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Technology Pathways for Creating Smarter, More Prosperous and Greener Cities

A Blueprint for Creating Jobs, Reducing Carbon Emissions and Improving Air Quality in Cities across North America

December 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 Siemens work in the Center of Competence Cities and about this report, please contact:

Julia Thayne
Innovation and Technology for Cities
Cities Center of Competence
(e) julia.thayne@siemens.com

Authors of the Report

Dr. Noorie Rajvanshi
Corporate Technology

Julia Thayne
Cities Center of Competence

Color and Visual 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:

- **CO_2eq**
- **Transport**
- **Buildings**
- **Energy**

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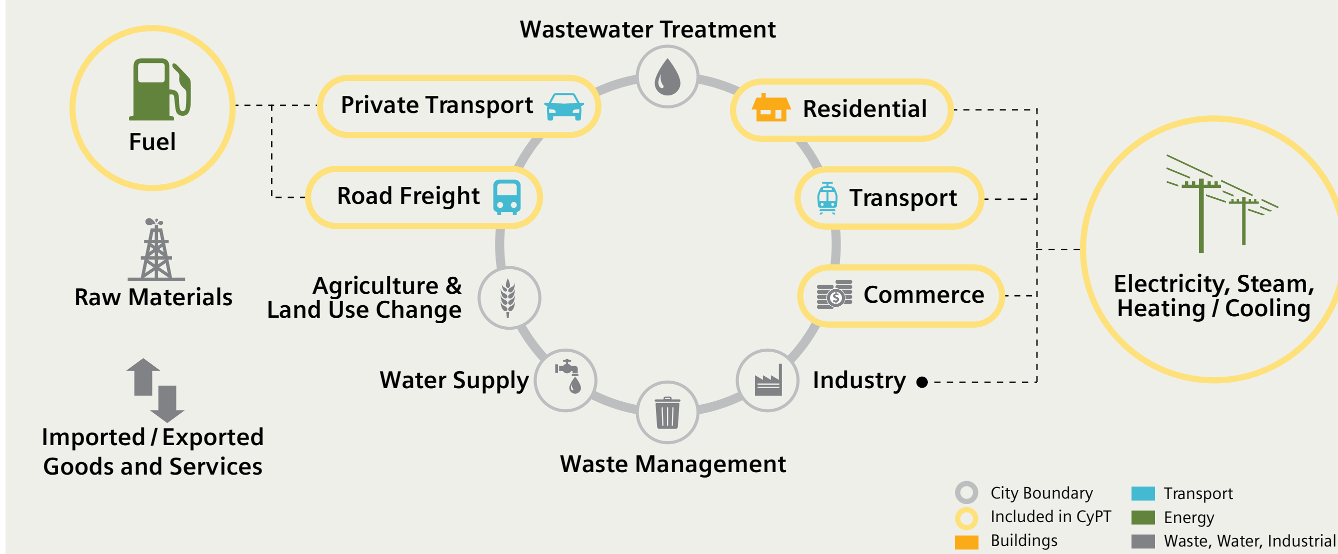
Introduction

For the past seven years, Siemens Cities Center of Competence (CoC) has been collaborating with more than 15 cities across North America to support Chief Sustainability Officers in evaluating technology and infrastructure options for deep carbon reduction. This report synthesizes results from those studies, sharing best practices, lessons learned, and trends in results, which can be used by any city in North America.



The CyPT utilizes the 2012 GPC Protocol for Community-Wide Emissions as its methodology for estimating GHG emissions. It covers Scopes 1, 2, and 3 emissions for energy generation and energy use in buildings and transportation. Essentially, this means that the CyPT takes into consideration both direct emissions occuring within the City bounderies (such as from exhaust fumes) and indirect emissions from the conversion of chemical energy to power, heat or steam of purchased energy from outside the city. The included Scope 3 emissions refer to the emissions produced as a result of fuel production and extraction. This also includes the construction and production of renewable power plants.

By the year 2030, over 5 billion people, or roughly 66% of world's population will be living in urban areas[1]. This growth represents an enormous challenge on how cities are being built and managed but also provides many opportunities to improve the lives of over two-thirds of the world's population. One such opportunity lies around climate action and deep carbon reductions.

In this report, we will share trends in cities' baseline data on building energy use, passenger mode shares, and share of renewables in the grid mix, as well as compare cities' targets and technology pathways for GHG reduction. We also look at different adoption rates for various technologies, and which technologies are the top performing depending on a city's characteristics.

What is the City Performance Tool?

Siemens City Performance Tool (CyPT) was developed with cities in mind, to help cities make informed infrastructure investment decisions, identifying which technologies from the transport, building, and energy sectors best fit a city's baseline in order to mitigate CO_2eq emissions, improve air quality, and add new jobs in the local economy.

Using a three-step process, Siemens works with cities to first build a GHG emissions baseline for its transport, buildings, and energy sectors, then chooses technologies to simulate on that baseline, and finally estimates economic and environmental impacts of investing in those technologies.

Siemens City Performance Tool was developed with cities in mind, to help cities make informed infrastructure investment decisions.

Results help cities drive their sustainability agendas. For example, the CyPT analysis for the City of Los Angeles, Climate LA, showed that LA's greenhouse gas reduction targets for 2035 and 2050 are achievable. Success will require transitioning to 100% generation of renewable electricity and to 45% of passenger travel by transit and active transport, through the implementation of LA's and California's current policy agendas and an additional 19 infrastructure technology measures. Emissions reductions would be accompanied by 72% improvement in air quality and almost two million local jobs. In addition, CyPT analyses for the Cities of Minneapolis and Phoenix supported the passage of a 100% renewable electricity target citywide and a more aggressive GHG reduction target by 2035, respectively.

1. https://www.unfpa.org/urbanization

Configuring the CyPT requires more than 350 inputs from a city's transport, energy, and buildings sectors, including population and growth, the supply mix of electricity generation, transport modalities, and travel patterns, building energy use, and the built environment footprint. Starting with the city's population, energy performance, and emissions baseline, the model estimates the future impacts of more than 70 technologies (only 60 percent of which are sold by Siemens) along three drivers:

1. **Cleaner underlying energy mix:** Shifting the energy generation mix from non-renewable to renewable energies (e.g., photovoltaics) and/or improving the efficiency of the current fossil fuel sources (e.g., Combined Cycle Gas Turbines).
2. **Improved energy efficiency in buildings and transportation:** Replacing existing technologies with more energy efficient technologies. For example, replacing traditional street lighting with LEDs and/or demand-oriented street lighting or automation of building HVAC system.
3. **Modal shift in transportation:** Modeling changes in the modal split of the city. For example, by creating a new metro line, a city potentially moves passengers away from high-emitting cars and into the metro.

The outputs of the model are CO_2eq emissions, air quality indicators, particularly nitrogen oxides (NOx), particulate matter 10 (PM10), gross full-time equivalents (FTE)[2], and capital and operating expenses.

The 11 cities featured in this report cover 6 of the 8 climate regions in North America. Almost all the cities have ambitious Greenhouse Gas (GHG) reduction targets starting from 30% GHG emissions reductions by 2025 for Phoenix to carbon neutrality by 2050 in Boston. Six of the 11 cities plan on reducing their GHG emissions by 80% by 2050 and 7 of these cities also have a climate action plan in place to chart a pathway for achieving GHG emission reduction targets. (Details of cities and their targets, climate action plans and link to CyPT reports can be found in Appendix I).

Emissions from building energy use are one of the biggest contributors to a city's emission footprint. The energy use intensity of buildings varies according to climate. This map developed by Building Science Corporation illustrates eight climate zones that divide North America. These zones are based on three main parameters: heating degree-days[3], temperature and moisture. Details about each of these 8 climate zones can be found in Appendix II.

2. Full-time equivalent is a person-year of work, calculated as 2,080 hours of work in the US.

3. The degree-day measurement is the difference in temperature between the mean (average) outdoor temperature over a 24-hour period and a given base temperature for a building space, typically 65°F. For example, if the mean temperature at a given location for January 3 is 35°F, then the heating degree days measurement for that day is 30 (65 - 35 = 30).

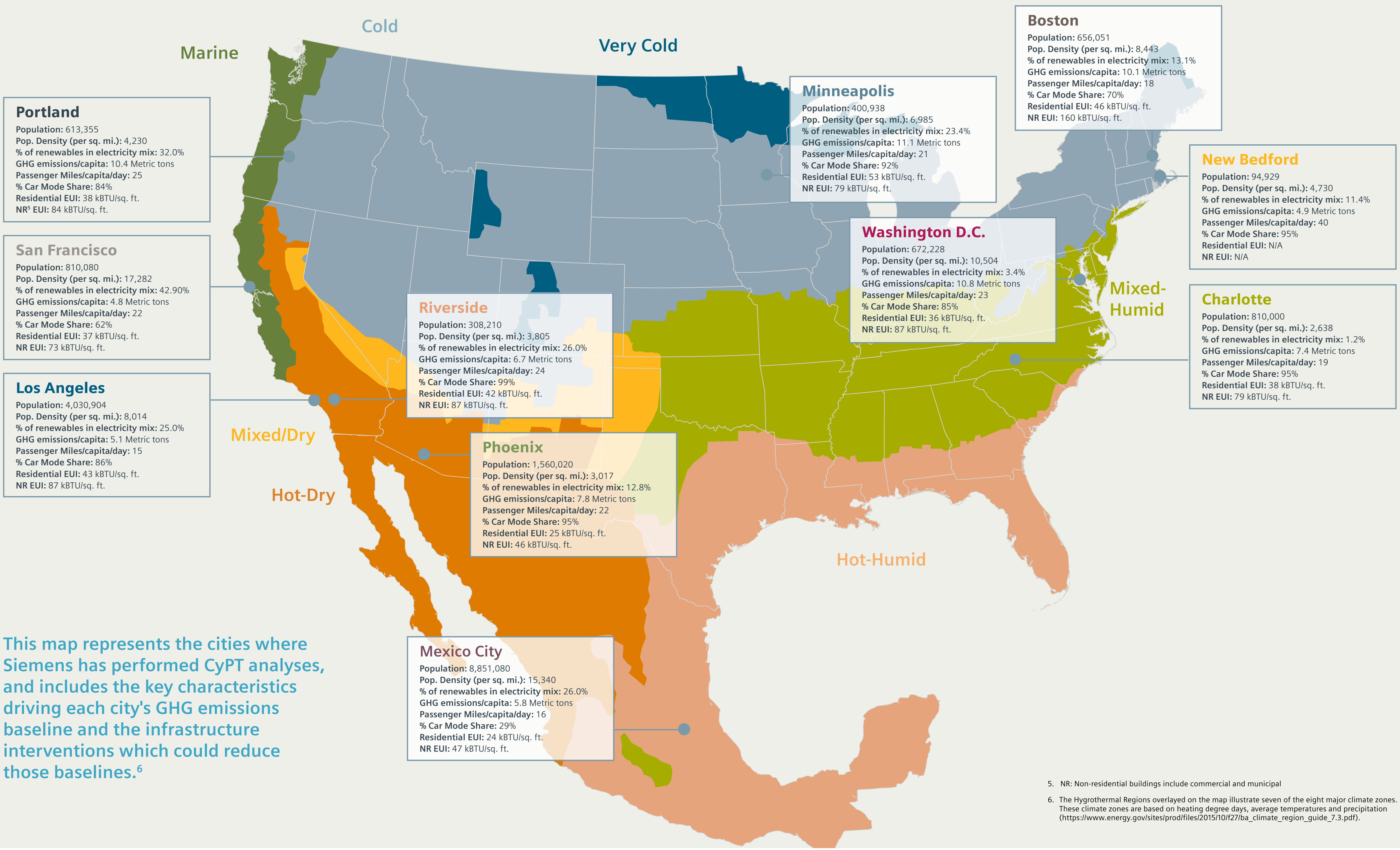
Key City Characteristics Driving Sustainability Action

Through CyPT analyses of more than 15 cities in North America, we found that there are three key types of data which drive a city's GHG baseline and determine the types of infrastructure interventions needed to reduce environmental impact.

1. General data points: Include some general characteristics like population, population density and per capita GHG emissions as well percentage of electricity generated by renewable fuels.
2. Transportation data points: Include transportation footprint in terms of passenger-miles (pmi) traveled per person per day and car mode share. For example, in Mexico City, on an average a passenger travels 15.5 miles in a day and only 29% of the travel takes place by a car and the remaining by use of public and active transit whereas in Riverside, on average a person travels 25 miles in a day and almost all of it (99%) by a car.
3. Building characteristics: Energy use intensity (EUI), measured in kBTU per square foot is a good indicator for energy use in buildings across different cities and climate zones. According to EIA's RECS and CBECS Database[4], the average EUI for residential buildings according to RECS is 38 kBTU/ft2 and the average EUI for commercial buildings is 82 kBtu/ft2 across all climate regions.

4. RECS database (https://www.eia.gov/consumption/residential/data/2009/) and CBECS database (https://www.eia.gov/consumption/commercial/data/2012/index.php?view=consumption#c1-c12)

Cities Today: A Snapshot of Key Characteristics of CyPT Cities



This map represents the cities where Siemens has performed CyPT analyses, and includes the key characteristics driving each city's GHG emissions baseline and the infrastructure interventions which could reduce those baselines.[6]

5. NR: Non-residential buildings include commercial and municipal

6. The Hygrothermal Regions overlayed on the map illustrate seven of the eight major climate zones. These climate zones are based on heating degree days, average temperatures and precipitation (https://www.energy.gov/sites/prod/files/2015/10/f27/ba_climate_region_guide_7.3.pdf).

Top-Performing Technologies for Sustainability Impact

Based on CyPT analyses across 11 cities, we find that certain energy building and transportation technologies outperform others in terms of reducing GHG emissions, improving air quality, and creating jobs. The tables in this section rank the 5 top performing technologies across the energy, building, and transportation sectors in each of the 11 cities. The results are presented for 4 key performance indicators – GHG reduction, air quality improvement (NOx emissions), job creation, and cost efficiency.

All values presented for each technology are calculated compared to a business as usual scenario for the same target year. Moreover, although the technologies might be the same (e.g. electric cars or electric buses) across different cities, the adoption rates might be different. Appendix III presents detailed tables for adoption rates for today and target year for all technologies modeled for each city. This appendix also presents information on total GHG emission reduction achievable through these technologies.

For example, in San Francisco a total of 36 building, transport, and energy technologies were analyzed for their impact on GHG emissions in 2050. Our analysis shows that these 36 technologies together could reduce the GHG emissions by 76% for San Francisco in 2050. Out of these 36 technologies, the top 5 are: 1) replacing 80% of current building heating with electric heat pumps, 2) adding over 20,000 electric car-sharing cars in the city, 3) replacing 20% of the car fleetwith electric cars, 4) implementing congestion charging, and 5) installing home automation technology in 80% of the homes. These 5 technologies make up over 46% of the 76% GHG emission reduction achievable for San Francisco. The other 30% comes from the remaining 31 technologies. Interesting to note that moving on to a different indicator tells a different story – e.g. in terms of cost efficiency (Reduction in annual CO_2e emissions per dollar invested including both CapEx and OpEx) the high performing technologies list is dominated by transportation technologies, specifically traffic management and congestion charging.

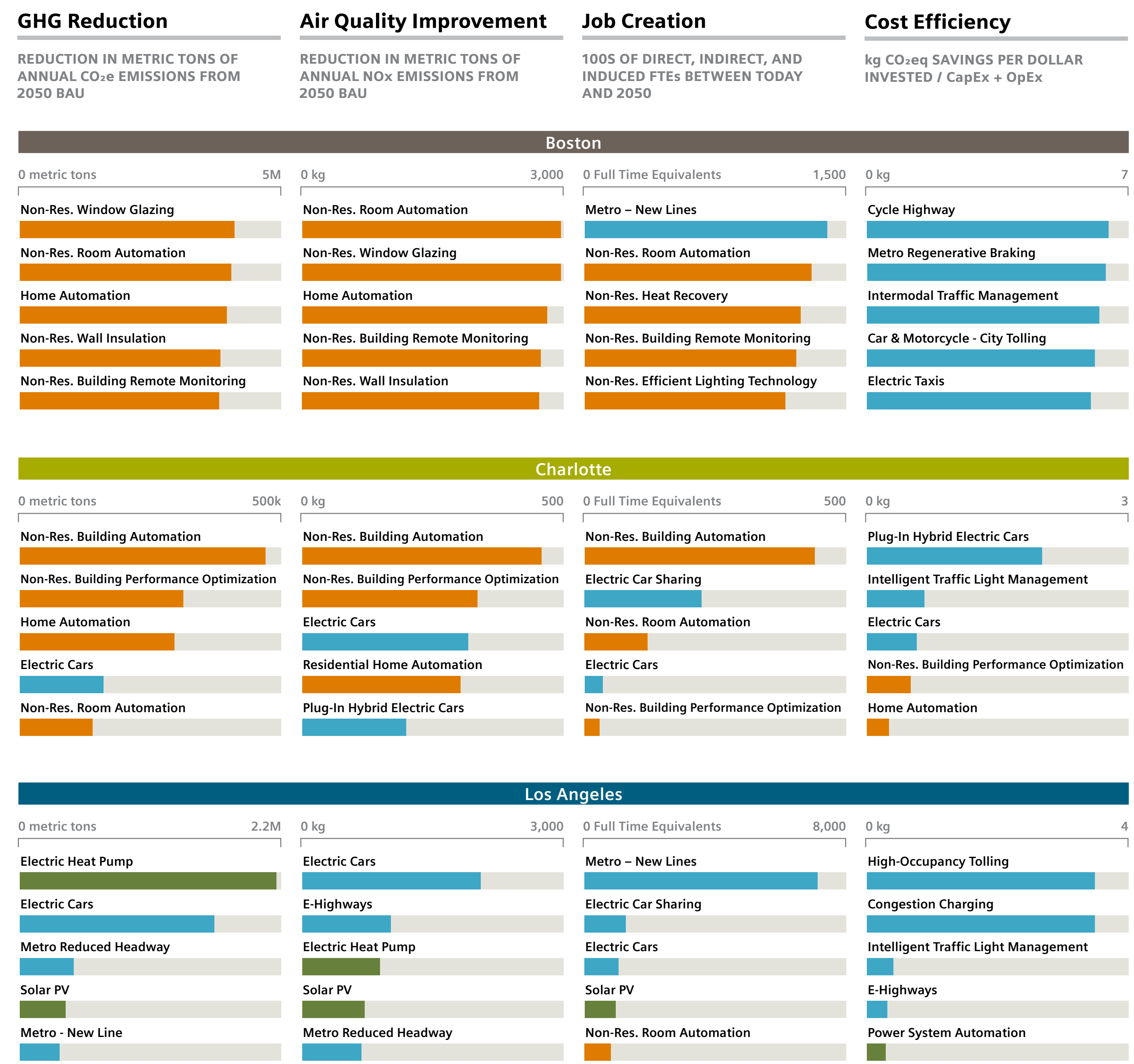
Looking across different cities in different regions of the country, we do see some trends irrespective of the location of the city especially in terms of top technologies that provide the biggest bang (CO_2 savings) for the buck. Technologies where cities might not need to invest a lot (e.g. creating dedicated bike lanes and updating existing traffic management systems to an intelligent system) could still provide significant reduction in emission due to shift in mode shares (more passengers using bicycles) or reduction in fuel usage due to smoother road travel and reduced congestion.

There is a clear trend regarding the most impactful technologies for air quality improvement (reduction in NOx) – and unsurprisingly these are almost exclusively transportation technologies. Electrification of public and private transportation has the ability to mitigate both NOx and PM10 emissions caused by the use of fossil fuels in internal combustion engines. In addition to electrification, other transportation technologies that directly or indirectly cause a mode shift towards public or active transit can have positive impact on air quality.

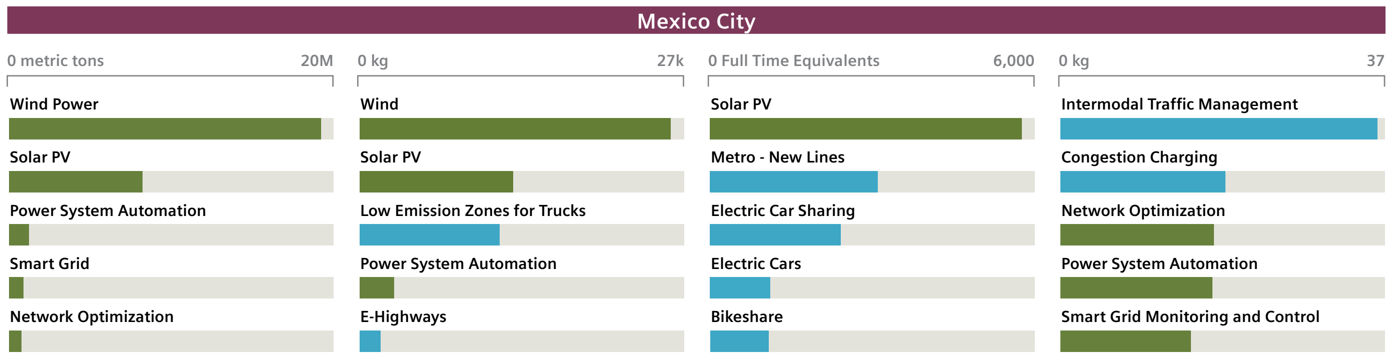
Technologies or levers that need significant infrastructure investments, such as laying new metro or tram lines as well as installing chargers for electrification of fleet, end up creating most jobs across various cities. Installing rooftop solar photovoltaics also shows up as a technology that contributes to a city's economy by creating installation and maintance jobs.

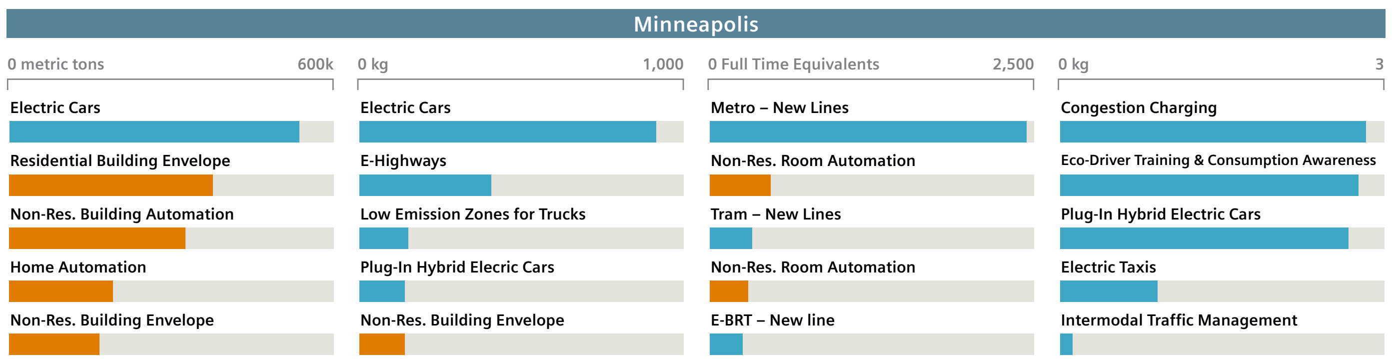
The color coding of this table also tells an interesting story. Cities located in the warmer climate regions experience the greatest emission reduction benefits from transport and energy technologies, whereas cooler climates see more benefit from building technology – an exception being Charlotte where higher adoption rates of building technology, as well as approximately 80% of emissions being contributed to buildings makes the case for 4 out of 5 top performing technologies being from building sector.

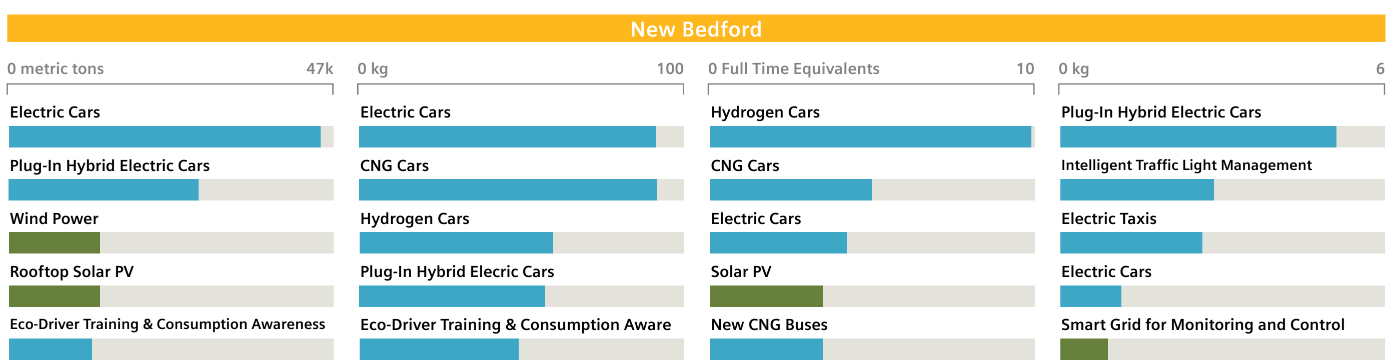
Electric mobility specifically for private transportation (i.e. electric cars) emerges as a common theme for a top performing technology across almost all the cities analyzed here. Even with an adoption rate as low as 20% for New Bedford, electric cars still provide 40% of the total GHG emission reduction achievable for the city from 10 modeled technologies.

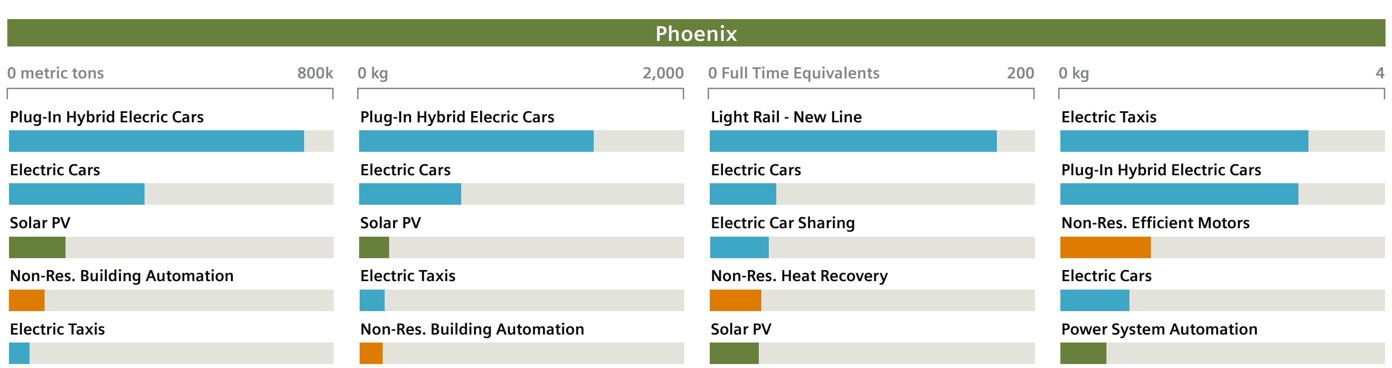


GHG Reduction	Air Quality Improvement	Job Creation	Cost Efficiency
REDUCTION IN METRIC TONS OF ANNUAL CO_2e EMISSIONS FROM 2050 BAU*	REDUCTION IN METRIC TONS OF ANNUAL NOx EMISSIONS FROM 2050 BAU*	100S OF DIRECT, INDIRECT, AND INDUCED FTEs BETWEEN TODAY AND 2050*	kg CO_2eq SAVINGS PER DOLLAR INVESTED / CapEx + OpEx



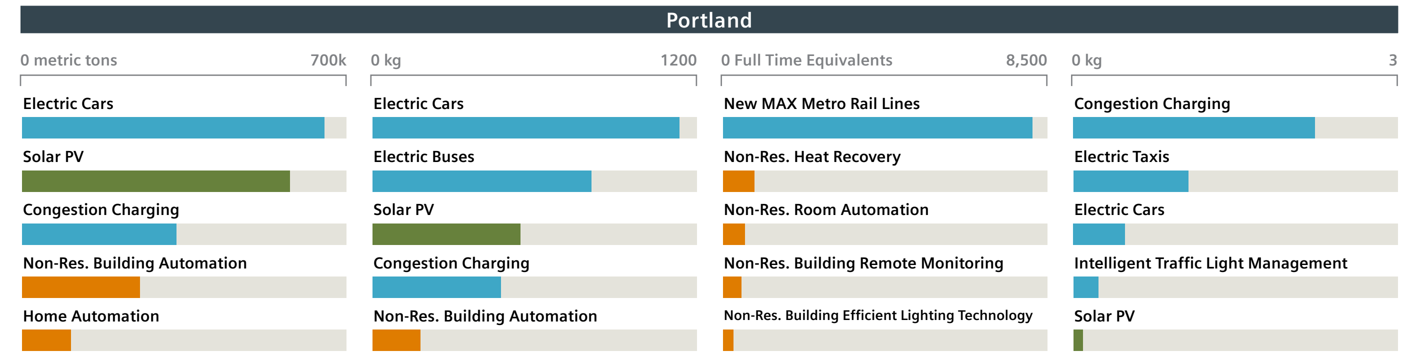


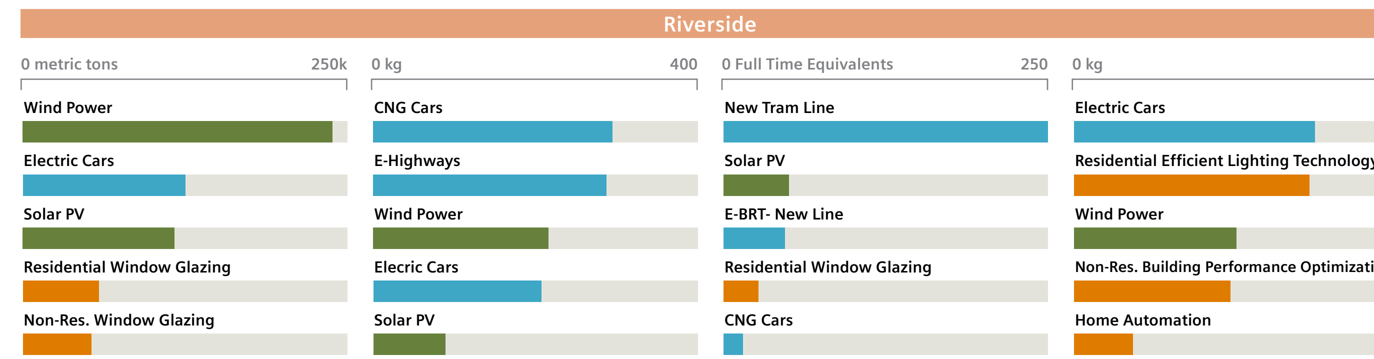


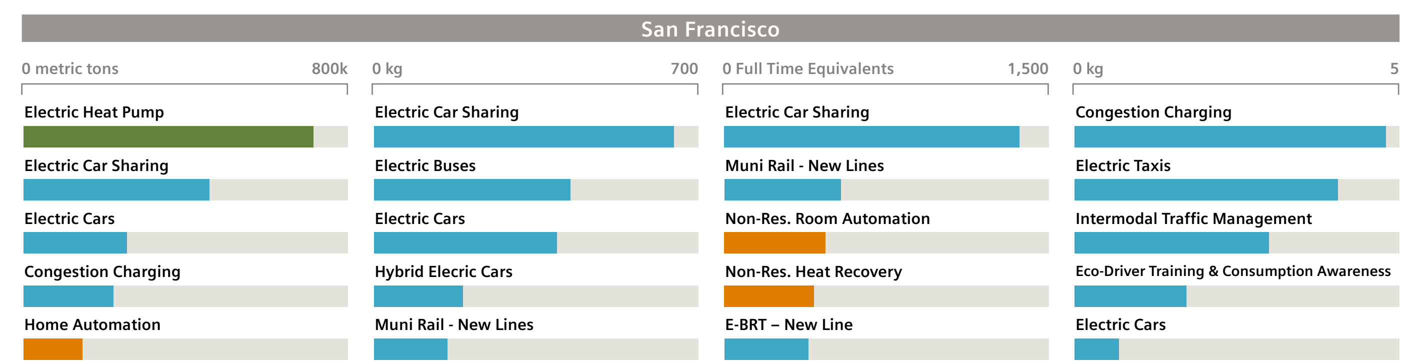


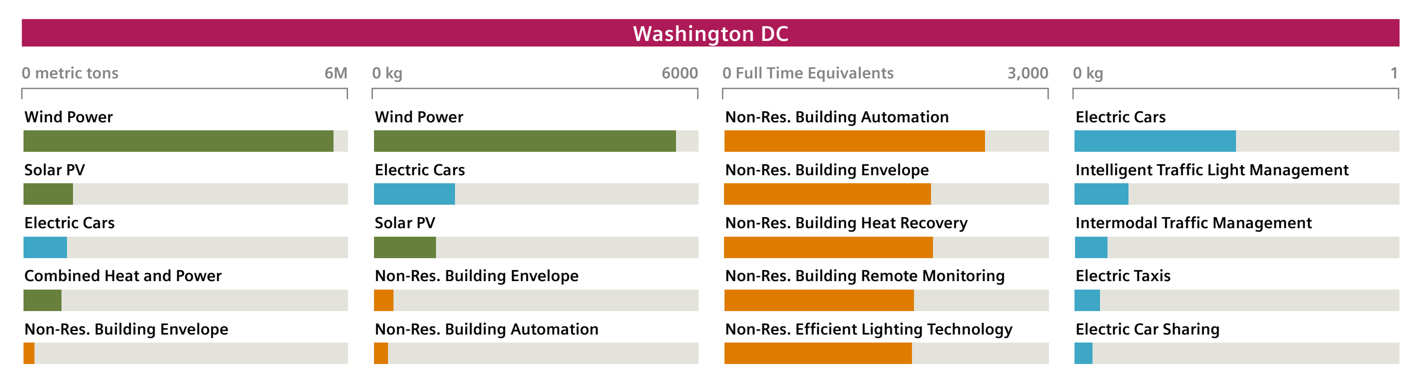
* NOTE: Figures for New Bedford, Phoenix, and Riverside are compared to a 2025 business-as-usual (BAU) scenario.

GHG Reduction	Air Quality Improvement	Job Creation	Cost Efficiency
REDUCTION IN METRIC TONS OF ANNUAL CO_2e EMISSIONS FROM 2050 BAU*	REDUCTION IN METRIC TONS OF ANNUAL NOx EMISSIONS FROM 2050 BAU*	100S OF DIRECT, INDIRECT, AND INDUCED FTEs BETWEEN TODAY AND 2050*	kg CO_2eq SAVINGS PER DOLLAR INVESTED / CapEx + OpEx









Achieving Deep Carbon Reduction

In this section, we synthesize results, reviewing how deep carbon reduction can be achieved by following the technology pathways set out by the CyPT analyses.

On the following eight pages, we've highlighted four representative cities from across North America. Two are based on climate (Hotter City – Phoenix and Colder City – Boston) and two on transportation patterns (Car-Centric City – Charlotte and Transit-Centric City – Mexico City).

There are two-page descriptions on each city. On the left of the first page are key characteristics of the city, as well as its GHG emissions profile from the year when Siemens conducted the analysis. The chart on the right side of the first page also includes a chart with a Sankey diagram that shows the source of the emissions, from transportation and buildings.

On the top half of the second page is a "waterfall chart" that illustrates the GHG emissions from a business-as-usual (BAU) scenario and then the positive impact of policies and infrastructure technologies on reducing these GHG emissions to a more desirable future state. It includes a breakdown of the sources of today's baseline emissions, either transportation or buildings. All three columns show what portion of these emissions comes from buildings versus transportation.

On the bottom of the second page are two tree maps, which show the contribution transportation and building technologies make to achieve the desired emission reductions. The tree maps show the technologies and their performance in terms of GHG reductions.

In cities located in warmer climate regions, buildings contribute to around 60% of the total GHG footprint for the city (e.g. Phoenix or Los Angeles), whereas in cities from colder climate regions, buildings dominate the emission profile with 80% or higher contributions. This provides cities with great potential for emission reduction driven by building technology sector. For example, initiatives like Retrofit Chicago Energy Challenge[7] encourage commercial, institutional, and private buildings to take voluntary steps to reduce energy consumption by 20 percent over five years by retrofitting existing buildings, while Philadelphia's Energy Benchmarking program[8] allows building owners to compare their energy usage to peers across the city and in process push them to do better while saving energy and money .

The primary mode of transportation in cities like Charlotte, Los Angeles, and Phoenix is private cars. More than 95% of the passenger distance travelled in these cities is attributed to single occupancy cars and is evident through the transportation emission profile. In cities that fit this profile, electrifying private transit (cars and taxis) provides the biggest impacts in terms of emission reduction.

7. http://www.retrofitchicago.net/
8. https://www.phila.gov/departments/office-of-sustainability/programs/energy-benchmarking/

Hotter City

Phoenix

Today

POPULATION

1.6M

MODE SHARE BY CAR

94.8%

ELECTRICITY MIX

13% renewables

2025

POPULATION

1.8M (15% increase)

MODE SHARE BY CAR

93.9%

ELECTRICITY MIX

25% renewables

Annual CO_2e (Metric Tons)

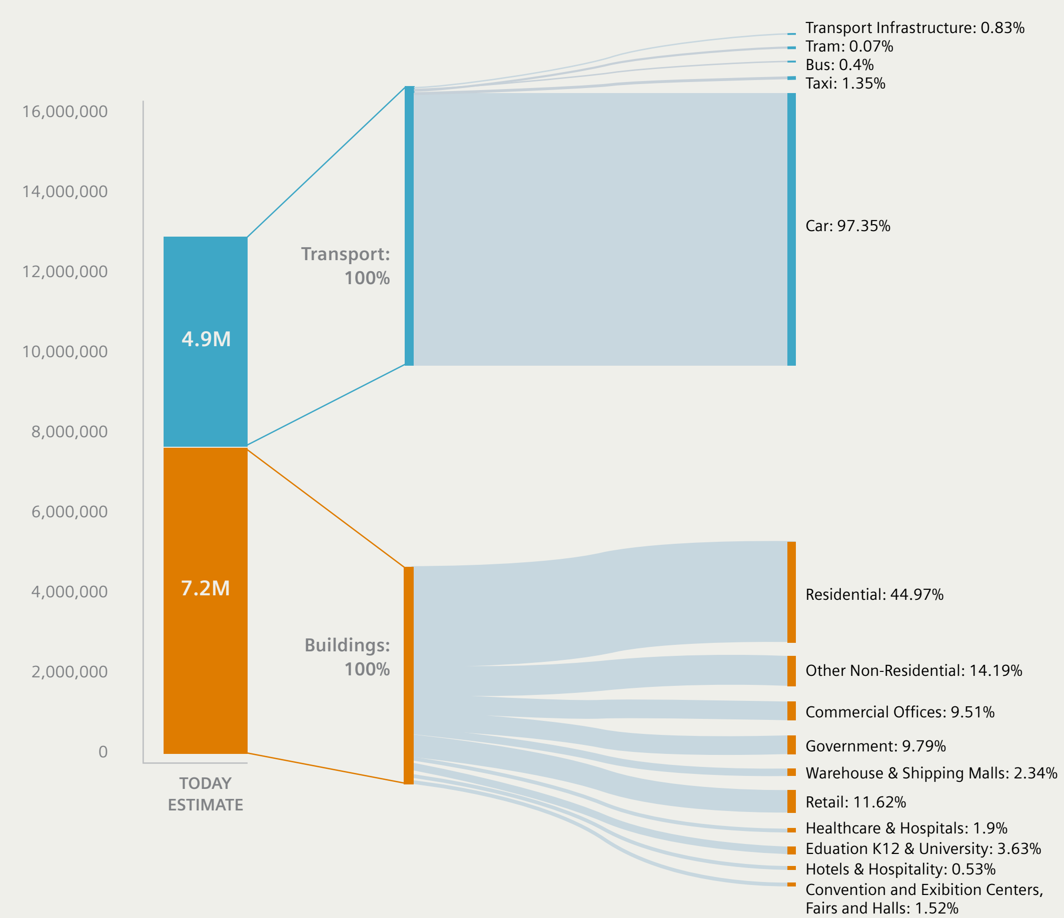
TODAY

12.1M

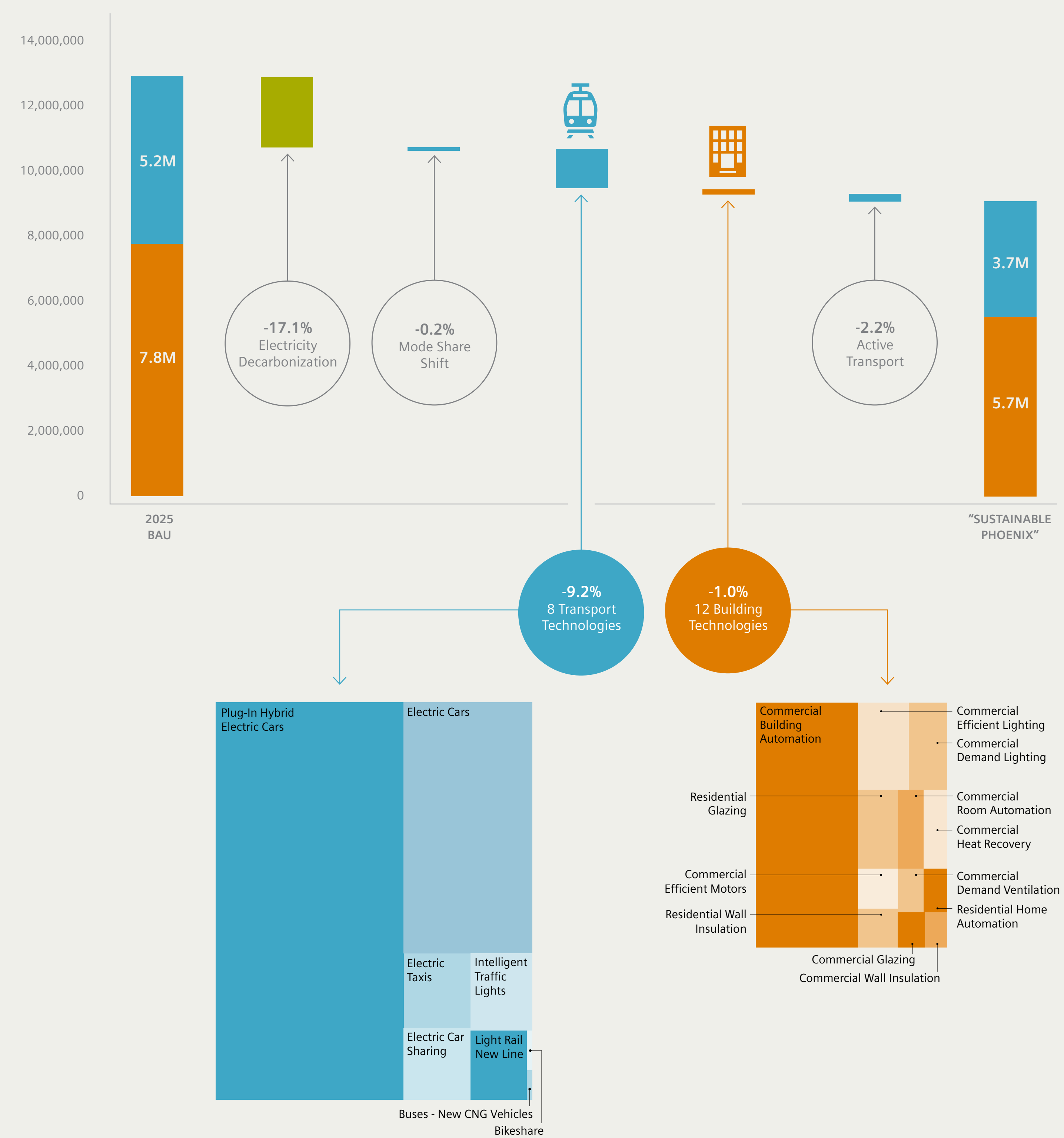
GHG EMISSION REDUCTIONS AS COMPARED TO 2025 BAU

-27.7%

Annual CO_2e (Metric Tons) – Today



Annual CO_2e (Metric Tons) – 2025



Colder City

Boston

Today

POPULATION

656k

MODE SHARE BY CAR

70.3%

ELECTRICITY MIX

13.1% renewables

2050

POPULATION

793k (21% increase)

MODE SHARE BY CAR

70.3%

ELECTRICITY MIX

60.5% renewables

Annual CO_2e (Metric Tons)

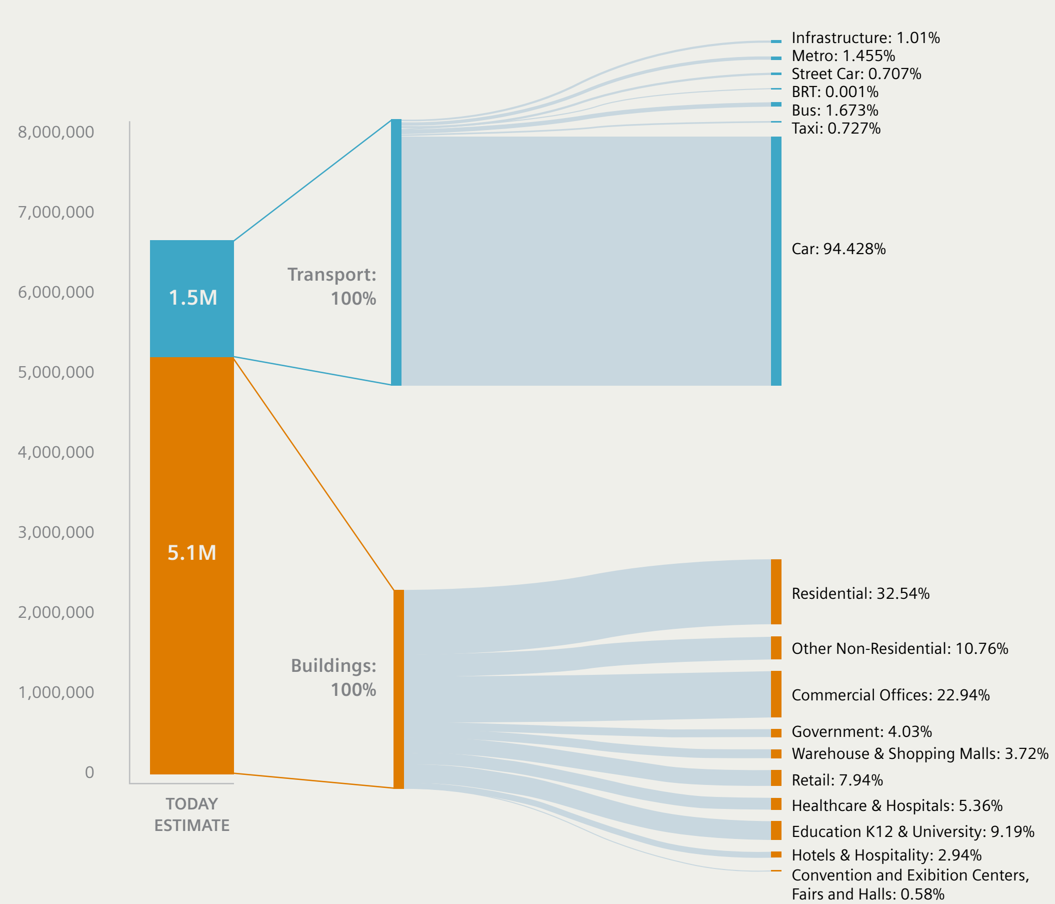
TODAY

6.6M

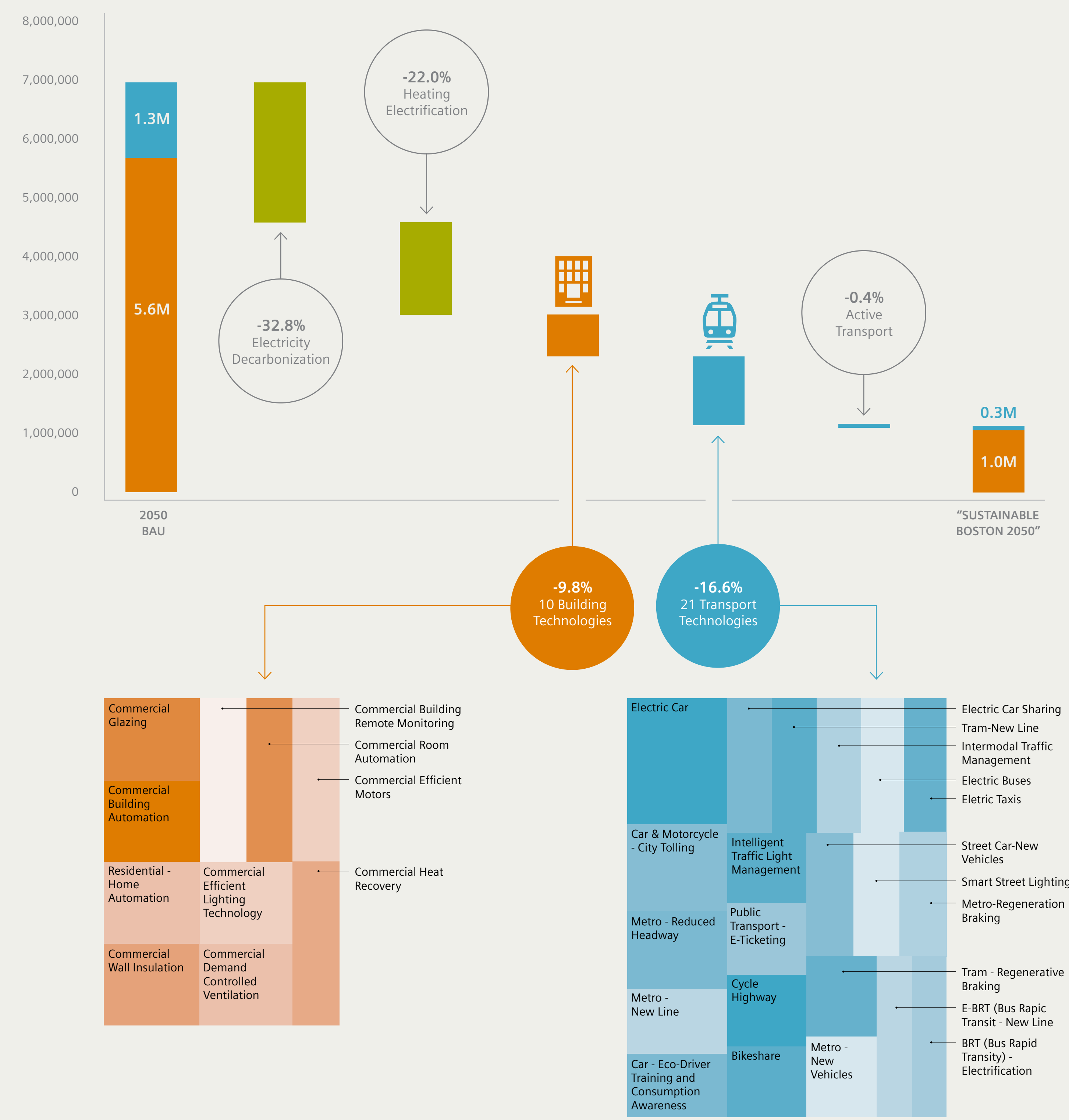
GHG EMISSION REDUCTIONS AS COMPARED TO 2050 BAU

-81.2%

Annual CO_2e (Metric Tons) – Today



Annual CO_2e (Metric Tons) – 2050



Car-Centric City

Charlotte

Today

POPULATION

810k

MODE SHARE BY CAR

95%

ELECTRICITY MIX

1.2% renewables

2050

POPULATION

1.2M (52% increase)

MODE SHARE BY CAR

95%

ELECTRICITY MIX

1.2% renewables

Annual CO_2e (Metric Tons)

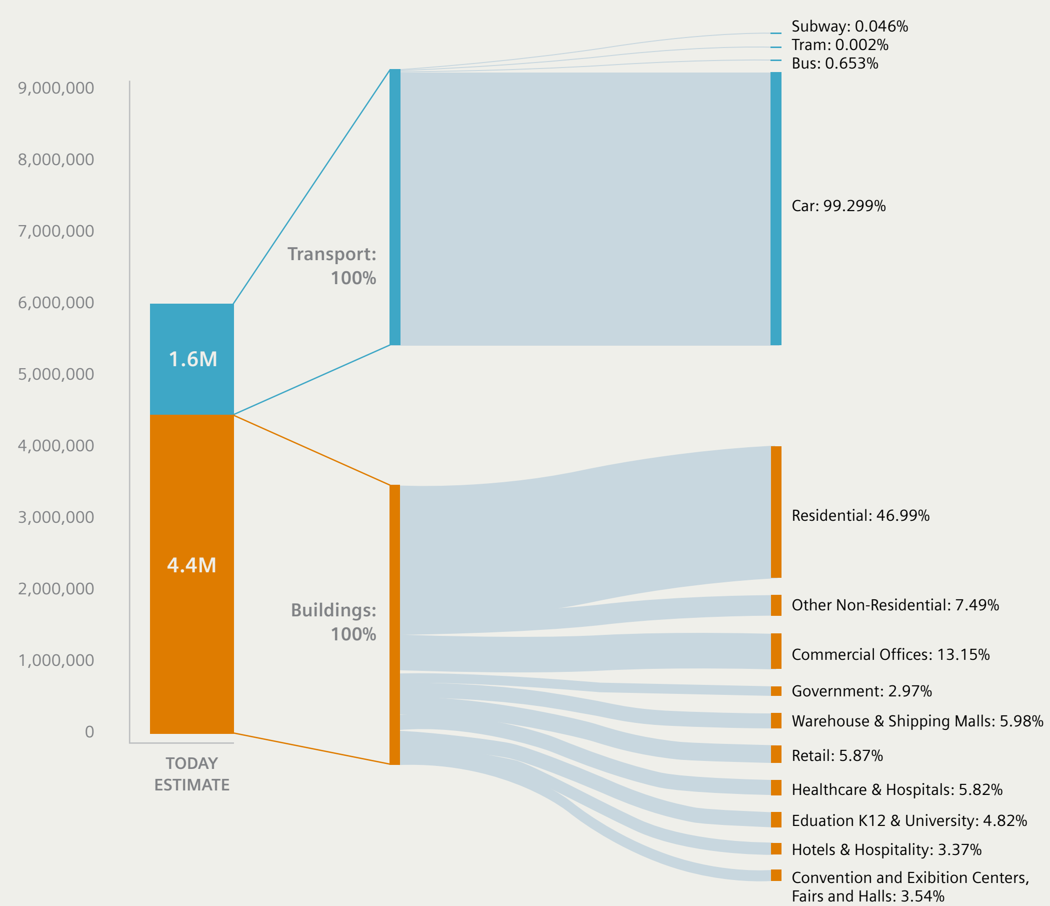
TODAY

6.0M

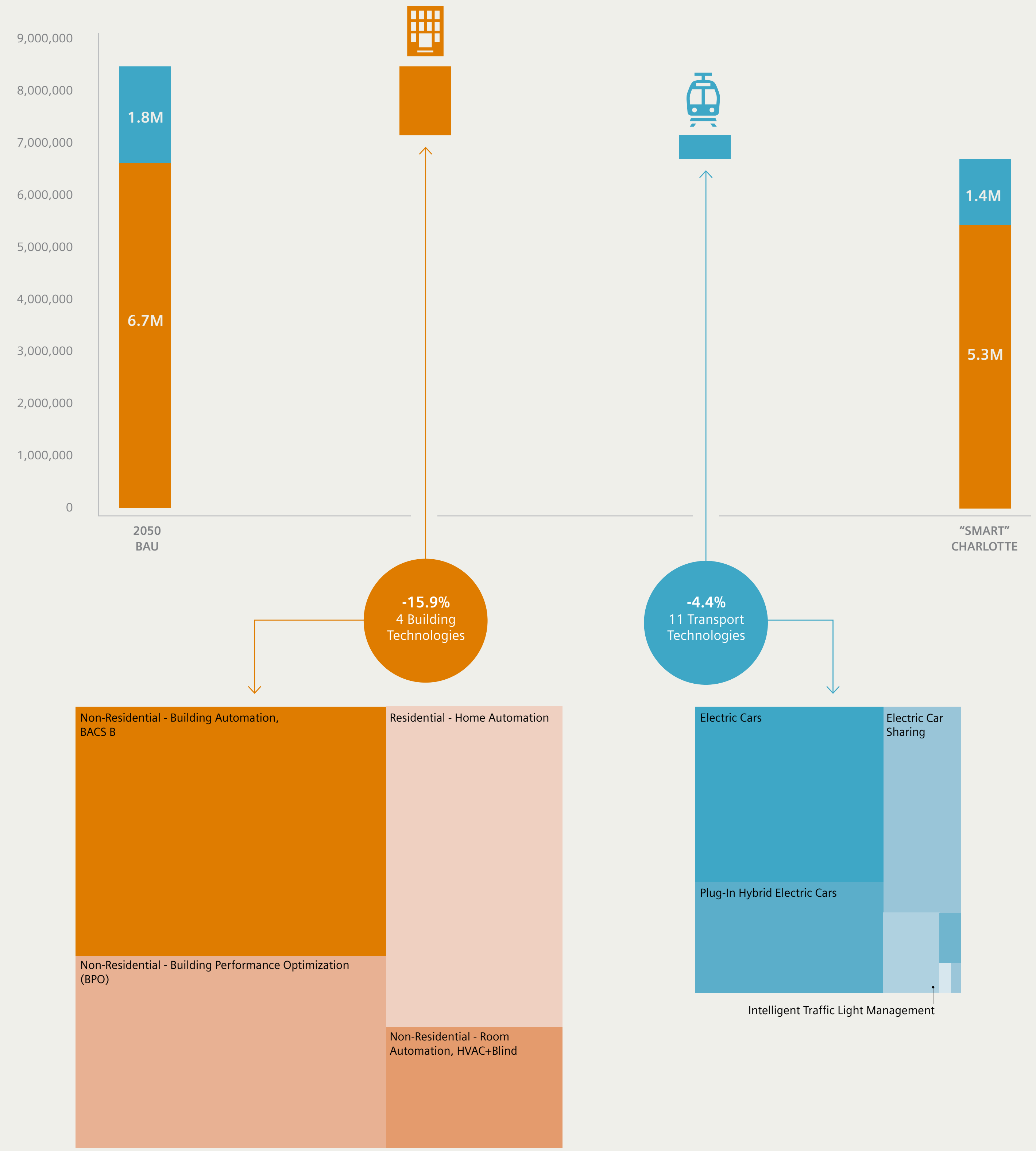
GHG EMISSION REDUCTIONS AS COMPARED TO 2050 BAU

-21.2%

Annual CO_2e (Metric Tons) – Today



Annual CO_2e (Metric Tons) – 2050



Transit-Centric City

Mexico City

Today

POPULATION

8.8M

MODE SHARE BY CAR

29%

ELECTRICITY MIX

26% renewables

2050

POPULATION

7.8M (12% decrease)

MODE SHARE BY CAR

29%

ELECTRICITY MIX

95% renewables

Annual CO_2e (Metric Tons)

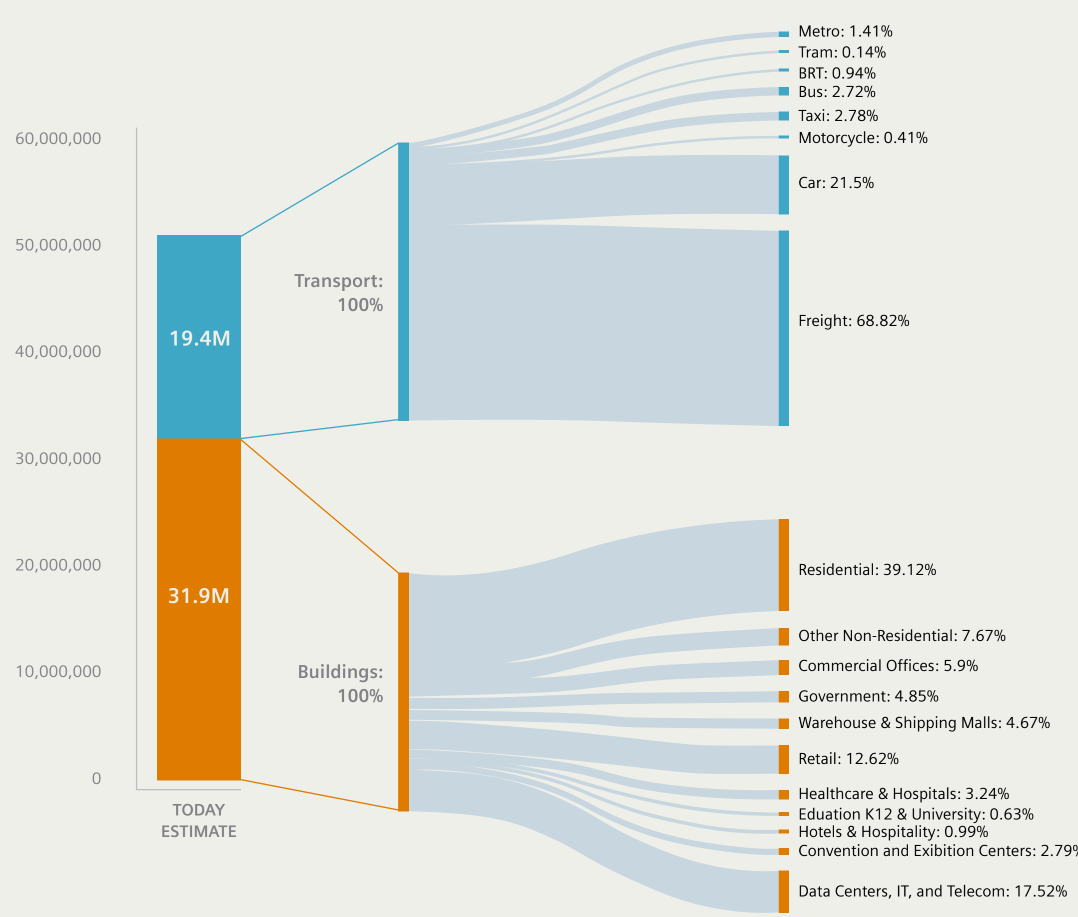
TODAY

51.3M

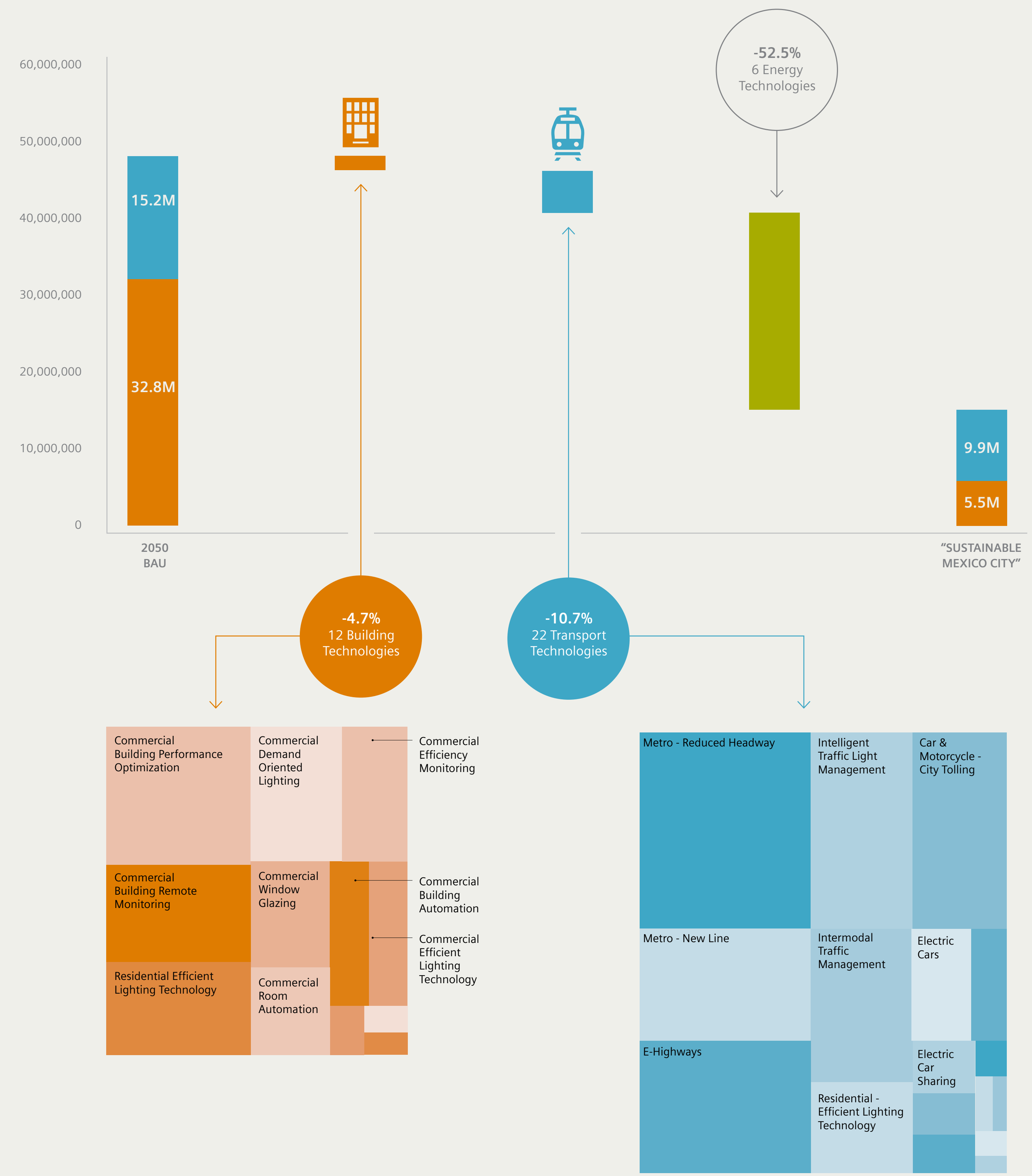
GHG EMISSION REDUCTIONS AS COMPARED TO 2050 BAU

-67.9%

Annual CO_2e (Metric Tons) – Today



Annual CO_2e (Metric Tons) – 2050



Conclusion

Sustainability is clearly emerging as one of the top priorities for cities across the world. While organizations like C40 Cities and Climate Mayors are helping cities set goals by translating global initiatives like Paris Agreement into local targets, cities are on their own to map out the path for achieving these targets. From targets as aggressive as becoming carbon neutral by 2050 for Boston or 90% GHG reduction by 2040 for Orlando, cities need a tangible climate action plan that prioritizes actions. With the help of CyPT we've been able to work with more than 15 cities in North America to help come up with technology strategies and infrastructure scenarios that will get them closer to their GHG reduction goals.

This report summarizes our work with these cities over last five years and produces trends so that cities that we've not had a chance to work with can capture some useful insights. Across the board, electrification of transport emerges at the top performing strategy, keeping in mind that this will only be a top performing strategy if the underlying electricity mix is produced from renewable fuels.

It is also worth noting that every city is unique! Through this report, some trends emerge; based on climate region, geographical location, population etc., what technologies are most beneficial and appropriate is very much dependent on the city. In addition, the adoption rates for uptake of these technologies also have a huge impact on their benefits.

Through technology workshops that bring together stakeholders representing various departments within the municipality (the Mayor's office, the planning department, public works, etc.), as well as the transit agency, the electric utility, and trusted advisors from non-profit organizations, local universities, and even private consultancies; we solicit input and feedback on technologies and implementation rates that will push the efforts for deep carbon reduction into reality.

Our hope is that through this report, cities are able to see that even the most aggressive GHG reduction targets are close to becoming reality through planning and prioritizing.

Appendix I

Cities where we've done CyPT projects

City	GHG Reduction Target	Climate Action Plan	CyPT Reports
Boston	Carbon Neutral by 2050	Yes	Not Available
Charlotte	None	No	Smart Vision for Charlotte
Los Angeles	80% by 2050	Yes	Climate LA
Mexico City	80% by 2050	No	Mexico City's Green Future
Minneapolis	80% by 2050	Yes	Minneapolis Can Reach 80 by 50
New Bedford	25% by 2025	No	Not Available
Phoenix	30% by 2025	No	Not Available
Portland	80% by 2050	Yes	Portland Takes (Climate) Action
Riverside	49% by 2035	Yes	Not Available
San Francisco	80% by 2050	Yes	San Francisco: Technology Pathways to a Sustainable Future
Washington DC	80% by 2050	Yes	The Digital District – Washington, DC

Appendix II

Climate Regions of North America

Subarctic/Arctic
A subarctic and arctic climate is defined as a region with approximately 12,600 heating degree days (65°F basis)[1] or greater.

Very Cold
A very cold climate is defined as a region with approximately 9,000 heating degree days (65°F basis)[2] or greater and less than approximately 12,600 heating degree days (65°F basis).

Cold
A cold climate is defined as a region with approximately 5,400 heating degree days (65°F basis)[3] or greater and less than approximately 9,000 heating degree days (65°F basis)[4].

Mixed-Humid
A mixed-humid climate is defined as a region that receives more than 20 inches (50cm) of annual precipitation, has approximately 5,400 heating degree days (65°F basis)[5] or less and where the monthly average outdoor temperature drops below 45°F (7°C) during the winter months.

Marine
A marine climate meets all of the following criteria:

- A mean temperature of the coldest month between 27°F (-3°C) and 65°F (18°C)
- A warmest month mean of less than 72°F (22°C)
- At least 4 months with mean temperatures over 50°F (10°C)

A dry season in summer. The month with heaviest precipitation in the cold season has at least three times as much precipitation as the month with the least precipitation in the rest of the year. The cold season is October through March in the Northern Hemisphere and April through September in the Southern Hemisphere.

Hot-Humid
A hot-humid climate is defined as a region that receives more than 20 inches (50 cm) of annual precipitation and where one or both of the following occur:*

- A 67°F (19.5°C) or higher wet bulb temperature for 3,000 or more hours during the warmest six consecutive months of the year; or
- A 73°F (23°C) or higher wet bulb temperature for 1,500 or more hours during the warmest six consecutive months of the year.

* *These last two criteria are identical to those used in the ASHRAE definition of warm-humid climates and are very closely aligned with a region where monthly average outdoor temperature remains above 45°F (7°C) throughout the year.*

Mixed-Dry
A mixed-dry climate is defined as a region that receives les than 20 inches (50 cm) of annual precipitation, has appoximately 5,400 heating degree days (65°F basis) or less, and where the average monthly outdoor temperature drops below 45°F (7°C) during the winter months.

Hot-Dry
A hot-dry climate is defined as a region that receives more than 20 inches (50 cm) of annual precipitation and where the monthly average outdoor temperature remains above 45°F (7°C) throughout the year.

1. Celsius: 7,000 heating degree days (18°C basis)
2. Celsius: 5,000 heating degree days (18°C basis)
3. Celsius: 3,000 heating degree days (18°C basis)
4. Celsius: 5,000 heating degree days (18°C basis)
5. Celsius: 3,000 heating degree days (18°C basis)

Appendix III

CyPT Technologies and Adoption Rates

Boston

Target Year - 2050 • No. of Technologies modeled: 35 • CO2 eq. emission reductions as compared to 2050 BAU: 84.4%

ENERGY Levers		Units	2016	2025
Generation	Solar PV (Rooftop + Utility Scale)	% of Total Electricity Generation	0.4%	40%
	Electric Heat Pump	Share of Heating Mix	3.3%	70%
T&D	Power System Automation	% of Electric Grid	0%	70%
	Smart Grid For Monioring and Control	% of Electric Grid	0%	70%
	Network Optimization	% of Electric Grid	0%	70%
BUILDING Levers		**Units**	**2016**	**2025**
Residential	Home Automation	% of Building Stock	0%	100%
Non-Residential	Wall Insulation	% of Building Stock	0%	100%
	Window Glazing	% of Building Stock	0%	100%
	Efficient Lighting Technology	% of Building Stock	1%	100%
	Demand Controlled Ventilation	% of Building Stock	0%	100%
	Heat Recovery	% of Building Stock	0%	100%
	Building Automation	% of Building Stock	0%	100%
	Buildings Efficient Motors	% of Building Stock	0%	100%
	Room Automation	% of Building Stock	0%	100%
	Building Remote Monitoring	% of Building Stock	0%	100%
TRANSPORTATION Levers		**Units**	**2016**	**2025**
Public Transportation	Electric Buses	Share of Public Bus Fleet	3%	70%
	Metro - New Line	Number of New Lines	n.a.	2
	Metro - New Vehicles	Share of Vehicles	n.a.	100%
	Metro - Reduced Headway	Seconds Between Trains	380	180
	Tram - New Line	Number of New Lines	n.a.	4
	E-BRT (Bus Rapid Transit) - New Line	Number of New Lines	n.a.	8
	BRT (Bus Rapid Transit) - Electrification	Share of Lines Electrified	26%	100%
	Metro - Regenerative Braking	Share of Lines	0%	100%
	Tram - Regenerative Braking	Share of Lines	0%	100%
	Seperated Bike Lanes	Miles	120	145
	Bikeshare	Number of Sharing Bicycles	1,600	8,000
	Public Transport - E-Ticketing	Users as Share of Travelers	65%	100%
Private Transportation	Electric Cars	% of Cars on the Road	0.1%	90%
	Electric Taxis	% of Taxis on the Road	0%	70%
	Electric Car Sharing	Number of Sharing Cars	0	2,380
	Congestion Charging	% Reduction in Traffic	n.a.	40%
	Eco-Driver Training & Consumption Awareness	% of Driver Participation	0%	80%
Transportation Infrastructure	Smart Street Lighting	Share of Street Lights	0%	100%
	Intelligent Traffic Light Management	% of Coordinated Traffic Signals	65%	100%
	Intermodal Traffic Management	Users as Share of Travelers	65%	100%

Charlotte

Target Year - 2050 • No. of Technologies modeled: 16 • CO2 eq. emission reductions as compared to 2050 BAU: 20.2%

BUILDING Levers		Units	2015	2050
Residential	Home Automation	% of Building Stock	2%	100%
Non-Residential	Building Performance Optimization	% of Building Stock	10%	100%
	Building Automation	% of Building Stock	0%	100%
	Room Automation	% of Building Stock	0%	100%
TRANSPORTATION Levers		**Units**	**2015**	**2050**
Public Transportation	Automated Train Operation (ATO) Metro	Share of Lines Equipped	0%	75%
	Metro - Reduced Headway	Seconds Between Trains	420	360
	Tram - Automated Train Operation (ATO)	Share of Lines	0%	12.5%
	Metro - Regenerative Braking	Share of Lines	30%	75%
	Tram - Regenerative Braking	Share of Lines	50%	75%
	Public Transport - E-Ticketing	Users as Share of Travelers	40%	100%
Private Transportation	Electric Cars	% of Cars on the Road	0%	15%
	Plug-In Hybrid Electric Cars	% of Cars on the Road	0%	15%
	Electric Car Sharing	Number of Sharing Cars	0	26,553
Transportation Infrastructure	Smart Street Lighting	Share of Street Lights	5%	70%
	Intelligent Traffic Light Management	% of Coordinated Traffic Signals	0%	60%
	Intermodal Traffic Management	Users as Share of Travelers	0%	50%

Los Angeles

Target Year - 2050 • No. of Technologies modeled: 17 • CO2 eq. emission reductions as compared to 2050 BAU: 60.2%

ENERGY Levers			2016	2050
Generation	Solar PV (Rooftop + Utility scale)	% of Total Electricity Generation	0%	6%
	Electric Heat Pump	Share of Heating Mix	6%	50%
BUILDING Levers			**2016**	**2050**
Residential	Window Glazing	% of Building Stock	53%	80%
	Home Automation	% of Building Stock	0%	30%
Non-Residential	Building Automation	% of Building Stock	22%	75%
	Room Automation	% of Building Stock	0%	50%
TRANSPORTATION Levers			**2016**	**2050**
Public Transportation	Electric Buses	Share of Public Bus Fleet	0%	100%
	Metro - New Line	Number of New Lines	n.a.	9
	Metro - Reduced Headway	Seconds Between Trains	660	240
	E-BRT (Bus Rapid Transit) - New Line	Number of New Lines	n.a.	4
	Public Transport - E-Ticketing	Users as Share of Travelers	0%	100%
Private Transportation	Electric Cars	% of Cars on the Road	1%	100%
	Electric Car Sharing	Number of Sharing Cars	100	25,000
	Congestion Charging	% Reduction in Traffic	n.a.	9%
	High-Occupancy Tolling	% Increase in Passengers Per Car	n.a.	65%
Transportation Infrastructure	Intelligent Traffic Light Management	% of Coordinated Traffic Signals	88%	100%
Freight Transportation	E-Highways	% of Freight Corridors Electrified	0%	75%

Mexico City

Target Year - 2050 • No. of Technologies modeled: 40 • CO2 eq. emission reductions as compared to 2050 BAU: 67.9%

ENERGY Levers		Units	2015	2050
Generation	Solar Pv (Rooftop + Utility Scale)	% of Total Electricity Generation	0%	20%
	Wind	% of Total Electricity Generation	2%	50%
T&D	Power System Automation	% of Electric Grid	60%	100%
	Smart Grid for Monioring and Control	% of Electric Grid	30%	100%
	Network Optimization	% of Electric Grid	15%	70%
	Smart Metering	Housing Connections	2%	75%
BUILDING Levers		**Units**	**2015**	**2050**
Residential	Efficient Lighting Technology	% of Building Stock	8%	20%
Non-Residential	Wall Insulation	% of Building Stock	5%	24%
	Window Glazing	% of Building Stock	2%	17%
	Efficient Lighting Technology	% of Building Stock	30%	49%
	Demand-Oriented Lighting	% of Building Stock	5%	20%
	Building Efficiency Monitoring	% of Building Stock	20%	39%
	Building Performance Optimization	% of Building Stock	10%	25%
	Demand Controlled Ventilation	% of Building Stock	5%	20%
	Building Automation	% of Building Stock	0%	3%
	Buildings Efficient Motors	% of Building Stock	0%	6%
	Room Automation	% of Building Stock	10%	25%
	Building Remote Monitoring	% of Building Stock	5%	14%
TRANSPORTATION Levers		**Units**	**2015**	**2050**
Public Transportation	Automated Train Operation (ATO) Metro	Share of Lines Equipped	0%	100%
	Hybrid Electric Buses	Share of Public Bus Fleet	10%	40%
	Electric Buses	Share of Public Bus Fleet	0%	25%
	Metro - New Line	Number of New Lines	n.a.	6
	Metro - Reduced Headway	Seconds Between Trains	160	120
	E-BRT (Bus Rapid Transit) - New Line	Number of New Lines	n.a.	8
	BRT (Bus Rapid Transit) - Electrification	Share of Lines Electrified	0%	100%
	Seperated Bike Lanes	Miles	30	150
	Bikeshare	Number of Sharing Bicycles	6,565	177,022
	Public Transport - E-Ticketing	Users as Share of Travelers	40%	100%
Private Transportation	Electric Cars	% of Cars on the Road	0%	42%
	Hybrid Electric Cars	% of Cars on the Road	0%	8%
	Plug-In Hybrid Electric Cars	% of Cars on the Road	0%	5%
	Electric Taxis	% of Taxis on the Road	20%	30%
	Electric Car Sharing	Number of Sharing Cars	0	43,000
	Congestion Charging	% Reduction in Traffic	n.a.	20%
	Eco-Driver Training & Consumption Awareness	% of Driver Participation	0%	8%
Transportation Infrastructure	LED Street Lighting	Share of Street Lights	15%	100%
	Intelligent Traffic Light Management	% of Coordinated Traffic Signals	0%	70%
	Intermodal Traffic Management	Users as Share of Travelers	0%	100%
Freight Transportation	Low Emission Zone for Trucks	Minimum Euro Class	n.a.	6
	E-Highways	% of Freight Corridors Electrified	0%	50%

Minneapolis

Target Year - 2050 • No. of Technologies modeled: 39 • CO2 eq. emission reductions as compared to 2050 BAU: 76%

BUILDING Levers		Units	2015	2050
Residential	Efficient Lighting Technology	% of Building Stock	3%	100%
	Home Energy Monitoring	% of Building Stock	0%	100%
	Home Automation	% of Building Stock	0%	100%
	Building Envelope	% of Building Stock	0%	100%
Non-Residential	Efficient Lighting Technology	% of Building Stock	21%	100%
	Demand-Oriented Lighting	% of Building Stock	0%	100%
	Building Efficiency Monitoring	% of Building Stock	0%	100%
	Building Performance Optimization	% of Building Stock	0%	100%
	Demand Controlled Ventilation	% of Building Stock	0%	100%
	Heat Recovery	% of Building Stock	0%	100%
	Building Envelope	% of Building Stock	0%	100%
	Building Automation	% of Building Stock	0%	100%
	Buildings Efficient Motors	% of Building Stock	0%	100%
	Room Automation	% of Building Stock	0%	100%
	Building Remote Monitoring	% of Building Stock	0%	100%
TRANSPORTATION Levers		**Units**	**2015**	**2050**
Public Transportation	Automated Train Operation (ATO) Metro	Share of Lines Equipped	0%	100%
	Electric Buses	Share of Public Bus Fleet	0%	100%
	Automated Train Operation (ATO) Regional Train	Share of Lines Equipped	0%	100%
	Metro - New Line	Number of New Lines	n.a	5
	Metro - New Vehicles	Share of Vehicles	n.a	100%
	Metro - Reduced Headway	Seconds Between Trains	600	180
	Tram - New Line	Number of New Lines	n.a	4
	E-BRT (Bus Rapid Transit) - New Line	Number of New Lines	n.a	10
	Seperated Bike Lanes	Miles	210	314
	Bikeshare	Number of Sharing Bicycles	1,033	4,040
	Public Transport - E-Ticketing	Users as Share of Travelers	55%	100%
Private Transportation	Electric Cars	% of Cars on the Road	0%	65%
	Plug-In Hybrid Electric Cars	% of Cars on the Road	0%	25%
	Electric Taxis	% of Taxis on the Road	0%	100%
	Electric Car Sharing	Number of Sharing Cars	400	2,828
	Congestion Charging	% Reduction in Traffic	n.a.	15%
	Eco-Driver Training & Consumption Awareness	% of Driver Participation	0%	8%
Transportation Infrastructure	LED Street Lighting	Share of Street Lights	1%	100%
	Smart Street Lighting	Share of Street Lights	0%	100%
	Intelligent Traffic Light Management	% of Coordinated Traffic Signals	10%	100%
	Intermodal Traffic Management	Users as Share of Travelers	10%	100%
Freight Transportation	Low Emission Zone for Trucks	Minimum EURO Class	n.a.	6
	E-Highways	% of Freight Corridors Electrified	0%	50%
	Freight Train - Electrification	% of Freight Railways Electrified	0%	100%

New Bedford

Target Year - 2025 • No. of Technologies modeled: 10 • CO2 eq. emission reductions as compared to 2025 BAU: 25.5%

ENERGY Levers		Units	2014	2025
Generation	Solar PV (Rooftop + Utility Scale)	% of Total Electricity Generation	0%	10%
	Wind	% of Total Electricity Generation	2%	30%
TRANSPORTATION Levers		**Units**	**2014**	**2025**
Public Transportation	Electric Buses	Share of Public Bus Fleet	0%	30%
	Bikeshare	Number of Sharing Bicycles	0	950
Private Transportation	Electric Cars	% of Cars on the Road	0%	20%
	Hybrid Electric Cars	% of Cars on the Road	0%	20%
	Electric Car Sharing	Number of Sharing Cars	0	95
	Eco-Driver Training & Consumption Awareness	% of Driver Participation	0%	8%
Transportation Infrastructure	Intelligent Traffic Light Management	% of Coordinated Traffic Signals	18.60%	100%
	Intermodal Traffic Management	Users as Share of Travelers	0%	30%

Phoenix

Target Year - 2025 • No. of Technologies modeled: 24 • CO2 eq. emission reductions as compared to 2050 BAU: 15.0%

ENERGY Levers		Units	2015	2025
Generation	Solar PV (Rooftop + Utility Scale)	% of Total Electricity Generation	0%	2%
	Combined Cycle Gas Turbine	% of Total Electricity Generation	0%	2%
T&D	Power System Automation	% of Electric Grid	0%	25%
	Smart Grid for Monioring and Control	% of Electric Grid	0%	25%
BUILDING Levers		**Units**	**2015**	**2025**
Residential	Wall Insulation	% of Building Stock	60%	65%
	Window Glazing	% of Building Stock	60%	65%
	Home Automation	% of Building Stock	1%	2%
Non-Residential	Wall Insulation	% of Building Stock	50%	55%
	Window Glazing	% of Building Stock	15%	20%
	Efficient Lighting Technology	% of Building Stock	50%	60%
	Demand-Oriented Lighting	% of Building Stock	5%	15%
	Demand Controlled Ventilation	% of Building Stock	2%	10%
	Heat Recovery	% of Building Stock	0%	25%
	Building Automation	% of Building Stock	5%	20%
	Buildings Efficient Motors	% of Building Stock	2%	10%
	Room Automation	% of Building Stock	2%	10%
TRANSPORTATION Levers		**Units**	**2015**	**2025**
Public Transportation	Tram - New Line	Number of New Lines	n.a.	1
	Buses - New CNG Vehicles	Share of Public Bus Fleet	70%	100%
	Bikeshare	Number of Sharing Bicycles	500	2,500
Private Transportation	CNG Cars	% of Cars on the Road	<0.1%	10%
	Plug-In Hybrid Electric Cars	% of Cars on the Road	0%	40%
	Electric Taxis	% of Cars on the Road	0%	100%
	Electric Car Sharing	Number of Sharing Cars	0	2,000
Transportation Infrastructure	Intelligent Traffic Light Management	% of Coordinated Traffic Signals	80%	100%

Portland

Target Year - 2050 • No. of Technologies modeled: 28 • CO2 eq. emission reductions as compared to 2050 BAU: 64.3%

ENERGY Levers		Units	2015	2050
Generation	Solar PV (Rooftop + Utility Scale)	% of Total Electricity Generation	~0%	10%
BUILDING Levers		**Units**	**2015**	**2050**
Residential	Home Automation	% of Building Stock	0%	100%
Non-Residential	Wall Insulation	% of Building Stock	0%	100%
	Window Glazing	% of Building Stock	75%	100%
	Efficient Lighting Technology	% of Building Stock	1%	100%
	Demand-Oriented Lighting	% of Building Stock	9%	100%
	Building Efficiency Monitoring	% of Building Stock	9%	100%
	Demand Controlled Ventilation	% of Building Stock	0%	100%
	Heat Recovery	% of Building Stock	0%	100%
	Building Automation	% of Building Stock	0%	100%
	Buildings Efficient Motors	% of Building Stock	0%	100%
	Room Automation	% of Building Stock	0%	100%
	Building Remote Monitoring	% of Building Stock	9%	100%
TRANSPORTATION Levers		**Units**	**2015**	**2050**
Public Transportation	Electric Buses	Share of Public Bus Fleet	0%	100%
	Metro - New Line	Number of New Lines	n.a.	3
	Metro - New Vehicles	Share of Vehicles	n.a.	100%
	Metro - Reduced Headway	Seconds Between Trains	420	180
	Tram - New Line	Number of New Lines	n.a.	1
	E-BRT (Bus Rapid Transit) - New Line	Number of New Lines	n.a.	1
	Metro - Regenerative Braking	Share of Lines	20%	100%
	Seperated Bike Lanes	Miles	300	330
	Bikeshare	Number of Sharing Bicycles	1,000	7,000
	Public Transport - E-Ticketing	Users as Share of Travelers	70%	100%
Private Transportation	Electric Cars	% of Cars on the Road	0%	70%
	Electric Taxis	% of Cars on the Road	~0	100%
	Electric Car Sharing	Number of Sharing Cars	~0	3,000
	Congestion Charging	% Reduction in Traffic	n/a	30%
Transportation Infrastructure	Intelligent Traffic Light Management	% of Coordinated Traffic Signals	0%	100%

Riverside

Target Year - 2025 • No. of Technologies modeled: 15 • CO2 eq. emission reductions as compared to 2025 BAU: 25%

ENERGY Levers		Units	2014	2025
Generation	Solar PV (Rooftop + Utility Scale)	% of Total Electricity Generation	0%	10%
	Wind	% of Total Electricity Generation	3%	20%
BUILDING Levers		Units	2014	2025
Residential	Window Glazing	% of Building Stock	50%	100%
	Efficient Lighting Technology	% of Building Stock	0%	100%
	Home Automation	% of Building Stock	0%	100%
Non-Residential	Window Glazing	% of Building Stock	50%	100%
	Efficient Lighting Technology	% of Building Stock	10%	100%
	Building Performance Optimization	% of Building Stock	0%	100%
TRANSPORTATION Levers		Units	2014	2025
Public Transportation	Tram - New Line	Number of New Lines	n.a.	3
	e-BRT (Bus Rapid Transit) - New Line	Number of New Lines	n.a	3
	Bikeshare	Number of Sharing Bicycles	0	940
Private Transportation	CNG Cars	% of Cars on the Road	0%	20%
	Electric Cars	% of Cars on the Road	0%	20%
	Electric Car Sharing	Number of Sharing Cars	0	300
Freight Transportation	E-Highways	% of Freight Corridors Electrified	0%	30%

San Francisco

Target Year - 2050 • No. of Technologies modeled: 35 • CO2 eq. emission reductions as compared to 2050 BAU: 75.1%

ENERGY Levers		Units	2014	2050
Generation	Solar PV (Rooftop + Utility Scale)	% of Total Electricity Generation	5.2%	32%
	Electric Heat Pump	Share of Heating Mix	0%	80%
BUILDING Levers		Units	2014	2050
Residential	Efficient Lighting Technology	% of Building Stock	25%	80%
	Home Energy Monitoring	% of Building Stock	0%	80%
	Home Automation	% of Building Stock	0%	80%
	Building Envelope	% of Building Stock	53%	83%
Non-Residential	Efficient Lighting Technology	% of Building Stock	50%	80%
	Demand-Oriented Lighting	% of Building Stock	5%	80%
	Building Efficiency Monitoring	% of Building Stock	0%	80%
	Building Performance Optimization	% of Building Stock	4%	80%
	Demand Controlled Ventilation	% of Building Stock	2%	80%
	Heat Recovery	% of Building Stock	0%	80%
	Building Envelope	% of Building Stock	50%	80%
	Building Automation	% of Building Stock	22%	80%
	Buildings Efficient Motors	% of Building Stock	5%	80%
	Room Automation	% of Building Stock	0%	80%
	Building Remote Monitoring	% of Building Stock	0%	80%
TRANSPORTATION Levers		Units	2014	2050
Public Transportation	Electric Buses	Share of Public Bus Fleet	36%	100%
	Metro - New Line	Number of New Lines	n.a.	2
	Tram - New Line	Number of New Lines	n.a.	4
	E-BRT (Bus Rapid Transit) - New Line	Number of New Lines	n.a.	8
	Tram - New Vehicles	Share of Vehicles	0%	100%
	Seperated Bike Lanes	Miles	33	275
	Bikeshare	Number of Sharing Bicycles	350	7,000
	Public Transport - E-Ticketing	Users as Share of Travelers	70%	100%
Private Transportation	CNG Cars	% of Cars on the Road	0%	1%
	Electric Cars	% of Cars on the Road	1%	20%
	Hybrid Electric Cars	% of Cars on the Road	0%	60%
	Electric Taxis	% of Cars on the Road	0%	100%
	Electric Car Sharing	Number of Sharing Cars	200	20,240
	Congestion Charging	% Reduction in Traffic	n.a.	15%
	Eco-Driver Training & Consumption Awareness	% of Driver Participation	0%	8%
Transportation Infrastructure	Smart Street Lighting	Share of Street Lights	0%	100%
	Intelligent Traffic Light Management	% of Coordinated Traffic Signals	40%	100%
	Intermodal Traffic Management	Users as Share of Travelers	30%	100%

Washington DC

Target Year - 2050 • No. of Technologies modeled: 24 • CO2 eq. emission reductions as compared to 2050 BAU: 91.1%

ENERGY Levers		Units	2015	2050
Generation	Solar PV (Rooftop + Utility Scale)	% of Total Electricity Generation	0.1%	16%
	Wind	% of Total Electricity Generation	0.8%	82%
	Combined Heat & Power	Share of Heating Mix	13.1%	30%
BUILDING Levers		**Units**	**2015**	**2050**
Residential	Home Automation	% of Building Stock	0%	100%
Non-Residential	Efficient Lighting Technology	% of Building Stock	1%	100%
	Demand Controlled Ventilation	% of Building Stock	0%	100%
	Heat Recovery	% of Building Stock	0%	100%
	Building Envelope	% of Building Stock	0%	100%
	Building Automation	% of Building Stock	0%	100%
	Buildings Efficient Motors	% of Building Stock	0%	100%
	Room Automation	% of Building Stock	0%	100%
	Building Remote Monitoring	% of Building Stock	9%	100%
TRANSPORTATION Levers		**Units**	**2015**	**2050**
Public Transportation	Electric Buses	Share of Public Bus Fleet	0%	100%
	Metro - New Line	Number of New Lines	6	7
	Metro - Reduced Headway	Seconds Between Trains	360	180
	Tram - New Line	Number of New Lines	n.a.	4
	E-RT (Bus Rapid Transit) - New Line	Number of New Lines	n.a.	7
	Bikeshare	Number of Sharing Bicycles	3,000	7,000
	Public Transport - E-Ticketing	Users as Share of Travelers	0%	100%
Private Transportation	Electric Cars	% of Cars on the Road	3%	100%
	Electric Car Sharing	Number of Sharing Cars	300	3,000
Transportation Infrastructure	Smart Street Lighting	Share of Street Lights	0%	70%
	Intelligent Traffic Light Management	% of Coordinated Traffic Signals	10%	100%
	Intermodal Traffic Management	Users as Share of Travelers	0%	90%

Appendix IV

CyPT Technologies Description

Building Levers

Residential/ Non-residential	Wall Insulation	Solid wall insulation e.g. made of expanded polystyrene (EPS) can be applied to already existing buildings. Applying the rigid foams to exterior side of walls raises thermal resistance. The insulation reduces the heat gain/loss through the walls and thus minimizes the heating/ cooling energy needed. Reduction of CO_2e, PM10, and NOx related due to energy savings.
Residential/ Non-residential	Window Glazing	Applying double/triple glazed windows made of two or three panes of glass and a space between them filled with air or insulating gases reduces heat and noise transmission as well as solar gain from solar radiation through the window. Due to better window insulation less heating and cooling energy is needed inside the building. Reduction of CO_2e, PM10, and NOx related due to energy savings.
Residential	Efficient Lighting Technology	Significant electrical energy can be saved by replacing conventional luminaires with more efficient lighting fixtures and/or changing magnetic ballasts to electronic ballasts. Further reductions in power consumption can be achieved with the use of light-emitting diodes (LEDs), which also have a far higher lifespan than conventional lighting. LED solutions combined with intelligent light management systems can lower lighting costs in a building by as much as 80%. Reduction of CO_2e, PM10, and NOx related due to electricity savings.
Residential	Home Energy Monitoring	HEM solutions include smart metering of relevant electricity consumers and a communication to the user. The user has direct and real-time access to electricity consumption data, creating awareness and transparency. Smart metering, communication of energy consumption and corresponding price models provide an incentive to save energy and motivate users to switch off appliances to save energy.
Residential	Home Automation	Home Automation allows the automatic adjustment of heating, cooling, ventilation and lighting depending on the environmental conditions and the room occupancy by applying sensors and actuators as well as control units. This reduces the energy demand of heating, cooling, ventilation, and lighting.
Residential/ Non-residential	Building Envelope	A high-performance building envelope can be part of the initial building design or it can be created through the renovation of an existing building. A high-performance building envelope would include insulation, high performing glazing, and airtight construction. Energy efficient solutions can be applied to every part of the building envelope including floors, roofs, walls, and facades, and it can also be used to reduce the energy loss of a building's technical installations (e.g. pipes and boilers).
Non-Residential	Efficient Lighting Technology	Electricity can be saved by replacing conventional light bulbs for room lighting by more efficient light-emitting diodes (LEDs). LEDs consume up to 90% less energy and have a longer lifespan in operation hours and turn off/on cycles. LED lamps are compatible to conventional lamps and can substitute them easily. LEDs provide an equal luminosity at lower specified power. Reduction of CO_2e, PM10, and NOx related due to electricity savings.
Non-Residential	Demand Oriented Lighting	Demand-oriented lighting is based upon presence (or motion) detection: Lighting is switched 'on' when someone enters a given area and deactivates after a pre-defined period of time without movement. It is usually combined with daylight measurement. The largest energy savings can be achieved in buildings with fluctuating occupancy, and when combined with other lighting technologies, it can reduce the lighting energy use within a building by 20 to 50%. Reduction of CO_2e, PM10, and NOx related due to electrical energy savings.
Non-Residential	Building Efficiency Monitor-ing (BEM)	Building Efficiency Monitoring provides real-time measurement of energy consumption and environmental conditions within an EXISTING building, via a centralized monitoring system connected to a network of field devices (such as meters, switches, and sensing devices). Standard energy reports are created to allow benchmark comparison with similar buildings to assess performance and highlight problems (e.g. kWh, CO_2, temperature). Monitoring services and performance reports create awareness and transparency and enable continuous improvement and reduction of overall energy consumption. Reduction of CO_2e, PM10, and NOx related due to thermal and electrical energy savings.
Non-Residential	Building Performance Optimization (BPO)	Building Performance Optimization (BPO) is a range of services designed to increase the energy efficiency of an EXISTING building by implementing proven building control strategies otherwise known as Facility Improvement Measures (or FIMs). BPO can improve THERMAL and ELECTRICAL energy efficiency in a building in many ways; typically via improved HVAC technology, by adapting the building to suit usage profiles or providing information and analytics for operational personnel. Reduction of CO_2e, PM10, and NOx related due to energy savings.

Technology Pathways for Sustainable Cities | Appendix IV

Non-Residential	Demand Controlled Ventilation	With demand-controlled ventilation (DCV), the amount of air introduced into a space is matched to the actual demand and is ideal for areas with fluctuating occupancy such as open-offices, conference rooms, and restaurants. CO_2 levels measured by air quality detectors identify periods of low occupancy and cause the fans to stop or reduce speed (at 50% air volume, the fan power is reduced by a factor of 8!). DCV also provides savings in heating and cooling, by adjusting set point temperatures (economy mode). Reduction of CO_2e, PM10, and NOx related due to electrical energy savings.
Non-Residential	Heat Recovery	Heating and cooling losses can be reduced through heat and cold recovery technologies integrated within a building's maintenance system. The technology utilizes a counter flow heat exchanger between the inbound and outbound air flow. For example, cold inbound air flow can be pre-heated by room temperature outbound air flow. The result is that fresh, incoming air requires less heat or cooling and a steady room temperature is maintained and less electricity or heat is utilized.
Non-Residential	Building Automation (BACS Class B)	Energy-efficient building automation and control functions save building operating costs. The thermal and electrical energy usage is kept to a minimum. It is possible to estimate the efficiency of a building based on the type of operation and the efficiency class of the building automation and control systems (BACS) installed. Energy Class B includes advanced building automation and controls strategies, such as demand-based operation of HVAC plant, optimized control of motors, and dedicated energy management reporting. Reduction of CO_2e, PM10, NOx are related to thermal and electrical energy savings.
Non-Residential	Energy Efficient Motors and Drives	Analyzing the drive technology in your building (fans, pumps, compressors, or process plant) can lead to significant cost- and energy-savings and help reduce emissions. As an example: changing a standard 30kW motor (IE1) to an equivalent energy efficient motor (IE3) can save 3,500 kWh per year, and 2,000kg of CO_2 emissions. Adding variable speed drive technology will ensure motors only draw as much energy as is actually required. Reduction of CO_2e, PM10, NOx are related to electrical energy savings.
Non-Residential	Room Automation	Room Automation provides control and monitoring of heating, ventilation, and air conditioning within individual zones based upon demand, with options for automatic lighting. An in-built energy efficiency function identifies unnecessary energy usage at the room operating units, encouraging room users to become involved in energy saving; and different lighting scenarios can be programmed. Reduction of CO_2e, PM10, NOx are related to electrical power utilized in the heating, ventilation and air-conditioning and lighting of a building.
Non-Residential	Building Remote Monitoring	Remote Monitoring allows individual building performance to be measured and compared against benchmark values for similar building types or sizes. Energy experts are able to remotely analyze building energy usage, to detect problems and make proposals for improvements. Reduction of CO2e, PM10, and NOx related due to energy savings.
Transport Levers		
Public	Electric Buses	Share of the vehicle fleet operated by battery electric vehicles. Battery electric vehicles are "zero" exhaust gas emission vehicles. Significant reduction of local emissions PM10, NOx. A charging infrastructure is set up. The electricity used for charging is generated according to the general local electricity mix.
Public	Metro – New line	Number of new metro lines at target year of average metro length, shifting passengers from all other mode according to the transportation performance of existing lines in the city. Public transport attractiveness is increased and energy demand per person kilometer is reduced together with related emissions.
Public	Tram – New Line	Light rail systems (LRT) are lighter and shorter than conventional rail and rapid transit trains. LRT systems are flexible and they can run on shared roadways or along dedicated tracks. These systems can be configured to meet a range of passenger capacity levels and performance characteristics. They can operate with high or low platforms, and they can consist of one or multiple carriages. Trams can be equipped with braking energy storage systems to further reduce energy demand.
Private	CNG Cars	Cars fueled by compressed natural gas can help reduce emission and noise.
Private	Electric cars	Share of conventional combustion vehicles replaced by battery electric vehicles. Battery electric cars are "zero" exhaust gas emission vehicles. Significant reduction of local emissions PM10, NOx. A charging infrastructure is set up. The electricity used for charging is generated according to the general local electricity mix.
Private	Hybrid Electric Cars	Share of conventional combustion vehicles replaced by hybrid electric vehicles at target year. Small combustion engine for base energy demand combined with an electric drive for acceleration and for brake energy recuperation. Energy demand is reduced due to a higher efficiency of the combustion engine, operating at optimum and brake energy recuperation together with related emissions.
Private	Electric Taxis	Share of conventional combustion vehicles replaced by battery electric vehicles. Battery electric cars are "zero" exhaust gas emission vehicles. Significant reduction of local emissions. A fast charging infrastructure is set up The electricity used for charging is generated according to the general local electricity mix.
Private	Electric Car Sharing	Number of sharing cars/1,000 inhabitants at target year; model of car rental where people rent e-cars for short periods of time, on a self-service basis. It is a complement to existing public transport systems by providing the first or last leg of a journey. Resulting in fewer driving emissions due to eCar and shift to non-vehicle travel, such as walking, cycling, and public transport.
Public	Bike Sharing	Number of sharing bikes/1,000 inhabitants offered at target year; resulting in a shift from all transport mode equally and lower energy demand per person kilometer together with related emissions.
Public	Cycling Highway	Additional number of cycling highways, increasing modal share of bikes. This lever reduces the modal share of other motorized vehicles and therefore emissions.
Public	Automated Train Operation (ATO) – Metro, Tram, Rail	Share of lines operated with ATO at target year. ATO controls or guides optimal throttle of engines, going optimal speed without violating the schedule. Reduced electricity demand per person km due to coasting. The saving potential correlates with the number of, and distance between, the stations. Reduction of CO_2e, PM10, and NOx related to lower electricity demand.
Public	Hybrid Electric Buses	Share of vehicle fleet operated by hybrid electric vehicles at target year. Small combustion engine for base energy demand combined with an electric drive for acceleration and for brake energy recuperation. Energy demand is reduced due to a higher efficiency of the combustion engine, operating at optimum, and brake energy recuperation together with related emissions.
Private	Plug-In Hybrid Electric Cars	Share of conventional combustion vehicles replaced by plug-in hybrid electric vehicles at target year. Small combustion engine for base energy demand combined with an electric drive for acceleration and for brake energy recuperation. Energy demand is reduced due to a higher efficiency of the combustion engine, operating at optimum, and brake energy recuperation together with related emissions.
Public	E-Bus Rapid Transit New Line (E-BRT)	Share of passenger transport at target year provided by bus rapid transit; a high performance public transport combining bus lanes with high-quality bus stations and electrical vehicles. Faster, more efficient service than ordinary bus lines. Results in modal shift from private transport to public transport, shift from combustion engines, and reduce energy demand per person km together with related emissions.
Passenger	Eco-Driver Training and Consumption Awareness (Road)	Frequent training of car drivers to optimize driving behavior and increase fuel economy of fleet average.
Passenger	Metro-Reduced Headway	Reduction of headway by introducing a rail automation system with moving block scheme. The lever increases the capacity of over utilized metro lines significantly. It induces a modal shift from other motorized mode to the metro system.
Passenger	Regenerative Braking – Metro, Tram	Share of lines equipped with regenerative braking. Regenerative braking systems are integrated within a metro car, and energy is captured through the braking process. Energy is then stored in the form of electricity, and it can later be used to power the metro. The benefit of this technology is relative to the overall size of the metro system.
Passenger	BRT-Electrification	Share of the vehicle fleet operated by battery electric vehicles. Battery electric vehicles are "zero" exhaust gas emission vehicles. Significant reduction of local emissions PM10, NOx. A charging infrastructure is set up. The electricity used for charging is generated according to the general local electricity mix.
Infrastructure	High-Occupancy Tolling	High Occupancy Tolling (HOT) is a more fine-tuned congestion pricing system. The price paid by the car owner will be solely dependent upon the number of passengers riding within the car. The fewer the passengers in the car, the higher the price to drive. ODT systems aim to incentivize car sharing and reduce the total number of vehicles on the road. Fewer vehicles will have a direct result on air quality and overall fuel consumption regardless of the type of vehicle. An ODT system is a tolling system, and it is not the same as implementing high occupancy lanes.
Infrastructure	E-Ticketing	This technology provides simple, affordable, competitive, and integrated ticketing. Electronic tickets offer a one-payment system for all forms of transport and simplify public transport use. Passengers can transfer seamlessly between different transportation modes and fees are calculated at the end of the trip. Passengers pay only for the services they use – automatically, electronically, transparently, and securely. Benefits are achieved through increased revenues, reduced operational costs, and improved reliability.

Infrastructure	Intelligent Traffic Light Management	Share of traffic lights, coordinated (green wave algorithms). Management systems controll traffic speed and volumes and coordinates traffic lights to help maintain the flow. Reduced energy demand, fuel consumption and air pollution caused by reducing traffic jams, and stop and go.
Infrastructure	Intermodal Traffic Management	Share of users integrated at target year equal to person kilometer considered to optimize capacities of the entire traffic infrastructure. Intermodal Traffic Management focuses on interoperable multimodal Real Time Traffic and Travel Information (RTTI) services provided to drivers/ travelers promoting change in mobility behavior from individual to public transport, reducing energy demand per person kilometer.
Infrastructure	Smart Street Lighting	Street lighting can comprise up to 40% of a city government's electricity bill. Intelligent street lighting can reduce this cost by replacing lamps with LED lighting, motion sensors, and wireless communication. These technologies enable lights to be dimmed when there are no cars, cyclists, or pedestrians in the vicinity. The system can differentiate between movements related to people and other movements and will not mistakenly turn on.
Infrastructure	LED Street Lighting	Share of low efficient street lights replaced by more efficient light-emitting diodes (LEDs). Saving electricity together with related emissions. Additionally, high reduction in maintenance due to longer lifetime (10 years versus 6-12 month) and possibility to dim the light depending on the environmental conditions.
Freight	E-Highways	Share of hybrid diesel-electric trucks and highways with overhead power lines at target year. As soon as trucks join the e-Highway they connect to the overhead power lines and switch into pure-electric mode. Leaving the e-Highway, the trucks switch back to using hybrid mode. Energy demand is reduced due to shift of transport to hybrid electric truck and electric transport together with related emissions.
Energy Levers		
Generation	Wind Power	Share of electricity provided by wind power at target year. Changing the energy mix and it's related emissions provides cleaner electricity for buildings and electric powered transport modes.
Generation	Photovoltaic	Share of electricity provided by photovoltaic at target year. Changing the energy mix and its related emissions provides cleaner electricity for buildings and electric powered transport modes.
Transmission	Network Optimization	A well-structured, secure, and highly available electricity supply infrastructure. Reduces grid losses resulting in less energy generation and related emissions to provide the demanded energy to customer.
Distribution	Smart Grid for Monitoring and Automation	Increased network performance with intelligent control. Optimization of decentralized energy resources – economically and ecologically. Possibility for bidirectional energy flow, reduces technical and non-technical grid losses in distribution and corresponding reduced energy generation and related emissions.
Transmission	Power System Automation and Optimized Network Design	Optimal combination of substation automation and change of voltage levels, power system structures, equipment (lines, transformers), change of disconnecting points, etc. in order to reduce (non-)technical losses, guarantee fast power system restoration after a fault in the network and simplified network operations.
Distribution	Smart Metering and Demand Response	Implementing smart meter devices and a meter data management system provides detailed information about how much energy is consumed at which place, allowing demand response and reduction of non-technical losses.