IRENA
International Renewable Energy Agency

RENEWABLE ENERGY POLICIES FOR CITIES

TRANSPORT

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International Renewable Energy Agency

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About IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future and serves as the principal platform for international co-operation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity.

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For further information or to provide feedback: publications@irena.org

Available for download: **www.irena.org/publications**

IRENA Headquarters

Masdar City

P.O. Box 236, Abu Dhabi, United Arab Emirates

www.irena.org

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ABOUT THE RENEWABLE ENERGY POLICIES FOR CITIES SERIES

Renewable Energy Policies for Cities: Transport is one of several briefs intended to help policy makers accelerate efforts to create sustainable cities powered by renewable energy. The series includes briefs focused on the power and buildings sectors, and this one, on transport. In addition, IRENA has produced a larger analytical report with case studies from three countries and an executive summary. The case studies are also available as stand-alone reports.

The series recognises that cities are critical actors in energy and climate policy making, complementing actions taken at the national and state/provincial levels of government. Cities are home to an everincreasing share of the world's population and are economic engines that use a large share of the energy consumed in the world. Thus, municipalities will play a major role in advancing and shaping the global energy transition. The briefs in this series focus on actions that may be undertaken independently by cities or in combination with initiatives at higher governmental levels.

The briefs carry a common understanding that the energy transition in cities is really a story of urban transformation. Renewables have impacts that extend well beyond the energy sector; they shape transport, buildings, land use and a host of other sectors critical to cities' functioning. Even within the energy sector, adoption of renewable energy involves more than a shift in energy sources; it includes an emphasis on greater energy efficiency and changed consumption patterns as well, both of which can change the face of a city. In sum, the energy transition is an opportunity to remake cities in a variety of ways that are better for people and the planet alike.

In addition, the *Renewable Energy Policies for Cities* series supports the International Renewable Energy Agency's (IRENA's) urban policy guidelines toolkit, an online resource that may be of particular interest to staff of municipal-level entities but is open to any interested individuals who want to strengthen their knowledge of options to facilitate the deployment of renewable energy in the urban environment. Part of IRENA's Policy Framework for the Energy Transition (PFET) (see Box), this innovative toolkit centres on the same areas of city-level action as IRENA's series of sectoral briefs: that is, renewable energy in (1) the power sector, (2) transport and (3) buildings. Based on a series of yes/no questions about basic circumstances in a city of interest (such as basic policy-making objectives, settlement density or the availability of public transit), the toolkit points out basic policy recommendations, as well as case studies and examples of how policies have been implemented in cities across the world. These recommendations are intended to offer a broad orientation; specifically tailored advice requires detailed assessments of a given city. These recommendations are intended to offer a broad orientation; specifically tailored advice requires detailed assessments of a given city.

BOX IRENA'S POLICY FRAMEWORK FOR THE ENERGY TRANSITION (PFET)

The PFET aims to translate the knowledge products developed by IRENA's Knowledge, Policy and Finance Centre on policy, socio-economic benefits and finance into actionable advice, and to bring the messages and recommendations to policy makers on the ground to create impact. The PFET includes a set of **packages** that synthesise the knowledge products of IRENA and proposes different **tools** to deliver the capacity building to policymakers. These tools may include but are not limited to: presentations that can serve to deliver capacity building exercises; interactive exercises to conduct during the trainings; and short videos to convey key messages. PFET materials have been prepared or are under development for IRENA's work on cities, auctions, targets, and heating and cooling policies.

PFET
Policy Framework for the Energy Transition

IRENA
International Renewable Energy Agency

THE RENEWABLE ENERGY POLICIES FOR CITIES SERIES INCLUDE THE FOLLOWING REPORTS AND AN ONLINE TOOL

- Renewable Energy Policies for Cities: **TRANSPORT**
- Renewable Energy Policies for Cities: **BUILDINGS**
- Renewable Energy Policies for Cities: **POWER SECTOR**

INTRODUCTION

Cities promote human interaction by bringing together the people and resources needed for commerce, recreation and cultural activities. Some of these connections are digital, some are informational, but a great many are physical. In a city's efforts to enable physical connections, transport of all kinds plays a central role. For urban stakeholders working to build greener cities in the years ahead, creating a sustainable transport sector will be critical to success (see Box 1).

Sustainable transport systems require a well co-ordinated and integrated set of policies, within and beyond the transport sector, and within and beyond cities. City leaders must harmonise the activities of business and civil society actors across a diverse set of transport modes, ensuring that required energy sources, supporting infrastructure and other transport inputs are available as needed. Policies in other sectors are also critical to creating a sustainable transport sector powered by renewable energy. The energy transition in the transport sector cannot be driven solely by changes in the composition of the energy mix. It needs to be accompanied by changes in the modal mix, urban infrastructure and land-use priorities. Other city-level actions could include policies to reduce the demand for transport, e.g., by promoting telecommuting and other behavioural changes. And of course, city leaders must also ensure that their transport strategy harmonises with policies emerging from regional and national governments.

Fortunately, cities worldwide are finding pathways through this thicket of challenges. Urban transport offers excellent opportunities to boost renewable energy use in cities. The transport sector is one of the largest energy users in the urban environment, accounting for 29% of total final energy consumption worldwide in 2018, and fossil fuels – in the form of gasoline and diesel fuels, plus power generated from coal – account for an overwhelming share (96%) of transport energy use (REN21 and FIA Foundation, 2020). Worldwide, the transport sector's carbon dioxide (CO_2) emissions increased by 29% in 2000–2016. In 2016, they amounted to 7.5 gigatonnes (Gt) or one-quarter of emissions from all energy-related sources[1] (SLoCaT, 2018a).

BOX 1 WHAT IS SUSTAINABLE TRANSPORT?

The United Nations defines sustainable transport as *"…the provision of services and infrastructure for the mobility of people and goods – advancing economic and social development to benefit today's and future generations – in a manner that is safe, affordable, accessible, efficient, and resilient, while minimising carbon and other emissions and environmental impacts"* (UN, 2016).

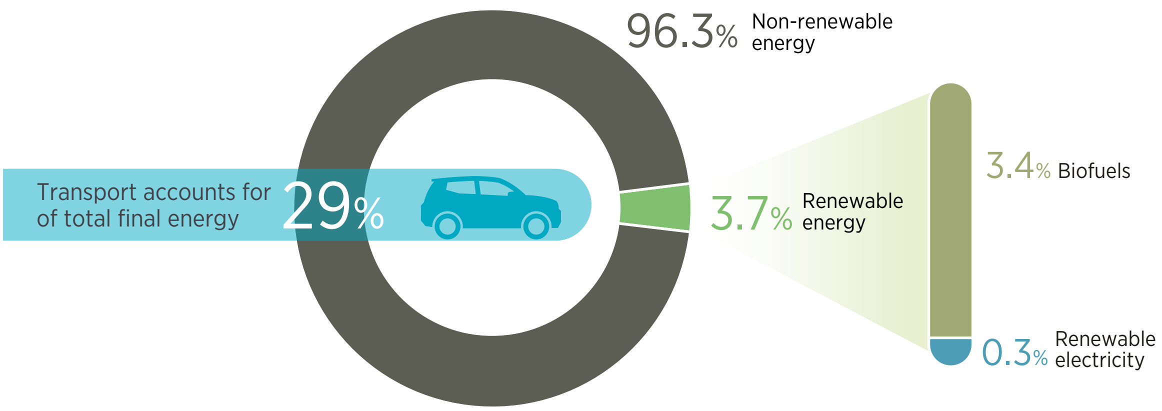
1 These statistics do not break out the urban share of transport emissions.

There is thus ample need – and opportunity – to enhance the role of renewable energy, especially in the context of robust increases in energy demand. Renewable energy use in transport (mostly in the form of ethanol and biodiesel) has risen from less than 1 exajoule (EJ) at the beginning of this century to close to 4 EJ in 2017 (IEA, IRENA, UNSD, World Bank and WHO, 2020). However, for the time being, renewables' share is still quite low, accounting for 3.1% in 2015 (SLoCaT, 2018a) and 3.7% in 2018 (3.4% for biofuels, and 0.3% for renewable electricity) (REN21 and FIA Foundation, 2020) (see Figure 1). The share of renewables is thus much lower in the transport sector than in the power sector or in heating and cooling.

A broad range of transport modes are important to cities. Road, rail, shipping and aviation[2] move people and goods. In the resulting web of connections, each mode offers unique opportunities for advancing the use of renewable energy (see Table 1 and Box 2). To harness this potential, it is important to consider the particular requirements of each mode. For example, cars, light rail and bicycles have very different requirements for fuel and infrastructure. Taking this diversity into consideration is also important when planning systems for their smooth and integrated operation.

2 Aviation plays a crucial role in urban supply chains and providing transport services for urban residents but it takes place principally outside of cities. This brief focuses on transport in the urban environment only.

Figure 1 Share of renewable energy in transport energy use, 2018



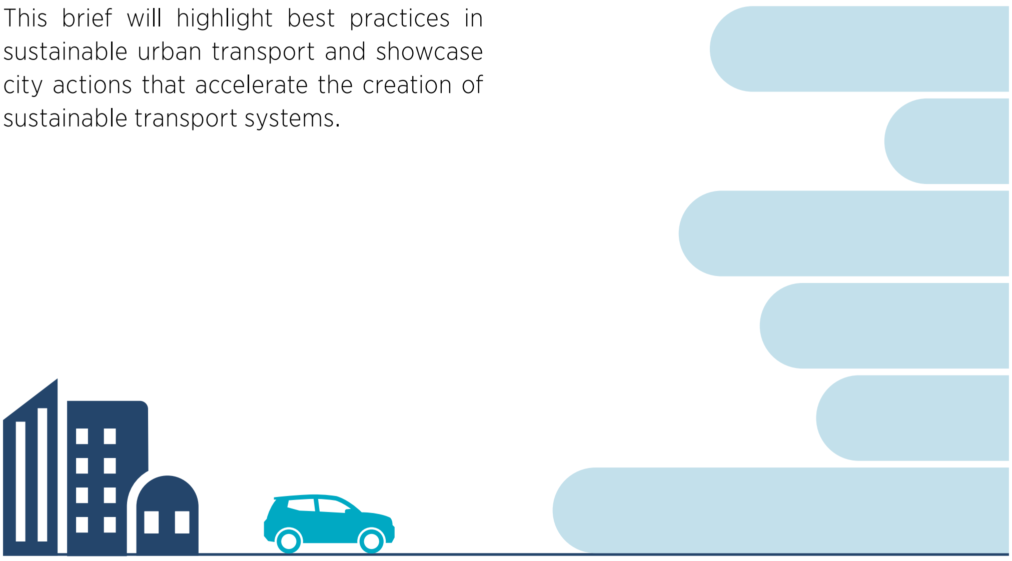
Source: Based on REN21 and FIA Foundation, 2020.

Table 1. Opportunities to advance renewable energy, by transport type

Transport mode	Opportunities to advance renewables
Road	Ethanol and biodiesel provided around 3% of global road transport fuel in 2018, suggesting ample room for expansion. As road transport is increasingly electrified, opportunities for using renewable electricity in this sector will grow. Already in 2016, 26% of the electricity consumed by electric vehicles worldwide was renewable. Fuel cell electric vehicles can be fuelled by green hydrogen.
Rail	Biofuels can be blended into locomotives fuelled by oil, and electric trains can be powered by renewable electricity. Renewable electricity accounted for 3.4% of energy used in inter-city railways worldwide in 1990, and around 9.0% in 2015. Some countries have reached up to 100% penetration of renewables in the rail sector.
Shipping	Ships can use biofuels, electricity-based hydrogen or ammonia, or wind or solar energy for propulsion. Renewable energy in shipping is not advancing markedly. But electric and hybrid-electric ferries can be found in Denmark, Finland, Norway and Sweden, and biodiesel ferries are found in the United States. Green ammonia is emerging as an option in particular for long distances.
Aviation	Some aircraft use biofuels blended into traditional jet fuel on a limited basis. As of 2018, more than 100 000 commercial flights used sustainable aviation fuels. Alternative propulsion technologies, such as electric or solar-powered aircraft and the use of synthetic fuels or green hydrogen, are other options for integrating renewable energy into aviation over the long term.

Source: IRENA, IEA and REN21, 2018.

This brief will highlight best practices in sustainable urban transport and showcase city actions that accelerate the creation of sustainable transport systems.



BOX 2 THE SIGNIFICANCE OF CITIES IN DEPLOYING RENEWABLE ENERGY

The boundaries of urban policy making are defined by the legal and regulatory authority vested in governments not only at the municipal level but also at the state, provincial and national levels. These boundaries are drawn in different ways across countries; some are governed in a highly centralised way while in others there is a considerable degree of devolution of authority.

IRENA's continuing work on renewable energy in cities (IRENA, 2016; 2021) has identified several dimensions of cities' roles in shaping climate adaptation and mitigation efforts, and as such in accelerating the deployment of renewable energy solutions as a key pillar of national sustainable energy targets (see Figure 1). Cities can be target setters, planners and regulators. They are often owners and thus operators of municipal infrastructure. Cities are always direct consumers of energy and therefore aggregators of demand, and can be conveners and facilitators and financiers of renewable energy projects. Finally, local authorities can play an important role in raising awareness by informing citizens of target setting and planning, and also by giving citizens an opportunity to provide comments and other inputs.

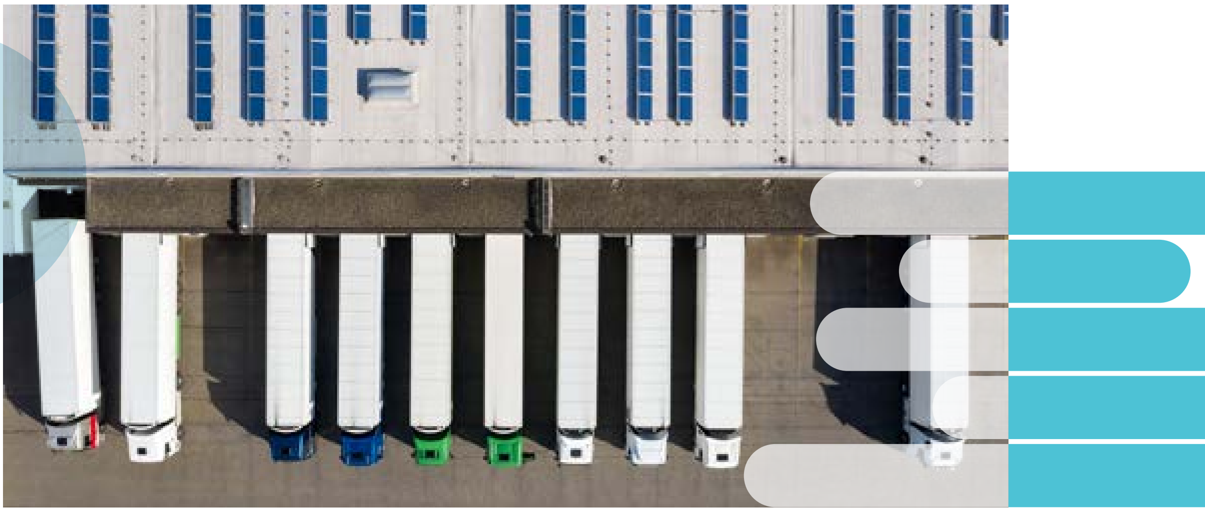
Cities can shape and accelerate the evolution of a sustainable urban transport sector through their varying roles as regulators, operators, financiers, facilitators, awareness builders, demand aggregators and target setters. Each of these roles differs from city to city and from country to country, but the large range of options for urban transport policy highlights that there is clearly something every city can do.

Figure 2 Roles of municipal governments in the energy transition

Source: IRENA urban policy analysis (based on IRENA 2016).

1. THE TRANSPORT POLICY LANDSCAPE

The policy landscape for promoting renewables in the transport sector is shaped by a number of objectives, which are set at the local level but may be influenced by broader national and international initiatives (see Section 1.1). There is general recognition among transport policy makers, practitioners and analysts that a three-fold approach is required to render the sector more sustainable. As is explained in Section 1.2, transformative policies for renewables and other measures can be categorised according to the main way they advance their objectives – i.e., do they seek to avoid, shift, or improve particular practices? Following a discussion of the overall transport landscape, the remainder of this brief is organised using these policy categories. The brief concludes with a look at various international transport policy peer networks that bring together cities and other actors, followed by a short summary of key observations.



1.1 DRIVERS OF RENEWABLES POLICIES FOR URBAN TRANSPORT

Transport sector policies are driven by a broad range of urban challenges. Enlarging the role of renewables directly addresses some of them.

- *Climate change:* Cities are increasingly at risk from climate disruptions. Given that transport represents a quarter of global energy-related carbon emissions, it is clear that a transport sector powered by renewables can be a major contributor to stabilising the world's climate.
- *Air pollution* imposes serious burdens on human health and costs on urban economies, many of which would be reduced or eliminated through the use of renewable energy (IRENA, IEA and REN21, 2018).
- *Congestion* is a perennial problem for many cities that costs citizens and businesses valuable time and productivity; encouraging the use of transit – preferably renewables-based electricity powering electric buses, trams and light rail – can free up road space.
- *Road safety* is a priority for many citizens and leaders, given the numbers of people who die or are injured in accidents each year (IRENA, IEA and REN21, 2018). The use of buses and other forms of mass transit – again, powered or fuelled by renewables – can reduce road injuries and deaths.

Some cities are inspired by international initiatives that favour renewables in transport. The 2015 **United Nations Sustainable Development Goals** contain a variety of targets centred on sustainable transport. The **Paris Agreement on Climate Change** sets global climate goals that would require a transition to renewable energy in most cities, supported by carbon neutrality in the transport sector (IRENA, IEA and REN21, 2018). And the 2016 **New Urban Agenda**, an output of the United Nations Conference on Housing and Sustainable Urban Development (Habitat III), sets a planning framework for sustainable cities, including sustainable transport (UN Habitat, n.d.).

Policies that shape the energy mix consumed by urban transport are made at the municipal, state/provincial and national levels. The majority of policy measures – such as air quality standards, vehicle fuel efficiency mandates, fuel quality requirements, biofuel blending mandates, carbon pricing and subsidies – are commonly handled at higher levels of government. But in some cases, cities have strong influence or even direct control over dimensions such as rules for vehicle use; mandates or incentives for electric vehicles (EVs) and charging infrastructure; investments in subways, trams and buses; the promotion of public transit systems and support for non-motorised transport modes including bicycling and walking.

Furthermore, critical urban land-use and zoning decisions are made in city halls. Mixed use urban development, for example, helps reduce urban travel needs, influences modal mix and thus shapes the demand and composition of energy for transport. Limiting overall demand growth allows renewables to play a much larger role than under a business-as-usual approach (Table 2).

Table 2. Transport policies by political jurisdiction

Policies typically set at:	
National or regional level	**Municipal level**
Air quality standards	Rules for vehicle use
Vehicle fuel efficiency mandates	Mandates or incentives for electric vehicles and charging infrastructure
Fuel quality requirements	Investment in subways, trams and buses
Biofuel blending mandates	Measures that render public transit systems more attractive
Carbon pricing	Support for other transport modes including bicycling and walking
Subsidies	Urban land-use and zoning decisions

Note: Municipal-level policies can also be released by authorities at different levels of governance, depending on the context in different countries.

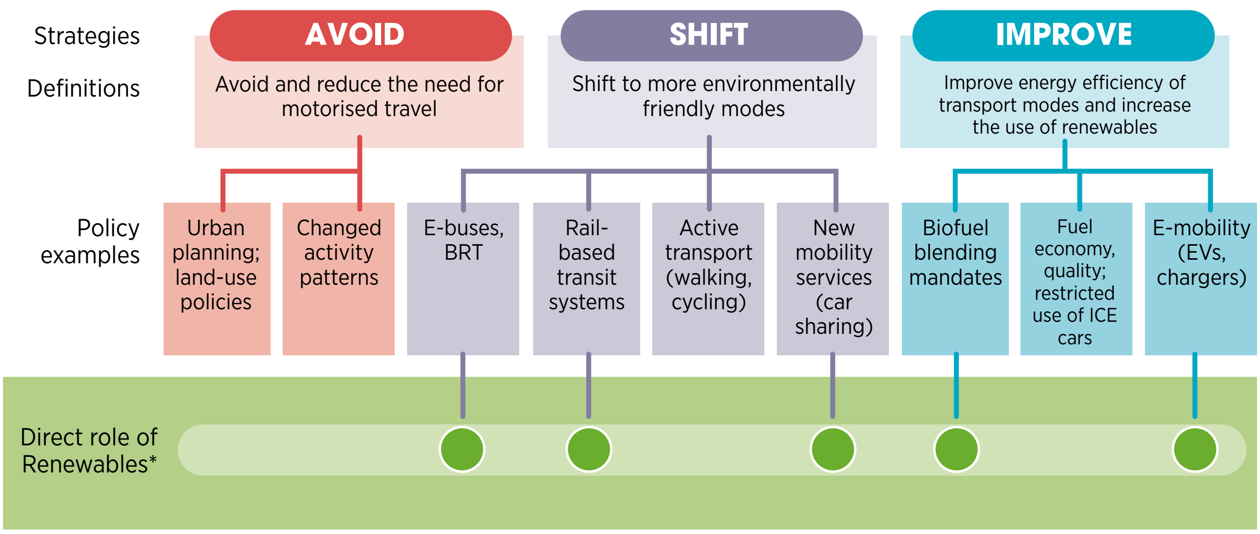
1.2 A TRANSPORT POLICY FRAMEWORK: AVOID-SHIFT-IMPROVE

Urban transport policies can be categorised by how they seek to decarbonise the transport sector: that is, do they seek to *avoid*, *shift*, or *improve* usage of various transport modes (see Figure 3)? In all three categories, decarbonisation can result from, or even contribute to, increased use of renewable energy (SLoCaT and PPMC, 2017; Huizenga, Peet and Gota, 2016). Policies in the *avoid* and *shift* categories are transformational in character, seeking to alter the fundamental demand for transport services by changing the underlying socio-economic and spatial structures in a city.

Policies that seek to *avoid* energy consumption reduce the need for travel. Examples include urban planning measures such as land-use strategies and transit-oriented development, for density, trip and route optimisation, telecommuting and simplified supply chains. From a carbon emissions and pollution reduction perspective, these strategies are most effective because they reduce the use of carbon-based energy in vehicles as well as in the construction of transport infrastructure. By reducing overall demand for transport energy, such policies allow renewables to supply a greater share of a city's energy use.

Policies that promote a *shift* in transport modes are designed to lower carbon emissions from transport by moving people into active (non-motorised) transport, public transit or other shared transport options. Examples include campaigns to promote biking and walking, preferred parking for car sharing, while reducing the overall urban space reserved for cars, and providing subsidies to lower the costs of using buses and trolleys (IRENA, IEA and REN21, 2018). There is a role for renewables in terms of powering some of these transport options.

Figure 3 Renewable energy's role in the *avoid-shift-improve* policy framework



* Through biofuels or renewable-generated electricity

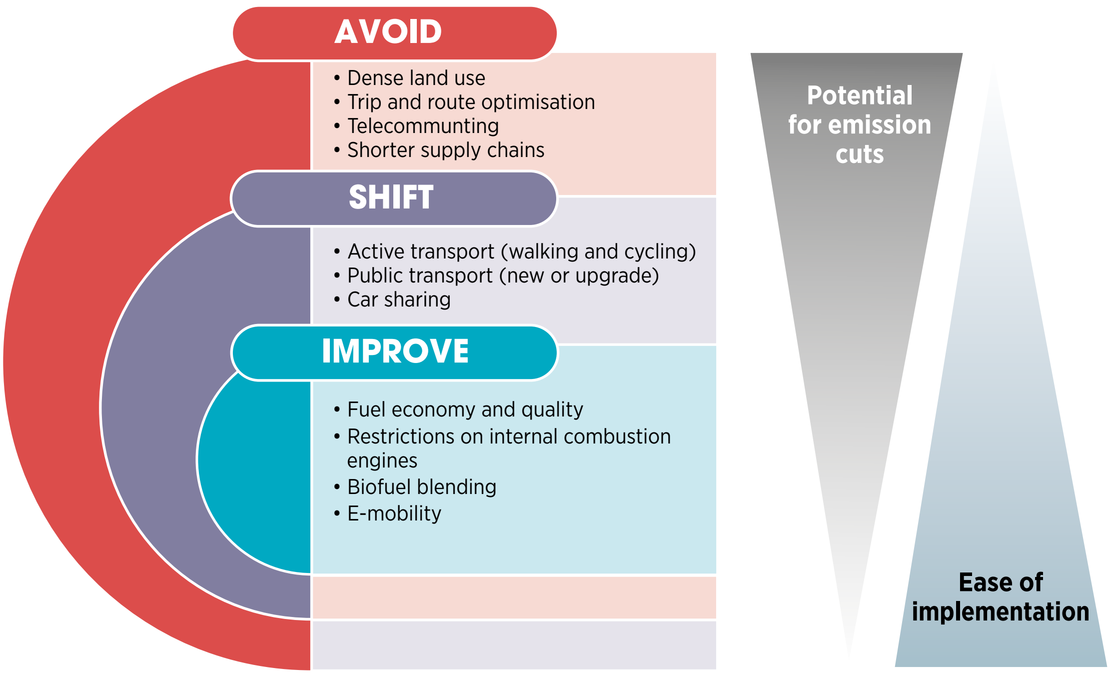
Source: Adapted with alterations from SLoCaT (2018b).

Policies that seek to *improve*, or lower, the carbon intensity of transport modes do so by increasing operational and energy efficiency and by fuel switching. Raising fuel economy standards and mandating shifts from oil or gas to biofuels are policy options. Even though their impact is typically less than efforts to avoid or shift energy use, these policy options yield meaningful levels of decarbonisation and pollution reduction (IRENA, IEA and REN21, 2018). Renewables have a role to play when they are prioritised over non-renewable resources, as when biofuels or renewables-based electricity replace fossil fuels.

As noted, the *avoid-shift-improve* policy baskets offer different levels of effectiveness in curbing carbon and other forms of air pollution, with *avoid* strategies offering the greatest cuts and *improve* strategies the least. But *avoid* policies require some of the greatest systems-level changes, such as redesigning land use for greater density, and therefore could take the longest and be the most politically difficult to implement.

Perhaps not surprisingly, in the Nationally Determined Contributions of nations working to meet the carbon reduction goals of the Paris Agreement, only 8% of the 356 proposed mitigation measures reported in 2018 were *avoid* strategies. Nearly two-thirds (65%) were *improve* strategies. As the name suggests, *improve* strategies deliver incremental change, which may be the easiest to implement politically. But they may not enable a sufficient contribution from the transport sector to meet the Paris goals. Figure 4 offers some trade-offs among the different strategies.

Figure 4 Trade-offs among *avoid-shift-improve* transport strategies



Source: IRENA urban policy analysis.

2. *AVOID* POLICIES

Avoid policies drive a small but powerful set of initiatives, some of which may fall outside of the transport sector yet have important implications for it. As mentioned, such policies help limit the overall need for transport. In doing so, they allow renewable power and fuels to account for a larger share of transport energy than would be possible under a business-as-usual approach with ever-growing demand. Thus, *avoid* policies can help accelerate the transition to a sustainable city powered by renewable energy. This section briefly discusses the importance of land-use policies focused on transit-oriented development (2.1) and changes in behavioural and activity patterns (2.2). Policies to restrict the use of motorised vehicles can also contribute to changing the modal mix in a city's transport system (Section 4 specifically discusses limits imposed on internal combustion vehicles).

2.1 LAND-USE POLICY

Land-use policy is a key *avoid* lever. Changes in land use can reduce or perhaps even eliminate the need for certain kinds of transport. If a city is designed in a way that expands access to its business district, trip lengths tend to be reduced, curtailing vehicle travel (Litman, 2019). In urban planning, transit-oriented development is a concept that is meant to maximise residential and business activity within walking distance of public transport nodes such as a metro or light rail station or a bus stop. It recognises the symbiotic relationship between high-density urban spaces, the use of public transport and reduced reliance on private cars.

If workplaces, stores and entertainment are located near multi-modal transport centres, the amount of travel is likely reduced. Finally, if land use is mixed – with housing, commercial outlets, institutions and entertainment outlets found together in a particular geographical area – travel distances tend to be shorter for the average resident (Litman, 2019).

Indeed, research shows that residents of dense cities (with a large number of homes, people or jobs per square kilometre) enjoy shortened travel distances, less reliance on private vehicles and fewer total vehicle miles travelled (Newman and Kenworthy, 2015).

2.2 CHANGED ACTIVITY PATTERNS

In addition to land-use policy, cities can avoid travel by encouraging new activity patterns. Telecommuting (Box 3) and online learning are examples. Facilitating simpler and shorter supply chains within cities can also reduce or eliminate trips. The energy required for such activities can be provided by renewable electricity.

To the extent that cities promote these practices, travel can be avoided. They typically involve low-cost solutions that can be realistically implemented across a number of contexts, provided that high-speed internet is widely available. These options present significant opportunities for greater social inclusion. They also highlight that progressive development in areas such as transport may involve not only direct investment in road and rail infrastructure but also in other types of infrastructure, for instance, telecommunication.

BOX 3 POLICIES PROMOTING TELECOMMUTING

Telecommuting allows employees to work at home, on the road or in a remote location for all or part of their workweek. The practice has been increasing in recent decades across some fields, such as information technology, design, accounting, and research and consulting. There are many benefits observed for employees and employers alike, including increased productivity, work-life balance and employee retention. Significantly, greater reliance on telecommuting reduces material and environmental costs, ranging from reduced need for office space to reduced transport costs for individuals and saved greenhouse gas emissions for the economy.

In 2019, the city of **San Antonio**, Texas (United States), included telecommuting in its strategy to cut ground-level ozone concentrations by reducing car trips. The city considered a plan to authorise more telecommuting for employees whose work does not require them to be in city offices, as well as flexible work schedules.

Following the outbreak of the COVID-19 pandemic in early 2020, many employers permitted or even required office workers to work remotely, giving an unplanned and involuntary boost to forms of telecommuting enabled by video conferencing software. Although it is too early to judge how entrenched such forms of work will become in the long run, expectations are that the role of centralised offices has been altered fundamentally.

San Antonio, Texas, United States

3. *SHIFT* POLICIES

Shift policies move people to less-carbon-intensive modes of transport. Walking and cycling (also called "active transport") will directly reduce a city's carbon emissions by eliminating the use of energy for motorised transport entirely, while making cities more people friendly. Although walking and cycling involve no shifting from fossil fuels to renewables, it is worth noting that cities that rely strongly on these modes frequently have well-developed public transit systems, because active transport and public transit are complementary modes that work well together. Cities would also do well to enlarge car-free areas, create cycle lanes and conduct city development work with a focus on traffic de-congestion and safer, more attractive pedestrian and cycle paths. If transit systems are powered by renewables, a policy that promotes walking and cycling can indirectly raise the share of renewable energy in total transport energy demand (Litman, 2019).

The following discussion of *shift* policies revolves around two aspects: the electrification of bus fleets and the parallel introduction of bus rapid transit (BRT) systems (3.1), and the operation of rail-based transit systems with renewables (3.2.). It should be noted that the first of these can also fall under the heading of *improve* policies where bus systems already play a strong role, but operations need to be cleaner.

3.1 MUNICIPAL BUS FLEETS: ELECTRIFICATION AND BUS RAPID TRANSIT SYSTEMS

Municipal bus fleets, which typically run on highly polluting diesel fuel, are strong candidates for electrification. A parallel transformation that also has some bearing on the use of renewable energy concerns the growing adoption of so-called BRT systems. This section discusses both.

According to the International Council on Clean Transportation (ICCT, 2012), the world's total bus fleet could grow to 20 million by 2030, up from 16 million in 2010. Municipal fleets represent about 1.5 million buses of this total (Sustainable Bus, 2020). Altogether, more than 300 cities worldwide have introduced at least some battery-powered electric or hybrid buses (SLoCaT, 2018a). For the time being, the stock of municipal electric buses (e-buses) is still quite small, but fast growing. It was estimated to be 386 000 at the end of 2017, more than double the figure two years earlier (FS-UNEP Centre and BNEF, 2018), and reached half a million in 2019 (BNEF, 2020). By 2025, the number could climb to 645 000, or close to 40% of the total municipal fleet; by 2040, the share could reach 67% (Sustainable Bus, 2020).

Among the remaining barriers to widespread adoption of e-buses are their higher up-front costs (although total life-cycle costs may not be much higher than those for diesel models), battery replacement costs (which can represent almost half the vehicle price) and the need for adequate charging infrastructure (Lu, Xue and Zhou, 2018).

China accounts for the vast majority of the global e-bus fleet – some 370 000 vehicles. This development has been supported at the central government level by generous subsidies for vehicle purchases and charging infrastructure, in parallel with reduced subsidies for diesel fuel. In 2009, the national government established a list of 13 pilot cities for "new energy vehicles" (新能源汽车) (OECD/IEA, 2018). The ministries of transport, finance, and industry and information technology jointly promulgated a rule in 2015 that new energy buses must account for 80% of all additions and replacements in Beijing, Shanghai, Tianjin, Hebei, Shanxi, Jiangsu Zhejiang, Shandong, Guangdong and Hainan; 65% in Anhui, Jiangxi, Henan, Hubei, Hunan and Fujian; and 30% in other cities and regions.

Local governments have also introduced a series of subsidies and tax reductions for new energy vehicles (ITDP, 2018). Municipal e-bus targets and local manufacturing of the vehicles have been key driving forces (Sustainable Bus, 2020). The Chinese city of Shenzhen is at the forefront of this development (see Box 4).

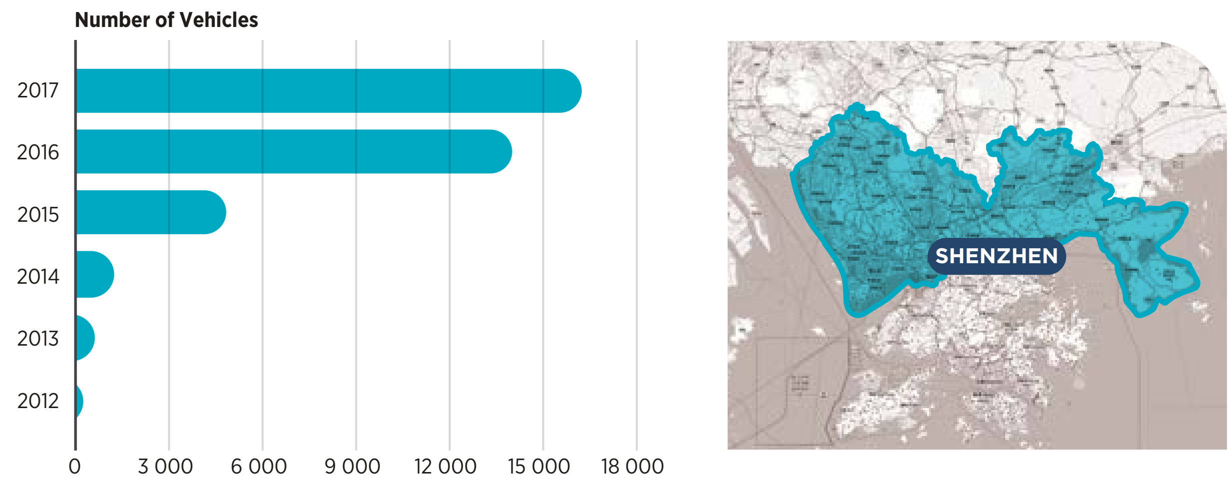
BOX 4 PIONEERING ELECTRIC BUS USE IN SHENZHEN

Chosen to be the first "new vehicle" pilot city, Shenzhen had by the end of 2017 completely switched its bus fleet to electric (see Figure 5). This made Shenzhen the world's first city with an entirely electric bus fleet (in parallel, the city also expanded its metro system, whose share of passenger trips almost doubled to 48% between 2013 and 2018 [Berlin, Zhang and Chen, 2020]). With financial support from the central government, Shenzhen provided substantial subsidies for buses and charging facilities, totalling RMB 3.3 billion (USD 490 million) in 2017 alone (Dixon, 2017).

E-buses deployed in Shenzhen consume 73% less energy than diesel buses and emit 48% less carbon (67 kilogrammes of carbon dioxide per 100 kilometres, compared to 130 kilogrammes for diesel vehicles). During 2017, the fleet's carbon dioxide emissions were cut by 1.35 million tonnes. Pollutants such as nitrogen oxides, hydrocarbons and particulate matter were also down (ITDP, 2018). According to the Shenzhen Municipal Transport Commission, the resulting energy savings amount to 366 000 tonnes of coal saved annually, substituted by 345 000 tonnes of alternative fuel (Dixon, 2017). As China reduces its heavy reliance on coal power plants, the advantages of e-buses will further expand.

Leasing rather than buying buses from manufacturers has allowed bus operators in Shenzhen to lower up-front costs and thus the need for debt financing. Manufacturers are providing lifetime warranties for vehicles and batteries, limiting risks to operators. Because e-buses tend to have shorter driving ranges per charge, more of them are needed than is the case for a diesel powered fleet, translating into greater procurement costs. Shenzhen managed to avoid most of these extra costs by co-ordinating charging and operation schedules; e-buses are charged overnight and recharged at terminals during off-peak hours (Lu, Xue and Zhou, 2018). Shenzhen has 510 bus charging stations with a total of 8 000 charging points, so that half the fleet can be charged at once (Dixon, 2017).

Figure 4 Electric bus adoption in Shenzhen, China



Source: Lu, Xue and Zhou, 2018. © OpenStreetMap contributors

Disclaimer: Boundaries and names shown on this map do not imply any endorsement or acceptance by IRENA.

3 Shenzhen is home to the car and bus manufacturer BYD, the world leader in e-bus production. Promoting local industry, Shenzhen has awarded nominally competitive tenders for e-buses to BYD. However, in February 2018 the central government reformed EV subsidies, prohibiting local authorities from discriminating against non-local vehicle manufacturers (OECD/IEA, 2018).

4 But performance is improving; the average daily mileage of e-buses in Shenzhen increased 41% between 2012 and 2016 (ITDP, 2018).

Support for e-buses is growing elsewhere, too. Under its FAME programme – "Faster Adoption and Manufacturing of Electric (& Hybrid) Vehicles" – India's government is planning to spend INR 40 billion (USD 600 million) over five years to subsidise e-buses and create needed charging infrastructure. Many Indian cities have begun to test e-buses on selected routes. China's BYD has contracts to supply buses to **Bengaluru, Hyderabad** and **Mumbai**, while India's Tata Motors and Ashok Leyland are providing buses to **Ahmedabad, Guwahati, Indore, Jaipur, Jammu, Kolkata** and **Lucknow** (BNEF, 2018).

In Europe, the Scandinavian cities **Oslo, Trondheim** and **Gothenburg** are operating small fleets of e-buses. Oslo's goal is to run its bus fleet entirely on renewable energy after 2020, including e-buses, hybrids and biogas/biodiesel buses (Ruter, n.d.). The European Commission–funded ZeEUS project (Zero Emission Urban Bus System) maintains ten demonstration sites to validate the economic, environmental and societal viability of e-buses, bringing together public transit authorities and operators, bus manufacturers and industry suppliers, energy providers, research centres and other stakeholders (ZeEUS, 2019). As of 2019, Europe had some 3 900 municipal e-buses. Future growth will be driven in large part by the EU mandate that by 2030, 30% of all bus purchases must be "clean" (Sustainable Bus, 2020).

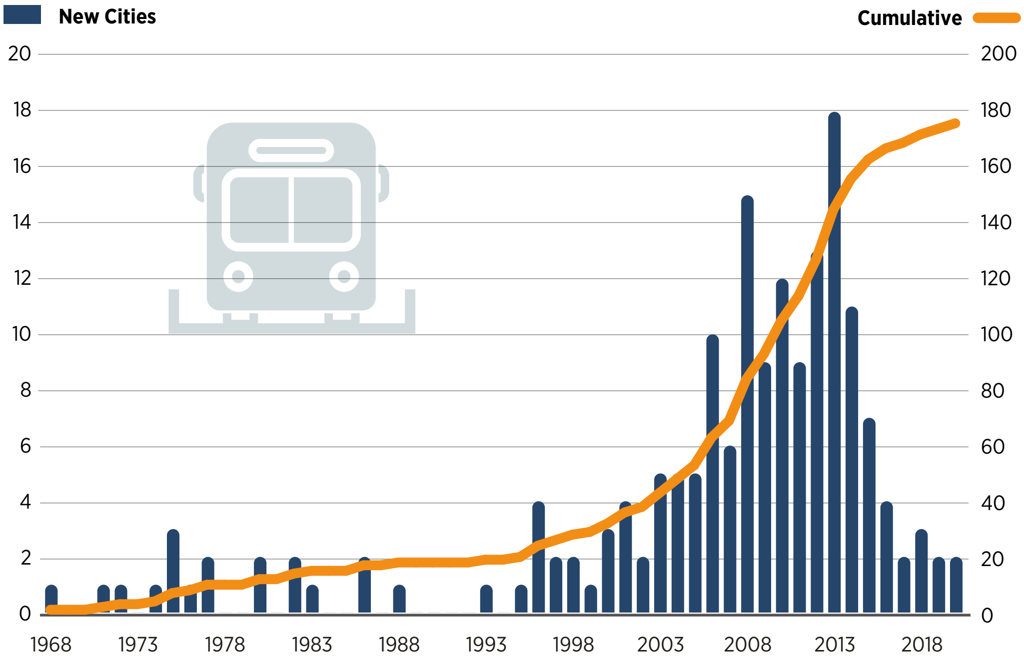
In Latin America, Chile's capital, **Santiago**, is a regional pioneer. Starting with 100 e-buses at the end of 2018, the number almost reached 800 by the end of 2020 (Randall, 2020a; Revista Electricidad, 2020), out of a total fleet of 6 700 buses (Volvo Buses, 2020). Motivated by the need to reduce greenhouse gas (GHG) emissions and dangerously high air pollutants, Chile's 2017 National Electromobility Strategy is a key driver. Prepared by the energy, transport and environment ministries, it sets a goal of 100% of public transit vehicles (and at least 40% of private vehicles) to be electric by 2050 (Orbea, 2018).

Santiago currently accounts for a third of all e-buses in Latin America. C40 Cities and the International Council on Clean Transportation are leading the Zero Emission Bus Rapid-deployment Accelerator (ZEBRA) project that seeks to speed the adoption of e-buses in the region. The initial focus is on Santiago, Medellin, Mexico City and São Paulo, which together will likely purchase 25 000 new buses over ten years, and ZEBRA wants them to be electric (Randall, 2020b).

In the United States, **Los Angeles** and **Seattle** have committed to electrifying their entire bus fleets (Slowik and Lutsey, 2018). The assumption is that electricity generation will over time switch from fossil fuel sources to renewables. One city that is not waiting for this overall transition is **Portland**. Transit agency TriMet introduced its first e-bus in April 2019 powered solely by wind energy. The first five e-buses were funded through a federal grant and TriMet's partnership with the utility Portland General Electric. TriMet plans to purchase up to 80 additional e-buses over 5–6 years and has committed to eliminating all diesel buses by 2040 (Dzikiy, 2019).

BRT systems are another option for many cities, and can be combined with growing use of renewables. BRTs were pioneered in the late 1960s in **Curitiba**, Brazil, and gathered real momentum in the decade leading up to 2013 (see Figure 6). The unique features of BRT systems – including dedicated right-of-way lanes, bus-only corridors, off-board fare collection, platform-level boarding and stations that typically are aligned to the centre of the road – make their service comparable to light rail or metro systems in terms of reliability, convenience and speed (ITDP, n.d.). BRT systems are also much lower in capital cost. Light rail costs are 1.5–2.6 times greater per kilometre than BRT systems. Metros cost 5–9 times more than BRT systems (ITDP, 2017).

Figure 6 Cities with BRT systems, per year and cumulative, 1968–2020



Source: Global BRT Data, 2020.

At the end of 2020, 176 cities worldwide had built BRT systems, with a combined track length of close to 5 300 kilometres. Though the pace of adding new systems has slowed in recent years, 23 cities are expanding their systems, and 103 cities are either building new systems or are planning to do so (Global BRT Data, 2020).

BRT can greatly reduce GHG and air pollutant emissions. Modern BRT fleets are far more fuel efficient and cleaner than private automobiles or the crowded, poorly maintained and highly polluting informal minibuses[5] that they typically replace (Carrigan et al., 2013). **Bogotá's** TransMilenio BRT, with a daily ridership of close to 2 million, is estimated to reduce CO_2 emissions by nearly 1 million tonnes per year. It has also led to a 43% cut in sulphur dioxide emissions, an 18% decline in nitrogen oxide emissions and a 12% reduction in particulate matter (Carrigan *et al.*, 2013).

The environmental and health benefits of BRT fleets can be further boosted by running them on renewable energy. Confronting severe air pollution, Bogotá introduced a TransMilenio e-bus powered by renewables in 2016. It saves 63 600 litres of diesel annually and avoids 135 tonnes of CO_2 emissions. The objective was to convert the entire BRT fleet to such buses over several years (Emblin, 2017). As part of its Paris Agreement commitments, Colombia considered replacing 75% of all public buses in Bogotá, **Medellín** and five other cities with zero-emission vehicles by 2040 (Bermúdez Liévano, 2018).

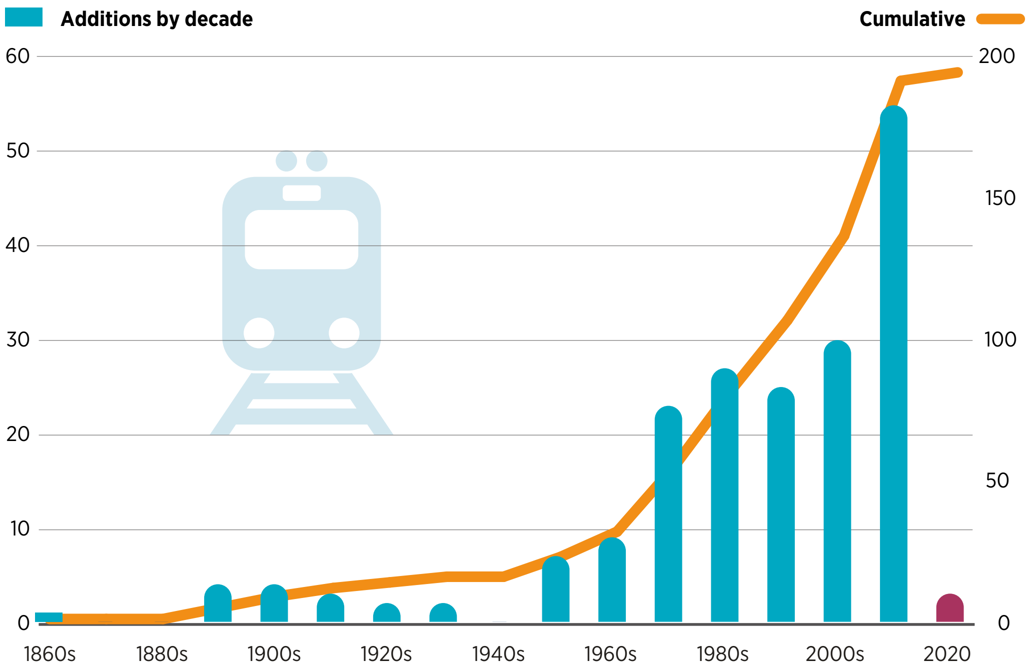
5 However, including key community stakeholders in the design of BRT systems is essential to ensure that the mobility needs of the urban poor are met and that the perspectives of drivers of informal jitneys are considered (Gouldson *et al.*, 2015).

3.2 RUNNING RAIL-BASED TRANSIT SYSTEMS WITH RENEWABLES

Public transit systems represent about one-fifth of passenger transport worldwide but only 7% of transport CO_2 emissions (SLoCaT, 2018b). They are generally less carbon intensive than individual motorised traffic. Unlike diesel buses, rail-based systems such as trams, light rail and metros also avoid the dangerous air pollutants generated by the use of diesel fuel. Electric light rail and metro systems are expanding (see Figure 7) and are especially viable in cities with high population density. The number of public transit journeys made in 39 countries representing half the world's urban population rose 18% between 2000 and 2015, to a total of 243 billion (UITP, 2017).

The sustainability of rail-based transport is enhanced by the degree to which its operations are powered by renewable energy (and in that regard, there are elements of *improve* policies bound up in this category). In the United States, the Bay Area Rapid Transit system (BART, serving **San Francisco** and other cities) is procuring renewable electricity under two power purchase agreements, including a 62-megawatt (MW) wind farm and a 45 MW solar photovoltaic plant with prices lower than from current suppliers (Hanley, 2017). The two agreements will cover 90% of BART's electricity needs from 2021. Stations can also directly generate their own power. By 2018, solar systems generating 1.4 million kilowatt hours (kWh)/year had been installed at four locations, and two more sites for an additional 2.9 million kWh/year were planned (BART, 2018).

Figure 7 Metro system openings, by decade, 1860s–2020



Sources: UITP, 2018; with updates from Wikipedia.

Altogether, the world's cities now have close to 200 metro systems, with most of the additions in the last decade in China and India. As of 2017, there were a total of 642 lines with a length of almost 14 000 kilometres, more than 11 000 stations and more than 114 000 carriages serving almost 54 billion passengers (UITP, 2018).

Several other cities are powering their metro systems in part with solar and wind power (or have plans to do so), including **Delhi** and **Chennai** (India), **Calgary** (Canada), **Santiago de Chile** and **Riyadh** (Saudi Arabia). **Monterrey** in Mexico relies on biogas from waste, and **Medellín** in Colombia on hydropower (IRENA, 2016).

Through a tendering process started in 2014, the Delhi Metro Rail Corporation (DMRC) installed 20 megawatt peak (MWp) of solar energy on the roofs of metro stations, depots and office buildings as of early 2017. By 2021, the city intends to have a capacity of 50 MWp. In addition, DMRC signed a power purchase agreement with the state government of Madhya Pradesh to procure 24% of the electricity generated from the Rewa Ultra Mega Solar Project (IRENA and GIZ, 2018). The solar electricity costs 10–15% less than from conventional sources (UITP, n.d.). In **Chennai**, the Chennai Metro Rail Limited plans to purchase solar and wind energy to power 80% of its daily operations. As of 2018, it had installed 7 MW of solar capacity at elevated stations and at a maintenance depot (ET Energyworld, 2018).

Santiago de Chile's metro system, which serves 2.4 million people every day, is expected to soon source 42% of its energy needs from renewables. Fifteen-year power purchase agreements have been signed with the El Pelícano solar power project (to supply 300 gigawatt-hours of electricity annually) and another 18% from a wind farm – both located in Chile's Atacama Desert (Mahapatra, 2017).

Delhi, India

4. IMPROVE POLICIES

Improve policies focus on improving the performance of vehicles vis-à-vis climate and air quality objectives, which may be accomplished by shifting to biofuel use (4.1), by restricting the use of vehicles with internal combustion engines (4.2) and by promoting e-mobility (4.3).

4.1 BIOFUEL BLENDING MANDATES AND BIOMETHANE USE FOR PUBLIC FLEETS

While general biofuel blending mandates are typically in the policy realm of national governments, cities can contribute to the decarbonisation of their own transport systems by implementing biofuel-blending mandates for public fleets. Blends with a relatively high level of biofuel content achieve greater levels of decarbonisation than lower-level blends but may also require engine modifications. National or subnational governments in at least 70 countries have enacted biofuel blending mandates, though only seven aim for shares higher than 10% (SLoCaT, 2018a).

Biofuels typically originate in rural areas, where crops and agricultural waste are used as feedstock. But cities may also be able to "mine" their own wastes, for instance, biomethane from landfills and wastewater sludge from municipal wastewater treatment plants. In many cases, this technology can be cost-effective in producing low-cost transport fuels for local consumption. Biomethane produced for fuel also captures methane that would otherwise have been released into the atmosphere, making it a particularly worthwhile technology to consider for cities.

Most policy making regarding fuel blends is done at the national level, but some cities have been driving their own initiatives. European cities are among the leaders in methane capture efforts, although recovery rates vary substantially (Ballinger and Hogg, 2015).

Air pollution concerns drove **Linköping**, a city of 150 000 inhabitants in Sweden, to power its fleet of 200 municipal buses with methane derived from landfills, wastewater treatment plants, food and organic wastes including from slaughterhouses, and crop residues and manure. The city is located in the middle of an agricultural district on the plains of eastern Sweden, which made building a biogas plant an obvious choice. The initiative started in 1996 and by 2002, the city's entire bus fleet was converted. Upgraded biogas is also used in trucks and in light duty vehicles including private cars, taxis and distribution vehicles. Today, Linköping has Sweden's largest biogas facility. By 2017, the municipality-owned Tekniska verken produced 120 gigawatt hours of energy from biogas, roughly equivalent to 13 million litres of gasoline. A subsidiary of Tekniska verken, Svensk Biogas, runs 12 filling stations in the region (Svenselius, 2018). A co-benefit of this undertaking is that it substitutes energy imports and thus bolsters retention of funds in the local economy (Mayer, 2013).

In neighbouring Norway, the capital of **Oslo** stopped dumping biodegradable waste in landfills in 2002, seven years before a national ban took effect. The city owns Norway's largest biogas plant, which powers some 150 buses and garbage collection trucks, and generates fertiliser for local farmers. Captured landfill gas also generates electricity for local schools (Tagliabue, 2013; Holmerz, 2015). Behind this success are longstanding campaigns to raise consumers' awareness of good practices in waste collection and separation.

Starting as early as 1994, the **Lille** Métropole Communauté Urbaine (LMCU) – an inter-municipal co operation body in France that includes 87 local authorities with a population of 1.2 million people – gradually switched its fleet of 400 buses to biogas and/or natural gas. Half of the metropolitan area's biodegradable wastes are turned into methane, and biogas is supplied by the Marquette sewage plant outside Lille. Parallel to these practices, LMCU has sought to make public transport more attractive, by offering a single ticket valid for all public transit across the metropolis, allocating dedicated bus lanes and improving the integration of bus lines with car parking, bicycle and pedestrian paths (GIZ and ICLEI, 2014).

Outside Europe, **Curitiba** in Brazil has been implementing a 100% biodiesel mandate for its municipal bus fleet, as part of its Biocidade programme (IRENA, 2015). The city of **Vancouver** has committed to reducing its vehicle fleet emissions by 50% as of 2030, relative to 2007 levels, and to transitioning public transit energy consumption to 100% renewables by 2050. The city aims to achieve this goal by switching its vehicle fleet to a combination of renewable diesel fuel based on waste organic feedstock and compressed natural gas, and by increasing the share of electric and hybrid vehicles (City of Vancouver, 2021).

4.2 RESTRICTIONS ON FOSSIL-FUEL-POWERED VEHICLES

The environmental performance of passenger cars can be improved either by mandating better fuel economy and requiring cleaner fuels (with less sulphur and other impurities), or by restricting the use of vehicles with internal combustion engines. Fuel economy and fuel quality measures are typically the prerogative of national or state governments. But cities generally do possess the authority to set certain standards and parameters for vehicles operating on their streets. Restrictions on vehicle type, and on the time and place of vehicle operations, are emerging in a growing number of municipalities.

Perhaps the most far-reaching of such policies are those that ban cars powered by fossil fuels. National level policy makers are often at the forefront, but local authorities are also acting more and more assertively. **Athens, Madrid** and **Mexico City** have decided to ban petrol- and diesel-powered cars by 2025, and **Paris** will do so by 2030 (REN21, 2018). Three dozen cities, including some of the most well known around the world, have signed the C40 "Fossil Fuel Free Streets Declaration" (see Box 5), which includes a commitment to transition away from vehicles running on fossil fuels (C40 Cities, n.d.). The vision of the declaration is "a future where walking, cycling, and shared transport are how the majority of citizens move around our cities". These policies create the context within which cleaner transport energy, whether in the form of biofuels or renewables-based electricity, will play a larger role.

BOX 5 C40 FOSSIL-FUEL-FREE STREETS

Participating cities pledge to procure only zero-emission buses from 2025 and to ensure that a major area of the city is a zero-emission zone by 2030. To meet this commitment, a range of measures will be taken (and progress will be reported on a bi-annual basis):

- Increase the rates of walking and cycling and the use of public and shared transport that is accessible to all citizens.
- Reduce the number of polluting vehicles on the streets and transition away from vehicles powered by fossil fuels.
- Procure zero-emission vehicles for city fleets as quickly as possible.
- Collaborate with suppliers, fleet operators and businesses to accelerate the shift to zero emission vehicles and reduce vehicle miles.

Source: C40 Cities, n.d.

Graz, Austria

Some cities restrict cars based on geography or time, with vehicles prohibited in particular districts, on particular days/times, or both. A series of policy options are used to put in place these restrictions, including:

- *Congestion pricing* has been implemented in European cities like **Milan** (Italy), **London** (United Kingdom) and **Stockholm** (Sweden), and also in other parts of the world such as in **Singapore, Tehran** (Iran) and **Washington, DC** (United States).
- *Vehicle quotas* through auctions or lottery systems are used especially in Chinese cities such as **Beijing, Shanghai, Shenzhen, Guangzhou** and **Tianjin**.
- *License plate restrictions* include **Mexico City's** *Hoy No Circula* ("Don't Drive Today"), *Pico y Placa* ("Peak and Plate") in **Medellín** (Colombia) and initiatives in other Latin American and Chinese cities, as well as in **Delhi** (India) and **Jakarta** (Indonesia).
- *Low-emission zones* have been adopted in hundreds of European cities.
- *Parking restrictions* can be seen in **Singapore** as well as cities in Europe, Japan and the United States.
- *Car-free streets* improve city life in more than 100 big cities – many of them in Latin America and Europe. In **Oslo** (Norway) – a city of 650 000 residents and about 350 000 cars – the city council banned cars in the city centre in 2019, replacing 750 street-side parking spots with bike lanes, parks and benches.

While only some of these policies are directly relevant to the deployment of renewable energy, they form a diverse package of measures towards the goal of a lower-carbon urban transport sector. Congestion charges in city centres, for example, can prioritise electric vehicles or those powered by biofuels (**Milan** and **London** exempt EVs from congestion and urban access charges [OECD/IEA, 2018]). Access restrictions such as those in Chinese cities act to deter people from purchasing conventional fuel vehicles and persuade them to instead buy EVs, which are usually exempt from restrictions (McKerracher, 2018). Such policies can also motivate people to rely more on public transit modes (trams, light rail and subways, which can be increasingly powered by renewable electricity; or buses using renewable fuels).

Further, to the extent that modal mixes can be improved, and demand for motorised transport reduced, it will be much easier for renewable energy to contribute a greater share of total transport energy. This needs to be understood against the backdrop of business-as-usual projections that transport volumes, and energy demand, will continue to grow rapidly.

4.3 POLICIES IN SUPPORT OF ELECTRIC MOBILITY

Many cities are advancing the use of street vehicles powered at least in part by electric motors, including fully electric and hybrid electric vehicles, which involve no direct emissions of air pollutants and lower the carbon footprint of urban transport. This sub-sector of transport, often dubbed "e-mobility", has particular requirements for fuels, vehicles and infrastructure. Municipal policies in support of e-mobility include targets and mandates, changes in subsidies, fleet procurement and conversion decisions, provision of charging infrastructure and other measures. SLoCaT, the Partnership on Sustainable Low Carbon Transport, is monitoring the adoption of policies around the world (see Table 3).

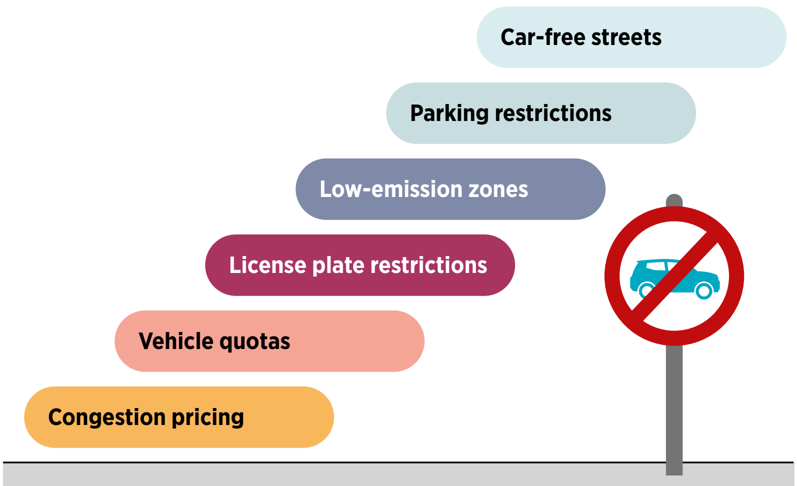


Table 3. E-mobility targets of selected cities

City (Country)	Year		Description of e-mobility target
	Announced	*Target(s) **	
Policy focus: Municipal buses			
Bangalore (India)	2018	2023	All buses to be electric
Rotterdam (Netherlands)	2018	2029	All buses to be zero emission
Medellin (Colombia)	2018	n.a.	All buses to be zero emission
Gothenburg (Sweden)	2018	2020/2025	• 80% reduction in bus emissions by 2020 • 95% of transport to be renewably powered by 2025
Seoul (Republic of Korea)	2018	2027	All diesel buses to be converted to compressed natural gas, electric or hydrogen powered
Paris (France)	2018	2025	4 700 clean buses (electric, hybrid, biogas)
Delhi (India)	2018	2019	Electric bus fleet of 1 000
Copenhagen (Denmark)	2017	2019	Only electric buses to be procured
Los Angeles (US)	2017	2030	2 300 electric or hydrogen buses
Mexico City (Mexico)	2017	2025	Procure only zero-emission buses
Brussels (Belgium)	2016	2030	Fully electrify municipal bus fleet
Policy focus: E-bicycles			
Oslo (Norway)	2017	2017	Subsidies for purchase of e-bikes and cargo bikes
Paris (France)	2018	2018	Subsidies for e-bikes and cargo bikes
Barcelona (Spain)	2014	2017 [end]	Subsidies for e-bikes
Policy focus: Private cars, taxis			
Oslo (Norway)	2016	2020	All new cars and light-freight vehicles to use renewable fuels or to be plug-in hybrids
Rome (Italy)	2018	2024	Ban on all oil-burning cars operating in the city
London (UK)	2018	n.a.	First electric taxis enter service
Beijing (China)	2017	n.a	All newly added or replaced taxis to be converted from gasoline to electricity
Los Angeles (US)	2017	2025/2035	Increase in share of electric or zero-emission vehicles to 10% (2025) and 25% (2035)
Seattle (US)	2016	2030	30% of all light-duty vehicles to be electric
New York (US)	2017	2025	20% of motor vehicles sold for use in New York City to be electric (from less than 1% at present)
Mexico City (Mexico)	2016	2025	Ban on diesel cars and vans
Reykjavik (Iceland)	2016	2025/2040	• All municipal vehicles to be free of greenhouse gas emissions (2025) • All vehicle traffic and public transport to be emission free (2040)
Policy focus: Electric vehicle charging infrastructure			
London (UK)	2017	2020	1 500 charging points to be installed
Beijing (China)	2016	2020	435 000 charging stations to be installed

Source: Adapted from SLOCAT (2018a).

* Where applicable, *i.e.*, where targets are formulated as reaching a desired share or number of clean vehicles, etc. Where policies are focused on subsidies, they presumably become operative at, or soon after, the announcement date.

Earlier, this brief considered the electrification of municipal bus fleets; the focus of this section is on policies promoting electric automobiles (principally privately owned). With regard to municipal car fleets, cities can bring considerable procurement power to the table – by opting to purchase or lease electric cars for municipal services, and by ensuring that renewable electricity is increasingly a part of a city's power options.

It should be noted that the pursuit of EVs does not in and of itself advance renewable energy. Decarbonising the power supply remains an important task in its own right. Municipalities and other governmental authorities can promulgate rules and regulations that expressly link both objectives (*e.g.*, deploying distributed solar rooftop or procuring renewables electricity). REN21 (2019) notes, however, that to date there are only limited examples of such direct policy linkages.

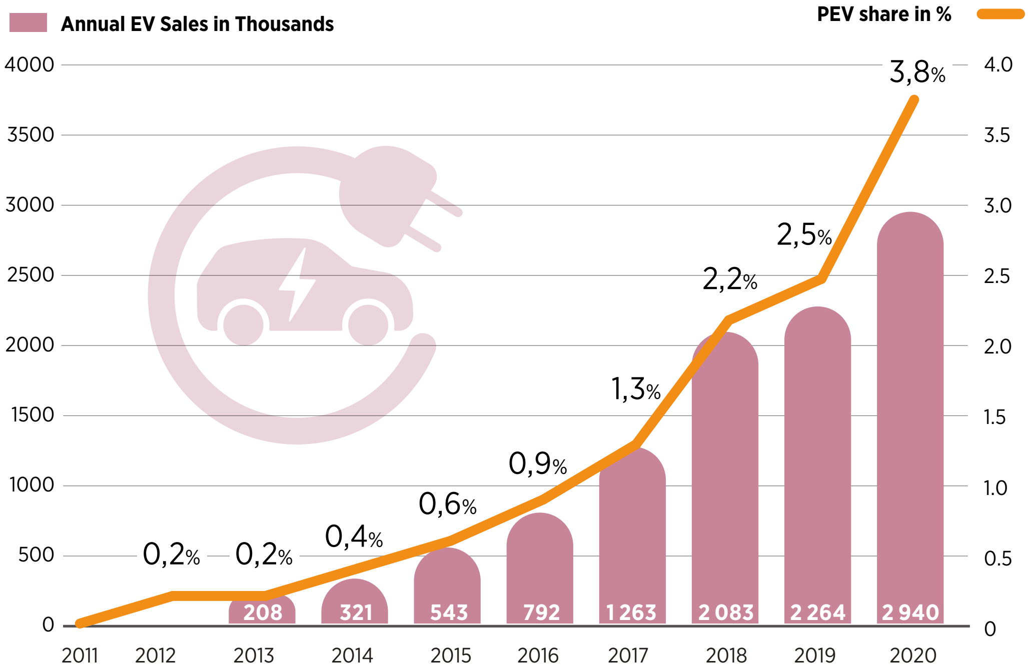
In Europe, studies find that the life-cycle emissions of EVs already compare favourably to even the most efficient internal combustion vehicles (ICCT, 2018). In China, even though coal remains the dominant power source, EVs are nonetheless estimated to emit only 61% of the CO_2 generated by gasoline-powered vehicles. This finding is based on a well-to-wheel life-cycle emissions analysis which includes the manufacture and use of vehicles, as well as fuel production and transport (Energy Foundation China, 2018). The advantages of EVs will grow as the power plant mix shifts towards renewables.

As EVs grow in number and increase urban demand for electricity, integrated planning is needed to allow the electric grid to support more variable demand and also accommodate a larger share of renewable energy from variable sources (*i.e.*, sun and wind). But the co-incidence of rising e-mobility and renewable energy can provide synergistic opportunities for decarbonisation. Steering consumers' charging habits towards times of ample renewable supply, for example, helps to ensure that each mile travelled is powered by clean energy. Integrated planning can also promote vehicle-to-grid services, in which vehicles can feed back energy to the grid. An interesting example of such integrated planning is the Living Lab Smart Charging Platform in the Netherlands, which involves 325 municipalities, companies, universities and grid operators to ensure that renewable energy is used in charging all EVs on the roads.

Policies in favour of passenger car electrification are being formulated at national and local levels in a growing number of countries. Support measures include public procurement and investment plans which help to create and stimulate an EV market. Various financial incentives reduce EV costs, including vehicle purchase subsidies, exemptions from applicable taxes and differentiated taxes that penalise polluting or inefficient vehicles and favour better-performing ones. Additionally, regulations such as fuel-economy and fuel-quality standards and zero-emission vehicle mandates can play an important role in the *improve* policy context.

Municipal governments may not always have the financial resources or the legal authority to pursue some of these policies. But they can promote EVs by offering their users free or discounted parking, free access to charging stations and access to priority traffic lanes, and thus complement national-level policies (OECD/IEA, 2018). Creating a sufficiently dense network of charging stations is an essential part of an EV strategy. Cities can directly invest in building such infrastructure and set deployment targets, issue regulations that standardise hardware and software and take measures to encourage privately owned charging stations through building codes and zoning regulations (IRENA, 2016).

Figure 8 Global electric passenger car sales, 2011–2020



Source: Irle, 2020.

Note: BEV = battery electric vehicle; PHEV = plug-in hybrid electric vehicle.

In 2020, global EV sales reached close to 3 million. Cumulative sales over the past decade surpassed 10 million vehicles (Irle, 2020).

What do the EV trends tell us? Global sales of electric passenger cars are increasing rapidly, albeit from a still very small base (see Figure 8). At the end of 2020, the global fleet of plug-in vehicles (including light trucks) surpassed 10 million, with close to 3 million sold during 2020 (Irle, 2020).

China is the global leader in EVs, and **Shenzhen** leads EV deployment in China. The number of such cars on its streets doubled to 80 000 in 2015 2017, and the city set a 2020 target of 3–5% for the EV share of its entire vehicle stock[6] (People Net, 2017). Another target the city adopted was to have one charging spot every 1.3 kilometres across the entire city area (Home of Vehicle, 2018). This involved installing some 195 000 chargers. The city also aimed to ensure that 10–30% of all parking spaces at all public buildings have charging spots (People Net, 2017). It is building a number of centralised charging stations, such as one at Lianhua Mountain, where a 168 kW solar photovoltaic roof will avoid 4 390 tonnes of CO_2 emissions over the next 25 years (Shenzhen News, 2018).

Action plans with increasing ambition were formulated by the municipality in 2009, 2016 and 2018 to stimulate EV manufacturing, procurement and replacement of conventional vehicles. Enabling policies include subsidies for EV purchases;[7] exemptions from vehicle purchase taxes; free parking and access to bus-only lanes. Shenzhen's pioneering role is stimulating a specialised local industry. Not only is the city already home to the EV manufacturer BYD, but also to 32 companies providing EV charging services (People Net, 2017).

6 Other targets include 100% e-buses by 2017, 100% electric taxies by 2019 and 100% new heavy construction vehicles by 2021.

7 From May to December 2020, city residents were offered subsidies of CNY 20 000 (about USD 3 100) for the purchase of an EV (with half that amount for plug-in-hybrids) (Crider, 2020).

Norway's capital, **Oslo**, has achieved one of the highest densities of EVs in the world. EVs are powered principally by hydropower. Policies such as an exemption from vehicle purchase taxes, reduced value-added taxes, exemption from toll road charges, free parking and free access to bus lanes all boosted the popularity of EVs (Bjerkan, Nørbech and Nordtømme, 2016). Furthermore, between 2008 and 2011, Oslo's City Council financed the installation of 400 public on-street charging points (IRENA, 2016). Elsewhere in Europe, **London, Copenhagen** as well as the Dutch cities of **Amsterdam** and **Utrecht** are pursuing a variety of measures to support the emergence of charging infrastructure (OECD/IEA, 2018).

In the western hemisphere, **Vancouver, San Francisco, San Jose, Los Angeles** and **New Orleans** are in the vanguard (OECD/IEA, 2018). In 2017, 20 US cities formed a partnership to pool procurement of EVs for their municipal fleets, including **New York City, Boston, Denver, Kansas City** and **Houston** (Lambert, 2017). Many of the 50 largest metropolitan areas in the country have taken a variety of actions, not only on charging infrastructure, but also on measures such as granting EVs special parking benefits or access to high-occupancy lanes. Among the cities with electric car sharing, **Los Angeles, Sacramento** and **Portland** have also focused on the needs of low-income residents. More than 20 cities have adopted EV fleet targets for municipal car fleets (Slowik and Lutsey, 2018).

The city of **Pittsburgh** aims to reduce transport-related GHG emissions by 50% by 2030. The so-called Electric Avenue project is part of an effort to achieve a fossil-free municipal passenger car and motorcycle fleet by that year and involves a clean-energy transport corridor along the city's Second Avenue. The project includes the purchase of EVs and installation of 25 charging stations powered by a 100 kilowatt solar canopy tied into the local district energy microgrid (Smart Pittsburgh, n.d.; Riley, 2017).

In Mexico, the state of Querétaro has adopted new regulations to promote the use of renewable energy and EVs by taxi owners. As an initial step, 45% of taxis, or about 3 000 vehicles, in **Querétaro City** are to be powered by natural gas instead of gasoline. Within 5–6 years, all taxis in the greater metropolitan area are planned to run on renewables. To achieve this goal, all new taxi concessions from 2020 onwards and any new taxi licenses will be given to only EVs (Mexico News Daily, 2018; Rosales, 2020).

Various elements of transport and energy policy need to be carefully calibrated. There is a risk that EV policies could disproportionately benefit those residents who are most able to afford EVs, at the expense of other urban residents. Policy making therefore needs to balance measures in favour of private vehicle use with support for public transit systems.

Brooklyn Heights, NY, United States

5. INTERNATIONAL COLLABORATIVE INITIATIVES

As in other end-use sectors, cities are not only undertaking their own individual transport policies but are also partnering with other actors in joint declarations of intent, sharing of best practices and capacity building efforts.

The international climate negotiations process gave rise to the "Lima Paris Action Agenda", later renamed the "Marrakech Partnership for Global Climate Action",[8] which entails a total of 21 transport-related international initiatives (SLoCaT and PPMC, 2017). A number of these have relevance for cities and energy, and together with selected other international networks, are profiled in Table 4. Sharing information and experiences and mobilising resources and expertise among like-minded cities can help them achieve objectives more readily and avoid pitfalls.

8 The LPAA was named after the two cities that hosted the international climate negotiations known as COP 20 and COP 21 in 2014 and 2015, respectively. In 2016, Marrakesh hosted COP 22.

Table 4. International urban-transport-related initiatives for climate action

Initiative (Year)	Objectives and achievements
Zero Emission Vehicle (ZEV) Network www.c40.org/networks/zero-emission-vehicles	Led by the city of London, the network serves as a platform for C40 cities to share best practices and policies for emissions reductions by promoting electric and other low-emission vehicles. Participating cities prioritise four focus areas: Developing and refining low- and zero-emission vehicle strategies; planning for electric vehicle (EV) charging/refuelling infrastructure; incentives to promote ZEV uptake and promoting ZEVs in bus, taxi and municipal fleets.
C40 Clean Bus Declaration of Intent (2015) climateinitiativesplatform.org/index.php/C40_Clean_Bus_Declaration	The C40 Clean Bus Declaration aims to get the commitment of cities to reduce emissions from these vehicles by adopting the most innovative technologies like electric, hydrogen and hybrid buses. A total of 26 cities with 165 million residents committed to switch 42 000 of more than 160 000 buses to low- and zero-emission models by 2020 (annual greenhouse gas [GHG] savings are expected to be almost 900 000 tonnes). The declaration calls upon bus manufacturers, public transport operators, multilateral development banks and others to support decarbonisation efforts.
International Association of Public Transport (UITP) Declaration on Climate Leadership (2014) www.uitp.org/climate-leadership	UITP is the only worldwide network to bring together all public transport stakeholders and all sustainable transport modes, including the transport business supply industry. UITP has over 1 500 members in 96 countries and represents the key players needed for low-carbon urban mobility. Through the Declaration on Climate Leadership, UITP encourages its members to make commitments to reduce carbon emissions and strengthen climate resilience. Commitments to date include bus fleet renewal in Dakar, Senegal; metro expansion in Moscow, Russia; and efficient transport infrastructure lighting in Rio de Janeiro, Brazil. These actions support UITP's goal of doubling the share of public transport by 2025 from 2005 levels and preventing half a billion tonnes of CO_2-equivalent emissions compared to business-as-usual projections.
EcoMobility Alliance (2011) https://sustainablemobility.iclei.org/ecomobility-initiative/	Initiated by ICLEI, the EcoMobility Alliance is a network that brings together ambitious local and regional governments, experts and businesses to work together on how to prioritise people and the environment when it comes to transport planning. The EcoMobility Alliance offers a platform for stakeholders to share the latest policy and technology developments in their cities and regions, with the goal of making effective reforms of their transport networks. To date, the network includes 23 cities from various regions of the world committed to building a sustainable transport future through low-carbon, people-centred and socially inclusive mobility options. Activities include capacity building, coalition building, and monitoring and reporting.

Source: Adapted from SLoCaT and PPMC (2017); Huizenga, Peet and Gota (2016); IEA (2018a, 2018b) and websites cited in the table.

Table 4. International urban-transport-related initiatives for climate action (continue)

Initiative (Year)	Objectives and achievements
MobiliseYourCity (2015) mobiliseyourcity.net/	With funding from the European Commission, France and Germany, the initiative aims to assist 100 cities (primarily in Africa, plus some Asian, Latin American and Central European cities) and 20 national governments in reducing urban transport-related emissions by at least 50% by 2050, through the development of integrated sustainable urban mobility plans. The MobiliseYourCity Partnership follows the *avoid/shift/improve* approach to empower cities to put people's need for connection and access at the forefront of sustainable mobility planning. The initiative offers technical assistance for Sustainable Urban Mobility Plans (strategic plans developed in an inclusive and integrated way in order to meet the mobility needs of people and businesses and to harmonise and integrate existing planning approaches) and National Policies and Programmes (an action-oriented framework for urban mobility developed by national governments) through different implementing organisations, such as the Agence Française de Développement (AFD) and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). Activities include capacity building, technical assistance and sharing of best practices.
Global Fuel Economy Initiative (GFEI) (2009) www.globalfueleconomy.org/	A partnership of the International Energy Agency, the United Nations Environment Programme, the International Transport Forum of the Organisation for Economic Co-operation and Development (OECD), the International Council on Clean Transportation, the Institute for Transportation Studies at the University of California–Davis and the FIA Foundation. The GFEI calls for doubling the efficiency of all new vehicles by 2030 and doubling that of the entire global vehicle fleet by 2050, relative to 2005 (avoiding more than 1 gigatonne of CO_2 per year by 2025 and more than 2 gigatonnes per year by 2050). GFEI works with local experts to develop tailored policy options for each country, based on assessments of the vehicle fleet and national context. Among other knowledge products, GFEI has generated an overview of different policy approaches for various vehicle types and individual country cases.
Electric Vehicles Initiative (EVI) (2010) www.iea.org/topics/transport/evi/	A multi-government policy forum to accelerate the adoption of EVs, its members include several OECD countries plus China and India. In 2017, EVI launched the "EV 30@30" campaign (goal of 30% market share for all EVs by 2030).
Global EV Pilot City Programme (PCP) (2018)	PCP is intended to build a network of 100 EV-friendly cities to help achieve the EV30@30 campaign. Currently consists of 34 cities mostly in North America, Europe and Japan. PCP works to establish common indicators to monitor relevant developments and exchange information on replicable solutions.
Urban Electric Mobility Initiative (UEMI) (2014) www.uemi.net/	Initiated by UN-Habitat and the SOLUTIONS project, UEMI aims to boost the share of EVs among 2-3 wheelers and light-duty vehicles and integrate electric mobility into a wider concept of sustainable urban transport that achieves a 30% reduction of urban GHG emissions by 2030. Working closely with city governments, it pools expertise, facilitates exchanges and supports implementation (development of action plans for pilot projects). UEMI is working with 22 cities with a combined population of over 46 million people to implement sustainable urban mobility measures. Pilot projects include: electric handcarts in Mombasa, Kenya; Bicycle Street (Fahrradstrasse) and Zone 30 in the Cachoeirinha neighbourhood, Belo Horizonte, Brazil; a pedestrian street along the Tam Bac River and electric two-wheelers in Hai Phong, Viet Nam; electric mobility in Kochi, India; electric bike sharing in Ibagué; open streets in Cape Town, South Africa; e-mobility options in Ghana; and sustainable mobility in Fiji.

SUMMARY

The central role of transport in generating carbon emissions, and the fact that renewables account for only a small share of energy consumed in the transport sector, makes the sector a worthy target for reform. A combination of policies that *avoid* carbon emissions, promote a *shift* in transport modes and *improve* the sector's efficiency offers a useful toolbox for urban leaders interested in remaking transport into a low-carbon sector.

One key way to avoid carbon emissions is through urban land-use policy, and specifically the redesign of cities to reduce the need for long trips. Cities that pursue dense development and prioritise access to transport essentially restructure urban life such that long, cross-town journeys become less necessary.

It is also possible to shift from private cars to more efficient modes of transport such as walking, biking and public transport, which decreases energy consumption and emissions for each kilometre of passenger travel. A shift can be encouraged by incentive schemes, providing charging infrastructure, setting mandates to blend fuels to burn more cleanly and even banning transport powered by fossil fuels.

It is important to *improve* transport systems by making them cleaner, more accessible and more affordable – and therefore more attractive – to the public. Electric cars tend to be cleaner than those that run on gas, especially if their electricity comes from plants powered by the wind or sun. Electrifying municipal bus fleets and using these in BRT systems can be a powerful combination. This is especially so where the system is powered by renewable energy. Deployment of those alternatives can be accelerated by providing charging infrastructure, setting mandates to blend fuels to burn more cleanly and even banning transport powered by fossil fuels.

Although transport is typically a local responsibility, cities can find help in meeting their visions and plans even at the global level. International associations of cities often showcase best practices and promote knowledge sharing, which can be invaluable for cities trying to think creatively about their transport challenges. Some of these practices, such as congestion pricing, may not promote renewable energy directly, but can be tweaked to do so, as for example, in exempting EVs from congestion charges.

REFERENCES

Ballinger, A. and Hogg, D. (2015), *The Potential Contribution of Waste Management to a Low Carbon Economy*, Zero Waste Europe, Zero Waste France and ACR+, Brussels.

BART (Bay Area Rapid Transit) (2018), "BART 2018 factsheet", www.bart.gov/sites/default/files/docs/2018_BART%20Factsheet.pdf.

Berlin, A., X. Zhang and Y. Chen (2020), "Case Study: Electric buses in Shenzhen, China", https://iea.blob.core.windows.net/assets/db408b53-276c-47d6-8b05-52e53b1208e1/e-bus-case-study-Shenzhen.pdf [study in support of IEA (2020), *Global EV Outlook 2020*, https://www.iea.org/reports/global-ev-outlook-2020].

Bermúdez Liévano, A. (2018), "Bogotá rejects Chinese electric buses", Diálogo Chino, 8 November, https://dialogochino.net/12261-bogota-rejects-chinese-electric-busses/.

Bjerkan, K. Y., T. E. Nørbech and M. E. Nordtømme (2016), "Incentives for promoting battery electric vehicle (BEV) adoption in Norway", *Transportation Research Part D: Transport and Environment*, Vol. 43, pp. 169 180.

BNEF (2020), "Electric vehicle outlook 2020: Executive summary", Bloomberg New Energy Finance, https://about.bnef.com/electric-vehicle-outlook/.

BNEF (2018), "India's EV push to focus on e-buses, taxis, three wheelers", BNEF Blog, 21 August, https://about.bnef.com/blog/indias-ev-push-focus-e-buses-taxis-three-wheelers/.

C40 Cities (n.d.), "Fossil fuel free streets declaration", www.c40.org/other/green-and-healthy-streets, accessed 26 August 2020.

Carrigan, A., R. King, J. M. Velasquez, M. Raifman and M. Duduta (2013), *Social, Environmental and Economic Impacts of BRT Systems: Bus Rapid Transit Case Studies from around the World*, World Resources Institute and EMBARQ, Washington, DC.

City of Vancouver (2021), "Greening the city's fleet", https://vancouver.ca/green-vancouver/green-fleets.aspx.

Crider, J. (2020), "Shenzhen gives residents incentives to buy EVs – Tesla included", CleanTechnica, 15 June, https://cleantechnica.com/2020/06/15/shenzhen-gives-residents-incentives-to-buy-evs-tesla-included/.

Dixon, T. (2017), "Shenzhen completes its bus fleet transitions to 100% electric buses", Clean Technica, 29 December, https://evobsession.com/shenzhen-completes-its-bus-fleet-transitions-to-100-electric-buses/.

Dzikiy, P. (2019), "Portland's new electric buses run on wind energy, a first in US transit", Electrek, 22 April, https://electrek.co/2019/04/22/portland-electric-buses-wind/.

Emblin, R. (2017), "Bogotá introduces world's first electric articulated bus", The City Paper Bogota, 16 June, https://thecitypaperbogota.com/bogota/bogota-introduces-worlds-first-electric-articulated-bus/17391.

Energy Foundation China (2018), "From cradle to grave, is EV car low carbon and energy effective?" www.efchina.org/Blog-zh/blog-20180626-zh.

ET Energyworld (2018), "Renewable energy to power 80% of metro rail operations, tenders floated", 16 August, https://energy.economictimes.indiatimes.com/news/renewable/renewable-energy-to-power-80-of-metro-rail-operations-tenders-floated/65418336.

FS-UNEP Centre and BNEF (2018), *Global Trends in Renewable Energy Investment 2018*, Frankfurt School and United Nations Environment Programme Collaborating Centre for Climate & Sustainable Energy Finance and Bloomberg New Energy Finance, Frankfurt, April, http://fs-unep-centre.org/sites/default/files/publications/gtr2018v2.pdf.

GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH) and ICLEI (2014), "Lille Metropole, France: Waste to fuel: Biogas powered buses in Lille Metropole", Urban NEXUS Case Study 07, Bonn, http://old.iclei.org/fileadmin/PUBLICATIONS/Case_Studies/Urban_NEXUS_cs07_Lille_ICLEI-GIZ_2014.pdf.

Global BRT Data (2020), "Panorama per year", https://brtdata.org/panorama/year, accessed 13 December 2020.

Gouldson, A., S. Colenbrander, A. Sudmant, N. Godfrey, J. Millward-Hopkins, W. Fang and X. Zhao (2015), "Accelerating low-carbon development in the world's cities", New Climate Economy Working Paper, Global Commission on the Economy and Climate, Washington, DC, https://newclimateeconomy.report/workingpapers/wp-content/uploads/sites/5/2016/04/NCE2015_workingpaper_cities_final_web.pdf.

Hanley, S. (2017), "BART ramps up renewable energy program", Clean Technica, 11 December, https://cleantechnica.com/2017/12/11/bart-ramps-renewable-energy-program/.

Holmerz, S. (2015), "Oslo's colourful solution to waste management", *Waste Management World*, Vol. 16, No. 3, https://waste-management-world.com/a/oslo-s-colourful-solution-to-waste-management.

Home of Vehicle (2018), "By end of this year, Shenzhen taxis will be 100% EV" (in Chinese) (今年底深圳出租车将实现100%纯电动化), www.d1ev.com/carnews/yongche/69018, accessed 19 August 2018.

Huizenga, C., K. Peet and S. Gota (2016), "Urban transport and climate change", in *State of the World: Can a City Be Sustainable?* Worldwatch Institute (ed.), pp. 195 210, Island Press, Washington, DC, https://doi.org/10.5822/978-1-61091-756-8.

ICCT (2018), "Effects of battery manufacturing on electric vehicle life-cycle greenhouse gas emissions", International Council on Clean Transportation, Washington, DC, www.theicct.org/publications/EV-battery-manufacturing-emissions.

ICCT (2012), *Global Transportation Energy and Climate Roadmap*, International Council on Clean Transportation, Washington, DC, www.theicct.org/sites/default/files/publications/ICCT%20Roadmap%20Energy%20Report.pdf.

IEA (2018a), "Electric vehicles initiative: Accelerating the introduction and adoption of electric vehicles worldwide", International Energy Agency, Paris, www.iea.org/areas-of-work/programmes-and-partnerships/electric-vehicles-initiative.

IEA (2018b), "EVI global EV pilot city programme", International Energy Agency, Paris, www.iea.org/areas-of-work/programmes-and-partnerships/evi-global-ev-pilot-city-programme.

IEA, IRENA (International Renewable Energy Agency), UNSD (United Nations Statistics Division), World Bank and WHO (World Health Organization) (2020), *Tracking SDG 7: The Energy Progress Report*, World Bank, Washington, DC.

IRENA (2021), *Renewable Energy Policies for Cities: Experiences in China, Uganda and Costa Rica*, International Renewable Energy Agency, Abu Dhabi.

IRENA (2016), *Renewable Energy in Cities*, International Renewable Energy Agency, Abu Dhabi, www.irena.org/publications/2016/Oct/Renewable-Energy-in-Cities.

IRENA (2015), "Renewable energy policy brief: Brazil", International Renewable Energy Agency, Abu Dhabi, www.irena.org/-/media/Files/IRENA/Agency/Publication/2015/IRENA_RE_Latin_America_Policies/IRENA_RE_Latin_America_Policies_2015_Country_Brazil.pdf?la=en&hash=D645B3E7B7DF03BDDAF6EE4F35058B2669E132B1.

IRENA and GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit) (2018), "Turning the urban rail system green: New Delhi, India", International Renewable Energy Agency, Abu Dhabi, www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Dec/IRENA_Cities_2018d_New-Delhi.pdf.

IRENA, IEA and REN21 (2018), *Renewable Energy Policies in a Time of Transition*, International Renewable Energy Agency, International Energy Agency and Renewable Energy Policy Network for the 21st Century, Abu Dhabi and Paris, www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Apr/IRENA_IEA_REN21_Policies_2018.pdf.

Irle, R. (2020), "Global BEV and PHEV volumes for 2020 H1", *EV-Volumes*, www.ev-volumes.com/news/global-bev-and-phev-volumes-for-2020-h1/.

ITDP (Institute for Transportation and Development Policy) (2018), "China tackles climate change with electric buses", Institute for Transport and Development Policy Blog, 11 September, www.itdp.org/2018/09/11/electric-buses-china/.

ITDP (2017), "2.2 Costs", https://brtguide.itdp.org/branch/master/guide/why-brt/costs.

ITDP (n.d.), "What is BRT?" www.itdp.org/library/standards-and-guides/the-bus-rapid-transit-standard/what-is-brt/.

Lambert, F. (2017), "U.S. cities' massive electric vehicle order increases to 114,000 vehicles, ~40 companies competing", Electrek, 15 March, https://electrek.co/2017/03/15/electric-vehicle-order-114000-vehicles-40-companies-competing/.

Litman, T. (2019), *Evaluating Active Transport Benefits and Costs: Guide to Valuing Walking and Cycling Improvements and Encouragement Programs*, Victoria Transport Policy Institute, Victoria, BC.

Lu, L., L. Xue and W. Zhou (2018), "How did Shenzhen, China build world's largest electric bus fleet?" World Resources Institute (WRI) Blog, 4 April, www.wri.org/blog/2018/04/how-did-shenzhen-china-build-world-s-largest-electric-bus-fleet.

Mahapatra, S. (2017), "Santiago Metro to meet 60% energy demand from renewable energy", Clean Techies, 25 June, https://cleantechies.com/santiago-metro-to-meet-60-energy-demand-from-renewable-energy/.

Mayer, N. (2013), "100% biogas-fuelled public transport in Linköping, Sweden", in *City-Level Decoupling: Urban Resource Flows and the Governance of Infrastructure Transitions – Annex: Case Studies from Selected Cities*, A Report of the Working Group on Cities of the International Resource Panel, M. Swilling, B. Robinson, S. Marvin and M. Hodson (eds.), United Nations Environment Programme, Paris.

McKerracher, C. (2018), "McKerracher: How city policies are reshaping auto markets", Bloomberg New Energy Finance Blog, 29 August, https://about.bnef.com/blog/mckerracher-city-policies-reshaping-auto-markets/.

Mexico News Daily (2018), "New legislation will require taxis to be powered by renewable energy", 24 July, https://mexiconewsdaily.com/news/taxis-to-be-powered-by-renewable-energy/.

Newman, P. and J. Kenworthy (2015), *The End of Automobile Dependence: How Cities Are Moving Away from Car-Based Planning*, Island Press, Washington, DC.

OECD/IEA (2018), Global EV Outlook 2018, Organisation for Economic Co-operation and Development/International Energy Agency, Paris, https://webstore.iea.org/download/direct/1045?filename=global_ev_outlook_2018.pdf.

Orbea, J. (2018), "How Santiago de Chile became a global leader on electric buses", The City Fix, 18 December, http://thecityfix.com/blog/santiago-de-chile-became-global-leader-electric-buses-jone-orbea/.

People Net (2017), "New energy vehicles exceeded 80 000 in Shenzhen, making its electric buses largest of the world" (in Chinese), (深圳市新能源汽车超8万辆 纯电动公交数局全球首位), 20 July, http://sz.people.com.cn/n2/2017/0720/c202846-30501747.html.

Randall, C. (2020a), "Santiago de Chile receives 150 new BYD buses", Electrive, 30 June, www.electrive.com/2020/06/30/santiago-de-chile-receives-150-new-byd-buses/.

Randall, C. (2020b), "ZEBRA to bring electric buses to South America", Electrive, 7 April, www.electrive.com/2020/04/07/zebra-to-bring-electric-buses-to-south-america/.

REN21 (2019), *Renewables 2019: Global Status Report*, Renewable Energy Policy Network for the 21st Century, Paris, www.ren21.net/gsr-2019/.

REN21 (2018), *Renewables 2018: Global Status Report*, Renewable Energy Policy Network for the 21st Century, Paris, www.ren21.net/wp-content/uploads/2019/05/GSR2018_Full-Report_English.pdf.

REN21 and FIA Foundation (2020), *Renewable Energy Pathways in Road Transport*, Renewable Energy Policy Network for the 21st Century, Paris, www.ren21.net/2020-re-pathways-in-road-transport/.

Revista Electricidad (2020), *Buses eléctricos: ponen en marcha el electroterminal más grande del país*, Santiago de Chile, Chile, www.revistaei.cl/2020/12/03/buses-electricos-ponen-en-marcha-el-electroterminal-mas-grande-del-pais/#.

Riley, K. (2017), "Smart partnerships pilot Pittsburgh's renewable energy plunge", Daily Energy Insider, 16 August, https://dailyenergyinsider.com/news/7233-smart-partnerships-pilot-pittsburghs-renewable-energy-plunge/.

Rosales, P. M. (2020), "Operan en Querétaro 300 taxis híbridos", *Diario de Querétaro*, 25 January, www.diariodequeretaro.com.mx/local/operan-en-queretaro-300-taxis-hibridos-4745583.html.

Ruter (n.d.), "Fossil free 2020", https://ruter.no/en/about-ruter/reports-projects-plans/fossilfree2020/.

Shenzhen News (2018), "Phase II of transmission plus charging station project on Lianhua Mountain goes into operation" (in Chinese) (莲花山变+充电站二期工程投产), www.sznews.com/news/content/2018-04/01/content_18791018.htm.

SLoCaT (2018a), *Transport and Climate Change Global Status Report 2018*, Partnership on Sustainable Low Carbon Transport, Brussels, http://slocat.net/tcc-gsr.

SLoCaT (2018b), *E-Mobility Trends and Targets*, as of 29 November 2018, Partnership on Sustainable Low Carbon Transport, Brussels, https://slocat.net/publications/e-mobility-trends-and-targets/.

SLoCaT and PPMC (2017), *Marrakech Partnership for Global Climate Action (MPGCA) Transport Initiatives: Stock-Take on Action Toward Implementation of the Paris Agreement and the 2030 Agenda on Sustainable Development: Second Progress Report*, Paris Process on Mobility and Climate, November, www.ppmc-transport.org/wp-content/uploads/2017/11/2017-MPGCA-Transport-Initiatives-Report_Final.pdf.

Slowik, P. and N. Lutsey (2018), "The continued transition to electric vehicles in U.S. cities", www.theicct.org/publications/continued-EV-transition-us-cities-2018.

Smart Pittsburgh (n.d.), "'Electric avenue': Charging into a fossil-free future", http://smartpittsburgh.org/programs/electric-avenue.

Sustainable Bus (2020), "Where are we going?", September, www.yumpu.com/en/document/read/64404900/sustainable-bus-2020-09.

Svenselius, M. W. (2018), "Linköping home to Sweden's largest biogas facility", Linköping University, 5 November, https://liu.se/en/news-item/storsta-biogasanlaggningen-finns-i-linkoping.

Tagliabue, J. (2013), "A city that turns garbage into energy", *New York Times*, 29 April, www.nytimes.com/2013/04/30/world/europe/oslo-copes-with-shortage-of-garbage-it-turns-into-energy.html.

UITP (2018), "World metro figures", Statistics brief, International Association of Public Transport, Brussels, September, https://cms.uitp.org/wp/wp-content/uploads/2020/06/Statistics-Brief-World-metro-figures-2018V3_WEB.pdf.

UITP (2017), "Urban public transport in the 21st century", Statistics brief, International Association of Public Transport, Brussels, October, www.uitp.org/sites/default/files/cck-focus-papers-files/UITP_Statistic%20Brief_national%20PT%20stats.pdf.

UITP (n.d.), "Solar power produced and used to power Delhi Metro", International Association of Public Transport, Brussels, https://india.uitp.org/articles/delhi-metro-solar-power-initiative.

UN (2016), *Mobilizing Sustainable Transport for Development*, United Nations, New York, https://sustainabledevelopment.un.org/content/documents/2375Mobilizing%20Sustainable%20Transport.pdf.

UN Habitat (n.d.), "Energy", http://unhabitat.org/urban-themes/energy/, accessed 26 August 2018.

Volvo Buses (2020), "Santiago pone el foco en conectividad y seguridad al momento de recibir 120 nuevos buses volvo con el sistema safety zone", press release, 21 January, www.volvobuses.com.ar/es-ar/news/2020/jan/santiago-chile-conectividad.html.

ZeEUS (Zero Emission Urban Bus System) (2019), "ZeEUS – Bringing electrification to the heart of the urban bus network", http://zeeus.eu/.

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