Compact Cities Electrified: China

EXECUTIVE SUMMARY

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New research from the Institute for Transportation and Development Policy and the University of California, Davis, finds that China could feasibly reduce public-sector expenditures on urban transport at the local, state, and country levels by a cumulative CN¥ 30 trillion through 2050. This could be achieved by using a combination of strategies to support vehicle electrification, compact city planning, and modal shift toward walking, cycling, and public transit. Furthermore, only the combination of these strategies, not any strategy alone, will be sufficient to approach the country's commitments to reduce carbon emissions in urban passenger transport.

This study investigates four possible scenarios for urban passenger transport in China:
Business as Usual: China's current trends in city planning and vehicle sales, including relatively rapid uptake of electric vehicles (including electric passenger cars, electric buses, e-bikes).
Electrification (Only): The fastest feasible replacement of internal-combustion vehicles (ICE) with electric ones.
Mode Shift (Only): The fastest feasible transformation of city planning priorities in favor of compact land use and public transport, walking, and bicycling.
Electrification + Mode Shift: The combination of the previous two scenarios.

The estimated requirements to achieve each scenario and the cumulative public-sector expenditure entailed are shown in Figure A.

In addition to cost savings, the *Electrification + Mode Shift* scenario would reduce electricity consumption by 411 billion kWh per year by 2050 compared to *Electrification (Only)*. Qualitatively, this scenario would improve road safety, promote economic inclusion of marginalized groups, and reduce air pollution.

	Percent of new light-duty vehicles that are electric	Cumulative lane-km of roadway built 2015– 2050	Cumulative track-km of metro rail built 2015–2050	Cumulative lane-km of protected bikeway built 2015–2050	Cumulative publicsector expenditure on urban passenger transport 2015–2050	Cumulative public sector expenditure on urban passenger transport 2015-2020
2015 Baseline	1%					
2050 *Business as Usual*	63%	2,500,000	3,700	2,700	17,000	CN¥ 130 trillion
2050 *Electrification (Only)*	100%	2,500,000	3,700	2,700	17,000	CN¥ 130 trillion
2050 *Mode Shift (Only)*	63%	810,000	14,000	41,000	190,000	CN¥ 98 trillion
2050 *Electrification + Mode Shift*	100%	810,000	14,000	41,000	190,000	CN¥ 98 trillion

Figure A. Infrastructure requirements and direct public costs by scenario

The research also measures greenhouse gas (GHG) emissions from urban passenger transportation in each scenario. The results add to a growing body of evidence[1] and show that achieving China's Paris Agreement commitments and Nationally Determined Contribution (NDC) will require both electric vehicles and a change in travel patterns. It is insufficient for *Electrification* to occur at the fastest possible rate. It is only by maximizing *Mode Shift* as well as *Electrification* that China can sufficiently reduce emissions—and only through a combination of these strategies can such a reduction be fast enough to be consistent with holding global warming below 1.5°C (represented by the blue area in Figure B).

1 e.g. International Transport Federation (2023). ITF Transport Outlook 2023.

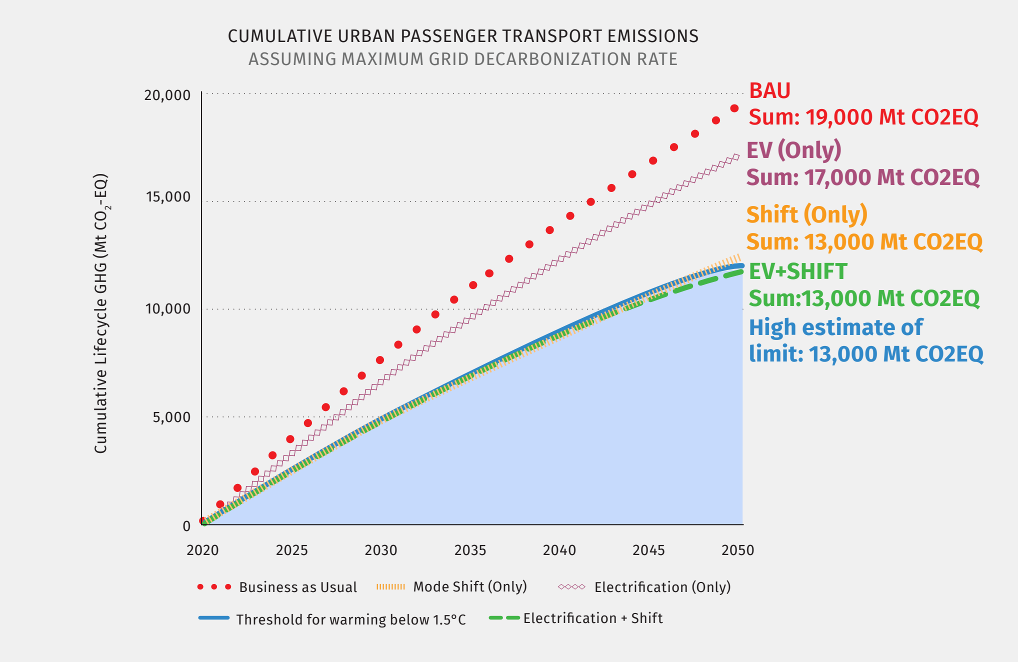

Figure B. Greenhouse gas emissions by scenario

To achieve the *Electrification + Mode Shift* scenario, China must restructure transportation and land-use policies to prioritize the movement of people rather than vehicles. Such restructuring will entail offering continued incentives and mandates for vehicle electrification, construction of compact mixed-use cities, and reallocation of street space and transportation funding from private motorized vehicles to walking, cycling, and public transport. In all scenarios, cars will still form an important part of the urban transport system, but the *Electrification + Mode Shift* scenario will offer the Chinese public a wide range of travel options that are clean and efficient.

By spending less money on building roads, governments will have more resources to devote to other public benefits or to lower taxes. And when Chinese citizens spend less money on fuel, they will be free to invest more in other areas of their life. By protecting our planet from the worst threats of climate change, we will make it possible for the country to prosper long into the future.

ACKNOWLEDGEMENTS

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CONTENTS

BACKGROUND

This study is the culmination of a decade of collaboration in transport modeling between ITDP and the University of California, Davis.[2] Ten years of effort have produced a detailed method for high-level modeling of urban and suburban passenger transportation, but this study of China and parallel studies of other countries are the first time the model has been used to publish analytical results for single countries.

Like its predecessor, *The Compact City Scenario—Electrified,* the current publication compares the economic and environmental implications of four scenarios for the future of urban passenger transportation: 1) the current trajectory; 2) intensive electrification; 3) intensive mode shift; and 4) a combination of the latter two. But while the previous report focused on the global need to pursue these strategies, this study describes the specifics for China. In addition to quantifying the emissions that each scenario would entail, we have also estimated the quantities and costs—or savings—of infrastructure that would result from different scenarios for the future of China. These results provide a "road map" for how those scenarios might be realized.

CHINA-SPECIFIC BACKGROUND

Chinese cities face the urgent need to revolutionize transportation planning given the ramping-up of private small passenger vehicles and the influx of new transport modes on the streets. Nonmotorized transport is regaining popularity. Bus and subway ridership is beginning to recover, but they still need time to return to pre-COVID levels.[3] According to the China Cycling Association, in 2022, more than 100 million people rode regularly or used bicycles as a means of transport, and nearly 10 million participated in outdoor cycling.[4] The shared-bike scheme is also becoming an essential part of people's everyday life. In Beijing alone, the number of trips made with shared bikes reached 1 billion in 2023, with the average distance of a single ride approaching 2.4 km and the average duration at 11.7 minutes. The ownership of private micro-vehicles has also experienced exponential growth —in 2022, 62 million powered two-wheelers were sold, with e-bikes accounting for 81% of the sales.[5]

1. Vehicle electrification goals in China fall into two major vehicle types: new energy vehicles (NEV; both passenger and commercial) and energy-saving passenger vehicles (meaning traditional ICE vehicles with lower average fuel consumption and hybrid electric vehicles). And their penetration rates are set for three milestone years: 2025, 2030, and 2035. China's 14th Five-Year Plan as well as the State Council's New Energy Vehicle Industry Development Plan (2021–2035) propose that by 2025, the annual sales volume of NEVs will reach about 20% of the annual total vehicle sales, and strives through 15 years of continuous effort to make pure electric vehicles the bulk [6] And according to the Carbon Peak Action Plan Before 2030, by 2030 the proportion of new energy and clean energy power transportation (vehicles) tools added that year should both reach about 40%.[7] A more specific automotive technology road map outlined by the China Society of Automotive Engineering commands that by 2035, all newly sold energy-saving passenger vehicles should be hybrid-electric vehicles (HEVs).[8]

2. However, the rapid spread of charging infrastructure and the intensive price competition between major car manufacturers have led to much faster adoption of NEVs. In 2022, China's NEV sales reached 6.887 million units, with a penetration rate of 28.2%, surpassing the 2025 target of 20% three years ahead of schedule.[9] China EV100 predicts that by 2024, sales of NEVs in China will hit 12.5 million units, with an expected penetration rate of 36% to 41%; the penetration rate will approach 50% by 2025, leading the country to achieve the 2035 target of 50% 10 years earlier.[10]

3. Energy-saving passenger vehicles are witnessing an even sharper climb than NEVs. This could be attributed to the disproportionate growth of plug-in hybrid electric vehicles (PHEVs). Data shows that in 2023, the number of insurance registrations for plug-in hybrid products increased by 84.69% year-on-year, more than double that of purely electric models.[11] One of the largest sources of growth among PHEVs is the Class A PHEVs of leading manufacturers including BYD and Geely Auto. BYD's Qin PLUS DM-i, for example, sold 430,000 units in 2023—the model alone accounted for one-tenth of the total Class A passenger car market size and about half of the new energy Class A sedan market.

4. The China Automotive Technology & Research Center (CATARC)'s CATARC's China Automotive Low Carbon Action Plan (2022) states that by 2030, NEVs should account for 50% of new car sales under the 2060 carbon neutrality scenario and 70% under the 2050 scenario. To significantly reduce carbon emissions in road transport, the 2030 NEV penetration rate should be raised to 70% or more.

2 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.
3 Ministry of Transport. "Statistical Bulletin on Transport Sector Development."
4 *China Economic Weekly* (2023), "Soaring cycling fever! More than 100 million people in China ride regularly, and sales of road bikes have surged over 200 percent since the end of May."
5 Energy Foundation China (2024), "China''s Bicycle Sharing and Electric Two- and Three-Wheelers: The World''s Best '"Last Mile"' Zero-Emission Solution."
6 The State Council of China (2020), New Energy Vehicle Industry Development Plan (2021-21–2035).
7 The State Council of China (2021),Carbon Peak Action Plan bBefore 2030.
8 China Society of Automotive Engineering (2023), "Energy-saving and NEV Technology Roadmap 2.0."
9 Hainan New Energy Vehicle Promotion Centre (2023), "Miao Wei, former Minister of Industry and Information Technology: The target of reaching 50% new energy vehicle penetration rate may be achieved ten years ahead of schedule." Retrieved from: https://mp.weixin.qq.com/s/GAZ1Z22i1THOhcqqk6PsyQ
10 China EV100 (2024), "Ouyang Minggao: nNew energy vehicle penetration rate close to 50% in 2025, plug-in hybrid will account for 50% of the total." Retrieved from: https://mp.weixin.qq.com/s/SnyiAAJ3TJ84VBCrXMUB0w
11 Ibid.

FOUR SCENARIOS

Like the global study and parallel reports for other countries, this research investigates four scenarios for urban passenger transport in China through 2050. These scenarios are diagrammed in Figure A. We start by understanding these scenarios qualitatively, including a summary of the impacts that they might have outside the scope of our modeling analysis—factors such as public health and economic inclusion. In Section 3 (page 12), we define these scenarios quantitatively for modeling.

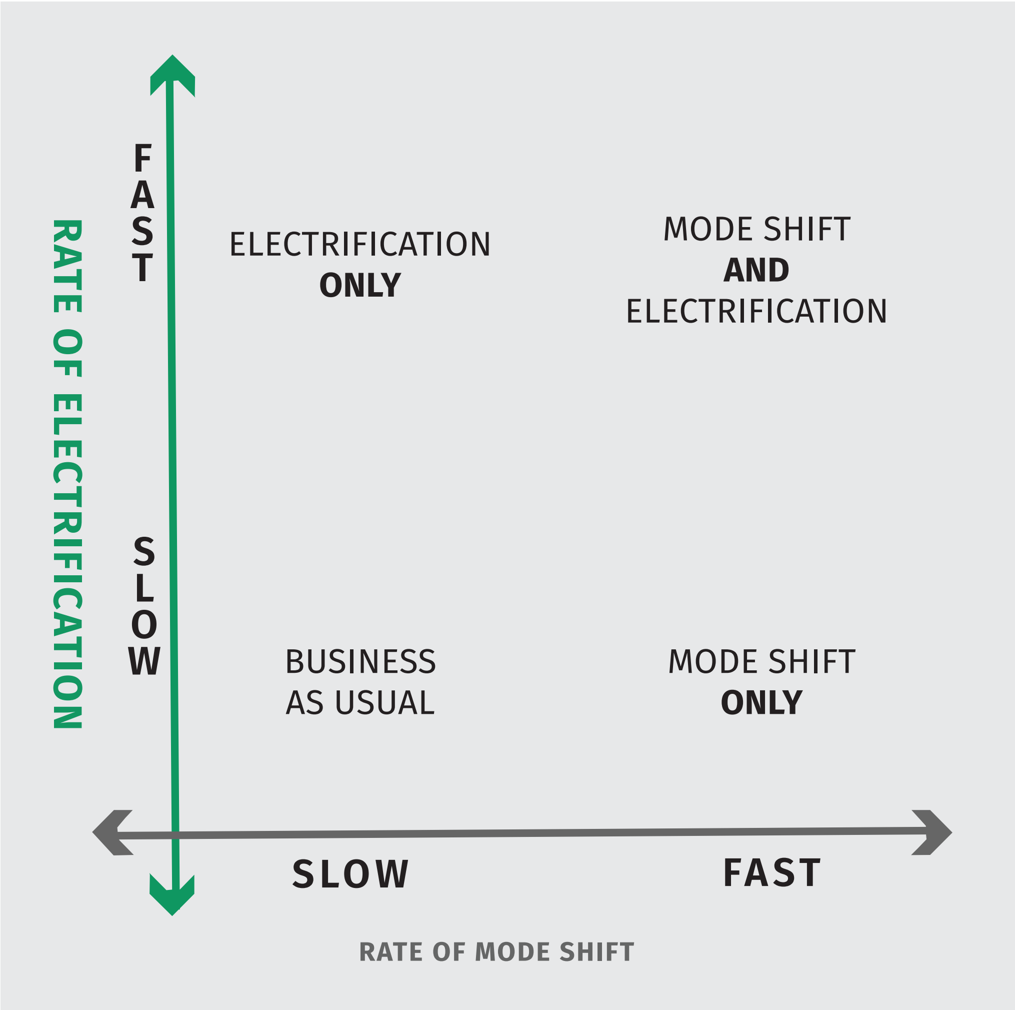

Figure A. Diagram of scenarios

Assumptions:

- China continues its current trajectory. Private motorized travel increases rapidly, becoming responsible for 87% of urban passenger travel by 2050. Electrification is fairly rapid, following current plans, with nearly half of new vehicles electric by 2030.

Qualitative impacts:

- Increase in traffic fatalities[12]
- High direct public and private costs[13]
- Reduced access to opportunities for low-income or historically marginalized people without cars, leading to increased wealth inequality[14]
- Increase in local air pollution, causing many premature deaths and increased healthcare costs[15]
- Increase in urban highways, dividing neighborhoods and subsidizing environmentally unfriendly sprawl[16]
- Increase in carbon emissions, leading to climate catastrophe[17]

12 Unsurprisingly, steady population growth has historically translated to a corresponding increase in road fatalities, particularly among pedestrians. See: National Safety Council (2021), Car Crash Deaths and Rates; Governors Highway Safety Association (2022), Pedestrian Traffic Fatalities by State: 2022 Preliminary Data.
13 For example, highway infrastructure spending per mile has risen dramatically: Accounting for inflation, $8 million in the 1960s per mile became $30 million per mile by the 1990s. See: American Economic Association (2023), Infrastructure Costs.
14 National Equity Atlas, Indicator: Car Access.
15 Despite great gains in air quality in the US, as of 2022, approximately 85 million people nationwide lived in counties with pollution levels above National Ambient Air Quality Standards. Increased natural events such as wildfires partially due to climate change will further erode air quality. See Union of Concerned Scientists (2014), Vehicles, Air Pollution, and Human Health; United States Environmental Protection Agency (2023), Air Quality National Summary, 1980–20–2022.
16 Greg LeRoy, JSTOR (2004), Subsidizing sprawl: Economic development policies that deprive the poor of transit, jobs.
17 Andrew Moseman, MIT Climate Portal (2022), Are electric vehicles definitely better for the climate than gas-powered cars? The answer is yes, though the extent to which improvement is meaningful is based on electricity source and manufacturing emissions. The *BAU* scenario will encourage car-oriented development with a limited increase of clean energy.

ELECTRIFICATION (ONLY)

Assumptions:

- Electrification proceeds even more rapidly than is currently planned, with 63% of new light-duty vehicle sales being electric by 2030.

Qualitative impacts:

- 👍 Sharp reduction in carbon emissions[18]
- 👍 Sharp reduction in local air and noise pollution[19]
- 👎 Increase in traffic fatalities
- 👎 High direct public and private costs
- 👎 Reduced access to opportunities for low-income people without cars
- 👎 Increase in urban highways, dividing neighborhoods and subsidizing environmentally unfriendly sprawl
- 👎 Consumption of limited supply of critical minerals, raising concerns related to extractive industries, conservation, national security, and supply chain

Key policies:

- Supply- and demand-side EV incentives
- Ambitious fuel economy and tailpipe GHG emission standards
- Battery reuse and recycling
- Equitable placement of standardized public charging points for EVs (including two-wheelers)
- Electric grid expansion and decarbonization

18 With high electrification, the emissions from transport will be reduced sharply. See: Andrew Mosemen, MIT Climate Portal (2022)., Are electric vehicles definitely better for the climate than gas-powered cars?
19 Tsoi et al., (2023), "The co-benefits of electric mobility in reducing traffic noise and chemical air pollution: Insights from a transit-oriented city."

Assumptions:

- Compact city planning is combined with reallocation of both funding and street space to walking, bicycling, and public transport. In this case, China slows the construction of new urban roadways, focusing instead on providing denser housing, mixed land use, and better bus/bicycle infrastructure on existing roadways. Car travel continues to rise in absolute terms, but much more slowly than in *Business as Usual,* and it remains the mode of choice for less than half of urban travel.

Qualitative impacts:

- 👍 Reduction in traffic fatalities[20]
- 👍 Increased access to opportunities, especially for low-income people, people of color, and other groups suffering from spatial segregation, people with disabilities, and the elderly or young[21]
- 👍 Increase in walking and cycling, which improves physical and mental health, reducing healthcare costs[22]
- 👎 High local air and noise pollution from ICE vehicles relative to Electrification (Only)

Key policies:

- Reallocation of transport budgets to walking, cycling, and public transport, especially BRT
- Street redesigns that shift space from travel lanes and parking to BRT lanes, physically protected bicycle lanes, and footpaths
- Promotion of bicycles, especially shared electric bicycles

20 Dangerous by Design (2022).
21 See: National Library of Medicine (2023), Does the compact city paradigm help reduce poverty? Note, this is most effective in mitigating poverty in combination with housing affordability measures; also see Urban Institute (not dated), Causes and consequences: Separate and unequal neighborhoods.
22 Matthew Raifman et al. (2021), Mortality iImplications of increased active mobility for a proposed regional transportation emission cap-and-invest program.

Assumptions:

- Compact cities and mode shift, combined with rapid electrification: Electrification and Mode Shift together.

Qualitative impacts:

- Reduction in traffic fatalities[23]
- Increased access to opportunities for all
- Increase in walking and cycling, which improve physical and mental health, reducing healthcare costs
- Extensive 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 for growth in urban highways
- Creation of low-emission areas to incentivize both Mode Shift and vehicle Electrification
- Achieving the Electrification or Mode Shift scenarios would require profound but feasible changes in China’s national policy—changes that are possible under China’s current political and economic structure. They would involve restructuring how transportation budgets are allocated, how street space is used, and how taxes and subsidies are applied to vehicles and fuel—but they are incremental changes that can be reached in the current system and would not require a “revolution” in any economic, social, or political sense.

23 Dangerous by Design (2022).

METHODOLOGY

This study uses the same methods as the 2021 *Compact City Scenario—Electrified* and the other 2023/2024 country-level studies published by ITDP and UC Davis. In each of these studies, we define four scenarios and estimate their impacts using the same modeling methods. This section will first describe the structure of these modeling methods and then outline our process for defining the scenarios that are taken as modeling input. For a more detailed description of the methodology, including a complete set of data, please review the accompanying methodological appendix.

3.1. Structuring the Model

Our study is limited to urban passenger transportation and does not include intercity travel, rural travel, or freight carriage of any kind. We define "urban" based on United Nations data, including all urban or suburban areas of 300,000 people or more.[24] This definition encompasses about 80% of the Chinese population. Other research shows that both *Electrification* and *Mode Shift* will be necessary to decarbonize rural/intercity[25] and freight[26] transport, and this focus limitation in our scope allows us to model urban and suburban travel with more precision.

The model is calibrated to industry-standard data from the International Energy Agency's *Mobility Model*[27] except where more detailed China-specific data is available. This calibration determines the estimation of conditions in the base year, the projection of the *Business as Usual* scenario, and factors such as emissions factors, fuel emission intensities, and costs.

This general modeling approach was reviewed as part of the 2021 publication, and a list of reviewers can be found there.[28] Our method provides a high-level comparison of different scenarios rather than a detailed bottom-up analysis. This results in a perspective that's relevant to the urban passenger transport sector broadly rather than focusing exclusively on a handful of specific policies.

3.2. Defining Scenarios

After setting the scope and calibrating the model, the next step is to quantitatively define the four scenarios for urban passenger transportation in China that were described on page X, above. Beginning from the base year of 2015[29] and looking at time points in 2030 and 2050, we describe possible futures. These scenarios are not intended to precisely define the only options for the future of the sector; rather, they are meant to give an idea of general trajectories that are possible for urban passenger transport.

For electrification, our forecasting is expressed in terms of the percentage of new vehicles that are electric. The *Business as Usual* and *Mode Shift* scenarios share the same lower electrification rates; the *Electrification* and *Electrification + Mode Shift* scenarios share the same higher electrification rates. There may be fewer new cars sold per year in the *Mode Shift* scenario, but the same percentage of those cars are electric. Similarly, modal splits and travel activities (defined in terms of person-miles traveled by different modes) are identical in the *Business as Usual* and *Electrification* scenarios, with higher levels of car use; these are also identical in the *Mode Shift* and *Electrification + Mode Shift* scenarios, with lower levels of car use.

After defining these scenarios, we will estimate their implications. For each scenario, based on the size of vehicle fleets and the amount of activity per vehicle, we estimate life cycle[30] greenhouse gas emissions (Section 4), energy consumption (Section 5), and total quantities and costs of infrastructure, vehicles, fuel, and operation (Section 6).

3.2.1. Scenarios for Electrification Rates

The ***Business as Usual*** **and** ***Mode Shift*** **scenarios** follow the same projections for the percentage of new vehicles that are electric, broken down by year and vehicle type—the *sales shares* of vehicles. In these scenarios, our projections are meant to align with the country's current trajectory. These projections, shown in Figure B, are based on estimates by ITDP's China team. Based on research by institutions such as BCG, McKinsey, Roland Berger, Goldman Sachs, and Bloomberg on China's road transport carbon neutrality and carbon peaking, the projected NEV penetration rate for 2030 is between approximately 57% and 70%. We assume a 60% NEV penetration rate under the *Business as Usual* scenario for 2030. NEVs include battery-electric vehicles (BEVs) and other NEVs, with the majority being PHEVs. From a carbon emissions perspective, we assume that PHEVs are equivalent to half BEVs and half ICEs. According to expert forecasts[31] the ratio of BEVs to PHEVs in 2030 will be 4:3. Consequently, from a carbon emissions perspective, it is estimated that BEVs will account for 47% in 2030. Similarly, assuming an 80% NEV penetration rate under the Business *as Usual* scenario for 2050, it is estimated that BEVs will account for 63% that year.

The ***Electrification*** **and** ***Electrification + Mode Shift*** **scenarios** follow sales share projections that

24 United Nations Department of Economic and Social Affairs (2018), World Urbanization Prospects.
25 International Transport Forum: OECD (2023), ITF Transport Outlook 2023.
26 Lynn H. Kaack, Environmental Research Letters (2018), Decarbonizing intraregional freight systems with a focus on modal shift.
27 The *Mobility Model* is only available under a closed license, and the full dataset cannot be shared. However, all relevant variables for the US are included in the methodological appendix and may be reviewed there.
28 ITDP & UC Davis (2021), *The Compact City Scenario—Electrified*.
29 The base year of 2015 rather than a more recent year was selected for three reasons, rather than a more recent year. First, for methodological reasons we required a constant base year across all of the 'Compact Cities Electrified ' sibling studies for various countries, to ensure reliability and comparability. Second, data is more reliably available for 2015 than for more recent years. Third, we hoped to avoid distortions due to COVID-19.
30 Including emissions not only 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.
31 https://auto.ifeng.com/qichezixun/20230608/1868175.shtml#:~:text=%E5%88%B02030%E5%B9%B4%E6%96%B0%E8%83%B-D,3%E6%88%963%3A4%3A3%E3%80%82

reflect the maximum speed of electrification feasible in China. These projections, shown in Figure B, are also adapted from the ICCT by ITDP China's team.[32].

	Percentages of New Vehicle Sales that Are Electric (Rather than Internal Combustion)					
	Business as Usual and Mode Shift (Only)			*Electrification (Only) and Electrification Mode Shift*		
	2015	2030	2050	2015	2030	2050
LDVs (Cars and light trucks)	1%	47%	63%	1%	63%	100%
2- Wheelers/ motorcycles (not including e-bikes)	70%	100%	100%	70%	100%	100%
buses	30%	100%	100%	30%	100%	100%

Figure B. Electrification rates by vehicle type, year, and scenario

3.2.2. Scenarios for Mode Shift Rates

The ***Business as Usual*** **and** ***Electrification*** **scenarios** include modal splits and travel activity projections based on the industry-standard International Energy Agency's (IEA) Mobility Model, which includes base-year estimates and future projections of travel breakdowns by mode. They can be seen in figures E and F.

The ***Mode Shift*** **and** ***Electrification + Mode Shift*** **scenarios** follow our own calculations, in two steps. First, we project possible future urban densities in China under a maximum-feasible policy to promote compact, mixed-use cities. Second, we identify the maximum feasible replacement of car and motorcycle travel and substitution with walking, bicycling, public transportation, telecommuting, or shorter trips, including a factor to show how mode shift can be more easily achieved in compact communities. For more detail on this modeling process, see Appendix C: Methodological Documentation [Add link].

The first step of the calculation draws on data from the European Commission's Global Human Settlement Layer[33] identifying the current trends in urban density and then also projecting a *compact cities* scenario in which various policies come together to achieve the following effect:

In the *Mode Shift* scenarios, cities in China immediately stop sprawling, consuming no new undeveloped urban land. Rather, population growth is concentrated in areas that currently have less than 8,000 people per km^2 to bring them to a population above that level. This threshold is arbitrary, but it reflects a general point at which it becomes feasible to serve urban areas with public transportation. The modeling approach is meant to generally represent a densification that could be achieved through "missing middle" housing[34] and zoning reform to permit by-right multifamily construction (without parking minimums) on all urban land.

Unlike in many other countries, much of China's urban population already lives at this relatively compact level, and the existing trend is toward further densification (see Figure C). However, a shift toward further compactness is still necessary: In the *Business as Usual* trajectory, by 2050 we expect that about 240 million urban Chinese will live at densities below 8,000 people per km^2. To meet the *Mode Shift* scenarios, that number must fall to about 60 million (from about 100 million today). This can be accomplished through relatively modest infill development, rather than drastic changes to neighborhoods.

32 Sen and Miller, Vision 2050
33 ghsl.jrc.ec.europa.eu/
34 Missing Middle Housing is "a range of house-scale buildings with multiple units—compatible in scale and form with detached single-family homes—located in a walkable neighborhood."

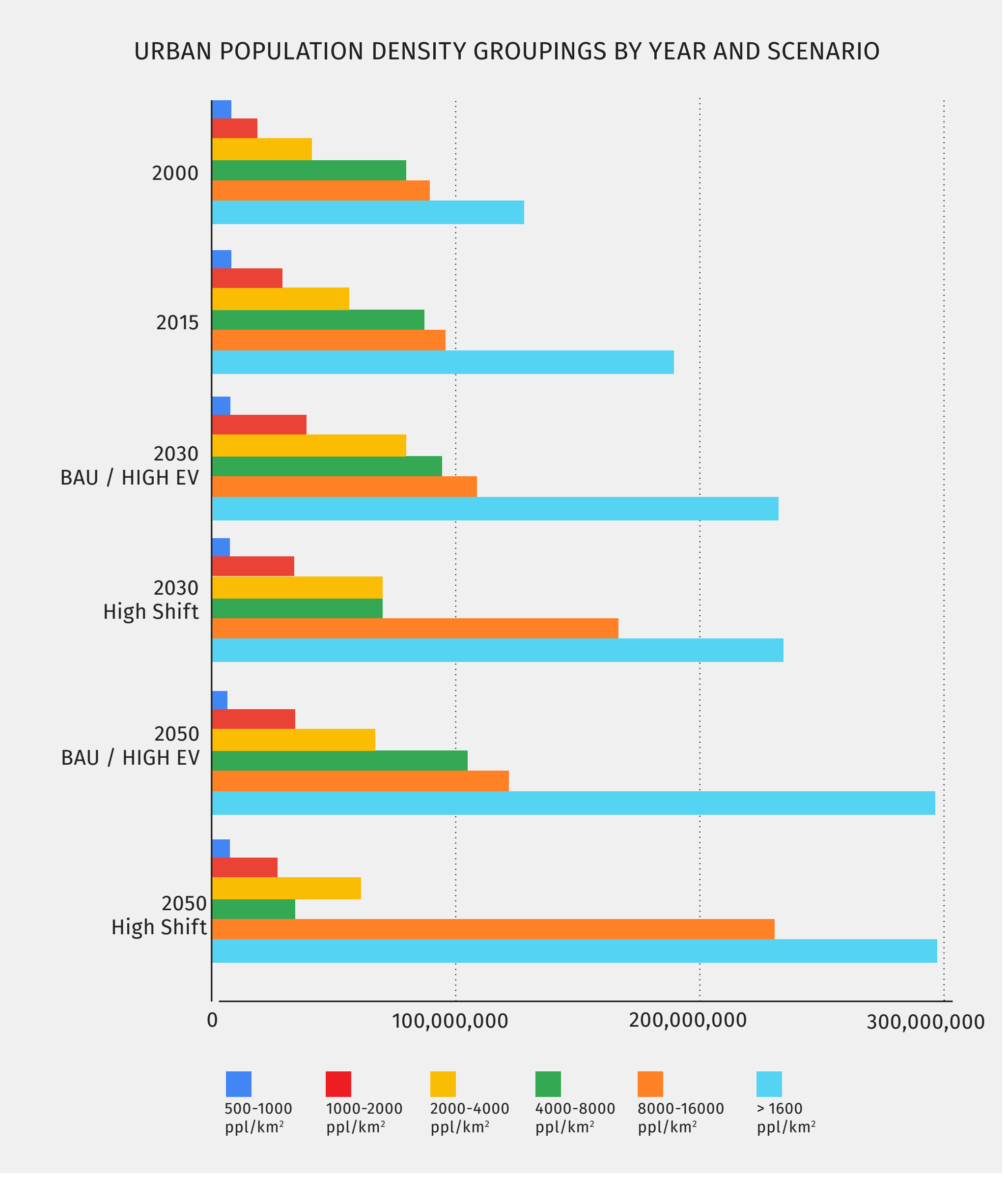

Figure C. Urban density groupings

In the second step, after estimating future densities, we used the projected potential urban densities to identify the maximum feasible reductions in car and motorcycle travel as a function of those densities. In more compact communities, it will be easier to replace car travel with travel by other modes. We estimate that a 19 percent reduction in car/motorcycle travel relative to 2030 *Business as Usual* and a 52 percent reduction relative to 2050 *Business as Usual* are achievable. The specific redistribution of this travel to other modes was based on expert judgment, reviewed by the China-specialist reviewers listed on page X; more detail can be found in Appendix C: Methodological Documentation. The results of this calculation are a modal shift relative to *Business as Usual,* shown in figures E and F, below.

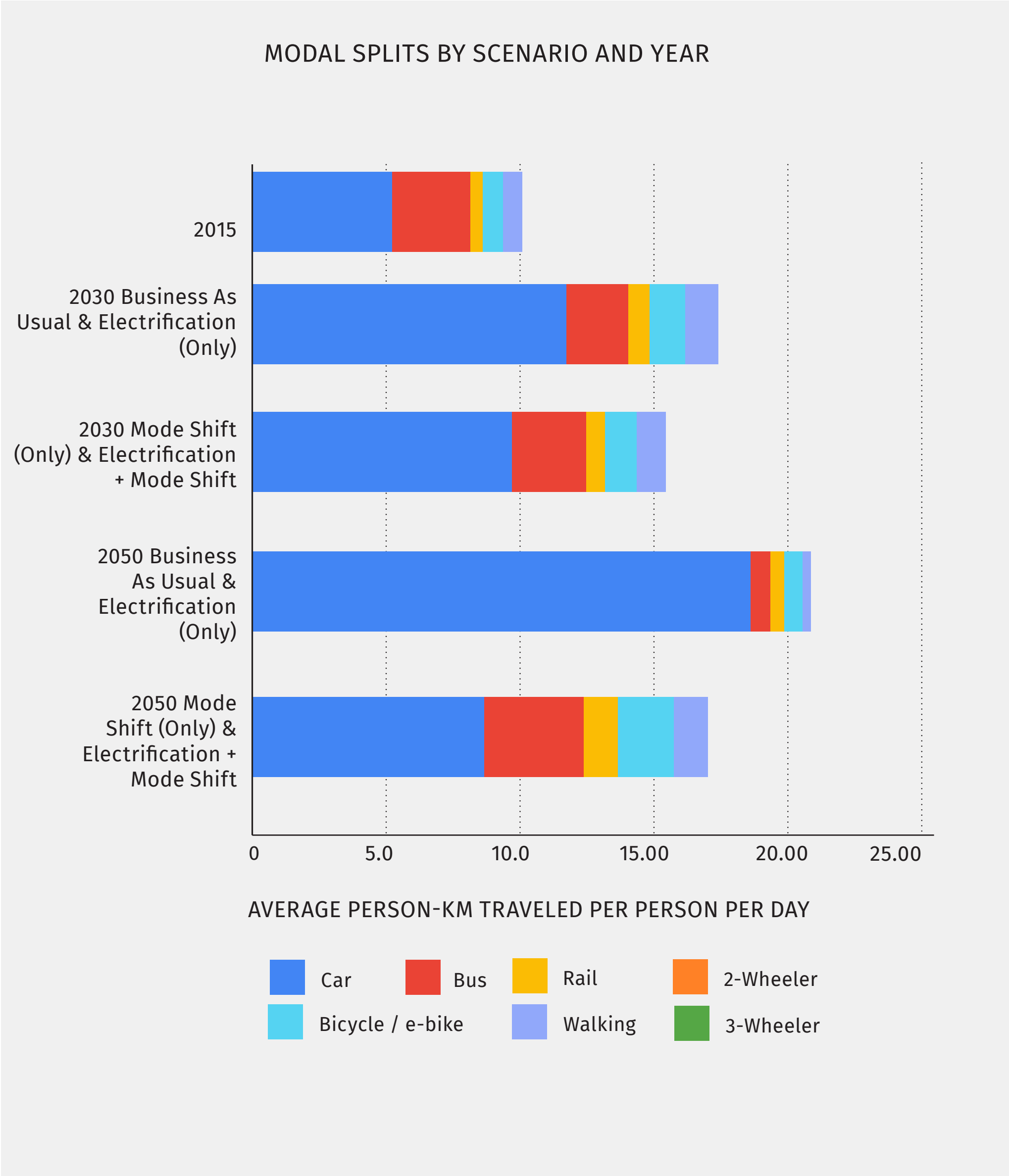

Figure E. Travel activity

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	54%	77%	65%	87%	47%
Bus	21%	10%	15%	5%	22%
Rail	4%	3%	4%	3%	7%
2-Wheeler	41%	0%	0%	0%	0%
Bicycle/e-bike	10%	5%	9%	4%	5%
Walking	11%	5%	7%	2%	8%

Figure F. Mode splits by percent of travel

SCENARIO COMPATIBILITY WITH CHINA CLIMATE COMMITMENTS

China's commitments to greenhouse gas reductions are ambitious. Our modeling shows that the country's decarbonization goals in the urban passenger transport sector cannot be met with *Electrification* or with *Mode Shift* alone , but require both strategies in concert.

4.1. China Climate Targets

China 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."

Additionally, President Xi Jinping declared a commitment to "carbon neutrality before 2060" at the UN General Assembly in 2020. A year later, China further outlined this goal in its Long-Term Low Greenhouse Gas Emission Development Strategy (LTS) to the UNFCCC.[35] A few mid-century targets provided include the following:

Reach peak carbon emissions by 2030 and carbon neutral by 2060 in its Nationally Determined Contribution (NDC)
Reduce carbon emissions from the transportation sector by more than 10% in 2030
Reduce carbon emissionsfrom the transportation sector by more than 10% in 2030

Furthermore, as of 2020, China has affirmed its commitment to reaching net zero by 2060.[36]

While these efforts are significant, the Climate Action Tracker[37] highlights that the net zero goal and its associated commitments are exclusively focused on CO_2 emissions, despite a net-zero goal for all GHG emissions being necessary for the 1.5°C limit in the Paris Agreement.

4.2. Scenario Impacts on Transport Emissions

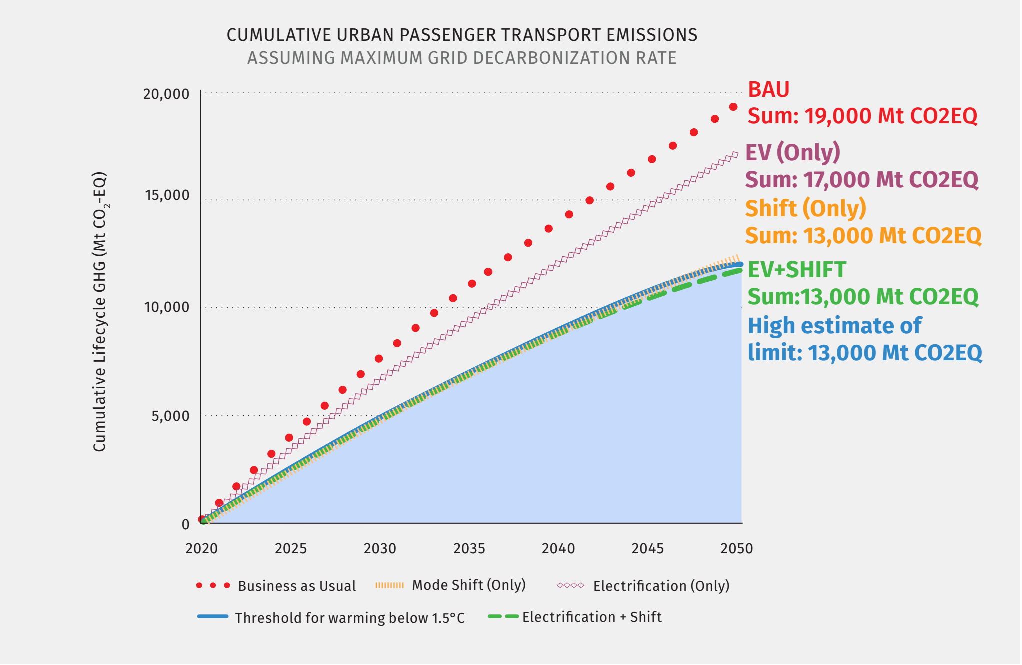

Figure G Greenhouse gas emissions by scenario

Because of China's successful electrification efforts and their projected effectiveness, the *Electrification* scenario alone only yields moderate results when compared to the Business *as Usual* scenario, and it fails to uphold China's climate commitments by a wide margin. While the *Mode Shift* scenario would cause a considerable reduction in greenhouse gas emissions, only the combined *Electrification + Mode Shift* scenario will reliably keep 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[38] in Figure G, above.[39]

Not only is *Electrification + Mode Shift* the only scenario that will reliably hold global warming within Paris Agreement goals, it is also the only scenario that approaches China's goal of achieving net zero carbon emissions by 2060.

35 UNFCCC. (2021),. China's Mid-Century Long-Term Low Greenhouse Gas Emission Development Strategy
36 https://www.gov.cn/gongbao/content/2020/content_5549875.htm
37Climate Action Tracker. (2023). , https://climateactiontracker.org/countries/china/targets/
38 Carbon budgets are allocated by the ratio of the US'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.
39 Note: Our analysis shows that the *Electrification + Mode Shift* scenario will exceed the 1.5° threshold by nearly 1Gt, a shortfall that will need compensation from decarbonization of other sectors of the American economy.

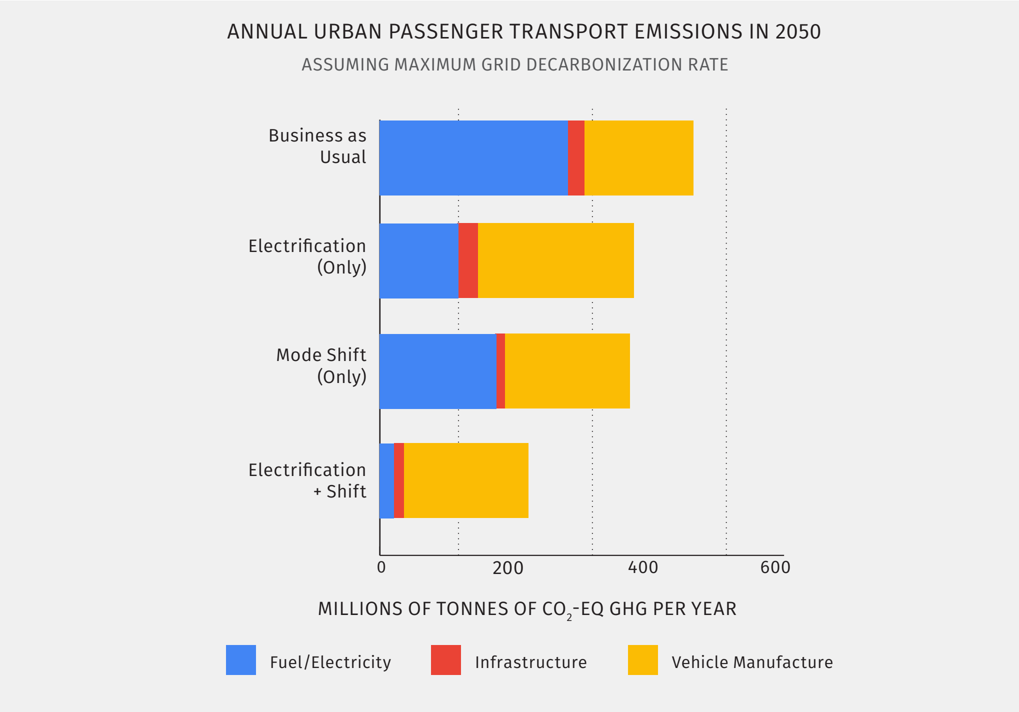

Figure H. Annual greenhouse gas emissions by scenario and source

With a decarbonized grid, electric vehicles will cause very low emissions through their operation. 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 and batteries as well as other industrial processes involved in vehicle manufacture and disposal. Under the *Electrification* scenarios, as can be seen in Figure H, more than half of emissions are from these sources, which are much more challenging to decarbonize. Indeed, electrification actually increases manufacturing emissions by about 34 percent relative to *Business as Usual* because of the emissions intensity of battery manufacture and of heavier vehicles.[40]

Electrification alone also requires exponential growth in scarce minerals critical for batteries. The environmental, environmental justice, and national security challenges entailed by that would be significantly mitigated by combining *Electrification* with *Mode Shift* and reducing overall dependence on passenger vehicles while electrifying.[41]

4.3. Modal Shift Reduces Dependence on Grid Decarbonization

Modal shift provides a hedge against obstacles that may arise in decarbonizing the electrical grid. By combining mode shift and electrification, China may still achieve substantial decarbonization even if the shift to electric vehicles and/or renewable electricity generation is slower than optimistically projected.

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

China's electricity grid currently has an emissions intensity of roughly 526 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 International Energy Agency's (IEA's) *Sustainable Development Scenario*. Following this assumption, the grid emissions intensity falls to about 10 g CO_2/kWh by 2050.

40 This 8 percent figure is conservative, based on the assumption of rapid decarbonization of the manufacturing sector by 2050. Eighty percent is a reasonable estimate today: See Andrew Moseman & Sergey Paltsev, MIT Climate Portal (2022), Are electric vehicles definitely better for the climate than gas-powered cars?
41 Center on Global Energy Policy (2023), Q&A: Critical minerals demand growth in the net-zero scenario.

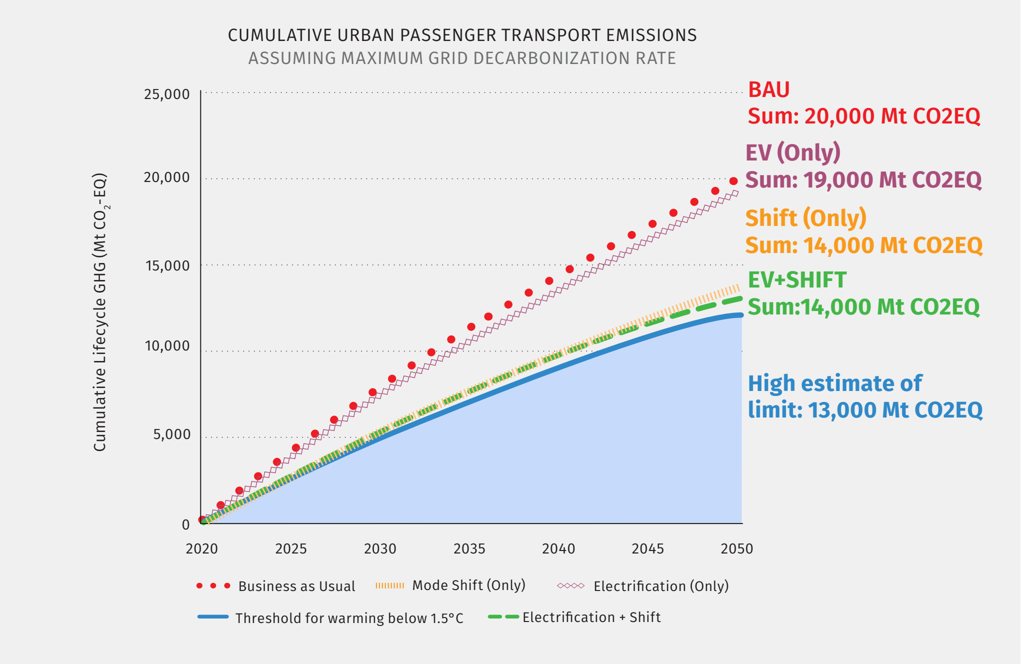

Figure G. Cumulative urban passenger transport emissions by scenario, with threshold

Current policies (as per IEA's Stated Policies Scenario) are only projected to reach a grid intensity of about 160 g CO_2eq/kWh by 2050 compared to 526 today. This is still an optimistic forecast, but in this case, our *Electrification* scenario loses much of its effectiveness in reducing cumulative emissions while *Mode Shift* loses less, shown in Figure G, above. In this case, none of the scenarios is under the blue area signifying compatibility with the 1.5°C threshold, but *Electrification + Mode Shift* comes the closest.

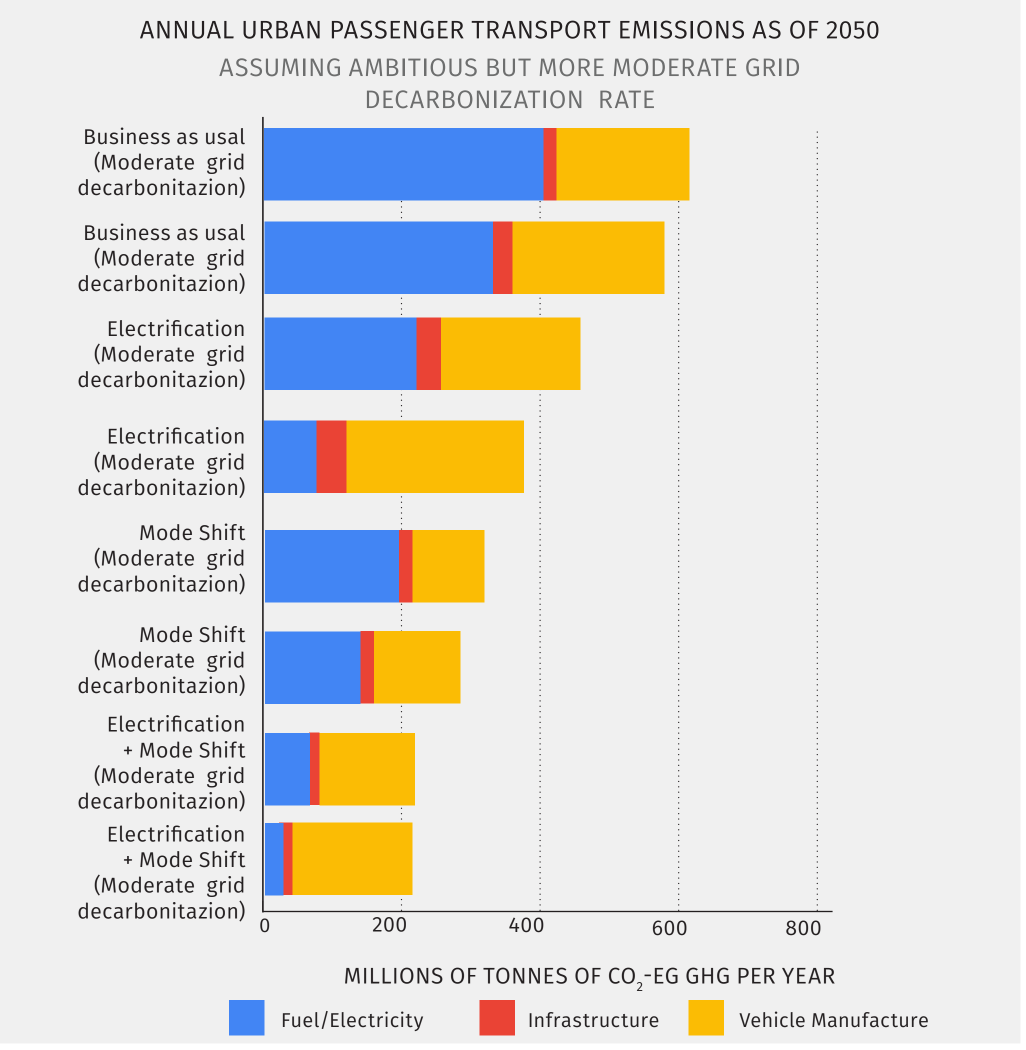

Figure H. Annual emissions as of 2050 by scenario and grid decarbonization

The more conservative grid decarbonization projections also shed light on China's prospects for reaching its goal of net zero by 2050, as seen in Figure H. If grid decarbonization proceeds in line with current stated policies, it will be impossible for China to achieve that goal without both *Electrification* and *Mode Shift*.

SCENARIO IMPACTS ON ELECTRICITY CONSUMPTION

Mode Shift not only provides a degree of redundancy with *Electrification,* it also reduces the burden of rapid grid decarbonization by dramatically reducing the increased electricity demand that vehicle electrification will cause. Furthermore, *Mode Shift* increases resiliency at all levels by providing redundancy in transportation options.

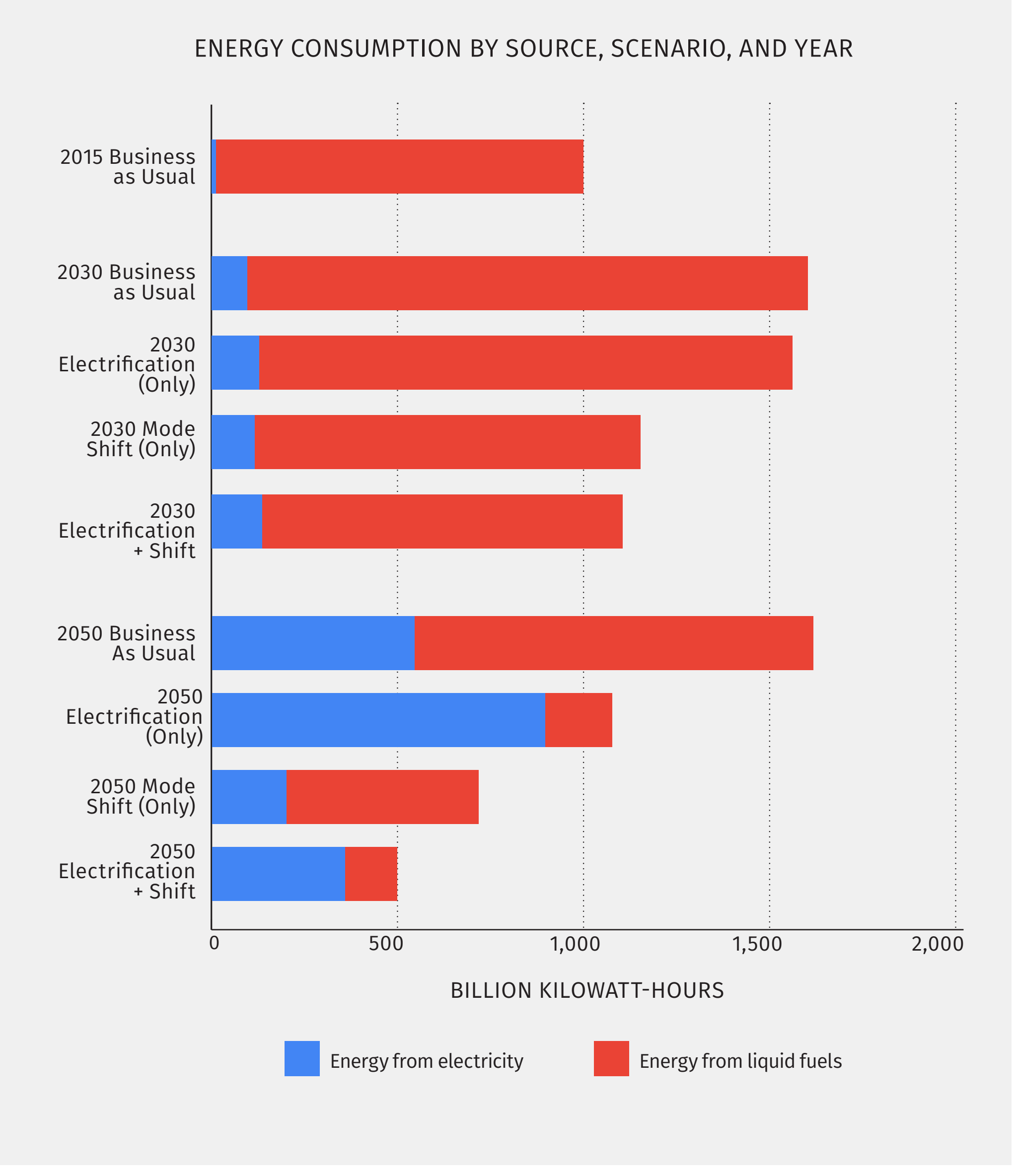

Figure K. Annual energy consumption

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 mile than internal-combustion vehicles. However, that reduction in total energy consumption comes with a great increase in electricity use, as seen in Figure K.

In the *Electrification* scenario, urban passenger transport in China will consume about 271 billion kWh of electricity annually by 2050. *Electrification + Mode Shift* reduces this consumption by about 50 percent (400 billion kWh), or the equivalent of the annual power generation of almost 83,000 wind turbines. That might mean a reduction in the costs of building infrastructure for renewable power generation or freeing up electricity for other urgent needs in the face of the climate crisis.

DIRECT PUBLIC AND PRIVATE EXPENSES IN EACH SCENARIO

The *Mode Shift* and *Electrification + Mode Shift* scenarios offer efficiencies that could save about 120 trillion CN¥ for the Chinese economy overall, including savings for the public and private sectors.

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 expenses of manufacturing, maintaining, fueling, and operating vehicles and the expenses of building and maintaining infrastructure. These are shown in Figure L.

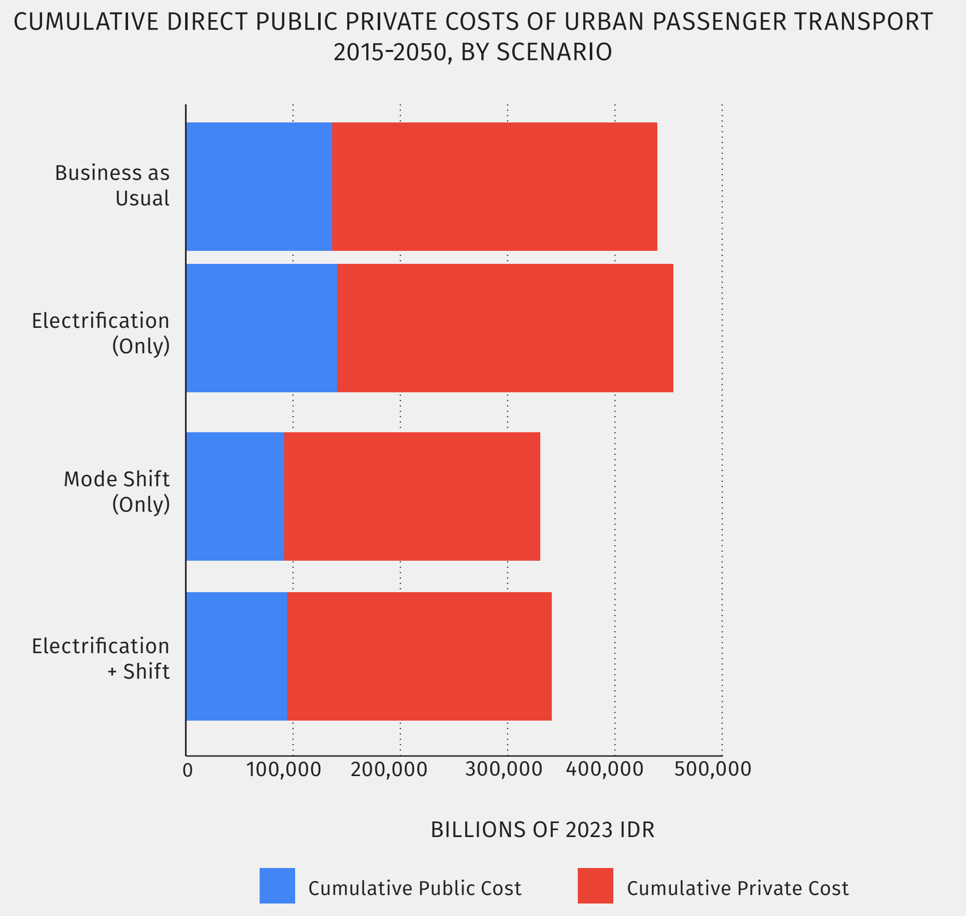

Figure L. Cumulative direct costs of urban passenger transport

These expenses can be divided into those borne ultimately by the public sector and by individuals.[42] *Mode Shift* would lead to enormous economic savings for the Chinese economy—a cumulative savings of about $60 trillion CN¥. Of this, about $9 trillion CN¥ in savings would accrue to national, state, and local governments, tabulated in Figure N in Section 7, below.

Our calculations only include the direct costs of urban passenger transport and not indirect costs such as healthcare expenses related to vehicle collisions or sedentary lifestyles; costs related to air, noise, or water pollution; costs of farmland or natural areas lost to suburban sprawl; or, conversely, the economic benefits derived from job creation[43]. All these indirect costs are likely to mean that the true economic benefit of *Electrification + Mode Shift* would be many times higher than we have calculated.

42 For the sake of conservatism, in these calculations we have assumed that the government will bear the entire cost of public transport operations—that is, fares will be free. We do expect that public transport subsidies will increase in the *Mode Shift* scenarios, though possibly not to this extreme.
43 Investments in public transit create nearly twice as many jobs per dollar as investments in new road-building. See: Transportation for America (2021), [Road and public transit maintenance create more jobs than building new highways](#).

MEASURABLE GOALS FOR URBAN PASSENGER TRANSPORTATION

It is possible for China to achieve the *Electrification + Mode Shift* scenario. This scenario offers enormous savings to the public sector as well as private individuals and enterprises, while also reducing emissions from urban passenger transportation to the level most closely consistent with the country's climate commitments. It will not require any additional funding beyond the resources that China already expends on urban passenger transportation—rather, *Electrification + Mode Shift* will only require a change in policies and a reallocation of resources.

There are three elements that must come together to achieve the *Electrification + Mode Shift* scenario: first, increased vehicle efficiency, primarily through electrification; second, land-use reform to make trips shorter by promoting compact mixed-use cities; third, facilitating *Mode Shift,* primarily by providing alternative infrastructure but also by pricing car travel according to its true cost.

In this section, we provide evidence-based goals for each of these three elements based on the quantitative analysis in this study. If achieved, these goals would bring the benefits of the *Electrification + Mode Shift* scenario. These goals could be accomplished in many ways, and in Appendix A, we provide basic policy agendas at the federal, state, and local levels that could help China reach them..

7.1. Goals for Electrification

To achieve the country's climate commitments, electrification must proceed much more rapidly than its current course. As discussed in Section 3.2.1, new sales of different vehicle types must be electrified at the rates shown in bold in Figure M below. Most importantly, 63 percent of all new light-duty vehicle sales (cars and light trucks) must be electric by 2030, and 100 percent by or before 2050.

Percentages of New Vehicles that Are Electric (Rather than internal-Combustion)

	Business as Usual and *Mode Shift (Only)*			*Electrification (Only)* and *Electrification + Mode Shift*		
	2015	2030	2050	2015	2030	2050
LDVs (Cars and light trucks)	1%	47%	63%	1%	63%	100%
2- Wheelers/ motorcycles (not including e-bijes)	70%	100%	100%	70%	100%	100%
Buses	30%	100%	100%	30%	100%	100%

Figure M. Sales of electric vehicles by year and scenario

7.2. Goals for Land Use

More compact, mixed-use urban form will have a twofold benefit for the cities of China. First, when people live closer to their places of work or leisure, trips will be shorter, and so even ICE cars will emit less and cost motorists less. Second, when trips are shorter, they are easier to take by bicycle or public transport, facilitating *Mode Shift.*

Achieving the *Electrification + Mode Shift* scenario and meeting the country's climate commitments will require China to maintain policies that enable compact urban development, while promoting mixed-use and transport-oriented development. As discussed in Section 3.2.2 above, Chinese cities must curb the growth of less-dense neighborhoods and commit to a more compact restructuring of urban residential areas.

7.3. Goals for Transportation Infrastructure

This analysis provides the clearest agenda for the third of the three components necessary to achieve the *Electrification + Mode Shift* scenario—the specific transportation infrastructure investments needed to achieve such levels of *Mode Shift* and the estimated savings that are possible by pursuing such a strategy.

Figure N, below, indicates the extent of infrastructure and vehicle investment that China must make to reach the *Electrification + Mode Shift* scenario. As shown in Figure N, the *Shift* element of the scenario will mean that central, state, and local governments will save about $1 trillion CN¥ by 2050. The expense of building and operating transit will be more than balanced by the reduced need to build and maintain highways.

Total New Infrastructure and Vehicles Required 2015–2030							
	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 governm ents (Trillion CN¥)
Business as Usual & Electrification (Only)	1,000,000	900	1,800	13,000	1,100,000	11,000	42
Mode Shift (Only) & Electrification + Shift	600,000	13,000	3,700	480,000	1,300,000	15,000	37
Total New Infrastructure and Vehicles Required 2015–2050							
	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 governm ents (Trillion CN¥)
Business as Usual & Electrification (Only)	2,500,000	2,700	3,700	17,000	2,200,000	31,000	130
Mode Shift (Only) & Electrification + Shift	810,000	41,000	14,000	190,000	3,600,000	61,000	$98

Figure N. Detailed description of infrastructure and investment requirements by scenario

This analysis provides a road map for transportation infrastructure investments in cities across China. It makes a few points clear:

- Nationwide, China will have to reduce urban road building by one-third to shift to the more space-efficient modes of transportation made possible by denser cities. This aligns with the study's findings concerning urban density, which show that the expansion of cities into rural or natural land must immediately stop, and that growth must instead take place through the densification of existing areas.
- Cities across the country will have to build more than 25,000 km (50,000 lane-km) of rapid transit by 2050. Nearly 75 percent of this will be bus rapid transit (BRT) rather than metro rail. This must be full BRT in contrast to regular bus lanes, as described in the BRT Standard, with center-running dedicated busways that have off-board fare payment, intersection priority, and platform-level boarding. In 2019, China BRT route's total length reached 6,149 km, with a compound annual growth rate of 14.33 percent from 2013 to 2019.
- Cities will also have to build hundreds of thousands of miles of bicycle lanes. These must be physically protected lanes, not merely lanes separated from vehicle traffic by painted lines, buffer space, or small bumpers that can be driven over. They also must be separated from pedestrian traffic.

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 and Bogotá have each built a mass transit system with more than a million riders a day in less than 15 years. Many Chinese cities have already been building metro rail systems at the rate required—all that must be done is to maintain that rate of investment and expand to BRT and bicycle lanes as well as rail.

APPENDIX C: METHODOLOGICAL DOCUMENTATION

Because of its length, the methodological documentation has not been included in this layout of the report. It is available at **Compact Cities Electrified China: Methodological Appendix**.

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