PAHLE INDIA FOUNDATION
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REFORMS REQUIRED TO SPUR INVESTMENT IN MOBILITY

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AC	Alternating Current
ADAS	Advanced Driver Assistance Systems
AFC	Alkaline Fuel Cell
AWS	Automatic Weather Stations
BASF	Badische Anilin und Soda Fabrik
BHEL	Bharat Heavy Electricals Limited
BMS	Battery Management System
BDFOT	Build Design Finance Operate and Transfer
BTL	Build Transfer Lease
BTO	Build Transfer Operate
CECRI	Central Electro-Chemical Research Institute
CGCRI	Central Glass and Ceramic Research Institute
CFCT	Centre for Fuel Cell Technology
CKD	Completely Knocked Down
CBG	Compressed Bio-Gas
CNG	Compressed Natural Gas
CAF	Construcciones y Auxiliar DeFerrocarriles
DC	Direct Current
DRDO	Defence Research and Development Organisation
DAMEPL	Delhi Airport Metro Express Private Limited
DMRC	Delhi Metro Rail Corporation Limited
DHI	Department of Heavy Industries
DMFC	Direct Methanol Fuel Cell
DEFC	Direct Ethanol Fuel Cell
EBITDA	Earnings before Interest, Tax, Depreciation, and Amortisation
EV	Electric Vehicle
FFC	Fare Fixation Committee
FAME India	Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India
FDI	Foreign Direct Investment
FYP	Five Year Plan
FY	Fiscal Year
HCNG	Hydrogen Compressed Natural Gas
HVAC	Heating, Ventilation, and Air Conditioning
IIT	Indian Institute of Technology
INR	Indian Rupee
IPR	Intellectual Property Rights
ICE	Internal Combustion Engine
ISO	International Organisation for Standardisation
ISRO	Indian Space Research Organization
JBM	Jay Bharat Maruti
JSW	Jindal South West
KYMCO	Kwang Yang Motor Company Limited

LCV	Light Commercial Vehicles
LRT	Light Rail Transit
LT/HT-PEMFC	Low/High Temperature Proton Exchange Membrane Fuel Cell
MOOPL	Metro One Operations Private Limited
MRG	Minimum Revenue Guarantee
MMOPL	Mumbai Metro One Private Limited
MCFC	Molten Carbonate Fuel Cell
MTR	Mass Transit Railway
MU	Million Units
MMRDA	Mumbai Metropolitan Region Development Authority
NAB	National Automotive Board
NMRL	Naval Materials Research Laboratory
NPA	Non-Performing Asset
OECD	Organisation for Economic Cooperation and Development
PBI	Polybenzimidazole
PMP	Phased Manufacturing Programme
PAFC	Phosphoric Acid Fuel Cell
PIMAC	Public and Private Infrastructure Investment Management Centre
PPP	Public Private Partnership
PMPML	Pune Mahanagar Parivahan Mahamandal Limited
QCB	Quality and Cost Based (Assessment)
RATP	Regie Autonome des Transports Parisiens
RoW	Right of Way
RMI	Rocky Mountain Institute
RTSC	Railway and Transport Strategy Centre
SAE	Society of Automotive Engineers
SAR	Special Administrative Region
SIAM	Society of Indian Automobile Manufacturers
SMEV	Society of Manufacturers of Electric Vehicles
SOFC	Solid Oxide Fuel Cell
SUV	Sports Utility Vehicle
TIDE	Trade, Innovation and Digital Economy
ToT	Transfer of Technology
USD	United States Dollar
VGF	Viability Gap Funding
VRLA	Valve Regulated Lead Acid (Battery)
XUV	Crossover Utility Vehicle

1. Introduction

Economic literature has identified urban centres as engines for economic growth. As the urban centre grows so does the demand for movement of people and goods. In other words, economic growth increases the demand for urban mobility. India's process of urbanisation is taking place at a time when the global community is increasingly moving towards green technology and reducing carbon emissions. We not only have to provide mobility options to our urban population but also manage the technology transition to green technologies.

Urban mobility entails mobility for the individual and for the masses. Specifically, mass urban mobility usually refers to road and rail transport. Buses and individually owned vehicles (2, 3 or 4 wheelers – 2W, 3W or 4W) make up the road transport segment. Metro and monorail make up the rail transport segment. Over the past decade, policy has focused on the construction and operation of metro rail for mass urban mobility in India. This is also intended to help India in reducing its carbon emissions. As of February 2019, 14 urban centres in the country are in various phases of metro rail construction and operation.

Metro rail projects have huge investment outlays, which when properly channelled can maximise the multiplier effect on economic activities. Urban mobility projects are typically funded by the government, domestic and foreign funding agencies, and public private partnership (PPP). A combination of the latter two options has most commonly been used in India. Several metro rail projects in the country have been co-financed by foreign funding agencies. However, it has been noted that in certain projects, foreign agencies have added the condition of using their domestic technology, which has the potential to dampen the multiplier. Given the incredibly high levels of capital investment required and the funding constraints of the government, it becomes important that other less binding options of funding are given due consideration.

In this context, it becomes critical that the PPP model, which is currently the model followed for most metro projects in India, is understood well. Understanding the PPP model will help identify any shortcomings which can then be addressed through policy, in order to ensure its success. Identifying the conditions for success of a PPP, will help policymakers tailor policy and regulations to engender such conditions. This may allow PPP to continue as a mode of funding for future metro projects in urban centres across the country. The viability of PPP contracts and their sustainability as a mode of funding urban infrastructure (specifically metro rail) will be examined in the following chapter.

Given the impetus to 'Make in India', the various ways of funding a project has implications on manufacturing in the country. This is where technology begins to play a more prominent role in urban mobility. Technology transition or the transfer of technology (ToT) is crucial both for mass urban mobility as well as the 2W, 3W and 4W segments. Given our huge labour force, technology transfers will have to be skilfully handled in order to maximise employment and other economic benefits stemming from them. Electric vehicles are already a reality in India as far as manufacturing and adoption is concerned. However, the latter has been a painstakingly slow process as price points and preference for conventional fuels prevent increase in demand. Policy makers have rightly emphasised the need to review the electric vehicles (EVs) segment as a contributor to urban mobility. This will be the second point of focus for this study and will be examined in detail in chapter 3.

Batteries which power EVs are considered green technologies, and much like metro rail, also contribute towards reducing carbon emissions and meeting green technology adoption targets. The lithium-ion battery and hydrogen fuel cells are two kinds of batteries touted as the best fit for EVs. As previously mentioned, technology forms an important backward linkage for the EV segment. However, India's domestic battery manufacturing capabilities have not yet been evaluated. This is important as we cannot have a foreign exchange draining situation, where we have to import both raw material and technology for manufacturing and/or assembly of either lithium-ion batteries or hydrogen fuel cells. Thus, it becomes important to understand the current state of the value chains as well as supply and demand of the battery and EV segments.

Apprehensions regarding travel range and servicing requirements are major obstacles to adoption of EVs. Any aversion to adopting EVs dampens existing demand, especially when customers consider price point of comparable vehicles running on conventional fuels. These apprehensions and perceptions can be changed with a focused policy push for EV adoption. Before recommending going down such a path however, Chapter 3 of this report explores which of the EV segments – 2W, 3W or 4W are worth investing in to drive up demand. Only after doing so are relevant policy recommendations made, based on EV segments identified for market and demand viability. All the chapters mentioned above have been analysed with an aim of coming up with actionable policy recommendations. The final chapter of this report will lay out the policy recommendations distilled from the findings of this study.

2. Public Private Partnership (PPP) in Metro rail

2.1 Introduction

Urbanisation has been widely accepted as an engine of economic growth. India's urbanisation, while not planned as efficiently as it could be, needs to be seen as such. Given our population density and per capita income, personalised modes of transport have already resulted in increased congestion in all our urban centres. A common need in most congested Indian cities is transportation. It is largely public transport that will provide the mass urban mobility that is sorely needed, and metro rail has been hailed as a solution for the same.

The Working Group on Urban Transport for the 12th Five Year Plan (FYP) mentions that to qualify for metro rail, a city should have,

a) a ridership of at least one million on organised public transport (any mode);
b) a population greater than two million;
c) a peak hour per direction traffic greater than 15,000 for at least 5 kilometres (kms) continuous length.

The construction and operation of the Delhi metro caught the imagination of city dwellers as well as state governments so much so that metro rail projects are now in various stages of development in almost all the important cities of the country. As of 16th February 2019, 585 kms of metro lines were operational in the country. About 600 kms of sanctioned metro lines which are under construction will be operational by 2024, while 1,000 kms of metro lines are in the planning stage.

2.2 Metro rail in India

It is well known that Metro rail is a capital-intensive project that requires substantial funding. Metro rail projects come under infrastructure development, which makes it the government's responsibility. However, given the large amounts of funding required for metro rail, often the government, private sector, and multilateral lending agencies will come together to complete the infrastructure project.

Metro rail operation and construction are underway in 16 cities (refer Table 2.1). Among the urban agglomerations, only Delhi & NCR has, and Mumbai and Bangalore plan to have metro rail networks greater than 100 kms. Given the cost of capital, it is not surprising that only a handful of cities have extensive network of metro rail. Bulk of the metro projects in the country is funded by multilateral lending agencies, which also implies that there is substantial state participation in such projects. Gurgaon Metro, on the other hand, is completely private. Public private partnership (PPP) in metro rail in India, has been followed at three places – Delhi Airport Metro Express, Mumbai Metro phase one or Mumbai Metro One, and Hyderabad Metro. It is well known that in a developing country capital is scarce. Apart from this, the common perception is that PPP in metro rail helps infuse the private sector's expertise in project management in the metro project, thereby increasing its financial viability.

Table 2.1: Metro Rail in India

Operational		Under Construction	
City	*Length (kms)*	*City*	*Length (kms)*
Delhi & NCR	327	Delhi & NCR	23
Noida- Greater Noida	29.7	Kolkata	108
Bengaluru	42.3	Bengaluru	72
Hyderabad	46	Chennai	10
Kolkata	27.3	Kochi	7.5
Chennai	45	Jaipur	2.5
Jaipur	9.6	Mumbai	171
Kochi	18.2	Hyderabad	26
Lucknow	8.5	Nagpur	38
Mumbai Line 1	11.4	Ahmedabad	36
Gurgaon	12	Lucknow	14
Mumbai mono rail	9	Pune	54
Total	586	Bhopal	28
		Indore	32
		Total	622

Source: Press Information Bureau, 16th February 2019.

We will now outline our understanding of each of the three PPP experiences in metro rail in India to distil learnings by analysing the problems and successes each project faced. The findings will also help identify areas which can be addressed through policy, to help boost investment in urban mobility infrastructure.

2.3 Delhi Airport Metro Express

This 22.7 km long metro rail was India's first PPP project between Delhi Metro Rail Corporation Limited (DMRC) and Delhi Airport Metro Express Private Limited (DAMEPL). Reliance Infrastructure Limited and Construcciones y Auxiliar DeFerrocarriles (CAF) India Private Limited were the investors in DAMEPL, with majority investment done by Reliance. Of the total project cost of INR 5,697 crores, DMRC brought in INR 2,812 crores while DAMEPL invested INR 2,885 crores. As per the contract the responsibility of civil works was with DMRC while DAMEPL was responsible for laying of system works. Originally planned to open before the Commonwealth Games of 2010, metro operations could commence only in 2011 but services had to be suspended in July 2012, less than 16 months after the commencement of commercial operation, because of defects detected in the civil structures, specifically, the problems with the bearing pads which serve as the interface between the columns/piers and girders.

These defects were then rectified by DMRC and the line was offered for re-inspection to the Commissioner of Metro Rail Safety in December 2012. With a formal clearance for commercial operation received on January 18, 2013, the line resumed operation in January 22 after 6 months of suspension. However, after the reopening, the speed of the train was reduced to 50 km/h from the previous 105 km/hr by order of the Commissioner, while the fare was raised by 50 per cent, with the minimum fare up from the former INR 20 to INR 30 and the maximum fare from INR 100 to INR 150. As per DAMEPL, this was based on a provision in the Concession Agreement that allowed increase of fares after completion of 2 years of operation.

During the period of operation suspension and civil structure defect rectification, DAMEPL was reported to have sent notice to DMRC raising the issue of terminating the Concession Agreement in October 2012, which was ascribed to its inability to run the line profitably and to its failure in raising revenue through non-fare businesses such as retail operations, property development, advertising and other commercial activities. This was because bidding for the PPP was based on a projected traffic of 42,500 per day; however, at 17,000 per day the actual traffic was less than half the projected figure. The cash flow of the private operator was affected as actual revenue collections were not even close to expected revenue. Therefore, citing a technical or safety reason, the private operator DAMEPL terminated the contract in June 2013. We believe there were three reasons for the failure of this PPP:

- First and foremost is the overestimation of traffic, which leads to incorrect revenue projections impacting cash flow and prolonging the breakeven of the project.

- Second, was improper risk sharing. Normally in PPP projects each partner handles that risk which they are best equipped to handle. In this case DAMEPL was probably better placed to handle the civil works, while DMRC should have handled those areas where it was better placed to handle the risk. Given faster project management execution skills of the private sector, if it had been given a free hand, DAMEPL could have finished the construction and commenced operations before the Commonwealth Games, which could have boosted traffic.

- Finally, the PPP contract signed lacked watertight provisions, as a result of which the private party was able to terminate the contract without incurring much penalty.

2.4 Mumbai Metro One

As per available information, Mumbai Metro One, which implies the metro rail services from Versova through Andheri to Ghatkopar was a public private partnership between the government agency, Mumbai Metropolitan Region Development Authority (MMRDA), Reliance Infrastructure, and Veolia Transport. In 2006, the estimated construction cost for the project was INR 2,356 crores with 69 per cent contribution of Reliance, 5 per cent contribution of Veolia, and the remaining 26 per cent contribution by MMRDA. However, construction cost escalated to INR 4,070 crores by the time the construction was complete. The primary reason for delay in construction was the inability of civic agencies to provide the right of way (RoW). MMRDA had provided an assurance that they would complete the RoW acquisition process within 6 months from when the concession agreement was under negotiation. However, the process turned out to be far more time-consuming as it took 83 months[1] to complete. There is an ongoing arbitration between Mumbai Metro One Private Limited (MMOPL) and MMRDA on the alleged non-compliance of commitments made by MMRDA. Private firms in this project had to raise money at market rates which was close to 13 per cent, which has since been re-financed at 11.75 per cent. Metro One Operations Private Limited (MOOPL), a venture between Reliance Infra (30 per cent) and RATP Dev Transdev Asia (70 per cent), operates Mumbai Metro One. Projected ridership per day in 2016 was one million, while actual ridership per day in 2017 was 0.38 million.

Mumbai Metro One began operations in June 2014 with an introductory fare of INR 10 for a one-way journey. It was subsequently increased, depending on the distance, up to INR 40. In July 2015, the fare fixation committee (FFC), had suggested a new fare range of from INR 10-110, in place of the existing INR 10-40. Citing heavy losses, MMOPL announced that starting December 1, 2015, the fares would be increased by ₹5. However, MMRDA, which had commissioned Mumbai Metro One, moved court against the FFC report as well as MMOPL’s proposed fare hike. In December 2017, the Bombay High Court quashed a recommendation of the first FFC along with the MMOPL's proposal. The Bombay High Court also asked to form a new FFC to decide on the fare structure. It was only earlier this year that a new three-member FFC was formed with representatives from the state and Central governments to look into the revision of fare[2]. Latest reports[3] say that lenders have classified their exposure to Mumbai Metro as a non-performing asset (NPA) and they are assessing a restructuring proposal. Box 1 presents our analysis of finances of Mumbai Metro.

[1] Report of the First Fare Fixation Committee for MMOPL, 8th July 2015

[2] Source: https://www.dnaindia.com/mumbai/report-fight-over-fare-mmrda-and-mmopl-at-it-2750256 Accessed on 25th June 2019.

[3] https://www.financialexpress.com/industry/banking-finance/mumbai-metro-one-syndicate-bank-seeks-advice-on-rs-1928-crore-loan/1611750/ Accessed on 25th June 2019.

Box 2.1: Analysis of Finances of Mumbai Metro

The initial estimate for the construction of the Mumbai metro was pegged at INR 2,35 crores. Promoters brought INR 1,194 crores through debt, INR 512 crores were obtaine through equity, and the remaining INR 650 crores were provided through viability ga funding (VGF). However, due to various delays, the promoters claim that the tota project cost escalated to INR 4,070 crores; of which INR 1,283 crores were brough through equity, INR 2,137 cores were obtained through debt, with VGF of INR 65 crores. The table below shows a very simple analysis of the cash flow for the promoter

Description	**Initial estimate (INR crore)**	**Incurred project cost (INR crore)**
Project cost	2356	4070
Debt from lenders	1194	2137
Yearly interest payment (assumption of 12 per cent interest rate)	143.3	256.4
Revenue from operations FY18	314	314
Operating expenses FY18	197	197
Revenue left for servicing debt in FY18	117	117
Probable share of interest paid for FY 18	82%	46%
Share of interest unpaid for FY 18	18%	54%
Principal repaid for FY 18	0%	0%

Source – (i) Report of Fare Fixation Committee, 2015, page 15 for project cost and debt. (ii) https://www.dnaindia.com/mumbai/report-mumbai-metro-1-revenue-crosses-rs-1000-crore-revenue-in-nearly-5-years-2718894 for Operating revenue and expenses of FY18.

Operational profit for FY 18 is INR 117 crores. However, in both the cases, the interes payment for debt servicing, assuming an interest rate of 12 per cent, is INR 143.3 an INR 256.4 crores respectively. Thus, even if the entire operational profit is used fo servicing interest payments, it can service only 82 per cent and 54 per cent of th outstanding interest payments, in each case respectively. This leaves very little financia room for the promoters to repay the principal debt. It is thus not surprising that som lenders have already marked their exposure to the project as NPA.

In Metro One though risks were shared appropriately, incapacity of civic agencies to give RoW led to delays which ultimately increased project cost. The cost of capital was also quite high and actual ridership quite low compared to projections, which led to cash flow issues for the operator. However, even after following due process, the operator could not increase fares which led to litigation. The three problems that clearly hinder Metro One are high capital cost, unrealistic traffic projections, and inability to raise fares.

2.5 Hyderabad Metro

The Hyderabad Metro is a true PPP, in the sense that all phases of this metro are in PPP mode. This is unlike the two cases discussed above where only one individual phase of the metro project, was in PPP mode. The total project cost of this metro is estimated to be around INR 18,975 crores, of which more than 90 per cent of the project cost has been brought in by the private firm, while the remaining 10 per cent will be from the Central Government through VGF. A snap shot of the finances of Hyderabad metro is presented in Table 2.2. The cost of capital for the Hyderabad Metro is around 12 per cent, which is a major constraint on profitability of the metro, so much so that for the year 2017-18 when the actual operations of the metro began, interest cost is 4,537 per cent of operational revenue.

Table 2.2: Selected financials of Hyderabad Metro in INR crore

Heads	2014-15	2015-16	2016-17	2017-18
Revenue from operations	5.5	14.3	10.1	62.6
Operating expenses	19.3	21.4	2.0	41.1
Interest expenses	618.8	1,224.1	1,975.6	2,842.5
Interest expense (%) of revenue operations	11,297	8,581	19,647	4,537

Source: L&T Metro Rail Limited

It is well known that the moratorium provided by international financial institutions[4] is not available for private players, and they have to pay interest at market rates right from the time they start using the funds. However, to incentivise the operator and compensate for the high capital cost of the project, the private operator has been given access to the commercial development of land available at the depots (around 212 acres) and 10 per cent of the carpet area of the station sites identified in the concession agreement. The land was to be handed over to the concessionaire on or prior to the appointed date (i.e. date on which financial closure is achieved). This, it is believed, would have eased some of the financial stress on the private operator. Table 2.3 shows the break-up of operations revenue for the Hyderabad Metro for select years.

Table 2.3: Break-up of Operations revenue for Hyderabad Metro in INR crore

Particulars	2016-17*	% of total*	2017-18*	% of total*
Fare revenue	-	-	28.6	45.7
Lease rentals	0.4	4.0	15.5	24.7
Advertising revenue	9.4	93.1	16.3	26.0
Consultancy and training	0.3	3.0	0.7	1.1
Other revenue	-	-	1.6	2.5
Total income	10.1		62.6	

** Rounded off, may not add to 100 or add up. Source: L&T Metro Rail Limited*

[4] International Financial institutions such as World Bank, Asian Development Bank, Japan International Cooperation Agency etc. do not provide loans to private firms.

It is very useful to note that the difference in the composition of revenue for 2016-17 and 2017-18. Both lease rentals and advertising revenue shot through the roof after metro services began. It is estimated that around 56 kms of the planned 72 kms network is operational with actual ridership of 0.255 million per day in April 2019. There is thus a ray of hope that as the network size grows, and services gain popularity, revenue from operations may increase substantially so as to reduce the quantum of loss.

2.6 Comparison of Fare and Ridership

After the success of the Delhi Metro, the idea of developing metro rail in several cities became appealing. However, while constructing and operating metro rail are important aspects, fare fixation based on ridership is also a crucial factor in the success of a metro rail project. Therefore, comparing the fare structure of other metro projects with that of Delhi Metro will help shed some light on what commonalities and differences exist in fare fixation (refer Table 2.4). The Delhi Airport metro fare is the highest. Since this metro line is an express, and provides other facilities such as Check-in counters for flights, the higher fare is justified. The fare bands for Mumbai Metro One and Hyderabad Metro exhibit the trait of differential pricing. The Delhi Metro fare bands clearly show that public ownership helps keep fares affordable.

It needs to be highlighted here that across metro rail projects, the upper and lower limits of fare seem to be the same. That is, fares start from INR 10 for the first 2 kms, and only go up to a maximum of INR 60, irrespective of the maximum distance travelled. It can therefore be concluded that fares are kept within this range on account of regulations, welfare requirements or by tacit agreement. It must also be noted here that fares for metro rail, given that it is a public good, are maintained within a widely affordable range owing to socio-political considerations. Therefore, once fixed, fares cannot be changed at will without inciting political and social backlash.

Table 2.4: Metro rail fare across selected metro networks

Mumbai Metro One		**Delhi Airport**		**Hyderabad**		**Delhi Metro**	
Distance (km)	*Fare (INR)*	*Distance (km)*	*Fare (INR)*	*Distance (km)*	*Fare (INR*	*Distance (km)*	*Fare (INR*
Upto 2	10	Upto 2	20	Upto 2	10	Upto 2	10
2 – 5	20	2 – 5	30	2 - 4	15	2 - 5	20
5 – 9	30	5 - 10	40	4 - 6	25	5 - 12	30
More than 9	40	10 - 18	50	6 - 8	30	12 - 21	40
		More than 18	60	8 - 10	35	21 - 32	50
				10 - 14	40	More than 32	60
				14 - 18	45		
				18 - 22	50		
				22 - 26	55		
				More than 26	60		

Compiled by authors from various sources that includes newspaper articles; and website of respective metro network, accessed on 14th June 2019.

Table 2.5 shows the ridership of each of the above metro networks. With a network of almost 320 kms, it is no surprise that the annual average ridership of Delhi Metro is the highest. However, with a ridership of almost 40,000 per km, Mumbai Metro One despite its short network tops the list. This indicates that metro rail through congested business areas has the potential for higher ridership numbers.

With respect to project cost per km, it can be seen that Delhi Metro seems to be the most economical followed by Delhi Airport metro, Hyderabad Metro, and Mumbai Metro One. If Mumbai Metro One had been completed within the estimated project cost of INR 2,356 crores, then it would have had the lowest project cost per km. We believe that lack of economies of scale and delay in executing the project may be among the reasons for such a high project cost per km for Mumbai Metro One.

Table 2.5: Ridership across selected metro networks

	Average ridershi per day/ (Time period)	**Total distance in operation (in km)**	**Total number of stations**	**Total Cost (in INR crores)**	**Ridership per km**	**Cost per km (in INR crores)**
Mumbai Metro One	4,50,000/ (Nov 17 Oct 18)	11.4	12	4,321	39473.68	379.04
Delhi Airport	54,731*/ (Nov 17)	22.7	6	5700	2411.06	251.10
Hyderabad	2,55,000/ (FY 19)	56	50	16,385	4553.57	292.59
Delhi Metro	22,85,000/ (FY 19	321	244	70,433	7118.38	219.42

** Peak ridership as on Nov 17. Compiled by authors from various sources that includes newspaper articles; and website of respective metro network, accessed on 24th June 2019.*

The discussion on fare and ridership clarifies that any changes to metro fares post-fixation take on a political hue. As a result, fares alone cannot make up the cost of construction of metro rail. In order to breakeven, private entities involved in metro rail construction and operation, must be allowed to seek non-fare revenue from the projects they have invested in. Such an allowance can be included in the PPP contract. However, before delving further into this, the next section will explain the nuances of the PPP contract.

2.7 Providing Perspective on the PPP Contract

For most infrastructure projects, specifically metro rail construction and operationalisation, the contract usually takes on the form of a concession agreement. This agreement defines the rights and responsibilities of the parties to the contract, which in the case of metro rail PPPs are the government and private sector entities involved. The very nature of the agreement gives it a government bias, wherein the government is afforded absolute discretion on all administrative matters related to the project. While this is often perceived as private industry's wilfulness towards not being able to turn a profit, it is no secret that the government views the private sector's approach and intentions with distrust.

Given such a trust deficit, it is no wonder that private industry find themselves at a disadvantage, especially when it comes to negotiating even ambiguous clauses and stray sentences in the agreement or contract. This is further compounded by the fact that the government insists on using standardised, legacy contract templates. The language and terms of which are usually outmoded. On the other hand, industry interactions have also shown that exit clauses have been eased over the years, which also explains how the private player in the Delhi Airport Express Line metro was able to exit the contract without bringing significant financial problems on itself.

Lock-in conditions do differ for private industry and from project to project. Indian contracts usually go by a debt plus equity formula for calculating contract termination compensation. This has a significant impact on the financial liabilities of those party to the contract. Therefore, foreign investors are wary of such calculation of termination compensation. In addition to these financial considerations is the issue of erroneous demand estimation, which upsell the viability of a project and eventually impact the contract term as well as operation and monitoring (O&M) costs.

The draft contract on which the government invites bids cannot be altered once the bid has been submitted, even during negotiation. The L1 or lowest bid condition by which the government awards contracts is by far the most hurtful to both the quality and financial viability of the infrastructure being built. The aversion to doing a Quality and Cost Based (QCB) assessment needs to be addressed. Industries often bid as low as they can, but accepting lowest bids seriously compromises the technological and material quality of the project's construction. This was evident in the issues brought up in the construction of the Delhi Airport Express Line.

Based on the contract document alone, it is often seen that the government's credit risk is borne by the private investor. Cost overruns, project operation viability, and VGF all make lenders wary of PPP contracts. These risks, which some investors may still be willing to accept, make foreign investors unwilling to buy into Indian debt – which is both expensive and often incomprehensible to foreign lenders. This indicates the need to review the contract template that the government uses, and make it more bankable overall.

Given that land acquisition and government approvals and certification often cause the longest delays for projects, the government needs to take on the risk and responsibility for both these activities, which fall entirely within its own ambit. No private player should have to bear the financial fallout of such procedural delays making the entire project a burden. Since force majeure clauses cannot be invoked to terminate a PPP contract, the only exception provided is financial default which is usually incurred by the private player. This was clearly the case with Mumbai Metro One, where lenders categorised their exposure to the project as an NPA.

It is apparent that inaccurate demand estimation and procedural delays caused by land acquisition or government approvals have led to eventual shortfalls in revenue for some of India's major metro rail projects. In the event of no change in government contract terms' language and credit risk sharing agreements, it would seem that no infrastructure project, let alone metro rail projects would ever prove to be profitable. This contention will be explored further in the next section, which examines case studies of foreign metro rail projects that capitalised on non-fare revenue to remain operational and profitable.

2.8 Case Studies of Successful Metro Projects for Comparison

Among the many urban and metro rail projects operated in major cities across the globe, the more recent and successful examples are those of Hong Kong and South Korea.

2.8.1 Lessons from Hong Kong Metro

The basic model of the Hong Kong metro is the rail and property model, where development, sale, and renting out of property forms the main revenue component. The MTR Corporation which operates the Hong Kong metro is divided in to four subsidiaries – Hong Kong Transport Operations, Hong Kong Station Commercial Business, Hong Kong Property and other Businesses, and Mainland of China and International Business. A World Bank & Imperial College[5] (2017) case study reports MTR Corporation is listed on the Hong Kong SAR and the China Exchange, with the Government owning around 76 per cent of shares and other shareholders owning the remaining. MTR Corporation is given development rights by Government as a form of support for new developments. It pays a land premium for these rights at a price level corresponding to the pre-railway status of land. It thus keeps the development gain resulting from the railway that it builds.

MTR Corporation often forms joint ventures with developers, and then sells the apartments in the development and rents out the retail space in the development. This subsidises both upfront capital and operational expenditure respectively. For the year 2015, railway operations accounted for 38 per cent of MTR Corporation's EBITDA, station commercial accounted for 26 per cent, property rental management for 19 per cent, and property development for 15 per cent. The fare-profit return on railway assets was less than 2 per cent, which as per the study, leads MTR Corporation to believe that the property aspects of their model are needed to justify the railway business. The success of MTR Corporation has flooded it with overseas work in cities such as London, Stockholm, Melbourne, and Sydney etc.

The approach that the MTR Corporation has taken is more nuanced than the generalised 'development of land parcels' picture that is often painted. The split in MTR Corporation's revenue went from 63 per cent fare revenue and 37 per cent non-fare revenue in 2016, to 36.2 per cent fare revenue and 63.8 per cent non-fare revenue in 2018.[6]

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[5] World Bank & Imperial College (2017). The Operator's Story: Case study of Hong Kong SAR, China's Story. World Bank and the RTSC at Imperial College London.
[6] MTR Corporation Annual Reports 2016 and 2018.

This reinforces the marginal fare-profit return highlighted earlier. The profitability of most of MTR Corporation's operations comes from its non-fare revenue earning activities.

The other more vital aspect in terms of planning and construction of metro rail by MTR Corporation has been that it has adapted each station, to the local demand and demographic. This has allowed it not only to capitalise on non-fare revenue aspects such as stations retail, commerce and advertising but also interconnectivity with other modes of transport such as air (Airport Express line) and buses (Mid-town station and Business District station). As a result, they have factored in both traffic and volume of sales in terms of both fares and commercial activity. This kind of adaptive planning and construction, without sticking to a 'one size fits all' model, is also supported by legislation which aids sanctioning process and allows for non-fare collections. Policy should take a leaf out of the Hong Kong Metro while planning and sanctioning future metro projects.

2.8.2 Lessons from South Korea's Metro Rail Projects

Post the Korean War (1950 - 1953), the development of transport infrastructure in South Korea picked up pace only in the 1970s. With the growth of the automobile industry in Korea and cars becoming a favoured mode of transport, rail networks in the country were reduced to carrying a mere 11 per cent freight and 15 per cent passenger traffic by the early 2000s.[7] It is around the same time that high-speed metro rail became a more favoured form of public transport in urban areas in South Korea. While the Seoul Subway Line 1 opened as early as 1974, the proliferation of metro rail only came about after high-speed rail technology was introduced in the late 1990s.[8]

The expansion of the urban rail network in major cities of South Korea was slow from 2002 to 2011 when just under a 100 kms of metro rail was built within a decade. This was largely on account of the fact that public financing could only take transport infrastructure so far. Beginning from 1994, the PPP model was adopted in order to further develop South Korea's transport infrastructure. The country's urban rail, which is largely metro rail, has since been constructed and operated by various different authorities. Most major cities have a mix of public and private operators for metro rail. Smaller cities took up development of light rail transit (LRT) in the late 1990s under PPP mode.[9] In terms of total investment, approximately USD 31.3 billion on 15 PPP projects was invested in development of metro rail transport infrastructure from 1994 to 2013.

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[7] 'Introduction to Transport in South Korea', Chapter 3 – The Public Private Partnership in Transport in South Korea, *A Study on the Optimal PPP Model for Transport: The Case of Road and Rail in South Korea*, Byungwoo Gil (University of Southampton) April, 2013: pg. 37.

[8] *Ibid*.

[9] 'Introduction to Transport in South Korea', Chapter 3 – The Public Private Partnership in Transport in South Korea, *A Study on the Optimal PPP Model for Transport: The Case of Road and Rail in South Korea*, Byungwoo Gil (University of Southampton) April, 2013: pg. 38.

The metro rail network across cities in South Korea involves a complex system of ownership and operation. For example, the Seoul Metropolitan Subway system's lines 1-4 are operated by the Seoul Metro Company (public enterprise of the Seoul City Council) jointly with Korail (Korea Rail Company, state-owned national rail company). Lines 5-8 are operated by the Seoul Metro Company on its own, whereas line 9 is operated by foreign entities Trans-Dev and RATP.[10] A corporate entity, Doosan owns and operates the driverless Sinbundang line through its subsidiary Neotrans. The Airport Express line was built and owned by a consortium of 11 companies, but is now largely owned and operated by Korail. Most of the smaller city councils have gradually taken over ownership of their respective LRTs and metro rails, as the private entities operating them went bankrupt.

The gradual transfer of ownership and operating costs to public entities is indicative of the fact that while PPP definitely allows for expansion of infrastructure, the high cost of capital and miniscule revenue returns spell almost certain doom for the private sector investor over time. The Korean government allocates almost USD 35 billion for transport each year. The Seoul Metropolitan Subway's annual loss of USD 269 million is covered under this budget.[11] Very few, if any, of the metro rail lines in South Korea run an operating profit. In the BTO model of PPP used for most transport infrastructure, the major issues faced by both public and private investors involved are based on inaccurate traffic estimation and the minimum revenue guarantee (MRG) that the Korean government provides to share traffic demand risk.

In order to ensure that investment in PPP transport projects, especially metro rail would be suitably vetted, the Korean government set up the Public and Private Infrastructure Investment Management Centre (PIMAC). This has helped increase rejection rates on both solicited and unsolicited proposals, as well as improved feasibility studies of submitted project proposals.[12] This is a useful takeaway from the South Korean metro rail infrastructure development experience. More importantly, it brings home the point that much like South Korea, India must re-evaluate whether there is truly a need to have metro rail in several Tier I and II cities. It might be more feasible in the long run to develop road infrastructure and bus networks for Tier II cities, and run metro rail projects only in cities that have high road traffic congestion.

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[10] 'Everything you wanted to know about the Seoul Metro system but were too afraid to ask', Michael Hill, Centre for Cities, 23rd February 2018. https://www.citymetric.com/transport/everything-you-ever-wanted-know-about-seoul-metro-system-were-too-afraid-ask-3702

[11] *Ibid*.

[12] 'Overview and Role of PIMAC', *PPP Procurement*, Korea Development Institute, 2018: pg. 7. https://www.kdi.re.kr/kdi_eng/kdicenter/ppp_overview_role_of_pimac.pdf

2.9 Way Forward for PPP in Metro projects

The discussion above makes it amply clear that two factors hamper PPP projects in metro rail – high cost of capital and inaccurate estimation of demand. If policy can find ways to address these as well as other crucial factors, then PPP in metro projects can indeed be the way forward.

2.9.1 High Cost of Capital

Cost of capital in a labour surplus country like India is high. Funding for private players come from sources that seek a good return for their capital. We have already seen the existing PPPs in metro rail face a high cost of capital with absolutely no moratorium on payment of interest. Thus, to increase the chances of success of PPPs in metro rail, policy should seek to reduce cost of capital. This is an issue that requires in depth thought and analysis; however, there are two obvious options which we mention in passing. The first option is to give a sovereign guarantee which by reducing the risk to the creditor will reduce the cost of capital.

2.9.2 Inaccurate Estimation of Traffic

A recurring issue in most metro projects has been the inaccurate estimation of passenger traffic. Bidders, including the winning bid, based their offers and cash flow projections on estimated traffic. However, the actual passenger traffic in the Delhi Airport as well as the Mumbai Metro One was found to be way lesser than the projected traffic. This highlights the need for a more realistic appraisal of metro rail as a public good, and the probability of use of this infrastructure by the average citizen. It is apparent that there may not be a way of accurately predicting passenger traffic, or ridership for metro rail. From this baseline assumption, investors (both public and private) must agree that losses may be incurred, not only in the initial years, but also for quite some years after commencement of operation.

It might therefore be best for a lower threshold of losses to be set, which can be borne by both the public and private partners, as part of the concession agreement. Eventually, in terms of operation, these losses are going to fall to the public sector partner. It must be noted that in order for operational losses to be borne, mounting losses need to be nipped in the bud.

Table 2.1 informs us that most of the densely populated cities of the country have upcoming metro rail projects or those in various stages of development and operation. There are studies which show that even in these cities the actual ridership has been way below the projected ridership. Future metro projects in cities that are less populated than these cities will also face the same problem. Thus, there are some lessons to be learnt from the low ridership experienced across all the metro rail networks in the country. One point that economic literature hints at is the relationship between ridership and per capita income. It is plausible that there is a threshold per capita income above which popularity of metro rails may increase. An economic study that determines the threshold per capita income will be helpful for the viability of future metro projects in the country.

2.9.3 Improving Evaluation and Feasibility of PPP Metro Rail Project Proposals

Pratap & Chakrabarti (2017)[13] note that South Korea established a Public and Private Infrastructure Investment Management Center (PIMAC) to eliminate the routine under-estimation of cost, over-estimation of benefit (optimism bias), and frequent fraud that had plagued the country's infrastructure planning. It rejected 46 per cent of projects that it reviewed compared with the 3 per cent rejection rate before its establishment, saving 35 per cent of spending.

The Committee on Revisiting & Revitalising the PPP model of Infrastructure Development chaired by Dr. V. Kelkar that submitted its report to the Ministry of Finance in December 2015, strongly emphasised the need for such an institution for India in the following words[14]: "In addition to changing mind-sets, there is an urgent need to rebuild India's PPP capacities. Structured capacity building programmes for different stakeholders including implementing agencies and customised programmes for banks and financial institutions and private sector need to be evolved. The need for a national level institution to support institutional capacity building activities must be explored. Every stakeholder without exception has strongly emphasised the urgent need for a dedicated institute for PPPs as was announced in the previous Budget. The Committee strongly endorses the "3PI" which can, in addition to functioning as a centre of excellence in PPPs, enable research, review, roll out activities to build capacity, and support more nuanced and sophisticated models of contracting and dispute redressal mechanisms (Chapter 6, paragraph 6.1.4). A dynamic 3PI can support a dynamic process of infrastructure design, build, and operate in India and thereby help deliver on the promise of reliable infrastructure services for all citizens."

Setting up a PPP institute – with equal participation from the public and private sectors - can be tasked with functions such as traffic estimation for infrastructure projects to be carried out under PPP. The Union Budget 2014-15[15] has already set the basis for such an institute when it was announced that, "India has emerged as the largest PPP market in the world with over 900 projects in various stages of development. PPPs have delivered some of the iconic infrastructure like airports, ports and highways which are seen as models for development globally. But we have also seen the weaknesses of the PPP framework, the rigidities in contractual arrangements, the need to develop more nuanced and sophisticated models of contracting and develop quick dispute redressal

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[13] K.V. Pratap & Chakrabarti, R. (2017). Public-Private Partnerships in Infrastructure: Managing the Challenges. Springer Nature. Singapore Pte Ltd.
[14] Source: Report of the Committee on Revisiting & Revitalising the PPP Model of Infrastructure Development Chaired by Dr. V.Kelkar Released, Press Information Bureau, 28 Dec 2015. Available at http://pib.nic.in/newsite/PrintRelease.aspx?relid=133954 Accessed on 25th June 2019.
[15] Source: Union Budget 2014: Finance Minister Arun Jaitley's full speech, Livemint, 10 July 2014, Available at https://www.livemint.com/Politics/n2CKOUxRPwNprqgu2StUlL/Union-Budget-2014-Finance-minister-Arun-Jaitley-full-speech.html Accessed on 25th June 2019.

mechanism. An institution to provide support to mainstreaming PPPs called 3P India will be set up with a corpus of INR 500 crores."

2.9.4 Forms of private participation

As per the Metro policy of 2017, PPP is not only Build Design Finance Operate and Transfer (BDFOT) by the private sector but also various other possible combinations. One of the forms that needs consideration is one where project capital can be obtained at lower cost through sovereign guarantee or intervention. This form will minimize the cost of capital as well as bring in private sector project execution efficiencies, which will optimize the overall project cost thus helping the metro project come in to the black at the earliest.

Per the other combinations possible under a PPP contract, there are the Build-Transfer-Operate (BTO) model and the Build-Transfer-Lease (BTL) model. Under the former, the private sector partner builds the infrastructure facility and transfers ownership of the same to the government, once construction is complete. However, the government can within the agreement allow the private sector partner to operate the infrastructure facility in order to recover some of the investment, by charging tariffs/fares from the end-users.[16] The BTO model is often found in operation across the globe for roads, railways and ports.

Under the BTL model, the government leases the infrastructure facility to the private sector partner for a period of 10 – 30 years, along with the operational rights. While very similar to the BTO model, the BTL model is meant for those projects where end users cannot be charged a high use fee. This is most apt in the metro rail context, where fare fixation is a recurring issue, and the BTL model might help address this in part while still allowing the private sector partner to make up for investment through the lease.

2.9.5 Reduced project cost

For Mumbai Metro One there were conditions precedent to the bidding, one of them was a pre-fixed fare structure. Recently when Delhi Metro increased its fares, there was an uproar. Though the Metro Act allows for fare hike through the appointment of an FFC, increasing fares becomes a political issue, which the ruling dispensation would prefer to avoid. This limits the capability of the private player to increase fares, which, as of now seems a difficult problem to solve. However, what policy can address is the converse of this problem i.e. reducing project cost. Following are two ways in which project cost can be reduced:

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[16] 'Introduction to Transport in South Korea', Chapter 3 – The Public Private Partnership in Transport in South Korea, *A Study on the Optimal PPP Model for Transport: The Case of Road and Rail in South Korea*, Byungwoo Gil (University of Southampton) April, 2013: pg. 45.

2.9.5.1 Indigenisation

Iyer and Kumar (2019)[17] find that foreign investments in the metro rail segment have created jobs, skilled our labour force, increased production, used their facilities for exports as well as to service their global orders. This has helped India to be a part of their global value chains in a couple of systems in the metro rail segment. Technical collaboration has helped a local firm learn the technology of production of rolling stock, which has made it competitive and has given a spurt to domestic manufacturing. Foreign firms supplying equipment to rolling stock manufacturing units have also set up plants in the country. There is evidence of a rolling stock manufacturing ecosystem developing in the country. The cost competitiveness achieved has not only helped exports but also reduced project costs. For example, our analysis shows that with increasing indigenisation of rolling stock production, the cost of a metro rail rolling stock rake has come down from INR 10 crores to around INR 8 crores. Thus, with greater indigenisation the project costs will come down. Policy should focus on greater indigenisation of production in metro rail segment.

2.9.5.2 Setting up a specialised organisation

Given its status as the first metro rail success story in India, the Delhi Metro Rail Corporation (DMRC) has been involved in various advisory capacities for most subsequent metro rail projects in the country. Thus, there seems to be a need for a central organisation that can specialise in planning and project execution of upcoming metro projects. This firm can modularise an upcoming metro project and then sub-contract it to those firms (public or private) that are best suited to deliver high class infrastructure or services at the lowest cost and within the specified time period. As we have argued earlier, if the cost of capital is brought down by some sovereign action, then world class private sector efficiencies can be tapped by this specialised firm for overall social welfare. Alternatively, as previously suggested in Section 2.8.3, a PPP Institute could also carry out similar functions.

2.9.6 Fare and Non-Fare Revenue

One of the main reasons for the success of a few of the Hong Kong and South Korean metro projects, is the provision made for the private sector investor to use land parcels in the vicinity of metro stations. Station advertising and retail also added to non-fare revenue which kept the private investors going. Fares are regulated and preferably kept as low as possible, to boost ridership as well as ensure that metro transport remains a favoured option among citizens. As a result, any change in fares becomes a political and economic flashpoint for most cities and their respective governments. However, the fact remains that dependence on fare revenue alone will not accord profitability to metro rail projects. Therefore, it is advisable to add provisos through requisite legislation, to allow

[17] Iyer, C.G. & Kumar, K. (2019). Impact of FDI in Urban Mobility: Some insights from Delhi Metro. PIF/2019/TIDE/DP/15. Pahle India Foundation. New Delhi.

private investors' party to concession agreements the right to seek non-fare revenue in order to make up operating and construction costs wherever possible, and plausible.

One such avenue of seeking non-fare revenue is leasing land near metro stations that have their own sub-stations for supplying auxiliary and traction power to metro lines. This land should be leased out for charging stations for electric vehicles (EVs), largely the commercial fleets of cabs and auto-rickshaws. This will allow the private partner to earn non-fare revenue through the lease, boost last mile connectivity for metro rail, and also provide both visibility and ease of access for EV charging (refer section 5.1.2).

3. The Push for Electric Vehicles (EVs) in India

3.1 Urban Mobility and Electric Vehicles

Public transport like metro rail and buses are crucial to mass mobility in urban areas. While they do move a large volume of people on a daily basis, they do not however wholly replace the demand for individual vehicles. The number of vehicles on Delhi roads in March 2018 stood at 1.09 crore, of which 70 lakh were two-wheelers (2W).[18] Mumbai has the highest car density of any city in India at 510 cars per km, putting car congestion in the financial capital at five times that of Delhi.[19] While road length has increased by only a third over the past decade, vehicle registrations (and by extension vehicle purchases) have increased three-fold. This is just one way of explaining the cause for vehicular congestion in most Indian cities.

Vehicular congestion causes more problems, such as pollution, traffic delays, and increased travel times. Indians bought 54,000 vehicles a day in 2018, as compared to 18,000 vehicles a day almost a decade ago. While automobile sales stagnated and dipped since 2018, approximately 51,000 vehicles were bought each day of January 2019.[20] A workable solution remains just out of reach, as people still have not switched to modes of public transport such as the previously discussed metro rail. In the absence of any method to effect large-scale behavioural change, individual vehicle use needs to be seen as a mode of urban mobility. Vehicular traffic takes on greater significance in light of other economic developments, specifically the increase in cab aggregators and food delivery firms. The entry of these two businesses in India has led to a greater number of vehicles being brought onto Indian roads.

Given the increased demand for automobiles in the first half of the past decade, the policy focus naturally shifted to EVs. Not only would EVs help address the issue of pollution, but also contribute to reducing the nation's overall carbon footprint. EVs therefore have been viewed favourably in all automobile segments, that is, two wheelers (2W), three wheelers (3W), and four wheelers (4W). Consequently, the production and uptake of EVs across segments will need to be evaluated from a demand perspective, to determine which segment would provide the best returns on investment.

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[18] 'Number of vehicles on Delhi roads over 1 crore, with more than 70 lakh two wheelers: Economic Survey', Press Trust of India, *Economic Times*, 23rd February 2019. https://economictimes.indiatimes.com/news/politics-and-nation/number-of-vehicles-on-delhi-roads-over-1-crore-with-more-than-70-lakh-two-wheelers-economic-survey/articleshow/68128689.cms?from=mdr

[19] 'Mumbai is now the most car congested city in India: Report', India Bureau, *Business Insider*, 25th March 2019. https://www.businessinsider.in/mumbai-is-now-the-most-car-congested-city-in-india-report/articleshow/68559891.cms

[20] 'The single statistic that shows why Indian roads are getting more congested each passing month', Sindhu Bhattacharya, *News 18*, 11th February 2019. https://www.news18.com/news/india/the-single-statistic-that-shows-why-indian-roads-are-getting-more-congested-each-passing-month-2031835.html

3.2 Industry Perspective on EVs' Production and Adoption

The study relied on both primary and secondary research. A database of 2W, 3W, and 4W (cars and electric bus) manufacturers was prepared (refer Tables 3.1, 3.2 and 3.4). We then contacted individual firms to request a semi-structured interview. We interacted with all firms that agreed to our request, though many did not respond. For our primary research we also met officials at the Society of Manufacturers of Electric Vehicles (SMEV) and Society of Indian Automobile Manufacturers (SIAM). Following the first round of interviews, we requested contacts from the firms we interacted with, in order to meet their suppliers.

3.2.1 Domestic Value Addition and Technological Capabilities

Based on these interactions with automobile and EV manufacturers, it is estimated that on average across various categories, upto 80 per cent components that go into an EV are low value components, while the remaining 20 per cent are high value components. Given the emphasis on Make in India, it is clear that the key components that go into an EV (such as batteries, electric motors, and controllers) which account for 50 per cent of the cost, are imported. Currently, secondary cells are imported and batteries are assembled in the country (refer Table 1, Appendix I). Electric motors and controllers are also imported into the country. Our existing automobile manufacturing ecosystem produces almost all of the remaining low value components such as seats, brakes, and wheels.

Stakeholders are confident that once market size reaches a critical value, there will be large scale investments for manufacturing the key components of an EV. If firms that own the technology agree, licensing will be the most obvious route. However, given the global market dynamics and intellectual property rights (IPR) issues, license for such technologies will not be easily available. Joint ventures, therefore, seem to be a preferred route for both technology owners as well as domestic players. Domestic automobile manufacturers already have engineering as well as research and development (R&D) capabilities. They do see reverse engineering as a route to gaining insight into new and nascent technologies, before taking a call on investing in the same. However, since technologies are in the early stages of development, especially for alternative battery chemistry – such as hydrogen fuel cells, or zinc, or even copper, it is expected that capital will only be invested in those technologies that prove to be most viable. Stakeholders say that setting up an electric motor manufacturing plant for EVs will require at least 7 to 10 years. Component specific issues need to be addressed, such as the challenge with procuring and securing a magnets supply chain for electric motors. Addressing such challenges will be necessary if domestic manufacturing capabilities are to be developed.

Our discussions with stakeholders also brought out interesting insights on technology development happening in the country. While some of them were referring to development of technology from a systems engineering perspective, others referred to development of technology at the individual component level. Big firms, as per our understanding, are trying to develop technology from an engineering systems or systems integration perspective and how it can adapt to Indian conditions. This enables these firms to scale up faster as the market size grows. It is also important to highlight that firms in the EV sector are not just traditional automobile manufacturers. There are also firms with expertise in other sectors, such as electrical circuitry, battery technology, and more that are moving into the EV space. This is indicative of the fact that EV manufacturing is not only through direct substitution of skills and employment from the automobile sector alone. There are smaller start-up firms that have initiated the research to create intellectual property in individual components such as electric motors.

These start-ups are creating linkages and developing products where none existed, and therefore deserve maximum policy support. Our interactions with stakeholders brought home the point that the INR 100 billion 'Fund of Funds' initiated by the government in December 2016, may have to be scaled up so that start-ups in the technology intensive EV sector receive enough assistance to develop technologies in their domain. One such support in these technology intensive industries can be in the form of special research grants or long-term research loans at special rates so as to help them create their proprietary technology using their in-house intellectual property. Intellectual property rights' (IPR) ownership is crucial to technological innovation, and the IPR of small and big firms alike must be protected through policy. This support will help in increasing research capacity and spur our efforts to become a technology supplier.

3.2.2 Government Policy to Facilitate Demand and Supply

The government has in the form of the Phased Manufacturing Programme (PMP), put in place policy for ensuring supply of EVs. The aim of the PMP is to develop domestic manufacturing of EVs, its assemblies/sub-assemblies, and parts/sub-parts, thereby increasing the domestic value addition and creating employment opportunities. It is hoped that PMPs will enable manufacturers to plan their investments for establishment of a robust indigenous EV manufacturing ecosystem in the country. To ensure that the subsidies given under Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India (FAME India) Phase II promote local manufacturing, the government recently revised the PMP[21] so as to be eligible for FAME India Phase II scheme. Without getting in to the details of the revised PMP, it must be noted that the government has tried to put in place a demand push and supply pull, in order to speed up development of the domestic EV market.

There is a concern that growth in EV manufacturing will come at the cost of the existing automobile sector. There are various studies that state that with around 20 moving parts, an EV is easier to build than an internal combustion engine (ICE) vehicle which may have around 2000 moving parts. With a shift towards EV there will be disruption in the existing supplier ecosystem with SMEs & MSMEs bearing the major brunt. Existing power train-related suppliers would lose market share. Clutch, radiators, gears, and engine parts may face demand destruction due to adoption of EVs. As a consequence, there will be repercussions on employment in the automobile sector, though we are

[21] Source: F.No. 7 (06)/2019-NAB-II(Auto), Department of Heavy Industries (DHI), Government of India.

unable to quantify it. Employment in the existing vehicle repairs or vehicle service sector will also be impacted. With lesser moving parts, EVs are relatively easier to manufacture than ICE vehicles, thus EVs have the potential to be commoditized than ICE vehicles. This will create a disruption that may not be beneficial for anyone, neither manufacturers nor consumers.

The discussion above makes it clear that manufacture of electric motors, batteries, and controllers will go a long way in increasing the localisation or value addition being done in the EV manufacturing segment in the country. The first step required in this direction is to increase the market size. The first and second phases of FAME India, along with the recent FY20 budget announcements are a policy push by government for demand creation. Stakeholders are confident that localisation will increase as our market size grows, and we can see a repeat of the success of the traditional automobile sector. The supply push being attempted through PMP can only be effective when the critical sales volume is attained.

There are two important issues our interviews with stakeholders have brought out that need to be flagged. First, as mentioned previously in this section, the push for EVs will have a significant impact on employment and the supplier ecosystem in the traditional ICE sector. The extent of this impact is not completely outlined yet. For the benefit of the sector and the country, this impact and solutions to smooth over the transition need further study. Second, battery technology that propels EVs is a relatively new technology that is not understood as well as ICE technologies. Given that batteries store lots of energy in a small volume, ambient temperatures that exceed a particular level can lead to fires in EV batteries. In a densely populated country like India, this can lead to unprecedented outcomes. There is a need for the relevant automobile regulatory authority to carefully examine this issue in EVs. Finally, special research grants or long-term research loans at special rates are needed from the government for domestic start-ups, so as to help them create domestic proprietary technology.

Investments in the EV space will take place over time, and as newer or alternative battery technologies are introduced. Even in the current ecosystem however, there are some differences in uptake of 4W, 3W and 2W EVs. The following sections will outline the present scenario with respect to each EV segment, and analyse which segments may prove to be worth investing in the short, medium and long term.

3.3 The Challenges for 4W EVs

3.3.1 Affordability

Leading automobile manufacturers like Tata Motors, Mahindra and Mahindra as well as foreign players like Volvo and Nissan, have forayed into 4W EV manufacturing. Mahindra Electric and Tata Motors are the only two Indian firms that manufacture electric vehicles. Mahindra Electric manufactures its 4W at its facility near Bangalore, while Tata Motors manufactures its 4W at its facility in Sanand, Gujarat. However, despite large and small firms alike investing in producing 4W EVs, there are certain challenges that prevent adoption of 4W EVs. The three main challenges for 4W in e-mobility are, price anxiety, range anxiety, and anxiety regarding charging infrastructure. In addition to these, it is well known that the Indian automobile market is price sensitive. Current prices for most average car models is '2x', the lowest price point being '1.75x'. The FAME India and PMP schemes, if availed properly, can help subsidise these prices. However, even with the subsidisation, most 4W EVs are well beyond the means of those in the middle-income bracket.

Price anxiety includes both purchase and lifetime costs. That is, the cost of the EV as well as the cost of the electricity for charging, as well as maintenance, repair and servicing costs. Lifetime costs, that is fuel, servicing, and maintenance expenses, of ICE and electric 4Ws can be compared. In order to provide a comparison of EV and ICE vehicle lifetime costs, we have taken all tariffs and costs applicable in Delhi, based on most recent figures available. From our calculations (refer Box 3.1), it is clear that owning an electric bike (2W EV) is not only affordable, but also more economical than owning an ICE 2W. First, electric bikes have similar prices to conventional ICE 2W (refer Box 3.1). Second, electricity tariffs, battery sizes, lower maintenance costs, and longer servicing intervals, ensure that the electric bike's fuel and lifecycle costs are much lower compared to an ICE 2W.

While the overall difference between a petrol or diesel-run car and an electric car is as low as INR 68,500, this is only after factoring in a 10 year life-cycle period and the 11 years it will take to recover the purchase cost differential between the two. The average customer, will not go through the effort of making an entire life-cycle cost comparison. Even if they do, the purchase cost is more than prohibitive for most low to middle income groups. Besides, the fact that it would take over a decade to recover cost differentials for an electric car, while also factoring in the current lack of charging infrastructure makes the electric 4W unviable for the common citizen. Therefore, while EVs afford economy in terms of fuel and maintenance costs, the initial purchase price is what leads to anxiety.

Box 3.1: Comparison of EV Costs to ICE Vehicle Costs

S.No	Description	4W	2W	Description
1	Avg mileage (km/lt)	10	60	
2	Avg distance travelled per day (in km)	35	35	
3	Avg distatce travelled per month (in km)	1050	1050	(1)*30
4	Fuel Required (in litres)	105	18	(3)/(1)
5	Delhi - Cost of Petrol per litre	71	71	
6	Total Fuel Cost per month (in INR) - Petrol	7457	1243	(4)*(5)
7	Electricity tarrif in Delhi (0-200kWh) (in INR)	3	3	
8	Electricity tarrif in Delhi (201-400kWh) (in INR)	5	5	
9	Avg Charge required for EV daily commute of 35 km (in kWh)	7	3	
10	Total energy required per month (in kWh)	210	90	(9)*30
11	Electricity cost per month (in INR)	945	270	4W = (8)*(10); 2W = (7)*(10)
12	Monthly Savings from EV (in INR)	6512	973	(6) - (11)
13	Cost of Avg. ICE Vehicle (in INR)	500000	60000	
14	Cost of EV (in INR)	1350000	50000	
15	Difference in Cost (in INR)	850000	-10000	(14) - (13)
16	Time to Recover Cost Differencial (in Years)	11		((15)/(12))/12
17	Total Cost of Petrol for ICE for 10 years (in INR)	894852	149142	(6)*12*10
18	Rounded off (in INR)	895000	150000	Rounding off 17
19	Lifetime Cost of ICE (in INR)	1395000	210000	(13) + (18)
20	Total Electricity cost for Electric over 10 years (in INR)	113400	32400	(11)*12*10
21	Lifetime Cost of EV (in INR)	1463400	82400	(14) + (20)
22	Difference in Lifetime Costs (in INR)	68400	-127600	(21) - (19)

As a result, penetration for e-mobility in the 4W segment has largely been on the commercial side. That is, only buses and car fleets (such as those of cab aggregators), have begun to be replaced with their electric versions. In the near term, most manufacturers and automobile associations see this as the primary market for 4W EVs. The manufacturers and respective associations are also of the opinion that the current focus should be on the commercial vehicle space for transitioning to e-mobility. It must be noted here that while e-buses are an effective alternative to buses running on conventional fuels or CNG, the contribution to improvement in air quality or reducing pollution is minimal. This should not however take away from the fact that if deployed on heavy-traffic or arterial routes, e-buses could contribute to improving the ambient air quality along the same.

Despite the challenges, the long term benefits of electric cars are definitely worth considering. The life of an electric car is approximately 40 years on account of reduced wear and tear (due to fewer moving parts) as well as longer servicing and parts replacement intervals. They would also contribute to reduced emissions and be more sustainable in the long term. However, in the short term the loss of jobs, costs of transition, and resistance of people to alternative transport technology are major obstacles. High-end electric 4W will still find a market but will not have the desired sales volume. The price point of mid-level electric cars cannot be brought down, until supporting infrastructure is put in place.

3.3.2 Commercial Fleets and Electric Buses

Table 3.1: Firms in the Electric Buses category

Company	**Factory Location**
Ashok Leyland	Chennai, & Krishna (Andhra Pradesh)
Eicher-Volvo	Pithampur, Madhya Pradesh
JBM Motors	Faridabad, Kosi (Uttar Pradesh)
Olectra Greentech	Hyderabad
PMI Foton	Dharuhera, Haryana
Tata Motors	Dharwad, Karnataka

Source: DHI, SMEV

Pune became the first city to adopt e-buses in January 2019. From the first 90 buses that were deployed on 15 routes, the fleet has now grown to 133 buses.[22] The transition to e-buses on specific routes has gone smoothly, with both the transit authority, the Pune Mahanagar Parivahan Mahamandal Limited (PMPML) and passengers finding the e-buses easy on both the environment and the pocket. PMPML however has not bought the e-buses it runs in the city. The buses are owned, operated and maintained by Olectra Greentech, the manufacturers of the e-buses. The PMPML pays the company on a per-kilometre basis to operate and maintain the e-buses. Overall, this is cheaper for the PMPML than even its fuel engine buses, where e-buses cost INR 68 (for a small e-bus) and INR 74 (for a large e-bus) per km, it costs them INR 90 per km to operate and maintain CNG and diesel engine buses.[23] Owing to the success of Pune's e-bus experiment, other cities such as Ahmedabad, Lucknow and Hyderabad have also begun to run e-buses on certain routes.[24]

The one issue with e-buses, as with all other EVs is the price point. The vehicle itself is not purchased outright by the transit authority in Pune, as buying the vehicle requires a quantity of money that the PMPML does not have. This is the issue across board for all

[22] 'Can electric buses solve India's transit crisis? This city may hold the answer', Sanaya Chandar and Kuwar Singh, *Quartz India*, 30th January 2020. https://qz.com/india/1766123/punes-e-bus-experiment-may-be-the-answer-to-india-transit-woes/

[23] *Ibid*.

[24] 'All the Cities in India with Electric Bus Service – Lucknow, Hyderabad, Sabarimala, Delhi and more', Arjit Garg, *News 18*, 12th February 2019. https://www.news18.com/news/auto/hyderabad-telangana-andhra-lucknow-sabarimala-delhi-all-the-cities-in-india-to-get-electric-bus-service-2033459.html

4W EVs. Manufacturers and associations state that price points are unlikely to change without the lowering of battery prices. This is likely only once alternative or new battery technology or chemistry is made viable, such as hydrogen fuel cells or zinc and copper batteries. Only when the price point comes within the affordable range for the middle class, will electric car sales actually make headway. However, even with a lower price point, automobile associations emphasise that expecting a complete transition to zero conventional fuel use might be unrealistic.

3.3.3 Transition from Conventional Fuels to e-Mobility

The goal, as highlighted by associations, has never been to cause unviable disruption in the automobile sector. While e-mobility is certainly one alternative, biofuels and fuel blends are also coming up as clean fuel options. This means that phasing out the ICE vehicle is not about to happen in the near or even medium term. 10 and 20 per cent ethanol blends, called E-10 and E-20 are already being made available, especially with the advent of the Bharat VI norms which mandate cleaner fuels. Additionally, there is also a hard push for CNG technology being upgraded to be cleaner and more affordable. The transition from conventional fuels to cleaner alternatives needs to be technology agnostic. That is, the market should be allowed to decide what mix of technologies and vehicles will ply the roads in the coming years.

The push for e-mobility and EVs predicates the existence of efficient charging infrastructure. While 2W and 3W battery charging needs are smaller, and therefore more easily met, this does not apply to 4W cars and buses yet and may not apply in the foreseeable future either. For e-cars, batteries are larger and need stronger currents as well as higher voltage for charging. When it comes to individual ownership of electric cars the anxiety over charging infrastructure is well-founded. While the infrastructure may be brought in the form of charging stations, or fast chargers (as they are currently known in Europe and North America), the next issue to deal with will be load dispatch and the disproportionate load on electricity distribution companies. In a country like India, where 'load shedding' and power cuts are still problems, having efficient charging infrastructure seems like a long-term goal (refer Box 3.2 for additional electricity requirements for charging EVs).

This should not necessarily be taken as a complete obstacle to the adoption of EVs, only a challenge to the adoption of 4W EVs. This challenge can also be overcome, however the solutions will require some time to be put in place. The most significant point here is that the well to wheel equation for 4W EVs is still fossil fuel based for the most part. This is owing to the fact that electricity is largely derived from thermal power (coal burning) in India. This is where renewable energy, especially solar energy can come in to make EVs a truly green option. Renewable power can be used for charging EVs, and should be considered the go-to option for this purpose. However, the mapping, investment and infrastructure required for this to be made reality will all require time.

3.5 The Import Burdens and Categorisation of 3W EVs

The auto-rickshaw has been a mainstay of public transport in India. The common man's beast of burden, in most major Indian cities. It was only a few years ago that the e-rickshaw became part of the Indian automobile milieu. While the first e-rickshaws were basic, open module, short-distance, passenger carriers, the conventional 3W (or auto-rickshaw) also began to transition to electric technology.

The growth and sheer size of 3W EVs market across India has led to entry of many firms (refer Table 3.1). This is a partial list of firms that have registered themselves with the government or SMEV. It is surprising to note that most of these firms are non-existent in the conventional (internal combustion engine) 3W category. Interestingly more than 40 per cent of the firms listed in Table 3.1 have ISO 9001 certification, which indicates their commitment to quality. This is not a complete list, as there are numerous firms in the unorganised sector that assemble 3W EVs. It is indeed plausible that some of the firms in Table 3.2 may have transitioned from the unorganised to the organised sector.

Table 3.2: Firms in the 3W category

Company	**Remarks***
Autolite India Limited	9 manufacturing units across the country
Electrotherm	3W under development
Gayatri Electric Vehicles	--
OK Play Electric	--
Saera Electric Auto Pvt. Ltd.	--
Goenka Electric Motor Vehicles Pvt. Ltd.	--
Clean Motion	Swedish firm
Kinetic Green	--
Devam Automobiles	--
Kalinga Ventures India Pvt. Ltd.	3 manufacturing units across the country
Mahindra Electric Mobility Ltd.	--
TVS Motor Company	Under development
Ampere	Industrial use 3W
Lohia Auto Industries	One manufacturing unit
NIBE Motors Pvt. Ltd.	Based in Nashik
Thukral Electric Bikes Pvt. Ltd.	One manufacturing unit
Terra Motors India Pvt. Ltd.	Japanese firm with two manufacturin units across the country
Champion Poly Plast	One manufacturing unit
Electrie-One Auto Pvt. Ltd.	--
J S Auto Pvt. Ltd.	One manufacturing unit
Pubang Etron Electric Motor Pvt. Ltd.	One manufacturing unit
Velev Motors India Pvt. Ltd.	One manufacturing unit

**from secondary research Source: DHI, SMEV.*

The trade of EV from the country presents an opportunity for us to understand the import dependence of the 3W EV ecosystem (refer Table 3.3).

Table 3.3: Import and Export of EV in INR Lakhs

Item	Imports		Exports		Net Exports	
	2017-18	*2018-19*	*2017-18*	*2018-19*	*2017-18*	*2018-19*
EV seating more than seven	22.0	93.3	15.8	286.0	-6.2	192.7
Motor cars	401.1	926.0	1165.0	1068.2	763.9	142.2
3W	1899.3	10905.9	42.1	636.7	-1857.2	-10,269.2
Other	36.3	86.6	68.3	498.5	32.0	411.9
Total*	2358.7	12011.8	1291.1	2489.4	-1,067.6	-9,522.4

** may not add up due to rounding off. Source: Ministry of Commerce and Industry, GoI.*

The huge imports, given the size of 3W EV market, is not surprising. It is possible that players in the unorganised sector import 3Ws in completely knocked down (CKD) form, assemble and then sell the 3Ws in the domestic market. This partially explains why 3W EVs have the largest share in imports. In addition to this, some of the larger firms such as Piaggio, which have traditionally manufactured conventional 3Ws (auto-rickshaws) are foreign firms, which are now getting into the electric 3W space. This potentially adds to the import burden brought about by the 3W segment.

3Ws in India fall into either the commercial or passenger categories. The former are largely diesel-run, and are usually used for transport of cargo, while the latter are used to ferry passengers and are more commonly seen in urban areas. The passenger 3Ws, or auto-rickshaw have mostly switched to compressed natural gas (CNG) as fuel. Therefore, in this segment, the conversion costs for moving from green fuel (CNG) to green fuel (electric) could prove to be futile. It would be better for traditional cycle rickshaws, to be upgraded or outfitted with electric batteries in order to help improve their range and revenue. It is the commercial 3Ws that could do with the switch to electric, as this would reduce their fuel costs as well as the pollution caused. Passenger 3Ws plying in unwieldy terrains (such as mountainous or desert) could face fuel supply issues. Passenger 3Ws in such areas should transition to electric as it would ease both fuel supply issues, and reduce the need to transport fuel over and to dangerous terrain.

Having electric 3Ws is necessary for the overall mix of automobiles and technology available on Indian roads, for the purpose of urban mobility. However, while 3Ws can definitely contribute to the number of EVs on the road, they also add significantly to India's import bill. This segment contends with CNG 3Ws as well. Recently, Mahindra Electric has begun production of electric 3Ws. Therefore, this segment may not need any further investment, other than a fillip to indigenous technological capability development.

3.6 The Case for 2W EVs

As already discussed above, the policy push for boosting EV production is a welcome move. However, the approach to EVs needs to be adjusted by accounting for customer expectations and doing a well-rounded cost benefit analysis in terms of demand, supply, and uptake. Most EV manufacturers in India have had the time to introduce new products to the domestic market, and conduct pre and post-introduction market research. There are several electric 2W manufacturers in India (refer Table 3.4).

Table 3.4: Firms in the 2W category

Company	**Factory Location**
Hero Electric	Ludhiana, Punjab
Okinawa Autotech Pvt. Ltd.	Alwar, Rajasthan
Ampere	Coimbatore, Tamil Nadu
Ather Energy	Bangalore, Chennai
22 KYMCO	Bhiwadi, Rajasthan
Ajanta Manufacturing Pvt. Ltd.	Kutch, Gujarat
Avan Motors Pvt. Ltd.	Pimpri-Chinchwad, Maharashtra
Avon Cycles Ltd.	Ludhiana, Punjab
Envee Wheels	Pune
Jitendra New EV Tech Pvt. Ltd.	Nashik
Mirakle5 Automobiles Pvt. Ltd.	Pune*
NDS Eco Motors Pvt. Ltd.	Bangalore
Shema E-vehicle and Solar Pvt. Ltd.	Sambalpur, Odisha
Supereco Automotive Pvt. Ltd.	Gwalior*, Madhya Pradesh
Tunwal E-vehicle Pvt. Ltd.	Gandhinagar, Gujarat
TVS Motor Company	Chennai*
Electrotherm	Kutch, Ahmedabad, Jaipur
Lohia Auto Industries	Kashipur, Uttarakhand
NIBE Motors Pvt. Ltd.	Nashik
Micromax Electric Pvt. Ltd.	Manesar, Gurgaon
Tork Motors Pvt. Ltd.	Chakan, Maharashtra
Velev Motors India Pvt. Ltd.	Chengalpattu, Tamil Nadu

**Registered office Source: DHI, SMEV.*

Hero Electric, Okinawa, and Ampere are among the major firms in this category. Though production numbers are difficult to come by, it is estimated that the production capacity of Hero Electric is close to 50,000 two wheelers per year. Geographically, production facilities seem to be concentrated in the western part of the country.

Interactions with EV manufacturers provided pertinent insights into demand for EVs and customer perceptions. The primary observation from EV manufacturers is that electric technology provides an alternative, not a substitute for fossil fuel technology. The average Indian customer is often looking for low distance (usually a 10-15 km range at maximum), low speed (owing largely to vehicular congestion and speed limits), and cheap mobility. This is true in both urban and rural areas. Since they cater to these criteria satisfactorily, 2W demand is steady yet middling. That is, the demand for 2W EVs is not yet at a volume that can encourage competition, which could subsequently help improve their affordability.

The primary consideration for a majority of customers is price point. This is more evident in the 2W segment than in the 3W and 4W segments. 2W EVs sell best if their prices are competitive (read: lesser) as compared to their conventional fuel counterparts. This is in large part due to the performance expectations at this price point, or the fact that customers expect that a vehicle that ferries them on a smaller radius, with lesser fuel economy should not cost them more than the average ICE 2W. Given such customer expectations on both performance and price points, EV manufacturers generally keep to 2W EVs as they find their own market niche among the rural and semi-urban areas in the country.

With 21 million units (2.1 crore) units sold in 2018-19[25], India remained the second-largest 2W market in the world.[26] Electric 2W are expected to become a significant part of this market. The specific demographic that 2W manufacturers hope will adopt EVs are the roughly 40 per cent people of this market that fall within the 10-15 km range of mobility. While the average Indian customer is sensitive to pricing, most 2W manufactured in India (including electric 2W) fall within the INR 40-60,000 price range. This economy in pricing is owed in large part to imports, specifically body fabrication, plastics, and accessories. If plastic and steel inputs are localised, then the price of electric 2W will be driven up. This is because imports, which are largely from China, help maintain a 20 per cent differential (even after factoring in import duties) which allows electric 2W manufacturers to keep prices affordable. This is more important given that the desired volume of sale has not yet been achieved. Most manufacturers' project that once sale volumes reach 1 million (10 lakh) units annually, it will help foster both competition and affordability in the electric 2W segment.

3.6.1 Charging Infrastructure and Electricity Requirements

The most important difference between the 2W and 4W segments in EVs is battery size and supporting infrastructure. Since electric 2W have smaller batteries, they are also designed to be portable in order to facilitate emergency charging. Additionally, an electric 2W's battery pack can be charged using any standard outlet. The current requirements and size of battery pack in electric 4W necessitate supporting infrastructure like separate charging stations, especially where the 4W fall in the mid-size hatchbacks, sedans, and SUV/XUV categories. Therefore, not only is pricing prohibitive to the adoption of electric 4W, but also the lack of a supporting infrastructure which may take years to develop yet. This is evident in India, where charging infrastructure is still an area industries are hesitant to invest in, given the low demand for EVs.

[25] 'Why two wheeler makers are unhappy', Murali Gopalan, *The Hindu Business Line*, 15th July 2019. https://www.thehindubusinessline.com/specials/india-file/why-two-wheeler-makers-are-unhappy/article28449453.ece

[26] 'Honda wants a piece of India's electric two-wheeler market', Aman Rawat, *Inc42*, 27th January 2020. https://inc42.com/buzz/honda-wants-a-piece-of-indias-electric-two-wheeler-market/

Box 3.2: Electricity Required for Charging EVs – A Case Study of Delhi[27]

a) Per capita monthly electricity consumption (for Delhi) = 131.17 kWh
b) Total number of households (in Delhi) = 41,97,000
c) Number of people (assumed) per household = 4
d) Charge required for Electric car (daily commute of 30 – 40 kms) = 6-8 kWh (avg 7 kWh)
e) Total energy required per month per car = 7 kWh x 30 (days) = **210 kWh**
f) Full charge for electric 2W (daily commute of 30 – 40 kms) = 2-4 kWh (avg 3 kWh)
g) Total energy required per month per e-2W = 3 kWh x 30 (days) = **90 kWh**

Assuming 100% households own 1 electric car;
h) Energy required for 100% households' electric cars per month = 88,13,70,000 kWh
= 881.3 MU

Assuming 100% households own 1 electric 2W;
i) Energy required for 100% households' electric 2W per month = 37,77,30,000 kWh
= 377.7 MU
j) Annual electricity generation in Delhi (2019-20) = 6,28,00,00,000 kWh
= 6,280 MU
k) Current monthly electricity generation in Delhi = 523333334 kWh
= 523.3 MU

Combinations of EV ownership and corresponding additional monthly electricity requirement;
l) For 2 2W per household (at 100% adoption) = 377.7 MU x 2
= 755.4 MU
m) For 2 4W per household (at 100% adoption) = 881.3 MU x 2
= 1,762.6 MU
n) For 1 2W + 1 4W per household (at 100% adoption) = 377.7 MU + 881.3 MU
= 1,259 MU

Another issue brought up by EV manufacturers with regard to charging EVs is the capacity of the power sector. It is important to ascertain what the additional energy requirements would be, in the event of a complete switch to EVs (that is assuming 100 per cent adoption of EVs, across socio-economic strata). For this, we chose to calculate the additional electricity requirements for Delhi, as a case study. In order to calculate the electricity required for charging EVs, we took the charge required for a 4W (electric car) or 2W (electric bike) for a 30-40 km commute. This range includes the 35 km average distance travelled by the common Indian per day.[28] The total monthly electricity

[27] Calculations based on data compiled from various sources, including Census 2011, Ministry of Statistics and Programme Implementation (MoSPI), Central Electricity Authority, various news articles, and interactions with EV manufacturers' and automobile industry associations.
[28] 'Indian commuters travel 35 km/day, says survey', Nandini Sen Gupta, *The Times of India*, 3rd March 2018. https://timesofindia.indiatimes.com/business/india-business/indian-commuters-travel-35-km/day-says-survey/articleshow/63140954.cms and 'Indians spend 7% of their day getting to their office', ET Bureau, *Economic Times*, 3rd September 2019.

requirement for an electric 4W and 2W therefore amount to 210 kWh and 90 kWh respectively (refer 'e' and 'g' in Box 3.2). The number of households in Delhi (based on Census 2011 figures) are taken into account. We have also calculated figures assuming a 100 per cent conversion to EV, or EV adoption rate. This puts the monthly energy requirement for EV charging at 881.3 MU (Million Units)[29] for households with an electric car or 377.7 MU for households with an electric bike.

Considering that 6,280 MU were generated in Delhi for 2019-20, and given that Delhi is energy neutral, that is the city consumes as much electricity as it produces – the electricity generated per month in Delhi stands at 523.3 MU. There are a few interesting points to highlight here. One, that at 210 kWh monthly energy required for charging an electric car, the electricity consumption of a household increases by 40 per cent (per capita consumption – 131.17 kWh x number of people per household - 4 = 524.68 kWh). Two, an electric bike increases the energy requirement of a household by 17 per cent. Three, it is likely that most households depending on socio-economic wherewithal, will own some combination of 4W and 2W. Therefore, considering some combinations of 4W and 2W ownership, monthly energy requirements are calculated at 755.4 MU, 1,762.6 MU, and 1,259 MU (refer 'l', 'm', and 'n' in Box 3.2). In all cases, the energy requirements for charging far outstrip the current monthly electricity generation for Delhi. The energy requirement is more than doubled for households with a 2W and 4W combination, and almost quadrupled for households with two 4W.

Given this multiplier effect that charging EVs has on energy requirements, the foremost consideration becomes, where will this extra electricity come from? This additional burden is only for Delhi, which is itself energy neutral. In cities and states which suffer from energy shortfalls, the situation may prove to be far more challenging. The one solution that can be considered to tackle this problem is that of electricity from renewable sources, mainly solar power. While renewable energy sources come with their own limitations, such as seasonality and storage, allowing for private production of solar power, purely for charging EVs may prove to be a viable option in the medium and long term.

The government holds out hope that EVs can replace light motor vehicles (LMVs), buses, trucks and heavy carriers, eventually. Industry players are hesitant to support such hope, as battery technology does not yet support the heavy load/high speed combination. Buses for public transport, on select heavy-traffic, arterial routes could be switched to electric. Electric buses for public transport have thus far been successfully introduced in Ahmedabad and Pune (refer section 3.3.2), where the latter is on track for complete transition to electric buses in the next three years. However, whether this will work for other cities, or for all routes in all cities remains to be seen.

Industry believes that with Lithium prices coming down gradually, the overall costs of electric technology for mobility will come down as well. However, this is not set to

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https://economictimes.indiatimes.com/jobs/indians-spend-7-of-their-day-getting-to-their-office/articleshow/70954228.cms

[29] 1 Unit = 1 kWh, therefore 1 MU = 1,000,000 kWh.

happen within the next five years. Therefore, for at least the next decade, Lithium as a raw material will have to be imported, mainly from China. This is notwithstanding the other plastics, fabrication, and accessories imports already coming in from China. The argument that introducing EVs will reduce import dependence, or provide import substitution, is a very narrow and myopic perception of the big picture. While EVs may contribute to reducing dependence on crude imports, it will by no means substitute conventional fuel technology in mobility. Incidentally, the government is also simultaneously pushing for greater production and adoption of biofuels such as Compressed Bio-Gas (CBG), biodiesel and ethanol blends. Given the success that adoption of CNG had in the past, it stands to reason that biofuels may be successfully adopted too.

In the competition between EVs, biofuels and conventional fuel technology for mobility, eventually affordability and costs of transition will decide what percentage of market is captured by each. This is not to say however, that the price points and costs of transition to EVs should not be encouraged. In fact, encouraging people to invest in EVs as a mode of transport may be the way to go. The next, and last section of this chapter will elaborate on how this might be achieved in the electric 2W segment.

3.7 Introducing a 2W Electric Vehicle Uptake Subsidy

Price point of EVs and lack of infrastructure support are the major obstacles to widespread adoption of EVs. While the latter will take time and significant investment, the former can be dealt with in the short to medium term. Introducing a subsidy for EVs for personal use, may prove to be more effective in terms of demand creation. The first phase of FAME India was aimed at demand creation, pilot projects, and charging infrastructure. While the demand creation was aimed at all vehicle segments (2W, 3W, passenger 4W, Light Commercial Vehicles (LCV) and buses), only 2.78 lakh (278,000) EVs were supported under this subsidy from 2015-2019.[30]

The Government also stated that the subsidy under FAME India scheme was directed towards and was only offered to commercial fleet owners, with the only extension being to 2W for personal use.[31] This is perhaps what prevented demand from building, under the first phase of FAME India. However, the second phase of FAME India was approved in March 2019. Cabinet approved an outlay of INR 10,000 crore for the next three years, for FAME.[32] Given this outlay, and taking into consideration that EV manufacturers hope to capture the approximately 40 per cent of 2W users that fall within the 10-15 km range of mobility (refer section 3.6), the budget required for such a subsidy can be calculated.

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[30] 'FAME India Scheme', Release 191377, Ministry of Heavy Industry and Public Enterprises, *Press Information Bureau*, 9th July 2019. https://pib.gov.in/newsite/PrintRelease.aspx?relid=191377

[31] 'Govt asserts subsidy for EVs only for commercial vehicles, not personal usage', Press Trust of India, *Economic Times*, 19th July 2019. https://economictimes.indiatimes.com/news/economy/policy/govt-asserts-subsidy-for-evs-only-for-commercial-vehicles-not-personal-usage/articleshow/70292418.cms?from=mdr

[32] 'FAME India Scheme', Release 191377, Ministry of Heavy Industry and Public Enterprises, *Press Information Bureau*, 9th July 2019. https://pib.gov.in/newsite/PrintRelease.aspx?relid=191377

The subsidy need only be very simple, where the cost of the vehicle is subsidised. The subsidy can be focused only on the 2W market initially, especially since industry states that this is where demand can truly be created. The subsidy need only be in force for 2 to 3 years, during which market can be created by boosting demand. It can also be staggered, such as being provided at 50 per cent of vehicle cost if transition occurs during the first year that the subsidy is in force, 35 per cent of vehicle cost in second year, and 20 per cent in the third year. The following calculation is for the amount required to provide such a subsidy (taking into account the 2W EV market).

a) Total 2W sold in India (in 2018-19, rounded down) = 2,00,00,000 (2 crore units)
b) Number of 2W users that could switch to 2W EV (40% of a) = 80,00,000 (80 lakh)
c) Average cost of 2W EV = INR 50,000 (average of INR 40,000 – INR 60,000)
d) Subsidy/vehicle at 50% of retail cost = 0.50 x 50,000 = INR 25,000
   Subsidy/vehicle at 35% of retail cost = 0.35 x 50,000 = INR 17,500
   Subsidy/vehicle at 20% of retail cost = 0.20 x 50,000 = INR 10,000
e) Given industry's inputs on needing sales volume of 10,00,000 (10 lakh) units, restrict subsidy distribution by number of vehicles. That is, only the first 15 lakh 2W bought in the first year will be eligible, 10 lakh 2W in the second year, and 5 lakh 2W in the third year.
f) Cost of subsidy for 1st year = 25,000 x 15,00,000 = INR 3,750 crores
   Cost of subsidy for 2nd year = 17,500 x 10,00,000 = INR 1,750 crores
   Cost of subsidy for 3rd year = 10,000 x 5,00,000 = INR 500 crores
g) Total cost of subsidy over 3 years = <u>**INR 6,000 crores**</u>

Even if the subsidy were to be maintained at 50 per cent of vehicle cost for all three years, it would total **INR 11,250 crores** and would effectively cover 45 lakh vehicles. At 35 per cent cost for 15 lakh units per year for all three years the subsidy would total **INR 7,875 crores**. While at 20 per cent cost for 15 lakh units per year for all three years, the total would be **INR 4,500 crores**. Whether at the conservative estimate of covering 40 lakh vehicles in a staggered subsidy format, for a limited number of years, or a blanket subsidy for 45 lakh vehicles over the same limited number of years, the required outlay of funds falls well within the INR 10,000 crore limit set aside for FAME India in 3 out of the above 4 scenarios.

Even considering the extreme case of having to subsidise 1 crore units of 2W EVs at 50 per cent of vehicle cost (factoring in the higher end price of INR 60,000), the total cost would be INR 30,000 crores. Split over three years, this would amount to INR 10,000 crores each year. The outlay for FAME India would only cover costs for a single year, while the remaining INR 20,000 crores would need to be provided for. Government revenues are already under scrutiny and being spent warily, given the present economic circumstances. However, it is precisely given these limitations that the above subsidy format has been suggested. Shortfalls in funds for such a subsidy should be filled from the Swachh Bharat Cess and/or Clean Environment (formerly Clean Energy) Cess. The collection for the former stood at INR 215.87 crores in 2018-19, and for the latter stood at INR 4.88 crores in the same year.[33]

This kind of subsidy may be well worth the investment, as it will help drive demand in a segment that is most likely to catch on in Indian markets. This subsidy will be directed at those lower to middle income groups that would actually benefit from owning and using EVs (given lower lifecycle costs like maintenance and repair/replacement). Even with low rates of success in implementation, that is even if only 5 – 10 lakh vehicles are bought per year, it will help boost visibility of EVs (especially 2W) and allow the benefits of their economical upkeep and utility to spread by word of mouth, if nothing else. Even if the mark of 10 lakh units a year is achieved, as highlighted by industry, this sales volume will be enough to drive up competition and subsequently affordability. This kind of subsidy, if well designed and implemented within strict guidelines, could prove to be a win-win for all. Such a subsidy might be a far better investment in alternative transport modes, while reducing carbon emissions, and improving urban mobility.

[33] 'Tax Revenue', Receipt Budget 2020-21, Union Budget 2020-2021. https://www.indiabudget.gov.in/doc/rec/tr.pdf

4. Battery Manufacturing in India

4.1 Lithium Ion Batteries

The thrust to EVs has also implied a push to consumption of Lithium (Li)-ion batteries. In addition to EVs, these batteries have applications in electronics and energy storage. Growing electronics consumption and policy push to EVs makes the case for having a well-developed Li-ion battery manufacturing segment in the country. This chapter focuses on the current value addition done in the Li-ion battery manufacturing in the country, the level of investment, and the domestic technologies available to manufacturers. The methodology followed to analyse the Li-ion battery manufacturing segment is similar to the one followed for the EV chapter.

4.1.1 Importance of Li-ion battery in a globalised world

In today's globalised and interconnected world, energy plays a vital role in telecommunications as well as transport sectors. Energy for these activities are obtained from minerals and elements available in the lap of Mother Nature. Table 4.1 shows the energy intensity for the various forms of fuels that humans have developed in the scientific age.

Table 4.1: Energy intensity for various fuels

Fuel	Energy intensity (Whr/kg)
Hydrogen	39,300
Gasoline, Diesel, Natural Gas	12,000-13,000
Lithium-ion battery	100-250
Lead acid battery	40

Source: Batteryuniversity.com, Accessed on 8th July 2019

Hydrogen has the best energy intensity but as we will see in our next chapter, Hydrogen technology is yet to transform itself for mass adoption. It can be seen that fossil fuels have better calorific value than batteries; however, having used too much of fossil fuel and the resultant climate change has forced us to look for cleaner alternatives. One of the cleaner alternatives available is batteries. Batteries are used in telecommunications as well as transport. Motor vehicles with lead acid batteries have been plying on the roads for some time now, however, lead acid batteries get discharged relatively faster to induce some kind of mass adoption. Li-ion batteries on the other hand have better energy intensity and for the same amount of charging give higher mileage. Thus, there is huge interest in Li-ion applications in the mobility segment.

Globally, major use of Li-ion batteries has been in electronic devices, EVs, and energy storage. Table 4.2 shows the share of Li-ion battery sales in different industry segment across the world.

Table 4.2: Share of Li-ion battery sales in different industry segments (Global)

Year	Electronic Devices	Electric Vehicles	Industrial use, Energy Storage	Others
2014	0.55	0.27	0.06	0.12
2015	0.41	0.47	0.04	0.08
2016	0.33	0.50	0.04	0.13
2017	0.27	0.57	0.05	0.11

Source: Avicenne Energy, 2019 (https://www.rechargebatteries.org/wpcontent/uploads/2019/05/Avicenne_The-Rechargeable-Battery-Market-2017-2025.pdf). Accessed on 8 July 2019.

It is interesting to note that during the period 2014 till 2018 there has been a shift in the share of consumption of Li-ion batteries in different industrial segments. Probably till 2014, electronic devices dominated the consumption of Li-ion batteries. However, after 2015, share of EVs has over taken that of electronic devices. It must be emphasised that overall market for Li-ion has grown exponentially since 2014, with bulk of the growth coming from EVs. In absolute terms, consumption of Li-ion batteries in electronic devices has increased during this period. Though their share remains almost constant, use of Li-ion batteries in energy storage and other segments has also increased.

In the Indian context, during this period, growing consumption of electronic devices and other uses have contributed to a huge jump in the imports of Li-ion rechargeable secondary cells (refer Table 4.3).

Table 4.3: Imports of Li-ion rechargeable secondary cells in INR Million

Year	Imports
2013-14	12,859.8
2014-15	5,687.6
2015-16	18,072.0
2016-17	22,058.7
2017-18	35,320.1
2018-19	85,740.8

Source: Ministry of Commerce and Industry, GoI

Starting from just a tad below INR 13 billion in FY14, imports have increased almost seven times to INR 86 billion in FY19. Given India's nascent Li-ion EV market, our analysis shows that majority of these secondary cells were used in the mobile phone segment. For example, we estimate that for FY19, share of EV consumption of Li-ion secondary cells was around 1 per cent compared to a share of around 80 per cent for mobile phones. Thus, it will be logical to expect that mobile battery manufacturers will invest highly in cell manufacturing activities in the country. We will attend to this in the next section.

4.1.2 Li-ion manufacturing segment in India

The huge demand for Li-ion secondary cells is an opportunity for manufacturers to set up cell manufacturing plants in the country. Currently, all the plants manufacturing Li-ion battery packs in the country import secondary cells and assemble them at their plants. A partial list of these plants can be seen from table 3.5 of previous chapter. Through secondary research this study has been able to identify the following firms that have announced their plans to set up a Li-ion cell manufacturing facility (refer Table 4.4).

Table 4.4: Firms planning to enter Li-ion cell manufacturing

Company	Targeted market*	Planned Production Capacity (GWh)	Planned investment (INR crores)	Sources (Accessed on 9 July 2019)
Reliance Industries	Energy Storage Mobile devices	25	US $3.5 bn	https://factordaily.com/reliance-adani-lithium-ion-battery-factories-india/
Adani Group	Energy Storage	--	--	https://www.eqmagpro.com/adai-group-announces-%e2%82%b955000-crore-investment-in-gujarat/
Raasi Group	Energy Storage (rooftop solar)	1	900-1100	http://www.newindianexpress.com/business/2018/jun/14/cecri-raasi-join-hands-to-set-up-indias-first-lithium-ion-battery-unit-1827884.html; https://renewablesnow.com/new/indian-lab-to-provide-tech-for-countrys-1st-li-ion-battery-plant-616325/
Avanze Inventive	--	1	1800	https://www.pv-magazine-india.com/2019/03/14/avanze-setting-up-1-gw-lithium-ion-cells-plant-in-andhra-pradesh/
Suzuki-Toshiba-Denso	EV	--	1137	https://www.autocarindia.com/industry/suzuki-toshiba-to-set-up-lithium-ion-battery-plant-in-gujarat-405993
BHEL (JV with Libcoin)	Energy storage	1	--	https://www.pv-magazine-india.com/2019/01/21/bhel-and-libcoin-to-build-indias-first-lithium-ion-gigafactory/
JSW Energy	Energy Storage Mobile devices	--	--	https://indiaesa.info/news-menu/894-india-s-gigafactories-reliance-adani-suzuki-jsw-hero-in-

Company	Targeted market*	Planned Production Capacity (GWh)	Planned investment (INR crores)	Sources (Accessed on 9 July 2019)
				race-to-set-up-multi-billion-dollar-battery-plants
Mahindra & Mahindra (collaboration with LG Chem Ltd.)	EV	--	--	https://www.livemint.com/auto-news/mahindra-in-talks-with-global-players-to-supply-its-electric-powertrains-and-other-parts-1559649172516.html
Exide Industries (JV with Leclanche)	EV, Energy Storage	1	1900	https://www.exideindustries.com/media/exide-announces-entry-into-lithium-ion-batteries-industry.aspx; https://www.thehindubusinessline.com/news/exide-to-make-lithium-ion-batteries-at-recently-acquired-tudor-facility/article24585021.ece
Amara Raja Batteries Limited	EV	0.1	--	https://www.livemint.com/Companies/BKHuDkSK2X9CkqNaT0gYK/Amara-Rajas-lithiumion-plant-eyes-300-billion-EV-market.html
Munoth Industries	Mobile devices	1	799	https://economictimes.indiatimes.com/industry/telecom/telecom-news/indias-first-lithium-ion-cell-factory-to-come-up-in-andhra-pradesh/articleshow/64547131.cms

** PIF estimate*

We believe that though the firms listed in Table 4.4 may initially start with assembly of battery packs; they plan to manufacture secondary cells in their facilities. As per our primary research, only three of the above firms have actually initiated ground level work for cell manufacturing facilities. The remaining firms are either scouting for technology or are in the pilot phase of their technology. Two of the above firms have also sourced domestic technology.

Another interesting point, as per our analysis, is that though mobile phone battery segment is the largest consumer of Li-ion batteries, only three firms have announced plans to set up cell manufacturing facilities to cater the same. Four firms plan to set up facilities to cater the EV market, while six firms have announced plans to cater the energy storage market.

Thus, there is a need for a strong push for the Li-ion secondary cell manufacturing to gather steam. We outline the steps required in our next section.

4.1.3 Way forward

Our primary survey comes out with numerous insights that suggest a way forward in the Li-ion battery manufacturing segment.

4.1.3.1 Investment and Technology

We have already seen that for FY19, more than INR 8,500 crores of secondary Li-ion cells were imported in to the country. The huge consumption of Li-ion batteries in mobile phones provides a ready market for the Li-ion cell plants. However, our analysis suggests that total investments on the ground, based on the three firms that are setting up their plants in India, in the Li-ion cell manufacturing segment may not be more than INR 3000 crores. This is in stark contrast with the investment in the established lead acid battery segment, which may be in multiples of INR 3000 crores. We believe that the investments are low to moderate in this segment due to the following reasons:

a) Almost all the firms listed in Table 4.4 plan to license technology for their plants. The biggest consumer for Li-ion secondary cells, currently, is the mobile phone segment. Given the competition in the global mobile phone segment, getting in to the supply chain of mobile phone industry, for the firms listed in Table 4.4, requires a scale and cost that will be very difficult to achieve in India. Moreover, the PMP for mobile manufacturing does mentions the requirement of setting up of battery pack assembly units in the country and not cell manufacturing units. Thus, mobile phone companies and their suppliers find it economical to import secondary cells from their huge manufacturing facilities abroad and assemble it here. We recommend that the government consider cell manufacturing for mobile batteries as a part of its PMP in mobile manufacturing.
b) Li-ion battery technology is a recent technology that is yet to mature. There are various chemistries that are currently competing against each other to emerge as the dominant industry standard. The cost and performance of each chemistry varies but follows the general thumb rule that lower cost implies lower performance. Given the amount of heat generated in a battery, efforts are ongoing to make the Li-ion fire safe especially if the ambient temperature goes above 45 degree Celsius, which is prevalent in many parts of India. Needless to add better performing chemistries also have higher license fees. Given the current flux in Li-ion technology and the relatively low demand for Li-ion batteries in the other segments, investors are waiting for the right signals[34] to invest in manufacturing facilities.

4.1.3.2 Status of domestic technology

Two research institutions in the country – Central Electro-Chemical Research Institute (CECRI), & Indian Space Research Organization (ISRO) – have successfully demonstrated independent technologies to produce Li-ion secondary cell in the country.

[34] FY20 Budget has provided the right signal.

These research institutions have also successfully transferred their technology to local firms. CECRI technology can be used for energy storage applications, however, more efforts are required before the process to manufacture Li-ion cells using CECRI technology is scaled up to industrial level. Firms that have obtained ISRO technology are also pilot testing the process before scaling it up. If these domestic efforts of scaling up are supported by policy now, then in future our country can save licensing fees which will be in the form of outflow of dollars.

4.1.3.3 Sourcing of raw material

As the NITI Aayog-RMI[35] study notes, "India has small reserves of key minerals required for lithium-ion (Li-ion) batteries. India does not have reserves of some of the most important Li-ion components including lithium, cobalt, nickel, nor, for that matter, of the copper used in conductors, cables, and busbars. Hence, reliable supply, not just of the raw materials but also of processed functional materials used in the anode and cathode, poses a challenge." In our interaction with stakeholders, some pointed out that they have contracts which make their suppliers responsible for the supply of Lithium and other active materials. However, few stakeholders also pointed out to the fact that China has moved at a faster pace in taking control of reserves in Latin America and Africa. In this context, the government's assurance of helping domestic producers secure their Lithium supplies is re-assuring and confidence building.

4.1.3.4 Policy push required

Based on our analysis, we recommend the following:

- The government should support the scale up of domestic technology by stepping up R&D funding, specifically for developing battery technology and alternate battery chemistry.
- A recycling policy of Li-ion batteries used in India should be announced soon as it will generate more activity and help domestic manufacturing when the recycled lithium finds its way back to battery manufacturing plants.
- Given the range of ambient temperatures in the country, automobile regulatory authorities should come up with fire safety standards for all battery manufacturers.

[35] India's Energy Storage Mission: A Make-in-India Opportunity for Globally Competitive Battery Manufacturing. NITI Aayog and Rocky Mountain Institute, 2017. http://www.rmi.org/Indias-Energy-Storage-Mission

4.2 Hydrogen Fuel Cell

4.2.1 Introduction

Hydrogen fuel cell technology is another promising clean technology, which has the potential to cater to our energy requirements as well as reduce emissions of undesirable gases. A fuel cell is an electrochemical cell that can provide electricity as long as the fuel required for the cell is supplied. Electrode in a fuel cell works as a catalyst and unlike a battery does not get exhausted. India has been quite active in the Hydrogen space from 2006 when it set up the National Hydrogen Energy Board with a roadmap. In order to appreciate the work India has done with regard to hydrogen fuel cells we need to first list out their types and respective applications, in order to understand the importance of each type. The methodology followed to analyse the Hydrogen Fuel Cell segment is similar to the one followed for the EV chapter.

4.2.2 Types of Hydrogen Fuel Cell

As per the report on fuel cell development in India[36], Low and High Temperature Proton Exchange Membrane Fuel Cell (LT- & HT-PEMFC), Direct Methanol & Ethanol Fuel Cell (DMFC & DEFC), Phosphoric Acid Fuel Cell (PAFC), Alkaline Fuel Cell (AFC), Molten Carbonate Fuel Cell (MCFC), and Solid Oxide Fuel Cell (SOFC) are the hydrogen fuel cells that have been developed so far. Table 5 shows the primary applications of each of these fuel cells.

Table 4.5: Different types of Hydrogen Fuel Cells

Type of cell	Primary Applications
PEMFC	Automotive and stationary power
DMFC	Portable power
AFC	Space vehicles and drinking water
PAFC	Stationary power
MCFC	Stationary power
SOFC	Vehicle auxiliary power

Source: Basu (2015)[37]

PEMFC technology that can be used for automotive and stationary power applications, as per our understanding, seem to be the technology that is market ready. Commercialisation of this technology has occurred in Japan, United States, Canada, and Germany. Many global automotive companies have a fuel cell vehicle either in developmental or the testing stage, some have even commercial models. PAFC

[36] Report on Fuel Cell Development in India, Prepared by Sub-Committee on Fuel Cell Development of the Steering Committee on Hydrogen Energy and Fuel Cells, Ministry of New and Renewable Energy, GoI, June 2016.
[37] Basu, S. 2015. Proton Exchange Membrane Fuel Cell Technology: India's Perspective. Proc Indian Natn Sci Acad, 81 (4), 865-890. DOI: 10.16943/ptinsa/2015/v81i4/48301.

technology has been used for power generation in the range of 100-400kW in the US and Japan. AFC is a low-cost technology that was used to provide power and drinking water in Apollo spacecrafts. However, with time the output of AFC reduces due to contamination and increases the cost. Demonstration of SOFC technology to produce power up to 25 kW has been going on for some time now in countries such as US, Canada, Germany, UK, Denmark, Japan, and Australia. Development and testing of MCFC technology have just been embarked in a few places globally, thus this technology will take some time to mature.

4.2.3 Hydrogen Fuel Cell work in India

Table 6 shows a snapshot of the work done in Hydrogen Fuel cell technology across various organisations in the country.

Table 4.6: Hydrogen Fuel Cell R&D in India

Organisation	Focus Area	Achievements
CECRI	PEMFC, DMFC, Hydrogen Generation	1kW PEMFC stack.
Centre for Fuel Cell Technology	PEMFC, Hydrogen Generation	PEMFC stacks up to 5 kW, Grid independent power systems (3 kW), Fuel cell systems for transport applications with Mahindra & Mahindra and Reva.
Central Glass and Ceramic Research Institute (CGCRI)	SOFC	Electrode and membrane materials for high performance SOFCs and Low Temperature SOFC. 400 W SOFC stack developed.
Spic Science Foundation	PEMFC, DMFC, Hydrogen Generation	5 kW PEMFC stacks, 250 W DMFC Stack, PEM-based water and methanol electrolyzers, fuel cell based stationary applications such as UPS.
IIT Bombay	PEMFC, DMFC, IT-SOFC, Hydrogen Generation	PEMFC system development, Catalysts for PEMFC, Working on HT-PEMFC and IT-SOFC, Hydrogen storage in complex hydrides
IIT Delhi	PEMFC, DAFC, Hydrogen Generation, SOFC	DEFC with power density of 70 mW/sq.cm, electrode-catalysts, Direct Glucose fuel cells. Non-PGM ORR catalyst and micro fuel cell for MEMS. Anode materials for hydrogen generation using PEM water electrolyzer, working on anode material for Direct Hydrocarbon SOFC and low temperature SOFC.
IIT Madras	PEMFC, DMFC, SOFC, Hydrogen Storage	DMFC with non- noble cathode catalyst. Non-PGM catalyst for PEMFC, SOFC material research
National Chemical Laboratories	PEMFC	Thermally stable PBI membranes, Demonstrated a 350 W (15 cell) PBI-based PEMFC stack

Organisation	Focus Area	Achievements
Naval Materials Research Laboratory (NMRL)	PAFC, PEMFC, Hydrogen Storage	700-1000 W capacity PAFC-based UPS/generators 1.2 kW PAFC system integrated in an electric vehicle developed under DRDO-REVA joint project. Development work on PEMFC and SOFC and hydrogen generation by autothermal reforming.
Bhabha Atomic Research Centre	SOFC, PEMFC	SOFC material and tubular SOFC under development
Banaras Hindu University	Hydrogen Storage, Hydrogen IC Engines, Hydrogen Production	Developed storage materials with improved storage capacity. Converted existing petrol-driven IC engines to operate with hydrogen as fuel.
Indian Institute of Science	PAFC, DMFC, PEMFC	PAFC with power density value of about 560 mW/sq.cm.
Mahindra & Mahindra	Hydrogen IC engine	Hydrogen powered 3W vehicle.
Tata Motors	Fuel cell technology for mobility	Working on a fuel cell based city bus, projects on using hydrogen blends as fuels. Tata teleservices involved in demonstration of fuel cell technology for mobile tower backup power.
Indian Oil Corporation	Hydrogen infrastructure, hydrogen for transport sector	Setup hydrogen dispensing stations. HCNG usage in 3-wheeled vehicles and light duty buses.
Reliance Industries Limited	PEMFC for stationar applications, SOFC	Established a fuel cell R&D lab in Mumbai.
Reva/Mahindra Electric	Fuel cell based small cars	Developed a car with NMRL with 1 kW PAFC stack on board. Involved in a similar project with CFCT.
Bharat Heavy Electricals Limited	PAFC, PEMFC, SOF	50 kW PAFC power plant, 1 kW PEMFC modules and a 3 kW PEMFC power pack. Partner institute in the development of a 5 kW PEMFC system.
ISRO	Fuel Cell power systems	Power systems based on a 100W PEMFC stack tha operates on hydrogen and air and delivers 12V D required for the functioning of Automatic Weathe Stations.

Source: Basu (2015)[38]

As per the government report on fuel cell development, there are a large number of groups that are engaged in R&D and demonstration activities of PEMFC but there is some way to go before PEMFC technology produced in the country can be

[38] Basu, S. 2015. Proton Exchange Membrane Fuel Cell Technology: India's Perspective. Proc Indian Natn Sci Acad, 81 (4), 865-890. DOI: 10.16943/ptinsa/2015/v81i4/48301.

commercialised. NMRL has transferred its PAFC technology to a leading private engineering firm, which has manufactured around two dozen of 3kW units for captive use of Defence Research and Development Organisation (DRDO). With respect to AFC technology, very limited basic research has been carried out few academicians. As can be seen from the table, demonstration of DMFC technology has been carried out by few organisations. The focus now is to demonstrate the same using DEFC. CGCRI has demonstrated its SOFC technology by developing a 400W stack.

As can be seen from the table private firms are also working in the Hydrogen fuel cell segment. Tata Motors for example has already demonstrated its PEMFC technology for inter-city buses[39]. Recently Tata Motors in collaboration with Indian Oil Corporation carried out a testing of its Hydrogen Fuel Cell bus[40]. This project had partial financial support from Department of Science & Industrial Research, Ministry for Science & Technology and the Ministry for New and Renewable Energy. Another landmark feature for this project was that the bus was fuelled at the country's first hydrogen dispensing facility at R&D Centre of Indian Oil in Faridabad. Tata Motors have also collaborated with ISRO to develop this bus.

Basu (2015) notes that fuel cell power systems designed and developed by ISRO were installed at Shillong and Thiruvananthapuram for powering Automatic Weather Stations (AWS). The AWSs work in fully outdoor conditions and are many of them are located in remote areas without grid power. The units are configured to operate in fully autonomous mode and are normally powered by solar panel-battery combination. The AWSs located in areas with long spells of rain and winter, generally, suffer from insufficient solar intensity for certain periods. This renders them non-functional since the battery tends to run out of charge due to insufficient recharging. Similarly, those located in high altitudes and latitudes are also prone to chronic low solar intensity resulting in under performance of the power system. ISRO designed and developed a Fuel Cell power system that operates on the stored hydrogen gas and is fully free of all the constraints mentioned above. The first unit was installed during April 2013 and the systems were designed to work in fully unmanned and autonomous mode. The systems make use of hydrogen from standard gas cylinders and ambient air, directly, and deliver stable electrical output.

This discussion makes it amply clear that, though we may not be market ready, we are developing capabilities in the Hydrogen Fuel cell technology space, which needs to be given all the support it requires.

4.2.4 Way forward

Our interaction with stakeholders and the discussion above makes it clear that government organisation as well as private firms are developing capabilities in the

[39] Yogesha, S.A., Brahmbhatt, S., Raja, M., Arikapudi, S. et al., "Development of Hydrogen Fuel Cell Bus Technology for Urban Transport in India," SAE Technical Paper 2019-26-0092, 2019

[40] https://www.financialexpress.com/auto/car-news/tata-motors-indianoil-corporation-flag-off-countrys-first-hydrogen-fuel-cell-powered-bus/1096895/

Hydrogen Fuel Cell technology space. We have demonstrated and manufactured (at a very small scale) stationary power and automotive systems. However, given the current level of material availability and manufacturing expertise, we have to import many critical components – for example, cooling pumps – for these technology demonstrations. In other words, engineering inputs and infrastructure for producing these technological systems in large numbers for trials /demonstration are lacking. Moreover, our technology efforts in the mobility segment are yet to attain maturity; we are yet to develop capabilities to miniaturise the systems we have already developed. Thus, it may take some time to commercialise these technologies. As the government report on fuel cell development puts it "In India, development of fuel cells is not reached to the stage, at which they may be taken up for manufacturing. Therefore, a strategy is required at national level to address the issues like balance of system development, system integration, manufacturing R&D for fabrication of repeat components and their demonstration." In the light of the above, we will like to make the following recommendations as the way forward:

- A very good entry to the Hydrogen Fuel Cell economy will be to deploy ISRO's fuel cell power systems – either through technology transfer or PPP – for appropriate end applications across the economy. This will kick start demand for Hydrogen and, hopefully, give the required push to set up appropriate supply infrastructure not only for Hydrogen but also for the components that go in to this technology.
- Insisting on early implementation of Hydrogen Fuel Cell technology in mobility will benefit foreign technology and firms. This might also suppress local technology development efforts. The government should try to accelerate local technology development by suitable deadline-based incentives, which will also give the required push to local technology development.

5. Recommendations

India's process of urbanisation is taking place at a time when the global community is increasingly moving towards green technology and reducing carbon emissions. This study reviewed the metro rail sector as a contributor to urban mobility, and the potential of the EV sector to contribute to the same. There are certain findings from our case studies and interactions with stakeholders in both sectors, which have been elaborated on in detail in the preceding chapters. We have therefore categorised our recommendations by metro rail, electric vehicles, and battery technology and presented them by category in this final chapter.

5.1 Metro Rail

This study has found that metro rail projects, while useful in terms of providing mass urban mobility and contributing to reducing carbon emissions, are capital intensive infrastructure projects. As a result, they rarely bring in profits to any of the involved stakeholders. This is a pattern observed in metro rail projects across the globe. While metro rail projects can scarcely be made more profitable purely through policy, there are some reforms which could help reduce project costs and time taken, along with managing risk-sharing between public and private partners. Our recommendations focus on these aspects.

5.1.1 Recommendations for PPP Contracts

- PPP contracts or concession agreements suffer from various issues, including ambiguous language and dependence on legacy contract templates (by the government). These issues must be addressed by introducing watertight provisions, modern legal terminology, and a willingness to negotiate contract terms without burdening either partner.
- PPP contracts for metro rail construction must provide easier exit clauses for the private sector entity. Alternatively, the contract could include a sovereign guarantee from the government, which would help reduce the credit risk burden of the private partner.
- Instead of keeping to the prevailing L1 (or lowest bidder) model for the bidding process, the government should allow for quality and cost based (QCB) assessment, for technology intensive infrastructure projects such as metro rail. It would be beneficial for the government to consider the L1+T1 model, where the bidding is determined not merely on competitive price, but also on the best technology offered at the quoted price point.
- All official permits, land acquisition, and clearances must be obtained by government agencies and provided to the private sector partner prior to commencement of construction. This is in the interest of ensuring that a realistic timeline is followed, without attendant delays from government agencies, thereby preventing cost overruns and revenue shortfalls. If required, this should be made part of the contract terms of the concession agreement.

5.1.2 Recommendations for Revenue and Monetisation

- The establishment of the 3P India institute to provide support to mainstreaming PPPs in India is a welcome step. The functions of this institute can include – feasibility studies, planning and project execution, as well as re-evaluation of the need for metro rail projects in Tier I and Tier II cities. This is extremely important in light of the fact that metro rail projects, while helpful, are in fact loss-making projects. Therefore, it is important that only those cities that truly need and have the space for them, develop such infrastructure.
- A common issue across all metro rail case studies was inaccurate estimation of passenger traffic (refer section 2.9.2), we suggest that estimation of traffic for metro rail factor in area-wise demographics, per capita income, and last mile connectivity to more accurately predict the propensity of the average commuter to choose metro rail over other modes of public transport.
- Certain metro stations have sub-stations in their vicinity which are designed to supply auxiliary (33kV) and traction (25 kV) power for metro lines. Since non-fare revenue is what keeps private sector partners afloat in metro rail projects, we recommend that wherever land parcels are available close to sub-stations of metro rail, that these be earmarked for development of charging stations. Additional electric capacity can be harnessed by installing solar panels at feasible locations. Leasing land for charging stations, will help the metro rail project make some money, and provide ease of access to charging infrastructure for commercial cab fleets, buses, and even individuals.

5.2 Electric Vehicles

While the government's policy push for faster adoption of EVs is a step in the right direction, ground realities in terms of resources and implementation must be considered. Our recommendations address some of the issues that EV adoption might face, and provide a way forward to facilitate EV uptake, by identifying the relevant areas in which policy interventions are required.

5.2.1 Overarching Recommendations for EVs

- The transition to EVs will impact the ICE automobile segment, including existing infrastructure, employment and skill sets. There is a need to quantify this impact, and study it further to identify solutions to manage the transition. While it is unlikely that there will be a complete transition to EVs even in the long term, any shocks to existing industry and supply chains must be identified and addressed beforehand.
- Irrespective of the level of EV adoption, charging EVs will require a significantly greater volume of electricity than is currently generated (refer Box 3.2). In order to meet this additional demand, the power sector will have to exponentially increase electricity production. This additional burden cannot possibly be borne entirely by thermal or hydro power. This is where renewable energy sources, such as solar power need to be considered as a vital part of the energy mix for charging

infrastructure. Power sector reforms, especially in terms of dispatch loads, standardisation of charging infrastructure, adjusting transmission and distribution based on additional demand for charging EVs on domestic connections, will be key to the success of EVs.

- The 'well to wheel' equation of EVs is still fossil-fuel based, given that most of India's energy needs are met from thermal power. In order to change this, solar power may have to be brought in as the primary source of energy for charging EVs. This will require careful mapping, investment, and regulation, especially in terms of charging infrastructure.

5.2.2 Recommendations for Electric 3Ws

- Commercial 3Ws ferrying cargo should be encouraged to transition to electric, as this will reduce fuel costs for them as well as pollution caused by these largely diesel-run automobiles.
- Cycle rickshaws can transition to electric technology, as it will help increase their range and revenue, with only a small capital investment.
- Passenger 3Ws in terrains such as mountains, hills and deserts can transition to electric, as it will reduce the need to transport fuel over and to such dangerous terrains, thereby addressing fuel supply and safety issues.

5.2.3 Recommendation for Electric 2Ws

- Electric 2Ws are the most viable segment for quick adoption in the Indian market, given their competitive purchase prices and minimal lifecycle costs (refer Box 3.1). Therefore, we recommend that a 2W specific subsidy (refer section 3.7 for details) be introduced within the ambit of FAME India, to spur demand and sales. This will not only help increase visibility, but also bring in affordability through competitive pricing (as demand goes up, prices will subsequently come down).

5.3 Battery Technology

- Research and development (R&D) funding to push domestic technological innovation, especially for developing alternate battery chemistry should be stepped up. Not only will this provide a foundation for domestic IPR to be built, but also help contribute to bringing down the prices of batteries and subsequently EVs. The latter will prove to be crucial for EV adoption. Alternatively special research grants or long-term research loans at special rates can be introduced to support R&D specifically for domestic start-ups.
- Since battery technology and chemistry are still evolving, the relevant automobile regulatory body needs to consider drafting safety, quality, and standardisation regulations for EV batteries.

APPENDIX I

Localisation or Value Addition in Electric Vehicles

India already has a thriving automobile sector, thus with respect to the mechanical, plastic, and certain electric parts, local supply chain is available. Table 1 shows a partial list of firms that supply components or are in the process to supply components to the EV segment.

Table 1: Component supplier to Electric Vehicle manufacturers

Company	Components*	Factory*
ACME Cleantech Solutions Pvt. Ltd.	Lithium batteries from cell level; stationary storage solutions – solar power; mobility –battery swapping and charging stations for EVs i.e. 2W, 3W and 4W.	Pantnagar, Uttarakhand
Advance Cable Technologies Pvt. Ltd.	Different types of cables; Exterior for EV	Bengaluru
BASF Catalysts India Pvt. Ltd	Cathode Active Material	--
Bosch Group of Companies	Motors, generators, braking system, horn, batteries, automotive belts, filters, charging coils, etc.	--
Delta Electronics (India) Pvt. Ltd.	EV charging solutions – AC EV charger, DC quick charger Site Management System; Energy Storage System – Power Conditioning System; Li Battery Portfolio – cells, modules, cabinets and containers	Rudrapur, Uttarakhand; Gurgaon, Haryana
Elektrisola India Pvt. Ltd.	Enamelled Copper Wire	--
Infineon Technologies India Pvt. Ltd.	Body and comfort; Chassis, safety and ADAS; powertrain automotive security; active antenna; hybrid and electric vehicles – inverter, converter charging solutions	R&D centre in Bengaluru
Exicom Tele-systems Ltd.	Power systems, Hybrid systems, rectifiers, controllers Li-ion battery solutions and charging solutions	Solan, Himachal Pradesh; Gurgaon, Haryana

Company	**Components***	**Factory***
Fusion Power System	Li-ion battery, Motor controller, charger, converter,	New Delhi; Gurgaon, Haryan
Global Powersource India Pvt Ltd.	Automotive and other kinds c batteries	Kolkata, West Bengal
Henkel Adhesives Technologies India Pvt. Ltd.	Adhesives, sealants, advanced driver assistance systems	--
LORD India Pvt. Ltd.	Adhesives, coatings, motion management devices, and sensing technologies	Nashik, Maharashtra
LPS Bossard Pvt. Ltd.	Fasteners, screws, nuts, washers	Rohtak, Haryana
Lucas-TVS Limited	Alternator, wiper, ignition coi starter motor, blower motor for HVAC, engine cooling fan	Uttarakhand; Rewari, Haryana, Maraimalai Nagar, Tamil Nadu; Chakan, Maharahtra; Puducherry; TV Koil; Padi
Marsili India Pvt. Ltd.	Motors, coils	--
Minda Corporation Ltd.	Ignition switch cum steering lock, fuel tank cap, latches and cable, tool box, helmet lock, seat lock, etc	Pune, Maharashtra; Pant Nagar, Uttarakhand; Aurangabad, Maharashtra; Noida, Uttar Pradesh
Napino Auto & Electronics Ltd.	Battery chargers, motor controllers, motors, BMS, starter generator	Manesar, Bhiwadi, Haridwar, Halol
Nitto Denko India Pvt. Ltd.	Adhesive tapes, films, wiring solutions for automotives	Manesar, Gurgaon, Haryana
OKAYA Power	Inverter batteries, VRLA batteries, Lithium batteries	Baddi, Himachal Pradesh
PPAP Automotive Ltd	Car body-related components both interior and exterior. Lik mouldings and linings for roof, wind shield, windows, doors, dashboard, etc.	Noida, Greater Noida, Chennai and Pathredi, Rajasthan
Roots Industries India Limited	Signalling device, Automotive Lamps, Friction products, Batteries, Alternators, Starter motors, Reverse sensors	Coimbatore, Tamil Nadu
SEG Automotive India Pvt. Ltd.	Boost Recuperation Machine, Generators, Starter Motors	Hassan, Karnataka
Sehgal Elmoto Ltd. (no website; unsure about the information)	Mopeds, scooter, motorcycles utility, quadricycle	Pimpri-Chinchwad, Maharashtra

Company	Components*	Factory*
SUNBEAM Auto Pvt. Ltd.	Die Casting, pistons	Gurgaon, Haryana
Sundram Fasteners Ltd.	High tensile fasteners, cold extrusion, hot forged parts, powertrain components, radiator caps, pumps and assemblies	Krishnagiri, Chennai, Rudrapur, Pant Nagar, Kanchipuram
TATA Chemicals Ltd.	Allied chemicals	Mithapur, Gujarat; Cuddalore Tamil Nadu
Trinity Energy Systems Pvt. Ltd	Meters, transformers, power capacitors,	Vadodara, Gujarat
Trontek Group	Batteries – Lithium ion and Lead Acid	Rajasthan
Versatile Auto Components Pvt. Ltd.	Bike front beeding, side steps, suspension springs, leg guard engine guard	Medak, Telangana

**from secondary research; - - information unavailable Source: SMEV*

It is clear from the table that quite a number of local firms do supply components to the EV manufacturers. However, in electric vehicles the critical technology that drives the vehicle is electric motor, which is powered by the battery, and controlled by electrical and electronic controllers. It is in these three components that we are yet to develop technological capabilities. There is to some extent assembly operations that are on, for example - local assembly of Lithium ion battery pack does happen but we are yet to have a cell manufacturing unit in the country. Lithium ion cells are imported and battery packs are then made from these cells in these battery assembly units, a few of which have been named in Table 5. Our interaction with numerous stakeholders suggests that for a 2W with Lithium ion battery, the maximum value addition or localisation achieved as a per cent of cost is 57 per cent. In the 3W category, Lead acid batteries rule the roost with more than 98 per cent of the market being captured by it. Localisation achieved by such 3W, as a per cent of cost will be more than 85 per cent. Lithium ion batteries are preferred in 4W and electric buses. We estimate the localisation achieved by 4W, as a per cent of cost to be around 50 per cent. Finally, for electric buses, depending on the technology used, the localisation achieved as per cent of cost is in the range of 30 to 48 per cent[41].

Despite current value addition being at the level that it is, stakeholders are confident about their capabilities of increasing localisation once the market attains a critical size, after which, probably, there will be no turning back. Our respondents felt that once demand grows, the automobile story can be repeated in EVs.

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[41]To give these numbers some perspective, as per OECD Trade in Value Added estimates, the value addition in 2011 for motor vehicles exported from India was around 37 per cent. Needless to add, these value addition numbers are not comparable with our numbers for a variety of reasons.

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