Reaching 80x50
City Performance Tool: San Francisco

SIEMENS
Ingenuity for life

Reaching 80x50

Technology Pathways to a Sustainable Future

City Performance Tool: San Francisco

About the Report

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 Global Center of Competence Cities (CoC) to specifically address the needs of urban planners and to enter into a structured dialogue and base lining assessment with urban decision makers.

About the San Francisco Department of the Environment

The Department creates visionary policies and innovative programs to improve, enhance, and preserve San Francisco's urban and natural environment, leading the way toward a sustainable future by developing wide-ranging environmental programs, fostering groundbreaking legislation, working collaboratively with key partners, and educating the public on comprehensive sustainability practices.

Color & Visual Guidelines in This Report

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:

- **Transport**
- **Buildings**
- **Energy**
- **Scenario 1**
- **Scenario 2**
- **Scenario 3**
- **PG&E**
- **SFPUC**
- **Projected Data (any color above + stripes)**

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Executive Summary

Siemens City Performance Tool (CyPT) in San Francisco

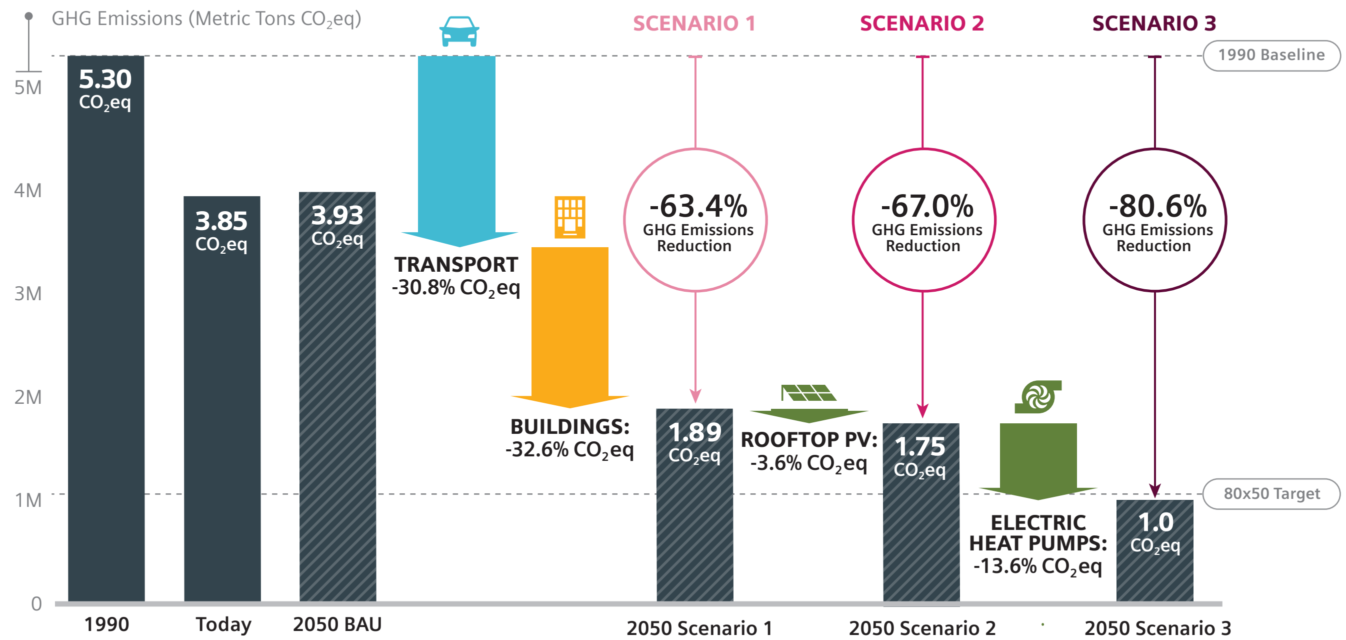
When Siemens approached the City of San Francisco about using the City Performance Tool (CyPT), Siemens understood that San Francisco was not a city interested in setting ambitious sustainability targets – it was a city that already had ambitious goals and was now focused on tools and intelligence to meet those targets, summarized as 0-50-100-Roots.

Over the course of a year, Siemens collaborated closely with the San Francisco Department of Environment (SFE) and nine other agencies to conduct an analysis of the City's infrastructure, defined as its entire built environment and transport system. The team used the CyPT model to test technology pathways for achieving San Francisco's "80x50" target (reducing CO_2eq emissions 80% by 2050 against a 1990 baseline) within the context of the local 0-50-100-Roots framework, as well as the State of California's policy leadership. This report reviews the technology pathways and their effects within San Francisco. Results illuminate how decisions by San Francisco as a whole – the public sector, utilities, business, and the citizenry – to invest in energy efficient buildings, clean energy, and a multi-modal transport network can accelerate the City's strong record of reducing GHG emissions, while creating jobs and improving air quality.

80x50 requires a collaborative effort, and the three scenarios and 36 technologies examined in this project require investment – and action – from both public and private sectors. The economic and engineering analysis provided by the CyPT provides guidance for prioritization of these investments, assisting residents, businesses, and governments alike to understand a credible and economically beneficial path to develop a sustainable future through energy efficiency in buildings and transport, renewable electricity, and decarbonization of both the grid and heat sources.

Deep Carbon Reduction Can Be Achieved

The CyPT tests three infrastructure scenarios for achieving 80x50. Under the most ambitious scenario, in which San Francisco implements 34 building and transport efficiency technologies at aggressive, but feasible rates, it saturates 80% of rooftops citywide with photovoltaics, and electric heat pumps replace at least 80% of carbon-based heat sources; San Francisco can reduce CO_2eq emissions by 80.6% from the 1990 baseline, reaching its 80x50 goal.

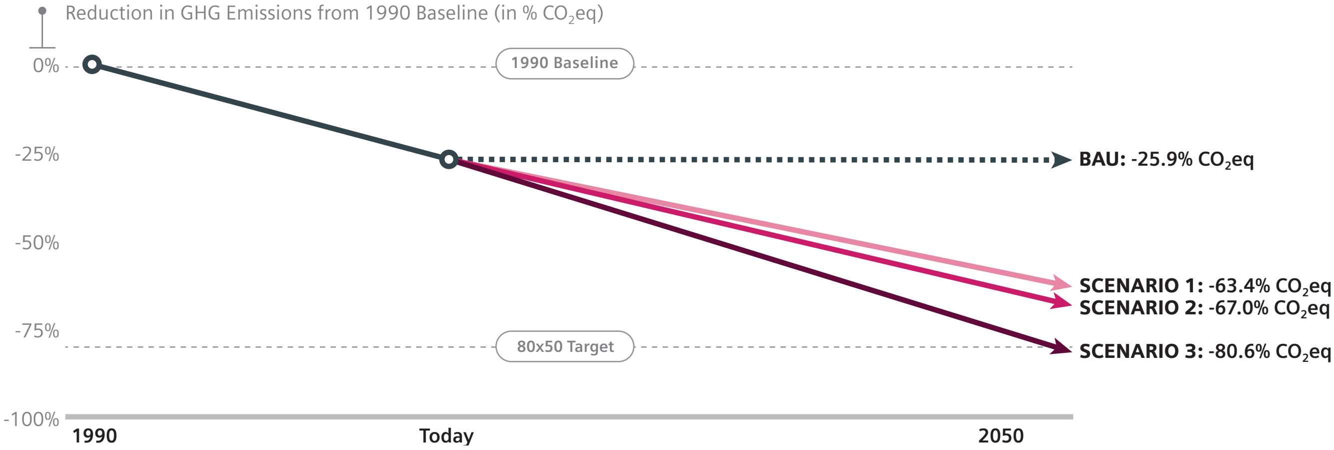


Source: CyPT Model

The Big Numbers

The proposed infrastructure scenario would reduce annual CO_2eq emissions 80.6% from the 1990 baseline. Operating and capital expenditures between today and 2050 total roughly $51 billion, and investments in 34 buildings and transport technologies would generate more than 420,000 full-time equivalent jobs (FTEs), with an FTE defined as the amount of work done by one full-time employee in a year. Although economic impacts apart from jobs creation were not calculated, implementation of energy, buildings, and transport technologies would certainly have positive ripple effects on the local economy, including inducing business investment and reducing citizens' cost of using the City's infrastructure.

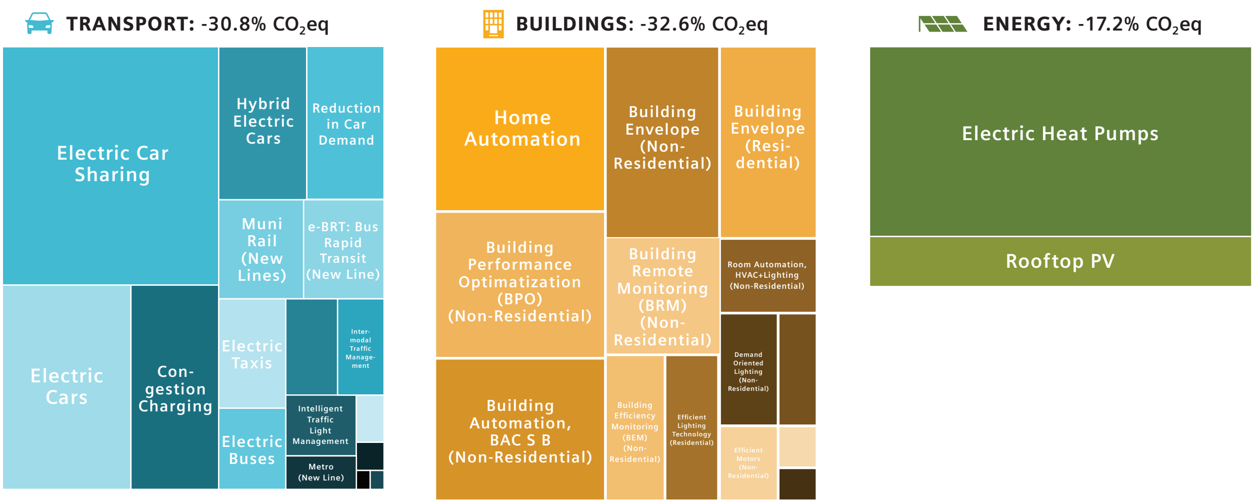
SCENARIO 3	COST PER PERSON	JOBS GENERATED
-80.6%	**$37,570**	**420,000**
Emissions Reduction by 2050	Capital and Operating Expenditures	Full-Time Equivalents



Source: CyPT Model, San Francisco Climate Action Strategy (2013)

High-Performing Technologies

The analysis identified three top-performing technologies in reducing CO_2eq emissions: electric car sharing (transport), home automation (buildings), and electric heat pumps (energy). Compared to our business-as-usual (BAU) scenario, electric car sharing offers the potential to reduce emissions by 0.5 million metric tons by 2050 - a 13% reduction from a single technology. At this scale, electric car sharing would also improve air quality by reducing local criteria emissions 20%, and generate roughly 90,000 full-time equivalents over the investment period.



Source: CyPT Model

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Background

For years, San Francisco has been recognized for progressive action on climate change and sustainability. For example, The Economist Intelligence Unit ranked San Francisco first on Siemens 2009 *Green City Index for North America*; the White House named the City a 2014 Climate Action Champion; and C40 Cities has given San Francisco multiple awards for its sustainability programs, among awards from other organizations.

Like other civic climate leaders, San Francisco is motivated to be a model for sustainable development in part because it must. The City's 2013 *Climate Action Strategy Update* details how climate change, through rising temperatures, will manifest in the Bay Area in 2050: Sea levels are expected to rise 11-19 inches, exposing some of the most valuable real estate in the world to systematic flooding, and parts of San Francisco International Airport (SFO) and Highway 101 will require dramatic investment for protection, or retreat. In addition, rising temperatures will increase energy consumption in the City's buildings, straining one of San Francisco's primary electricity sources, the hydroelectric power plants of the Hetch Hetchy system. In the absence of action, storm surge and heavy rain could inundate local streets, freeways, bridge approaches, CalTrain, Bay Area Rapid Transit system (BART), the Port of San Francisco, SFO, and wastewater infrastructure. All told, the effects of climate change threaten to cause $62 billion worth of infrastructure damage in the Bay Area.

In hiring the country's first Chief Resilience Officer, San Francisco recognized that adapting to climate change necessitates building resilience. The recently released *Resilient San Francisco: Stronger Today, Stronger Tomorrow* (2016) outlines San Francisco's strategy to plan, implement governance structures and policies, and invest in critical infrastructure to prepare the City for long-term challenges posed by climate change.

From the level of the inhabitant, to the utility, to the government, San Francisco's broad range of climate action programs is perhaps the best indication of the City's deep cultural and institutional understanding of and support for its journey towards deep carbon reduction. But as with any highly ambitious target, far more remains to be done.

While resilience and sustainability lend different perspectives to the climate challenge, their implications are strongly aligned; to paraphrase Hippocrates: first, do no more harm. For two decades, the City has recognized it is a contributor to climate change, and has set sustainability targets commensurate with its responsibilities:

» San Francisco was one of the first cities worldwide to set greenhouse gas (GHG) emissions reduction targets against 1990 levels of 80% by 2050 ("80x50"), with interim goals of 25% by 2017, and 40% reduction by 2025.

» San Francisco's strategy for meeting these climate action goals is simple: 0-50-100-Roots. The City aims for city-wide zero waste by 2020, 50% of all trips made by sustainable transportation modes, 100% of energy consumed sourced from renewables, and returning carbon to trees and soils through carbon sequestration.

San Francisco implements innovative sustainability programs and policies to support these targets.

» Since 2001, San Francisco Department of Environment has run a series of partnerships with the local utility, Pacific Gas and Electric Company (PG&E), to deliver energy efficiency services and incentives to businesses and multifamily buildings, prioritizing small and hard–to-reach businesses.

» In 2011, San Francisco was the fourth city in the United States to require commercial buildings to track and submit annual energy consumption data, and the second to require an energy audit or retrocommissioning every five years. Benchmarking enables a virtuous cycle of planning, management, and competition. Audits and retrocommissioning provide decision makers with specific, actionable proposals to make upgrades to save money and energy.

» Since 2006, the City has required US Green Building Council's Leadership in Energy and Environmental Design (LEED) certification for all municipal new construction and tenant improvements of 5,000 square feet and larger; in 2012 the bar was raised from Silver to Gold. Similar requirements apply to private sector new buildings and major renovations – both commercial and residential. As a result, 103 million square feet in San Francisco have been certified under the LEED program.

» In May of 2016, San Francisco launched the CleanPowerSF Community Choice Aggregation (CCA) program, which provides residents and businesses with electricity generated from a higher percentage of renewable sources than the grid baseline. Participants have the option to upgrade their electricity supply mix to 100% renewable energy, and also may opt out. CleanPowerSF is the fourth CCA program in California, and the ability to manage electricity sourcing is a major new lever enhancing San Francisco's capacity to realize the goal of 100% renewable energy by 2030. However, this report conservatively does not include the impact of CleanPowerSF, as we did not have a basis to project market uptake of the 100% renewable option, nor the pace at which the program may beat California's Renewable Portfolio Standard.

These programs are delivering dividends in reducing energy consumption and emissions.

» Since 2006, the San Francisco Energy Watch energy efficiency program, delivered by the Department of Environment in partnership with PG&E, has delivered more than 10,000 energy efficiency projects and cut participants energy expenditures by more than $40M per year.

» Amongst properties that have consistently complied with the Existing Commercial Buildings ordinance, energy consumption has decreased by approximately 8%.

» Of the 103 million square feet of properties certified under the LEED program citywide, 67% have achieved Gold or Platinum certification. Further, 89 million square feet of properties have received the Environmental Protection Agency's (EPA) ENERGY STAR® program certification.

» As a result of many factors – such as energy codes, energy efficiency investments, cleaner electricity supply, growth of the rooftop photovoltaics market, San Francisco's GHG emissions in 2012 were third party verified to have achieved a 23.5% reduction below 1990 levels. During this same time period, San Francisco's gross domestic product (GDP) increased 40% and the population increased by 11%, demonstrating that GHG reductions can be decoupled from economic growth, and even contribute to it.

From the level of the inhabitant, to the utility, to the government, San Francisco's broad range of climate action programs is perhaps the best indication of the City's deep cultural and institutional understanding of and support for its journey towards deep carbon reduction. But as with any highly ambitious target, far more remains to be done.

» While San Francisco is the second densest city in the United States, it is also the least affordable. Continued increases in density are controversial, yet the city faces a housing affordability crisis as job growth in both San Francisco and the greater Bay Area have dramatically outpaced residential construction. More than 62,000 housing units are in the development pipeline as of June 2016.

» Further, though California's goals for building energy codes are zero net energy for all new low-rise residential by 2020, and all new commercial & multifamily by 2030. San Francisco's historic row houses are not just an icon, but represent a largely untapped opportunity, as more than 50% of housing units were built before the energy code was enacted in 1978.

» While San Francisco has the second highest transit ridership in the nation, and 30% of households do not own a car, San Francisco also ranks as the second most congested city in the US, exceeded only by Los Angeles. This congestion evokes considerable costs, both from a financial and a health perspective. In 2014, car commuters in the San Francisco/Oakland area spent an average of 78 hours stuck in traffic. Combined with the amount of fuel wasted during this time – about 33 gallons per commuter – each San Francisco auto commuter incurred an average cost of $1,675 that year. As a consequence, annual health and social costs associated with heart attacks, strokes and premature death caused by breathing in motor vehicle emissions rose to $156 million for the San Francisco/Oakland area in 2015, and annual costs are projected to further increase to $188 million by 2030.

These challenges are infrastructure challenges. While the City has set extensive policies around energy, buildings, and transport to encourage long-term behavior change, the city as a whole will also have to make strategic investments in infrastructure. San Francisco collaborated with Siemens to understand the benefits and costs of changes to urban energy, buildings, and transport systems to realize these goals.


BikeShare
BayAreaBikeShare
Live
Musically

Context

Introducing the CyPT

Cities like San Francisco are constantly striving to test the cost efficiency of their current infrastructure solutions and explore new, more effective technologies that will help them meet their environmental targets.

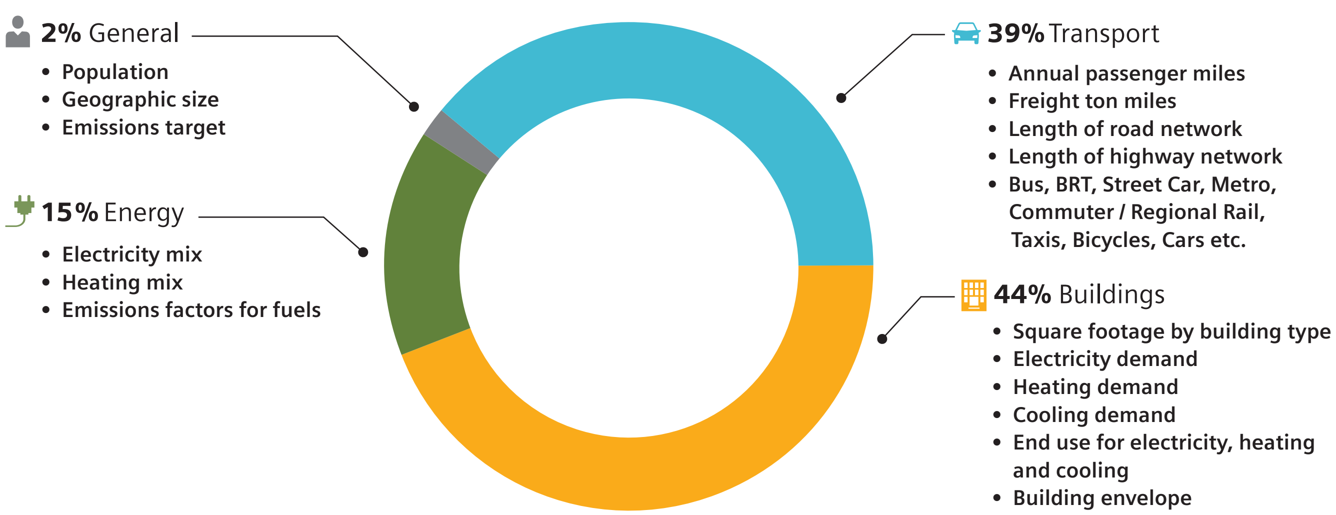
To help cities make informed infrastructure investment decisions, Siemens has developed the City Performance Tool (CyPT) to identify which efficiency technologies from the transport, building, and energy sectors best fit a city's baseline in order to mitigate CO_2eq emissions, improve air quality, and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

The CyPT model compares the performance of more than 70 technologies; only 60% represent technologies sold by Siemens. This provides an opportunity for Siemens to compare its portfolio with other climate change mitigation solutions, such as wall insulation and window glazing.

The CyPT model was configured with more than 350 inputs from San Francisco's transport, energy and buildings sectors, which include the supply mix of electricity generation, transport modalities and typical energy, travel and building space usage. We refer to this as a city's energy DNA, which we split into transport and buildings energy consumption. How high the energy use is and how it is split between the transport and buildings sector depends on how people use transport and building space as well as how the city generates its electricity and heating.

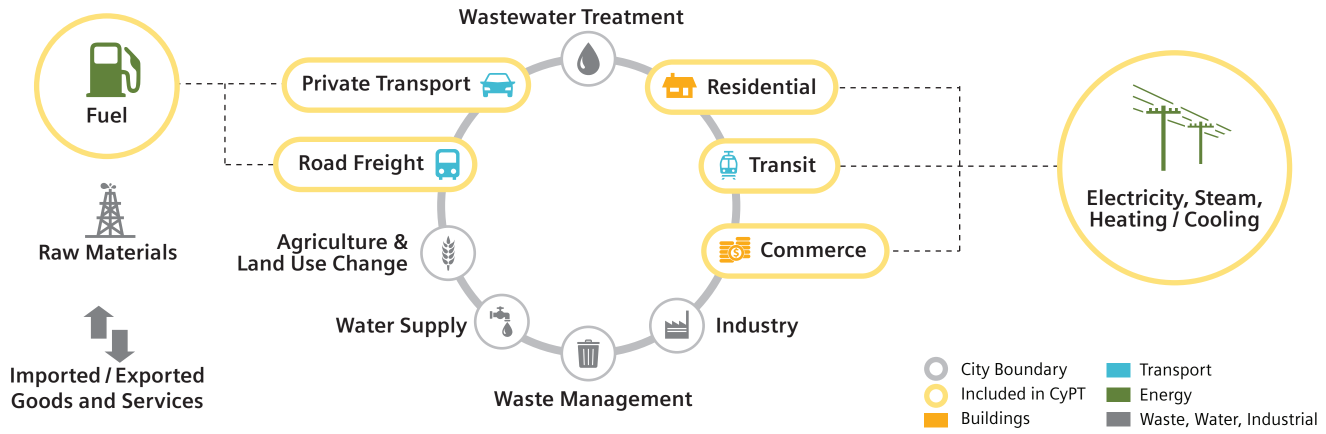
As soon as the DNA is calculated we estimate the CO_2eq emissions and PM10 and NOx levels. The model measures the impact of technologies on the CO_2eq, PM10 and NOx baselines of the city with CO_2eq accounting performed at scopes 1 and 2 for the building and transport sectors. This means that we have taken into consideration both direct emissions that are occurring within the city boundaries, such as from exhaust fumes, but also indirect emissions from the consumption of purchased electricity and heat. Scope 3 emissions look at the energy required to feed the electricity and heating generation in the city.

CyPT Inputs



To help cities make informed infrastructure investment decisions, Siemens has developed the CyPT to identify which efficiency 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.

Scope of Emissions Model



The model also tests the performance of each technology on two economic indicators. First, the total capital investment needed to deliver the technologies. Second, the total number of gross jobs that could be created in the local economy. These include installation, operation and maintenance jobs, which are calculated as full-time equivalent jobs of 2,080 hours per year. Manufacturing jobs are not accounted because some of these technologies may be produced outside the city's functional area, with no local benefits to the economy.

Starting with the city's population, energy performance, and emissions baseline, the model estimates the future impacts of technologies along the following 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 transport: Replacing existing technologies with more energy efficient technologies. For example, replacing traditional street lighting with LED and/or demand-oriented street lighting.
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 subway.

The CyPT model has so far been applied to assess the environmental and economic development opportunity space available to cities, such as Copenhagen, Vienna, London, Minneapolis and Nanjing. Siemens has collaborated with each city to identify infrastructure solutions that best fit the city's energy demand and production characteristics. For example, in Copenhagen, the CyPT analysis revealed that implementing 15 energy efficiency technologies in just 40 building owners' buildings could reduce annual emissions by 10%. The City of Copenhagen is now discussing ways to act on that recommendation, whether by piloting those energy efficiency technologies in a public building or by creating an incentive program to encourage building owners to retrofit. Whereas the Minneapolis report revealed that, apart from renewable energy, electric cars were the single most effective lever in reducing emissions. The City's Sustainability Department is now launching a series of inclusive conversations, and eventually a plan, to build an e-vehicle strategy for the city.

Why Perform a CyPT Analysis in San Francisco?

The CyPT analysis synthesizes the City's data and policy work from the past, and helps illuminate action required now and in the future. San Francisco has performed a number of modeling exercises around projecting impacts of policies, and has significant experience delivering incentives and financing for building retrofits, rooftop PV installations, and electric vehicle infrastructure development. It has a clear understanding of how those programs and policies might affect a future baseline, and it can gauge which technologies in the CyPT portfolio might complement those policies. However, unlike other studies the City has done, the CyPT analysis takes a comprehensive look at energy, buildings, and transportation to understand how investments can work synergistically across sectors. Moving across silos, and viewing infrastructure as a system, rather than as sections, will be essential parts of meeting the 80x50 target. The CyPT analysis also focuses solely on infrastructure and technology, complementing SFE's policy initiatives. Finally, the CyPT analysis relies on actions taken by both public and private sectors. Achieving 80x50 must be a collaborative effort. Residents, businesses, and local government – all will need to invest in technologies, such as electric cars, rooftop PV panels, home automation, and even wall insulation. The CyPT analysis guides these investments, helping residents, businesses, and governments alike to understand their responsibilities in moving towards smart, sustainable cities.

Achieving 80x50 must be a collaborative effort. Residents, businesses, and local government – all will need to invest in technologies, such as electric cars, rooftop PV panels, home automation, and even wall insulation. The CyPT analysis guides these investments, helping residents, businesses, and governments alike to understand their responsibilities in moving towards smart, sustainable cities.

A Collaborative CyPT Process

From the beginning, Siemens and SFE engaged with nine City-related agencies and more than 25 people in first setting the objectives for the analysis, then collecting data and choosing infrastructure scenarios, and finally, checking results against stakeholder feedback.

AGENCY	DATA INPUTS	PERSONNEL
SFE	GHG emissions, emissions factors, electricity use, heating consumption, stakeholder feedback	• Barry Hooper, Green Built Environment Senior Coordinator • Lindsey J. Hirsch, Green Built Environment Analyst • Sachiko Tanikawa, Municipal Climate Action Coordinator • Brian Reyes, Climate + Sustainability Analyst • Imma Dela Cruz, Energy Program Associate • Krute Singa, Commute Smart Program Manager • Suzanne Loosen, Clean Transportation Specialist • Bob Hayden, Clean Air/Clean Transportation Program Mgr
SFMTA	Public transit network, traffic lights, stakeholder feedback	• Eddie Tsui, Traffic Signal Engineer • Darton Ito, Manager, Long Range Planning & Policy • Stephan Schmidt, Associate Transportation Planner
SFCTA	Passenger miles traveled, stakeholder feedback	• Drew Cooper, Transportation Planner • Bhargava Sana, Transportation Planner
SF Planning	Building square footage by use, stakeholder feedback	• Scott Edmondson, Lead Planner • Michael Webster, GIS Analyst • Jon Swae, Lead Planner
PG&E	Electricity consumption, stakeholder feedback	• Kin Robles, Community Energy Manager • Amy Dao, Community Energy Manager • Armando Navarro, Community Energy Manager
SFPUC	Electricity consumption, street lights	• Jonathan Cherry, Project Manager
BAAQMD	PM10 + NOx emissions, stakeholder feedback	• Phil Martien, Air Quality Engineering Manager
SPUR	Stakeholder feedback	• Laura Tam, Sustainable Development Policy Director
CSE	Electric vehicles, stakeholder feedback	• Vanessa Minei, Clean Transportation Marketing Manager
CEC	Average fuel economy data, stakeholder feedback	• Gary Yowell, Associate Automotive Standards Engineer

*A full list of acronyms is available in Appendix V.

Early on in the CyPT analysis, SFE set three clear objectives. The objectives range from long-term to short-term, and reflect the complexity of San Francisco's infrastructure challenges.

» The first objective is to understand the technology pathways necessary to achieve 80x50.

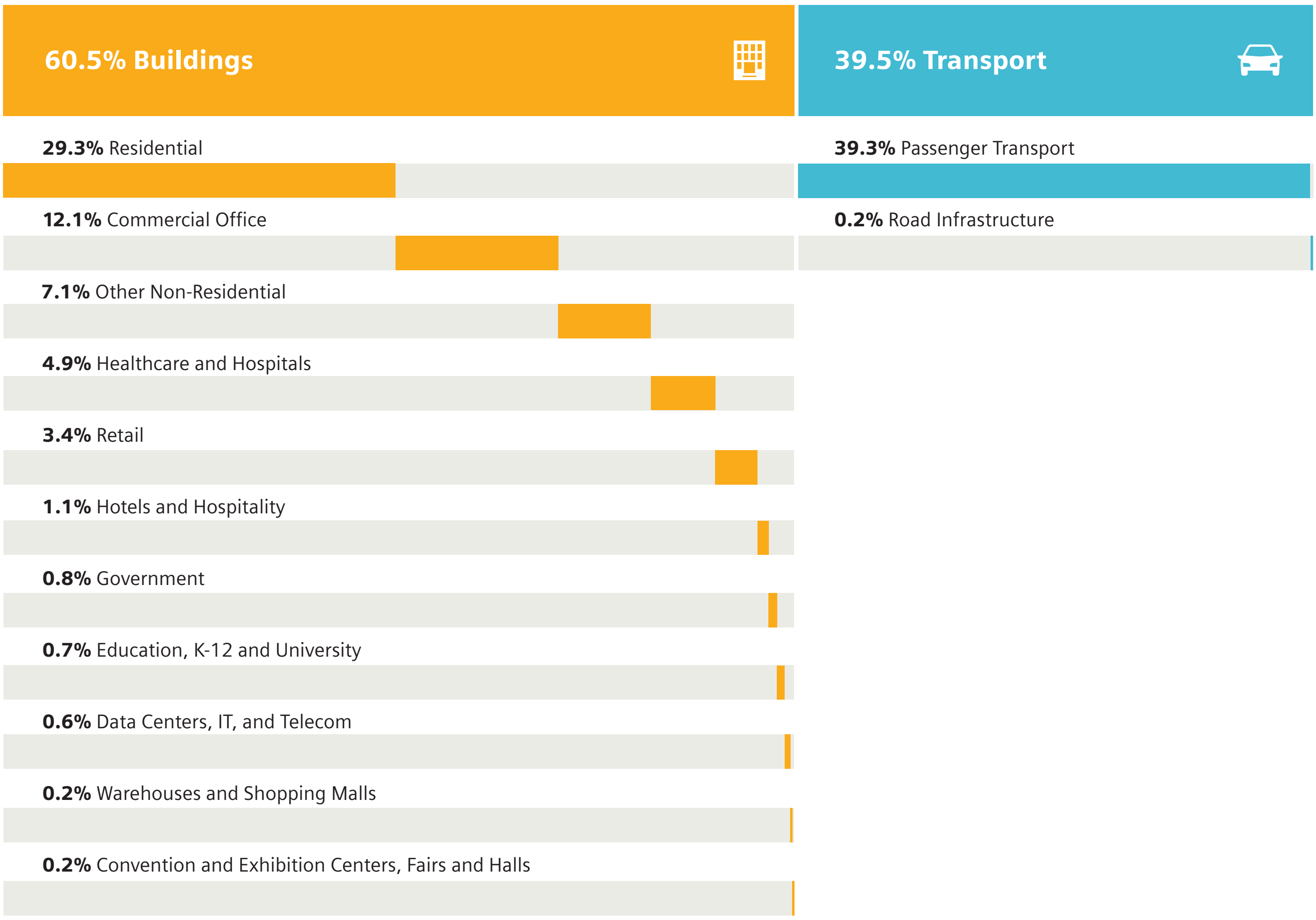
» The second is to understand the implications of San Francisco's goal to implement 100% renewable energy by 2030. This included energy efficiency and bold ideas, such as saturating rooftops with photovoltaics, and decarbonizing thermal energy supply transitioning from primarily fossil fuel 'natural gas' fired domestic water heating and space heating to delivering 80% of buildings heat consumption via electric heat pumps by 2050.

» The final objective is to inform the best package of measures to consider for requirement in 1-4 unit residential buildings at time of sale and/or date certain.

Once objectives were set, Siemens worked closely with SFE and the nine stakeholder groups to source the 350 inputs for the CyPT model. During a series of workshops and webinars, Siemens aligned with the City on creating an inventory of baseline and projected future data; San Francisco's infrastructure plans for the future; and its past GHG emissions inventories. This information formed the basis of a partial GHG emissions inventory, which would serve as the baseline for the CyPT analysis.

Breakdown of GHG Emissions in CyPT Scope

Within the CyPT model, residential and non-residential buildings constitute 60% of emissions, at 2.3 million metric tons. This compares to approximately 2.8 million metric tons documented in San Francisco's 2010 GHG inventory. Passenger transport (excluding the airport and ferry) constitute 40% of emissions in the CyPT scope, at 1.5 million metric tons. This compares to 2.2 million metric tons in the 2010 inventory. CyPT emissions calculations differ from the City's due to differences in counted activities, geographic scope, and emissions scope. Appendix IV contains a detailed summary of these differences.



Source: CyPT Model

Workshops and webinars with stakeholder groups also informed the CyPT technologies included in the analysis. Of the 73 technologies, San Francisco chose to model 34. The City also chose to model the technologies at aggressive, but feasible, implementation rates. For example, some cities have modeled the uptake of home automation in 100% of residential buildings by 2050. In San Francisco, stakeholders suggested that 100% implementation – of anything – was unrealistic, so implementation rates for buildings were capped at 80% of the building stock. Similarly, Muni provided estimates for the number of bikeshare bikes San Francisco might reasonably support. Appendix III gives detailed descriptions of what underlies these technologies.

Building CyPT Technology Implementation Rates, Today and 2050

BUILDINGS			**TODAY**	**2050**
Residential	LED Lighting	(% of existing building stock)	25%	80%
	Home Energy Monitoring	(% of existing building stock)	0%	80%
	Home Automation	(% of existing building stock)	0%	80%
	Building Envelope	(% of existing building stock)	53%	80%
Non-Residential	LED Lighting	(% of existing building stock)	50%	80%
	Demand-Oriented Lighting	(% of existing building stock)	5%	80%
	Building Efficiency Monitoring	(% of existing building stock)	0%	80%
	Building Performance Optimization	(% of existing building stock)	4%	80%
	Demand Controlled Ventilation	(% of existing building stock)	2%	80%
	Heat Recovery	(% of existing building stock)	0%	80%
	Building Envelope	(% of existing building stock)	50%	80%
	Building Automation, BACS B	(% of existing building stock)	22%	80%
	Efficient Motors	(% of existing building stock)	5%	80%
	Room Automation, HVAC+Blinds+Lighting	(% of existing building stock)	0%	80%
	Building Remote Monitoring	(% of existing building stock)	0%	80%

Ultimately, the City's stakeholder groups decided to use the CyPT to model three infrastructure scenarios, which would help the City test its stated objectives.

Transport CyPT Technology Implementation Rates, Today and 2050

TRANSPORT			TODAY	2050
Public	Electric Buses	(Share of Fleet)	36%	100%
	BART - New Lines	(Total # of Lines)	4	6
	MUNI Rail - New Lines	(Total # of Lines)	6	10
	e-BRT (Bus Rapid Transit) - New Lines	(Total # of Lines)	0	8
	MUNI Rail - New Vehicles	(Share of Fleet)	0%	100%
	Bike Lanes	(Miles)	33	275
	Bikeshare	(# of Bikes)	350	7,000
	Public Transport - E-Ticketing	(Share of total ticketing)	70%	100%
Private	Reduction in Car Demand	(Shift in person miles from cars to all other modes equally)	0%	20%
	CNG Cars	(Share of Fleet)	0%	1%
	Electric Cars	(Share of Fleet)	1%	20%
	Hybrid Electric Cars	(Share of Fleet)	0%	60%
	Electric Taxis	(Share of Fleet)	0%	100%
	Electric Car Sharing	(Total # of Shared eCars)	200	20,240
	Congestion Charging	(% Reduction in Road Traffic)	0%	15%
Infrastructure	Eco-Driver Training & Consumption Aware-ness	(Participation of Eligible Drivers)	0%	8%
	Smart Street Lighting	(Share of Lights)	0%	100%
	Intelligent Traffic Light Management	(Share of Lights)	40%	100%
	Intermodal Traffic Management	(Share of Integrated Users)	30%	100%

Scenarios

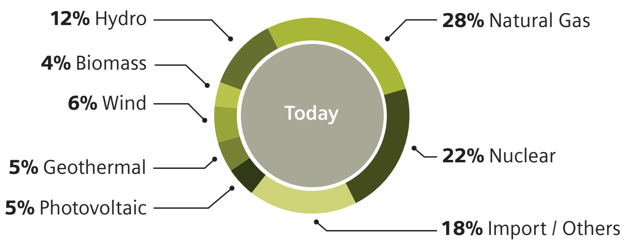
Between Today and 2050

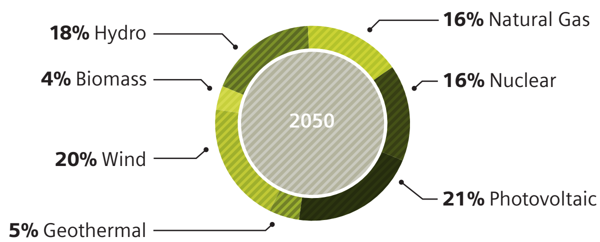
Establishing three CyPT scenarios meant reconstructing present day emissions as a baseline in the CyPT model and projecting out to 2050. These calculations reflect the current infrastructure complexity of San Francisco, and incorporate expected changes in the future.

Like some other cities in the U.S., San Francisco relies on multiple electric utility providers. Unlike many other cities in the U.S., San Francisco's two electric utilities, PG&E and SFPUC, produce vastly different emissions per kilowatt hour of electricity delivered. Relative to most large U.S. utilities, PG&E supplies

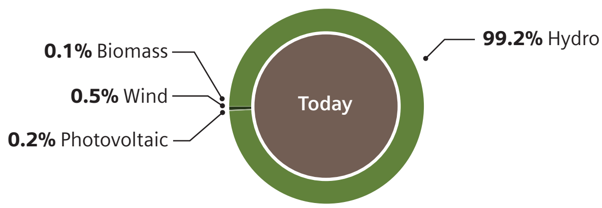
PG&E vs **SFPUC**

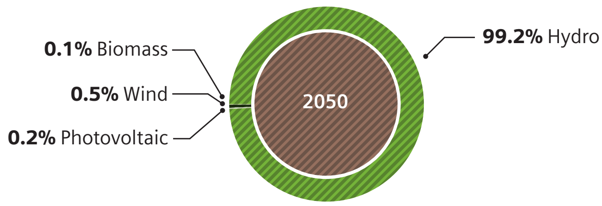
ELECTRICITY MIX





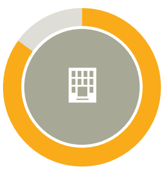
ELECTRICITY MIX





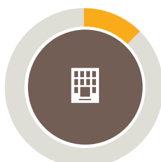
NON-RESIDENTIAL BUILDING STOCK USING PG&E ELECTRICITY

86%
(209.3 million ft²)



NON-RESIDENTIAL BUILDING STOCK USING SFPUC ELECTRICITY

14%
(33.3 million ft²)



TRANSPORT OPTIONS USING PG&E ELECTRICITY

BART | Electric Cars | Electric Car Share

TRANSPORT OPTIONS USING SFPUC ELECTRICITY

Muni Rail | Muni Bus | eBRT (Bus Rapid Transit)

Siemens applied the CyPT to three infrastructure scenarios, which reflect San Francisco's infrastructure complexity and expected changes, as well as the City's ambition to revamp energy, buildings, and transport sectors to be almost emissions free.

relatively clean power, yet electricity from SFPUC power is virtually emissions-free. The figure on the previous page demonstrates how the CyPT model connected city activities to the proper electricity source, in order ensure the savings estimated from a given action are as accurate as possible.

The City identified three key changes between today and 2050 that would affect the CyPT model's baseline.

» Population Growth

The Bay Area Council Economic Institute estimates San Francisco's population growth between today and 2040. Extending its estimates to 2050, we projected that the City's population would grow from ~850k residents today, to 1.4 million in 2050. This is a growth rate of 60%, and if accurate, will mean that the city's density will grow from 18,080 people per square mile today to 28,965 people per square mile in 2050. In city terms, that's like growing from the density of modern-day Istanbul to the density of Beijing – all in under 40 years.

» Change in living space size

Given the increased density of the city, living spaces are expected to decrease in size. Residential units today are on average 1,280 square feet. In the future, we predict that new residential units will be on average 1,158 square feet, a nearly 10% reduction in size. This means that, if energy codes continue to tighten, and even if people continue to consume the same amount of energy per square foot (e.g., Energy Use Intensities or EUIs remain the same), the reduction in average unit size equates to an automatic reduction in overall energy use in the new, smaller units.

» Renewable Power Standards (RPS)

California has stringent policies around renewable portfolio standards, and the City of San Francisco is pushing those standards by setting the ambitious target of having 100% renewable energy by 2030. To simulate how PG&E might comply with those standards, we assumed that PG&E's electricity mix is 86% clean in 2050, with only 14% of electricity supplied by natural gas fired generation.

Importantly, the CyPT baseline did not include San Francisco's Community Choice Aggregation program CleanPowerSF. CleanPowerSF will increase renewable energy supply by purchasing cleaner electricity, and automatically enrolling residents and businesses across the city to receive power from a higher percentage of renewable energy sources than the grid baseline. While this program significantly enhances San Francisco's capacity to realize the goal of 100% renewable energy by 2030, we did not have a basis to project market uptake of the 100% renewable option, nor the pace at which the program may beat California's Renewable Portfolio Standard. Therefore this study conservatively does not project impacts from the CleanPowerSF program. Similarly, while San Francisco was not the ultimate winner of the recent U.S. Department of Transportation's Smart Cities Grant competition, both public and private sector-led efforts to develop and deploy connected autonomous vehicle sharing (CAVS) are afoot, which could catapult the City towards more efficacious transportation while reducing emissions. Future studies should incorporate these and other initiatives.

The CyPT Baseline: Today in San Francisco

POPULATION

849,744

AVERAGE RESIDENTIAL UNIT SIZE

1,280 ft²

TOTAL NON-RESIDENTIAL BUILDING FOOTPRINT

2.42M ft²

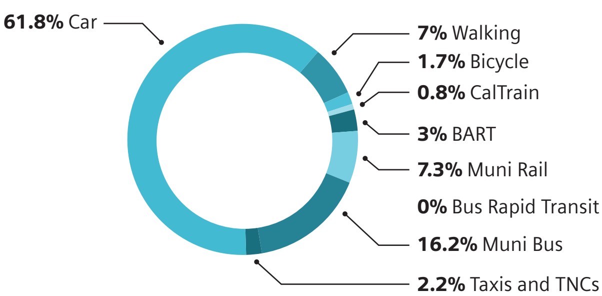
PG&E		SFPUC
1.5%	Government	19%
46.3%	Office	0%
0.3%	Data Centers	0%
0.8%	K-12 & Universities	31%
7.1%	Hospitals & Healthcare	7%
2%	Hotels, Hospitality & Leisure	8%
0%	Exhibition Halls & Convention Centers	9%
19%	Retail	0%
1.3%	Warehouses & Shopping Malls	0%
21.5%	Other Non-Residential	25%

AVERAGE MILES TRAVELED PER PERSON, PER DAY

20.6

Miles / Person / Day

% OF TOTAL PASSENGER MILES TRAVELED



Sources: Bay Area Economics Institute, SF Planning, SFE, PG&E, SFPUC, SFMTA, SFCTA

Three Infrastructure Scenarios

To reflect the City's objectives for this project, Siemens applied the CyPT to three scenarios which reflect San Francisco's infrastructure complexity and expected changes, as well as the City's ambition to revamp energy, buildings, and transport sectors to be almost emissions-free. Each scenario builds on the last: Scenario 1 examines a deep deployment of an extensive array of energy efficiency technologies that the CyPT is configured to analyze. Scenarios 2 and 3 consider the potential additional greenhouse gas emissions reduction from widespread distributed renewable energy development and electrification of thermal energy supply, which appear necessary in order to meet the city's goals and responsibilities for a sustainable future.

Scenario 1
In the first scenario, we modeled the impacts of 15 building technologies and 19 transport technologies on San Francisco's emissions baseline. The figure in the previous section displays those technologies and their implementation rates.

Scenario 2
In the second scenario, we modeled the impacts of the 34 technologies, plus systematic development of distributed solar electricity citywide. Based on consultation with SFE, we estimated that 776,600,000 kWh/year of electricity could be produced by rooftop PV panels in 2050. This distributed clean electricity was applied to offset electricity supplied by PG&E via the grid.

Scenario 3
In the third scenario, we modeled the impacts of the 34 technologies, the effects of distributed renewable energy, and market adoption of electric heat pumps. We assumed that by 2050, 80% of building heating consumption and domestic water heating currently supplied by natural gas would be generated by electric heat pumps. Market adoption of electric heat pumps was applied to both PG&E and SFPUC customers.

Results

Siemens and the City analyzed the CyPT results for individual technologies and for the three infrastructure scenarios. As mentioned previously, the CyPT model calculates the proposed technologies' impacts between today and 2050 on reducing carbon emissions, improving air quality, and creating jobs. Of the four CyPT indicators, CO_2eq emissions and jobs (full-time equivalents) were the two Siemens and the City prioritized when determining technology effectiveness.

Market adoption of electric heat pumps is the single most impactful lever considered in this analysis. It compounds the effects of the building and transport technologies and takes advantage of the ambitious deployment of distributed renewable energy, reducing CO_2eq emissions by an additional 14 percentage points (from 67.0% under Scenario 2 to 80.6% under Scenario 3). Within this analysis, San Francisco would not reach the 80x50 goal in the absence of a transition to electric heating. As the emphasis of the CyPT model is prioritization among efficiency technologies, it was outside the scope of analysis to estimate the economic and air quality impacts of rooftop solar and electrification of thermal supply, but we observe that heat pumps are generally cost-effective at time of natural replacement today, and similarly the installed cost of rooftop PV declined 55% in California between 2009-2014.[1]

Individual Technology Impacts

When viewed individually, a few key technologies emerged as the most cost efficient and best at reducing GHG emissions, improving air quality, and creating jobs.

In the buildings sector, the efficiency levers with the best performance regardless of electricity supplier are: home automation (3.9% overall reduction in annual CO_2eq emissions from 2050 BAU); building performance optimization (3.5% reduction); non-residential building automation, BACS B (3.4%); non-residential building envelope (wall insulation and window glazing, 3.0%); and residential building envelope (2.6%).

Most major cities, San Francisco included, have policies to incentivize building automation in new commercial, mixed-use, and multi-family residential structures. But the key to success in reducing energy consumption from buildings will be to extend automation to existing buildings today. This could mean incentivizing investment in building automation at the time of natural replacement for building appliances. It might also mean using the optimization of performance of existing buildings as an interim step before moving to full automation.

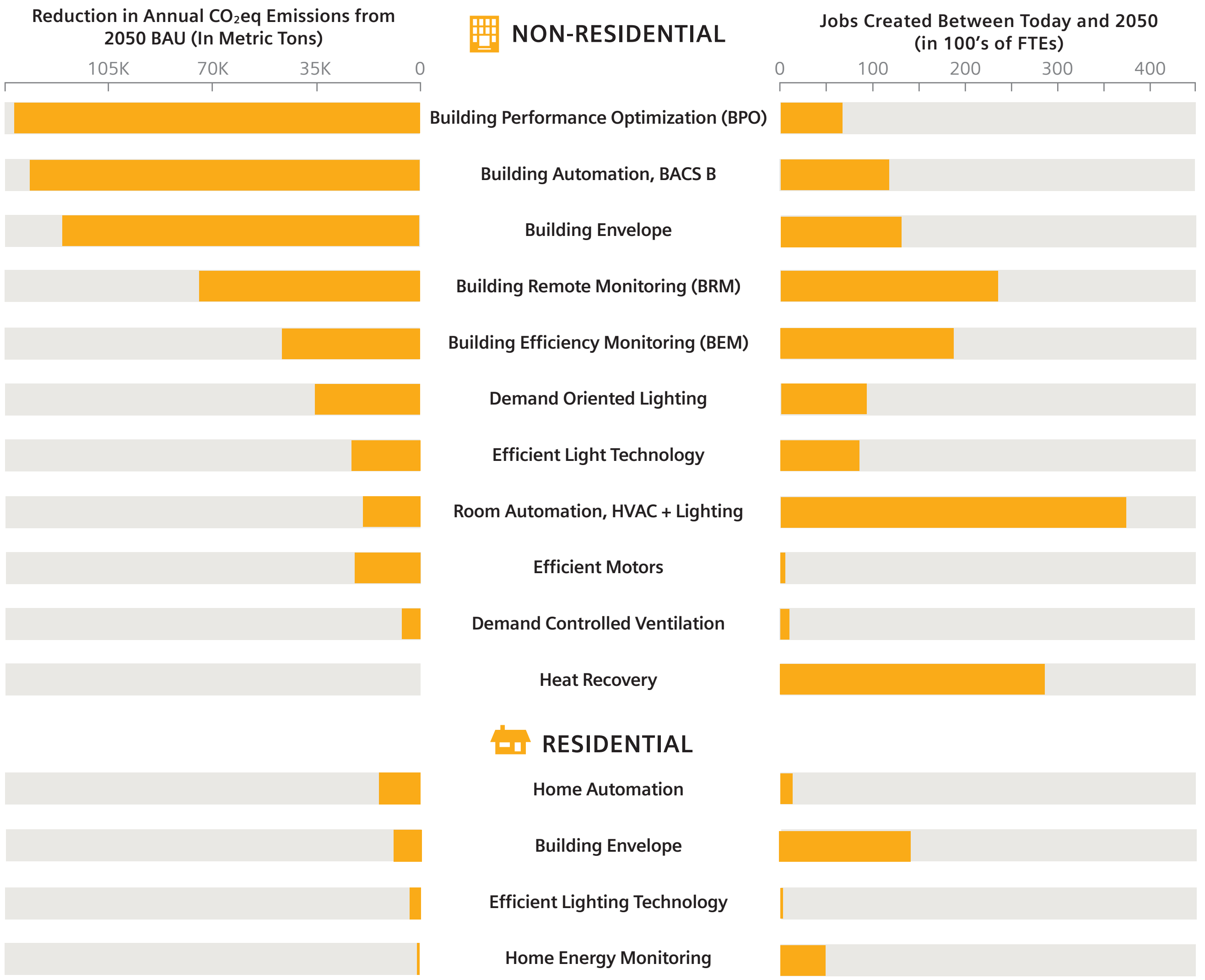
Building automation reduces energy consumption for all electrical appliances and for space heating. In technology terms, the CyPT lever Building Automation simulates installing sensors to determine how much heating/cooling is needed in a room, as well as whether lighting and appliances should be turned on or off. These sensors are tied to a control unit, which sends a remote signal to actuators that automate temperature, lighting, and ventilation adjustments. Non-residential Building Performance Optimization is based on a centralized monitoring system with real-time measurement of energy consumption and environmental conditions. The Building Envelope refers to installing wall insulation (expanded polystyrene) and double/triple-glazed window panes in the existing building stock. Wall insulation improves a building's U-value, reducing heat losses during the winter and heat gains during the summer by up to 90%.

Provided that the decarbonization of electricity supplies continues as projected, and building envelopes

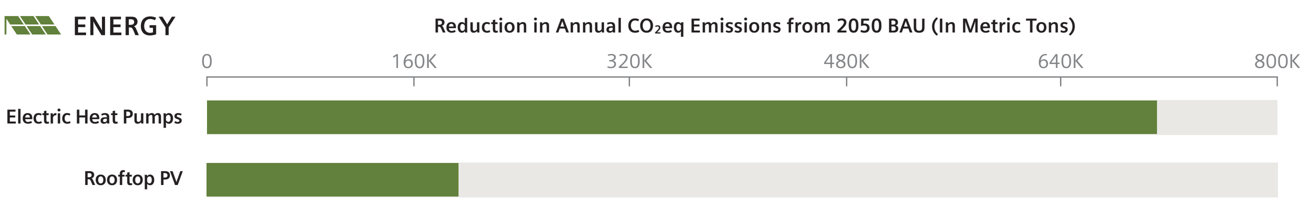
1 LBNL (2015) Tracking the Sun VIII, Installed Price of Residential and Non-Residential Photovoltaic Systems. https://emp.lbl.gov/sites/all/files/lbnl-188238_1.pdf

Under Scenario 1, CO_2eq emissions in 2050 reduce to 1.94 million metric tons, a 63.4% reduction from the 1990 baseline. In Scenario 2, emissions reduce further to 1.75 million metric tons, a 67.0% reduction. Under Scenario 3, emissions reduce to 1.03 million metric tons, an estimated 80.6% reduction from the 1990 baseline.

Building Lever Results: CO_2eq Emissions and Full-Time Equivalents

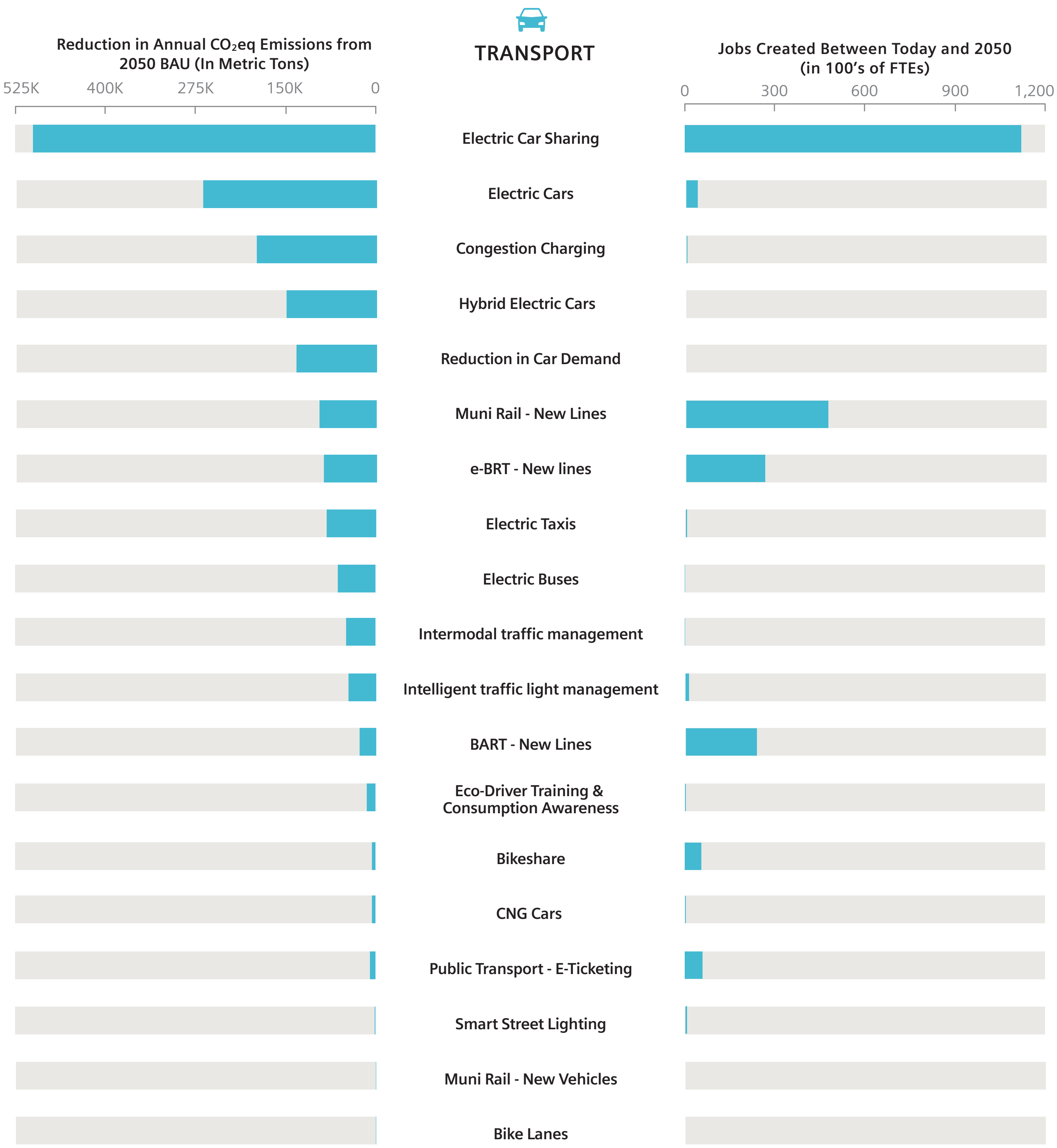


Energy Lever Results: CO_2eq Emissions



continue to improve, electrification of heating and water heating represents an additionally compelling opportunity. In Scenario 3, widespread adoption of heat pumps afforded a 14% reduction in emissions. Though economic and air quality implications of electrifying thermal loads are outside the scope of this analysis, we observe that nearly all thermal appliances will require replacement by 2050, generally multiple replacements, and electrification at time of natural replacement will be the most cost-effective approach.

Transport Lever Results: Full-Time Equivalents and CO_2eq Emissions



Market uptake of energy efficiency technologies and of electric heat pumps will have different effects on customers served by PG&E and SFPUC. Because electricity provided by SFPUC is virtually emissions-free, moving to electric heating in buildings served by SFPUC could reduce building-level CO_2eq emissions by up to 80%. By comparison, moving to electric heating in buildings served by PG&E could reduce building-level CO_2eq emissions by 60% from the 2050 BAU, if rooftop PV power is also adopted. Bottom line, there is a 20 percentage point difference in the impact of adopting electric heat pumps in commercial and residential buildings, which is entirely attributable to the differences between PG&E's and SFPUC's electricity grid mixes. Having a higher percentage of renewable energy in the grid mix compounds the effects of investing in building technologies, whether those technologies are aimed at energy efficiency or at electrification of heating.

In the transport sector, electric car sharing, electric cars, and Car & Motorcycle – City tolling (congestion charging) were the top three levers. These levers improve the efficiency of transport modes powered by liquid fuels and PG&E electricity, thereby reducing emissions from those modes.

CyPT technologies that affect transport modes with low or no emissions – e.g., walking, cycling, and PUC-powered transport modes, such as new eBRT lines, bikeshare, and new Muni Rail lines – appear to have no impact when looking solely at emissions. But investments in these technologies are essential to increasing public transit mode share and enhancing multi-modal transport. According to estimates based on SF-CHAMP, today, cars and taxis are 64% of the mode share (measured as a percentage of total passenger miles traveled for all trips). When all 19 transport levers are applied, car/taxi mode share drops to 37% of the total. Mode share for BART increases from 3% to 11%. Mode share for buses (including for new BRT lines) increases 9 percentage points, from 16% to 25%. And mode share for MUNI Rail increases from 7% to 14% of the total. Expanding the public transit network, coupled with setting limitations on private transport to discourage unnecessary driving, have huge implications for shifting mode share from 36% of miles traveled via sustainable modes to 63% in 2050.

Cross-Sector

When results were compared across sectors, four key technologies emerged as the most cost efficient and best at reducing GHG emissions, improving air quality, and creating jobs: electric heat pumps, electric car sharing, electric cars, and congestion charging.

Top Performing Technologies Across Sectors

COST EFFICIENCY*	GHG REDUCTION	AIR QUALITY IMPROVEMENT	JOB CREATION*
Congestion Charging	Electric Heat Pumps	Electric Car Sharing	Electric Car Sharing
Electric Taxis	Electric Car Sharing	Electric Buses	Muni Rail (New Lines)
Intermodal Traffic Management	Electric Cars	Electric Cars	Room Automation, HVAC + Lighting (Non-Residential)
Eco Driver Training & Consumption Awareness	Rooftop PV Panels	Hybrid Electric Cars	Heat Recovery (Non-Residential)
Electric Cars	Congestion Charging	Muni Rail (New Lines)	eBRT (New Lines)

* Job creation and cost efficiency were not estimated for electric heat pumps and rooftop PV

Electric Heat Pumps

Market adoption of electric heat pumps for 80% of citywide heat consumption is the single most impactful lever considered in this analysis. Given that San Francisco is in a heating climate, air-source heat pumps could be an energy-efficient alternative to moving warm air from outdoors to indoors during cold days. Further, thermal electrification actually compounds the effects of the building and transport technologies and takes advantage of the ambitious deployment of distributed renewable energy, reducing CO_2eq emissions by an additional 14 percentage points (from 67.0% under Scenario 2 to 80.6% under Scenario 3). Future studies should look at the feasibility of such a widespread shift in heating, estimating how much thermal electrification would cost compared to natural replacement, as well as who would bear those costs.

Electric Car Sharing

The CyPT model projects expanding San Francisco's car sharing systems from 200 vehicles today to 20,240 (fully electric vehicles) in 2050. As with buildings, switching from fossil fuel energy supplies to San Francisco's relatively clean electricity supply is a major opportunity, which makes electric car sharing the second most impactful lever in terms of reducing GHG emissions from transport.

As defined by the model, the electric car sharing system would be point-to-point, allowing individuals to rent eCars for short periods of time and drop them off in designated zones throughout the city. This means not only that individuals could use the eCars for short trips where transit is not available, but also that the eCar system would provide first-mile/last-mile connections to public transit. Although not explicitly covered by the model, eCars could also be launched as shared, electric, and connected vehicles, meaning that each car would serve multiple people and draw from (and potentially feed into the grid), and connect to traffic management infrastructure. This would support the vision San Francisco articulated in its bid for the U.S. Department of Transportation's Smart Cities Grant, which outlined the City's move towards a new transport paradigm that includes SECAVs (or shared, electric, connected, and autonomous vehicles).

Studies by University of California – Berkeley Professor Susan Shaheen estimate the impacts of conventional shared vehicles: each shared car results in 4-13 fewer cars on the road; reduces average mileage traveled by car by 16-41%; and shifts mode share from private cars to sharing cars and public transport. eCars have the added benefit of no local tail pipe emissions, so there are not only fewer cars on the road, but cleaner cars. Costs for the electric car sharing lever include the costs of the cars, plus the costs of charging stations. Because the CyPT model estimates job creation based on the level of investment, the roughly $9 billion investment for the eCar sharing system is estimated to generate roughly 115,000 FTEs between today and 2050 – or $80k in investment per FTE.

Supporting deployment of more than 20,000 electric car share vehicles would require both development of charging networks – where San Francisco and its utilities are regional leaders – and, perhaps more challenging, redoubled effort to ensure shared electric vehicles are ubiquitous and convenient to both pickup and release back to the shared pool in a manner that reflects the full set of shared vehicle use cases. The City's first foray into electric car share was unfortunately short lived. In 2012, BMW launched DriveNow service in San Francisco, expanding to the US from its initial base in Berlin, Munich, Dusseldorf, Hamburg, London, and Vienna. In the European cities, DriveNow was predicated on an ability to pick up and drop off vehicles anywhere in a participating city, supported by an annual pass (paid for by DriveNow) that allowed the vehicle to park in almost any public stall. This approach was incompatible with San Francisco's regulations for parking and car sharing, which designates specific parking spaces for car sharing but is only compatible with round trip or peer-to-peer car sharing services. In 2015, DriveNow withdrew from the San Francisco market.

Electric Cars

Far from being competitive, market adoption of electric cars would in fact support implementation of an eCar sharing scheme. The model projects that 20% of all cars in San Francisco will be fully electric in 2050, with 60% of the total fleet being hybrid electric. Although the model is not sophisticated enough to account for all of the synergies between eCar sharing and electric car levers, there could be many. First, private electric cars could share some of the same charging infrastructure as eCar sharing cars, thus cutting down on costs. Further, the size of the private vehicle fleet will shrink as more people give up their cars and shift to eCar sharing, which would only compound the technologies' impacts on GHG mitigation.

Congestion Charging

The congestion charge modeled for the San Francisco CyPT analysis targets a 15% reduction in road traffic. Although the CyPT model does not specify a certain geography to which the congestion charge applies, or a specific price, the model assumes that the charge would be high enough and broad enough to disincentivize driving. It also assumes that the travel demand displaced from cars is replaced by all other modes on non-motorized or public transport – e.g., the congestion charge lever simulates a large mode shift towards transit.

Like with the electric car sharing lever, the projected shift in travel demand from cars and taxis to cycling, walking, and public transit assumes that the latter are desirable options. Though this report may seem to promote electrification of motorized transport as the priority options for reducing GHG emissions from transport, the opposite is true. Yes, in order to reach its sustainability targets, San Francisco will need to embrace electric vehicles – every city will. But by the same token, cities can greatly reduce emissions, and improve congestion, by inducing mode shift. To do so, they will have to improve and expand service, building new types of transit (like BRT) and creating safe streets for pedestrians and cyclists.

The CyPT model estimates that adoption of 19 transport technologies will shift mode share from 36% of miles traveled via sustainable modes today to 63% in 2050. This is the level of transit adoption we're already seeing in major cities in Europe and Asia, and those cities are only continuing to build out their public transit. San Francisco could do the same, looking to London as an example of a city that used a combination of sticks and carrots to move people out of their cars and into public transit.

One lever that would induce mode shift that the CyPT was not equipped to address is the consideration of a second tunnel to shuttle BART trains from the East Bay to Downtown San Francisco. Constructing an additional tunnel would undoubtedly create tons of jobs, not to mention double the capacity of the biggest inter-city mass transit mode in the Bay Area. As articulated in a paper by SPUR, building a second tunnel would have the added benefit of improving BART's reliability and resiliency, preventing single-tracking during natural disasters or unexpected mechanical failures and allowing all-night rail transit. Although we could not estimate the impacts of a second tunnel, we did look at automating BART trains to reduce headways to 75 seconds – a somewhat similar effect to constructing a new TransBay tunnel. This had the highest impact of any transport lever in inducing mode shift and one of the highest in creating jobs.

Scenario Results

Under Scenario 1, CO_2eq emissions in 2050 reduce to 1.94 million metric tons, a 63.4% reduction from the 1990 baseline. In Scenario 2, emissions reduce further to 1.75 million metric tons, a 67.0% reduction. Under Scenario 3, emissions reduce to 1.03 million metric tons, an estimated 80.6% reduction from the 1990 baseline. If San Francisco implements 34 building and transport technologies at aggressive, but feasible rates; develops 776,600,000 kWh/year of rooftop PV power, and electric heat pumps reach 80% market adoption, it can reach its 80x50 goal.

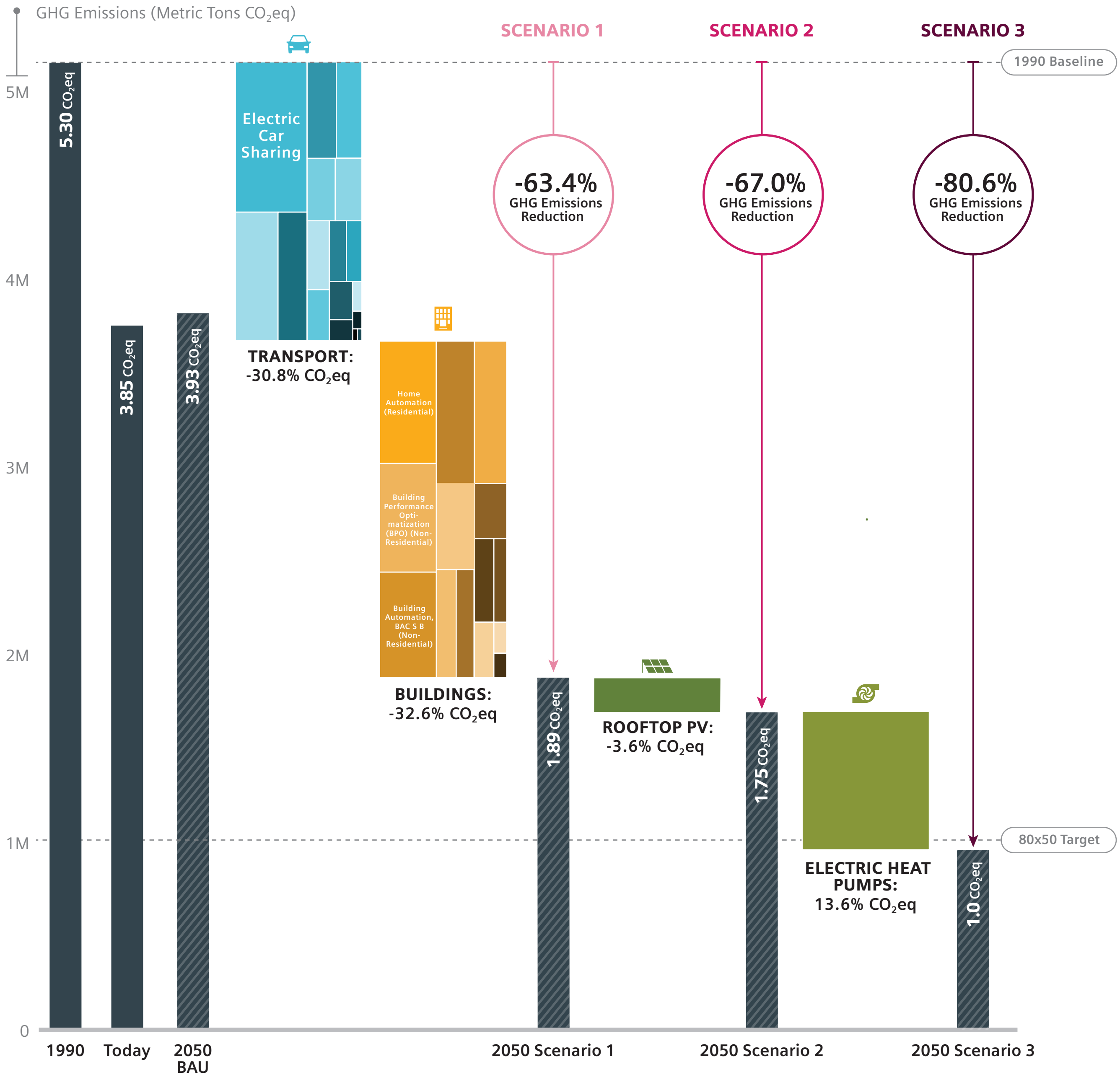
Apart from environmental indicators, the CyPT focuses on capital and operating expenditures for investing in new technologies, as well as gross FTEs generated by these investments. What the CyPT does not account for are paybacks to public and private sectors through energy savings, additional revenue streams in both transportation and on the grid, or natural replacement costs for defunct equipment. Especially given the lengthy observation period (between 2016 and 2050), natural replacement costs would very likely be incurred for most, if not all, of the sectors in scope. CyPT results therefore undersell the benefits of investing in these infrastructure scenarios by taking a partial view on their benefits. Future studies would do well to look beyond these economic and environmental indicators, and perhaps even estimate the marginal costs of investing in electrification, automation, and digitization. This would give a fuller depiction of San Francisco's gains from planning for a sustainable future.

With these considerations in mind, $51 billion in capital and operating expenditures for the 34 technologies over the 34-year investment period may not seem such a high price tag. Calculated on a per capita basis, $63 billion becomes roughly $37,570 invested per person between today and 2050. Per square foot, the 15 building technologies would cost an estimated $120. Per passenger mile traveled, the 19 transport technologies would require $5 of investment.

The $51 billion estimate includes most of the investments the public sector will need to make in infrastructure, such as eBRT or light rail. It includes some of the costs the private sector will need to incur, such as for building automation and envelope retrofitting. These figures do not include the installation of the rooftop PV panels or the adoption of electric heat pumps, which each entail significant costs and offer significant financial benefits. Though these technologies are not fully developed in the existing CyPT model, future analyses should integrate distributed renewables and electrification fully into the total cost-benefit analysis.

Over the 34-year time period, investments in energy efficient infrastructure (Scenario 1) are estimated to generate more than 420,000 full-time equivalent positions. That number includes all direct, indirect, and induced FTEs resulting from the installation, operation, and maintenance of the 34 buildings and transport technologies. It is a gross, not net, figure, meaning that, for example, a bus driver hired to drive a diesel-powered bus would be the same bus driver driving a new electric bus.

In Scenarios 1, 2, and 3, electricity consumption by buildings and transport drops from the 2050 business-as-usual case. In Scenarios 1 and 2, electricity consumption falls 30%, with consumption from buildings decreasing by 18% and consumption by transport increasing by 406%. Electricity consumption increases so precipitously, because mode share shifts from only 36% sustainable modes today to 63% in 2050. In Scenario 3, electricity consumption rebounds a bit, due to increased consumption from building heat pumps, but still reduces from the 2050 business-as-usual case. We do not estimate the financial or employment impact from accelerating development of distributed renewable energy and electrification of thermal energy supply, but there would be considerable savings both to residents and business owners as these technologies reduce energy consumption. Conversely, there would be increased revenues to the electric utilities from the transport sector, notably from electric cars, electrified bus rapid transit (eBRT), and electric carsharing.



Source: CyPT Model, San Francisco Climate Action Strategy (2013)

The London Experience

A Case Study on Congestion Charging

The City of London implemented its Congestion Charge Zone (CCZ) with two main objectives: to decrease congestion and to reduce pollution. The CCZ would also help the city garner revenues to be used to finance other essential transportation projects.

On the morning of February 17, 2003, motorists driving in a designated zone in central London began paying a fee to travel through the city's streets. Between 7am and 6pm from Monday to Friday, all vehicles had to pay a flat fee of £5 for driving in the congestion zone, a price that has since increased to £11.50. By the end of that first day, 57,000 motorists had paid the fee.

The £11.50 daily tariff associated with the CCZ allows drivers to enter, leave and re-enter the CCZ as many times as necessary throughout the day. Instead of implementing barriers and tollbooths, drivers register their Vehicle Registration Number (VRN) in a database. Cameras keep track of vehicles entering and exiting the CCZ, checking it against the database to verify if the congestion charge has been paid or if the vehicle is exempt (e.g. two-wheeled motorbikes and taxis). Drivers can pay the fee through an Auto-Pay system, online, by phone, text message or post. If the congestion charge is not paid, a monetary penalty is applied; penalties for a fee not paid range from £65 to £130 pounds, depending on the delay in payment.

Transport for London (TfL), the city's transportation authority, is in charge of both the CCZ and the LEZ. The agency is responsible for managing the database that allows the system to identify which vehicles are noncompliant with either the congestion charge or emissions standards. Information from the Driver and Vehicle Licensing Agency (DVLA), the Driver and Vehicles Standards Agency (DVSA), generic vehicle weight data typical of the make and model, and drivers and operators who have registered with the TfL is used to compile this database. TfL also levies and enforces any penalty charges against noncompliant drivers, and assigns the revenues garnered from both the CCZ and LEZ to other strategic transportation projects, such as a hybrid bus program and updating cycling highways.

Since the inception of London's CCZ, traffic entering the original charging zone has remained at a steady 27% below pre-charging levels in 2002. That means there are about 80,000 less vehicles entering the original CCZ every day. Bicycling has also increased significantly during this period, with cycling levels up 66% since the CCZ's inception. In 2014-2015, revenues collected from the congestion charge amounted to £257 million, which has been used to cover the costs associated with the CCZ and to finance other projects to improve London's transport network.

Conclusion

The San Francisco Department of the Environment set three clear objectives for its work with Siemens:

» Understand the technology pathways necessary to achieve 80x50.

» Understand the implications of San Francisco's goal to implement 100% renewable energy by 2030, including accelerated deployment of distributed renewable energy via rooftop photovoltaics and electrifying thermal energy supply.

» Inform the best package of measures to consider for requirement in 1-4 unit residential buildings at time of sale and/or date certain.

The analysis provides insights into all three.

» San Francisco can reach 80x50 in the buildings and transport sectors if it adopts 34 market-ready building and transport technologies; develops 776,600,000 kWh/year of rooftop PV power; and promotes market adoption of electric heat pumps for 80% of building thermal energy consumption.

» The model projects 68% of PG&E's electricity mix in 2050 will be supplied by California Qualified Renewable sources and large hydroelectric generation will supply an additional 18% for a total of 86% emissions-free power, and SFPUC will continue to supply 100% emissions free electricity. Under business as usual without considering the impacts of the 34 technologies, the additional PV, or the electric heat pumps, we estimate that annual CO_2eq emissions would drop 25.8% from the 1990 baseline.

» San Francisco, be bold. Market adoption of electric heat pumps is the single most impactful lever we modeled in the CyPT analysis. It compounds the effects of the building and transport technologies and the additional PV power, reducing CO_2eq emissions by an additional 14 percentage points (from 67.0% under Scenario 2 to 80.6% under Scenario 3). This analysis would not show San Francisco reaching 80x50 if not for the simulated transition to electric heating.

» After thermal electrification, home automation and the residential building envelope are the highest performers in reducing absolute CO_2eq emissions from buildings. However, residential efficient lighting technology (e.g., replacing conventional lighting with LED lighting) is the most cost efficient, measured in terms of reduction in annual emissions per dollar invested.

Future analyses could expand on this one by incorporating some of San Francisco's recently passed legislation, such as CleanPowerSF, and by looking towards future trends in technologies, such as autonomous vehicles, connected vehicles, or shared rides.

Next Steps

Analyses are much easier to write than to implement. When contemplating next steps to achieving a target as ambitious as 80x50, we have worked with cities to understand the short-, medium-, and long-term actions they must take to strategically invest in infrastructure. For San Francisco, this means combining carrots with sticks and outlays of capital with expansion of revenues, to build robust, multi-modal transport networks and a stronger, more resilient building stock.

Many of these investments will merit further discussion. For example, congestion charging has already proven to be successful in reducing congestion and transport emissions in many European cities, but it has yet to be installed in any U.S. city. Converting to electric heating may be costly, and residents and developers are likely to bear most of the initial costs. One electric car sharing project has already failed in San Francisco; a re-boot would require a re-tooling of project logistics and perhaps even project financing. We hope that the CyPT analysis sparks discussions about all of these technologies, ultimately leading to a series of short-, medium-, and long-term actions that will boldly take San Francisco to where no city has gone: 80x50.

Technology Pathway to 80 x 50

- Potential CO_2eq Reduction (in metric tons) from 2050 BAU
- Potential CO_2eq Reduction (%) from 2050 BAU
- Capital and Operating Expenditures between Today and 2050
- Full-time Equivalents Generated between Today and 2050

SHORT-TERM

332K	-8%
$6.7B	50K

STRATEGY	12 CyPT TECHNOLOGIES
Retrofit the exisiting building stock	Residential - Efficient Lighting Technology Residential - Building Envelope Non-Residential - Efficient Lighting Technology Non-Residential - Building Envelope
"Green" traffic infrastructure	Intelligent Traffic Light Management, Eco-Driver Training and Consumption Awareness, Smart Street Lighting, Electric taxis
Encourage mode shift	Public Transport (E-ticketing), MUNI Rail (New vehicles) Bay Area Bikeshare, Separated Bike Lanes

MEDIUM-TERM

1.2M	-30%
$22B	260K

STRATEGY	15 CyPT TECHNOLOGIES
Use retrocommissioning to transition to automation	Residential: Home Energy Monitoring Non-Residential: Demand oriented lighting Non-Residential: Building Efficiency Monitoring (BEM) Non-Residential: Building Performance Optimization (BPO) Non-Residential: Demand controlled ventilation Non-Residential: Heat recovery
Move towards a greener - and shared - car fleet	CNG cars, Electric cars, Hybrid electric cars, Electric car sharing
Incentivizecleaner modes of transportation	Congestion Charging, Intermodal traffic management
Build out the public transit network	MUNI Rail - New Lines, e-BRT - (Bus Rapid Transit) - New Lines

Technology Pathway to 80 x 50 (continued)

LONG-TERM

500K	-12%
$22B	110K

STRATEGY	8 CyPT TECHNOLOGIES
Embrace full building automation	Residential: Home Automation Non-Residential: Building Automation, HVAC + lighting Non-Residential: Room Automation, BACS B Non-Residential: Buiding Remote Monitoring (BRM)
Introduce policies that further encourage public transit use	Reduction in car demand
Complete public transit network to bolster regional growth	BART - New Lines, BART - Reduced Headway, Electric buses

ADDITIONAL ENERGY MEASURES

912K	-23%

STRATEGY	2 CyPT TECHNOLOGIES
Maximize rooftop PV panels*	
Convert to electric heating**	

TOTAL

2.9M	-74%***
$51B	420K

* Incremental benefit of installing rooftop PV panels, in addition to implementing building technologies.Costs and jobs not included in total.

** Incremental benefit of converting to electric heat pumps, in addition to implementing building technologies and installing rooftop PV panels. Costs and jobs not included in total.

*** An 80.6% reduction from the 1990 baseline.

Appendix I

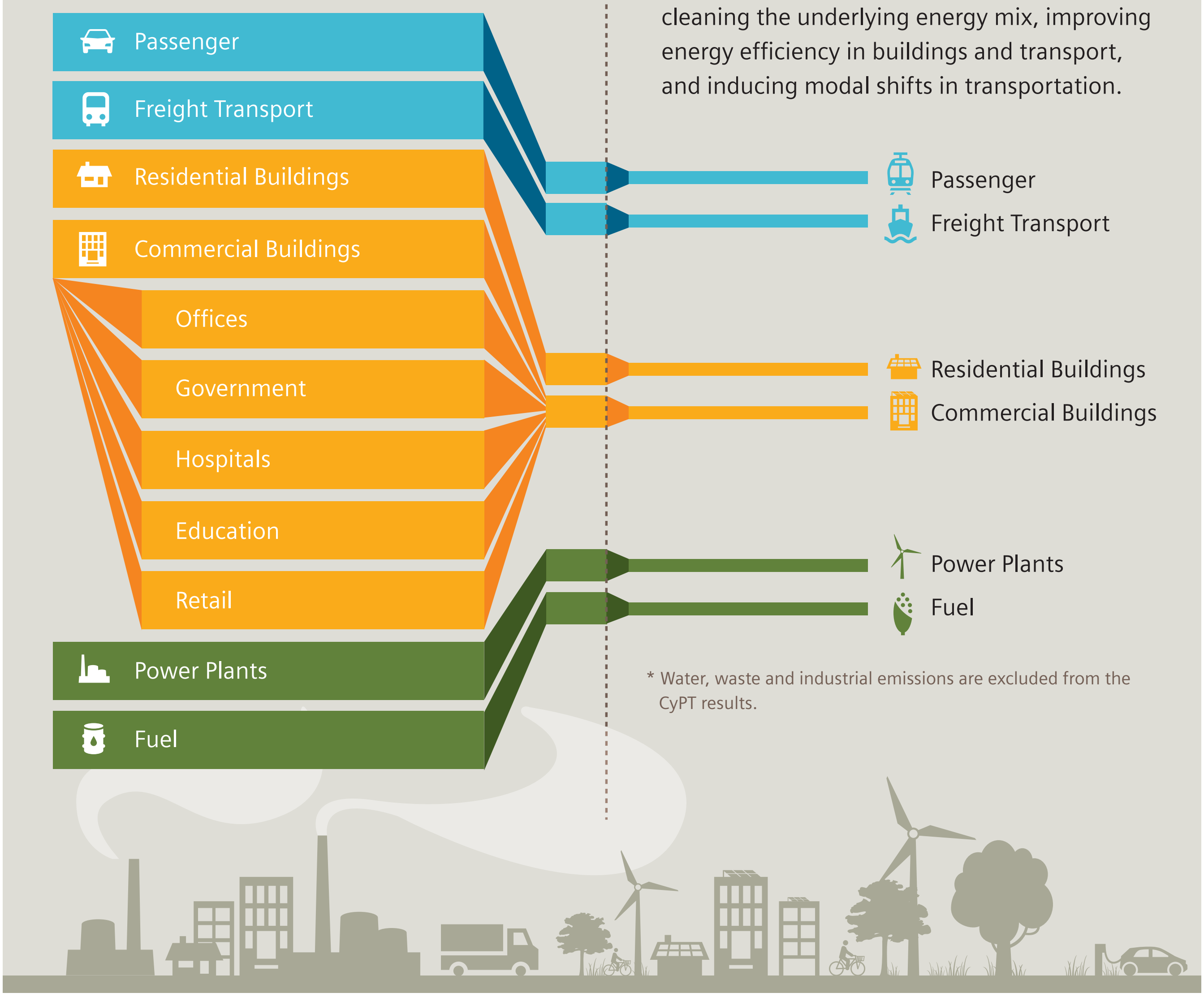
How the CyPT Model Works

STEP 1

Energy Mix Analysis
The CyPT works by using 350 city-specific data points to build an emissions baseline based on activities occurring within the city boundaries. It uses the 2012 GPC Protocol for Community-Wide Emissions to estimate emissions from residential and commercial buildings, passenger and freight transport, and energy consumption.

STEP 2

CyPT Results*
Once that emissions baseline is established, Siemens collaborates with a city to determine which of the 73 technologies and policy levers in the CyPT apply and at which implementation rates. Scenarios of infrastructure technologies at various implementation rates are then run through the CyPT model. Results of the model demonstrate how the CyPT levers reduce emissions by cleaning the underlying energy mix, improving energy efficiency in buildings and transport, and inducing modal shifts in transportation.



* Water, waste and industrial emissions are excluded from the CyPT results.

Appendix II

CyPT Indicators

The CyPT tracks technologies' impact on four indicators.

1. CO_2eq Emissions

CO_2eq stands for a carbon dioxide equivalency measure that allows for various greenhouse gasses (GHGs) to be expressed in terms of CO_2 as a common unit. Equivalency is determined by multiplying the amount of the GHG by its global warming potential (GWP), where GWP indicates how much warming a given GHG would cause in the atmosphere over a certain period of time (usually 100 years). For example, CO_2 has a GWP of 1, whereas methane (CH4) has a GWP of 25. Therefore, 1kg CH4 * 25 = 25kg CO2e.

2. NOx

Nitrogen Oxides (NOx) most commonly refer to nitric oxide (NO) and nitrogen dioxide (NO_2). Some level of NOx occurs naturally in the air, but NOx is predominantly caused by human activity that is harmful to the atmosphere, particularly the burning of fossil fuels. In urban settings especially, NOx emitted from vehicle emissions can cause significant air pollution.

3. PM10

Particulate matter 10 (PM10) describes very small liquid and solid particles floating in the air that measure only 10 microns in diameter (about 1/7th the thickness of human hair). These particles are small enough to breathe into human lungs and among the most harmful of air pollutants. PM10 has many negative health impacts once lodged in the lungs, and can increase the severity of asthma attacks, cause or worsen bronchitis, and weaken the body's immune system. The most common sources of PM10 include vehicle emissions, wood burning stoves and fireplaces, and dust from construction, landfills and agriculture.

4. Jobs (Full-time equivalents)

The CyPT measures the gross number of direct, indirect, and induced jobs created in the local economy by investing in CyPT technologies. These include installation, operation and maintenance jobs, which are calculated as full time equivalent jobs of 2,080 hours per year. Manufacturing jobs are not accounted for, because some of these technologies may be produced outside the city's functional area, with no local benefits to the economy.

Appendix III

CyPT Technologies

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 CO2e, PM10, and NOx related due to energy savings.
Residential / Non-Residential	Glazing	Applying double/triple glazed window made of two or three panes of glass and a space between them filled with air or insulating gases and 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 CO2e, PM10, and NOx related due to energy savings.
Residential	Efficient lighting technology	Significant electrical energy can be saved by replacing conventional luminaires by 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 CO2e, 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 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 lasting 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 CO2e, PM10, and NOx related due to electricity savings.

BUILDING LEVERS

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 CO2e, PM10, and NOx related due to electrical energy savings.
Non-Residential	Building Efficiency Monitoring (BEM)	Building Efficiency Monitoring provides real-time measurement of energy consumption and environmental conditions within a 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, CO2, temperature). Offering monitoring services and performance reports creating awareness and transparency and enable continuous improvement and reduction of overall energy consumption. Reduction of CO2e, PM10, and NOx related due to thermal and electrical energy savings.
Residential	Home Automation	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 CO2e, PM10, and NOx related due to energy savings.
Non-Residential	Building Performance Optimization (BPO)	(Share of Fleet)
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. CO2 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 CO2e, PM10, and NOx related due to electrical electricity savings.

BUILDING LEVERS

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	BACS Class C	Building Automation and Control System (BACS) are building technologies that can be installed in existing or new buildings. An Energy Class C building corresponds to a standard BACS, which includes: Networked building automation of primary plants, No electronic room automatic or thermostatic valves for radiators, No energy monitoring. Emission reduction is achieved from the electrical power utilized in the heating & cooling of buildings, water circulation, and emissions generated through the combustion process of fuel (renewable or fossil-based).
Non-Residential	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 CO2e, PM10, NOx are related to thermal and electrical energy savings.
Non-Residential	BACS Class A	Building Automation and Control System (BACS) are building technologies that can be installed in existing or new buildings. An Energy Class A building corresponds to a high energy performance BACS and Technical Building Management Systems (TBM). Class A BACS systems include: Networked room automation with automatic demand control, • Scheduled maintenance, Energy monitoring, Sustainable energy optimization
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 CO2 emissions. Adding variable speed drive technology will ensure motors only draw as much energy as is actually required. Reduction of CO2e, PM10, NOx are related to electrical energy savings.
Non-Residential	Room Automation HVAC	Room Automation provides demand-based control and monitoring of heating, ventilation, and air conditioning within individual zones. An in-built energy efficiency function identifies wasteful use of energy and encourages users to become involved in energy saving. Reduction of CO2e, PM10, NOx are related to electrical power utilized in the heating, ventilation and air-conditioning of a building.
Non-Residential	Room Automation HVAC+ lightingd	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 CO2e, PM10, NOx are related to electrical power

BUILDING LEVERS

Non-Residential	Room Automation HVAC+ lighting+ blinds	Room Automation provides demand-based control and monitoring of heating, ventilation, air conditioning, lighting and shading within individual zones. An in-built energy efficiency function identifies wasteful use of energy and encourages users to become involved in energy saving. Automated lighting and shading is designed to minimize heat gains yet maximize natural light. Reduction of CO2e, PM10, NOx are related to electrical power utilized in the heating, ventilation and air-conditioning, lighting and shading 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.
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.

TRANSPORT LEVERS

Passenger	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.
Passenger	New line – Metro	Number 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.
Passenger	New line – Tram	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.
Passenger	CNG Cars	A compressed natural fueled cars can help reduce emission and noise
Passenger	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.

TRANSPORT LEVERS

Passenger	Hybrid electric cars	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 CO2 emissions. Adding variable speed drive technology will ensure motors only draw as much energy as is actually required. Reduction of CO2e, PM10, NOx are related to electrical energy savings.
Passenger	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.
Passenger	Electric car sharing	Number of sharing cars/1000 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.
Passenger	Bike sharing	Number of sharing bikes/1000 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.
Passenger	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.
Passenger	Bikeshare	(# of Bikes)
Passenger	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 CO2e, PM10, and NOx related to lower electricity demand.
Passenger	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.
Passenger	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.

TRANSPORT LEVERS

Passenger	e-Bus rapid transit new line (eBRT)	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	Hydrogen cars	Hydrogen vehicles with fuel cell technology are zero emission vehicles. These cars require a hydrogen refueling infrastructure, and this lever assumes that a specified proportion of cars will be replaced by hydrogen cars. The relative cleanliness of a hydrogen car is determined by the electricity utilized to generate the hydrogen. Emission reductions are achieved through replacing diesel and petrol combustion cars with hydrogen cars.
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	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	Occupancy Dependent Tolling	Occupancy-dependent tolling (ODT) 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 increases revenues, reduced operational costs and improved reliability.

TRANSPORT LEVERS

Infrastructure	Intelligent traffic light management	Share of traffic lights, coordinated (green wave algorithms) - Management systems controlled traffic speed and volumes and coordinates traffic lights to help maintain the flow. Reduced energy demand, fuel consumption and air pollution caused by traffic by reducing traffic jams, stop and go.
Infrastructure	Intermodal traffic management	Share of users integrated at target year equals 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 people and others and will not mistakenly turn on.
Infrastructure	LED Street lighting	Share of low efficient street light 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.
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	Hydrogen cars	Hydrogen vehicles with fuel cell technology are zero emission vehicles. These cars require a hydrogen refueling infrastructure, and this lever assumes that a specified proportion of cars will be replaced by hydrogen cars. The relative cleanliness of a hydrogen car is determined by the electricity utilized to generate the hydrogen. Emission reductions are achieved through replacing diesel and petrol combustion cars with hydrogen cars.

ENERGY LEVERS

Generation	Windpower	Share of electricity provided by windpower at target year changing the energy mix and ist realted 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 at customer side
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.
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 providing detailed information about how much energy is consumed at which place which allows demand response and reduction of non-technical losses

Appendix IV

How the CyPT Model Differs from San Francisco's GHG Emissions Inventory

An Overview

The Siemens City Performance Tool (CyPT) is a software model designed to help city governments prioritize infrastructure investments based on their estimated environmental and economic impacts. Based on more than 350 data points, the CyPT model calculates city-specific estimates of technologies' impacts on reducing CO_2eq emissions, improving air quality, and adding new jobs in the local economy. Siemens decision to focus on those three indicators was deliberate: cities today are leading the world in sustainability efforts, matching efforts to "go green" with efforts to create green economies. Results from CyPT analyses have aided city-decision makers around the world in developing long-term strategic plans for meeting those ambitious sustainability targets, as well as informing short-term actions to boost local growth.

Modeling Emissions

One of the first steps in a CyPT project is to develop an emissions baseline for the City based on activities occurring within the City boundaries. Although, like inventories from most cities around the world, the CyPT utilizes the 2012 GPC Protocol for Community-Wide Emissions methodology to develop this baseline, it differs from the Protocol in a few key ways.

» The CyPT covers activities only from energy, buildings, and transport sectors. It includes residential and commercial buildings, but excludes industrial buildings. It includes freight and passenger transport, but excludes airports and water transport (ferries, commercial ships, for examples). It excludes water and wastewater treatment and distribution, as well as solid waste generation.

» The CyPT covers Scopes 1, 2, and 3 emissions for energy generation (electricity and heating) and energy use in buildings and transportation. Essentially, this means that the CyPT takes into consideration both direct emissions occurring within the City boundaries (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.

Because emissions inventories in cities generally cover more activities than the CyPT does, the CyPT may seem to "underestimate" emissions. Actually, this "underestimation" of emissions represents a deliberate choice by Siemens to focus on the sectors integral to emissions reduction, as well as those relevant to Siemens expertise. In cities, energy, buildings, and transport usually account for almost 80% of GHG emissions. Any action taken to mitigate emissions in a city – or to achieve as ambitious a target as reducing GHG emissions by 80% by 2050 – must consist of measures within those sectors.

The decision to report on certain scopes of emissions results from the CyPT's approach to modeling lifecycle impacts of energy, buildings, and transport technologies. Under the CyPT, a system boundary for emission and energy accounting is chosen so that it is not only consistent over all our technologies, but also provides the city with the most opportunity for achieving the full potential for real global emission reduction.

The section below investigates specific differences between the emissions inventory reported in San Francisco's Climate Action Strategy (CAS) and the emissions inventory from Siemens CyPT analysis. Perhaps the most important similarity between the CAS and the CyPT is their use of the GPC Protocol for Community-wide GHG Emissions Methodology developed by ICLEI, WRI, and the C40 in 2012.

Comparing San Francisco's Inventory to the CyPT

1. Difference in emissions factors

CyPT assumes that the emissions factor for electricity provided by direct access is the same as PG&E's.

» The emissions factor for Direct Access power has been historically much more carbon intensive than PG&E's, which means CyPT may underestimate emissions for consumers of Direct Access electricity.

CyPT assumes that the emission factor for electricity provided to BART is the same as PG&E's. In fact, most of BART's power is supplied by the Northern California Power Agency (NCPA), with only 1/8 of total BART system electricity provided by PG&E.

2. Difference in coverage
CyPT only covers residential, commercial, and government buildings. San Francisco includes industrial, as well as some government buildings outside City boundaries.

» This is an extremely important factor in explaining some of the main differences between SF and CyPT buildings emission inventories. For example, PG&E reports commercial and industrial electricity and natural gas consumption together. It is impossible to separate those two categories given the data PG&E submits to SFE, so Siemens cannot do a direct comparison of energy consumption by commercial buildings covered by the CyPT with energy consumption by commercial buildings covered by the SF inventory. This means that CyPT estimates for both emissions and consumption of natural gas and electricity will be lower than estimates from the SF inventory.

CyPT does not cover energy used in water/wastewater treatment in distribution, nor in solid waste generation.

CyPT does not cover SFO, ferries, or ships and boats.

» Importantly, SFO is included in the City's GHG inventory but excluded from the CyPT. Because SFO is a significant consumer of emissions-free electricity (it is powered by SFPUC), this means that discrepancies would occur between Siemens and San Francisco's estimates of energy consumption, but not in estimates for emissions.
CyPT does not cover emissions from energy industries, such as small distributed energy generation centers within the city (e.g., UCSF).

CyPT does not cover fuel from off-road equipment, such as lawn and garden, construction, industrial, and light commercial equipment that are owned by the city

CyPT does not cover fugitive emissions from natural gas leakage at the consumer.

3. Difference in scope
The main difference between Scope 3 emissions for the CAS inventory and the CyPT inventory is as follows:

» For the SF inventory, Scope 3 means only T&D losses.

» For the CyPT invesntory, Scope 3 emissions mean T&D losses and upstream emissions from production of fuel (both feedstock and fuel stages).

The table below highlights some differences in terms of Scopes covered by the SF CAS versus the CyPT.

4. Difference in definition
One of the main ways in which the SF and CyPT GHG inventories differ is with respect to defining categories under which emissions fall.

» Under the SF GHG inventory, electricity and natural gas consumption fall into one of three categories: residential, commercial, and municipal. These categories are generally defined by which organization provides electricity to those consumers. Residential consumption is powered by PG&E. Commercial includes commercial and industrial consumption of electricity from PG&E. Municipal includes all buildings powered by SFPUC, including SFO, some Port buildings, hospitals, and schools.

» Under the CyPT methodology, electricity and natural gas consumption are assigned to building categories based on use. So, for example, a hospital owned by the City and powered by SFPUC would still fall under the "Hospitals" building sub-category within

CATEGORY	SF GHG INVENTORY			CYPT		
	Scope v1	Scope 2	Scope 3	Scope 1	Scope 3	Scope 3
Natural Gas	✔			✔	✔	✔
Intra-Regional and SF Road Vehicles	✔	✔		✔	✔	✔
Muni Buses	✔			✔	✔	✔
Caltrain	✔			✔	✔	✔

the main “Commercial” building category, rather than falling under “Municipal” as it does in the SF GHG inventory. This means that the “Municipal” category for CyPT consists of only municipal office buildings, while hospitals, schools, and other buildings owned by the City and powered by SFPUC are categorized as “Commercial” buildings in the CyPT. However, these “Commercial” buildings are still included in the model containing “Municipal” buildings and powered by the SFPUC electricity mix.

» The proper comparison, therefore, is between emissions reported by the “Municipal” category in the CAS and emissions from all buildings in the “Clean City” model.

» Furthermore, industrial consumption of electricity is entirely excluded from the CyPT analysis (although this is likely a negligible amount in San Francisco).

Appendix V

Sources

Bay Area Air Quality Management District

Bay Area Council Economic Institute

Bay Area Rapid Transit

Caltrain

California Energy Commission, Commercial End-Use Survey (2006)

California Energy Commission, Residential Appliance Saturation Study (2009)

City CarShare

Pacific Gas & Electric Company

San Francisco County Transportation Authority, SF-CHAMP (2012)

San Francisco Department of the Environment, Community GHG Inventory (2012)

San Francisco Department of the Environment, San Francisco Climate Action Strategy Update (2013)

San Francisco Municipal Transportation Agency

San Francisco Planning Department

San Francisco Public Utility Commission

Tom-Tom Traffic Index

Transport for London

U.S. Department of Energy

U.S. Department of Transportation, National Transit Database (2015)

Appendix VI

Acronyms

BAAQMD	Bay Area Air Quality Management District
BART	Bay Area Rapid Transit
CEC	California Energy Commission
PG&E	Pacific Gas & Electric Company
SFCTA	San Francisco County Transportation Authority
SFE	San Francisco Department of the Environment
SFMTA	San Francisco Municipal Transportation Agency
SFPUC	San Francisco Public Utility Commission
TfL	Transport for London
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation


POWELL AND MARKET
HYDE AND BEACH
20
Hard Rock CAFE