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Center of Competence Cities

Powering the Future of Urban Mobility

How Shared eMobility Will Change Our Streets and Cities

September 2018
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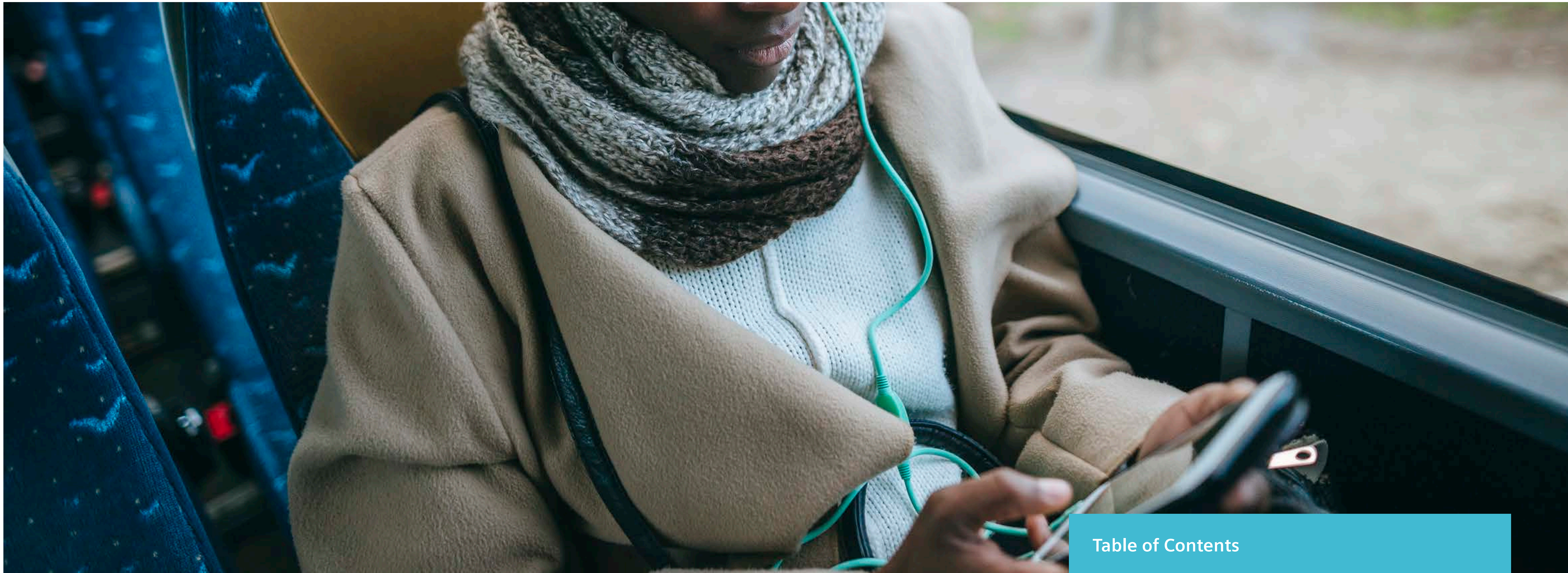

About Siemens

Infrastructure is the backbone of a city's economy and urban development projects help to create a livable and sustainable smart city. With automated and intelligent infrastructure technologies, Siemens expertise is integrating hardware and software to improve quality of life, capacity, and efficiency in metropolitan areas. Siemens established the Center of Competence Cities (CoC Cities) to specifically address the needs of urban planners and to enter into a structured dialogue and base-lining assessment with urban decision-makers.

For more information about this report and Siemens work in cities, please visit:

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Introduction

For the past seven years, Siemens has been working with mayors' offices around the world to chart technology pathways to more sustainable futures. What we have learned through our 40+ projects with cities as diverse as London, Seoul, New Bedford, MA (USA), San Francisco, Phoenix, Buenos Aires, Mexico City, Adelaide, Australia, and Shenzhen is this – The key to deep carbon reduction lies in three actions:

1) Reducing energy use through energy efficiency, especially in buildings

2) Cleaning the electricity grid, by adopting 100 percent renewable electricity

3) Electrifying everything, from heating to transportation

Simple, right?

Of course, each one of these actions entails thousands of sub-actions. Cleaning the electricity grid might mean first shutting down existing fossil fuel-powered plants, then powering up new utility-scale solar. Reducing energy use in buildings might entail first measuring the amount of energy used in buildings, then implementing design standards or retrofit programs.

Indeed, many of the sub-actions rely on overhauls of current city policies, regulations, technologies, behaviors, and design, and these actions will necessarily take place over time. Wiring new buildings' heating systems for electricity and mandating electric vehicle (EV) charger hookups in new residential developments are just a few examples of how cities are incentivizing changes to the status quo in order to pave the way for long-term sustainability.

Although many cities' sustainability targets are set for the long-term (2035 or 2050), what is clear through our research is that planning and investments for sustainable infrastructure need to be rolled out now.

As just one example, to reach the level of transportation electrification needed to achieve one city's carbon reduction target of 80 percent greenhouse gas (GHG) emissions reduction by 2050, the city would have to install 100 EV chargers per week between 2018 and 2050 to accommodate full electrification of vehicles traveling its streets[1].

Estimates of technology adoption rates, behavioral changes, and infrastructure investments needed to reach sustainability targets – while high – should not intimidate cities into inaction. Rather, they provide important opportunities for cities to think carefully about how they can leverage change for public good. Commensurate with estimates of adoption rates or infrastructure investments are projections of their economic and environmental benefits. Implementing sustainable technologies can create thousands, if not millions, of new jobs, while delivering immediate benefits in terms of cleaner air and better quality of life.

This notion of leveraging change for public good is the starting point for this white paper, *Powering the Future of Urban Mobility.*

From the City to the Street

The research presented in this paper takes Siemens analyses about long-term sustainability planning in cities from bird's eye-view to street level. It focuses in on passenger mobility, or how people use different modes of transportation to navigate urban areas. This is one of the toughest, but most critical topics for cities to address today and into the future.

Transportation is an unavoidable daily routine for urban inhabitants. Whether traveling to work, to school, to home, to the store, to the park, or to see friends, city dwellers rely on a diverse set of modes to accommodate their needs. Our city streets also serve as extensions of the public realm, transforming temporarily into markets, meeting places, soccer pitches, and more.

However, in recent years, population growth, aging infrastructure, urban sprawl and densification, and shifting transport needs have changed the demands on urban mobility networks. Cities today are facing more congestion, more travel delays, more traffic-related air pollution, and more transport-related costs than ever before. The changing demands on urban mobility networks are also playing themselves out on our streets. In many cities around the world, fatalities and injuries on city streets are rising, as they become less safe places to be, or move.

Cities today are facing more congestion, more travel delays, more traffic-related air pollution, and more transport-related costs than ever before.

New mobility services, or new business models and new technologies, are emerging with the promise of helping cities fix these transportation challenges. Chief among them are **autonomy** (or vehicles that leverage sensing technology to interact automatically with their surrounding environments, thereby reducing the need for drivers and increasing the safety of travel), **connectivity** (or digitally connected infrastructure, which provides information, and sometimes commands, to anything or anyone on streets), **electrification** (or battery-powered vehicles, which have zero tailpipe emissions), and **shared mobility** (or vehicles in which ownership and/or use is shared among individuals).

Individually, all these offer benefits of improved safety, travel time, and experience alongside reduced environmental impact. Combined, they promise to radically overhaul our urban mobility networks as we know them — dropping traffic incidents to near zero rates, improving local air quality by upwards of 50 percent, making travel more efficient by up to 70 percent, and unlocking millions of miles of streets and parking lots for new development[2].

Research on these four new mobility services puts forward a variety of timelines for when they might be adopted, and how. From consulting companies, to think tanks, to university research centers, to industrial giants, everyone is weighing on possible urban mobility futures. Some forecast that urban inhabitants will be residing in a robo-wasteland, in which everyone uses their own autonomous vehicle (AV) to travel around an increasingly sprawling urban area. Others project that urban areas will become denser as shared, electric, connected, and autonomous vehicles reduce the need for parking, allow for denser housing, and even make way for more parks and open spaces[2]. The only thing clear from these postulations is that nothing is clear, or guaranteed: **The future will be what we make of it.**

1. Based on Siemens calculations. For a full list of Siemens reports about cities, sustainability, and innovation, please visit www.siemens.com/cities.
2. Refer to References section at the back of this report for a full list of references. Specific references are also listed in the Shared eMobility Calculator.

Shared, Electric Mobility

The future will be what we make of it. This is the guiding premise for our paper, which, based on the results of a Siemens-built future urban mobility calculator, explores how cities globally can optimize new mobility services, starting with shared, electric mobility (eMobility). We understand from our customers and our partners that shared and electric mobility services are the most likely to be adopted, at scale and across regions, by cities in the near-term. However, future research by Siemens will incorporate autonomy, connectivity, and any other new mobility trends that promise to disrupt urban mobility as we now know it.

The following sections are based on results from this future urban mobility model, which, for this paper, has been pre-programmed based on inputs for three urban "typologies," but in general is flexible to any urban context.

The model incorporates current data, estimates, and experts' inputs on how three modes of passenger transportation (private cars, public buses, and shared fleets) will change over time. We chose these three modes, because they are the most prevalent in cities and have the highest negative impact on greenhouse gas (GHG) emissions and air quality. We view changes in these modes through the trends of electrification, utilization, and mode shift towards shared mobility.

The model sources projections for three urban typologies, are based on McKinsey Global Institute's and others' previous research on future urban mobility. Typology 1 encompasses emerging economy, high-density (EEHD) cities, like those found in South Asia, East Asia, Latin America, and Sub-Saharan Africa. Typology 2 includes high-income, low-density (HILD) cities, like those found in much of North America and Oceania. Typology 3 covers high-income, high-density (HIHD) cities, many of which are located in Europe, in parts of North and Latin America, and across Asia. Although these typologies are not exhaustive, they capture the majority of cities worldwide, thereby enabling any city decision-maker reading this paper to find their city contained within it.

The model also sources these projections across three timeframes. Because this research is intended to help city decision-makers scenario plan for shared eMobility, we chose three timeframes that capture, short-, medium-, and long-term actions. Data for "today" helps city decision-makers level set about where they are today in terms of shared and electric mobility. Estimates for 2035 and 2050 are both informational and aspirational. They represent the most optimistic projections for how technology, policy, and design will help guide travel behaviors and technology adoption rates for the most sustainable outcomes. Importantly, 2035 and 2050 represent target dates for local, national, and international GHG emissions goals. Future research by Siemens will look at nearer-term dates, in order to facilitate capital planning for city departments, transit agencies, and other affected institutions.

Outputs of the model span sectors, and speak not only to the cross-sector coordination that transforming urban mobility networks poses, but also to the broad swath of people who will need to be involved to effect those changes and the cross-sector impacts that will result. They range from outputs related to energy (additional electricity consumption from EVs), to transportation (passenger miles traveled), to capital planning and public works (numbers and types of chargers), to sustainability (GHG reductions and air quality improvements), to urban design, land use, and real estate development (reduction in total parking area needed).

Planning, Together

Spurring collaboration among the actors who control the forces driving shared, electric mobility – or "planning, together" – is the ultimate objective of this paper, and the model behind it. Implicit in the model outputs is therefore not only the people taking action behind them, but the coordination among them.

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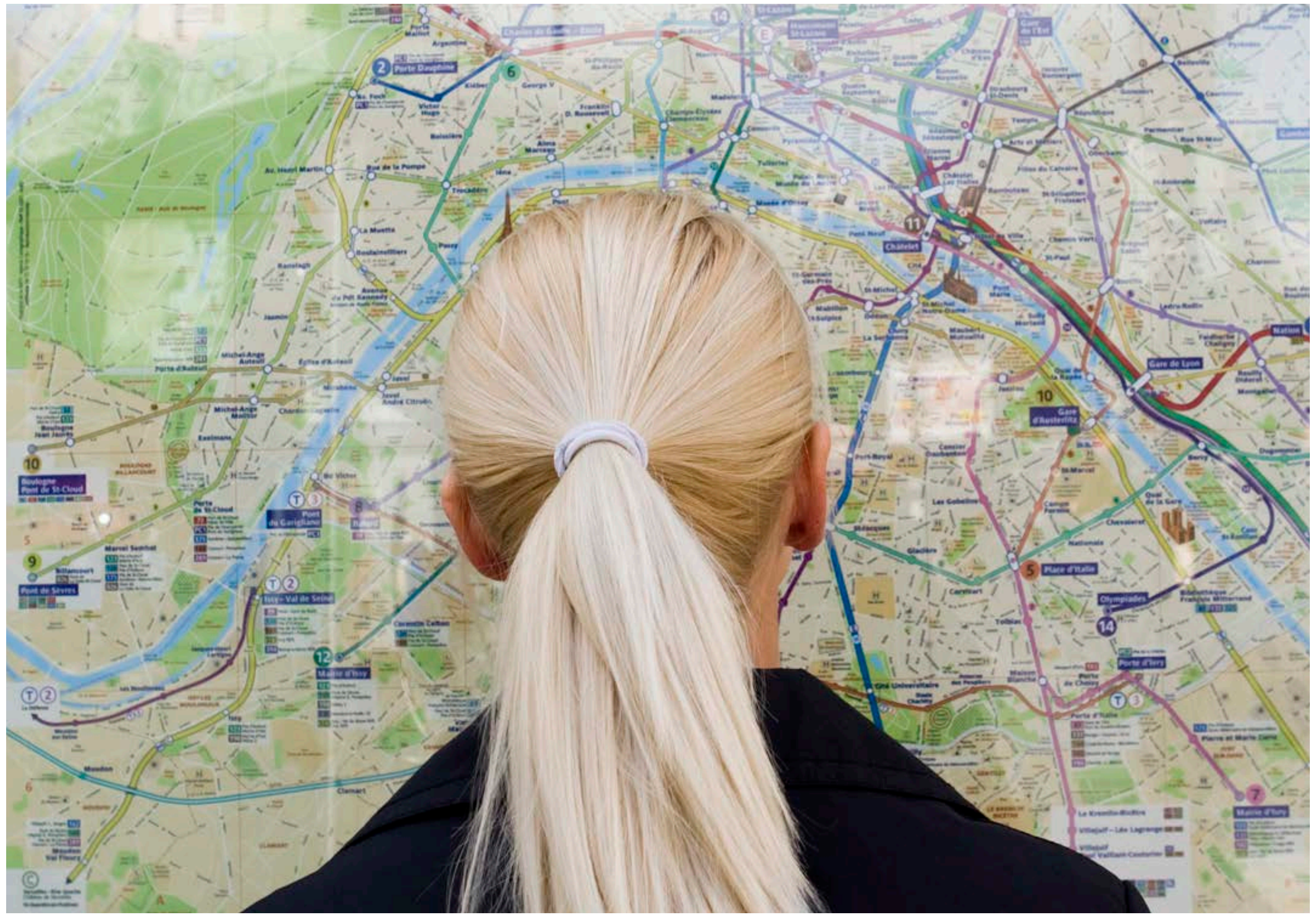
For example, in order to optimize investments in EV chargers for private cars, a city's electric utility, department of transportation, public works department, and regional transit agency would collaborate on two fronts: Providing transportation alternatives to private cars, and investing in the charging infrastructure that would support the use of transit or shared fleets. While this largely government-owned group might structure the policies, incentives, and purchases behind these two actions, architects, urban designers and real estate developers would shape them. Designers of some new urban developments today are already planning for fewer parking spaces and EV car hookups in the spaces that remain. These plans would need to be accelerated, expanded, and contextualized in order to reach mass adoption of EVs globally. We built this model to support similar causes.

Whereas the typologies and model outputs presented in this paper are static, the model sitting behind them is dynamic. We plan to make the model public for everyone's use, and we invite anyone to contact us to set up a workshop in which we use the model as a discussion tool for scenario planning, setting joint targets, and defining work streams. For now, we hope readers are able to use this paper to spark conversation, and action, to achieve a more sustainable, accessible, and equitable mobility future.



How to Read This Document

To aid the reader, this highly visual document is organized into sections, each of which expands upon an urban typology, reviewing through charts and graphics the inputs and outputs of the model specific to that context.

Color Guidelines

We have used colors and visual cues in powerful ways to enhance the meaning and clarity of data visualization throughout this report. Please refer to the following as you are browsing:

- **Electricity**
- **Transportation**
- **Emerging Economy, High Density City**
- **High-Income, Low Density City**
- **High-Income, High Density City**

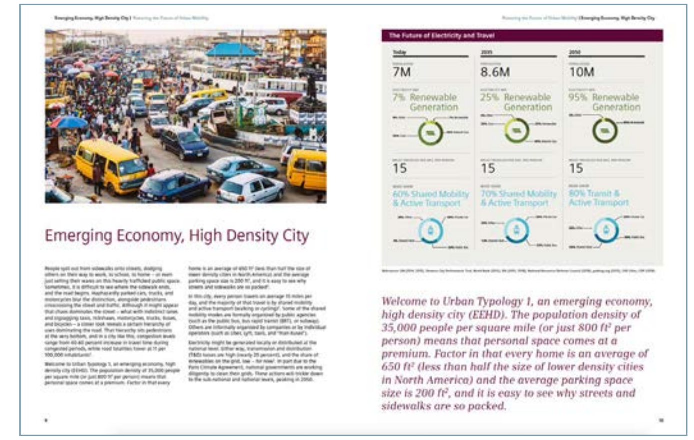


Figure 1a

Figure 1b

Figure 2

Figure 3

Visualizing Inputs and Outputs

Charts on characteristics and trends (Figures 1a and 1b) visualize inputs into the model – and expectations of how that typology is expected to grow and change over time based on our sources and our projections. Inputs include population, density, the electricity mix, miles traveled per day per person, uptakes of electric vehicles, performance of batteries and EV chargers, and EV charging models. These inputs feed into the model's calculations to result in outputs.

Charts relating to results (Figure 2) visualize outputs of the model – and projections of how changes to behavior, policy, design and adoption of electric vehicle technology will result in infrastructure investments and impacts to the electricity grid and land use. These are the charts we expect to resonate with city decision-makers the most, as they provide one set of estimates for the investments and impacts of shared eMobility.

Each typology section also includes an illustration (Figure 3) of how a future street might look, given these inputs and outputs. These illustrations are meant to be digested from left to right, from today to 2035 to 2050. They give us a glimpse into the spatial opportunities shared eMobility presents.

The final section concludes the paper, offering thoughts as to how future research could build on our findings.

Emerging Economy, High Density City

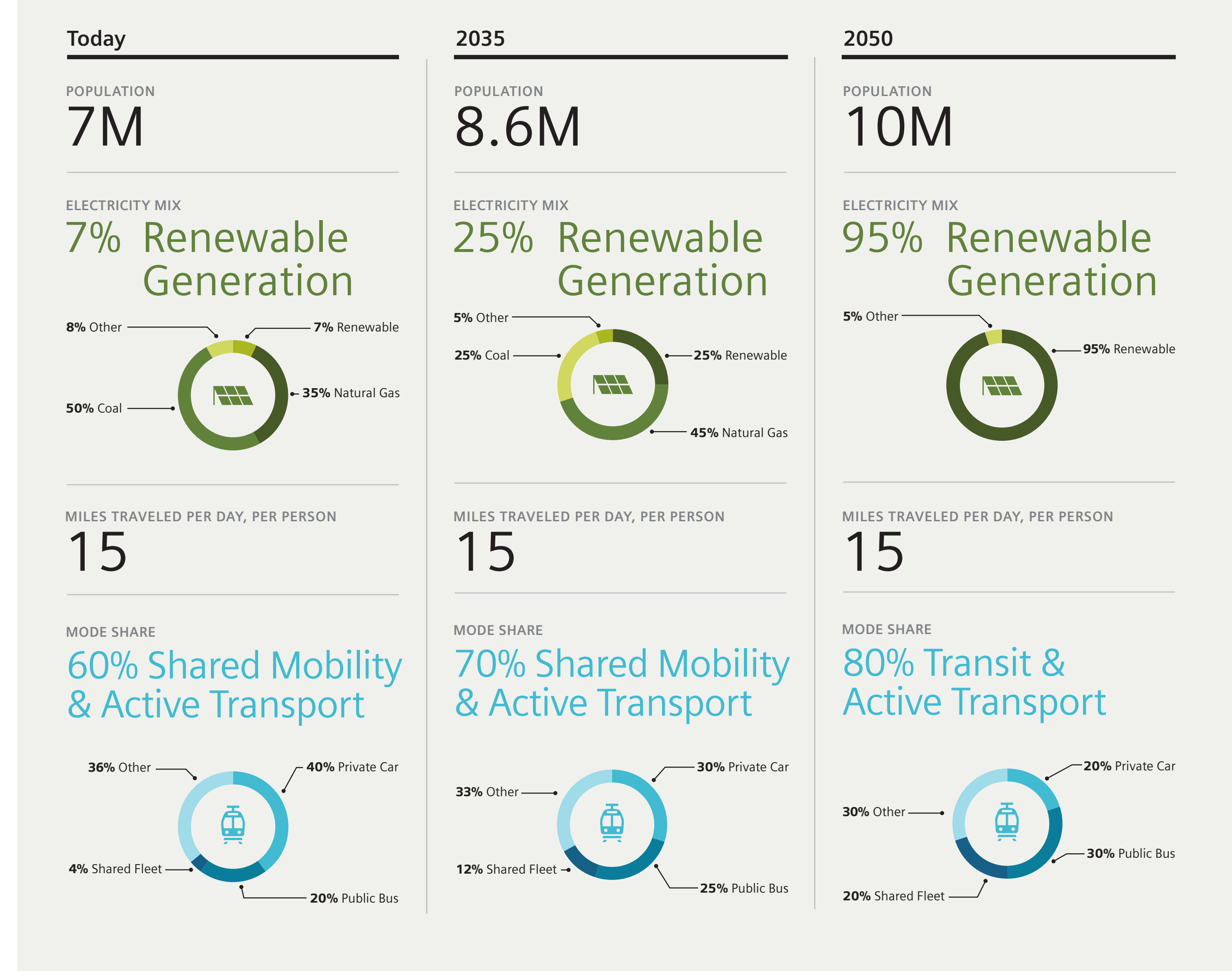
People spill out from sidewalks onto streets, dodging others on their way to work, to school, to home – or even just selling their wares on this heavily trafficked public space. Sometimes, it is difficult to see where the sidewalk ends, and the road begins. Haphazardly parked cars, trucks, and motorcycles blur the distinction, alongside pedestrians crisscrossing the street and traffic. Although it might appear that chaos dominates the street – with indistinct lanes and zigzagging taxis, rickshaws, motorcycles, trucks, buses, and bicycles – a closer look reveals a certain hierarchy of uses dominating the road. That hierarchy sits pedestrians at the very bottom, and in a city like this, congestion levels range from 40-60 percent increase in travel time during congested periods, while road fatalities hover at 11 per 100,000 inhabitants[2].

Welcome to Urban Typology 1, an emerging economy, high density city (EEHD). The population density of 35,000 people per square mile (or just 800 ft^2 per person) means that personal space comes at a premium. Factor in that every home is an average of 650 ft^2 (less than half the size of lower density cities in North America) and the average parking space size is 200 ft^2, and it is easy to see why streets and sidewalks are so packed[2].

In this city, every person travels on average 15 miles per day, and the majority of that travel is by shared mobility and active transport (walking or cycling)[2]. Some of the shared mobility modes are formally organized by public agencies (such as the public bus, bus rapid transit (BRT), or subway). Others are informally organized by companies or by individual operators (such as Uber, Lyft, taxis, and "man-buses").

Electricity might be generated locally or distributed at the national level. Either way, transmission and distribution (T&D) losses are high (nearly 20 percent), and the share of renewables on the grid are low – for now[2]. In part due to the Paris Climate Agreement, national governments are working diligently to clean their grids. These actions will trickle down to the sub-national and national levels, peaking in 2050.

The Future of Electricity and Travel



References: UN (2014, 2015), Siemens City Performance Tool, World Bank (2012), IEA (2015, 2018), National Resources Defense Council (2018), USDOT (2018), C40 Cities, CDP (2018).

Welcome to Urban Typology 1, an emerging economy, high density city. The population density of 35,000 people per square mile (or just 800 ft^2 per person) means that personal space comes at a premium. Factor in that every home is an average of 650 ft^2 (less than half the size of lower density cities in North America) and it is easy to see why streets and sidewalks are so packed.

The pressures posed by increasing population (annual growth of 1.2 percent eclipses the developed world's growth rate of 0.3 percent), increasing travel demand, and increasing car ownership have only strengthened the argument for moving to electric mobility. Today's air quality levels contain very high PM2.5 concentrations corresponding to Air Quality Index (AQI) bordering on unhealthy. These could rise to hazardous levels, if business-as-usual continues into the future[2].

Similarly, even gradually increasing current levels of shared mobility and active transport could have positive ripple effects on congestion. Every shared vehicle removes roughly seven to 12 vehicles from the road, and at an average parking space size of 200 ft^2 and two parking spaces per car, one shared car alone frees up enough land for seven housing units[2].

Because streets, sidewalks, parking spaces, and vehicle lanes are somewhat ambiguously delineated, siting electric charging infrastructure can be problematic. Connecting it to the grid, even more so. For these two reasons, the expectation is that most charging will be done in homes or at public bus or shared fleet depots. Opportunity charging (also known as fast charging) for private cars and shared fleets will likely take place in organized spaces – offices, shopping malls, and repurposed gas stations. As streets become more organized over time, opportunity chargers could also be installed along former parking spaces, or plugged into street lights. Opportunity chargers for public buses could punctuate fixed routes, allowing for buses to travel further distances and accommodate larger numbers of people within them.

EV Technology Trends

			Today	2035	2050
Private Car	**Uptake of electric vehicles**	% eVMT / total VMT	1%	40%	60%
	Battery capacity	*kWh*	40	75	80
	Charger speed				
	opportunity	*kW*	30	50	60
	depot	*kW*	7	20	40
	Charger model share				
	opportunity	*% of total*	20%	25%	30%
	depot	*% of total*	80%	75%	70%
Public Bus	**Uptake of electric vehicles**	% eVMT / total VMT	1%	40%	75%
	Battery capacity	*kWh*	275	325	350
	Charger speed				
	opportunity	*kW*	150	400	450
	depot	*kW*	75	100	150
	Charger model share				
	opportunity	*% of total*	15%	15%	15%
	depot	*% of total*	85%	85%	85%
Shared Fleet	**Uptake of electric vehicles**	% eVMT / total VMT	1%	40%	75%
	Battery capacity	*kWh*	40	75	80
	Charger speed				
	opportunity	*kW*	100	250	300
	depot	*kW*	25	75	150
	Charger model share				
	opportunity	*% of total*	20%	30%	40%
	depot	*% of total*	80%	70%	60%

References: Bloomberg, Business Insider, BYD, ChargePoint, CleanTechnica, Columbia University, Electrek, EVgo, EIA, IEA, McKinsey Global Institute, NRDC, Proterra, Rocky Mountain Institute, Tom-Tom Traffic Index, Tsinghua University, UC Berkeley Transportation Sustainability Research Center, US Department of Transportation, and Zillow.

The pressures posed by increasing population, increasing travel demand, and increasing car ownership have only strengthened the argument for moving to electric mobility.

Results

The effects of electrification of private cars, public buses, and shared fleets, combined with the shift to shared mobility, are felt almost immediately.

By 2035, when EVs represent 40 percent of each of these modes, annual GHG emissions (compared to 0 percent electrification) will have dropped by 16 to 83 percent, depending on the mode, and NOx will have reduced by 6 to 36 percent. In 2050, the benefits accelerate, with reductions in traffic-related GHG emissions totaling 74 percent (or 34 percent of total citywide GHG emissions) and reductions in traffic-related air pollution of 62 percent[1]. Although we did not model noise pollution, one can almost imagine how much quieter the streets will be (especially if there is less congestion and honking!), in addition to how much cleaner the air.

The conversion to EVs saves money. Compared to gasoline for internal combustion engine (ICE) cars, electricity costs EV owners almost USD$1 million less per day. In a city where average gross domestic product (GDP) hovers at roughly USD$10,000, saving this amount of money on daily gas costs could equate to almost 100 annual salaries[1].

Another major benefit of the modal shift towards public buses and shared fleets is the freeing up of parking spots. Today, parking occupies roughly 20,000 acres, or close to 13,000 soccer (football) fields. In 2050, that number will be halved, and the amount of land freed from parking could fit ~340,000 new homes[1].

The conversion to EVs saves money. Compared to gasoline for internal combustion engine cars, electricity costs EV owners almost USD$1 million less – per day.

These shifts, towards both electric mobility and shared mobility, will require investments in charging infrastructure, and in-home and opportunity chargers for private cars rank highest in terms of total number of chargers needed. This is for two reasons: First, private car owners often want to be able to charge both at home and at work (thereby requiring at least two chargers for every car,) and Second, in-home chargers charge more slowly than opportunity chargers, thereby rendering them difficult to share among multiple cars.

Although this outcome is not unique to the EEHD city, it is significant in its implication. The key to reducing investment in EV chargers is to accelerate the shift towards shared mobility. There will still be a need, a significant need, to invest in EV chargers, but there will be fewer underutilized EV chargers (e.g., chargers for private cars), if more people are traveling by public bus, shared fleet, or other shared or active mobility mode.

The key to reducing investment in EV chargers is to accelerate the shift towards shared mobility. There will still be a need, a significant need, to invest in EV chargers, but there will be fewer underutilized EV chargers.

Compared to private cars, shared fleets and public buses are less charger-intensive. In total, public buses will need about 1,100 chargers to travel 30 percent of all passenger miles in 2050 (25 percent in 2035). The vast majority of these will be depot chargers, meaning that will be located in bus depots, where buses are parked when they are not in use. In a city where T&D losses are at 20 percent, it will be important to ensure that the bus depots are EV-ready. They will need to accommodate the almost 6,000 percent increase in daily electricity demand from public buses between today and 2050, when public buses will consume upwards of 2,500 MWh of electricity per day – or the equivalent of 1.3 million cell phones charging[1].

The need to have electricity available at bus depots, as well as at areas where the ~2,300 depot chargers for shared fleets will operate, presents some interesting opportunities for urban designers and real estate developers. Areas for charging could be designed as public spaces, where people can charge other devices (eScooters or cell phones, as examples), connect to WiFi, and have some place to sit. If these areas are owned privately, they could also earn additional revenue for developers, especially if they build their own microgrids to generate the electricity for charging and their own WiFi networks for connectivity.

What Shared eMobility Means in the Emerging Economy, High Density City

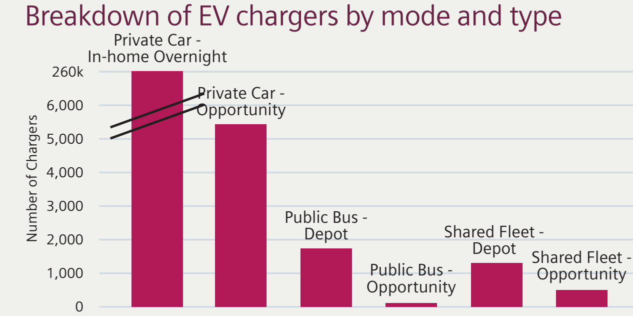
EV Infrastructure and Electricity Consumption

2035

INFRASTRUCTURE IMPACTS

271k EV Chargers

Breakdown of EV chargers by mode and type



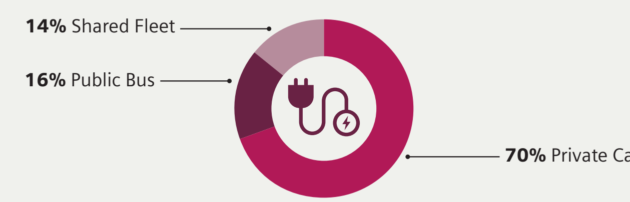
GRID IMPACTS

3800% increase in electricity consumption from transportation

9GWh of electricity consumption from transportation

2.3M equivalent to annual consumption of electricity by # of cell phones

Breakdown of total additional electricity consumption



COST IMPACTS

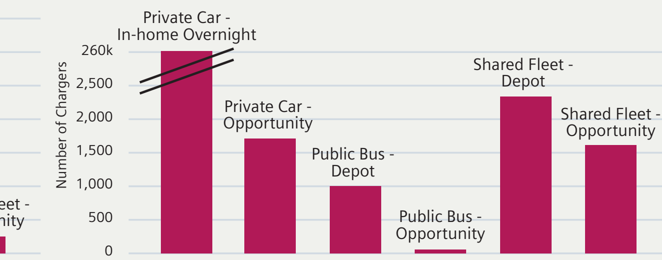
$600k savings in gasoline costs per day

2050

INFRASTRUCTURE IMPACTS

269k EV Chargers

Breakdown of EV chargers by mode and type



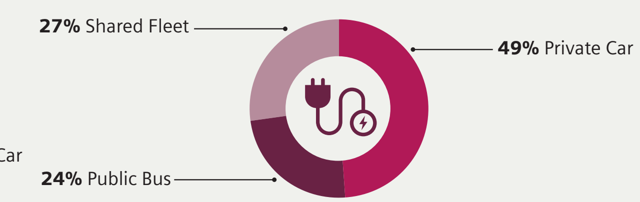
GRID IMPACTS

4600% increase in electricity consumption from transportation

11GWh of electricity consumption from transportation

2.7M equivalent to annual consumption of electricity by # of cell phones

Breakdown of total additional electricity consumption



COST IMPACTS

$1M savings in gasoline costs per day

Sustainability Impacts

2035

16-83% reduction in GHG emissions compared to 0% electrification

6-36% improvement in air quality (NOx) compared to 0% electrification

2050

58-89% reduction in GHG emissions compared to 0% electrification

59-79% improvement in air quality (NOx) compared to 0% electrification

Land Use and Parking

2035

325K number of homes that could fit in the number of parking spaces reduced by shared eMobility

5k acres of parkland that could fit in the number of parking spaces reduced by shared eMobility

2050

660K number of homes that could fit in the number of parking spaces reduced by shared eMobility

10k acres of parkland that could fit in the number of parking spaces reduced by shared eMobility

Envisioning the Future Street, from Today to 2050

Today, the street is a space which all road users share, and while chaotic and perhaps unsafe, street life is bustling and alive. There is little green space, few street trees, and there are plenty of road signs, lights, and honking. A meridian in the middle of the wide road separates the flow of traffic by direction of movement. Congestion is abundant and it takes a long time to get anywhere. Buses and public transport are crowded. The land use surrounding major corridors is diverse – most buildings are a mix of uses. Retail on the bottom. Informal street vendors crowding the street. Offices and housing above the retail. Buildings are different heights and different widths. There's no universal "design language" for the buildings. Pollution is abundant.

In 2035, the meridian becomes a large central boulevard, which splits the direction of traffic. Adjacent to the meridian on either side are dedicated high-occupancy vehicle (HOV) lanes, which are punctuated intermittently by opportunity chargers. Bus passengers exit the bus on the meridian side, giving them a safe exit point. The meridian has trees lining its side, protecting the pedestrians and cyclists which enjoy its design. Next to the bus and HOV lane is a traffic lane, which serves people on electric scooters, electric autos/rickshaws, and smaller private/shared vehicles. There are dedicated lanes which are divided by speed of traffic, to smooth traffic and improve the experience for other road users. Construction begins on new metro lines.

In 2050, metro lines are expanded, and new lines are added. These additions ease congestion further, meaning that less and less people use the private traffic lane. With limited space for private traffic, people are incentivized to use public transport. The amount of extra space between the 'sidewalk' and the building facades transitions to spaces for vendors and plazas. During the business week, small businesses pop up to use the space, while on weekends the community gather here for celebrations and get-togethers. A district energy center is built, and connects to all the buildings — the main source of energy comes from locally produced solar. Buildings themselves are more mixed use - with community centers, green roofs, offices, and housing all being intermittently dispersed across developments.

High-Income, Low Density City

The easiest way to travel around a high-income economy, low density (HILD) city is by car, and in fact, many such cities were designed explicitly for them.

Roads, including through downtown areas, often more closely resemble boulevards, with pedestrian crossings punctuating them at traffic signal intervals. As opposed to an EEHD city, there is not a lot of variety of activity on the sidewalks, or on the streets. Streets are occupied by mostly cars, SUVs, some buses, and the occasional truck. Traffic, while occasionally at a standstill, flows in a relatively organized manner. In residential areas, parking is increasingly difficult to find, as the average household has between one and two cars – or one car for every two people. A city of 1.75 million people therefore has upwards of 700,000 cars[2].

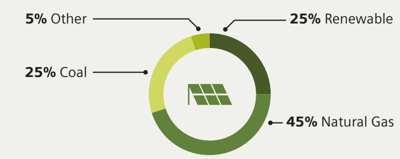
At a population density of 6,000 people per square mile, space is abundant, and the HILD city is characterized by sprawl. Parking spaces are 50 percent bigger than in EEHD cities (300 ft^2 versus 200 ft^2), and a car, on average, has access to three parking spaces – 3.3 in Los Angeles, for example. Due in part to this sprawl, people travel an average of 20 miles per day, 75 percent of which is by private car. In 2035 this share drops to 65 percent, and to 45 percent in 2050, as planning efforts at density and transit-oriented communities, coupled with deployments of new business models incentivizing mobility-as-a-service (rather than private car ownership) take root[2].

The Future of Electricity and Travel

Today

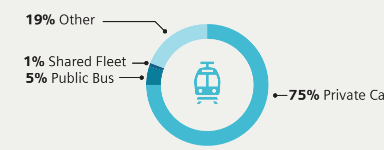
POPULATION
1.75M

ELECTRICITY MIX
25% Renewable Generation



MILES TRAVELED PER DAY, PER PERSON
20

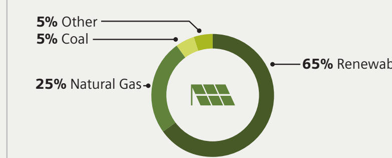
MODE SHARE
25% Shared Mobility & Active Transport



2035

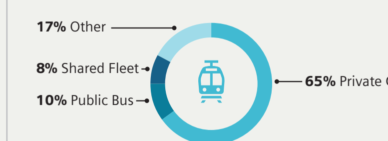
POPULATION
1.84M

ELECTRICITY MIX
65% Renewable Generation



MILES TRAVELED PER DAY, PER PERSON
20

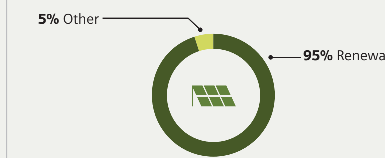
MODE SHARE
35% Shared Mobility & Active Transport



2050

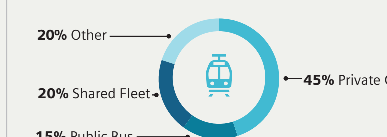
POPULATION
1.93M

ELECTRICITY MIX
95% Renewable Generation



MILES TRAVELED PER DAY, PER PERSON
20

MODE SHARE
55% Shared Mobility & Active Transport



References: UN (2014, 2015), Siemens City Performance Tool, World Bank (2012), IEA (2015, 2018), National Resources Defense Council (2018), USDOT (2018), C40 Cities, CDP (2018).

At a population density of 6,000 people per square mile, space is abundant, and the High-Income Economy, Low Density city is characterized by sprawl. Due in part to this sprawl, people travel an average of 20 miles per day, 75 percent of which is by private car.

Because the average private car is owned for 15 years, public buses and shared fleets are the first modes to reach 100 percent electrification in 2050. In fact, close to 15 major auto manufacturers have pledged to sell EVs in the future, and 12 leading cities, including HILD poster child Los Angeles, have signed on to eBus only fleets by 2028[2]. It is clear that there is momentum for electrification.

Charging for public buses takes place almost exclusively in depots. Sprawling cities also have large bus depots, and rather than wade through the regulatory rigmarole of getting planning permission for installing opportunity chargers in the public realm, transit operators shift routes to allow for depot charging.

Shared fleets and private cars, on the other hand, are incentivized to use public opportunity chargers. As the percentage of renewable electricity on the grid grows, utilities want vehicles to be charging during the day, when there is excess electricity available. In turn, owners and fleet operators would be incentivized to do so, with lower rates compared to slow-charging overnight at home or in a depot.

EV Technology Trends

			Today	2035	2050
Private Car	**Uptake of electric vehicles**	% eVMT / total VMT	1%	35%	60%
	Battery capacity	*kWh*	40	75	80
	Charger speed				
	opportunity	*kW*	30	50	60
	depot	*kW*	7	30	50
	Charger model share				
	opportunity	*% of total*	10%	20%	25%
	depot	*% of total*	90%	80%	75%
Public Bus	**Uptake of electric vehicles**	% eVMT / total VMT	5%	50%	100%
	Battery capacity	*kWh*	275	325	350
	Charger speed				
	opportunity	*kW*	250	500	600
	depot	*kW*	100	150	200
	Charger model share				
	opportunity	*% of total*	10%	10%	10%
	depot	*% of total*	90%	90%	90%
Shared Fleet	**Uptake of electric vehicles**	% eVMT / total VMT	1%	50%	100%
	Battery capacity	*kWh*	40	75	80
	Charger speed				
	opportunity	*kW*	100	250	300
	depot	*kW*	25	75	150
	Charger model share				
	opportunity	*% of total*	20%	30%	40%
	depot	*% of total*	80%	70%	60%

References: Bloomberg, Business Insider, BYD, ChargePoint, CleanTechnica, Columbia University, Electrek, EVgo, EIA, IEA, McKinsey Global Institute, NRDC, Proterra, Rocky Mountain Institute, Tom-Tom Traffic Index, Tsinghua University, UC Berkeley Transportation Sustainability Research Center, US Department of Transportation, and Zillow.

Because the average private car is owned for 15 years, public buses and shared fleets are the first modes to reach 100 percent electrification in 2050.

Results

The effects of electrification of private cars, public buses, and shared fleets, combined with the shift to shared mobility, are profound.

An increasing percentage of renewable electricity on the grid heightens the environmental impacts of eMobility. In 2035, GHG emissions reductions by mode range from 30 to 90 percent compared to 0 percent electrification, and by 2050, those percentages from to 60 to 100 percent. In total, moving to shared eMobility in this HILD city reduces citywide GHG emissions by 24 percent – an important marker when the target for 2050 is 80 percent GHG reduction[1].

In total, moving to shared eMobility in this HILD city reduces citywide GHG emissions by 24 percent – an important marker when the target for 2050 is 80 percent GHG reduction.

Levels of PM10, or the air pollutant infamous for causing and exacerbating respiratory conditions, drop by 20 to 40 percent depending on the mode in 2035 (compared to 0 percent electrification), and by 35 to 83 percent in 2050. Depending on the routing of the public buses and shared fleets, vast swaths of the city might find their air quality almost 100 percent improved[1]. In fact, with the onset of autonomous vehicles, and the automated trip routing they might incorporate, it is possible that schools, libraries, and other spaces where vulnerable populations previously experienced poor air quality might now have some of the best air quality across the city.

Despite energy being "cheap" compared to cities in Typology 1 or 3, the savings in gas money from converting to EVs is significant: $1.5 million per day. That is roughly six times the average cost of a home in a HILD city, or 40 times the GDP per capita. The amount of money saved on gas per year could entirely fund the purchase of more than 2,000 homes, increasing the affordable housing stock in a HILD city by 15 percent[1].

The number of electricity chargers needed and the amount of electricity consumed by EVs peaks in 2035, staying roughly constant until 2050. This means that the majority of the investments in chargers and in grid modernization will have to be made between 2018 and 2035 – or more realistically, between 2018 and 2025.

Part of what makes planning for shared eMobility so tough is its interdisciplinary nature: At the same time as a transportation planner is designing routes to maximize the number of bus passengers, an energy planner has to site locations for EV chargers, taking into consideration the size of the bus battery, the type of charger, whether that bus will always be on that route (or if another bus might operate in its place), etc.

The variation in how many EV chargers are needed, and when, lends itself to new business models, and even new models of collaboration between public and private sectors and between transportation and energy industries. One business model might entail a private company or a utility offering a city EV charging-as-a-service, in which the private company or utility is responsible for making sure there are EV chargers where and when needed. Already, there are start-ups offering portable EV chargers and chargers-as-a-service for private cars on streets, in office parking garages, and at shopping malls. Another business model might entail a utility taking on the responsibility of a transit agency (or vice versa), with coordination between energy and transportation sectors requiring organizational integration. A third type of collaboration might take the shape of a digital twin – a geospatial software simulation of different shared, eMobility scenarios, which can be shared among actors committed to planning together.

The number of electricity chargers needed and the amount of electricity consumed by EVs peaks in 2035, staying roughly constant until 2050.

Whatever form this future collaboration for designing, deploying, operating, and maintaining EV infrastructure takes, it is clear that jobs will result from it. Early attempts by cities to benefit from the rise in shared eMobility might take the form of economic development strategies to attract or organically develop tech and operations companies. They may also be to ensure that local universities, especially technical colleges, offer trainings to provide the skills necessary to excel in the field.

What Shared eMobility Means in the High-Income, Low Density City

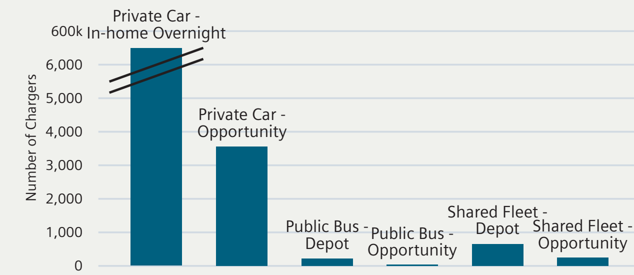
EV Infrastructure and Electricity Consumption

2035

INFRASTRUCTURE IMPACTS

518k EV Chargers

Breakdown of EV chargers by mode and type



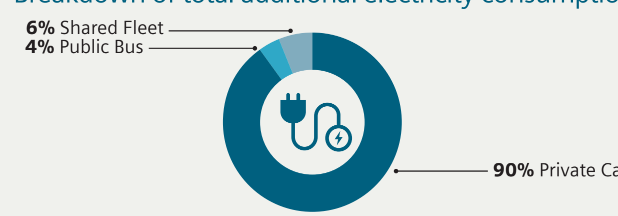
GRID IMPACTS

2940% increase in electricity consumption from transportation

6GWh of electricity consumption from transportation

1.4M equivalent to annual consumption of electricity by # of cell phones

Breakdown of total additional electricity consumption



COST IMPACTS

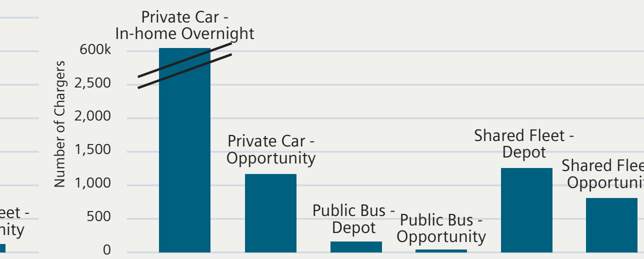
$1M savings in gasoline costs per day

2050

INFRASTRUCTURE IMPACTS

604k EV Chargers

Breakdown of EV chargers by mode and type



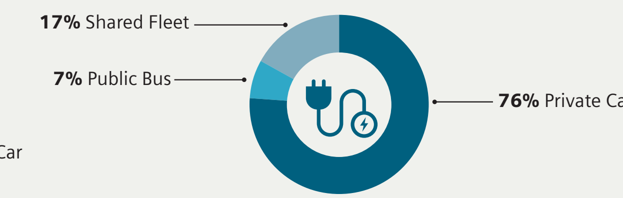
GRID IMPACTS

3050% increase in electricity consumption from transportation

6GWh of electricity consumption from transportation

1.5M equivalent to annual consumption of electricity by # of cell phones

Breakdown of total additional electricity consumption



COST IMPACTS

$1.5M savings in gasoline costs per day

Sustainability Impacts

2035

29-97% reduction in GHG emissions compared to 0% electrification

20-28% improvement in air quality (NOx) compared to 0% electrification

2050

59-100% reduction in GHG emissions compared to 0% electrification

35-59% improvement in air quality (NOx) compared to 0% electrification

Land Use and Parking

2035

154K number of homes that could fit in the number of parking spaces reduced by shared eMobility

5k acres of parkland that could fit in the number of parking spaces reduced by shared eMobility

2050

474K number of homes that could fit in the number of parking spaces reduced by shared eMobility

15k acres of parkland that could fit in the number of parking spaces reduced by shared eMobility

Envisioning the Future Street, from Today to 2050

Today, residential streets are characterized by a mix of single-family and multi-family homes, with on-street parking, driveways, and a surprising lack of people enjoying their front lawns or engaging with neighbors.

By 2035, the nature of the neighborhood is starting to shift. There are a few on-street chargers with priority charging spaces on the street, and neighborhood shuttles become more popular. Along the street there exist "on-demand shuttle stops" so that citizens without mobile phones can still order a shuttle. The stops respond to requests by visually and audibly confirming when the next shuttle will arrive. Shuttles are free to use in low-density neighborhoods with no other access to public transport. Next to the shuttle stop is moveable furniture – chairs of different types, which can be used regardless of age, ability, or size. Some of the street lights have been outfitted with electric vehicle chargers. There is no on-street parking, but houses still have driveways and use their garages for privately owned cars.

By 2050, car ownership by individuals has declined. People prefer to use the free shuttles, or pay for an on-demand ride-sharing/hailing service. Shuttles and on-demand fleets charge at depots, meaning that the old on-street charging system is less needed. Driveways and front lawns are converted into one long communal park for the neighborhood. There is flexible furniture, so people gather to eat together, or lounge. Garages are converted into alternative uses – such as bedrooms, offices, studios.
A district energy center locally produces and distributes energy among neighbors. It's clear that the entire street can be used as a sidewalk, a cycling path, or even as space for a soccer game. The street has some mobile chargers, which are operated by someone who not only can charge a car, but also can pick up packages dropped off by electric robots.

High-Income, High Density City

In high-income, high density (HIHD) cities, streets and sidewalks are places to move, and stay. Compared to the other two urban typologies, HIHD cities offer the most organized street and sidewalk life, as well as the greatest accessibility. Buses operate regularly, picking up passengers at delineated spots. Bike lanes offer some respite to cyclists otherwise intertwined in traffic. Metro stations punctuate the landscape, with entrances either above ground or far below.

The main mobility challenge for HIHD cities is not necessarily the inaccessibility of transportation options, nor the lack of diversity in them. It is that the current mobility network has no additional capacity for increased population (whether that population is just visiting, working, or lives in the city). A mismatch between where people can afford to live and where people can find work has resulted in many moving outside into the city periphery, and therefore needing to commute into the city center for work.

Due to the robustness of mobility networks, only 60 percent of the average 15 miles traveled per day per person is by private car. That percentage is expected to drop to 30 percent by 2050, when design, new business models, regulatory incentives, and behavior shift towards more shared mobility and active transport[2].

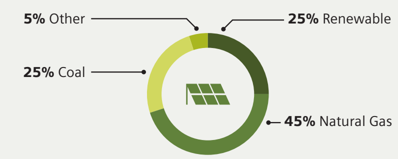
HIHD cities are among the most bullish with regards to renewable electricity. Indeed, many of the leading global cities (members of the C40 Cities Network) have pledged carbon neutrality or 80 percent GHG emissions reduction by 2050. Both will require 100 percent or near 100 percent renewable electricity on the grid, in addition to 100 percent transportation electrification.

The Future of Electricity and Travel

Today

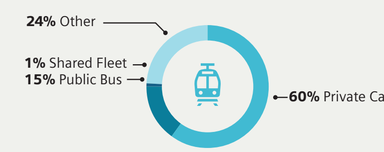
POPULATION
4M

ELECTRICITY MIX
25% Renewable Generation



MILES TRAVELED PER DAY, PER PERSON
15

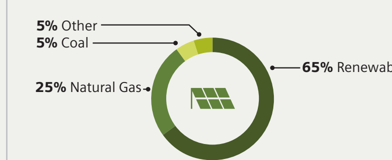
MODE SHARE
40% Shared Mobility & Active Transport



2035

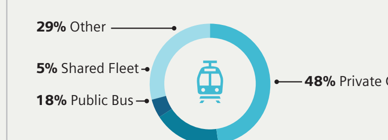
POPULATION
4.2M

ELECTRICITY MIX
65% Renewable Generation



MILES TRAVELED PER DAY, PER PERSON
15

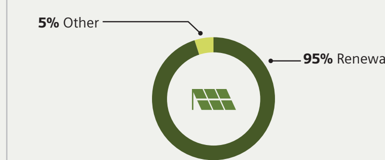
MODE SHARE
52% Shared Mobility & Active Transport



2050

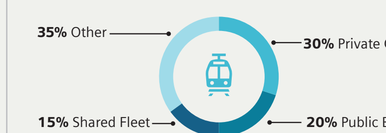
POPULATION
4.4M

ELECTRICITY MIX
95% Renewable Generation



MILES TRAVELED PER DAY, PER PERSON
15

MODE SHARE
70% Shared Mobility & Active Transport



References: UN (2014, 2015), Siemens City Performance Tool, World Bank (2012), IEA (2015, 2018), National Resources Defense Council (2018), USDOT (2018), C40 Cities, CDP (2018).

The main mobility challenge for High-Income, High Density cities is not necessarily the inaccessibility of transportation options, or the lack of diversity in them. It is that the current mobility network has no additional capacity for increased population.

As in HILD cities, public buses and shared fleets are expected to electrify first, with private cars following along as auto original equipment manufacturers (OEMs) increase the number of EV models offered over the next 10 years. In fact, the number of commercially ready EV models is expected to pass 250, even by as soon as 2025[2].

The density of the HIHD cities, combined with the relative lack of private space, makes opportunity charging for private cars and shared fleets more attractive. Already, cities like London are rolling out public chargers at higher rates than we see in most other contexts, using mobile charging technology (such as Ubitricity's chargers) to install EV chargers on existing infrastructure, like street lights.

Public buses, on the other hand, will continue to rely on depot chargers. Rather than siting depot chargers in large depots on the periphery of the city (like in a HILD or EEHD city), the HIHD city will likely site them in smaller "sub-depots" scattered across the city. Smaller sub-depots allow transit operators to provide reliable service, while acknowledging the spatial restrictions and high land use costs posed by dense cities.

EV Technology Trends

			Today	2035	2050
Private Car	Uptake of electric vehicles	% eVMT / total VMT	1%	40%	60%
	Battery capacity	*kWh*	40	75	80
	Charger speed				
	opportunity	*kW*	30	50	60
	depot	*kW*	7	30	50
	Charger model share				
	opportunity	*% of total*	20%	25%	30%
	depot	*% of total*	80%	75%	70%
Public Bus	Uptake of electric vehicles	% eVMT / total VMT	1%	40%	60%
	Battery capacity	*kWh*	275	325	350
	Charger speed				
	opportunity	*kW*	250	500	600
	depot	*kW*	100	150	200
	Charger model share				
	opportunity	*% of total*	15%	15%	15%
	depot	*% of total*	85%	85%	85%
Shared Fleet	Uptake of electric vehicles	% eVMT / total VMT	1%	30%	90%
	Battery capacity	*kWh*	40	75	80
	Charger speed				
	opportunity	*kW*	100	250	300
	depot	*kW*	25	75	150
	Charger model share				
	opportunity	*% of total*	20%	30%	40%
	depot	*% of total*	80%	70%	60%

References: Bloomberg, Business Insider, BYD, ChargePoint, CleanTechnica, Columbia University, Electrek, EVgo, EIA, IEA, McKinsey Global Institute, NRDC, Proterra, Rocky Mountain Institute, Tom-Tom Traffic Index, Tsinghua University, UC Berkeley Transportation Sustainability Research Center, US Department of Transportation, and Zillow.

The public buses and shared fleets are expected to electrify first, with private cars following along as auto original equipment manufacturers (OEMs) increase the number of EV models offered over the next 10 years.

Results

Implications of transportation electrification on the grid and on land use are almost equally significant in the HIHD city.

In 2050, electricity consumption from private cars, public buses, and shared fleets totals 6,775 MWh daily, up 2,500 percent from their levels of electricity consumption today[1]. Because anywhere from 30 to 40 percent of EV charging for private cars and shared fleets will take place via opportunity chargers, the HIHD city will need to think not only about how to modernize or build new infrastructure that enables the safe and reliable delivery of electricity, but also about how to do so across a distributed network.

In 2050, electricity consumption from private cars, public buses, and shared fleets totals 6,775 MWh daily, up 2,500 percent from their levels of electricity consumption today.

Investing upfront in digitally connected infrastructure, in which grid and chargers can speak to each other, will be important for a number of reasons, including to ensure the supply of electricity when and where it is needed, and also, to validate how chargers are being used.

Two possible technology solutions for achieving safe, reliable distribution are micro grids and grid-connected (or "smart") EV chargers. A microgrid comprises local generation of electricity (powered by, for example, solar panels or combined heat and power turbines), which can connect or disconnect from the main electricity grid manually or automatically. Smart EV chargers "talk" to the microgrid or grid, allowing for the grid to moderate the amount of electricity transmitted through the charger based on the amount of electricity available on the grid, electricity rates, and other factors.

Not all EV chargers are "smart," and smart chargers, in generating and transmitting data and automating actions, can require a WiFi connection. Although this data connection has no material impact on the overall data consumption of a city, it nonetheless is an important consideration when investing in infrastructure. Equally, not all electricity grids are smart. Software to manage EV chargers' connection to the grid (among other distributed energy resources' or DER's connection to the grid) will be necessary to ensure the safety and reliability of the system.

This paper does not estimate the return on investment (ROI) for chargers and other EV infrastructure (and future research should certainly do so). But not all benefits of shared eMobility are measured in dollars and cents. For example, in the HIHD city, moving to electric private cars, public buses, and shared fleets will reduce traffic-related GHG emissions by 91 percent by 2050 – or 20 percent of today's emissions. That is in addition to decreasing traffic-related air pollution by 78 percent, and saving $1.4 million in gasoline/diesel costs per day[1].

As importantly, moving to shared eMobility in the HIHD city will free up land. By 2050, 12,000 acres of parking spaces could be converted to fit almost 400,000 new homes, or 34 parks the size of London's Hyde Park, or 200,000 new homes and 17 parks[1]. Regardless of how these projections are sliced, they are staggering. Shared eMobility furnishes urban inhabitants with the opportunity to rethink space in their cities, at a time when cities are growing faster than they ever have before, and facing pressures that are new and threatening.

Not all benefits of shared eMobility are measured in dollars and cents. For example, in the HIHD city, moving to electric private cars, public buses, and shared fleets will reduce traffic-related GHG emissions by 91 percent by 2050 – or 20 percent of today's emissions.

What Shared eMobility Means in the High-Income, High Density City

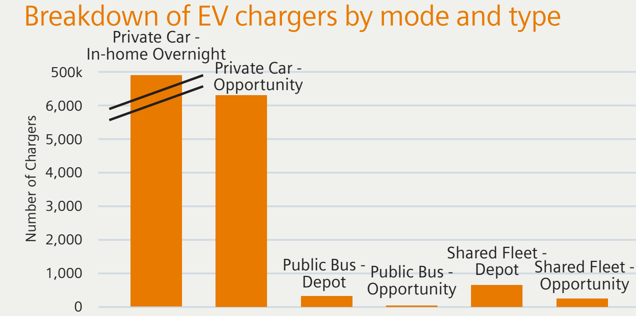
EV Infrastructure and Electricity Consumption

2035

INFRASTRUCTURE IMPACTS

463k EV Chargers

Breakdown of EV chargers by mode and type



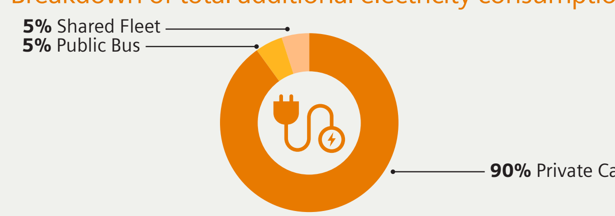
GRID IMPACTS

3180% increase in electricity consumption from transportation

8GWh of electricity consumption from transportation

2.1M equivalent to annual consumption of electricity by # of cell phones

Breakdown of total additional electricity consumption



COST IMPACTS

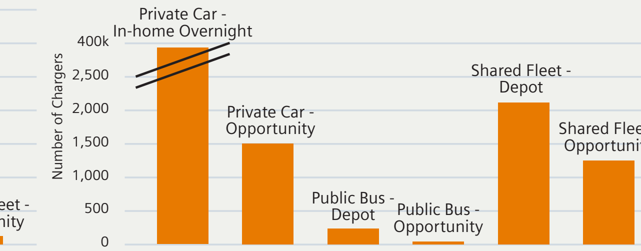
$1.5M savings in gasoline costs per day

2050

INFRASTRUCTURE IMPACTS

384k EV Chargers

Breakdown of EV chargers by mode and type



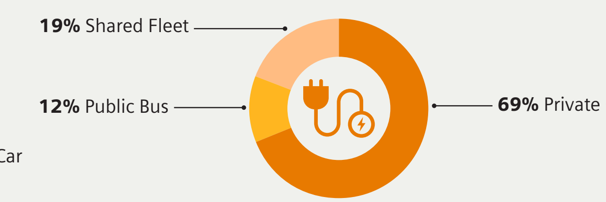
GRID IMPACTS

2570% increase in electricity consumption from transportation

7GWh of electricity consumption from transportation

1.7M equivalent to annual consumption of electricity by # of cell phones

Breakdown of total additional electricity consumption



COST IMPACTS

$1.4M savings in gasoline costs per day

Sustainability Impacts

2035

50-96% reduction in GHG emissions compared to 0% electrification

45-53% improvement in air quality (NOx) compared to 0% electrification

2050

79-100% reduction in GHG emissions compared to 0% electrification

79-98% improvement in air quality (NOx) compared to 0% electrification

Land Use and Parking

2035

258K number of homes that could fit in the number of parking spaces reduced by shared eMobility

5k acres of parkland that could fit in the number of parking spaces reduced by shared eMobility

2050

653K number of homes that could fit in the number of parking spaces reduced by shared eMobility

12k acres of parkland that could fit in the number of parking spaces reduced by shared eMobility

Envisioning the Future Street, from Today to 2050

Today, some streets already have EV chargers for private vehicles, or public fleets available. They are not abundant, but they are strategically located in key neighborhoods and zones. On-street traffic is a conglomeration of buses, taxis, private vehicles, and transportation network company (TNC) vehicles. The curb is largely reserved for on-street parking, with the odd bus stop sporadically placed. There are some street trees and usually wide-enough sidewalks for walking. Multiple transport options mean people can choose to walk, cycle, bus, train, or drive to their destination. Land use is mixed is some areas, and less so in other areas. Some cities already have road pricing implemented and others are in the process of setting this up.

By 2035, the HIHD city is a bit denser, and construction emerges where land is under-utilized such as parking garages or surface parking lots. What was once an entire office block is now part offices, part business incubator, hotel suites, etc. The ground floor is reserved for commercial, retail, entertainment that activates street life. The streets have protected bike lanes, and traffic is a mix of traditional vehicles, eFleets, and new shuttles. Roofs are converted to gardens, patios, and solar panel sites. All parking garages keep one floor of parking for eFleet operations, but others are converted to offices and homes.

By 2050, most traffic is limited to shuttle services, with the occasional pod. Pods are discouraged, but are available for people with impairments. On-street charging is redundant and only happens in depots. New metro lines and high-speed train connections to surrounding suburbs make smaller periphery cities accessible in a matter of minutes, making commuting by car or pod an inefficient use of time and space.

Conclusion

This paper may seem to oversimplify the future of shared eMobility in cities. [After all, we do rely on a model that calculates results for three urban typologies, three modes, and three timeframes.] However, the reality is that shared eMobility, and more broadly the future of urban mobility, is not one-size-fits-all. Each city will have to decide how and when it wants to leverage new mobility services for its broader benefit – or whether it wants to leverage them at all.

What we have attempted to show in this paper, however, is that shared eMobility can be used to effect positive change in cities. It frees up land, it reduces GHG emissions, it saves money, and it improves air quality. It also allows urban inhabitants to rethink public and private spaces in cities, especially as parking spaces become vacant and chargers are deployed in the public realm.

The conversations and the planning that happen now should be cross-sector and inclusive. Much of what we discuss in this paper is contingent on policy, politics, and behavioral changes that incentivize shared eMobility. The advent of autonomous vehicles may change some of these assumptions. Therefore, setting in place today the cross-sector working groups, the automated sharing of open data and digital planning models, and the design principles for future urban mobility infrastructure will help ensure that new mobility services result in tangible positive impacts on quality of life – whether you are in Mexico City, Pune, London, Tianjin, or Atlanta, GA, USA.

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Cathe Reams, Siemens, CoC Cities

Chris King, Siemens Digital Grid, Chief Policy Officer

David Armour, Siemens, CoC Cities

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Martin Powell, Siemens, CoC Cities

Sebastian Castellanos, World Resources Institute, Urban Efficiency & Climate Associate

Shin-pei Tsay, Gehl Institute, Executive Director

Wendy Tao, Siemens Mobility, Intelligent Traffic Systems, Head of Smart Cities Portfolio

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Electrek
EVgo
US Energy Information Administration (EIA)
International Energy Agency (IEA), World Energy Prices and Global EV Outlook
McKinsey Global Institute
National Resource Defense Council (NRDC)
Proterra
Rocky Mountain Institute (RMI)
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Tsinghua University
UK Government, National Travel Survey
United Nations (UN), DESA
UC-Berkeley, Transportation Sustainability Research Center
US Department of Transportation
World Bank, World Development Indicators Database and CURB Tool
World Resources Institute (WRI)
Zillow

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