Electric vehicle scenarios for India: Implications for development and mitigation

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Abstract
The transport sector globally is overly dependent on liquid fossil fuels. Electric vehicles (EVs) are touted as a way of diversifying the fuel mix and helping to reduce dependence on fossil fuels. There could also be other co-benefits of EVs, such as improved energy security, decarbonising of the electricity sector, CO₂ mitigation and reduction in local air pollution. The Indian government has recently launched a national electricity mobility mission to promote EVs. There is, however, much uncertainty in terms of the penetration of EVs in the transport sector, particularly those related to infrastructure and policies. While the literature on EVs has focused more on the role of electric cars, it could be electric two-wheelers which could make early headway, as is the case in China where nearly 120 million such vehicles had been sold by the end of 2012. Three scenarios (Business as Usual (BAU), Electric Vehicles, and Electric Vehicles Plus 2°), for EVs from 2010 to 2050, are analysed using the bottom-up energy system ANSWER MARKAL model. The paper makes use of global CO₂ prices for aligning the model with global stabilisation targets. Electric two-wheelers and electric four-wheelers achieve cost competitiveness in the BAU scenario by 2035, but tax incentives in the EV scenario help in advancing this to 2020 for electric two-wheelers and to 2025 for electric four-wheelers. The diffusion of EVs would, however, depend on availability for charging infrastructures and a strengthened grid for handling increased electricity demand. EVs are not a mitigation option unless electricity is cleaned up, and EVs, together with smart grids and renewables, can provide a solution for this.

Keywords: electric vehicles, energy security, CO₂ mitigation, co-benefits

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1. Introduction
The transport sector, amongst the largest energy-consuming sectors, is globally overly dependent on liquid fossil fuels. Of all the fuel used in the transport sector in 2010, 93% was oil-based, of which road transportation accounted for 77% (IEA 2011: 109). The sector’s share in total oil consumption has increased over the years, up from 45% in 1973 to 61% in 2010 (IEA 2012). The sector is also a major source of GHG emissions and accounts for 23% of total global energy-related CO2 emissions (IEA 2010). The transport sector is also associated with several environmental and health hazards. As a result, emission mitigation and reducing energy consumption have been at the centre of various national and global energy and environmental policy debates in recent years, with transport one of the key sectors involved. In the BLUE scenario prepared by the International Energy Agency (IEA) (2010), transport accounts for 37% of total emission reduction in the long term up to 2050, compared with the baseline scenario.

Several options have been considered to reduce emissions and energy consumption of the road transport sector. These include various supply-side measures such as fuelswitching (e.g. increased use of biofuels and compressed natural gas), improved fuel standards, advanced internal combustion (IC) engine technology; and demand-side measures such as modal shifts (e.g. the extension of rail and urban transport networks). One of the key ways in which future emissions can be avoided is through the development and use of low-carbon technologies (IPCC 2007). In the context of decarbonising transport, electric vehicles (EVs) are one such option. EVs include battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and fuel-cell vehicles (FCVs). EVs are important to decarbonise transport sector in the long-run (IEA 2013; Offer et al. 2010: 24). According to IEA projections, in order to meet the global 2°C stabilisation target by 2050, three-fourths of all vehicles sold in 2050 would need to be EVs of some type (IEA 2013). EVs are touted as a way of bringing in more renewable energy within the electricity sector if the batteries can be used as storage and therefore help to reduce dependence on fossil fuels. There could also be other co-benefits of increase in share of renewable electricity and EVs, such as decarbonising of the electricity sector, CO2 mitigation, and reduction in local air pollution.

1.1 Electric vehicles
The history of EVs in transportation goes back to the late 1880s, when the first electric car was introduced in the German market. Such vehicles gained popularity, and more vehicles were introduced in other European and US markets. However, after the introduction of petrol-based vehicles in the early 20th century, interest in EVs started declining, and after the economic crash of 1929 many companies manufacturing EVs went bankrupt (Hoyer 2008: 65). EVs again came into prominence for a short period briefly after World War II, but it was in the early 1990s, when concerns around vehicular emissions and global climate change started growing, that EVs started getting attention from manufacturers and policy makers. This renewed interest in EVs has been referred to as ‘third age’ of EVs (IEA 2013). It has witnessed large improvements in battery capacity and technology, and a sharp decline in costs of EVs and related components. Improvements in technology have also opened up the possibility of deploying EVs as both a generation and storage device, thereby using it for bidirectional power transfer (Guille & Gross 2009: 4379).

Today the global EV stock has passed 180 000, representing 0.02% of total passenger cars (Guille & Gross 2009), with the USA and Japan the two biggest markets. Different countries have adopted different strategies and policies to promote EVs. While some, like the US, have focused on demand and supply side incentives, others, like Japan and Germany, have focused more on building the charging infrastructure for EVs (NEMMP 2012). India has also launched a national electricity mobility mission plan (NEMMP) to incentivise production and use of EVs, including exploring their role in public transportation. While other countries have focused more on electric four-wheelers (E4Ws), it is electric two-wheelers (E2Ws) which have witnessed rapid increase in sales in China. For example while the global cumulative sales of electric and hybrids (including plug-in hybrids) were only 5.8 million by end of 2012, E2Ws have achieved a near-commercial status in China with nearly 120 million such vehicles being sold by end of 2012. However, this success of E2Ws in China has not been replicated elsewhere.

While several policies are being used to promote EVs, little is known about the effectiveness of policies and the development trends of EVs (Choi & Oh 2010: 2263). There is also much uncertainty about the future role of EVs in the transportation sector, particularly matters related to infrastructure and policies. In this paper we look at the scenarios for EVs in India and attempt to resolve some of these issues. We first offer a literature review of different modelling exercises and policy documents within India, and on the basis of it create alternative storylines for electric vehicles. These alternative storylines are then used to analyse a business-as-usual (BAU) scenario, an electric vehicle (EV) scenario, and and electric vehicle sce-
nario in a low-carbon society (EV_LCS). The LCS is pegged to a global stabilisation target of 2°C. Using the scenario analysis, the three alternative storylines for EV in the case of India are explored. The scenarios span from 2010 to 2050 and are analysed using the bottom-up energy system ANSWER MARKAL model.

1.2 the Indian transport sector
The Indian transport sector is dominated by two-wheelers, which account for 75% of total vehicles sold in the country (NEMMP 2012). Production of vehicles has increased by more than 80% in the last five years (2007-12) (see Figure 1). Despite this rise in production, the current level of vehicle penetration in India is amongst the lowest in the world at 11 cars and 32 two-wheelers per thousand persons. This leaves a large scope for upward movement, which is further evidenced by demand projections. For example, in the short term, India’s demand for passenger vehicles is expected to go up from a little over two million units in 2010-11 to around ten million units by 2020. During this period the global demand is expected to rise from 73 million units to 108 million units (NEMMP 2012).

In terms of fuel, Indian transport is mostly dependent on liquid fossil fuels, most of which is imported. India today imports close to 80% of its crude oil demand (Figure 2). Transport accounts for about one-third of total crude oil consumption in the country, of which road transportation accounts for 80% (NEMMP...
Consumption as well as imports of crude oil have increased exponentially in recent years. While consumption has increased fourfold during 1991-2011, imports have gone up by eight times in the same period.

This high share of imports has implications for the Indian economy and also for energy security. Over-dependence on liquid fossil fuels also leads to increased emissions of GHG gases and other pollutants such as SO$_2$ and NO$_x$, which not only cause local air pollution but also contribute to global climate change. Rising energy consumption in the transport sector has also led to a rise in emissions. Between 1994 and 2007, total GHG emissions from India went up by more than 40%, while those from the transport sector increased by more than 77% (MoF 2012a).

In the case of alternative fuels, India currently has a national policy for biofuels which runs up to 2017. The policy mandates blending biofuels, currently 10% by 2017 and 20% in the longer term. India has also recently launched a national electric mobility mission plan (NEMMP) with a total proposed investment of INR 224 billion (equivalent to USD 3.6 billion) till 2020. The current market for EVs is very small in India. Though there are different types of E2Ws (scooters and motorcycles), E4Ws (electric cars), and electric buses, the overall share of EVs is negligible. In the 1990s, some Indian firms (Vikram, Mahindra & Mahindra, Bajaj Auto) had introduced electric two- and three-wheelers in the market, but they had to discontinue them few years later for various reasons. Another Indian firm, Reva (now acquired by Mahindra & Mahindra), launched an electric car in the early 2000s which continues to sell few units even today. Mahindra & Mahindra launched another electric car, Mahindra e2O, in India in 2013. In 2010, Toyota introduced the Prius Hybrid model and has followed it up by introducing the Camry Hybrid in 2013. In the same year, Tata Motors introduced a CNG-electric hybrid bus, the first such bus in India (Tata Motors 2010). Recently a few other Indian firms, such as Maruti Suzuki and Tata Motors, have announced plans to introduce electric cars in the short-to-medium term (Banerjee 2013; Tata Motors 2012). Some studies have looked at separate aspects of EVs (e.g. technical, economic, and energy and environmental) (He et al. 2012; Huo et al. 2012; Pasaoglu et al. 2012); while a few others have tried to study multiple aspects of EVs (Choi & Oh 2010; He 2012; Offer et al. 2010). Studies which model EVs in the short-to-medium term are limited but growing (Offer et al. 2010; Ou et al. 2010).

Within EVs, electric 4Ws have generally drawn more attention; though there have been recent studies which have specifically looked at electric 2Ws (Weinert et al. 2008). There have also been studies which have tried to analyse growth drivers and barriers to EVs (Ou et al. 2010; Weinert et al. 2008). While a majority of such studies have considered barriers from a macro-economic perspective, there have been few which have specifically considered the behavioural aspects, giving insights into barriers to large-scale adoption of EVs and other alternative fuel vehicles (Eppstein et al. 2011; Offer et al. 2011). The literature has enumerated several co-benefits of EVs, such as greater energy security (Offer et al. 2010: 24; Skerlos & Winebrake 2010: 706), reduced GHG emissions (Skerlos & Winebrake 2010: 706), and improved urban air quality (Fontaine 2008: 23; Offer et al. 2010: 25). However, quite a few studies have also pointed out that the ability of EVs to reduce GHG emissions could be limited when electricity is derived from coal (Huo et al. 2011: 37; Weinert et al. 2008: 2544). This suggests that the source of electricity becomes important when one considers the GHG mitigating potential of EVs. Achieving the full GHG reduction potential of EVs would then demand decarbonising the electricity sector, which could give a push to renewable energy in the electricity sector. Common barriers to EVs include the relatively high purchase cost compared to conventional vehicles, lack of charging infrastructure, the high cost of batteries, slow charging of batteries, and the limited range of EVs (Densing et al. 2012: 137; Fontaine 2008: 23; Iyer & Badami 2007: 4326; Offer et al. 2010: 25; NEMMP 2012; Weinert et al. 2008: 2553)

There are few India-centric studies on EVs. EVs in India have been mostly studied within the global context (IEA 2013; IEA 2010; Kyle & Kim 2011; Magne et al. 2010) and therefore have limited coverage in terms of parameters such as electricity prices and additional investments in electricity production. The document released along with NEMMP contains a detailed description of the current status of EVs in the country and the planned scenario for EVs, but only up to 2020. While the existing literature on the Indian scenario offers several important insights, these suffer a few limitations. Most of the studies have a short-term horizon. A few global studies have considered...
the long-term horizon but they lack details of developments in the domestic electricity sector which could impact on EVs and their co-benefits. As has been pointed out in some literature, there are linkages between the transport and electricity sectors. Many changes are proposed in the Indian electricity sector which could have far-reaching implications. For example, several initiatives such as the Jawaharlal Nehru National Solar Mission (JNNSM) have been launched to promote the share of renewables in the generation mix. Similarly, carbon capture and storage technologies have been proposed for coal power plants to sequester carbon. A roadmap for transition to smart grids has also been drawn. These changes, as and when they occur, hold the potential to both decarbonise the electricity sector and make load management in the Indian electricity system more efficient. There is a need to consider the implications of these changes in the Indian electricity sector on EVs in the long term. EVs could in turn have vital implications for energy security, local air quality, GHG mitigation, and increasing renewables share in the electricity sector. India is still at a relatively early stage of development and, as mentioned, the per capita penetration of vehicles is still low. There is thus a need to consider these development and mitigation aspects of EVs in the long term. The next section describes the methodology used to model future role of EVs in India.

3. Methodology

3.1 Modelling framework

The assessment of future paths for analysing the role of electric vehicles in India is carried out using an energy system model, ANSWER MARKAL. The assessment includes transport as well as the power sector, embedded within the model to study long-term transitions up to 2050. An integrated bottom-up modelling framework is used, with an energy system model and end-use sector models. The ANSWER MARKAL model framework has a detailed representation of transport as well as power sector technologies. It is supported by an end-use demand model, which provides demand projections for alternative scenarios. Technology choices within the transport sector depend a lot on the investments into infrastructures (rail, road, metros, etc) and therefore the model transitions within the transport sector are handled separately in the transport model. In the ANSWER MARKAL model, only the competition between alternative technologies for a given mode is handled (e.g. between electric and petrol cars).

The modelling framework uses the strength of bottom-up models which have a highly disaggregated representation of the economy with a very detailed characterisation of technologies and reflecting the optimistic engineering paradigm (Grubb et al. 1993). Bottom-up models primarily focus on the energy sector of economy and have been extensively used for analysis at national and regional level (Chiotti et al. 2013; Hainoun 2010; Kesicki 2012; McDowall et al. 2012; Winkler et al. 2009). Bottom-up models are used to assess the energy supply and demand-side technology-based policies that are not driven by price (Sarica & Tyner, 2013; Börjesson & Ahlgren, 2012). They have detailed representation of technological options in energy supply and the end-use sector in terms of costs, fuel inputs, and emission characteristics.

Assessing the role of EVs in the long term involves analysing different energy markets and the interaction between them (such as the electricity, oil and gas markets). It also requires a detailed representation of the technologies involved. A bottom-up modelling framework like MARKAL is well suited to this and has been used previously to study long-term transitions in India (Shukla & Dhar 2011; Shukla et al. 2008).

3.2 Scenarios

Three scenarios are considered for the study and are described below

3.2.1 Business as Usual scenario (BAU)

This scenario assumes future economic development along the conventional path and therefore the future socio-economic development mirrors the resource intensive development path which has been followed by the current developed countries. The annual GDP growth rate of 8% for the time period 2011–2032 is consistent with economic growth projections for India (Government of India [GoI] 2006) from 2007–2032 period. Population growth and urbanization are assumed to follow the UN median demographic forecast (UNPD, 2013). The demand for road transportation has been forecasted using a logistic regression function to project the growth of transport sector passenger and freight demand. The modewise break-up for the BAU and EV scenarios are given in Table 1.

The penetration of EVs for intercity road transportation is challenging on account of the limited distance they can travel on a single charge, and therefore constraints were introduced to limit the EV at the maximum to urban transportation. The demand for urban transportation was taken from Dhar et al. 2013.

This BAU scenario assumes a mild mitigation action and therefore a stabilisation target of 650 parts per million by volume CO₂ equivalent is considered. The carbon price is assumed to rise from USD3/t CO₂ in 2010 to USD 20/t CO₂ in 2050 (Clarke et al. 2007).

The BAU scenario considers that cities will develop better infrastructures for public transport as an integral
part of urban planning. In line with government intent (MoUD 2006) all Indian cities of two million people or more are assumed to have metros or bus rapid transit systems in the future. This is the reason for the rising share of buses in urban transport.

Electric and hybrid vehicles currently face low taxes and excise duty, but receive support in terms of other enabling conditions (Table 2). The BAU scenario assumes future policies will follow the current trends.

### Table 2: Enabling environment for EVs in BAU and EV scenarios

| Source: Facilitations for propagating electric vehicles (n.d.); MoF (2012b); MoF (2012c); State government taxes in India (n.d.); Tiwari & Jain (2013) |
|---|---|
| **BAU scenario** | **EV scenario** |
| *Excise duty / import duty* | *Excise duty / import duty* |
| Currently EV and hybrid cars carry 12% duty, the same as petrol or diesel cars with engine capacities under 1500 cc and shorter than 4m. Bigger and longer cars have 24-27% duty. Batteries and other parts for EV have no preferential treatment in imports. | Considers full duty exemption till 2025 on cars and batteries, which can help lower capital costs by around 30% from BAU. The post-2025 tax rate increases and tax parity is achieved by 2040. |
| *Sales tax (VAT)* | *Sales tax (VAT)* |
| Varies across states, resulting in different prices for cars, but incentives are provided in a few states. No concessions for VAT considered. | Considers half the VAT as in BAU to factor for positive local environmental benefits till 2025; thereafter an increasing tax rate with tax parity by 2040. |
| *Charging infrastructures* | *Charging infrastructures* |
| No specific investment in charging infrastructures, so EVs make use of spare grid capacity. Therefore a maximum share constraint put on two-wheelers: 10% by 2050; 7% by 2050 for cars. | An intelligent electric grid which can allow usage of EVs both as storage and source of electricity. This would also entail strengthening the primary transmission (132/220/400/765 KV) and secondary transmission (66/132 KV) and distribution networks. As a result, 10% increased investment on transmission and distribution is considered but constraints on EVs are removed. |
| *Dedicated lanes for cycles* | *Dedicated lanes for cycles* |
| A few cities have dedicated cycle lanes or good infrastructures for cycles. Funding from the centre under the Jawaharlal Nehru National Urban Renewal Mission should create cycle lanes and a better infrastructure for cycles in the cities, but these limited to non-motorised cycles. Motorised two-wheelers, unlike cyclists, will receive no priority. | Dedicated cycle lanes created in million-plus cities and E2Ws with a maximum speed of 25 km/hour allowed on them. Two-wheelers could move faster than average traffic, increasing the appeal of E2Ws. A minimum share of 40% of motorised two-wheelers are considered electric by 2050. A shift of at least 25% of non-EV bicycles to EV also considered. |
| *Public transport* | *Public transport* |
| BRT systems expected in all million-plus cities. | With improvement in infrastructure for electricity charging, city bus companies should use it; so a minimum 10% share for buses for intra-city is considered. |
| *Goods transport* | *Goods transport* |
| Goods transport within cities mainly done by LCVs, tempos, etc, mainly running on diesel. In future, LCVs are expected to diversify into CNG as fuel. | Improvement in infrastructure for electricity charging and tax incentives mean that transport companies are expected to move to Evs, so a minimum 10% share for EV LCVs for intra-city is considered. |
Electric Vehicle scenario
Electric vehicles can deliver multiple co-benefits (improved environment, energy security, renewable integration, etc), and the scenario assumes that governments recognise these aspects of EVs and push their penetration. Therefore the scenario considers that there will be domestic policy support (see Table 2) for EVs which improve their competitiveness. Governments also provide greater incentives for research and development in battery technologies, EV drive trains and smart grid technologies to enable usage of EVs as a storage for renewable technologies. The EV scenario also considers that battery costs, which account for close to half of EV cars’ costs, come down to less than half of today’s levels in the next 10-15 years (Bloomberg New Energy Finance 2012). Advancements in battery technologies, improvements in battery capacities, declining component costs, and economies of scale in production will drive the price reduction of batteries. Improved batteries with higher energy density will also help reduce the weight of batteries which will further lead to reduction in the cost of EVs.

Electric Vehicles Plus 2°C (EV_LCS) scenario
EVs can increase or decrease the emissions from transport, depending on the CO\textsubscript{2} content of electricity – which can get sufficiently altered if there are stringent climate regimes (Shukla & Dhar 2011). This scenario combines the policy support together with a high carbon tax corresponding to the globally agreed vision of a 2°C temperature rise, which in turn corresponds to a stabilisation target of 450 ppmv CO\textsubscript{2}-eq. The carbon price trajectory corresponding to stabilisation at 450 ppmv CO\textsubscript{2}-eq concentration target, is USD 46 per ton of CO\textsubscript{2} in 2020 and rises to USD 200 per ton of CO\textsubscript{2} in 2050 and based on outputs from IMAGE and MESSAGE models (Rao et al. 2008).

4.0 Results
4.1 Energy demand

BAU scenario
In the BAU scenario the overall demand for energy increases nearly sixfold between 2010 and 2050. The overall dependence on fossil fuels continues, though there is diversification towards natural gas. Electricity starts emerging as a significant option after 2020. This is driven by three trends: investments in rail-based transportation for inter-city passenger and freight movements, implementation of metro projects in all major cities, and diffusion of EVs (buses, cars, three- and two-wheelers). The share of EVs in overall electricity demand is 53.8% in 2020 and this increases to 67.3% in 2050. See Figure 3.

EV and EV_LCS scenarios
The overall demand for energy in the EV scenario is lower due to the greater role of EVs which are typically more energy-efficient at the end-use level. In the EV_LCS scenario, the high carbon price means the hybrids and more efficient vehicles become cost-competitive, which further reduces demand for energy. The fuel mix in the EV_LCS scenario also gets further diversified with a greater penetration of biofuels. See Figure 4.

4.2 Technology choices
BAU scenario
Electric two-wheelers using lead acid batteries at the current cost structures achieve cost competitiveness with conventional two-wheelers by around 2035. Small two-wheelers and electric bicycles are cost-competitive as early as 2020, but their limited carrying
capacity, speed limits and issues with regard to reliability restrict their wider diffusion.

Electric cars using lithium ion batteries but with a limited driving range (below 100 km) achieve cost competitiveness with conventional gasoline- and diesel-based vehicles by 2035. However, this technology may not be easily scalable for a wider set of users who require a longer driving range and features comparable to conventional cars.

**EV and EV_LCS scenarios**
The policy actions (see Table 2) for EV help in advancing the EV story, and by 2020 a substantial share of electricity is seen in the fuel mix (Figure 4a). Due to the policy incentives, EV two-wheelers become competitive by 2020. The policy of allowing them on cycle tracks gives a further fillip, but there is also a shift from non-motorised to motorised bicycles and smaller EV two-wheelers. Electric cars also become competitive due to tax incentives by 2025 (10 years earlier than BAU), but the more expensive electric cars with a driving range beyond 300 km do not become competitive even with the proposed policy incentives.

**4.2 CO₂ emissions**

**BAU scenario**
The overall CO₂ emissions from transport increase nearly five times between 2010 and 2050 and electricity is also a major contributor towards these and therefore greater diffusion of EVs does not deliver any significant benefits for mitigation. See Figure 5.

**EV and EV_LCS scenarios**
The EVs help to lower energy demand (Figure 4a), but the CO₂ emissions in most cases remain either
equal or slightly higher than in BAU. This is on account of the high CO₂-intensity of electricity (Table 3). However, when the policy actions for EV are combined with a high carbon tax, as happens in EV_LCS scenario, a major overall reduction in CO₂ emissions happens. See Figure 6.

The role of electric vehicles in mitigating CO₂ emissions is closely related to the CO₂ content of electricity. In the low-carbon scenario, due to increased share of renewable, nuclear, and carbon capture and storage, the emission intensity of grid electricity becomes nearly one eighth of the corresponding BAU figure in 2050 (see Table 3).

### Table 3: Emissions intensity of the grid (t CO₂/MWh)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>2010</th>
<th>2020</th>
<th>2030</th>
<th>2040</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>EV LCS</td>
<td>0.99</td>
<td>0.73</td>
<td>0.34</td>
<td>0.19</td>
<td>0.08</td>
</tr>
<tr>
<td>BAU</td>
<td>0.99</td>
<td>0.94</td>
<td>0.86</td>
<td>0.74</td>
<td>0.69</td>
</tr>
</tbody>
</table>

5. **Discussions and conclusions**

There is already some production experience of EVs in India. These include E2Ws (scooters and motorbikes), E4Ws (cars), and electric heavy vehicles (buses). However, the penetration of these vehicles is still limited. There are limited incentives for EVs, but they require all the elements of the enabling framework, including infrastructures for charging and smart grids to leverage renewables. The EVs currently available have attractive costs but limited driving range, lower carrying capacity and very low volumes, which are not helpful in building customer confidence.

India exhibits a pattern of EV sales more similar to China’s than to other markets (like Japan and the USA), where E2Ws have had a larger market penetration than E4Ws. This, then, indicates a possibility that the same growth pattern of EVs could continue in the short-to-medium term. However, significant penetration of E2Ws may not be realised till cities develop the necessary infrastructure.

In the BAU scenario, current policy trends were followed and both E2Ws and E4Ws achieve cost competitiveness by 2035. Inadequate investments into grids and charging for EVs would act as a barrier, however. Battery costs emerged as a significant barrier as more than 30% of the cost of the vehicle is the cost of the battery. In the analysis we considered a battery life of three years, but if manufacturers are able to provide a longer warranty for battery the competitiveness of EVs would improve. Policy support in the form of excise and sales tax waivers for two-wheelers helps in making them cost-competitive by 2020, whereas EV cars achieve cost competitiveness by 2025. A wider diffusion for these would require the strengthening of transmission networks and the creation of smart grids to make use of EVs as a storage for electricity.

The role of EVs in mitigation of CO₂ emissions is closely related to the CO₂ content of the electricity. In the BAU scenario, EVs can even lead to higher CO₂ emissions – though if climate constraints exist, a cleaner electricity can convert EVs into a mitigation option. EVs can, however, deliver other co-benefits such as improved urban air quality, reduced local pollution and direct health impacts, and could therefore offer win-win solutions in a carbon-constrained world. Indian cities have a high use of bicycles and many cities are creating bicycle lanes under the Jawaharlal Nehru National Urban Renewal Mission. Most E2Ws have speeds below 25 km per hour, and if they were allowed on bicycle lanes it could provide an additional incentive to switch from gasoline-powered to electricity-powered two-wheelers.

### References


