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THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

BATTERY SWAPPING FOR ELECTRIC TWO-WHEELERS IN INDIA

STRATEGY HINTERLANDS

MAY 2022

REPORT CONTENTS

PERSPECTIVE

Amitabh Kant, CEO, NITI Aayog

As India goes through an accelerated phase of development, mobility will play a vital role in supporting India's economic growth. As Indian cities urbanize rapidly, policymakers need to actively explore clean mobility options. In the urban context, improvement of public transportation and electric vehicles (EVs) have immense potential to meet the twin challenges of increased demand and reduced pollution.

The report on ***Battery Swapping for Electric Two-Wheelers in India – Strategy Hinterlands*** identifies solutions to battery swapping application on two-wheelers to aid in India's EV transition. The battery swapping model promises future reductions in battery price which in turn would further accelerate the adoption of EVs in India. It would serve to allay concerns related to range anxiety and would reduce the upfront cost of EVs in the country.

The report focuses on the time benefit of avoiding point charging and how stakeholders, especially battery swapping operators (BSOs), could be supported in maintaining best practices for operational safety and end-of-life care.

This publication is part of NDC Transport Initiative for Asia (NDC-TIA) of the International Climate Initiative (IKI) and is being coordinated in India by NITI Aayog.

NITI Aayog has come up with the draft battery swapping policy. We look forward to public comments.

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POSITION BRIEF

MAY 2022

CHARTING AN AGENDA FOR BATTERY SWAPPING FOR TWO-WHEELERS IN INDIA

AMIT BHATT, ICCT AND SIDDHARTH SINHA, NITI AAYOG

Battery swapping has the potential to enhance the attractiveness of electric mobility by addressing both the early market purchase price disparities with conventionally powered vehicles and, importantly, the recharging time challenges associated with electric vehicles (EVs). For light-duty vehicles such as electric two-wheelers (E2Ws), a depleted battery can be swapped with a fully charged one at a swap station in just a few minutes.

E2Ws produce zero tailpipe emissions and make clear sense for the Indian market. Analysis in the working paper that follows shows that gasoline-powered two-wheelers are the costliest to own and operate in India in the long-term at every level of utilization —even when the cost of gasoline is extremely low at INR 65 per liter. Additionally, because of the greater utilization of each battery in the swapping model, swappable batteries reach their end of life earlier than batteries used by a single EV owner, and this enhances the potential for faster rollout of more advanced battery technologies as they emerge.

The EV ecosystem in India is still at a nascent stage, and because EV technologies are rapidly evolving worldwide, many in the industry who might consider engaging with the potential of the battery-swapping business model are waiting for additional signals from the government. The International Council on Clean Transportation (ICCT), with support from NITI Aayog, explored the landscape of battery swapping for E2Ws in India and undertook quantitative analysis to ascertain the impact of various parameters on the total cost of ownership (TCO). The research suggests strategy frameworks to spur battery swapping in India.

Given that future reductions in battery price would undermine one of the major premises underlying the battery-swapping model—that it significantly defrays the upfront cost of purchasing the vehicle—**early policy in India would do well to focus on the core benefits of battery swapping that are less likely to change in the near and medium term, and to prioritize standards setting and similar actions that are most effectively handled by government**. We suggest an emphasis on (a) the time benefit of avoiding point charging and (b) how stakeholders, especially battery swapping operators (BSOs), could be supported in maintaining best practices for operational safety and end-of-life care.

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OPPORTUNITY COST OF POINT CHARGING

ICCT analysis found that TCO per kilometer (km) for both conventional two-wheelers and E2Ws is lowest when they are used for commercial operations with higher daily utilization rates such as e-commerce deliveries and shared mobility. The figure below illustrates this for the ride-hailing use case. Observe that the E2Ws are consistently more cost effective than the gasoline vehicle, and point charging remains most affordable at low and medium utilization rates (less than 100 km per day), even with relatively high charges for domestic electricity. For daily utilization of 140 km and higher, however, battery swapping is the most economical option. Although not shown below, ICCT also found that if the total cost per kilowatt hour (kWh) to battery swap is lowered to INR 20 per kWh from the current INR 34 per kWh, then battery swapping emerges as the most attractive option for daily utilization rates from 120 km and up.

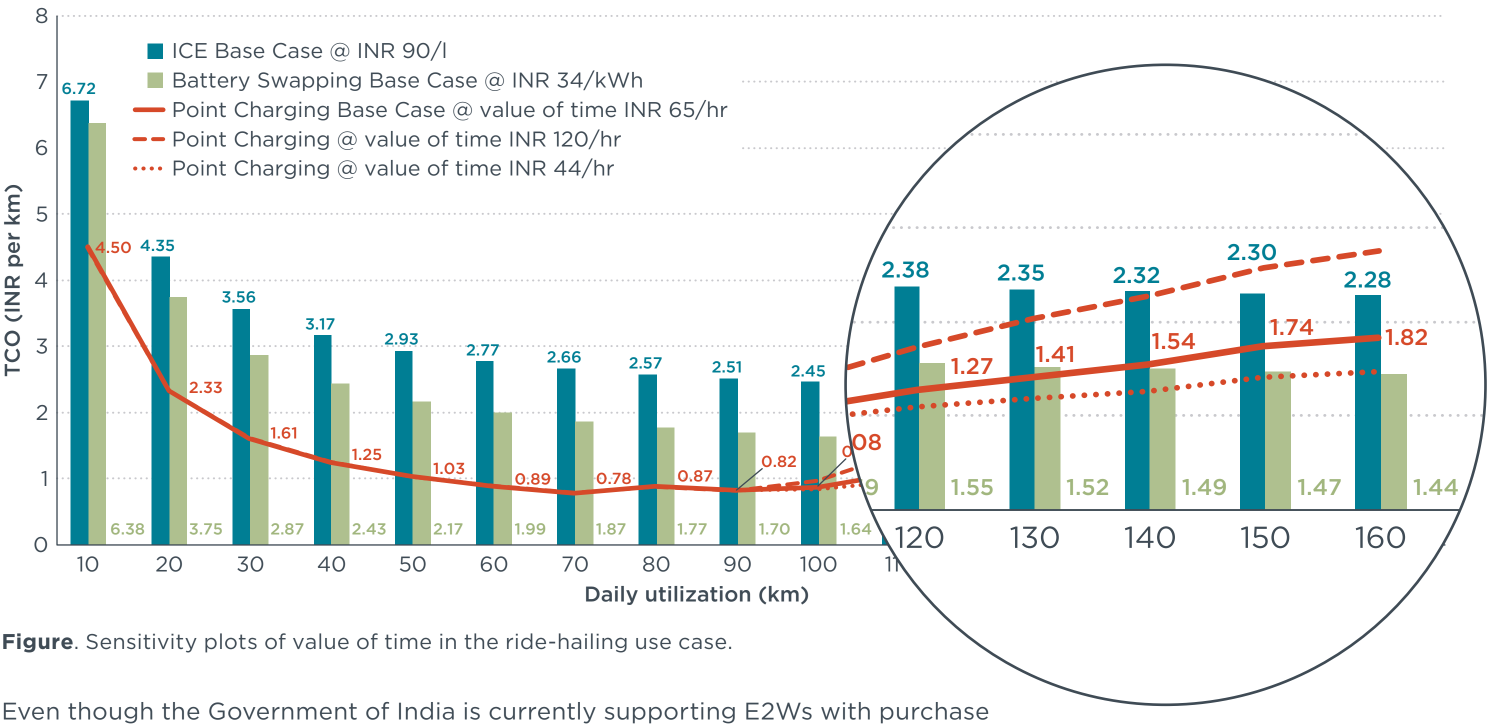

Figure. Sensitivity plots of value of time in the ride-hailing use case.

Even though the Government of India is currently supporting E2Ws with purchase incentives linked to battery size under the Faster Adoption and Manufacturing of Electric Vehicles (FAME) scheme, these are not extended to E2Ws meant for battery swapping, as they are sold without pre-fitted batteries. In recognition of the value of battery swapping for certain users, this might be addressed by extending future FAME subsidies to EVs sold without pre-fitted batteries, and it might be designed such that a portion of the incentive could be availed by the EV manufacturer and the rest could accrue to the BSO. Analysis also showed that an additional purchase subsidy from states (similar to the one in Delhi) over and above the federal scheme like FAME could bring about a 10% reduction in TCO at the low utilization rates of less than 40 km per day that are typical of personal use. However, as a purchase-subsidy-based scheme, this would not be tied to the amount of use of the vehicle.

OPERATIONAL SAFETY AND HANDLING OF RETIRED BATTERIES

Among the challenges that battery swapping faces is the absence of relevant battery safety, quality, and performance parameters for BSOs. Safety and reliability of the battery is a crucial concern in the battery-swapping model. For battery swapping to gain traction and acceptance among users of EVs, it is imperative that there be stringent operational and safety standards for BSOs.

Compliance with such standards could also be supported with incentives. Different from a purchase-subsidy scheme, India could consider a usage-linked incentive scheme that would apply to a consortium of battery-swapping stakeholders including BSOs, EV manufacturers, fleet operators, and electricity distributors. Such a consortium would facilitate collaboration among stakeholders to overcome challenges faced by each partner and could internally strategize to determine the incentive share that will flow to each partner based on their contribution. Mandates could be imposed on the consortium to ensure the proper treatment of retired EV batteries and to steer them away from unorganized recycling processes or landfills, to reduce their life-cycle greenhouse gas emissions, and maximize their economic value. Experiences from pilot programs could be leveraged to design a full-scale incentive program that might consider additional provisions such as incentives for fleet operators that commit to 100% electrification by a certain date and an efficiency-based, tiered incentive structure that rewards EVs with lower energy consumption per kilometer.

WORKING PAPER 2022-17

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Battery swapping for electric two-wheelers in India: Strategy hinterlands

Authors: Pramoda Gode, Sumati Kohli, and Jennifer Callahan

Keywords: Battery swapping, electric vehicles, two-wheelers, FAME

Introduction

Battery swapping offers a plug-and-play solution for charging the battery of an electric vehicle (EV). It involves switching out a depleted battery for a fully charged one at a swapping station within the battery swapping operator's (BSO) network. For light-duty vehicles such as electric two-wheelers (E2W) and electric three-wheelers (E3W), this recharge process can be carried out manually in mere minutes. This is comparable to gasoline refueling time and significantly shorter than conventional point charging.[1]

In India, battery swapping for E2Ws has received a relatively lukewarm reception so far. This is partly because of a lack of supporting policy and partly because India is currently early in the EV journey overall. While considerable time has passed since the national Government of India and state governments have declared their intention to support all meritorious charging options that could potentially quicken the pace of EV adoption, the national government has only very recently expressed its commitment to spur battery swapping specifically, and associated policy specifics have yet to emerge.[2]

This paper first describes the advantages of battery swapping as a charging option, especially for E2Ws. We then provide a sampling of some of the more recent developments in the Indian EV ecosystem that concern battery swapping. Following that, the paper builds on previous ICCT research[3] and presents the results of a sensitivity analysis that evaluates the impact of changes in different cost components on total cost of ownership (TCO) for two-wheelers. Next, the barriers for widespread

1 A full charge of a typical electric two-wheeler requires about 1 to 1.5 hours at a Level 2 public charging station or about 3 to 5 hours at home using a conventional 3-pin plug socket.

2 Government of India, "Budget 2022–23: Speech of Nirmala Sitharaman, Minister of Finance," February 1, 2022, https://www.indiabudget.gov.in/doc/budget_speech.pdf

3 Nibedita Dash and Anup Bandivadekar, *Cost comparison of battery swapping, point charging, and ICE two-wheelers in India,* (ICCT: Washington, D.C., 2021), https://theicct.org/sites/default/files/publications/cost-compare-india-ice-2ws-ldvs-nov21.pdf.

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icct THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION adoption of battery swapping for E2Ws are examined from a strategy standpoint. Based on the findings, the paper concludes with suggested strategy frameworks to explore.

Benefits of battery swapping

BSOs provide battery as a service by deploying a wide and dense network of swap stations. A swap station consists of one or more charging kiosks; each kiosk typically houses about 12 to 15 batteries. Swappable batteries are typically smaller in size than fixed batteries. Swappable batteries are modular by design, usually around 1 to 1.5 kWh in capacity, and weigh about 10 to 12 kg. The smaller batteries result in lower weight of the E2W, and that yields better energy efficiency and greater range on the available charge. An E2W is designed to run with one or two such batteries, whereas vehicles such as e-rickshaws and e-autos can be fitted with two, three, or four such batteries, depending on their energy consumption and range requirement. This set-up ensures that the BSO's batteries can be used across various light-duty EVs.

There are also applications in passenger cars. The Chinese EV manufacturing giant NIO offers a 3-minute battery-swapping solution for its electric cars and has completed more than 2.9 million swaps with a network of about 300 swap stations.[4] Battery swapping for medium- and heavy-duty vehicles, including electric buses, is also technically feasible, but has to be automated due to the weight and size of the batteries. It requires special equipment such as battery-swapping arms and supporting ancillary infrastructure, and this increases both the capital investment needed and the operating costs. In 2019, Ashok Leyland, in collaboration with Sun Mobility, conducted a battery swapping pilot for 18 electric buses that were a part of Ahmedabad's bus rapid transit system.[5] Similar pilots are reported to have been conducted in places including China and South Korea.

For E2Ws, the charging kiosk has a small real estate footprint and can be located in the parking lots of shopping malls, restaurants, grocery stores, and other heavily trafficked locations. Generally, the capital investment required for setting up a new charging kiosk is significantly lower than setting up a new Level 2 charger. Taipei City has one of the most mature battery swapping ecosystems in the world, and riders of E2Ws in the city are never more than a short distance of a kilometer away from a swap station.[6]

Battery swap stations can be extremely efficient at delivering power. NIO established its own vertically integrated battery swapping network for electric cars. BloombergNEF analysis showed that NIO's swap stations disburse an average of 1,543 kWh per day per station—33 times the rate of China's average public chargers.[7]

BSOs can also decide when to charge batteries, to avoid stressing the grid and paying higher energy prices. Additionally, when large-scale battery swapping implementation is achieved, BSOs can profit through energy arbitrage, which happens when they operate bi-directionally and help power urban microgrids and provide load-balancing services such as voltage support to keep critical systems running.[8]

4 NIO, "NIO Announces NIO Power 2025 Battery Swap Station Deployment Plan," news release, July 9, 2021, https://www.nio.com/news/nio-announces-nio-power-2025-battery-swap-station-deployment-plan

5 Rutam Vora, "Ashok Leyland Gets Set for Electric Bus Drive in Ahmedabad," T*he Hindu Business Line*, January 24, 2019, https://www.thehindubusinessline.com/specials/auto-focus/ashok-leyland-ahmedabad-electric-bus/article26082273.ece

6 Micah Toll, "Check Out Gogoro's Giant New Battery Swap Stations for its Electric Scooters," *Electrek*, September 23, 2019, https://electrek.co/2019/09/23/check-out-gogoros-giant-new-battery-swap-stations-for-its-electric-scooters/

7 Ira Broudway, "A California Start-up Now Offers a Full EV Battery in Just 10 Minutes," *BloombergQuint*. June 10, 2021, https://www.bloombergquint.com/business/california-startup-ample-offers-a-full-ev-battery-in-just-10-minutes

8 Amy Rose et al., "Policy and Regulatory Environment for Utility-Scale Energy Storage: India," (National Renewable Energy Laboratory, December 2020), https://www.nrel.gov/docs/fy21osti/78101.pdf.

Battery swap systems have built-in IoT and CAN that facilitate constant tracking and monitoring of battery performance through data analytics.[9] BSOs use this data to estimate real-time demand and optimize the distribution of battery inventory across their swap stations. This information can enable them to then offer incentives to customers to deposit depleted batteries at more geographically preferred swap stations. IoT also enables the BSO to capture driver behavior and discern driving patterns that impact the rate of discharge of the battery. This information can further be leveraged to design customized subscription plans or insurance and financial products related to the vehicle.

In the case of battery theft, BSOs can choose to remotely disengage their batteries using lock smart technology. This technology also ensures that the batteries are discharged only on the subscribed vehicle and charged only in the BSOs' kiosks; this severely limits the value of a stolen battery.

The charging kiosk is a temperature-controlled charging environment in which batteries are slow charged to lower energy losses and prolong life. The BSO monitors, maintains, and manages all the batteries centrally. Before each swap, the BSO has the opportunity to identify any faults and remove the battery from circulation, if required.

Because swapping results in higher utilization, swappable batteries are retired earlier than batteries used by a single user. This provides an opportunity for faster roll-out of advancements in battery technology, both chemistry and design, because retired batteries can be replaced with more energy-efficient ones in a shorter time frame. In 2019, Gogoro updated its batteries and the new ones had 27% more energy; this resulted in an admirable driving range of 170 km for the E2Ws subscribed to the network.[10] As BSOs also aggregate the demand for EV batteries, it is easier to implement and ensure better reuse, recycling, and end-of-life practices.

Subscribing to batteries gives an E2W user the flexibility to travel longer with minimum downtime for charging. BSOs either charge the EV user a flat fee per swap or a subscription cost. Because the down time associated with recharging is minimal, it is possible to achieve greater utilization of the EV. Moreover, since the E2W owner does not own the battery, the upfront acquisition cost of the vehicle is significantly reduced and total ownership costs are more distributed over the lifespan of the vehicle. The E2W owner also does not have to deal with any risk associated with a faulty battery.

Battery swapping for E2Ws can be operationalized via manned services or automated unmanned kiosks. The manned swap stations are independently managed by franchisee owners. Under such a franchisee model, local businesses are brought on-board for a profit-sharing fee per swap and BSOs do not have complete control over the charging environment and handling of batteries. Zypp Electric, Bounce,[11] BatterySmart, and Revolt Motors offer or have offered such models, but these are not discussed in this paper. This paper discusses only the swapping that is operationalized via unmanned kiosks.

Landscape of battery swapping in India

In 2020, there were a few important developments in the EV landscape of India that favored battery swapping. First, the Ministry of Power included battery swapping stations in the list of recognized public charging options, which brought them under the

9 Internet of things (IoT) describes the network of physical objects, so known as, "things," that are embedded with sensors, software, and other technologies that is used for the purpose of connecting and exchanging data with other devices and systems over the Internet. A Controller Area Network (CAN bus) is a robust vehicle bus standard designed to allow microcontrollers and devices to communicate with each other's applications without a host computer.

10 "Time for an Upgrade," Gogoro, accessed November 2, 2021, https://network.gogoro.com/tw/en/switch/

11 In early December 2021, Bounce launched its Infinity E1 scooter with a swappable battery pack. Bounce has also announced a strategic alliance with Park+ to install 3,500 battery swapping stations across 10 Indian cities.

purview of the guidelines and standards set by the Ministry for charging infrastructure for EVs.[12] Next, Delhi became the first Indian state to announce a state government purchase incentive for battery-swappable EVs.[13] The purchase incentive is directly issued to the bank account of the end user, the E2W owner, within 8 to 10 weeks of vehicle purchase. Around the same time, the Ministry of Road Transport and Highways allowed the sale and registration of EVs without a pre-fitted battery.[14]

In January 2021, HOP Electric launched two E2W models that have swappable batteries.[15] Multiple subscription plans are offered and the consumer can choose the one that fits their needs the best based on their usage.

In June 2021, Taiwanese company Gogoro, the world's largest BSO, announced its foray into India via a partnership with Hero Electric. The joint venture has chosen Delhi and Bengaluru for the initial roll out of E2Ws in the fourth quarter of 2022.[16] Gogoro has also entered into strategic partnership with Foxconn, the world's largest contract electronics manufacturer, to support its ambitious expansion plans in India and China.[17]

In August 2021, Swiggy, India's second-largest online food-delivery platform, announced a partnership with Reliance BP Mobility to build an ecosystem of battery swapping stations to support Swiggy's operations across India.[18]

In December 2021, Bounce launched its first electric scooter that comes with a swappable battery, called the Infinity E1.[19] In spring 2022, the company also started offering monthly subscription plans under the battery-as-a-service business model.

In February 2022, the finance minister of India announced, as part of the Union Budget 2022–23 speech, that the central government will roll out a battery swapping policy and the policy will be supported by inter-operability standards. Although no further specifics have been provided, the speech indicated that the private sector will additionally be encouraged to develop business models that offer battery or energy as a service.[20]

There has been considerable interest in battery swapping for E3Ws in India from EV manufacturers, businesses, and investors. However, BSOs have not been able to garner similar interest for E2Ws, and there is nothing like the kind of acceptance and success that some companies have enjoyed in Taiwan and China. This is despite India being the world's biggest two-wheeler market.

12 Ola Mobility Institute, "Policy Update: Ministry of Power, Government of India recognizes Battery Swapping Technology," June 10, 2020, https://mobilityinstitute.medium.com/policy-update-ministry-of-power-government-of-india-recognises-battery-swapping-technology-a5634030048

13 Government of National Capital Territory of Delhi. "Delhi Electric Vehicles Policy, 2020," August 7, 2020, https://transport.delhi.gov.in/sites/default/files/All-PDF/Delhi_Electric_Vehicles_Policy_2020.pdf; An incentive of INR 5,000 per kilowatt-hour (kWh) of swappable battery capacity to the EV owner and an additional incentive of INR 5,000 per kWh of swappable battery capacity to the battery swapping operator.

14 Ministry of Road Transport and Highways, "MoRTH Allows Sale and Registration of Electric Vehicles Without Batteries," news release, August 12, 2020, https://pib.gov.in/PressReleseDetailm.aspx?PRID=1645394

15 The batteries can also be charged at home using a 84V – 6A smart charger in under 3 hours.

16 Shubhangi Bhatia, "MotoCorp Likely to Launch EV Product in India in Q4 2022," *ETAuto*, October 6, 2021, https://auto.economictimes.indiatimes.com/news/two-wheelers/taiwans-gogoro-hero-motocorp-likely-to-launch-ev-product-in-india-in-q4-2022/86784521

17 "Hon Hai, Gogoro team up on global electric vehicle battery exchange", *Focus Taiwan*, June 23, 2021, https://focustaiwan.tw/sci-tech/202106230029

18 "Swiggy and Reliance BP Mobility to Set Up EV Battery Swapping Stations," *AutoCar Professional*, August 5, 2021, https://www.autocarpro.in/news-national/swiggy-and-reliance-bp-mobility-to-set-up-ev-battery-swapping-stations-79774?amp=1&__twitter_impression=true

19 "Bounce Launches Infinity E1 at Starting Price of Rs 45,099", *The Economic Times*, December 2, 2021, https://economictimes.indiatimes.com/industry/renewables/bounce-launches-infinity-e1-at-starting-price-of-rs-45099/articleshow/88049570.cms

20 Government of India. Budget 2022-23: Speech of Nirmala Sitharaman, Minister of Finance, February 1, 2022, https://www.indiabudget.gov.in/doc/budget_speech.pdf

User economics of battery swapping

ICCT previously compared the 5-year TCO of representative E2W models in Delhi using point charging and battery swapping against ICE vehicles for three use cases—personal, ride-hailing, and last-mile delivery.[21] For point charging, charging at home was the primary mode of recharge and public charging was only considered for top-up charging. Top-up charging is generally required when the daily utilization is greater than the range provided by the E2W on a single, full charge. In the case of battery swapping, all the energy requirements of the E2W were considered to be met by swapping the battery in a BSO's network.

There are inherent uncertainties involved in some of the input values of a TCO model, things like the cost of gasoline, electricity tariff for home charging, cost per kWh to battery swap, vehicle utilization, and the value of time. In order to assess the impact of these uncertainties on the TCO, here we employ two deterministic sensitivity analysis techniques, tornado plot and what-if analyses. For this we evaluated the Okinawa iPraise+, which delivers about 111 km on a full charge.[22]

Tornado plots

First, we ascertained the relative importance of each uncertain input variable on the outcome by creating tornado plots. These diagrams, which are shown in Figure 1, provide a graphical representation of how sensitive the TCO is to each input variable. The bigger the size of the bar, the bigger the influence of the variable on the TCO. For the sake of representation, we chose a fabricated variation of +/- 20% in the input variables. Based on the degree of variability that we can expect in the input variables, we deemed that a +/- 20% variation is reasonable for representation purposes. Moreover, since the variation is applied uniformly across all input variables, the actual quanta of variation is not critical, because we are interested only in ascertaining the relative importance of input variables at this stage.

The tornado plots are centered at the TCO corresponding to the baseline values for each use case. For point charging, the baseline TCO in INR/km is 1.47, 1.0, and 1.74 for the personal, last-mile, and ride-hailing use cases, respectively. For battery swapping, the baseline TCO in INR/km is 2.72, 1.55, and 1.47 for the personal, last-mile, and ride-hailing use cases, respectively. For ICE, the baseline TCO in INR/km is 3.44, 2.38, and 2.30 for the personal, last-mile and ride-hailing use cases, respectively.

21 Dash and Bandivadekar, *Cost comparison of battery swappin, point charging, and ICE two-wheelers.*

22 Ibid.

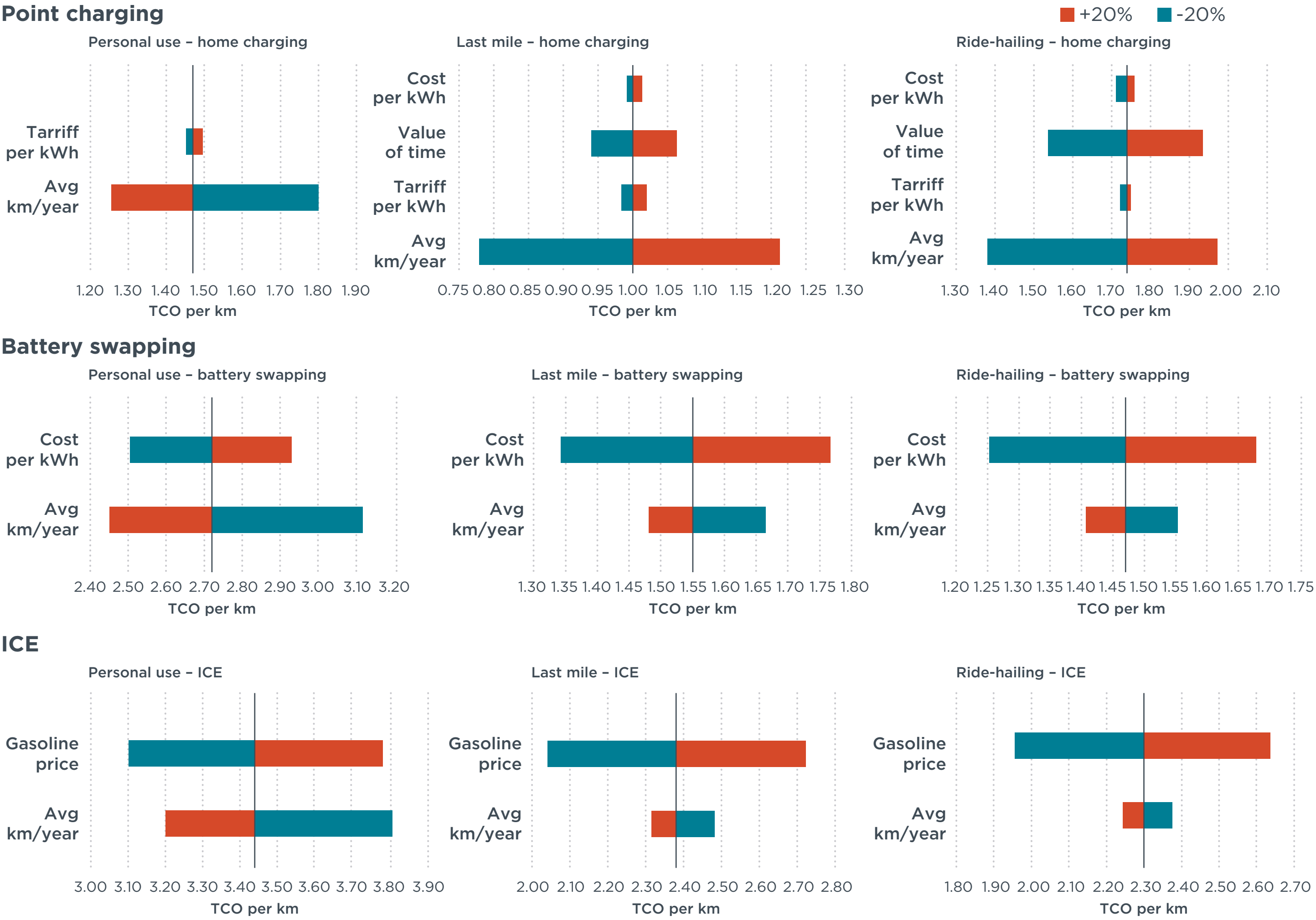

Figure 1. Tornado plots showing the impact of a fictitious +/- 20% variation in the input variables of the TCO.

Findings of tornado plots. In the case of point charging, the electricity tariff and cost per kWh for top-up point charging were found to have minimal impact on the outcome of TCO. Meanwhile, the value of time and average number of kilometers traveled per year emerged as the most impactful variables. (Average kilometers per year is the product of daily utilization and number of working days.) In the case of personal use, for which the daily utilization is low, an increase in average kilometers traveled in a year results in lower TCO/km. On the flip side, for the last-mile and ride-hailing use cases, which have high levels of daily utilization (>100 km), any increase in average kilometers traveled in a year results in additional costs within the 5-year period; this is because the battery needs to be replaced after a certain number of kilometers.

For battery swapping and ICE, other than utilization, the cost to refuel/recharge was found to have significant impact. Further, we find that the last-mile and ride-hailing use cases exhibit very similar sensitivity trends. We structured the next set of sensitivity analyses with these learnings in mind.

What-if analyses

This "one-at-a-time" sensitivity analysis is appropriate because the underlying relationships that govern our simulations are linear and because there is no interaction among the different input variables. Point charging, battery swapping, and ICE two-wheelers were evaluated at different levels of daily utilization in increments of 10 km (for convenience), from 10 km to 160 km. For each of the simulation runs, one of the three parameters listed in Table 1 were varied from their baseline values, and the others remained constant.

Table 1. Variation of input variables for sensitivity analyses

Input variable	Baseline value	Sensitivity values	Charging solution affected
Price of gasoline, INR per liter	90	65 and 110	ICE
Cost for swapping, INR per kWh	34	20 and 40	Battery swapping
Value of time, INR per hour	65	44 and 120	Point charging

Price of gasoline. We examined the average price[23] of gasoline in Delhi for 2019, 2020, and 2021 (up to August) and found that it was cheapest at INR 69 per liter and most expensive at INR 102 per liter. We established the upper bound at INR 110 per liter and lower bound at INR 65 per liter for the sensitivity analysis.

Figures 2 and 3 show the result of this simulation against the baseline value of INR 90 per liter at different levels of daily utilization. The vertical bars represent the baseline TCO/km of point charging and battery swapping. It can be observed from the bar graphs that point charging is the most economical charging solution up to 130 km of daily utilization. Beyond that level, though, battery swapping emerges as the more economical charging solution. The three curves in the graphs represent the base case and corresponding low and high bounds (sensitivity cases) of the price of gasoline. The low and high curves define the area that represents the degree of variation in the TCO that can be expected due to uncertainty in the price of gasoline.

For the ride-hailing use case, at 10 km of daily utilization, the TCO/km for battery swapping is INR 6.38, for point charging it is INR 4.50, and for ICE vehicles it ranges from INR 6.25 to INR 7.10, depending on the price of gasoline. Similarly, for personal use, at 10 km of daily utilization, the TCO/km for battery swapping is INR 7.07, for point charging it is INR 5.03, and for ICE vehicles it ranges from INR 6.94 to INR 7.80, depending on the price of gasoline. Beyond 20 km of daily utilization, ICE vehicles emerge as the most expensive to own and operate.

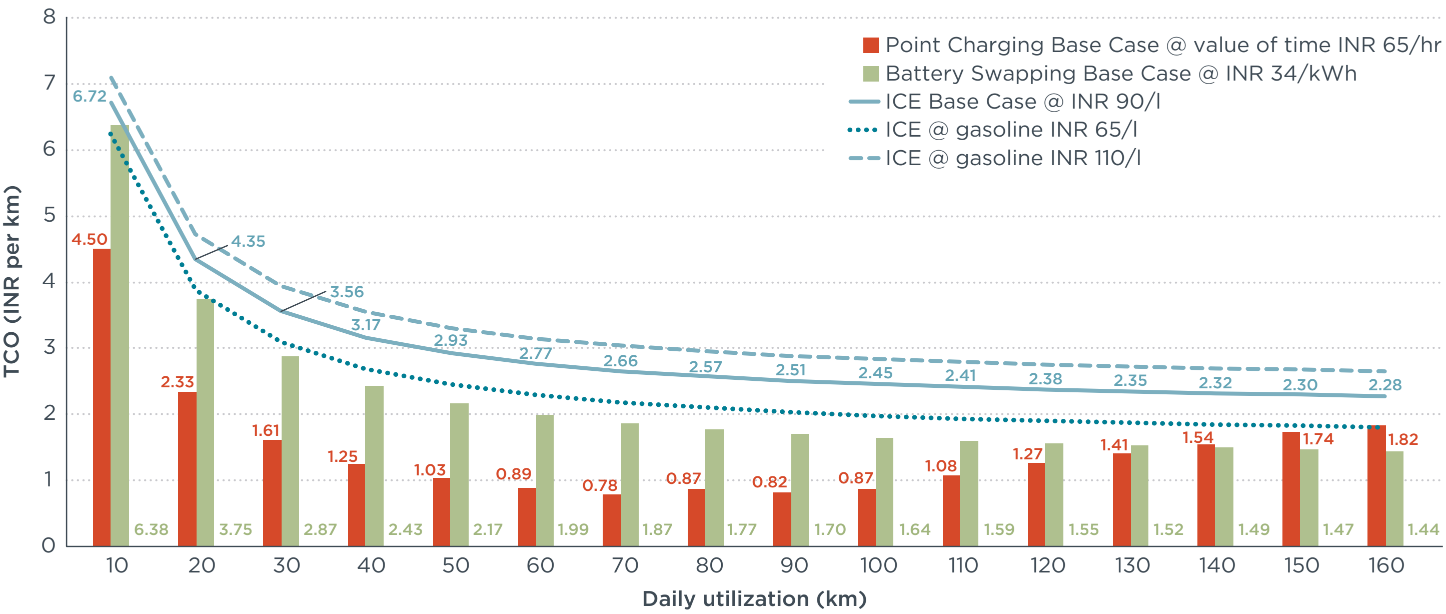

Figure 2. Sensitivity plots of price of gasoline in the ride-hailing use case.

23 "Petrol Price in Delhi," Good Returns, accessed on August 3, 2021, https://www.goodreturns.in/petrol-price-in-new-delhi.html#Historical+Petrol+Price+in+New+Delhi

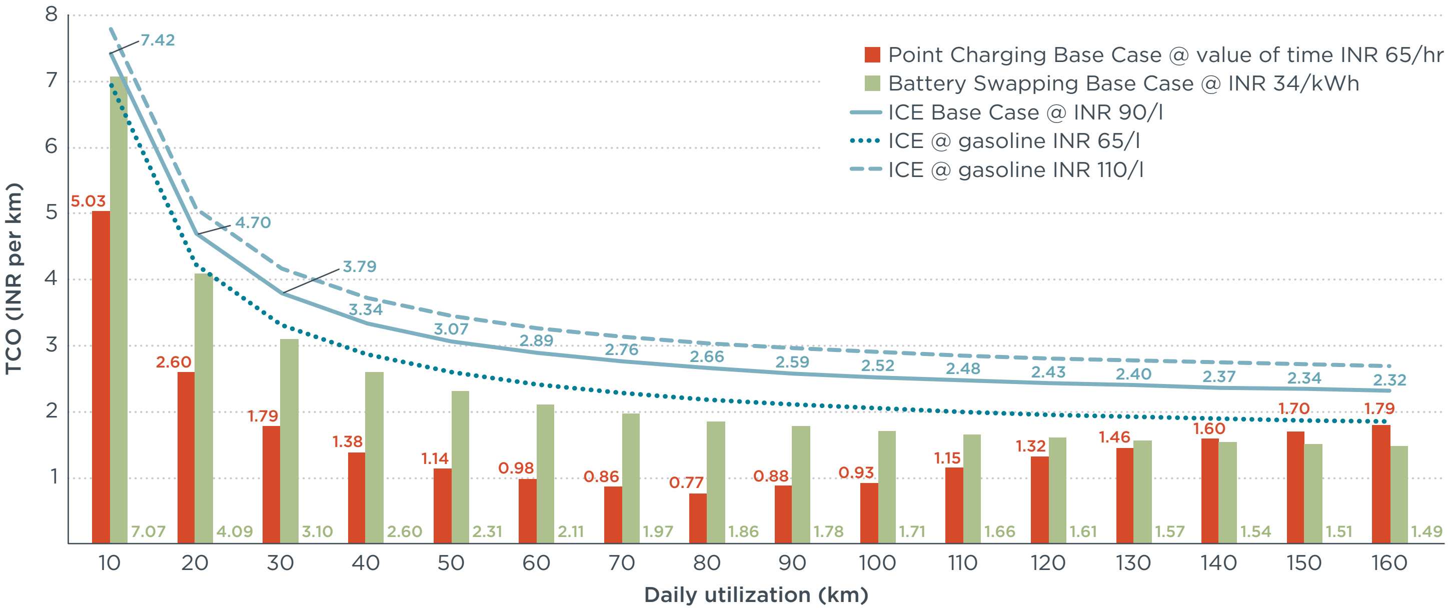

Figure 3. Sensitivity plots of price of gasoline in the personal use case.

Cost per kWh. To battery swap, two types of payment schemes are generally offered—a daily, weekly, or monthly subscription for unlimited swaps or a fixed fee per swap.[24] In order to normalize these two distinct offerings, we considered the cost per kWh of the battery in our sensitivity analysis. BSO's vary the pricing by geography and by security deposit. We established the upper bounds at INR 40 per kWh and evaluated a more competitive price of INR 20 per kWh as the lower bound for the sensitivity analysis. Figures 4 and 5 show the result of this simulation against the base line value of INR 34 per kWh at different levels of daily utilization.

The vertical bars represent the baseline TCO/km of point charging and ICE vehicles. It can be observed from the bar graphs that point charging is significantly more economical than owning and operating an ICE vehicle at all levels of utilization.

The three curves in the graphs represent the base case and corresponding low and high cases (sensitivity cases) of cost to swap. The low and high curves define the area that represents the degree of variation in the TCO that can be expected due to uncertainty in the cost to swap.

For the ride-hailing use case, at 120 km of daily utilization, the TCO/km for ICE is INR 2.38, for point charging it is INR 1.27, and for battery swapping it ranges from INR 1.12 to INR 1.74, depending on the cost to swap. Similarly, for personal use, at 120 km of daily utilization, the TCO/km for ICE is INR 2.43, for point charging it is INR 1.32, and for battery swapping it ranges from INR 1.17 to INR 1.80, depending on the cost to swap.

It can be discerned that upwards of 120 km of daily utilization, battery swapping starts to emerge as the more economical charging solution. This inflection point corresponds to the range offered by the E2W on a single full charge, which stands at 111 km for the Okinawa iPraise+.

24 Hop offering is INR 2,500 per month for unlimited swaps and Sun Mobility's offering is INR 50/per swap, battery size 1.5 kWh.

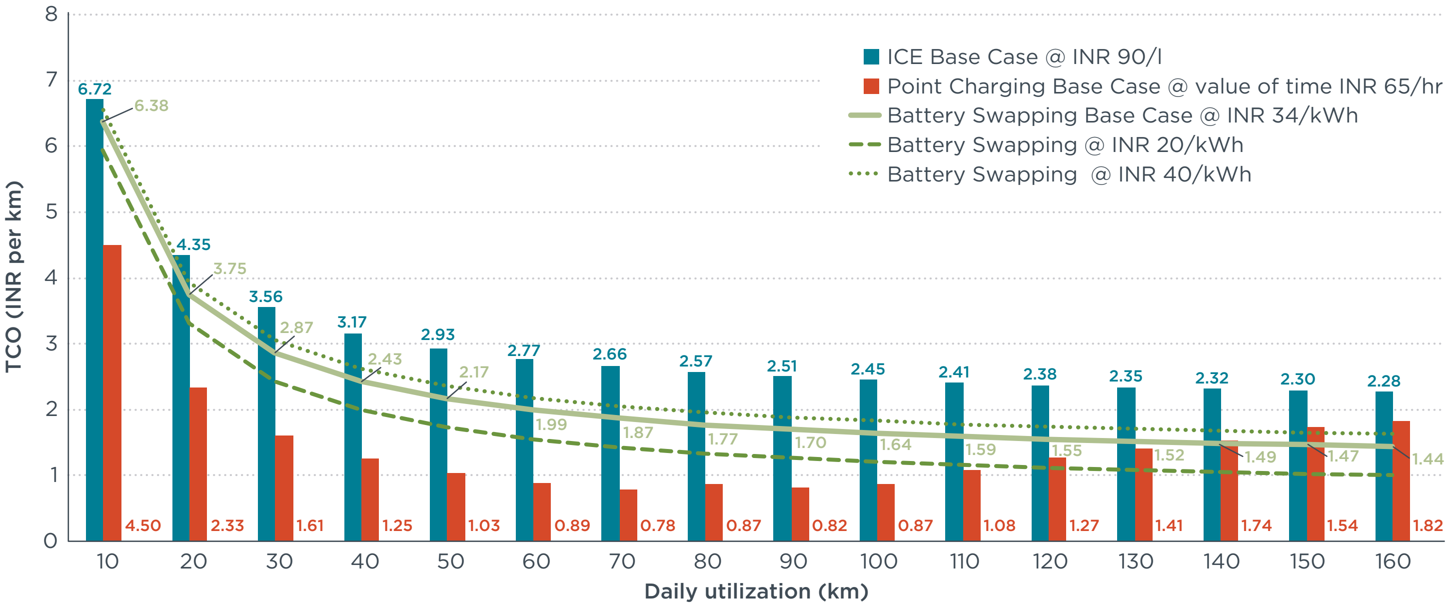

Figure 4. Sensitivity plots of cost per kWh to swap in the ride-hailing use case.

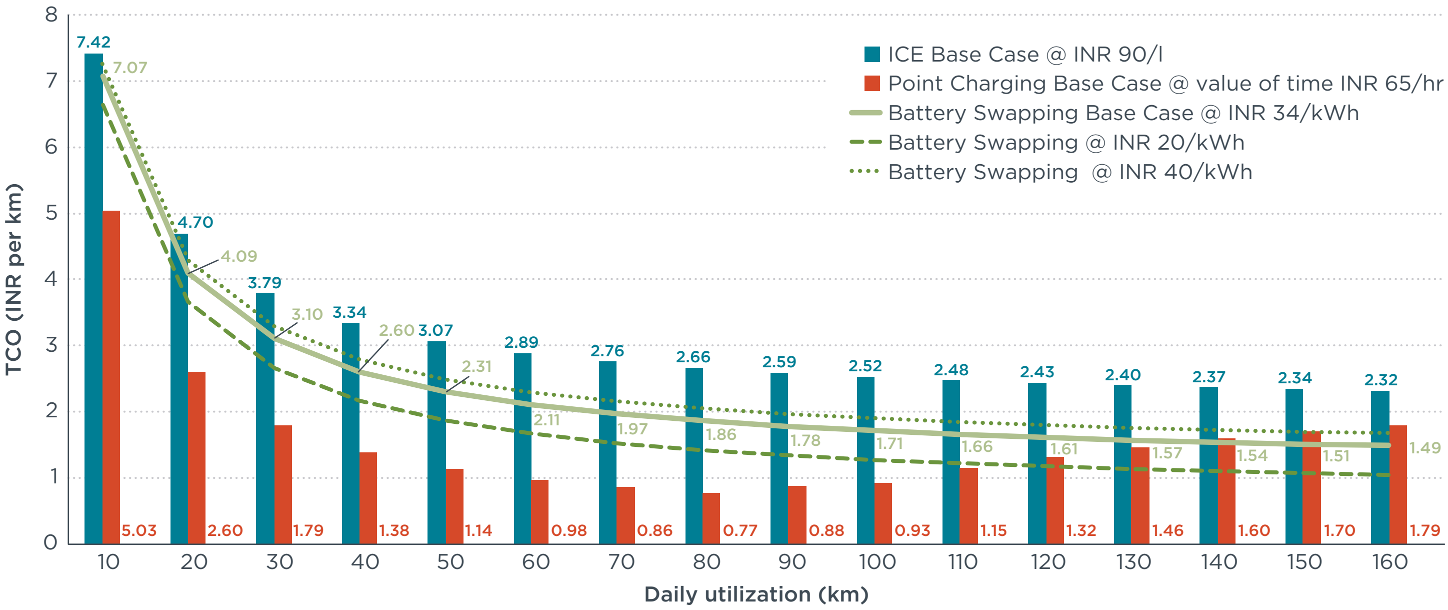

Figure 5. Sensitivity plots of cost per kWh to swap in the personal use case.

Value of time. The hourly earning potential determines the value of time. Because earning potential can be practically limitless, establishing the upper and lower bounds from the wide range of possible values would not serve the purpose of the sensitivity analysis. Hence, we decided to focus only on commercial use cases for this input variable.

In commercial operations, the average daily utilization can exceed the range delivered by the EV on a single full-charge. In such circumstances, any time spent on top-up charging will result in loss of earnings. Further, the higher the potential for earning, the greater the loss is in opportunity cost for public charging and, consequently, the higher the TCO. For this parameter, we evaluated INR 44 per hour[25] as the lower limit and INR 120 per hour as the upper limit for hourly earnings. The upper limit was established

25 Tata Institute of Social Sciences, "Understanding Food Delivery Platform: Delivery Persons' Perspective," https://tiss.edu/uploads/files/Online_Food_Delivery_Platform.pdf; Palak Thakur, Aakansha Jain, and Aravind Harikumar, "Emerging Role of Bike (Motorcycle) Taxis in urban mobility," (The Energy and Resources Institute: New Delhi, 2020), https://www.teriin.org/sites/default/files/2020-03/emerging-role-bike-discussion-paper_1.pdf

based on the aspirational monthly salary of INR 25,000 of gig workers for 9 hours of daily work over a 6-day work week. Figure 6 shows the result of this simulation against the baseline value of INR 65 per hour at different levels of daily utilization.

The vertical bars represent the baseline TCO/km of battery swapping and ICE vehicles. It can be observed from the bar graphs that point charging is significantly more economical than owning and operating an ICE vehicle at all levels of utilization.

The three curves in the graph represent the base case and corresponding low and high cases (sensitivity cases) of the value of time. The low and high curves define the area that represents the degree of variation in the TCO that can be expected due to uncertainty in the value of time.

When daily utilization exceeds the range provided by the E2W on the full charge, the value of time starts making a significant impact. For the ride-hailing use case, at 160 km of daily utilization, the TCO/km for the ICE vehicle stands at INR 2.28, whereas for battery swapping it is INR 1.44. The TCO/km for point charging varies from INR 1.47 to INR 2.76, depending on the value of time.

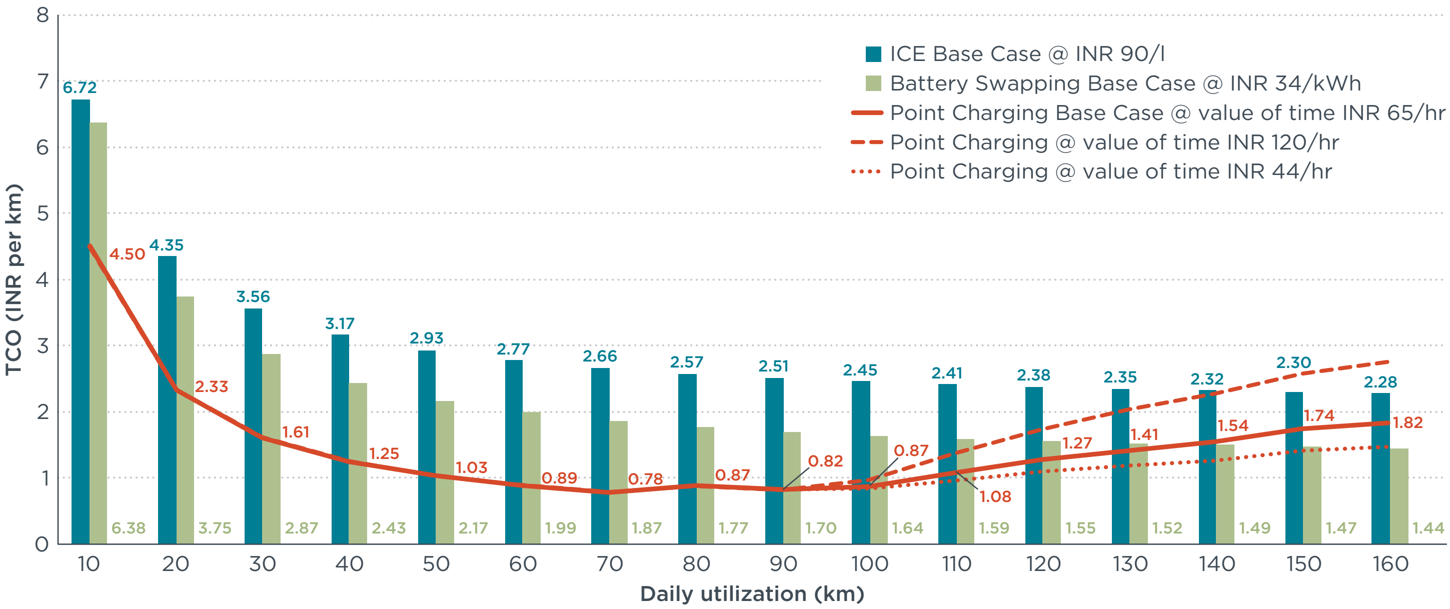

Figure 6. Sensitivity plots of value of time in the ride-hailing use case.

Additional sensitivity analyses

Electricity tariff. The Delhi Electricity Regulatory Commission (DERC) has an incremental charging structure for domestic customers based on number of units of electricity consumed per month and the tariff ranges from INR 3 per kWh to INR 8 per kWh. However, the Delhi EV policy has set a preferential tariff for EV charging for domestic users at INR 4.5 per kWh. Still, there are many cumbersome steps involved. For one, the preferential rate for EV charging is only applicable if the connection is dedicated for EV charging and serves no other purpose. To avail the subsidized rate, EV users need to apply for and pay for a separate, metered connection. EV users who need to engage a charging equipment provider to come and install a charger are eligible for a 100% subsidy toward equipment costs, up to INR 6,000. Any additional installation costs incurred are then paid by the consumer through monthly electricity bills.[26] Some

26 Shikha Rokadiya, "Charging Electric Two-Wheelers: A Cost or a Chance to Catalyze the Market?," *ICCT Staff Blog* (blog), September 20, 2021, https://theicct.org/blog/staff/charging-electric-2w-india-sept21.

EV users are also facing resistance from housing societies, and that needs to be dealt with before they can have a functional set-up to charge their E2W.

Additionally, the customer is wholly responsible for any pilferage and for the safety of the charger; DERC has no liability in these matters. Because of this, there is some uncertainty around the energy charges that users would incur for point charging. For this sensitivity analysis, we utilized INR 8 per kWh as an upper limit for this parameter and INR 3 per kWh as the lower limit. Table 3 shows the result of this simulation against the baseline value of INR 4.5 per/kWh at different levels of daily utilization.

Table 3. Results of the sensitivity analysis of electricity tariff for personal use case

Daily utilization, km	Electricity tariff at INR 3/kWh	Electricity tariff at INR 4.5/kWh	Electricity tariff at INR 8/kWh
10	5.00	**5.03**	5.12
20	2.56	**2.60**	2.68
30	1.75	**1.79**	1.87
40	1.34	**1.38**	1.47
50	1.10	**1.14**	1.22
60	0.94	**0.98**	1.06
70	0.82	**0.86**	0.95
80	0.74	**0.77**	0.86
90	0.84	**0.88**	0.97
100	0.89	**0.93**	1.01
110	1.12	**1.15**	1.23
120	1.29	**1.32**	1.39
130	1.43	**1.46**	1.52
140	1.57	**1.60**	1.66
150	1.68	**1.70**	1.76
160	1.77	**1.79**	1.84

At lower levels of daily utilization, the variance in TCO/km due to uncertainly in home electricity tariff is -4% to +9%. As the utilization increases, the impact reduces and the variance is less, -2% to +5%.

Further, at an average daily utilization of 40 km (about 10,000 km in a year, which is typical of the personal use case), the TCO amounts to about INR 13,800 per year. The uncertainty in the home electricity tariff results in a variation of about INR 500 to INR 1,000 per year.

Faster Adoption and Manufacturing of Electric Vehicles (FAME) purchase incentive. FAME is the flagship national program of the Government of India to create demand for EVs, to support domestic production of EVs, and to develop charging infrastructure. Currently, the FAME purchase subsidy of INR 15,000 per kWh for E2Ws is not applicable to E2Ws sold without batteries. In this sensitivity analysis we evaluate the impact of a hypothetical FAME subsidy on the TCO. We assume that the incentive will be structured in the same way as the purchase incentive offered by Delhi for battery swapping—50% of the incentive goes directly to the owner and the remaining 50% is awarded to the BSO to defray the cost of any deposit that may be required from end users. Figure 7 shows the result of this simulation at different levels of daily utilization for personal use.

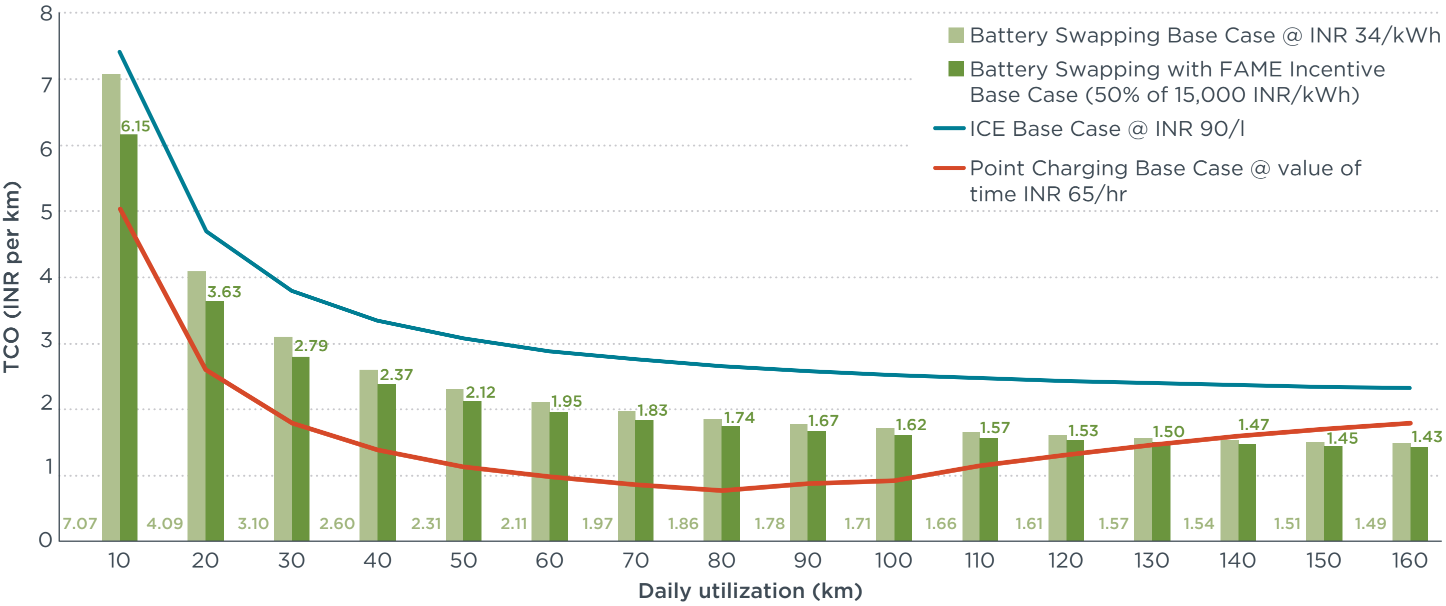

Figure 7. Battery swapping with hypothetical FAME incentive for personal use case.

The two curves in the graph represent the TCO/km of the base cases of point charging and ICE vehicles, and the vertical bars represent the baseline TCO/km of battery swapping without and with a hypothetical FAME-style purchase subsidy. It can be observed from the bar graphs that at lower levels of daily utilization, the subsidy makes a greater impact on TCO. For the personal use case, at a typical utilization of 40 km per day, there is a difference of 0.23 in TCO/km, and that is quite significant.

Conclusions of sensitivity analyses. ICE vehicles are the costliest to own and operate in the long-term at every level of utilization—even when the cost of gasoline is extremely low at INR 65 per liter.

Point charging remains most affordable at low and medium utilization rates (< 100 km per day), even with relatively high charges for domestic electricity. However, our analysis did not quantify the effort and resources required to apply, install, monitor, and safeguard an exclusive and dedicated domestic electricity connection to charge the E2W. It also did not consider the economic value of a convenient parking spot for charging the E2W at home.

For last-mile and ride-hailing use cases, the daily travel requirement is greater than the range delivered by the E2W on a full charge (about 111 km for the E2W evaluated in this study, recall). For these use cases, in order to complete daily operations, a top-up charge at a public charging station is required. The associated opportunity cost of charging and the additional energy costs incurred for public charging quickly add up. Greater annual mileage also means quicker replacement of the battery. This additional expenditure lowers the cost advantage of point charging. The greater the value of time of the user, the greater the decrease in the cost advantage of point charging.

For daily utilization more than 140 km, battery swapping is the most economic option. If the cost per kWh to battery swap is lowered to INR 20 per kWh from the current INR 34 per kWh, then battery swapping emerges as the most attractive option for daily utilization rates more than 120 km.

Further, a hypothetical Delhi-style purchase subsidy under a federal scheme such as FAME can bring about a 10% reduction in TCO at the low utilization rates (< 40 km) that are typical of the personal use case.

Ecosystem challenges for battery swapping

From the previous section, we see that battery swapping for E2Ws can be a cost-effective proposition for use cases with high daily utilization, irrespective of the uncertainty in input values. At the same time, there are barriers restricting more widespread adoption of battery swapping for E2Ws in India, and these are discussed below.

National-level push. The purchase incentive of INR 15,000 per kWh of battery capacity disbursed to the EV manufacturer under the FAME scheme can be passed on to the EV owner as a reduction in the purchase cost.[27] In the battery-swapping model, because the battery is not purchased by the E2W customer, there is no associated subsidy under the current FAME scheme.

In the battery-swapping model, the cost of the battery manifests, if indirectly, in the charges paid by the E2W owner to the BSO that owns the battery. The EV manufacturer also incurs research and development costs to produce battery-swappable E2W models that conform to the design requirements of the BSO. Thus, the costs remain in the absence of any current subsidy.

Additionally, to qualify for the FAME incentive, an EV needs to have a three-year warranty on its battery. When the EV is purchased with a pre-fitted battery, this warranty is provided by the manufacturer. But in the case of battery swapping, the manufacturer is not expected to provide warranty on a component that it does not provide. The recent decision by the Government of India has made it possible for a user to purchase an EV without its pre-fitted battery. This could be a vital step in bringing battery swapping under larger programmatic consideration.

Uneven support at the state level. Seventeen of the 28 Indian states have adopted regional-level EV policies; additionally, Himachal Pradesh and the union territory of Chandigarh have approved draft policies and at least three other states had a draft policy under consideration as of February 2022.[28] State-level incentives include purchase subsidies and incentives for setting up battery-swapping stations, but other than Delhi, Maharashtra, and Goa, no Indian state has approved a purchase subsidy for E2Ws sold without pre-fitted batteries. Each of the three states offer 50% of the subsidy to the BSO and the remaining 50% to the vehicle OEM or owner, as applicable.

While most of the adopted state-level EV policies provide subsidies and concessions for point charging providers, not all of them explicitly mention battery-swapping stations as eligible.

Andhra Pradesh, Assam, Delhi, Gujarat, Karnataka, Kerala, Odisha, and Uttar Pradesh offer a capital subsidy on charging equipment/machinery (excluding batteries) for battery-swapping stations. Andhra Pradesh, Delhi, and Odisha also offer to reimburse 100% of the state-level goods and services tax (SGST) for the purchase of advanced batteries for swapping stations. Andhra Pradesh is the only state to offer 100% net SGST, accrued to the state (until 2024), as reimbursement for providing battery-swapping services. Haryana is also considering such a waiver on batteries, according to its draft policy.

Cost of electricity. BSOs are unable to acquire electricity at an attractive price for all of their swap stations. While India's power sector regulations dictate that only consumers

27 The purchase incentive under the FAME 2 scheme is INR 15,000 per kWh, subject to a cap of 40% of the cost of the vehicle; for a typical electric two-wheeler, this can be 30% to 40% of the purchase cost.

28 States with policies are Karnataka, Delhi, Kerala, Maharashtra, Uttarakhand, Goa, Tamil Nadu, Andhra Pradesh, Madhya Pradesh, Uttar Pradesh, Telangana, Gujarat, Assam, Odisha, Meghalaya, West Bengal, and Rajasthan; those with draft policies under consideration are Punjab, Haryana, and Bihar.

with a contracted demand of 1 MW or higher can purchase electricity via open access,[29] Andhra Pradesh, Delhi, and Madhya Pradesh have removed this restriction via their adopted state EV policies. Open access enables customers to buy electricity at a lower price from a number of competitive electricity providers, rather than being limited to buying from the local provider. A typical battery-swapping station generates only a fraction of the minimum requisite load to be granted open access.

Model availability and scale of deployment. EV manufacturers are not especially supportive of the prospect of a third party fitting a battery in their EV.[30] In the case of any mishap related to the battery, the vehicle manufacturer's reputation is possibly tarnished. HOP Electric and Bounce Infinity are two companies in the Indian E2W market that offer both battery swappable E2Ws and a swap network. HOP Electric offers two E2W models with swappable batteries, the HOP Leo and the HOP Lyf, and they have a top speed of 50 km/h and 45 km/h, respectively.[31] In early 2021, HOP Energy set up a pilot network of five custom-built swap kiosks within a small geographic area in the city of Jaipur. Each kiosk has 12 battery slots, and the operation has a total inventory of about 100 batteries. The pilot network consists of about 45 E2Ws. HOP has announced plans to expand to Tier-1 cities and quadruple production capacity with the addition of a new manufacturing facility.[32] By 2022, HOP is also looking into producing its own kiosks to lower costs.

Lack of standardization in battery design across E2W models. E2W manufacturers have adopted a wide array of approved designs and standards for EV batteries and thus there are EV batteries with different form factors, connectors, et cetera.[33] It is not practical for a BSO to stock EV batteries with every different combination of approved designs and thus it is customary for BSOs to design and develop a "one size fits all" portable battery module and battery management system, the electronic system that manages the performance of the battery. After developing these proprietary designs, BSOs work with EV manufacturers to launch customized E2Ws that conform to their requirements. This approach enables the BSOs to aggregate demand and achieve a viable scale of operation, but also limits the vehicles that can use its services.

On one hand standardization allows for interoperability and provides flexibility to the user in terms of subscriber networks. On the other hand, it can restrict EV manufacturers from innovating and building better-quality vehicles. Manufacturers have been reluctant to forfeit control over the most expensive part of their vehicle and their ability to differentiate themselves from the competition.

Interoperability and reliability of service. When an individual buys an E2W without a pre-fitted battery and signs up with a particular BSO's service, they essentially become a captive user of the BSO's service. If the user is unhappy with the service being offered by the BSO or if the BSO shuts down, the EV user could be left with an unusable EV.

Assurance of quality and safety of battery. The E2W owner who uses a BSO's service is not assured of consistent driving range with every allotted battery. The calendric lifetime of a battery is dependent on various factors, and the nature of the discharge cycle(s) of the battery is one of them. The discharge cycle depends on the operating

29 Ministry of Law and Justice, "The Electricity Act 2003," June 2, 2003, https://cercind.gov.in/Act-with-amendment.pdf

30 Nishant Sharma, "Industry Confused As India Takes The Battery Out Of EVs To Boost Demand," *Bloomberg Quint,* September 15, 2020, https://www.bloombergquint.com/business/industry-confused-as-india-takes-the-battery-out-of-evs-to-boost-demand

31 Products details available at https://hopelectric.in

32 Pratik Rakshit, "HOP Electric Mobility to set Up Second Manufacturing Facility in India," *India Today,* September 1, 2021, https://www.indiatoday.in/auto/latest-auto-news/story/hop-electric-mobility-to-set-up-second-manufacturing-facility-in-india-1847867-2021-09-01

33 Meaning the connection device used to connect the battery and the body of the vehicle to transmit electrical energy and data.

style of the E2W user, and because the battery is used by numerous drivers within the BSO's network, its ability to hold charge is a reflection of its cumulative previous usage. That is out of the control of any individual EV user.

Additionally, if the battery is ever exposed to extreme operating conditions, that can compromise it. For example, flooding can cause water to seep into the battery module and trigger a short-circuit that can, in turn, lead to thermal runaway and fire.

To ensure the safety of all EVs subscribed in the network, the quality protocol of the BSO plays an important role in ensuring that any problems are detected early on and that any issue identified is promptly repaired.

Tax structure for out-of-vehicle batteries. Battery swapping is a capital-intensive business. In addition to the batteries that are in circulation with each subscriber, BSOs need to have additional batteries charging on standby—between 30% and 70% more batteries than are in circulation. Additionally, while a 5% GST applies to batteries pre-fitted to an EV, if the batteries are purchased separately, an 18% GST is applied. The higher rate of taxation has a significant impact because the BSO has to maintain a substantial inventory of spare batteries in addition to those that are in circulation at any given time.

Strategy considerations

The Government of India's decision to allow the sale and registration of EVs without batteries has generated much interest and many in the industry are anticipating a long-term strategy. Meanwhile, the EV ecosystem is still nascent in India and EV-related technologies are advancing quickly and significantly worldwide. Considering the rapid changes this industry has experienced over the past few years, there are additional and closely linked areas that need to be deliberated upon for scaling battery swapping.

Cost of batteries. The average cost of battery cells has dropped remarkably in the last decade and reached an average price of INR 10,047 per kWh in 2021.[34] This is a result of increased production volumes, rapidly advancing technology, more efficient supply chains, and decreased manufacturing costs. The relative contribution of the battery to the overall price of the EV is on the downward trajectory and this will diminish the impact of one of the underlying premises of the battery swapping business—that it relieves the significant upfront cost burden of owning the battery.

Data-enabled decision making. Embedded IoT devices that are fitted as a standard in battery swapping operations can provide data on utilization and energy consumption of the EVs. This information from the BSOs can be a proxy for driver earnings when the E2W is used for commercial operations such as last-mile delivery or ride-hailing. Enabling this flow of information will result in more informed lending practices.

Accessible financing. The fiscal benefits associated with an E2W are magnified when they are used for commercial operations with higher daily utilization rates, such as the E2Ws used for e-commerce deliveries and shared-mobility. Still, financing has not been easily available for this sector. High interest rates of 20% to 24% are common for private users who take out loans to purchase two-wheelers, and financial institutions are even more hesitant to finance E2Ws without their battery. Some kind of certification at the national level, like a stamp of approval from a competent authority, could make financing more readily available for BSOs and E2W users.

34 "Battery Pack Prices Cited Below $100/kWh for the First Time in 2020, While Market Average Sits at $137/kWh," *BloombergNEF,* news release, December 16, 2020, https://about.bnef.com/blog/battery-pack-prices-cited-below-100-kwh-for-the-first-time-in-2020-while-market-average-sits-at-137-kwh/

Adaptable battery architecture. An alternative to producing custom-built E2Ws that conform to a BSO's proprietary battery-swapping architecture is to use an adapter plate or dock. An adapter plate is a structural frame for the BSO's battery that has the same form and shape as the original battery of the E2W. Each plate is designed by the BSO to adhere to all the engineering requirements of the OEMs and enables the BSO's battery to interface with the E2W in the same way its original battery would and without compromising safety standards. Still, a slightly different and customized adapter plate needs to be designed by the BSO for each vehicle model. The power electronics and the battery management system that communicates the temperature, voltage, current, and more between the battery and the EV also need to be tweaked for each model. This approach allows the OEM to retain design control over the product and yet lets individual customers interested in swapping embrace this charging option and exit the BSO's network in case of poor service. This approach has been successfully implemented by Ample to enable 10 electric car models from five different manufacturers to use their swappable batteries.[35]

Sun Mobility has also developed such a dock for integrating their swappable batteries with E2W models, but the cost is prohibitive for large-scale deployment and Sun Mobility has yet to establish any partnerships with E2W OEMs and create an offering of battery swappable E2Ws. Note, too, that India's model test agency, Automotive Research Association of India (ARAI), requires each combination of battery and E2W to be tested independently before approving it as roadworthy. An E2W manufacturer needs to undergo the costly and time consuming testing and certification process repeatedly for each BSO it wants to partner with.

Operational standards. Safety and reliability of the battery is one of the primary concerns surrounding the prospects of battery swapping. Hence, if battery swapping for E2Ws is to become popular, it is paramount that the Government of India specify at the earliest minimum operational and safety standards for BSOs without compromising the performance of the battery and E2W. Minimum performance guarantees for number of swaps per battery, energy supplied by battery can be the starting point. It is also essential to set standards for charging and cooling of the swappable battery system, and protocols for testing, maintenance, safety, hazard identification and risk assessment. In 2020, the Bureau of Indian Standards appointed Sectional Committee ETD-51 to draft battery swapping standards for light EVs and the findings are still awaited.

In early May 2021, China approved the National Standard for Battery Swap Safety Requirements for Electric Vehicles (GB/T 40032-2021). These standards came into effect from November 1, 2021, and they set forth minimum safety requirements for the battery and specify stringent on-road testing protocols and inspection rules for battery-swappable vehicles.

Industry-led standardization. In March 2021, Honda Motor Co., Yamaha Motor Co., KTM AG, and Piaggio signed a letter of intent to set-up a consortium to oversee the development of a common battery swapping technology. The consortium aims to define technical specifications for L-category vehicles: mopeds, motorcycles, tricycles, and quadricycles. The four founding members have invited other interested manufacturers to be a part of this international consortium.[36] These universal swappable batteries will first feature in their new vehicle models in Europe and later be offered to international markets.[37]

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35 Jonathan M. Gitlin, "This Startup Has an Intriguing Concept for EV Battery Swaps," *ARS Technica*, March 4, 2021, https://arstechnica.com/cars/2021/03/this-startup-has-an-intriguing-concept-for-ev-battery-swaps/

36 "Piaggio, KTM, Honda and Yamaha to Create Swappable Batteries Consortium," *Reuters*, March 1, 2021, https://www.reuters.com/article/us-piaggio-batteries-consortium-idUSKCN2AT1QC

37 Praveen M, "KTM, Yamaha, Honda and Piaggio to Get Common Battery Tech in the Future," *ZigWheels*, March 3, 2021, https://www.zigwheels.com/news-features/news/ktm-yamaha-honda-and-piaggio-team-up-for-common-swappable-battery-technology/41326/

In 2018, a stakeholder group comprised of E3W manufacturers was convened by Centre for Battery Engineering and EVs at IIT Madras, a premier academic and research institution in India, to figure out industry-led specifications for swapping batteries of E3Ws and e-autos. The group developed the Locked Smart – Vehicle Battery Charger Cloud Protocol (LS - VBCC) suite which set-out draft specifications for communication protocols between various interfaces such as battery and the vehicle, battery and the kiosk charger, and battery and the cloud.[38]

Suggested strategy frameworks

Considering the advantages, opportunities, and challenges described in the previous sections, we present here two broad strategy frameworks that can be explored for battery swapping of E2Ws in India. The first has distinct limitations, though, and these can be somewhat addressed by the second framework.

A purchase-subsidy based scheme. EVs sold without pre-fitted batteries can be bought under the umbrella of a national program or state-level programs to promote battery swapping. To be consistent with the current disbursal pattern and avoid ambiguity with regard to the terms of the scheme, the purchase subsidy can be awarded in its entirety to the EV manufacturer, and the manufacturer can choose to either pass it on in its entirety, or pass on a fraction of it, to the BSO. The arrangement can depend on the EV manufacturers' relationship with the BSO and can be determined by the parties according to the relative contribution of both parties. The BSOs should be required to register with the government authorities, with minimum safety and operational parameters prescribed for them.

While it is possible for the public agencies to evaluate the various business models and pricing plans of BSOs and create an attractive incentive program, business models and E2W models are evolving at a much faster pace than what regulators can reasonably keep up with. Note, too, that the public agencies do not prescribe the rates for public point charging and charging point operators determine the tariff based on market forces and local conditions.

Therefore, alternate mechanisms for incentivizing this charging model could be explored. One such option is to detach the quantum of incentive from the size of the battery and shift focus toward the EV's contribution to kilometers electrified by linking the usage of the E2W with the subsidy it receives.

Usage-linked incentive scheme. This approach is based on identifying the market segments where battery swapping is the most dependable, economic, practical, and suitable charging option for E2Ws.

A pilot program can be instituted at the national level or by states that act as a project proponent, wherein the incentive accrues based on the utilization of the E2Ws and is disbursed on a periodic basis. Such a scheme would apply to consortiums of BSOs, EV manufacturers, fleet operators, and electricity distributors. A consortium arrangement would allow each partner to focus on their core competency and encourage collaborative action to overcome hurdles that each partner might be facing independently with respect to battery swapping.

To ensure adequate scale of operations and create a viable proposition for all partners, the project proponent should specify a minimum number of E2Ws that need to be deployed under such a scheme and specify a minimum utilization target for the fleet. The scheme should be limited to lithium-ion batteries with a pre-defined minimum

38 Rajesh Chandramouli, "EV Makers Come Together, Set Up Common Standards," *Times of India*, February 14, 2020, http://timesofindia.indiatimes.com/articleshow/74124650.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst

cyclic life to ensure that only good quality batteries with advanced cell chemistries are employed under the scheme. Since the incentive is directly proportional to the number of kilometers traveled by the E2W, it will also support the overarching goal of transport electrification while minimizing any misuse wherein incentives could be claimed to purchase the E2Ws that are not subsequently utilized.

BSOs can collaborate with EV manufacturers to provide the requisite warranty on their batteries and EVs. The closed-loop style operations will further relieve the fleet operator from uncertainty surrounding battery safety and performance. The vehicle OEMs will have every opportunity to set-up their E2Ws to safely deliver commercial-scale daily utilization levels.

The consortium set-up will also provide an additional lever to electricity distributors to negotiate favorable terms to flatten the electricity demand curve and pave the way for dynamic load balancing, net metering, and banking facilities.

Further, the consortium can internally strategize on how to split the incentive amongst themselves based on their relative contributions, and the project proponent need not be burdened with this element of the scheme. Mandates can be imposed on the consortium to ensure the proper treatment of retired EV batteries to steer them away from unorganized recycling processes or landfills, to reduce their life-cycle greenhouse gas emissions, and maximize their economic value.

Experiences from such pilot programs can be leveraged to design a full-scale incentive program which can consider additional provisions such as time-bound incentives for fleet operators that commit to 100% electrification and an efficiency-based, tiered incentive structure that rewards EVs with lower energy consumption per km.

Conclusion

Battery swapping allows for maximum asset utilization and there is minimal down time for charging the EV. Battery swapping also eliminates the technology risk of the EV battery for the user. Even though E2Ws can offer significant cost savings for commercial-scale utilization, fleet operators and shared-mobility providers have not yet given battery swapping serious consideration for a variety of reasons, including a lack of suitable battery-swappable E2W models, lack of adequate policy support, and the relative immaturity of the battery swapping eco-system in India. A few strategic alliances have formed between fleet operators, EV manufacturers, and battery-swapping service providers for E3W operations, but there has not been much traction on the two-wheeler front. For battery swapping to take hold with India's ubiquitous two-wheelers, well-designed pilot programs could be created for experiential learning, and then long-term policies could pivot from there. More explorative work needs to be done before battery swapping can be regarded as a long-term charging solution for all E2W use cases in India. For the time being, battery swapping for E2Ws can be envisioned as a complementary charging solution rather than an absolute replacement to point charging.

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