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INCENTIVIZING ELECTRIC VEHICLES TO MEET FUEL CONSUMPTION STANDARDS FOR PASSENGER CARS IN INDIA

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BACKGROUND AND STUDY OBJECTIVES

Annual global electric vehicle sales have grown from just hundreds in 2010 to 1.2 million in 2017, led primarily by China, Europe, and the United States (Lutsey, Grant, Wappelhorst, & Zhou, 2018). The electric vehicle market in India however, has been a negligible part of this early global uptake. Only 0.02% (Yang, 2018) of total passenger vehicle sales in fiscal year 2017–18 in India were electric vehicles. Yet, policy officials have set electric vehicle sales goals as high as 40% (Society of Indian Automobile Manufacturers, 2017) to 100% (India Aims to Become 100% E-vehicle Nation by 2030: Piyush Goyal, 2016, March 26; NITI Aayog, n.d.) of the market share by 2030. Achieving such a radical market transformation over the next decade hinges on the adoption of a portfolio of effective policy measures.

Thus far, key policy measures that have been introduced in India for electric vehicle promotion are largely fiscal, such as demand incentives in the form of subsidies on the purchase price of electric vehicles, and preferential tax structures on manufacturing and sales of electric vehicles. A lesser discussed incentive mechanism involves manufacturers introducing electric vehicles into their fleets and receiving a certain percentage of compliance flexibility with their greenhouse gas-based corporate average fuel consumption (CAFC) standards.[1]

The two key elements that determine the extent of incentives available with CO_2 compliance due to electric vehicles include the accounting method for calculating CO_2 emissions of electric vehicles and the types of credit mechanisms available to manufacturers by including electric vehicles in their fleet. The types of emissions accounting methodologies prevalent globally include treating electric vehicles as zero-emission vehicles, equating the electrical energy consumption from electric vehicles with emissions from the equivalent volume of gasoline, and the scientifically accurate approach of determining net upstream impacts when an electric vehicle displaces a combustion vehicle from the fleet. The main credit mechanism available to electric vehicles in most vehicle standards globally, including India, is in the form of super-credit multipliers, which allow for an electric vehicle to be counted as multiple vehicles in the determination of corporate average compliance values.

The combination of the chosen accounting method for CO_2 emissions from electric vehicles along with compliance credits due to electric vehicles gives manufacturers an alternative, and less stringent,[2] corporate average CO_2 compliance target, compared to a target that is determined with no preferential incentive for electric vehicles. Thus, manufacturers are encouraged to invest in electric vehicles, albeit at the cost of potential trade-offs in fuel economy improvements of the remaining conventional vehicles in their fleet. Although the overall objective of such incentives is to promote inherently more fuel-efficient technologies in the market, the extent of compliance relaxation on emissions from conventional vehicles has the potential to become very significant. This can especially be concerning in the early to mid-stages of the electric

1 Different countries have different metrics regulated under standards. For example, the United States regulates both fuel economy and GHG, China and India regulate fuel consumption, and the EU regulates CO_2. Since all these metrics can be converted using appropriate conversion factors, these terms are used interchangeably throughout this report.

2 Assuming the accounting method adopted for CO_2 emissions from EVs represents a less energy-intensive pathway compared to conventional combustion engines.

vehicle growth curve when hundreds of thousands of conventional vehicles continue to be introduced and regulated under fleet-level targets.

It is therefore very important to carefully evaluate the integration mechanisms adopted for electric vehicles in fuel consumption standards. Excessive compliance flexibility to promote electric vehicles can potentially discourage deployment of best available technology in the combustion vehicles in the fleet and may even allow for market shifts toward a larger, heavier fleet.

Considering the above, the following questions emerge as the key research objectives of this analysis:

1. What compliance flexibility mechanisms are available to manufacturers that benefits inclusion of electric vehicles in their fleet in major global markets (the United States, the European Union, China, and India)?
2. To what extent are electric vehicle-related provisions in Indian fuel consumption standards impacting emission levels from conventional vehicles? How does India compare with global benchmarks in this aspect?
3. What is the cost-effectiveness of deploying electric vehicles as a strategy for complying with fuel consumption standards with and without the adopted regulatory provisions in India?
4. Based on global best-practices, how should India adapt existing policy measures to effectively promote electric vehicles while also aspiring toward more stringent standards?

This study is limited to the evaluation of integration mechanisms of electric vehicles in CO_2 standards specified for passenger cars only. The terminology to refer to electric vehicles varies by region. For example, while electric vehicles are referred to as New Energy Vehicles (NEVs) in Chinese regulations, they are referred to as Low-Emission Vehicles (LEVs) or Zero Low-Emission Vehicles (ZLEVs) in EU norms, and as Zero-Emission Vehicles (ZEVs) in U.S. regulations. In terms of technologies covered, most global standards include battery-operated vehicles (BEVs), plug-in hybrid vehicles (PHEVs), and fuel-cell vehicles (FCVs) under the definition for electric vehicles. Thus, any reference to the term “EVs” in the first half of this paper, which pertains to a regulatory review in major markets, refers to all the three technologies. In the second half of the paper, which pertains to a CO_2 risk analysis, scenarios for India are developed considering an electric vehicle market comprised of BEVs and PHEVs only.

GLOBAL REGULATORY REVIEW: INTEGRATION OF ELECTRIC VEHICLES IN FUEL ECONOMY REGULATIONS

In this section, we summarize CO_2 regulations for passenger cars in major global markets, namely, the United States, the European Union, China, and India, specifically to understand the accounting methods adopted for calculating CO_2 emissions attributed to electric vehicles, as well as the type of credit mechanisms available for electric vehicles.

Further, policies and measures related to sales quotas for electric vehicles, which are interlinked with CO_2 standards, are also reviewed here. For example, China has recently released a New Energy Vehicle (NEV) mandate policy for passenger vehicles that is interlinked with its existing CO_2 standards. Similarly, the European Union has proposed a sales target-based mechanism for promoting electric vehicles in its proposal for post-2020 CO_2 standards. The United States has sales mandates for electric vehicles at a state-level. The California ZEV mandate, adopted by 10 states in the United States, has been a pioneer program for electric vehicle deployment, and is also briefly reviewed here.

UNITED STATES

While fuel economy standards were first enacted in the United States in 1975, aligned fuel economy and greenhouse gas (GHG) standards were jointly issued first for the 2012–16 policy period and have further been notified for the 2017–25 period as well (EPA, 2010; EPA, 2012). While the GHG standards fall under the purview of the U.S. Environment Protection Agency (EPA), the fuel economy standards fall under the purview of the National Highway Traffic Safety Administration (NHTSA). Since compliance with the NHTSA standards is based on measurements of fuel economy (miles per gallon) and not tailpipe CO_2 emissions, the focus of this review is on the incentive mechanisms for electric vehicles as outlined in the GHG standards notified by the EPA. Both the 2012–16 and the 2017–25 policy periods have been studied in this review.

CO_2 ACCOUNTING METHOD FOR ELECTRIC VEHICLES

In the 2012–16 policy period, tailpipe emissions from BEVs and electric operation of PHEVs were set at a value of zero gram per mile with control structures in place on the eligibility to use this method. Manufacturers that produced less than 25,000 electric vehicles in 2012 could use the zero-gram-per-mile accounting method for the first 200,000 electric vehicles produced during the policy period. Manufacturers that produced more than 25,000 electric vehicles in 2012 could use the zero-gram-per-mile accounting method for the first 300,000 electric vehicles produced during the policy period. If these caps were exceeded, manufacturers would no longer be eligible to use the zero-gram-per-mile accounting method and were required to switch to a methodology that accounts for the net increase in upstream emissions attributable to the electric vehicles (assuming each electric vehicle was displacing a gasoline-based conventional vehicle).

While issuing these production-based caps, the EPA projected about 500,000 vehicles availing the zero-gram-per-mile incentive between 2012–16. This projection was considered as an “optimistic scenario” by the EPA, i.e, CO_2 losses would be within a reasonable range of 3%, while incentivizing electric vehicles. No manufacturers surpassed the 25,000 electric vehicle threshold in 2012, although General Motors (GM) came the closest with over 18,000. The four highest-selling EV automakers[3] each sold between 75,000 and 110,000 electric vehicles over the 2012–16 period. As a result, all manufacturers received zero-gram-per-mile accounting for all 2012–16 electric vehicles. Overall, for 2012–16, there were more than 480,000 electric vehicles sold in the United States, slightly below EPA's optimistic scenario (EPA, 2018).

For the 2017–25 policy period, the EPA has adopted a modified approach for incentivizing electric vehicles compared to 2012–16. For the initial 2017–21 period, tailpipe emissions from electric vehicles were set at a value relative to the zero-gram-per-mile incentive with no caps on the number of eligible vehicles to use this method. For the 2022–25 period, control structures have once again been put into place on the use of zero-gram-per-mile accounting. These control structures are designed to reward aggressive market players and consist of sales-based caps (instead of production-based caps) as follows: manufacturers that sell more than 300,000 electric vehicles during 2019–21 can use the zero-gram-per-mile accounting method for the first 600,000 electric vehicles produced during the policy period. All other manufacturers can use the zero-gram-per-mile accounting method for the first 200,000 electric vehicles produced during the policy period. Once these caps are exceeded, manufacturers are required to switch to net upstream emissions accounting.

The EPA states that the caps are designed to be large enough to sufficiently incentivize electric vehicle growth to a reasonable scale after which CO_2 losses from conventional vehicles in the fleet become more significant and cannot be overlooked as a tradeoff anymore. Based on sales in 2017, it is unclear if any automaker will meet the 300,000 electric vehicle threshold for 2019–2021 sales. The two highest-selling EV automakers, GM and Tesla, both sold between 43,000 and 46,000 electric vehicles in 2017.

Table 1 summarizes the EPA's approach toward determining tailpipe CO_2 emissions from electric vehicles.

Table 1. Summary of capping mechanism on zero emissions incentive for electric vehicles under U.S. GHG regulations

Policy period	Control structure	Cap on number of EVs eligible for zero emissions incentive (per company)	Accounting method prescribed after exceeding caps
2012–16	Manufacturers producing > 25,000 EVs in 2012	300,000	Net increase in upstream emissions from displacing a comparable gasoline vehicle
	All others	200,000	
2017–21	None	None	N/A
2022–25	Manufacturers selling > 300,000 EVs in 2019–21	600,000	Net increase in upstream emissions from displacing a comparable gasoline vehicle
	All others	200,000	

It is interesting to note that before finalizing the fixed per-company capping structure to limit eligibility for the zero-gram-per-mile incentive in the 2022–25 period, the EPA had also considered the possibility of setting a fixed industry-wide cap of 2 million vehicles, which would get distributed to manufacturers in proportion to their sales over 2019–21. This alternative structure would have allowed greater control on limiting the loss of GHG

3 Tesla, Nissan, GM, and Ford

emissions from the remaining conventional vehicles in the fleet under a specified level. However, it would also result in greater uncertainty for manufacturers in developing their CO_2 compliance strategies based on electric vehicle incentives, as their caps would have been a function of not only their own future electric vehicle sales, but electric vehicle market strategies of all other competitors as well. Thus, EPA finalized the fixed per-company caps instead of an industry-wide cap with the rationale that an industry-wide capping structure could potentially discourage manufacturers from investing in electric vehicles due to the uncertainties associated with long-term compliance planning.

To calculate the upstream emissions from an electric vehicle, emission factors for grid electricity generation, transmission, and distribution, as well as feedstock extraction, processing, and transportation are specified and applied to the electricity consumed by an electric vehicle over standard test cycles. Upstream emissions from a comparable gasoline vehicle are calculated based on fuel consumption values derived from the 2025 GHG target for that vehicle and upstream emissions factors specified for future gasoline in 2025. Table 2 below summarizes the key inputs and emission factor values specified by the EPA for calculating the net upstream emissions due to electric vehicles over comparable gasoline vehicles.

Table 2. Emission factors specified by the EPA for calculating net upstream emissions from electric vehicles

Parameter	Value	Remarks
Grid electricity generation emission factor	g CO_2/Wh	Emission factor based on EPA simulations that consider: • Incremental electricity demand from electric vehicles projected to be sold between 2022–25 and on road in 2030 • Spatial variations in electric vehicle demand based on distribution of hybrid vehicle sales in 2006–09 • Temporal variation in electric vehicle demand with 25% peak charging and 75% off-peak charging
Grid electricity transmission and distribution network efficiency	93.5%	—
Feedstock related multiplier for upstream emissions from grid electricity	1.2	Multiplier based on U.S. Department of Energy's GREET model assuming a grid consisting of 33.4% natural gas, 66.3% coal, and 0.3% other feedstocks
Upstream emission factor for future gasoline	2478 g CO_2/ gallon gasoline consumed	Based on DOE's GREET model

CREDITS AVAILABLE FOR ELECTRIC VEHICLES

In the 2012–16 period, the EPA had proposed super credits or multipliers ranging between 1.2 and 2 for electric vehicles. However, super credits were removed in the final rule as a precautionary measure to keep the potential losses of CO_2 benefits from remaining ICE fleet under reasonable limits.

A phased super credit structure was reconsidered and ultimately adopted for the initial 2017–21 period in the 2017–25 rule, with a maximum multiplier value of 2 for BEVs and

FCVs and 1.6 for PHEVs. The EPA stated that although advanced technologies were not necessary for compliance with the 2012–16 standards, some manufacturers would need advanced technologies to comply with the 2017–25 standards, and hence super credits can act as catalysts in increasing the market penetration of such technologies. Super credits have been removed for the 2022–25 period as the EPA expects that by then the electric vehicle market share would have grown to an extent that can significantly undermine the GHG benefits associated with the program. Table 3 below summarizes the proposed super-credit structures for electric vehicles by the EPA. The estimated model year 2017 advanced technology multiplier credits averaged nearly 2 g/mile, with manufacturers such as GM and BMW getting more than 3 g/mile and 5 g/mile from multiplier-based credits, respectively.

Table 3. Super-credit structures for electric vehicles under U.S. GHG regulations

Policy period	Multiplier for BEV/FCV	Multiplier for PHEV
2012–16	1 (no super credits)	1 (no super credits)
2017–19	2	1.6
2020	1.75	1.45
2021	1.5	1.3
2022–25	1 (no super credits)	1 (no super credits)

Note: PHEVs are subject to an eligibility condition of an all-electric range of at least 10.2 miles over the EPA highway test cycle to receive super credits.

ZEV MANDATE

It is important to note that California and nine other states in the United States also have ZEV mandates in place (California Air Resources Board, n.d; California Air Resources Board, 2016). These 10 states, which collectively account for about 29% of the total U.S. auto market, have significantly higher market shares of electric vehicles compared to states without ZEV mandates. For perspective, these states accounted for approximately two-thirds of the total new electric vehicle sales in the United States in 2017, with California alone accounting for about 50% (Lutsey, 2018). Table 4 below summarizes the increasingly stringent ZEV credit obligations for manufacturers from 2018–25. The minimum ZEV floor volume represents the percentage obligation that must be met through pure ZEVs, i.e, BEVs and FCEVs. Manufacturers may meet the remaining percentage obligation through sales of eligible PHEVs (TZEVs)[4] or choose to meet the entire mandate obligation through pure ZEVs.[5] A few additional technologies[6] that are eligible to earn ZEV credits under the California program are not commonly produced.

4 TZEVs or transitional zero-emission vehicles refer to PHEVs that meet the following eligibility criteria: (i) compliant with SULEV emission standards; (ii) zero evaporative emissions (iii) 15-year or 150,000-mile extended emissions warranty; (iv) 10-year or 150,000-mile warranty on energy storage device.

5 Manufacturers classified as "Intermediate Volume Manufacturers" may meet their entire requirement through TZEVs as well.

6 Hydrogen internal combustion engines (HICE), extended-range, battery-electric vehicle (BEVx) such as BMW i3 REX, and neighborhood electric vehicles.

Table 4. Summary of credit obligations in the California ZEV mandate

Model year	ZEV credit mandate	Minimum ZEV floor volume
2018	4.5%	2%
2019	7%	4%
2020	9.5%	6%
2021	12%	8%
2022	14.5%	10%
2023	17%	12%
2024	19.5%	14%
2025	22%	16%

Pure ZEVs earn credits as a function of their all-electric range (AER) on the EPA's Urban Dynamometer Driving Schedule (UDDS) test cycle with a maximum credit value of 4. TZEVs earn credits as a function of their equivalent all-electric range with a maximum credit value of 1.3. Manufacturers may bank excess credits for future use or sell them to other manufacturers. Manufacturers can fulfill credit requirements through both earned and purchased credits. However, if manufacturers fail to meet their credit requirements, they are subject to a penalty of USD 5,000 per credit deficit, in addition to the credit deficit owed.

Credits earned from the California ZEV mandate cannot be used toward compliance with GHG standards and hence the detailed regulatory provisions of the California ZEV mandate are not reviewed in this study.[7] On the contrary, the California ZEV mandate includes a provision for manufacturers to use credits from overcompliance with their GHG standards toward meeting their ZEV obligations between 2018 and 2021.[8] Manufacturers can use excess GHG credits to meet up to 50% of their minimum ZEV floor volume and allowable TZEV volume. Such an approach rewards manufacturers who meet their efficiency targets in conventional vehicles and in meeting their ZEV credit obligations.

EUROPEAN UNION

The European Union first specified GHG emission standards for passenger cars in 2009 and set fleet average targets for 2015. In 2014, they set standards for 2020. Further, in 2017, a proposal for the post-2020 period was formulated, which is currently under legislative review. Both the regulations specified in 2009 and in 2014, as well as the proposal submitted in 2017 for the post-2020 targets, have been studied in this review to understand the treatment awarded to electric vehicle-related compliance flexibilities (European Commission, n.d.).

CO_2 ACCOUNTING METHOD FOR ELECTRIC VEHICLES

Emissions from BEVs and the electric operation of PHEVs are considered as zero for the calculation of corporate average compliance targets under the European Union's CO_2 standards. As such, EU standards are technology-neutral and there are no specific references to tailpipe accounting mechanisms for electric vehicles based on upstream

7 Overcompliance with the ZEV mandate automatically makes it easier for the manufacturer to meet the GHG standards.

8 To avail this flexibility during model years 2018–21, manufacturers were required to pre-apply by the end of 2016 with a projected overcompliance of at least 2 g/mile for each model year.

impacts within the EU regulations for the entire 2021–2020 period. However, the preamble to the 2020 standards specified in 2014 states that upstream emissions from energy supply, as well as from vehicle manufacturing, are significant components of the carbon footprint of road transport in the European Union and will increase even further going forward. The preamble further states that policy action should be taken to account for upstream emissions, particularly those from energy supplies, to ensure that the intended program benefits for the remaining fleet do not get eroded. However, there is no inclusion on any upstream accounting methodology in the post-2020 proposal.

CREDITS AVAILABLE FOR ELECTRIC VEHICLES

The European Union's CO_2 standards make no specific reference to credit systems specifically for electric vehicles within the regulations, however, super credits have been specified for all vehicles with a CO_2 emission rate of less than 50 g/km. Since tailpipe emissions from electric vehicles are considered as zero in the European Union, these credits apply to electric vehicles as well. It is assumed that for PHEVs to be eligible for such credits, the combined weighted CO_2 emissions from operation in both charge-depleting and charge-sustaining modes leads to a CO_2 emission rate of less than 50 g/km.[9] A phased super-credit structure was specified for the 2012–16 policy period, with the per-vehicle multiplier ranging from a value of 3.5 to 1 (no super credit). However, super credits get reintroduced once again in 2020 with a per-vehicle multiplier value of 2 and get phased out by 2023. No super credits have been specified for the interim 2017–19 period. The super credits available for the 2020–22 period however, are subject to a per-manufacturer cap. While there is no limit set on the maximum number of vehicles that can avail of super credits on a per-manufacturer basis, the maximum possible relaxation in CO_2 targets due to super credits per manufacturer has been capped at 7.5 g CO_2/km over the period. No such caps were specified for the super credits available for 2012–16. Table 5 below summarizes the super-credit multiplier values for low-emission vehicles in the European Union.

Table 5. Super credit for low-emission vehicles under EU regulations

Policy period	Super credits for vehicles with emissions < 50 g CO_2/km
2012	3.5
2013	3.5
2014	2.5
2015	1.5
2016	1
2017–19	Not specified
2020[a]	2
2021[a]	1.67
2022[a]	1.33
2023 onwards	1

[a] Maximum possible benefit due to super credits is capped at 7.5 g CO_2/km per manufacturer for 2020–22

9 The procedure for determining fuel consumption, CO_2 emissions, electric energy consumption, and electric range for PHEVs in the European Union is specified in United Nations Economic Commission for Europe (UN-ECE) Regulation 101. Following the guidelines in UN-ECE R101, the electric range of PHEV tends to be estimated in a rather optimistic way. As a result, more vehicles are likely to be below the 50 g/km limit than there would be under WLTP.

Total EV sales reached approximately 1% of new passenger car registrations in 2015 and 2016 (Mock, 2017). BMW was the highest-selling electric vehicle manufacturer making up 4% of new electric vehicle registrations, while Daimler and Renault-Nissan ranked second, comprising about 1.75%. ICCT analysis (Tietge, 2018; Senzeybek, Tietge, & Mock, 2017) indicates that BMW and Renault-Nissan can receive up to 2 g/km reduction toward their targets for 2021, based on the average weight of their fleet in 2017. Thus, although the extent of compliance flexibility awarded by the European Union's super-credit values is significant, manufacturers would have to significantly increase sales of electric vehicles during 2020–22 to reach the maximum possible benefit cap value of 7.5 g/km.

ZLEV SALES CREDITS

Recognizing the strategic importance of electric vehicles for the EU market, the European Union has specified voluntary sales-based targets for low-emission vehicles (termed as ZLEVs) in its post-2020 standards. The voluntary targets are 15% of total new vehicle sales for 2025–29, and 35% for 2030. Vehicles with zero emissions (BEVs and FCEVs) count as full vehicles toward these targets. Vehicles with emissions between 0 g/km and 50 g/km (qualifying PHEVs) count partially proportional to their actual emission value. Vehicles that emit 50 g/km or higher count as zero. Manufacturers that overachieve their ZLEV sales targets will receive a proportional relaxation in their fleet-wide CO_2 compliance target. For example, assuming a manufacturer achieves 17% BEV sales in 2025, its fleet-wide CO_2 compliance target will be relaxed by a factor of 1.02. Similarly, if a manufacturer achieves 34% BEV sales in 2030, its fleet-wide compliance target will be relaxed by a factor of 1.04. The extent of compliance relaxation is limited to a maximum adjustment of 1.05, i.e., manufacturers receive incentives to overachieve their ZLEV targets up to 5%.

ICCT analysis (Dornoff, Miller, Mock, & Tietge, 2018) indicates that the compliance flexibility offered by these ZLEV targets is the equivalent of having super-credit multipliers with a maximum value of 1.2 from 2025–29 and 1.1 in 2030. The analysis further indicates that the maximum incentive level (adjustment factor of 1.05) from overachieving ZLEV targets is the equivalent of a maximum CO_2 benefit of 4 g/km per manufacturer (compared to 7.5 g/km from super credits over 2020–22). However, no penalties are specified at present in the proposal for manufacturers that fail to achieve their ZLEV targets. Such a mechanism is referred to as a one-way adjustment in the proposal.

CHINA

China's Phase I and Phase II standards (Ministry of Industry and Information Technology, 2004) for passenger vehicles were adopted in 2004 for compliance over the 2005–07 and 2008–11 period. China further released Phase III standards (Ministry of Industry and Information Technology, 2011) in 2011 for compliance over the 2021–15 period, and then Phase IV standards (Ministry of Industry and Information Technology, 2014) in 2016 for compliance over the 2016–20 period. Compliance flexibilities in the form of incentives for NEVs were only introduced in the Phase IV standards, and hence, only the Phase IV standards are included in the scope of this review. In 2017, China issued a national level NEV mandate policy (Cui, 2018) that runs parallel to the Phase IV standards and allows further compliance flexibilities to a manufacturer's CAFC targets through credits earned based on the type of NEV vehicle manufactured, which is also reviewed here.

CO_2 ACCOUNTING METHOD FOR ELECTRIC VEHICLES

Energy consumption from electric vehicles and the electric operation of PHEVs is considered as zero for calculation of corporate average fuel consumption and CO_2 compliance targets in China's Phase IV standards. Further, no control mechanisms are specified for the eligibility of electric vehicles to avail the zero-emissions accounting approach.

CREDITS AVAILABLE FOR ELECTRIC VEHICLES

As summarized in Table 6 below, the Phase IV standards specify super credits for electric vehicles with a multiplier value of 5 for 2016–17, 3 for 2018–19, and 2 in 2020. There is no cap specified for the maximum possible benefits that can be claimed due to super credits.

Table 6. Super credits for new energy vehicles under China Phase IV standards

Policy period	Super credits for BEV, FCV, and PHEV (R > 50 km)	Other vehicles (including PHEV[10]) < = 2.8 l/100km
2016–17	5	3.5
2018–19	3	2.5
2020	2	1

NEV MANDATE

China issued sales mandates for electric vehicles in September 2017. The sales mandates run parallel to China's Phase IV compliance standards and are a modified version of the California ZEV mandate. Manufacturers earn NEV credits for every eligible NEV introduced into the fleet in a year and are subject to a target of reaching a certain volume of these credits annually. The policy formally went into effect April 2018 and establishes NEV credit targets of 10% of the conventional passenger vehicle market in 2019 and 20% in 2020. If manufacturers go over their NEV credit targets, they can sell the excess credits[11] to other manufacturers, transfer them to their affiliate companies, or use them to comply with any deficits in their CAFC targets. Vehicles eligible to earn NEV credits include BEVs with a maximum vehicle speed greater than 100 km/h and electric range greater than 100 km, PHEVs with an electric range greater than 50 km, and FCVs with an electric range greater than 300 km. Table 7 and Table 8 below summarize the credit structures in place in China's NEV mandate policy based on curb weight, energy consumption, and electric range for BEVs and based on curb weight, electric range, and non-electric fuel consumption for PHEVs.

10 PHEV with an electric range less than or equal to 50 km.

11 Only credits earned on NEVs meeting predefined mid- and high-efficiency levels are eligible to be sold to other manufacturers, while credits earned on vehicles under the lowest efficiency thresholds defined in the policy are not eligible for sale.

Table 7. Summary of NEV credit structure for eligible[12] BEVs under China's NEV mandate policy

Criteria 1	Criteria 2	NEV credits per vehicle	Cap on maximum credit value
curb weight [M]	energy consumption [Y]		
< = 1000	> 0.014 * M + 0.5	0.5 * (0.012 * R + 0.8)	2.5
> 1000 and < =1600	> 0.012 * M + 2.5		
> 1600	> 0.005 * M + 13.7		
< = 1000	> 0.0098 * M + 0.35 and < = 0.014 * M + 0.5	(0.012 * R + 0.8)	5
> 1000 and < = 1600	> 0.0084 * M + 1.75 and < = 0.012 * M + 2.5		
> 1600	> 0.0035 * M + 9.59 and < = 0.005 * M + 13.7		
< = 1000	< = 0.0098 * M + 0.35	1.2 * (0.012 * R + 0.8)	6
> 1000 and < = 1600	< = 0.0084 * M + 1.75		
> 1600	< = 0.0035 + 9.59		

Notes: M = curb weight in kg; Y = energy consumption in kWh/100 km; R = electric range. Table adopted from Hongyang Cui, "China's New Energy Vehicle Mandate Policy (Final Rule)," (ICCT, 2018), https://www.theicct.org/publications/china-nev-mandate-final-policy-update-20180111.

Table 8. Summary of NEV credit structure for PHEVS under China's NEV mandate policy

Criteria 1	Criteria 2	Criteria 3	NEV credits per vehicle	Cap on maximum credit value
electric range [R]	curb weight [M]	energy consumption [Y]		
< 50	NA	NA	Not eligible for credits	NA
> = 80	< = 1000	> 0.014 * M + 0.5 when tested under electric mode	1	NA
	> 1000 and < = 1600	> 0.012 * M + 2.5 when tested under electric mode		
	> 1600	> 0.005 * M + 13.7 when tested under electric mode		
> = 80	< = 1000	< = 0.014 * M + 0.5 when tested under electric mode	2	NA
	> 1000 and < = 1600	< = 0.012 * M + 2.5 when tested under electric mode		
	> 1600	< = 0.005 * M + 13.7 when tested under electric mode		
> = 50 and < 80	all	Fuel consumption when tested under non-electric mode (l/100 km) no lower than 70% of Phase IV fuel consumption limits	1	NA
> = 50 and < 80	all	Fuel consumption when tested under non-electric mode (l/100 km) lower than 70% of Phase IV fuel consumption limits	2	NA

Notes: M = curb weight in kg; Y = energy consumption in kWh/100 km; R = electric range. Table adopted from Hongyang Cui, "China's New Energy Vehicle Mandate Policy (Final Rule)," (ICCT, 2018), https://www.theicct.org/publications/china-nev-mandate-final-policy-update-20180111.

12 Only BEVs with a maximum speed > 100 km/h and an electric range > 100 km are eligible to receive NEV credits. BEVs falling below these limits receive no credits.

INDIA

India first issued corporate average fuel consumption standards in 2015 were implemented from FY 2017–18 (Ministry of Power, 2015). The standards are phased into two compliance periods with Phase I applicable from 2017–18 to 2021–22, and Phase II from 2022–23 and onward. A draft compliance proposal detailing the accounting methods to be used for demonstrating compliance with the standard was issued in 2018 (Ministry of Road Transport and Highways,2018). This summary includes a review of both the standards and the draft compliance proposal to understand the treatment regarded to electric vehicles.

CO_2 ACCOUNTING METHOD FOR ELECTRIC VEHICLES

India has adopted an approach similar to Japan's for attributing CO_2 emissions to electric vehicles in the calculation of corporate average compliance standards, as summarized in Table 9 below. The electric energy consumption of BEVs in kWh/100 km is converted to gasoline equivalent terms in l/100 km using an energy conversion factor specified in the compliance proposal. Further, it is assumed that this gasoline equivalent fuel is consumed in a conventional vehicle and specified CO_2 conversion factors based on the carbon content of gasoline are applied to obtain the CO_2 emissions.

Table 9. Conversion factors to determine CO_2 emissions from electric vehicles

Conversion factor	Value
Electrical energy consumption (kWh/100 km) to gasoline equivalent fuel consumption (l/100 km)	0.1028
Gasoline equivalent fuel consumption (l/100 km) to CO_2 emissions (g/km)	23.7135
CO_2 emissions from electrical operation of EV (g/km) = electrical energy consumption (kWh/100 km) * 0.1028 * 23.7135	

CREDIT AVAILABLE TO ELECTRIC VEHICLES

India has proposed super credits for both BEVs and PHEVs. The multiplier value for BEVs is set at 3 and the multiplier value for PHEVs is set at 2.5. There is no time frame indicated for limiting the applicability of these multipliers. Further, there are no caps specified on the maximum possible benefit that can be extended to a manufacturer due to the proposed super credits. In addition to BEVs and PHEVs, India offers super credits for low-emission vehicles like the European Union and China and is the only country with super credits on vehicles using hybrid technologies as well. Table 10 below summarizes the super credits prevailing in the Indian passenger vehicle regulations.

Table 10. Super-credit multipliers under Indian CAFC regulations

Technology	Super credit	Caps
BEVs	3	None
PHEVs and range extender hybrid vehicles	2.5	None
Strong hybrid vehicles	2.0	None

Fiscal year 2017–18 is the first compliance year for the auto sector in India with corporate average fuel consumption targets. ICCT analysis indicates that four manufacturers in India benefit from super-credit multipliers in 2017–18: Volvo, Toyota, Mahindra & Mahindra, and Tata Motors (Yang, 2018). Mahindra & Mahindra is the top-selling electric vehicle manufacturer of the four and receives a compliance relaxation of 0.7 g/km due to super credits. Volvo receives the highest benefit of 4.4 g/km because although its overall volume in the market is much lower, it has a much higher share of electric vehicles within its fleet. For perspective, Mahindra & Mahindra held 7.3% of the total passenger vehicle market in 2017–18, while Volvo held under 0.1% of the market share. Yet, Volvo's sales of electric vehicles were 3.2% of its total sales and only 0.017% of total sales for Mahindra & Mahindra.

SUMMARY

To summarize, all major global markets offer incentives in the form of super-credit multipliers, with the value of super-credit multipliers being much higher in China and India in comparison to the European Union and the United States As evaluated in an ICCT study (Lutsey, 2017) on U.S. and EU markets, super-credit multipliers can dilute CO_2 standards significantly and are associated with significant environmental costs. For example, ICCT analysis (Tietge, 2018) indicates that Renault-Nissan and BMW, which account for about 22% market share of passenger vehicles in the European Union, can receive a 2 g/km reduction in their 2021 compliance standards in the European Union based on their fleet composition 2017. Similarly, Hyundai, Volkswagen, and Daimler, which account for about 36% of the European Union market share, can receive up to a 1 g/km reduction. Excepting India, all other markets have some degree of control in place on the compliance relaxation possible due to super-credit multipliers. The United States, the European Union, and China have structured the super credits to phase out over a five-year period, with the European Union additionally restricting the maximum possible benefit due to super credits to 7.5 g/km per manufacturer. Further, the European Union is proposing to move toward incentivizing electric vehicles through sales-based targets in its post-2020 standards. ICCT analysis (Dornoff, Miller, Mock, & Tietge, 2018) indicates that the proposed EU targets are approximately equivalent to a maximum super-credit multiplier of 1.2 during 2025–29 and 1.1 in 2030. Further, the maximum possible incentive is restricted to overachieving the sales targets by up to 5%, after which no further incentives are provided. ICCT analysis indicates that this upper limit of 5% translates to a maximum benefit of about 4 g/km per manufacturer.

On the emissions accounting side, excepting India, all major markets allow electric vehicles to be treated as zero-emission vehicles for compliance purposes. However, the use of such a preferential emission-accounting method is capped to a fixed volume of electric vehicles per manufacturer in the United States, after which emissions from electric vehicles are to be determined through a scientifically accurate approach based on the net increase in upstream emissions due to electric vehicles displacing equivalent conventional vehicles in the fleet. While the European Union and China have both acknowledged the importance of accounting for upstream emissions from electric vehicles in their respective regulatory document, no clear rules have been issued in either markets so far. India has adopted a middle-ground approach between the two approaches globally. Electric vehicles in India are not treated as zero-emission vehicles nor are they required to account for upstream emission impacts. Instead, they are assumed to be displacing an equivalent volume of gasoline that would have been combusted in a conventional vehicle and resulting emissions.

It is important to note that the reference markets evaluated in this study (United States, the European Union, China) have recognized the importance of sales-based targets for electric vehicles to achieve rapid market penetration. The California ZEV program has been a pioneer program that was first adopted all the way back in 1990 and has been amended many times thereafter. Nine other states in the United States have also adopted California's ZEV regulations. Collectively, California and the other ZEV mandate states account for more than two-thirds of the electric vehicle market in the United States, with California alone accounting for more than half of it. In 2017, China has adopted its own national level electric vehicle mandate (NEV mandate policy), which is a modified version of the California ZEV mandate. However, unlike in the California program, credits earned from China's NEV mandate can also be used toward meeting compliance with the fleet average CO_2 standards. Thus, emissions from conventional vehicles in China face additional risk for erosion from such dual-credit compliance provisions (Cui, 2018), over and above from super-credit incentives and zero-emissions accounting incentives. The California mandate on the contrary, rewards manufacturers who consistently overachieve their fleet average standards (between 2018–21) by allowing them to use excess GHG credits toward meeting their ZEV credit obligations.

As super credits phase out in the European Union in 2023, a sales target-based mechanism will incentivize electric vehicles (ZLEVs). The proposed ZLEV target mechanism overcomes some of the issues associated with the super-credit structures in the current standards. For example, the magnitude of incentive available to ZLEVs will be linked to their actual tailpipe emission values (instead of uniformly attributing the same credit to all ZLEVs below the 50 g/km threshold). For perspective, about 33% of all ZLEVs registered in European Union in 2016 were within the upper limits (40 g/km to 50 g/km) of the eligibility threshold for receiving incentives. However, in-spite of these improvements, European Union's proposed ZLEV mechanism has a major setback in that no penalties are specified for manufacturers that fail to achieve their ZLEV targets. Impact assessment studies conducted by the European Union indicate that the ZLEV targets already align with technology plans of manufacturers in European Union (Dornoff, Miller, Mock, & Tietge, 2018), with major manufacturers[13] declaring goals higher than the European Union's 15% target in 2025. Thus, changing the ZLEV targets to enforceable mandates with penalties seems to be a requisite for ensuring greater market penetration of electric vehicles with more stringent CO_2 reduction targets (Mock, Lutsey, & Tietge, 2018).

Unlike the United States, China, and EU markets, India does not have sales targets declared for electric vehicles. It is also important to note that both California's ZEV mandate, and European Union's ZLEV targets are one aspect of a broader program design to support the rapid growth of the electric vehicle market over the next decade. Other program elements include a host of fiscal and non-fiscal measures targeted at expanding charging networks, increasing awareness levels in consumers, building supply chains, and increasing stakeholder coordination at state and local levels.

13 BMW, Daimler, Renault-Nissan, and Volkswagen.

SCENARIO ANALYSIS: CO_2 RISK POTENTIAL IN INDIA UNDER VARIOUS MARKET AND POLICY CONDITIONS

KEY ASSUMPTIONS AND APPROACH

As outlined in the regulatory review in this report, electric vehicle-related policy elements in GHG standards that have the potential to impact emission levels from conventional vehicles include super-credit multipliers and preferential emissions accounting methods. Further, the electric vehicle market in India is still nascent and market penetration projections for 2030 are as high as 40% to 100% of new vehicle sales. While there is uncertainty on the exact growth trajectory that India will witness in the absence of clear technology mandates, the Indian approach to integrating electric vehicles in GHG standards is more lenient compared to global regulations.

Thus, it becomes important to evaluate the CO_2 risk of integrating electric vehicles in GHG standards over a range of market scenarios and policy conditions. Based on the potential for risk, it is also important to examine the possibility of introducing control mechanisms to contain program losses below reasonable levels. Such an analysis is conducted in this study through four hypothetical scenarios, as illustrated in Table 11, where all scenarios differ primarily in the rate of electric vehicle uptake. The scenarios span up to fiscal year 2030, with a baseline year assumption of 2017.

Table 11. Summary of market assumptions for scenario analysis

Input	Scenario I	Scenario II	Scenario III
Scenario description	Slow EV uptake	Moderate EV uptake	Rapid EV uptake
PV growth curve	3.28 million new vehicle sales in 2017 growing to 5.45 million in 2030		
EV growth curve[a]	From 0.03% in 2015, growing to 5% in 2030 Total EV sales are assumed as 80% BEV sales and 20% PHEV sales	From 0.03% in 2015, growing to 20% in 2030 Total EV sales are assumed as 80% BEV sales and 20% PHEV sales	From 0.03% in 2015, growing to 40% in 2030 Total EV sales are assumed as 80% BEV sales and 20% PHEV sales
Target emission level of fleet	At an average of 130 g CO_2/km in 2017, with an annual efficiency improvement of 2.8% until 2030		

Notes: PV growth curves are based on internal projections by the ICCT. EV growth curves are modeled based on hypothetical assumptions between the years 2015 and 2030 by considering extrapolations from actual EV sales in India of about 0.03% of PV market in FY 2015–16.

[a] The current PHEV market in India is next to negligible and there is very little insight on the growth forecast for PHEVs going forward. Keeping this in perspective, for three scenarios out of four evaluated in this study, it is assumed that, unlike the European Union EV market, which is mostly PHEV dominated, India's EV sales will be BEV-oriented, like in China, comprising 80% BEV sales and 20% PHEV sales for the duration of the period modeled in this study.

For each of the above market scenarios, CO_2 risk is assessed for a range of super-credit structures, including the currently prevailing multiplier values in India. Further, three different types of emissions accounting methods for electric vehicles are applied, including the currently prevailing gasoline equivalence emissions accounting approach, as outlined in Table 12 and Table 13 below.

Table 12. Summary of super-credit structures analyzed

Super-credit structure	Description	Multiplier values for electric vehicles
No super credits	No super-credit incentive	BEVs: 1x until 2030; PHEVs: 1x until 2030
Structure 1	Currently prevailing multiplier values applied until 2030	BEVs: 3x until 2030; PHEVs: 2.5x until 2030
Structure 2	Multiplier values reduced and applied until 2030	BEVs: 2x until 2030; PHEVs: 1.5x until 2030
Structure 3	Currently prevailing multiplier values applied until 2022	BEVs: 3x until 2022, 1x after; PHEVs: 2.5x until 2022; 1x after
Structure 4	Multiplier values phased out by 2022	BEVs: 3x until 2020, 2x until 2022, 1x after; PHEVs: 2.5x until 2020, 1.5x until 2022, 1x after

Table 13. Summary of emissions accounting methods analyzed

Methodology	Details
Zero emissions accounting	Emissions from BEVs and electrical operation of PHEVs are considered as zero.
Gasoline equivalence emissions accounting (Currently prevailing preferential emissions incentive)	Electricity consumed by BEVs and electrical operation of PHEVs is equated to liters of gasoline consumed based on an energy equivalence factor as specified by the Government of India. CO_2 emissions are estimated based on stoichiometric conversion of the carbon content in the equivalent volume of gasoline.
Net upstream emissions accounting [a] **(No preferential emissions incentive)**	The difference in emissions from upstream activities from electricity (generation, transmission, and distribution) and upstream activities from an energy equivalent volume of gasoline (refining, distribution) is calculated for the electricity consumed by BEVs and electrical operation of PHEVs. Emission factor assumed are as follows: Generation[b]: 820 g CO_2/kWh in 2015, reducing to 610 g CO_2/kWh in 2030. Transmission and distribution[c]: Network efficiency of 81% with an annual improvement of 2% until efficiency reaches a maximum value of 95%.

Notes: See Annex for details on approach toward determining electricity and fuel consumption from PHEVs.

[a] The upstream boundary of emissions from electricity is limited to generation, transmission, and distribution, and excludes emissions from fuel extraction and transportation.

[b] Emission factors are generation weighted averages for all grid-connected power plants in India. The 2015 value is as reported by the Central Electricity Authority, Government of India, and is based on the actual power plant mix in India in 2015. The 2030 value is the modeled output for an NDC-compliant scenario in 2030, as per the LBNL study, "Techno-Economic Assessment of Deep Electrification of Passenger Vehicles in India," (May 2017).

[c] Efficiency of Indian T&D network as per EIA estimates, 2015. Further, an annual efficiency improvement rate of 2% is assumed based on CAGR computed from historical T&D efficiencies of the Indian network as reported by the EIA between 2000–13. It is assumed that the network efficiency will improve until a maximum level of 95%, which is the current OECD average.

The results from such a scenario analysis are further evaluated in the context of potential control mechanisms from global best practices. Control mechanisms evaluated include:

- Phasing out super credits (as followed in the United States, the European Union, and China)
- Capping the maximum possible benefit due to super credits per manufacturer (as followed in the European Union)
- Capping the number of electric vehicles that can avail of preferential emissions accounting before accounting for net upstream emission impacts (as followed in the United States)

RISK ASSESSMENT METRICS

The key metric used in this study to quantify the CO_2 risk potential due to incentives for electric vehicles over the modeled policy period is the percentage of erosion in overall program benefits,[14] which is defined as follows:

$$\frac{\sum_{i=\text{Baseline year}}^{2030}\left[\left(\text{ICEV emission level due to EV incentives}_i\,\frac{g}{km} - \text{ICEV emission level without EV incentives}_i\,\frac{g}{km}\right) \times \text{ICEV Volume}_i \times \text{Lifetime VKT}_i\right]}{\sum_{i=\text{Baseline year}}^{2030}\left[\left(\text{Baseline fleet standard}_i\,\frac{g}{km} - \text{fleet standard}_i\,\frac{g}{km}\right) \times \text{Fleet Volume}_i \times \text{Lifetime VKT}_i\right]}$$

It is important to note that the above equation only denotes the CO_2 erosion due to electric vehicle incentives in percentage terms. The overall erosion in CO_2 benefits on a mass basis is obtained from the numerator in the above equation, which is also quantified separately in this study for reference.

Further, since net upstream emissions accounting corresponds to the real emissions produced when an electric vehicle displaces a conventional vehicle in the fleet, the percent of erosion in overall program benefits is zero for where net upstream emissions accounting is used without any other preferential policies (super credits) for electric vehicles. Based on the definition used in this analysis, the percent of erosion is also zero for a fleet based entirely on conventional vehicles.

14 A value of 180,000 km is assumed as the total vehicle miles traveled (VKT) by ICEVs over their lifetime.

Representative BEV and PHEV models

As of now, there are two major BEV models available in the passenger car segment in India, namely, the Mahindra e2o plus, a mini hatchback, and the Mahindra eVerito, a compact sedan. Considering that compact hatchbacks comprise the highest-selling passenger car segment in India (more than 65% sales in 2015–16[15]), the e2o plus is assumed as a representative vehicle for the Indian BEV fleet. A comparison of specifications of the e2o plus, eVerito, and top five BEVs globally by sales is provided in Table 15 below.

Table 14. Key specifications of globally top-selling BEVs in comparison to representative model assumed for India

Manufacturer	Model	Segment[a]	Price range[b] (USD)	Curb weight (kg)	Length (mm)	Battery capacity (kWh)	Range (km)	Electrical energy consumption (kWh/100 km)	2017 global sales[c]
BAIC	EC-Series	B	20,000–25,000	1,295	4,025	30.4	200	17	78,079
Tesla	Model S	E	70,000– 75,000	2,163	4,978	75	417	21	54,715
Nissan	Leaf	C	30,000–35,000	1,557	4,470	40	243	19	47,195
Tesla	Model X	SUV	75,000–80,000	2,407	5,037	75	381	22	46,535
Zhi Dou	D2	A	20,000–25,000	670	2,806	18	155	13	42,342
Renault	Zoe EV	B	30,000–35,000	1,480	4,085	41	250	19	31,932
BMW	i3 EV	MPV	40,000–45,000	1,343	4,013	33	183	18	31,410
Mahindra & Mahindra	e2o plus[d]	A	10,000–15,000	940	3,590	11	110	11	4,026
Mahindra & Mahindra	eVerito	B	15,000–20,000	1,265	4,247	18.55	140	15	

[a] Approximate classification as per EU system (A: mini-cars, B: small-cars, C: mid-size cars, D: large cars, E: executive cars; SUV: sports utility vehicle, MPV: multi-purpose vehicle)
[b] Price range reported before any applicable subsidies
[c] Global sales as of August 2018, reported by EV Sales, http://ev-sales.blogspot.com/2018/01/world-top-20-december-2017.html
[d] Representative model assumed for Indian market in this study

The Volvo XC90 is the only major PHEV on the Indian market currently and there seems to be limited insight on forthcoming model launches from manufacturers for the Indian market. In the absence of data, the recently released (2017) SAIC Rowe ei6 in China, is considered as a representative model for the Indian market. The Roewe ei6 has been the third highest-selling PHEV in China in first and second quarter sales in 2018 (Pontes, 2018). Majority of the top-selling PHEVs globally are either EREVs (extended range electric vehicle), such as the Chevrolet Volt, or SUVs. The Roewe ei6 is a mid-range PHEV sedan and has a driving range (NEDC) just above the subsidy threshold of 50 km in China and is assumed to be a closer approximation of the Indian market compared to EREVs and SUV segment PHEVs. A comparison of specifications of the Roewe ei6 and globally top-selling PHEVs is provided in Table 15 below.

15 Sales data for FY 2015–16 was procured from Segment Y Automotive Intelligence Pvt. Ltd.

Table 15. Key specifications of globally top-selling PHEVs in comparison to representative model assumed for India

Manufacturer	Model	Segment[a]	Price range[b] (USD)	Curb weight (kg)	Length (mm)	Battery capacity (kWh)	All electric range[c] (km)	2017 global sales[d]
Toyota	Prius Prime	C	25,000–35,000	1,526	4,646	8.8	40	50,830
BYD	Song DM	SUV	35,000–40,000	1,800	4,565	18.4	70	30,920
Chevrolet	Volt	C	35,000–40,000	1,598	4,582	18.4	85	26,291
Mitsubishi	Outlander	SUV	35,000–40,000	1,895	4,694	12	35	25,571
BYD	QIN	D	35,000–40,000	1,720	4,740	13	70	20,791
SAIC	Roewe ei6[e]	D	30,000–35,000	1,430	4,671	9	53	15,190[f]

[a] Approximate classification as per EU system (A: mini-cars, B: small-cars, C: mid-size cars, D: large cars, E: executive cars; SUV: sports utility vehicle, MPV: multi-purpose vehicle)
[b] Price range reported before any applicable subsidies
[c] The electric range reported for Tang, QIN, and Roewe ei6 are NEDC-based values, however, WLTC-based values are more representative of real-world conditions over NEDC-based values and are about 25% lower than NEDC-based values. The electric range reported for Volt, Outlander, and Fusion Energi are based on EPA test cycles which are conceptually similar to WLTC.
[d] Global sales as of August 2018, reported by EV Sales, http://ev-sales.blogspot.com/2018/01/world-top-20-december-2017.html
[e] Representative model assumed for Indian market in this study
[f] Sales for first and second quarters in 2018 (launched in 2017)

RESULTS AND KEY OBSERVATIONS

While the complete set of results for the total and percent of erosion in overall program benefits for each of the modeled policy and market combinations is included in the Annex to this report, key observations, including the impact of potential control mechanisms, that emerge from the analysis are summarized here.

The potential for erosion in the average annual emission levels of conventional vehicles under slow, moderate, rapid, and aggressive electric vehicle markets with the prevailing incentives in Indian standards is illustrated in Figure 1 through Figure 3 below. The theoretical emission levels from conventional vehicles due to inclusion of electric vehicles in the fleet can be very high in rapidly scaling markets for electric vehicles. Therefore, these figures also indicate emission levels due to incentives for electric vehicles assuming a maximum value of about 134 g/km.[16] The chosen reference limit of 134 g/km corresponds to the fleet-wide standard value based on the average curb weight of the Indian PV fleet in FY 2015–16 (~1103 kg).

The figures clearly indicate that if the current incentives for electric vehicles prevail, conventional vehicles can significantly lag from fleet average levels, and in rapidly growing electric vehicle markets, can even stay stagnant around the baseline year emission levels throughout the modeled policy period.

16 Based on internal ICCT analysis, the actual sales-weighted average emission level of the Indian PV fleet in FY 2015–16 was much lower at 123 g/km.

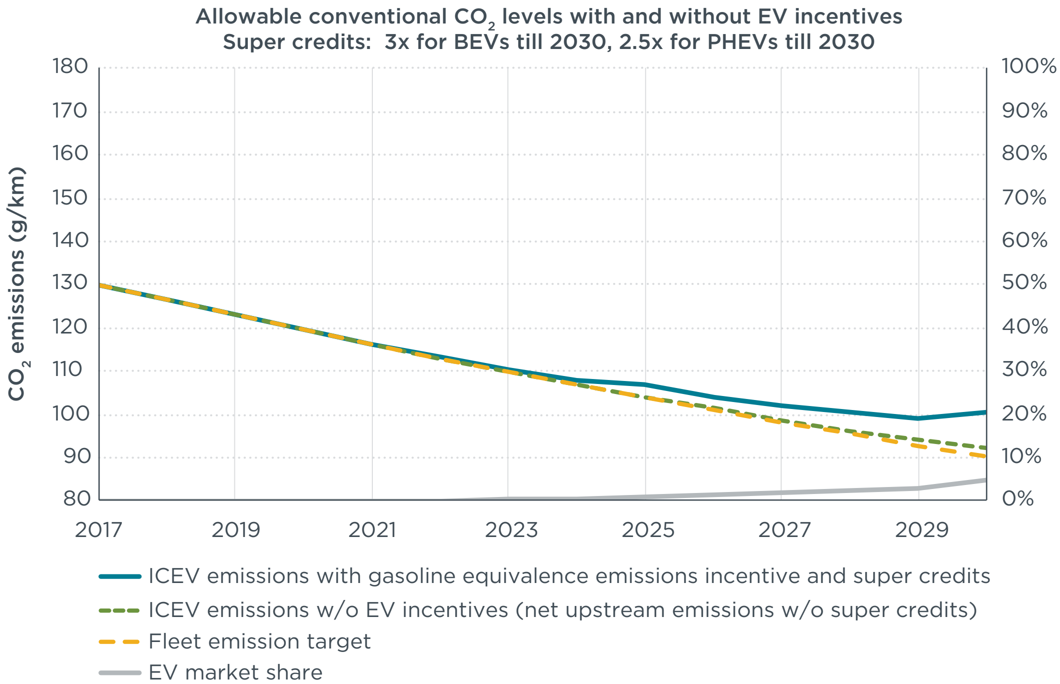

Figure 1. Allowable emission levels from conventional vehicles with current incentive structure in Indian PV standards – 5% electric vehicles by 2030

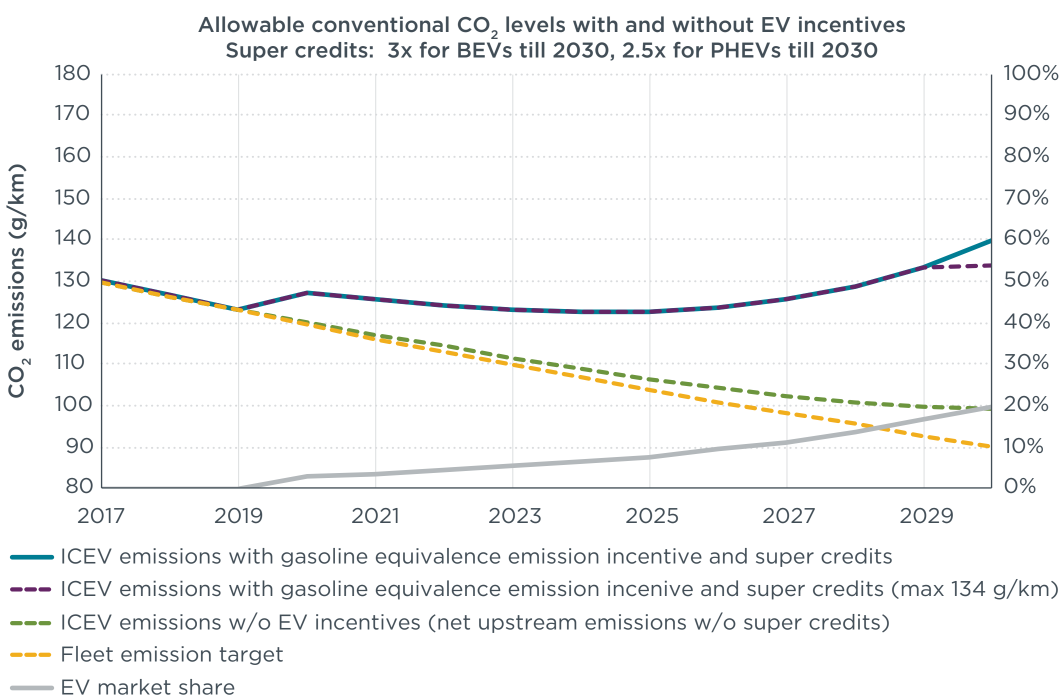

Figure 2. Allowable emission levels from conventional vehicles with current incentive structure in Indian PV standards – 20% electric vehicle market share by 2030

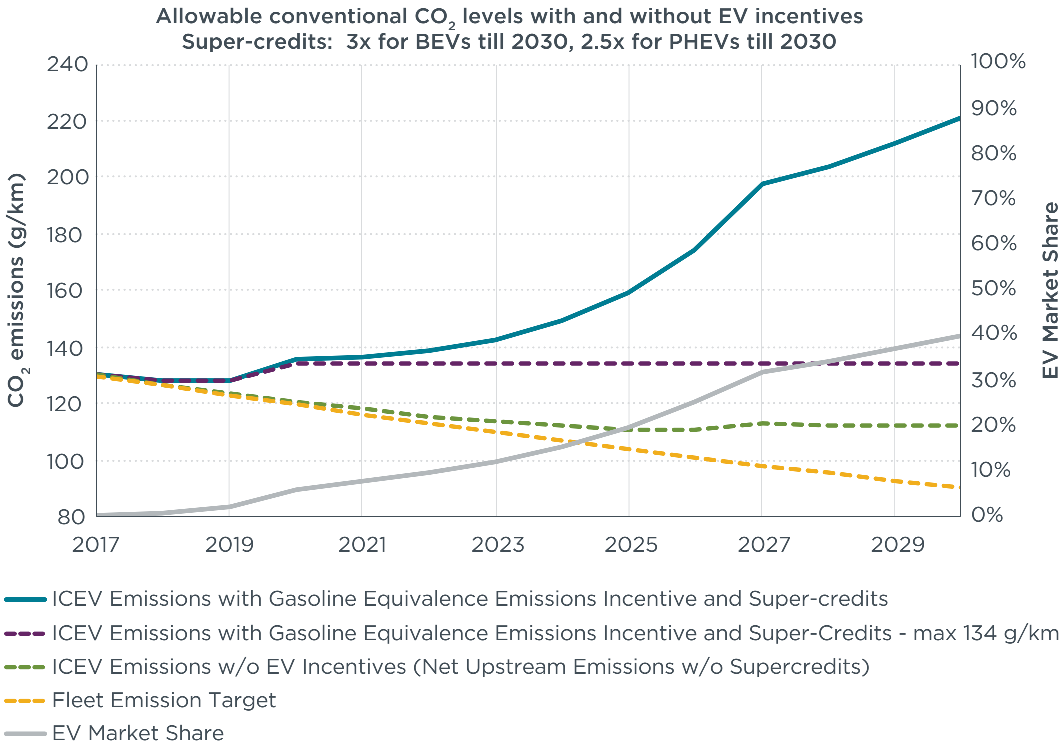

Figure 3. Allowable emission levels from conventional vehicles with current incentive structure in Indian PV standards – 40% electric vehicle market share by 2030

It is apparent that in all market growth scenarios, control mechanisms on incentives for electric vehicle are warranted to keep erosion in emission levels of conventional vehicles under check. The design of any such control is primarily dictated by what can be considered an "acceptable" level of CO_2 risk in the Indian context. Although the determination of such a threshold is a subject of detailed deliberation and outside the scope of this study, as an initial reference point based on global benchmarks, control mechanisms are evaluated here, assuming that the percent of erosion in conventional vehicle emissions due to electric vehicle incentives should not exceed 5% of the overall intended program benefits. For perspective, the 2012–16 EPA standards incorporated incentives for electric vehicles while projecting overall program losses to the tune of 3%, and the 2017–25 standards project overall program losses to the tune of 5%.

Table 16 through Table 18 below summarize the cumulative percent of erosion from overall program benefits under various combination of super-credit and emissions accounting approaches for electric vehicles by 2030. While the super-credit-based structures and controls are arranged in rows with the control stringency increasing down the rows, the emissions-accounting-based controls are presented in columns with the control stringency increasing across the columns. The cells in red indicate the risk level associated with the existing set of policy conditions and cells in blue indicate the percentage risk level associated with no incentives for electric vehicles (0%). The cells in green indicate the combination of super-credit and emissions-accounting-based controls that have the potential to contain the percent of erosion from overall program benefits below the 5% range. In Table 17, Table 18, and Table 19, values in parentheses indicate the percent of erosion levels assuming emission levels from conventional vehicles will not exceed the chosen reference limit of 134 g/km throughout 2030.

Table 16. Cumulative percent of erosion in overall program benefits under various control mechanisms – 5% electric vehicle market share by 2030

	Gasoline equivalence emissions accounting
Prevailing super credits until 2030	9.1%
Phase out super credits by 2022–23	1.9%
No super credits	1.8%

Table 17. Cumulative percent of erosion in overall program benefits under various control mechanisms – 20% electric vehicle market share by 2030

	Gasoline equivalence emissions accounting	Cap gasoline equivalence emissions accounting to 250,000[a] EVs in total program	Net upstream emissions accounting
Prevailing super credits until 2030	64.4% (62.6%)	25.8% (25.8%)	23.3% (23.3%)
Phase out super credits by 2022–23	17.4% (17.4%)	3.2% (3.2%)	1.2% (1.2%)
Phase out super credits by 2022–23 with a cap on maximum super-credit benefit to 7.5 g/km	17.4% (17.4%)	3.2% (3.2%)	1.2% (1.2%)
No super credits	14.1% (14.1%)	0.5% (0.5%)	0% (0%)

Note: Values in ( ) indicate the percent of erosion, assuming emission levels from conventional vehicles will not exceed a reference limit of 134 g/km
[a] Cap value assumed for illustrative purposes and not suggestive of an exact value

Table 18. Cumulative percent of erosion in overall program benefits under various control mechanisms – 40% electric vehicle market share by 2030

	Gasoline equivalence emissions accounting	Cap gasoline equivalence emissions accounting to 250,000[a] EVs in total program	Net upstream emissions accounting
Prevailing super credits until 2030	155.1% (58.5%)	56.8% (41.6%)	53.9% (39%)
Phase out super credits by 2022–23	41.7% (41.4%)	7.7% (7.7%)	2.5% (2.5%)
Phase out super credits by 2022–23 with a cap on maximum super-credit benefit to 7.5 g/km	41.7% (41.4%)	5.3% (5.3%)	2.5% (2.5%)
No super credits	33.9% (33.9%)	2.5% (2.5%)	0% (0%)

Note: Values in ( ) indicate the percent of erosion, assuming emission levels from conventional vehicles will not exceed a reference limit of 134 g/km
[a] Cap value assumed for illustrative purposes and not suggestive of an exact value

As indicated in Table 16 through Tabe 18 above, with the prevailing super-credit structures and emissions accounting mechanism, program losses will be above the 5% range in all scenarios of electric vehicle uptake. Further, the above tables indicate the following possibilities as potential control mechanisms to contain the percent of erosion levels in the 5% range, depending on the rate of market uptake for electric vehicles:

- If uptake is slow, i.e, reaching about 5% of the market share by 2030, phasing out super-credit incentives before 2022–23 can contain erosion levels below the 5% range, while still retaining the gasoline equivalence emissions accounting method, with no further controls needed.
- If uptake is moderate, i.e. reaching about 20% of the market share by 2030, phasing out of super-credit incentives before 2022–23 alone is insufficient to contain erosion levels below the 5% range. However, if such a measure is coupled with a cap placed on the number of vehicles that can make use of the gasoline equivalence emissions accounting method, erosion levels can be kept below the 5% threshold. An illustrative value of 250,000 vehicles was assumed as such a cap value in this analysis.
- If uptake is fast, i.e. reaching about 40% market share by 2030, and if the current gasoline equivalence emissions accounting method prevails, super credits will have to eliminated altogether to contain erosion levels below the 5% range. Super-credits can only be considered here if they are phased out by 2022–23 and net upstream emissions accounting is adopted for all-electric vehicles.
- Further, it is also interesting to point out that in all-electric vehicle growth scenarios, placing a cap on the maximum permissible benefit due to super credits to manufacturers did not result in any additional reduction in erosion levels compared to phasing out of super credits alone by 2022–23. A cap value of 7.5 g/km (as followed in the European Union) was assumed in this analysis.

Although the rate of electric vehicle uptake is modeled as the key scenario variable in this study, it is important to understand the sensitivity of other important factors that can impact the percent of erosion in overall CO_2 benefits and selection of appropriate control mechanisms. Two key factors include:

1. The rate of improvement in GHG intensity of the Indian grid
2. The rate of efficiency improvement of the Indian PV fleet required by the standards

As an example, Table 19 below outlines the sensitivity of the percent of erosion in overall benefits to the above factors in a moderate electric vehicle growth scenario (20% electric vehicle share by 2030) assuming that super-credit benefits get phased out by 2022–23; and gasoline equivalence emissions accounting is retained as the emissions accounting method for electric vehicles. The results from this sensitivity analysis indicate that even under ambitious GHG reduction scenarios where the annual rate of efficiency improvement of the PV fleet and the Indian grid are 5%, the percent of erosion from overall program benefits due to incentives for electric vehicles remain well above a 5% loss threshold. Thus, an additional control on the preferential emissions accounting method such as capping the number of eligible electric vehicles seems to be warranted under all likely scenarios of overall fleet and grid GHG intensity improvements in India over the next decade.

Table 19. The percent of erosion in overall program benefits as a function of the annual rate of reduction in efficiency of Indian PV fleet and the annual rate of GHG intensity reduction of Indian grid under a moderate EV growth market

		Annual rate of reduction in GHG intensity of Indian grid				
		-1%	-1.5%	-2.0%	-3.0%	-5%
Annual rate of reduction in efficiency of Indian PV fleet	-2.0%	23.9%	20.7%	19.3%	16.5%	11.9%
	-2.2%	23.2%	20.1%	18.8%	16.0%	11.6%
	-2.4%	22.6%	19.5%	18.2%	15.6%	11.2%
	-2.6%	22.0%	19.0%	17.8%	15.1%	10.9%
	-2.8%	21.5%	18.6%	17.4%[a]	14.8%	10.7%
	-3.0%	20.9%	18.0%	16.9%	14.4%	10.4%
	-3.2%	20.4%	17.6%	16.5%	14.0%	10.1%
	-3.4%	19.9%	17.2%	16.1%	13.7%	9.9%
	-4.0%	18.6%	16.1%	15.1%	12.8%	9.3%
	-5.0%	16.9%	14.6%	13.6%	11.6%	8.4%

[a] The percent of erosion level pertaining to currently assumed model parameters.

COST-EFFECTIVENESS OF DEPLOYING ELECTRIC VEHICLES AS A STRATEGY FOR COMPLYING WITH FUEL CONSUMPTION STANDARDS

To show the impact of emissions accounting of EVs on the overall cost-effectiveness, we compare four different vehicle efficiency packages against various EV accounting methods. These packages consist of Incremental (aerodynamics and rolling resistance improvements, low friction lubricants, engine friction reduction, improved accessory loading, and electrical power steering), Moderate (Incremental plus variable valve timing and lift, gasoline direct injection and turbocharging), Advanced (Moderate plus start-stop system and exhaust gas recirculation) and Hybrid (incremental plus variable valve lift, engine downsizing and strong-hybridization). These packages result in 11.5% to 35% reductions in fuel consumption at a cost of between USD 200 and USD 2000 per vehicle, respectively.

We compared the cost of deploying vehicles such as E2OPlus and Everito with the four internal combustion engine packages. We find that with the use of a gasoline equivalent emissions accounting or even a zero upstream emissions accounting method, the cost-effectiveness of EVs in the Indian context is no greater than a strong hybrid approach. However, when a multiplier of three, such as that proposed in India's regulations, is used, the electric vehicles are as cost-effective a strategy as using advanced efficiency package, as shown in Figure 4.

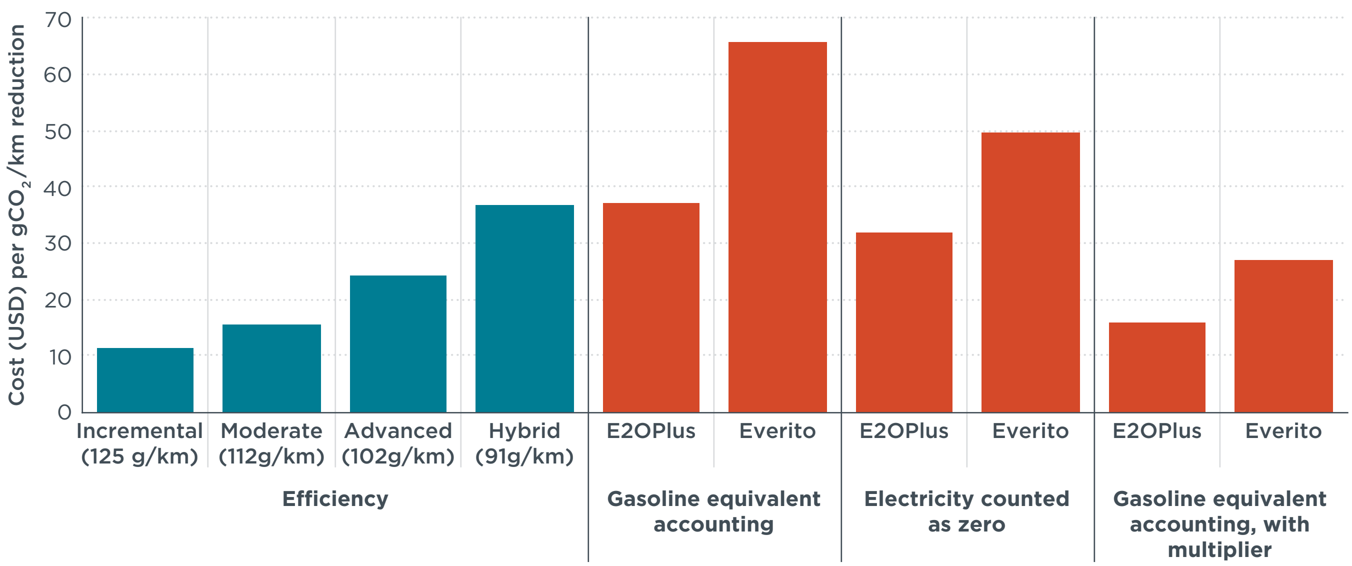

Figure 4. Cost-effectiveness of gasoline efficiency and electric vehicle packages under various electric vehicle accounting mechanisms in India

CONCLUSION AND KEY RECOMMENDATIONS

The market projections for electric vehicle growth in India are ambitious but uncertain. Further, the CO_2 standards enforced in India are amongst the more lenient ones globally (ICCT, 2018) and the credit structures available for electric vehicles in Indian standards are more generous in nature compared to global practices. Thus, it becomes necessary to understand the potential CO_2 risk presented by a range of market and policy conditions.

Based on our analysis, we make the following conclusions to echo the four questions raised in the beginning of this paper.

1. What compliance flexibility mechanisms are available to manufacturers that benefits inclusion of electric vehicles in their fleet in major global markets (the United States, the European Union, China, and India)?

Globally, barring China, India has the largest super-credit multipliers in place for electric vehicles, and the only major market with no controls defined for the applicability for super credits. For example, while the United States, the European Union, and China phase out the values of super-credit multipliers over a five-year period, India offers a constant (high) multiplier for compliance with corporate average standards. Further, unlike the European Union, which caps the maximum permissible compliance benefit to manufacturers from super credits, India has no such thresholds defined.

In terms of emissions accounting methodologies, electric vehicles are counted as zero-emission vehicles in compliance calculations in the European Union, China, and up to pre-defined manufacturer volume thresholds in the United States. Zero-emissions accounting offers the highest compliance flexibility to conventional vehicles and can lead to significant lost CO_2 benefits from the intended program benefits if not controlled as the electric vehicle market scales. While the U.S. regulations recognize this and have capped the maximum number of vehicles per manufacturer that can avail of this benefit after which net upstream emissions[17] due to electric vehicles are to be accounted for, regulations in the European Union and China do not have such caps defined. Net upstream emissions accounting assigns higher emission values to electric vehicles depending on the emissions intensity of the grid and other upstream processes and can curb the compliance flexibility available to conventional vehicles as the electric vehicle market grows. India, on the other hand, has adopted a “middle-ground” between zero emissions accounting and net upstream accounting, i.e, Indian regulations specify a conversion factor based on energy equivalence for electricity consumed to gasoline consumed, which is then assumed to be combusted in a conventional vehicle to obtain stoichiometric values of CO_2. When compared to the existing as well projected reductions in emissions intensity of the Indian grid in accordance with its post-2020 climate action plans, the net upstream emissions accounting method always results in higher emissions than the gasoline equivalence approach for India.

17 Net upstream emissions accounting refers to estimating the difference in upstream emissions from electricity consumed in an electric vehicle and the upstream emissions from gasoline consumed in an equivalent conventional vehicle displaced from the fleet by the electric vehicle.

2. To what extent are electric vehicle-related provisions in Indian fuel consumption standards impacting emission levels from conventional vehicles? How does India compare with global benchmarks in this aspect?

Based on the market and policy conditions analyzed in this study, the currently prescribed super-credit structures in India for electric vehicles offer excessive relaxation to conventional vehicles, even when using the somewhat middle-ground approach of gasoline equivalent emissions accounting for electric vehicles. For example, if the electric vehicle uptake in India reaches about 20% market share by 2030, the percent of erosion in overall benefits will be about 64%. For comparison, under a similar market growth assumption for the United States, prior ICCT analysis indicates that the percent of erosion in overall benefits will be around 26% if the United States retains super-credit multipliers and zero upstream emissions accounting through 2030. Similarly, for the European Union, the percent of erosion in overall benefits will be around 41% if the European Union retains super-credit multipliers and zero upstream emissions accounting through 2030 (corresponding to about 28% electric vehicle market share by 2030). Thus, it is apparent that the impact of high super-credit multiplier values in India far outweighs any compensation offered by the gasoline equivalent emissions approach over zero upstream emissions accounting. Further, since the projected electric vehicle uptake by Indian policy makers is much higher (40% to 100%), the erosion in emission benefits in conventional vehicles becomes even higher and concerning in such scenarios. Even if it is assumed that emissions from conventional vehicles will not exceed a reference limit of approximately 134 g/km throughout the modeled period, the percent of erosion levels are well above the 5% range, which seems to be the upper limit for "acceptable" losses from electric vehicle-related incentives in global standards.

In terms of tailpipe emission levels, this study indicates that average emission levels from conventional vehicles can be as high as 100 g/km, 140 g/km, and 221 g/km in 2030 under a 5%, 20%, and 40% electric vehicle market share scenario. This is in comparison to an average fleet-wide emission target of 90 g/km in 2030. Thus, if the current structure of integrating electric vehicles in fuel consumption standards remains unchanged, emission levels from conventional vehicles are allowed to lag well behind fleet average levels and even exceed 2017 levels in 2030. This can lead to a scenario that prevents the adoption of the best available control technologies in conventional vehicles, or even a market shift toward a heavier conventional vehicle fleet. This becomes even more concerning considering that Indian fuel consumption standards are not as stringent in comparison to global benchmarks in the first place (ICCT, 2018).

3. What is the cost-effectiveness of deploying electric vehicles as a strategy for complying with fuel consumption standards with and without the adopted regulatory provisions in India?

Using a multiplier of three reduces the cost of deploying EVs by nearly 60% when compared with the gasoline equivalent accounting only. At this level, electric vehicles are a cost-effective pathway to meet India's passenger vehicle efficiency standards ahead of some of the most advanced ICE technologies, including hybrids, assuming that no multipliers are used for hybrid vehicles. Strengthening of the passenger vehicle fuel efficiency standards in a post-2020 environment will further increase the cost-effectiveness of deploying electric vehicles, even if multipliers are reduced somewhat.

4. Based on global best-practices, whether India need to improve policy measures to effectively promote electric vehicles while also aspiring toward more stringent standards? If so, how to improve?

The quantitative analysis in this paper emphasizes the importance of balancing electric vehicle deployments with real fuel efficiency improvements:

- Electric vehicle-related provisions in PV standards may be assessed to not allow the overall risk to exceed 3% to 5% of intended benefits. For perspective, the 2012–16 EPA standard projected program losses to the tune of 3%, and the 2017–25 EPA standard estimates program losses from electric vehicle incentives to be around 5%.
- The prevailing super-credit multiplier values prescribed in the Indian standards offer excessive compliance flexibility to manufacturers under all-electric vehicle growth scenarios. As also followed in the United States, the European Union, and China, super credits in India are appropriate only if they are phased out as electric vehicle markets start to scale. Thus, gradually lowering the multiplier benefit and phasing them out completely by 2022–23 before the next phase of standards come into effect is recommended. This can offer adequate time for manufacturers to avail incentives for initial market entry, while controlling emission levels from conventional vehicles.
- The types of control structures required on the preferential emissions accounting approach for electric vehicles to limit program losses is strongly dependent on the electric vehicle market uptake to be seen in India. While phasing out of super credits alone serves as an effective control measure to curb the percent of erosion levels below 5% in slow electric vehicle markets, placing a cap on the maximum number of electric vehicles that can be incentivized through gasoline equivalence emissions accounting before switching to net upstream emissions accounting can help in curbing losses in rapidly scaling markets. While assigning a cap on the maximum possible benefit due to super credits on the lines of EU norms (~7.5 g/km) may serve as an additional precautionary check against other unforeseen variables, such a measure does not seem to offer any significant level of additional control over super credits being phased out before 2022–23 (while electric vehicle markets are still in early years of scaling).
- Key auto markets globally have recognized the strategic importance of sales target-based mechanisms for promoting deployment of electric vehicles. The California ZEV mandate for example, has been a pioneer program running since 1998. The program now applies to 10 states in the United States, which collectively account for almost a third of the total electric vehicle sales in the United States. China, too, has issued a sales mandate policy for electric vehicles in 2017, which is linked to its fuel consumption standards. China's electric vehicle sales mandates begin in 2019. Similarly, the European Union has proposed a sales target-based mechanism for incentivizing electric vehicles in its proposal for post-2020 emission standards. India too, can evaluate pathways for establishing sales mandate policies for rapid deployment of electric vehicles, alongside more stringent CO_2 standards in the post-2020 period.

In conclusion, based on global trends, electric vehicle market uptake depends upon several policy measures and cannot be attributed to a single incentive mechanism. Like-wise in India, the trajectory for electric vehicle growth by 2030 will depend not just on electric vehicle-related incentives in GHG standards, but a host of other financial as well as non-financial initiatives. Incentivizing manufacturers to invest in electric vehicles as an alternative to investing in efficiency improvements in conventional vehicles may have the potential to provide the initial spur needed for the market to grow, however cannot be looked at as a long-term policy strategy once electric vehicle markets start to scale. It is also important for India to have a well-defined and aggressive portfolio of electric vehicle-related policies such as sales mandates to create industry confidence in making investments in the electric vehicle supply-chain. As key global markets shift toward electric drive in the transport sector, India may miss out on a major competitive advantage to regions such as China, Japan, South Korea, the United States, and the European Union without a manufacturing base for electric vehicles and battery systems (Lutsey, Grant, Wappelhorst, & Zhou, 2018).

With the current degree of uncertainty prevailing on electric vehicle-related policies in India, emphasis should be on concerted actions and policy measures at the national, state, and local levels to promote electric vehicles. Any integration mechanisms for electric vehicles in GHG standards should be based on careful consideration of realistic market projections, with appropriate controls in place to keep program losses within acceptable trade-off levels in the larger scheme of India’s climate goals.

REFERENCES

California Air Resources Board. (n.d.) Zero Emission Vehicle Program. Retrieved from https://ww2.arb.ca.gov/our-work/programs/zero-emission-vehicle-program/about.

California Air Resources Board. (2016). California's ZEV Regulation for 2018 and Subsequent Model Year Vehicles [webcast presentation]. Retrieved from https://www.arb.ca.gov/msprog/zevprog/zevtutorial/zev_tutorial_webcast.pdf.

Cui, H. (2018). *China's New Energy Vehicle Mandate Policy (Final Rule)*. Retrieved from the International Council on Clean Transportation https://www.theicct.org/publications/china-nev-mandate-final-policy-update-20180111.

Dornoff, J., Miller, J., Mock, P., & Tietge, U. (2018). *The European Commission Regulatory Proposal for Post-2020 CO_2 Targets for Cars and Vans: A Summary and Evaluation*. Retrieved from the International Council on Clean Transportation https://www.theicct.org/sites/default/files/publications/ICCT_EU-CO2-proposal_briefing_20180109.pdf.

EPA. (2010) Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards, Final Rule. Retrieved from https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-model-year-2012-2016-light-duty-vehicle.

EPA. (2012). 2017 and Later Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards. Retrieved from https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-model-year-2017-and-later-light-duty-vehicle.

EPA. (2018). *GHG Emission Standards for Light Duty Vehicles: Manufacturer Performance Report for the 2016 Model Year*. https://www.epa.gov/regulations-emissions-vehicles-and-engines/greenhouse-gas-ghg-emission-standards-light-duty-vehicles.

European Commission. (n.d.). Reducing CO_2 Emissions from Passenger Cars. Retrieved from https://ec.europa.eu/clima/policies/transport/vehicles/cars_en#tab-0-0.

India Aims to Become 100% E-vehicle Nation by 2030: Piyush Goyal. (2016, March 26). *The Economic Times*. Retrieved from https://economictimes.indiatimes.com/industry/auto/news/industry/india-aims-to-become-100-e-vehicle-nation-by-2030-piyush-goyal/articleshow/51551706.cms.

International Council on Clean Transportation. (2018, April) *Passenger Cars CO_2 Emissions and Fuel Consumption (Global), Normalized to NEDC*. Retrieved from https://www.theicct.org/sites/default/files/NEDC_CO2_cars_Apr2018_updated.pdf.

Lutsey, N. (2017). *Integrating Electric Vehicles within U.S. and EU Efficiency Regulations*. Retrieved from the International Council on Clean Transportation https://www.theicct.org/integrating-EVs-vehicle-CO2-regs.

Lutsey, N. (2018). *California's Continued Electric Vehicle Market Development*. Retrieved from the International Council on Clean Transportation https://www.theicct.org/sites/default/files/publications/CA-cityEV-Briefing-20180507.pdf.

Lutsey, N., Mikhail Grant, M., Wappelhorst, S, & Zhou, H. (2018). *Power Play: How Governments Are Spurring the Electric Vehicle Industry*. Retrieved from the International Council on Clean Transportation https://www.theicct.org/publications/global-electric-vehicle-industry.

Ministry of Industry and Information Technology. (2004). China Phase I and II Standards for Passenger Vehicles - GB 19578-2004. Retrieved from https://www.transportpolicy.net/standard/china-light-duty-fuel-consumption/.

Ministry of Industry and Information Technology. (2011). China Phase III Standards for Passenger Vehicles - GB 27999-2011. Retrieved from https://www.transportpolicy.net/standard/china-light-duty-fuel-consumption/.

Ministry of Industry and Information Technology. (2014). China Phase IV Standards for Passenger Vehicles - GB 19578-2014 and GB 27999-2014. Retrieved from https://www.transportpolicy.net/standard/china-light-duty-fuel-consumption/.

Ministry of Power. (2015). Fuel Consumption Standards for Passenger Vehicles in India [Notification S.O. 1072(E)]. Retrieved from https://beeindia.gov.in/sites/default/files/ctools/Notification%2023.4.2015.pdf.

Ministry of Road Transport and Highways. (2018). *Administrative and Technical Procedure for Measurement and Monitoring (Average) Fuel Consumption in l/100 km of M1 Category* [vide Amendment no. 7 to Doc. No.: MoRTH/CMVR/TAP-115/116: Issue No.: 4]. Retrieved from https://www.icat.in/pdf/fuel_consumption_standards.pdf.

Mock, P., (Ed.). (2017). European Vehicle Market Statistics, Pocketbook 2017/18. Retrieved from the International Council on Clean Transportation https://www.theicct.org/sites/default/files/publications/ICCT_Pocketbook_2017_Web.pdf.

Mock, P., Lutsey, N., & Tietge, U. (2018, June 21). Off the Hook : Europe's Current ZLEV Proposal Would Allow CO_2 Emissions of New Combustion Engine Vehicles to Increase [blog post]. Retrieved from https://www.theicct.org/blog/staff/eu-zlev-proposal-allow-co2-emissions-new-combustion-engine.

NITI Aayog. (n.d.) Public Consultation on the Future of Electric Mobility – Inviting Comments from all Stakeholders on Zero Emission Mobility. Retrieved from http://niti.gov.in/writereaddata/files/new_initiatives/ZEV%20Policy-Public%20Consultation%20Queries.pdf.

Pontes, J. (2018, July 29). China Electric Car Sales Up 77% In June. *CleanTechnica*. Retrieved from https://cleantechnica.com/2018/07/29/china-electric-car-sales-up-77-in-june-cleantechnica-report/.

Riemersma, I & Mock, P. (2017). *Too Low to Be True? How to Measure Fuel Consumption and CO_2 Emissions of Plug-in Hybrid Vehicles, Today and in the Future*. Retrieved from the International Council on Clean Transportation https://www.theicct.org/publications/too-low-be-true-how-measure-fuel-consumption-and-co2-emissions-plug-hybrid-vehicles.

Senzeybek, M., Tietge, U., & Mock, P. (2017). *CO_2 Emissions from New Passenger Cars in the EU: Car Manufacturer's Performance in 2016*. Retrieved from the International Council on Clean Transportation https://www.theicct.org/publications/co2-emissions-new-passenger-cars-eu-car-manufacturers-performance-2016.

Society of Indian Automobile Manufacturers (2017). *Adopting Pure Electric Vehicles: Key Policy Enablers*. Retrieved from http://www.siam.in/uploads/filemanager/114SIAMWhitePaperonElectricVehicles.pdf.

Tietge, U. (2018). *CO_2 Emissions from New Passenger Cars in the EU: Car Manufacturer's Performance in 2017*. Retrieved from the International Council on Clean Transportation https://www.theicct.org/publications/co2-emissions-new-passenger-cars-eu-car-manufacturers-performance-2017.

Yang, Z. (2018). *Compliance with India's First Fuel Consumption Standards for New Passenger Cars (FY 2017–18)*. Retrieved from the International Council on Clean Transportation https://www.theicct.org/sites/default/files/publications/India_fuel_consumption_standards_20180925.pdf.

APPENDIX

Absolute and percentage risk to emissions from conventional vehicles due to incentives for electric vehicles in Indian PV standards under various electric vehicle growth scenarios from 2017–30

Scenario: 5% electric vehicle market share by 2030	Total CO_2 erosion over vehicle lifetime due to EV incentives (million metric tonnes)			% CO_2 erosion from overall program benefits		
Super-credit multipliers	Zero tailpipe emissions	Gasoline equivalent	Net upstream emissions	Zero tailpipe emissions	Gasoline equivalent	Net upstream emissions
(No super credits) BEVs: 1x until 2030; PHEVs: 1x until 2030	8.0 (8.0)	4.4 (4.4)	0.0 (0.0)	3.2% (3.2%)	1.8% (1.8%)	0.0% (0.0%)
(Currently prevailing multipliers) BEVs: 3x until 2030; PHEVs: 2.5x until 2030	33.4 (33.4)	22.7 (22.7)	10.2 (10.2)	13.4% (13.4%)	9.1% (9.1%)	4.1% (4.1%)
BEVs: 2x until 2030; PHEVs: 1.5x until 2030	19.9 (19.9)	13.1 (13.1)	5.2 (5.2)	8.0% (8.0%)	5.2% (5.2%)	2.1% (2.1%)
BEVs: 3x until 2022, 1x after; PHEVs: 2.5x until 2022, 1x after	8.7 (8.7)	4.9 (4.9)	0.1 (0.1)	3.5% (3.5%)	2.0% (2.0%)	0.1% (0.1%)
BEVs: 3x until 2020, 2x until 2022, 1x after; PHEVs: 2.5x until 2020, 1.5x until 2022, 1x after	8.5 (8.5)	4.7 (4.7)	0.1 (0.1)	3.4% (3.4%)	1.9% (1.9%)	0.0% (0.0%)
Scenario: 20% electric vehicle market share by 2030	**Total CO_2 Erosion over vehicle lifetime due to EV incentives (million metric tonnes)**			**% CO_2 erosion from overall program benefits**		
Super-credit multipliers	**Zero tailpipe emissions**	**Gasoline equivalent**	**Net upstream emissions**	**Zero tailpipe emissions**	**Gasoline equivalent**	**Net upstream emissions**
(No super credits) BEVs: 1x until 2030; PHEVs: 1x until 2030	53.0 (53.0)	35.2 (35.2)	0.0 (0.0)	21.2% (21.2%)	14.1% (14.1%)	0.0% (0.0%)
(Currently Prevailing Multipliers) BEVs: 3x until 2030; PHEVs: 2.5x until 2030	212.1 (187.2)	160.7 (156.1)	58.0 (58.0)	85% (75.1%)	64.4% (62.6%)	23.3% (23.3%)
BEVs: 2x until 2030; PHEVs: 1.5x until 2030	127.4 (129.4)	95.7 (95.7)	31.2 (31.2)	51.9% (51.9%)	38.4% (38.4%)	12.5% (12.5%)
BEVs: 3x until 2022, 1x after; PHEVs: 2.5x until 2022, 1x after	69.7 (69.7)	48.2 (48.2)	4.5 (4.5)	27.9% (27.9%)	19.3% (19.3%)	1.8% (1.8%)
BEVs: 3x until 2020, 2x until 2022, 1x after; PHEVs: 2.5x until 2020, 1.5x until 2022, 1x after	63.4 (63.4)	43.3 (43.3)	2.9 (2.9)	25.4% (25.4%)	17.4% (17.4%)	1.2% (1.2%)
Scenario: 40% electric vehicle market share by 2030	**Total CO_2 erosion over vehicle lifetime due to EV incentives (million metric tonnes)**			**% CO_2 erosion from overall program benefits**		
Super-credit multipliers	**Zero tailpipe emissions**	**Gasoline equivalent**	**Net upstream emissions**	**Zero tailpipe emissions**	**Gasoline equivalent**	**Net upstream emissions**
(No super credits) BEVs: 1x until 2030; PHEVs: 1x until 2030	133.9 (109.7)	84.5 (84.5)	0.0 (0.0)	53.7% (44.0%)	33.9% (33.9%)	0.0% (0.0%)
(Currently prevailing multipliers) BEVs: 3x until 2030; PHEVs: 2.5x until 2030	514.0 (147.4)	386.9 (145.8)	134.5 (96.5)	206.1% (59.1%)	155.1% (58.5%)	53.9% (38.7%)
BEVs: 2x until 2030; PHEVs: 1.5x until 2030	316.4 (144.4)	225.7 (133.1)	70.8 (69.6)	126.9% (57.9%)	90.5% (53.4%)	28.4% (27.9%)
BEVs: 3x until 2022, 1x after; PHEVs: 2.5x until 2022, 1x after	173.2 (130.9)	114.0 (109.3)	9.1 (9.1)	69.5% (52.5%)	45.7% (43.8%)	3.6% (3.6%)
BEVs: 3x until 2020, 2x until 2022, 1x after; PHEVs: 2.5x until 2020, 1.5x until 2022, 1x after	159.7 (130.7)	104.0 (103.2)	6.2 (6.2)	64.0% (52.4%)	41.7% (41.4%)	2.5% (2.5%)

Note: Values in parenthesis indicate absolute and percentage risk values based on the assumption that emission levels from conventional vehicles with or without EV incentives will not exceed a value of about 134 g CO_2/km. This is assumed as an indicative sunk investment level of the auto sector in India and corresponds to the average fleet-wide standard value based on the average curb weight of the Indian PV fleet in 2015–16.

ANNEX

ELECTRICITY AND FUEL CONSUMPTION FROM PHEVS

Since PHEVs can drive both in charge-depleting and charge-sustaining modes, and as such there is no discrete point in time when PHEVs switch from one mode of operation to another, fuel consumption and emissions are strongly influenced by driving and recharging practices of users on road (Riemersma & Mock, 2017). Regulations in large PHEV markets, such as in the United States[18] and the European Union,[19] have detailed test procedures in place for determining the fuel consumption, electrical energy consumption, and electric range of PHEVs. The test procedures in both regions specify utility factors that are a function of the electric range of the vehicle and allow for an estimation of the ratio of driving in both modes and a thus a calculation of weighted average fuel consumption, electricity consumption, and equivalent CO_2 as per the following formula:

C = UF * C1 + (1-UF) * C2

Where:
C = weighted fuel consumption in liters per 100 kilometers (km)
C1 = fuel consumption in liters per 100 km in charge depleting mode
C2 = fuel consumption in liters per 100 km in charge sustaining mode
UF = utility factor as a function of electric range

and similarly;

E = (De * E1 + Dav * E2) / (De + Dav)

Where:
E = weighted electricity consumption in kWh per 100 km
E1 = electricity consumption in kWh per 100 km in charge depleting mode[20]
E2 = electricity consumption in kWh per 100 km in charge sustaining mode[21]
De = electric range of the vehicle
Dav = 25 km (average distance assumed to be driven between two battery charges)

While the European Union test cycles are based on the Worldwide Harmonized Light Vehicles Test Procedure (WLTP) effective September 2017, testing in United States is based on a weightage from two test cycles, namely, the Urban Dynamometer Driving Schedule (UDDS or city cycle) and the Highway Fuel Economy Test Driving Schedule (HWFET or highway cycle).[22] Further, since utility factors are a function of electric range, which in turn depends on driver behavior and recharging practices, utility factors are defined differently for the European Union and United States representing variations in regional practices.

18 Test procedures for PHEVs as specified by Society of Automotive Engineers (SAE) practice J11711.

19 Test procedures for PHEVs as specified by United Nations Economic Commission for Europe (UN-ECE) Regulation R101.

20 Charge-depleting mode referred to as “condition A” in AIS-102 (Part 1).

21 Charge-sustaining mode referred to as “condition B” in AIS-102 (Part 1).

22 The city and highway cycles are weighted by 55% and 45%, respectively, to obtain the final results.

In comparison, the Indian test procedure for determination of emissions from PHEVs[23] is based on the Modified Indian Driving Cycle (MIDC) and uses an approach followed by the European Union prior to the adoption of WLTP based utility factors. Under the current Indian regulations, the weighted fuel consumption from both modes of operation is determined as per the following equation:

$$C = (De * C1 + Dav * C2) / (De + Dav)$$

Where:
C = weighted fuel consumption in liters per 100 km
C1 = fuel consumption in liters per 100 km in charge depleting mode[24]
C2 = fuel consumption in liters per 100 km in charge sustaining mode[25]
De = electric range of the vehicle
Dav = 25 km (average distance assumed to be driven between two battery charges)

and similarly;

$$E = (De * E1 + Dav * E2) / (De + Dav)$$

Where:
E = weighted electricity consumption in kWh per 100 km
E1 = electricity consumption in kWh per 100 km in charge depleting mode[26]
E2 = electricity consumption in kWh per 100 km in charge sustaining mode[27]
De = electric range of the vehicle
Dav = 25 km (average distance assumed to be driven between two battery charges)

The above approach may not be representative of real-world results as the assumption of 25 km as the average distance driven in charge sustaining mode is arbitrary, especially if the PHEVs under consideration are of the extended range electric vehicle (EREV) type. For example, the Chevrolet Volt, one of the top-selling PHEVs is an EREV with an EPA-rated electric range of 53 miles (85 km) while the Ford Fusion Energi, another globally top-selling PHEV has an EPA-rated electric range of 21 miles (34 km). Further, the wide variation in test cycle ranges will vary further based on driver behavior and recharging practices.

It is reported that the electric range of a PHEV determined based on WLTP is approximately 25% lower than the electric range determined as per the erstwhile NEDC with fuel consumption values closer to those observed in real-world scenarios (Riemersma & Mock, 2017). Since the MIDC is very similar to NEDC, and the Indian regulations specify the same assumption for the average distance driven in charge sustaining mode as the earlier EU regulations for PHEVs, it can be assumed that this limitation applies to the range determined from Indian regulations as well. Further, it is difficult to make any validations on the accuracy of the Indian test procedures for PHEV range and fuel consumption determination to real-world conditions as the current Indian PHEV market is next to negligible with no data or studies available. Thus, considering these two major limitations (arbitrary range fixed in charge sustaining mode and

23 Test procedures for PHEVs as specified by Automotive Industry Standards (AIS) 102 Part 1.
24 Charge-depleting mode referred to as “condition A” in AIS-102 (Part 1).
25 Charge-sustaining mode referred to as “condition B” in AIS-102 (Part 1).
26 Charge-depleting mode referred to as “condition A” in AIS-102 (Part 1).
27 Charge-sustaining mode referred to as “condition B” in AIS-102 (Part 1).

inherent limitations of MIDC test cycle) in the Indian test procedures for determining emissions from PHEVs, the WLTP based utility factor approach as followed in the European Union is adopted for quantifying emissions from PHEVs in this study instead of the Indian protocol.