Smart City Master Planning and Sector-specific Smart City Infrastructure Projects for **Visakhapatnam**

ELECTRIFICATION OF 2-WHEEL & 3-WHEEL TRANSPORT— FEASIBILITY STUDY FINAL REPORT

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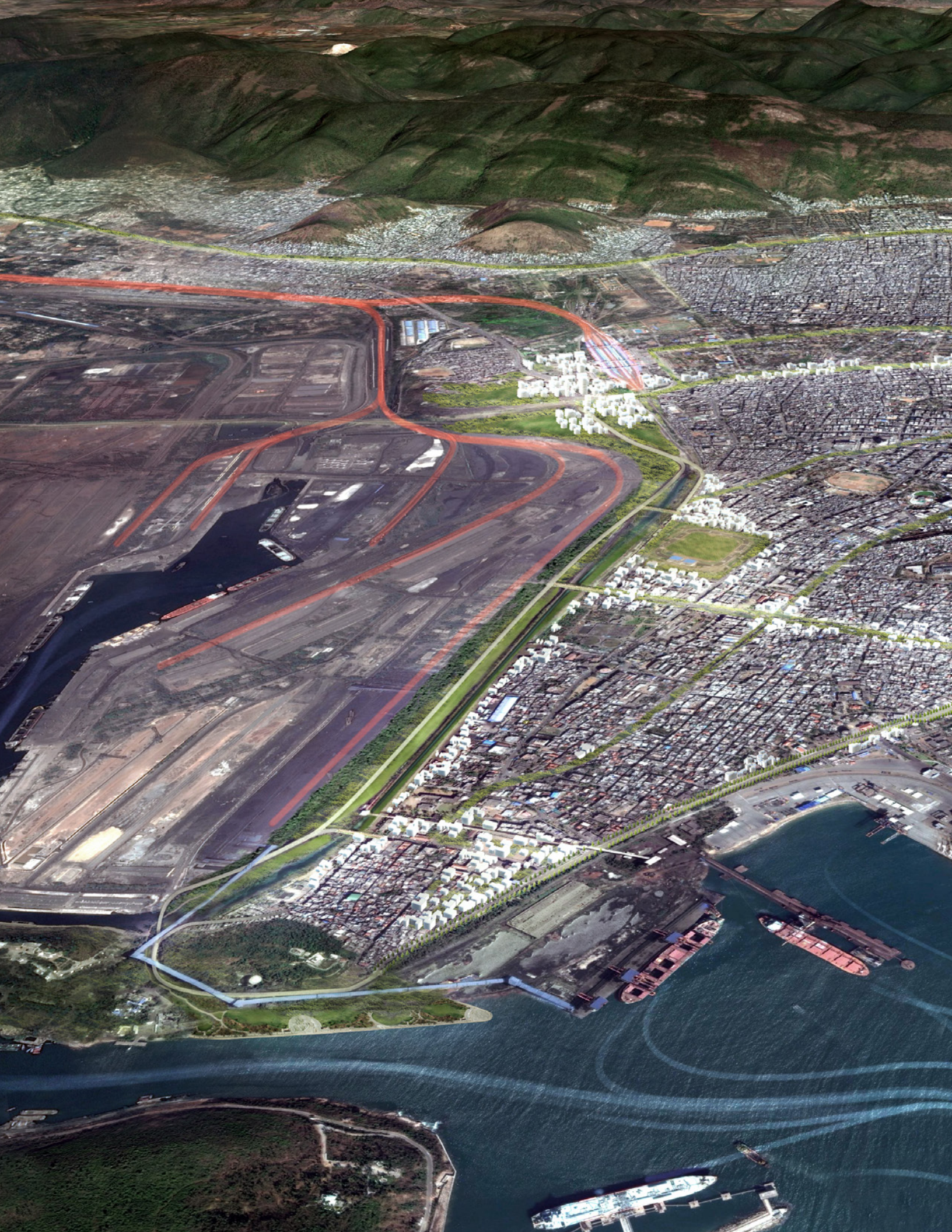
Acronyms and Abbreviations

Ah	Ampere-hours
APEPDCL	Andhra Pradesh Eastern Power Distribution Company Ltd.
APGENCO	Andhra Pradesh Power Generation Company
CEO	Chief Executive Officer
CMAR	Construction Manager at Risk
DB	Design-Build
DBF	Design-Build-Finance
DBFOM	Design-Build-Finance-Operate-Maintain
DBOM	Design-Build-Operate-Maintain
EoI	Expression of Interest
GHG	Greenhouse Gas
GVMC	Greater Visakhapatnam Municipal Corporation
HPSC	High Powered Steering Committee
IT	Information Technology
km	Kilometers
kV	Kilovolt
MW	Megawatts
MWh	Megawatt-Hour
NREDCAP	New & Renewable Energy Development Corporation of Andhra Pradesh Limited
O&M	Operations and Maintenance
OT	Operational Technology
PV	Photovoltaic
RFP	Request for Proposals
RFQ	Request for Qualifications
SCADA	Supervisory Control and Data Acquisition
SOQ	Statement of Qualification
SPV	Special Purpose Vehicle
ULB	Urban Local Bodies
VfM	Value for Money
VUDA	Visakhapatnam Urban Development Authority
W	Watts



EXECUTIVE SUMMARY

The goal of this project is to improve air quality through reduction in greenhouse gas (GHG) emissions associated with transportation, specifically, 2-wheel and 3-wheel vehicles.

The goal of this project is to improve air quality through reduction in greenhouse gas (GHG) emissions associated with transportation, specifically, 2-wheel and 3-wheel vehicles. This goal is consistent with Visakhapatnam's socioeconomic development vision, as approved by Chief Minister Naidu in June 2016, which calls for Green Living and Smart Business. The project contributes to Green Living by preserving and enhancing the natural environment (specifically, air quality). It also contributes to Smart Business by creating economic development opportunities in the manufacturing, distribution, retailing and servicing of electric vehicles in the Greater Visakhapatnam Region.

Air pollution was identified by local residents during the preparation of Visakhapatnam's Smart Cities challenge proposal as one of the main urban problems facing the city. Substituting electric vehicles for diesel-powered auto-rickshaws and gas-powered scooters and small motorcycles will reduce emissions from these types of vehicles to zero. However, some of the reduction will be offset by greenhouse gases (GHG) emitted by coal-burning power plants, the source of most electricity in Andhra Pradesh. In addition to the environmental benefits, lowering GHG emissions in Visakhapatnam will contribute indirectly to human health because cleaner air will help lower rates of respiratory disease such as emphysema.

Market conditions are generally ripe for large-scale introduction of electric vehicles in India. The cost of vehicles and the batteries that they run on continue to drop substantiall every year. A number of manufacturers are making 2-, 3- and 4-wheel electric vehicles in India. The national policy environment is also supportive, as the Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) program, which offers purchase incentives for clean fuel technology cars intended to boost sales to 7 million vehicles by 2020.

AECOM carried out demand-side analysis of autorickshaw owner/drivers by interviewing 15 drivers on the street and at Visakhapatnam main railway station in a pre-survey, and then conducting a focus group

with 40 autorickshaw owners and drivers convened at GVMC in September 2017. The results of the survey and the focus group are presented in Appendix A. The overarching findings are that rickshaw owner/drivers are generally willing to switch to electric vehicles under the following conditions:

1. E-rickshaws loaded with six passengers and a driver must be able to climb Visakhapatnam's steep hills;
2. A battery-swapping system must be in place OR a network of charging stations around the city must be developed;
3. The cost of purchasing and operating an e-rickshaw must be competitive with the price of diesel rickshaws.

At present, only the third condition has been satisfied. The purchase price of e-rickshaws is about the same as that of diesel autorickshaws. Moreover, the energy costs of operating e-rickshaws is much less than that of conventional vehicles (between 1/25th and 1/50th the cost, depending on the vehicle). Drivers are generally aware that e-rickshaws are cheaper to operate, but they do not know how large the potential savings is.

Promoting the electrification of 2W and 3W vehicles requires not just the sale of electric vehicles in the local market, but rather the creation of a supportive ecosystem for their sale, storage, operation and maintenance. The initiative has to be feasible and satisfactory for a number of different parties: for owners and drivers of the electric vehicles; for the customers of the e-rickshaws; for the manufacturers and distributors of the vehicles; and for the developer/operators of networks of charging stations or battery-swapping shops. In response to that requirement, the following four components have been included in the program:

Component 1: EV product development. The supply of 2-wheel and 3-wheel vehicles must meet the demand of the current owner/operators of conventional vehicles to a degree sufficient for the owners to switch. Some e-rickshaws already meet the requirements, but are more expensive; the technical performance of other e-rickshaws may have to improve in order to capture market share. This program can contribute to EV product development by facilitating communication among user groups in Visakhapatnam and manufacturers of EVs.

Component 2: EV demand enhancement. The program will publicize the advantages of electric vehicles, especially the substantially lower energy costs. It may be necessary to demonstrate publicly the speed and torque of fully loaded e-rickshaws. To further boost demand, the program can make use of FAME subsidies to reduce the purchase cost of 2-wheel and 3-wheel electric vehicles.

Component 3: Development of EV battery recharging infrastructure. This analysis considers two options:

1. Introduction of an EV battery swapping program. This could start on a pilot basis in the Area-Based Development pilot zone. Existing service stations could be used as the swapping centres. This options will be discussed with leaders in battery-swapping systems such as Ashok Leyland and SUN Mobility.
2. Develop a network of charging stations. "Supercharging" stations could be developed on municipally owned properties or at existing service stations. The latter would allow the fossil fuel distribution companies to keep a foot in the game as the vehicle fleet of the city changes over to electric. Conventional charging stations can be established in apartment buildings and office buildings by their owners.

Component 4: Phasing out of conventional 2W and 3W vehicles. This gradual process of prohibition and then withdrawal of electric vehicles should take place over a multi-year period (e.g., five years). Prohibition of sale of such vehicles in Visakhapatnam after an initial period can evolve into prohibition of registration, then introduction of a pollution tax, and finally a ban on the use of conventional 2W and 3W vehicles within municipal limits.

It is anticipated that the private sector will play the primary role in the implementation of most of the components, as described below.

Table 1 Anticipated Implementation Arrangements of the Program

Component	Implementation Arrangements	Comments
1. EV product development	Private manufacturers using own sources of finance	GVMC can facilitate exchanges between customers and manufacturers
2. EV demand enhancement	Partnership between AP/GVMC and private manufacturers	Public information campaign can be co-financed by all participating parties
3. Development of EV battery charging infrastructure	▪ Battery swapping system: private ownership/operation ▪ Network of charging stations: PPP between AP/GVMC and private owner/developers	Public subsidy may be required to cover part of the development cost of the network
4. Phasing out of conventional 2W and 3W vehicles	GVMC to implement	AP Government financing may be required

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1. PROJECT RATIONALE

The goal of this project is to improve air quality through reduction in greenhouse gas (GHG) emissions associated with transportation, specifically, 2-wheel (2W) and 3-wheel (3W) vehicles. This goal is consistent with Visakhapatnam's socioeconomic development vision, as approved by Chief Minister Naidu in June 2016, which calls for Green Living and Smart Business. This project contributes to Green Living by preserving and enhancing the natural environment (specifically, air quality). It also contributes to Smart Business by creating economic development opportunities in the manufacturing, distribution, retailing and servicing of electric vehicles in the Greater Visakhapatnam Region (GMR).

Air pollution was identified by local residents during the preparation of Visakhapatnam's Smart Cities challenge proposal as one of the main urban problems facing the city. Research carried out in 2015 by Guttikunda, Goel, Mohan, Tiwari, and Gadepalli[1] showed that vehicle emissions is the biggest contributor to air pollution in Visakhapatnam, edging out coal dust from the port by a small margin.

Table 2 Estimated Emissions per 2W and 3W Vehicle in GMR

Vehicle Type	Avg. Km/ Vehicle/Year	CO Emissions (kg/year/ vehicle)	HC Emissions (kg/year/ vehicle)	Nox Emissions (kg/year/ vehicle)	CO2 Emissions (kg/ year/vehicle)	PM Emissions (kg/year/ vehicle)
2-wheelers	9,500	12.19	5.16	3.04	302.07	0.23
3-wheelers	36,000	46.20	30.48	14.40	3,322.92	1.79

Sources: GOI Ministry of Road Transport and Highways (MoRTH 2015); Guttikunda, Goel, Mohan, Tiwari and Gadepalli: Particulate and Gaseous Emissions in Two Coastal Cities - Chennai and Vishakhapatnam, Air Quality Atmosphere & Health, December 2015; http://www.aptransport.org/html/pollution-control.html; http://www.cpcb.nic.in/Emission_Factors_Vehicles.pdf

Table 3 Estimated Total Annual 2W and 3W Emissions in GMR

Vehicle Type	Avg. Km/ Vehicle/Year	Registered Vehicles (#)	CO Emissions (metric ton/ year)	HC Emissions (metric tons/ year)	Nox Emissions (metric tons/ year)	CO2 Emissions (metric tons/ year)	PM Emissions (metric tons/ year)
2-wheelers	9,500	574,135	7,000	2,963	1,745	173,428	131
3-wheelers	36,000	34,826	1,609	1,062	501	115,724	62
Total	**45,500**	**608,961**	**8,609**	**4,025**	**2,246**	**289,152**	**193**

Source: GOI Ministry of Road Transport and Highways (MoRTH 2015); Guttikunda, Goel, Mohan, Tiwari and Gadepalli: Particulate and gaseous emissions in two coastal cities - Chennai and Vishakhapatnam, Air Quality Atmosphere & Health, December 2015; http://www.aptransport.org/html/pollution-control.html; http://www.cpcb.nic.in/Emission_Factors_Vehicles.pdf

1 Guttikunda, Goel, Mohan, Tiwari and Gadepalli: Particulate and gaseous emissions in two coastal cities - Chennai and Vishakhapatnam, Air Quality Atmosphere & Health, December 2015

Substituting electric vehicles for diesel-powered autorickshaws and gas-powered scooters and small motorcycles will reduce emissions from these types of vehicles to zero. It is estimated that this will reduce carbon emissions by 57,295 metric tonnes per year (50% reduction) by transitioning fully to 3-wheelers and by 105,000 metric tonnes per year (57% reduction) by transitioning to electric 2-wheelers in the city. However, since most power in Andhra Pradesh State is thermal (coal), driving 2-wheel and 3-wheel electric vehicles will still result in air pollution, since the production of electricity is associated high levels of GHG emissions. With electrification of two and 3-wheel vehicles, the US National Renewable Energy Laboratory estimates that pollution will drop by at least one-third as a result. And the location of the pollution will change from urban areas with high population density to rural areas around power plants with lower population densities.

Table 4 CO2 Emissions Reduction with Electrification by Vehicle Type

Vehicle Type	Average Km/ Vehicle/Year	Registered Vehicles (#)	CO2 Emissions (metric tonnes/year)	CO2 Emissions Reduction with Electrification (metric tonnes/year)	CO2 Emissions Reduction with Electrification (%)
2-wheelers	9,500	574,135	173,428.00	-105,000	-57%
3-wheelers	36,000	34,826	115,724.01	-57,295	-50%

Source: GOI Ministry of Road Transport and Highways (MoRTH 2015); Guttikunda, Goel, Mohan, Tiwari and Gadepalli: Particulate and gaseous emissions in two coastal cities - Chennai and Vishakhapatnam, Air Quality Atmosphere & Health, December 2015; www.aptransport.org/html/pollution-control.html; www.cpcb.nic.in/Emission_Factors_Vehicles.pdf; www.yourstory.com/2017/07/smart-electric-waste-disposal-vehicles

In addition to the environmental benefits, lowering GHG emissions in Visakhapatnam will contribute indirectly to human health because cleaner air will contribute to lower rates of respiratory disease such as emphysema.

Electrifying transportation also makes sense in Andhra Pradesh because it is a net electric-power exporter. Some of the surplus power can be used locally in an environmentally friendly manner.

2-wheel (2W) and 3-wheel (3W) electric vehicles (EV) were selected for this study because they constitute a large share of the vehicle fleet, and therefore their substitution can have a big impact on air quality. It was also considered easier to electrify these smaller, less powerful types of vehicles because it can be done with limited or no investment in public charging stations, as batteries can be small and portable, facilitating charging at home or in the workplace using existing power distribution infrastructure. 4W EVs (cars), on the other hand, require charging infrastructure, as the batteries are too large and heavy to remove.

2. ASSESSMENT OF EXISTING CONDITIONS

2.1 Policy Environment

National Government Policy

The Government of India (GoI) approved the National Mission on Electric Mobility in 2011 and subsequently unveiled the "National Electric Mobility Plan 2020" in 2013. As a part of the mission, the Department of Heavy Industry (DHI), under GoI's Ministry of Heavy Industries and Public Enterprises, formulated the FAME-India (Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India) scheme. The FAME scheme is proposed to be implemented over a period of six years, wherein it is intended to support the development of the hybrid/electric vehicles market and its manufacturing ecosystem to achieve self-sustenance by 2020. The first phase of the scheme was implemented over a period of 2.5 years (i.e. from April 2015 to September 2017).[2] Responsibility for implementation of FAME has been transferred from the Department of Heavy Industry to NITI Aayog, the national policy commission.

The FAME scheme has four focus areas: Technology Development, Demand Creation, Pilot Projects and Charging Infrastructure. Phase I of the scheme has an approved outlay of INR 795 crore, out of which INR 495 crore is allocated for spending on demand incentives.[3]

Table 5 Fund Allocation in Phase I of FAME-India Scheme

S. No.	Component of the Scheme	Phase I (Apr 2015 - Sep 2017, in Indian Rupees)
1	Technology Platform (including testing infrastructure)	INR 190 Crore
2	Demand Incentives	INR 495 Crore
3	Charging Infrastructure	INR 30 Crore
4	Pilot Projects	INR 70 Crore
5	IEC/Operations	INR 10 Crore
	Total	**INR 795 Crore**

Source: http://www.fame-india.gov.in/ViewNotificationDetails.aspx?RowId=5

2 Source: http://www.fame-india.gov.in/ViewNotificationDetails.aspx?RowId=12

3 Demand incentives are available as a direct subsidy on the retail price of eligible vehicles to consumers. Demand incentives are also available for retrofitment kits across all vehicle segments and technologies for up to 15% to 30% of kit price depending on the amount of fuel consumption reduced, as well as the price of the kit.

Geographies covered under Phase I of the Scheme:
Taking into account the high level of environmental pollution and dependence upon fossil fuel in road transport in high density urban centres, the first phase of the scheme was restricted to the following areas:

- Cities under “Smart Cities” initiative;
- Major metro agglomerations: Delhi NCR, and Greater Mumbai, Kolkata, Chennai, Bengaluru, Hyderabad, Ahmedabad;
- All state capitals and other urban agglomerations/cities with population above 1 Million as per the 2011 national census;
- Cities of north eastern states.

A demand incentive is in the form of a purchase price reduction provided to vehicle buyers by the registered dealers on purchase of hybrid or electric vehicles. The reduction varies by vehicle type and technology, as shown in the table below.

Table 6 FAME Demand Incentives by Vehicle and Technology

Vehicle Type		Incentive	Mild Hybrid Electric Vehicle (INR)	Strong Hybrid Electric Vehicle (INR)	Plug-In Hybrid Electric Vehicle (INR)	Battery Electric Vehicle (INR)
	2- Wheeler (Scooter)	Min.	1,800	-	13,000	7,500
		Max.	4,300		15,600	22,000
	2- Wheeler (Motorcycle)	Min.	3,500	-	15,000	9,600
		Max.	6,200		18,000	29,000
	3-Wheeler (Auto Rickshaw)	Min.	3,300	-	25,000	11,000
		Max.	7,800		46,000	61,000
	4-Wheeler (Passenger Car)	Min.	11,000	59,000	98,000	60,000
		Max.	24,000	71,000	118,000	138,000
	Light Commercial Vehicle (LCV)	Min.	17,000	52,000	73,000	102,000
		Max.	23,000	62,000	125,000	187,000
	Bus	Min.	3,000,000	5,100,000	-	-
		Max.	4,100,000	6,600,000		

Source: http://www.fame-india.gov.in/ViewNotificationDetails.aspx?RowId=5

In order to receive the incentive, dealers must submit their claims on a monthly basis to their respective original equipment manufacturers, which in turn submit their claims to the Department of Heavy Industry through National Automotive Board (NAB).[4]

4 Aadhaar is a 12 digit unique-identity number issued to all Indian residents based on their biometric and demographic data. As on 30th July 2017, over 99% of Indians aged 18 and above had been enrolled in Aadhaar.

A total of 111,897 vehicles benefited from incentive financing worth INR 151.5 crore from the FAME India scheme during the scheme's first 23 months (i.e., April 2015 to February 2017). A total of 35,075 2-wheeled vehicles have received demand incentives worth INR 26.75 crore during that same period. Over 63% of FAME-India incentives by value have thus far been used by owners of four-wheeled mild hybrid vehicles, where 73,633 units availed the demand incentive worth INR 95.72 crore.

Table 7 Penetration of FAME Demand Incentives by Vehicle Type

Vehicle Type	No. of Total Vehicles Supported	Total Incentives (INR)
2-Wheeler - Low Speed with Conventional Battery	33,496	251,220,000
2-wheeler - Low Speed with Advanced Battery	193	3,281,000
2-Wheeler - High Speed with Conventional Battery	1,386	13,028,400
4-Wheeler (Passenger Car) - Mild Hybrid	73,633	957,229,000
4-Wheeler (Passenger Car) - Strong Hybrid	1,949	136,430,000
4-Wheeler (Passenger Car) - Full Electric	1,230	152,520,000
LCV - Full Electric	10	1,870,000
Total	**111,897**	**1,515,578,400**

Source: http://dhi.nic.in/writereaddata/UploadFile/Rajya%20Sabha%203073.pdf

The main conclusions to be drawn are:

- The 2-wheeler segment has benefitted very little from the FAME-India scheme. Only 18% of the FAME-India incentives by value have so far gone to the 2-wheeler segment.
- Within the state of Andhra Pradesh, only 1,255 vehicles have benefitted from the scheme thus far. Despite incentives as high as INR 140,000 (USD 2,175) on some cars the scheme has made little progress, with the sales of electric and hybrid cars making up only a fraction of the 3 million passenger vehicles sold in India in 2016. The scheme, which expired on 31 March 2017, has now been extended by six months while future policy is worked out, as two government officials have confirmed. Another official has added that a lack of clarity on the policy risks further delaying of investment in the automobile sector.
- The 3-wheeler segment has not benefitted at all from the FAME-India scheme.

In addition to FAME, NITI Aayog has recommended that government open a battery plant by the end of 2018 and uses tax revenues from the sale of petrol and diesel vehicles to set up charging stations for electric vehicles. This recommendation is aimed at electrifying all vehicles in the country by 2032 and will likely shape a new mobility policy, said government and industry sources.[5] "Limit registration of conventional vehicles through public lotteries and complement that with preferential registration for electric vehicles, similar to that in China,[6]" the NITI Aayog report said, in one of its more ambitious proposals. Among suggestions included in the report are: bulk procurement of electric vehicles; building standardized, swappable batteries for 2- and 3-wheelers to bring down their cost and having favorable tariff structures for charging cars; and prioritizing battery and charging infrastructure development. Additionally, the report suggested setting a 2018 goal to set up a 250 MWh battery plant with an aim to reach one gigawatt of production by 2020, setting up battery swapping stations by 2018, and common manufacturing facilities for components and increasing subsidies on all battery electric vehicles to bring them to cost parity with conventional models by 2025.

Government of Andhra Pradesh Policy

The State Government of Andhra Pradesh (AP) is keen on positioning the state as India's most attractive destination for electric vehicles manufacturing. To that end, GoAP is formulating a long-term strategy for creating a supportive ecosystem for the development of electric vehicles. The AP Economic Development Board (APEDB) intends to establish an "Electric Vehicles Task Force" that will coordinate and develop synergies between the departments, industry and all other key stakeholders, respective to the specificity of the task force.[7]

The Andhra Pradesh Industrial Infrastructure Corporation (APIIC) is a state-level nodal agency mandated for development of industrial infrastructure across the state through creation of industrial parks/ estates. APIIC is also assigned the responsibility of allotting industrial land to entrepreneurs. In order to boost state's economy, APIIC has recently allotted land at concessional rates to companies like KIA Motors, Apollo Tyres, etc. for setting up of vehicle manufacturing plants and related ancillary products. To attract EV manufacturers and their ancillaries within the state, APIIC can also offer them industrial land at concessional rates.

5 https://www.reuters.com/article/us-india-autos-policy-exclusive/exclusive-indias-green-car-plan-prioritizes-electric-vehicles-over-hybrids-idUSKBN183010

6 http://www.reuters.com/article/india-autos-policy/rpt-indias-green-car-plan-prioritises-electric-vehicles-over-hybrids-idUSL4N1I8080

7 http://www.deccanchronicle.com/nation/current-affairs/190917/ap-plans-to-set-up-electric-vehicles-task-force.html

The Andhra Pradesh Department of Industries[8] is responsible for extending incentives to industrial entrepreneurs. Special package of incentives can be carved out to attract EV manufactures to set-up their manufacturing plants within the state. The current “Industrial Development Policy 2015-2020” offers incentives in the form of VAT/ GST reimbursement, power cost reimbursement, stamp duty reimbursement, subsidy on plant & machinery, subsidy for sustainable green measures on total fixed capital investment, etc. In addition to these, other tailor made incentives can also be extended for EV manufactures and their ancillaries.

The state already has a thriving ecosystem for automobile and component manufacturing, with a presence of Isuzu, Kia Motors, Hero Motors, Rockman industries, Ashok Leyland, Apollo Tyres and Amara Raja Batteries.

In formulating its EV policy, the AP government is also engaging with players across the value chain and is set to hold a consultative meet with various stakeholders to ensure that the state comes up with a robust policy. The state plans to build partnerships in the EV segment and augment the EV ecosystem with countries such as Japan, Korea, China and Taiwan.

Various investors have shown interest in the manufacture of e-autos, buses and vehicles in the state. The Andhra Pradesh Economic Development Board (APEDB) is said to be willing to facilitate their entry into Andhra Pradesh.

AP is also home to some of the biggest names in India in battery manufacturing like Amara Raja Batteries, HBL Power Systems and Nippo Batteries. Although India is yet to become self-sufficient in manufacturing lithium batteries that are required to run EVs, the presence of large scale battery manufacturers in the state of Andhra Pradesh would be a great advantage, due to synergies and linkages in the value chain. The EV policy will be developed in line with the existing Automobile and Auto-component policy in the state.

AP also became the first Indian State to adopt electric waste disposal vehicles. This is the first time that any state in India has adopted smart and electric waste disposal vehicles. In the summer of 2017, Chief Minister Nara Chandrababu Naidu inaugurated the deployment of pollution-free electric autorickshaws with advanced hydraulic disposal system at AP Secretariat. The vehicles have been supplied to the government by an electric vehicle manufacturing startup, Gayam Motor Works (GMW), the first company in the country to develop indigenous battery swapping technology for electric vehicles.

8 Three line departments of AP State Government viz. Department of Industries, Department of Transport, Department of Energy are jointly working at present to draft a State Electric Vehicle & Energy Storage Policy which will be released by end of this year. The neighbouring state of Karnataka is the first state in India to release such policy last month.

The manufacturer claims that the replacement of diesel autos with electric autos also means zero fuel consumption and zero greenhouse gas emissions. GMW estimates that each diesel auto replaced will reduce approximately 35 tons of carbon emissions over a period of five years. They estimate this could reduce up to a total 200,000 tons of carbon emissions by replacing more than 5,000 municipal disposal vehicles across the state with electric vehicles. GMW claims that the their vehicle reduces the running cost from INR 3.50/km to INR 0.50/km by replacing a diesel autorickshaw with a GMW SmartAuto. With this forethought, the State government plans to scale these smart and electric vehicles to other municipalities in the State.[9]

City of Visakhapatnam Policy

As part of its current initiative to expand EV policies into other markets than just the 2-, 3- or 4-wheelers, the State of AP government has earlier deployed 100 electric bikes and State-wide electric vehicle deployments to enhance the urban experience without negative aesthetic and environmental impact in the city of Visakhapatnam[10]. Chief Minister Chandrababu Naidu inaugurated the use of 100 LIMITLESS Electric bicycles in Visakhapatnam to provide the GVMC with economical mobility option for daily supervision and patrols by using electricity generated by thermal power. The LIMITLESS E-Bikes are manufactured by Gayam Motor Works (GMW),[11] an electric vehicle start-up. A public bicycle sharing system utilizing these e-bikes is currently in planning by The Greater Visakhapatnam Smart City Corporation to promote the adoption of cleaner emission transportation in the city.

2.2 Indian City-Level Pilot Projects in 2W and 3W Electric Vehicles

In addition to the following Indian case studies in electric vehicles, the Shanghai experience is presented in Appendix C.

Case Study 1: Electric Vehicles in Bangalore

Description
Bangalore is a pioneer in India in promotion of electric vehicles. This case study focuses on two different aspects of EV promotion in Bangalore: sale of electric cars and leasing of electric taxis.

Electric Car Sales
The Bangalore-based manufacturing firm REVA introduced electric cars in Bangalore in 2001. Since then, about 1,000 vehicles have been sold.

9 https://yourstory.com/2017/07/smart-electric-waste-disposal-vehicles/

10 http://www.gayammotorworks.com/solar-energy-electric-vehicles-freeze-indias-fossil-fuel-growth-copy/

11 http://www.gayammotorworks.com/solar-energy-electric-vehicles-freeze-indias-fossil-fuel-growth-copy/

There are also over 110 official REVA charging points across the city.[12] REVA is now owned by Mahindra Electric.[13]

Under Faster Adoption and Manufacturing of (Hybrid) Electric Vehicles in India (FAME-India) Scheme of the Government of India, 25 charging stations have been installed at six different locations in Bengaluru by Mahindra REVA Electric Vehicles Pvt. Ltd.[14]

EV users charge their vehicles almost entirely at home and in a few cases at their places of work. Use of electric vehicles in Bangalore is constrained by the limited public availability of charging infrastructure.

To reduce the upfront cost of the 4W EV, REVA introduced a battery leasing pilot project. This effort was well-received by customers. The company is expanding battery leasing, providing a monthly lease payment option to consumers, with maintenance for the duration of the lease done by REVA. On expiration of the lease, consumers have the option to continue with the same lease plan or upgrade to the latest battery packs available in the future. Another model that the company is considering for increased consumer awareness is making REVA EVs available at big campuses and other central locations for use on a pay-per-use basis.[15]

On a single charge, the Mahindra Reva E20 has a range of 100 km. A single full charge takes about five hours. The car comes equipped with a 15 amp socket and can be charged practically anywhere. The running cost of the E20 is 10% of the ICE petrol vehicle and is the only vehicle in India which can run on solar energy.

Leasing of Electric 4W Taxis

Lithium Urban Tech, an electric taxicab company, has been operating in Bangalore since 2015.[16] The company is paving the way for a larger presence of electric vehicles in the city. Lithium Urban Tech currently provides employee transport services to companies in Bangalore and Delhi. Lithium services the corporate clientele such as Tesco Plc, Unisys Corp, Accenture Plc, Adobe Systems Inc. and VMware Inc. With a fleet size of approximately 400 4W EVs operating in Bangalore and Delhi NCR as of Feb 2017, Lithium Urban Tech is already the largest buyer of EVs in India. In Bangalore, Lithium has a fleet size of approximately 250 4W EVs.[17] It plans to commence operations in Chennai, Pune, Hyderabad and Mumbai during FY18. Lithium eventually

12 https://www.innovations.harvard.edu/sites/default/files/1108934.pdf

13 www.livemint.com/Home-Page/NPF4F0P9CY4ZFpt9zaaHiM/Mahindra-takes-control-of-Reva.html; Mahindra acquires 55.2% stake in Reva, will make a Rs45 crore infusion of fresh equity. May 26, 2010.

14 https://www.drivespark.com/four-wheelers/2017/bangalore-electric-charging-station-e-vehicles-govt-pilot-program-023166.html

15 https://www.innovations.harvard.edu/sites/default/files/1108934.pdf

16 http://www.livemint.com/Companies/JezSx7LG5lVZrXnkuM1XwN/Lithium-Urban-Tech-paves-the-way-for-EV-revolution-in-India.html

17 https://economictimes.indiatimes.com/news/company/corporate-trends/lithium-urban-with-mahindra-electric-working-to-customise-vehicles-for-corporate-transport/articleshow/57240858.cms

plans to enter the electric mobility value chain by expanding in areas such as car sharing, ride sharing, mass transit, BRTS, intra-city freight and last mile connectivity.

Lithium has built an analytics platform that enhances vehicle and charger productivity, resulting in 10-30% reduction in transportation costs for its clients. The company has managed to set up its own city-wide captive charging stations overcoming the challenge of a non-existent EV ecosystem.[18]

Lithium has been chosen by the Government of India to build 60 public DC fast charging stations across the Delhi National Capital Region.[19]

Case Study 2: Electric Rickshaws in New Delhi

Introduction of e-rickshaws

Delhi has made proliferation of e-rickshaws a priority in the battle against air pollution. More than 1,500 e-rickshaws were introduced in Delhi in 2013 and an additional 90,000 were added in the first half of 2014. In 2017, the Chief Minister of Delhi, in response to increasingly high levels of air pollution in the capital, announced a subsidy of INR 30,000 for purchase of e-rickshaws. The total subsidy of INR 15 crore is to be distributed to 6,000 E-rickshaw owners. The subsidy is given from the Air Ambience Fund by the Delhi Pollution Control Committee (DPCC).[20]

E-rickshaws queuing for customers in Delhi

Source: http://bit.ly/2gBIUY2

18 http://www.ey.com/Publication/vwLUAssets/ey-standing-up-india/$File/ey-standing-up-india.pdf

19 http://www.ey.com/Publication/vwLUAssets/ey-standing-up-india/$File/ey-standing-up-india.pdf

20 https://economictimes.indiatimes.com/news/politics-and-nation/arvind-kejriwal-releases-rs-30000-subsidy-each-for-6000-e-rickshaw-owners/articleshow/59612040.cms

Despite these important supply-side and demand-side interventions, there is no discrete, city-level policy or program for promotion of e-rickshaws. Safety considerations have also contradicted the proliferation of e-rickshaws. In 2014 Delhi introduced stricter regulations on quality inspection of vehicles. Many manufacturers failed to comply. The Delhi government then banned e-rickshaws, which resulted in political backlash and protests from the e-rickshaw union. Government then lifted the ban with the stipulation that all vehicles undergo inspection for safety and operational capabilities. However, on July 31, 2014, the Delhi High Court directed the city government to stop the use of e-rickshaws until a law is framed to regulate them.[21]

Subsequently, the ministry of Law and Justice passed the Motor Vehicles (Amendment) Ordinance, 2015. This presidential ordinance recognised 'E-rickshaw' or 'E-cart'. The ordinance has the following definition:

For the purposes of this section, "e-cart or e-rickshaw" means a special purpose battery powered vehicle of power not exceeding 4000 watts having three wheels for carrying goods or passengers, as the case may be, for hire or reward, manufactured, constructed or adapted, equipped and maintained in accordance with such specifications, as may be prescribed in this behalf" [22]

The need for charging stations

The challenge that still needs to be addressed is the severe lack of charging stations to support e-rickshaws plying on the streets. Not a single authorised charging point is available anywhere in the city. As a result, unauthorised "garages" have cropped up that allow charging of e-rickshaws for a fee. These garages, mostly using domestic connections, generally charge about Rs 100 for a single charge. Incidents of power thefts by e-rickshaw drivers and owners are not unusual.[23]

In response to the lack of charging stations, the Municipal Corporation of Delhi (MCD) has made available parking lots for installation of charging stations for e-rickshaws. The locations include the parking lots near Badli Metro station, village Singhalpur (Haryana irrigation canal), Railway Reservation Office near Kela godown, Keshavpuram and Sector 11, Rohini.

Delhi Urban Shelter Improvement Board (DUSIB) has given the land for the first official charging point at Raghubir Nagar. The request for land for setting up charging points was first initiated by the power department.

21 http://thecityfix.com/blog/e-rickshaws-transform-mobility-india-safety-regulation-sridhar-padmanabhan-pawan-mulukutla-ramya-swayamprakash/

22 http://bit.ly/2y3VYk6

23 http://timesofindia.indiatimes.com/city/delhi/e-rickshaws-to-get-legal-charging-points/articleshow/59118432.cms

Most of the parking lots remained vacant during the night. Hence the MCD has decided to appoint a contractor who will install the charging points at the selected parking lots, collect a minimal amount from e-rickshaws and allow them to charge their vehicles. The contractor will also be responsible for maintaining the law and order situation at these places during the night when the e-rickshaws will be charged.

In future, the MCD is also planning to open all the parking lots developed near the Metro stations as charging points for e-rickshaws. These would include the six parking lots which would be developed in North Delhi on Delhi Metro Rail Corporation land. This will also help MCD to deal with unauthorised parking of vehicles on the roadside.[24]

2.3 Demand-Side Analysis

AECOM carried out demand-side analysis of autorickshaw owner/drivers by interviewing 15 drivers on the street and at Visakhapatnam main railway station in a pre-survey, and then conducting a focus group with 40 autorickshaw owners and drivers convened at GVMC in September 2017. The results of the survey and the focus group are presented in Appendix A. The overarching findings are that rickshaw owner/drivers are generally willing to switch to electric vehicles under the following conditions:

- E-rickshaws loaded with six passengers and a driver must be able to climb Visakhapatnam's steep hills;
- A battery-swapping system must be in place or a network of charging stations around the city must be developed;
- The cost of purchasing and operating an e-rickshaw must be competitive with the price of diesel rickshaws.

At present, only the third condition has been satisfied. The purchase price of e-rickshaws is about the same as that of diesel autorickshaws. Moreover, the energy costs of operating e-rickshaws is much less than that of conventional vehicles (between 1/25th and 1/50th the cost, depending on the vehicle and the source). Drivers are generally aware that e-rickshaws are cheaper to operate, but they do not know how large the potential savings is.

There are e-rickshaws on the market that claim to have sufficient torque to climb Visakhapatnam's hills with a full passenger load. This remains to be demonstrated. The rickshaw drivers' union and largest distributor of e-rickshaws have independently agreed to a public demonstration on Nowroji Road before the end of 2017.

The introduction of a battery swapping system or a development of a charging station network will require additional investment. Identifying a feasible way to develop this energy infrastructure is a major focus of this study.

24 http://www.hindustantimes.com/delhi-news/charging-points-for-e-rickshaws-at-north-mcd-parking-lots/story-rrh2KUiNeiYQt3knra9CiJ.html

Loan financing is a standard way to enhance demand. In India about 30% of 2W vehicles are financed through loans, but most of these are in rural areas. In cities, the overwhelming majority of 2W purchases are financed by savings. According to the India Financial Scape Survey, which included a national sample of 34,000 households, only 1% of urban 2W purchases are financed by loans.[25] This in spite of financing offered routinely by manufacturers such as Mahindra at Hero Motors. It is reasonable to conclude that for most households, the purchase of a 2W in the range of INR 35,000-60,000 is a manageable investment that does not require financing. The urban poor, however, face the same challenge of documenting their income and demonstrating financial stability when applying for 2W vehicle loans as they do when approaching formal sector financial institutions for any type of loan.

The data on 2W financing is not aggregated by type of energy source; it is not known whether financing is used any more often by purchasers of electric 2-wheelers vs. gas-powered. Given that "early adopters" of progressive technology such as EVs tend to be middle-income households, access to financing is not considered to be a constraint. However, demand could be enhanced by simplifying the process of accessing subsidies for EV purchase. Now the buyer must apply for the loan and the FAME subsidy separately, as two distinct processes. Integrating the two with a "one stop" approach would increase the attractiveness of the subsidies, and may increase its application.

2.4 Supply-Side Analysis

Technical and Cost Profile of Existing 2-Wheel and 3-Wheel Electric Vehicles

In February 2017, the average cost of the ten most popular new gasoline-powered 2-wheelers was INR 68,748 while the cost of the ten most popular new electric 2-wheelers was INR 38,748. The ten most popular gasoline 2-wheelers provide an average range of 804km between refueling, adequate for 30 days of daily riding for the average resident in Visakhapatnam. The ten most popular electric 2-wheelers provide an average range of 78km, enough for at least 3 days of daily riding between recharges for the average Visakhapatnam resident.

There are many gasoline 2-wheeler dealerships for brands such as Hero, Honda, and Bajaj throughout Greater Visakhapatnam. They offer the same make and model of 2-wheelers at similar prices with similar incentive schemes. Based on the five most popular vehicles available in the Indian market, the average cost of a new gasoline-powered 3-wheeler was INR 142,600 and was INR 128,714 for a new electric 3-wheeler. In Visakhapatnam, autorickshaw drivers report that the diesel 3-wheelers they drive cost in the range of INR 140,000 – INR 180,000, higher than the national average. The range of electric 3-wheeled vehicles is currently capped between 90-140 km depending on battery size; however this could improve depending on battery improvements or battery size capacity within vehicles.

25 Indicus Analytics, 2012.

In Visakhapatnam AECOM was able to identify two retailers of 3W EVs: Sri Lakshmi E Automobiles, with three outlets in GMR, and Eraja, which sells 3W vehicles that it manufactures in Gajuwaka. Sri Lakhsmi E Automobile distributes the TumTum e-rickshaw by Super Eco (production: Gwalior). This 6-seater retails for INR 172,000 and has a 3,000 W motor that runs on five 12V lead acid batteries stored under the passengers' seats. The dealer has sold about 40 vehicles since opening its doors 14 months ago.

Profile of U.S. Providers of Goods and Services Related to 2W and 3W Electric Vehicles

The main contributions that U.S. companies are in a position to make to this project are the manufacturing/sale of EV batteries and the development of charging station networks. There are many U.S. companies involved in both activities, as shown in the Table in Appendix B. However, none of them is currently in the Indian domestic market, according to information available on their websites.

In terms of battery manufacturing, the biggest prize would be to attract a U.S. battery manufacturer to establish a production facility in Visakhapatnam as a beachhead into the Indian market. This would boost the employment generation impact of the project. Visakhapatnam would be a logical choice not because of large population, but because it could be a pilot project with national implications, if this project goes forward. Elon Musk, CEO of Tesla, has sent out some tantalizing tweets in 2017 about the possibility of Tesla entering the Indian market. He has also met with AP State officials on the subject. To date Tesla has not made a commitment to enter India or AP in the near future.

The Andhra Pradesh Electricity Regulatory Commission (APERC)'s involvement would be required for regulating the tariff for retail sale of electricity through charging stations.

3. DEVELOPMENT OF TECHNICAL OPTIONS

Promoting the electrification of 2W and 3W vehicles is a complex, multifaceted undertaking that is more akin to a program or initiative than an individual project. It requires not just the sale of electric vehicles in the local market, but rather the creation of a supportive ecosystem for their sale, storage, operation and maintenance. The initiative has to be feasible and satisfactory for a number of different parties: for owners and drivers of the electric vehicles; for the customers of the e-rickshaws; for the manufacturers and distributors of the vehicles; and for the developer/operators of networks of charging stations or battery-swapping shops. While the users, customers, manufacturers and distributors will in all likelihood be private entities, public entities could play a role in developing or operating the networks of charging stations. The design of the program will therefore include a number of components, each of which will have to demonstrate its technical, financial and economic viability separately. The program will be considered feasible as a whole if and only if each of its components is independently considered feasible. More importantly, the success of some of the components is a pre-condition for success of some others. This nature of the interrelationships among the components will be considered in more detail below.

Component 1: EV product development

The supply of 2-wheel and 3-wheel vehicles must meet the demand of the current owner/operators of conventional vehicles to a degree sufficient for the owners to switch. In the case of 3-wheelers, the requirements of the users are known to a sufficient degree (see Section 2.3 above). Some e-rickshaws claim to meet those requirements today. One of those e-rickshaws (the Super Eco TumTum) is available commercially in GMR today. Other such e-rickshaws (those manufactured by Gayam Motor Works, for example), are not yet locally available. In some cases, manufacturers may have to improve their offering by making vehicles higher-performance (faster, more torque, and/or more portable batteries).

The leaders of the program can contribute to EV product development, to the extent that it is necessary, by facilitating communication among user groups in Visakhapatnam and manufacturers of EVs. AECOM has begun this dialogue by sharing information about the local demand profile with EV manufacturers.

Component 2: EV demand enhancement

Publicize the advantages of electric vehicles, especially the substantially lower energy costs. It may be necessary to demonstrate publicly the ability of e-rickshaws to climb hills. Drivers in Visakhapatnam have expressed their scepticism about this. Both the drivers and the distributors have agreed in principle to participate in a demonstration on a steep hill in the city.

To further boost demand, the program can make use of FAME subsidies to reduce the purchase cost of 2-wheel and 3-wheel electric vehicles. At the moment, the price of electric 2-wheel 3-wheel vehicles is similar to that of conventional ones. When the manufacturers finish satisfying the stated speed and torque requirements of the buyers, however, the price may have to rise.

Component 3: Development of EV battery recharging infrastructure

This analysis considers two options:

- Introduction of an EV battery swapping program. This could start on a pilot basis in the Area-Based Development pilot zone. Existing service stations could be used as the swapping centres. This option will be discussed with leaders in battery-swapping systems such as Ashok Leyland and SUN Mobility.
- Develop a network of charging stations. This could start on a pilot basis in the Area-Based Development pilot zone. “Supercharging” stations could be developed on municipally owned properties or at existing service stations. The latter would allow the fossil fuel distribution companies to keep a foot in the game as the vehicle fleet of the city changes over to electric. Conventional charging stations can be established in apartment buildings and office buildings by their owners. Additional charging stations could be developed on municipally owned properties as a back-up network for emergency charging.

Component 4: Phasing out of conventional 2W and 3W vehicles

The process of prohibition and then withdrawal of electric vehicles should take place over a multi-year period (e.g., five years). An indicative process, to be tested in the market, could be:

- Prohibit the sale of conventional 2W and 3W vehicles in Visakhapatnam after one year
- Prohibit the registration of new conventional vehicles after one year
- Impose a pollution tax on the use of conventional vehicles after two years
- Offer to purchase older vehicles at 10% of current purchase price after four years
- Prohibit the use of conventional 2W and 3W vehicles after five years.

4. ESTIMATION OF PROJECT COST

Component 1: EV product development

The R&D costs for new EVs, to the extent that they are required, will be borne by the manufacturers. It is assumed that future EV sales justify these costs.

Component 2: EV demand enhancement

- The cost of the public information campaign is estimated at 30 lakhs. Half the cost is anticipate to be borne by electric vehicle manufacturers; the other half will be borne by GVMC.
- The cost of the FAME subsidies are borne by the national government.

Component 3: Development of EV battery recharging infrastructure

Two sets of costs: one for a network of charging stations, another for a network of battery swap shops.

Assumptions for charging station network:

- Phased program starting in city center. Phase 1 = 9.6 square miles. Phase 2 = 4.0 square miles.

- Initial network of charging stations is located exclusively on municipally owned properties. There is one charging station on average every square mile. 25% of the charging stations are superchargers, and 75% are conventional chargers. The average capacity of a charging station increases every two years in response to increasing demand.

Table 8 Assumptions for Development of Battery Charging Network

	Phase 1	Phase 2	Total
Total area (square miles)	9.6	4.0	13.6
Number of conventional charging stations	7	3	10
Number of super charging stations	3	1	4
Total charging stations	**10**	**4**	**14**

Period	Average capacity of one charging station
Year 1	10 vehicles
Year 2	10 vehicles
Year 3	10 vehicles
Year 4	20 vehicles
Year 5	20 vehicles
Year 6	20 vehicles

Note: Investment periods are Year 0 and Year 3.

- The land area needed for the charging stations is equal to the number of spaces at the end of Year 5 plus 25% for circulation.
- The land cost is assumed to be zero, as the land is already owned by GVMC.

The tables below set out a rough cost estimation for the development of a network of charging stations. The total cost, including operation and maintenance, over a 6-year period is estimated to be approximately US$ 950,000.

Table 9 Development Cost of Charging Stations (Individual and Cluster)

Quantity	Home charging stations	Parking facility charging station	Curb-side charging station	Supercharger*
1 charging station	$600	$2,300	$5,200	$25,900
Cluster of 10 charging stations	$6,000	$23,000	$52,000	$97,000
Cluster of 20 charging stations	$12,000	$46,000	$104,000	$176,000

*Includes cost of transformer(s), cost accuracy is +/- 50%.

Table 10 Development Cost of a Network of Charging Stations

	Conventional charging stations			Super-charging stations			
Period	Quantity	Unit Cost	Subtotal	Quantity	Unit Cost	Subtotal	**Total**
Year 0	7	$23,000	$161,000	3	$97,000	$291,000	**$452,000**
Year 3	3	$46,000	$138,000	1	$176,000	$176,000	**$314,000**
Grand total							**766,000**

Note: Year 0 stations can accommodate 10 vehicles; Year 3 stations can accommodate 20 vehicles. , cost accuracy is +/- 50%.

Table 11 O&M Costs for a Network of Charging Stations O&M Costs of a Network of Charging Stations

Period	Conventional charging stations	Super-charging stations	Total
Year 1	$8,050	$14,550	**$22,600**
Year 2	$8,050	$14,550	**$22,600**
Year 3	$8,050	$14,550	**$22,600**
Year 4	$14,950	$23,350	**$38,300**
Year 5	$14,950	$23,350	**$38,300**
Year 6	$14,950	$23,350	**$38,300**
Total			**$182,700**

The assumptions for a network of swap shops are as follows:

- No new structures are required; battery swapping is an additional service offered by an existing commercial establishment.
- Candidate establishments include service stations, supermarkets, and convenience stores.
- The costs of providing the service are borne by the private sector. The price to the customer covers the cost of service.

Component 4: Phasing out of conventional 2W and 3W vehicles

Assuming the purchase of 35,000 vehicles over a two year period at 10% of their replacement cost (e.g., INR 230,000 x 0.10 = INR 2,300), the cost of this component is approximately 8 crore (USD 1.2 million). The Department of Transport[26] is responsible for registration of vehicles and collection of vehicle taxes. Hence, for implementation of Component 4, support from this department would be required for issuance of requisite government orders and policies.

26 The Department of Transport has already issued government orders to grant exemption from payment of Motor Vehicle Tax in respect of those vehicles that are operated with battery / compressed natural gas / solar energy for a period of 5 years from the date of registration of such vehicles.

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5. PRELIMINARY FINANCIAL AND ECONOMIC ANALYSIS

Affordable transportation options expand choice and quality of life for residents, workers and visitors. The affordability of 2-wheelers, as the dominant existing personal transportation mode used in the Visakhapatnam region, is critical in the transition from gasoline to electric as the dominant energy supply in personal transport vehicles. Transportation affordability can be assessed by estimating the percentage of a household's annual income dedicated to transportation-related expenditures. This study relies upon the capital cost of purchasing new gas-powered or electric 2-wheeled or 3-wheeled vehicles. It does not include related vehicle ownership costs such as operations and maintenance. This study also categorizes households earning low to moderate incomes, roughly 48% of households sampled, whose incomes lie between INR 5000 – INR 20,000 (AECOM Representative Household Socio-Economic Survey, 2016).

Table 12 Household Income in Greater Visakhapatnam Region

Quintile	Min Monthly HH Income (INR)	Max Monthly HH Income (INR)	Avg Monthly HH Income (INR)
First	5,000.00	15,000.00	10,000
Second	10,001.00	20,000.00	15,001
Third	15,001.00	20,000.00	17,501
Fourth	20,001.00	160,000.00	90,001
Fifth	25,001.00	160,000.00	92,501

Sources: AECOM Representative Household Socio-Economic Survey, 2016

Households within the first and second quintiles for annual income in the Greater Visakhapatnam Region currently find new gasoline 2-wheelers expensive to purchase at a cost that is 40–60% of their annual income.

Table 13 Affordability of Gasoline 2-wheelers

Income Quintile	Avg Annual HH Income (INR)	Avg Gasoline 2-wheeler Purchase Price (INR)	Ave Price / Avg Annual HH Income Ratio
First	120,000	68,748	57%
Second	180,006	68,748	38%
Third	210,006	68,748	33%
Fourth	1,080,006	68,748	6%
Fifth	1,110,006	68,748	6%

Sources: AECOM Representative Household Socio-Economic Survey, 2016; Economic Times, Top 10 selling bikes & scooters in February 2017; www.bikewale.com/hero-bikes; www.indiacarnews.com/news/tork-t6x-14468

Electric 2-wheelers are less expensive for households within the first, second, and third quintiles, with the cost of a new electric 2-wheeler ranging between 22-32% of their annual incomes. On average, a new electric 2-wheeler would cost approximately INR 30,000 less to purchase than a new gasoline 2-wheeler. This affordability advantage of electric 2-wheelers could support the full transition from petroleum-based to electric-based personal transportation in the Greater Visakhapatnam region. The price comparison must be made in the context of a technical performance comparison; most gas-powered 2-wheelers are faster than their electric counter-parts.

Table 14 Affordability of Electric 2-wheelers

Income Quintile	Avg Annual HH Income* (INR)	Avg Electric 2-wheeler Purchase Price (INR)	Ave Price / Avg Annual HH Income Ratio
First	120,000	38,782	32%
Second	180,006	38,782	22%
Third	210,006	38,782	18%
Fourth	1,080,006	38,782	4%
Fifth	1,110,006	38,782	3%

Sources: AECOM Representative Household Socio-Economic Survey, 2016; Survey of average prices, September 2017

Based on AECOM's 2016 Representative Household Socio-Economic Survey, 80% of households are "somewhat willing" to "very willing" to pay more for access to better road transport options. Households along the income spectrum that are considering the purchase of a new 2-wheeled vehicle can afford to purchase electric, and financing strategies might better support the majority of lower to moderate income earners in affording the transition to electric 2-wheeler ownership.

Table 15 Willingness to Pay for Access to Better Road Transport Options

	Very willing to pay more	Somewhat willing to pay more	Not willing to pay more
Access to better road transport options	33%	47%	20%

Source: AECOM Representative Household Socio-Economic Survey, 2016

The first, second and third quintiles of household incomes would be over-leveraged in purchasing a gasoline-powered 3-wheeler as a capital investment for a household-owned and -operated business. However, multi-year savings or financing instruments that amortize investments over the longer-term (5 to 10 year) can lessen risk and make 3-wheeled vehicles more affordable for single household ownership.

Table 16 Affordability of Gasoline 3-Wheelers

Income Quintile	Avg Annual HH Income (INR)	Avg Gasoline 2-wheeler Purchase Price (INR)	Avg Price / Avg Annual HH Income Ratio
First	120,000	142,600	119%
Second	180,006	142,600	79%
Third	210,006	142,600	68%
Fourth	1,080,006	142,600	13%
Fifth	1,110,006	142,600	13%

Electric 3-wheelers are slightly more affordable, ranging from 61% to 107% ratio of average vehicle price to average annual household income in the Greater Visakhapatnam Region. While utilizing multi-year savings or longer-term amortization instruments can lessen risk and make 3-wheeled vehicles more affordable for single household ownership, subsidies can further incentivize households to purchase electric 3-wheelers as capital investments to support their livelihoods.

Table 17 Affordability of Electric 3-Wheelers

Income Quintile	Avg Annual HH Income* (INR)	Avg Electric 2-wheeler Purchase Price (INR)	Avg Price / Avg Annual HH Income Ratio
First	INR 120,000	INR 128,714	107%
Second	INR 180,006	INR 128,714	72%
Third	INR 210,006	INR 128,714	61%
Fourth	INR 1,080,006	INR 128,714	12%
Fifth	INR 1,110,006	INR 128,714	12%

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6. BUSINESS MODEL AND PROJECT FINANCING

Globally, business models based solely on direct revenues from EV charging services are currently financially infeasible. Hence, it is essential to put a financing program in place which can support the EV charging infrastructure. The program will aim to leverage public funds as well funds from other sources to create a capital stack for financing the project. Such a stack will help the project owner / sponsor in providing assurance to the private sector so as to attract them for making initial capital expenditure for deployment of EV charging infrastructure. The said stack can be built from the following sources:

- Requesting Grants from State Government through its various line departments like (i) Department of Energy, Infrastructure & Investment, (ii) Department of Transport, (iii) Department of industries, (iv) Municipal Administration & Urban Development Department, etc.
- Funding support from central government, bi-lateral / multilateral donor agencies, etc., as and when available.
- Leveraging Corporate Social Responsibility (CSR) funds available from major companies including, but not limited to, EV manufacturers, Battery manufacturers, etc.
- Monetizing advertisement potential at charging station or by selling the naming rights / commercial sponsorship for the charging station.

Components of the project that may have different business models, including:

- Purchase of new e-rickshaws
- Establishing and maintaining a network of battery-swapping outlets.
- Establishing and maintaining a network of charging stations

Banks and other financial institutions have not yet launched any financial assistance schemes for EV buyers in India, unlike petrol vehicles. Start-ups like Ather Energy see it as their biggest challenge: “94 per cent of vehicles sold in India, especially two wheelers, are financed by bank or other financial organizations. However, banks (public or private sector), and non-banking financial institutions are yet to launch loan schemes for EVs,” says Dhivik Reddy, Co-founder of Bengaluru-based Go GreenBOV.[27]

27 https://www.entrepreneur.com/article/284107

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7. INSTITUTIONAL ARRANGEMENTS FOR PROJECT IMPLEMENTATION

From the procurement perspective, the project owner / sponsor has several the project procurement options available ranging from a traditional Design-Bid-Build (DBB) to an alternative procurement delivery methods where the private sector expertise on financing and maintenance can be leveraged to support the planned improvements.

From the private sector's perspective of commercial and financial viability, a Design-Build-Finance-Operate-Maintain (DBFOM) model could be a suitable procurement structure for implementation of the proposed project, wherein the private partner will take on the responsibility for the following obligations:

- Mobilizing funds towards capital expenses to be incurred for the project,
- Taking up construction of the charging stations as per the minimum development obligations specified by the public partner (project owner / sponsor),
- Procurement of equipment and machinery as per the output specifications provided by the public partner (project owner / sponsor),
- Collections of user charges/tariffs at the pre-determined rates approved by the project owner / sponsor,
- Operating and maintaining the charging stations (for a pre-determined concession period) in conformity with the applicable standards and Key performance Indicators (KPIs) set by the public partner (project owner / sponsor).

The public partner (project owner / sponsor) will fulfil the below obligations:

- Handing over of the physical possession of encumbrance free land parcels (with necessary right of way to the private partner) for development of the charging stations across various locations within the city.
- Granting all such approvals, permissions and authorisations which the private partner may require or is obliged to seek from public partner (project owner / sponsor) in connection with implementation of the project,
- Providing necessary assistance to the private partner in securing subsidies / concessions available under the "State Electric Vehicle & Energy Storage Policy" which is to be issued by the state Government by the end of 2017.

- Determining and publishing the user charges/tariffs in consultation with Andhra Pradesh Electricity Regulatory Commission (APERC),
- Making “Availability Payments” to the private partner

The private sector is allocated the responsibilities of designing, building, financing, operating and maintaining the facility, while the project owner / sponsor will retain the demand risk by making availability payments. The capital costs to be incurred by the private partner will be fixed at the outset. In return for its services, the private partner will be reimbursed through a predetermined performance-based payment plan. As per this plan, the private partner will be entitled to receive pre-determined payments called Availability Payments (APs) for each time period (quarterly / semi-annually / annually) after making deductions/adjustment against: (i) the revenues received from user charges/tariffs, and (ii) penalties (if any) for non-compliance of the private partner to the KPIs (such penalties will be pre-determined as a part of the definitive agreements).

8. ANTICIPATED SOCIAL IMPACTS

The impact of this project is anticipated to be positive because of the clear and definitive positive environmental impacts. The emissions-free vehicles will contribute to reduced GHGs, which will improve air quality in Visakhapatnam Metropolitan Region. The better air quality will reduce the incidence and severity of respiratory disease among the local population. This will help people to live longer, *ceteris paribus*, and will reduce health care costs for Visakhapatnamites.

The project is also inclusive to the extent that the introduction of 2W EVs will improve the affordability of transportation to low-income groups. As the analysis shows, 2W vehicles are affordable to the top three quintiles of the population, but pose affordability challenges to the bottom 40% of households as ranked by income level. Electric 2-wheelers are cheaper than gas-powered 2-wheelers. So the project, to the extent that it is successful in substituting 2W EVs for gas 2-wheelers will help make personal transportation more affordable to low-income and middle-income housesholds in GMR.

The only anticipated possible negative social impact of the project is the requirement for households to purchase new electric 2-wheelers will create some financial burden on those families. The fact that the project will be implemented gradually will lessen the financial burden. A buy-back provision, in which GVMC purchases old gas-powered 2-wheelers at the end of the project period (e.g., five years from now) at 10% of the current purchase price of a new gas vehicle, would also improve affordability.

There is no requirement for a full social impact assessment of this project.

Measurement of the social impacts of this project should be focused on health. The indicators will relate to incidence of respiratory disease. Example indicators may include:

- % of local residents with emphysema per 1000 population
- % of local residents with [other respiratory disease to be determined] per 1000 population
- number of deaths per year from emphysema or other respiratory diseases
- number of deaths per year from [other respiratory disease to be determined]

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9. ANTICIPATED ENVIRONMENTAL IMPACTS

The environmental impacts of this project are anticipated to be positive. The emissions-free vehicles will contribute to reduced GHGs, which will improve air quality in Visakhapatnam Metropolitan Region. The substitution of electric 2W vehicles for gas 2-wheelers will result in a reduction of about 140 metric tons of particulate matter and 185,000 metric tons of carbon dioxide per year.

There is no requirement for a full environmental impact assessment of this project.

Measurement of the environmental impact of this project should be focused on air quality improvement. Example indicators may include:

- % reduction of PM2.5 emissions from transportation due to electrification of 2W and 3W vehicles
- % reduction of PM10 emissions from transportation due to electrification of 2W and 3W vehicles
- % reduction of CO2 emissions from transportation due to electrification of 2W and 3W vehicles
- % reduction of PM2.5 levels in VMR
- % reduction of PM10 levels in VMR
- % reduction of CO2 levels in VMR

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APPENDIX A – RESULTS OF THE DEMAND-SIDE RESEARCH

Pre-survey of rickshaw drivers (23 September 2017)

Parthasarthy and Bachmann interviewed about 15 drivers. Three individual interviews and three group interviews with 3-4 participants each. Findings:

- Fundamental rickshaw economics in Visakhapatnam: drivers earn about INR 800/day in gross revenue from rider fares on average. Diesel costs INR 200-250/day. Maintenance and repair runs about INR 25,000/year, or INR 80/work day. So they clear about INR 500/day on a cash basis, without taking into account vehicle purchase/depreciation. (If you factor in a INR 160,000 diesel rickshaw that you replace every eight years, then depreciation is INR 64/day, and profit is INR 435/day.)[1]
- About 90% of rickshaw drivers own their vehicles
- Few owners own more than one vehicle. The large majority own only one vehicle, and they drive it for a living. Participants said there are no fleets of vehicles.
- Drivers are concerned about the running time of E-rickshaws. They want 8 hours of running time, which some consider to be a maximum safe workday. One driver favored hybrid models to eliminate the risk of being stranded without power.
- Drivers' main concern is slow speed and low torque of EVs. EVs on the market today top out at about 25 km/hour, while diesel rickshaws go 45-50 km/hr. Drivers feel EVs are too slow. More importantly, drivers worry that EVs cannot climb Visakhapatnam's many hills. This is their #1 reservation about E-rickshaws.
- CNG rickshaws have been introduced in Vijaywada. They go 45-50 km/hr, but have low torque. Drivers felt they are unfit for Visakhapatnam for that reason.
- Purchase price is not an issue, as the 3W EVs on the market go for INR 115,000 to INR 172,000, while diesel cost 140,000-180,000. No-one said they didn't want to buy an EV because it costs too much.
- Popular diesel rickshaws include Piaggio and Bajaj. Bajaj Mega and Bajaj Mega Maxima are common in Visakhapatnam.
- Some drivers know that operating costs for EVs are lower, with charging costs estimated by them at INR 100/day. One said that if daily operating costs for 3W EV dropped to INR 100, then they would be willing to make the switch.
- Drivers said that E-rickshaws may have insufficient torque to get 3 passengers over hills, and that they definitely have insufficient torque to get 6 passengers over hills. So the large rickshaws are less suitable for conversion to electric at this time, according to them.
- Others said if (1) the EVs loaded with 6 passengers can climb Visakhapatnam's hills, and (2) there are charging stations in different locations around town, they would be willing to make the switch.
- Most drivers are aware that 3W EVs are being introduced, but are not particularly enthusiastic about switching.
- Mahindra has announced that they will introduce 3 models of 3W EV in Visakhapatnam. Drivers read about it in the paper. They didn't know the dates of introduction.

1 One conclusion we could draw here is that the underlying economics are fairly robust, and rickshaw owners may have disposable income that they could put towards an EV, if they wanted to.

- We happened to run into the one electric 3W on the shopping street around the corner from GVMC. The owner (tel 9618910895) had purchased it earlier in the day from E-Lakshmi. He showed us the receipt for the INR 30,000 downpayment. The total cost was INR 172,000. His whole family was dressed up and driving it around on its maiden voyage (see photo). He said he bought it because (1) it's the wave of the future in Visakhapatnam so it's a safer investment than diesel, and (2) it's better for the environment. It can go 8
  hours or 120 km on a single charge. It goes 30 km/hr. He didn't know how it performs on hills; he hadn't tried it yet.

Focus group (25 September 2017)

GVMC assembled 50+ rickshaw and taxi drivers at GMVC main complex to discuss electric 3W and 4W vehicles. 27 of the participants were rickshaw drivers, and 23 were rickshaw owners. (Most if not all the owners drove their own vehicles.) The balance participants were taxi drivers. There were 13 present at the opening of the workshop; more continued to enter during the 1 hour and 15 minute session. GVMC was represented by Mr. Anand. AECOM was represented by John Bachmann and Mr. Partasarthy.

Main findings:

- The #1 concern voiced by rickshaw owners was the inability of 3W EVs to climb Visakhapatnam's hills. Many participants echoed this concern. They want a vehicle with sufficient torque to pull 6 passengers ("6 + 1," including the driver) up Nowroji St. at RK Beach.
- The #2 concern voiced by rickshaw owners was the difficulty of recharging EV batteries. They are enthusiastic about swappable batteries. Other solutions discussed were spare batteries and a city-wide network of charging stations.
- If these concerns are addressed and the financial conditions are right, they are generally supportive of the shift to EVs.
- One technical conclusion is that, given the priority placed on torque and the support for the swappable battery, can manufacturers make a 3W EV that can climb the hills, has a battery small enough to swap out, and continues to be available at a price that is competitive with diesel autorickshaws? For follow-up with manufacturers.

Additional feedback:

- The head of the taxi drivers' union proposed that manufacturers and/or distributors organize a demonstration of 3W EV torque on Nowroji St.
- Drivers say current E-rickshaws can only pull 2 passengers up Nowroji hill.
- Owners are open to purchasing E-rickshaws, under certain conditions, but do not want to give up diesel rickshaws. They want to own both.
- In the future most owners want 6-passenger rickshaws, not 3-passenger.
- Union head mentioned that lack of service centres and spare parts for E-rickshaws is a constraint.
- Re: speed, drivers said they need E-rickshaws that can travel at speeds 40 km/hr or greater. 30 km/hr considered insufficient.
- Re: price, they are OK with current prices, but note that it's a case of apples and oranges, since technical performance (torque, speed) of diesel rickshaws is higher.
- At the same time (and in contradiction to above), owners requested a purchase subsidy to make it more financially attractive for owners to switch to electric.
- Many drivers work for 10-12 hours at a stretch. Therefore, batteries that last only 8 hours are considered insufficient. Drivers could accept 12-hour batteries as a solution, but prefer a network of charging stations.

- Drivers like the idea of E-rickshaw charging in current petrol stations. But they expressed concern about the charging time required. [JB: So super-chargers would be required.]
- Drivers expressed highest satisfaction with a swappable battery system with a network of distributors as a solution for the recharge problem. This was considered preferable to charging stations because there is less time lost waiting for the charge. But they expressed concern about distributors introducing low-quality batteries into the system.
- They want to know what the charging time for the batteries is.
- Drivers normally do not park their rickshaws in garages at night; they generally leave them on the street. This makes it harder to charge the battery at night, especially if it is not removable. Even if it is removable, they may have to carry it a substantial distance to their homes. This means it should not be too heavy.
- Owners generally use their diesel rickshaws for 10 years.
- When CNG rickshaws were introduced in Visakhapatnam, queues in gas stations were very long. They don't want a repeat of that.
- A concerns 4W vehicles, drivers said:
  - Battery charging duration is a concern
  - Driving distance on one charge should be sufficient to cover their daily distance of about 200 km
  - Hybrid is a good option
  - They are generally willing to go to EV if these concerns are addressed.

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APPENDIX B – SUPPLY SIDE INFORMATION

Visit to E-rickshaw dealership (25 September 2017)

Sri Lakshmi E Automobiles
Mr. K. Giri Krishna Sai Naidu
#43-9-131, TSN Colongy, Sri Kanya Rd, Visakhapatnam 530016
Cell 9966499166
Office 8885238899

The following information was provided by Mr. Naidu during the on-site visit.

- They sell two models, one E-rickshaw and one small 3W pick-up vehicle. Manufacturer is SuperEco. E-rickshaw model is TumTum. 3,000W motor. Made in Gwalior, UP.
- The TumTum goes 50 km/hr (to be verified - the owner we interviewed on 23 September said it goes 30 km/hr).
- The TumTum can climb a 45 degree incline. It can pull 7 people over Nowroji hill. [JB: I suggested that in December we arrange a demonstration of that for drivers. He agreed enthusiastically.]
- The recharge time of the 5 lead acid batteries (2 under one seat, 3 under another) is 5 hours.
- Each battery is 12V and 140 Ah (a measure of capacity of battery power). Total voltage = 60V.
- DC adapter is provided with the rickshaw.
- The range is 140 km on a full charge.
- The batteries are heavy and large (about 50% bigger than a regular car battery). Impractical to remove them for charging. Also difficult to swap out in a swappable battery system.
- If lithium ion battery, then one battery would be sufficient. The size would be similar to that of a car battery. The cost of the vehicle would increase by INR 50,000–60,000. [JB: Confirm with manufacturers.]
- Purchase price is INR 172,000
- It costs only INR 15 to recharge the batteries in full. This is equivalent to INR 0.1/km. Compare to INR 5/km for diesel rickshaw. Energy cost is therefore 1/50th of diesel vehicle.
- This company has three retail outlets in GMR. The other two are in rural locations (Anakapalle and one other). Sales are more robust in rural areas as farmers appreciate the low energy cost and only go short distances, so no range issue. Also, power is free in villages.
- Their only competition for retailing 3W EVs is a company called Eraja in Gajuwaka that manufactures and distributes EVs.
- Transport cost from Gwalior is INR 10,000/vehicle. No quantity discount from shipper, as the number of vehicles purchased is low. If sales increase, then transport costs could go down.
- They have sold 37 vehicles, including pick-up version, since opening 14 months ago. Sales were slow initially and are picking up. They are selling about five per week now.

E-rickshaw technical specifications and price data

Profile of U.S. Providers of Goods and Services Related to 2W and 3W Electric Vehicles

FIRM TYPE: Battery manufacturer

Firm Name	Description of Offering	Present in India? (Y/N)	Potential for participation in Visakhapatnam
Tesla	Gigafactory: Production of batteries for Tesla. The factory's planned annual battery production capacity is 35 gigawatt-hours (GWh), with one GWh being the equivalent of generating (or consuming) 1 billion watts for one hour. This is nearly as much as the entire world's current battery production combined. The Gigafactory is less than 30 percent done to date. With the Gigafactory ramping up production, Tesla's cost of battery cells will significantly decline through economies of scale, innovative manufacturing, reduction of waste, and the simple optimization of locating most manufacturing processes under one roof.	No. Musk tweet 02/2017 indicated summer 2017 entry, but in May another tweet signaled delay. http://money.cnn.com/2017/05/22/technology/tesla-india-elon-musk/index.html	Medium
Panasonic	Makes batteries for Tesla in Hawaii and Reno (Gigafactory). Tesla to prepare, provide and manage the land, buildings and utilities. Panasonic to manufacture and supply cylindrical lithium-ion cells and invest in the associated equipment, machinery, and other manufacturing tools based on their mutual approval. A network of supplier partners is planned to produce the required precursor materials. Tesla to take the cells and other components to assemble battery modules and packs. To meet the projected demand for cells, Tesla will continue to purchase battery cells produced in Panasonic's factories in Japan. Tesla and Panasonic will continue to discuss the details of implementation including sales, operations and investment. https://www.greentechmedia.com/articles/read/tesla-and-panasonic-kick-off-battery-production-at-the-gigafactory_01/04/2017	No	High
Delco	Built specifically to meet the unique demands of the Chevy Volt, the ACDelco EREV Battery performs a multitude of functions – from activating the relay which starts the Volt's engine generator, to its backup of the sophisticated electronics. This battery has 115 minutes of Reserve Capacity (RC). It also features an absorbed glass mat construction and a competitive 24 month limited warranty*. The ACDelco EREV Battery is the only purpose-designed 12-volt replacement battery for the Volt specifically for the Chevrolet Volt's system requirements.	No	Low
Motorcraft	They only make batteries for Ford and Lincoln vehicles	No	Low
U.S. Battery	For golf carts, utility vehicles, NEVs Electric Vehicle Deep Cycle (flooded lead-acid) Batteries are made in a variety of sizes for 6-volt, 8-volt, and 12-volt application for use in golf cars, utility vehicles, and NEV applications. The batteries use XC2™ Formulation, Diamond Plate Technology and a tough polypropylene exterior case	No. Distributors in China	Low

FIRM TYPE: Battery manufacturer

Firm Name	Description of Offering	Present in India? (Y/N)	Potential for participation in Visakhapatnam
Johnson Controls	Offers a portfolio of lithium-ion battery technology for a range of vehicles: advanced start-top vehicles (12 volt lithium-ion battery with 12 volt lead-acid battery), Micro-hybrid Vehicles (48 volt battery system), plug-in hybrid vehicles (PHEVs) and electric vehicles (EVs). With global manufacturing facilities, they can provide lithium-ion batteries that meet customers' power and energy needs around the world. Johnson Controls offers a portfolio of lithium-ion battery technology for a range of vehicles. Provide lithium-ion batteries that meet customers' power and energy needs around the world. Flexible technology solutions are designed to meet differing capacity, voltage and amp hour requirements. A modular architecture makes our lithium-ion batteries powerful and versatile. Using either cylindrical or prismatic cells, we design every battery to integrate into a variety of vehicles with different space and energy requirements. Latest generation high-voltage, hybrid electric vehicle (HEV) battery system delivers improved electric driving range and up to 20–40 percent greater fuel economy than conventional vehicles.	No. But JCI is also looking to make in-roads in the Indian market in the near future, one of the fastest growing major economies in the world. Manufacturing in China.	Medium – long term maybe
Valence Technology	Lithium ion battery manufacturer Valence Technology's Lithium Phosphate has been powering the first commercial electric transportation buses of their kind in the US and Europe – enabling clean, green, quiet and economic public transportation services. Valance manufactures batteries for cars, scooters, trucks, trains, and buses. Valence Technology Lithium Iron Magnesium Phosphate battery systems have been used for several electric vehicle prototypes. Their testing has verified lithium iron magnesium phosphate technology (LiFeMgPO4) as one of the most inherently safe type of lithium batteries available. Valence Technology, headquartered in Austin Texas, is a global leader among safe lithium ion battery manufacturers. Valence powers some of the world's most innovative and environmentally friendly technology, ranging from grid storage to commercial electric vehicles, from industrial heavy equipment batteries to marine drive, house power and navigation equipment. Through these relationships, Valence is building connections to large automakers, such as Renault, which is a PVI partner; Peugeot, which is an Oxygen partner; Volvo, which is a Wrightbus partner; and Ford and Isuzu, which are Smith Electric Vehicles partners.	No (manufacturing facility in China)	Low
East Penn	A private, family-owned company operating the largest single-site, lead-acid battery manufacturing facility in the world.	No	Low
AltairNano	Altairnano is a 40 year-old company that entered into the battery industry roughly ten years ago when our material scientists identified novel ways to use nanoscale technologies to process lithium titanate oxide (LTO) materials. Altairnano's technoloøv helos commercial hvbrid electric and electric vehicles Operate in "diesel off mode" from zero to 30 miles per hour Quietly "electrically idle" using battery power – not diesel Perform in fully loaded, GVW 6-8 intercity operations Perform in severe service and off-road vehicles Start and operate in -40°C without battery heaters	No	Low
Autolite	Autolite entered into the joint venture for lithium ion batteries last year with Dhampur Sugar. under a technical tie-up, battery cells are being sourced from a Chinese company while battery pack manufacturing and battery management services are undertaken locally at the manufacturing facility located in the electronics city in Gurgaon. http://auto.economictimes.indiatimes.com/news/commercial-vehicle/lcv/autolite-enters-e-rickshaw-space-to-grow-lithium-ion-battery-business/58360355	Yes	High

FIRM TYPE: Charging station developer

Firm Name	Description of Offering	Present in India? (Y/N)	Potential for participation in Visakhapatnam
Tesla	Tesla has home chargers and on-the-road chargers. The latter is what they call a super-charger, which they claim to be the fastest chargers in the world. The super chargers are capable of fully charging a Tesla car within minutes. They don't have operations in India but they are in talks with the Indian government about entering the Indian market. https://inc42.com/buzz/elon-musk-tesla-electric-car/	No	Low
Chevrolet	Doesn't seem like they have their own network but partner with other companies – Aerovironment and Chargepoint		
ChargePoint	World's largest and most open EV charging network for homes, workplaces, businesses and fleets. They design, build and support all of the technology that powers the network, from charging station hardware to energy management software to a mobile app. https://www.chargepoint.com/files/ChargePointFacts.pdf	Yes – only software engineering ops	Medium
Ford	Aerovironment is preferred installation partner and authorized charging station		
CarCharging Group	The Blink charging network acquired by CarCharging Group in 2013. Blink Network is proprietary cloud-based software that operates, maintains, and tracks all EV charging stations connected to the network and the associated charging data. Blink Network provides cloud-based services that enable the remote monitoring and management of EV charging stations, payment processing, and station location, directions, availability, and applicable fees. Have two types of chargers: **Level 2**- typically 240V, single phase AC input, most common type of charging. Can deliver somewhere between 10 - 25 miles per hour of charging. **DC Fast Charging** - typically 480V, 3-Phase AC input and is used for charging electric vehicles in commercial locations, as it requires more electrical infrastructure. Can charge 0% to 85% in ~30 minutes), not typically compatible with all electric cars.	No	Low
Aerovironment	AeroVironment is used by around 25,000 drivers and preferred by auto manufactures including Nissan, Ford, FIAT, Kia, and Mitsubishi. Products includes electric vehicle charging systems (home, workplace, commercial and public charging stations) and EV drive train and battery testing and simulation systems. Products (Business) http://www.evsolutions.com/ev-charging-products-for-business https://www.ainonline.com/aviation-news/defense/2015-08-05/indian-company-reveals-uav-partnership-aerovironment	No JV with Indian company for UAV	Low
BTC	BTCPower aims to be become a major player in the market for electric power management and charging systems for plug-in hybrid and electric vehicles. Products include level 2 and 3 chargers for homes, and EV fast chargers. The Level 3 fast charger, for use in a commercial environment, will have a full range of financial transaction processing and Point-of-Sale integration options, that can be expanded to include bill payment, sales of a range of prepaid cards, check cashing and ATM functionality, in order to make the short time (10 minutes average) that the fast charge of the vehicle takes extra well spent.	N	Low
GE	Acquired by ChargePoint http://oilprice.com/Alternative-Energy/Renewable-Energy/Largest-EV-Charging-Network-Just-Landed-A-Huge-Deal-With-GE.html		

FIRM TYPE: Charging station developer

Firm Name	Description of Offering	Present in India? (Y/N)	Potential for participation in Visakhapatnam
EVGo	Provide charging solutions and stations directly to electric car owners as well as businesses. They provide Fast Charging Station or Level 2 charging station solutions for businesses. There isn't information on the website to deduce if they manufacture these charging stations but they seem to offer solutions to businesses that might need it.	N	Low
SemaConnect	SemaConnect is an electric vehicle infrastructure company located in Bowie, Maryland founded in 2008. Provider of electric vehicle amenities to the North American commercial and residential property market, including CBRE, JLL, Hines, Greystar, Cisco Systems, and Standard Parking.	N	Low
Envision Solar	Their chargers get all of the energy from the sun. The onboard battery storage allows drivers to charge their EV during the day, at night and even when there's a black out. Cars can be charged in a matter of minutes after they arrive with an EV ARC™ and if users need DC fast charging, they can get that done faster and less disruptively than any other solution out there. http://www.envisionsolar.com/about-envision-solar/	N	Low
Energetics (VSE Corp.)	Energetics Incorporated, a wholly owned subsidiary of VSE Corporation, is a full-service technology and management consulting firm serving public- and private-sector clients. From the website it doesn't seem like they develop charging stations.		
Telefonix (Power Post EVSE)	Telefonix recognized the need for low-current commercial charging stations. When electric vehicles are parked for several hours during the day, such as at work, it makes sense to spread that energy use over a longer period of time. This lowers the cost of charging equipment and reduces the potential for spikes in energy demand. Because PowerPost products only require a 20 amp circuit, expensive upgrades to a facility's electrical supply are less likely. http://www.powerpostevse.com/products.html	N	Low
Clipper Creek	Clipper Creek is somewhat of an underdog even though they've been selling chargers fr a decade. Without the sexy design of some of their other competitors, Clipper Creek builds gray boxes that do the job, but are more geared at fleet installation than for business or residential. The company is clear to point out that their charging stations can be installed anywhere, and in fact, they do the installations of the home charging stations for the Tesla Roadster. Their stations are meant for Level II charging only, and come in a variety of Voltage and Amperage configurations to match customers' needs. https://www.clippercreek.com/#	N Teamed up with solar city, by supplying chargers to them.	
Leviton	A well-established electrical supply giant. They include an industry-first 10 year warranty on their new lineup of "Evr-green" home and commercial charging stations. The Evr-green stations support both Level I and Level II charging, and will work with Coulomb Technologies' already existing ChargePoint Network of charging stations. Leviton has also developed a standard method of installation that they are calling an "industry-first plug-in prewire system" for their Level II chargers that enables consumers to make their homes "plug-in ready" prior to purchasing any electric car. The prewire systems start at under $200 not including installation, and are meant to reduce installation times, lower installation costs and provide flexibility for any future upgrades. Preferred EVSE provider for Honda fit and Kia Soul EVs.	No	Low

FIRM TYPE: Charging station developer

Firm Name	Description of Offering	Present in India? (Y/N)	Potential for participation in Visakhapatnam
EV Connect	EV Connect, Inc. provides electric vehicle charging solutions for commercial, enterprise, hospitality, university, and government facilities in California and New York. The company operates a cloud-based platform for the management of charging stations and the drivers that use them. Its platform provides charge station-agnostic command and control; enterprise and energy systems integration via an open API; driver communications and support; and demand-response functionality across multiple charging networks. The company's clients include Yahoo!, Marriott, Western Digital, 21st Century Fox, Los Angeles Metropolitan Transportation Authority, New York Power Authority, and various other municipalities and commercial enterprises. EV Connect, Inc. was founded in 2009 and is based in Los Angeles, California.	No	Low
ABM	ABM is one of the leading installer of EV Charging Stations and has installed over 8000+ EV stations across the U.S. ABM's experienced team leads you through the entire process, from site evaluation and installation preparation to equipment sales with flexible financing options. They have partnerships with Evgo and Chargepoint. https://www.abm.com/electric-vehicle-charging-stations/	No	Low
EVSE LLC	EVSE LLC, a subsidiary of Control Module Inc., designs and manufactures smart Level 1 and Level 2 EV Chargers for the workplace, parking facilities, public locations, fleets and multi-dwelling units. EVSE LLC chargers come in single and dual pole or wall mounts, and patented ceiling mounted chargers. All chargers come in standalone mode (no network), or fully networked (including integration with smart grid / automated demand response applications. Our flexible charger platform adapts to your operations.	No	Low
EverCharge	They primary provide solutions for apartments, condominiums and fleets. They handle the complete process from site evaluation to installation and maintenance	No	Low
Evatran (Plugless Power)	They use a wire-free charging technology. Plugless uses inductive charging technology to eliminate the need to plug in your EV. Two aligned magnetic coils send power to your EV over an air gap between your vehicle and the included Wireless Charging Station.	No	Low
EvoCharge	Founded in 2009, EVoCharge is one of North America's original EV charging infrastructure providers and is an experienced multinational innovator, developer, manufacturer and supplier of Electric Vehicle Supply Equipment (EVSE) and industry-leading EVoReel cable management solutions & products. EVoCharge's Retractable Reel EV Charge Cable Management Solution products are marketed under the brand name "EVoReel®". The industry-leading EVoReel cable management solution simplifies and improves the users overall electric vehicle charging experience.	No	Low
JuiceBar LLC	Garage Juice Bar, LLC is a Connecticut-based company dedicated to producing sustainable Electric Vehicle Supply Equipment (EVSE). Juice Bar charging stations offer choice, you choose whether to charge a fee or offer free EV charges to your customer. Juice Bar's that include the optional Point-of-Sale & Communications System offers additional choices such as the ability to offer customer rewards, loyalty points and access cards.	No	Low
Lear Corp	Lear is at the forefront of powering hybrid and battery-powered vehicles. They reduce the cost, weight and mass of high power electrical distribution systems and high voltage terminals & connectors stems from their complete systems capability and production-proven technology. Lear has established a market-leading position in high voltage battery chargers and electric vehicle supply equipment. They offer battery chargers with the industry's lowest mass, highest efficiency and smallest package size, and their products are in production today with multiple OEM customers.	Yes, but in automotive space	Low

https://chargedevs.com/newswire/which-companies-are-the-top-dc-fast-charger-manufacturers/

http://www.reportsnreports.com/reports/1006601-global-electric-car-chargers-market-by-manufacturers-countries-type-and-application-forecast-to-2022.html?utm_sc

http://www.apexnews.co/electric-vehicle-charging-services-market/

Table 18 Technical Specifications and Average Prices for Most Popular 2-wheelers in India

Motorcycle Make and Model	Type	Energy Capacity (gasoline litres / ampere hours)	Maximum Range (km)	Price (INR)	Monthly payment with 3 year amortization (INR)	Monthly payment with 5 year amortization (INR)
Hero Splendor	petrol	11.00	710	51,273	1,424	855
Hero HF Deluxe	petrol	9.50	789	45,927	1,276	765
Hero Passion	petrol	12.50	1050	52,845	1,468	881
Honda CB Shine	petrol	11.00	715	63,015	1,750	1,050
Bajaj Pulsar	petrol	15.00	600	99,998	2,778	1,667
Royal Enfield Classic 350	petrol	13.50	500	137,500	3,819	2,292
Hero Glamour	petrol	13.60	748	64,673	1,796	1,078
Bajaj CT 100	petrol	10.50	935	38,784	1,077	646
Bajaj Platina	petrol	11.50	1035	46,479	1,291	775
TVS Apache	petrol	16.00	960	86,985	2,416	1,450
Go Green Kavach	electric	35.00	120	53,000	1,472	883
Hero Electric Cruz	electric	20.00	70	37,390	1,039	623
Hero electric Maxi	electric	20.00	70	29,990	833	500
Avon E Lite	electric	12.00	50	29,918	831	499
Avon E Mate	electric	20.00	65	48,082	1,336	801
Hero Electric Photon	electric	33.00	80	42,990	1,194	717
Indus Yo Xplor	electric	24.00	60	41,161	1,143	686
Hero Electric Wave	electric	33.00	100	39,390	1,094	657
Hero Electric E Sprint	electric	33.00	65	39,190	1,089	653
Indus Yo Style	electric	33.00	100	26,712	742	445
Average Petroleum 2W	**petrol**	**12.41**	**804**	**68,748**	**1,910**	**1,146**
Average Electric 2W	**electric**	**26.30**	**78**	**38,782**	**1,077**	**646**

Sources: Auto Car Pro, India Sales: Top 10 Motorcycles 2016-17; www.autocarpro.in/analysis-sales/india-sales-motorcycles-2016-24400; www.zigwheels.com; www.bankbazaar.com/top-10-e-bikes-india.html; www.bikedekho.com

Table 19 Technical Specifications and Average Prices for Most Popular 3-wheelers in India

Auto Rickshaw Make and Model	Type	Energy Capacity (gasoline litres / ampere hours)	Maximum Range (km)	Price (INR)	Monthly payment with 5 year amortization (INR)	Monthly payment with 10 year amortization (INR)
Tuk-Tuk 3-wheeler	petrol	-	-	112,500	1,875	938
TVS 3-wheeler	petrol	-	-	135,000	2,250	1,125
Mahindra Alfa Passenger Carrier	petrol	-	-	150,000	2,500	1,250
Piaggio Ape City	petrol	-	-	115,500	1,925	963
Bajaj RE Auto rickshaw	petrol	-	-	200,000	3,333	1,667
Musafir E Rickshaw	electric	110.00	-	96,000	1,600	800
Mayuri Delux	electric	100.00	90	88,000	1,467	733
Krishna Passenger E-Rickshaw	electric	-	90	97,000	1,617	808
Hero Raahii	electric	-	-	110,000	1,833	917
Mayuri 950	electric	100.00	90	95,000	1,583	792
GMW eShaft Passenger E-Rickshaw	electric	120.00	90	140,000	2,333	1,167
GMW Urban ET Passenger SmartAuto	electric	100.00	110	275,000	4,583	2,292
Average Petroleum 3W	**petrol**	**NA**	**NA**	**142,600**	**2,377**	**1,188**
Average Electric 3W	**electric**	**106.00**	**94**	**128,714**	**2,145**	**1,073**

Sources: Top 5 Auto Rickshaw Companies in India with Price: www.bikedekho.com; www.toppost.co/best-battery-operated-electric-rickshaw-e-rickshaw-in-india; www.gayammotorworks.com; www.erickshawprice.com

APPENDIX C – SHANGHAI 2W EV CASE STUDY

Green Transport and EV as a Response to Air Pollution

- Framework policies/plans
  - 2013: Air Pollution Prevention and Control Action Plan (2013- 2017) promulgated by Government
  - Shanghai Clean Air Action Plan (Nov 2013) **"The 13th** Five-year Plan For Economic And Social Development Of The People's Republic Of China (2016–2020)": embraces development of low-carbon transport
- Regulations
  - Phasing out of gas powered 2-wheel vehicles by discontinuing registration, banning sale, tightening emissions standards, inspecting vehicles, and banning their use
  - Promoting electric 2-wheel vehicles by setting technical standards and giving them the same regulatory status as bicycles: no license, helmet or insurance required; can go in bike lane. Also small subsidies for purchase of electric scooters
  - Uneven development across cities: some cities have embraced them, others have banned them
  - Opposition to E2W is growing over time because of traffic safety concerns. Shanghai banned E2W in 2016. Enforcement is uneven
- PPP for development of network of charging stations

N.B. This case study was prepared by AECOM using the cited secondary sources.

National and local promotion of electric vehicle charging networks

- China's goal : 4.8 million charging stations in operation by 2020. Overall charging needs: 5 million EVs.
- One-half of the charging stations to be located in three smog-affected regions of China—the Beijing-Tianjin-Hebei Area, the Pearl River Delta and the Yangtze River Delta.
- Beijing, Shenzhen, Hangzhou and Guangzhou have formulated their own plans for EV and charging station popularization (outside of Central Government's initiatives)

Source: Forbes, 2016

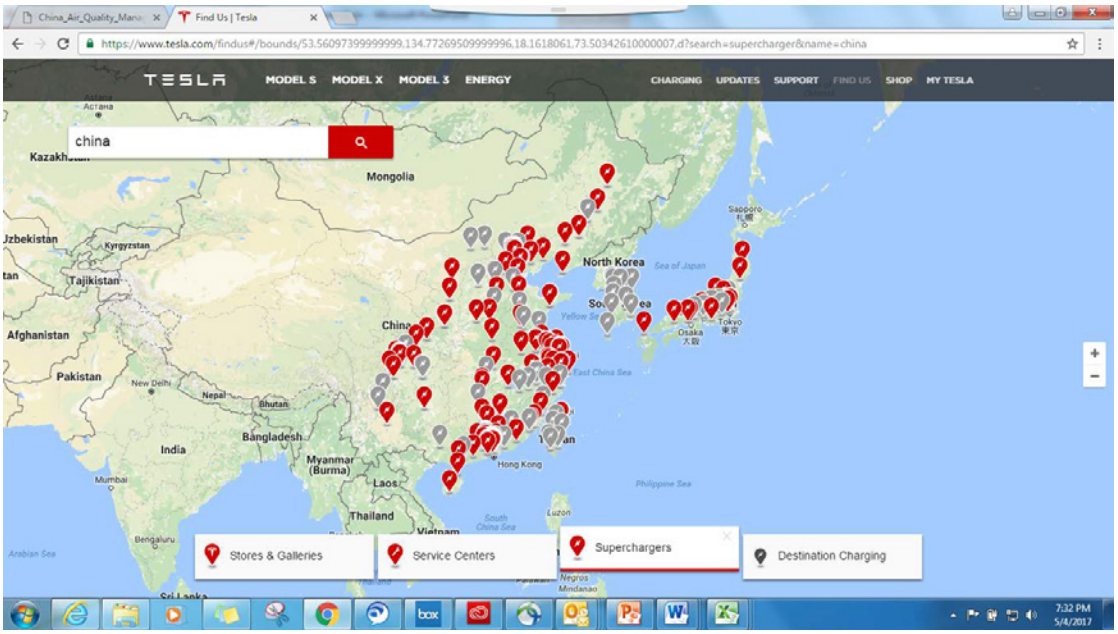
Alternative modes for delivering charging stations

- Public delivery of charging station networks:
  - **2009:** first charging station built in Shanghai:
  - **2015:** installation of 50 fast-charging stations along the 1,260km (780 mile) route between Beijing and Shanghai by State Grid, one of China's two dominant electric utilities. To be used by vehicles produced by Chinese carmakers BAIC Motor and BYD; BYD's joint venture with Daimler of Germany; and Dongfeng-Nissan, a Sino-Japanese joint venture
  - **09/2016**: 81,000 public charging stations in China, up 65% over the previous 9 months
- Vehicle manufacturer delivery of charging station networks:
  - **May 2014**: China allows private companies to invest in electric charging and replacement stations when China's State Grid announced that it would support the development of privately-owned distributed energy resources.
  - **Tesla** signed an agreement with China Unicom to equip 400 of the state telecom company's retail outlets with charging stations (see map next slide)
  - **BMW** built a pilot charging network for its i8 and i3 electric vehicles in Shanghai
  - **09/2016**: 50,000 private charging stations in China, up 12% over the previous 9 months

Source: Financial Times, 2015

Alternative modes for delivering charging stations

Tesla manufacturer' charging station networks



Public sector development of charging stations for buses

- China's power industry goal: dictate when and how plug-in gasoline-electric hybrids and all-electric cars are charged, by owning the charging equipment and setting technical standards.
- Trade strategy for China to avoid legal pitfalls: Central government to subsidize the development of a network of charging stations for electric buses and other municipal vehicles
- Subsidizing the charging stations could help make electric cars more affordable, and in turn help Chinese automakers achieve economies of scale in their home market

Source: New York Times, 2011

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