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# Pathways for Electrification of South Asia’s Transportation Sector

## A Product of the South Asia Group for Energy

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## Introduction

With more than 1.5 billion people in total, the region of South Asia, comprised of Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and, Sri Lanka, accounted for nearly 20% of the world’s population but only 8.6% of the global total greenhouse gas (GHG) emissions in 2018. However, while it has lower per capita emissions relative to global average, it is one of the regions of the world experiencing fastest growth in emissions, growing about 60% over the past decade (World Bank, 2021). Additionally, this region is globally one of the worst affected by air pollution. For example, India, Pakistan and Bangladesh account for 42 out of the top 50 world’s most polluted cities (Forbes, 2021).

Within this region, given its population and economy, India is the dominant polluter accounting for 80 percent of the region’s emissions (World Bank, 2021). The transport sector in India accounts for 13.5% of its energy related emissions, with road transport responsible for 90% of final energy consumption in the sector (IEA, 2020). India also has the dominant share in terms of new sales of all kinds of transport vehicles (see Table 1).

*Table 1: New Vehicle Sales in South Asian Countries in 2019 (Global Economy, 2019)*

Country	Passenger Vehicle Sales 2019	Commercial Vehicle Sales 2019
India	2,962,115	854,743
Pakistan	162,689	25,025
Bangladesh	3,000	1,900
Sri Lanka	8,100	1,445
Nepal	7,505	14,300

Therefore, given India’s outsized share in aggregate in emissions and given the prior work by this consortium, the emphasis is on insights from analyses conducted in the Indian context. However, while the basic techno-economic arguments and the policy implications are likely generally applicable to the whole region, caution is warranted and additional research is needed on each of the countries in the region including India.

Road transport accounts for a large share of passenger and freight traffic in India, and that share has grown significantly in recent years. India’s road transport accounts for 87% of passenger traffic and 60% of freight traffic

movement in the country (MORTH-India, 2021). The transport sector is also the largest and the fastest-growing oil consuming sector. Oil products, mostly diesel and gasoline, supplied 95% of total energy in the sector, and road transport energy demand accounted for 90% of the total oil demand (IEA, 2020). Within the HDV sector, trucking dominates fuel consumption, accounting for 43% of the overall diesel consumption, or about 36 MMT in 2018-19. India imported 87% of its oil in 2017-18 and is projected to import 91% by 2030 ((Karali et al, 2019); (Ghate, 2017)).

The main alternative drivetrains to petroleum or diesel-based drivetrains are electric, natural gas and hydrogen. A comparative analysis of three fuel types—battery-electric, hydrogen fuel cell, and diesel for medium and heavy-duty vehicles—shows that the long-term economics of battery-electric vehicles look more favorable compared to others with a Total Cost of Ownership (TCO) of 0.71 \$/mi as against a TCO of 0.78 \$/mi for diesel trucks and 0.97 \$/ for fuel cell vehicles. However, these numbers are highly dependent on the annual mileage and the cost of fuel (Burke, 2020). Additionally, for hydrogen to be used at a large scale, the challenges of bulk transport and storage along with reduction in cost of producing green hydrogen need to be tackled (Majumdar et al, 2021).

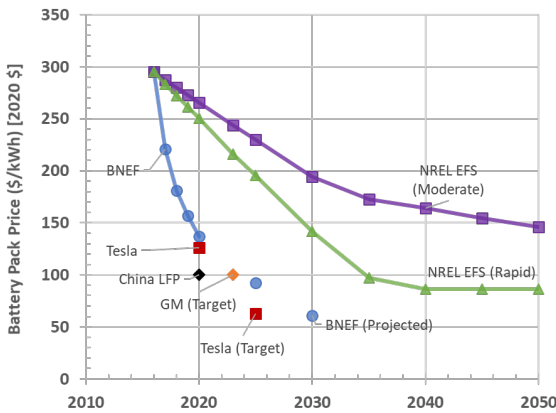


Figure 1: Global average battery pack prices projected and actual (BNEF 2020 & author compilation)

charging infrastructure is also being expanded rapidly, with the number of public charging points reaching 90k in the US, 350k in EU and 800k in China by the end of 2020 (Bloomberg, 2021).

India and other countries such as Pakistan and Sri Lanka have announced ambition for moving towards electric mobility. For example, Pakistan has announced a target of 50% of 2Ws/3Ws and urban bus sales to be electric by 2030, while aiming for 30% of passenger vehicles and truck sales to be electric by 2030 (IEA, 2021). India notified Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India (FAME) scheme in 2015, and the 2nd phase (FAME-II) of the scheme was rolled out in 2019 (Ministry of Heavy Industries, 2019). Total outlay for subsidizing upfront capital cost of electric vehicles was USD 0.5 billion and USD 1.5 billion in FAME-I and FAME-II respectively. Recently, India’s Minister for Road Transport Nitin Gadkari announced that India is aiming to have 80% of 2W/3W sales, 70% of commercial vehicle sales and 30% of passenger vehicle sales to be electric by 2030 (HT Auto, 2021). However, these targets are yet to be notified as official Government of India (GoI) policy.

The next section summarizes key insights from recent studies on techno-economic analyses of electric vehicles in India. However, given the similar road transport context in other South Asian countries, and a globally connected battery market, we contend that the analytical conclusions would be applicable to the entire region.

## Insights from existing studies

Heavy duty vehicles (HDVs) comprising heavy-duty trucks and buses account for only 10% of the global vehicle stock but are responsible for 46% of the greenhouse gas (GHG) emissions from road transport (IEA, 2020). HDVs account for the majority of oil consumption and emissions from road transport in developing countries such as India. Analysis from the International Council on Clean Transportation (ICCT)<sup>1</sup> showed that while in the US, 65% of oil was consumed by passenger vehicles, with trucks and buses accounting for ~35%; for India, these statistics are reversed. Given low penetration of passenger cars, 65% of oil consumption is driven by HDVs (trucks and buses). Moreover, India is heavily dependent on crude oil import— nearly 88% of total crude oil consumption, resulting in ~USD 100 billion import bill for oil in 2020 and expected to more than double by 2050. Thus, for decarbonizing the transport sector as well as enhancing energy security of the region, focus must be to move towards zero-emission-vehicle (ZEV) sales in the HDV category.

Additionally, commercial vehicles such as buses, trucks and taxis drive significantly larger distances per day compared to privately owned vehicles. This makes the financial case for electrification more compelling by saving on fossil fuel costs for every km traveled, thereby reducing the payback period for electric vehicles, which have higher upfront costs. Below we summarize three recent studies conducted for India’s transportation sector. However, given similar road conditions and driving patterns that exist in most parts of the region, the economics of EVs are expected to be comparable in other South Asian countries.

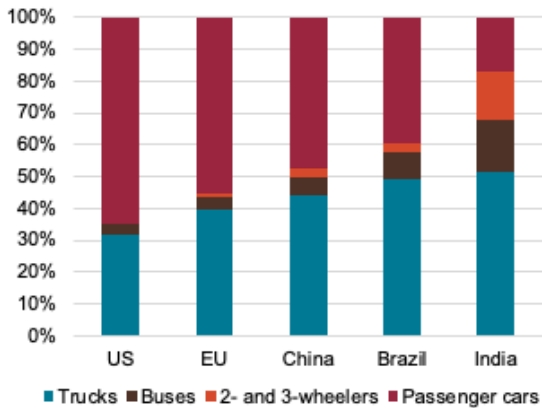


Figure 2: Share of oil consumption by different vehicle categories (2019)

### Electric trucks are already cost effective

In a forthcoming study, Lawrence Berkeley National Laboratory (LBNL) conducted a bottom-up assessment<sup>2</sup> of total cost of ownership (TCO) of electric trucks in various segments, and assessed the electricity demand and avoided oil consumption in the Indian context (Karali et al, forthcoming). The analysis examined several truck weight categories, estimating the required battery pack size based on standard operating conditions for each truck category. The modeling estimated TCO and payback period for truck operators, impact on diesel consumption, CO2 emissions, oil import, and the impact of truck charging load on national electricity demand.

The calculations for TCO included capital cost, fuel and maintenance cost, battery replacement every 2000 cycles and general operation cost which includes driver cost, insurance cost, permits and tolls. Figure B below shows the estimates for 12-ton and 25-ton trucks (latter being the most popular truck size in the region). A 25-ton truck would need a battery pack of 580 kWh for about 400 kms of average daily distance travelled, with 80% maximum depth of discharge. TCO of electric trucks is already lower than diesel trucks. Specifically, TCO of 12-ton truck is estimated to be INR 27.1/km which is 10% lower than a comparable diesel truck, for a battery price of \$150/kWh, and it would be 15% lower if battery costs are assumed at \$100. For a 25-ton electric truck, TCO is estimated to be INR 35.0/km, which is 30% lower than a diesel truck TCO of INR 50.2/km.

However, the capital cost for an electric truck is 179% and 58% higher than a comparable diesel 12-ton and 25-ton truck respectively. Therefore, upfront capital subsidy or other incentives such as low-cost financing are needed to

<sup>1</sup> ICCT expert opinion

<sup>2</sup> These costs are estimated at scale, and align well with observed prices in more advanced markets such as China. India would need a critical mass or scale of deployment to realize these prices in the market, akin to the experience with LED prices under the UJALA program.

drive early adoption by truck owners, which is a very fragmented market. At the same time, fast charging infrastructure along highways would be key to address range anxiety and minimize time spent on charging stops. The study assessed charging infrastructure needs for a 44-truck fleet (25-ton category), and TCO including this cost is estimated to be INR 41.9/km.

Table 2: Cost comparison of electric & diesel trucks in different weight classes

Electric trucks vs diesel trucks	7.5-ton	12-ton	25-ton	40-ton
Difference in capital cost (%)	102%	262%	232%	235%
Difference in TCO (%)	-3%	-10%	-30%	-24%
Payback Period (years)	6.3	4.9	2.5	3.1

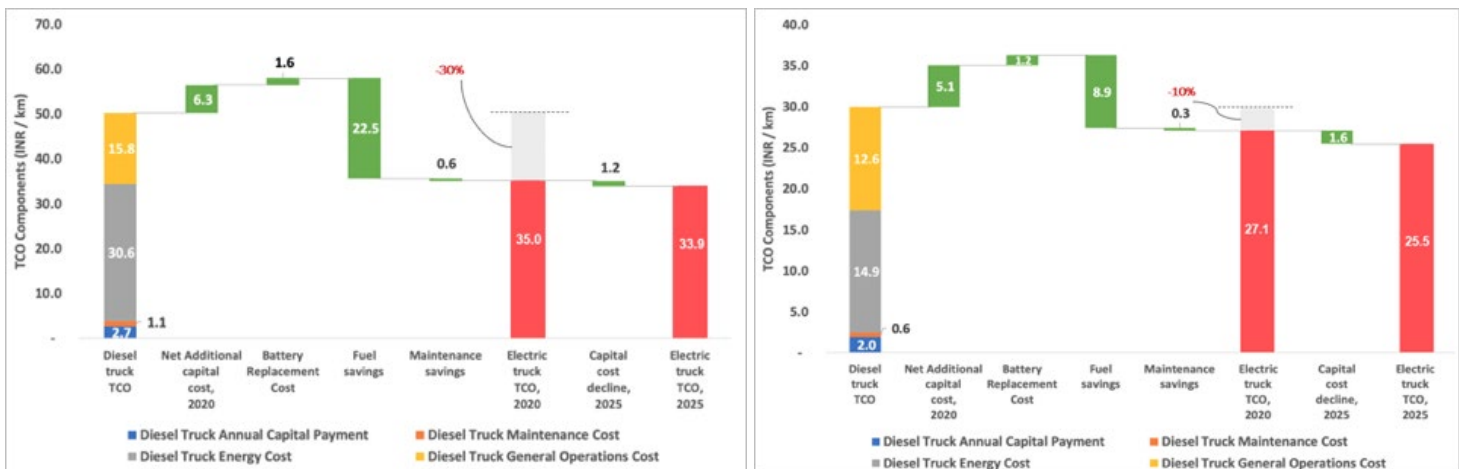


Figure 3: Total Cost of Ownership (TCO) of electric & diesel trucks (left: 25-ton, right: 12-ton)

The study also evaluated the impact of electrification of trucks on their payload capacity, while considering potential for reducing truck weight in future using lighter materials, such as aluminum, instead of steel for the truck body. For 12-ton and 25-ton trucks with a battery pack size of 319 kWh and 580 kWh respectively, extra battery weight of 1,422 kgs and 2,539 kgs is added to the truck body. The effective payload capacity of a 12-ton electric truck is estimated to be 13% lower than a corresponding diesel truck, and 11% lower for a 25-ton truck. However, with lightweighting, this gap between payload capacity reduces to 6% and 5% for 12-ton and 25-ton electric trucks respectively. Thus, we do not anticipate additional battery weight to be a major obstacle to electrification.

### Intercity buses could be more profitable by going electric

There has been push for intra-city bus electrification in India, with about 40% of subsidy outlay under FAME-II allocated for public buses. A report from LBNL has shown that deploying intracity electric buses with lower TCO than diesel buses can help reduce losses incurred by state bus agencies in addition to significant air pollution benefits (Khandekar et al, 2018). State Road Transport Undertakings (SRTUs) in India operate more than 135,000 buses, covering 15.75 billion kilometers daily (Central Institute of Road Transport, 2016). In 2016, approximately 15% of SRTU buses were used for intracity operations, while 85% were used for intercity operations (Singh-UITP, 2016). Intercity operations also make up about 85%–95% of total private bus operations (Gaika, 2020). Inter-city buses

drive longer distances per day, and hence would have shorter payback period. Thus, electrifying inter-city bus routes presents a big opportunity for India’s transport electrification efforts.

Using a bottom-up model, a forthcoming study from LBNL has assessed TCO of electric and diesel buses (12 m AC/non-AC) over three inter-city route lengths in India: 0–150 km, 151–250 km, and 251–350 km (Khandekar et al, forthcoming). Popular routes in the western and southern regions of India were used for simulation of bus operations and travel times. TCO included capital cost, fuel cost, maintenance and driver costs. Assuming a current diesel price of Rs.75/ltr and electricity price of Rs.7/kWh, this analysis showed that electric buses can reduce TCO by 20% compared with diesel buses today without subsidy, including the cost of charging infrastructure and battery replacement. The TCO for a 12-m AC electric bus, including the charging infrastructure cost, was determined to be 33.74 INR/km, compared to 47.83 INR/km for a diesel bus, for 600-km daily distance traveled over 16 hours (based on simulating bus schedules for 120-,160-, and 280-km routes for Maharashtra State Road Transport Corporation, MSRTC). Fuel costs (diesel and compressed natural gas) account for the majority of the material costs for SRTUs. For instance, MSRTC spends 32% of TCO on diesel expenses. Deployment of electric buses would enhance profitability up to 45% on intercity AC service routes, thereby helping SRTUs improve their financial condition while providing a better passenger experience.

For non-AC buses, TCO of an electric bus is comparable to a diesel one.

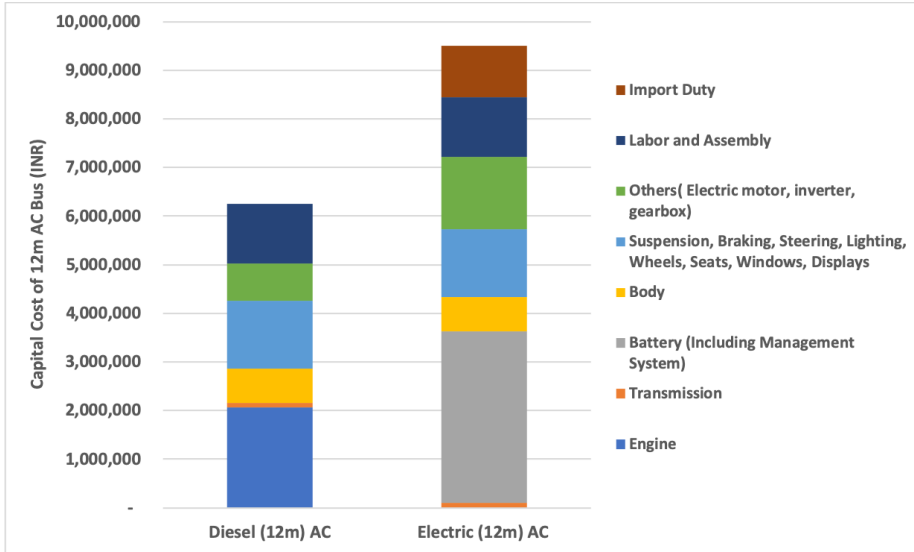
*Table 3: TCO for 12-m AC diesel and electric buses for two route lengths*

	<b>TCO Comparison of 12m-AC Electric vs Diesel Bus</b>			
	<b>12-m AC electric</b>	<b>12-m AC diesel</b>	<b>12-m AC electric</b>	<b>12-m AC diesel</b>
Daily distance traveled (km)	600		400	
Capital cost (INR)	95,07,717	61,68,619	95,07,717	61,68,619
Fuel cost (INR/km)	9.10	25.00	9.10	25.00
Maintenance cost (INR/km)	5.00	10.00	5.00	10.00
Charging infrastructure cost (INR/km)	2.90	0.00	2.90	0.00
Driver cost (INR/km)	7.80	7.80	7.80	7.80
Battery replacement cost, year 7 (\$/kWh)	60	N/A	60	N/A
<b>TCO (INR/km)</b>	<b>₹33.74</b>	<b>₹47.83</b>	<b>₹38.21</b>	<b>₹50.34</b>

The manufacturing cost of a 12-m AC electric AC bus is 50% higher than the cost of a comparable diesel bus, assuming a \$156/kWh battery cost. However, taking the recent market battery pack price of \$100/kWh, and 30% import duty on assembled battery packs, upfront cost of an electric bus is estimated to be 35% higher than a diesel bus today<sup>3</sup>. This estimate assumes a 324-kWh battery that gives 200-250 km on a single charge. 1C charging (i.e. the battery can be charged 0 to 80% within an hour) is commercially available and deployed in several countries, and a 25-minute midpoint stop and 30-minute turnaround time at the end of the route would provide plenty of time for the bus battery to charge while completing 600 km/day on average. For a 20-electric-bus fleet<sup>4</sup>, 10 chargers would be typically required, though we assume 14 chargers to handle overflow in case of delayed operations. Given

<sup>3</sup> This assumes that the market operates at scale

<sup>4</sup> Our assessment shows that 20 electric buses would be required to replace a fleet of 18 diesel buses, to account for downtime due to charging, indicating a replacement ratio of 110%.



the gap in upfront cost of the buses, strategic policy and financial initiatives would be needed to nudge the market towards adoption.

Figure 4: Bottom-up capital cost of 12-m AC diesel and electric bus (Khandekar et al, forthcoming)

## Electrification of commercial taxi fleets could drive significant economic and environmental benefits

A forthcoming study from University of California, Los Angeles, developed a framework for spatially-detailed estimation of charging infrastructure, and the economic and environmental benefits of electrification of commercial taxi fleet in New Delhi. Using a real-world dataset comprising ~730,000 app-taxi trips spanning ~15 million kilometers (km) in Delhi (shared by Ola, a premier on-demand taxi service in India), the analysis concluded that deploying 23,000 electric taxis having 200 km range per full-charge along with a network of 3000 50 kW DC fast chargers could meet 100% of app-taxi demand in Delhi. The study determines fleet-level average levelized cost of driving, comprising of vehicle cost, maintenance, fuel or electricity and charging infrastructure cost (if applicable), using Mahindra eVerito as the electric car model. The study finds that an electric taxi fleet would reduce levelized cost per km by 21% and 37% relative to CNG and diesel vehicles respectively. This assumes a battery price of \$160/kWh, a subsidy of Rs. 10,000/kWh for

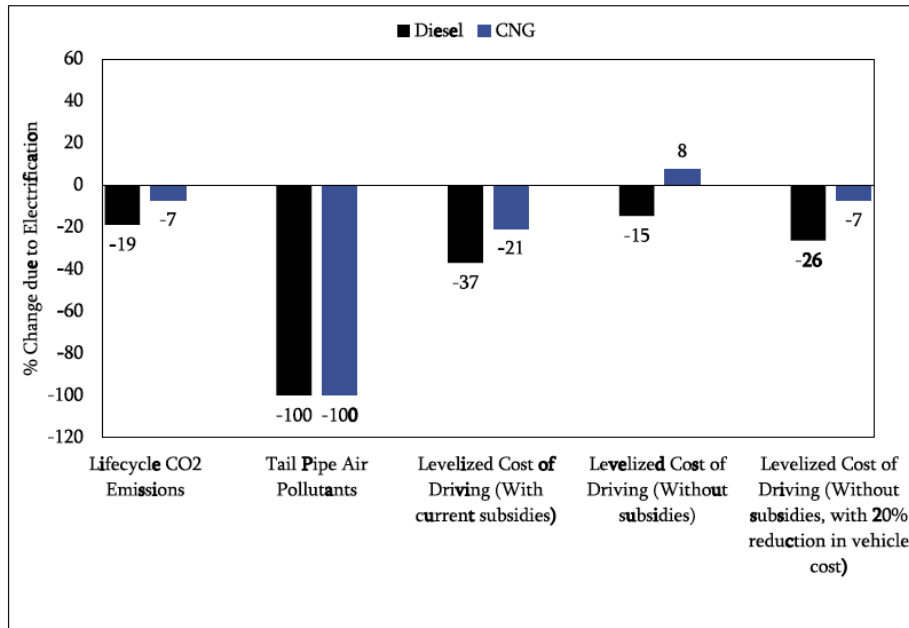


Figure 5: Impact of electrification on CO<sub>2</sub> emissions and the levelized cost of driving under different scenarios for diesel and CNG vehicles

batteries under FAME-II, and charging tariff of Rs 5.5/kWh (preferential tariff for EV charging provided by Delhi government).

Battery-electric vehicles are 2-3 times more energy efficient than ICE vehicles, and would reduce commercial fleet operation costs while reducing GHG emissions and avoiding tailpipe emissions at the point of use. Various studies have found that road transport accounts for 20-30% of PM2.5 emissions in Delhi NCR (UrbanEmissions.Info, 2016). Given the urgency of tackling severe levels of air pollution in Delhi, especially during the winter months, electrification could be an economically and environmentally sound strategy. Several major cities around the world have initiated similar schemes, for instance, London is working with all major taxi providers to only use electric vehicles in the city center by 2025 (Mayor of London, 2019).

The study evaluates several different approaches to siting of charging stations, and concludes that fleet performance is fairly robust to optimal vs random siting of charging points. Using real estate price data from commercial sources, the siting framework excludes areas with land prices above an assumed threshold of INR 10,000 per sq.ft. The impact of aggregate charging demand from the entire app-taxi fleet on Delhi’s power grid would be miniscule, increasing the peak grid demand by less than 1%. While the simulations in the study indicate that 60% of the charging would happen between 6 am and 6 pm, this demand<sup>5</sup> could be primarily met by solar resources, which would further improve the economics by lower solar tariffs (~Rs.2/kWh).

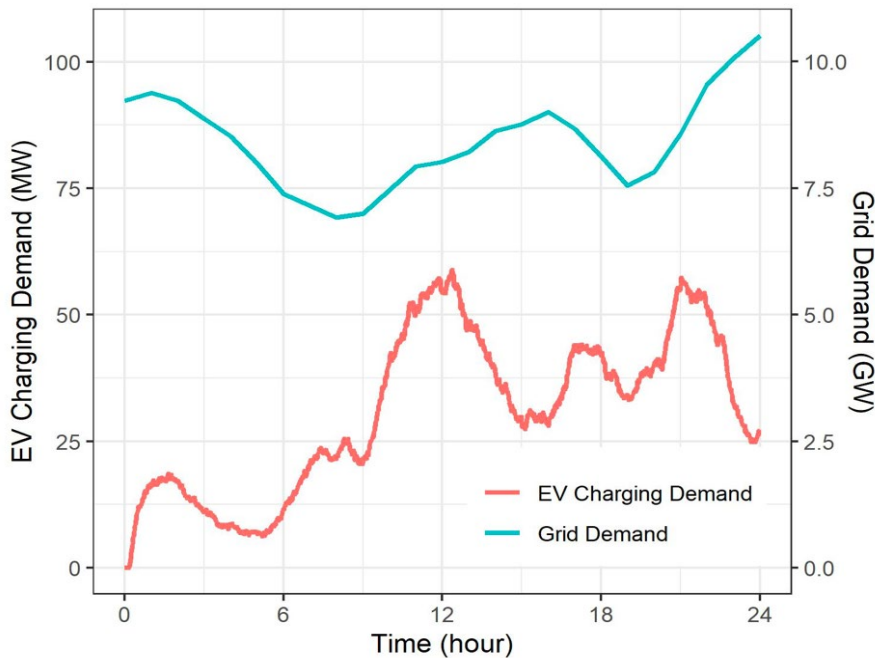


Figure 6: Daily average grid demand and EV charging demand in Delhi

<sup>5</sup> Simulations for this taxi fleet show this demand profile; but with higher scale, this demand would likely be price sensitive, offering opportunity for smart charging



## Challenges and Policy Recommendations

Given their air quality concerns, limited domestic crude oil production, and recent major developments in alternatives to petroleum-based drivetrains, most importantly, electric vehicle technology and renewable electricity, countries in South Asia have the opportunity to leapfrog to a cleaner and more sustainable transportation system, while improving energy security and reducing air pollution related impacts. A combination of supply push and demand-pull strategies can help kick-start this transition, which some countries are beginning to undertake, most notably, India.

For example, the second-phase of India's FAME policy, introduced in 2019, builds on the framework laid out by FAME -I with substantially larger budget outlay of USD 1.5 Billion primarily for subsidies to promote vehicle adoption and a smaller portion set aside for subsidies for investments in charging infrastructure. Unlike EV policies in most other countries of the world, it is notable for prioritizing adoption of EVs in the public bus transport sector, which received over 40% of the subsidies followed by subsidies for 2-wheeler and 3-wheelers which are used by poorer households and the least allocation for cars which are mainly used by wealthier households. An additional innovative aspect of subsidies for buses is that these were to be disbursed based on kilometers of actual bus operation rather than as a flat vehicle purchase subsidy. As a consequence, FAME demonstrates a strong focus on high-mileage vehicles for electrification, which will accrue larger environmental and equity benefits compared to the typical clean vehicle subsidy offered on passenger vehicles.

However, and the disruption caused by the Covid-19 global pandemic notwithstanding, progress in terms of achieving targeted level of sales under these schemes has been slow for a variety of reasons including lacunae in the policy ecosystem which necessitate some additional complementary policies. Policies for clean vehicle adoption would do well to implement lessons from the success India has achieved in the renewable electricity generation which has seen a virtuous cycle of large-scale procurement driven by guaranteed long-term contracts which reduce risk and uncertainty for investors which led to low cost power procurement. Similarly, standardized technology specifications for a few different sizes of electric buses, complemented by actual bidding & procurement on a decentralized (STU) level, could catalyze the requisite scale in the market for price reductions. A central agency could also aggregate volumes for price discovery. Upfront incentives for capital cost, tax subsidies, concessional financing rates for operators, and adoption of innovative leasing models for electric vehicles are some additional policy levers that could be deployed. Zero-emission-vehicle (ZEV) mandates on OEMs with tradable credits could provide a trajectory for domestic OEMs and accelerate EV sales, as observed in California, United States.

Secondly, investing in research and development and building indigenous capacity of both Li-ion battery and EV production would be crucial to ensure that transition to electric transportation yield important additional benefits to emissions reduction in the form of employment and domestic value creation. For instance, with the huge dependence of India's manufacturing GDP on the auto sector (~50%), there is a need to enable a thriving domestic EV manufacturing sector that can deliver quality vehicles at affordable costs, and remain globally competitive. In 2021, Government of India announced USD 3.5 billion of production linked incentives (PLI) for EV production over the next five years, which is expected to create over 7.5 lakh additional jobs. Along with the PLI scheme for battery manufacturing, with an outlay of USD 2.5 billion, domestic manufacturing of batteries along with electric vehicles is being incentivized. China currently dominates Li-ion battery production with a share of over 75% of batteries that were sold globally in 2020.

Thirdly, a robust network of charging stations would also be critical to enable faster adoption by addressing range anxiety of drivers. India's Ministry of Power has notified guidelines to install one charging station in a 3x3 km grid in large cities, and one charging station every 25 km along major highways. Our preliminary assessment shows that by investing ~USD 2 billion a year, India can build ~1000 HDV charging stations along major highways every year. As the fleet size grows, the cost of charging infrastructure as a percentage of TCO falls rapidly. Preferential EV tariffs would play a key role in early adoption by reducing payback period. Even though some Indian states have announced preferential EV tariffs, a streamlined process with the local distribution companies needs to be set up. Additionally, dedicated renewable energy contracts for EV charging could provide cheap clean power, nominally fixed for 25 years, especially to HDVs such as trucks. As trucks transport the majority of freight in these countries, low operating costs could be an inflation-control tool as the region undertakes energy transition. It should be noted that additional electricity load due to EVs, even with aggressive rates of adoption, could be managed so as to mitigate adverse impacts on the electricity infrastructure and markets. At the same time, focusing on commercial vehicles (taxi fleets, buses and trucks) could also present interesting smart charging opportunities for cost-effective grid integration of RE and accessing low cost RE power, especially during solar hours.

Finally, it is worth reiterating that much of this article is based on work carried in the Indian context and more specifically on battery electric vehicles, and therefore cannot simply be extrapolated to other South Asian countries. Financing mechanisms such as targeted subsidies, low-cost loans and counter-guarantee instruments would be key for enabling a large-scale transition. There is a clear need for greater research into the techno-economics, infrastructure needs, and potential policy mechanisms relevant to not just battery electric vehicles but clean transportation in general that are specific to the environmental, economic, political and social context of each country in the south Asian region.

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The consortium represents excellence in research and international development in the energy sector to advance the Asia Enhancing Development and Growth through Energy (Asia EDGE) priorities in the South Asia region.



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