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The Digital District

How Smart Technologies Can Help Build a Sustainable Future for Washington, DC

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Acknowledgements

About Siemens

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. Siemens 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.

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

Projected Data (any color above + stripes)

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Executive Summary

Siemens City Performance Tool (CyPT) in Washington, DC.

This report analyzes technology pathways to achieving the ambitious target found in the District of Columbia's sustainability plan, *Sustainable DC*: "80x2050" or reducing carbon emissions 80 percent by the year 2050. It builds on momentum generated by the District's *Sustainable DC* vision of becoming the greenest, healthiest, and most livable city in the United States by 2032, and incorporates many of the plans, policies, and programs that the District has rolled out over the past five years.

Overall, Siemens finds that the District can *exceed* its 80x50 goal if it makes significant investments in clean energy, energy efficiency, and a safe and accessible transportation network.

» With the help of 25 energy, buildings, and transportation technologies, the District can reduce annual greenhouse gas emissions 90 percent by 2050 based on a 2006 baseline – well past its 80 percent goal.

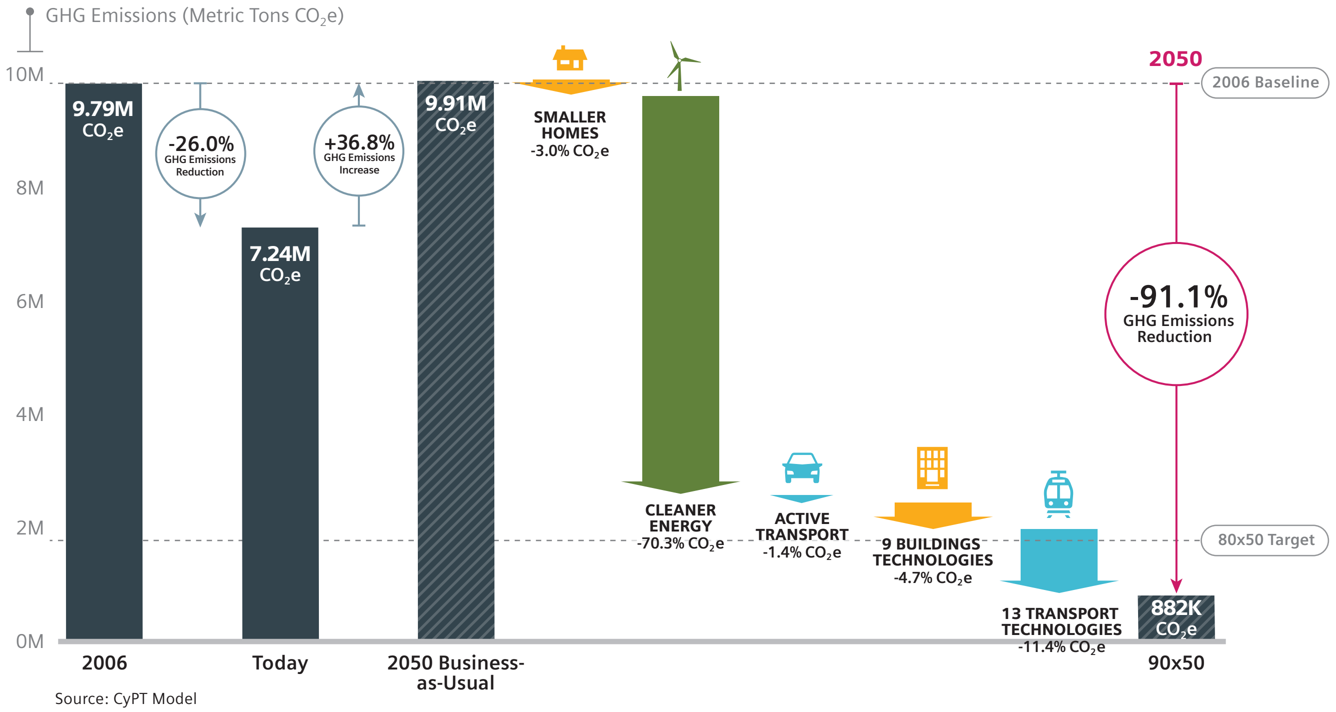
» Achieving "90x2050" has powerful benefits beyond emissions reduction. Between today and 2050, implementing the 25 technologies could generate 1.9 million person-years of employment, or roughly 60,000 full-time equivalent positions per year, as well as improve air quality by 55 percent for particulate matter 10 (PM10) and by 70 percent for nitrogen oxides (NOx).

» Renewable-powered electricity, electric heating, and combined heat and power (CHP) are the three most significant levers in reducing the District's overall emissions. With 100 percent of electricity from renewable sources (including renewable energy credits, or RECS) and 56 percent of heating from electricity and CHP, the District can lower its annual emissions by 70.6% percent in 2050, based on the 2006 baseline.

» Other important levers for the District include building automation systems, frequent and reliable Metrorail lines, an intelligent traffic management system, and a connected electric vehicle network. The software powering these four levers could serve as the "digital backbone" for a Digital District, continuing DC's rise as a Smart City leader.

» 90x2050 won't happen in silos. District inhabitants and businesses must do their part in reducing emissions by installing building automation systems and using low- or zero-emissions transport modes, and City agencies, the District's electricity and natural gas providers, and WMATA will have to collaborate to deliver some of the most challenging, but impactful technologies this report recommends.   installing building automation systems and using low- or zero-emissions transport modes, and City agencies, the District's electricity and natural gas providers, and WMATA will have to collaborate to deliver some of the most challenging, but impactful technologies this report recommends.

DC Can Exceed 80x2050



Source: CyPT Model

Photo via Digital Vision

Photo via Nick Borten

Table of Contents

Background

This report analyzes technology pathways to achieving the ambitious target found in the District of Columbia's sustainability plan, *Sustainable DC:* "80x2050" or reducing carbon emissions 80 percent by the year 2050.

This report analyzes technology pathways to achieving the ambitious target found in the District of Columbia's sustainability plan, *Sustainable DC*: "80x2050," or reducing carbon emissions 80 percent by the year 2050.

Throughout the analysis, Siemens drew on expertise from the District Department of the Environment (DOEE), DOEE's sister agencies and other stakeholders to build a deep decarbonization model using Siemens City Performance Tool (CyPT). DOEE, the District Department of Transportation (DDOT), Metropolitan Washington Council of Governments (MWCOG) and Washington Metropolitan Area Transit Authority (WMATA) helped to provide data, identify future scenarios, and choose infrastructure technologies for modeling.

The analysis builds on momentum generated by the District's *Sustainable DC* vision of becoming the greenest, healthiest, and most livable city in the United States by 2032. It incorporates *Climate Ready DC* (2016), *moveDC* (2014), the District's Renewable Portfolio Standard (RPS), the Green Building Act (2006), the District's Energy Conservation and Green Construction Codes, the recently announced DC Green Bank, and *Clean Energy DC* (2016).[1] Whereas Clean Energy DC is the District's policy-oriented plan to achieve the goal of cutting carbon emissions by 50 percent by 2032, this study looks at how technology can help the District reduce carbon emissions 80 percent by 2050. The study also incorporates the regional GHG emissions reduction plan developed by MWCOG, *Multi-Sector Approach to Reducing Greenhouse Gas Emissions in the Metropolitan Washington Region* (2016).

Photo via pixabay

The following sections outline how the District can benefit from low-carbon technology, and design a road map for technology implementation. *The City Performance Tool* explains how Siemens' deep decarbonization model works. *Sustainability in the Face of a Changing DC* describes the forces that are shaping the District's built environment. It establishes the future scenario that this analysis assumes as its 2050 baseline, upon which impacts of additional technologies are modeled. *How Technology Can Help* unpacks the 25 energy, buildings, and transportation technologies modeled using the CyPT, and compares their impacts on reducing emissions, improving air quality, and creating local jobs. Finally, *80x2050* reveals one technology pathway for reaching *Sustainable DC*'s target, with quantified benefits of achieving deep decarbonization and recommendations on how the City can help implement the vision.

1 DOEE Newsroom, Accessed 2017, https://doee.dc.gov/release/mayor-bowser-announces-plan-establish-dc-green-bank

The City Performance Tool

To facilitate the deep decarbonization analysis for the District, Siemens used the City Performance Tool (CyPT), which identifies how technologies from transport, building, and energy sectors can mitigate carbon dioxide equivalent (CO_2e) emissions, improve air quality, and add new jobs.

For this deep decarbonization analysis, Siemens used the City Performance Tool (CyPT) to identify how technologies from transport, building, and energy sectors can mitigate carbon dioxide equivalent (CO_2e) emissions, improve air quality, and add new jobs.

The CyPT model has assessed environmental and economic development opportunities available to cities across the globe, including San Francisco, Copenhagen, London, Minneapolis, Seoul, and Vienna. 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, including population and growth, the supply mix of electricity generation, transport modalities, and travel patterns, building energy use, and the built environment footprint.

CyPT Inputs

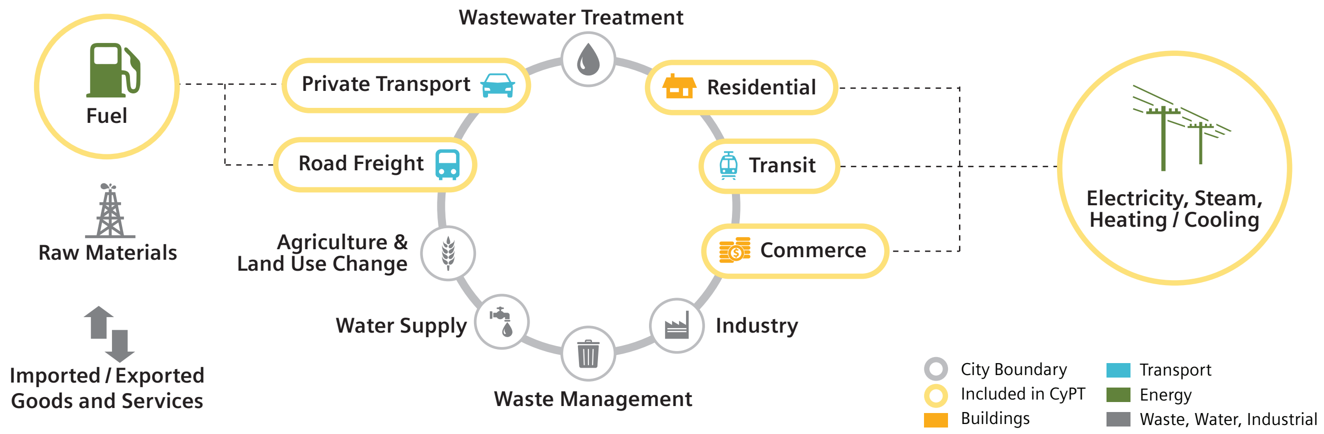
2% General
- Population
- Geographic size
- Emissions target

15% Energy
- Electricity mix
- Heating mix
- Emissions factors for fuels

39% Transport
- Annual passenger miles
- Freight ton miles
- Length of road network
- Length of highway network
- Bus, BRT, Street Car, Metro, Commuter / Regional Rail, Taxis, Bicycles, Cars etc.

44% Buildings
- Square footage by building type
- Electricity demand
- Heating demand
- Cooling demand
- End use for electricity, heating and cooling
- Building envelope

Scope of Emissions Model



Starting with the city's population, energy performance, and emissions baseline, the model estimates the future impacts of more than 70 technologies (only 60 percent of which are sold by Siemens) along 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 CO_2e emissions, nitrogen oxides (NOx), particulate matter 10 (PM10), gross full-time equivalents (FTE), and capital and operating expenses. [2]

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

Sustainability in the Face of a Changing DC

Customizing the CyPT model to fit the energy usage, built environment, and travel patterns of District residents, businesses, and visitors required understanding the forces shaping the city today.

Customizing the CyPT model to fit the energy usage, built environment, and travel patterns of District residents, businesses, and visitors required first understanding the forces shaping the city today.

Since 2010, the District's population has risen 13.2 percent, with metropolitan DC's economy growing by 3.8 percent and the number of jobs by 6.2 percent. Industries like local government, restaurants and grocery stores, colleges and universities, accounting and payroll, and amusement and recreation have dominated that growth.[3] Recent estimates from the DC Office of Planning suggest that 900 people per month move to the District.[4] Despite a growing population and burgeoning economy, overall CO_2e emissions for the District have dropped. Our capital city –a leader nationally in LEED and ENERGY STAR certified buildings, in green power purchases, and now in green financing – is showing the rest of the country that decoupling emissions and growth is not just desirable, but also possible.[1,5]

Projections of the District out to 2050 mimic this pattern of growth and development. MWCOG projects that the District's population will rise 57 percent between today and 2050, from 670,000 people to more than a million. Given the District's fixed geographical boundaries, its density in 2050 will be comparable to modern-day Shanghai. Without taking deliberate measures to ensure sustainable, affordable outcomes, emissions and expenses in the District could spiral out of control.

Our baseline future scenario for 2050 assumes that the realization of most of *Sustainable DC*'s initiatives and the evolution of market forces will help steer the District's growth. *Sustainable DC* and DOEE's other plans and initiatives call for more renewable energy on the grid. Our model assumes that the electricity mix will be close to 100 percent renewable by 2050 including renewable energy credits (or RECS). They also call for a shift towards active transport, defined as walking, biking, and taking public transit. Our model assumes a 10 percent shift in mode share from cars to active transport. Market forces are shrinking residential unit sizes far below 1,000 ft², and pushing especially commercial buildings towards thermal electrification (or using electric heat pumps instead of natural gas to heat buildings). Our model incorporates these market forces.

Four Forces Shaping DC's Future

The estimated results of these four forces on the District's CO_2e emissions in 2050 are staggering. Reduced residential unit sizes, a cleaner electricity mix, thermal electrification and an active transport-dominated mode share could reduce District's community-wide greenhouse gas (GHG) emissions by 75 percent based on the 2006 baseline year.

Diminishing Residential Unit Size

Market forces are already causing the average unit size in the District to decrease.[6] This analysis assumes that today's average residential unit is 1,122 ft². In 2050, that average unit size is assumed to drop seven percent to 1,047 ft², a number which will continue to decline as larger, existing units are replaced by newer, smaller ones.[7]

Thermal Electrification

Clean Energy DC identifies thermal electrification and deployment of distributed energy systems (e.g., solar energy and microgrids) as two strategies for further reducing emissions from buildings. The model's baseline assumes that 36 percent of all buildings are heated by electricity, 4.6 percent by district heating, 2.3 percent by oil), and the remainder by a combination of natural gas boilers, furnaces, and combined heat and power (CHP).[8] CHP, also known as cogeneration, achieves fuel efficiencies bordering on 80 percent by producing electricity and capturing thermal energy to heat and cool buildings.

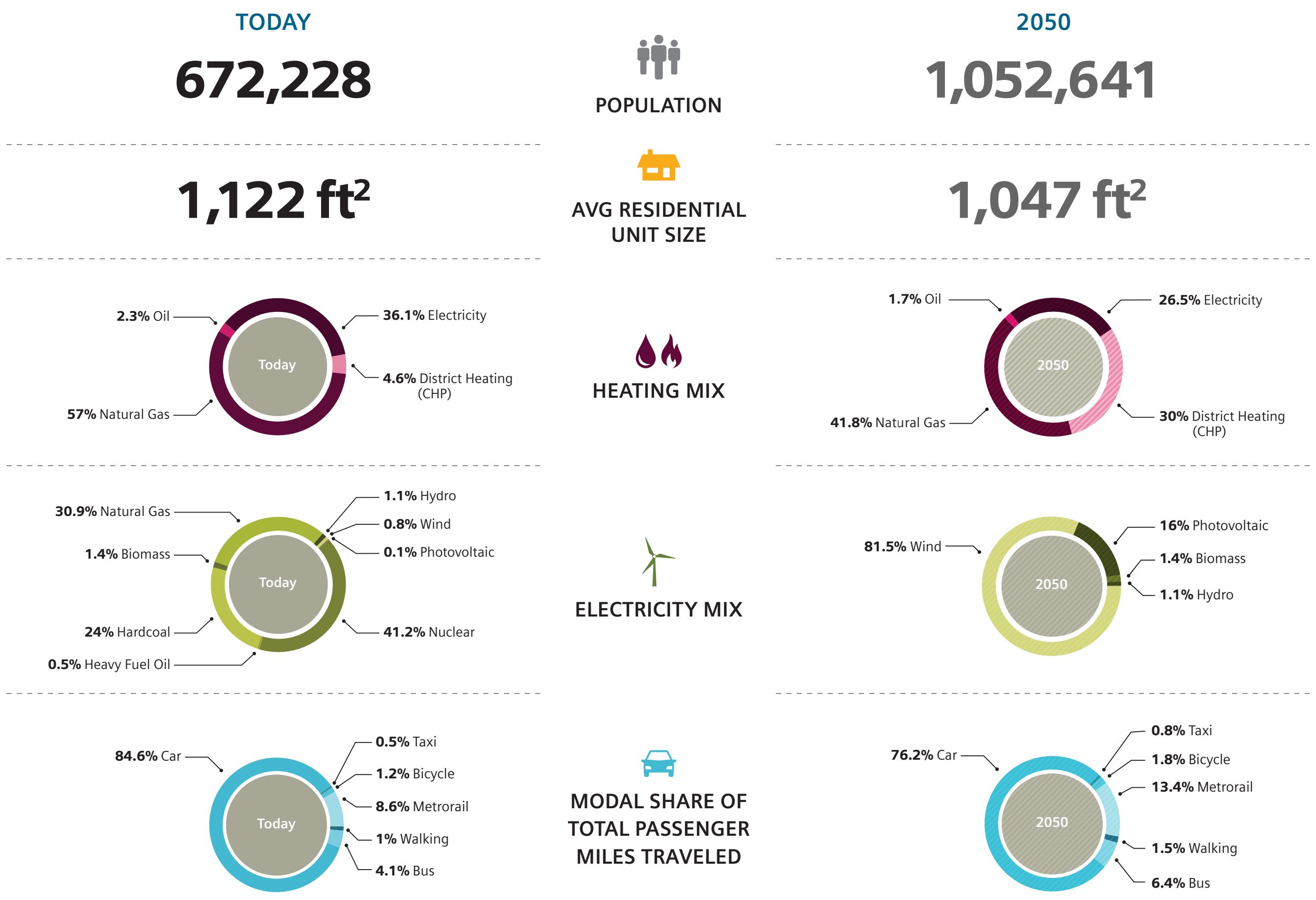
Clean Electricity Mix

By 2032, 50 percent of the District's electricity is mandated to come from renewable sources, including five percent from local solar generation.[9] According to *Clean Energy DC*, that number is expected to rise to 100 percent by 2050 through a combination of cleaner energy from Pepco (the District's electricity provider), neighborhood-scale energy systems (e.g., microgrids), ratepayer contracts with renewable energy suppliers, and renewable energy credits (RECS).

Shift in Mode Share

Our baseline assumes a roughly 10 percent shift in passenger miles traveled from passenger vehicles (cars) to all other modes by 2050. Given *moveDC*'s proposed investments in active transportation (which includes buses and Metro), this may be conservative. However, based on the current drop in ridership on Metro rail and the surge in rideshare use, the District and the wider metropolitan area will need to make concerted efforts, and sustained investments, in active transportation in order to meet *moveDC*'s targets.

Today to 2050: How DC's Population, Energy Consumption, and Travel Patterns Are Expected to Change



Sources: *CleanEnergy DC*, DC Office of Planning, EIA, EPA eGrid, *MoveDC*, National Transit Database, National Household Travel Survey, WMATA

3 Brookings Metropolitan Policy Program, Metro Monitor 2017, https://www.brookings.edu/interactives/metro-monitor-2017-dashboard/

4 DC Office of Planning, Accessed 2017, https://planning.dc.gov/sites/default/files/dc/sites/op/publication/attachments/District%20of%20Columbia%20QuickFacts_2016.pdf

5 DOEE, Accessed 2017, https://doee.dc.gov/service/green-buildings

6 CurbedDC, Accessed 2017, http://dc.curbed.com/2016/9/15/12929106/home-size-washington-dc

7 WDCEP, DC Development Report, http://wdcep.com/resource/dc-development-report/

8 EIA, RECS (2015) and CBECS (2012), https://www.eia.gov/consumption/commercial/data/2012/

9 DOEE, Clean Energy DC (2016), https://doee.dc.gov/cleanenergydc

How Technology Can Help

This section lays out the 25 technologies that can help the District achieve 75 percent emissions reduction – and push beyond that 75 percent to reach 80 percent by 2050.

While modeling the reduction of the District's emissions by 75 percent may have been relatively straightforward, actually achieving it will undoubtedly be complex.

This section lays out the 25 technologies that can help the District achieve 75 percent emissions reduction – and push beyond that 75 percent to reach 80 percent by 2050. The technologies are market-ready, meaning that they are commercially available,[10] and include replacing 100 percent of the current bus fleet with electric buses; installing automation systems in existing homes and businesses; adding four new street car lines; converting 100 percent of the District's street lights to automated LED lights; installing rooftop photovoltaic (PV or solar) panels to generate 16 percent of electricity consumed in the District; and moving to district heating and cooling powered by combined heat and power (CHP) plants.

Building CyPT Technology Implementation Rates, Today and 2050

BUILDINGS	TODAY	2050	UNIT
Residential -Home Automation	*	100%	% of total building stock
Non-Residential -Efficient Llight Technology	*	100%	% of total building stock
Non-Residential -Demand Controlled Ventilation	*	100%	% of total building stock
Non-Residential -Heat Recovery	*	100%	% of total building stock
Non-Residential -Building Envelope	*	100%	% of total building stock
Non-Residential -Building Automation, BACS B	*	100%	% of total building stock
Non-Residential -Efficient Motors	*	100%	% of total building stock
Non-Residential -Room Automation, HVAC + Blinds	*	100%	% of total building stock
Non-Residential - Building Remote Monitoring	*	100%	% of total building stock

***** Insufficient information was available to determine market penetration rates of efficient lighting and building automation technologies, despite anecdotal evidence of adoption

Transport CyPT Technology Implementation Rates, Today and 2050

TRANSPORT	TODAY	2050	UNIT
Electric Buses	0%	100%	share of fleet
Metro - New Line	6	7	total number of lines
Intelligent Traffic Light Management	10%	100%	share of coordinated traffic lights
Electric Passenger Cars	0%	70%	share of car fleet
Electric Taxis	3%	100%	share of taxi fleet
Electric Car Sharing Program	300	3,000	cars
Intermodal Traffic Management	0%	90%	users as share of travelers
Bikeshare	3,000	7,000	bikes per 1000 inhabitants
Street Car - New Lines	1	5	total number of lines
e-BRT (Bus Rapid Transit) - New Lines	0	7	total number of lines
Metro - Reduced Headway	360	180	second of avg. peak-time headways
Smart Street Lighting	0%	70%	share of street lights
Public Transport - E-ticketing	0%	100%	users as share of travlers

10 Undoubtedly, future-looking technologies – autonomous vehicles, artificial intelligence, blockchain methodology, to name a few – will change how people interact with the built environment, influencing sustainability positively or negatively depending on how they are adopted. Follow-on studies would do well to address these questions.

Energy CyPT Technology Implementation Rates, Today and 2050

ENERGY	TODAY	2050	UNIT
Wind	0.8%	82%	share of electricity mix
Solar	0.1%	16%	share of electricity mix
Combined Heat and Power	13.1%	30%	share of heating mix

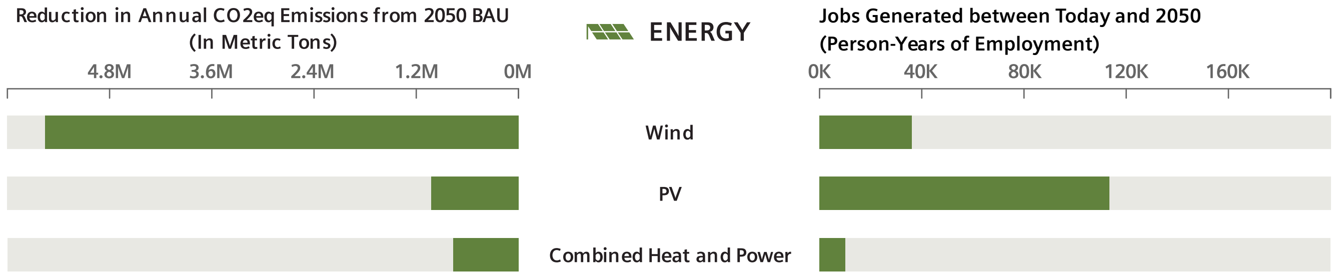
After running the CyPT model to estimate impacts of the 25 technologies, we found that cleaning the electricity mix through wind and solar power and moving to district heating delivered by CHP offer the highest overall benefits in terms of emissions reduction.

Shifting from 0.8 percent electricity generated by wind power today to 81.5 percent in 2050 alone drops emissions by 5.5 million metric tons – more than half of what's projected overall for the 2050 business-as-usual (BAU) scenario. Although solar power's CO_2e impacts are modeled at only 1/5th of those of wind, implementing solar power at both the building and utility scales is a much larger jobs generator. The inclusion of CHP in the analysis reflects the District's interest in having local control over electricity, heating, and cooling. Distributed energy systems, in general, allow buildings or campus to exert greater influence on how energy is generated and used. They also provide additional resilience, as they can exist off-grid, feed energy back into the grid, or draw power from the grid.

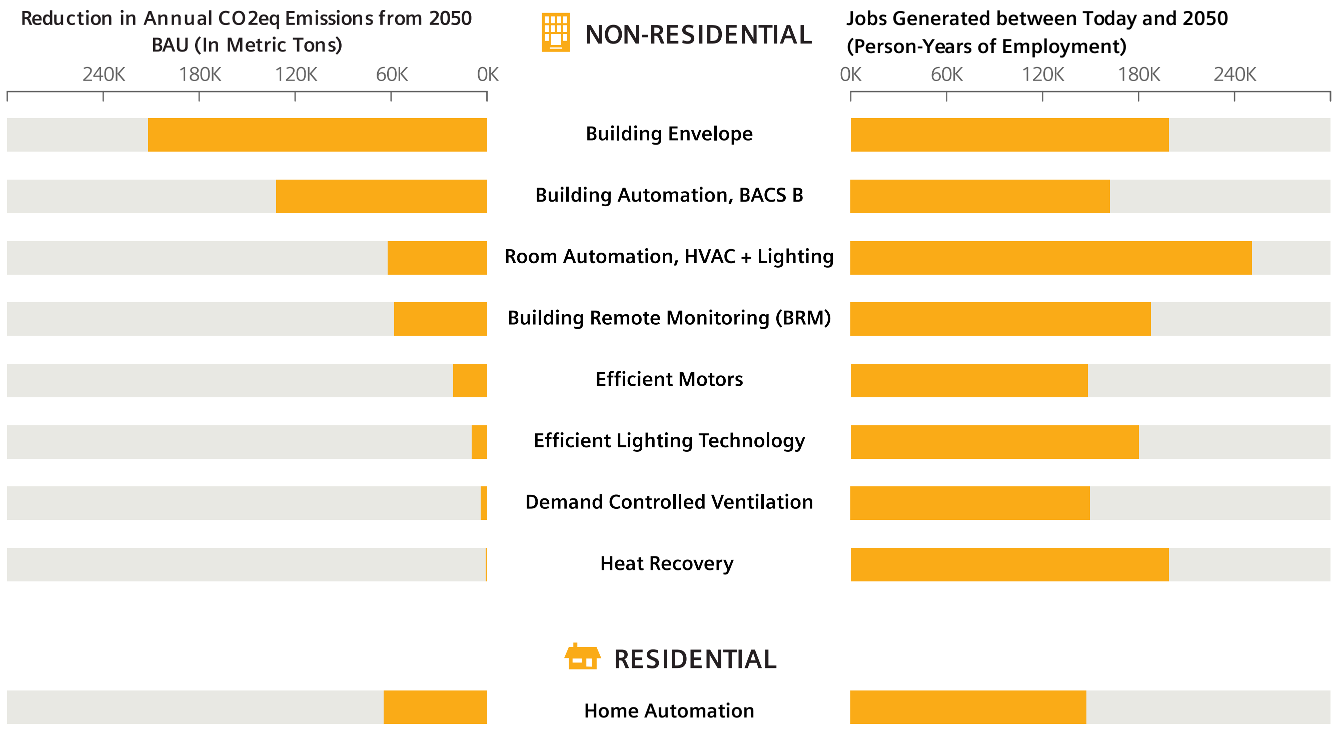
Besides providing half a million metric tons of CO_2e reductions, the nine building levers modeled are the highest generators of full-time equivalent jobs (FTEs) among the three sectors. Installing, operating, and maintaining energy efficiency and automation equipment in existing homes and businesses is expected to gross 1.6 million FTEs between today and 2050. The 1.6 million figure includes FTEs resulting directly from investment in the nine types of building technologies, as well as indirect and induced FTEs. A little more than half of the direct jobs would be for low-skilled labor, with the remaining half split between building technicians and engineers with graduate level degrees or higher.

The 13 transport levers would contribute the most to local air quality improvements. Notable among the individual transport results is the impact of electric cars in reducing NOx. Replacing 70 percent of all existing combustion engine vehicles on the road today with electric vehicles would improve NOx levels by 65.5 percent and PM10 levels by 16.9 percent from the 2050 business-as-usual scenario. To facilitate this massive transition to electric vehicles, the District – both the City and its citizens – would need to invest heavily in charging infrastructure, and not just for passenger cars. Electric buses, electric Bus Rapid Transit (BRT), electric taxis, electric car sharing programs – in short, all of the modeled electric transportation technologies would rely on both en-route and stationary charging.

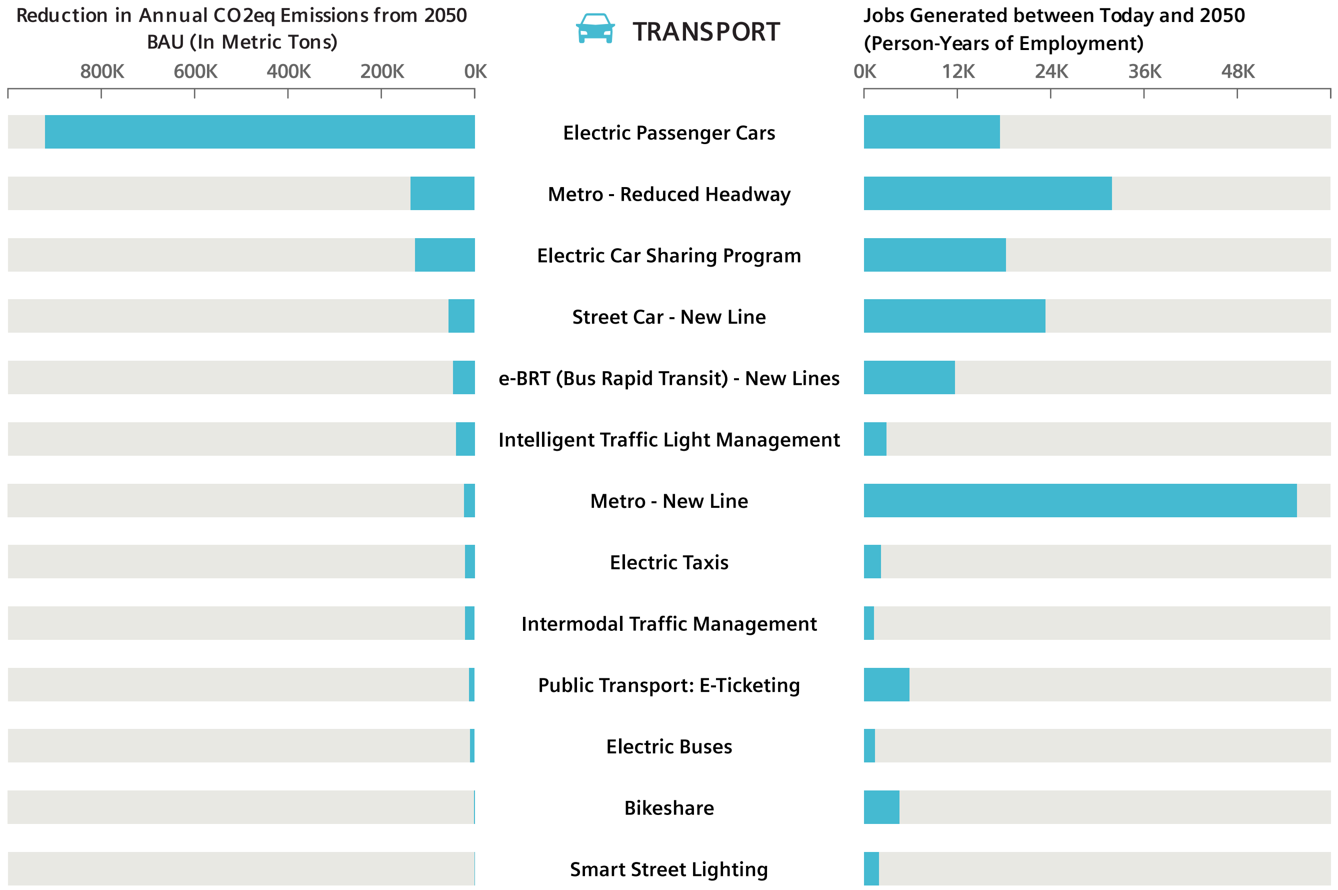
Energy Lever Results: CO_2eq Emissions and Full-Time Equivalents



Building Lever Results: CO_2eq Emissions and Full-Time Equivalents



Transport Lever Results: CO_2eq Emissions and Full-Time Equivalents



Four levers stood out as having the most potential for reducing emissions, improving air quality, and generating jobs in the District.

1) Solar Power: Rooftop PV on Residential and Commercial Buildings

We project that the share of DC's electricity consumption generated by solar power will jump from 0.1 percent in 2012 to 16 percent by 2050, which is the National Renewable Energy Laboratory's (NREL) estimate of the District's technical potential for rooftop PV power as a percent of annual energy consumption.[11] In order to reach that 16 percent, District residents and businesses would need to cover all eligible building rooftops with PV panels or regional combine utility-scale generation with some rooftop solar.

Photo via Dept of Energy Solar Decathlon

DC already has a number of programs and policies in place to incentivize solar energy. The most prominent is the District's Renewable Portfolio Standard legislation, which requires 5 percent of total electricity supplied to come from local solar energy. This creates the highest renewable energy credits in the country. The DC Sustainable Energy Utility (DCSEU) also offers technical assistance and financial incentives to District residents and businesses to help increase energy efficiency and renewable energy development.[12] And the DC Property Assessed Clean Energy program provides financing to cover 100 percent of the upfront costs of solar energy and energy efficiency. Because of these policies and programs, the District had 2,792 homes powered by solar, 1,180 solar-related jobs, and 169 solar-related companies at the close of 2016. The price per kilowatt hour for solar PV has declined by 64 percent during the last five years, and solar installations are expected to quadruple during the next five years.[13]

Installing rooftop solar panels is not just an environmental strategy for the District; it is an economic one. Jobs to install rooftop solar pay roughly $40,000 per year, only require a high school diploma, and accrue locally (e.g., they are "sticky" jobs).[14] According to research from University of California – Berkeley, large-scale solar installations (e.g., utility-scale solar) generate even more and higher-wage jobs than small-scale solar (e.g., rooftop PV), although these jobs are less likely to accrue locally.[15] Our model suggests that implementing enough rooftop solar to generate 16 percent of the District's electricity consumption could generate roughly 100,000 direct, indirect, and induced FTE[16] positions between today and 2050. Some of those positions would be permanent (e.g., maintenance); some would be temporary (e.g., installation); and some would be indirect or induced based on the investment in solar (e.g., jobs created in industries supplying materials for solar panels or jobs created in local retail establishments boosted by higher wages and consumption). Building-level solar power can save residents and businesses money on annual energy costs, and it can also generate revenues. DCSEU reports that building-level solar power has saved residents 70 percent of energy costs on an average home in DC.[11]

2) Building Automation: Automating Temperature, HVAC, and Lighting in Homes and Businesses

Because buildings constitute roughly three-quarters of the District's total emissions, switching over to cleaner and more efficient forms of energy for both electricity and heating will significantly reduce emissions. Reaching that 80x2050 target, however, will require additional energy efficiency, especially in the District's existing building stock. Our analysis shows that, next to improving building envelopes with wall insulation and double- or triple-glazed windows, installing building automation systems in homes and businesses is the single most effective energy efficiency lever for DC.

Building automation refers to the automatic adjustment of heating, cooling, ventilation, and lighting. Sensors feed information on environmental conditions and room occupancy to a centralized database, which then signals actuators and control units to reduce temperature f or to let in fresh air. This reduces building energy demand by more than 30 percent in some climates, as building occupants no longer manually operate HVAC systems. Many municipalities are choosing to lead by example in building automation, greening their own buildings in addition to passing policy measures that mandate or incentivize energy efficiency in new and existing buildings. The types of technologies used for these retrofits – sensors to detect room occupancy, actuators to control lighting,

11 NREL, 2016, http://www.nrel.gov/docs/fy16osti/65586.pdf

12 DCSEU, Accessed 2017, https://www.dcseu.com/

13 SEIA, Accessed 2017, http://www.seia.org/sites/default/files/Washington%20DC_Federal_3.10.2017.pdf

14 BLS, 2015, https://www.bls.gov/ooh/construction-and-extraction/solar-photovoltaic-installers.htm

15 UC-Berkeley, http://laborcenter.berkeley.edu/are-solar-energy-jobs-good-jobs/

16 Full-time equivalent (FTE) is a labor term that reflects the number of person-hours in a year of work. In the U.S., 2,080 hours of work represents one FTE. An FTE could be filled by one person, two people, or

Photo via pixabay

and smart thermostats and smart meters for water, electricity and natural gas – establish a digital backbone for buildings.

This digital backbone allows municipalities (or companies) to track and manage in real-time their energy and water use; identify where maintenance currently is or is predicted to be necessary; and automate orders for parts, among other actions. Importantly, this digital backbone for buildings can also be incorporated into a larger dashboard that tracks data across asset classes and across municipal agencies. With a dashboard that aggregates data on:

- » Electricity, natural gas, and other fuel usage by municipal buildings and fleets;
- » Condition, number and value of City assets, including buildings and vehicles;
- » Occupation of buildings and movement of fleets

he City not only could optimize its own assets, but also understand its buying power and leverage it to negotiate better public-private contracts for asset s and services. Such a dashboard could also be opened, optionally, to the private sector as a voluntary transparency program.

3) A Robust Metrorail Service: Improving Frequency and Reliability of Trains

Despite competition from ridesharing and potentially from autonomous vehicles, public transit can and will be an important part of a future multi-modal transport network in the District. Our analysis models the addition of a new separated line through the Downtown core that would connect to the wider metropolitan area Metrorail network. We also model improved service on all Metrorail lines, with average headway (the time between trains) reduced from 360 seconds to 180 seconds.

Implementation of a communicated-based train control (CBTC) system would allow reduction of headway to as low as 90 seconds. In addition to offering environmental benefits, CBTC augments reliability and safety of light rail service, because trains communicate to each other and to an operations and control center where they are along the track. Unlike some technologies, CBTC is future-flexible: it works equally on trains with and without drivers, and where Siemens has installed CBTC (on driverless trains in Paris and on driver-conducted trains in New York City), it has increased network capacity, carrying up to 20 percent more passengers daily with greater reliability and less energy expended.[17]

Photo via Siemens AG

Beyond carrying lots of people over long distances, rail offers economic benefits that will continue to be important long-term despite new transportation business models and

17 Siemens, Smart Cities in the Digital Age (2016)

technologies. These benefits are avoidance of additional road and parking capacity, reduced congestion and travel times, increased property values, and increased property tax revenues. In the District, two million jobs (or 54 percent of all regional jobs) are accessible within a ½ mile radius of Metrorail stations and 300,000 more jobs are accessible within 1 mile radius of Metrorail stations. A report from WMATA from 2011 showed that public transit saves the Capital region almost 148,000 hours/day in congestion. Metrorail also boosts property values, adding 6.8 percent more value to residential, 9.4 percent to multi-family, and 8.9 percent to commercial office properties within a half-mile of a rail station.[18]

4) Intelligent Traffic Management: Smoothing Flows of Traffic throughout the District

The Tom-Tom Traffic Index ranks Washington, DC's traffic among the top 100 worst in the world for cities. During congested periods, travel time takes 29 percent longer than it does when there's no congestion at all, so a journey that should only take 30 minutes, for example, would take 39 minutes with congestion. As the District competes nationally and internationally for talent, investment, and jobs, it will need a multi-modal transportation network that incorporates rail, cars, buses, trucks, pedestrians, cyclists, motorcyclists, shuttles and even drones, moving them efficiently on already crowded streets, highways, and rail lines.

Intelligent traffic management systems serve as one aspect of a "digital backbone" for future transport networks, and the District Department of Transportation (DDOT) already uses many of the technologies that support an intelligent traffic management system: Sensors to monitor traffic speed and density; a centralized databased of information from traffic signals and sensors; automatic messaging on roadside displays about real-time travel times; an app that provides real-time data to the public on congestion, camera feeds, construction, and event locations; and pilot projects for bus signal prioritization and parking management and pricing.

Siemens projects in Berlin, Germany and in Ann Arbor, MI, have shown how these types of technologies add value to cities. After the installation of a parking management system in Berlin, time spent looking for parking dropped 43 percent, reducing GHG emissions by 30 percent and payment avoidance (e.g., people not paying for parking or for penalty tickets) by 20 percent.[17] The system also brought revenue to the city, as cars were able to more easily park, and payments were enforced automatically. A Siemens project "smart" traffic control system (known as an adaptive control system) in Ann Arbor, MI, improved travel times through a busy corridor by up to 20 percent, even during university athletic events.[19]

What the District will need to develop further as it builds out its digital backbone are decision-support technologies for the smart transport infrastructure it already owns. These will include technologies that take data DDOT has collected, determine a course of action that will help mitigate congestion real-time, and recommend or automatically take action using the technologies DDOT already has at its disposal.

Photo via Horia Varlan

18 WMATA, Making the Case for Transit: WMATA Regional Benefits of Transit (2011)

19 Siemens, Ann Arbor SCOOT Mobility Study, https://w3.usa.siemens.com/mobility/us/en/Documents/SIE_WP_Ann%20Arbor.pdf

Photo via Siemens AG

80x2050 and Its Co-Benefits

Combining the benefits of the 25 energy, buildings, and transport technologies, we find that they could reduce the District's annual CO_2e emissions 90 percent from the 2006 baseline – well beyond the goal of 80x2050.

Combining the benefits of the 25 energy, buildings, and transport technologies, we find that they could reduce the District's annual CO_2e emissions 90 percent from the 2006 baseline – well beyond the goal of 80x2050. Installing, operating, and maintaining the 25 technologies would generate 1.9 million gross FTEs between today and 2050, as well as improve air quality by 55 percent for particulate matter 10 (PM10) and by 70 percent for nitrogen oxides (NOx) compared to the 2050 business-as-usual scenario. Considering that the District's population is expected to grow 57 percent to more than a million people, the CyPT-projected emissions reduction and job growth would be unprecedented, setting the District apart on a worldwide stage of cities working to decouple economic growth from an increase in CO_2e emissions.

A) 2006 Baseline
The CyPT estimates annual GHG emissions from buildings and transportation in 2006[20] as 9.8 million metric tons.

B) 2016 Estimate
Based on actions that the District has taken, annual emissions have dropped -26 percent between 2006 and 2016.

C) 2050 Business-as-Usual
If residents and businesses in DC continue to act exactly as they have, and if the population grows as expected, the CyPT estimates that emissions between 2016 and 2050 will rise to 9.9 million metric tons. This represents a 37 percent increase in annual emissions from 2016, but only a 1 percent increase from 2006.

D) Smaller Homes
If the market continues to exert downward pressure on housing size (the average residential unit falls from 1,122 to 1,047 ft²), 2050 emissions will be -1 percent lower than 2006 emissions.

E) Cleaner Energy
If, on top of that reduction in residential unit size, electricity consumption is 100 percent from renewable sources and 56 percent of heating consumption is from electricity and CHP, annual emissions will be roughly -73 percent lower than in 2006.

F) Active Transportation
A 10 percent reduction in passenger miles traveled by car, in addition to changes to housing size and electricity and heating mixes, would result in a -75 percent reduction in annual emissions compared to 2006.

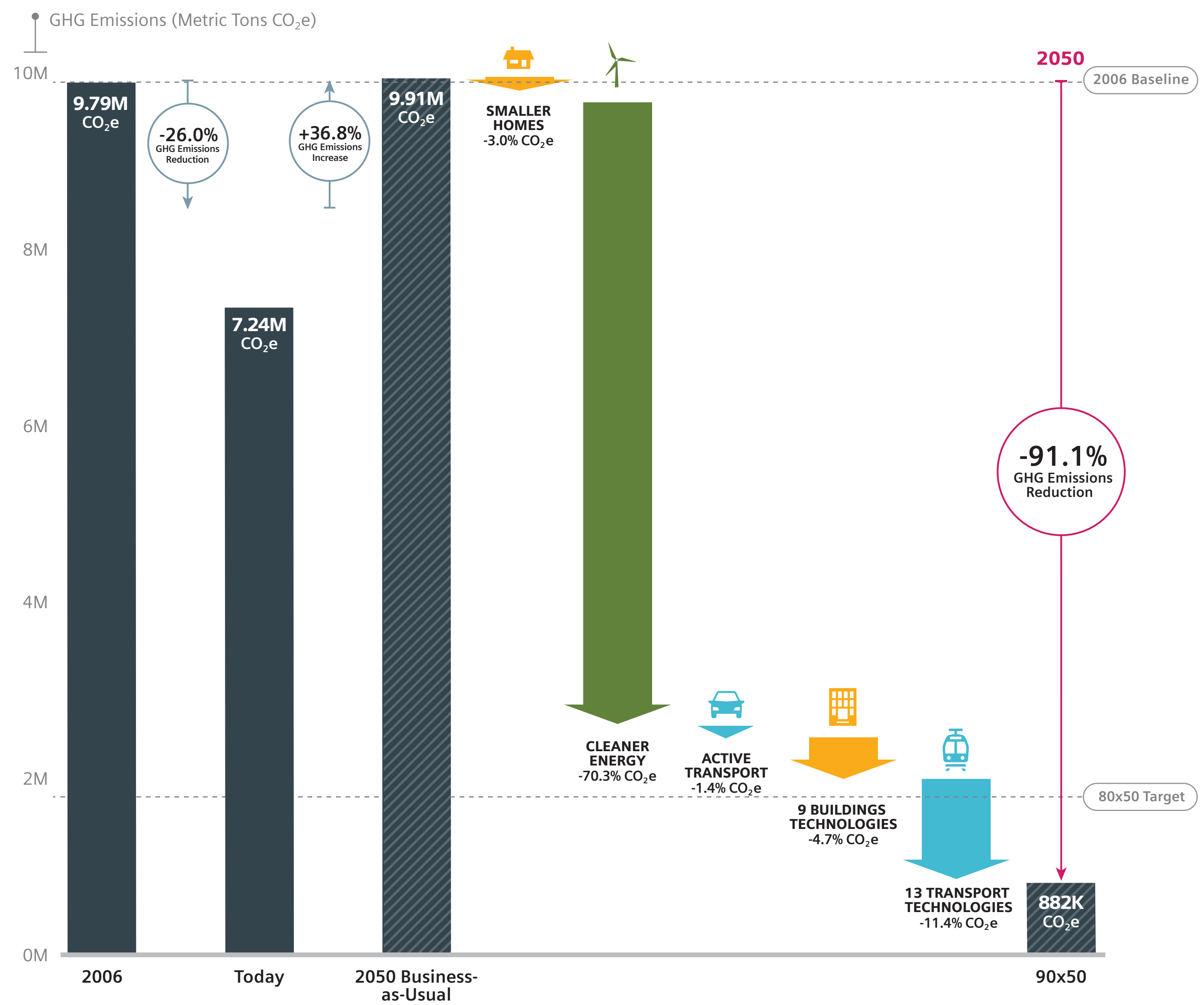
G) Buildings Technologies
Coupled with renewable-powered electricity and more efficient and, in some cases, electric heating, nine building technologies reduce emissions by close to 5 percent.

H) Transport Technologies
Thirteen transportation technologies reduce emissions a further 11 percent. Switching to 70 percent electric passenger vehicles in the District alone delivers 920k metric tons of CO_2e emissions reductions, or 10 percent of all emissions reductions.

I) "90x2050"
The combined benefits of the 25 energy, buildings, and transport technologies; market forces; policy changes; and behavioral changes could reduce the District's annual CO_2e emissions 91 percent from the 2006 baseline – well beyond the goal of 80x2050.

20 DC's baseline year against which it measures all sustainability targets

DC Can Exceed 80x2050



Source: CyPT Model

Source: CyPT Model

The Digital District | Conclusion

Conclusion

While 2050 may seem far away, strategic planning and investments must be made now to ensure the District remains on track for meeting its 80x2050 *Sustainable DC* target.

Although the District's target for emissions reduction is technically 80x2050, our analysis supports that the District stands to gain much more if it pushes past the target to reach 90 percent. Developing clean energy is not just good for sustainability in the District and the surrounding metropolitan area; it is good for economic development, and has the potential to create jobs for skilled and unskilled workers and foment a pipeline of work that seeds future innovation and start-ups. Energy efficiency measures can save residents and businesses money – money that can then be used for better health, for a higher quality of life, and for goods currently deemed unattainable. In a city where the amount of available, affordable housing is not keeping pace with population growth, this extra money will enhance quality of life for more residents. A robust transport network can reduce congestion and improve accessibility to jobs, healthcare, government services, retail, and parks.

Given Mayor Muriel Bowser's commitment to equity, the increased accessibility offered by a robust transport network is not only desirable, but essential.

While 2050 may seem far away, strategic planning and investments must be made now to ensure the District remains on track for meeting its 80x2050 *Sustainable DC* target. With all of the responsibilities the District has to constituents' issues today, including to intermediary targets set for the next five, 10, and 15 years as identified in *Clean Energy DC* and *Climate Ready DC*, it can be difficult to motivate stakeholders to act. However, many of the technologies analyzed in this report can be implemented now, with help from the private sector and with immediate public benefit. Additionally, the long lifespan and infrequent replacement of many key building, transportation, and energy systems means that market adoption must begin now in order to reach full market penetration by 2050.

Photo via pixabay

This chart reflects how public and private sectors and the public can collaborate in delivering the 25 technologies discussed in this report. Five principal groups are assigned responsibility: the City, consumers, businesses, the utilities serving the District, and the regional transit agency WMATA. Additional stakeholders will likely be responsible for designing and delivering long-term sustainability in DC, but these five groups are critical to driving success.

"Control" is assigned when a group owns, leases, or manages the asset – or, in the case of the City, owns, leases, or manages the infrastructure necessary to facilitate that technology. For example, the City could give right-of-way on District streets to WMATA to operate a new electric Bus Rapid Transit line. The City could also build public electric vehicle charging infrastructure for private vehicles or set aside land for WMATA to store and charge electric buses.

A group is assigned "Influence" when it is able to advocate for the investment, furnish additional funding or financing for the technology, provide incentives/disincentives for consumers and businesses to adopt the technology, and, in the case of the City, pass policies and regulations that mandate technology adoption. For example, the City and WMATA could work together to develop an intermodal traffic management app that helps people with trip planning and payment in the District. However, consumers and businesses would be essential to making such a program successful and could even assist in its development. A business might set up an electric car sharing program within DC, but it would be up to WMATA, the District's utility company, and consumers to make sure that the program connected with existing transit operations, had access to reliable charging infrastructure, and attracted enough users.

The District government has already made strides to work across government silos and with the private sector. The Office of Public-Private Partnerships, for example, solicits private sector innovation and financing, and offers new procurement models to hasten technology delivery, and the planned Green Bank will offer financing for energy efficiency and renewable energy projects.

A recent Siemens report lays out nine types of smart city initiatives, for cities like Washington, DC, that are easiest for private sector partners to finance.[21] They include building controls, vehicle routing, parking management systems, road pricing, low-energy street lighting, and electric buses and other electric vehicles. For these smart city investments, a private sector partner or group of partners might make an equity investment, where return on investment (ROI) is not guaranteed, but risk is shared with the public sector (e.g., building a new airport). It might provide project finance when there is a widely proven ROI, such as upgrading an already overburdened passenger rail network. Or it might offer asset finance on clear, well-proven projects with highly-dependent ROIs (e.g., energy-efficient buildings, smart routing systems, smart parking systems, or a clean CHP plants).

Deep decarbonization in the District will require big efforts from DOEE, its sister agencies, and partnering quasi-public and private sector entities - but the pay-offs will also be big. In reaching 90x2050, there lies an opportunity to make the District the healthiest, greenest, and most livable city in the United States by improving air quality, lowering traffic congestion, increasing the quantity of and pay for jobs, and providing better connectivity and accessibility for residents, businesses, and visitors.

21 Siemens Financial Services, SmartStart: Modeling Private Sector Finance Adoption for SmartStart Cities (2016)

Breaking Down 90x2050 into Stakeholder Action

Stakeholder can influence | Stakeholder has control

BUILDINGS

	CITY	CONSUMERS	BUSINESSES	UTILITIES	WMATA
Residential -Home Automation	Influence	Control		Influence	
Non-Residential -Efficient Llight Technology	Influence		Control	Influence	
Non-Residential -Demand Controlled Ventilation	Influence		Control	Influence	
Non-Residential -Heat Recovery	Influence		Control	Influence	
Non-Residential -Building Envelope	Influence		Control	Influence	
Non-Residential -Building Automation, BACS B	Influence		Control	Influence	
Non-Residential -Efficient Motors	Influence		Control	Influence	
Non-Residential -Room Automation, HVAC + Blinds	Influence		Control	Influence	
Non-Residential - Building Remote Monitoring	Influence		Control	Influence	

TRANSPORT

	CITY	CONSUMERS	BUSINESSES	UTILITIES	WMATA
Electric Buses	Control			Influence	Control
Metro - New Line	Influence				Control
Intelligent Traffic Light Management	Control				
Electric Cars	Control	Control	Control	Influence	Influence
Electric Taxis	Control		Control	Influence	
Electric Car Sharing	Control	Influence	Control	Influence	Influence
Intermodal Traffic Management	Control	Influence	Influence		Control
Bikeshare	Control	Influence	Influence		
Street Car - New Lines	Control		Influence		Influence
e-BRT (Electric Bus Rapid Transit) - New Lines	Control			Influence	Control
Metro - Reduced Headway	Influence				Control
Smart Street Lighting	Control			Influence	
Public Transport - E-Ticketing	Control				Control

ENERGY

	CITY	CONSUMERS	BUSINESSES	UTILITIES	WMATA
Wind	Influence	Influence	Influence	Control	
PV	Control	Control	Control	Control	
Combinted Heat and Power	Control	Control	Control	Control	

Photo via pixabay

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 CO_2e 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% of which 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 DC'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. Energy Use Intensity (EUI) 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_2e emissions and PM10 and NOx levels. The model measures the impact of technologies on the CO_2e, PM10 and NOx baselines of the city with CO_2e 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.

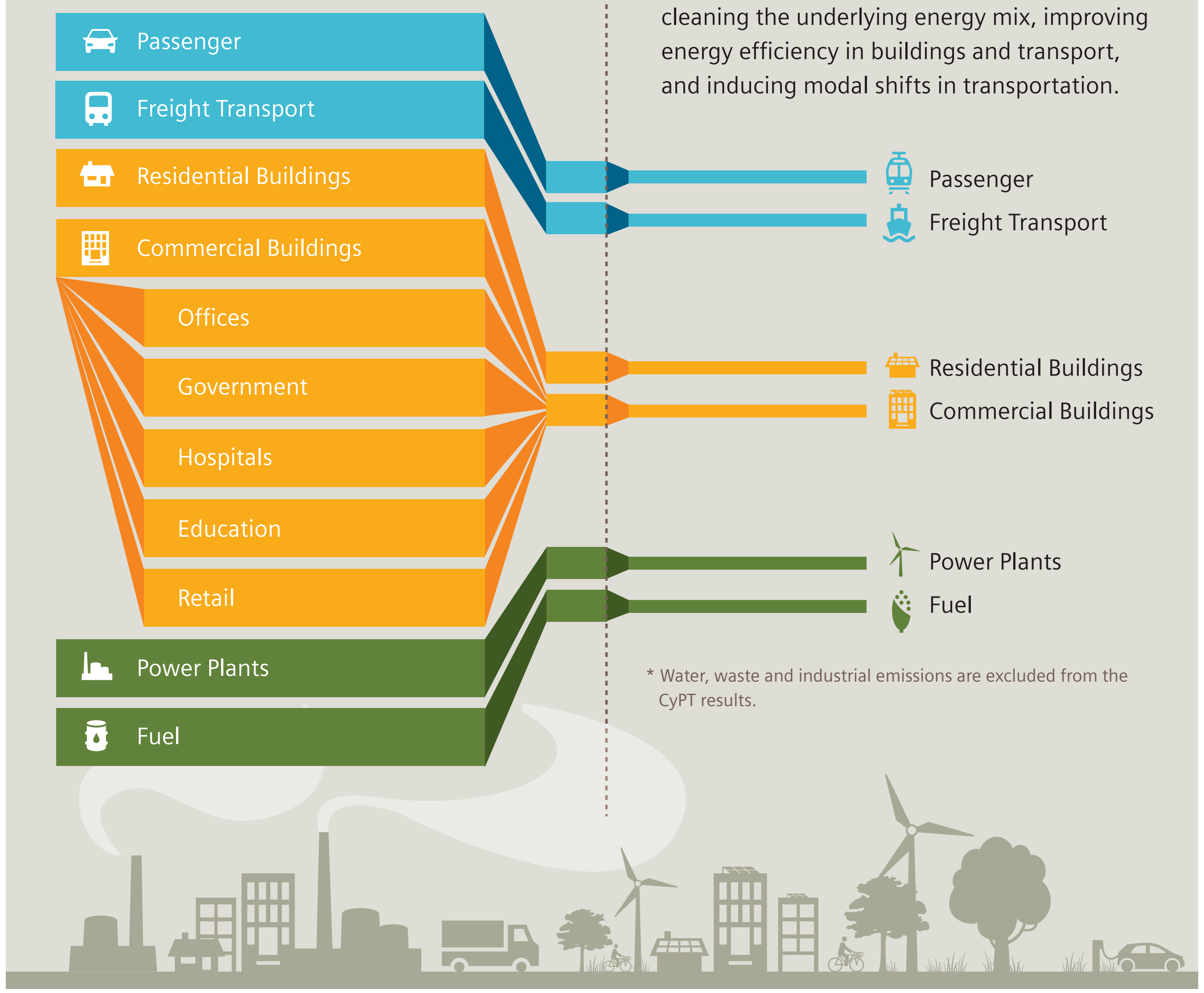
The model also tests the performance of each technology on two economic indicators. First, the total capital investment needed to deliver the technologies and secondly, the total gross number of jobs that could be created in the local economy. These include installation, operation and maintenance jobs,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

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 Technologies

BUILDING LEVERS

Residential / Non-Residential	Wall Insulation	Solid wall insulation e.g. made of expanded polystyrene (EPS) can be applied to 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 minimizes the heating/cooling energy needed. Reduction of CO_2e, 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 CO_2e, PM10, and NOx related due to energy savings.
Residential	Efficient lighting technology	Significant electrical energy can be saved by replacing conventional luminaires with more efficient lighting fixtures and/or changing magnetic ballasts to electronic ballasts. Further reductions in power consumption can be achieved with the use of light-emitting diodes (LEDs), which also have a far higher lifespan than conventional lighting. LED solutions combined with intelligent light management systems can lower lighting costs in a building by as much as 80%. Reduction of CO_2e, PM10, and NOx related emissions can also be attributed 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 consumers 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 operational hours and turn off/on cycles. LED lamps are compatible to conventional lamps and can substitute them easily. LEDs provide an equal luminosity at lower specified power. Reduction of CO_2e, PM10, and NOx emissions are possible 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 CO_2e, PM10, and NOx emissions are possible 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 an EXISTING building, via a centralized monitoring system connected to a network of field devices (such as meters, switches and sensing devices). Standard energy reports are created to allow benchmark comparison with similar buildings to assess performance and highlight problems (e.g. kWh, CO_2, temperature). Offering monitoring services and performance reports creates awareness and transparency and enables continuous improvement and reduction of overall energy consumption. Reduction of CO_2e, PM10, and NOx related due emissions are also realized due to thermal and electrical energy savings.
Non-Residential	Building Performance Optimization (BPO)	Building Performance Optimization (BPO) is a range of services designed to increase the energy efficiency of an EXISTING building by implementing proven building control strategies otherwise known as Facility Improvement Measures (or FIMs). BPO can improve THERMAL and ELECTRICAL energy efficiency in a building in many ways; typically via improved HVAC technology, by adapting the building to suit usage profiles or providing information and analytics for operational personnel. Reduction of CO_2e, PM10, and NOx 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. CO_2 levels measured by air quality detectors identify periods of low occupancy and cause the fans to stop or reduce speed (at 50% air volume, the fan power is reduced by a factor of 8!). DCV also provides savings in heating and cooling, by adjusting set point temperatures (economy mode). Reduction of CO_2e, PM10, and NOx are also realized due to electrical electricity 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.

BUILDING LEVERS

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 CO_2 emissions. Adding variable speed drive technology will ensure motors only draw as much energy as is actually required. Reduction of CO_2e, PM10, NOx are related to electrical energy savings.
Non-Residential	Room Automation 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 CO_2e, PM10, NOx are related to electrical power utilized in the heating, ventilation and air-conditioning of a building.
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 CO_2e, PM10, NOx are related to electrical power utilized in the heating, ventilation and air-conditioning and lighting of a building.

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 CO_2e, 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 CO_2e, 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 – Metro	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 – 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	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.

TRANSPORT LEVERS

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.
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) - 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 per km due to coasting. The saving potential correlates with the number of and distance between the stations. Reduction of CO_2e, PM10, and NOx related to lower electricity demand.
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.

TRANSPORT LEVERS

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 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.

TRANSPORT LEVERS

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	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.

The estimated results of these four forces on the District's CO_2e emissions in 2050 are staggering. Reduced residential unit sizes, a cleaner electricity mix, thermal electrification and an active transport-dominated mode share could reduce District's community-wide greenhouse gas (GHG) emissions by 75 percent based on the 2006 baseline year.

A) 2006 Baseline
The CyPT estimates annual GHG emissions from buildings and transportation in 2006[10] as 9.8 million metric tons.

B) 2016 Estimate
Based on actions that the District has taken, annual emissions have dropped -26 percent between 2006 and 2016.

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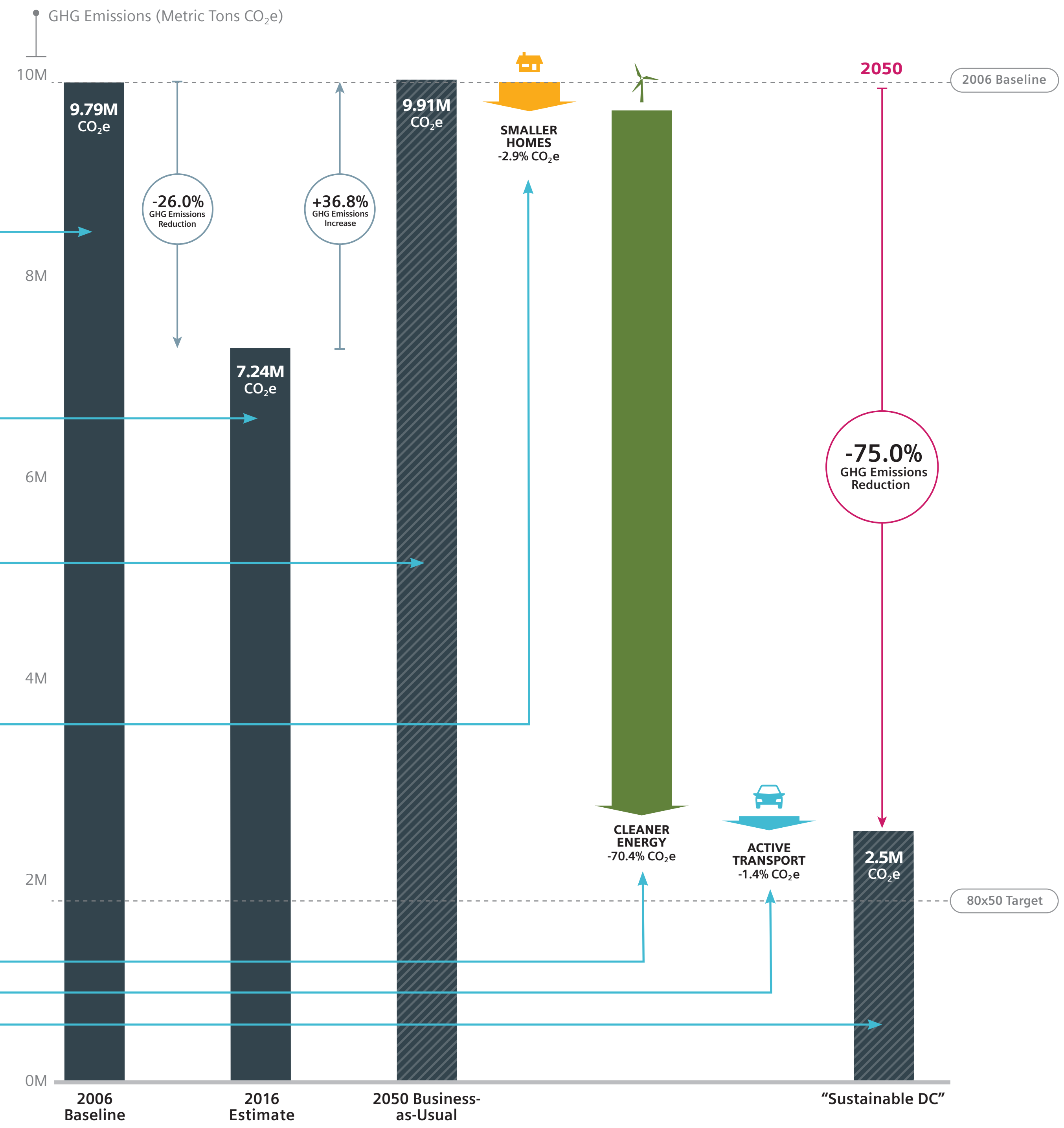
F) Active Transportation
A 10 percent reduction in passenger miles traveled by car, in addition to changes to housing size and electricity and heating mixes, would result in a -75 percent reduction in annual emissions compared to 2006.

G) "Sustainable DC"
Combined, these changes in the market, policy, and behavior represent a significant decrease in overall emissions, from 9.8 million metric tons in 2006 to 2.5 in 2050. This is a -78 percent decrease in GHG emissions per capita.

Actions Have Consequences:

How Smaller Homes, Cleaner Energy, and More Active Transportation Choices Affect Emissions



Source: CyPT Model

10 DC's baseline year against which it measures all sustainability targets