Compact Cities Electrified: India

BRIEF FOR POLICYMAKERS

ITDP

UC DAVIS
UNIVERSITY OF CALIFORNIA

ACKNOWLEDGEMENTS

LEAD AUTHORS:

Lewis Fulton — **University of California, Davis**

D. Taylor Reich — **Institute for Transportation and Development Policy (Global)**

SUPPORTING AUTHORS:

Farhana Sharmin — **University of California, Davis**

Vaishali Singh — **ITDP India**

A. V. Venugopal — **ITDP India**

REVIEWERS:

Amit Bhatt — **International Council on Clean Transportation**
India Managing Director

Sarika Chakravarty — **National Institute of Urban Affairs (NIUA)**
Team Lead - UrbanShift Country Project

Aswathy Dilip — **ITDP India**
Managing Director

Kashmira Dubash — **ITDP India**
Senior Programme Manager, Communications & Development

Ravi Gadepalli — **Independent Consultant - Public Transport and Electric Mobility**

Sivasubramaniam Jayaraman — **ITDP India**
Senior Programme Manager & National Lead, Transport Systems & Electric Mobility

Pawan Mulukutla — **World Resources Institute – India**
Director, Integrated Transport, Electric Mobility & Hydrogen

Sharif Qamar — **The Energy and Resources Institute (TERI)**
Associate Director, Transport and Urban Governance

Nilesh Rajadhyaksha — **National Institute of Urban Affairs (NIUA)**
Programme Director, Urban Strategy Unit; Head, U20 Technical Secretariat

Aditya Ramji — **University of California, Davis**
Director, India ZEV Research Center

PUBLICATION DESIGN AND COPY TEAM:

Aishwarya Soni — **ITDP India**
Deputy Manager, Strategic & Visual Communications

Keshav Suryanarayanan — **ITDP India**
Deputy Manager, Communications & Development

Varsha Jeyapandi — **ITDP India**
Associate, Communications

PUBLISHED OCTOBER 2023

COVER PHOTO: Two women access a BRT station in the city of Pimpri-Chinchwad in the metropolitan area of Pune.
SOURCE: ITDP India

Compact Cities Electrified: India

Executive Summary

New research from ITDP and UC Davis shows that achieving India's Paris Agreement commitments will require both electric vehicles and modal shift. Electrifying vehicles and shifting toward compact cities built on walking, cycling, and public transport will each have profound positive impacts. However, even if both electrification and modal shift occur at the fastest possible rate, it is only by combining them that India can reduce emissions to a level consistent with holding global warming below 1.5°C (the blue shaded area in Figure A).

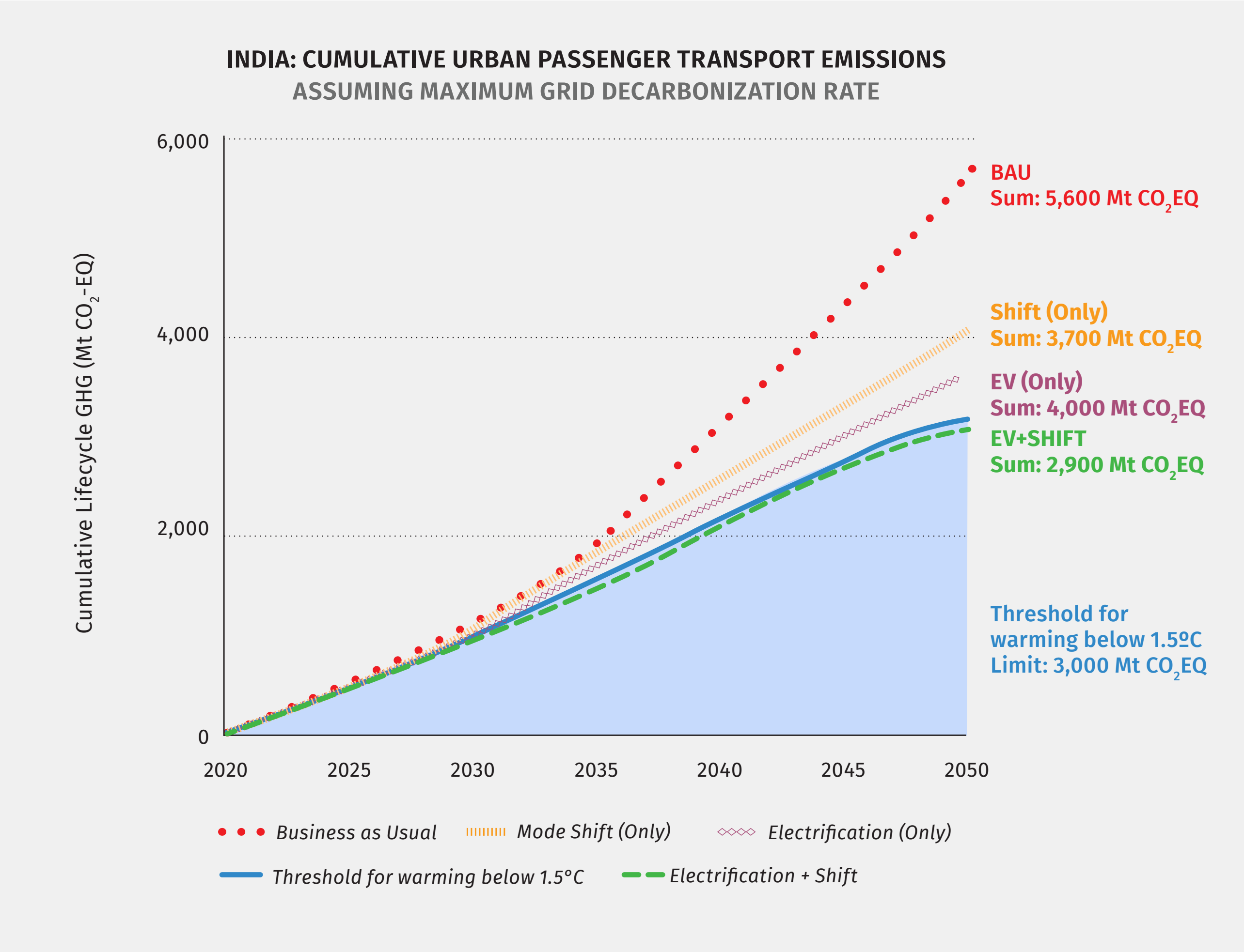


FIGURE A

This study investigates four possible scenarios for the next 30 years of urban passenger transport (not including intercity or freight transport) in India:

Business as Usual:	India's current trajectory toward a car-oriented society powered by fossil fuels.
Electrification (Only):	The fastest feasible replacement of internal-combustion vehicles with electric ones.
Mode Shift (Only):	A society-wide transformation of city planning priorities in favor of public transport, walking, and bicycling.
Electrification + Shift:	The combination of the *Electrification (Only)* and *Mode Shift (Only)* scenarios.

In addition to meeting climate commitments, the study finds that the Indian government could save over INR 150 lakh crore (in 2023 INR, or USD 1.8 trillion) over the next 30 years. By investing in compact electrified cities rather than continuing the car-centric trend, India would greatly reduce the expense of road construction and maintenance. Figures B1 and B2 show the specific investments that would be required. This change in policy would reduce travel costs for residents of Indian cities while facilitating economic inclusion, reducing air pollution, minimizing road fatalities, and lowering energy demands.

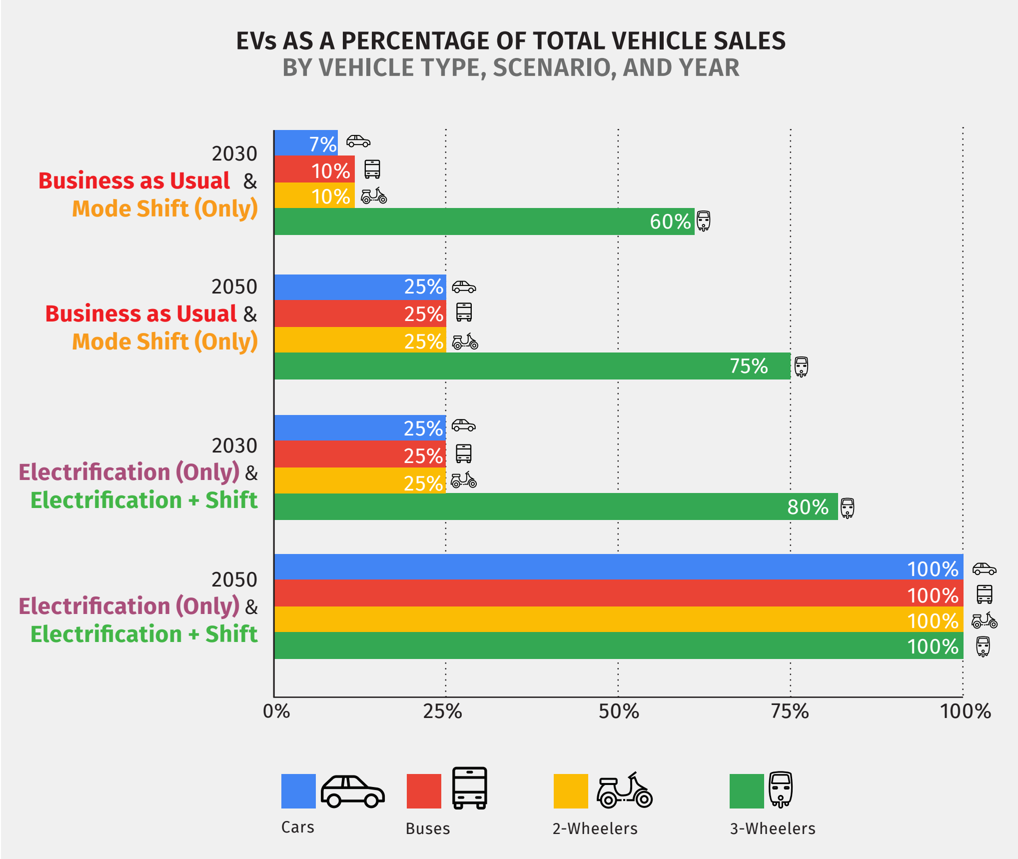


FIGURE B1

Total new infrastructure and vehicles required through 2030							
	Road, two-way km	BRT, two-way km	Railway, two-way km	Physically protected bicycle lanes, two-way km	Buses (total urban buses and minibuses)	Train cars	Total cost to governments (lakh crore 2023 INR)
Business as Usual & Electrification (Only)	110,000	100	550	1,000	630,000	7,500	149
Mode Shift (Only) & Electrification + Shift	71,000	2,200	700	19,000	660,000	8,500	141
Total new infrastructure and vehicles required through 2050							
	Road, two-way km	BRT, two-way km	Railway, two-way km	Physically protected bicycle lanes, two-way km	Buses (total urban buses and minibuses)	Train cars	Total cost to governments (lakh crore 2023 INR)
Business as Usual & Electrification (Only)	460,000	350	900	2,500	1,600,000	20,000	573
Mode Shift (Only) & Electrification + Shift	120,000	12,000	1,800	39,000	2,000,000	28,000	423

FIGURE B2

To achieve this future, India must enact national, state, and city-level policies to reallocate both street space and transportation funding from private motorized vehicles to walking, cycling, and public transport. Simultaneously, the country must encourage rapid electrification through policies including fee-rebate systems, public charging infrastructure, and emissions regulation.

CONTENTS

BACKGROUND

This study is the culmination of a decade of collaboration in transport modeling between ITDP and the University of California, Davis.[1] Ten years of effort have produced a detailed method for high-level modeling of urban passenger transportation, but this study of India—along with sibling studies of other countries—is the first time the model has been used to publish analytical results for a single country.

Like its predecessor, *The Compact City Scenario—Electrified*, the current publication compares the impacts of maximum-feasible electrification, modal shift, and the combination of the two. But while the previous report focused on the global need to pursue both strategies, this study describes the specifics of what will be needed for India to accomplish these goals. We have estimated the quantities and costs of infrastructure that will be required in different scenarios for India's future to provide a "road map" for how those scenarios might be realized.

METHODOLOGY

We begin by defining four scenarios for urban passenger transport in India through 2050 (described in detail in the next section). Beginning from a base year of 2015[2] and looking to future time points in 2030 and 2050, we describe possible futures. For electrification, our forecasting is expressed in terms of sales shares; for mode shift, it is expressed in terms of person-kilometers traveled by different modes.

After defining scenarios, we estimate their implications. For each scenario, we estimate the size of vehicle fleets and the amount of activity per vehicle, along with the infrastructure that will be required. We then estimate energy consumption, life cycle[3] greenhouse gas emissions, and direct costs.[4]

The model is calibrated to industry-standard data from the International Energy Agency's *Mobility Model*,[5] except where more detailed India-specific data is available. The model and results have been reviewed and approved by experts representing a range of specialist institutions, both Indian and international, to ensure accuracy. (These experts' names and affiliations are listed on this brief's title page.) Our method provides a high-level comparison of different scenarios rather than a detailed bottom-up analysis. For a more detailed description of the methodology, including a complete set of data, please review the accompanying methodological appendix.

1 ITDP & UC Davis (2021), *The Compact City Scenario—Electrified*; ITDP & UC Davis (2017), Three Revolutions in Urban Transportation; ITDP & UC Davis (2015), A Global High Shift Cycling Scenario; ITDP & UC Davis (2014), A Global High Shift Scenario: Impacts and Potential for More Public Transport, Walking and Cycling with Lower Car Use.

2 Selected for data availability, compatibility between sibling studies, and to avoid distortions due to COVID-19.

3 Including not only emissions from the production and consumption of fuel or electricity but also from the manufacture and disposal of vehicles and the construction and maintenance of infrastructure.

4 Including the costs of manufacturing, operating, maintaining, and insuring vehicles; providing fuel; hiring drivers for shared or for-hire modes; and constructing, maintaining, and operating infrastructure.

5 Unfortunately, the *Mobility Model* is only available under a closed license and the full dataset cannot be shared.

FOUR SCENARIOS

BUSINESS AS USUAL ("BAU")

The Chennai urban environment portraits how current trends in passenger transportation and personal vehicle travel mean an increase in air pollution, noise pollution, and traffic fatalities.
SOURCE: ITDP India

Assumptions:

- India continues the trajectory of the last decade. Private motorized travel increases rapidly, in line with forecasts by the International Energy Agency (IEA), reaching roughly eight times current levels by 2050.

Qualitative impacts:

- Increase in traffic fatalities
- High direct public and private costs
- Reduced access to opportunities for low-income people without cars, leading to increased wealth inequality
- Increase in local air pollution, causing many premature deaths and increased healthcare costs
- Increase in urban highways, dividing neighborhoods and subsidizing environmentally unfriendly sprawl
- Increase in carbon emissions, leading to climate catastrophe
- High congestion

ELECTRIFICATION (ONLY)

India's largest EV charging station in Gurugram, the business capital of Haryana.
SOURCE: Sudarshan Jha via Shutterstock

Assumptions:

- All new or imported vehicles are electric by 2040—in line with the COP26 Glasgow Declaration—and a quarter of new vehicles are electric by 2030.

Qualitative impacts:

- 👍 Sharp reduction in carbon emissions
- 👍 Sharp reduction in local air and noise pollution
- 👎 Increase in traffic fatalities, as in *BAU*
- 👎 High direct public and private costs, as in *BAU*
- 👎 Reduced access to opportunities for low-income people without cars, as in *BAU*
- 👎 Increase in urban highways, dividing neighborhoods and subsidizing environmentally unfriendly sprawl, as in *BAU*

Key policies:

- Supply- and demand-side EV incentives
- Ambitious fuel economy and tailpipe carbon dioxide standards
- Battery reuse and recycling
- Public charging infrastructure
- Electric grid expansion and decarbonization

MODE SHIFT (ONLY)

Besides decarbonization, modal shift has the potential to improve mobility for poorer people especially, making cities more equitable. **SOURCE:** Pune Smart City

Assumptions:

- Compact city planning is combined with reallocation of both funding and street space to walking, bicycling, and public transport. Car travel continues to increase but much more slowly, reaching less than half of Business as Usual levels by 2050.

Qualitative impacts:

- Reduction in traffic fatalities
- Decreased congestion
- Increased access to opportunities, especially for low-income people
- Increase in walking and cycling, which improve physical and mental health, reducing healthcare costs
- High local air and noise pollution from internal-combustion (ICE) vehicles, relative to *Electrification (Only)*
- Insufficient carbon reductions to meet the the terms of the Paris Agreement

Key policies:

- Reallocation of transport budgets to walking, cycling, and public transport, especially bus rapid transport (BRT)
- Street redesigns that shift space from cars to BRT lanes, physically protected bicycle lanes, and footpaths
- Promotion of bicycles, especially shared electric bicycles
- Modernization, rather than replacement, of the informal public transport sector

ELECTRIFICATION + SHIFT

Electrification of public transport systems and a shift away from cars towards walking and bicycling is possible by substantial synergies between those scenarios.
SOURCE: Bhubaneswar Smart City Limited

Assumptions:

- Compact cities and mode shift, combined with rapid electrification: *Electrification + Shift*.

Qualitative impacts:

- Reduction in traffic fatalities
- Decreased congestion
- Increased access to opportunities for all
- Increase in walking and cycling, which improve physical and mental health, reducing healthcare cost
- Extreme reduction in local air and noise pollution
- Massive reduction in carbon emissions consistent with the terms of the Paris Agreement

Key policies:

- All policies listed for *Electrification (Only)* and for *Mode Shift (Only)*, except growth in urban highways
- Creation of low-emission zones to incentivize both modal shift and vehicle electrification

The difference between these scenarios is the split of travel between modes (illustrated in Figure C1 and Figure C2) and the sales rates of different categories of electric vehicles (shown in Figure D). The *Electrification (Only)* scenario shifts travel to electric modes but leaves the overall split unchanged, while *Mode Shift (Only)* replaces cars with other modes but does not electrify vehicles. *Electrification + Shift* does both. The *Mode Shift (Only)* and *Electrification + Shift* scenarios do not entail any reduction in access to opportunities: people will be able to navigate their cities just as conveniently as in *Business as Usual*, but by different modes.

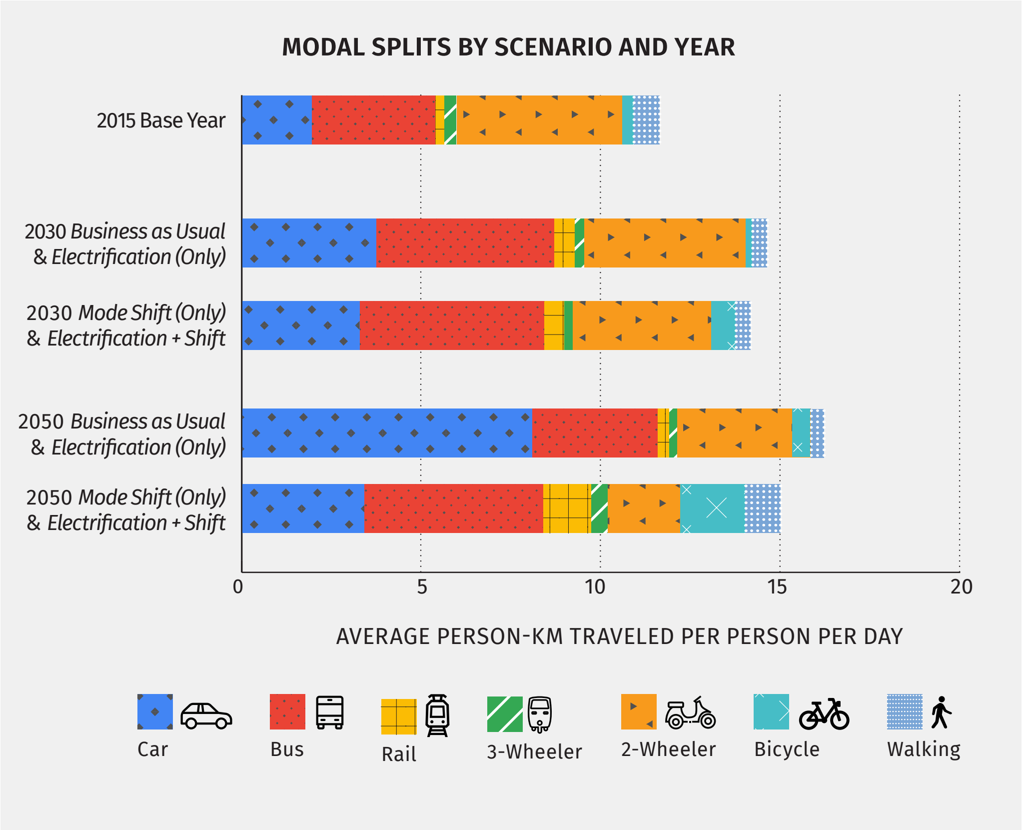


FIGURE C1

Modal Splits by Scenario and Year (by person-km traveled, rather than by trip; independent of overall travel activity, which grows over time)					
	2015 Base Year	2030 Business as Usual & Electrification (Only)	2030 Mode Shift (Only) & Electrification + Shift	2050 Business as Usual & Electrification (Only)	2050 Mode Shift (Only) & Electrification + Shift
Car	18%	33%	27%	57%	26%
Bus	32%	24%	29%	15%	36%
Rail	5%	5%	6%	4%	6%
3-Wheeler	4%	2%	3%	1%	2%
2-Wheeler	32%	29%	23%	17%	7%
Bicycle/e-bike	2%	3%	6%	3%	14%
Walking	6%	4%	6%	3%	9%

FIGURE C2

(Modal splits are by person-km traveled, rather than by trip; they are independent of overall travel activity, which grows over time in all scenarios)

Note that the *Business as Usual* and *Electrification* scenarios have the same modal splits and differ only in their rates of vehicle electrification (described in figures D1 and D2).[6] Similarly, *Mode Shift* and *Electrification + Shift* have the same modal splits and differ only in electrification rates.

Business as Usual & Mode Shift (Only)

6 These rates are consistent with estimates from the IEA (2023) Global EV Outlook and with the UC Davis internal forecasting model for India.

	EV % of Vehicle Sales			EV % of Vehicle Fleets		
	2015	**2030**	**2050**	**2015**	**2030**	**2050**
Light-duty Vehicles	0%	7%	25%	0%	4%	12%
2W motos	0%	10%	25%	0%	6%	12%
3Ws	0.10%	60%	75%	0.10%	35%	60%
E-bikes	0.10%	5%	15%	0.10%	3%	10%
Transit buses	0.10%	10%	25%	0.10%	6%	12%

FIGURE D1

Electrification (Only) & Electrification + Shift						
	EV % of Vehicle Sales			EV % of Vehicle Fleets		
	2015	**2030**	**2050**	**2015**	**2030**	**2050**
Light-duty Vehicles	0%	25%	100%	0.10%	12%	95%
2W motos	0%	25%	100%	0.10%	12%	95%
3Ws	0%	80%	100%	0.10%	50%	98%
E-bikes	0%	25%	60%	0.10%	12%	40%
Transit buses	0.10%	25%	100%	0.10%	12%	95%

FIGURE D2

Achieving the *Electrification (Only)* or *Mode Shift (Only)* scenarios would require a transformation in Indian policy. These scenarios represent the maximum feasible changes under India's current political and economic structure. They would require large changes in how transportation budgets are allocated, how street space is used, and how taxes and subsidies are applied to vehicles and fuel—but they are progressive changes that build off existing efforts and can be reached in the current system, and they would not require a "revolution" in any economic, social, or political sense.

These scenarios are extensive but not implausible. Under the *Mode Shift (Only)* projections for 2050, there will still be more than three times as much driving as there is today—but only a third as much as in the *Business as Usual* projections for 2050. Similarly, the *Electrification (Only)* scenario will use progressive policies to incentivize electrification over time.

CLIMATE

India has made commitments to reduce greenhouse gas emissions and help prevent catastrophic climate change in this century. Specifically, all 196 Paris Agreement signatories agreed to "[limit] the increase in the global average temperature to well below 2°C above pre-industrial levels and [pursue] efforts to limit it to 1.5°C." India in particular has committed to reduce the emissions intensity of its GDP by 45 percent by 2030 (relative to 2005) and to achieve the target of Net Zero by 2070.

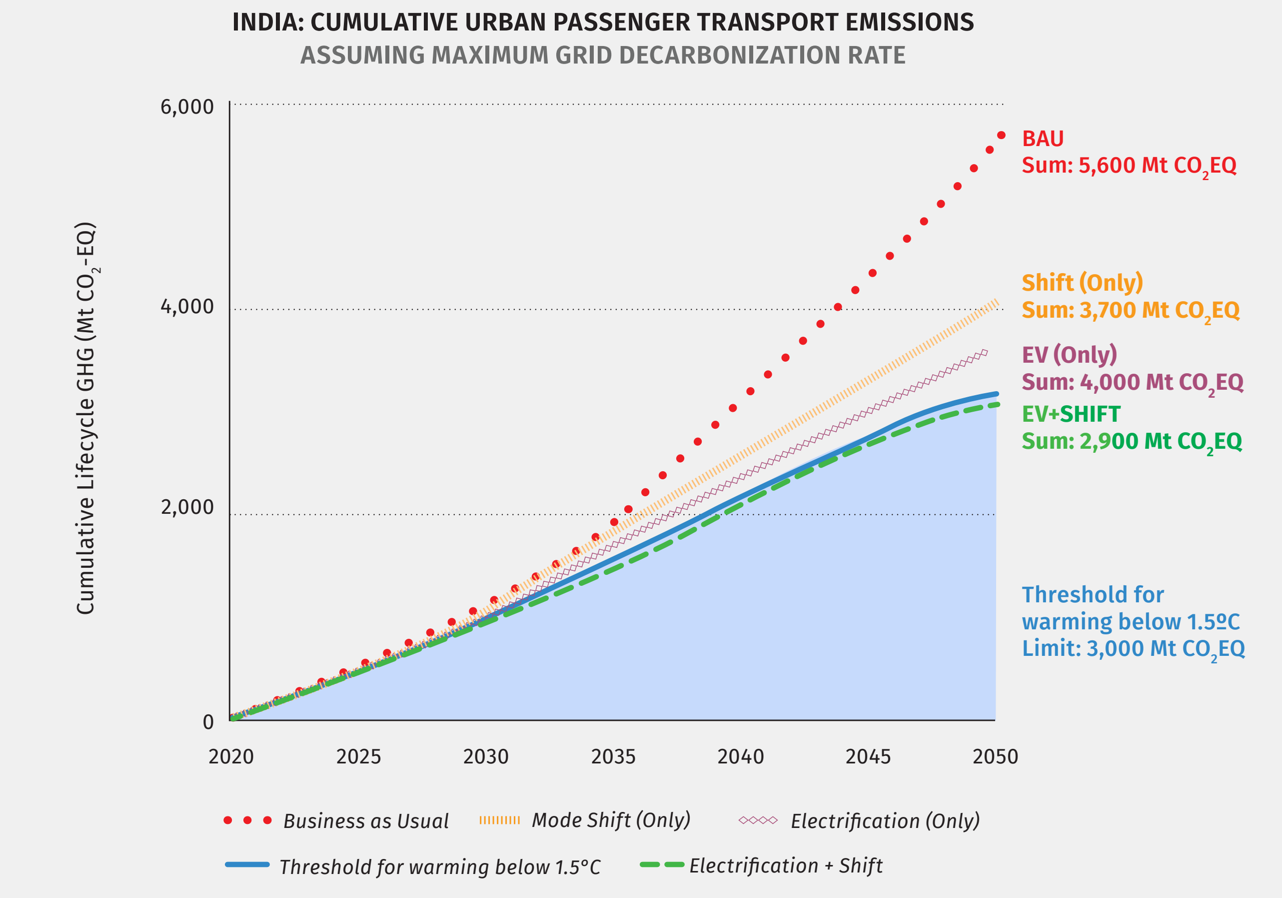


FIGURE E

Although the *Electrification (Only)* and the *Mode Shift (Only)* scenarios would each cause considerable reductions in greenhouse gas emissions, only the combined *Electrification + Shift* scenario is sufficient to keep India's cumulative urban passenger transport emissions within a level potentially compatible with limiting climate change to 1.5°C in this century, as shown by the area under the blue threshold curve[7] in Figure E, above. When we say "potentially compatible," we mean that if similar GHG reductions in other countries and sectors matched this scenario, it would be possible (though not guaranteed) that climate change would stay within 1.5°C.

7 Carbon budgets are allocated by the ratio of India's cumulative emissions in the *Business as Usual* scenario to worldwide emissions in the *Business as Usual* scenario. For more detail, see the methodological appendix.

Not only is *Electrification + Shift* the only scenario compatible with holding global warming within Paris Agreement goals, it is the only scenario that approaches India's goal of achieving Net Zero by 2070.

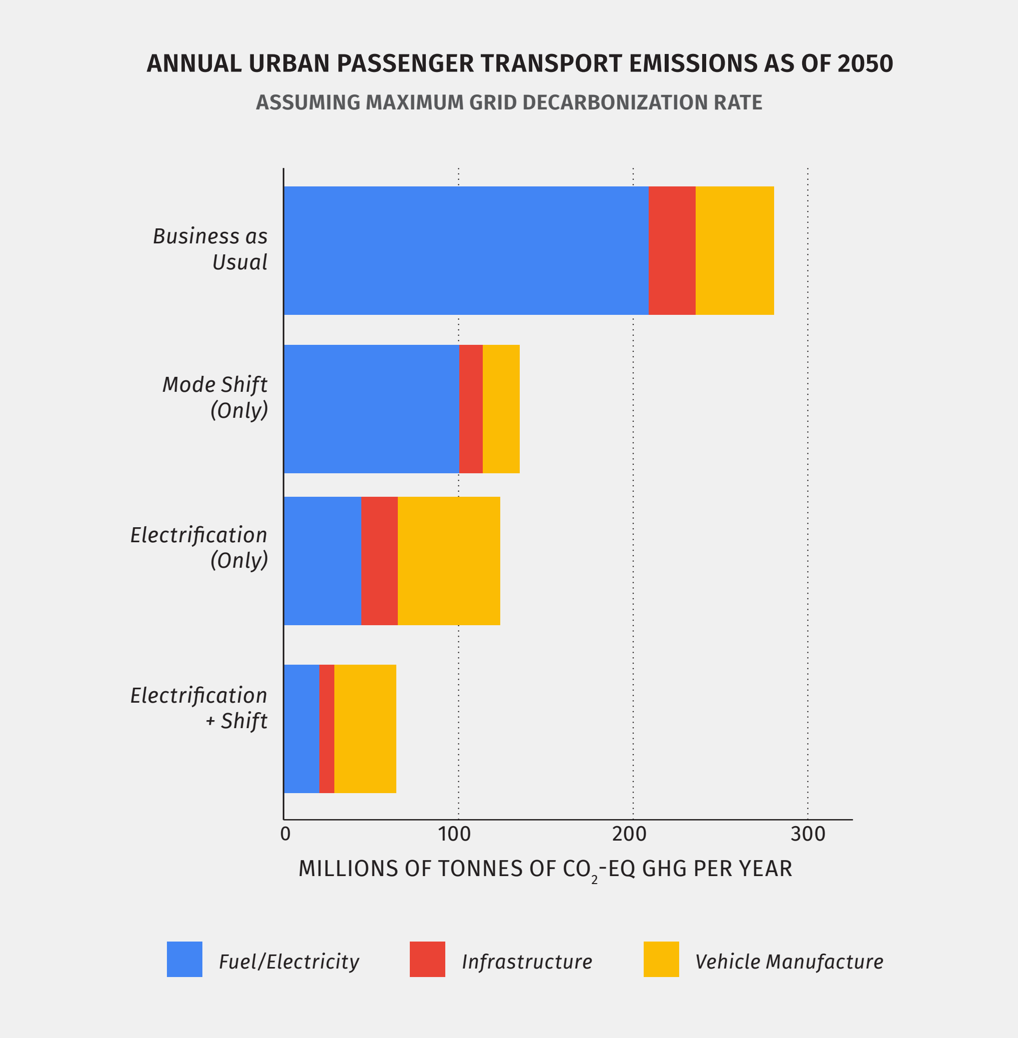


FIGURE F

With a decarbonized grid, operating electric vehicles will cause very low emissions. However, the use of cars, electric or not, will still lead to substantial emissions from the paving and maintenance of roads and from the production of steel, batteries, and other industrial processes involved in vehicle manufacture and disposal. Under the *Electrification* scenarios, as can be seen in Figure F, a majority of emissions are from these sources, which are much more challenging to decarbonize. For India to reach Net Zero by 2070, these "life cycle" emissions must be minimized, which can only be accomplished by combining *Electrification with Mode Shift*.

REDUNDANCY

Electrification alone can substantially reduce transport emissions, but electric vehicles are only as clean as the grid that powers them.

India's electricity grid currently has an emissions intensity of roughly 450 g CO_2eq per kWh. The results displayed in the previous section have assumed a highly ambitious level of grid decarbonization in line with the IEA's *Sustainable Development Scenario*. Following this assumption, the grid emissions intensity falls to almost 0 g CO_2/kWh by 2050—in line with India's Paris Agreement commitments.

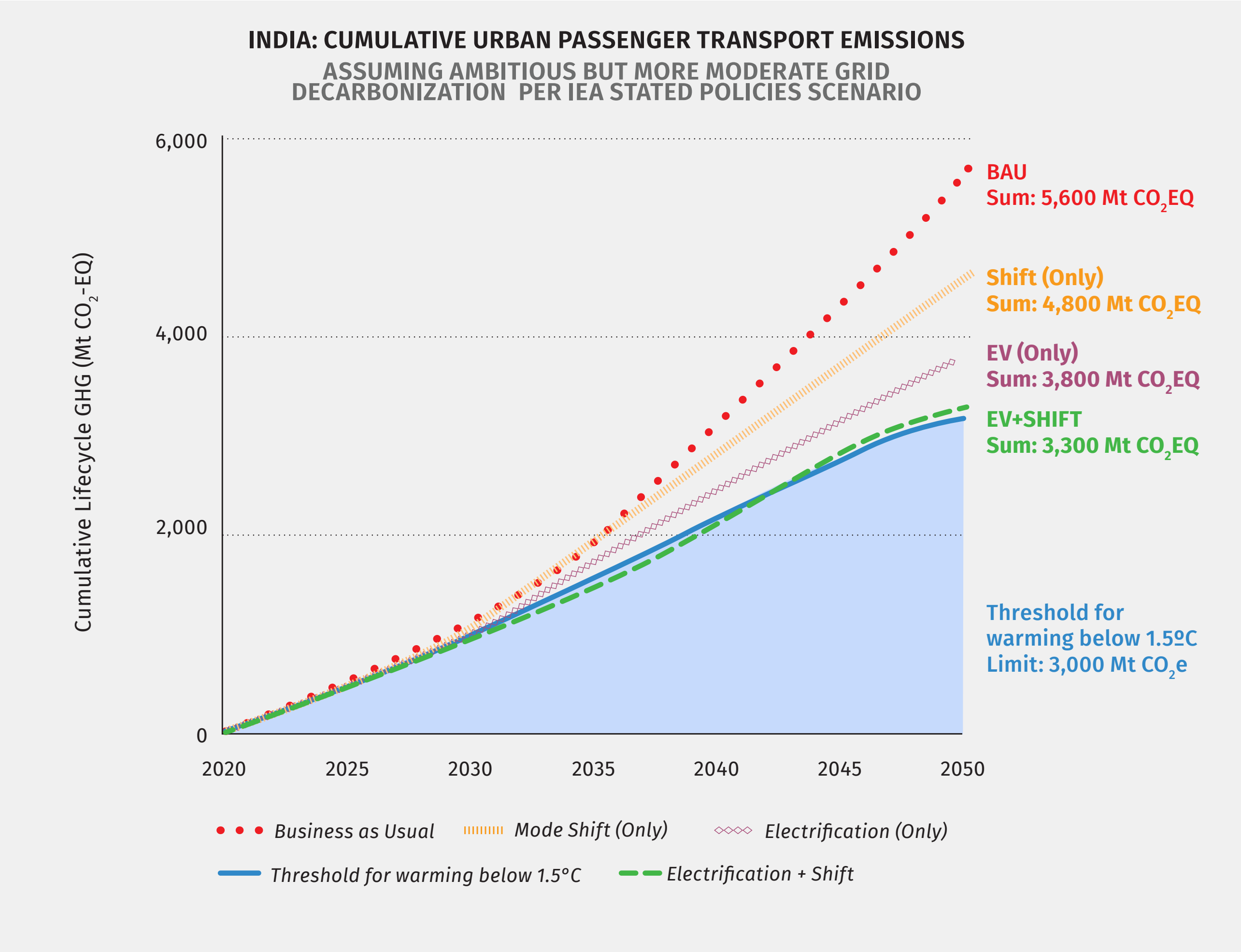


FIGURE G However, even if India fully implements all of its current policies for renewable electricity (as per IEA's *Stated Policies Scenario*), it will only reach a grid intensity of about 250 g CO_2eq/kWh by 2050. This is still an optimistic forecast, but in this case, our *Electrification (Only)* scenario loses some of its effectiveness in reducing cumulative emissions, while *Mode Shift (Only)* loses almost none (shown in Figure G, above). In this case, none of the scenarios remain in the blue area signifying compatibility with the 1.5°C threshold, but *Electrification + Shift* comes the closest.

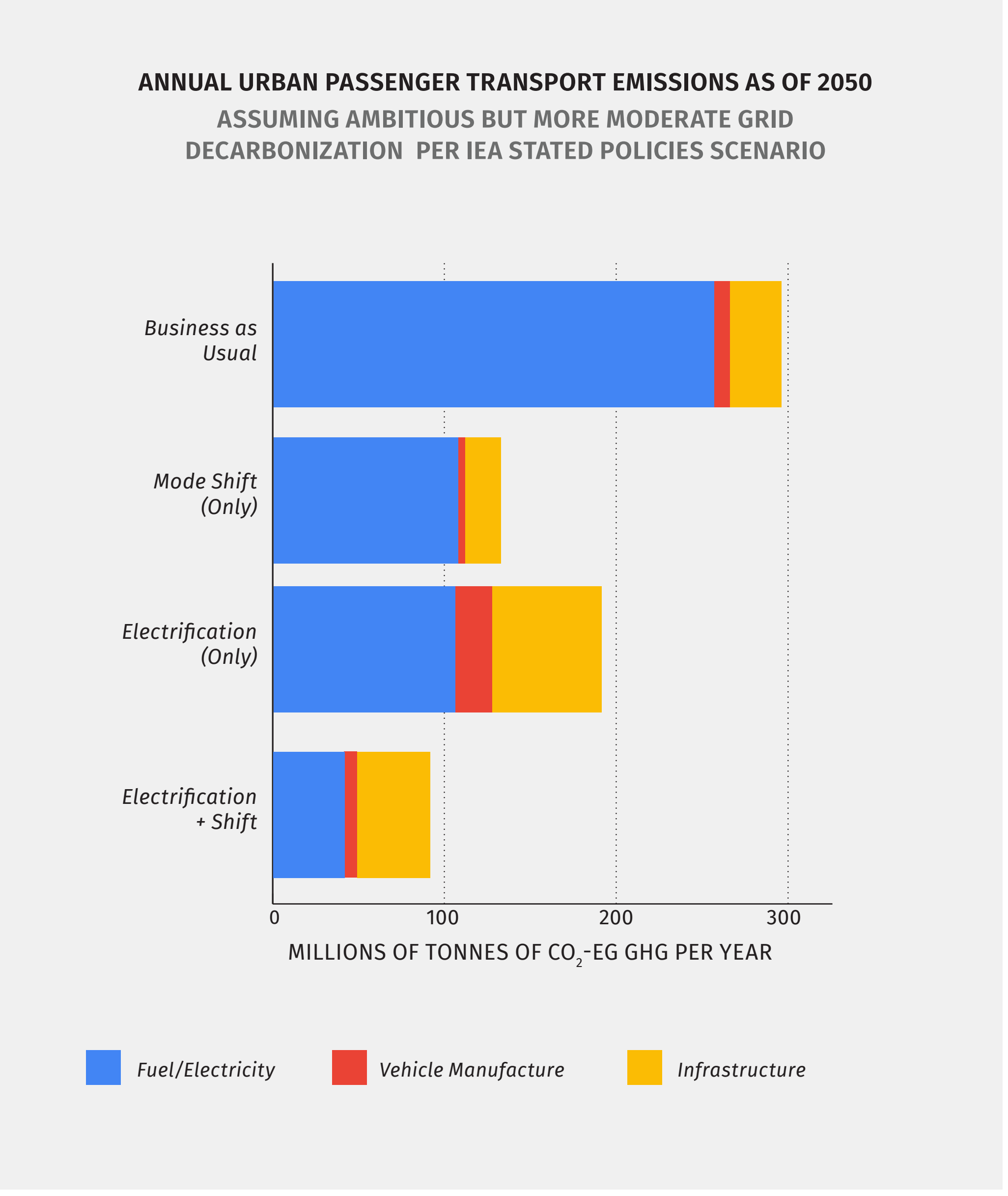


FIGURE H

The more conservative grid decarbonization projections also shed light on India's prospects for reaching its goal of Net Zero by 2070, as seen in Figure H. If grid decarbonization proceeds in line with current stated policies, it will be very difficult, if not impossible, for India to achieve that goal without both *Electrification* and *Mode Shift*.

Modal shift provides redundancy. By combining *Mode Shift* and *Electrification*, India may still achieve substantial decarbonization even if the shift to electric vehicles and/or renewable electricity generation is slower than needed.

Not only does *Mode Shift (Only)* reduce the urgency of rapid grid decarbonization, it also, by reducing overall electricity demands, makes decarbonization easier.

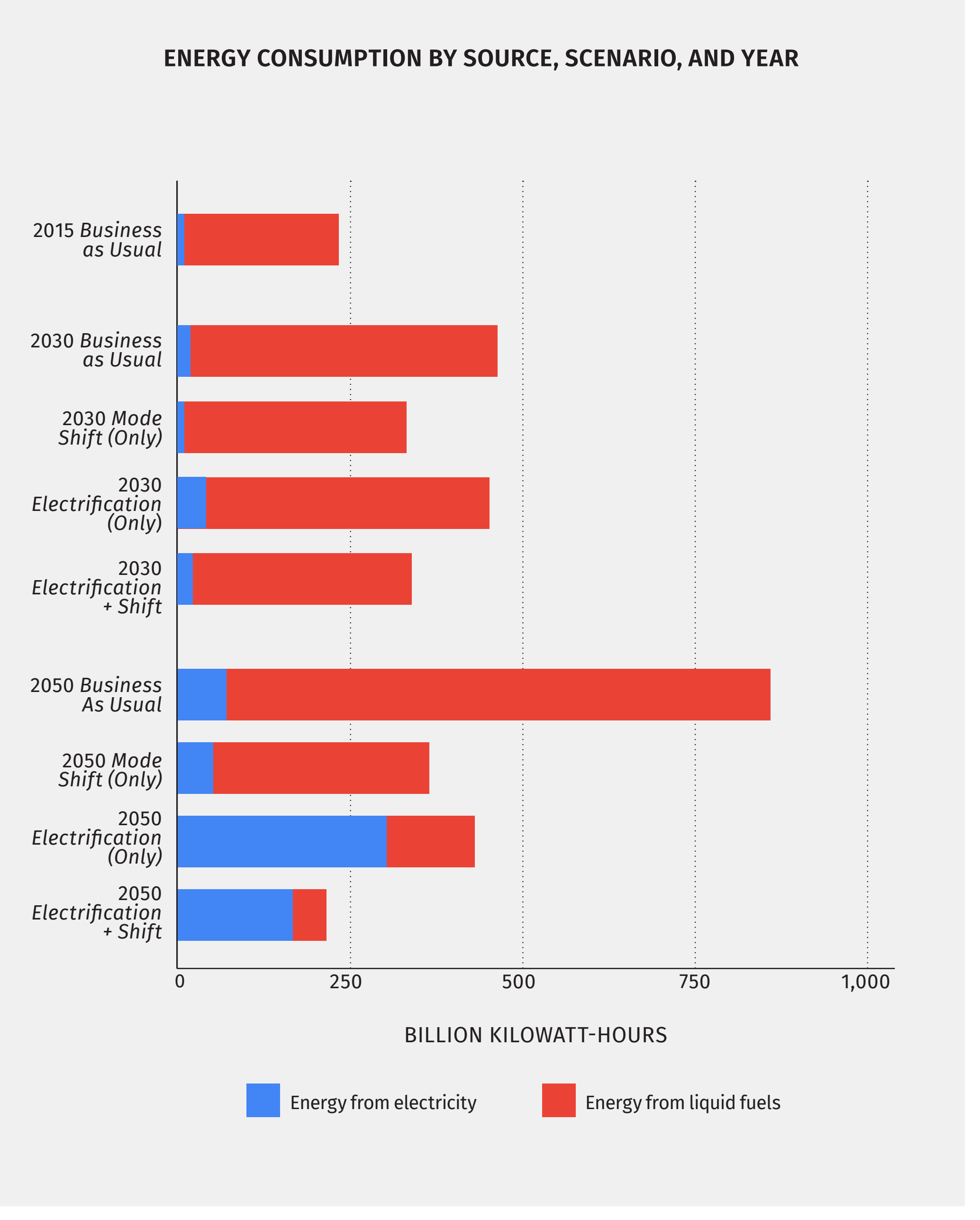


FIGURE I

The *Electrification (Only)* scenario represents a major reduction in total energy consumption relative to *Business as Usual*, because electric vehicles are much more efficient per kilometer than internal-combustion vehicles. However, that reduction in total energy consumption comes along with a great increase in the use of electricity in particular.

In the *Electrification (Only)* scenario, urban passenger transport in India will consume 1 exajoule of electricity annually by 2050, or $3x10^{11}$ (300 billion) kWh. *Electrification + Shift* reduces this consumption by 30 percent (a reduction of 0.3 exajoules, or 100 billion kWh), which is equivalent to the annual power generation of about 20,000 wind turbines. That might mean a reduction in the societal costs of converting to renewable electricity, or it might mean freeing up electricity for consumers or for other energy-intensive aspects of development.

ECONOMY

The structure of a transportation system has many impacts on a nation's economy, direct and indirect. Our model tabulates only the direct impacts: the costs of manufacturing, maintaining, fueling, and operating vehicles and the costs of building and maintaining infrastructure. These are shown in Figure J.

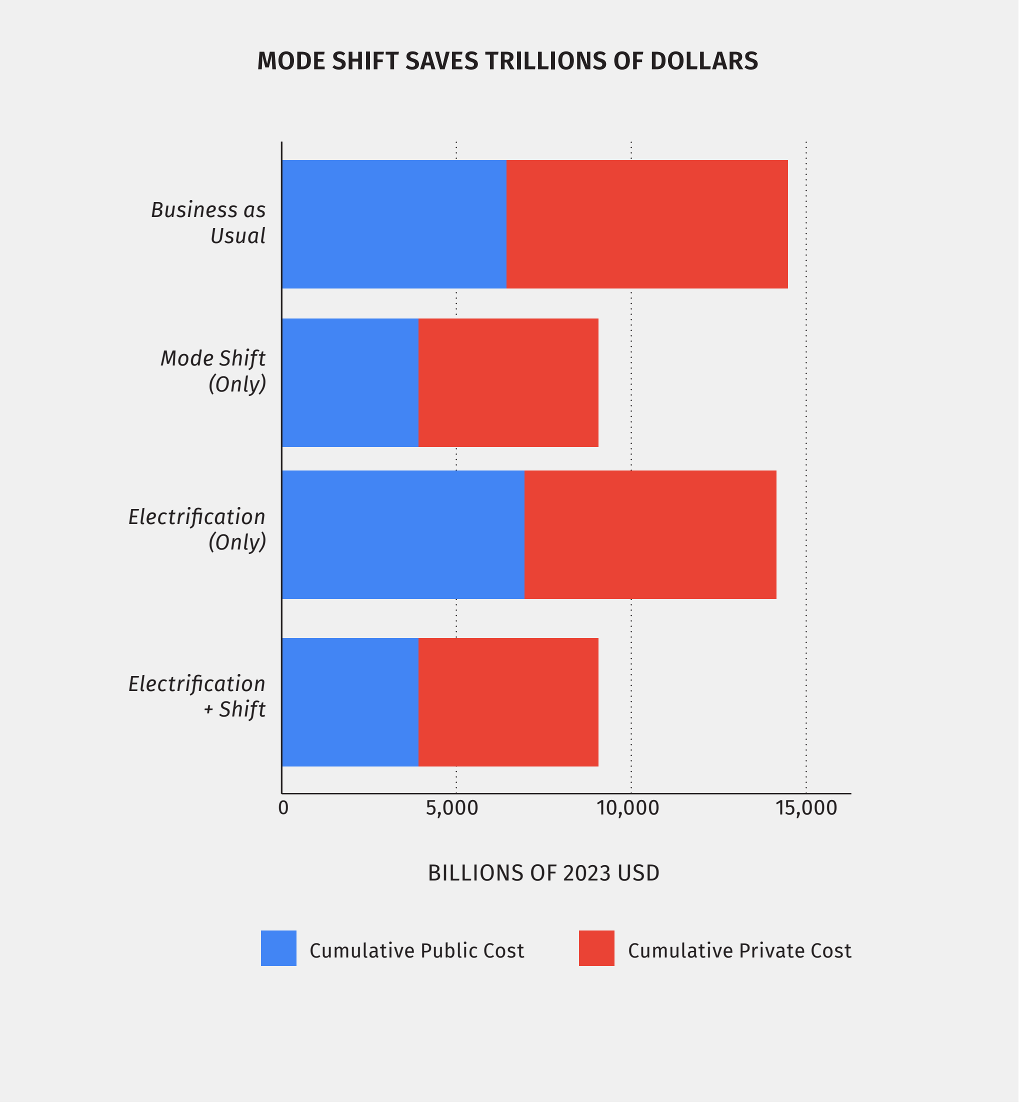


FIGURE J

These costs can be divided into those borne ultimately by the public sector and those borne by individuals.[8] *Mode Shift* would lead to enormous economic savings for the Indian economy: a cumulative savings of more than 400 lakh crore INR (5 trillion USD) through 2050. Of this, at least 150 lakh crore INR in savings would accrue to national, state, and local governments, as tabulated in figures K1 and K2.

8 For the sake of conservatism, we have assumed that the government will bear the entire cost of public transport operations, even minibuses—that is, fares will be free. We do expect that public transport subsidies will increase in the *Mode Shift* scenarios, though probably not to this extreme.

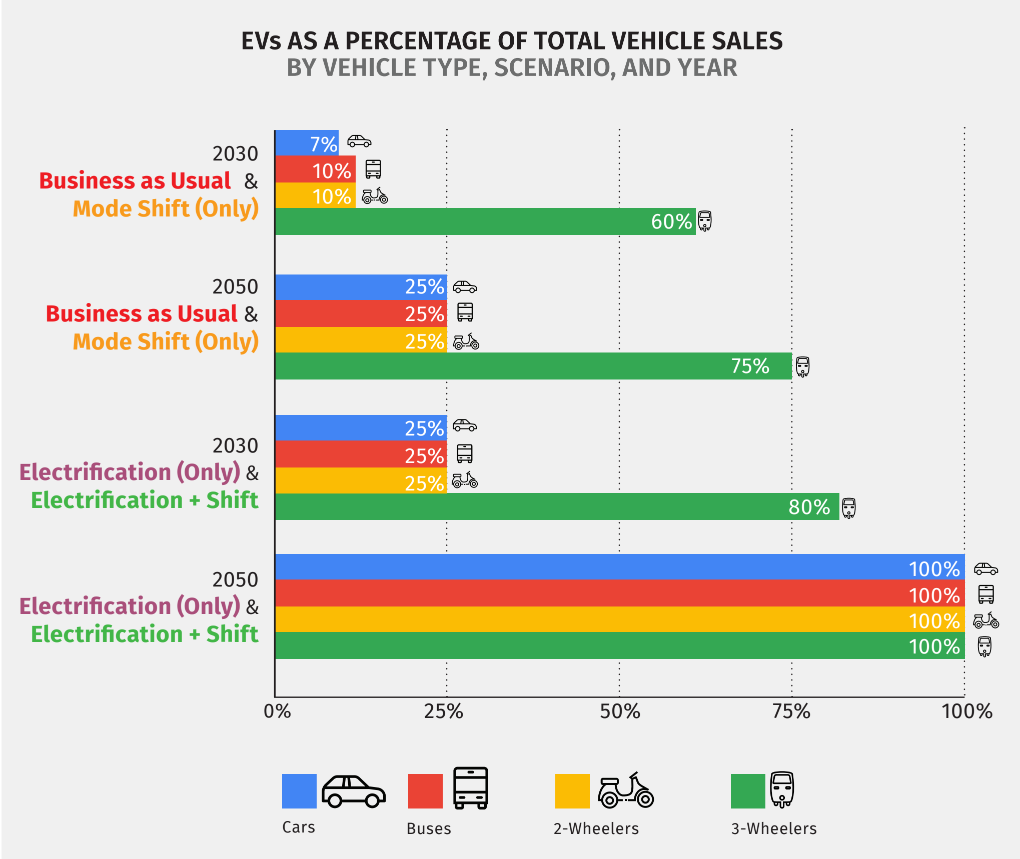


FIGURE K1

Total New Infrastructure and Vehicles Required Through 2030							
	Road, two-way km	BRT, two-way km	Railway, two-way km	Physically protected bicycle lanes, two-way km	Buses (total urban buses and minibuses)	Train cars	Total cost to governments (lakh crore 2023 INR)
Business as Usual & Electrification (Only)	110,000	100	550	1,000	630,000	7,500	149
Mode Shift (Only) & Electrification + Shift	71,000	2,200	700	19,000	660,000	8,500	141
Total New Infrastructure and Vehicles Required Through 2050							
	Road, two-way km	BRT, two-way km	Railway, two-way km	Physically protected bicycle lanes, two-way km	Buses (total urban buses and minibuses)	Train cars	Total cost to governments (lakh crore 2023 INR)
Business as Usual & Electrification (Only)	460,000	350	900	2,500	1,600,000	20,000	573
Mode Shift (Only) & Electrification + Shift	120,000	12,000	1,800	39,000	2,000,000	28,000	423

FIGURE K2

The columns in Figure K2 only list the number of vehicles and infrastructure required for the various scenarios, but the tabulation of total expenses includes the cost of operations and maintenance. Full details are available in the methodological appendix. Although the costs of expanding public transport service in the *Mode Shift (Only)* and *Electrification + Shift* scenarios are high, they are more than balanced by the savings brought by a reduced need to pay for road and highway expansions.

ACTION PLAN

India should pursue the following seven goals to achieve the *Electrification + Shift* scenario:

1. **Cities are compact and reachable:** Refocus urban growth toward compact development built around walking and cycling, and connected by a backbone of public transport. In any areas less dense than 4,000 people per km^2, plan for infill development to increase urban density.

2. **Every citizen gets a fair share of road space:** To provide every citizen with a fair share of limited road space, prioritize space-efficient modes like walking, cycling, and public transport and discourage modes that occupy more space per person, such as single-occupant cars. This includes pricing and regulating on-street parking and removing requirements for off-street parking. This can also include congestion pricing mechanisms.

3. **Walking and cycling are attractive:** Ensure that a network of safe, shaded, and clean walking and cycling-friendly streets is available in all cities.

4. **Public transport is accessible and affordable:** Ensure that public transport is within easy reach, affordable, convenient, comfortable, and dependable for all.

5. **Everyone breathes clean air:** Prioritize green vehicle technology like electrification by incentivizing them and disincentivizing polluting ICE vehicles, including private cars and two-wheelers. These may include fee-rebate structures or low-emission traffic zones.

6. **Cities embrace green mobility:** Set a timeline for zero-emission vehicle purchasing targets and ICE phase-out targets for all public and private vehicles, including cars, vans, buses, light- and heavy-duty trucks. Zero-emission vehicle targets should be set for new and used car markets.

7. **Everyone moves around the city seamlessly:** Remove hindrances to the mobility of all, especially persons with disabilities, women, children, and elderly people, to facilitate their independent mobility.

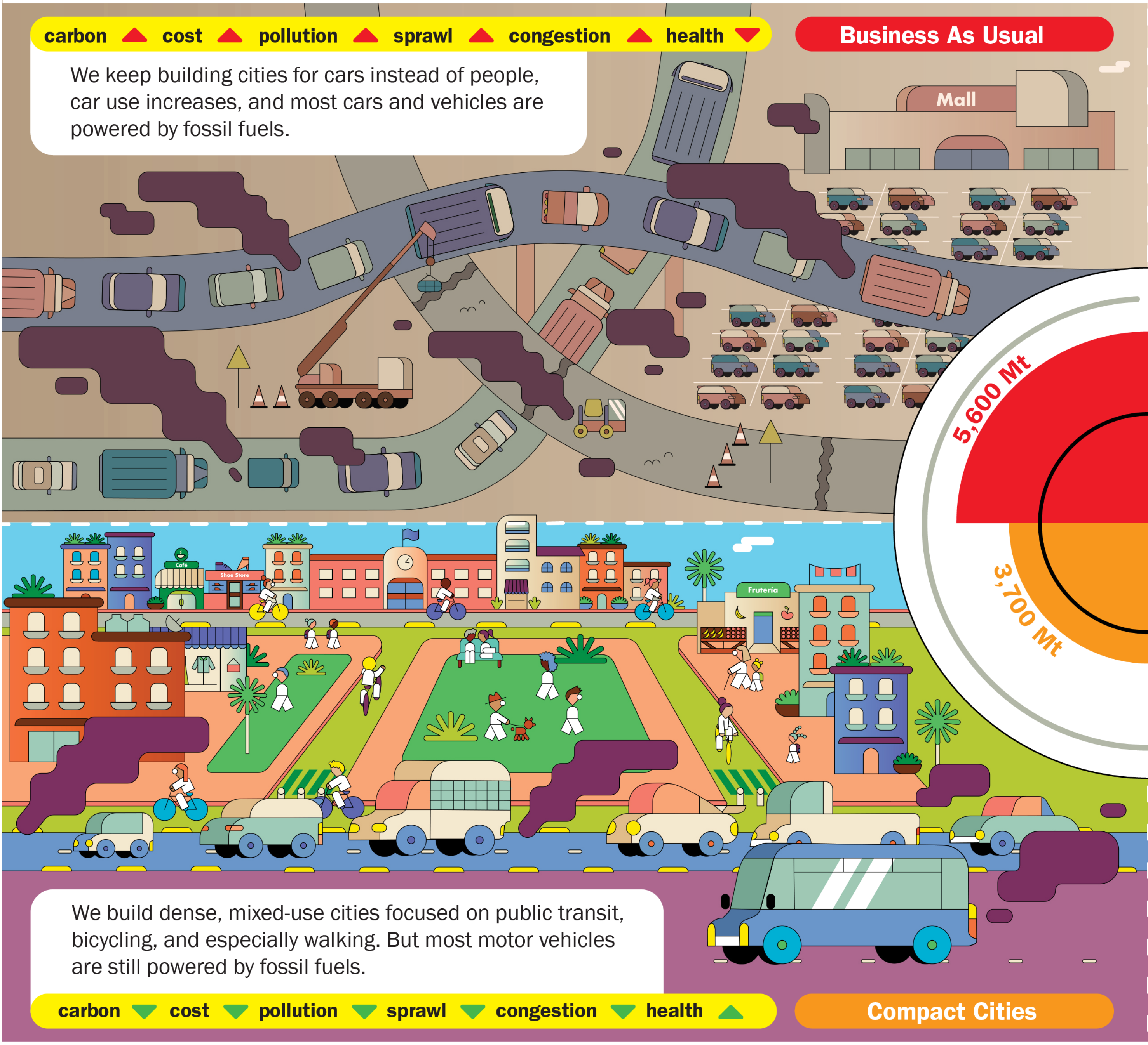
The government should introduce the required policy measures and programs to achieve the above strategies. This scale of transformation, while massive, is not unprecedented. Paris decreased car travel by almost 50 percent in 30 years by investing in other modes and traffic-control strategies. Jakarta, Tehran, and Bogotá have each built a mass transit system with more than a million riders a day in less than 15 years. There’s no reason Indian cities can’t do the same.

Decisions in city planning last for decades, even centuries, and India’s cities are growing fast. But in many ways, the task that lies ahead for India is easier than for countries like the US, where highways have already been built and now must be replaced by public transport. India has the opportunity not to build those highways at all.

Compact Cities Ele

The Only Way to 1.5°C

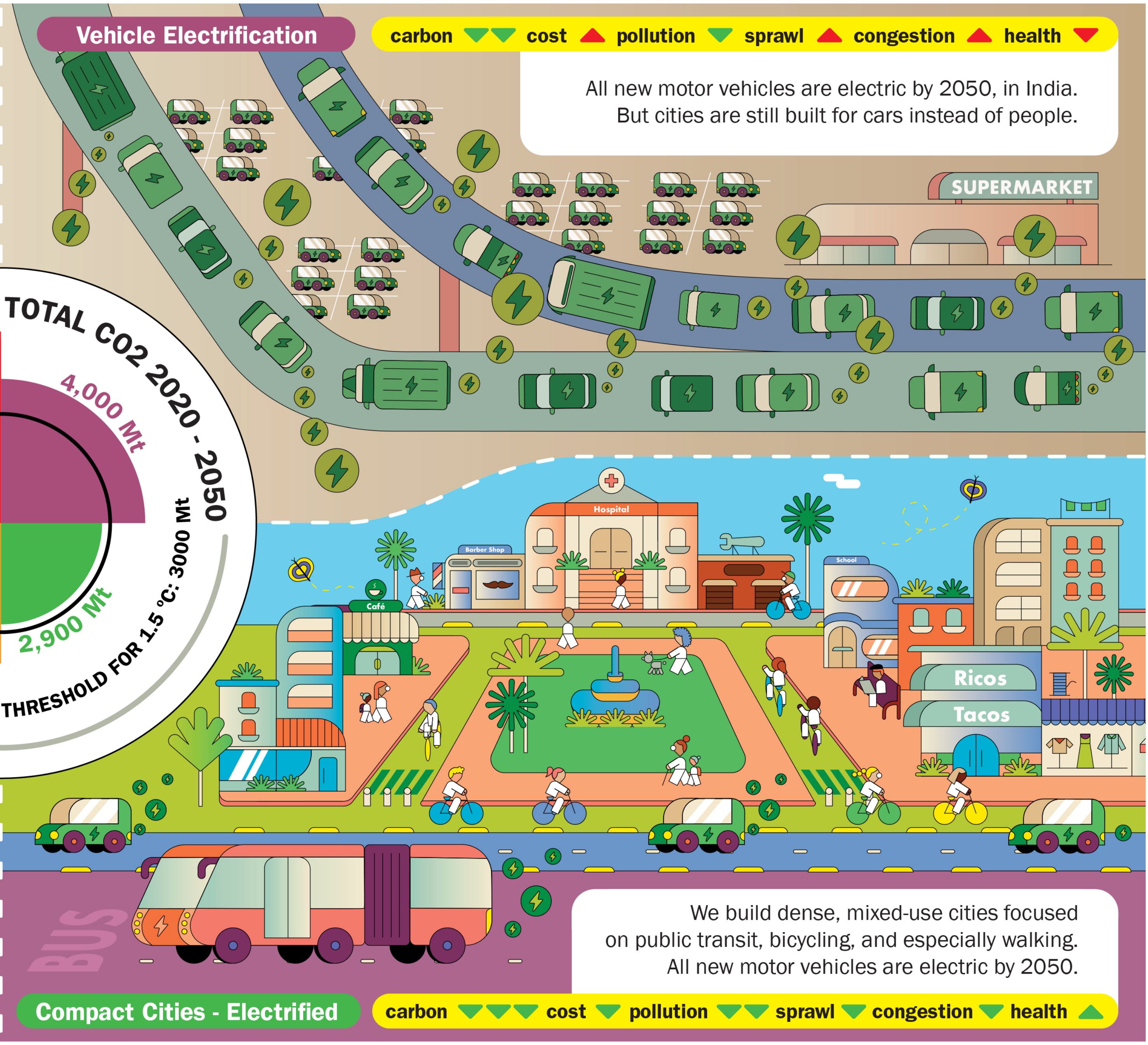
To achieve India's Paris Agreement commitments, we must choose how our cities
possible scenarios for the future. Only one scenario is consistent with limiting glob



Read the report, Compact Cities Electrified: India by ITDP and UC Davis, at: bit.ly/cceindia

ctrified: India

will grow. ITDP's recent research, Compact Cities Electrified: India, studied four
bal warming to less than 1.5°C and avoiding the worst effects of climate change.



ITDP
Institute for Transportation & Development Policy

UC DAVIS
UNIVERSITY OF CALIFORNIA

Taylor Reich
ITDP

Lew Fulton
UC DAVIS

OCTOBER 2023