AUTHORS AND GRANTERS

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WHY THIS GUIDANCE DOCUMENT?

Three-fold Objective

01. Inform state and local officials, and other stakeholders, who may have embryonic knowledge, about the basics of electric mobility and what it involves.

02. Present pros and cons of different options (e.g. hybrid Vs Pure EV or Swapping Vs Charging) in a neutral manner for informed decision making.

03. Present a road map for making things happen at the city level.
5 PARTS TO THIS GUIDANCE DOCUMENT

Part 1: Understanding India: Potential gains and unique features
Part 2: Pillars of an electric mobility eco-system
Part 3: Road map for electrification of transport in the Indian context
Part 4: Public policy measures in India and international regions
Part 5: Business models for different re-energising systems
## POTENTIAL GAINS FOR INDIA

### Social, Environmental and Economic

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Better air quality</td>
<td>Improving public health in cities</td>
</tr>
<tr>
<td>GHG mitigation</td>
<td>Towards a greener India</td>
</tr>
<tr>
<td>Promotes renewables</td>
<td>Through EV batteries</td>
</tr>
<tr>
<td>Enhances energy security</td>
<td>Reduces imported fuel use in transport sector</td>
</tr>
<tr>
<td>Increases Plant Load Factor</td>
<td>Increases efficiency of power plants</td>
</tr>
<tr>
<td>Technological leadership</td>
<td>Position India as a leader in auto-tech</td>
</tr>
</tbody>
</table>
Out of the 15 most polluted cities of the world are in India.

36% Of NOx emissions in Delhi were due to vehicles in 2016.

20% Of PM2.5 emissions in Delhi were due to vehicles in 2016.
REDUCED DEPENDENCE ON IMPORTED FUEL

India's Import Bill for Petroleum Products from 1981 – 2015 (in INR Billions)

Consumption of petroleum fuel: 32.5 million tonnes in 1981 → 184.7 million tonnes in 2015.
REDUCED GREENHOUSE GAS EMISSIONS

• 35% of India’s electricity is from non-coal sources
• Will improve as share of electricity from clean sources goes up
• India is already committed to increasing renewables; Energy mix to be cleaner with more and more electric storage brought in by EVs
**EV Battery: Benefits Renewables and Power Grid**

**Improved Plant Load Factor (PLF)**
- EVs may create additional off-peak demand
- Help power plants attain greater efficiency
- All-India PLF in March 2018 = 65.33;
- Hence, utility companies are entering charging infrastructure business

**Increased share of renewables**
- Solar and wind are intermittent
- Batteries can store renewables for prolonged use
- Retired batteries for stationery usage
LEAD THE RAPIDLY CHANGING GLOBAL MARKET

- India’s auto industry -> 30 million jobs, 7.1% of GDP
- Timely shift – relevance in global and domestic markets
- Get technology leadership in at least some segments
- Do things differently from the way it is being done elsewhere
- No mineral reserves for lithium and cobalt; prevent dependency on battery imports
PROFESSOR JHUNJHUNWALA TO PRESENT FROM HERE ON
INDIA’S UNIQUENESS

• Small and affordable vehicles
• Drives slower and smaller distance a day
• Have higher temperatures
• Have higher interest costs
• Can not afford to subsidise as much
COMPOSITION OF THE VEHICLE FLEET

98% of the vehicles:
- small and affordable vehicles (two-wheelers and economy cars)
- public transport
- goods vehicles (three-wheelers, small goods vehicles, buses and trucks)

Only 2% of the vehicles are high end cars, unlike in developed countries
**DOMINANT TRAVEL MODES**

<table>
<thead>
<tr>
<th>Dominant travel modes in cities with 5+ Million population</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking</td>
<td>15-35%</td>
</tr>
<tr>
<td>Public transport</td>
<td>30-60%</td>
</tr>
<tr>
<td>Motorized 2-wheelers</td>
<td>10-22%</td>
</tr>
<tr>
<td>Motorized 3-wheelers</td>
<td>5-15%</td>
</tr>
<tr>
<td>Cars</td>
<td>5-15%</td>
</tr>
</tbody>
</table>

In smaller cities: share of walking and motorized 3 and 2 wheelers is greater than that of cars and public transport

NTDPC, 2013, p. 387
TRIP LENGTHS

- High urban densities. India lives and moves differently.
- An average vehicle would travel much less in India as compared to the developed world

**Takeaway**

Short trip lengths mean that EV owners can do several journeys on a single charge. Policy decisions on battery size and range for electric vehicles will need to account for this

- **71%** Of the trips are of less than 5 km
- **16%** Of the trips are of length greater than 10 km

Census 2011
TRAVEL SPEEDS AND AMBIENT TEMPERATURES

• India’s average vehicle speed in a city is less than 25 kmph
  – Significantly different from developed countries where avg speeds are 40 to 60 kmph

• Ambient temperature: exceeds 40 °C and sometimes even 45 °C.
  – Excessive heating and cooling severely impacts battery life
  – Shorter battery life -> frequent replacement -> increased costs of ownership

Takeaway

Policies should promote vehicles and battery packs designed to function in these conditions
INDIA’S NEEDS A DIFFERENT APPROACH FROM THE WEST

• EV costs today may be 1.5 to 2 times or even more of petrol vehicles
  – Battery pricing falling rapidly: but will take considerable time for parity
  – Our affordability is low: most can not afford expensive EVs
  – Up to 40% subsidy in US, China and Europe, bringing down the gap
    • Subsidy in India will be limited

• India’s approach has to be different
  – If we wait for battery prices to fall, we will land up importing vehicles and technology
  – Will hurt our GDP and jobs
HOW INDIA’S APPROACH CAN BE DIFFERENT

While no options are closed, India’s approach could be different.

- World uses large battery to overcome range-anxiety: increase costs / weight
- We can not afford it and will do it differently
  - Make vehicle lighter and more energy efficient to reduce battery size
  - Use small batteries and not large in affordable vehicles
    • Will often tackle range anxiety by battery swapping rather than Fast charging
    • Use lower-cost NMC / NCA batteries: even if they can not be very-fast charged
  - To maximise battery life, we will tend to charge slow, rather than fast
  - To handle higher temperature impacting battery-life, we will charge swapped battery after cooling in a conditioned environment
  - Will convert battery capital costs into operational costs as charged battery is leased
    • A Battery not dedicated to a vehicle and therefore usage not limited to a single vehicle: larger use of a battery reduces interest costs in a high interest-rate environment
    • Battery used for longer hours imply faster depreciation and replacement in shorter time frame – works well in falling-costs situation
  - Overall make EV capital costs similar to that for petrol-vehicles and operational costs for EVs equal or lower than that for petrol vehicles with swapping
PILLARS OF AN ELECTRIC MOBILITY ECOSYSTEM

4 Pillars

ELECTRIC VEHICLE
All-electric, plug-in hybrid, hybrid

BATTERIES
Lithium Ion batteries – NMC, LTO, LFP
Battery Management System

RE-ENERGISING SYSTEMS
Charging and swapping infrastructure

OTHER FACTORS
Manufacturing capacity, research and development, power grid

WORLD RESOURCES INSTITUTE
1. **Plug**: Used for plugging into electric outlets at home or at a public charging station

2. **Regeneration brakes**: Capture energy lost when braking and store it in battery

3. **Rechargeable battery**: Energy storage unit of the car; built from chemical cells

4. **Controller and electronics**: Regulates the supply of power from the battery to the electric motor

5. **Electric motors**: Obtains electrical energy from the battery to move the steering and power the vehicles

Source: Authors
BATTERIES

- Account for 50% of vehicle cost
- Falling battery prices and rising energy densities

Declining costs and improving energy densities

- Lithium Ion battery costs USD per kWh
- Specific Energy Density Wh per Kg
## COMPARISON BETWEEN VARIOUS LITHIUM ION BATTERIES

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>Nickel Manganese Cobalt (NMC)</th>
<th>Li Titanate Oxide (LTO)</th>
<th>Li Phosphate (LFP)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost of Cells</strong></td>
<td>USD per kWh</td>
<td>130</td>
<td>400</td>
<td>175</td>
</tr>
<tr>
<td><strong>Energy-density</strong></td>
<td>Wh per Kg</td>
<td>250</td>
<td>&lt;100</td>
<td>125 -150</td>
</tr>
<tr>
<td><strong>Charge-Discharge Cycles</strong></td>
<td>Number</td>
<td>2500</td>
<td>10000 +</td>
<td>2500</td>
</tr>
<tr>
<td><strong>Charging Time without impacting life</strong></td>
<td>Mins</td>
<td>45 to 60 mins fast charge</td>
<td>10 to 20 mins</td>
<td>45 to 60 mins</td>
</tr>
<tr>
<td><strong>Impact of Fast Charging</strong></td>
<td>--</td>
<td>Impacts appreciably</td>
<td>No impact</td>
<td>Impacts appreciably</td>
</tr>
<tr>
<td><strong>Bulkiness (Size and Weight)</strong></td>
<td>--</td>
<td>Compact and low wt</td>
<td>Large size and wt</td>
<td>Medium size and wt</td>
</tr>
<tr>
<td><strong>Impact of high temperature (45 deg C)</strong></td>
<td>--</td>
<td>High</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td><strong>Inherent Safety</strong></td>
<td>--</td>
<td>Low</td>
<td>High</td>
<td>Medium</td>
</tr>
</tbody>
</table>
FACILITIES FOR RE-ENERGISING BATTERIES

Charging
• Slow charging (at-home or designated parking spots in universities or offices)
• Fast charging (at public stations)

Swapping
• A discharged battery is exchanged for a charged battery at swapping facilities.

Range Extension
• Intermediate option

Image source: PulginIndia (left), Nikkei Asia (right)
<table>
<thead>
<tr>
<th>Slow Chargers</th>
<th>Fast Chargers</th>
<th>Swapping</th>
<th>Slow Charging with Range Extension (RE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charge batteries at 0.1C to 0.2C</td>
<td>Charges batteries fully in about an hour.</td>
<td>Swapping a discharged battery with a fully charged one</td>
<td>Charge batteries at 0.1C to 0.2C</td>
</tr>
<tr>
<td>Charge batteries up to 80-90% of capacity in 4 to 8 hours</td>
<td>Can be AC or DC</td>
<td>Takes only few mins; eliminates waiting time for drivers</td>
<td>Charge batteries up to 80-90% of capacity in 4 to 8 hours</td>
</tr>
<tr>
<td>Best for preserving the life of any kind of battery</td>
<td>Need an external charger which converts AC input to the DC output for charging the battery</td>
<td>Battery cost is separated from vehicle’s</td>
<td>Best for preserving the life of any kind of battery</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Battery is owned by an Energy Operator (EO) – gives charged battery as a service</td>
<td></td>
</tr>
</tbody>
</table>
SWAPPING BATTERY MAKES BUSINESS SENSE

An Energy Operator (EO) purchases battery and leases charged batteries taking into account depreciation, interest costs and charging and swapping costs
  – Most sensitive element impacting charge per km is vehicle efficiency (km/kWh).
  – Battery costs per kWh, battery life cycles, air-conditioning costs and electricity costs matter
• As price of battery decreases, swappable battery could cost lesser
  – margins for energy operator would improve
• As swappable Batteries have small life of about 4 years, early-investment not much affected
Swapping will work, only when a user finds close-by station to swap batteries
• In the beginning, existing petrol stations could be used side-by side selling petrol
  – Next, expand to more stations as demand grows

For an electric bus, swapping facility could be installed and operated at the bus-depot
• To begin with few routes of one depot can be fully electrified and be given swapping infra
• Gradually all routes and all buses of the depot can be electrified
OTHER FACTORS

• Manufacturing
  – Vehicles, battery pack assembly, controllers, motors
• Research and development
  – Industry, academia and government tie-ups
• Impacts on the Power Grid
DR OP AGARWAL TO PRESENT FROM HERE ON
WHAT ARE THE CHALLENGES WITH ADOPTION OF ELECTRIC MOBILITY IN INDIA?

**CHALLENGES**
- Limited Driving Range
- Long Recharge Time
- High capital cost
- Resistance to Change
- Availability of battery materials

**STRATEGY**
- Recognize India’s uniqueness
- Adapt to our context
- Delink capital cost of battery from that of vehicle

**THREE PHASED ROADMAP**
- I Pilot
- II Scaling-up
- III Self Propelled
## ROAD MAP FOR ELECTRIFICATION

### PILOT PHASE
- Short phase
- Vehicles with high demo value are deployed
- Intra city bus fleets
- Fleet cars belonging to public agencies
- 2 and 3 wheelers with RE-swap and battery swap

### SCALING UP
- Incentives and persuasion to reach tipping point
- May need financial incentives
- Free parking, easier permits, feedebates, low off peak electricity charges
- Public investment in charging/swapping
- Good candidates: auto rickshaws and small taxi owners

### SELF - PROPELLED
- Technology is established
- Used by people in normal course
- All parts of e-mobility will have become financially sustainable
POLICIES AND REGULATIONS - WHAT IS NEEDED?

• Comprehensive action on many fronts
• Recognition:
  – public good of electrification > price disadvantages to market
• A strong case for public policies to:
  – Absorb the price risks of a new technology
  – Bring it to parity with its traditional counterpart
### EV Policies of State/Regional Governments in India

#### Demand side interventions
- Purchase incentive for EVs
- Higher taxes on diesel and petrol cars
- Scrapping incentive to ICE vehicle owners
- Creating app-based cab aggregation, Subsidies for purchasing last mile electric vehicles (e.g. autos)

E.g. Delhi Electric Vehicle Policy 2018

#### Supply side interventions
- Incentives to EV and battery manufacturers
- Creating EV manufacturing zones
- Reimbursing 100% land conversion fee
- Faster approval of applications for setting up charging stations
- Zero wheeling charges for supplying renewables to re-energizing stations

E.g. Telangana, Karnataka, Maharashtra
POLICIES AND REGULATIONS – WHAT EXISTS INTERNATIONALLY?

The Case of Norway

- EV policy part of the larger GHG abatement goal
- ZEV policies began in 1990s
- BEVs = 47% of fleet in 2018
- Political unity on ‘polluter pays principle’
- Stringent green tax system -> all new cars sold by 2025 are either zero or low emission
- Exemption from purchase tax, road tax
- 100% government support for installing normal and high power charging
POLICIES AND REGULATIONS – WHAT EXISTS INTERNATIONALLY?

The Case of Shenzhen, China

• 100% electric bus fleet
• National and local subsidies
• Buses are leased to cut costs
• Cooperation between bus operator and charging infra provider
• Charging facilities to private cars as for optimal use of the system
WAY FORWARD

• Several States have already formulated EV policies
• Actions towards implementation will require coordinated action by multiple departments
• Need for a multi-department and high level EV mission in the State to oversee and direct implementation
• A detailed road map needs to be developed in one or two cities by the states
• This will include decisions on:
  – Vehicle segments to be electrified in the first phase
  – Identifying locations for charging and swapping facilities
  – Inviting potential businesses to set up charging and swapping facilities
  – Awareness campaigns
QUESTIONS
<table>
<thead>
<tr>
<th><strong>Pros and Cons of Slow and Fast Charging and RE</strong></th>
<th><strong>EVs with Slow + Fast Charging (EV-F)</strong></th>
<th><strong>EVs with swapping (EV-S)</strong></th>
<th><strong>EVs with slow charging plus range-extension swapping (EV-RE)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Battery Size in kWh</strong></td>
<td>Medium to Large</td>
<td>Small</td>
<td>Small</td>
</tr>
<tr>
<td><strong>Cost of Battery for vehicle-owner</strong></td>
<td>Medium to Large</td>
<td>Nil (Energy Operator will invest in battery)</td>
<td>Small</td>
</tr>
<tr>
<td><strong>Home Charging time and impact on Battery-life</strong></td>
<td>Night time 6 hours: best for battery</td>
<td>NA</td>
<td>Night time 6 hours: best for battery</td>
</tr>
<tr>
<td><strong>Infrastructure required at home</strong></td>
<td>15A power plug</td>
<td>None</td>
<td>15A power plug</td>
</tr>
<tr>
<td><strong>Range Extension by</strong></td>
<td>Fast Charge</td>
<td>Swapping</td>
<td>Add-on battery swapping</td>
</tr>
<tr>
<td><strong>Wait-time for range extension and impact on battery life</strong></td>
<td>1.5 hours low impact &lt;30 min severe impact</td>
<td>Few minutes</td>
<td>Few minutes</td>
</tr>
<tr>
<td><strong>High temperature (45°C) Impact</strong></td>
<td>High</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td><strong>How often range extension required</strong></td>
<td>Could be less than 5%, if vehicle has large battery</td>
<td>Frequently</td>
<td>5 to 10%</td>
</tr>
<tr>
<td><strong>User Convenience</strong></td>
<td>Range extension pain</td>
<td>daily swapping pain, but no home charging</td>
<td>High</td>
</tr>
<tr>
<td><strong>Can you go unlimited range?</strong></td>
<td>Not unless you keep stopping for fast charge</td>
<td>Yes, with repeated swap</td>
<td>Yes with repeated swap of Range-extension battery</td>
</tr>
<tr>
<td><strong>Number of vehicles served per charger/swapper in 10 hours</strong></td>
<td>10</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>-------------------------------------------------------------</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td><strong>Infrastructure for charging/swapping</strong></td>
<td>Fast Charger at many locations</td>
<td>Battery swapping at reasonable number of locations, existing petrol pumps inadequate</td>
<td>Battery swapping at limited locations (swap in minutes); existing petrol pumps will do</td>
</tr>
<tr>
<td><strong>Need for Infra-investment</strong></td>
<td>Medium</td>
<td>Very High</td>
<td>High</td>
</tr>
<tr>
<td><strong>Business viability in India</strong></td>
<td>Not clear unless charges for fast charging is high</td>
<td>Viable</td>
<td>Viable</td>
</tr>
<tr>
<td><strong>Vehicle Capital Cost for user</strong></td>
<td>Large</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td><strong>Vehicle Operation Cost</strong></td>
<td>Low (cost of electricity) for 90 to 95% time</td>
<td>Close to petrol cost</td>
<td>Low for 90 to 95% of time (electricity cost only), but close to petrol cost for range extension (5 to 10% of time)</td>
</tr>
<tr>
<td><strong>Business of existing (57000) petrol pumps and jobs</strong></td>
<td>No</td>
<td>Will preserve</td>
<td>Will preserve</td>
</tr>
<tr>
<td><strong>EV batteries as Grid-storage</strong></td>
<td>Difficult</td>
<td>Swap-batteries in charger-cum-swapper station can be used as storage</td>
<td>Swap-batteries in charger-cum-swapper station can be used as storage</td>
</tr>
</tbody>
</table>
POLICIES AND REGULATIONS – WHAT IS NEEDED?

Central Government

› Set vehicle and charging standards
› Create tax incentives for EVs in recognition of their contribution to public good
› Mandate an increasing share of EVs in sale of motor vehicles and public fleets
› Strategic international tie-ups
› Collaborative R and D
› Procurement of EVs for Govt of India vehicles

State and Local Government

› Procure electric buses for SRTUs and mandate all buses to be electric
› Create infrastructure for re-energizing
› Establish preferential permits and tax breaks
› Require procurement of EVs for government
› Mandate registration of certain segments only as EVs from a certain date
## Policies and Regulations – What Exists in India?

<table>
<thead>
<tr>
<th>Ministry of Power</th>
<th>Ministry of Heavy Industries</th>
</tr>
</thead>
<tbody>
<tr>
<td>› Electricity as a Service - Amendment of EC Act 2001</td>
<td>› Faster Adoption and Manufacturing of (Hybrid &amp;) Electric Vehicles (FAME 1) Scheme</td>
</tr>
<tr>
<td>› Charging infrastructure for EVs–Guidelines and Standards</td>
<td>› Charging standards for slow and fast chargers, communication protocols</td>
</tr>
<tr>
<td></td>
<td>› National Electric Mobility Mission Plan for 2020</td>
</tr>
</tbody>
</table>