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Ingenuity for life

Portland Takes (Climate) Action

Reaching 80x50

City Performance Tool: Portland

Reaching 80x50 | About the Report

Acknowledgements

About Siemens' Center of Competence, Cities

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

About the City Performance Tool

To help cities make informed infrastructure investment decisions, Siemens 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 CO2e emissions, improve air quality, and add new jobs in the local economy.

About the Portland Bureau of Planning and Sustainability

The Bureau of Planning and Sustainability's (BPS) mission is to make Portland more prosperous, healthy, resilient and equitable, now and in the future.

Siemens would like to thank BPS for their support in providing data and lending expertise on Portland's energy, building, and transportation networks.

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Summary

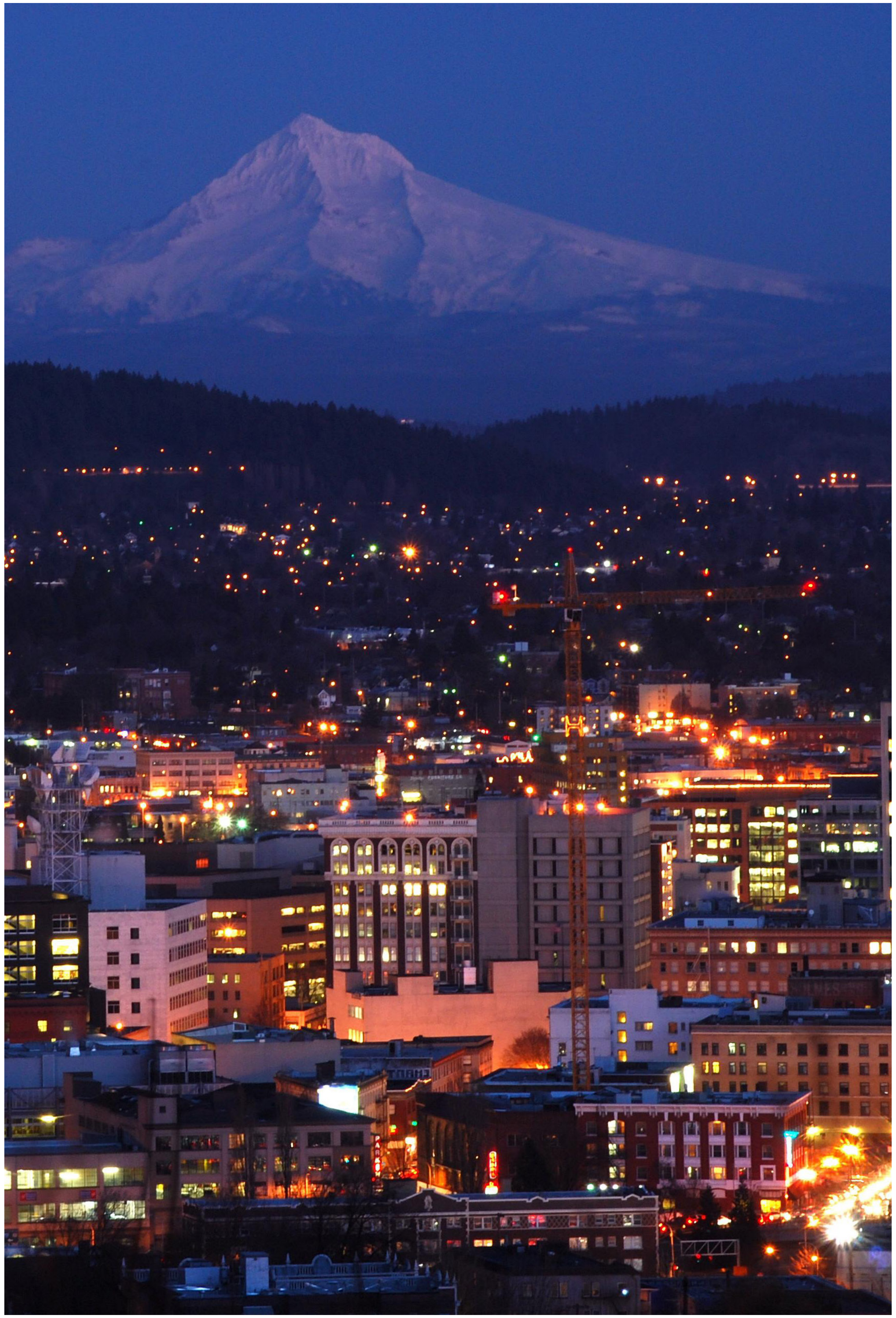
As Portland and other leading cities in sustainability have found, meeting long-term climate action goals means doing it all. Electricity grids have to run on the cleanest, most efficient sources of energy. Businesses, residents, and industry have to reduce the amount of energy they use. Transportation has to become de-carbonized, and people need to move more by public transit, by foot, and by bike. The question for Portland in reaching its climate target of 80 percent greenhouse gas (GHG) emissions reduction by 2050 is therefore not what to do, but rather, in which order to take action and with what priority to enact specific technologies and policies.

This report responds to this question by looking at Portland at three points in time: 1990, the year against which the City measures its baseline emissions and all emissions reductions; Today, when 76% of emissions (in our scope of analysis) are from building energy consumption and 24% from transportation; and 2050, Portland's target year for achieving emissions reduction of 80 percent. It builds a scenario for 2050 in which Portland has achieved its "80x50" goal through behavioral changes and technology adoption, and demonstrates what stands to be gained not only from emissions reduction and air quality improvement, but also from the creation of local jobs.

The main message? Between 1990 and today, Portland has cut emissions by more than 21 percent. Between today and 2050, it will have to cut them by an additional 69 percentage points. To do so, our analysis shows that Portland will have to adopt 27 energy, building and transportation technologies, stick to its 100 percent Renewable Portfolio Standard (passed by the state legislature just this year), and incentivize mode shift from cars to public transit, walking, and biking.

According to our analysis, the most important technologies for the municipality, residents, and businesses of Portland to adopt will be electric vehicles, building automation, a congestion charge, and rooftop solar power. This means that by 2050, 70% of vehicles in Portland will be electric (which amounts to roughly ~300,000 cars and between 20,000 and 40,000 charging stations); businesses will have to be 44% more energy efficient (dropping from an average energy use intensity of 84.3 to 47.6); and per capita electricity consumption will drop to 7 MWh from 11.5 MWh today.

For generations, Portlanders have worked with intention to create a city that is culturally vibrant, intellectually curious, innovative and beautiful. Portland is now committed to achieving an 80% reduction in GHG by 2050 and to doing so in ways that are fundamentally linked to advancing equity. This report suggests that this ambitious GHG goal is technically achievable; reaching the goal—and the equally important equity outcomes—will require sustained action by Portland, Multnomah County, and the many partners committed to a sustainable community.



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Portland Is Taking (Climate) Action

In 1993, Portland became the first local government in the United States to adopt a plan to address global warming, and its efforts to date have produced measurable results. Even while experiencing rapid population and economic growth, in 2014 Portland's greenhouse gas (GHG) emissions were 21 percent below 1990 levels. On a per capita basis, emissions have fallen by more than 40 percent.

Portland is retrofitting homes and buildings, keeping energy costs down and creating quality jobs. Portland neighborhoods are becoming more walkable and providing more amenities, and residents are driving less and using less gasoline. And municipal operations are significantly more efficient.

Despite these accomplishments, Portland—together with its peer cities around the world—has a long road ahead to achieve its climate goals. To achieve an 80 percent greenhouse gas (GHG) reduction by 2050 while also advancing city priorities around equity, jobs, public health, and affordability, Portland needs new approaches, new partners, and the best available information to focus its efforts where the benefits are greatest. The broad-scale coordination and planning needed to achieve Portland's 2050 goal will require that governments, businesses, nonprofits, community organizations, academia and residents collaborate extensively and take the lead in their own activities.

Many of the same efforts that are reducing carbon emissions are making Portland a better place to live.

Portland, 1990 to Today

Buildings:

- Portland homes use 14 percent less energy per person today than in 1990.
- The number of solar energy systems installed in Portland increased from a dozen in 2003 to nearly 4,000 today.
- Portland is home to more than 180 certified LEED green buildings.

Transportation:

- Even with a 33 percent increase in population, seven percent fewer gallons of gasoline were sold in Multnomah County in 2014 than in 1990.
- Seven percent of Portlanders bike to work, nine times the national average, with 12,000 more people bike commuting today compared to 1990.
- Transit ridership has almost doubled over the past 20 years, and TriMet provided 100 million rides in 2014.
- Since 1990, the Portland region has added four light rail lines, the Portland Streetcar, and 260 miles of bikeways.
- In 2015 Tilikum Crossing, the first new bridge across the Willamette River in more than 40 years, opened. The $140 million bridge carries light rail, streetcar, buses, cyclists, and pedestrians, but no private vehicles.

Municipal:

- Since 1990, LED street lights and traffic signals, renewable power from in-pipe hydro, biogas, and solar energy, and a policy of investing in all energy-efficiency measures with a payback of 10 years or less reduced city government's energy bill by 25%, saving $7 million annually.

Portland's Climate Action Plan

Portland's fourth plan, adopted in 2015, reaffirmed its goal to reduce total local GHG emissions 80 percent below 1990 levels by 2050. It details eight core areas for action and establishes 2030 objectives designed to cut total local emissions by 40 percent in 2030 to be on track for an 80 percent reduction by 2050. It also emphasizes integrating equity, creating local jobs, strengthening natural systems, and saving residents and businesses billions of dollars.

Portland's Climate Action Plan establishes 2030 Objectives across eight issue areas.

1. Buildings and Energy
2. Urban Form and Transportation
3. Consumption and Solid Waste
4. Food and Agriculture
5. Urban Forest, Natural Systems and Carbon Sequestration
6. Climate Change Preparation
7. Community Engagement, Outreach and Education
8. Local Government Operations

Of these, the first two areas relate directly to the technology opportunities assessed by the City Performance Tool. The objectives for these areas are as follows:

2030 Objective: Buildings and Energy

- Reduce the total energy use of all buildings built before 2010 by 25 percent.
- Achieve zero net carbon emissions in all new buildings and homes.
- Supply 50 percent of all energy used in buildings from renewable resources, with 10 percent produced within Multnomah County from on-site renewable sources, such as solar.

2030 Objective: Urban Form and Transportation

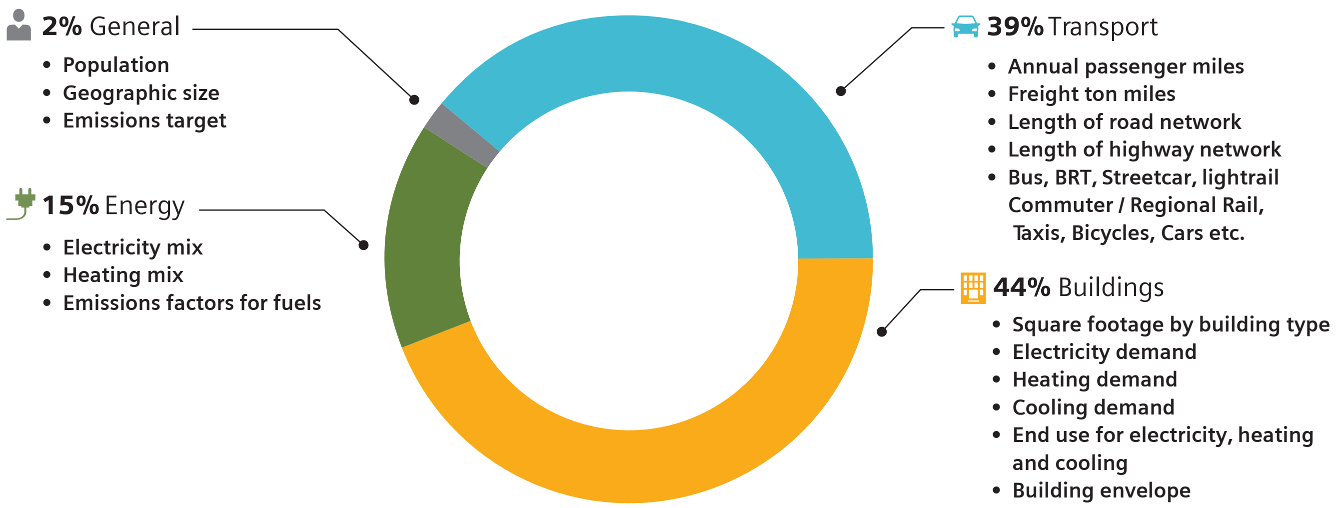
- Create vibrant neighborhoods where 80 percent of residents can easily walk or bicycle to meet all basic daily, non-work needs and have safe pedestrian or bicycle access to transit.
- Reduce daily per capita vehicle miles traveled by 30 percent from 2008 levels.
- Improve the efficiency of freight movement within and through the Portland metropolitan area.
- Increase the fuel efficiency of passenger vehicles in use to 40 miles per gallon and manage the road system to minimize emissions.
- Reduce lifecycle carbon emissions of transportation fuels by 20 percent.

Why Portland Is Using the City Performance Tool

Portland's Bureau of Planning and Sustainability (BPS) partnered with Siemens to help answer how – and how quickly – the City could reach its goal of 80% greenhouse gas (GHG) emissions reduction by 2050. BPS also wanted to understand the benefits and costs of changes to urban energy, buildings, and transport systems as Portland realizes its climate and equity goals. To facilitate the deep decarbonization analysis, Siemens used the City Performance Tool (CyPT), a software model developed to help cities project impacts of different pathways towards carbon neutrality and other sustainability goals.

The CyPT uses 350 data inputs on a city's transport, energy, and buildings sectors, to construct a baseline emissions assessment for a city projecting how population growth, shifting sources of electricity, and changing patterns of travel and energy use will affect a city's future. Once the baseline emissions profile is established, the CyPT quantifies impacts of technologies from transport, building, and energy sectors on mitigating carbon dioxide equivalent (CO_2e) emissions, improving air quality, and adding new jobs.

CyPT Inputs

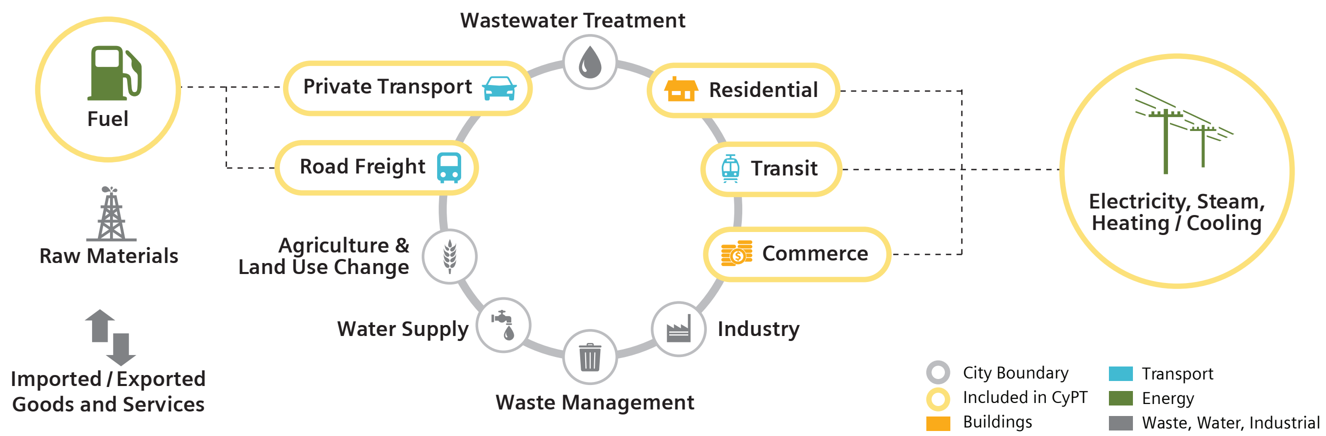


After working with BPS to source these data from Multnomah County, Trimet, the Portland Department of Transportation, and others, Siemens co-hosted with BPS a technology workshop, in which stakeholders from the local community could identify policy and technology scenarios under which Portland could reach its 80x50 target.

The future impacts of the recommended policies and technologies are the subject of the rest of this report, which quantifies the performance of these recommendations against five key performance indicators: CO_2e emissions, nitrogen oxides (NOx), particulate matter 10 (PM10), gross full-time equivalents (FTE), and capital and operating expenses.[1]

To date, Siemens has used the CyPT to assess environmental and economic development opportunities available to cities across the globe, including San Francisco, Copenhagen, London, Minneapolis, Seoul, Vienna, and Washington, DC. For each city, the model reveals how incorporating renewables, reducing energy used in buildings, and developing a robust and active transportation network will impact municipalities, residents, and businesses. Results inform stakeholder groups about their role in building a sustainable urban future, providing a platform for public sector, the private sector, and the public alike to discuss the urgency in which they need to act.

Scope of Emissions Model



[1] An FTE is a person-year of work, calculated as 2,080 hours of work in the U.S.

Can Portland Reach 80x50?

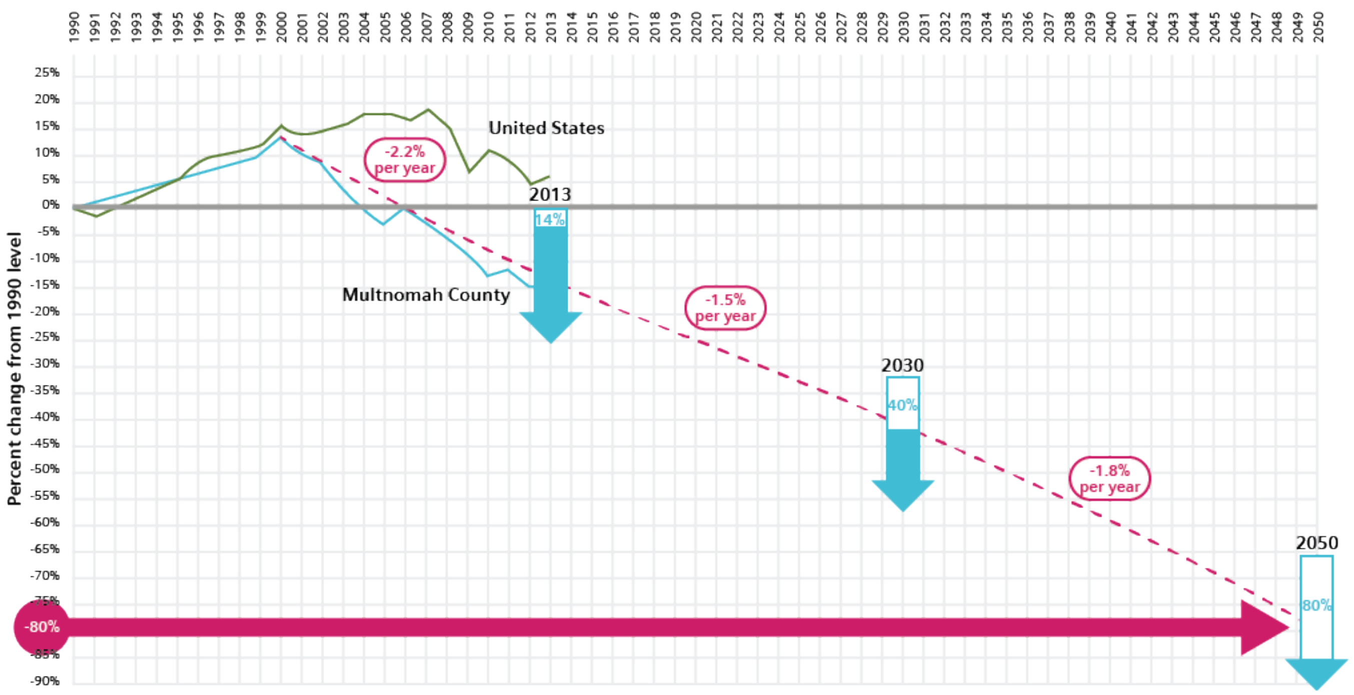
The CyPT results for Portland take into consideration how far Portland has come in reducing emissions, as well as how far it still must go to reach its climate and equity targets, identified in its Climate Action Plan.

Between 1990 and 2013, Multnomah County, the county that includes the City of Portland, saw emissions drop 2.2% per year, for an overall decrease of 14% by 2013. Although the annual rate of decrease in emissions needed to hit the County's 2030 and 2050 targets is lower than 2.2% (they are 1.5% and 1.8%, respectively), it is expected that reducing overall emissions will become more difficult as growth in population and expansion of the built environment challenge how people, businesses, and the City use energy and travel around the county.

Meeting the target of 80x50, therefore, necessarily means adopting policies, practices, and technologies that green the City's energy mix, reduce energy used by buildings, and accelerate the shift to more sustainable modes of transportation.

After extensive analysis using the CyPT, **Siemens and the City found that Portland can reduce emissions 82% by 2050.** The target is achieved by not only following approved plans and policies, but also implementing 27 energy, buildings, and transportation technologies.

Emission Targets for Portland

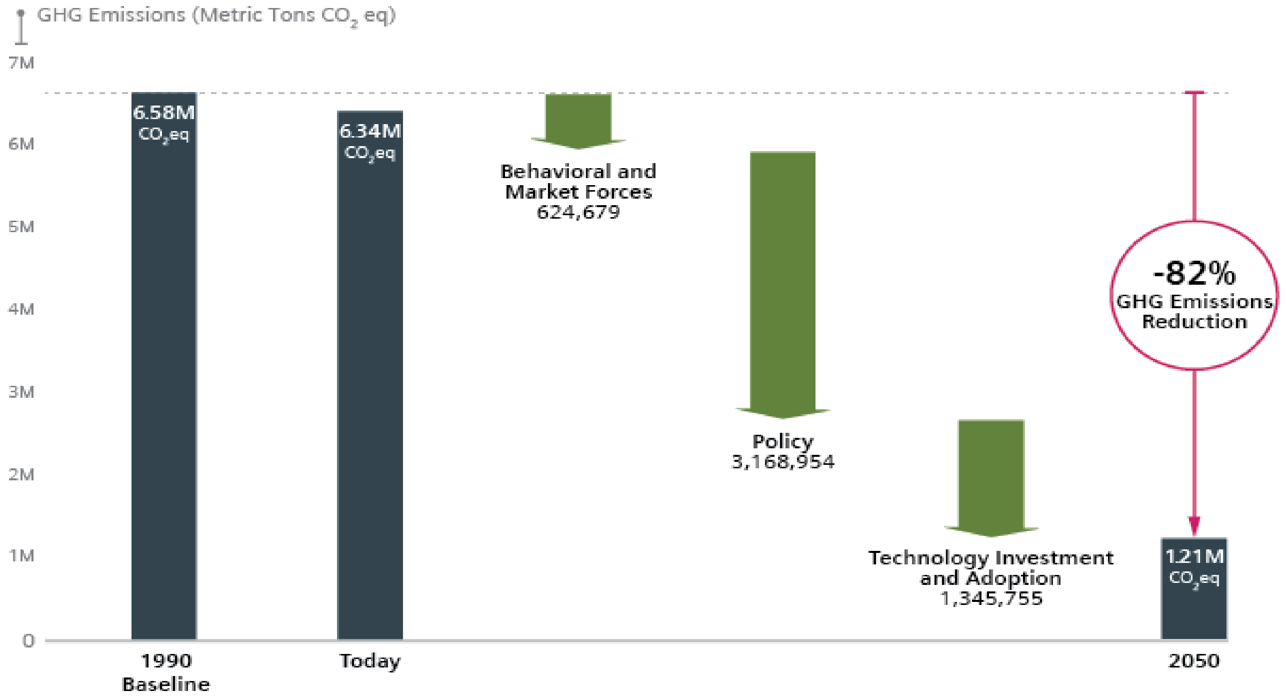


Source: Portland Climate Action Plan, 2015

Reducing emissions in Portland's energy, buildings, and transportation sectors has important co-benefits. With the implementation of 27 technologies, particulate matter 10 (PM10) levels in Portland will drop by 48% from today's levels, greatly improving local air quality. And roughly 2.5 million full-time equivalent position-years will result from installation, operation, and maintenance of low-carbon investments, contributing to Portland's pattern of green growth.

Portland Can Reach 80x50

27	-82%	-48%	+2.5M
Technologies	CO2eq Emissions	Particulate Matter	Full-time Equivalent Positions



The Roadmap to 80x50

The path to achieving this level of deep decarbonization, however, is not simple. Underpinning 80x50 are three essential types of change:

1. Behavioral change;
2. Policies; and
3. Technology investment and adoption.

In our 80x50 scenario for Portland, ***behavioral change*** *will be responsible for 12% of total emissions reductions between today and 2050.*

Between today and 2050, Portland is expected to experience population growth of 65%, with population density growing from 4,200 people per square mile today to about 7,000 people per square mile in 2050. Many other global cities, including Washington, DC, and San Francisco, are predicting similar levels of population growth, and one major question facing policymakers is how cities with relatively small city areas (San Francisco is just 49 square miles) will accommodate growth not just within their boundaries, but also in their metropolitan areas. Providing affordable housing to all communities is one of the most challenging issues to Portland's long-term sustainability.

Market forces are already inducing the shift towards smaller living spaces, in part due to this pressure on city space. Between today and 2050, average residential unit size in Portland could drop 10% from a current average of 1,500 ft^2, which would bring almost a commensurate decrease in home energy consumption.

Policy *adoption will contribute to 62% of total emissions reductions.*

Oregon recently strengthened a statewide Renewable Portfolio Standard, which will divest all coal from tits electricity supply. In addition, the Climate Action Plan calls for 10% of electricity consumption to be generated by local solar power from rooftop photovoltaic panels. Overall, these two policy initiatives will bring the percentage of zero-carbon resources powering the City's electricity mix from an estimated 32% today to 92% in 2050.

Of all of the strategies discussed in this report, ensuring the transition to 92% zero-carbon electricity is by far the most impactful in terms of reducing emissions – and should be prioritized over all other actions, to the extent to which the City can influence grid decarbonization.

Technology investment and adoption *will constitute 26% of total emissions reductions between today and 2050.*

Although the CyPT can be programmed to look at behavioral changes, market forces, and policies, its best use is to understand the impacts of buildings and transport technologies on urban sustainability.

With regards to transportation, Siemens modeled significant changes to Portland's public and private passenger transport networks, which would shift mode share from 84% of passenger miles traveled by car today to just 26% in 2050. This exceeds the Climate Action Plan's target of reducing vehicle miles traveled (VMT) by 30%.

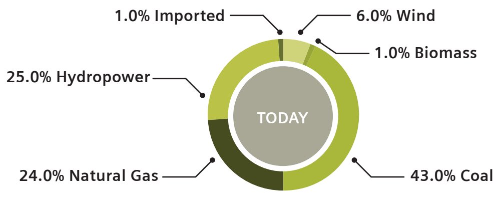
Underlying the tremendous shift in mode share is the uptake of 16 transportation technologies, including:

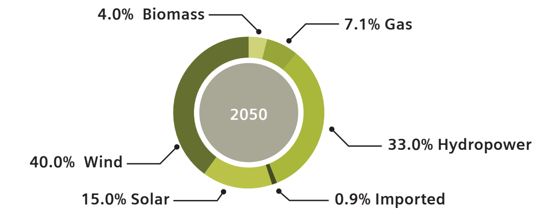
- Ambitious expansion of the public transit network. The 2050 CyPT model for Portland includes three new MAX (lightrail) lines, one new Streetcar line, and one new electric Bus Rapid Transit (eBRT) lines.
- Congestion charge intended to reduce car traffic by 30%.
- Near-complete electrification of cars, buses, shared cars, and taxis. As almost every climate action analysis shows, the path to carbon neutrality is lined with electric vehicle charging stations. As the electric grid decarbonizes, electrifying all modes of transportation becomes one of the key factors in reducing on-site emissions to close to zero. Fortunately, the City of Portland is already leading on electric vehicles, and the Electric Vehicle Strategy recognizes the importance of thoughtfully deploying charging stations and e-car sharing programs that leverage synergistic benefits of existing technologies car and charging technologies. The challenge will to push the transformation of the transportation sector three steps further – to connected mobility, to shared mobility, and to autonomous mobility. Although this study does not cover the impacts of autonomous vehicles, Portland has already begun to plan for autonomy with an initiative that prioritizes fleet autonomous vehicles that are electric and shared. Follow-on studies from this report could dive deeper into how the City could leverage partnerships and finance to unlock the benefits of connected, autonomous, shared, and electric mobility.

With regards to buildings, the City and its businesses and residents will have to invest both time and money in near-complete deployment of building automation technologies. Seventy-six percent of Portland's emissions (in the scope of the CyPT) come from buildings, and widespread investment in automating and optimizing the operations of existing buildings is an essential component of achieving Portland's GHG goals.

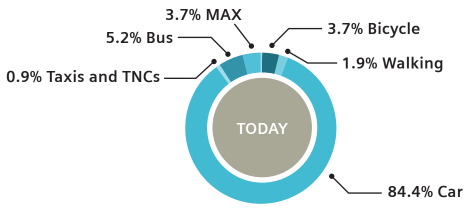
TODAY		2050
613,355	POPULATION	1,000,000
1,500 ft²	AVG RESIDENTIAL UNIT SIZE	1,350ft²

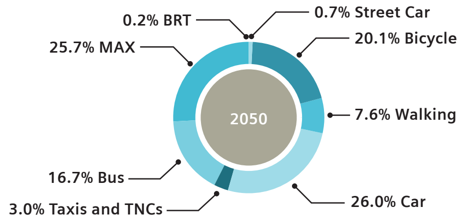
ELECTRICITY MIX





MODE SHARE





BUILDINGS		TODAY	2050	UNIT
Commercial	Average EUI	84.3	47.6	kBTU/ft²
Residential	Average EUI	37.5	28.6	kBTU/ft²
Non-Residential	Building Automation, BACS B	0	100	% of building stock
	Window Glazing	0	100	% of building stock
	Wall Insulation	0	100	% of building stock
	Building Remote Monitoring	0	100	% of building stock
	Room Automation, HVAC+Lighting	0	100	% of building stock
	Efficient Motors	0	100	% of building stock
	Efficient Lighting Technology	0	100	% of building stock
	Demand-oriented Lighting	0	100	% of building stock
	Demand Controlled Ventilation	0	100	% of building stock
	Heat Recovery	0	100	% of building stock

ENERGY	TODAY	2050	UNIT
Rooftop PV Power	~0%	10%	% of electricity mix

TRANSPORTATION	TODAY	2050	UNIT
New MAX (Lightrail) Lines	5	8	Total number of lines
Headway between MAX trains	420	180	Seconds of avg. peak-time headways
New MAX Vehicles	0	100	Share of MAX vehicle fleet
Regenerative Braking on MAX trains	20	100	Share of lines equipped with regenerative breaking
Streetcar Lines	3	4	Total number of lines
Electric Bus Rapid Transit Lines	0	1	Total number of lines
Electric Buses	0	650	Number of buses
Electric Cars	~0	315,000 (70% of all cars)	Number of electric cars
Electric Car Charging Stations	~0	60,000 (~5 cars per charging station)	Number of charging stations
Electric Car Sharing Cars	~0	3,000	Cars
Electric Taxis	~0	700 (100% of taxis)	Number of Taxis
Congestion Charging	n/a	30%	% reduction in traffic
Intermodal Traffic Management	30%	90%	Users as share of travelers
Public Transport e-Ticketing	70%	100%	Users as share of travelers
Bikeshare	1000	7000	Total number of sharing bikes
Separated Bike Lanes	300 miles	330 miles	miles

Where to Start

The degree of change required for meeting 80x50 can be overwhelming, and the level of deep decarbonization that Portland and its sister cities in sustainability are working to attain will require doing a lot of everything.

Nonetheless, the CyPT analysis demonstrates that certain energy, buildings, and transport technologies outperform their counterparts in terms of reducing emissions, improving air quality, and creating jobs. The table on the next page, ranks the top 5 technologies, cross-sector, for each of the key performance indicators in the CyPT model.

Comparing performance across sectors and indicators, three strategies rise to the top. Based on their inordinate contribution to reducing emissions, while promoting green growth, the City of Portland should pursue:

(1) Converting 70 percent of all cars on the road to electric

There are roughly 415,000 cars on Portland's streets today, and given that the average life of a car on U.S. streets is 15-20 years (depending on locality), it is reasonable to expect that all 415,000 of those cars – of which almost all are gasoline-powered – could be replaced by 2050. To incentivize the transition to a fully electric vehicle (EV) fleet, the City of Portland could promote tax credits and incentives, deploy some public charging infrastructure, and work with private sector partners to reduce the difficulty of rolling out EV charging stations. Portland's 2017 Electric Vehicle Strategy details the City's plans to accelerate the transition to EVs, and other cities are pursuing similar action. San Francisco, for example, has incorporated electric vehicle charging into new buildings, mandating that developers include hookups for electric vehicles in parking spaces. Other cities are working through their utility companies to offer programs to businesses and residents to purchase EV chargers at a lower cost, and still others are setting aside land so that private sector partners can create spaces for EV charging of large, shared fleets.

(2) Establishing a congestion charge that reduces road traffic by 30%

Cities in the U.S. have talked about congestion charging (or city tolling) for a long time, but to-date, have not been successful in implementing one. Globally, cities such as London and Singapore, are already iterating on their first round of congestion charging. They are expanding congestion charge zones, moving to occupancy-based and dynamic tolling, and using proceeds from tolling to build out transit networks and invest in innovative transport technologies and pilots.

Research shows that pricing road use is essential to reducing initially the number of cars on the road at peak hours, immediately improving air quality and reducing congestion. Eventually, road pricing reduces average vehicle ownership, reducing transportation costs for households and businesses and improving the efficiency of the transportation system.Although Singapore is sometimes discarded as an extreme case due to its size, political make-up, and policy history, there are lessons to be learned from the small nation-state about the urgency that's necessary to bring widespread acceptance of transformative change.

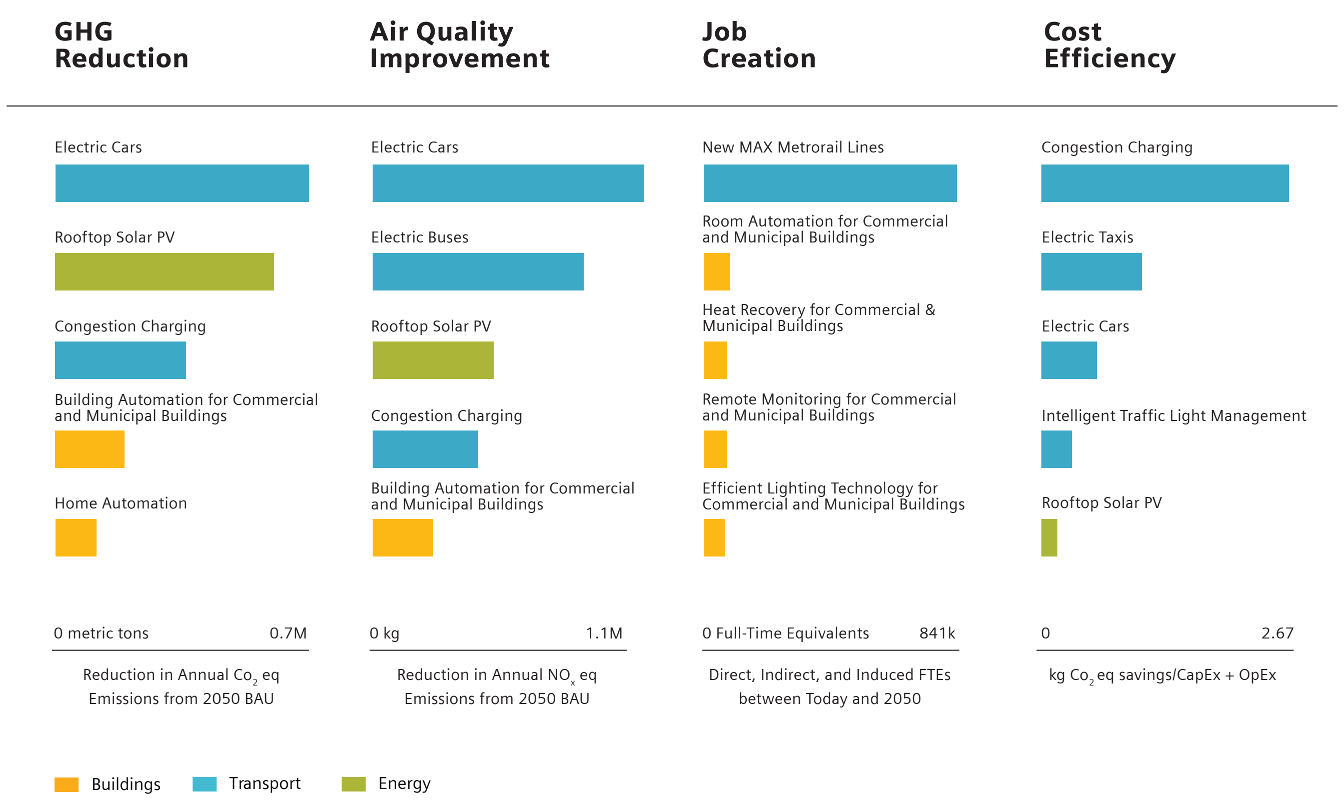
(3) Automating 100% of commercial and municipal buildings.

Retail products, such as Nest and Alexa, have made automation easier for single-family homes and some businesses. However, automating electricity and heating consumption in all buildings, especially older ones, will require updating older appliances and existing HVAC systems. Financing mechanisms like energy performance contracts, can help overcome the barriers of financing the capital investment required for retrofits.

Many cities are contemplating point-of-sale policies, so that new owners are required to retrofit existing buildings at the time of purchase. They are also exploring offering local tax credits for home and business improvements to extend beyond the traditional rebates for LED lighting, for example. In Portland, commercial buildings 20,000 square feet and larger are required to benchmark and disclose their energy use annually, and beginning in 2018, homes must obtain and disclose a Home Energy Score before they can be listed for sale. In the most progressive cities with regards to climate action, local agencies are considering policies, which mandate or offer incentives for new construction to be net zero (e.g., energy consumption by the building meets energy generated by the building and/or is powered only by renewable energy).

Portland today is home to more than 180 certified LEED green buildings. However, to meet the demands of 80x50, all new construction will need to achieve substantially better energy performance. In Oregon, which has a statewide energy code that local jurisdictions may not alter, this requires continuing engagement by the City, County, and energy and construction technical experts to move building code requirements toward net-zero energy performance.

Top Performing Technologies



Appendix I

CyPT Model Methodology

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 CO2e emissions, improve air quality, and add new jobs in the local economy.

As of the publication of this document, the CyPT model has assessed environmental and economic development opportunities available to cities across the globe, including San Francisco, Copenhagen, London, Minneapolis, Seoul, Vienna, and Washington, DC. Siemens 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' portfolios could reduce annual emissions by 10 percent. The Copenhagen city government 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 their portfolios. The Minneapolis report revealed that, apart from renewable energy, electric cars were the single most effective lever in reducing emissions. Minneapolis' Sustainability Department is now launching a series of inclusive conversations across city and county agencies, the electric utility, and the public to help build an electric vehicle strategy.

Configuring the CyPT requires more than 350 inputs from a city's transport, energy and buildings sectors, and therefore necessitates inter-departmental collaboration. Inputs include population and growth, the supply mix of electricity generation, transport modalities, and travel patterns, building energy use, and the built environment footprint. We use this information to build the city's energy DNA, which we split into transport and buildings energy consumption. 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 CO2e emissions and PM10 and NOx levels. The model measures the impact of technologies on the CO2e, PM10 and NOx baselines of the city with CO2e accounting performed for Scope 1 and 2 emissions from 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, and 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.

The model estimates the future impacts of more than 70 technologies (only half of which are in Siemens' product portfolio) 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 LEDs 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 metro.

The outputs of the model are CO2e emissions, nitrogen oxides (NOx), particulate matter 10 (PM10), capital investment, and gross full-time equivalents (FTE).[2] FTEs include direct, indirect, and induced jobs from installation, operation and maintenance. Manufacturing jobs are not accounted for because some of these technologies may be produced outside the city's functional area, with no direct impact on local jobs.

2 An FTE is a person-year of work, calculated as 2,080 hours of work in the U.S.

Appendix II

Differences in Emissions Accounting between Siemens CyPT and Portland's Climate Action Plan

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, commercial, and government 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.

- The main difference between Scope 3 emissions for the Portland Climate Action Plan (CAP) inventory and the CyPT inventory is as follows:
  - For the Portland inventory, Scope 3 means only T&D losses.
  - For the CyPT inventory, Scope 3 emissions mean T&D losses and upstream emissions from production of fuel (both feedstock and fuel stages).

Because emissions inventories in cities generally cover more activities than the CyPT does, the CyPT may seem to "underestimate" emissions. This "underestimation" of emissions represents a deliberate choice by Siemens to focus on the sectors relevant to Siemens expertise. In cities, energy, buildings, and transport usually account for almost 80 percent of GHG emissions, using a conventional production-based approach. Actions to mitigate emissions in a city – or to achieve as ambitious a target as reducing GHG emissions by 80 percent by 2050 – must address those sectors.

For the CyPT analysis, 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 consistent over all our technologies and also provides the city with concrete opportunities to achieve emission reductions.

The section below investigates specific differences between the emissions inventory reported in Portland's CAP and the emissions inventory from Siemens CyPT analysis. Perhaps the most important similarity between the CAP and the CyPT is Portland's use of the GPC Protocol for Community-wide GHG Emissions Methodology developed by ICLEI, WRI, and the C40 in 2012.

Differences in Accounting between CyPT and CAP

CyPT only covers residential, commercial, and government buildings.

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

Neither Portland's CAP nor CyPT includes the PDX airport, ferries, or ships and boats.

CyPT does not cover emissions from energy industries, such as small distributed energy generation centers within the city (e.g., Lewis & Clark College).

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. In Portland, these are believed to be relatively low, given NW Natural's investment in modernizing its pipe infrastructure.

In addition to the conventional production-based inventory, Portland's 2015 CAP includes a consumption-based emissions inventory that incorporates Scope 3 emissions associated with all goods and services provided to Portland businesses, residents, and public agencies. This approach helps provide a more comprehensive understanding of the sources of emissions and points to opportunities to reduce emissions through consumer choices and business supply chains.

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.
Non-Residential	Building Performance Optimization (BPO)	Building Performance Optimization (BPO) is a range of services designed to increase the energy efficiency of an EXISTING building by implementing proven building control strategies otherwise known as Facility Improvement Measures (or FIMs). BPO can improve THERMAL and ELECTRICAL energy efficiency in a building in many ways; typically via improved HVAC technology, by adapting the building to suit usage profiles or providing information and analytics for operational personnel. Reduction of CO2e, PM10, and NOx are also realized due to energy savings.
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 are also realized 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 realized due 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. 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.

BUILDING LEVERS

Non-Residential	Room Automation HVAC+ lighting	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 utilized in the heating, ventilation and air-conditioning and lighting of a building.
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.

TRANSPORT LEVERS

Passenger	Electric buses	Share of the vehicle fleet operated by battery electric vehicles. Battery electric vehicles are "zero" exhaust gas emission vehicles, resulting insignificant 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 - Subway	Number of new metro lines at target year of average metro length, shifting passengers from all other mode according to the transportation performance of existing lines in the city. Public transport attractiveness is increased and energy demand per person, per kilometer is reduced together with related emissions.
Passenger	New line – Light rail	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	Compressed natural gas (CNG) fueled cars can help reduce emissions and noise.
Passenger	Electric cars	Share of conventional combustion vehicles replaced by battery electric vehicles. Battery electric cars are "zero" exhaust gas emission vehicles resulting in ignificant reduction of local emissions of PM10, NOx. A charging infrastructure is set up. The electricity used for charging is generated according to the general local electricity mix.
Passenger	Hybrid electric cars	Share of conventional combustion vehicles replaced by hybrid electric vehicles at target year. Small combustion engine for base energy demand combined with an electric drive for acceleration and for brake energy recuperation. Energy demand is reduced due to higher efficiency of the combustion engine.
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 modes equally and lower energy demand per person kilometer together with related emissions.

TRANSPORT LEVERS

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	Automated train operation (ATO) Streetcar, 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 per 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
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.
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, combustion to electric engines and reduces energy demand per person, per 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.

TRANSPORT LEVERS

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.
Infrastructure	E-ticketing	This technology provides simple, affordable, competitive and integrated ticketing. Electronic tickets offer a one-payment system for all forms of transport and simplify public transport use. Passengers can transfer seamlessly between different transportation modes and fees are calculated at the end of the trip. Passengers pay only for the services they use – automatically, electronically, transparently, and securely. Benefits are achieved through increased revenues, reduced operational costs and improved reliability
Infrastructure	Intelligent traffic light management	Share of traffic lights, coordinated (green wave algorithms) - Management systems control traffic speed and volumes and coordinate traffic lights to help maintain the flow. Reduced energy demand, fuel consumption and air pollution caused by reducing traffic jams, and stop and go trips.
Infrastructure	Intermodal traffic management	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 and 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 dim 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. Additional high reduction in maintenance due to longer lifetime (10 years versus 6-12 month) and possibility to dim the light depending on the environmental conditions.
Freight	E-Highways	Share of hybrid diesel-electric trucks and highways with overhead power lines at target year. As soon as trucks join the e-Highway they connect to the overhead power lines and switch into pure-electric mode. Leaving the e-Highway, the trucks switch back to using hybrid mode. Energy demand is reduced due to shift of transport to hybrid electric truck and electric transport together with related emissions.

ENERGY LEVERS

Generation	Onshore wind power	Share of electricity provided by onshore wind power at target year changing the energy mix and its related emissions provides cleaner electricity for buildings and electric powered transport modes
Generation	Photovoltaic power	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
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	Optimization of transmission and distribution of electricity, including reduction of non-technical losses and improvement of grid resilience.
Distribution	Smart Metering and Demand Response	Implementing smart meter devices and a data management system providing detailed information about how much energy is consumed at which place. This allows demand response and reduction of non-technical losses.