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DEVELOPING AN ELECTRIC MOBILITY ROADMAP: INTERNATIONAL EXPERIENCES FROM SUBNATIONAL CASE STUDIES FOR VIETNAMESE CITIES

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EXECUTIVE SUMMARY

Highlights

- Cities and other subnational actors, such as states and provinces, have begun developing roadmaps to decarbonize the transport sector.
- This paper reviews global case studies to inform cities in Vietnam as they develop their own electric mobility (e-mobility) roadmaps.
- It then provides suggestions on how to develop an e-mobility roadmap, its necessary components, and possible policies to include.
- There are four phases in creating a roadmap: planning and preparation, visioning, development, and implementation, monitoring, and revision.
- Major electric vehicle (EV) adopters gravitate toward climate-focused and charging-focused roadmaps, but emerging EV adopters lean toward EV-focused or manufacturing-focused roadmaps.
- Although Vietnamese cities are emerging EV adopters, it is beneficial to consider a broad scope for a roadmap on transport decarbonization.
- The success of a roadmap depends on proactive stakeholder engagement, including outreach to civil society and the private sector.
- To develop an effective policy package for a roadmap, policymakers should target specific actors and aspects in the e-mobility ecosystem.

CONTENTS

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Key Findings

When compared to the case study cities, Vietnamese cities have contexts similar to other Asian cities. However, in terms of the percentage of passenger trips taken on public transit, they are surprisingly comparable to Californian cities. Like other Asian cities such as Delhi and Shanghai, Vietnamese cities typically have an extremely high two-wheeler ownership and a relatively low four-wheeler ownership per capita. In terms of population and economic indicators, Vietnamese cities are not unlike their counterparts in Latin America, such as Mexico City and Santiago, both of which are emerging e-mobility adopters. Interestingly, in the three Vietnamese cities and three of the California case studies—Los Angeles, San Diego, and San José—less than 10 percent of all transportation is by public transport. This indicates a potential need to both electrify and encourage sustainable modal shift to achieve transport decarbonization.

Although the Southeast Asian cities examined in this paper do not have subnational e-mobility roadmaps, they can offer unique lessons in terms of e-mobility adoption and other transport decarbonization solutions. Bangkok's progress in electrifying the city's inland water transport could help inform Vietnamese cities where ferries are a common mode of transport. Jakarta's ambition in electrifying the city's public transport system, despite a relatively low modal share, could encourage Vietnamese cities to prioritize electric buses over private transport. Kuala Lumpur is going to benefit from Malaysia's holistic approach to avoid, shift, and improve its transport sector. This will provide potential takeaways on how to improve the reliability of bus systems and incentivize more compact urban land use.

Most case study cities characterized as emerging EV adopters tend to favor roadmaps that specifically promote e-mobility uptake, charging, and manufacture, but Vietnamese cities have the special opportunity to break away from this pattern and opt for a broader scope of climate action, air quality control, or sustainable modal shift. Given Vietnam's national climate goals and existing transportation challenges in its cities, a roadmap that takes into consideration emission reduction, air quality improvement, and sustainable modal shift may better accelerate transport decarbonization. For example, it is recommended that Vietnamese cities prioritize the electrification of buses over private transport in their roadmaps, given e-buses' role in catalyzing medium- and heavy-duty vehicle electrification, reducing fossil fuel usage, and consequently improving air quality.

There are a few instances of global original equipment manufacturers (OEMs) setting EV and battery plants in Southeast Asia, but Vietnam is a unique case in which a local e-mobility OEM, Vinfast, is present and supplying EVs across different modes. OEMs are considered an important e-mobility actor that can impact the success of e-mobility roadmaps. The presence of local OEMs to produce EVs and charge equipment can help reduce the need for subnational jurisdictions to rely on imports and build up a domestic, context-specific e-mobility supply chain. During the roadmap development process, subnational governments need to work with the appropriate stakeholders to devise sound EV adoption targets, especially with OEMs.

After its development, there will still be many barriers to effectively implement an e-mobility roadmap, but they can be met with a carefully crafted policy package that targets relevant e-mobility actors, such as EV consumers. This paper proposes a framework of seven e-mobility policy categories and summarizes which of the subnational case studies propose or enact them. For the roadmaps with a broader scope of transport decarbonization, subnational entities should set up policy priorities to coordinate with other governmental bodies, enact transportation regulatory measures, raise public awareness, address the environmental impacts of e-mobility adoption, and support the buildup of charging infrastructure.

1. INTRODUCTION

1.1 Introducing E-Mobility, a Key Technical Solution for Transport Decarbonization

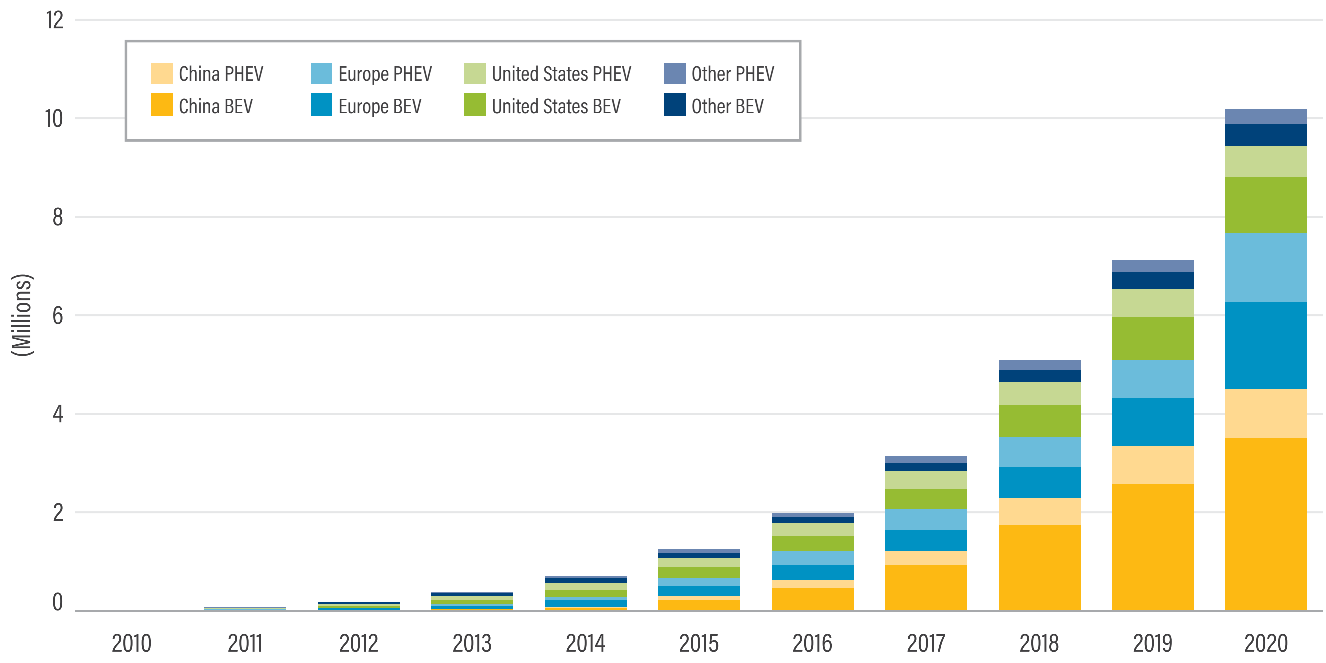
Electric mobility, often abbreviated as e-mobility, is a key emission mitigation measure for the transport sector. It refers to the electrification of vehicles that are intended for the movement of people and goods. Electric mobility presents a host of co-benefits, including energy storage through grid integration and the reduction of air and noise pollutions, but it also presents various challenges, such as grid impact and road safety (UNEP 2019; Das et al. 2020; Pardo-Ferreira et al. 2020; Rachal 2022; UNEP 2022).

Mass adoption of electric vehicles (EVs), in fact, is reflected in recent trends and figures, and this is true for all modes of vehicles, from buses to scooters. Global electric light-duty vehicle (LDV) sales have continued to grow despite the global pandemic, and their stock reached over 10 million vehicles in 2020, a 400-fold increase since 2010 (Figure 1). Electric micro-mobility, including e-bikes and e-scooters, has also matched the explosive growth of electric LDVs, partly thanks to pandemic-induced mobility measures such as the construction of both temporary and permanent bike lanes (Jiang et al. 2020; Glusac 2021; IEA 2021c). Other modes of EVs, including medium-duty (MDVs) and heavy-duty vehicles (HDVs), are also growing, but at slower rates (IEA 2021b). For the last five years, however, the number of electric bus models available has outpaced that of electric trucks (IEA 2021c).

Vietnam has experienced rapid socio-economic development in the last two decades, but as a result, air pollution, motorization, and fossil fuel consumption have all increased in its cities, causing public health and infrastructure concerns (Le et al. 2021; Ngoc et al. 2021). Road transport was the largest emitter in Vietnam's transport sector in 2014, and it will continue to be so in 2030 under business-as-usual (BAU) scenarios (Oh et al. 2019). Under this context, e-mobility is a key measure to help the country meet its larger climate goals set out under the Paris Agreement and combat the rising negative impacts of the transport sector in its expanding cities (Le et al. 2021).

The major driving force behind transportation challenges in Vietnamese cities are two-wheelers—specifically, motorcycles and mopeds—which have grown exponentially in number (Le et al. 2021; Ngoc et al. 2021; Tran et al. 2022). Rising from 1.2 million in 1990 to 65 million in 2020, motorcycles are now the most prominent mode of transportation in all major Vietnamese cities, replacing public transport, walking, bicycling, and even passenger cars (Ngoc et al. 2021). Combined with mopeds, motorcycles are largely responsible for Vietnam's air pollution, contributing 90 percent of carbon monoxide (CO) and volatile organic compounds (VOC) and 60 percent of suspended particles (Tran et al. 2022).

Figure 1 | **Detailed Global EV Growth between 2010 and 2020, Represented by Passenger Car (LDV) Stock**



Source: IEA 2021c.

1.2 E-Mobility Roadmaps: Importance, Phases, and Components

The Importance of E-Mobility Roadmaps

E-mobility adoption depends on multistakeholder coordination and collaboration. Offering a pathway for key stakeholders to follow to achieve widescale e-mobility, an e-mobility roadmap guides national and local-level governments to establish targets, develop policies, and mobilize resources from different stakeholders.

Adopting roadmaps for e-mobility has become a common method for both local and national governments. For example, China updated its New Energy Vehicle Industry Development Plan for 2021–2035, establishing more comprehensive policies to develop a robust domestic EV industry (State Office of China 2020). Following the national roadmap, Chinese cities like Shenzhen and Shanghai also published their EV industry roadmaps (Shanghai People's Government 2021; Shenzhen Fagaiwei 2021). Similarly, Singapore, Malaysia, and Thailand released roadmaps to enhance e-mobility adoption, and these roadmaps would impact e-mobility deployment in their capital cities (Amir 2020). Seventeen U.S. states and a significant number of U.S. and European cities have also released roadmaps and action plans related to e-mobility in pursuit of their low carbon emissions targets (Gilman 2020; Electrification Coalition 2021).

Roadmap Development Phases

Well-organized roadmaps that build consensus around EV adoption often follow this general process, but the timing of each phase varies:

- **Phase 1: Planning and preparation.** Identify the key stakeholders, establish the scope, and determine the general approach of the roadmap development.
- **Phase 2: Visioning.** Define targets and desired pathways for the e-mobility roadmap.
- **Phase 3: Roadmap development.** Conduct scenario and impact analyses, begin the roadmap draft, and conduct a thorough roadmap review.
- **Phase 4: Roadmap implementation, monitoring, and revision.** Hold expert workshops, reassess timelines and priorities, and develop roadmap progress monitoring mechanisms.

Necessary Components of a Roadmap

There is no standard format of an e-mobility roadmap. However, a few common components have been identified for city leaders:

- **Stakeholder analysis:** Identify and include subnational stakeholders who can directly engage with the government starting in Phase 1, including manufacturers, utility companies, transit operators, academic experts, financial institutions, and civil society organizations. These stakeholders would collaborate to develop a comprehensive roadmap, then be crucial in implementing it in Phase 4.
- **Situation analysis:** Conducted during Phase 1, situation analysis surveys the existing conditions of the city (or subnational entity), especially its energy and transport sectors. Additional studies could include an economic overview, environmental metrics such as air quality, existing sectoral policies by jurisdictions, and relevant overall strategic plans.
- **Goals, targets, and milestones:** Using preliminary findings from situation analysis, draft and refine clear and tangible targets with defined milestones in Phase 2. The approach of target setting can stem from a climate, vehicle, or industry perspective.
- **Impact analyses:** Conduct cost-benefit analyses and use scenario modeling as part of Phase 3, including at least one baseline BAU scenario, to evaluate the potential impacts and the optimal pathway(s) of e-mobility adoption.
- **Policy priorities and timelines:** To guide overall e-mobility development progress, incorporate policy priorities and timelines in Phase 3. This could be either a general guidance to allow for legislative flexibility or a detailed plan with specific action items.
- **Resources and budget allocation:** To fund e-mobility initiatives, subnational governments must create dedicated funding sources, such as a percentage of sales or fuel tax, or allocate a portion of its annual budget, pooling from relevant departments like transportation, environment, and technology. This will ensure the timely and successful implementation of the targets and milestones established in Phase 4.

Successfully implementing an e-mobility roadmap also requires a carefully considered policy package tailored to the roadmap's scope and focuses. Section 4.3 will delve into how such a policy package can be assembled. Although most components of a roadmap correspond to a development phase, roadmap development is often an iterative process impacted by change in political will, rapid technological advancement, and other unforeseen factors.

1.3 Case Study Selection and Analysis Methodology

Case Selection Overview

The analysis in this paper includes subnational roadmaps from city, provincial, and state governments, but most case studies are city-level to provide the experiences most relevant to Vietnamese cities. There are two justifications for including case studies beyond city-level in this study. First, in Vietnam's administrative structure, Hanoi, Ho Chi Minh City, and Da Nang are the highest-ranking cities, called "centrally managed municipalities" (*thành phố trực thuộc trung ương*), and enjoy the same status as the country's 58 provinces (City of Da Nang 2013; Doan and Nguyen 2021). Further, provincial and state level case studies offer unique lessons learned when it comes to developing roadmaps with an EV industry focus.

The case studies were selected based on five criteria to best provide comparable lessons for EV adoption in Vietnamese cities: EV market classification, geographic relevance, research capabilities, roadmap presence, and unique lessons from states and provinces. Detailed explanations of these criteria can be found in Appendix B1.

Among the criteria, EV market classification and roadmap presence are the most influential in determining case study selection. In this paper, countries and regions are classified as either major or emerging EV markets. Table 1 illustrates each case study's EV market classification and whether an e-mobility roadmap is present. In cases where no subnational-level roadmaps exist—namely, Bangkok, Jakarta, and Kuala Lumpur—selection is based on the comparability of their regional contexts to Vietnamese cities.

Table 1 | **List of Case Studies by Countries and Their EV Market Classification**

EV MARKET CLASSIFICATION	COUNTRY	CASE STUDY	PRESENCE OF AN E-MOBILITY ROADMAP
Major adopter	China	Beijing	Yes, on the subnational level
		Hainan	Yes, on the subnational level
		Shanghai	Yes, on the subnational level
		Shenzhen	Yes, on the subnational level
	Japan	Tokyo	Yes, on the subnational level
	The Netherlands	Amsterdam	Yes, on the subnational level
	Norway	Oslo	Yes, on the subnational level
	Sweden	Stockholm	Yes, on the subnational level
	United Kingdom	London	Yes, on the subnational level
	United States	Boston	Yes, on the subnational level
		California	Yes, on the subnational level
		Los Angeles	Yes, on the subnational level
		San Diego	Yes, on the subnational level
		San Francisco	Yes, on the subnational level
		San José	Yes, on the subnational level

Table 1 | **List of Case Studies by Countries and Their EV Market Classification (Cont.)**

EV MARKET CLASSIFICATION	COUNTRY	CASE STUDY	PRESENCE OF AN E-MOBILITY ROADMAP
Emerging adopter	Thailand	Bangkok	Yes, on the national level
	Indonesia	Jakarta	No
	Malaysia	Kuala Lumpur	Yes, on the national level
	India	Delhi	Yes, on the subnational level
		Karnataka	Yes, on the subnational level
		Maharashtra	Yes, on the subnational level
	Mexico	Mexico City	Yes, on the subnational level
	Chile	Santiago	Yes, on the subnational level

Note: Here and in ensuing tables, state and province case studies are italicized.

Sources: Hall et al. 2019; Khan et al. 2022. "Presence of an EV Roadmap" compiled by WRI authors.

1.4 Comparing Case Study Cities to Vietnamese Cities

After the case studies were selected, the four descriptive statistics were applied to illustrate the underlying similarities and differences of case study cities with the three selected Vietnamese cities: Da Nang, Hanoi, and Ho Chi Minh City. While none of the case studies align perfectly with their Vietnamese counterparts based on all four descriptive statistics, there are several case studies sufficiently similar to Vietnamese cities based on individual indicators. This study prioritizes case studies that match Vietnamese cities on one or more descriptive statistics. Table 2 illustrates a list of these case studies by each descriptive statistic; Table A7 in Appendix A contains the actual data points for each descriptive metric.

1.5 About This Paper

This paper is part of a series that analyzes international experiences of e-mobility adoption for stakeholders in Vietnam, and especially those in Da Nang, Hanoi, and Ho Chi Minh City, each meant to represent a macro-region of the country. In 2018, these three cities were selected as part of the Association of Southeast Asian Nations (ASEAN) Smart Cities Network (ASCN) with the common goal of promoting smart and sustainable urban development using technology such as vehicle electrification. Then, in 2021, the government of Vietnam chose Ho Chi Minh City as a pioneer city for e-mobility adoption (NDC Transport Initiative for Asia 2021; Dharmaraj 2022).

In 2020, Vietnam updated its National Determined Contributions (NDCs) to achieve a conditional 27 percent reduction in total greenhouse gas (GHG) emissions by 2030, amounting to 250.8 million tonnes of carbon dioxide equivalent (CO_2eq). To achieve this, a key mitigation measure is "changing the energy and fuel structure in industry and transportation" (Climate Watch 2020; The Socialist Republic of Vietnam 2020). Thus, under the larger framework of the NDC Transport Initiative for Asia (NDC-TIA) program, the aim of this first study is to provide an overview of existing subnational-level roadmaps of major e-mobility adopters in different regions, then provide a comparative case analysis to identify common practices and different pathways for Vietnamese cities. This study will be complemented by a second study on national-level roadmaps for national-level stakeholders in Vietnam.

Using subnational case studies to capture state and provincial plans as points of comparison, this paper examines the benefits of different roadmap types, describes strategies for policy implementation, and lists some of the barriers to roadmap adoption. First, the study lays out the background of e-mobility roadmaps, provides summaries of the case studies, and categorizes subnational roadmaps based on their focuses (solely on e-mobility or something broader). Then, the paper discusses prerequisite steps and potential barriers in developing a roadmap. The paper then turns to the actual process, covering planning

Table 2 | **Case Studies Similar to Vietnamese Cities, by Descriptive Statistics**

EV MARKET CLASSIFICATION	REGION	CITY	DESCRIPTIVE METRIC (UNIT)	COMPARED TO THE OTHER TWO VIETNAMESE CITIES	SIMILAR CASE STUDY CITIES
Emerging adopter	Northern Vietnam	Hanoi	Less densely populated than 75% of the case studies	Da Nang: similar *HCMC: denser*	Beijing, Los Angeles, Oslo, San Diego
			Lower GDP/GRP per capita than 75% of the case studies	Da Nang: similar HCMC: similar	Delhi, Jakarta, Santiago
			Lower public transit modal split than 75% of the case studies	Da Nang: similar HCMC: similar	San Diego, San José, Los Angeles
			Lower passenger car ownership than 75% of the case studies	Da Nang: similar HCMC: similar	Delhi, Shanghai, Tokyo
			Higher motorcycle ownership than 50% of the case studies	*Da Nang: higher* *HCMC: higher*	Delhi, Mexico City
	Central Vietnam	Da Nang	Less densely populated than 75% of the city case studies	Da Nang: higher HCMC: higher	Beijing, Los Angeles, Oslo, San Diego
			Lower GDP/GRP per capita than 75% of the city case studies	Hanoi: similar *HCMC: denser*	Delhi, Jakarta, Santiago
			Lower public transit modal split than 75% of the city case studies	Hanoi: similar HCMC: similiar	San Diego, San José, Los Angeles
			Lower passenger car ownership than 75% of the city case studies	Hanoi: similar HCMC: similar	Delhi, Shanghai, Tokyo
			Higher motorcycle ownership than 75% of the case studies	*Hanoi: lower* HCMC: similar	Bangkok, Jakarta, Kuala Lumpur
	Southern Vietnam	Ho Chi Minh City	*Less densely populated than 50% of the city case studies*	Hanoi: lower HCMC: similar	Bangkok, San José, Shanghai
			Lower GDP/GRP per capita than 75% of the city case studies	Hanoi: similar Da Nang: similar	Delhi, Jakarta, Santiago
			Lower public transit modal split than 75% of the city case studies	Hanoi: similar Da Nang: similar	San Diego, San José, Los Angeles
			Lower passenger car ownership than 75% of the city case studies	Hanoi: similar Da Nang: similar	Delhi, Shanghai, Tokyo
			Higher motorcycle ownership than 75% of the case studies	*Hanoi: lower* Da Nang: similar	Bangkok, Jakarta, Kuala Lumpur

Note: See Table A7 for the concrete data under each descriptive metric. All case studies referred to in this table are cities; no states or provinces are included. Characteristics highlighted in italics are anomalies.

Sources: See Table A3 for detailed list of sources.

and preparation and through to implementation and monitoring. Throughout each section, experiences from actual case studies are referenced and analyzed. The paper also provides preliminary recommendations for Vietnamese cities throughout, based on case study observations.

2. TYPES OF SUBNATIONAL ROADMAPS

2.1 Roadmap Scopes and Focuses

Whether stated in the official document or not, the ultimate goal of almost all e-mobility roadmaps often is transport decarbonization, even when the pursuit for e-mobility is partly driven by economic motivations.[1] A roadmap's purpose, targets, policy guidance, and other critical components should align with the stated scope and focuses of its authors.

While some of these roadmaps focus on directly enabling e-mobility adoption, from quickly boosting EV uptake to providing adequate charging infrastructure, others emphasize broader aspects beyond transportation, such as air quality and modal shift. Observations from case study roadmaps show diverse combinations.

- **Roadmaps with a precise e-mobility scope:**
  - **EV uptake**: Increase the uptake of EVs, usually focused on passenger cars but sometimes including buses, trucks, and two-wheelers.
  - **EV industry**: Establish a supply chain of EVs by incentivizing original equipment manufacturers (OEMs) to produce and assemble EV parts, batteries, and EV supply equipment (EVSE).
  - **EV charging**: Provide adequate infrastructure to power electrified transportation modes through charger deployment, battery-swap systems, and grid improvements.
- **Roadmaps with a broader scope:**
  - **Climate**: Reduce GHG emissions from the transport and energy sectors, contributing to subnational and national emission reduction goals.
  - **Air quality**: Improve public health outcomes by reducing smog, soot, and other air pollution from vehicles powered by internal combustion engines (ICEs).
  - **Modal shift**: Exploit the advantages of e-mobility, such as noise reduction and ride comfort, and encourage modal shift away from private car trips.

Table 3 shows a list of roadmaps reviewed in this study with their categorized focuses. The remainder of the section will address each type, explain what characteristics are central to each, and describe how cities have implemented each type of roadmap to get closer to achieving their e-mobility objectives.

2.2 Roadmaps Focused on E-Mobility

Roadmaps focused on e-mobility can prioritize any of the given areas of adoption: vehicle uptake, industry development, or charging provision. They tend to set specific targets, such as percentage of EVs in new sales, number of EV manufacturing jobs, and number of charging points deployed. Target-setting requires technical evidence and political commitments but can be a great tool to mobilize support for the transition to e-mobility. Examples of detailed targets for this type of roadmap can be found in Appendix A2.

Of the 24 subnational roadmaps analyzed, 11 are classified as having an EV uptake focus. Delhi, an emerging adopter case study, aims to become the EV capital of India, and its roadmap reflects this ambition by setting a target of 25 percent of all new vehicle registrations to be EVs by 2025. The Delhi roadmap breaks down incentives and policy priorities by vehicle modes, including different private and commercial two- and three-wheelers (Government of NCT of Delhi 2020). Delhi's roadmap is tailored to the local transportation context, which is useful for cities in Vietnam where two-wheelers are also a primary mode of transportation.

Some cities issued roadmaps focused on charging infrastructure, often complementing lengthier EV uptake roadmaps. Charging-focused roadmaps usually include clear objectives and priorities that focus on the number of chargers, vehicle-to-charger ratios, and the different charger types (for instance, public, private, and workplace; fast and slow chargers). Nine of the roadmaps researched could be categorized as charging-focused roadmaps. China's Hainan Province issued a specific development plan for charging infrastructure, *Hainan New Energy Vehicle Charging Infrastructure Development Plan (2019–2030)* (General Office of the Hainan Government 2019), which identifies existing issues with promoting charging infrastructure and provides targets, milestones, and action plans to enhance local charging infrastructure deployment.

Table 3 | Subnational Case Study Roadmaps and Their Focus Categories

REGION & COUNTRY	SCOPE	ROADMAPS FOCUSED ON E-MOBILITY			BROADER ROADMAPS		
	Focus	EV Uptake	EV Industry	EV Charging	Climate	Air Pollution	Modal Shift
China	Beijing	X		X			
	Hainan	X	X	X			
	Shanghai	X	X	X		X	
	Shenzhen	X	X	X		X	
Europe	Amsterdam				X		
	London			X			
	Oslo				X		X
	Stockholm			X	X		
Japan	Tokyo	X					
United States	Boston	X					
	California	X		X	X	X	
	Los Angeles				X		
	San Diego	X		X	X		
	San Francisco				X		X
	San José				X		X
ASEAN	Bangkok	n/a	n/a	n/a	n/a	n/a	n/a
	Jakarta	n/a	n/a	n/a	n/a	n/a	n/a
	Kuala Lumpur	n/a	n/a	n/a	n/a	n/a	n/a
India	Delhi	X		X			
	Karnataka	X	X				
	Maharashtra	X	X				
Latin America	Mexico City				X	X	
	Santiago					X	
Scope Tally		**25**			**17**		
Focus Tally		**11**	**5**	**9**	**9**	**5**	**3**

Note: Non-cities are italicized. Case study cities, states, and provinces may have multiple reviewed roadmaps. This table shows focus categories for all historical and existing roadmaps for each case study. Roadmaps focused on e-mobility are highlighted by red gradient colors, and broader roadmaps by blue gradient colors.

Source: WRI authors.

EV industry roadmaps are usually issued at the national level to develop a country's EV value chain and enhance local manufacturing capacity, supporting the local economy and subsequently promoting EV adoption through domestic consumption and shifts in consumer adoption behavior. These roadmaps may also be issued by subnational governments, especially at the provincial level, to support regional EV industry, foster EV technological innovations, and promote EV workforce development. Five out of the 24 subnational case studies used industry-focused roadmaps, and many of them are provinces and states. Shanghai's industry-focused roadmap sets targets for EV research and technological development (R&D) and business incentives for OEMs (Shanghai People's Government 2021).

2.3 Broader Roadmaps

To implement broader climate action, many cities and provinces have set targets that aim to improve air quality, reduce emissions, and incorporate more renewable energy sources. Others integrate their sustainable transportation and compact urban planning policies with electrification. The scope of these broader roadmaps goes beyond e-mobility, but they have e-mobility embedded as a key solution to combat climate change, improve public health outcomes, and mitigate transportation challenges. For these types of roadmaps, vehicle electrification percentages can be used to derive potential GHG and air pollution reductions, which can be estimated using a scenario analysis methodology.

Fourteen of the roadmap case studies investigated in this paper have a broader scope, with nine more focused on climate action and five on combatting air pollution. Although most climate-focused roadmaps also tend to address air pollution, that is not always the case. For example, Oslo's EV approach is embedded within the city's *Climate Strategy for Oslo towards 2030*, which aims to reduce the city's emissions by 95 percent across all sectors; e-mobility and modal shift make up a quarter of the priority areas in the strategy (KlimaOslo 2016). In comparison, Santiago's roadmap, *The Plan for the Prevention and Atmospheric Decontamination for the Metropolitan Region*, is much more explicit about reducing air pollution in addition to GHG emissions in the city (Ministry of Environment of Chile 2017).

There are three roadmap case studies that view e-mobility as an instrument for a broader, more sustainable transportation modal shift. For instance, according to the *Proposed Electric Vehicle Roadmap for San Francisco*, San Francisco's transportation priority is shifting trips from cars to more sustainable modes like public transport, walking, and biking. The roadmap set a target to grow the share of sustainable trips from 57 percent in 2019 to 80 percent in 2030 (Electric Mobility Subcommittee 2019).

2.4 Case Studies with No Existing Subnational Roadmaps

Three Southeast Asian cities included in the case studies—Bangkok, Jakarta, Kuala Lumpur—do not have existing subnational roadmaps. However, their respective countries—Thailand, Indonesia, and Malaysia—all have some form of national e-mobility roadmap, ranging from decrees to actual roadmaps. Given that all three cities are considered primate cities, holding a position of economic and population dominance over the rest of their respective countries, it is safe to assume that e-mobility adoption in these cities will shape the implementation of the national e-mobility roadmaps, and vice versa (Robinson 1981; Falkus 1993; Wong 2006). Table A4 in the Appendix illustrates detailed policy priorities and other specific mentions regarding these cities drawn from the national roadmaps.

Based on the review of the three countries' national roadmaps, Thailand and Indonesia have set out to develop a robust EV industry. This is supported by the fact that both countries produce approximately 1–2 million motor vehicles—ICEVs or otherwise—every year, making them top producers in Southeast Asia (OICA 2019; Mahalana and Yang 2021; AHK Indonesian and GTAI 2019; Amir 2020; *The Nation Thailand* 2021). Compared to those more industry-focused roadmaps, Malaysia's approach has a broader scope, focusing on climate action and modal shift (KASA 2021).

For Vietnamese cities, there are several takeaways from their Southeast Asian counterparts. Bangkok's adoption of electric ferries to replace ICE ferries on its inland waterways can offer valuable lessons to Ho Chi Minh City, given the presence of inland water transport there (Winijkul 2020; The National Electric Vehicles Policy Committee 2021). Jakarta's electric public transport ambition, despite the city's low public transport modal share, shows that pursuing wide adoption of electric buses is possible for Vietnamese cities, but it needs to be supported by policy strategies that reduce total cost of ownership and promote modal shift from two-wheelers to buses (Dixon et al. 2020; Ngoc et al. 2021). Kuala Lumpur can also shed light on which strategies work best for modal shift, whether it is from improving the reliability and frequency of bus systems or incentivizing more compact urban land use to reduce private vehicle dependency (KASA 2021).

2.5 Preliminary Recommendations for Vietnamese Cities

Although stakeholders in Vietnamese cities need to determine the exact path forward, it is clear from our case studies that, for emerging EV adopters, e-mobility roadmaps with a precise scope are the norm. Because Vietnamese cities are considered emerging EV adopters, a precise e-mobility roadmap, focusing on EV uptake and EV industry, could be effective. Based on Delhi's experience, EV charging can be addressed through follow-up actions like issuing charging installation guidebooks and establishing an online information portal for charging (Department of Transport, Delhi n.d.; Shah et al. 2021; Shah et al. 2022). In addition to the focuses discussed in this section, an e-mobility roadmap for Vietnamese cities should put emphasis on electrifying motorcycles and mopeds, the most common road transport modes in the country (Ngoc et al. 2021).

However, given Vietnam's national climate goals and existing transportation challenges in its cities, a roadmap with broader focuses may better accelerate transport decarbonization. E-buses, given the mode's relative technological maturity, are often seen as an introductory mode that can pave the way for the electrification of MDVs and HDVs (Welch 2020). They can also be the backbone of a city's public transport, delivering flexible geographic coverage with lower costs compared to a heavy rail system (Hensher 2007). In terms of e-bus adoption in Vietnam, Ho Chi Minh City's leadership has expressed an intention to promote public transport and limit personal vehicles; additionally, the domestic EV manufacturer Vingroup has announced that a total of 150 to 200 e-buses will be deployed in the cities of Hanoi, Ho Chi Minh City, and Phu Quoc (Sustainable Bus Editorial Staff 2021; Pham 2022). Considering the air pollution impacts from private two-wheelers and the alignment of e-buses with the broader focus of climate action and sustainable modal shift, Vietnamese cities could break away from the observed pattern of emerging EV adopters, opting instead for broader-scope transport decarbonization roadmaps that advance climate action, combat air pollution, and encourage modal shift.

3. PREPARING FOR A SUBNATIONAL E-MOBILITY ROADMAP

3.1 Defining the Scope and Steps

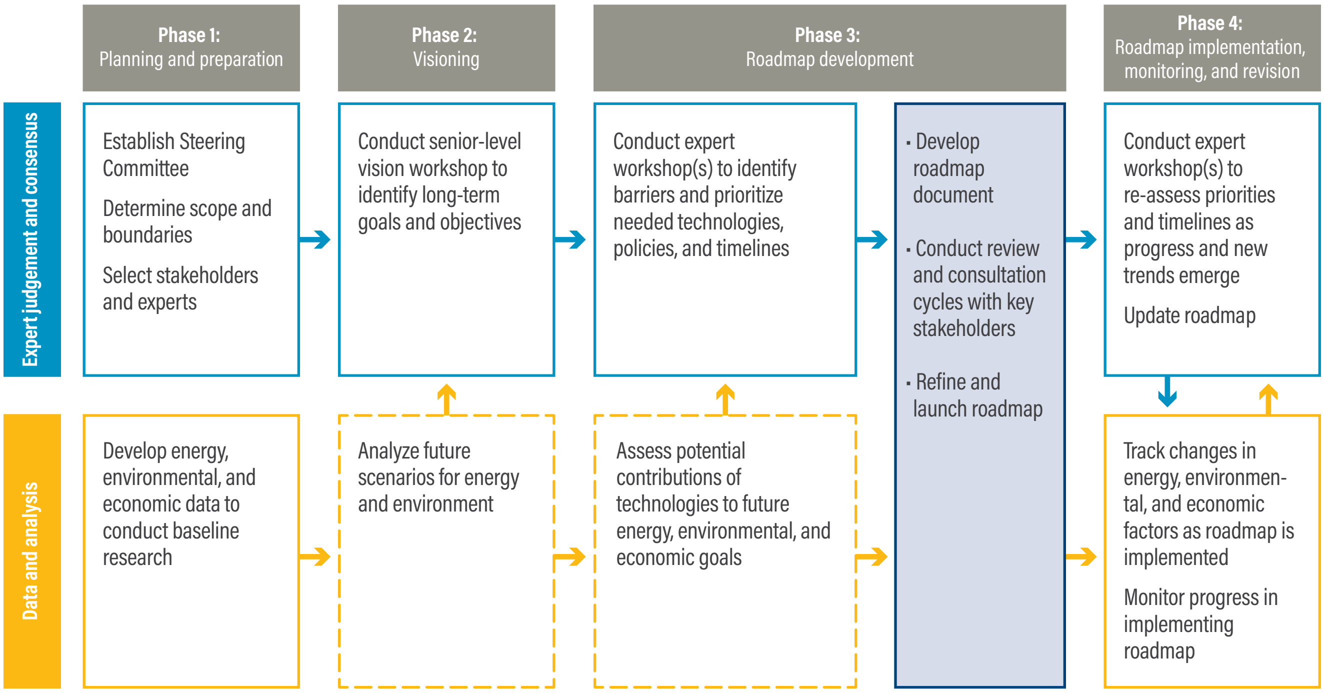
E-mobility roadmaps can vary greatly depending on the type of objectives established by the city. Using e-mobility focused roadmaps as a basis, this section will walk through the common components identified within the case studies and outline the general process of developing and implementing an e-mobility roadmap. After first explaining what studies and analyses are needed for a roadmap, the section will address the barriers to roadmap creation then present a detailed breakdown of the general process and components of a roadmap.

There are a few proposed roadmap models and frameworks available for promoting the adoption of transformative urban technology like e-mobility; these include the Energy Technology Roadmap Development Process, the Technology Roadmapping framework (TRM), and the SMART model (Lee et al. 2013; IEA 2014; Letaifa 2015). Subnational entities, including the Vietnamese cities discussed in this paper, can choose the approach that best fits their respective political, regulatory, and social norms. Because of its level of detail and relevance to e-mobility, this study utilizes the International Energy Agency (IEA)'s energy technology roadmap development process as a reference (Figure 2). Each phase will be demonstrated with case study examples (IEA 2014).

3.2 Studies and Analyses

When developing an e-mobility roadmap, the roadmap authors must analyze the existing conditions of the city's transport and energy sectors, including vehicle profiles, travel behavior, existing EV adoption, charging infrastructure, electricity sourcing, and grid system characteristics. Adopting EVs will have quantitative costs and benefits, as well as qualitative barriers and opportunities, all of which may also be discussed in the roadmap. The roadmap can then be tailored to prioritize the policies and actions most capable of addressing the needs of the local community. For example, the Karnataka roadmap was designed with the primary objective of making the state's capital city, Bengaluru, a major EV hub of India by bringing together e-mobility research, development, manufacturing, and adoption (Commerce and Industries Department of Karnataka 2017; Transportation Electrification Partnership 2019).

Figure 2 | **Energy Technology Roadmap Development Process**



Note: Dotted lines indicate optional steps, based on analysis capabilities and resources.

Source: Reproduced from IEA (2014, 6).

There are two categories of technical studies and analyses that can help inform a subnational e-mobility roadmap: localized existing conditions analysis, and impact and scenario analysis. Localized studies and analyses can help enhance the applicability of the roadmap and make the action plans more implementable. These analyses are done in Phase 1 of the roadmap creation process. In Phases 2 and 3, impact and scenario analyses are usually conducted to identify the potential impact of different vehicle electrification scenarios and provide tailored solutions to the city. Appendix B5 enumerates the different analyses that can be conducted for understanding localized existing conditions, as well as impact and scenario modeling.

3.3 Identifying Barriers

Barriers to Subnational Roadmap and E-Mobility Adoption

Barriers to adopting an e-mobility roadmap can be identified throughout the roadmap creation process, such as during the initial baseline analysis and the subsequent scenario analysis. As emphasized by the case studies, it is useful to understand the barriers to roadmap adoption and categorize them by the four phases of roadmap creation and adoption, as shown in Table A6(a) (IEA 2014). Some of these roadmap-adoption barriers may be different for a national-level roadmap, as the differences in scale between subnational- and national-level e-mobility present unique challenges. It is essential to identify the barriers to e-mobility and policy adoption in the creation process to ensure that the roadmap includes solutions to overcoming these obstacles. Otherwise, the roadmap will fail at its purpose. Table A6(b) in the Appendix maps out general e-mobility adoption barriers that subnational governments may encounter.

To overcome these barriers, subnational governments need to work with relevant stakeholders in each jurisdiction, including financial institutions, policymakers, civil society organizations, government executive offices, and manufacturers of EVs, batteries, and charging equipment. Some barriers require straightforward solutions because they result from the absence of certain laws or government functions. To address them, subnational governments could legislate the appropriate laws, such as safety standards, or develop the needed capacity, like setting a department or working group dedicated to e-mobility. Other barriers require a more nuanced approach, as their existence is the product of multiple factors. For instance, financial barriers to e-mobility policy adoption may be addressed by seeking domestic or international funding sources for climate action. Subnational governments may also legislate revenue streams through earmarked tax categories, such as road use tax and transportation-related charges like congestion fees. Market and consumer types of barriers call for public awareness campaigns, test drive events, and accessible online information portals.

Subnational governments in the case studies proposed a variety of tools and strategies throughout the roadmap to tackle these barriers, but, most importantly, they assembled an appropriate policy package tailored to the unique set of conditions in their jurisdictions in Phase 3 (see Section 4.3).

3.4 Engaging the Private Sector

Besides in a few instances, the e-mobility private sector is oftentimes not included in the decision-making process of e-mobility roadmaps, though they have an impact on the success of its implementation.

In developing e-mobility roadmaps, the most important private sector actor is the OEMs. As noted earlier, all roadmaps must be informed by a survey of the local capacity for vehicle manufacturing and assembly. To achieve e-mobility goals and targets, subnational governments may rely on the import of EVs, EV components, batteries, and charging equipment from other countries—but the presence of OEMs enables direct supplies of different modes of EVs for adoption, including passenger cars, buses, or two- and three-wheelers. Additionally, these OEMs can export components and vehicles regionally and globally, helping to build an EV industry that would not need to rely solely on local demand. In fact, many global OEMs have set up EV plants to serve their target markets either on their own or with local automakers in joint ventures. For example, Tesla, the world's largest EV market shareholder, opened a plant in Shanghai to serve China, one of its biggest markets. Vinfast, a major Vietnamese automaker, is moving forward with plans for a plant in North Carolina to produce both EV automotives and batteries, aiming to tap into the North American market (Dobush 2018; Doll 2022). Joint ventures are common in China, India, and Southeast Asia. For instance, Mercedes-Benz, along with local partners Thonburi Automotive Assembly Plant (TAAP) and Thonburi Energy Storage Systems (TESM), opened a factory to manufacture plug-in hybrid vehicle (PHEV) batteries near Bangkok, investing €100 million to respond to Thailand's high demand for PHEVs (Mercedes-Benz 2019).

Thus, it is important for subnational governments to assess the capacity of vehicle manufacturers in their jurisdictions and work with national governments to attract automakers and other OEMs to set up EV production plants.[2] EV manufacturing capacity of case

Box 1 | Roadmaps and E-Mobility Implementation at City, Province, and Country Levels and Their Relationships

Besides the stated barriers faced when creating an e-mobility roadmap, nuances exist for different administrative levels of government.

Due to the size of their government budgets, limited legislative power, and the shifting agendas between different mayors, cities tend to have less leverage over EV adoption policies related to energy supply and the EV industry when compared to province- and country-level governments. However, in some instances, these challenges may be less applicable to city-level governments that enjoy political authority similar to larger states, provinces, or territories. Moreover, lessons learned from one city can inform implementation in other cities, so—if done successfully—implementation of e-mobility in one city may influence the process and strategy in other cities or even of the entire country.

Many subnational e-mobility roadmaps reference larger national roadmaps, indicating a certain level of alignment and amplifying efforts to promote EV adoption in subnational administrative regions. Such alignment can contribute to successful adoption by leveraging national enabling policies and incentive. For example, the Shenzhen New Energy Vehicle (NEV) Industry Roadmap (2016–2020) follows the larger framework of the "Fourteenth Five-Year Plan" and exclusively acknowledges the national subsidy in effect, then posits its municipal subsidy as an addition to the national one to encourage faster and wider adoption of EVs.[a]

On the other hand, subnational e-mobility experiences can inform nationwide implementation. Although there are no confirmed national e-mobility roadmaps that reference subnational ones, there is evidence that e-mobility lessons learned from one city can become the paradigm for the rest of the country. For example, the deployment of electric logistics vehicles (ELVs) in Shenzhen is highly regarded in China because the city is the first of any subnational government in China to announce ELV-specific subsidies. Shenzhen's ELV subsidy scheme is inspiring those recently announced in Chinese cities like Beijing and Luoyang.[b]

Notes: [a] Liu, Q., R. McLane, D. Mullaney, and Z. Wang. 2020a. [b] Liu, Q., R. McLane, D. Mullaney, and Z. Wang. 2020b. *New Energy Vehicles* is a term used by the Chinese government to designate zero-emission vehicles eligible for public subsidies, including BEV, PHEV, and FCEV. See Glossary for definitions. Boasting 62,000 ELVs by the end of 2018, Shenzhen—despite some initial stumbles—succeeded not only in growing its ELV fleet, but also in incentivizing and building a robust charging network that make operating these ELVs viable (RMI 2019; Liu et al. 2020b; Commercial Vehicle Industry [商用车行业] 2021).

Sources: Shenzhen Fagaiwei 2016; Liu et al. 2020a; EV Resources [电车资源] 2020; Qiu et al. 2021.

study cities and states with conditions like Vietnamese cities can be found in Table A5. For Vietnamese cities, it is useful to evaluate the presence of OEMs in their jurisdictions and issue an industry-focused roadmap, as suggested in Section 2.4; more importantly, major OEMs such as Vingroup should be consulted during the development process in order to ensure the roadmap's effectiveness. London's engagement of the private sector during roadmap development and implementation, for instance, will be discussed in the following section.

4. CREATING A SUBNATIONAL E-MOBILITY ROADMAP

As outlined above, this paper follows the IEA 2014 Energy Technology Roadmap framework. This section will walk through each of the four phases in detail, incorporating relevant observations from different case studies.

4.1 Phase 1: Planning and Preparation

At the beginning of Phase 1, the subnational government should conduct a series of baseline analyses on the existing local e-mobility conditions to identify stakeholders and determine who should lead the roadmap development.

A working group or a steering committee can then be created to formulate guidance for the development of the roadmap and oversee its execution. That group or committee may consist of government officials, relevant technical staff, and key stakeholders (utilities, grid developers, academic institutions, civil society associations, and OEMs). For subnational entities with a centralized style of governance, the working group usually consists of different governmental departments and limited private sector participation. However, entities with a more decentralized governance structure usually form working groups that involve many private sector stakeholders. Alternatively, in some case studies, roadmaps with broader focuses beyond e-mobility were developed without a dedicated working group and steering committee.[3]

As an example of subnational entities with a centralized style of governance, Beijing's e-mobility working group within the municipal government formed the Municipal Office of New Energy Vehicle Joint Meeting [市新能源汽车联席会议办公室], consisting of officials from various municipal departments, each with a specific role to play in enabling e-mobility adoption (The People's Government of Beijing Municipality 2017).[4] While the private sector's involvement might be minimal in the case of Beijing, London's EV-charging roadmap incorporated both civil society and private sector actors. London's e-mobility charging working group included many private sector stakeholders and, leading up to the development of the roadmap, hosted a series of workshops on a range of issues, including users' needs, land and energy issues, and financial models (The Mayor's Electric Vehicle Infrastructure Taskforce 2019).[5] As a result of inputs from public and private sector members of the working group, the roadmap focuses on the medium term rather than the long term, likely to allow for flexibility and accommodations for changes in EV adoption and advances in charging technologies in the near future (The Mayor's Electric Vehicle Infrastructure Taskforce 2019).

Faced with limited administrative resources or technical expertise, subnational governments could opt to be more removed from the process and instead form a technical group, consisting of international experts and local stakeholders to conduct analyses and develop the roadmap. The technical group will take on most of the roadmap creation work and consult the subnational government for high-level inputs, or only for approval of the final product. For example, C40 Cities Finance Facility (CFF) helps cities overcome financial barriers when pursuing climate solutions. CFF worked with Carbon Trust Mexico to draft a technical report with detailed existing-conditions analysis and scenario planning to help the government facilitate an eventual plan to implement e-mobility in Mexico City (C40 CFF and Carbon Trust México 2018).

Once the technical experts are identified for the working group, the scope and general approach of the roadmap needs to be determined. By answering the questions below, the working group will be able to clearly define the scope of a roadmap. Here, responses to these questions are drawn from case study observations, providing specific insights for Vietnamese cities.

Question 1: Should the roadmap be developed with a broader scope of transport decarbonization or public health, or focus solely on e-mobility?

- Case study 1: Oslo

The city of Oslo has a goal of reducing its emissions by 95 percent by 2030, as compared to its 2009 baseline. The city decided to pursue this goal mainly through an e-mobility solution pathway and has plans to replace all fuel-based vehicles with zero-emission vehicles by 2030 (City of Oslo 2020).

Question 2: Should the roadmap focus on specific urban passenger transport modes or the overall transport sector (freight, urban, rural, and others)?

- *Case study 2: Los Angeles*

As part of the regional government's ambition to increase competitiveness and future economic growth within the freight sector in the greater Los Angeles region and across California, electrifying freight is a key focus of Los Angeles's e-mobility roadmap (Transportation Electrification Partnership 2019). The roadmap specifies mode-specific freight electrification targets, targets for the number of chargers, and building a zero-emission freight corridor by 2028.[6]

Question 3: Which vehicle mode should the city or the subnational entity prioritize for electrification? For instance, bus and public fleets first, private vehicles later?

- *Case study 3: Mexico City*

To align with the National Plan of Development (*Plan Nacional de Desarrollo, PND*) 2013–2018, Mexico City's e-mobility roadmap prioritizes public and shared transportation to promote sustainable urban mobility (C40 CFF and Carbon Trust México 2018). The roadmap specifies vehicle-based electrification targets of 20 percent for public transport fleets and 80 percent for taxis and ride-hailing vehicles by 2030. The target for private passenger vehicles is set lower at 15 percent, based on percentage of sales. Achieving fleet-based targets is more difficult than achieving sales-based targets, which is why Mexico City's roadmap prioritizes public and shared fleets ahead of private vehicles (C40 CFF and Carbon Trust México 2018).

Question 4: Which EV-related technologies should the city or the subnational entity prioritize? For instance, which EV type (PHEV versus BEV) or lithium-ion battery chemistry type (LFP versus NMC and NCA)?[7]

- *Case study 4: Shenzhen*

Not many of the case study roadmaps prioritized EV-related technologies; however, Shenzhen's past three financial subsidy rules explicitly make PHEVs eligible for general EV subsidies, indicating an understanding among policymakers that PHEVs are a transitional solution as society progresses toward full e-mobility (Shenzhen Municipal Financial Committee and Shenzhen Municipal Development and Reform Commission 2017 and 2019; Shenzhen Municipal Development and Reform Commission 2020).

Question 5: What other city or subnational e-mobility specific targets should the roadmap consider? This may include, for example, sustainable transport goals, prioritizing buses, reducing ICE motorcycles, or sustainable energy targets.

- *Case study 5: San Francisco*

In contrast to other cities, whose e-mobility targets are typically a specific number of EVs or chargers, San Francisco is striving for 100 percent of vehicle miles traveled (VMT) by 2030 to be done by EVs. Additionally, the city set a target of 2040 for all trips originating in, ending in, or passing through San Francisco to be emissions-free (Electric Mobility Subcommittee 2019).

4.2 Phase 2: Visioning

As cities develop their roadmaps, it is important to establish clear and tangible objectives with detailed timelines and specific milestones. Goal setting can come from a combination of perspectives, and the categorization used in Section 2 can be a useful framework to begin. Objectives for other relevant components may also be included, such as charging infrastructure, EV-related technologies, energy, and relevant value chains. For example, Los Angeles' roadmap includes three calls to action from a broad vision, with specific interim objectives for the city to achieve zero emissions by 2028, as shown in Figure 3 (Transportation Electrification Partnership 2019).

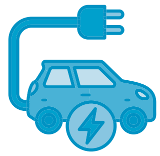
After initial vision and preliminary goal setting, the roadmap working group should conduct scenario and impact analyses to better understand and measure the fiscal, operational, environmental, and social impacts that different e-mobility scenarios may have on the city. These additional analyses allow working committees or technical groups to better determine the pathways toward an e-mobility roadmap tailored for the city.

4.3 Phase 3: Roadmap Development

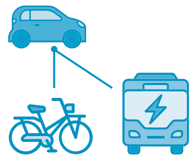
Lawmaking bodies should be included as stakeholders to bolster and legislate e-mobility promotion policies, improve existing policies, and formally devise financing policies for both public and private sector interests. For example, Shenzhen's 2016 to 2020 e-mobility roadmap was originally issued as a general

Figure 3 | **Los Angeles Zero Emissions 2028 Roadmap's Three-Pronged Call to Action**

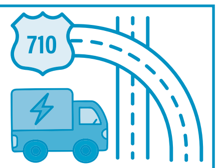
1. Accelerating the adoption of light-duty passenger electric vehicles (EVs) to be 30 percent of all vehicles on the road, and at least 80 percent of all vehicles sold by 2028.



2. Shifting over 20 percent of all trips in single occupancy vehicles to zero emissions public and active transit by 2028.



3. Ensuring that by 2028 all public investments into goods movement, freight vehicles (i.e., trucks and cargo handling equipment), and related infrastructure to support goods movement will advance zero emissions solutions, and ensure that the I-710 is the first zero emissions goods movement corridor in the nation.



Source: Reproduced from Transportation Electrification Partnership 2019.

e-mobility work plan, but was then further formalized with detailed laws, financial subsidies, and implementation criteria (Shenzhen Municipal Development and Reform Commission 2016; Shenzhen Municipal Financial Committee and Shenzhen Municipal Development and Reform Commission 2017 and 2019; Shenzhen Municipal Development and Reform Commission 2020).

Drawing from the roadmaps reviewed, Table 4 summarizes some of the key policies promoting e-mobility to showcase possible policies a city or other subnational actors may adopt to accelerate e-mobility. These policies are categorized based on the framework from a 2013 report that analyzed municipal policymakers' inputs on electric mobility (Bakker and Trip 2013). One additional category is added to cover environmentally driven policies, such as end-of-life EV battery recycling. Due to the limited information reviewed, the table may not cover all policies implemented in each subnational entity.

The seven policy categories each address an important actor or aspect in the e-mobility ecosystem. The first two major actors considered here are consumers and suppliers. Both groups are impacted by charging infrastructure, so it is designated as its own policy category. In addition to consumers and suppliers, subnational governments—including any legislative bodies—play a key role in enabling e-mobility adoption through regulatory measures and public awareness. Besides those two important aspects, subnational governments should also strive to collaborate with other subnational governments and to align with higher level governments on policies and standards. Finally, environmental impacts of an e-mobility transition can often be overlooked. Box 2 explains the policies in this category in detail and underlines why they are important for subnational governments in terms of sustainable development.

There will likely be both beneficiaries and potential losers in an e-mobility transition, so it is necessary to determine if additional regulatory oversight or mitigation measures are needed. Some of the common beneficiaries and losers include consumer segments based on gender, income, race, abilities, industries, and communities dependent on the traditional automotive value chains versus the emerging EV ones. Therefore, a public consultation process during the roadmap development phase is necessary to engage stakeholders and assess social impacts. Undergoing a public consultation process before actual the implementation allows for feedback from the public and other external stakeholders, who may have been left out during the previous phases. Most importantly, the consultation process can also generate stakeholder buy-in, reduce future issues when implementing the roadmap, and thus increase overall efficacy of the policy process.[8]

For roadmaps with different scopes and focuses, there may be policy categories more suitable to help realize the intended goal and vision. Table 5 illustrates

Table 4 | **Major Policies Supporting E-Mobility Adoption in Subnational Roadmaps**

POLICY CATEGORY	SPECIFIC POLICIES	SUBNATIONAL CASE STUDIES THAT HAVE PROPOSED OR ENACTED THEM
Supporting consumers	Direct subsidies to consumers (for purchase and ownership)	*California*, *Hainan, Karnataka*, Los Angeles, *Maharashtra*, Mexico City, Oslo, San Francisco, Santiago, Shenzhen, Stockholm, Tokyo
	Vehicle import tariff reduction	*Hainan*
	Car sharing initiative	Boston, Los Angeles, San Francisco, San José, Tokyo
	Accessible financing options, such as preferential loan rates for EV purchase and subsidies for low-income populations	Delhi, Los Angeles, San José
	ICE scrappage	Delhi, San Francisco, Shanghai, Tokyo
Supporting charging infrastructure	Public charging incentives	Delhi, Los Angeles, Mexico City, *Karnataka,* San José, Santiago, Shanghai, Tokyo
	Private charging incentives	San José, Santiago, Shanghai, Shenzhen, Tokyo,
	Technical assistance, such as installation and deployment guidance plans	*California,* Delhi, *Hainan,* London, San José, Stockholm
	Preferential electricity rate for charging EVs	*Karnataka,* Oslo, San Francisco, San José, Shanghai, Stockholm
	Spatial planning for charging (land supply, charging hubs, charger-covered corridors, and pole-mounted charging)	Amsterdam, Beijing, Boston, *Hainan,* London, San Francisco, Stockholm, Tokyo
Supporting suppliers	Research and development incentives, such as vehicle-grid integration (VGI) and batteries	Boston, *California*, London, Los Angeles, Mexico City, San Francisco, Shanghai, Shenzhen, Tokyo
	Financial support for OEMs and EV-related corporations	*Hainan*, Shanghai
	EV-related workforce development	*Hainan, Karnataka*, Los Angeles, *Maharashtra*, Mexico City, Shanghai
	EV industry goals on output, investments, and job creation	*Karnataka*, *Maharashtra,* Shanghai
Regulatory measures	Registration exemptions and incentives	Beijing, Boston, *Hainan,* Shanghai, Shenzhen, Oslo, Tokyo
	Operation exemptions and incentives, such as road access and parking	Amsterdam, Beijing, *Karnataka*, London, Los Angeles, Mexico City, Oslo, San Francisco, San José, Stockholm
	EV-ready building codes	Beijing, Boston, *Karnataka, Maharashtra,* San Francisco, Shanghai, Shenzhen, Stockholm, Tokyo
	Low-emission zones	Amsterdam, London, Los Angeles, Mexico City, Oslo, San Francisco
	Efficiency and safety standards for EVs (including fuel economy standards, energy efficiency standards, and hardware safety standards)	*California, Hainan,* Oslo, San Francisco, Santiago, Shenzhen, Stockholm
Raising ambition and awareness	Zero-emission vehicle (ZEV) mandates and mode-specific targets	Boston, California, Hainan, London, Los Angeles, San Francisco,
	Public awareness campaigns	Boston, Los Angeles, San Francisco, Tokyo
	One-stop-shop information portals on charging spots, incentives, and adoption progress	Amsterdam, Delhi, London, San Diego, San José
	Pilot EV projects: public, shared, or government fleet	Beijing, Boston, *Hainan*, San Francisco, Mexico City, San Diego, San José, Shanghai, Shenzhen

Table 4 | **Major Policies Supporting E-Mobility Adoption in Subnational Roadmaps (Cont.)**

POLICY CATEGORY	SPECIFIC POLICIES	SUBNATIONAL CASE STUDIES THAT HAVE PROPOSED OR ENACTED THEM
Coordination with other governments	Alignment with national roadmaps	Beijing, Delhi, *Hainan, Karnataka, Maharashtra,* Shanghai, Shenzhen,
	Awareness of interjurisdictional policies	San Diego, San José
	Standardize charging and Interoperability	*California*, London, San Francisco, Shenzhen
Environmental considerations	Battery recycling programs	Mexico City, San José, Shenzhen
	Grid reforms: increasing renewable mix and resiliency	*Hainan,* London, Los Angeles, Oslo, San Francisco, San José, Tokyo, Stockholm
	Transport demand strategies specific to EVs	San José, Stockholm*
	Simultaneous modal shift strategies	San Francisco, San José

Note: Non-cities are italicized. Unless noted with an asterisk, policy information is collected from the roadmap source document. The transport demand strategy specific to EVs in Stockholm is a hybrid truck making deliveries downtown, normally not permitted due to noise and pollution concerns (Scania 2019).

Source: Compiled by WRI authors.

Box 2 | **E-Mobility Policies with Sustainable Development in Mind**

Despite its overall environmental benefits, e-mobility adoption has a few negative impacts on the environment. The first is the transfer of the fossil-powered vehicles that EVs should replace. Major EV adopter countries and regions, such as Europe, Japan, and the United States, export used and inefficient ICEVs to developing countries that lack adequate policies to regulate the quality of imported cars. This displaces rather than removes the emissions from those used vehicles and undermines global efforts to decarbonize transport.[a]

The second impact comes from the batteries that power EVs. The distribution of raw materials used to produce these batteries is highly uneven among different countries, and the excessive mining of these raw materials, such as lithium and cobalt, often leads to violations of workers' rights and environmental degradation. Either effect weakens climate-based e-mobility adoption targets.[b] Although not a direct impact of e-mobility, it is important to consider the average fleet turnover of ICEVs. Without strong incentives for consumers to retire their fossil-fuel vehicles, be they motorcycles or cars, owners are likely to hold onto their vehicles longer, as has been observed in the United States.[c] Without intervention, this means that existing ICEVs will still emit and pollute on the road while EV adoption stagnates.

To counteract e-mobility's negative environmental impact and promote long-term sustainable development, subnational governments need to enact policies with environmental considerations, as shown in Table 4. To stop the polluting and inefficient used vehicles trade, subnational governments need to work with national governments to legislate or enforce stricter vehicle efficiency standards for used vehicles. To mitigate the environmental and human tolls of battery manufacturing, subnational governments should work with OEMs and incentivize battery recycling, as in Mexico City and Shenzhen, and invest in battery recycling research and development if necessary. Lastly, to tackle the slow fleet turnover challenge, subnational jurisdictions should provide scrappage incentives for consumers switching from ICEVs to EVs, as demonstrated in the roadmaps of Delhi, San Francisco, Shanghai, Tokyo. Most roadmaps analyzed in this paper focus on e-mobility adoption, and a handful on modal shift. However, few aim to supply recycled batteries for e-mobility or have plans to accelerate the retirement of existing fossil-fuel-powered vehicles.

Sources: a. Skibell 2021; UNEP 2020; Scherger 2021; b. Ambrose and O'Dea 2021; c. Vehicle Technologies Office and IHS Markit 2019.

how the policy categories mapped in Table 4 can be preliminarily selected. For example, a roadmap that focuses on EV uptake would benefit from, first and foremost, policies that support consumers; however, regulatory measures, raising ambition and awareness, and policies supporting charging infrastructure all play an important role in helping to realize the EV-update roadmap.

After a full spectrum of policies are considered for a subnational e-mobility roadmap, the next priority for governments is financing the implementation. Borrowing from financing tools that have enabled e-bus adoption, Table A7 in the Appendix delves into more details about securing funding streams to pay for e-mobility adoption costs, particularly for high-impact modes like e-buses. Without adequate funding and financing, it is close to impossible to achieve any tangible EV adoption targets. For that reason, fiscal incentives and support mechanisms can be seen as the eighth key policy category.

4.4 Phase 4: Roadmap Implementation and Monitoring

Roadmap implementation refers to the review process, updates, monitoring, and consultation of the roadmap. This section will provide only a simple framework of implementation, since the scope of this paper focuses on the development of subnational e-mobility roadmaps. Implementation conditions vary greatly from one subnational jurisdiction to another, so those responsible for implementing the subnational roadmaps should adapt this simple framework to the local political and policy landscapes. A subnational-level roadmap generally includes the following guideline for implementing e-mobility adoption in the city:

- General strategies to achieve goals listed in the roadmap
- Action plans or action line items
- Detailed implementation timelines
- Continuous stakeholder and public consultation schedule
- Public e-mobility information portal, including items such as an adoption dashboard, EV consumer guide, and charging map
- Progress review report, with updates on target adoption rates

During the roadmap development process, measures to secure implementation need to be established using effective practices such as holding regular stakeholder meetings and surveys, in addition to other online and in-person communication techniques. These measures should be described as concretely as possible and, ideally, framed as strategies to achieve the goals and targets set out in the roadmap. By laying out specific, timebound action items and their responsible parties, a roadmap can develop an action plan with timelines that will hold internal stakeholders accountable for implementation. If the public lacks a

Table 5 | **Policy Category Prioritization Based on Roadmap Scopes and Focuses**

	SCOPES AND FOCUSES	CATEGORY 1	CATEGORY 2	CATEGORY 3	CATEGORY 4
Roadmap scope is e-mobility only	**EV uptake**	Supporting consumers	Regulatory measures	Raising awareness	Supporting charging infrastructure
	EV industry	Supporting manufacturers	Regulatory measures	Raising awareness	Supporting charging infrastructure
	EV charging	Supporting charging infrastructure	Environmental considerations	Coordination with other governments	Raising awareness
Roadmaps with a broader scope	**Climate**	Coordination with other governments	Regulatory measures	Raising awareness	Environmental considerations
	Air quality	Regulatory measures	Coordination with other governments	Supporting charging infrastructure	Environmental considerations
	Modal shift	Regulatory measures	Supporting charging infrastructure	Supporting consumers	Raising awareness

Note: Policy categories are ordered from left to right by their relevance, with 1 being the most relevant to the given roadmap scope and focus. Subnational governments should not limit their roadmap policy package to a few categories, but the table provides a starting framework.

Source: Compiled by WRI authors.

clear understanding of e-mobility adoption—often the case in subnational jurisdictions looking to promote e-mobility—an accessible online informational portal is crucial to help the interested public (adoption dashboard), potential EV buyers (EV consumer guide on incentives and vehicle models), and existing EV users (charging map) to find the information they need, in turn boosting confidence and sustaining e-mobility adoption. Other areas of measure include progress monitoring and indicator tracking to ensure the timely achievement of certain milestones established within the roadmap. For example, Amsterdam's e-mobility roadmap focuses on improving air quality, so the roadmap proposes two monitoring mechanisms: one monitors air quality and the other monitors the total number of EVs on the road.[9]

5. CONCLUSION

E-mobility roadmaps vary in detail—some only serve as preliminary studies that provide general objectives, while others contain thorough analyses, concrete targets, and detailed action plans. Our subnational roadmap analysis reveals many of the necessary factors for success. Identifying and understanding the technological, institutional, and financial pros and cons relevant to local contexts can help prioritize policies and actions needed to enable adoption. Additionally, the implementing government should consider involving a diverse set of stakeholders during the roadmap development process and proactively engaging with the private sector. Successful roadmaps also use goals and milestones with clear numerical targets for different types of vehicle categories to raise awareness and ambition. These roadmaps will usually develop an appropriate policy package to help with implementation, which should be monitored by progress tracking mechanisms.

How does the general roadmap development guidance translate to the context of Vietnamese cities? To start, developing roadmaps with broader focuses may better accelerate transport decarbonization in Vietnam, combining e-mobility with modal shift strategies like promoting electric public transport. This will in turn align with Vietnam's national climate goals and mitigate existing transportation challenges in its cities. Before the actual roadmap development process in Vietnamese cities, it is important to consider, as comprehensively as possible, the needed existing condition analyses, potential barriers, and their mitigation measures. Roadmap working groups should also engage the private sector as much as possible in the initial phases, especially global and local EV OEMs like Honda and Vinfast. During the roadmap development process, the leading government agency (oftentimes a department of transport) should consider collaborating with other relevant agencies, such as departments that oversee environmental protection, energy supply, industry, finance, and technology. A wide spectrum of stakeholder inputs can contribute to a more comprehensive e-mobility roadmap with various policy options, as has been observed in Beijing. Having finalized the roadmap, during the implementation phase, it is crucial for Vietnamese cities to continue to monitor progress based on a set of predefined metrics, as was done in Amsterdam and San José, and—based on the implementation results—iterate and adjust their e-mobility strategies as needed.

APPENDIX A. ADDITIONAL INFORMATION ON THE CASE STUDIES

Table A1 | **Status of Target Adoptions in Subnational Roadmaps Reviewed**

CASE STUDY	TARGET	GOAL	STATUS
Amsterdam	Municipal boats	2024, all municipal boats are emissions free	2021, 44% of boats (7 out of 16)
	Built-up area emission free rates	2030, 100% emission free	2019, 27% of taxis are emission free, 7% of buses, 5% of scooters
	Charging stations	2025, 62 rapid-charging stations for taxis	2019, 21% of chargers
Beijing	Private cars	2018, 60,000 new car registration EV quotas	2018, 90% met
Boston	Private cars	2025, 23% of all new car purchases	2018, 2.8% of new vehicle registrations
California	All vehicles	2025, 1.5 million on the road	2021, 425,300 EV registration, 28% adoption (Alternative Fuels Data Center 2021)
Delhi	All vehicles	2024, 25% of all new vehicle registrations are BEVs	2021, 34% adoption (8.2–9% of all new sales are BEV)
Hainan	All vehicles	2020, 30,000 EV stock, 4.3% of total stock	2020, achieved
Karnataka	E-mobility investments	(Undated) 310 billion rupees, or $4.15 billion	(No results)
	New e-mobility Jobs	(Undated) 55,000	(No results)
London	Public rapid chargers	2020, 300 rapid chargers	2021, 100% adoption
	Public non-rapid chargers	2020, 3,500 non-rapid chargers	2021, 100% adoption
	Private rapid chargers	2035, 2,300–4,100 rapid chargers	2021, 12–22% adoption
	Private non-rapid chargers	2035, 33,700–47,500 non-rapid chargers	2021, 13–18% adoption
	Public transport (buses)	2025, 2,000 zero-emissions buses (2037, 100% zero-emissions fleet)	2020, 25% adoption toward the 2025 target
	Taxis/private-hire vehicles	2033, 100% zero-emissions-capable	2020, 3,800 PHEVs and 64 BEVs, about 3% adoption
Los Angeles	Private cars	2028, 30% EVs in stock	2019, 6% of all vehicles were EVs, 25% adoption (California DMV 2020; California Energy Commission 2021)
Maharashtra	All vehicles	2023, 500,000 in stock	2019, 34,613 EVs, 7% adoption (Tornekar 2019)
	E-mobility investments	2023, 250 billion rupees, or $3.35 billion	(No results)
	New e-mobility jobs	2023, 100,000 people employed	(No results)

Table A1 | **Status of Target Adoptions in Subnational Roadmaps Reviewed (Cont.)**

CASE STUDY	TARGET	GOAL	STATUS
Mexico City	Public transport (buses)	2030, 20% of non-Sistema de Transporte Colectivo (STC) buses are electric	2018, 20% adoption
	Private vehicles	2030, 15% of new light-duty vehicles sales are hybrid or electric	2018, 15% adoption
	Shared cars (taxis & TNCs)	2030, 80% of all taxi and Transport Network Company (TNC) vehicles electrified	(No results)
	Public service fleet	2030, 30% of new utility vehicles fleet are hybrid or electric	2018, 30% adoption
	Electric micro-mobility	2030, 30% of all publicly accessible, shared bikes are electric	2018, 30% adoption
Oslo	Private cars	2030, phase out-fossil fuel-based vehicles	2020, 16% of the private car fleet is electric
	Public transport (buses)	2028, all public transport is emissions free	2018, 10% of city buses are electric
San Diego	Public service fleet	2027, increase the number of EVs in the County's fleet to 501 vehicles	2021, 16% or 78 EVs in the municipal fleet are electric
	Public service fleet emissions	2030, reduce the County's vehicle fleet's GHG emissions by 20% compared to the 2014 baseline, to 15,500 $MTCO_2e$	2020, 62% of emissions reduction achieved toward the 2030 target
	Public chargers	2028, contribute to the regional EV charging network by installing 2,040 Level 2 charging stations at county facilities	2019, 6%, 39 Level 2 chargers at public charging stations and 84 at County-fleet only charging stations, totaling 123
San Francisco	All vehicles	2040, all transportation through San Francisco will be emission-free	2019, 11% of cars registered in San Francisco were EVs (California DMV 2020; California Energy Commission 2021)
San José	Grid reform: renewable energy	2030, 60% renewable in local grid power mix, and 668 MW of renewable capacity installed	2021, 92% achieved for power mix and 32% achieved for renewable capacity
	Public transport modal share	2030, 10% of commute trips to be taken on public transit	2019, 45% achieved or 4.5% of trips taken on public transit
	Private vehicle (single-occupancy) modal share	2030, reduce commute trips in single-occupancy vehicles to 46%	2019, 44.8% achieved or 75.8% of single-occupancy vehicle commute trips
	Vehicle distance traveled (miles)	2030, 21% reduction from 2017 level of vehicle distance traveled	(No results)
	Walking and bicycling	2030, 20% of all commute journeys to be done on foot or bicycle	2020, 12.5% achieved, or 2.5% of trips on foot or bicycle
Santiago	Public transport (buses)	N/A, 130 operating in electric corridors	2019, 150% (200 buses) operating
	Public transport (buses)	2040, 100% electric buses	2020, 12%
	Shared cars (taxis)	N/A, 5% electric taxis	2021, 0.2%

Table A1 | Status of Target Adoptions in Subnational Roadmaps Reviewed (Cont.)

CASE STUDY	TARGET	GOAL	STATUS
Shanghai	Private vehicles	2025, over 1.2 million vehicles on the road	2019, 25%
	Private vehicle purchases	2025, 50% of new vehicles are EVs	2021, 20% of new sales were EVs
	Industry output	2025, over CNY 350 billion ($54.6 billion)	2020, 19% (66.4 billion CNY)
	Public transport (buses)	2020, all transit buses are NEVs	2020, 48% NEVs
	Shared cars (taxis)	2025, NEVs make up 100% of taxis	2020, 5% of taxis NEVs
	Hydrogen fuel cell vehicles	2025, 10,000 HFCVs	2020, 15% of HFCV
Shenzhen	Private vehicles	2025, 1,000,000 NEVs	2019, 36% NEV target accomplished
	Shared cars (TNCs)	2025, 55,000 NEVs	2019, 30,000 ride hailing EVs, 55% accomplished
	Freight vehicles	2025, 113,000 NEVs	2019, 72,100 NEV freight vehicles, 64% accomplished
	Public service fleet	2025, 8,000 NEVs	2019, 5,400 NEV sanitation and dumping trucks, 68% accomplished
Stockholm	Private vehicles	2040, 46% to 80% of vehicles are electric or plug-in hybrids	2020, 32% of newly registered vehicles
	Public charging	2022, 4,000 public charging points	2019, 37.5% of public chargers
Tokyo	Private vehicle sales	2030, 50% of sales are ZEVs	2018, 1.6% of sales are ZEVs
	Public transport (buses)	2030, over 300 buses	2021, 100 hydrogen fuel cell buses, 33.3% adopted
	Fast chargers	2030, 1,000 fast chargers installed	2018, 30%
	Hydrogen stations	2030, 150 hydrogen stations	2018, 9% or 14 stations

Note: Non-cities are italicized.

Source: Compiled by WRI authors.

Table A2 | **Key Contents of Important Subnational Roadmaps Reviewed**

CASE STUDY	KEY ROADMAPS	POLICIES	TARGETS	KEY CHARACTERISTICS
Amsterdam	Clean Air Action Plan (2019)	▪ Six low emission zones, gradually prohibiting the entry of different most polluting vehicles ▪ Charging station application based on EV ownership ▪ Charging infrastructure expansion ▪ Priority parking and loading spaces for EV drivers ▪ EV purchase subsidies for individuals and corporations	▪ 2030: All of city's built-up area will be emission-free ▪ 2030: Meet various air quality targets set out by WHO ▪ 1) Concentration of particulate matter ($PM_{2.5}$) below the WHO's guideline of 10.0 µg/m3 ▪ 2) NO_2 concentration reduced to 14.4 µg/m^3 ▪ 3) CO_2 emissions reduced by 9%	▪ Low emission zones ▪ Air quality goals ▪ Purchase subsidies ▪ Priority parking ▪ Residential charging expansion
Beijing	Beijing's Implementation Advice on Further Increasing the Construction and Management of Electric Vehicle Charging Infrastructure (2017–2022) Beijing's Management Plan of Promotional Application of New Energy Vehicles (2018–2020)	▪ Developed by the Joint Municipal Office of New Energy Vehicles ▪ EV-ready wiring codes and ordinances ▪ Targets to electrify buses and government and public service fleets ▪ Separate roadmap for EV infrastructure and targets for charging service radius and vehicle-to-charger ratio	▪ 2022: At least one charger every 5 km in all flat areas in the city, and every 0.9 km in selected target areas, such as the CBD, Daxing Airport (new airport), and Winter Olympics facilities ▪ 2022: 1:1 vehicle to charger ratio in residential areas	▪ Both vehicle and charging roadmaps ▪ Service radius requirement for targeted areas with predicted EV use
Boston	Zero-Emission Vehicle Roadmap (2020)	▪ Sales, fleet, and charger targets for every 5 to 10 years ▪ Public charging infrastructure in every neighborhood ▪ Expansion of Level 2 and DC chargers across the city and in municipal parking lots ▪ Municipal fleet to transition to all EVs ▪ EV car share in the city ▪ EV purchase incentives, such as fee reduction	▪ 2022: Release an RFP for an EV car-share ▪ 2022: Develop curbside charging policy and launch pilot ▪ 2023: Free-to-access public charging infrastructure in every neighborhood ▪ 2025: Set numbers of Level 2 and DC chargers installed ▪ 2035: Municipal LDVs emission-free ▪ 2040: Every household within 10-minute walk of EV car share or charging ▪ 2050: Boston is carbon-neutral ▪ 2050: Municipal MDVs emission-free ▪ 2060: Municipal HDVs emission-free	▪ Municipal fleet electrification ▪ Charging facility targets ▪ Purchase subsidies ▪ Carbon neutrality ▪ EV car share ▪ Charging facility accessibility target

Table A2 | **Key Contents of Important Subnational Roadmaps Reviewed (Cont.)**

CASE STUDY	KEY ROADMAPS	POLICIES	TARGETS	KEY CHARACTERISTICS
California	California Vehicle-Grid Integration Roadmap (1990) California Vehicle-Grid Integration Roadmap (2014) and its update (2017)	▪ ZEV mandate to reduce local air pollution caused by vehicles ▪ AB 32 Scoping Plan resulted in a low carbon fuel standard in 2009 ▪ Clean Vehicle Rebate Project in 2010 ▪ In 2012, advanced clean car rules that regulate GHGs and local air pollutants ▪ Many state utility companies transition to Time of Use rates (TOU) ▪ PG&E, a major utility company, provides a clean-fuel rebate worth half a year of electricity ▪ Determine VGI value and potential by confirming VGI electrical system impacts, confirming VGI market potential, formulating VGI business models, and supporting VGI R&D ▪ Develop VGI enabling policies, regulations, and business processes by ensuring coherence between state policies, programs, and national standards; defining VGI-related products and programs; defining VGI program or product eligibility; clarifying VGI-related product and program requirements; clarifying settlement; defining verification and conflict resolution protocols; and defining signals and messages ▪ Support VGI enabling technology development by developing enabling technology requirements and improving and identifying performance	▪ 2017: 3% of all car sales to be ZEVs ▪ 2015: ZEV Action Plan procurement target is 10% ▪ 2025: ZEV Action Plan procurement target is 25%	▪ Exclusive focus on VGI ▪ Tackling the barriers of VGI implementation
Delhi	Delhi Electric Vehicles Policy (2020)	▪ Support and incentivize battery-swapping as a charging solution: 100% of the net State Goods and Services Tax, accrued by the Delhi government, shall be provided as reimbursement to energy operators for purchase of advanced batteries to be used at swapping stations ▪ A comprehensive online information portal or "EV finder," providing an interactive map of charging spots, EV cost-saving calculator, and available EV dealers and models across vehicle modes ▪ 2- and 3-wheeler scrappage program to encourage registered owners to decommission ICE vehicles for electric ones	▪ 2024: 25% of all new vehicle registrations to be BEVs	▪ One-stop-shop website for EV adoption ▪ Scrappage program for ICE vehicles ▪ Preferential financing options for BEVs with advanced batteries ▪ Flexibility to accommodate BEVs sold without batteries (for battery-swapping)

Table A2 | **Key Contents of Important Subnational Roadmaps Reviewed (Cont.)**

CASE STUDY	KEY ROADMAPS	POLICIES	TARGETS	KEY CHARACTERISTICS
Hainan	Hainan New Energy Vehicle Development Plan (2019-2030)	▪ Zero-tariff policies on EV imports to introduce more high-end operations and service providers ▪ Implementation plan for a national ecological civilization pilot zone to tackle pollutions	▪ 2020: All new and exchanged government fleet and state-enterprise fleet to be NEV ▪ 2020: Urban air quality to be moderate or good 98% of the time ▪ 2025: Renewable energy sources to make up 50% of all energy supply ▪ 2030: 0% ICE vehicles in new vehicle sales	▪ Align with larger ecological and climate change policies ▪ EV sales target ▪ Municipal fleet electrification
Karnataka	Electric Vehicle & Energy Storage Policy 2017	▪ Incentives for EV manufacturing ▪ Support for R&D and skill development ▪ Support for charging infrastructure ▪ Additional support to increase adoption in the capital city, Bengaluru	▪ Make the state a preferred destination for EV manufacturing ▪ Investment target of INR 31,000 crore and 55,000 jobs created ▪ Develop R&D in e-mobility	▪ Global and national EV adoption stocktaking for roadmap design ▪ Key motivation for EVs is the industrial policy ▪ Support for battery swapping infrastructure
London	Guidance Note for Local Zero Emission Zones (2019)	▪ Establish Zero-Emission Zones (ZEZs) as part of the move toward zero-emission transport ▪ Healthy streets: Promote a significant share of all trips to be done by active and public transit; build streetscapes to support this shift ▪ Improve air quality to protect human health and achieve WHO air quality guidelines ▪ Larger ZEZs to be implemented after 2025 ▪ Scheduled scaling of ZEZs in other UK cities and outside of London proper	▪ 2033: All licensed taxis and private hire vehicles zero-emission capable ▪ 2037: Zero-emission bus fleet ▪ 2041: 80% of all trips in London to be made on active or public transit ▪ 2041: Reduction in overall traffic levels by 10–15% ▪ 2050: Remaining vehicles on London's roads to be zero-emission	▪ A spatial approach to e-mobility and emission reduction ▪ Integration of all aspects of the A-S-I model ▪ Scaling components

Table A2 | **Key Contents of Important Subnational Roadmaps Reviewed (Cont.)**

CASE STUDY	KEY ROADMAPS	POLICIES	TARGETS	KEY CHARACTERISTICS
Los Angeles	Zero Emissions 2028 Road Map 2.0 (2019)	▪ Low-emission vehicle hubs to accommodate neighborhoods with limited alternative transportation modes ▪ Income-sensitive feebate programs that encourage switches to EVs ▪ Support ride-hailing firms to electrify their fleets ▪ Accelerate the deployment of 84,000 public and workplace charging stations by providing up-front incentives, a streamlined and low-cost permitting process, piloting charging solutions for MUDs, installing curbside charging, and building DCFC charging plazas ▪ Explore congestion pricing to boost transit ridership and reduce car use ▪ Support emerging mobility as first- and last-mile solutions ▪ Support and invest in active transit infrastructure ▪ Public investment in building a zero-emissions freight corridor along the I-710 ▪ Target policies to address the key needs and use cases of HDV electrification ▪ Create a voluntary last-mile ZEZ pilot project	▪ 2028: Reduce GHG emissions by 50% ▪ 2028: Passenger LDVs make up 30% of all vehicles on the road and 80% of all vehicles sold ▪ 2028: 84,000 public and workplace charging stations installed ▪ 2028: Shift over 20% of all single-occupancy vehicle trips to zero-emissions public and active transit ▪ 2028: 100% electric buses in public transit ▪ 2028: 100% of shared car use to be electric ▪ 2028: Neighborhoods with a walk score lower than 65 to receive low-emission vehicle hubs ▪ 2028: All short-haul, vertical take-off, and landing transit to be electric ▪ 2028: 60% of MDV trucks to be electric ▪ 2028: Create the first zero-emission freight corridor in the US along I-710	▪ Equity consideration for disadvantaged neighborhoods ▪ Targets for multiple public and shared transport modes ▪ "Shift" in A-S-I ▪ Last-mile zero emissions zone pilot ▪ Zero-emissions freight corridor ▪ Emphasis on MDVs and HDVs
Maharashtra	Maharashtra's Electric Vehicle Policy (2018)	▪ Purchase incentives for e-buses ▪ Financial incentives and land use exemption for charging stations ▪ Industrial development subsidies incentives for manufacturers ▪ Skill development and research development in university and industrial training institutes	▪ Within 5 years of the policy issuance, by 2023: 0.5 million EVs ▪ 2023: Generate $3.4 billion (25k crore INR) investment in the EV ecosystem ▪ 2023: 0.1 million jobs created	▪ State-level plan ▪ Exclusive to BEV ▪ Main focus on "Improve" and "Shift" in A-S-I ▪ Selective piloting in six cities in the state
Mexico City	Electromobility strategy 2018–2030 for Mexico City (2018)	▪ Develop fiscal incentives for developing HPEV and BEV technologies ▪ Priority parking and other non-fiscal incentives for EVs ▪ Tax incentives for charging facility operators ▪ Electrification of shared mobility systems ▪ Develop a legal framework to promote advanced mobility technology ▪ Develop incentives for electrification for both public and private operators	▪ 2024: Monitoring systems established to evaluate the benefits and inclusiveness of e-mobility ▪ 2025: Groundwork laid for public transport electrification with fully functional e-mobility projects in place	▪ More qualitative targets than quantitative targets ▪ Equity consideration with evaluation mechanism ▪ Incentive-focused EV policies

Table A2 | **Key Contents of Important Subnational Roadmaps Reviewed (Cont.)**

CASE STUDY	KEY ROADMAPS	POLICIES	TARGETS	KEY CHARACTERISTICS
Oslo	Climate and Energy strategy (2016)	▪ Invest and plan for shifting trips from cars to public transit and active transit ▪ Confine through traffic to major roadways ▪ Integration of rail, sea, and road transport ▪ Encourage modal shifts among younger generations ▪ Reduce car use and traffic volume in inner city ▪ Improve alternative modes of transportation infrastructure	▪ 2020: Zero-emission bus fleet ▪ 2020: Public transit will only use renewable fuels ▪ 2020: 16% increase in daily bike travel ▪ 2020: All new cars and LDV trucks to use renewable fuels or be PHEV ▪ 2025: 25% increase in daily bike travel ▪ 2030: Reduce traffic volume by 1/3	▪ "Shift" in "A-S-I" ▪ Strong travel demand management in conjunction with electrification ▪ Public and shared transport electrification
San Francisco	Proposed Electric Vehicle Roadmap for San Francisco (2019)	▪ Transit First: Encourage modal shift from private cars to public and active transit ▪ Better vehicle technology in City vehicles to reduce fleet emissions ▪ Raise public awareness of options and benefits of e-mobility through awareness campaign, EV help desk, test rides, transport demand management, wayfinding, and signage ▪ Create incentives for electric mobility over gasoline and diesel vehicles for EV purchase and lease, preferential airport and highway access, preferential parking policy on- and off-street ▪ Ensure convenient and equitable access to charging infrastructure in multi-unit dwellings, City garages, private commercial garages, and on the curb; build smart charging; e-mobility workforce training; develop a DC fast chargers masterplan ▪ VGI to maximize EV benefits ▪ Shift the grid more toward renewable power ▪ Evaluable limitations of the grid and provide solutions ▪ Electric fleet pilots for MDVs and HDVs, follow up with incentives and regulations, and build port-charging for heavy-duty applications ▪ Electrify school transportation ▪ Promote stationary battery storage ▪ Advocate for and require emerging mobility options to be emission-free, including but not limited to TNCs, car share, taxis, car rentals, and autonomous vehicles	▪ 2020: Drivers and the public fully informed about EV benefits ▪ 2022: Effective and scalable range of charging options for all ▪ 2025: Reduce emissions by 1.4 million tonnes CO_2eq ▪ 2025: Most EVs to be powered by GHG-free electricity; access to preferential electricity rates in place ▪ 2025: EVs to be 50% of all new passenger vehicles, and no increase in total vehicle registration; 100% in 2030 ▪ 2025: 50% of emerging mobility vehicle miles travelled to be from EVs; 100% in 2030 ▪ 2025: 2,000 e-MDV and e-HDV trucks registered in the city; 10,000 in 2025 ▪ 2025: 1/3 of incoming commuter vehicles to be EVs, 2/3 in 2030 ▪ 2030: Reduce emissions by 1.1 million tonnes CO_2eq ▪ 2040: All trips originating in, ending in, or passing through San Francisco to be emission-free	▪ "Shift" in "A-S-I" ▪ Municipal fleet electrification ▪ VGI component ▪ Charging facility for multi-unit dwellings ▪ Focus on electrifying emerging public and shared transport such as ride-hailing

Table A2 | **Key Contents of Important Subnational Roadmaps Reviewed (Cont.)**

CASE STUDY	KEY ROADMAPS	POLICIES	TARGETS	KEY CHARACTERISTICS
Santiago	Plan for the Prevention and Decontamination of Atmospheric Pollution for the Santiago Metropolitan Region (2017)	▪ Coordinate ZEV and low-emission vehicle purchase incentives ▪ Promote a regulatory framework to determine vehicle energy efficiency standards	▪ 2018: Develop an incentive strategy for ZEV and low-emission vehicles ▪ 5% of new taxi registrations must be electric (Timeline unclear)	▪ Relatively limited in scope ▪ Initial stage of vehicle electrification
Shanghai	Implementation Plan for Expediting the Development of the NEV Industry (2021–2025)	▪ Fuel cell vehicle commercial demonstration programs ▪ Develop supporting policies, laws, and regulations for NEV-related tech development ▪ Support local manufacturers and technology firms ▪ NEV industrial parks (specifically hydrogen fuel cell) ▪ Cooperation between enterprises, academic institutions, and research institutions ▪ NEV license plates issuance to be suspended starting 2023 ▪ All new buses, cruising taxis, logistical vehicles, urban sanitation vehicles, and official vehicles for governmental agencies should be new energy vehicles, mostly electric or fuel cell vehicles. Vehicles for special purposes that cannot be fulfilled with NEVs detailed in a "negative list." ▪ Encourage the upgrade to direct current fast charging with appropriate subsidies ▪ Install more charging facilities in public areas like park-and-ride parking lots, parks, hotels, and hospitals ▪ Implement residential charging requirements using mainly slow charging with emergency fast charging ▪ Utilize favorable policies in the Lingang New Area and offer 15% corporate income tax for NEV technology related firms (25% for others)	▪ 1.2 million locally produced new energy cars per year by 2025 ▪ New energy car industry to reach 350 billion in production value by 2025, accounting for more than 35% of the production value in car manufacturing in the city ▪ 50% of all newly purchased private vehicles for individuals to be electric ▪ 100% NEV for governmental vehicles ▪ Adoption of 10,000 fuel cell vehicles by 2025 ▪ 10,000 fast charging by 2025	▪ Heavier focus on fuel cell vehicle technological development and demonstration ▪ Cooperation between private sector/enterprises and academics on shared research ▪ Upgrade from slow to fast charging ▪ Electrification of public service vehicles ▪ Hydrogen industrial parks and designated areas (in Anting and Lingang) for NEV development ▪ Utilization of favorable policies in the free trade zones

Table A2 | **Key Contents of Important Subnational Roadmaps Reviewed (Cont.)**

CASE STUDY	KEY ROADMAPS	POLICIES	TARGETS	KEY CHARACTERISTICS
Shenzhen	Shenzhen New Energy Vehicle Promotion and Application Work Plan (2021–2025) Shenzhen New Energy Vehicle Promotion and Application Work Plan (2016–2020) New Energy Industry Development Plan of Shenzhen (2009–2015)	▪ Loosen the requirement for new NEV quota application ▪ Allow NEV purchases for those who already own one vehicle in Shenzhen ▪ Subsidy for newly purchased private NEVs: 20,000/year for BEVs and 10,000 per year for PHEV (2020) ▪ Subsidy for trade-in: 20,000/year for BEV and 10,000/year for PHEV (2020) ▪ Perfect NEV maintenance standards, especially battery and charging standards ▪ Guarantee land use for charging infrastructure in new residential constructions and other sectors ▪ Strengthen policy guarantee and adjust subsidy and quota on NEVs according to market supply and demand to foster sustainable mobility ▪ Amplify financial support of NEVs research, development, purchase, and charging subsidies either directly or through loan interest deductions and risk compensation ▪ Increase inter-departmental coordination in the city and regional governments on EV deployment ▪ Increase the share of NEVs in the public realm	▪ 2025: 55,000 ride-hailing vehicles will be NEVs ▪ 2025: 113,000 freight/logistics vehicles will be NEVs ▪ 2025: 8,000 service (construction and sanitation) vehicles will be NEVs ▪ 2025: 500 government vehicles will be NEVs ▪ 2025: 780,000 private passenger vehicles will be NEVs ▪ 2025: Average charging radius to be smaller than 0.9 km ▪ 2025: Ratio of chargers to private passenger vehicles and government vehicles to reach 1:1	▪ Adjustable subsidies for NEVs to better respond to change in vehicle market and the transport sector ▪ Coordination among different government departments on EV deployment ▪ NEV targets by detailed vehicle types ▪ Development of safety standards for NEVs
Stockholm	Master Plan for Developing EV Charging in Stockholm (2016)	▪ Offer charging possibilities on city-owned parking facilities ▪ Provide information about charging technology and installation requirements to parking companies, business owners, and homeowners ▪ Provide spots for "charging streets;" i.e., clusters of 4–10 chargers on strategically chosen streets managed by willing partners	▪ 2020: Provide 0.1 public charging units per EV, about 1,500 units ▪ 2020: 500 of the new charging units on public streets at about 50 locations, with 10 charging opportunities per site	▪ Focus on charging infrastructure rather than vehicles ▪ Outsourcing of charger management from the city to the local private sector

Table A2 | **Key Contents of Important Subnational Roadmaps Reviewed (Cont.)**

CASE STUDY	KEY ROADMAPS	POLICIES	TARGETS	KEY CHARACTERISTICS
Tokyo	Tokyo ZEV Promotion Strategy	▪ Promote infrastructure development for ZEVs in the form of chargers and hydrogen stations ▪ Heavily subsidize the installation of public and private chargers, as well as hydrogen stations ▪ Encourage the installation of chargers by taking advantage of large building construction and urban development ▪ Request that the national government ease restrictions on hydrogen stations ▪ Leverage municipal facilities to install public chargers and hydrogen station ▪ Subsidize and encourage the conversion of existing buses and cargo vehicles to ZEVs ▪ Make service vehicles in the municipal fleet ZEVs ▪ Subsidize ZEV purchases, especially to boost the sale of ZEVs as passenger vehicles ▪ Promote vehicle-to-home, vehicle-to-grid, vehicle-to-building technologies as a form of energy management and to build disaster resilience ▪ Work with private businesses to raise awareness of ZEVs and charging infrastructure ▪ Introduce ZEVs to rental car and car-sharing services ▪ Target islands in the metropolitan area for ZEVs awareness promotion ▪ Experience learning opportunities at the Tokyo Hydrogen Museum and at various events to showcase vehicle-to-load system tech ▪ Identify municipal ZEVs with a sticker as a promotion strategy	▪ 2025: Install 5,000 chargers ▪ 2030: Market share of ZEVs in new passenger car share to reach 50% ▪ 2030: Introduce 300+ zero-emission buses ▪ 2030: All new small bus routes (with approximately 30 passenger capacity) must be ZEVs ▪ 2030: Install approx. 1,000 fast chargers and 150 hydrogen stations for public use ▪ 2050: All vehicles on the road to be ZEVs ▪ 2050: Expand use of renewable energy to realize zero emissions from well-to-wheel	▪ Equal emphasis on EV and HFCV ▪ Policy on charging/fueling infrastructure informed by surveying diverse stakeholders ▪ Development of vehicle-to-load technologies ▪ Public awareness and education

Note: Non-cities are italicized.

Source: Compiled by WRI authors.

Table A3 | **Data Sources for Case Study Descriptive Statistics**

	GDP PER CAPITA USD CONVERSION BETWEEN YEARS:	POPULATION DENSITY	PUBLIC TRANSPORT SHARE MOBILITY INDEX
	U.S. Bureau of Labor Statistics. n.d. "CPI Inflation Calculator." Accessed September 30, 2021. https://www.bls.gov/data/inflation_calculator.htm. Exchange rate to USD: **Exchange Rates. 2020. "[Target Current]/USD Exchange Rate in 2020." https://www.exchangerates.org.uk.**		**Deloitte. 2020. "The 2020 Deloitte City Mobility Index." Deloitte Insights. https://www2.deloitte.com/xe/en/insights/focus/future-of-mobility/deloitte-urban-mobility-index-for-cities.html. Index methodology:** **McCarthy, K. 2020. "The 2020 Deloitte City Mobility Index—Methodology." Deloitte. https://www2.deloitte.com/content/dam/insights/us/articles/4331_Deloitte-City-Mobility-Index/2020/DCMI_Methodology_2020_WEB.pdf.**
Amsterdam	Wong, D. 2018. "Canadian Cities Rank Low For Density, but Also Economic Output." Better Dwelling. January 10. https://betterdwelling.com/canadian-cities-rank-low-density-also-economic-output/.	**Area:** University College London. 2019. "Amsterdam." Amsterdam—The INEQ-CITIES Project. January 24. https://www.ucl.ac.uk/ineq-cities/atlas/cities/amsterdam. **Population:** European Commission. 2010. "Noord-Holland." Regional Innovation Monitor Plus. July 22. https://ec.europa.eu/growth/tools-databases/regional-innovation-monitor/base-profile/noord-holland.	Dixon, S., R. Dubbeldeman, and L. Middelkoop. 2020. "Amsterdam—Deloitte City Mobility Index 2020." Deloitte. https://www2.deloitte.com/content/dam/insights/us/articles/4331_Deloitte-City-Mobility-Index/Amsterdam_GlobalCityMobility_WEB.pdf.
Bangkok	Office of National Economic and Social Development Council. 2019. "Gross Regional and Provincial Product (GPP)." https://www.nesdc.go.th/nesdb_en/more_news.php?cid=156&filename=index.	**Area:** Strategic Management Division. 2020. "Bangkok Statistics 2020." *Statistical Yearbook*. Bangkok: Office of Strategy and Evaluation. https://webportal.bangkok.go.th/public/user_files_editor/130/BMA%20STATISTIC/BMA_STAT_63.pdf. **Population:** Department of Provincial Administration. 2021. "Number of Population from Registration by Age, Sex Region and Province: 2021." National Statistical Office of Thailand. http://statbbi.nso.go.th/staticreport/Page/sector/EN/report/sector_01_11101_EN_.xlsx.	Siridhara, S. 2020. "Sustainable Urban Transport Index for Bangkok and Impacts of COVID-19 on Mobility." Draft final report. UN ESCAP. https://www.unescap.org/sites/default/d8files/knowledge-products/SUTI_and_COVID-19_Impact_Bangkok_0.pdf.
Beijing	**GDP per capita in USD:** Table 2.1 in Beijing Municipal Bureau of Statistics and NBC Survey Office in Beijing. 2021. "Beijing Statistical Yearbook 2020." *Statistical Yearbook*. Beijing: Beijing Municipal People's Government. http://nj.tjj.beijing.gov.cn/nj/main/2020-tjnj/zk/indexeh.htm.	**Area and population:** Table 3.3 in Beijing Municipal Bureau of Statistics and NBC Survey Office in Beijing. 2021. "Beijing Statistical Yearbook 2020." *Statistical Yearbook*. Beijing: Beijing Municipal People's Government. http://nj.tjj.beijing.gov.cn/nj/main/2020-tjnj/zk/indexeh.htm.	Dixon, S., M. Hecker, and C. Jiong Lin Ma. 2018. "Beijing—Deloitte City Mobility Index." Deloitte. https://www2.deloitte.com/content/dam/insights/us/articles/4331_Deloitte-City-Mobility-Index/Beijing_GlobalCityMobility_WEB.pdf.

Table A3 | **Data Sources for Case Study Descriptive Statistics (Cont.)**

	GDP PER CAPITA USD CONVERSION BETWEEN YEARS:	POPULATION DENSITY	PUBLIC TRANSPORT SHARE MOBILITY INDEX
Boston	Aysheshim, K.D., J.R. Hinson, and S. Panek. 2020. "Local Area Gross Domestic Product Methodology, Survey of Current Business, March 2020." Survey of Current Business, *The Journal of the U.S. Bureau of Economic Analysis*. https://apps.bea.gov/scb/2020/03-march/0320-county-level-gdp.htm.	**Area:** U.S. Census Bureau. 2019. "Suffolk County, Massachusetts." https://data.census.gov/cedsci/profile?g=0500000US25025. **Population:** U.S. Census Bureau. 2019. "Suffolk County, Massachusetts Populations and People." https://data.census.gov/cedsci/table?q=Suffolk%20County,%20Massachusetts%20Populations%20and%20People&g=0500000US25025&tid=ACSDP5Y2019.DP05.	Burrows, M., C. Burd, and B. McKenzie. 2011. "Commuting by Public Transportation in the United States: 2019." American Community Survey Reports. U.S. Census Bureau. https://www.census.gov/content/dam/Census/library/publications/2021/acs/acs-48.pdf.
Da Nang	United Nations Economic and Social Commission for Asia and the Pacific (ESCAP). 2020. "Da Nang City, Viet Nam." https://www.unescap.org/sites/default/d8files/2020-08/DaNangCity_0.pdf.	General Statistics Office of Vietnam. 2020. "Statistical Summary Book of Vietnam 2020 [Niên Giám Thống Kê (Tóm Tắt) 2020]." *Statistical Yearbook. Hanoi*: Statistical Publishing House.	Nguyen Huu, D., and V. Ngoc. 2021. "Analysis Study of Current Transportation Status in Vietnam's Urban Traffic and the Transition to Electric Two-Wheelers Mobility." *Sustainability* 13 (May): 27. doi:10.3390/su13105577.
Delhi	Planning Department of Delhi. 2021. "Chapter 2—State Economy." In *Economic Survey of Delhi 2020–21*, 23. Economic Survey of Delhi. Delhi, India: Government of Delhi. http://delhiplanning.nic.in/sites/default/files/2.%20State%20Economy.pdf.	**Area and population:** Government of Delhi. 2020. "About Us—Government of National Capital Territory of Delhi." May 6. https://portal.delhi.gov.in/about-us.	Dixon, S., T. Milligan, and V. Smith. 2018. "Delhi—Deloitte City Mobility Index 2018." Deloitte. https://www2.deloitte.com/content/dam/insights/us/articles/4331_Deloitte-City-Mobility-Index/Delhi_GlobalCityMobility_WEB.pdf.
Hanoi	Hanoi Statistics Office. 2020. "Gross Domestic Product in the City in 2020 Is Estimated to Increase by 3.98% [Tổng sản phẩm trên địa bàn thành phố năm 2020 ước tăng 3,98%]." Government. Hanoi Information Portal. December 29. https://m.hanoi.gov.vn/web/guest/tintuc_sukien/-/hn/ZVOm7e3VDMRM/7320/2842543/13/tong-san-pham-tren-ia-ban-thanh-pho-nam-2020-uoc-tang-398.html;jsessionid=i+QMG-nsnR8xYg7edIlfl-zF.undefined.	**Area:** Director of Ha Noi Department of Information and Communications. 2010. "Population and Area." Ha Noi Portal. January 15. https://english.hanoi.gov.vn/overview. **Population:** General Statistics Office of Vietnam. 2020. "Statistical Summary Book of Vietnam 2020 [Niên Giám Thống Kê (Tóm Tắt) 2020]." *Statistical Yearbook.* Hanoi: Statistical Publishing House.	Nguyen Huu, D., and V. Ngoc. 2021. "Analysis Study of Current Transportation Status in Viet Nam's Urban Traffic and the Transition to Electric Two-Wheelers Mobility." *Sustainability* 13 (May): 27. doi:10.3390/su13105577.

Table A3 | **Data Sources for Case Study Descriptive Statistics (Cont.)**

	GDP PER CAPITA USD CONVERSION BETWEEN YEARS:	POPULATION DENSITY	PUBLIC TRANSPORT SHARE MOBILITY INDEX
Ho Chi Minh City	**GDP total:** World Bank. 2019. "Viet Nam | Data." https://data.worldbank.org/country/Viet Nam. **City percentage of GDP:** Vo, M. 2019. "Ho Chi Minh City: Global Cities Rental Guide." Cushman & Wakefield. https://www.cushmanwakefield.com/-/media/cw/global/insights/global-cities-retail-guide/apac/Viet Nam_hochiminhcity_retailguide.pdf?rev=199d6538a72e4c7d84d7a549000dc338. **City population:** Huynh, D.T., and J. Gomez-Ibañez. 2017. "Viet Nam." In *The Urban Transport Crisis in Emerging Economies*, edited by D. Pojani and D. Stead, 267–82. The Urban Book Series. Cham: Springer International Publishing. doi:10.1007/978-3-319-43851-1_13.	**Population:** General Statistics Office of Vietnam. 2020. "Statistical Summary Book of Vietnam 2020 [Niên Giám Thống Kê (Tóm Tắt) 2020]." *Statistical Yearbook*. Hanoi: Statistical Publishing House. **Area:** Hai, P.M. 2018. "Sustainable Urban Transport Index (SUTI)—2018." UN ESCAP: Transport Development & Strategy Institute (TDSI). https://www.unescap.org/sites/default/files/SUTI%20%20Mobility%20Assessment%20Report%20%20-%20Ho%20Chi%20Minh%20City.pdf.	Nguyen Huu, D., and V. Ngoc. 2021. "Analysis Study of Current Transportation Status in Viet Nam's Urban Traffic and the Transition to Electric Two-Wheelers Mobility." *Sustainability* 13 (May): 27. doi:10.3390/su13105577.
Jakarta	Statistics Indonesia (BPS). 2021. "Gross Domestic Regional Products." Jakarta Investment Centre. https://invest.jakarta.go.id/economic-data.	**Area:** Anugerah, A.R., P.S. Muttaqin, and D.A. Purnama. 2021. "Effect of Large-Scale Social Restriction (PSBB) during COVID-19 on Outdoor Air Quality: Evidence from Five Cities in DKI Jakarta Province, Indonesia." *Environmental Research* 197 (June): 111164. doi:10.1016/j.envres.2021.111164. **Population:** BPS-Statistics of DKI Jakarta Province. 2021. "Total Population of DKI Jakarta Province by Age Group and Gender 2019–2021." https://jakarta.bps.go.id/indicator/12/111/1/jumlah-penduduk-provinsi-dki-jakarta-menurut-kelompok-umur-dan-jenis-kelamin.html.	Dixon, S., T. Milligan, and V. Smith. 2020. "Jakarta—Deloitte City Mobility Index 2020." Deloitte. https://www2.deloitte.com/content/dam/insights/us/articles/4331_Deloitte-City-Mobility-Index/Jakarta_GlobalCityMobility_WEB.pdf.
Kuala Lumpur	Department of Statistics Malaysia. 2021. "Federal Territory of Kuala Lumpur @ a Glance." August 20. https://www.dosm.gov.my/v1/index.php?r=column/cone&menu_id=bjRlZXVGdnBueDJKY1BPWEFPRlhIdz09.	**Area and population:** Department of Statistics Malaysia. 2021. "Federal Territory of Kuala Lumpur @ a Glance." August 20. https://www.dosm.gov.my/v1/index.php?r=column/cone&menu_id=bjRlZXVGdnBueDJKY1BPWEFPRlhIdz09.	Chiu Chuen, O., M.R. Karim, and S. Yusoff. 2014. "Mode Choice between Private and Public Transport in Klang Valley, Malaysia." *The Scientific World Journal* 2014: 1–14. doi:10.1155/2014/394587.

Table A3 | **Data Sources for Case Study Descriptive Statistics (Cont.)**

	GDP PER CAPITA USD CONVERSION BETWEEN YEARS:	POPULATION DENSITY	PUBLIC TRANSPORT SHARE MOBILITY INDEX
London	Dixon, S., T. Milligan, and V. Smith. 2020. "London—Deloitte City Mobility Index 2020." Deloitte. https://www2.deloitte.com/content/dam/insights/us/articles/4331_Deloitte-City-Mobility-Index/London_GlobalCityMobility_WEB.pdf.	**Area:** Dixon, S., T. Milligan, and V. Smith. 2020. "London—Deloitte City Mobility Index 2020." Deloitte. https://www2.deloitte.com/content/dam/insights/us/articles/4331_Deloitte-City-Mobility-Index/London_GlobalCityMobility_WEB.pdf. **Population:** Greater London Authority. 2020. "London's Population." London Datastore. https://data.london.gov.uk/dataset/londons-population.	Dixon, S., T. Milligan, and V. Smith. 2020. "London—Deloitte City Mobility Index 2020." Deloitte. https://www2.deloitte.com/content/dam/insights/us/articles/4331_Deloitte-City-Mobility-Index/London_GlobalCityMobility_WEB.pdf.
Los Angeles	Aysheshim, K.D., J.R. Hinson, and S. Panek. 2020. "Local Area Gross Domestic Product Methodology, Survey of Current Business, March 2020." Survey of Current Business, *The Journal of the U.S. Bureau of Economic Analysis*. https://apps.bea.gov/scb/2020/03-march/0320-county-level-gdp.htm.	**Area:** U.S. Census Bureau. 2019. "Los Angeles County, California." https://data.census.gov/cedsci/profile?g=0500000US06037. **Population:** U.S. Census Bureau. 2019. "Total Population." https://data.census.gov/cedsci/table?q=Population%20Total&g=0500000US06037&tid=ACSDT5Y2019.B01003.	Dixon, S., J. Qua, and S. VanDiver. 2020. "Los Angeles—Deloitte City Mobility Index 2020." Deloitte. https://www2.deloitte.com/content/dam/insights/us/articles/4331_Deloitte-City-Mobility-Index/Los-Angeles_GlobalCityMobility_WEB.pdf.
Mexico City	OECD. 2018. "OECD Regions and Cities at a Glance 2018—Mexico." OECD Publishing. https://www.oecd.org/cfe/MEXICO-Regions-and-Cities-2018.pdf.	**Area:** INEGI. 2020. "Densidad de Población." Cuétame de México. http://cuentame.inegi.org.mx/poblacion/densidad.aspx?tema=P. **Population:** INEGI. 2020. "Ciudad de México (09)." México in Figures. Instituto Nacional de Estadística y Geografía. INEGI. https://en.www.inegi.org.mx/app/areasgeograficas/?ag=09.	Dixon, S., E.R. Pacheco Villagrán, and G. Monica. 2018. "Mexico City—Deloitte City Mobility Index." Deloitte. https://www2.deloitte.com/content/dam/insights/us/articles/4331_Deloitte-City-Mobility-Index/Mexico_GlobalCityMobility_WEB.pdf.
Oslo	OECD. 2019. "OECD Regions and Cities at a Glance 2018—Norway." OECD Publishing. https://www.oecd.org/cfe/NORWAY-Regions-and-Cities-2018.pdf.	Statistics Norway. 2021. "Municipality—Oslo." Statistics Norway. https://www.ssb.no/kommunefakta/kommune.	Dixon, S., L. Herzig, and J. Vollan. 2018. "Oslo—Deloitte City Mobility Index." Deloitte. https://www2.deloitte.com/content/dam/insights/us/articles/4331_Deloitte-City-Mobility-Index/Oslo_GlobalCityMobility_WEB.pdf.
San Diego	Aysheshim, K.D., J.R. Hinson, and S. Panek. 2020. "Local Area Gross Domestic Product Methodology, Survey of Current Business, March 2020." Survey of Current Business, *The Journal of the U.S. Bureau of Economic Analysis*. https://apps.bea.gov/scb/2020/03-march/0320-county-level-gdp.htm.	**Area:** U.S. Census Bureau. 2019. "San Diego County, California." https://www.census.gov/quickfacts/fact/table/sandiegocountycalifornia/PST045221. **Population:** U.S. Census Bureau. 2020. "ACS Demographic and Housing Statistics—San Diego County, California." https://data.census.gov/cedsci/table?g=0500000US06073.	Dixon, S., T. Milligan, and V. Smith. 2020. "San Diego—Deloitte City Mobility Index 2018." Deloitte. https://www2.deloitte.com/content/dam/insights/us/articles/4331_Deloitte-City-Mobility-Index/SanDiego_GlobalCityMobility_WEB.pdf.

Table A3 | **Data Sources for Case Study Descriptive Statistics (Cont.)**

	GDP PER CAPITA USD CONVERSION BETWEEN YEARS:	POPULATION DENSITY	PUBLIC TRANSPORT SHARE MOBILITY INDEX
San Francisco	Aysheshim, K.D., J.R. Hinson, and S. Panek. 2020. "Local Area Gross Domestic Product Methodology, Survey of Current Business, March 2020." Survey of Current Business, *The Journal of the U.S. Bureau of Economic Analysis*. https://apps.bea.gov/scb/2020/03-march/0320-county-level-gdp.htm.	**Area:** U.S. Census Bureau. 2019. "San Francisco County, California." https://data.census.gov/cedsci/profile?g=0500000US06075. **Population:** U.S. Census Bureau. 2019. "ACS Demographic and Housing Statistics—San Francisco County, California." https://data.census.gov/cedsci/table?q=San%20Francisco%20County,%20California&tid=ACSDP5Y2019.DP05.	Burrows, M., C. Burd, and B. McKenzie. 2011. "Commuting by Public Transportation in the United States: 2019." American Community Survey Reports. U.S. Census Bureau. https://www.census.gov/content/dam/Census/library/publications/2021/acs/acs-48.pdf.
San José	Aysheshim, K.D., J.R. Hinson, and S. Panek. 2020. "Local Area Gross Domestic Product Methodology, Survey of Current Business, March 2020." Survey of Current Business, *The Journal of the U.S. Bureau of Economic Analysis*. https://apps.bea.gov/scb/2020/03-march/0320-county-level-gdp.htm.	**Area:** U.S. Census Bureau. 2019. "Santa Clara County, California." https://www.census.gov/quickfacts/santaclaracountycalifornia. **Population:** U.S. Census Bureau. 2020. "ACS Demographic and Housing Statistics—Santa Clara County, California." https://www.census.gov/quickfacts/santaclaracountycalifornia.	Hexagon Transportation Consultants, Inc. 2018. "Downtown Strategy 2040 EIR: Transportation Analysis." Consultant report. San José: City of San José. https://www.sanjoseca.gov/home/showpublisheddocument/44040/637082060174570000.
Santiago	World Bank. n.d. "GDP per Capita (Current US$)—Chile | Data." Accessed September 28, 2021. https://data.worldbank.org/indicator/NY.GDP.PCAP.CD?locations=CL.	**Area and population:** INEGI. 2018. "Censo 2017 Comuna: Población, Viviendas por Área y Densidad." 2018. https://geoine-ine-chile.opendata.arcgis.com/datasets/1c64fcb18f5a41e088b25ef9f42b58d7_0/about.	Dixon, S., J. Rossell, and D. Falcon. 2020. "Santiago—Deloitte City Mobility Index." Deloitte. https://www2.deloitte.com/content/dam/insights/us/articles/4331_Deloitte-City-Mobility-Index/Santiago_GlobalCityMobility_WEB.pdf.
Shanghai	**GDP per capita in CNY:** Table 1.5 in Shanghai Statistical Bureau. 2021. "2020 Shanghai Statistical Yearbook." *Statistical Yearbook*. Shanghai: Shanghai Municipal People's Government. http://tjj.sh.gov.cn/tjnj/zgsh/tjnj2020en.html. **Currency exchange rate of USD:CNY:** Table 2.1 in Beijing Municipal Bureau of Statistics, and NBC Survey Office in Beijing. 2021. "Beijing Statistical Yearbook 2020." *Statistical Yearbook*. Beijing: Beijing Municipal People's Government. http://nj.tjj.beijing.gov.cn/nj/main/2020-tjnj/zk/indexeh.htm.	**Area and population:** Table 2.2 in Shanghai Statistical Bureau. 2021. "2020 Shanghai Statistical Yearbook." *Statistical Yearbook*. Shanghai: Shanghai Municipal People's Government. http://tjj.sh.gov.cn/tjnj/zgsh/tjnj2020en.html.	Dixon, S., M. Hecker, and C. Jiong Lin Ma. 2020. "Shanghai—Deloitte City Mobility Index 2020." Deloitte. https://www2.deloitte.com/content/dam/insights/us/articles/4331_Deloitte-City-Mobility-Index/Shanghai_GlobalCityMobility_WEB.pdf.

Table A3 | **Data Sources for Case Study Descriptive Statistics (Cont.)**

	GDP PER CAPITA USD CONVERSION BETWEEN YEARS:	POPULATION DENSITY	PUBLIC TRANSPORT SHARE MOBILITY INDEX
Shenzhen	**GDP per capita in CNY:** Table 1.3 in Shenzhen Statistics Bureau, and NBC Survey Office in Shenzhen. 2020. *Shenzhen Statistical Yearbook 2020.* 30th ed. Shenzhen: China Statistics Press. http://tjj.sz.gov.cn/attachment/0/811/811560/8386382.pdf. **Currency exchange rate of USD:CNY:** Table 2.1 in Beijing Municipal Bureau of Statistics, and NBC Survey Office in Beijing. 2021. "Beijing Statistical Yearbook 2020." *Statistical Yearbook.* Beijing: Beijing Municipal People's Government. http://nj.tjj.beijing.gov.cn/nj/main/2020-tjnj/zk/indexeh.htm.	**Area and population:** Table 1.2 in Shenzhen Statistics Bureau, and NBC Survey Office in Shenzhen. 2020. *Shenzhen Statistical Yearbook 2020.* 30th ed. Shenzhen: China Statistics Press. http://tjj.sz.gov.cn/attachment/0/811/811560/8386382.pdf.	Dixon, S., M. Hecker, and C. Jiong Lin Ma. 2018. "Shenzhen—Deloitte City Mobility Index." Deloitte. https://www2.deloitte.com/content/dam/insights/us/articles/4331_Deloitte-City-Mobility-Index/Shenzhen_GlobalCityMobility_WEB.pdf
Stockholm	Dixon, S., K. Hallenheim, and K. Thelander Svensson. 2020. "Stockholm—Deloitte City Mobility Index 2020." Deloitte. https://www2.deloitte.com/content/dam/insights/us/articles/4331_Deloitte-City-Mobility-Index/Stockholm_GlobalCityMobility_WEB.pdf.	**Area:** Statistics Sweden. 2020. "Stockholm Metropolitan Area (Sweden): Municipalities—Population Statistics, Charts and Map." City Population. https://www.citypopulation.de/en/sweden/metrostockholm/. **Population:** Statistics Sweden. 2021. "Population in the Country, Counties and Municipalities on 30 June, 2021 and Population Change in April–June 2021." Statistiska Centralbyrån. http://www.scb.se/en/finding-statistics/statistics-by-subject-area/population/population-composition/population-statistics/pong/tables-and-graphs/quarterly-population-statistics--municipalities-counties-and-the-whole-country/quarter-2-2021/.	Dixon, S., K. Hallenheim, and K. Thelander Svensson. 2020. "Stockholm—Deloitte City Mobility Index 2020." Deloitte. https://www2.deloitte.com/content/dam/insights/us/articles/4331_Deloitte-City-Mobility-Index/Stockholm_GlobalCityMobility_WEB.pdf.
Tokyo	Dixon, S., T. Kono, and Y. Tanaka. 2020. "Tokyo—Deloitte City Mobility Index 2020." Deloitte. https://www2.deloitte.com/content/dam/insights/us/articles/4331_Deloitte-City-Mobility-Index/Tokyo_GlobalCityMobility_WEB.pdf.	Dixon, S., T. Kono, and Y. Tanaka. 2020. "Tokyo—Deloitte City Mobility Index 2020." Deloitte. https://www2.deloitte.com/content/dam/insights/us/articles/4331_Deloitte-City-Mobility-Index/Tokyo_GlobalCityMobility_WEB.pdf.	Dixon, S., T. Kono, and Y. Tanaka. 2020. "Tokyo—Deloitte City Mobility Index 2020." Deloitte. https://www2.deloitte.com/content/dam/insights/us/articles/4331_Deloitte-City-Mobility-Index/Tokyo_GlobalCityMobility_WEB.pdf.

Table A3 | **Data Sources for Case Study Descriptive Statistics (Cont.)**

	PASSENGER CAR STOCK (OWNERSHIP)	TWO-WHEELER STOCK (OWNERSHIP) OR POPULATION
Bangkok	Department of Land Transport Thailand. 2020. "Registered Cars (Collection)." Transportation Statistics. 2020. https://web.dlt.go.th/statistics/.	n/a
Beijing	Beijing Traffic Management Bureau. 2021. "Figures Related to Traffic Management since 2000 [2000年以来交通管理相关数字]." http://jtgl.beijing.gov.cn/jgj/jgxx/95495/ywsj/index.html.	n/a
Delhi	Planning Department of Delhi. 2021. "Appendix—Table 12.1 Motor Vehicles in Delhi." In *Economic Survey of Delhi 2020–21*, 453. Economic Survey of Delhi. Delhi, India: Government of Delhi. http://delhiplanning.nic.in/sites/default/files/2.%20State%20Economy.pdf.	n/a
Da Nang, Hanoi, Ho Chi Minh City	Le, A.T., T.Y.L. Nguyen, and D.T. Do. 2021. "Study of Electric Mobility Development in Viet Nam." NDC Transport Initiative for Asia. Bonn and Eschborn, Germany: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. https://www.ndctransportinitiativeforasia.org/resources-list/study-of-electric-mobility-development-in-viet-nam.	Le, A.T., T.Y.L. Nguyen, and D.T. Do. 2021. "Study of Electric Mobility Development in Viet Nam." NDC Transport Initiative for Asia. Bonn and Eschborn, Germany: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. https://www.ndctransportinitiativeforasia.org/resources-list/study-of-electric-mobility-development-in-viet-nam.
Jakarta	BPS-Statistics of DKI Jakarta Province. 2020. "Number of Motorized Vehicles by Vehicle Type (Units) in DKI Jakarta Province 2018–2020." https://jakarta.bps.go.id/indicator/17/786/1/jumlah-kendaraan-bermotor-menurut-jenis-kendaraan-unit-di-provinsi-dki-jakarta.html.	n/a
Kuala Lumpur	Yap, C. 2013. "10 Facts about Malaysia's Vehicle Population." Motor Trader, March 2. https://web.archive.org/web/20150511142237/http://www.motortrader.com.my/news/10-facts-about-malaysias-vehicle-population/.	*Department of Statistics Malaysia. 2020. "Population Statistics." https://www.dosm.gov.my/v1/index.php?r=column/cthree&menu_id=UmtzQ1pKZHBjY1hVZE95R3RnR0Y4QT09.
Mexico City	Sosa, I., and A. Morales. 2020. "Motorcycles Grow More than Cars in Mexico City and Its Metropolitan Region [Crecen motos más que autos en la ZMVM]." Reforma, October 12. https://www.reforma.com/aplicacioneslibre/preacceso/articulo/default.aspx?__rval=1&urlredirect=/crecen-motos-mas-que-autos-en-la-zmvm/ar2048364?referer=--7d616165662f3a3a6262623b727a7a-7279703b767a783a--.	Sosa, I., and A. Morales. 2020. "Motorcycles Grow More than Cars in Mexico City and Its Metropolitan Region [Crecen motos más que autos en la ZMVM]." Reforma, October 12. https://www.reforma.com/aplicacioneslibre/preacceso/articulo/default.aspx?__rval=1&urlredirect=/crecen-motos-mas-que-autos-en-la-zmvm/ar2048364?referer=--7d616165662f3a3a6262623b727a7a-7279703b767a783a--.
Oslo	Statistics Norway. 2021. "07849: Registered Vehicles, by Type of Transport and Type of Fuel (M) 2008–2021." Statbank. https://www.ssb.no/en/statbank/table/07849/.	Statistics Norway. 2021. "07849: Registered Vehicles, by Type of Transport and Type of Fuel (M) 2008–2021." Statbank. https://www.ssb.no/en/statbank/table/07849/.
Shanghai	Shanghai Traffic Police. 2021. "'Authoritative Release' in the First Half of 2021, 372,000 Newly Registered Motor Vehicles and 133,000 New Energy Vehicles Were Registered in Shanghai!" Baidu, August 3. https://baijiahao.baidu.com/s?id=1707065524432571553&wfr=spider&for=pc.	n/a
Tokyo	Tokyo Automobile Parts Wholesale Cooperative. 2016. "Number of Automobiles Owned by Tokyo." http://www.tokyo-ap.coop/deta/deta.html.	Prefectures Grading Research. 2014. "Motorcycle Number Ranking." http://grading.jpn.org/y1206009.html.

Note: An asterisk (*) denotes that the primary source does not have two-wheeler stock and the data area differs from the population area in the previous table.

Table A4 | **List of National E-Mobility Roadmaps and Their Relevance to the Three Southeast Asian Case Study Cities**

ASEAN CASE STUDY	NATIONAL E-MOBILITY ROADMAP DOCUMENT, OR RELATED LEGISLATIVE FRAMEWORK	RELEVANCE TO CITY-LEVEL E-MOBILITY ADOPTION, OR SPECIFIC MENTIONS IN THE ROADMAPS
Bangkok	Roadmap for Thailand's EV development from 2021–2035 (The National Electric Vehicles Policy Committee 2021)	▪ **E-buses**: In Bangkok, the conversion of traditional combustion buses to electric city transit buses will be reported. An unspecified number of bus operation companies will be selected to receive a grant and retire ICE buses. ▪ **E-ferry**: In Bangkok, the Ministry of Transport has already deployed battery-driven ferry boats to offer services along the Chao Phraya River and Bangkok's main canals. ▪ **Battery R&D:** A lithium-ion battery test center is planned near Bangkok.[10]
Jakarta	Presidential Regulation No.55/2019 on Battery Electric Vehicles (BEV) (Government of Indonesia 2019)	▪ **E-buses**: The public transit operator, TransJakarta, hopes to operate a zero-emissions fleet by 2030 by converting its diesel-fueled buses to all electric.[11] ▪ **E-taxis**: In Jakarta, the largest taxi operator has 30 electric vehicles in its fleet.[12] ▪ **Road access privilege**: For non-fiscal incentives, the regulation recommends the exemption of EVs from certain driving restrictions, such as the odd-even license plate road rationing policy currently in place in Jakarta. ▪ **Workforce development**: The regulation recommends issuing certification for human resources involved in BEV manufacturing.
Kuala Lumpur	Low Carbon Mobility Blueprint: Decarbonizing Land Transport (KASA 2021)	▪ **EV adoption:** Between 2014 and 2018, almost a third of petrol-based passengers cars registered in Malaysia were in Kuala Lumpur. The city is identified as a target area for transitioning away from ICE cars and modal shift toward public transport.[13] ▪ **Modal shift**: Two of the five national strategies in the roadmap promote public transport and active mobility, replacing private transport for passenger movement as much as possible.

Note: The original document for the Thailand Roadmap is not found beyond secondary accounts, so two additional sources are added to corroborate its existence.

Sources: Government of Indonesia 2019; IHS Markit 2019; The Ministry of Environment and Water (KASA) 2021; The National Electric Vehicles Policy Committee (of Thailand) 2021; *The Nation Thailand* 2021.

Table A5 | **Capacity of EV Manufacturing in Selected Subnational Case Studies**

COUNTRY	CASE STUDY OR VIETNAMESE CITY	AUTOMAKER PRESENT WITH EV-CAPABLE PLANTS	MANUFACTURED VEHICLE MODES	ESTIMATED ANNUAL EV MANUFACTURE CAPACITY
China	Beijing	BAIC Hyundai Li Auto Mercedes-Benz*	LDV-cars and batteries	≈ 1.81 million
	Hainan	Haima Auto	LDV-cars	≈ 0.01 million
	Shanghai (Changzhou, Hefei)	Li Auto NIO* SIAC Tesla	LDV-cars	≈ 1.74 million
Norway	Oslo	N/A, mostly importing EVs	N/A	≈ 0
Japan	Tokyo (Kanagawa)	Nissan	LDV-cars	≈ 0.24 million
United States	Los Angeles	BYD	MDV-buses	≈ 1,500
	San Diego	Aptera	LDV-cars	≈ 0.01 million
	San Francisco, San José (Newark, Fremont)	Tesla	LDV-cars	≈ 0.60 million
ASEAN - Thailand	Bangkok (Chachoengsao, Rayong, Samut Prakan)	Honda	2Ws	≈ 1.32 million
		Toyota Mercedes* Great Wall Motors	LDV-cars and batteries	≈ 0.52 million
ASEAN - Indonesia	Jakarta (Bekasi, Karawang)	Hyundai Wuling Toyota	LDV-cars	≈ 0.52 million
ASEAN - Malaysia	Kuala Lumpur (Rawang, Shah Alam)	Perodua Volvo	LDV-cars	≈ 0.33 million
India	Delhi	Revolt Motors	2Ws	≈ 0.12 million
	Karnataka	Honda Mahindra Reva TVS Motor	2Ws 3Ws	≈ 5.35 million
Mexico	Mexico City (Toluca)	General Motors (GM)	ICE Engines	≈ 0
Chile	Santiago	N/A, mostly importing EVs	N/A	≈ 0
ASEAN - Vietnam	Da Nang	N/A	N/A	≈ 0
ASEAN - Vietnam	Hanoi (Haiphong)	Vinfast	2Ws	≈ 0.05 million
			LDV-cars	≈ 0.03 million
			MDV-buses	N/A
ASEAN - Vietnam	Ho Chi Minh City	N/A	N/A	N/A

Note: The annual EV production capacity are loose estimates only. Some are based on maximum capable outputs, some from actual production output from one year, and others from sales data. Non-cities are italicized. An asterisk (*) denotes that their manufacturing facilities are not located in the city proper of the case studies, but in the metropolitan regions; specific locations in the metropolitan region are noted directly below the relevant city, in parentheses.

Source: Compiled by WRI authors, drawing from MarkLines and automakers' websites.

Table A6(a) | Key Barriers for Subnational Roadmap Adoption

PHASE 1: ROADMAP PLANNING AND PREPARATION	Lack of clear goal or motivation for e-mobility adoption
	Lack of reliable data sources to inform existing conditions analysis
	Lack of EV technological capacity and know-how
PHASE 2: ROADMAP VISIONING	Overambitious target-setting that becomes impossible to meet
	Underwhelming target-setting that does not bring about meaningful outcomes
	Lack of milestones or interim targets to measure progress toward the overall target
	Failure to engage appropriate sets of stakeholders relevant to the roadmap's objectives
	Lack of action plans or failure to effectively engage stakeholders
PHASE 3: ROADMAP DEVELOPMENT	Lack of scenario analysis to consider alternative possible outcomes
	Vague policy recommendations with no legislative pathways or implementation details
	Failure to properly assess the impact of e-mobility adoption on socio-economic costs, grid capacity, and transportation demand
	Failure to conduct effective public consultations and incorporate feedback from the public
	Failure to revise targets based on the results of scenario and impact analyses
PHASE 4: ROADMAP IMPLEMENTATION, REVIEW, AND MONITORING	Limited terms of political leadership to ensure the completion of the roadmap, or change in political leadership that interrupts or abandons roadmap implementation
	Lack of a dedicated government unit to oversee and monitor roadmap implementation
	Lack of an effective review or progress-monitoring mechanism to assess EV adoption that results from the roadmap
	Other contradictory regulations or laws that hinder policy recommendations proposed by the roadmap

Source: WRI authors.

Table A6(b) | Key Barriers during E-Mobility Policy Adoption

	FISCAL	LEGISLATIVE/ REGULATORY	POLITICAL	MARKET/ CONSUMER
E-Mobility Policy Adoption Barriers	▪ Limited budget to support fiscal incentives for EV purchase	▪ Certain modes of EVs might be outlawed along with their ICE counterparts (i.e., two-wheelers)	▪ Limited terms of political leadership to ensure the completion of the roadmap	▪ Lack of public awareness of EVs, including variety of models or environmental benefits
	▪ Limited budget to support fiscal incentives for EV manufacturers	▪ Lack of safety standards for vehicles, batteries, or chargers	▪ Change in political leadership that adversely changes, interrupts, or abandons roadmap implementation	▪ Range anxiety or other consumer hesitancy toward EVs as a viable trip replacement
	▪ Import tariff and VAT on fully assembled EVs, EV parts, and/or batteries	▪ Other contradictory regulations or laws that hinder policy recommendations for the roadmap	▪ Lack of a dedicated government unit to advance EV adoption	▪ Lack of direct consumer rebate or accessible financing options to reduce upfront EV costs

Note: These policy adoption barriers are independent of an e-mobility roadmap, though some barriers may still be applicable in the context of roadmap development and implementation.

Source: WRI authors.

Table A7 | **Descriptive Statistics for Case Studies Similar to Vietnamese Cities**

DESCRIPTIVE STATISTICS	DA NANG	HANOI	HO CHI MINH CITY	SIMILAR CASE STUDIES (IN THE SAME QUANTILE)	
Population density (Person/ km²)	856	2,455	n/a	Los Angeles	959
				Beijing	1,312
				Oslo	1,628
				San Diego	2,031
Population density (Person/ km²)	n/a	n/a	4,476	Santiago	2,588
				Bangkok	3,524
				Shanghai	3,830
				San José	3,885
GDP/GRP per Capita (2020 USD)	$3,059.00	$5,285.00	$8,500.00	Delhi	$6,695.29
				Santiago	$13,231.70
				Jakarta	$16,973.87
Public Transit Modal Split (% of all trips)	0.2%	8.8%	4.7%	San Diego	3.0%
				Los Angeles	4.8%
				San José	9.9%
Passenger Cars per Thousand People	69	94	39	Shanghai	181
				Delhi	198
				Tokyo	234
Motorcycles per Thousand People	n/a	402	n/a	Oslo	40
				Mexico City	434
				Delhi	475
Motorcycles per Thousand People	523	n/a	528	Bangkok	721
				Kuala Lumpur	1,111
				Jakarta	1,528

Table A8 | **Potential Funding and Financing Mechanisms to Support E-Bus Project Development**

CATEGORY	EXAMPLES
Non-reimbursable funds	Private grants, public grants, capital expenditure grants, operational expenditure grants, R&D grants, public transportation budgets, farebox revenues, bus scrappage payments, sales taxes, environmental impact taxes, payroll taxes
Investment capital	Soft loans, green bonds
Legal arrangements	Bus leases, battery leases, lease-purchase contracts, leaseback agreements, concessions, public procurement contracts, advertising contracts

Source: Li et al. 2019.

APPENDIX B. METHODOLOGY

B1. Case Study Selection Criteria

Case studies selection for this paper considered the below five criteria:

- **EV market classification:** Given the disparate e-mobility market penetration worldwide, countries and regions are defined in this report as either major or emerging EV markets, based on available sales or new registration data of EVs. A country or region's EV market classification applies to the subnational entities within them.
    - **Major EV adopters** are countries and regions that have high EV adoption rates and markets. Within these regions, we selected subnational entities focused on e-mobility with abundant EV policies, established supply chains, multiple stakeholders, and more mature markets. The first case group includes subnational roadmaps in major EV adopting regions—including China, Europe, Japan, and the United States—accounting for over 96 percent of the 5 million light-duty EVs and the top 25 cities in terms of EV sales (Hall et al. 2019).
    - **Emerging EV adopters** are regions that consist of lower- and middle-income economies and are not the top global EV market holders. These emerging adopters have growing EV markets and ambitions to develop an EV industry. They seek to electrify their transportation systems to achieve climate action goals (Khan et al. 2022). This second group includes three ASEAN countries (Indonesia, Malaysia, and Thailand), India, and two Latin American countries (Chile and Mexico).
- **Geographic relevance:** Several case studies from Southeast Asia and the Global South were selected to provide experiences relevant to Vietnam's geographic location, even if they did not completely meet the other criteria.
- **Research capabilities:** Given that data and information on e-mobility are not always collected and accessible, especially regarding non-car transport modes such as electric bikes, case studies were chosen where relevant resources such as vehicle registration data and policy documents are readily available.
- **Roadmap presence:** Almost all case studies have at least one e-mobility roadmap issued or endorsed by the subnational government. In a few instances, national-level roadmaps or strategies are interpreted for subnational entities with no established e-mobility roadmaps.
- **Unique lessons from states and provinces:** On the subnational level, cities are not the only entities issuing e-mobility roadmaps. Many provinces and states are doing so to accelerate EV adoption, but have also proposed objectives less common than those in city-level roadmaps, such as becoming EV component manufacturing hubs, as is the case in the Indian states cited in this paper (Kanuri et al. 2021). This study includes several state- and provincial-level case studies to offer unique lessons for roadmap development.

B2. Roadmap Collection Methodology

E-mobility roadmaps are defined as assessments of the EV landscape, technical feasibility, outlines, and draft working group information. The roadmap analysis utilizes publicly available documents in English, Hindi, Mandarin, and Spanish. General search terms included: "EV Roadmap," "eMobility," "electric vehicle," "V2G", "zero-emissions," "battery-electric," "demand charge," "time-of-use," "rate structure," and "new energy vehicles," with subnational or city names. Some of the multi-lingual search terms include: "*electromobilidad*" (Spanish), "新能源汽车、电动汽车" (Simplified Chinese), "*elbiler*" (Norwegian), and "*Miljöbilar*" (Swedish). The analysis focuses on information for selected regions and localities, public EV policy documents, news sources, and publications from research institutions that mention public transit (buses and other modes), medium- and heavy-duty commercial vehicles, light-duty passenger vehicles, shared cars (Transportation Network Companies, taxis, car sharing), 2- and 3-wheelers, EV charging infrastructure, utility preparation, and vehicle-grid integration topics. The following exclusions were made during the research: code of regulations or legal documents, funding or proposal requests, and documents focused only on hydrogen, renewable natural gas, or other alternative fuels without battery-electric technology.

The following represents an outline of the roadmap search strategy for each selected subnational government:

1. Browse city or subnational general information.
2. Search national and local government websites.
3. Find EV policies.
4. Look for any e-mobility roadmaps.
5. Collect the following data points from documents:
    - Year of implementation or timeline
    - Method of subnational program
    - Government structure and oversight
    - Action review components or mechanisms
    - EV-specific working groups and mayoral involvement

B3. Case Study Descriptive Statistics

To benchmark case studies against target Vietnamese cities (Da Nang, Hanoi, and Ho Chi Minh City), this paper used the following four descriptive statistics:

1. **Population density**
    - Definition and unit: Person (population) per square kilometer (area)
    - Function: A proxy for the volume and type of mobility demand
2. **GDP or Gross Regional Product (GRP) per capita**
    - Definition and unit: 2020 USD (monetary value) per person (population)

- Function: A proxy for the affordability of EVs for consumers and financial resources available to invest in EV manufacture, deployment, and infrastructure

3. **Public transit modal split**
   - Definition and unit: Percentage of trips to and from a region done with public transport, modes that are regulated by the region's transport authorities
   - Function: An indicator to identify the potential focus of an e-mobility roadmap and whether other transportation measures are needed (For instance, if public transport modal share is low, in addition to electrification, it is necessary to encourage modal shift from private vehicles to public transport.)

4. **Normalized vehicle stock by fuel type**
   - Definition and unit: Number of registered vehicles—conventional ICE and electric—per person (population)
   - Function: A proxy for the volume of mobility demand and an indicator of a region's current mobility structure, and whether it warrants interventions such as modal shift toward more active and shared trips

B4. Roadmap Analysis Methodology

Roadmaps do not have a consistent framework, as the focus, targets, action plans, and structures can all be different. An information collection framework to acquire comparable information allows for a robust analysis. This section explains the framework's three main components.

How will the targets be set?

Political will is key to target setting. Without firm political backing, any established targets on e-mobility adoption can be jeopardized by new subnational administrations and leadership (ICCT and WRI 2021). Based on this reality, subnational entities should not solely rely on technical analysis to set their targets for e-mobility roadmaps. Instead, four guiding principles can be followed: create a long-term transport electrification (ZEV) mandate aiming for full electrification; act early and set interim targets; stay true to zero-emissions technologies by avoiding transitional technology like HEV; and strive for cleaner electricity and hydrogen mix as fuel source (ICCT and WRI 2021).

How will the targets be achieved?

Cities and subnational regions plan to achieve their e-mobility targets through three strategies: action timeline, supporting policies, and a specific plan to transition from conventional ICE vehicles to e-mobility. See Tables A.1 and A.2 for different roadmap goals and targets.

An action timeline should contain clear and measurable milestones, such as interim targets or key e-mobility outcomes. Ideally, the action timeline should also detail responsibilities for each stakeholder between different milestones to provide maximum clarity and actionability.

Supporting policies for e-mobility adoption in a roadmap should be relevant and consistent. They should not be contradictory to the goals, visions, and targets of a roadmap. Ideally, they should be integrated and comprehensive, leveraging the effects of one another and covering as many e-mobility–related aspects as possible.

A transition plan can help governments better manage the fiscal, economic, and environmental impacts of EV adoption (Wappelhorst and Cui 2020). Fiscally, even as the total cost of ownership and individual EV component costs are trending downward, transitioning from conventional vehicles is a significant price tag for many consumers and governments (Henze 2020; IEA 2021c; Stauffer 2021). Economically, EV adoption relies on the supply of EVs and charging components, a transition plan to guide outreach to the OEMs, and ensuring jobs transition from the conventional auto industry toward EV manufacturing. The scrappage of existing ICE vehicles should also be planned as part of the roadmap to prevent irresponsible disposal of used ICE vehicles and materials.

What is the policy context for these targets and their implementation? How is progress monitored?

The e-mobility roadmap should consider the current policy landscape and address what regulatory updates are required to shift from BAU usage of ICE vehicles to the adoption of e-mobility solutions. This is best achieved through a systems-thinking approach, which can ensure the shift to e-mobility achieves maximum co-benefits and minimal trade-offs. As shown in the stakeholder analysis, e-mobility adoption involves a wide range of stakeholders, so if comprehensive policies are included in the roadmap, the implementation efforts will be more far-reaching. Potential categories include financial incentives, industrial mandates, technical protocols and standards, public education, demand-side policies, and supply-side policies.

The roadmap's policy recommendations must include key financial policies and incentives for the local economy and consumer market because the societal transition to e-mobility cannot happen without the government and private institutions providing strong financial backing and incentives to EV OEMS and buyers.

Lastly, a roadmap should devise mechanisms to monitor its implementation progress, such as target measurement methodology, monitoring agencies, government budget integration, a roadmap revision schedule, and supplemental policies or action plans.

Is there uniformity between subnational e-mobility roadmaps and the national ones or national-level policies?

E-mobility roadmaps in a city may be linked with a national counterpart or a set of national policies, especially when it comes to fiscal incentives for EV purchases and manufacturing. In theory, subnational roadmaps should not contradict any national roadmaps or policies; for example, if a subnational roadmap aims to rely on imports for e-mobility adoption, the national roadmap or policy should not impose any heavy tariffs on imported EVs.

For the purpose of this study, the authors examined whether fiscal incentives on a national level for EV purchase and manufacturing benefit the subnational entities selected for case study. If so, it was further determined whether the incentives were consistent or contradictory with the goal of the subnational roadmaps.

B5. Two Types of Technical Studies and Analyses

Localized Existing Conditions Analysis

Localized studies and analyses can help enhance the applicability of the roadmap and make the action plans more implementable. These analyses are done in the first phases of the roadmap creation process, and it is important to identify the additional research required. This includes:

- Existing conditions analyses—all roadmaps
  - Establish baseline scenarios, with thorough analysis and projections of the city's vehicle profiles, travel behaviors, future mobility projections, and energy and grid system conditions.[14]
  - Conduct analysis of challenges and opportunities to electrifying the city.
  - Conduct analysis of relevant stakeholders, existing business and operational models, land use rights and conditions, and vehicle manufacturing and assembly capacity.
  - Review existing local and national policy mechanisms of the city to plan for potential policies and actions moving forward.
- Existing conditions analyses—roadmaps with broader scopes
  - If the roadmap's scope is broader and intends to promote sustainable transport modal shift, additional transportation analyses should be considered, such as transportation cost as a percentage of household income, land use patterns related to population and job density, and the degree of formality of mass transportation.
  - If the roadmap's scope is broader and intends to tackle air pollution and reduce GHG emissions, additional air quality and emissions analyses should be considered, including local GHG inventory of all emission sources, annual air quality index data, and volatile organic compounds (VOCs) and particulate matter (PM) tests.
- Existing conditions analyses—roadmaps with an e-mobility scope
  - Review existing policy profiles and best practices for EV adoptions around the world.
  - Conduct a survey of existing EV-related technologies. Stakeholders may also create a specific roadmap just on technological deployment, such as California's VGI Roadmap (California ISO 2014).

Impact and Scenario Analysis

Impact and scenario analyses are usually conducted to identify the potential impact of different vehicle electrification scenarios and provide solutions that are tailored to the city. Often, these analyses are done in the second phase of the roadmap creation process, but—given the data and methodological requirements for such analysis—it is important for roadmap working groups to mobilize adequate resources and expertise during the first phase or earlier. Some roadmaps identify additional studies and include the analyses' results with derived action items and policies. Potential studies may include:

- Electrification scenarios and related emission, cost, energy, and employment impacts, which help decide the city's electrification targets
- Technology availability, maturity, and local future projections, which identify technology needs and feasible pathways
- Case studies for certain operation and business models to identify successful strategies
- Barrier analysis to help identify and resolve the main barriers impeding the city from achieving its EV targets

B6. Project Limitations

The unavailability of information and constraints of desktop research were the two main limitations of this project. Because of the nature of government documents, the roadmap development process is not fully transparent. Furthermore, not enough time has passed since the implementation of all the policies to weigh the successes and failures of the roadmaps' key aspects. Another limiting factor of this research is the lack of public databases or central information. The timelines for the roadmaps do not all align, and some processes began significantly earlier than others. Lastly, there is the challenge of generalization, as all city and subnational case studies have been adapted to the Vietnamese context despite unique cultural, political, and economic contexts.

In terms of the larger e-mobility discourse, limited information availability means that this paper's analysis tends to focus on private passenger car electrification, since this data is the most available. Although information is presented wherever possible, the authors of this paper acknowledge that more research is needed on other forms of road transport, including electric micro-mobility, electric transit and school buses, and electric freight. While maritime and aviation are not within the scope of this paper, they are significant subsectors responsible for emissions in transportation. Thus, further studies can be beneficial for stakeholders in Vietnam.

Because other papers in the NDC-TIA E-Mobility Series will address EV charging demand and the effects of consumer behaviors on e-mobility adoption, this paper does not examine these topics in depth to avoid redundancy.

LIST OF ABBREVIATIONS

ASEAN	Association of Southeast Asian Nations
BAU	Business-as-usual
BEV	Battery-electric vehicle
CO_2eq	Carbon dioxide equivalent
ELV	Electric logistics vehicle
EV	Electric vehicle
EVSE	Electric vehicle supply equipment, primarily EV chargers or a charging station for EV
FCEV	Fuel cell electric vehicle
GHG	Greenhouse gas
HDV	Heavy-duty vehicle, usually referring to trucks
ICE	Internal combustion engine
LATAM	Latin America
LDV	Light-duty vehicle, usually referring to passenger cars
LFP	Lithium Iron Phosphate, a type of lithium-ion battery free of cobalt, unlike NCA and NMC
MDV	Medium-duty vehicle, usually referring to buses
NCA	Nickel Cobalt Aluminum Oxide, a type of lithium-ion battery that contains cobalt; similar to NMC
NDC	National Determined Contributions
NEV	New energy vehicle, defined as clean vehicles by the Chinese government
NMC	Nickel Manganese Cobalt, a type of lithium-ion battery, a type of lithium-ion battery that contains cobalt; similar to NCA
PHEV	Plug-in hybrid electric vehicle
R&D	Research and (technological) development
TNC	Transport network company
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
V2G	Vehicle-to-grid
V2X	Vehicle-to-everything integration
VGI	Vehicle-grid integration
ZEV	Zero-emission vehicle, typically defined as battery-electric and hydrogen fuel cell vehicles

GLOSSARY

2-wheeler: Vehicle that operates with two wheels and can reach a speed above 50 kilometer per hour, such as a motorcycle, moped, and throttle-based electric bicycle

3-wheeler: Vehicle that operates with three wheels, such as e-rickshaws

Avoid-Shift-Improve (A-S-I): A sustainable environmental planning approach that consists of three hierarchical avenues: Avoid/Reduce, Shift/Maintain, and Improve. The "Avoid" avenue stresses choosing to use none of or less of a resource. The "Shift" avenue switches from a less sustainable method of consumption to a more sustainable one; if the more sustainable option is already in use, the consumer maintains its use. The "Improve" avenue increases the resource efficiency of an existing good or service.

E-mobility: Electric mobility, mainly referring to transportation powered by electricity instead of fossil fuel and the infrastructure needed to supply the electricity

Electric vehicles: Vehicles, including passenger cars, 2-wheelers, 3-wheelers, buses, and other machines used to transport human or goods, powered by electricity; in this publication, EVs referred to are those powered by rechargeable battery packs with no secondary propulsion source, such as hydrogen fuel cells

Micro-mobility: Lightweight vehicle that operates under 25 kilometer per hour and typically operates with two wheels, like pedal-assist bicycles and scooters

Modal shift: A change from one form of transportation to another so that the share of the original form decreases, often from a less environmentally sustainable mode to a more environmentally sustainable one

Scenario, scenario analysis: A series of hypothetical situations, each with a set of distinct assumptions, that examine all feasible outcomes and test decisions before they take place (Usually when used for low carbon technology, a baseline BAU scenario is necessary.)

Subnational: Any government or governing body beneath the country level, including towns, cities, states, provinces, and regions

Subnational EV Roadmap: A published strategy for governments or government-backed entities to achieve widescale electric mobility adoption. Although the roadmaps tend to focus primarily on electrification of passenger cars and other private forms of transportations, the published document has a broader focus to also promote electrification of public and shared transport, as well as sustainable mobility modes such as walking and biking.

Vehicle: A means of transporting people and goods, often operated on wheels

Well-to-wheel: All emissions related to fuel production, processing, distribution, and use

ENDNOTES

1. A given roadmap's scope can either be precisely on e-mobility or broader. However, within each scope, a roadmap can have more than one focus, and a subnational entity may have several roadmaps with varying scopes and focuses.

2. Examples of EV manufacturing in Southeast Asia include Korean automaker Hyundai's "first ASEAN manufacturing hub" in Bekasi, near Jakarta. Supporting Indonesia's planned EV transition, Hyundai is strategically establishing an all-EV manufacturing plant that will supply the country's most popular BEV passenger car models. (Hyundai 2021; Roberts 2022). For passenger cars, plants that manufacture and assemble ICE vehicles can be adapted to produce PHEVs and EVs. This benefits subnational governments with existing auto manufacture industry in their jurisdiction. Volvo's electrification of its Shah Alam plant in Malaysia near Kuala Lumpur offers one example of this (Persson 2017). Aiming to go fully electric globally by 2030, Volvo will launch one new locally assembled EV model every year beginning in 2022 (Volvo Car USA 2021; NST Business 2022).

3. For efficiency, governments may also opt for repurposing an existing working group or steering committee—previously established for related topics like clean air or economic development—for e-mobility roadmap development, but this is not recommended.

4. The working group established an office dedicated to e-mobility adoption, and the working group is hosted within the Beijing Municipal Science & Technology Commission (Niu 2018). The office executes the vision, policy priorities established in the working group, and various functions, such as implementing mode-specific EV pilots, engagement with OEMs, and public awareness campaigns (D1ev.com 2021).

5. Authored by the mayor's EV Infrastructure Taskforce, the roadmap's development process involved 350 stakeholders and 140 different organizations from London boroughs and the business, energy, infrastructure, and government sectors (The Mayor's Electric Vehicle Infrastructure Taskforce 2019).

6. The freight-specific focus is reflected in one of the roadmap's guiding principles: "[w]hen visitors and athletes arrive for the Olympics, people and goods can move emissions-free throughout the region" (Transportation Electrification Partnership 2019).

7. Although more energy-dense, batteries that contain cobalt in their chemistry, namely NMC and NCA, generally have a higher cost per watthour to produce, compared to cobalt-free LFP ones (Kane 2022; Ambrose and O'Dea 2021). Initially, subsidies for EV battery production in China excluded LFP batteries because they tend to fall below the energy density requirement, but as the subsidies for EVs phase out in China, the competition has now increased for the two battery types (Qu 2021). Many OEMs, including Tesla and Shenzhen's own BYD, clearly favor LFP, with the latter featuring the LFP chemistry in its latest blade battery configuration (Kane 2022; BYD 2021). Cobalt availability, production cost, battery safety, and optimal temperature should all be considered when subnational governments determine which lithium-ion battery chemistry type to incentivize.

8. Public consultation and engagement also provide an opportunity to gather insights on consumer behavior, which can help a roadmap to be more effective in the long term by informing its proposed policy package.

9. First, the city council of Amsterdam will annually receive data and metrics from a national agency on air quality. The city of Amsterdam will also conduct an annual survey of the number of EVs operating in the city. (Gemeente Amsterdam 2019).

10. The battery test center is jointly governed by the Ministry of Industry and the Thailand Automotive Institute (TAI), with cooperation from German-based product inspection and certification corporation TÜV SÜD.

11. However, the current incentives outlined in Indonesia's policy document do not explicitly support e-bus manufacturing. The total cost of ownership of e-buses remains high for the city and the country.

12. The production and R&D incentives listed by Indonesia's policy document to support domestic electric passenger car manufacturing will likely help supply more e-taxis to different operators.

13. However, most of the strategies pertaining to EV adoption in Malaysia's roadmap are national regulations that will impact Kuala Lumpur as well as the rest of the country.

14. Travel behaviors are important to transportation—and, by extension, EV roadmap planning—because they reveal the relationship between several factors, such as spatial structure of a city, land use, and road networks. Understanding the regularity and characteristics of human mobility can help inform decision-makers to develop the best strategy for transport decarbonization (Tang 2019).

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