands and at metro stations for feeder buses. Rapid charging points, which enable quick charging (5-10 minutes), can also be created at prominent bus stops which will eliminate the need for large batteries. However, these can
cost 5X of Level-1 charging stations (~$22,000 per terminal), so might not be viable on a large scale.

**Exhibit 113 – Infrastructure Requirement for High Gas/HEV Scenario for Buses**

<table>
<thead>
<tr>
<th>Extra Generation Required (MW)</th>
<th>Charging Infrastructure Investment (Rs. Crores)</th>
<th># Charging Terminals</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>10</td>
<td>310</td>
</tr>
<tr>
<td>2020 - With 20% Peak Charging</td>
<td>2020</td>
<td></td>
</tr>
<tr>
<td>Majority of xEV charging is expected to occur in off-peak hours</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Exhibit 114 – Infrastructure Requirement for High Gas/HEV/BEV Scenario for Buses**

<table>
<thead>
<tr>
<th>Extra Generation Required (MW)</th>
<th>Charging Infrastructure Investment (Rs. Crores)</th>
<th># Charging Terminals</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>20</td>
<td>500</td>
</tr>
<tr>
<td>2020 - With 20% Peak Charging</td>
<td>2020</td>
<td></td>
</tr>
</tbody>
</table>

**Note:** Price per charging station – ₹10,00,000 ($22,000) for fast charging (10% of stations), ₹4,50,000 ($10,000) for level 2 charging (20% of stations), ₹2,00,000 ($4,400) for level 1 charging (70% of stations). Charging station efficiency -18 hours/day; majority of xEV charging is expected to occur in off-peak hours.

**Source:** Booz & Company analysis

**VIII.4.5. Summary: Potential Interventions for xEV Buses**

To promote xEV buses in the Indian market, potential interventions are required along various dimensions.

- **Demand Side:** xEVs can be mandated in public transportation (10-20% of intra-city buses) to create critical mass for OEMs. Incentives of ₹20-5 lakhs for HEVs, ₹34-18 lakhs for PHEVs and ₹37-20 lakhs for BEVs (decreasing annually) can be given to the first 3,000 buses starting 2013, subject to localization and quality.

- **Manufacturing:** On the supply-side, domestic manufacturing incentives can be linked to the level of localization of xEV components (e.g., 0-5% to 25-30% for xEVs). Custom duty exemptions on xEV components can be phased out to promote localization.

- **Research and Development:** Joint funding of basic research in battery cells and electric motors by OEMs and government with a total investment of ₹580 crores for 5 years is estimated. In addition, ₹80 crores investment would be required for component validation and testing infrastructure.

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- **Infrastructure**: Additional power generation capacity required is expected to be negligible (<5 MW). The charging infrastructure is estimated to entail investments of ₹10-20 crore.

Total investments of ₹1,100-1,300 crore would be required to promote xEVs over the next 10 years in the bus segment (Exhibit 115). In the High Gas/HEV scenario, total of ₹1,100-1,200 crore investment is expected. It includes ~₹500-550 crore of demand incentives provided by the government, ~₹500-600 crore for R&D and ₹25-45 crore for power infrastructure, fuel procurement for power generation and charging infrastructure which can be supported jointly by government and industry bodies. In the High Gas/HEV/BEV scenario, a total investment of ~₹1,200-1,300 crore is expected.

**Note**: Fuel procurement for power generation includes cost of coal = ₹2.4/ kWh

**Source**: Booz & Company analysis

**VIII.4.6. Benefits**

A cost benefit analysis based on investments required and quantifiable returns indicate that net NPV of benefits ~₹3,300-3,700 crores can be achieved through xEV buses, depending upon the penetration scenario (Exhibit 116). In the High Gas/HEV scenario, NPV of benefits is ₹3,300 crores with liquid fuel savings of 0.5 MT till 2020. Additionally, about ~1,500 – 1,600 incremental employment opportunities would be created in the manufacturing sector. In the High Gas/HEV/BEV
scenario, NPV of benefits is ₹3,700 crores with liquid fuel savings of 0.6 MT and the potential to create ~1,200 additional manufacturing jobs by 2020. Each manufacturing job, on an average, will lead to 3 service jobs.

Exhibit 116 - Net Benefits from xEV Buses

Note: A terminal multiple of 10 is used; hurdle rate = 12% in NPV calculation

Source: Booz & Company analysis

Adoption of xEVs can prove to be friendly to the environment as it can potentially reduce premium bus CO₂ emissions by ~6% in 2020 (Exhibit 117). xEV penetration can only be realized in premium bus segment; total emissions include material, well to tank and tank to wheel as its further segments. Refer to the appendix for detailed assumptions on CO₂ emission calculations.

Exhibit 117 - Total CO₂ Emissions for Premium Buses

(Mt CO₂)

Source: MIT research, Argonne National Lab research, Expert interviews, Booz & Company analysis

VIII.4.7. Challenges & Ease of Implementation

While the benefits from adopting xEV buses are promising, the ease of implementation assessed on the basis of capabilities, price-performance gap and buyer preference is moderate. There are prototypes developed by Tata Motors and Ashok Leyland, which
indicate presence of moderate capabilities. However, the price-performance gap is high as the buses need high range and has to operate on high load factors. The buyer preference is moderate; xEV buses can be adopted by the State Transport Utilities, if the relative cost of ownership improves. In summary, the overall future for xEV buses holds tremendous potential, mandates of xEV buses in STUs can help in achieving significant scale.

VIII.5. THREE WHEELERS

VIII.5.1. Consumer Demand and Related Incentives

On the demand side, consumer perceptions were captured across several dimensions to understand the adoption preferences for xEV 3 Wheelers.

Interviews of over 1600 consumers were conducted to understand their preferences for xEV 3 wheelers which reflected an overall high latent demand for xEV 3 wheelers. A tier wise segmentation of interviews reflect Tier 4 cities having the highest preference for battery electric 3 wheelers followed by Tier 2 cities (Exhibit 118). Among all Tier 1-4 cities, Chennai, Guwahati, Ujjain and Mumbai have shown high overall preference. They can be tapped by the OEMs for the initial rollout plan of battery electric 3 wheelers. Additiona,ly, consumers expressed a preference for incentives in the form of free permits and cash. These could be instrumental in driving demand in the market.

Exhibit 118 - Preference by City Tier - xEV 3Ws

![Preference Indicated, %](chart)

3 wheeler xEVs were perceived worse than their ICE counterparts on attributes such as top speed, pickup and monthly maintenance cost, with more than 50% of the consumers having a negative opinion about xEVs on these parameters (Exhibit 119).
Interestingly, pickup and top speed also featured as top two key barriers inhibiting adoption of 3 wheeler xEV technologies, along with battery replacement cost (Exhibit 120).

Consumers also indicated maintenance cost, range and running cost as the top factors while buying 3 wheeler xEVs (Exhibit 121). Incentives can help in generating demand for xEV
3Ws. Consumers have indicated high preference for incentives such as low/ no tax, availability of retro kits and reduced permit ( Exhibit 122).

**Exhibit 121 – Top Factors Considered While Buying xEV 3Ws**

![Graph showing top factors considered while buying xEV 3Ws]

*Source:* Nielsen Field Survey, Booz & Company

**Exhibit 122 – Incentives required for adoption of xEV 3Ws**

![Graph showing incentives required for adoption of xEV 3Ws]

*Source:* Nielsen Field Survey, Booz & Company

In addition to capturing the consumer views on the basis of face to face interviews, conjoint analysis was performed to evaluate sensitivity of consumers around parameters like price, running cost, recharge time and range. Based on conjoint analysis; consumers have shown high sensitivity to acquisition cost/ price for xEV 3 wheelers. However, moderate sensitivity was observed for running cost, recharge time and range (kilometres travelled by the vehicle after charging) for xEV 3Ws (Exhibit 123, Exhibit 124, Exhibit 125).

Thus, incentive on acquisition cost is likely to be effective in generating demand for xEVs. Also, OEMs should strive towards increasing range, improving the fuel efficiency and
reducing the battery cost of xEV 3Ws to increase demand. Furthermore, OEMs should collaboratively set up rapid charging stations to harness latent demand for higher range.

### Exhibit 123 – Latent Demand for HEV 3Ws (Conjoint Analysis)

Note: HEV 3W Base Price = 2.7 Lakh, Running cost = ₹0.8 per km  
Source: Nielsen Field Survey, Booz & Company

### Exhibit 124 – Latent Demand for PHEV 3Ws (Conjoint Analysis)

Note: PHEV 3W Base Price = 3.75 Lakh, Running cost = ₹1 per km, Charging time = 7 hours  
Source: Nielsen Field Survey, Booz & Company analysis

### Exhibit 125 – Latent Demand for BEV 3Ws (Conjoint Analysis)

Note: BEV 3W Base Price = 1.5 Lakh, running cost = ₹1.4 per km, Charging time = 7 hours, Range = 80 km  
Source: Nielsen Field Survey, Booz & Company

This information is confidential and was prepared by Booz & Company solely for the use of our client; it is not to be relied on by any third party without Booz's prior written consent.
The total cost of ownership analysis reflects that BEV 3 wheelers are expected to reach their potential 2020 penetration. The latent demand for BEV 3 wheelers by 2020 is expected to be ~3% which is greater than the deemed 2% potential. However, HEV and PHEV 3 wheelers latent demand may not meet the 2020 potential on their own (Exhibit 126). There is a large gap in the expected penetration and potential even with heavy incentives. Hence, the focus could be on developing the BEV potential.

Exhibit 126 – Difference between Latent Demand and Goal for xEV 3Ws (2020)

![Exhibit 126](chart.png)

Note: BEV considered have range of 80-100 kms, top speed (<30 kmph) and shall require 6-8 hours for charging; 3W xEVs are assumed to be lead acid battery based; vehicle prices are based on OEM discussions.

Source: OEM and Expert Interviews, Booz & Company analysis

In order to generate upfront demand, these vehicles can be incentivized by free permits and incentives of ₹10,000 for the first 20,000 BEVs every year starting from 2012 for five years after which they can be phased out. Low speed 3W BEVs can be used in pockets with high traffic, small campus and small towns. Further, retrofit solutions can be provided same incentive as OEMs, provided that they meet all quality/ safety standards.

To ensure quality and localization, certain guidelines/ qualifying conditions should be laid out to the OEMs which includes:

- Local assembly of vehicles
- Ensuring that the xEV 3-wheelers meet minimum safety and quality standards of vehicles which should be approved by an agency such as ARAI
VIII.5.2. Supply-side Strategy
On the supply side, domestic manufacturing can be promoted by linking incentives to localization of xEV components. Free permits can be subject to minimum level of localization of xEV component value. Starting from present state of 30-35% localization, there can be a minimum 5% incremental localization over the next 5 years, thereby reaching 60% local production for lead-acid based xEV 3 wheelers. Secondly, current import duty benefits on xEV components can be phased out over a period of 5 years to encourage localization.

Other incentives like tax holidays to OEMs and component manufacturers, central support for greenfield xEV plants, duty exemption for capital equipment used by OEMs for xEV assembly, soft loans and grants could be extended to all vehicle segments to facilitate production. These have been detailed in the 4 wheeler segment (VIII.2.2. Supply-side Strategy)

VIII.5.3. Research and Development Investment
There is considerable conceptual and practical overlap in technology and manufacturing processes of 3 wheelers with cars and 2-wheelers. Moreover, the major research focus areas across these three segments remain the same – that of motors and batteries. Hence, the research centric investments in the 2-wheeler and 4-wheeler space should be enough to drive 3-wheeler technology as well.

VIII.5.4 Infrastructure
In order to support the battery charging requirements of the additional 3 wheelers, incremental 10-15 MW of electricity generation would be required, based on scenarios of HEV/ BEV penetration of 3 wheelers. However, it would entail investments of ₹50-75 crore for charging infrastructure (Exhibit 127).
In the High Gas/ HEV Scenario for 3 wheelers, additional 10 MW of power generation capacity will be required. Charging infrastructure investment of ₹50 crores is estimated for 11,000 charging terminals (Exhibit 127).

In the High gas/ HEV/ BEV Scenario for 3 wheelers, additional 15 MW of power generation will be required. This is 5 MW higher than the High gas/ HEV Scenario. Charging infrastructure of ₹75 crores for 18,000 charging terminals is expected (Exhibit 128).

### VIII.5.5. Summary: Potential Interventions for xEV 3 wheelers

To promote xEV 3 Wheelers in the Indian market, potential interventions are required along various dimensions.

- **Demand-Side:** Interventions on the 3 wheeler demand side could be two fold - providing free permits and incentives of ₹10,000 for the first 20,000 BEVs every year from 2012 for five years, subject to localization and quality guidelines. Initial demand for OEMs can be generated by mandating BEVs in public transportation in certain areas of cities.
SIAM: National Hybrid/Electric Mobility Study

- **Manufacturing**: On the manufacturing side, domestic production can be promoted by linking incentives to localization of xEV components. Also, the custom duty exemption on xEV components can be phased out over the next 5 years to encourage localization.

- **Research and Development**: Due to overlap of technological and testing requirements with other vehicle segments, additional R&D investments shall not be required.

- **Infrastructure**: Additional power generation capacity required is expected to be negligible (10-15 MW). However, the charging infrastructure is estimated to entail investments of ₹50-75 crores.

Looking at the overall picture, it seems significant investments would be required to promote xEV 3Ws. For High Gas/HEV scenario, expected total investment is of ₹500-600 crores. It includes ₹400-500 crores government investment for supporting the demand side incentives and industry investments of ₹95-120 crores for power infrastructure, fuel procurement for power generation and charging infrastructure (Exhibit 129).

In the High Gas/HEV/BEV scenario, expected total investment rises to ₹800-900 crores, most of the increase as compared to high Gas/HEV scenario is accounted by the demand incentive investment of 700-750 crores (Exhibit 129).

**Exhibit 129 – Total Investments for supporting xEV Potential in 3W**

<table>
<thead>
<tr>
<th>High Gas / HEV Scenario</th>
<th>High Gas / HEV / BEV Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Investment (Rs. Crores)</strong></td>
<td><strong>Investment (Rs. Crores)</strong></td>
</tr>
<tr>
<td>Demand Incentives</td>
<td>Power Infrastructure</td>
</tr>
<tr>
<td>400 - 450</td>
<td>40 - 50</td>
</tr>
</tbody>
</table>

**Note**: Fuel procurement for power generation includes cost of coal = ₹2.4 / kWh; Incentive of ₹80K (70K for permit and 10K as cash incentive) taken per BEV 3W

**Source**: Booz & Company analysis
VIII.5.6 Benefits

The High gas/ HEV strategy is expected to provide NPV of ₹1,200 crores, liquid fuel savings of 0.2 MT and ~1,400 – 1,600 additional jobs till 2020. High gas/ HEV/ BEV strategy is expected to provide NPV of benefits ₹1,700 crores, 0.3 MT liquid fuel savings and 1,200 additional jobs till 2020 (Exhibit 130).

Exhibit 130 – Net Benefits From xEV 3W

Note: A terminal multiple of 10 is used; hurdle rate = 12% in NPV calculation
Source: Booz & Company analysis

However, adoption of xEVs would not impact the total CO₂ emissions due to negligible improvement of xEVs from status quo (Exhibit 131). Close to 1% drop in CO₂ emissions can be attained in the two high xEV scenarios over status-quo.

Exhibit 131 – Total CO₂ Emissions from xEV 3Ws
(Mt CO₂)

Note: Total emissions include material, well to tank and tank to wheel as its further segments
Source: MIT research, Argonne National Lab research, Expert interviews, Booz & Company analysis
VIII.5.7. Challenges & Ease of Implementation

While we have discussed the benefits, the implementation poses certain challenges. Overall ease of implementation is perceived to be moderate based on current capabilities, price performance gap and buyer preference. Current capabilities are low due to absence of a commercial vehicle. Further, there is a big gap in price versus performance, as 3 wheelers need a high range and operate on high load factors. The buyer preference seems to be high, however only a few consumers have used these vehicles, so might take time to build. A mandate on use in certain areas could provide a good boost to demand.

VIII.6. LIGHT COMMERCIAL VEHICLES

VIII.6.1. Consumer Demand and Related Incentives

Interviews of ~430 consumers were conducted to capture their perceptions and preferences about xEV LCVs. Tier 1 and 3 cities have shown a higher preference for HEV LCVs than the BEV and PHEV LCVs (Exhibit 132). Tier 2 cities have a higher preference for PHEV LCVs. Tier 4 cities have indicated a similar preference for all the three technologies. OEMs can target Jalandhar, Ranchi and Mumbai for the initial roll-out as they have shown high preference for hybrid technology.

Exhibit 132 – Preference by City Tier - xEV LCVs

Source: Nielsen Field Survey, Booz & Company analysis

On the demand side, consumer preferences and perceptions were captured along various dimensions. The consumer interviews revealed that LCV xEVs are perceived as worse on attributes such as top speed and monthly maintenance cost as compared to ICEs (Exhibit 133).
Exhibit 133 - Perceptions of xEV LCVs compared to ICE

<table>
<thead>
<tr>
<th>Feature</th>
<th>Better than ICE</th>
<th>Same as ICE</th>
<th>Worse than ICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mileage</td>
<td>25%</td>
<td>23%</td>
<td>42%</td>
</tr>
<tr>
<td>Top Speed</td>
<td>7%</td>
<td>36%</td>
<td>57%</td>
</tr>
<tr>
<td>Pick Up</td>
<td>9%</td>
<td>43%</td>
<td>55%</td>
</tr>
<tr>
<td>Sturdiness</td>
<td>10%</td>
<td>46%</td>
<td>43%</td>
</tr>
<tr>
<td>Range</td>
<td>12%</td>
<td>37%</td>
<td>46%</td>
</tr>
<tr>
<td>Carrying Capacity</td>
<td>10%</td>
<td>41%</td>
<td>47%</td>
</tr>
<tr>
<td>Price</td>
<td>41%</td>
<td>36%</td>
<td>35%</td>
</tr>
<tr>
<td>Maintenance /month</td>
<td>19%</td>
<td>43%</td>
<td>58%</td>
</tr>
<tr>
<td>Availability of Spares</td>
<td>10%</td>
<td>54%</td>
<td>30%</td>
</tr>
<tr>
<td>Looks</td>
<td>21%</td>
<td>52%</td>
<td>20%</td>
</tr>
</tbody>
</table>

**Source**: Nielsen Field Survey, Booz & Company analysis

Further, key barriers which inhibit adoption of LCV xEV technologies include poor pick up, low top speed and high battery replacement cost (Exhibit 134).

Exhibit 134 - Key Barriers Inhibiting Adoption of LCV xEV Technologies

**Source**: Nielsen Field Survey, Booz & Company analysis
Top factors considered by consumers while buying LCV xEVs include pick up, maintenance cost and running cost (Exhibit 135).

However to ensure an initial build of vehicles incentives need to be provided to the consumers. Consumers have indicated preference towards no/low tax and availability of low cost batteries which could potentially push up the sales for LCV xEVs (Exhibit 136).

Source: Nielsen Field Survey, Booz & Company analysis

Exhibit 135 – Top Factors Considered while Buying xEV LCVs
SIAM: National Hybrid/Electric Mobility Study

Based on ~430 consumer interviews and a subsequent conjoint analysis, sensitivity was tested for various parameters such as price, running cost, range (Exhibit 137, Exhibit 138, Exhibit 139). High consumer sensitivity to price and running cost was observed for xEV LCVs. Incentive on price is likely to be effective in generating demand. Also, improving fuel efficiency and ensuring consumers are aware about could push up hybrid LCV sales. In addition, high sensitivity was observed for recharge time in case of plug-in hybrid LCVs and battery operated LCVs. OEMs can collaboratively set up rapid charge stations, which would share their individual investment and can push demand.

Source: Nielsen Field Survey, Booz & Company analysis

**Exhibit 137 – Latent Demand for Hybrid LCVs (Conjoint Analysis)**

Price Sensitivity: HEV LCV

Running Cost Sensitivity: HEV LCV

**Exhibit 138 – Latent Demand for Plug-in Hybrid LCVs (Conjoint Analysis)**

Price Sensitivity: PHEV LCV

Running Cost Sensitivity: PHEV LCV

Recharge Time Sensitivity: PHEV LCV

Note: Base Price = ₹4.6 Lakh, Running cost = ₹2.35 per km, Range = 500 km
Source: Nielsen Field Survey, Booz & Company analysis

This information is confidential and was prepared by Booz & Company solely for the use of our client; it is not to be relied on by any third party without Booz's prior written consent.
Note: Base Price = ₹5.22 Lakh, Running cost = ₹1.67 per km, Charging time = 7 hours, Range = 500 km
Source: Nielsen Field Survey, Booz & Company analysis

Exhibit 139 - Latent Demand for Battery Electric LCVs (Conjoint Analysis)

Note: Base Price = ₹5.23 Lakh, Running cost = ₹2.18 per km, Charging time = 7 hours, Range = 55 km
Source: Nielsen Field Survey, Booz & Company analysis

As discussed above, demand side incentives such as on acquisition cost, providing rapid charging stations etc. are essential to reach sufficient scale and eventually lower costs. In addition, incentives of ₹50,000 for HEVs and ₹100,000 for BEVs can be given to first 50,000 units every year from 2013 for the next 5 years and can eventually be phased out (25,000 units in first half of 2018 and 12,500 units in the second half of 2018). Further, 60-70% of the demand incentives can be reserved for HEVs/ PHEVs and 20-30% for BEVs. Also, retrofit solutions can be provided same incentives as OEMs, given that they meet quality and safety standards. To ensure quality and localization, certain guidelines/ qualifying conditions should be laid out to the OEMs which include:

- Local assembly of vehicles
- Ensuring that the xEV LCVs meet minimum safety and quality standards of vehicles which should be approved by an agency such as ARAI
- Minimum warranty on vehicles including batteries

The demand incentives can be subject to a minimum level of localization of xEV component value of the vehicle, based on the bill of material. Starting from present state of 30-35% localization, there can be a minimum 5% incremental localization over the next 5 years, thereby reaching 60% local production for the xEV LCVs. Moreover, current import duty benefits on xEV components can be phased out over a period of 5 years to encourage localization.
These demand incentives can increase the sales of the xEV LCV segment which looks very promising with a latent demand of ~81,000 HEVs and ~38,000 BEVs by 2020 (Exhibit 140).

**Exhibit 140 – LCV xEV Latent Demand**

![Graph showing proposed xEV incentives and LCV latent demand](image)

**Note:** Electricity cost is taken at commercial usage rates at ₹8 / unit and increased at 5% p.a.; vehicle prices are based on OEM discussions.

**Source:** OEM and Expert Interviews, Booz & Company analysis

### VIII.6.2. Supply-side Strategy

The demand-side incentives should be matched by a robust manufacturing strategy by xEV LCV OEMs and suppliers. For building manufacturing capabilities of xEV LCVs, a 3-stage approach spanning ~8-10 years could help in building a strong supply-side and bridging the current gaps (Exhibit 141).

**Exhibit 141 – Manufacturing Strategy for LCV OEMs and Suppliers**

1. **Stage 1 – Domestic Assembly** (1–4 Yrs.)
   - **Research:** Initiate investments in R&D and PD centres
   - **Product Development:** Indigenized components (BMS, transmission system, electric motors, etc.)
   - **Sourcing:** Increasing local sourcing
   - **Manufacturing:** Local assembly of xEVs using imported / local components

2. **Stage 2 – Indigenized Products** (5–8 Yrs.)
   - **Research:** Indigenized components (BMS, transmission system, electric motors, etc.)
   - **Product Development:** >60% local sourcing for xEV components, Custom duty exemptions phased out
   - **Sourcing:** Nearly 100% local sourcing
   - **Manufacturing:** Local assembly of xEVs using local components

3. **Stage 3 – Locally Developed Technologies for India and exports** (~8–10 Yrs.)
   - **Research:** Indigenized components (BMS, transmission system, electric motors, etc.)
   - **Product Development:** Enhance capability of R&D and PD centres, and production plants for exports
   - **Sourcing:** Indigenously developed components targeting India and export markets
   - **Manufacturing:** High capability

Incentives for manufacturing cap be similar to 4W.
The focus in the first stage, in the initial 1-4 years, should be on developing high capabilities in local assembly of xEVs using imported or locally manufactured components. Moreover, moderate capabilities can be built in increasing local sourcing. Investments in Research and Development and Product Development can be initiated as well.

Having developed the local assembly of xEVs, the second stage ~5-8 years from now, should focus on developing indigenized products. Research and Development should focus on indigenized components such as BMS, transmission system, electric motors. Atleast 60% xEV components should be locally sourced and the custom duty exemptions should be phased out.

The third and the final stage, ~8-10 years from start, should locally develop technologies for India and exports. Focus should be on enhancing capabilities of Research and Development and Product Development centres and production plants to supply in the Indian market as well as for exports. High capabilities should be developed across the value chain with indigenously developed components and nearly 100% local sourcing.

Other incentives like tax holidays to OEMs and component manufacturers, central support for greenfield xEV plants, duty exemption for capital equipment used by OEMs for xEV assembly, soft loans and grants could be extended to all vehicle segments to facilitate production. These have been detailed in the 4 wheeler segment (VIII.2.2. Supply-side Strategy)

**VIII.6.3. Infrastructure**

Supporting the demand-side incentives and supply capabilities, a sustainable infrastructure is critical. Based on various scenarios an estimated 10-20 MW of extra generation would be required. Charging infrastructure would entail an investment of ₹75-120 crores to build 18,000-27,000 charging terminals.

In the High Gas/ HEV Scenario for LCVs, additional 10 MW of power generation capacity will be required. Charging infrastructure investment of ₹75 crores is estimated for 18,000 charging terminals (Exhibit 142). In the High gas/ HEV/ BEV Scenario for LCVs, additional 20 MW of power generation will be required. This is 10 MW higher than the High gas/ HEV Scenario. Charging infrastructure of ₹120 crores for 27,000 charging terminals is expected (Exhibit 143).

**Exhibit 142 - Infrastructure Requirements for High Gas/HEV Scenario for LCVs**
Note: Price per charging station – ₹2,25,000 ($5,000) for fast charging (10% of stations), ₹36,000 ($800) for level 2 charging (20% of stations), ₹18,000 ($400) for level 1 charging (70% of stations). Charging station efficiency = 18 hours per day.
Source: Booz & Company analysis

VIII.6.4. Research and Development Investment
There is considerable conceptual and practical overlap in technology and manufacturing processes of xEV LCV with xEV cars, 3 wheelers and buses. Moreover, the major research focus areas across these three segments remain the same – that of motors and batteries. Hence, the research centric investments proposed in the other vehicle segments should be enough to drive LCV xEV technology as well.

VIII.6.5. Summary: Potential Interventions for xEV LCVs
To promote xEV LCVs in the Indian market, potential interventions are required along various dimensions.

- **Demand Side:** Demand side incentives such as on acquisition cost, providing rapid charging stations etc. can help in reaching sufficient scale and eventually achieving lower costs. Incentives of ₹50,000 for HEVs and ₹100,000 for BEVs for the first 50,000 vehicles every year starting from 2013 can be provided, subject to localization and quality. Also, xEV LCVs can be mandated in the government fleet.

- **Manufacturing:** On the supply-side, domestic manufacturing incentives can be linked to the level of localization (e.g., 35% to 60% for lead-acid based BEVs).
Along with, custom duty exemptions on xEV components can be phased out to promote localization.

- **Research and Development**: Due to overlap of technological and testing requirements with other vehicle segments, additional R&D investments shall not be required.

- **Infrastructure**: Additional power generation capacity required is expected to be negligible (10-20 MW). However, the charging infrastructure is estimated to entail investments of ₹75-120 crores.

Total investments of ₹1,400-1,800 crores would be required to support xEV potential in LCVs (Exhibit 144). In the High Gas/ HEV scenario, total of ₹1,400-1,500 crores investment is expected. It includes ~₹1,250 - 1,300 crores of demand incentives provided by the government and ~₹150 crores for power infrastructure, fuel procurement for power generation and charging infrastructure. In the High Gas/ HEV/ BEV scenario, total investments of ₹~1,700-1,800 crores are expected.

**Exhibit 144 – Total Investments for supporting xEV Potential in LCVs**

<table>
<thead>
<tr>
<th></th>
<th>High Gas / HEV Scenario</th>
<th>High Gas / HEV / BEV Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand Incentives</td>
<td>1250 - 1300</td>
<td>1500 - 1550</td>
</tr>
<tr>
<td>Power Infrastructure</td>
<td>55 - 65</td>
<td>90 - 100</td>
</tr>
<tr>
<td>Fuel Procurement for Power Generation</td>
<td>15 - 20</td>
<td>25 - 30</td>
</tr>
<tr>
<td>Charging Infrastructure</td>
<td>70 - 80</td>
<td>115 - 125</td>
</tr>
<tr>
<td>Total</td>
<td>1,400 - 1,500</td>
<td>1,700 - 1,800</td>
</tr>
</tbody>
</table>

**Note**: Fuel procurement for power generation includes cost of coal = ₹2.4 / kWh

**Source**: Booz & Company analysis

**VIII.6.6. Benefits**

Net benefit of ~₹1,500-3,000 crores can be achieved through xEV LCVs (Exhibit 145). In the High Gas/ HEV scenario, NPV is ₹1,500 crores with liquid fuel savings of 0.3 MT till 2020 and employment opportunity of ~8,500 - 9,200 jobs. In the High Gas/ HEV/ BEV scenario,
NPV of benefits is ₹2,700 crores with liquid fuel savings of 0.5 MT and the potential to create ~8,000 additional jobs by 2020.

**Exhibit 145 – Net Benefits from xEV LCVs**

**Note:** Terminal multiple of 10 has been used  
**Source:** Booz & Company analysis

Adoption of xEVs can prove to be environmental friendly as it can potentially reduce LCV CO2 emissions by ~2% in 2020.

**Exhibit 146).**

**Exhibit 146 – Total CO2 Emissions from LCVs**  
(Mt CO2)
VIII.6.7. Challenges & Ease of Implementation

Based on an assessment of capabilities, price-performance gap and buyer preference, the overall ease of implementation is low, due to which it can be challenging to implement. Present capabilities are low with no commercial vehicle/prototype as of now. The price performance gap is high. The buying preference is moderate with some latent demand for xEV LCVs. However, OEMs will have to develop choices for the consumers and reliability for durability and performance.

VIII.7. SUMMARY OF PROPOSED INTERVENTIONS

Table 17 - Summary of Proposed Interventions

<table>
<thead>
<tr>
<th>Vehicle Segment</th>
<th>Lever</th>
<th>Suggested Intervention</th>
<th>Agencies Involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 Wheeler</td>
<td>Demand Side</td>
<td>Demand Assurance – Procurement of xEVs for government fleets</td>
<td>Ministry of Heavy Industries, Planning Commission</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Demand Incentives -</td>
<td>Ministry of Heavy Industries, Ministry of Urban Development, Ministry of Finance, Planning Commission</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Mild HEV – ₹25k</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Full HEV – ₹50k</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• PHEV - ₹1 lakh</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Low performance BEV – ₹1 lakh</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• High performance BEV – ₹1.5 lakh</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>to 2 lakh xEV per year for 5 years tapering it off in the 6th year</td>
<td></td>
</tr>
<tr>
<td>Supply Side</td>
<td>• Link incentives to localization of xEV components. Starting with current 0-5% localization, incentives could be modeled to benefit the manufacturers achieving a minimum 5% incremental localization over the next 5 years.</td>
<td>Ministry of Heavy Industries, NMCC, DIPP</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• To promote local manufacturing, benefits similar to NMIZ in the National Manufacturing policy, as well as 3-5 year tax holidays can be provided.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Other benefits like accelerated depreciation of capital equipment for xEV manufacture, soft loans etc. can also be considered</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Research &amp; Development</td>
<td>Investments to the tune of 500 crore for battery and motor research and 50 crore for two component validation and testing centers</td>
<td>OEMs and Ministry of Heavy Industries, Department of Science and Technology, MNRE, Ministry of Finance, Planning Commission</td>
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<tr>
<td>Infrastructure</td>
<td>150-225 MW additional power generation</td>
<td>Ministry of Power, Ministry of Urban development, Ministry of Road Transport, Ministry of Heavy Industries, Ministry of Finance, MNRE, Planning Commission</td>
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<tr>
<td>₹750 – 1,000 crore for charging infrastructure</td>
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<td>2 wheeler</td>
<td>Demand Side</td>
<td>Ministry of Heavy Industries, Ministry of Urban Development, Ministry of Finance, Planning Commission</td>
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<td></td>
<td>Demand Incentives -</td>
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<tr>
<td></td>
<td>• Scooters</td>
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<td></td>
<td>‧ HEV / Low Speed BEV (0.5 – 1.5 kwh battery) - ₹5k - 7.5k</td>
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<tr>
<td></td>
<td>‧ High Speed Low Durability BEV (1.5 – 2.5 kwh battery) - ₹5k – 7.5k</td>
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<tr>
<td></td>
<td>‧ High Speed High Durability BEV (1.5 – 2.5 kwh battery) - ₹10k – 12.5k</td>
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<td></td>
<td>‧ BEV Motorbikes (&gt;2.5 kwh battery) - ₹15k</td>
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<td>to 10 lakh xEV per year for 5 years tapering it off in the 6th year</td>
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<td></td>
<td>Supply Side</td>
<td>Ministry of Heavy Industries, NMCC, DIPP</td>
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<tr>
<td></td>
<td>• Link incentives to localization of xEV components. Starting with current 30-35% localization, incentives could be modeled to benefit the manufacturers achieving a minimum 5% incremental localization over the next 5 years</td>
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<td></td>
<td>• To promote local manufacturing, benefits similar to NMIZ in the National Manufacturing policy, as well as 3-5 year tax holidays can be provided.</td>
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<td></td>
<td>• Other benefits like accelerated depreciation of capital equipment for xEV manufacture, soft loans etc. can also be considered</td>
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<td></td>
<td>Research &amp; Development</td>
<td>OEMs and Ministry of Heavy Industries, Department of Science and Technology, MNRE, Ministry of Finance, Planning Commission</td>
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<td></td>
<td>Investments to the tune of 500 crore for battery and motor research and 50 crore for two component validation and testing centers</td>
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<td></td>
<td>Infrastructure</td>
<td>Ministry of Power, Ministry of Urban development, Ministry of Road Transport, Ministry of Heavy Industries, Ministry of Finance, MNRE, Planning Commission</td>
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<td></td>
<td>600 MW additional power generation</td>
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<td></td>
<td>Bus</td>
<td>Ministry of Heavy Industries, Planning Commission</td>
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<td>Demand Side</td>
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<td></td>
<td>Demand Assurance – Procurement of xEVs for intra-city bus fleets, metro feeders etc.</td>
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<td>Demand Incentives -</td>
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<td></td>
<td>‧ HEV – ₹20 lakh – 5 lakh</td>
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<td>Ministry of Heavy Industries, Ministry of Urban Development,</td>
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<td>3 Wheeler</td>
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<td><strong>Demand Side</strong></td>
<td>Demand Incentives -</td>
<td>Ministry of Heavy Industries, Ministry of Urban Development, Ministry of Finance, Planning Commission</td>
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<td></td>
<td>• Free permits</td>
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<tr>
<td></td>
<td>• Cash incentives - ₹10,000</td>
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<tr>
<td></td>
<td>to 20000 BEV 3 wheeler per year for 5 years starting 2012</td>
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<tr>
<td><strong>Supply Side</strong></td>
<td>Link incentives to localization of xEV components, Starting with current 30-35% localization, incentives could be modeled to benefit the manufacturers achieving a minimum 5% incremental localization over the next 5 years</td>
<td>Ministry of Heavy Industries, NMCC, DIPP</td>
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<td>• To promote local manufacturing, benefits similar to NMIZ in the National Manufacturing policy, as well as 3-5 year tax holidays can be provided.</td>
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<td></td>
<td>• Other benefits like accelerated depreciation of capital equipment for xEV manufacture, soft loans etc. can also be considered</td>
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<tr>
<td><strong>Research &amp; Development</strong></td>
<td>Additional investments not required. Could be covered by investments in other segments due to overlap</td>
<td>OEMs and Ministry of Heavy Industries, Department of Science and Technology, MNRE, Ministry of Finance, Planning Commission</td>
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<tr>
<td><strong>Infrastructure</strong></td>
<td>2-4 MW additional power generation</td>
<td>Ministry of Power, Ministry of Urban Development, Ministry of Road Transport, Ministry of Heavy Industries, Ministry of Finance, MNRE, Planning Commission</td>
<td></td>
</tr>
<tr>
<td></td>
<td>₹10-20 crore for charging infrastructure</td>
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<tr>
<td><strong>Supply Side</strong></td>
<td>Link incentives to localization of xEV components, Starting with current 0-5% localization, incentives could be modeled to benefit the manufacturers achieving a minimum 5% incremental localization over the next 5 years</td>
<td>Ministry of Heavy Industries, NMCC, DIPP</td>
<td></td>
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<td></td>
<td>• To promote local manufacturing, benefits similar to NMIZ in the National Manufacturing policy, as well as 3-5 year tax holidays can be provided.</td>
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<td></td>
<td>• Other benefits like accelerated depreciation of capital equipment for xEV manufacture, soft loans etc. can also be considered</td>
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</tr>
<tr>
<td><strong>Research &amp; Development</strong></td>
<td>Investments to the tune of 500 crore for battery and motor research and 80 crore for two component validation and testing centers</td>
<td>OEMs and Ministry of Heavy Industries, Department of Science and Technology, MNRE, Ministry of Finance, Planning Commission</td>
<td></td>
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<td></td>
<td>• To promote local manufacturing, benefits similar to NMIZ in the National Manufacturing policy, as well as 3-5 year tax holidays can be provided.</td>
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<td></td>
<td>• Other benefits like accelerated depreciation of capital equipment for xEV manufacture, soft loans etc. can also be considered</td>
<td></td>
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<tr>
<td><strong>Infrastructure</strong></td>
<td><strong>Demand Side</strong></td>
<td><strong>Planning Commission</strong></td>
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</tbody>
</table>
| 10-15 MW additional power generation | Demand Incentives -  
  - HEV – ₹50,000  
  - BEV – ₹1,00,000 | Ministry of Power,  
Ministry of Urban development, Ministry of Road Transport,  
Ministry of Heavy Industries, Ministry of Finance, MNRE, Planning Commission |
| ₹50-75 crore for charging infrastructure | to 50000 units per year for 5 years starting 2013 | |

<table>
<thead>
<tr>
<th><strong>LCV</strong></th>
<th><strong>Supply Side</strong></th>
<th><strong>Ministry of Heavy Industries, Ministry of Urban Development, Ministry of Finance, Planning Commission</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand Side</td>
<td></td>
<td></td>
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</tbody>
</table>
- Link incentives to localization of xEV components. Starting with current 30-35% localization, incentives could be modeled to benefit the manufacturers achieving a minimum 5% incremental localization over the next 5 years  
- To promote local manufacturing, benefits similar to NMIZ in the National Manufacturing policy, as well as 3-5 year tax holidays can be provided.  
- Other benefits like accelerated depreciation of capital equipment for xEV manufacture, soft loans etc. can also be considered | Ministry of Heavy Industries, NMCC, DIPP |

| **Research & Development** | **Additional investments not required. Could be covered by investments in other segments due to overlap** | OEMs and Ministry of Heavy Industries, Department of Science and Technology, MNRE, Ministry of Finance, Planning Commission |

<table>
<thead>
<tr>
<th><strong>Infrastructure</strong></th>
<th><strong>10-20 MW additional power generation</strong></th>
<th><strong>Ministry of Power, Ministry of Urban development, Ministry of Road Transport, Ministry of Heavy Industries, Ministry of Finance, MNRE, Planning Commission</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>₹75-120 crore for charging infrastructure</td>
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</tbody>
</table>
IX. BENEFITS FROM xEVs

By focussing on xEVs, India could meet its objectives set out for the National Hybrid/Electric Mission. The benefits could be evaluated along five dimensions:

- **Fuel Security** - India could achieve annual liquid fuel savings of 2.2-2.5 Million Tonnes translating to ₹13,000 -14,000 crore by targeting the sales figure of 7 million unit sales in 2020. Cumulative liquid fuel savings over the next 10 years are expected to be 7-8 MT. Bulk of these fuel savings (>50%) could come from battery electric two wheelers. Four wheelers are also expected to account for 20-25% of these fuel savings, followed by buses, light commercial vehicles and three wheelers in decreasing order of fuel savings.
Environmental Impact - Adoption of xEVs will help achieve potential reduction of ~1.3%-1.5% in CO₂ emissions, compared to ICE vehicles\textsuperscript{15}.

Local Manufacturing Capability - xEV strategy for India should be designed to give a fillip to domestic manufacturing. This will help create capabilities and establish the Indian Automobile Industry in the league of technology leaders. Moreover, most of the in-house production activity will reach sustainability before 2020 and will give significant return on investments.

Affordable xEV solution - By providing demand incentives upfront, along with support for R&D and local manufacturing, government can facilitate creation of affordable xEV solutions which can meet consumer expectations. Technology innovation, battery cost evolution and scale are expected to drive affordability of xEVs in the future. Hence an initial investment shall lead to a sustainable and green mobility solution for the country.

Employment Generation - Through local manufacturing of xEVs, at least 60,000 – 65,000 additional jobs can be generated by 2020 (Table 18). For every manufacturing job, three service jobs are possible – so an additional ~180K to ~200K jobs could be created by 2020. These service jobs would be in operation and maintenance of electronic equipment and would be distinctly different from existing service jobs. Hence a total of about 240k – 265k additional employment opportunities could be created with a focus on driving the automobile industry towards hybridization/electrification.

<table>
<thead>
<tr>
<th>Table 18: Manufacturing Jobs Created by Segment</th>
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<tbody>
<tr>
<td></td>
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<tr>
<td>High Gas/HEV</td>
</tr>
<tr>
<td>High Gas/HEV/BEV</td>
</tr>
</tbody>
</table>

All the quantifiable benefits and investments across segments have been detailed below (Table 19). 2 wheeler xEVs seem to have the highest return on investment with a net present value of ₹28,000 crore. Given the relative ease of implementation of the roadmap for 2 wheelers, their electrification should be executed in the near future. 4 wheeler xEVs also have significant returns which justifies the upfront investment and a prioritized view to develop xEV cars.

\textsuperscript{15} A monetary number to carbon emission reduction has not been assigned
In conclusion, with a collaboration of government, OEMs and other stakeholders, a clear plan for xEV development and deployment in India could be chalked out. Over the next 10 years, this is going to prove as a stepping stone in India’s attempt to reduce its crude oil import dependency and provide Indian consumers with an economically viable and sustainable alternative mobility solution.

X. APPENDIX

X.1. ASSUMPTIONS

X.1.1. Potential for xEVs

Potential for xEVs and related fuel savings were calculated using sales penetration, total vehicle sales, distance travelled and mileage. The inputs and assumptions have been outlined in Table 20.

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16 Other investments include investments in R&D, power infrastructure, charging infrastructure (wherever applicable) and electricity generation.
### X.1.2. Total Cost of Ownership Model

Total cost of ownership model was used to obtain the likely sales for powertrains based on relative economy. Inputs and assumptions used are detailed below:

- **Fuel efficiency improvement** - 2% per annum for ICE
- **Petrol price** assumed as increasing from ₹63 in 2011 to ₹126 in 2020 (based on EIA World Energy Outlook 2010 estimate); for high fuel price case, petrol price assumed as increasing to ₹185 in 2020
- **Residential electricity price** - ₹4.5 / Unit, commercial electricity price - ₹8 / Unit in 2011, growing at 5% p.a.
- **Battery performance (range)** improvement 8% till 2015; 4% beyond 2015
- **4W xEVs, Bus xEVs and LCV hybrids** are assumed to be based on li-ion battery; **2W BEVs, 3W xEVs, LCV BEVs/ PHEVs** are assumed to be based on lead acid battery
- **4W BEV maintenance cost** ₹0.1/ km

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<table>
<thead>
<tr>
<th></th>
<th>HEV</th>
<th>PHEV</th>
<th>BEV</th>
<th>2011</th>
<th>2020</th>
<th>HEV</th>
<th>PHEV</th>
</tr>
</thead>
<tbody>
<tr>
<td>2W</td>
<td>High HEV</td>
<td></td>
<td></td>
<td>15%</td>
<td>11.8</td>
<td>32</td>
<td>30%</td>
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<tr>
<td></td>
<td>High HEV/BEV</td>
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<tr>
<td>3W</td>
<td>High HEV</td>
<td></td>
<td></td>
<td>2%</td>
<td>0.5</td>
<td>1</td>
<td>25%</td>
</tr>
<tr>
<td></td>
<td>High HEV/BEV</td>
<td></td>
<td></td>
<td>3%</td>
<td></td>
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<tr>
<td>4W</td>
<td>High HEV</td>
<td>11%</td>
<td>4%</td>
<td>2%</td>
<td>2.5</td>
<td>8.5</td>
<td>24%</td>
</tr>
<tr>
<td></td>
<td>High HEV/BEV</td>
<td></td>
<td></td>
<td>4%</td>
<td></td>
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<tr>
<td>Prem. Bus</td>
<td>High HEV</td>
<td></td>
<td></td>
<td>2%</td>
<td>0.004</td>
<td>0.014</td>
<td>32%</td>
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<tr>
<td></td>
<td>High HEV/BEV</td>
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<td></td>
<td>5%</td>
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<tr>
<td>LCV</td>
<td>High HEV</td>
<td>8%</td>
<td></td>
<td>2%</td>
<td>0.3</td>
<td>1.5</td>
<td>20%</td>
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<tr>
<td></td>
<td>High HEV/BEV</td>
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<td></td>
<td>4%</td>
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</table>

**Note:** Retrofits are assumed to have 80% of the fuel efficiency gain compared to OEM produced HEV / PHEV. Fuel efficiency of ICE: 2W – 65 kmpl, 3W – 38 kmpl, 4W – 12 kmpl (petrol), Premium Bus – 2.4 kmpl, LCV – 18 kmpl

**Source:** OEM Interviews, Secondary Research, Booz & Company analysis
SIAM: National Hybrid/Electric Mobility Study

- 4W A2 BEV price 2011 – ₹10 lakh (high price case); 8 lakhs (low price case); A3 BEV price 2011 – ₹13 lakh (Price in 2011 refers to expected price if OEMs bring the commercial product to the market based on current price and performance)
- Acquisition cost difference for 4W hybrid – ₹90,000
- 2W BEV scooter price 2011 – ₹63,000 (for a durable high speed model); 2W BEV bike price – ₹90,000
- Bus price (2011) – ₹1 Crore (HEV), ₹1.2 Crore (PHEV), ₹1.25 Crore (BEV)
- 3W price (2011) – ₹1.5 lakh (BEV), ₹2.7 lakh (HEV), ₹3.75 lakh (PHEV)
- Battery size (2011) –
  - 2W BEV scooter – 1.92 kWh; 2W BEV bike – 3 kWh
  - 3W – HEV – 1.2 kWh; PHEV - 5.1 kWh; BEV – 7.92 kWh
  - 4W –
    - A2 – HEV – 1 kWh; PHEV – 5.2 kWh; BEV – 15 kWh
    - A3 – HEV – 1 kWh; PHEV – 5.2 kWh; BEV – 24 kWh
  - Bus – HEV – 15 kWh; PHEV – 65 kWh; BEV – 100 kWh
  - LCV – HEV – 1.1 kWh; PHEV – 4.6 kWh; BEV – 7 kWh
- Mileage (2011) -
  - 2W BEV scooter – 28.9 km per unit; 2W BEV bike – 38 km per unit
  - 3W – HEV – 34 kmpl; PHEV – 34 kmpl on ICE, 10.1 km per unit electric; BEV – 10.1 km per unit
  - 4W –
    - A2 – HEV – 18 kmpl; PHEV – 22.5 kmpl on ICE, 6.7 km per unit electric; BEV – 8 km per unit
    - A3 – HEV – 14 kmpl; PHEV – 18 kmpl on ICE, 6.7 km per unit electric; BEV – 6.7 km per unit
  - Bus – HEV – 3.8 kmpl; PHEV – 4.3 kmpl on ICE, 0.9 km per unit electric; BEV – 1 km per unit
X.1.3. Carbon Dioxide Emissions
Reduction in CO₂ emissions were also calculated on a well-to-wheel basis. The inputs and assumptions used by each vehicle segment are detailed below:

2W
- Gasoline mileage: 70 kmpl
- BEV mileage: 3 kWh/100km

3W
- Gasoline mileage: 27.5 kmpl, Diesel mileage: 38 kmpl
- HEV mileage: 25% improvement over ICE
- BEV mileage: 9 kWh/100km
- CNG: ~17% lower emissions than gasoline, 1.5% annual efficiency improvement

4W
- Gasoline mileage: 16 kmpl, Diesel mileage: 16.7 kmpl (weighted average for A3 sales in 2011), HEV mileage: 23.9 kmpl, PHEV mileage: 30.6 kmpl
- BEV mileage: 15 kWh/100km, PHEV mileage: 26 kWh/100km, 8% improvement till 2015 and 4% improvement thereafter
- CNG: ~17% lower emissions than gasoline, 1.5% annual efficiency improvement

Bus
- Premium Diesel mileage: 2.4 kmpl, High Floor Buses (M&HCV) mileage: 5.2 kmpl,
  HEV mileage: 3.2 kmpl, PHEV mileage: 3.4 kmpl
- BEV mileage: 100 kWh/100km, PHEV mileage: 112 kWh/100km, 8% improvement till 2015 and 4% improvement thereafter
- Biofuel % in Gasoline: 20%
- CNG: ~6% lower emissions than (1% for diesel equivalent) gasoline, 1.5% annual efficiency improvement

LCV
SIAM: National Hybrid/Electric Mobility Study

- Premium Diesel mileage: 2.4 kmpl, High Floor Buses (M&HCV) mileage: 5.2 kmpl, HEV mileage: 3.2 kmpl, PHEV mileage: 3.4 kmpl
- BEV mileage: 100 kWh/100km, PHEV mileage: 112 kWh/100km, 8% improvement till 2015 and 4% improvement thereafter
- Biofuel % in Gasoline: 20%
- CNG: ~6% lower emissions than (1% for diesel equivalent) gasoline, 1.5% annual efficiency improvement

X.1.4. Other Assumptions

Motor Size\(^{17}\) (2011) -

- 2W – BEV – 1.1 kW
- 3W – HEV – 1.5 kW; PHEV – 3.5 kW; BEV – 5 kW
- 4W – HEV – 60 kW; PHEV – 60 kW; BEV – 80 kW
- Bus – HEV\(^{18}\) – 45 kW; PHEV – 100 kW; BEV – 100 kW
- LCV\(^{19}\) – HEV – 60 kW; PHEV – 60 kW; BEV – 80 kW

X.2. ENVIRONMENTAL EMISSIONS (OTHER THAN CO2)

Adoption of xEVs is expected to result in significant reduction in many environmental pollutants such as CO, VOC and NOx emissions, due to lower fuel usage. However, SOx emissions are expected to increase due to xEVs, primarily due to higher consumption of electricity. However, these emissions will be in relatively isolated locations, and can be contained easily. Hence given the higher concentrations of population in urban areas, there should be a net beneficial environmental impact due to adoption of xEVs. Exhibit 147 details the well to wheel emission spectra for xEVs in US figures are likely to be comparable to India given similar fuel mix), while Table 21 quantifies the percentage reduction in environmental pollutants due to xEVs.

\(^{17}\) Based on inputs from OEMs. These assumptions are not part of TCO analysis. However, motor size influences performance and hence it informed discussion around incentive structure
\(^{18}\) CNG hybrid
\(^{19}\) Assumed similar to 4 wheelers
X.3. Automotive Regulations in Brazil

Among the developing nations, Brazil has been pro-active in curtailting environmental emissions and reducing its dependence on petroleum by emphasizing on bio-fuels, specifically ethanol. Brazil has a very successful flex fuel program, and most passenger vehicles can run on both bio-fuel and gasoline. Some of the key factors which have contributed towards the success of this program have been listed below:

- The existence of 33,000 filling stations with at least one ethanol pump available by 2006
- Mandatory use of E25 blend of gasoline throughout the country led to achieving more than 50% of fuel consumption in the gasoline market from sugar cane-based ethanol in 2008

Note: US average grid mix in 2006: Coal + Oil Fired = 52%, Gas Fired = 19%; India average grid mix in 2010: Coal + Oil Fired = 53%, Gas Fired = 10.5%

Source: Argonne National Laboratory, Austin Energy, Booz & Company Analysis

Table 21 - Emissions Reduction over ICE

<table>
<thead>
<tr>
<th>% change compared to ICE</th>
<th>VOC</th>
<th>CO</th>
<th>NOx</th>
<th>PM</th>
<th>SOx</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEV</td>
<td>-20%</td>
<td>-1%</td>
<td>-18%</td>
<td>-6%</td>
<td>-29%</td>
</tr>
<tr>
<td>PHEV</td>
<td>-45%</td>
<td>-34%</td>
<td>-39%</td>
<td>+2%</td>
<td>+53%</td>
</tr>
<tr>
<td>BEV</td>
<td>-91%</td>
<td>-98%</td>
<td>-82%</td>
<td>+23%</td>
<td>+266%</td>
</tr>
</tbody>
</table>

Note: US average grid mix in 2006: Coal + Oil Fired = 52%, Gas Fired = 19%; India average grid mix in 2010: Coal + Oil Fired = 53%, Gas Fired = 10.5%
SIAM: National Hybrid/Electric Mobility Study

- 93% usage of flex-fuel vehicles in São Paulo, the main ethanol producer state where local taxes are lower, and prices at the pump are more competitive than gasoline.

Brazil is also planning to launch buses based on bio fuels in selected cities. Some of these initiatives have been described in Exhibit 148. The public transportation companies in Brazil will have to adapt their engines to Euro 5 or renew its fleet to meet the new regulation. Also, these buses will have to use biodiesel with ethanol accounting for 10% to 20% of the fuel.

**Exhibit 148 - Selected Cities in Brazil with Alternative Powertrains in Public Transport System**

- **São Paulo**
  - 1,200 buses using Diesel with 20% of Biofuel
  - The target is to have its 15,000 buses fleet using B20 until 2018
  - Testing hybrid buses
  - The target is to have 200 hybrid buses in 2011 with R$ 50 million investment from Volvo

- **Curitiba**
  - First City in Brazil to have Bus Rapid Transit
  - 24 buses using 100% biofuel
  - The target is to increase the number to 140 until 2012
  - Using Euro III Motor from Scania and Volvo

- **Rio de Janeiro**
  - Testing buses using Diesel with 20% of Biofuel
  - The target is to have 8,500 buses using B20 until 2016
  - Testing hydrogen bus in its Federal University

**Source:** EMIS, Booz & Company analysis

Brazil has also been coming out with regulations on automotive emissions: PROCONVE L6 regulation (Euro 5) is slated to be implemented in 2013-15 for passenger vehicles, which has been described in Exhibit 149.
X.4. ELECTRIC TROLLEY BUSES

A comparison of electric trolley bus solution, with the hybrid / electric mobility solutions is important to understand the related costs, and benefits. Several cities and states with infrastructure base for trams are considering trolley buses e.g. San Francisco, Seattle, Edmonton and Canada. Several OEMs such as Mercedes-Benz, Bombardier and Renault-Matra manufacture electric trolley buses. However, in India, high infrastructure and acquisition cost of electric trolley buses makes them less attractive than xEV buses. Overhead wire system is very costly to build, it is estimated that it takes ~₹653 Crore to build overhead wire system for a 20 km long route with 15 stops (west London transit structure). With this investment, government can incentivize ~2,000 xEV buses (considering ₹30 Lakh incentive per bus). There are very few cities in India with existing tram system, hence this investment would need to be made afresh in most cities.

Also, there are other challenges such as there is no current production capability among Indian OEMs, hence low cost solutions would take some time to develop. Also, the acquisition and maintenance cost of electric trolley buses is very high, as explained in Exhibit 150. An Indian OEM highlighted that the infrastructure cost will be very high for setting up overhead cables; also trolley bus will be expensive as big batteries are still
required for flyover operation. Also, the government will need to consider safety issues of electric cables in populated urban areas.

Exhibit 150 – Acquisition Costs for Various Powertrains
(₹Million)

Source: OEM Interviews, Swedish Transport and Communications Research Board, TCO Model, Edmonton Transit System, Booz & Company Analysis

X.5. TAXIS

Analogous to private four-wheelers, there is significant latent demand for xEV taxis across the country (Exhibit 151). With their lower cost, HEVs have the highest demand, ranging from ~26%~53%. However, latent demand for BEVs is also significant with a maximum of ~18% in Tier-2 cities. This is much higher than the latent demand for private four-wheeler BEVs. Preference for xEV taxis is high in tier-1 and tier-2 cities, perhaps due to the presence of large established fleet operators in these areas. Consumers here have quoted low maintenance cost and high mileage as the main benefits driving adoption. Tier-3 cities have the lowest latent demand for xEVs, with consumers in these cities voicing high concern about battery replacement costs. OEMs can initiate development of charging infrastructure targeted at commercial taxi operators in cities like Mumbai, Cuttack and Hyderabad where consumers have indicated a high xEV preference.
However, uptake of xEV taxis is currently limited due to the prevailing consumer perception. xEV taxis are perceived as worse than ICE with respect to their mileage, top speed and pick up (Exhibit 152). These also constitute the key factors inhibiting the adoption of xEV taxis.

Exhibit 153).
SIAM: National Hybrid/Electric Mobility Study

**Note:** 700 interviews across 16 cities – Delhi, Mumbai, Chennai, Kolkata, Hyderabad, Ahmedabad, Lucknow, Guwahati, Ranchi, Jalandhar, Ajmer, Trivandrum, Cuttack, Mangalore, Ujjain, Rohtak

**Source:** Nielsen field research, Booz & Company analysis

Exhibit 153: Key Barriers Inhibiting Adoption of Taxi xEV Technologies

To understand consumer preferences in detail, conjoint analysis was conducted varying key parameters – price, running cost, recharge time and range. A survey conducted on 700 respondents across 16 cities, indicated that running cost is the most effective lever in increasing HEV, PHEV and BEV acceptance (Exhibit 154, Exhibit 155, Exhibit 156). Price also plays an important role in decision making for HEVs and PHEVs.

Exhibit 154: Latent Demand for HEV Taxis (Conjoint Analysis)

**Note:** Base parameters for HEV: Price - ₹5.14 lakhs, Running cost - ₹3.5/km, Recharge time - 0.5 hrs, Range - 500km

**Source:** Nielsen field survey, Booz & Company analysis

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Measures to reduce the running cost would have to act on battery replacement cost as it is an important component. While acquisition cost is not the only deterrent for xEV taxi purchase, lowering the price might create a more attractive value proposition. Survey respondents indicate that lowering taxes and introducing subsidies on (new and replacement) batteries might increase xEV taxi acceptance (Exhibit 157). Widespread availability of xEV kits would also help tap into the latent demand.
Exhibit 157: Incentives Required for Adoption of Taxi xEVs

![Bar chart showing incentives required for adoption of Taxi xEVs]

**Note:** 700 interviews across 16 cities – Delhi, Mumbai, Chennai, Kolkata, Hyderabad, Ahmedabad, Lucknow, Guwahati, Ranchi, Jalandhar, Ajmer, Trivandrum, Cuttack, Mangalore, Ujjain, Rohtak

**Source:** Nielsen field research, Booz & Company analysis

Such steps targeted towards commercial taxi operators coupled with generic four-wheeler xEV initiatives would help increase xEV penetration in this segment.