A case study on potential impact of Electric Vehicle charging for an electricity distribution utility in India

Bhawna Tyagi[1] Chandana Sasidharan[2*] Shyamasis Das[3]

[1,2,3] Alliance for an Energy Efficient Economy (AEEE)
New Delhi, India

[1] bhawna.tyagi34@gmail.com [2]chandana.sasidharan@gmail.com [3] shyamasis@aeee.in

***Abstract*— In India, electric mobility is currently at its infancy. At the crossroads of this possible market disruption is the electricity sector. While additional electricity sales due to Electric Vehicle (EV) charging would help increase the revenue volume of an electricity distribution utility, charging demand may accentuate the peak load of the service area and have a bearing on the cost of power procurement for the distribution utility. Thus, it becomes essential to evaluate the additional electricity demand from EV adoption, its possible pattern and contribution to base and peak load. This will enable DISCOMs to operate its distribution network efficiently and the State Electricity Regulatory Commissions to introduce appropriate instruments to avoid any negative impact on the electricity supply. This study models the peak and off-peak contribution from EV charging and estimates the impact on the cost of power procurement of electricity utilities in a state. The study finds that EV charging significantly increases the energy consumption from 12 AM to 6 AM. The study also finds that the number of EVs which can potentially impact the average cost of supply varies across different DISCOMs.**

Keywords- Electric Vehicle; Peak Load; Energy Demand; DISCOM; Tariff.

I. INTRODUCTION

The emerging Electric Vehicle (EV) sector in India is found to be quite distinct from the electric mobility landscape in matured markets. Unlike in those countries, India is witnessing significant traction in electrification in the two-wheeler (2-W) and three-wheeler (3-W) segments, which constitute a significant share in the current vehicular mix [2]. As a matter of fact, 2-Ws and 3-Ws constitute about 61% of the petrol sales and 28% percent of the diesel consumption respectively [1]. With only 0.06% car market shared by EVs (both battery electric vehicles (BEV) and plug-in hybrid electric vehicle (PHEV)) until 2017, the uptake of electric technology in the four-wheeler (4-W) segment has been slow [3]. However, with growing support from the policymakers towards e-mobility, more electric 4-Ws are envisaged on roads. These apart, many of the Indian cities are planning to introduce electric buses for intra-city transport on the back of the announcement of FAME-II (Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India) scheme [4][5] [6].

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Charging infrastructure is the backbone of e-mobility. Availability of adequate charging stations or points is a prerequisite for scaling up EV adoption. The charging need can be catered by public EV charging stations or private charging. To meet this charging demand, it is essential to ensure that the capacity of the electricity distribution companies (DISCOMs) is able to cater to the increase in electricity demand from EV charging. While additional electricity sales due to EV charging would help increase the revenue volume of a distribution utility, charging demand may accentuate the peak load of the service area and have a significant bearing on the cost of power procurement for the distribution utility. This apart, it may incur additional cost for network upgradation. Thus, it becomes essential to estimate the additional electricity demand from EV adoption, their possible pattern and contribution to base and peak load. This will enable DISCOMs to operate its distribution network efficiently and to further encourage EV adoption by the public. This exercise is also important in developing frameworks to enable tariff setting for EV charging from India.

Understanding the probable daily pattern of EV charging and its contribution to the peak and off-peak load is the starting point of this assessment. Following a comprehensive review of existing literature, the study models the additional energy consumption and peak demand in different EV charging scenarios considering the charging requirement across EV segments (2-W, 3-W, 4-W and bus). Subsequently, the impact on the cost of power procurement of DISCOMs in a state is evaluated and presented as a case study.

II. ELECTRIC VEHICLE CHARGING

A. Peak and Energy Demand

Large-scale EV adoption will create both opportunities and challenges for the electric power sector. In terms of challenges, charging of EVs could cause a sudden spike in peak demand thereby putting stress on the local distribution infrastructure. Thus, it is important to consider the potential electricity and power demand from EV adoption in the utility resource planning processes. This requires an estimation of when, where, and how much EV will charge, and allows utilities to adjust their load projections to incorporate additional load from EVs [7]. There are only a few studies which estimated the impact of EVs on peak and energy demand in the case of India. A study by Lawrence Berkeley National Laboratory (LBNL) estimated that the increase in additional load from BEV charging by 2030 is only 82 TWh/yr (i.e. about 3.3% of the total electricity load in India) if Government of India achieves its 100% target of electrification of vehicles [8]. The contribution of BEV to peak-load is estimated to be 23 GW i.e. about 6% of the total peak load by 2030 (402 GW). If all parameters are varied by +/-25%, the overall range for BEV energy consumption in 2030 is 62–103 TWh/yr (2–4% of the non-BEV energy load) and for peak load is 19–39 GW (5–10% of the non-BEV peak). They have also calculated that BEV charging load could earn about Rs 70,000 Cr/yr ($10 billion/yr) of additional revenue for utilities by 2030 assuming marginal tariff of INR 9/kWh. The crucial assumption considered by the study is that travel demand will remain constant till 2030 and all BEV owners have access to public charging infrastructure.

The study by Forum of Regulators (FoR) estimated that a baseline 50% loaded commercial feeder can absorb up to 20% of additional EV load from fast charging [9]. Similarly, the residential feeder can safely handle a ratio of 60%:40% from the residential load and EV load (fast charging) respectively. However, they estimated that the threshold should be 20% in case of peak co-incident charging scenario. The impact of slow charging on both the feeders was negligible. The study calculated that if investment in the EV charging stations socialized to all the consumers then tariff increase varies from INR 0.0007 kWh to 0.0040 kWh. However, the impact on tariff increase is substantial if passed only to EV users and varies from INR 0.1790 kWh to 0.2810 kWh.

Ali and Tongia concluded that EVs could add up to 50 per cent to peak demand and could add 3% points to peak demand growth between 2017 and 2030. Total electricity demand for EVs may vary between 37 and 97 TWh under 33% and 100% penetration of EVs in sales by 2030, considering only intra-city (urban) passenger travel [10]. If all the PHEV use a similar amount of electricity as BEV then aggregate demand is less than 9 BUs. Vehicle category wise electricity consumption in 2030: 2W varies from 5TWh to 16 TWh with mileage 54.4 km/kWh; 3W varies from 8TWh to 16 TWh with mileage 19.2 km/kWh; 4W Car varies from 9TWh to 26 TWh with mileage 9.4 km/kWh and Taxis varies from 4TWh to 10TWh with mileage 9.4 km/kWh and buses varies from 11TWh to 28TWh with mileage 0.8 km/kWh.

The three studies carried out analysis using the Government of India targets for electrification and developed results from a macro perspective based on EV target achievements. In analyzing the contribution to peak and energy demand, the electric bus has been misrepresented except in the study by Ali and Tongia (2018) [10]. The battery size of EV buses varies from 100 kWh to 350 kWh, it could cause a sudden spike in peak demand [4]. Thus, it makes it crucial to do category wise contribution to energy and peak demand. This has been reflected in a study by Ali and Tongia (2018). However, the study does not provide a comprehensive methodology to estimate category wise contribution of other EV categories. There is a need to evaluate the EV charging at a micro level, considering the contribution from major EV segments. EVs represent a significant addition to demand at a micro level compared to the macro level [7]. Thus, it makes the case to study impact at DISCOM level of EV adoption.

B. Pattern of Electric Vehicle Charging

Electric Power Research Institute (EPRI) studied the charging pattern of the Salt River Project (SRP) service territory in Arizona [11]. They have considered both BEV and PHEV vehicles in their analysis. Vehicle data logging devices were used to track 100 EVs during driving and charging events to acquire minute-level, high-resolution data. Approximately 81% of charging occurred at home, while only ~3% of charging occurred in public charging locations. Factors that affect EV charging consumption are driving habits as well as the ambient temperature, which can affect battery chemistry and the auxiliary power needed for air conditioning and heating. They also found that temperature variation does not alter the load shapes significantly.

India specific EV charging pattern is discussed only in one study by OLA Mobility Institute published in 2019 to understand the operational challenges faced by electric mobility project in Nagpur [12]. Their study observed that power demand of cab drivers at charging stations peaked during noon time (12pm-4pm) and at night (8 pm- 12 am) - with 63.5% of charging happening at this time. However, the pattern of EV charging was limited to cab fleet. There is not much precedence in terms of EV category wise charging pattern.

III. CASE STUDY

As EVs represent a significant addition to the load and energy demand at the distribution level compared to the transmission level, a case study is performed at DISCOM level [1]. The case study intends to evaluate the impact of EV penetration at distribution companies (DISCOMs) in Delhi. Due to ease in data availability, the four major DISCOMs of Delhi has been considered i.e. BSES Yamuna Power Limited (BYPL), BSES Rajdhani Power Limited (BRPL), Tata Power Delhi Distribution Limited (TPDDL) and North Delhi Municipal Corporation (NDMC).

A. Data and Methodology

The electricity data is collated for the year 2018-19. Load curve data for DISCOMs are taken from State Load Despatch Centre Delhi. Other data is retrieved from 2018-19 tariff order of DISCOMs. The rated charger power and battery capacity are taken from Ministry of Power (MoP) and Faster Adoption and Manufacture of (Hybrid and) Electric Vehicles (FAME) guidelines. The excel based model is used to study the EV charging pattern and evaluate the impact on Energy Demand, Peak Power and contribution to Actual Cost of Supply (ACoS) [5][6][13][14][15][16][17].

B. Assumptions

The study has taken a baseline of 1100 EVs where 100 are electric buses to study the peak and energy demand. The remaining 1000 EVs is sub-divided into two-wheeler (2W), three-wheeler (3W) and four-wheeler (4W) category using the proportion in the Niti Aayog-RMI study [18]. It is assumed that bus charging for intra-city transport will happen at the depot during nighttime [4]. For other EV categories, the both daytime and nighttime charging is accounted for. A certain percentage has been allocated between public charging during day and home charging at night maintaining the overall assumption that the bulk of charging would happen at home. It is assumed that the depth of discharge of the battery is only 70%, and corresponding charging energy demand is evaluated with an efficiency factor of 95%. The battery sizes and capacity of chargers are assumed according to market norms and government guidelines where-ever applicable and is available in annexure.

C. Electric Vehicle Charging Scenarios

The charging pattern of the EV could vary according to the convenience of the EV user. Hence three EV charging scenarios have been considered to study the EV charging pattern, based on the most extreme, most probable and average charging power requirement.

- Scenario I: If all vehicles are starting charging at the same time.
- Scenario II: If 50% of vehicles are starting charging at the same time.
- Scenario III: If 30% of vehicles are starting charging at the same time.

Figure 1, 2 and 3 represent EV charging for 2W, 3W and 4W categories both at public charging stations as well as at residences in Scenario I, II and III. 4W charging takes more time in residences compared to 2W and 3W category due to the slow charging process of larger battery. In case of public charging stations, 4W contributes the maximum to power demand under all the three scenarios. Observably, the charging power and energy demand increase is highest at night in all three cases.

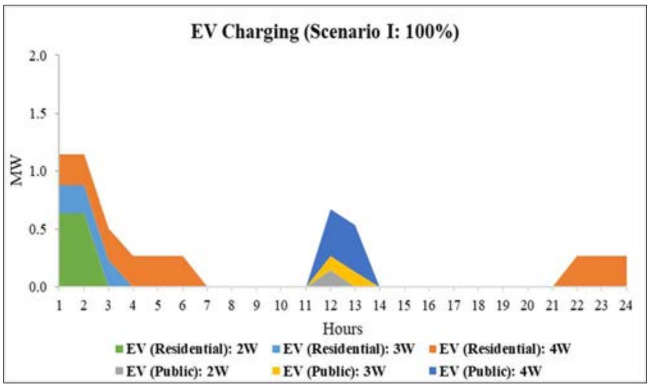

Figure 1. Scenario I: 100% EV Charging (excluding Bus)

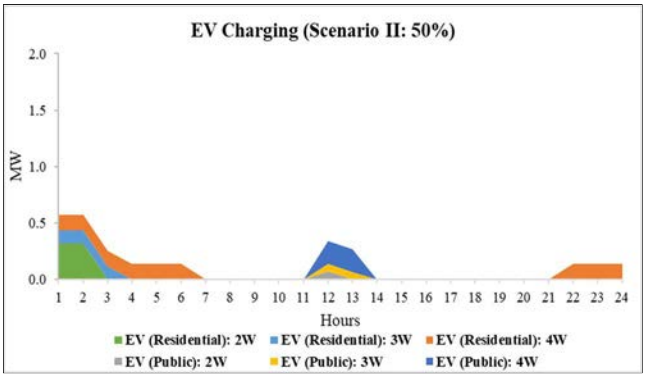

Figure 2. Scenario II: 50% EV Charging (excluding Bus)

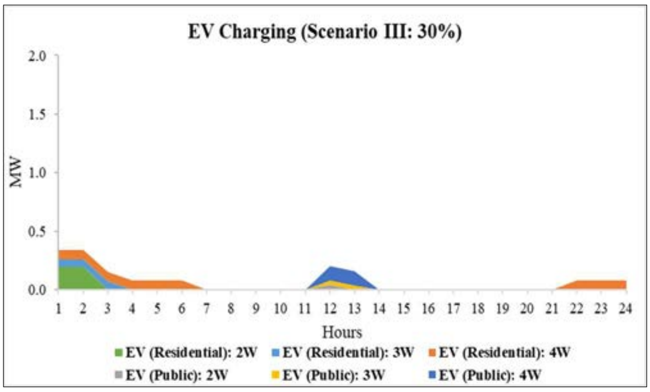

Figure 3. Scenario III: 30% EV Charging (excluding Bus)

Unlike other vehicle category, electric buses have significantly high battery capacity and hence its charging is accounted for separately. The bus charging causes a sudden increase of energy and peak demand at night as shown in figure 4 with maximum impact if all buses charges at the same time.

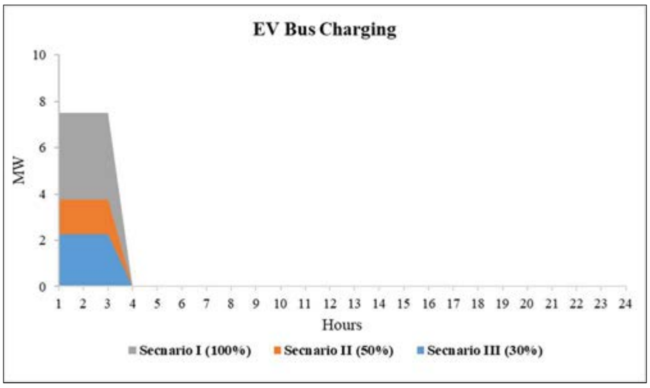

Figure 4. Electric Bus Charging showing three scenarios

D. Impact on Energy Demand for Delhi

The increase in energy consumption for Delhi from EV charging is shown for the most extreme situation where all EV charging starts at the same time and every EV is charged at least once a day. The entire day time energy demand is divided into 4 slots of 6 hours each. Impact of EV pre and post-adoption is shown in figure 5 and 6. Energy consumption increase from 24% to 31% between 12 AM to 6 AM. Most of the energy consumption from EV charging is happening at home.

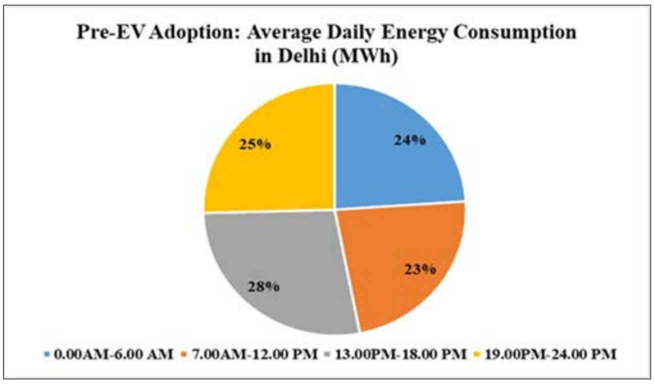

Figure 5. Pre-EV Adoption: Average Daily Energy Consumption

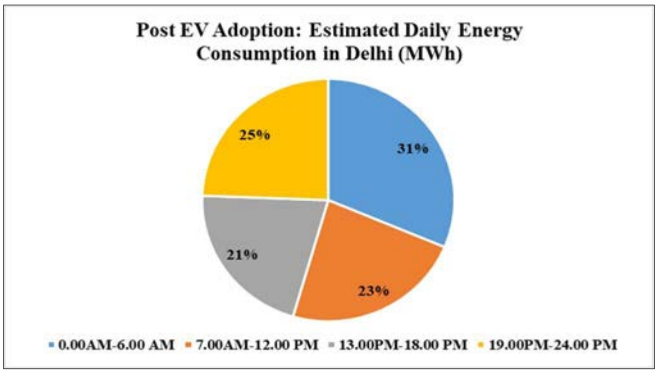

Figure 6. Post-EV Adoption: Average Daily Energy Consumption

E. *Impact on Peak and Energy Demand for DISCOMs in Delhi*

The next step is to evaluate the contribution of EV charging on power and energy demand for each DISCOM. The load profiles selected cover 24 hours and taken for an arbitrary day during summer for all the four DISCOMs. The load curves reveal that the DISCOMs other than NDMC experience evening and night peak demand. In case of NDMC the peak demand occurs in mid-day. The impact of EV charging is evaluated for adoption of 1000 EVs (include 2W, 3W and 4W) and 100 electric buses are presented in figure 7, 8, 9 and 10.

Among other EV categories, the contribution from the electric bus charging is the highest, and most evident in the load curve. There is a sudden increase in the peak around 12 AM. The charging contribution from the other 1000 EV constitute only a marginal fraction of the total demand of all DISCOMs and hence it's not evidently visible on the load curves. The impact of 1000 EVs is higher in for NDMC compared to other DISCOMs, though even their contribution from electric bus charging is the most significant share. For all the other DISCOMs though EV charging increases the energy and peak demand the impact is marginal.

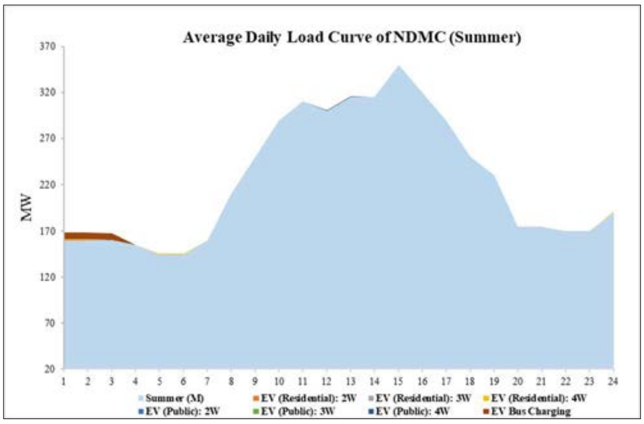

Figure 7. Impact of EV adoption on NDMC load curve

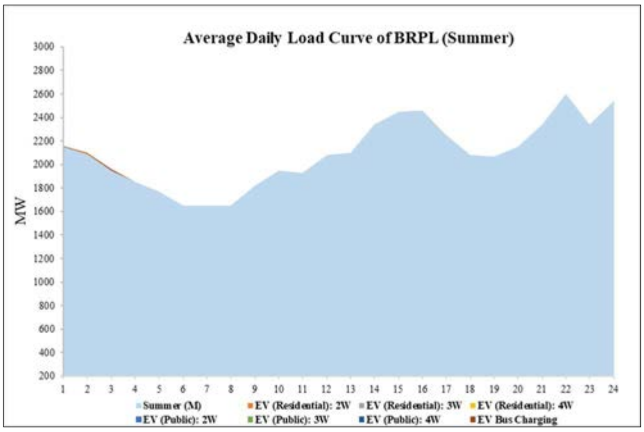

Figure 8. Impact of EV adoption on BRPL load curve

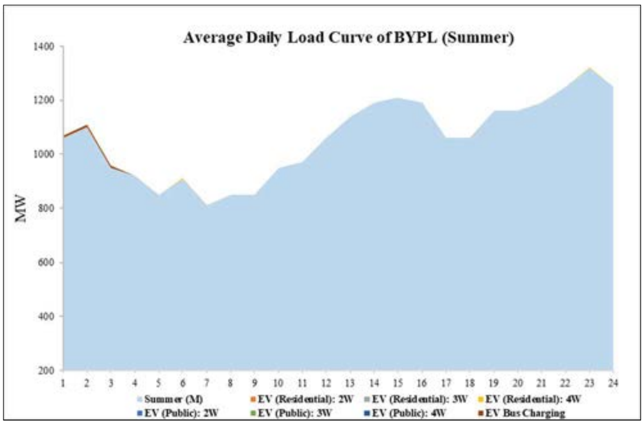

Figure 9. Impact of EV adoption on BYPL load curve

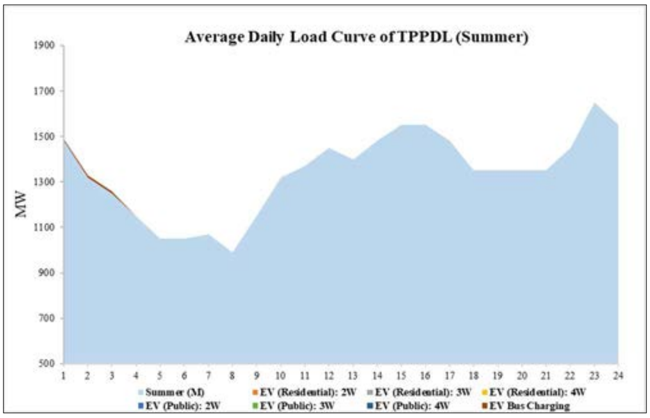

Figure 10. Impact of EV adoption on TPDDL load curve

IV. DISCUSSION

The study finds the impact of EV adoption would alter the energy consumption pattern of Delhi and increase the energy demand at night from 24% to 31%. At DISCOM level. electric bus charging would be the major contribution to increase in load from EV charging. As depot charging and residential charging is considered, the peak demand form EV charging would happen at nighttime between 12 AM to 6 AM. In case of public charging stations, 4W charging contributes the maximum to power demand under all charging scenarios.

To meet the additional demand from EV charging, DISCOMs need to purchase additional energy. EV charging also results in an increase in additional sales of energy for DISCOMs. At low levels of adoption, the impact on cost of supply from EV is marginal. Using the data from tariff order, the number of EVs which will have implication on the ACoS has been estimated as discussed in Table 1. In the case of NDMC, 0.24 million EVs cause 1% increase in ACoS resulting in additional power requirement of 451 MW and energy consumption by 1020 MWh. While in the case of BRPL, BYPL and TPDDL, 1% increase in ACoS caused by 2.76 million, 1.42 million and 2.06 million respectively. It has been observed that EV penetration will have major impact on NDMC ACoS vis-à-vis other DISCOMs. Impact of EV adoption on increase in average cost of supply is not same across DISCOMs in the same state.

Table 1. Impact of EV adoption on Peak and Energy Demand

DISCOM	Number of EVs (in '000)	Additional Power Requirement for EV Charging (MW)	Increase in Energy Consumption from EVs (MWh)
NDMC	240	451	1020
BRPL	2,760	5021	11346
BYPL	1,420	2587	5846
TPDDL	2,060	3749	8473

V. Conclusion

The study concludes that micro level studies are important to understand the impact from EV charging in a DISCOM area. The impact on power and energy demand on a DISCOM load curve is dependent on the number of vehicles and the pattern of EV charging. Among other EV category, energy needed for electric buses requires special attention, especially for DISCOMs that have peak power demand at night. The impact on average cost of supply for a DISCOM is also affected by penetration level of EV. However, the impact is not consistent across DISCOMs at the same penetration level.

Further investigation is needed to account for seasonality in energy demand, as the load curves varies in winter, monsoon and summer. As more clarity on pattern of EV charging will be gained, the results could be refined further. Additionally, accounting contribution from renewable generation is important which can contribute towards daytime charging.

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References

[1] S. Kumar, N. Yadav, S.Das and S. Mathew, "Green Vehicle Rating for 2 and 3 wheelers in India," Alliance for an Energy Efficient Economy, New Delhi, 2018. [Online]. Available: https://www.aeee.in/green-vehicle-rating/

[2] Ministry of Road, Transport and Highways, "Action plan for E-Vehicles," PIB Delhi, 4 July 2019. [Online]. Available: http://pib.nic.in/PressReleasePage.aspx?PRID=1577135

[3] International Energy Agency, "Global EV Outlook 2018: Towards cross-modal electrification," 2018. [Online]. Available: https://webstore.iea.org/global-ev-outlook-2018.

[4] S.Das, C. Sasidharan and A.Ray, "Charging India's Bus Transport," Alliance for an Energy Efficient Economy, New Delhi, 2019. [Online]. Available: https://www.aeee.in/wp-content/uploads/2019/07/full-report-charging-india-bus-transport.pdf

[5] Ministry of Heavy Industries and Public Enterprises, "Notification,", The Gazette of India, 28 March 2019.

[6] Ministry of Heavy Industries and Public Enterprises, "Notification,", The Gazette of India, 8 March 2019

[7] Coingard, P. MacDougall, F. Stadtmueller and E. Vrettos, "Will Electric Vehicles Drive Distribtuion Grid Upgrades? The case of California," IEEE Electrification Magazine, June 2019.

[8] N. Abhyankar, A. Gopal, C. Sheppard, W. Y. Park and A. Phadke, "Techno-Economic Assessment of Deep Electrification of Passenger Vehicles in India," Report: LBNL-1007121, 2017. [Online]. Available: https://www.lbl.gov/.

[9] Forum of Regulators, "Study on Impact of Electric Vehicles on the Grid," 2017. [Online]. Available: http://www.forumofregulators.gov.in/Reports.aspx.

[10] Mohd. S. Ali and R. Tongia, "Electrifying Mobility in India: Future Prospects for the Electric and EV Ecosystem," Report: 052018, 2018. [Online]. Available: www.brookings.com.

[11] Electric Power Research Institute (EPRI), "Electric Vehicle Driving, Charging, and Load Shape Analysis: A Deep Dive Into Where, When, and How Much Salt River Project (SRP) Electric Vehicle Customers Charge," Technical Report No. 3002013754, 2018. [Online]. Available: https://www.epri.com/#/?lang=en-US.

[12] N. Arora and A. Raman, "Beyond Nagpur: The Promis of Electric Mobility Lessons from India's First Multimodal E-mobility Project," OLA Mobility Institute, Delhi, 2019. [Online]. Available: www.ola.institute.

[13] Delhi Electricity Regulatory Commission (DERC), "Order on True UP for FY2016-17 Aggregate Revenue Requirement and Distribution Tariff (Wheeling & Retail Supply) for FY 2018-19 for North Delhi Municipal Corporation (NDMC)," 2018.

[14] Delhi Electricity Regulatory Commission (DERC), "Order on True UP for FY2016-17 Aggregate Revenue Requirement and Distribution Tariff (Wheeling & Retail Supply) for FY 2018-19 for BSES Yamuna Private Limited (BYPL)," 2018.

[15] Delhi Electricity Regulatory Commission (DERC), "Order on True UP for FY2016-17 Aggregate Revenue Requirement and Distribution Tariff (Wheeling & Retail Supply) for FY 2018-19 for BSES Rajdhani Private Limited (BRPL)," 2018.

[16] Delhi Electricity Regulatory Commission (DERC), "Order on True UP for FY2016-17 Aggregate Revenue Requirement and Distribution Tariff (Wheeling & Retail Supply) for FY 2018-19 for Tata Power Delhi Distribution Limited (TPDDL)," 2018.

[17] Ministry of Heavy Industries and Public Enterprises, "Standardisation of Protocol for EV charging Infrastructure- Bharat Public EV charger Specifications regarding,", Order, 21 November 2017.

[18] NITI Ayaog and Rocky Mountain Institute, "India's Electric Mobility Transformation: Progress To Date and Future Opportunities," April 2019. [Online]. Available: https://rmi.org/wp-content/uploads/2019/04/rmi-niti-ev-report.pdf.

Annexure

Table 2. Charging Specifications for different EV categories

Parameters		Units	2W	3W	4W
Number of EVs		Number	710	155	135
Rated Battery Capacity		kWh	2.0	5.0	25.0
Rated Charger Power	Residential	kW	1.0	2.0	2.5
	Public	kW	2.0	3.3	15.0
Proportion of vehicle charged at public places		%	10%	25%	20%

*Note: In case of bus, 100 buses considered with rated battery capacity of 250 kWh of 12 m bus and charged at bus depot.

BIOGRAPHICAL INFORMATION

Bhawna Tyagi was born on 17th March 1993. She holds a Master's in Economics from Ambedkar University and Bachelor's in Economics (Hons) from Delhi University. Her research interest includes natural resource management, energy and macro-economic analysis.

She is presently associated with Alliance for an Energy Efficient Economy, Delhi. In 2018, she worked as Senior Officer (Economist) with Infrastructure Leasing and Financial Service (IL&FS) contributing to various infrastructure verticals, especially energy. In 2015, she was with The Energy and Resources Institute (TER). She has taken training on Gravity modelling, CGE modelling, Randomized Controlled Trials (RCTs) and Systematic Reviews and Evidence Summaries.

Chandana Sasidharan is an IEEE member from Kerala, India. She has a Bachelor's Degree in Electrical and Electronics Engineering from Government Engineering College, Thrissur and Master's degree in Renewable Energy from TERI School of Advanced Studies. She is currently associated with Alliance for an Energy Efficent Economy in the power utilites and urban infrastrucutre team. Her research interests include Distributed Energy Resources, Renewable Energy, Energy Storage, Energy efficiency and EV charging. She has six years of industrial experience and is proficient in electrical Power System studies and energy modelling.

Shyamasis Das has 10 years of research and advisory experience in Power Distribution, Energy Management, and Policy & Regulation. He has served International Development Organizations, Governments, Public Agencies, Utilities, Project Developers, Industry Houses, and NGOs. He is credited with executing several important projects with high-profile clients including the World Bank, IEA, GGGI, DFID, KfW, GIZ, Govt. of India, BEE, EESL, UP Power Corporation Limited, Tata Power-DDL, BSES, BESCOM, India Smart Grid Forum (Ministry of Power) and major multi-national companies. In his present role, he is managing the power utility and urban infrastructure portfolio of AEEE and his research interest concerns the critical aspects of electric mobility, especially the inter-linkages of EV and power distribution. Shyamasis holds an International Master's in Energy Management from Ecole des Mines de Nantes, France.