India's EV Transition

Managing Fuel Tax Revenue Loss

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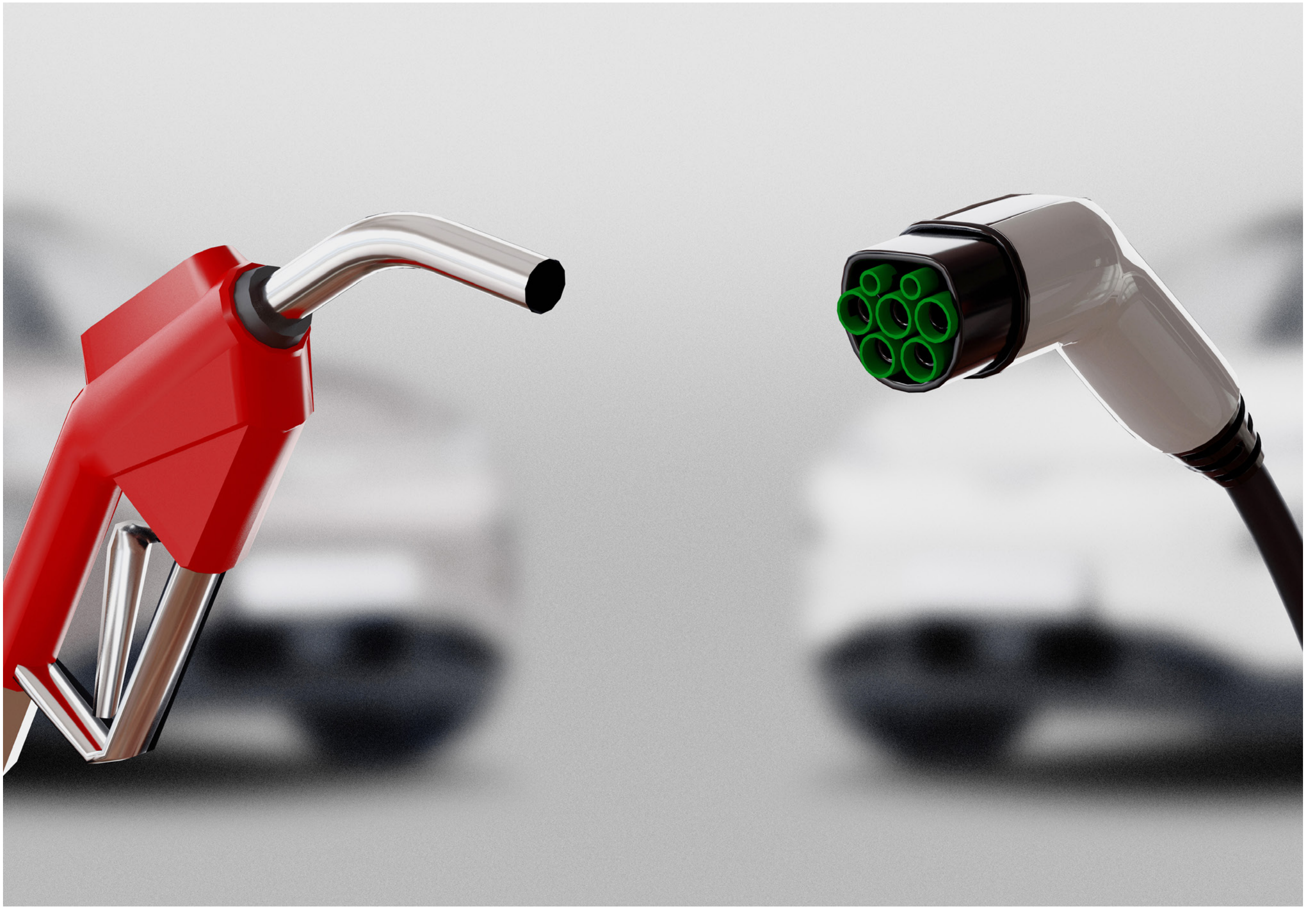

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Executive summary

In the financial year (FY) 2021, electric vehicle (EV) sales exceeded one per cent of the total vehicle sales in India for the first time. With the recent spate of union and state policies in favour of EVs and rising fuel prices, there has been a rapid uptick in EV sales across passenger vehicle categories. Overall, this is excellent news, but the exponential growth of EVs in the vehicle stock will create a new challenge for the exchequer – **revenue lost in fuel taxes on petroleum products.**

A. What will be the revenue loss for the state and centre?

Most governments around the world are fiscally dependent on fuel tax revenues (FTR). According to the Petroleum Planning and Analysis Cell (PPAC), almost 13 per cent of the Government of India's revenue in 2019–20 came from the excise duty and cess on motor spirit and high-speed diesel (PPAC 2022). Moreover, 15 per cent of the revenue from all the states and union territories (UTs) came from the value-added tax (VAT) on petroleum products.

Due to the EV transition, the Government of the National Capital Territory of Delhi (GNCTD) will have INR 1,457 crore or 10.2 per cent lesser FTR than the business-as-usual scenario (B-a-U) in 2030. This loss in revenue is almost equal to the funds allotted in the GNCTD's transport budget for viability gap funding for cluster buses in 2020–21. Similarly, the Government of India will lose 10 per cent or INR 1,896 crore of revenue from fuel taxes due to EV penetration in Delhi.

B. What is the best alternative to recover revenue loss?

Many provincial and federal governments worldwide have experienced FTR loss due to high EV uptake. We study six global government interventions to identify a feasible and scalable alternative tax regime to replace fuel taxes without impeding the EV transition. We evaluate these options across eight parameters: revenue recovery potential, impact on EV costs, ease of implementation, equity, and potential to reduce emissions and congestion, improve fuel efficiency, and promote public transport. Increasing the already high fuel taxes, although attractive, will be grossly unjust for many groups and is not recommended.

Introducing annual flat taxes for EVs or increasing their GST will be highly disruptive to the EV transition. Alternatives that do not adhere to the 'user pays principle' have a low potential to reduce congestion or emissions. **Based on the parameters considered, a distance-based tax is the best alternative to compensate for the revenue loss from fuel taxes.** Taking Delhi as a case study, we estimate the FTR lost by state and central governments in two EV penetration scenarios for Delhi's vehicle stock. We conclude that a distance-based tax (DT) regime is the best option for recovering revenue without impeding the EV transition. We demonstrate that an intelligent DT regime can reduce the impact on EV costs and simultaneously send policy signals for technology shifts and modal shifts, thus adhering to equity and sustainable mobility principles. We use the effect on the total cost of ownership (TCO) to show the impact of the distance tax on users.

C. How can we operationalise and enforce the alternative?

Locating and tracking a vehicle in space and time is fundamental to charging users based on distance fairly. We list and compare six technologies considered for distance-based taxes. We compare the options based on four parameters – ease for users, interoperability, ease of setting up infrastructure, and enforcement. Within each parameter, each technology is rated high, medium, or low based on the ease of implementation.

Our analysis suggests that a global navigation satellite system (GNSS) is best suited for a long-term transition to a DT regime in India. The most accepted GNSS is a popular US technology known as the global positioning system (GPS). In India, GNSS technology is already being used for tracking commercial passenger vehicles and is being piloted to replace 'fast tags' in national highway tolling. The scope of this technology can be expanded to a DT regime on all roads.

We recommend **four steps** to transition from fuel taxes to a DT regime using the GNSS technology.

- **Pilot technology to establish interoperability:** To establish interoperability, it is imperative to test the applicability of the existing GNSS technology in

Figure ES1 Distance taxation is the best option for recovering FTR loss

Alternative options for compensating FTR loss	Can recover revenue	Does not disrupt EV TCO	Is easily implement able	Is equitable/ just	Can reduce emissions	Can reduce congestion	Can promote public transport	Can improve fuel efficiency
Distance-based tax	High	High	Low	Medium	High	Medium	Medium	High
Increase existing fuel tax rates	High	High	High	Low	High	Medium	High	High
Annual fee on EVs	High	Low	Medium	Low	Low	Low	Medium	Low
Increase tax on electricity	Medium	Medium	Medium	Low	Low	Low	Low	Medium
Increase GST on EVs	Low	Low	High	Low	Low	Low	Low	Low
Increase toll tax	Low	Medium	High	Low	Low	Low	Low	Low

Source: Authors' analysis

Potential: High / Medium / Low

India for use in various road pricing policies such as congestion charging, HDV distance taxation, low emission zone pricing, parking, etc.

- **Prepare policy to guide pricing strategies :** To develop a distance-based pricing policy with clear goals and principles to support a locally driven transition.
- **Build public acceptability for road pricing:** Building public acceptability in paying for road usage as well as cultivating public trust in the implementation agency is imperative for a successful distance tax regime.
- **Pilot road pricing regimes to generate revenue**: GNSS based road pricing for tolls, congestion, pollution, etc., will build the infrastructure to manage revenue without requiring a abrupt transition from fuel taxes.

1. Introduction

In the financial year (FY) 2021, electric vehicle (EV) sales exceeded 1 per cent of the total vehicle sales in India for the first time. EV sales have remained well under 1 per cent for eight years since the first EV policy – *National Electric Mobility Mission Plan 2020* (NEMMP) – was launched in 2012. With the recent spate of union and state policies and rising fuel prices, there has been a rapid uptick in EV sales across passenger vehicle categories. Overall, this is great news, but an exponential increase in the share of EVs in the vehicle stock creates a new challenge for the exchequer – revenues lost in the form of fuel taxes on petroleum products. This study recommends a feasible and scalable alternative tax regime to replace fuel taxes without impeding the EV transition while adhering to equity and sustainable mobility principles.

In this study, we estimate the fuel tax revenue (FTR) lost by state and central governments in two kinds of EV penetration scenarios for Delhi's vehicle stock. We analyse various alternatives to recover this lost revenue. We model different scenarios to analyse the effectiveness of a distance-based tax (DT) regime to send policy signals to promote technological and modal shifts. Lastly, we use the impact on the total cost of ownership (TCO) to show the effect of a distance tax on users.

Further, this study briefly explores and evaluates alternative technologies that are available for implementing the DT regime. The evaluation is based on various norms such as ease for vehicle users, interoperability, ease of setting up infrastructure, and ease of enforcement. We conclude the study by recommending potential interventions needed in the near term to implement such a direct taxation regime.

2. How dependent are central and state exchequers on fuel tax revenue?

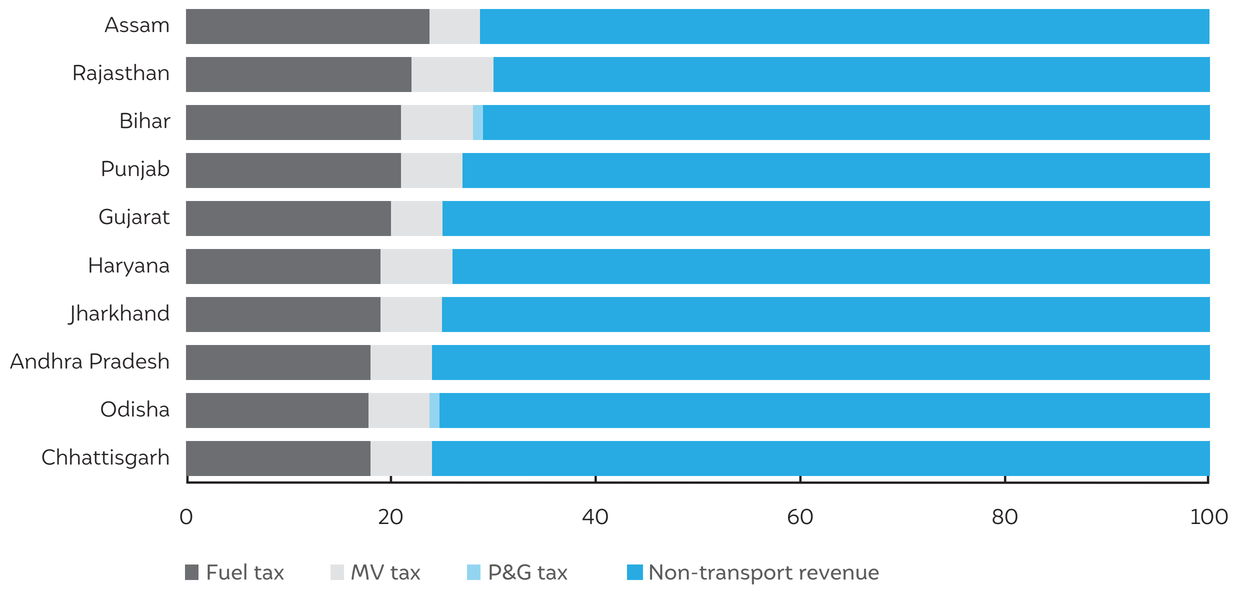
Fuel taxes are significant sources of revenue for federal and provincial governments worldwide. In the United States, the combined FTR of state and local governments in 2019 contributed to 1.5 per cent of their general revenue (FHWA 2020). The accrued revenues are earmarked for the development and maintenance of state highways, local roads and streets, and mass transit services. On the contrary, in Australia fuel is taxed primarily to raise government revenue rather than directly fund transport infrastructure (Black 2020). In Europe, fuel taxes are fiscally significant for governments, and tax systems are designed to achieve environmental policy objectives (Kunert 2018). In some eastern European countries, like Estonia and Slovenia, a part of the FTR is legally earmarked for road infrastructure. However, countries like Russia, Romania, Latvia, and Lithuania have abolished allocation of a fixed percentage of the FTR toward road development to improve the management of their public finances. Taxes earned from the fuel levy alone contribute to 5 per cent of the total tax revenue of South Africa (Stander and Brink 2019).

Indian scenario

Like governments around the globe, taxes on petroleum products form a major component of revenue for the central and state governments in India. Almost 13 per cent of the Government of India's (GoI) revenue in 2019–20 came from the excise duty and cess on motor spirit and high-speed diesel (HSD). Using data from the Petroleum Planning and Analysis Cell (PPAC) and an RBI analysis of state budgets (RBI 2021), we find that 15 per cent of the total revenue of all the states and union territories (UTs) came from the value-added tax (VAT) on petroleum products.

Apart from levying fuel taxes, central and state governments in India levy taxes on vehicles and the movement of passengers and goods (MoRTH 2019). These taxes are not a part of the goods and service tax (GST) regime. However, GST is levied on the purchase of motor vehicles. The Indian government's policies and documents do not earmark specific uses for funds collected via fuel duties in India. Taxes, like highway tolls, aim to directly finance projects by collecting fees from users (Purohit and Purohit 2010). Motor vehicle

Figure 1 The share of fuel taxes in total revenue can be as high as 22% in some states (2019–20)



Source: Authors' analysis of PPAC data(PPAC 2022) and RBI data on state finances (RBI 2021).

taxes as well as passenger and goods taxes and tolls are minor sources of revenue in comparison to fuel taxes. They account for about 3 per cent of the total tax revenue of all states and UTs. The scope of this study is limited to FTR and strategies to recover loss of the same on account of the EV transition.

Figure 1 shows the share of the revenue from the tax on petroleum products with respect to the total tax revenue earned by states. It shows the top ten states with the highest dependency on fuel taxes for revenue.

3. What is the expected revenue loss from EV transition?

As EVs do not require petrol, diesel, or any other petroleum product, revenues from fuel taxes will drop due to the EV transition. With increasing EV penetration, understanding the impact on FTR is of interest to various policymakers (Gao and Plotnikov 2017).

3.1 Global learnings

A 2014 study evaluated the impact of corporate average fuel efficiency (CAFE) regulations, and the effects of an increase in the share of hybrid and alternative fuel vehicles in the fleet, on federal tax revenue in the United States (Vasudevan and Nambisan 2014). The study predicts a revenue loss of 37 per cent for the US federal government in 2025 (in comparison to 2009) with a 20 per cent annual increase in hybrid and alternative fuel vehicle sales. Jenn, Azevedo, and Fischbeck (2015) estimate the cumulative revenue loss up to USD 900 million between 2011 and 2025 for all states in the US based on the lifetime tax revenue deficit from representative EV models. Chamberlin et al. (2016) use the US Federal Highway Administration's (FHWA) policy analysis tool to estimate vehicle stock growth in Utah. They find that there will be a 40 per cent revenue loss in the 31 per cent EV penetration scenario in 2040.

We have reviewed the literature on FTR loss due to the EV transition. FTR may also be affected by changes in mode shares, fuel efficiencies, travel demand, local fuel demand, etc. All of these are beyond the scope of this study and are, thus, considered consistent across the different scenarios.

We study the case of Delhi to estimate FTR loss for central and state governments in 2030. As seen in the literature, calculating future revenue loss will require two assumptions – the vehicle stock and EV penetration level. We use Goel and Guttikunda's (2015) projections of Delhi's vehicle stock as the business as usual (B-a-U) scenario in 2030. We test the revenue implications of two EV penetration scenarios compared to the B-a-U.

3.2 EV penetration scenarios for revenue loss

The two EV penetration scenarios for 2030 are derived from a previous CEEW study (Soman et al. 2020) and a NITI-RMI study (NITI Aayog and Rocky Mountain Institute 2019). These are national EV sales penetration scenarios for 2030 and only look at the passenger vehicle

Table 1 EV sales and stock penetration in scenarios for 2030

2030 EV penetration scenarios			4W	2W	3W	Taxi	Bus	HDV	LDV
Scenario 1	EV30	Sales penetration	39%	80%	35%	100%	30%	1%	20%
		Stock penetration	9%	16%	7%	26%	5%	0%	5%
Scenario 2	EV40	Sales penetration	62%	100%	80%	100%	40%	1%	20%
		Stock penetration	14%	20%	16%	26%	6%	0%	5%

Source: Authors' Analysis for stock penetration on sales penetration from (Soman et al. 2020) and (NITI Aayog and Rocky Mountain Institute 2019)

segments of four-wheelers (4W), two-wheelers (2W), three-wheelers (3W), taxis, and buses. Delhi has seen a significantly faster increase in EV penetration than the rest of India. We estimate the market share of EVs in Delhi and India as of 2021 from registration data. Per our estimation, the market shares of EVs are higher across all segments in Delhi. For instance, the share of EVs in Delhi's 4W segment is 3.2 times the share in the overall Indian 4W market. Such factors are derived for all passenger segments. The reference national penetration assumptions from Soman et al. (2020) and the NITI Aayog and Rocky Mountain Institute study (2019) were multiplied with these factors to develop EV penetration assumptions for Delhi for Scenarios 1 and 2, respectively (see Table 1).

For light-duty vehicles (LDVs) and heavy-duty vehicles (HDVs), we have assumed EV sales penetration of 20 per cent and 1 per cent, respectively, in 2030 (considered the same in both scenarios). We considered 20 per cent EV sales in the LDV segment, as Delhi already sees about 7 per cent EV penetration in the light goods vehicle and 3W goods segments combined. These EV penetration scenarios for 2030, and data on the sales penetration of EVs (from the Vaahan Dashboard as of December 2, 2021)(Ministry of Road Transport and Highways 2021), are used to interpolate the sales penetration of EVs between 2021 and 2030 linearly. Thus, the EV stock of 2030 derived for both scenarios is imposed on the B-a-U to derive the share of other technologies for Delhi in these scenarios. It is assumed that EVs will replace all other technologies equally. The total number of vehicles in each segment, vehicle kilometres travelled (VKT), and modal share of segments remain the same in the B-a-U and the two scenarios. The change across scenarios is limited to EV penetration in the vehicle stock.

3.3 Methodology for revenue loss

The FTR is estimated using a bottom-up approach. The number of vehicles in use, fuel efficiencies, and annual vehicle kilometres travelled for the selected seven vehicle segments (2W, 3W, 4W, Taxi, bus, HDV, LDV) are taken from Goel and Guttikunda's (2015) estimates for 2030. We employ central excise duty (ED) and state VAT – including the air ambience charges levied on petrol and diesel by the GoI and Government of the National Capital Territory of Delhi (GNCTD) as of December 1, 2021 (IOCL, n.d.) – for estimating revenue in 2030. Currently, VAT is not levied on CNG in Delhi. However, some states levy a CNG VAT as high as 24.5 per cent (PTI 2022). The centre has proposed capping the CNG VAT at 5 per cent to bring CNG vehicles at par with EVs (Chatterjee 2020). Hence, in all the scenarios considered here, we assume the CNG VAT to be 5 per cent in 2030.

For the central and state governments, FTR is calculated as the sum of the products of the assumed VAT and the estimated consumption of each fuel type (as shown in the equation).

$$FTR = (ED + VAT)_i \times \sum_{s\,=\,2W,3W,4W,Taxi,Bus,HDV,LDV}^{i\,=\,p,d,c} V_{is} \times VKT_{is} \times \frac{1}{f_{is}}$$

Note: V = vehicles in use, f = fuel efficiencies, VKT = annual vehicle kilometres travelled, s = vehicle segments (2W, 3W, 4W, taxi, bus, HDV, LDV), p = petrol, c = CNG, d = diesel.

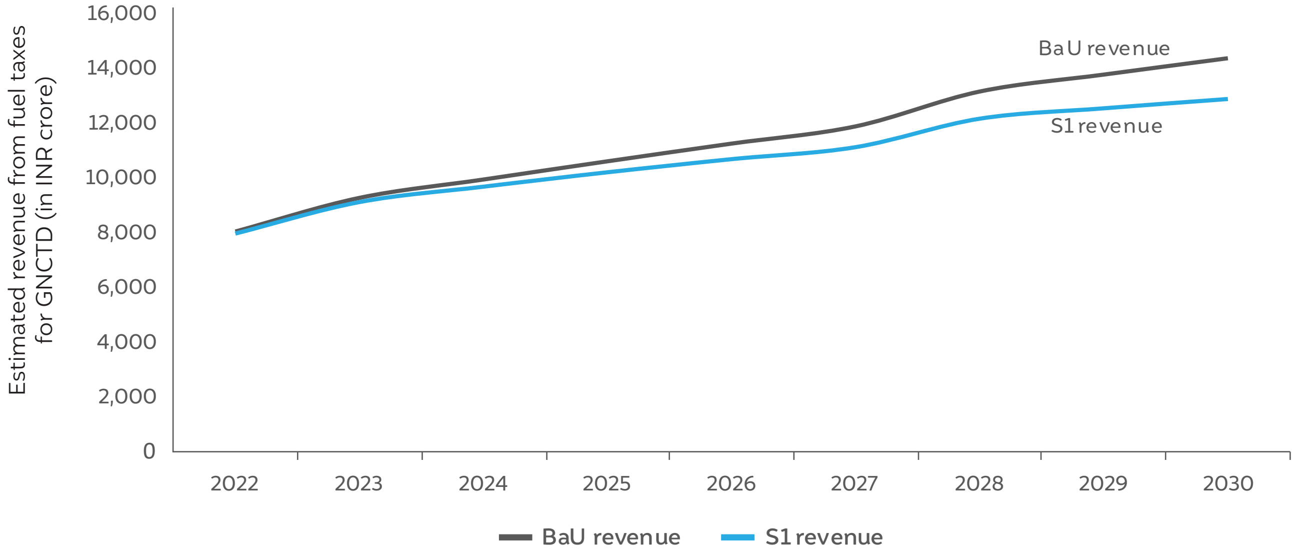
3.4 Revenue loss estimates

FTR is calculated for the B-a-U, Scenario 1 (EV30), and Scenario 2 (EV40) of EV penetration. The difference between FTR in the B-a-U and each scenario accounts for FTR loss in the respective scenario. The B-a-U estimate of FTR for the GNCTD in 2030 is 3.6 times the revenue collected by it through the VAT on petroleum products in 2019–20 (PPAC 2021).

Figure 2 shows revenue losses in both scenarios. In Scenario 1, the GNCTD has 10.2 per cent lesser FTR in comparison to B-a-U in 2030 due to EV penetration. This amounts to INR 1,457 crore. This loss in revenue almost equals the funds allotted for viability gap funding for cluster buses in 2020–21 in the capital's transport budget (GNCTD 2021). Similarly, the GoI loses 10 per cent or INR 1,896 crore of revenue from fuel taxes in Delhi.

In Scenario 2, the GNCTD has a 14.1 per cent lesser FTR in comparison to the B-a-U scenario in 2030. This

Figure 2 FTR for the GNCTD can reduce by 10.2 by 2030 due to EV penetration



Source: Authors' analysis

amounts to INR 1,923 crore. This loss in revenue is one-fifth of the GNCTD's entire transport budget in 2020–21 (GNCTD 2021). Similarly, the GoI loses 13.6 per cent or INR 2,570 crore of the B-a-U revenue from Delhi.

4. What are the alternative options to recover revenue loss?

Such a revenue loss has been experienced by many regional and national governments around the world with high EV uptake. Most of them did not plan for it and had knee-jerk reactions to the revenue lost. Referring to these reactions, we look at the six possible reactions that may be adopted by the centre and states in India in a 2030 EV scenario: introduce an annual flat tax on EVs, increase existing fuel tax rates, increase the GST on EVs, increase the electricity duty, increase the toll tax, and introduce distance-based taxes.

4.1 Alternative revenue options considered

An annual flat tax on EVs

An annual flat tax may be levied on EVs to recover the revenue lost from fuel taxes. This is easy to implement for most governments. As of 2017, 16 states in the United States had already started levying annual registration fees on EVs to recover FTR losses (Gao and Plotnikov 2017). These annual charges on EVs vary from USD 50 to USD 300 across the country. This sort of taxation is disruptive to the EV transition. EV sales in Georgia fell by 80 per cent after it introduced an annual registration tax for EVs (Walton 2017). An annual tax on EVs is debatable even in countries like Norway where 65 per cent of the cars sold in 2021 were electric (Klesty 2022). Even with high sales, EVs make only 15 per cent of the stock in Norway and disruption to the EV transition must be avoided while managing EV trade-offs (Meaker 2021).

We calculated the annual tax levied on EVs in 2030 to recover the estimated revenue loss due to EV penetration (see Table 2). If the taxes are collected annually, EV users will pay a higher tax per unit of distance than Internal Combustion Engine (ICE) users. With a flat tax, a person driving less pays the same fee as a person driving more. Essentially, a flat tax cross-subsidises those who drive more by taxing those who drive less. This is unjust for private EV users who drive less.

Table 2 Estimated annual fee for EVs if FTR loss in 2030 is compensated by a flat tax on EVs

Estimated EV tax (INR/annum)	
4W	23,110
2W	10,215
3W	17,707
Taxi	71,752
Bus	1,16,360
HDV	2,21,432
LDV	1,02,574

Source: Authors' analysis

An annual flat tax on EVs can recover the revenue lost from EVs; however, it will disrupt the EV transition by adding costs. This will also be unjust to EV owners who drive less. Further, the flat tax regime cannot be used to manage congestion, promote fuel efficiency, or induce a shift to public transport.

Increase existing fuel tax rates

Increasing fuel tax rates may help governments recover the revenue lost from the EV transition. In the past, the GoI has taken advantage of decreasing crude oil prices to increase fuel taxes and corresponding revenues (Suneja 2021). We calculated the increase that would be required in state VAT and the central excise duty to compensate for the FTR loss in INR per unit of fuel. In Scenario 1, increased taxes on petrol, diesel, and CNG will lead to a hike of 7 per cent, 3 per cent, and 1 per cent in the respective fuel prices. In Scenario 2, state and central tax increases will lead to a 9 per cent, 5 per cent, and 2 per cent price increase for petrol, diesel, and CNG, respectively. Table 3 shows the required increase in fuel taxes in INR/litre to recover revenue losses in Scenarios 1 and 2.

Table 3 Required increase in state VAT and central excise duty on fuel to recover FTR Loss in 2030

Fuel	Scenario 1		Scenario 2	
	State VAT	Central excise	State VAT	Central excise
Petrol (INR/litre)	3.20	3.72	4.45	5.17
Diesel (INR/litre)	1.03	1.73	1.47	2.48
CNG (INR/kg)	0.22	0.62	0.34	0.96

Source: Authors' analysis

Increasing existing fuel taxes does not require any new infrastructure for implementation. This method to recover lost FTR will not impede the EV transition in any way. As fuel taxes are based on usage, they promote higher fuel efficiency and can discourage the use of private transport. However, fuel prices are a politically sensitive subject worldwide, including in India. Attempts made by governments to raise fuel prices between 2006 and 2019 were followed by protests in 24 countries (Mahdavi, Martinez-Alvarez, and Ross 2020). Increasing fuel taxes is particularly unjust for users who drive old vehicles with low fuel efficiency. Raising fuel taxes also impacts agricultural and rural economies directly (Sands et al. 2011). Taxing rural and agricultural populations to compensate for revenue loss due to EV uptake, which is concentrated in urban areas, is not just.

Furthermore, increasing fuel taxes is not a long-term solution for revenue recovery, as more and more fuel taxes will have to be levied on non-EVs as their numbers dwindle – until the point where there are no more non-EVs to recover revenue from.

Increase the GST on electric vehicles

To compensate for FTR loss, policymakers in Norway are considering charging VAT on the sale of 'luxury EVs' and a new tax on second-hand sales of EVs (Meaker 2021). Presently, India levies a 5 per cent GST on EVs and a 28 per cent GST on ICE vehicles. We calculate the recovery of revenue lost in both scenarios if the EVs sold in 2030 are taxed at 28 per cent instead of 5 per cent. This increase in the GST on EVs can recover twice the revenue lost in Scenario 1 and 2.5 times the revenue lost in Scenario 2. Although the revenue recovery potential of this option is good, it will impact the upfront costs of EVs directly. The GST increase is also unjust to users who drive less (just like the flat tax). This tax system cannot be used to incentivise fuel efficiency or public transport usage. Additionally, the GST is levied pan-India. An increased GST will disrupt regional markets where EV penetration may still be lagging. Since most EVs in India are 2W or 3W, charging a higher GST could disrupt the positive impact the EV transition has had on improving the livelihoods of many last-mile transport service workers in India.

Increase electricity duty

EV penetration will undoubtedly lead to higher demand for electricity; therefore, Indian state governments have an option to generate revenue through electricity duties. Currently, Delhi has a special EV tariff of INR 4.5/kWh (Goswami 2021), while electricity consumption in the capital is taxed at 5 per cent. We estimate that the increase in revenue from the electricity duty is 3 per cent of the revenue lost by GNCTD in both scenarios. Hence, the current rate of the electricity duty is insignificant for recovering the FTR loss.

We also estimate that the electricity tax rate in Delhi will have to increase by more than 150 per cent to generate enough tax revenue from EVs to recover the lost FTR. This would double energy prices for EVs in Delhi, making the special tariff rate redundant as well as disrupting the transition to EVs. In the absence of smart metering infrastructure, higher electricity duties cannot be charged for EVs alone. Increasing duties for all electricity consumers will be grossly unfair to all households. Such a regime will also not address the FTR loss of the central government. Even though increasing the electricity duty has the potential to incentivise

> **Distance tax maintains 'user pays principle' like fuel taxes, but does not lose revenue as vehicles become more efficient.**

energy-efficiency improvements in EVs, it requires smart charging infrastructure and a considerable increase in tariffs.

Increase toll tax

Increasing toll taxes is a short-term alternative for recovering FTR loss (IEA 2021). In India, toll tax is primarily meant to recover road infrastructure costs such as highways, bridges, crossings, etc. After the recovery of costs, tolls continue to be collected for infrastructure maintenance. Although the Ministry of Road Transport and Highways (MoRTH) regulates the pricing of tolls in India, the rates vary across the country. The tax is collected by the centre, state, or a private party, depending on the project. Increasing existing toll tariffs for EVs only may be ineffective in recovering revenue as EV movement will mainly be concentrated in urban areas and not on highways. Increasing toll tariffs for all highway users will be unfair as the FTR loss will be due to the electrification of urban trips. Moreover, high toll tariffs may push vehicle traffic to interior roads, adding to congestion. The only advantage of increasing toll tariffs is that they can be designed to incentivise public transport.

Distance tax

Also called mileage-based user fees (MBUF) or road user charges (RUCs), distance taxes are per kilometre rates, charged according to utilisation. Essentially, it is a fee charged per unit of distance. Distance tax can recover revenue loss effectively in a fuel-neutral manner. Its impact on EV costs can be minimised if designed well. As the costs are distributed over time, a distance tax is a better alternative than flat taxes. It is also fairer because charges are based on usage. It can be designed in a way to manage emissions and congestion and promote public transport.

Several governments have begun studying, testing, and executing distance tax systems as an alternative to fuel taxes (Varn, Eucallitto, and Gander 2020). The FHWA has awarded funding to eight states to pilot distance taxes under its *Surface Transportation System Funding Alternatives* programme (Lombardo 2021). Oregon established a distance tax in 2015 that allows users to volunteer to transition from fuel to distance taxes (Matthews et al. 2021). EV and hybrid users in Utah can also volunteer to move to a distance tax from a flat registration tax (Moulineaux 2020). The transport selection committee in the United Kingdom parliament recently recommended replacing the excise duty on fuel with distance taxation to recover FTR loss from the EV transition (Austin 2022).

4.2 Comparison of alternative options for recovering revenue

We compare the tax alternatives across eight parameters. Since the alternative adopted must not disrupt the EV transition, the impact on EV costs is a prime factor in the evaluation of these options. To consider the practicality of taxation, we evaluate these options on the potential to recover revenue and ease of implementation. We assess whether these options are just for users. We also explore the potential of these options to be designed for reducing congestion, improving fuel efficiency, and encouraging the use of public transport. Based on the evaluation, we rate the potential of these options as high, medium, and low, against each of the parameters (see Figure ES1).

Potential to recover revenue

As shown in the analysis earlier, annual flat taxes on EVs, increasing existing fuel tax rates, and distance taxes can generate enough revenue to compensate for the lost revenue with respect to B-a-U relatively easily. Hence, they have a high potential for revenue recovery. Increasing the GST slab of EVs to 28 per cent can generate revenue in the short term but its effectiveness reduces as EVs become cheaper and have higher stock penetration. Thus, it has medium potential. We have established that the electricity duty will have to be increased exponentially to recover revenue for the state government alone. Similarly, increasing tolls cannot recover revenue from most urban movement vehicles. Hence, both of these alternatives have a low potential.

Potential to not disrupt EV TCO

We have demonstrated how annual flat taxes and increased EV GST have direct implications for EV TCO. The literature also argues that taxing EVs is disruptive to the transition (Varn, Gander, and Eucallitto 2020). Hence, these two alternatives have a low potential. Increasing the electricity duty will have a relatively lesser impact on the EV TCO due to the energy efficiency of EVs. Increasing tolls will also have a limited impact on the EV TCO unless most EV kilometres are on highways and not in urban areas. Hence, increasing tolls taxes and the electricity duty have medium potential. Increasing fuel taxes will have no impact on the EV TCO. Distance taxes can be designed to minimise the impact on the EV TCO. Hence, these two alternatives have a high potential.

Potential ease of implementation

Increasing the GST, fuel taxes, or tolls does not require additional infrastructure. Hence, these revenue alternatives have a high potential for ease of implementation. Although the electricity duty can be charged using existing infrastructure, charging only EVs on electricity consumption will require smart charging infrastructure. Hence, this alternative has medium potential. Annual flat taxes on EVs can be implemented easily for commercial vehicles using current channels of tax collection. However, annual flat tax collection from private EVs may be tricky as no such infrastructure exists for private vehicles. Hence, this alternative has medium potential. Distance tax has a low potential to be implemented easily due to the complexities of measuring and charging for distance.

Potential to be equitable/just

Increasing the GST and an annual flat tax for EVs is unjust to EV users. Increasing fuel taxes is unjust to users with old vehicles because they have lower fuel efficiencies. It is also unjust as it has implications for consumer prices. If implemented without smart charging infrastructure, increasing the electricity duty will be unjust to general electricity consumers. Increasing toll taxes will be unjust to highway users. The distance tax can be made equitable through design by considering vehicle or spatial parameters, for example, lower taxes for smaller cars or higher taxes in the city centre. Hence, distance taxes have medium potential and all other alternatives have a low potential to be equitably or just.

Potential to reduce emissions

Increasing the GST, introducing annual flat taxes, and increasing the electricity duty are directed at EVs and cannot be used as instruments to reduce emissions. Toll taxes are limited to highways and cannot be used to discourage emissions. Hence, these alternatives have a low potential for reducing emissions. As fuel taxes adhere to the user pays principle, increasing their rates will discourage usage, and thereafter, emissions. Similarly, distance tax is also usage-based and can discourage emissions. Further, the distance tax can be designed to promote low-emission vehicles. Hence, increasing fuel taxes and distance taxes have a high potential to reduce emissions.

Potential to reduce congestion

Similar to the emission reduction potential, GST increase, flat taxes, and the electricity duty cannot discourage congestion by taxing usage. Increasing tolls might increase congestion on other roads. Hence, these have a low potential to reduce congestion. Fuel taxes and distance taxes can discourage usage and, hence, congestion. The distance tax can be taken one step further and have differential pricing for the size of the vehicle or occupancy.

Potential to promote fuel efficiency

Similar to emissions, alternatives that adhere to the user pays principle have the potential to promote fuel efficiency. The electricity duty adheres to this principle but can promote energy efficiency in EVs only. Hence, it has medium potential. Increasing fuel and distance taxes have a high potential to promote fuel efficiency.

Our evaluation shows that increasing fuel taxes and distance taxation are the most viable options. Increasing fuel taxes is not optimum because it is unjust. The distance tax can be designed to be fair to users. Hence, distance-based taxation is the best way to recover the revenue loss from the EV transition as per the parameters considered in this study. The distance tax has medium potential to reduce emissions and congestion. In the following section, we demonstrate through case studies how DT can be used to recover revenue while minimising the impact on the EV TCO and sending policy signals for reducing congestion, pollution, and private vehicle use.

5. Can distance taxation recover revenue with minimal impact on EV costs?

Our objective here is to show that a distance tax regime can be designed to minimise the impact on EV costs while maintaining revenue levels and simultaneously sending policy signals for a shift to clean technologies and public transport.

- We apply three types of DT pricing strategies to recover the 2030 FTR loss in Scenario 1.
- All three DT pricing cases achieve the same revenue as B-a-U for the state and centre.
- We evaluate the impact of distance pricing on the net present value (NPV) of the TCO of the EV and ICE vehicle segments.

We use the CEEW TCO tool (unpublished) to calculate the TCO of the 2W, 3W, 4W, taxi, and bus segments. For the HDV and LDV segments, we use the World Resources Institute (WRI) TCO evaluator (n.d.). The annual vehicle kilometres travelled (VKT) for each vehicle segment is taken from estimates by Goel and Guttikunda (2015). A 10 per cent yearly discount factor is assumed for calculating the NPV of costs in the future.

5.1 Distance tax cases

Case 1: DT for EVs only

In Case 1, we look at a DT scenario where only EVs are taxed for the distance travelled.

- All ICE segments continue to be taxed for fuel consumption as in B-a-U.
- The revenue loss from the EV uptake in Delhi in 2030 for the centre and state is recovered by a distance tax on EVs only.
- We derive DT pricing for the EVs in INR/km to recover the revenue loss and restore B-a-U revenue.
- This is done assuming that revenue lost from each vehicle segment is compensated by taxing EVs in the same segment.

Figure 3 shows the minimum distance tax to be levied on EVs to recover revenue loss. This has a considerable impact on EV TCOs as shown in Table 4.

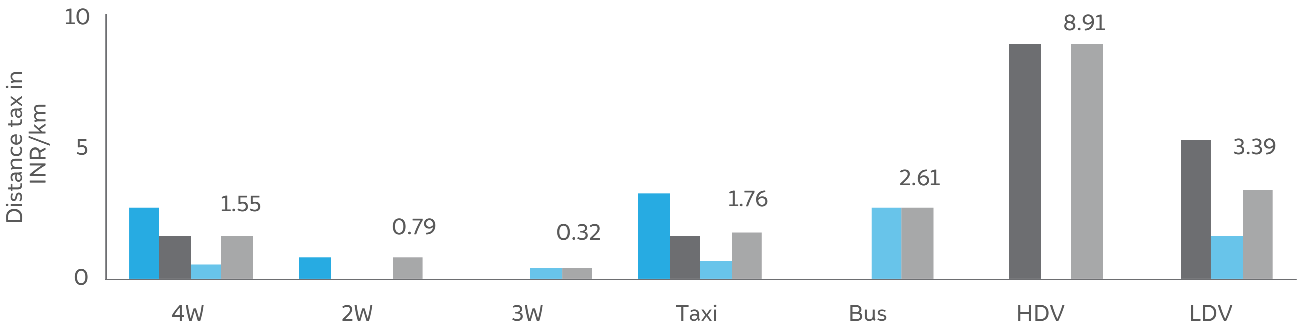
- There is zero impact on the TCOs of other fuel types.
- The distance prices for EVs must come down to reduce the impact on the EV TCO.
- In this case, reducing the derived price will compromise the revenue constraint. Hence, to minimise the impact on EV costs in a DT regime, it is necessary to include other fuel segments.
- This tax regime cannot recover revenue and promote cleaner technologies simultaneously.
- In this case, EVs will have to be taxed higher than other fuel types that are more polluting to recover revenue.
- A DT regime on EVs only is not the best solution for revenue recovery and can significantly impede the EV transition by affecting costs.

Case 2: DT for all (with a clean technology signal)

In Case 2, we consider a tax regime where all fuel types are included in the DT regime.

- There is no fuel tax in this tax regime.
- Taxes for CNG per unit of distance remain the same as the B-a-U fuel tax.
- Revenue lost from EV penetration in each segment is recovered from the same segment. Overall revenue is also the same as the B-a-U revenue.
- DT increases in the following order in each vehicle segment: EV, CNG, petrol, and diesel. This is to ensure that the DT policy sends a clean technology signal.
- The TCO impact on EVs in the 4W, 2W, taxi, HDV and LDV segments is reduced in the pricing derived in Case 2.

Figure 3 **EVs will have to be taxed at par or higher than CNG if only EVs are included in the DT regime (Case 1)**



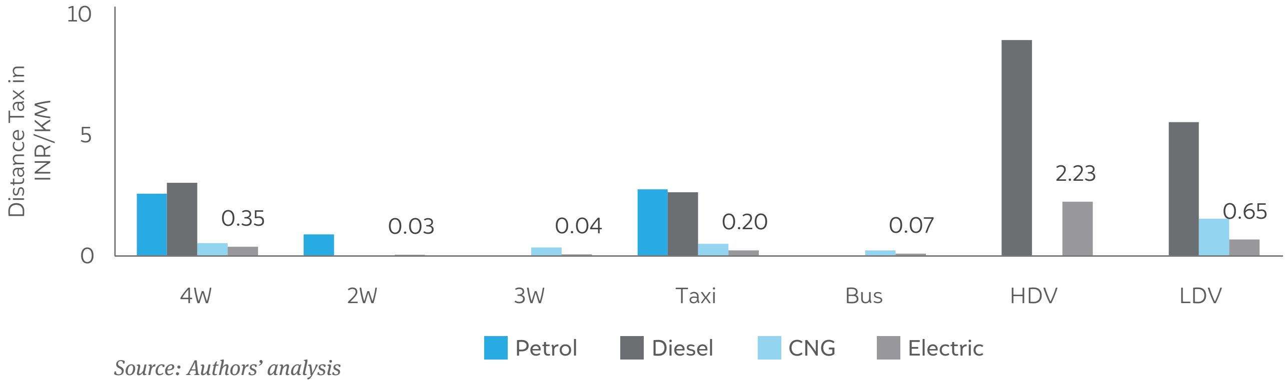
Source: Authors' analysis

Table 4 **The impact on EV TCO cannot be reduced if only EVs are included in the DT regime (Case 1)**

	4W	2W	3W	Taxi	Bus	HDV	LDV
EV TCO increase (per cent)	19%	106%	30%	46%	5%	9%	27%

Source: Authors' analysis

Figure 4 DT regime can be designed to promote cleaner technologies (Case 2)



Source: Authors' analysis

- 3W and bus segments only have EVs or CNG in the vehicle stock. The CNG tax and total revenue from the segment are kept the same as B-a-U. Hence, the TCO impact on electric 3W and buses cannot be reduced in this tax regime.

Case 3: DT for all (with a clean technology and public transport signal)

In Case 3, we consider a tax regime where all fuel types are taxed based on distance. It adds to the tax regime in Case 2 by sending a signal for a shift to public transport as well.

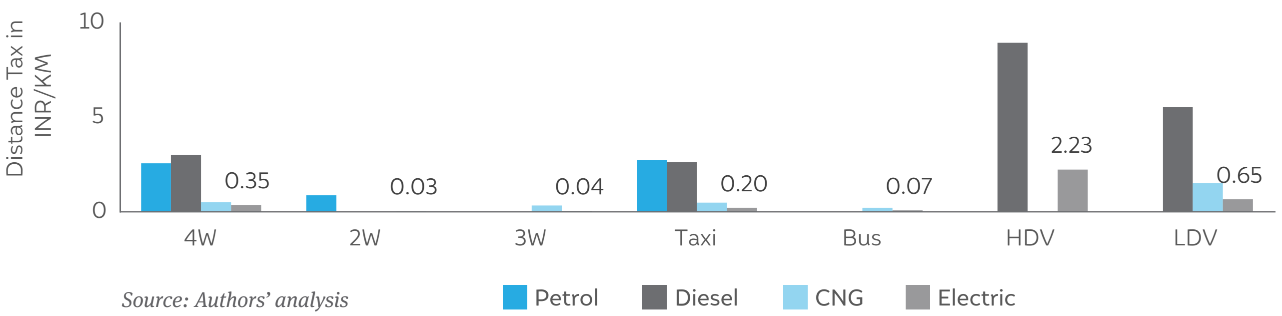
- Within each fuel segment, the DT for buses is less than that for 3W, 3W is less than 2W, 2W is less than a taxi, and taxi is less than a 4W. For example, a petrol 2W will always be taxed lower than a petrol taxi and a petrol taxi will always be taxed lower than a diesel taxi in this tax regime.
- For any vehicle segment, DT for EV < CNG < petrol < diesel.
- For any fuel technology, DT for bus < 3W < 2W < taxi < 4W.
- HDV and LDV will continue to be taxed as in Case 2.
- Inequality among fuel segments is derived from the inequality of $kgCO_2$ emission per passenger kilometre based on emission factors (WRI 2015) and occupancy factors of the vehicle segments.
- Segment-wise tax revenue is not constrained by the B-a-U revenue.
- Total revenue remains equal to the B-a-U revenue.
- The impact on the EV TCO is less than 5 per cent in all segments.
- There is no DT for buses.
- CNG tax remains the same or lesser than B-a-U.
- From Case 1 to Case 3, the impact of the DT regime on EV TCO is reduced significantly.
- The Case 3 tax regime has less than a 5 per cent increase on EVs in any segment.

Table 5 Impact on EV TCO can be reduced by including other fuel types in the DT regime (Case 2)

Fuel type	4W	2W	3W	Taxi	Bus	HDV	LDV
EV TCO increase (%)	5%	54%	30%	12%	5%	3%	8%
Petrol TCO increase (%)	-5%	3%		4%			
Diesel TCO increase (%)	13%			28%		0%	2%
CNG TCO increase (%)	0%		0%	0%	0%		0%

Source: Authors' analysis

Figure 5 DT regime can be designed to promote cleaner technologies and public transport simultaneously (Case 3)



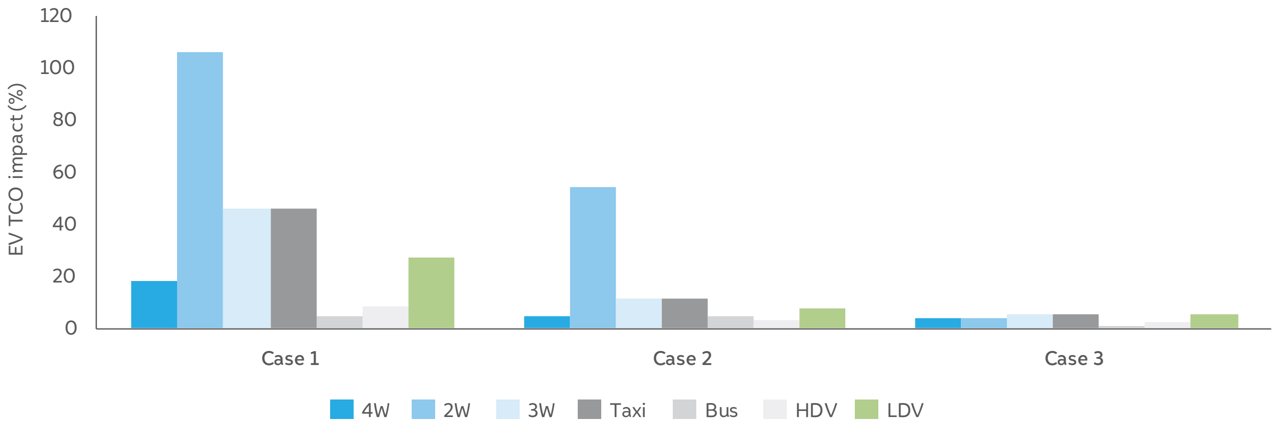
Source: Authors' analysis

Table 6 Impact on EV TCO can be minimised by a higher tax on polluting technologies and modes (Case 3)

Fuel type	4W	2W	3W	Taxi	Bus	HDV	LDV
EV TCO increase (%)	4 %	4 %	4 %	5 %	0 %	2 %	5 %
Petrol TCO increase (%)	-1%	3%		-12%			
Diesel TCO increase (%)	18%			16%		0%	2%
CNG TCO increase (%)	0%		0%	-4%	-6%		0%

Source: Authors' analysis

Figure 6 Impact on EV TCO across vehicle segments is reduced from Case 1 to Case 3 of the DT regime

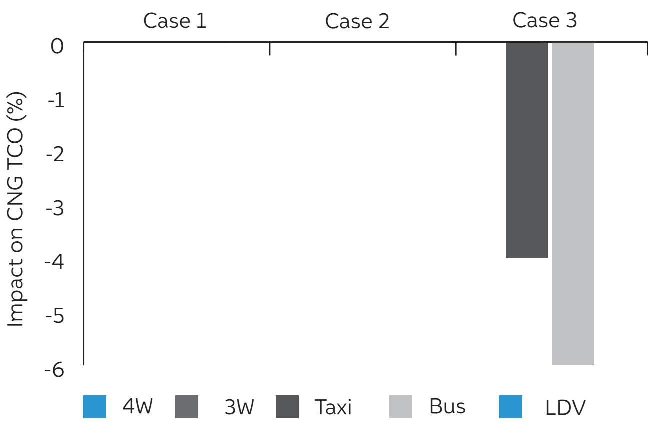


Source: Authors' analysis

5.2 DT impact on TCO: Cases for different fuel technologies

Figure 7 shows how the EV TCO has been reduced significantly across segments while recovering the same level of revenue as the B-a-U scenario. This can be explained by contextualising the change in the tax burden on CNG, petrol, and diesel vehicles. We also evaluate the impact of the three DT pricing strategies on the TCO of CNG, petrol, and diesel vehicles.

Figure 7 Taxes on CNG have been reduced in the DT regime in comparison to fuel taxes



Source: Authors' analysis

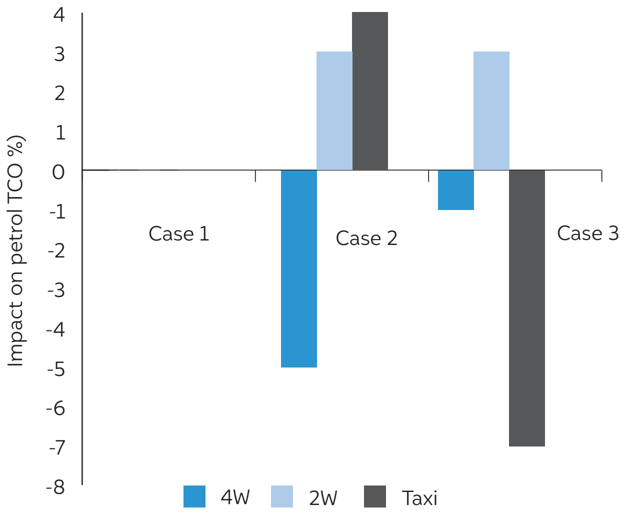
CNG

- The tax burden on CNG vehicles remains the same as B-a-U in Cases 1 and 2.
- The TCO of CNG vehicles is not affected in Cases 1 and 2.
- In Case 3, the TCO of CNG vehicles is impacted favourably due to a lower tax with respect to the B-a-U scenario.
- The TCO of a CNG bus is reduced by 6 per cent in Case 3.
- The TCO of a CNG taxi is reduced by 4 per cent in Case 3.

Petrol

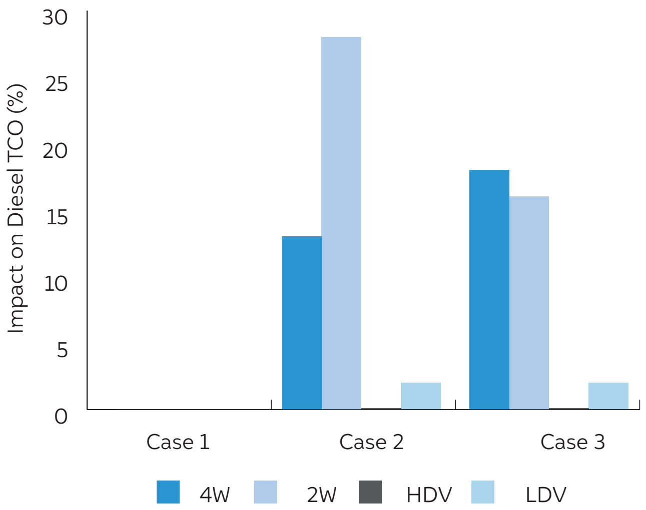
- The tax burden on petrol vehicles remains the same as B-a-U in Case 1.
- The TCO of petrol 2Ws is increased by 3 per cent in Cases 2 and 3.
- The TCO of petrol taxis is increased by 4 per cent in Case 2 but reduced by 12 per cent with respect to the B-a-U in Case 3.
- The TCO of petrol 4Ws is reduced by 5 per cent and 1 per cent in Cases 2 and 3, respectively.

Figure 8 There is a slight increase in the TCO of petrol 2Ws in DT Case 3



Source: Authors' analysis

Figure 9 The TCO of diesel vehicles will increase in the DT regime



Source: Authors' analysis

Diesel

- The tax burden on all diesel vehicles remains the same as B-a-U in Case 1.
- The tax burden on diesel HDVs remains the same as B-a-U in all three cases. Hence, there is no impact of DT on the HDV TCO.
- The TCO of diesel LDVs is increased by 2 per cent with respect to B-a-U in Cases 2 and 3.
- The TCO of diesel taxis is increased by 28 per cent and 16 per cent in Cases 2 and 3, respectively.
- The TCO of diesel 4W is increased by 13 per cent and 8 per cent in Case 2 and Case 3, respectively.

In Case 3, apart from EVs, the TCO increase with respect to B-a-U is limited to petrol 2Ws (2 per cent), diesel 4Ws (18 per cent), diesel taxis (16 per cent), and diesel LDVs (2 per cent). The architecture setup for DT can also be leveraged for other forms of road taxation such as congestion, pollution, tolls, and parking, adding to the value proposition for this tax regime.

From the cases considered, we find that a differential DT pricing can recover revenue while having minimal impact on the EV TCO. We also show here that the pricing can be designed to promote clean technologies and send positive public transport policy signals.

6. What technologies could be used for distance tax?

There are multiple technology options for implementing a DT regime (Jonkers, van Huis, and Vonk Noordegraaf 2015). Oregon employs a distance tax with basic odometer reporting using global positioning systems (GPS) and in-vehicle units. Many European countries use dedicated short-range communication (DSRC) systems to charge commercial vehicles for distance and weight. Singapore's electronic road pricing (ERP) is based on the DSRC system as well (Yu 2020). The choice of technology has a major impact on implementing a DT regime (CTCN, n.d.).

Locating and tracking a vehicle in space and time is fundamental to charging users based on distance (Ochieng et al. 2010). We list and compare six technologies that are used for distance taxation or which have been mentioned in the literature for the same purpose.

6.1 Alternative technology options considered

Automatic number plate recognition (ANPR) system

In a typical ANPR system, cameras are situated at the entry and exit points of a charging zone, and they record video images of the rear of a vehicle. The cameras use image recognition (Kuo 2018) to read the number plates of vehicles. Gantries need to be set up on the road by authorities to mount the cameras. The camera detects when a vehicle passes by that point. When the vehicle passes the next gantry with a camera, the distance can be calculated from the first.

This is the technology used in UK's congestion charge (TfL, n.d.). ANPR technology has been applied for varied purposes like monitoring traffic violations (Jaya,

> **GNSS devices in vehicles can be interoperably used for existing tax collection like tolls as well as newer taxes like congestion charges.**

Zainuddin, and Syarif 2019), automatic toll collection (Soomro, Javed, and Memon 2012), and parking management (Aalsalem, Khan, and Dhabbah 2015). The system is also being considered by residential societies to record the inflow and outflow of vehicles (Jadhav et al. 2022). ANPR cameras have already been installed in many Indian cities and highways to monitor traffic violations (Ahlawat 2022; The Hindu 2021).

Radio frequency identification (RFID) system

RFID systems consist of tags in vehicles and RFID readers on the road. The reader detects the tag in the vehicle similar to how the ANPR camera detects a vehicle number plate. RFID is already used in India for toll charging, popularly called 'fast tags' (NPCI, n.d.). The tag is cheap to install, and the detection is better than ANPR technology. However, the technical interoperability of this system is limited. Although RFID is used around the world for collecting highway tolls (Eckfeldt 2005), large-scale local roadside infrastructure in urban areas will be required to estimate distance taxes effectively for all vehicle segments on various types of roads. We were not able to find any application of RFID technology for distance taxation.

Dedicated short range communication system (DSRC)

DSRC is also called the tag and beacon system. A beacon on the roadside will communicate via a microwave signal with an electronic vehicle tag. When the vehicle passes through a charging point, the microwave signal is automatically transmitted to the in-vehicle unit or on-board unit (OBU). Monthly bills, similar to monthly phone bills, are sent to the driver.

Europe has prescribed standards for DSRC technology to collect tolls on heavy goods vehicles (Broaddus and Gertz 2008). Austria and the Czech Republic use the technology with an OBU for taxing heavy vehicles (Oehry, Foss, and de Estevan Ubeda 2001). Germany, Belgium, and Switzerland combine DSRC with other technologies to impose distance taxes on goods vehicles (Broaddus and Gertz 2008). Even though it has been widely implemented, scaling up DSRC is expensive due to the requirement of roadside infrastructure or gantries. Singapore is moving from its decades-old electronic road pricing (ERP) based on DSRC to a global navigation satellite system (GNSS) based tax system (Yu 2020).

Global navigation satellite system (GNSS)

GNSS is also referred to as a mobile positioning system. Similar to DSRC, GNSS also requires an OBU. The OBU calculates the position of the vehicle at regular intervals and determines the total distance travelled. GNSS are of two types depending on the intelligence of the OBU: thin client devices and thick client devices. Thick devices are more expensive but ensure better privacy as only the calculated tax amount is communicated to the enforcer. In thin devices, the data is shared with the enforcer and the tax is calculated as well. A GNSS can be used to design a detailed pricing scheme according to the time of entry, distance, place of the vehicle, prevailing pollution, etc. It also has the potential to be used as a replacement for existing taxes like highway tolls.

A GNSS can be scaled up at the backend easily without the need for any roadside infrastructure. Germany uses GNSS-based tolling of heavy vehicles combined with DSRC (Broaddus and Gertz 2008). Belgium, Switzerland, Slovakia, and Hungary also use GNSS-based distance tax for freight vehicles (Jonkers, van Huis, and Vonk Noordegraaf 2015). The Indian government plans to transition all national highway tolling in India to a GNSS-based system (PIB 2020). MoRTH has also mandated 'vehicle location tracking' devices in all commercial passenger vehicles (PIB 2018). GNSS-based systems are gaining traction among policymakers for effective taxation of transport. Due to the interoperability of this technology, the DT regime can easily fit into this infrastructure.

Smartphone-based DT

A smartphone-enabled DT is the cheapest form for both users as well as governments, as it requires no additional infrastructure on the road or in the vehicle. It is also interoperable to charge other road pricing for congestion or pollution. The main challenge here is enforcement. As the monitoring device (smartphone) is not necessarily attached to the vehicle, it may not be representative of the distance travelled. This becomes more complex in shared vehicles used by multiple drivers. Enforcement and privacy are the main concerns in this case. No government has applied this technology for distance tax yet. However, with evolving smartphones, both these concerns may be addressed and offer scope for pilots.

Odometer checks

In this system, drivers could be charged per kilometre driven if their vehicles are regularly inspected for emissions. There are multiple problems with this pricing strategy. Firstly, not all states in India have the

Figure 10 GNSS technology is the best option for distance tax

Technology options for Distance Tax regime	Ease for users	Interoperability	Ease in setting up infra	Ease in enforcement
Global Navigation Satellite System (GNSS)	Medium	High	Medium	High
Smartphones	High	High	High	Low
Automatic Number Plate Recognition (ANPR)	High	Medium	Low	Medium
Radio Frequency Identification (RFID)	High	Low	Medium	High
Dedicated Short Range Communication (DSRC)	Low	Medium	Low	High
Odometer Checks	High	Low	High	Low

Source: Authors' Analysis

Potential High Medium Low

infrastructure to conduct such inspections. Secondly, it will not give any reference to where the vehicle was driven. Thirdly and most crucially, an odometer-based system cannot enable other road pricing, including congestion pricing. Oregon uses odometer reporting by users along with fuel consumption monitoring devices in vehicles to charge users for distance (Van Rensburg and Krygsman 2018). Switzerland uses odometer readings to improve the enforcement of GNSS-based tolling (Ali 2018). We did not find any example where only an odometer check is used for a complete distance tax measurement.

6.2 Comparison of technologies for distance tax

We evaluate the technology options available to measure and charge for the distance travelled by vehicles. We compare the options based on four parameters. Each technology is rated high, medium, or low within each parameter, based on the ease of implementation (see Figure 11).

Ease for users

To a large extent, the technology used for taxation influences user acceptance (Schade 2017). We explore to see if it is easy for users to adopt and pay distance taxes through the technologies considered. This includes the costs that users have to incur to enrol in the tax regime.

All vehicles have number plates. There are no particular costs for users to adapt to ANPR systems. RFID tags are relatively cheaper to install as well. User privacy is higher in RFID systems than in ANPR systems. Odometer checks and smartphone-based distance tax systems will also not incur any fees. DSRC-based tax systems need users to install an OBU. A GNSS-based system's ease of use will depend on the overall structure adopted. In a GNSS, privacy concerns are higher in a thin OBU, and costs are higher in a thick OBU system.

Ease in setting up infrastructure

Technology is also a factor influencing tax collection costs (Walker, Pickford, and Blythe 2008). We explore to understand the effort required by governments to set up distance taxes using these technologies. We compare the technologies based on the infrastructure required and corresponding costs of running the tax system.

ANPR cameras are expensive, and a high density of cameras will be required to measure distance in space and time. This system will also be ineffective in typical Indian situations where there are large volumes of two-wheelers on densely congested urban roads. Even though RFID readers are less expensive in themselves, they require road installation which can be costly. Similarly, DSCR technology also requires roadside equipment or gantries. Though it is easy to implement in a limited road network, large-scale use involving local and regional roads will be very costly. As both in-the-vehicle and on-road equipment are required, project management costs may be higher for DSCR. Odometer checks and smartphone technologies do not require any on-road infrastructure and neither does a GNSS-based system. For a limited road network, the GNSS may be costlier for the government than a DSRC system, but it is cheaper when implemented at scale.

Interoperability

A pricing scheme needs to be flexible enough for governments to implement a wide range of policies to meet different aims (Ochieng et al. 2010). We compare the technologies based on how well they cooperate with existing tax systems, like highway tolls. We also compare if the technology can be used for other taxes like congestion charges or travel demand management.

The interoperability of a technology depends on its functionality. For example, an RFID system that taxes vehicles on the road can only determine if the car passed the point where the RFID readers were installed. RFID cannot replace a tax system based on GNSS in an urban area. However, a tax system based on GNSS in urban areas can replace RFID technology on highway tolls. Similar to RFID, ANPR, DSRC, and odometer checks have lower interoperability than GNSS. Smartphones can be used for varied types of taxation and can be considered to be more interoperable than GNSS.

Ease in enforcement

Enforcement is directly linked to the effectiveness of the tax system in raising revenue. We compare the ease for governments to enforce compliance with a tax system. Enforcement of DT tax using a smartphone system is the most challenging. People need to have their phones with them while driving, and the corresponding app must be running; therefore, enforcing this alternative is tricky. An ANPR system is relatively easier to enforce. It can be used for the enforcement of other technologies as well. Roadside enforcement methods can be used for DSRC and GNSS systems easily. Enforcement of odometer checks is a challenge, especially in old vehicles where users can tamper with odometers.

Our assessment follows a simplistic view of the technologies. The functional architecture of DT can have multiple sub-systems, which different technologies can support. Our evaluation of these technologies for ease for users, technology interoperability, ease of setting up local, on-road infrastructure, and ease of enforcement reveals that a GNSS-enabled system is best suited for a sustainable shift to an alternative DT regime in India. The most accepted GNSS technology is the American GPS.

7. Recommendations for establishing a distance tax regime in India

Our analysis indicates that a transition to a GNSS-based DT system is the best way to manage revenue trade-offs in a zero-emissions vehicle (ZEV) future. Such a system is interoperable and can be leveraged to send clear policy signals for shifts towards sustainable modes and technologies. GNSS technology is already gaining traction in other transport applications. The MoRTH has mandated VLT devices on new passenger commercial vehicles to enhance passenger safety, monitor them, and for faster emergency response.

Recently, MoRTH has also offered financial assistance to states to set up monitoring stations (MoRTH 2021). The National Highway Authority of India has invited proposals for planning the transition of national highway tolls to GNSS from the current RFID technology (IHMCL 2021). As GNSS is interoperable, these steps will pave way for a DT regime in the future. However, such a large transition is politically sensitive and requires inclusive planning and a clear roadmap. We recommend **four steps** for a transition from the current fuel tax regime to a DT regime in the long term.

7.1 Pilot technology to establish interoperability

To establish interoperability in the short term, it is imperative to test existing GNSS technologies in India for various road pricing strategies. Increasingly, EV variants in the 2W and car segments come equipped with a GPS. The MoRTH has laid out guidelines for VLT in passenger transport vehicles to enhance safety and emergency response. Although the guidelines indicate the installation of OBUs by transport operators, the interoperability of the OBUs is unclear. The ministry has also announced that it intends to enable GPS-based tolls on highways (IHMCL 2021). Technology pilots will help understand the improvements that the standards require. The existing technology must also be tested in urban areas for other applications like congestion charging, HDV distance taxation, low-emission zone pricing, parking, etc. This will help in understanding the interoperability of existing GNSS vehicle device standards in India and in deriving recommendations for improvement.

7.2 Prepare policy to guide pricing strategies

A distance-based pricing policy with clear goals and principles must be adhered to for a national transition. The purpose of the policy cannot be revenue generation alone. As seen in successful implementations of DTs worldwide, revenue neutrality should simply be a condition to drive the targeting of congestion and air pollution; the national goals of decarbonising transport may be superimposed on these local goals. **Any pricing in a DT policy must strictly send the right policy signals to promote cleaner technologies and higher occupancy modes (like public transport).** When combined with other spatial and temporal pricing, DT pricing must follow the sustainable mobility framework of 'avoid-shift-improve' (Ringenson and Kramers 2022).

7.3 Build public acceptability for road pricing

Such an overall road pricing will be politically sensitive as it will affect the entire population owning or using vehicles. The impact on operation costs should be considered while transitioning any user to the DT regime. Governments must discuss the social and environmental benefits of the DT regime with stakeholders. To implement DT successfully, it is of utmost importance to gain public support for the transition. Ensuring privacy protection and gauging the perception of users on privacy can have an enormous effect on boosting the acceptance of a DT regime. **Public acceptance can be built slowly by applying the same technology to various types of road pricing like congestion charges or low emission zones.** Transparent communication and engagement with stakeholders regarding the benefits of the tax reform, types of data collected, who has access to it, how long is it stored, etc., can be communicated. Building public trust in the implementation agency is imperative for a successful transition to a DT regime.

7.4 Pilot road pricing regimes to generate revenue

While the feasibility of DT has been demonstrated globally, a pilot demonstration will be critical to establish ease of implementation and build public support for the new scheme. We recommend the pilot application of the DT regime in the state of Delhi. Delhi is fertile ground for a DT pilot as addressing pollution is a significant policy concern for the centre and state. The MoRTH guidelines on VLT can be implemented by the GNCTD with 100 per cent funding from the centre for the monitoring stations. For this, OBUs required for VLT, which is currently limited to transport vehicles, can be extended to all vehicles in Delhi. The DT transition for existing ICE vehicles in Delhi may be challenging in terms of differential fuel pricing for DT and non-DT participants. However, **an overarching DT regime set up for tolls, congestion, pollution, etc., will gain public acceptance and build infrastructure to compensate for the FTR loss.** Such a system can recover FTR loss organically without requiring a declared transition from fuel taxes.

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