A Guidance Document for Electric Mobility Roadmap for Smart Cities in India

Prepared by WRI India for the Smart Cities Mission of the Ministry of Housing and Urban Affairs
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Preface

Dear Friends,

Cities are both influential and vulnerable performers in the fight against climate change. Many cities are facing annual threats of extreme events, expected to become worse in the next decade. Local governments must be empowered to mitigate the and adapt to climate change through interventions in key sectors, including buildings.

Transport accounts for nearly one-third of the CO2 emissions in Cities. Significant potential exists to reduce this by looking at cleaner fuels to drive transport systems. Cleaner fuels also help improve air quality and thereby contribute to improving urban air pollution. Electric vehicles offer an opportunity to make our urban transport systems cleaner.

“ClimateSmart Cities Assessment Framework (CSC-AF)” is aimed at providing a clear roadmap to Indian smart cities towards combatting climate change while planning their actions and investments. WRI India, as a knowledge partner to CSC-AF is glad to share this advisory as a handholding guidance document for the cities.

The advisory provides guidance on developing implementable road maps for the adoption of electric mobility. Making such a transition requires concerted and coordinated action by multiple agencies and this road map allows an understanding of the comprehensive set of actions required. It also suggests a phased plan of implementation.

I wish to place my appreciation for this assessment framework and extend my best wishes to all the cities which are part of this initiative.

Sincerely,

O.P. Agarwal
CEO, WRI India
INTRODUCTION

Electric mobility brings multi-dimensional benefits. World over, countries are moving rapidly in this direction to benefit from reduced greenhouse gas emissions and clean air. India is also doing the same as is evident from the National Electric Mobility Mission and the FAME program. Actions in cities and states play an important role in helping the country make a transition towards electric mobility. In addition the city and state governments stand to benefit from the improved air quality, improved plant load factor for the electricity grid, and an opportunity for economic development with a new avenue for creating employment opportunity. Recognizing this, some of the states have also adopted electric vehicle policies. The Smart Cities Mission’s (SCM) ClimateSmart Assessment Framework is rightly positioned to assist cities in creating electric mobility infrastructure on the ground.

This document presents an implementation roadmap that can be used by cities to move towards electric mobility and implement their Electric Vehicle Policy. It first highlights some of the challenges in moving towards electric mobility. This helps understand the rationale for the transition strategy that is being suggested. This document, thereafter, recommends a phased transition comprising a pilot phase, a scale up phase and a self-propelled phase. The objective of the “pilot” phase is to demonstrate a credible pathway to make a beginning in which calls for a significant amount of direct Government action. This is followed by a “scale up” phase, where the Government offers a bouquet of incentives and disincentives for market-based action towards electric mobility, till a tipping point is reached. Finally, in the self-propelled phase the market takes over and moves towards electric mobility without any Government intervention. In this context, it is also recognized that some of the recommended actions fall outside the authority of a city and need action by the State Government. Yet both of these are being presented as joint actions by the State and City level will be essential.

CHALLENGES IN TRANSITIONING TO ELECTRIC VEHICLES

While there are wide ranging benefits, a transition to electric mobility faces several challenges that need to be overcome. It will be useful to keep these challenges in mind while designing a transition road map. The more prominent among these challenges are the following:

- Comfort with the existing system and resistance to change - Nearly all stakeholders are comfortable with the current set of motor vehicles and do not see a need for change to meet their travel needs. As for the customers, ICE vehicles have served them well for over a hundred years and they have got used to it. As for manufacturers and oil companies, they have made heavy investments in car manufacturing facilities and any change of technology will need significant additional investments.

- Lack of public awareness - Electric vehicles are relatively unknown to the normal customer. They do not know what the benefits are for them. Others have incomplete knowledge about the limitations of the technology and do not know how these limitations really don’t hurt them too much.

- High vehicle and Battery Costs - The capital cost of EVs is still about 50% higher than their petrol / diesel counterparts. These high costs do get offset, to some extent, by lower operating costs, but the uncertainty in how they will perform creates doubts in consumers’ minds about the risk of investing in high capital costs. The possibility of this being made up from future savings in operating costs would be uncertain till there is adequate experience in the market to reassure a consumer that savings indeed do accrue.

- Limited driving range and long recharge time - EVs can only be driven for a smaller distance on a single charge compared to the distance that a petrol/diesel vehicle can be driven on a single filling. If the driving range is limited, it becomes important to find a battery charger / swapper at frequent intervals. This is different from what consumers are used to with petrol and diesel vehicles

- Lack of charging and swapping stations - There is a wide network of petrol and diesel filling stations already. As against this a network of battery charging and swapping stations is yet to come up.
Managing batteries post use in EVs - With an increasing number of EVs, the number of batteries that will need to be disposed, post use in EVs, will increase. There are two options to manage this - Battery recycling, where batteries that can no longer be used in EVs are stripped of usable components and only the rest disposed. Battery re-purposing, where batteries that are no longer useful for EVs can be used for secondary storage.

Natural calamities and extreme weather – inclement weather such as excessive heat will impact the life of the batteries. Besides, during floods and deluges, electrical charge stored in batteries can prove dangerous if it is passed on to the water.

Impact of road gradient on vehicle performance - As the road topography is one of the important factors which influences the energy consumption of the vehicle, an accurate range estimation is necessary in cities. Regenerative braking can help in improving the fuel efficiency of the EVs.

Need for coordinated action – Successful transition needs actions on multiple fronts, each of which are the responsibility of multiple departments and agencies of the Government at local and state level. In the absence of effective coordination, this proves difficult.

Some of the frequently asked questions about electric mobility – vehicle types, re-energising modes – are given in Annexure 1.

MULTI-PRONGED TRANSITION STRATEGY

Given the challenges mentioned above, a successful transition to electric mobility will require a multi-pronged strategy comprising the following actions, all taken up in a synchronized and coordinated manner:

- Awareness campaigns
- Demand creation
- Re-inventing the state’s power grid
- Setting up the charging and swapping infrastructure
- Manufacturing and workforce skill development
- Financing
- Institutional arrangements for coordinated action

The road map presented in this report suggests steps to deal with each of them in a phased manner.
ROAD MAP FOR IMPLEMENTING THE EV POLICY / DEPLOYING EV IN SMART CITIES

Given the challenges highlighted earlier it is clear that a large-scale transition, across a wide spectrum of vehicles, will be difficult to achieve in the short run. A phased strategy will be needed, typically comprising of a pilot phase, a scale up phase and a self-propelled phase. The expectations during each of these phases would be as below:

- Pilot phase – where an initial set of vehicles, routes and organizations are identified for adoption of electrification to create visibility and demonstrate the feasibility of electric vehicles. This phase has to be short. It will primarily involve direct action by the Government and Government agencies to have an initial nucleus of electric vehicles on the road.
- Scale-up phase - where incentives and other regulatory strategies will persuade market-based action that will lead to a higher number of electric vehicles getting registered till a tipping point is reached – this could last for 3 – 4 years.
- Self-propelled phase - where the technology has established itself and people take to it in the normal course

Figure 2 shows the three phases, their timeline and guiding principles. Following that specific actions for each phase are listed.

Specific actions required during each phase would be the following:

Pilot phase actions

This phase seeks to create a demonstration of the feasibility of EVs through direct action by the Government and Government agencies. Some of these actions will aimed to create demonstration during the pilot phase itself and others will aim to prepare for next phase, namely the scale up phase. More specifically, the following actions need to be taken up during this pilot phase:

Figure 2 | Shows a three phased roadmap for a Smart City to deploy EVs on the ground

A 3-PHASE ROADMAP FOR A SMART CITY TO IMPLEMENT ELECTRIC MOBILITY

PILOT

- Demonstrate feasibility of EVs through direct Government action

SCALE-UP

- Introduce a bouquet of incentives and regulatory measures to persuade market-based action

SELF-PROPELLED

- EV technologies have entered mainstream; Focus on sustaining growth and bringing in the most up to date but context-driven technologies
Have a nucleus of EVs on the road

- Register a pilot set of electric vehicles, primarily those to be used by Government agencies and use them extensively to demonstrate the feasibility of EV use
- Identify a pilot set of routes for operating electric buses and have the State Transport Corporation run such buses on these routes
- Identify a pilot set of organizations that can also run electric vehicles to enhance the demonstration effect

The criteria for selecting such pilot vehicles would be the following:

- Relatively longer usage in a day so that economies of the operating costs are captured adequately
- High visibility to create demonstration value
- Adequate vehicle clusters and operating cost savings to justify investments in captive battery re-energizing facilities

The criteria for selecting pilot routes for operating electric buses should be the following:

- Choice of routes having travel distances that are within the range of a single charge, and with adequate stop time at the end of a trip to top up the charge for the return trip
- Routes with high passenger flows
- Ideally routes without very steep gradients

The criteria for selecting pilot organizations to operate EVs in the pilot phase should be the following:

- Organizations with a large enough fleet of vehicles to justify investment in dedicated charging and swapping facilities
- Organizations with adequate public dealing for their vehicles to be visible enough to create a demonstration value

Based on the above criteria, the pilot vehicles could include vehicles used by senior government officials, other government owned vehicles, vehicles of municipal corporations, buses of the State Transport Corporation, vehicles used by the local airport authorities, etc. Pilot routes for operating electric buses should be those with a route length that falls within the range of a single charge and it has enough stop time for a top up charge at the end of one trip. Ideally, such routes should have high enough passenger volumes to enable a higher demonstration effect.

Specific actions required for operationalizing pilots are given below:

- The State Transport Corporations (STCs) should acquire some electric buses to operate on the selected pilot routes. They could start with a small number and quickly move towards all their buses on these routes being electric
- Charging /swapping infrastructure should be set up at both ends of the pilot routes. Specific detailed studies will have to commissioned to determine the number of charging points at each place, the type of charging facility required and the specific location of the charging points, depending on the availability of land and other factors.

Awareness campaigns

Lack of awareness is a big challenge. The high capital costs and uncertain benefits of lower operating costs coupled with the concern relating to the range need to be overcome. Much like the aggressive campaigns that persuaded people to shift to LED bulbs, it will be critical to have large and targeted awareness campaigns on electric mobility.

Ambitious marketing efforts will be needed starting right from the pilot phase so that they have the desired effect during the scale up phase. Actions to be taken to design an impactful marketing campaign are:

- Hiring a marketing agency with a track record in nudging a positive change in consumer behavior
- The marketing agency should pursue the following ideas:
  - Highlight monetary benefits - It will be most important to inform the consumers about the savings in operating costs from electric vehicles. This should be followed by information on where these vehicles can be bought, the charging and swapping infrastructure available, etc.
  - Understand consumer mindset - Create targeted and customized advertisement campaigns for users of – 2, 3 and 4 wheelers, and buses – because of the differences in consumer mindsets and budgets. This will require a market survey that first understands what and how much consumers know about electric vehicles.
Spread messages through multi-media. The state government should use a combination of platforms – social media, print media, advertisements on TV, radio, to shape public opinion on electric vehicles.

What one can touch and feel, one can believe. To get consumers to believe the benefits of electric vehicles, the government and industry together should hold live exhibitions (e.g. a road show and a public festival on electric vehicles) where citizens drive electric vehicles, charge / swap batteries and see how this technology works.

Institutional arrangements
One of the biggest challenges of a comprehensive transition towards electric mobility is the need for coordinated action on several fronts. Unfortunately, the institutional fragmentation that exists does not allow coordinated action for implementing the policy. This is more acute when the agencies involved function under different levels of Government. The key agencies involved will be the State Transport Department, the State Power Department, the local municipality, the State Police department, the State Urban Development department, the State Industries department, and the State Transport Corporation. It would be necessary to create a coordination mechanism that ensures that a comprehensive action plan is implemented in a timely manner.

For this, the State Government should set up an Electric Mobility Mission, headed by a person of eminence, and well respected by all. This mission should be the implementing arm of the government. The head of the Electric Mobility Mission would report directly to either the Chief Minister or the Chief Secretary of the state.

The role of the Mission will be to effectively coordinate implementation, and make things happen, as opposed to an advisory role where experts only give advice but have no role in ensuring implementation. The organizational structure of the Electric Mobility Mission will have to be lean to ensure streamlined and rapid action.

The first step in this will be in identifying the right person to head the Mission. The mission should have full time members deputed by the departments of transport, power and urban development, who would interface with the respective departments to ensure coordinated and timely action. The Mission would also undertake the needed detailed studies to support implementation.

Create capacity for the EV manufacturing ecosystem
It will also be necessary to initiate action towards plugging skill gaps and developing a pool of talent with the right skills for the electric mobility ecosystem. Towards this end, the following will need to be taken up in the pilot phase:

- Conduct a skill-gap study for the state to understand what electric and shared mobility related skill sets the workforce possesses as the baseline for a skilling strategy; emphasize on research and development for electric technologies
- Introduce course curriculum in state schools and colleges on topics directly related to electric mobility; this should be done in partnership with established universities in the country such as IITs and NITs
- Begin revising course modules in the polytechnic institutes and aggressively market the new trainings and courses on electric mobility; tie up with industry for this

Other actions required during the pilot phase
Signalling Demand
It will be necessary for the Government to take the initiative in signaling demand for EVs so that the auto industry sees the commercial value in making the investment to manufacture EVs. This could be done by the government mandating some category of vehicles to move to EVs over a graded time frame. Some actions to signal demand for electric vehicles include:

- Identify public and private fleets which would be required to switch to electric vehicles so that this signals potential demand for manufacturers
- Require corporate fleets of large conglomerates to go electric. Either they can purchase new electric cars or hire fleet services from electric car operators. Simultaneously, publicly funded charging stations set up in and around these locations would find many users and would easily achieve commercial viability.
Electrification of taxi fleets operating at airports. Their parking spaces can be used to establish charging facilities.

Issuing mandates that require all para-transit vehicles such as three wheelers to be EVs.

Re-inventing the power grid
The power grid needs to be upgraded for handling the power demand that will emerge from an increase in the number of electric vehicles. Actions to prepare the grid for electric mobility would include:

- Study the load curve of the city as the basis for developing electricity tariffs and demand-side management programs such as Time of Day and Time of Use pricing. This is so that it is possible to incentivize consumers to charge at lower prices during off-peak hours. This will be beneficial for the grid as well as it will help discourage demand during peak time.

- Set-up bi-directional grid in which batteries of the vehicles can supply surplus power back to the grid. If the power is generated through solar, the energy mix of the state will be even cleaner. It will also reduce the dependence of cities on other states for purchasing power. This will stabilize the grid during peak demand and prevent crashes. Vehicle-to-grid connection will allow in adequately responding with Time of Day or Time of use pricing which will nudge consumers to charge vehicles during non-peak hours.

- Install smart meters which can record electricity usage by consumers for different times of the day.

- Use the data generated from smart meters to study the electricity use behavior of residential and commercial customers and feed this data to create demand-side management strategies for grid impacts.

Setting up a wide network of charging and swapping infrastructure
Government will have to take the lead in setting up an initial set of charging and swapping facilities so that it encourages purchase of EVs. Actions to be taken:

- As a starting point, set up charging facilities at government offices and other commercial centres, parking lots and residential locations public transport depots and vehicle fleet depots would also be good locations, especially to serve dedicated vehicle fleets.

- Amend building by-laws and codes that are set by the municipal bodies and housing department to allow the creation of charging points in residential and commercial buildings. E.g., the electrical load permitted in buildings will have to be amended to set up charging points for cars and two wheelers in the residential buildings.

- Use major highways running through cities to set up charging stations. This will depend on the geographical layout of the cities. As per the guidelines from the Ministry of Power, Cities should create charging and swapping stations every 25 km along the highways and ensure access for consumers.

- Convert the existing parking spaces into ‘E-parking’. Examples of such spaces could be the parking lots at airports, shopping malls and multi-floor parking at metro stations.

Manufacturing and Workforce skill development
Manufacturing electric vehicles in India will give rise to new industries. Some states have an existing manufacturing ecosystem. Thus far the state of Kerala doesn’t have a strongfoothold in auto manufacturing. But as new industries open up, so will new employment opportunities. The state could reap these with a workforce skilled to readily contribute to the new value chain. Availability of skilled labour will also attract businesses to invest in the cities or in the vicinity.

Actions for growing EV manufacturing base should comprise:

- Assessing which directly and indirectly linked industries already exist in the city or in vicinity.

- Tie-up with manufacturers of electric motors and drives, which have a wide range of application in electric vehicles and preferably form joint units with state level public sector undertakings in the state.

- Partner with bus manufacturers through incentives that invite them to set up a manufacturing hub in the state.

- Bring together industry and academia by creating research parks for collaborative work on electric mobility.

- Create new skills centers which drive on collaboration between the industry, academia and the government. For instance, for

- Introduce coursework in the state engineering colleges and universities which teach...
graduates analytical and technical skills that will be needed in a number of jobs directly and indirectly linked to electric vehicles

- Create training modules to upgrade the capacity of the existing workforce especially in the STUs, Transport, Power departments in the state

**Financing**

Transitioning to electric mobility will require innovative financing solutions. These will be required for:

- Financing charging and swapping infrastructure, and
- Purchase of vehicles

These strategies will assist the state in creating a minimum-subsidy electrification roadmap. The primary goal of allotting subsidies is to help kick start the market to a stage where private companies are hedged from the risks that come with sinking money in a new technology. Subsidies should, therefore, be for strictly an initial phase. Public investment in charging and swapping infrastructure and deploying electric vehicles will bear the fruits thereafter. Then the market will pace up; there would be enough demand from consumers for the private players to respond.

**Financing charging and swapping infrastructure**

In the pilot phase, an initial set of the charging/swapping facilities will be set up through public funding. A certain threshold number, which will depend from city to city, should be set up either with public financial support or by public agencies.

**Financing purchase of vehicles**

There could also be innovative business models that can achieve the same objective. Some possibilities would be the following:

- OEMs could lease the EVs instead of selling them. There could be a lease fee, that is equivalent to the saving in operating costs and the loan repayment installment.
- EVs could be sold to a customer but batteries, which are a significant component of the cost, could be leased. This will help bring down the capital cost to levels similar to ICE vehicles and lease fees could be paid out of savings in operating costs
- An interest subsidy could be a way of reducing the cost of capital and could be extended in the initial years as a way of attracting people to the use of EVs.

The State could consider setting up an EV promotion fund that can supplement the incentives offered under the FAME-2 scheme and offer a mix of low interest loans and grants. These could include:

- Loan support to cover the higher capital costs of electric vehicles, to be serviced through savings in operating costs – these would be most useful for vehicles like taxis, autorickshaws and buses
- Grant or low interest incentives for investment in charging and swapping infrastructure to reduce the risk of low demand in the early years of the transition
- Additional funding to government departments and other government agencies to procure electric vehicles in place of ICE vehicles for government use
- Viability gap grant support for PPP/private sector initiatives
- Grant support needed for market awareness campaigns, skill development and capacity building
- Financial support needed to promote investments in manufacturing EVs and the ecosystem for EVs
- Grant support to the STU for procuring electric buses to convert buses on pilot routes to entirely electric

A formal scheme that includes potential sources for this fund the mechanism for disbursal will need to be formulated.

**Scale up phase**

The scale up phase will require a bouquet of incentives and other regulatory measures that persuade market-based action towards electric mobility. The pilot phase would have created enough of a demonstration for such market-based action provided incentives and regulatory disincentives provide the needed nudge.
Persuading vehicle owners to adopt electrification will either need financial incentives to make the shift attractive or will need certain regulatory restrictions on petrol/diesel fueled vehicles. A shift based on persuasive incentives and limited restrictions will be less disruptive and will find wider acceptance. This will also need intensive marketing and publicity to encourage the shift.

Incentives should aim to make the Total Cost of Operations of EVs comparable to that of ICE vehicles and could be by way of:
- Reduction in the capital cost through capital subsidy or lower taxes
- Reduction in electricity charges, especially for off-peak use
- Public investment in charging facilities and low electricity tariffs
- Free parking and other preferences of this nature

Regulatory disincentives could be in the form of limiting the number of permits issued to petrol/diesel vehicles and a significantly higher fee for them vis-à-vis an electric vehicle.

A bouquet of these incentives needs to be designed and aggressively marketed. This will go a long way in accelerating the adoption of EVs during the scale up phase.

The types of vehicles that will be good to target for electrification during the scale up phase will be the following:

**Buses**
While the pilot phase would convert some of the buses operated by the State Transport Corporations, the scale up phase should target other public bus services, through a combination of financial incentives and permit conditions. In particular, this should target buses operating on high density routes.

**Two-wheelers**
To promote the electrification of two-wheelers during the scale up phase, the state could:
- First, promote e-commerce delivery businesses who use scooters and motorcycles to deliver goods at the doorstep of consumers. These vehicles could use swappable batteries. The delivery businesses could either by themselves, or through aggregation with other similar businesses, set up captive swapping facilities.
- Second category could be electric bikes that offer last-mile connectivity to metro stations, bus terminals, railways stations and water jetty stations/piers

**Shared car fleets**
Some segments of vehicles that could adopt electric vehicles would be the following:
- Airport taxi fleet owned by the regional airports.
- Ride-hailing companies such as Ola and Uber
- Employee transport vehicles

**Three-wheelers**
Three wheelers can also be persuaded towards electrification through:
- Financial subsidy to cover a part of the higher capital cost
- Easier registration and issue of permits – for some ecologically sensitive and heritage areas only electric three-wheelers may be permitted
- Financial support for conversion from ICE to electric

**Urban freight vehicles**
A good candidate to start electrification of freight vehicles will be the three-wheelers that carry small cargos. Yet another candidate in this could be the small goods vehicles used by municipal bodies.

Potential locations for charging and swapping batteries for these vehicles would be the freight hubs. The government via the State electricity board or DISCOMs or an energy company could help in installing an initial set of charging outlets for these vehicles.

**Personal motor vehicle owners**
Cost-sensitive personal motor vehicle owners, who have relatively longer travel distances in a day, can be persuaded to take up electric vehicles. This will also need intensive campaigning and investments in a wider network of charging/swapping facilities. Catalyzing the setting up of a distributed charging network across the city would add to the attractiveness and confidence, even though most personal vehicles can be charged at home. Catalyzing a battery swapping industry, especially at existing petrol stations, will add to the confidence of personal motor vehicle owners. In setting up such facilities, it would be good to look at the best options for
re-energizing different types of vehicles. Details of possible re-energizing options for different types of vehicles is placed at Annexure 2.

Self-propelled phase

In the self-propelled phase, all components of the electric mobility eco-system will function as sound business propositions and should not need any special treatment vis a vis other technology. The role of the government will primarily be on enforcing policies and mandates and amend them if needed such that the electric mobility market is competitive and fair. The state should focus on periodically revising its technology standards so that the best available technology is put to use. However, concessions to enable a new technology to compete with an older one should not be necessary. Learnings from the preceding stages will drive the actions in this last phase.

SUMMARIZING THE THREE PHASES OF THE ROADMAP

Table 1 summarises the actions required during each of the phases of the electric mobility roadmap. It gives a summarised view of the city’s targets, timeline, and key steps to grow the EV-Infrastructure and EV-Ecosystem in the city.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Pilot</th>
<th>Scale – up</th>
<th>Self – propelled</th>
</tr>
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<tbody>
<tr>
<td>Timeline (assuming beginning from 2020)</td>
<td>2020- 2021 (2 years)</td>
<td>2022 – 2026 (5 years)</td>
<td>2027 onwards</td>
</tr>
<tr>
<td>Key principle</td>
<td>Demonstrate feasibility of EVs through direct Government action</td>
<td>Introduce a bouquet of incentives and regulatory measures to persuade market-based action</td>
<td>Electric vehicle technologies have entered main stream; Focus on sustaining growth and bringing in the most up to date but context-driven technologies</td>
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<tr>
<td>Actions</td>
<td>Convert buses operated on selected routes, by Government owned companies</td>
<td>Operationalize the incentives and regulatory measures and the plans already announced</td>
<td>Enforce regulations and safety standards</td>
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<tr>
<td></td>
<td>Introduce EVs into the Government fleet, especially vehicles of senior officers</td>
<td>Monitor progress and evaluate if other measures are needed</td>
<td>Explore secondary application of batteries; by this stage a generation of retired EV batteries would be ready for use for stationery purposes</td>
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<tr>
<td></td>
<td>Launch an awareness campaign</td>
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<td></td>
<td>Design a bouquet of incentives and regulatory measures for introduction during the scale up phase</td>
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<td>Signal demand by announcing future plans</td>
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<td>Action</td>
<td>Details</td>
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<td>Review workforce skill gaps and launch a skill development plan</td>
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<tr>
<td>Establish a limited network of charging facilities for the EVs introduced during the pilot phase</td>
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<td>Set up an EV Mission Design and set up an EV promotion fund</td>
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<table>
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<tr>
<th>EV-Manufacturing Ecosystem</th>
<th>Tie-ups with international manufacturers of electric vehicles and its components</th>
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<td></td>
<td>Form partnerships with international players while simultaneously building PSUs in the state</td>
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<td></td>
<td>Focus on building industrial strength in vehicle manufacturing but also individual vehicle components</td>
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ANNEXURE - 1
FREQUENTLY ASKED QUESTIONS

1. What is an electric vehicle? What are the different types of electric vehicles?

Electric vehicles (EVs) can operate wholly or partially on electricity, whereas Internal Combustion Engine (ICE) vehicles depend entirely on fossil fuels to power them. The different types of electric vehicles are:

Battery-Electric Vehicles (BEV)
These vehicles only use electricity stored in an on-board battery pack to power the electric motor and propel the vehicle. On a full charge, the low-cost vehicles are designed to travel around 110–160 kms, though recent developments in battery technologies are enhancing the driving energy. More expensive vehicles have much higher driving range, some exceeding 500 kms. The batteries can be charged either at home or at the workplace or even at publicly available charging or swapping stations.

Hybrid-Electric Vehicles (HEV)
These vehicles combine an ICE diesel or gasoline powertrain along with an on-board small battery and an electric motor. The electric drive train is generally used for shorter driving distances whereas the diesel/gasoline drive train is used for long distances. HEVs have a battery but it is recharged automatically during regenerative braking or while the vehicle is idling. Most of the power to propel a HEV comes from the ICE but the addition of an electric motor increases fuel efficiency, reduces the use of petrol/diesel, and decreases emissions. Use of regenerative braking, and idling power to feed the battery are additional features that increase fuel efficiency.

Plug-In Hybrid Electric Vehicles (PHEV)
Like HEVs, these vehicles also have both an internal combustion engine and an electric motor. However, unlike in an HEV, the electric drive train can also be charged using an electricity outlet and does not depend entirely on regenerative braking or idling. As a result, they can use the electric drive train for longer distances and are more efficient in the use of petroleum. Consumers have the option to switch to gasoline if they cannot recharge the batteries.

2. What are the different ways in which the battery of an electric vehicle can be re-energised?*

Electric vehicles use batteries as their source of energy. Batteries store a limited amount of energy and vehicles can move only a limited distance before this energy runs out. Hence, the battery in a vehicle provides a limited range, namely the distance it can travel before the battery runs out of charge. The range of the vehicle depends upon the usable capacity of the battery installed in the EV, measured in Kilo Watt Hour (kWh), and the energy consumed by the vehicle, measured in Watt Hour per Kilometer (Wh/km). When a battery runs out of charge, it needs to be re-energised. This can be done in two ways:
- Batteries are recharged either through slow charging or fast charging.
- A discharged battery is exchanged for a charged battery at swapping facilities.

The amount of electricity stored in the battery determines the distance it can travel using electricity. But typically, this is around 16 to 60 kms. They are cheaper to run and create lesser pollution than their conventional counterparts.

Fuel Cell Electric Vehicles (FCEV)
These vehicles combine hydrogen and oxygen to make electricity that powers the electric motor. Producing electricity from hydrogen only leaves water and heat as by-products. This means FCEVs don’t have any tail pipe emissions. It takes about ten minutes to refuel pressurised hydrogen. Driving ranges are around 300 – 500 kms. Regenerative braking can be used for capturing lost energy.

Battery charging
Charging facilities can be set up at home, work places or parking lots. They can also be created in areas which have a cluster of vehicles, such as bus depots or locations where taxis tend to collect when they are not being used. Charging can be slow or fast. Batteries behave best when slow charged to their full capacity (commonly during the night-time at lower temperature in most parts of India), ready to be used for its full range. But if the vehicle needs to go for more than this range in a day, it will either have to be recharged mid-way or swapped with a charged battery. If recharged mid-way, this will need to be done at fast charging stations or if swapped,

it will need access to a battery swapping station. An intermediate option is to have a mechanism for adding a battery, over and above a fixed battery, on the few occasions when a vehicle needs to travel more than the distance that the fixed battery can power. This is known as “Range Extension”.

An important concern is the time required for charging. Different types of chargers take different times to charge a battery fully. There are three types of chargers:

- **Slow charger**: If the charger charges the battery to 80-90% of its capacity in 4 to 8 hours, it is referred to as a slow charger.
- **Fast charger**: If the charger charges a battery in one hour, it is referred to as a fast charger.
- **Ultra-fast charger**: If the charger charges a battery in 30 minutes or less, it is referred to as an ultra-fast charger.

The use of slow, fast or ultra-fast charger does not just depend upon the availability of the chargers. Instead, chargers must be matched with the specific battery chemistry to ensure minimum impact on the life cycle of the batteries during charging. The life cycle of a battery depends upon the battery chemistry used, depth of discharge (DoD) used (impacting the usable capacity of the battery), its rate of charging/discharging and the temperature at which it is charged/discharged. For example, a low-cost graphite-NMC battery available today cannot be fast charged to full usable capacity in less than an hour without impacting the number of life cycles, even when charged at 25°C. On the other hand, the higher cost LTO battery can be fully charged within 20 minutes without any appreciable impact on battery-life, even if the temperature goes up to 45°C. These facts, as well as the type of vehicle used and the battery-size and chemistry, need to be understood well while building public charging infrastructure.

**Battery swapping**

Unlike charging, in battery swapping a discharged battery is replaced with a charged one. The discharged battery is then separately charged in a controlled environment.

**EVs with swapping (EV-S)**

The time needed for charging can be a problem and many more charging points will be needed compared to the number of petrol/diesel dispensing units. Adequate space, for accommodating the number of charging stations needed, may not be easily available. In such cases, the alternative is to swap the discharged battery with a charged one. Swapping takes only a few minutes, which eliminates the need for drivers to wait for too long while the vehicle is being charged.

Battery swapping can also help in addressing the issue of high upfront cost of EVs. In the swapping option, the battery is separated from the vehicle and need not be owned by the vehicle owner. Instead, it can be owned by an Energy Operator (EO). An EO will provide a charged battery, in exchange for a discharged one, as a service. S/he will buy the batteries, charge them and lease them to vehicle owners at convenient charge-cum-swap centres. A vehicle-owner can sign up with one such EO and lease the charged battery from them. Swapping can be done manually for small vehicles, such as two and three-wheelers, since they have light batteries. However, 4-wheelers and buses, with heavier batteries, will need mechanical or automated swapping.

**EVs with slow charging plus range-extension swapping (EV-RE)**

Yet another option could be that a vehicle is designed to have a small built-in “fixed” battery. This battery will be charged every night. But since the battery is small, the range will not be large. Since most personal vehicles in India are driven only for short distances, this small range may be good enough for most days. For the few occasions when the vehicle needs to travel longer distances, the vehicles can have a slot for a second battery called range-extension swappable LS batteries (or RE battery). When vehicles need to be driven for ranges longer than what is offered by the fixed battery, they will need to go to a swapping station to install an additional RE battery.
ANNEXURE – 2

OPTIMAL REENERGISING OPTIONS FOR DIFFERENT TYPES OF VEHICLES*

There are different reenergizing options for batteries. Each of these would be optimal for different types of vehicles. These options are discussed below.

Two-wheelers

Economy two-wheelers use small sized batteries (1 kWh to 1.5 kWh) providing a range of about 50 kms. Home charging using 15A AC outlet during night-time, would enable it to ply on a majority of the days for most users. The day users need to travel longer, they would have two options. If the vehicle is parked for a few hours in a parking lot, they could use AC001 to charge during the day. The charging could take one to three-hours. Alternately, they could drive to a swapping station to lease and add a range-extension battery for a further 50 kms range. This range-extension battery can be swapped in about three minutes and can be done as many times as needed, providing unlimited range to the vehicle. The key public infrastructure that they would require is public AC001 public charging facilities in parking lots and swapping stations all over the city. Public parking places as well as petrol stations and popular eateries on highways are ideal locations.

Three-wheelers

All kinds of three-wheelers, e-rickshaw, e-auto, e-auto (large) and e-auto (goods) are economically viable today, if they use battery swapping. They would normally use swappable 3 kWh battery. These vehicles would require public swapping infrastructure all over the city, preferably at distances no more than 1.5 kms apart. The large auto and goods autos may use larger sized batteries like 6 kWh to 8 kWh and may use swapping or charging. They could use public AC001 for charging during the night as well as day, requiring three to four hours to fully charge. Alternatively, they may sometimes prefer to use DC Fast charger such as DC001, which would enable the batteries to fully charge in about 45 minutes. Thus, a city would require AC001 and DC001 deployed at parking lots in the city and at eateries on highways, in addition to three-wheeler swapping infrastructure, all over the city and on highways as public infrastructure.

Economy Cars

A small and medium sized car, costing less than INR 10 lakhs, will inadvertently have small batteries of size 10 kWh to 15 kWh, providing a range of about 100 kms. For most consumers, this range would be enough for a large majority of the days and the battery can be charged at home in about five to seven hours using 15A AC outlet. The day they need to travel longer distances, they could swap-in a range-extension battery providing another 100 kms. If they need to travel even longer distance (like inter-city), they could go again to a petrol pump on the highway and swap the Range extension battery. Range limitation is therefore overcome. The swapping can be done in less than five minutes. The second option would be to use DC001 at city-parking lots, in office-buildings and at highway-eateries. This would require about 45 minutes wait-time to fully charge the battery. City parking lots or office-buildings with AC001 could also supplement the charge for these vehicles for about two to three hours, when the vehicles are parked there. Thus, the economy cars require the Range-extension battery-swapping infrastructure in the city and in highways petrol-pumps, DC-001 at city-parking lots, office buildings and highway-eateries as well as AC001 at city parking lots and office buildings.

Premium Cars

These are cars, which would be in the higher price segment – more than INR one million - and could therefore afford to have larger batteries. The size of the batteries may vary from about 30 kWh to almost 75 kWh or even larger, giving a driving range between 200 kms to 500 kms. It will be difficult to charge these vehicles at home using AC001 chargers, as it would take anywhere from 10 hours (for 30 kWh battery) to about 25 hours (for 75 kWh battery) to charge. The vehicles would have to be fast charged. The batteries they use would be somewhat expensive and allow faster charging, so that the full battery could possibly be charged in about 30 minutes. Partial charge would be faster. For example, a car with batteries offering range of 500 kms may have a top up charge of 200 kms in as little as 12 minutes. The fast chargers to be used will invariably be DC and would require output from 30 kW to about 80 kW.

* Source: WRI India and CBEEV, IIT Madras. (2019). A Guidance Document on Accelerating Electric Mobility in India (pp.87-88). New Delhi
Buses

Buses will be of two types. First will be intra-city buses. These buses will make multiple trips (say 8 to 10) in a day between two points (depots or bus-terminus) in a city. The single distance will rarely be over 30 – 50 kms, depending on the area of the city. It is possible to use a battery of about 60 kWh giving as much as 50 kms range for a twelve-meter AC bus. One could swap batteries at each end. Alternatively, they could be fast charged at locations where they stop at the end of a trip and where the crew is allowed some time for rest. All that the city will then need is Charging-cum swapping infrastructure at the depots / bus terminus or fast charging facilities.

The second type of bus would be intra-city long-distance buses. One could then use larger batteries of 150 kWh to 250 kWh having a range of 125 kms to 200 kms. The buses would leave the originating station fully charged. Before they run out of charge, they would recharge for about thirty to forty minutes (or little more) at an intermediate bus-terminus on the route. These bus terminals would need CCS fast chargers for buses, which would charge at 750V, commonly used by buses, and at rates of 200 kW to 300 kW. They would be able to charge the bus-batteries to about 80% of the capacity in 30 to 40 minutes. The bus routes have to be planned while taking this into account.
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