100% Renewable Boston

How Boston can accelerate the transition from fossil fuels to clean, renewable energy

ENVIRONMENT MASSACHUSETTS
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Photo (above) by SunPower via NREL
The Williams Building in downtown Boston

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Contents

Why should Boston lead the way to 100% renewable energy?

Boston residents are feeling the impacts of our dependence on dirty energy like oil and gas — from rising sea levels and severe storms to asthma attacks and missed days of school and work.

Over the years, Boston has often been a leader in efforts to expand clean energy, reduce harmful air pollution, and fight climate change. Now, with federal leaders doing everything they can to keep the nation hooked on fossil fuels, it's time for local officials to step up again.

In order to improve the health, safety, and quality of life for city residents, Boston's leaders should accelerate the move to a carbon-free future and join dozens of other U.S. cities in committing to achieve 100% renewable energy economy-wide by mid-century.

Boston is at risk from global warming

As pollution from coal, oil, and gas changes our climate, Boston can expect to see significant impacts. If we fail to achieve rapid reductions in global warming pollution worldwide, the effects of climate change will likely grow much worse for Boston in the coming decades.

As part of Climate Ready Boston, the city's climate adaptation plan, researchers assessed the likely future impacts of global warming in Boston. If we continue along our current trajectory, by 2070 Boston could experience up to 90 days of temperatures above 90 °F each year, with up to 33 days above 100 °F. Heavy rainstorms will become more severe, while sea levels could rise by up to 7.4 feet by the end of the century.

Even with only 3 feet of sea level rise, significant flooding would occur during high tides, on days when there is no storm. Between 10 and 20 percent of the land in the city's most at-risk neighborhoods — Charlestown, East Boston, Downtown, and South Boston — would be flooded during a normal monthly high tide.

The impacts of global warming are expected to be more severe for vulnerable populations in Boston, including senior citizens, low-income people, and people of color.[1]

Although Boston can't stop the worst impacts of global warming on its own, the city can take major steps to reduce carbon emissions while setting a bold example for other cities to follow.

Dirty energy is harming our health

Pollution from oil and gas used for electricity, transportation, and heating is harming our health. Nitrogen oxides and volatile organic compounds combine to form smog, which contributes to respiratory conditions ranging from coughing and wheezing to

asthma and even permanent lung damage. Particulate matter can cause similar respiratory symptoms, and is also linked to cardiovascular disease and premature birth.[2]

In 2015, the Boston metropolitan area experienced 92 days with elevated particulate matter pollution, and 41 days with elevated smog pollution. These numbers don't account for the fact that people who live or work near highways, industrial facilities, or airports often experience even higher levels of dangerous pollution.[3]

A future powered by renewable energy is within reach

Clean energy has grown rapidly in Massachusetts in recent years. Today, there is more than 300 times as much solar capacity installed in Massachusetts as there was ten years ago.[4] State officials recently made a major commitment to offshore wind.[5] Companies working in solar, wind, energy efficiency, and other clean energy technologies currently employ more than 100,000 people in Massachusetts.[6]

Massachusetts has enormous clean energy potential, with solar capable of providing twice as much electricity as the entire state uses each year, and offshore wind capable of powering the state eleven times over.[7]

A recent report from the Environment Massachusetts Research & Policy Center examined seven detailed studies of high renewable energy scenarios, and concluded that there are no insurmountable technological or economic barriers to powering the nation with 100 percent renewable energy from sources like solar and wind.[8]

Boston has a history of climate action

In 2007, then-mayor Thomas Menino signed an executive order on climate change, committing Boston to reduce its carbon emissions by at least 80 percent by 2050. To help achieve this goal, Mayor Menino directed city officials to create a community-wide energy and greenhouse gas inventory and establish a comprehensive Climate Action Plan. The order also pledged that the city would lead by example by increasing energy efficiency and reducing fossil fuel use associated with municipal buildings and operations.[9] Boston's community-wide Climate Action Plan was released in 2011 and updated in 2014.

In his 2017 State of the City address, Mayor Martin Walsh doubled down on the city's climate action commitment, promising to make Boston carbon-neutral by 2050.[10] Boston does not yet have a plan to meet this commitment, but officials and researchers are developing strategies to make Boston carbon-neutral as part of the next revision of the city's Climate Action Plan.

The city's overall emissions have declined by 17 percent since 2005, but some sectors, such as transportation and heating, have shown less progress.[11] Meeting Mayor Walsh's carbon neutral commitment will require the city to expand existing clean energy and energy efficiency programs, while adopting new policies to reduce emissions and rapidly transition to 100 percent renewable energy across all sectors.

It's up to cities to lead

In his first months in office, President Donald Trump has announced plans to withdraw from the Paris Climate Agreement and begun to roll back some of

the country's key climate and clean energy policies, such as the Clean Power Plan.

The problems posed by our dependence on dirty energy are more urgent than ever, especially with the federal government moving in the wrong direction. City officials can help fill this leadership gap by adopting an ambitious vision for our clean energy future and taking bold, innovative steps to achieve it.

Already, 36 U.S. cities have committed to a goal of 100 percent renewable electricity. In June, the U.S. Conference of Mayors adopted a resolution supporting the transition to 100 percent renewable energy in cities across the country.[12]

Mayor Walsh has taken positive steps recently by pledging to uphold the goals of the Paris Climate Agreement and committing to make Boston carbon-neutral. Now, it is up to the Mayor and other city officials to create a roadmap that will transition Boston to 100 percent renewable energy as quickly as possible.

Recommendations

To accelerate the transition to 100 percent renewable energy, Boston officials should look to the most innovative, forward-thinking policies adopted by other cities across the country. In this report, we present case studies of leading municipal clean energy policies across 12 different sectors. While every city is different, these case studies serve as a marker for what's possible and a benchmark to measure Boston's efforts against.

Some of the recommendations below have been included in city planning documents, such as the Climate Action Plan or Go Boston 2030, but have not yet been implemented; some are currently being implemented on a limited scale; and others have not been included in the city's plans at all. The city should move quickly to follow through on the commitments already included in its planning documents, and scale up existing pilot programs to serve all residents, businesses, and institutions throughout the city.

For Boston to be a national leader on clean energy and climate action, city officials should aim to match or exceed the success of these ambitious policies adopted by other cities.

Energy-efficient buildings

1: Net zero buildings

- **Cambridge, MA** adopted a detailed plan to reduce building sector emissions by 70% by 2040 through net zero carbon requirements for new and existing buildings.
- **RECOMMENDATION:** Boston should create a net zero plan with specific year-by-year benchmarks and policy actions to reach zero emissions from the building sector, and act quickly to ensure that all new buildings are built to achieve net zero carbon standards.

2: Energy efficiency in large buildings and institutions

- Civic leaders in **Pittsburgh, PA** created the Pittsburgh 2030 District to encourage large real estate owners and institutions to improve the energy efficiency of their buildings.
- **RECOMMENDATION:** Boston should build on successful efforts by groups such as the Green Ribbon Commission, Health Care Without Harm, and A Better City, which bring together health care institutions, universities, and businesses to reduce emissions from their properties.

Local renewable energy

3: Solar-ready requirements and solar mandates

- **Austin, TX** requires new single-family, multi-family, and commercial buildings to have a "solar-ready zone" on their roofs capable of accommodating a solar installation.
- **Lancaster, CA** requires new residential buildings to be built with solar panels installed on their roofs.
- **RECOMMENDATION:** Boston should require all new buildings with a sufficient solar resource to be built with solar panels, as part of achieving a net zero carbon building target.

4: Renewable energy and energy efficiency in municipal buildings

- **Las Vegas, NV** powers its municipal buildings with 100 percent renewable electricity, including energy from on-site solar installations.
- **San Francisco, CA** improved energy efficiency and installed solar panels at the Moscone Center, the city's largest convention center.
- **RECOMMENDATION:** Boston should adopt a goal of powering all of its municipal facilities with 100% renewable electricity by 2025. Boston should require new municipal buildings to be built to net zero carbon standards, complete deep energy retrofits on existing buildings, and install solar panels on every suitable city-owned rooftop.

5: Renewable energy for low-income residents

- **Washington, D.C.** created a program to cover the full cost of solar installations on the houses of low-income residents.
- **RECOMMENDATION:** Boston should expand access to clean energy and energy efficiency for low-income families through targeted outreach and special incentive programs.

6: Large renewable energy installations

- **Indianapolis, IN** installed 29 megawatts of solar at the Indianapolis International Airport and Indianapolis Motor Speedway.
- **RECOMMENDATION:** Boston should pursue opportunities for medium- and large-scale renewable deployment in the city, including solar installations on large rooftops and over parking lots.

Renewable electricity supply

7: Renewable power purchase agreements

- In **Boston and Cambridge, MA**, the Massachusetts Institute of Technology, Boston Medical Center, and Post Office Square Redevelopment Corporation signed a power purchase agreement for 146 gigawatt-hours of clean power each year for 25 years from a solar farm in North Carolina.
- **RECOMMENDATION:** Boston should encourage or require other institutions and businesses to follow this example, and to procure electricity from renewable energy installations in Massachusetts or other New England states whenever possible.

8: Community choice aggregation

- **Marin County, CA** created a community choice aggregation program providing a default of at least 50 percent renewable electricity to residents and businesses.
- **RECOMMENDATION:** Boston should follow the example of nearby communities like Arlington, Somerville, and Dedham, and immediately create a community choice aggregation program with at least 5-10 percent additional Class 1 renewable energy above the state's minimum requirements. Boston should also develop a more comprehensive program that would bring the city to 100 percent renewable electricity over time.

Clean transportation

9: Electric vehicles

- **Chicago, IL** introduced electric garbage trucks into its municipal fleet, and the Chicago Transit Authority purchased electric buses.
- **Sacramento County, CA** deployed 29 electric school buses in three school districts.
- **Portland, OR** made it easier for residents to switch to electric vehicles by simplifying the process of installing a home charging station and increasing the number of public charging stations.
- **RECOMMENDATION:** Boston should adopt an aggressive plan to convert municipal vehicles to electric models, including heavier vehicles like garbage trucks and school buses. Boston should also make it easier for residents to install charging stations at their homes and charge their electric vehicles on the go.

10: Public transit

- In the **Bay Area, CA**, officials are planning to power the subway system with 100 percent renewable energy.
- **Cleveland, OH** has installed 3 bus rapid transit lines, resulting in improved travel speeds and increased ridership.
- **RECOMMENDATION:** Boston should move ahead with plans to install high-quality bus rapid transit lines in key corridors, and work with the MBTA to power the transit system's subways, buses, and trains with 100% renewable electricity.

Other technologies

11: Renewable heating and cooling

- **Sitka, AK** encouraged residents to switch to air source heat pumps through incentives and public education.
- **Boulder, CO** is creating a comprehensive, city-wide strategy to shift residential heating systems to renewable technologies.
- **RECOMMENDATION:** Boston should create a Solarize-like program to make it easier for residents and businesses to switch to renewable heating and cooling technologies, including air source heat pumps, ground source heat pumps, and solar thermal. Boston should also develop a roadmap to shift heating and cooling for all buildings in the city to renewable technologies by 2050.

12: Microgrids and energy storage

- **Fort Collins, CO** created a microgrid connecting businesses, city and county buildings, and the Colorado State University campus, allowing for increased renewable energy penetration.
- **New York, NY** set a target of installing 100 megawatt-hours of energy storage by 2020.
- **RECOMMENDATION:** Boston should set an energy storage target, and move forward with microgrids and other community energy projects that prioritize renewable energy resources.

Energy-efficient buildings

Boston's commercial, residential, and industrial buildings are responsible for 73 percent of the city's greenhouse gas pollution.[13] The first step towards eliminating this pollution is to reduce the energy consumed to heat, cool, and power these buildings. By reducing the total amount of energy used, we can make it easier to replace any remaining energy with clean resources like solar and wind.

In recent years, net zero energy buildings, which produce as much energy as they consume on an annual basis, have become more common. A few leading cities are working to achieve net zero carbon emissions across all of their buildings, meaning that all greenhouse gas emissions are balanced by clean energy production. Major businesses and real estate owners, as well as institutions like hospitals and universities, are taking a close look at their energy consumption and working together to implement energy efficiency measures across entire neighborhoods.

1: Net zero buildings

Cambridge, MA: Net Zero Action Plan

Since adopting the city's first Climate Protection Action Plan in 2002, Cambridge officials have worked to reduce carbon emissions community-wide by at least 80 percent by the year 2050.[14] Because Cambridge is a densely populated community with walkable neighborhoods and good public transit options, most of the city's greenhouse gas emissions come from heating and powering its buildings rather than from transportation. In fact, the building sector is responsible for more than 80 percent of Cambridge's carbon emissions.[15]

In 2013, responding to a petition brought by citizen activists, city officials convened the Getting to Net Zero Task Force, charged with developing a plan to eliminate emissions from Cambridge's buildings. The task force, composed of business and institutional leaders, issue experts, and concerned citizens, worked to determine how all buildings across the city could reduce their energy consumption, produce on-site renewable energy, and purchase off site renewable energy on the road to becoming net zero carbon.

Task force members, along with technical experts, created the Net Zero Action Plan, which was formally adopted by the city council in 2015. The plan lays out a roadmap for the city to reduce carbon emissions from the building sector. Approximately 18 percent of the emission reductions are expected to come from new, highly-efficient residential and commercial buildings, while 51 percent will come from retrofitting existing buildings. The remaining carbon reductions will be realized with Cambridge-based renewable energy (11 percent) and renewable energy from the electric grid (20 percent).[16]

The plan lays out five major action areas to achieve net zero carbon emissions. First, the city will improve the energy efficiency of existing buildings by working with utility companies to develop a custom energy retrofit program based on performance standards, and by exploring a requirement for energy efficiency retrofits whenever buildings are per-

mitted or sold. Second, the city will require all new construction to be built to net zero energy standards, beginning with municipal buildings in 2020 and phasing in requirements for residential, commercial, and institutional buildings by 2030. Third, Cambridge will pursue a low carbon energy supply strategy, including sourcing energy from renewable installations in Cambridge and elsewhere in the region. Fourth, the city will consider creating a "local carbon fund" to offset emissions from buildings that are unable to achieve a net zero standard. Finally, Cambridge will work actively to communicate with residents, businesses, and institutions throughout the transition to net zero carbon.

The plan sets out which policies will be implemented each year in order to achieve the goal of reducing building emissions by 70 percent by 2040.

Since the release of the Cambridge Net Zero Action Plan, other Massachusetts towns and cities, including Lexington, have begun to develop similar plans.[17] Cambridge officials have taken steps to implement the city's plan, including the recent launch of a community choice aggregation program that includes additional solar energy from panels installed in Cambridge.[18] And the city is not resting on its laurels; in fact, Cambridge city councilors recently passed a resolution committing to achieve 100 percent renewable energy by 2035.[19]

In Boston:

Unlike Cambridge, Boston has not yet adopted a road map to get to net zero energy for its building sector. With Boston in the middle of a building boom, now is the perfect time for city officials to ensure that all new buildings are designed to meet a citywide net zero energy goal. Absent proactive efforts by Boston's leaders, new buildings will likely continue to use natural gas for heating, and developers and property owners will miss opportunities to maximize the energy efficiency of their buildings, putting the city's climate goals further from reach.

Boston city agencies have worked together to pilot the construction of energy positive buildings, which produce more energy than they consume. So far, energy positive buildings have been completed in Jamaica Plain and Roxbury, with additional projects currently in development.[20]

Historically, Boston has been a leader in green building requirements. In 2007, Boston adopted a requirement for all large-scale building projects to adhere to LEED Certification standards, through Article 37 of the zoning code. After the adoption of Article 37, Boston became home to over one hundred LEED-certified buildings, including the first LEED Platinum high rise.[21] Although LEED certification indicates that builders and architects have taken certain steps to make their buildings more sustainable, it does not guarantee that a building is net zero energy or highly energy efficient. LEED-certified buildings may still be heated with natural gas, and developers can get credit for steps that have a minimal impact on energy use, such as using low-VOC (volatile organic compound) building materials or improving stormwater management.

The Boston Clean Energy Coalition, a coalition of local and statewide organizations, is currently advocating for a net zero carbon requirement for buildings in Boston.[22]

2: Energy efficiency in large buildings and institutions

Pittsburgh, PA: 2030 District

The Pittsburgh 2030 District, a public-private partnership launched by the Green Building Alliance in 2012, works with property owners to improve the sustainability of buildings in the city's Downtown and Oakland neighborhoods. To date, 2030 districts have been established in 17 cities in the United States and Canada, coordinated by the organization Architecture 2030, with a goal of transforming the built environment to reduce energy and water consumption.[23] The Pittsburgh 2030 District is the largest such district in the country by far, including 78.7 million square feet of real estate.[24]

The Pittsburgh 2030 District is targeting a 50 percent reduction in energy use, water consumption, and transportation emissions from existing buildings by 2030, with an additional goal of making all new buildings and major renovations carbon neutral.[25] Participation in the program is voluntary, with businesses and institutions representing 72.5 percent of the total real estate square footage in Downtown and Oakland currently enrolled.[26] Some of the city's largest institutions participate in the program, including Allegheny General Hospital, Carnegie Mellon University, Duquesne University, and the University of Pittsburgh.

Since 2013, 2.64 billion kBtu of energy has been saved through the 2030 District's efforts. This quantity of energy represents $52 million in reduced energy costs, and is the equivalent of an SUV driving nearly 4.5 billion miles.[27]

With each of the participating businesses and institutions, an energy efficiency baseline was established using the EPA's Energy Star Portfolio Manager, which is an online tool that tracks energy and water consumption, as well as the 2003 Commercial Building Energy Consumption Survey (CBECS).[28] As of 2016, the partners in the Pittsburgh 2030 District have reduced the energy consumption of their buildings by 10.4 percent and transportation emissions are down by 24.2 percent.[29]

While some of the participants in the 2030 District are driven by environmental concerns, many are also motivated by the energy savings that their buildings will obtain. The Wyndham Pittsburgh University Center, a hotel, replaced a kitchen ventilation system with a more efficient model, saving $15,000 per year. The Downtown City-County Building improved its HVAC system, installed LED lighting fixtures, and replaced hard drives with a virtual network, reducing energy costs by more than $106,000 annually.[30]

In Boston:

Through the Mayor's Carbon Cup, Boston recognizes major businesses, nonprofit institutions, and commercial real estate companies that have committed to reduce their carbon emissions by at least 35 percent by 2020.[31]

The Boston Green Ribbon Commission (GRC), whose members include major businesses and nonprofit institutions as well as city and state leaders, works to develop shared strategies for fighting climate change in coordination with the city's Climate Action Plan.[32]

Boston's major hospitals participate in the GRC's Health Care Working Group, coordinated by Health Care Without Harm, and chaired by the CEOs of Partners Healthcare and Boston Medical Center. From 2011 to 2015, Boston's hospitals saved 537 billion Btu through their energy efficiency efforts, reducing greenhouse gas emissions by the equivalent of eliminating 126 million miles of passenger vehicle travel. These hospitals reduced their electricity consumption by 13.1 percent and natural gas consumption by 26.1 percent. Health Care Without Harm calculated that the reduction in pollution resulting from these energy conservation measures saved an estimated $1.6 million in societal costs and helped prevent hundreds of asthma incidents and other respiratory symptoms.[33]

The GRC's Commercial Real Estate Working Group works to reduce greenhouse gas emissions from the city's commercial buildings. The Commercial Real Estate Working Group is facilitated by A Better City, whose Challenge for Sustainability provides toolkits and other resources for major real estate owners and business leaders to reduce the environmental footprint of their properties.[34]

Local renewable energy

Renewable energy installations in American cities are growing rapidly. As of the end of 2016, the top 20 cities for solar power accounted for 5 percent of the country's solar photovoltaic capacity, despite representing only 0.1 percent of the total land area.[35] For all that progress, we've only just begun to tap the clean energy potential of our cities. A recent study from the National Renewable Energy Laboratory found that Springfield has the technical potential to generate 29 percent of all electricity consumed in the city with rooftop solar panels, while for Worcester, the technical potential for rooftop solar is 42 percent of electricity consumption.[36]

There are several advantages to siting clean energy generation facilities within cities. Producing energy closer to where it is consumed can help to reduce energy losses and offset peak electricity demand. Installing clean energy locally also ensures that the financial and employment benefits flow to residents, businesses, and institutions within the city.

Cities are taking several approaches to increase local renewable energy production. Some cities are requiring new buildings to be constructed with solar panels on their roofs, or at least to be built "solar-ready" — that is, with roofs that are free of obstructions and strong enough to have solar panels installed at a later date. Other cities are maximizing solar energy production on city-owned buildings and properties, and working to connect low-income communities with clean energy installations. Finally, cities are taking advantage of opportunities to install medium- and large-scale solar and wind energy facilities.

3: Solar-ready requirements and solar mandates

Austin, TX: Solar-ready requirements for new construction

In February 2017, the Austin city council voted to amend the local building code to require new buildings to be built solar ready.[37] Though it is the third city in Texas to require solar-ready construction, following both Houston and Lewisville, it is the first city in the state with multi-family and commercial construction requirements.[38]

Under these new provisions, the city will require all new buildings to have a "solar-ready zone" on their roofs. One-family and two-family residential buildings are required to have a solar-ready zone of no less than 240 square feet per dwelling, while townhouses must set aside at least 160 square feet of solar-ready roof space. For multi-family buildings, the requirement is at least 35 percent of total roof area. These zones must be oriented to maximize solar exposure and must be free from obstructions, and the building's electric service panel must be able to accommodate a solar installation. There are some exceptions to the residential requirements — for example, if the roof is too small or obstructed

from sunlight for more than 50 percent of annual daylight hours.[39]

For commercial buildings, at least half of the building's "potential solar area" must be built to solar-ready standards. The solar-ready zone must be free from obstructions.

Austin's solar-ready ordinance is set to go into effect on October 1, 2017.

Lancaster, CA: Solar mandate

Since 2014, the city of Lancaster has required solar installations on new residential construction. This policy requires 1 to 1.5 kilowatts of solar capacity per 7,000-square-foot lot. Builders can satisfy this mandate by installing solar panels on every house, or meeting the requirement on an aggregate basis throughout a subdivision. Mayor Rex Parris, a Republican, has said that he wants to make Lancaster "the solar capital of the world."[40]

Recently, Lancaster doubled down on its solar commitment by passing a policy requiring new homes to have enough solar to meet the building's full energy needs, estimated at two watts per square foot. Because not every house can accommodate that much rooftop solar, builders can also pay a fee of $1.40 per square foot of construction, or a installing some solar and paying a portion of the fee. Homeowners can include the cost of solar in their mortgages, without needing to seek separate financing.[41]

The plan is currently awaiting approval by the California Energy Commission before it goes into effect. Lancaster is expecting that all new homes will be net zero energy by 2020, with the commercial sector following not far behind in 2030.[42]

In Boston:

Designing new buildings with an eye towards utilizing their full solar potential would help to maximize the percentage of Boston's electricity that can be generated with on-site solar installations.

Boston has yet to adopt solar-ready requirements or solar mandates for commercial and residential buildings. The Boston Department of Neighborhood Development has issued guidelines for solar-ready design in affordable multi-family housing developments.[43]

In Massachusetts, building codes are set at the state level, making it difficult for municipalities to use the building code to drive additional improvements in sustainability. The state Board of Building Standards and Regulations recently adopted a solar-ready requirement for low-rise commercial buildings and single-family residential buildings, which will become effective by January 2018.[44] The requirements do not include multi-family residential buildings or taller commercial buildings.

Unlike the building code, zoning codes are set by individual cities and towns. Some municipalities, including Cambridge, are exploring ways to use the zoning code to enact solar-ready requirements.

4: Renewable energy and energy efficiency in municipal buildings

Las Vegas, NV: 100% renewable electricity for municipal buildings

In December 2016, the city of Las Vegas became the largest American city to power all of its municipal facilities with 100 percent renewable electricity.[45] The city is now providing clean electricity to all of its municipal buildings, traffic signals, fire stations, service yards, warehouses, administrative building, and public spaces, as well as more than 50,000 street lights.

In 2006, Las Vegas's then-mayor Oscar Goodman signed the U.S. Conference of Mayors Climate Protection Agreement.[46] Las Vegas adopted a goal of reducing carbon emissions by 70 percent below 1990 levels, with on-site renewable generation a key part of the city's strategy.[47] In November 2015, May Carolyn Goodman, the city's current mayor, announced that Las Vegas would achieve 100 percent renewable electricity for its municipal buildings, through a partnership with the utility company NV Energy.[48] Renewable energy has become a point of pride for Las Vegas. As Mayor Goodman said, "We can brag that the city, this city of Las Vegas, is one of the few cities in the entire world that can boast using all of its power from green sources."[49]

To achieve 100 percent renewable electricity, Las Vegas pursued three complementary strategies: installing solar panels on municipal buildings, improving energy efficiency, and purchasing renewable power from an off-site solar farm. The city installed a total of 3 megawatts of solar parking canopies at municipal buildings and properties. There is also a 3 megawatt solar plant at the city's Water Pollution Control Facility.[50] Altogether, the city's solar installations produce 12 million kilowatt-hours (kWh) of clean energy per year, accounting for approximately 10 percent of annual electricity consumption in municipal buildings and facilities.[51]

At the same time that city leaders have worked to increase solar energy production, they have also reduced the total amount of energy consumed in municipal buildings. Las Vegas's new City Hall, completed in 2012, is a good example of how energy efficiency and on-site renewable energy installations go hand-in-hand. The building has high-efficiency windows, insulation, and heating and air conditioning systems, plus a solar installation that meets 10 percent of the electricity demand.[52] Other city-owned buildings, including the Mob Museum (originally the Las Vegas Post Office) and the nine-story Development Services Building, have received extensive energy efficiency upgrades.[53] Additionally, by 2013, the city had replaced 80 percent of existing streetlights with LED fixtures, which use less energy than other outdoor lighting technologies. In total, the city's energy costs have decreased from $15 million in 2008 to less than $10 million in 2016.[54]

Even with these extensive energy efficiency measures, the city's on-site solar installations don't produce enough electricity to meet all of the energy consumed in municipal buildings and facilities. To make up the difference, Las Vegas purchases most of its municipal electricity from Boulder Solar 1, a 100 MW photovoltaic plant in Boulder City, near Las Vegas. The city will also obtain some of its electricity from the Hoover Dam, approximately 35 miles away, beginning in October 2017.[55]

San Francisco, CA: Solar and energy efficiency at the Moscone Center

In 2001, San Francisco residents passed ballot measures establishing the Mayor's Energy Conservation Account (MECA) and allowing city leaders to issue bonds to pay for solar installations on municipal buildings.[56]

In 2004, under Mayor Gavin Newsom, San Francisco launched the Moscone Center Energy Project to install solar panels and improve energy efficiency at San Francisco's primary convention and exhibition center. The city installed 5,400 photovoltaic panels on the Moscone Center roof, covering a surface area of 60,000 square feet.[57] The installation produces enough clean electricity to power 550 homes on an annual basis, equivalent to 5% of the convention center's electricity consumption.[58] At the time it was built, the Moscone Center solar installation was the largest municipally-owned renewable power system in the country. In addition to generating local, clean energy, the solar panels protect Moscone Center's roof from ultraviolet rays and thermal degradation, prolonging the roof's life and decreasing heating and cooling demands.

The city also improved the energy efficiency of the Moscone Center by upgrading the facility's lighting and other building systems. These upgrades reduced annual energy usage by 21 percent and saved 4.2 million kilowatt-hours of electricity annually.[59]

The $8.1 million solar and energy efficiency project was funded by MECA, along with rebates from the California Public Utilities Commission and the California Energy Commission.[60] The solar installation and energy efficiency upgrades were projected to reduce carbon dioxide emissions by 1,933 tons per year, the equivalent of avoiding 4.6 million miles of driving.[61]

Currently, there are 19 solar energy installations on municipal buildings and facilities in San Francisco, with a total capacity of 7.9 megawatts.[62]

In Boston:

Boston has already made some progress in improving energy efficiency and installing renewable energy at municipal buildings. New high-efficiency LED exterior lighting at City Hall reduced energy costs by $12,000 annually, while interior lighting and HVAC upgrades at the Central Library's Johnson Building are expected to save $22,000 per year.[63]

Boston has completed a preliminary analysis identifying city buildings where cost savings from energy efficiency upgrades would cover the cost of the improvements. Officials expect to complete the first phase, targeting the largest opportunities for savings, by the end of 2017, with further upgrades anticipated in future years. City officials have also examined what it would take to supply Boston's municipal buildings with clean energy from on-site solar installations or by purchasing renewable energy credits (RECs).[64]

While REC purchases are one way to meet municipal energy demand with renewable sources, city officials should utilize on-site renewable electricity generation and energy efficiency as their first strategies, in order to maximize the benefits to local residents, businesses, and the environment. If the city does purchase RECs, the credits should come from Class 1 renewable energy projects.

5: Renewable energy for low-income residents

Washington, D.C.: Solar Advantage Plus program

Washington's clean energy plan aims to have at least 50 percent of the city's electricity come from renewable sources by 2032.[65] To help achieve this goal, the District's government has prioritized making clean energy opportunities more widely available to low-income residents.

In January 2015, the District Department of the Environment and the DC Sustainable Energy Utility (DCSEU) launched the year-long Solar Advantage Plus program to support the installation of solar panels on the houses of low-income residents. Rebates from the Solar Advantage Plus Program covered the full cost of solar panels on homes owned or rented by low-income families. The District allocated $1.4 million for the program, with a goal of installing 134 solar photovoltaic systems on low-income households.[66]

Currently, officials in the District of Columbia are developing a new solar initiative called Solar for All, aimed at increasing solar energy deployment and ensuring that the benefits of solar are available to small businesses, nonprofits, seniors, and low-income residents.[67] The program will work to reduce electricity bills for at least 100,000 low-income households by half by the end of 2032.[68] Additionally, officials have announced Solar Works DC, a program that will train more than 200 low-income residents for careers in the solar industry and install solar panels for up to 300 low-income families over the next three years.[69]

In Boston:

Solar panels have been installed on the roofs of several affordable housing developments in Boston, including installations developed by Boston Community Capital at the Mishawum Park Apartments in Charlestown and Old Colony Homes in South Boston.[70] The Levedo Building in Codman Square, a project of the Codman Square Neighborhood Development Corporation, includes rooftop solar panels that provide about 25 percent of the power for common areas in the 24-unit building.[71]

Providing access to solar energy for low-income families who rent units in non-affordable housing developments has proven more difficult. Recently, Resonant Energy completed the pilot phase of the Boston Interfaith Community Solar Project, which brought solar installations to Second Church in Dorchester, Bethel AME Church in Forest Hills, and the Church of Saint Augustine and Saint Martin in the South End. The project was originally intended to be larger, with excess energy from the solar panels going to low-income families in surrounding neighborhoods, but cuts to the value of credits under the state's solar net metering program required project organizers to scale it back.[72] Resonant Energy is currently working on a portfolio of 18 solar installations benefitting residents and small businesses in Codman Square.

In October 2016, Newton announced the Community Solar Share Initiative, which will allocate a portion of the electricity generated by a solar installation on a city-owned property to low-income residents.[73]

6: Large renewable energy installations

Indianapolis, IN: Solar installations at the Indianapolis International Airport and Indianapolis Motor Speedway

In 2008, Indianapolis Power & Light established a feed-in tariff to pay solar owners for the renewable electricity they generate.[74] This feed-in tariff resulted in the construction of two major solar installations: the IND Solar Farm at the Indianapolis International Airport and the IMS Solar Farms at the Indianapolis Motor Speedway. Together, these solar projects have a capacity of 29 megawatts.[75]

The IND Solar Farm is a 20 megawatt-installation covering a total of 183 acres, making it the largest airport-based solar farm at the time of construction. Completed in 2015, the IND Solar Farm provides enough clean energy to power 3,650 homes on an annual basis.[76] The project was privately funded and constructed in three phases, with a total cost of $55-65 million.[77]

Indianapolis' second major solar project is a 68-acre installation at the Indianapolis Motor Speedway. At the time of its construction in 2014, IMS Solar Farm was the world's largest solar project completed at a sporting facility, with a capacity of 9.6 megawatts. The installation was projected to reduce carbon emissions by 10,288 tons per year.[78]

In Boston:

Currently, there are more than 800 kilowatts of solar capacity at Boston Logan International Airport, including installations at the rental car center, parking garages, and terminal buildings. Additionally, Massport has installed 51 kilowatts of solar at Hanscom Field in Bedford, and 20 building-integrated six foot in diameter wind turbines at the Logan Office Center.[79] Altogether, these renewable energy installations provide enough electricity to power 135 homes.[80]

While the Boston area lacks large swaths of undeveloped land for ground-mounted solar installations, there are other opportunities for medium- and large-scale renewable deployment in the city — for example, rooftop solar installations on big box stores, warehouses, and university buildings, as well as solar canopies over large parking lots.

Boston also has significant wind energy potential. The Massachusetts Water Resources Authority has installed a 1.5-megawatt wind turbine in Charlestown and two 600-kilowatt turbines in Deer Island. Together, these turbines generate more than 5 million kilowatt-hours of electricity and save around $600,000 every year.[81]

Renewable electricity supply

While on-site renewable electricity generation can meet a significant percentage of demand, Boston will also need to import solar and wind power from beyond city limits in order to achieve a goal of 100 percent renewable energy. Boston's residents, small and large businesses, institutional leaders, and city officials all have a role to play in determining the source of Boston's electricity.

Through power purchase agreements, large businesses and institutions can obtain renewable energy at a predictable cost, while helping to ensure that more solar and wind energy installations are built. Community choice aggregation is a way for cities and towns to choose the default electricity supplier for residents and businesses, and many communities have used aggregation to increase the amount of clean, local energy in their electricity mix.

7: Renewable power purchase agreements

Boston and Cambridge, MA: Solar power purchase agreement for the Massachusetts Institute of Technology, Boston Medical Center, and Post Office Square Redevelopment Corporation

In 2016, three Boston-area institutions — the Massachusetts Institute of Technology (MIT), Boston Medical Center (BMC), and Post Office Square Redevelopment Corporation — announced a 25-year collaborative agreement to purchase clean energy from a solar farm in North Carolina.[82] This power purchase agreement (PPA), spearheaded by A Better City, is expected to result in the production of 146 gigawatt-hours of clean power and avoid a total of 119,500 metric tons of carbon dioxide emissions every year, the equivalent of taking 25,250 cars off the road.[83]

A Better City, an organization representing more than 130 member companies in and around Boston, developed the idea of a collaborative power purchase agreement in response to a $100,000 Renewable Energy Leadership Prize offered by the Boston Green Ribbon Commission, with funding from the Barr Foundation. A Better City hired CustomerFirst Renewables to consult through the PPA process and arrange prices, terms and conditions.[84] CustomerFirst Renewables reviewed 41 bids, including projects in 14 states, before deciding on the Summit Farms solar project in North Carolina.

The Summit Farms project, owned and operated by Dominion Resources, includes 255,000 new solar panels over 650 acres. The construction of the project took six months and created more than 1,000 jobs in the process.

The three institutions agreed to buy the rights to the power generated by Summit Farms for 25 years, with 73 percent of the electricity purchased by MIT, 23 percent by BMC, and the remaining 1 percent by the Post Office Square Redevelopment Corporation, which operates a parking garage and a park in downtown Boston. BMC and Post Office Square's

purchases are equivalent to 100 percent of their annual electricity consumption, while MIT's portion reduces the net emissions from purchased electricity used on its campus by 17 percent.[85]

MIT's share of the agreement, at 44 megawatts, is the largest renewable energy purchase by an academic institution in the eastern United States, while Post Office Square's agreement was the smallest utility-scale PPA ever, demonstrating that aggregation can expand access to the renewable procurement market for buyers who would otherwise be excluded. All three institutions are purchasing and retiring the renewable energy credits (RECs) from the Summit Farms project, ensuring that the clean energy will count toward their emission reduction goals.[86]

The institutions participating in the project were motivated by a shared desire to reduce their greenhouse gas emissions and make a long-term commitment to clean energy, while avoiding the uncertainty generated by fluctuating energy prices.[87] The institutions will purchase electricity from the project at a fixed price, which is expected to be result in cost savings over the 25-year agreement.[88]

The project will also support research and education at MIT. The school will collect detailed data on the performance of the North Carolina installation, and compare it to data from identical solar panels installed within the MIT campus.[89]

In Boston:

Electricity consumed by Boston's commercial and industrial buildings is responsible for 28 percent of greenhouse gas emissions city-wide, according to a 2013 inventory.[90] If more of the city's large businesses, hospitals, universities, and commercial real estate owners entered into power purchase agreements for solar or wind power, it would go a long way toward helping Boston to achieve 100 percent renewable energy.

Recently, Partners HealthCare announced plans to purchase clean energy from a 28.8-megawatt wind farm in New Hampshire. The project will reduce carbon emissions by the equivalent of taking more than 10,000 cars off the road.[91]

Boston should encourage or require large commercial real estate owners, businesses, and institutions purchase their energy from renewable sources. For example, as part of a city-wide net zero carbon plan, Boston could require building owners to demonstrate that they have reduced or eliminated carbon emissions associated with powering their buildings, through a combination of on-site renewable energy installations, energy efficiency improvements, and off-site renewable energy purchases.

To the greatest extent possible, institutions and businesses should purchase power from renewable energy installations based in Massachusetts or other New England states, in order to maximize the benefits to our regional economy and accelerate the greening of New England's electric grid. With Massachusetts' first offshore wind projects expected to begin construction in the coming years, these entities could enter into long-term contracts to purchase offshore wind energy.

8: Community choice aggregation

Marin County, CA: Marin Clean Energy

In 2008, activists and leaders in Marin County launched an effort to create a community choice aggregation program. Marin Clean Energy (MCE) began providing power to customers in 12 municipalities in Marin County in 2010. The program has since expanded to include Napa County, Richmond, Benicia, and other nearby cities, now serving more than 250,000 accounts and providing 2,913 gigawatt-hours of electricity each year.[92]

Through MCE, residents and business owners are enrolled into the default Light Green program with at least 50 percent renewable electricity, at a cost similar to what residents would pay for the standard mix of electricity from the local utility company, Pacific Gas & Electric (PG&E). Customers can also upgrade to the Deep Green program, with 100 percent renewable electricity from California wind and solar projects, for about $4 per month extra for most residential customers. MCE also recently launched a Local Sol option, where residents can purchase 100 percent renewable energy from the Cooley Quarry in Novato, a city in northern Marin County.[93] Customers can also choose to opt out of MCE's programs and receive PG&E's standard service with 33 percent renewable electricity.

As of March 2017, MCE has allocated approximately $115,000 for low income solar rebates, saved customers $1 million in energy costs, and provided more than $1 million in payments to solar customers for feeding excess solar power into the grid.[94] MCE has also participated in the construction of 19 megawatts of renewable energy projects, including rooftop solar installations at the San Rafael Airport and the Cost Plus World Market in Larkspur, and solar parking canopies at the Buck Institute for Research on Aging.

The MCE Solar One Project in Richmond, scheduled to come online in late 2017, will be the largest publicly-owned solar project in the Bay Area, providing enough power for 3,417 homes on an annual basis. MCE is partnering with the City of Richmond's RichmondBUILD program to place low-income residents in construction jobs associated with the Solar One Project.[95] In total, MCE estimates that its renewable energy projects have supported more than 2,800 jobs in California.[96]

Since 2010, other cities and counties have followed Marin County's lead in establishing community choice aggregation programs. California currently has eight operational CCAs, with others expected to come online soon. A study from researchers at UCLA concluded that California's CCAs reduced carbon dioxide emissions by 600,000 metric tons in 2016, the equivalent of taking more than 125,000 passenger vehicles off the road.[97]

Local activists in California are working to develop a "CCA 2.0" model, with an increased emphasis on local renewable energy generation and equitable access to clean energy, particularly for low-income communities and people of color. The Local Clean Energy Alliance, a coalition in the Bay Area, has articulated a vision for CCA that includes social justice, equity, green jobs, and workforce development as key goals, alongside sustainability and public health.[98] The Local Clean Energy Alliance is advocating for East Bay Community Energy, a CCA program covering Alameda County, to include a strong local renewable energy program when service begins in 2018.[99]

In Boston:

In Massachusetts, cities and towns can create community choice aggregation programs with the approval of the state's Department of Public Utilities. More than 115 cities and towns have been approved for CCA at some point, although not all of these municipalities are currently using CCA.[100] Boston has not yet established a CCA program.

Although many Massachusetts communities have pursued aggregation for the sole purpose of reducing electricity costs for residents and businesses, there is growing interest in using CCA as a tool to increase the amount of renewable energy in a community's electricity supply. Communities such as Arlington, Somerville, and Dedham have created CCA programs with additional renewable energy at a cost comparable to what residents would pay for standard electric service from their utility company.[101] Brookline recently created a CCA program with 25 percent additional renewable energy above the state's minimum requirement, for a total of 37 percent renewable energy.[102] In many cases, these communities have worked closely with the Metropolitan Area Planning Council to secure cost-effective aggregation contracts that maximize the percentage of renewable energy.

In pursuing additional renewable energy through CCA, Boston and other cities and towns should prioritize the purchase of Class 1 renewable energy credits (RECs), which come from clean energy installations in Massachusetts and nearby states. Credits from other parts of the country may be cheaper, but it is often difficult to ensure that these RECs actually represent additional renewable energy added to the electric grid.

In the short term, Boston officials should adopt a CCA program that includes at least 5-10 percent additional renewable energy from Class 1 sources on top of the state's minimum requirement. Boston should also study the potential to create a more comprehensive CCA program that would bring the city's default electricity mixture to 100 percent renewable energy from New England solar and wind projects over time. The city should consider how CCA could serve as a tool to promote local renewable energy development and economic opportunity for Boston residents from all walks of life, along the lines of the "CCA 2.0" model under development in California.

Currently, the Boston Climate Action Network, a local grassroots organization, is running a campaign to convince Boston to adopt a CCA program with 5–10% additional renewable energy. The campaign has been endorsed by City Council President Michelle Wu and City Councilor Matt O'Malley, along with several community leaders and organizations.[103]

Clean transportation

Transportation is responsible for nearly 27 percent of Boston's greenhouse gas emissions.[104] In addition to their climate impact, gas-powered cars and trucks are also major sources of particulate matter, smog-forming emissions, and other harmful pollutants.

Creating a transportation system powered by renewable energy will require several parallel strategies. Investing in pedestrian and bicycle infrastructure, improving existing bus and rail lines, and expanding public transit services will reduce the need for people to travel by car. Gas-powered vehicles should be replaced with models that run on electricity, and that electricity should be generated from clean sources like solar and wind.

Boston can take advantage of two transformative innovations in the transportation sector. First, electric vehicles, including passenger cars as well as larger vehicles like buses and garbage trucks, are increasingly cost-competitive. A recent analysis for New York City Transit found that the cost of an electric bus is $168,000 less than a diesel bus over a 12-year lifespan, due to reduced fuel and maintenance costs.[105] Second, bus rapid transit lines have the potential to provide fast, convenient public transportation in neighborhoods throughout Boston and beyond.

9: Electric vehicles

Chicago, IL: Electric garbage trucks and buses

Chicago and nearby communities have pioneered the inclusion of electric vehicles across the public fleet, including larger vehicles like buses and even garbage trucks. In 2012, Chicago officials signed a contract to buy up to 20 Motiv electric garbage trucks over five years. The city deployed these trucks on routes of up to 60 miles, hauling a maximum of 9 tons of trash each.[106] Each truck is expected to cut oil consumption by 55 barrels and reduce carbon emissions by 23 tons per year. As an added benefit, the trucks produce no tailpipe emissions, improving air quality in neighborhoods along the route.[107] Charging takes approximately 8 hours using Motiv Universal Fast Chargers.[108]

In 2014, the Chicago Transit Authority (CTA) purchased two electric buses funded by the U.S. Department of Transportation's TIGGER II and Clean Fuels grant programs and a grant from the Chicago Metropolitan Agency for Planning. Each bus replaced a 2001 diesel-consuming bus. The electric buses take 3-5 hours to charge, and can run 80-120 miles on a single charge. The CTA projected that each electric bus would save the authority $25,000 annually in avoided fuel costs. Additionally, CTA estimated that each bus would help avoid $55,000 in health-related costs annually, through reduced pollution. [109]

The implementation of these two buses went so well that the CTA has already made plans to switch more of its bus fleet to electric. The authority was awarded a $8.1 million USD federal grant by the

Federal Transit Administration to buy 27 more standard-sized electric buses, which would create the largest all-electric bus fleet in the US so far.[110] This purchase could foreshadow an even larger investment in electric buses in the near future. In 2020, the CTA will purchase 1,000 buses, more than half the size of the existing fleet of 1,888 buses, and the authority is considering making some of those new buses electric.[111]

Sacramento County, CA: Electric school buses

In March 2017, the Sacramento Metropolitan Air Quality Management District announced plans to introduce 29 electric school buses throughout Sacramento County, the largest deployment of electric school buses in the United States to date.[112] The electric school buses have been introduced in three school districts: Twin Rivers Unified School District, Sacramento City Unified School District, and Elk Grove Unified School District.[113] The purchase of the new electric buses, as well as the electric vehicle charging infrastructure, was funded by the California Air Resources Board (CARB) through a $7.5 million grant.[114]

The project aims to reduce heavy-duty vehicle emissions and promote the acceptance of electric vehicle technologies, with a focus on reducing pollution in communities that disproportionately suffer from the health impacts of poor air quality. Participating school districts may loan the electric buses out to other school systems in order to promote the shift to a zero-emission bus fleet.[115]

Portland, OR: Electric vehicle charging stations and municipal fleet

A 2016 study by Indiana University's School of Public and Environmental Affairs ranked Portland, Oregon, as the most EV-friendly city in the country. Portland has the highest per-capita number of electric vehicle charging stations among the 36 cities evaluated in the study.[116]

The city has taken several steps to encourage electric vehicle ownership, including simplifying the process to acquire a home charging station permit. Portland offers innovative self-inspection programs for the installation of residential charging stations. This program allows certified contractors to sign off on the installation, with inspectors conducting only random sample inspections, which reduces both the costs of labor and installation.[117]

Additionally, public charging stations are widely available. Throughout the state of Oregon, more than 1,200 public charging stations have been installed, with almost 12,500 EVs sold through March 2017. [118]

Portland officials are also leading by example. In 2015, the Portland City Council adopted a policy to replace its municipal fleet vehicles with electric vehicles whenever feasible. Although the initial investment per car was higher, the city found that the fuel savings, plus government incentives, made electric vehicles cost-competitive with gas-powered vehicles. By April 2016, the city had purchased 50 electric vehicles, representing more than 20 percent of the total sedan fleet. [119]

In Boston:

Boston was recently ranked eleventh among major cities for electric vehicle policies, suggesting that the city has taken some good steps but could do more to encourage electric vehicle adoption.[120]

In 2011, Boston installed 22 dual electric vehicle charging stations with funding from the Green Communities division of the state's Department of Energy Resources.[121] The city has also acquired electric vehicles and charging stations through the Massachusetts Department of Environmental Protection's Electric Vehicle Incentive Program (EVIP).[122]

Massachusetts will receive $75 million from the settlement resulting from the Volkswagon emissions scandal. Boston should seek a share of this funding to install electric vehicle charging stations and purchase electric school buses.[123]

Advocates have pushed for the state's Board of Building Regulations and Standards (BBRS) to require new buildings to be built "EV-ready," with the electrical infrastructure in place to support the installation of electric vehicle charging stations. Designing a building to be EV-ready makes it easier and less costly to install charging stations at a later date. The BBRS considered a proposal to add EV-ready requirements to the building code in 2016 but did not adopt it.[124]

In March 2017, a coalition of 30 cities, including Boston, announced their intent to purchase 114,000 electric vehicles. This coordinated effort is intended to boost electric vehicle demand across the country, at a time when federal officials are considering weakening clean car standards. This purchase is equivalent to 72 percent of all plug-in vehicles sold in 2016.[125]

10: Public Transit

Bay Area, CA: Powering mass transit with 100% renewable energy

Commuters on the Bay Area Rapid Transit (BART) system, in San Francisco and surrounding communities, take an average of 446,000 trips every weekday, ranking fifth among U.S. subway systems for ridership.[126] According to BART, its riders save nearly 140,000 gallons of gas and avoid 2.7 million pounds of carbon dioxide every weekday, compared to travel by car.[127]

The subway and elevated rail lines in the BART system run on electricity. In May 2017, the BART board of directors adopted a goal of sourcing 50 percent of the system's electricity from renewable energy by 2025 and 100 percent by 2045, making it the first electrified public transit system in the country to commit to a 100 percent renewable electricity target.

As part of meeting this goal, the agency plans to expand on-site solar generation, adding two 1-megawatt solar plants to an existing half-megawatt solar installation. BART will secure the remainder of its renewable energy by negotiating directly with power suppliers.[128] BART issued a request for proposals in May, and expects to choose suppliers for 10- to 30-year contracts by December of this year.[129]

While announcing the commitment, BART's Sustainable Manager Holly Gordon said, "Given that renewable energy supply costs have fallen significantly in recent years and have approached cost parity with other supply sources, BART has an opportunity to set clean energy goals that are both ambitious and realistic."[130]

In addition to its renewable energy commitment, BART is working to reduce energy consumption with the purchase of 1,081 efficient train cars. The new fleet will have white roofs that deflect heat, requiring less energy to cool the interior.[131] The new train cars will weigh less than older versions and include efficient LED lighting.[132] Additionally, train cars will use sensors to detect when passengers need to enter or exit and open doors only when needed, in order to reduce heat and air conditioning losses.[133]

Cleveland, OH: Bus rapid transit

Cleveland's HealthLine is a seven-mile bus rapid transit (BRT) corridor that links the city's two major employment hubs, Downtown and University Circle, reducing travel time from 40 to 28 minutes. Service is offered 24 hours a day, seven days a week, with buses every five minutes during peak times and every 8-15 minutes during off-peak times.

The HealthLine BRT was opened in 2008, with a total cost of $200 million.[134] The line includes 36 stations, with off-board fare collection, platform-level boarding, and a central median alignment in order to improve travel times.[135] The corridor also includes bike lanes.

By 2013, ridership had increased by 67 percent along the corridor, with the HealthLine carrying 15,800 riders per day.[136] In addition to the health and climate benefits associated with increased public transit use, the project has resulted in significant economic benefits. According to a study from the Institute for Transportation and Development

Policy (ITDP), the HealthLine had the highest return-on-investment of any public transit project in the nation, with $114 in economic development for every dollar invested. The Healthline has attracted a total of $5.8 billion in development around the transit line. [137] The ITDP recognized the HealthLine as the best bus rapid transit line in the United States, granting it a silver rating.[138]

Cleveland added a second BRT line, the Cleveland State Line, in 2014. The line travels along 4.1-mile route connecting Downtown Cleveland to Cleveland State University. After one year, ridership in this corridor increased by 38 percent. A third BRT service, the MetroHealth Line, is expected to open in October 2017.[139]

Cleveland's health care institutions have played an active role in expanding the region's BRT system. The Cleveland Clinic and University Hospital will spend up to $6.25 million over 25 years for the naming rights for the HealthLine, and the MetroHealth System will pay up to $4 million over 25 years for the MetroHealth Line. According to hospital leaders, Cleveland's BRT lines bring several benefits to public health, including reducing air pollution and making it easier for residents to access health services.[140]

In Boston:

While MBTA subway and light rail service runs on electricity, commuter trains and most buses in the Boston area are powered by diesel or natural gas engines. In order to achieve a transit system powered by 100 percent renewable energy, the MBTA should pursue two parallel strategies: increasing the amount of renewable energy in its electricity supply, and converting buses and commuter trains to run on electricity.

The MBTA has installed solar panels and wind turbines on some of its properties, and recently announced plans to lease space at 37 of its parking facilities for solar installations.[141]

Boston's closest equivalent to bus rapid transit is the MBTA's Silver Line, which provides service from Downtown Boston to Logan Airport, the Seaport District, Roxbury, and the South End. Another Silver Line service is scheduled to open in spring 2018, connecting Chelsea and East Boston with downtown Boston. Some portions of the Silver Line use bus rapid transit elements, such as a separated right of way and off-board fare collection, but other portions are similar to a standard bus line running in mixed traffic, which can cause delays and slow travel time.

The Greater Boston BRT Study Group, a coalition of civic and business leaders, issued a report in 2015 identifying 12 corridors with the technical potential to accommodate BRT lines, and five corridors with "great promise" for high-quality BRT service.[142] The BRT Study Group has continued its work as Boston BRT, and is working to bring "Gold Standard" BRT service to Boston.[143]

In March 2017, city officials released Go Boston 2030, a transportation plan that aims to increase public transit ridership by one-third while reducing one-person car trips by 50% by 2030. The plan features several proposals for Bus Rapid Transport (BRT), including lines connecting Dorchester, Roxbury, and Mattapan with the Longwood Medical Area. The plan also includes improvements to existing Silver Line service.

Other technologies

Moving Boston to 100 percent renewable energy will require the adoption of innovative technologies across all sectors of the economy and all categories of energy use. Air source heat pumps and ground source heat pumps use electricity to cool and heat a building efficiently, replacing oil and gas heating systems. Energy storage systems and microgrids can enable the integration of larger amounts of renewable energy onto the electric grid.

11: Renewable heating and cooling

Sitka, AK: Air source heat pumps

Sitka is a community in the Alaska panhandle with a population of just under 9,000.[144] Currently, 99 percent of Sitka's electricity comes from two small hydroelectric plants, Blue Lake and Green Lake.[145] Most residents heat their homes with fuel oil, but when oil prices rise, many switch from oil to electric resistance heating, putting a strain on the community's electricity supply.[146] With electricity demand projected to increase in the coming years, local leaders have searched for ways to reduce energy consumption.

One promising strategy is to switch to air source heat pumps, which are significantly more efficient than electric resistance heaters. Air source heat pumps have helped Sitka residents save money on their utility bills, while making minimal demands on the community's overtaxed electric grid. After switching from oil heating to an air source heat pump, one Sitka family reduced its monthly oil bill by approximately $300 while spending only $20 more per month on electricity. As of July 2016, there were approximately 80 air source heat pumps operating in Sitka.[147]

The Cold Climate Housing Research Center (CCHRC) released a study in 2015 examining the effectiveness of air source heat pumps (ASHP) in the region's climate. CCHRC interviewed 30 customers, with all but one saying that the air source heat pump provides their home or commercial space with "adequate" or "expected" heating comfort. This latter finding coincided with other studies conducted in northeastern and northwestern states.[148] Air source heat pumps result in approximately $1,000 per year in savings when compared to a standard oil heating system in a prototype 2000-square-foot house.[149]

The Sitka Electric Department joined forces with the Sitka Conservation Society to create a user-friendly website to help Sitka residents to learn about air source heat pumps, along with information on other energy efficiency opportunities. The website provides detailed information on how air source heat pumps work and how to acquire one, as well as stories from residents who have installed heat pumps at their homes.[150]

The Alaska Housing Finance Corporation offered interested residents up to $10,000 to complete qualified energy efficiency building improvements.[151] Additionally, the Sitka Electric Department offered rebates of up to $1,500 for residents installing heat pumps.[152]

Boulder, CO: Thermal decarbonization strategy

Located at the base of the Rocky Mountains and home to the largest campus of the University of Colorado, Boulder has been working to fight climate change since the passage of a city council resolution in 2002 calling for a "local action plan" to reduce carbon emissions.[153] In 2007, Boulder became the first municipality in the country to incorporate a voter-approved Climate Action Plan (CAP) Tax, which funds efforts to reduce global warming pollution.[154] The CAP Tax is based on the amount of electricity consumed, with an average contribution per year of $21 for residents, $94 for businesses, and $9,600 for industries.[155] The CAP Tax provides $1.8 million every year towards the implementation of the city's Climate Action Plan, and has helped the community avoid 50,000 tons of emissions between 2007 and 2015.[156]

According to the city's greenhouse gas inventory, natural gas is responsible for about 15 percent of Boulder's greenhouse gas emissions, with residential heating systems accounting for one third of that figure. With a grant from the Carbon Neutral Cities Alliance, Boulder developed a strategy to transition single-family homes away from natural gas and other fossil-fuel based heating systems, and towards clean technologies like air source heat pumps.

Researchers began by assembling a database with information on households currently using natural gas, in order to predict when homeowners are likely to replace their heating systems and which alternative technologies would be most effective. Next, they evaluated various types of renewable heating and cooling technologies, including air-source and ground-source heat pumps, solar thermal, and electric baseboard heating, as well as alternative technologies to replace the use of gas for heating water and for cooking. By modeling the performance of these technologies in typical single-family homes, researchers determined which renewable heating technologies would provide the greatest cost savings and carbon reductions.

The report recommends for the City of Boulder to create a community outreach program to encourage the adoption of renewable thermal technologies, similar to the "Solarize" programs established in Massachusetts and other states. This outreach program would help to increase customer awareness and interest in renewable heating options, and reduce the complexity of switching to air source heat pumps and other technologies. The city could also reduce costs by simplifying the permitting and inspection process for clean energy and renewable heating installations, particularly when multiple improvements are done at the same time. The report also recommends the creation of emissions-based incentives for energy efficiency upgrades, where greater incentives would be available for buildings that install zero-carbon heating systems.

Using the data gathered through this research, the city could provide a timeline and guide for every building owner in the city that explains the current thermal use and plans to reduce it with energy saving strategies. The city could also provide each household with a detailed analysis of the costs and benefits of switching to renewable heating.[157]

The City of Boulder plans to incorporate the report recommendations into its clean energy transition strategy.[158]

In Boston:

While air source heat pumps have recently gained a foothold in the Massachusetts market, most homes in Boston are still heated with gas or oil. District energy systems in downtown Boston and the Longwood Medical Area provide heating for institutional and commercial buildings with a significantly lower carbon footprint, but the steam used to heat these buildings is still generated with fossil fuels.

Other technologies besides air source heat pumps can be used to heat and cool buildings without the use of fossil fuels. Solar thermal installations use the sun's energy to provide hot water and heat spaces within a home. Geothermal or ground source heat pumps use the relatively constant temperature of the earth to heat or cool a building. While not feasible for every location, ground source heat pumps are more energy-efficient than air source heat pumps.

Boston and four other New England cities have received a grant from the Carbon Neutral Cities Alliance to develop a pilot program to help residents switch to air source heat pumps and other alternative heating technologies. Through this grant, Northampton has already launched its HeatSmart initiative, which is offering air source heat pumps at a 10 to 15 percent discount.[159] Additionally, the Massachusetts Clean Energy Center (MassCEC) is piloting Solarize Mass Plus, an extension of its successful Solarize program that provides community-wide marketing and discounts for residents and businesses to install solar photovoltaic panels. Communities participating in Solarize Mass Plus will have access to an additional clean energy technology, including solar hot water, air source heat pumps, or electric vehicles.[160]

12: Microgrids and energy storage

Fort Collins, CO: Fort Collins Microgrid Project

In 2011 the City of Fort Collins, Colorado State University and Colorado Clean Energy Cluster businesses joined forces to create the Fort Collins Zero Energy District (FortZED), with a goal of developing solutions to energy problems and facilitating innovative clean energy projects.[161]

One of FortZED's main projects is the Fort Collins Microgrid Project, launched in October 2008. The goal is to produce locally all of the electric and thermal energy consumed in the district, while serving as a model for how to incorporate distributed renewable energy resources throughout the Fort Collins region. The microgrid includes New Belgium Brewery, InteGrid laboratory, city and county government buildings, and the Colorado State University campus.[162] The participating businesses and institutions own a variety of energy technologies, including solar photovoltaic panels, combined heat and power systems, microturbines, and fuel cells.[163] The Fort Collins Microgrid receives, storages and distributes a total of 5 megawatts, accounting for 10-15 percent of all electricity demand in the city.[164] This project was especially beneficial as it allowed the City of Fort Collins to reduce its peak loads by 20-30% on two distribution feeders and deliver improved efficiency and reliability on the grid, while increasing the penetration of renewable energy.[165]

New York, NY: Energy storage target

In September 2016, New York City announced a goal of installing 100 megawatt-hours of energy storage by 2020, as part of the city's plan to cut greenhouse gas emissions by 80 percent by the year 2050. By accelerating the growth of energy storage, city officials hope to enable the integration of more solar and wind energy into the grid, while keeping the cost of electricity under control by reducing energy demand charges and deferring expensive distribution system upgrades.[166]

One example of a successful energy storage project in New York City is the 400 kilowatt-hour battery installation at the Metropolitan Transit Authority's 1.6-million square foot office building in downtown Manhattan. The MTA energy storage facility, composed of vanadium redox flow batteries, is intended to act as a backup during an emergency, such as the city experienced during Superstorm Sandy in 2012.[167] The batteries also help to reduce peak load at the building and balance the grid at times of stress and congestion. The MTA storage project has helped to demonstrate how vanadium flow battery technology is capable of multi-hour and multi-megawatt energy storage, and may inspire similar installations at other buildings in New York City.[168]

As of the end of 2016, only 4.8 megawatt-hours of storage have been installed towards New York City's 100 megawatt-hour goal, but city leaders plan to accelerate the installation of energy storage by streamlining the siting and permitting process and clarifying safety requirements.[169]

In Boston:

The Boston Community Energy Study, released by the Boston Planning and Development Authority (BPDA) in 2016, identified 42 areas in Boston that are well suited for community energy projects, which could include microgrids and district energy systems. These community energy projects would make use of technologies including solar photovoltaics panels, solar thermal panels, combined heat and power, energy storage, and air source heat pumps. The study found that the cost savings, health benefits, and reduced carbon emissions resulting from these community energy projects would result in a total benefit of $600 million – $1.7 billion over 25 years.[170]

Boston's climate adaptation plan, Climate Ready Boston, recommends the development of microgrids, energy storage, and other community energy solutions throughout the city in order to protect critical facilities and vulnerable populations during natural disasters exacerbated by global warming. Currently, the BPDA is working with Eversource to study the feasibility of a microgrid project at the Raymond L. Flynn Marine Park in South Boston.[171] Additionally, the Massachusetts Clean Energy Center is working with the Boston Fire Department to install an energy storage system, potentially in conjunction with solar photovoltaic panels, at the department's training facility on Moon Island in Boston Harbor.[172]

Notes

1. *Climate Ready Boston*, City of Boston, December 2016, <https://www.boston.gov/departments/environment/climate-ready-boston>.

2. Elizabeth Ridlington et al., *Our Health at Risk: Why Are Millions of Americans Still Breathing Unhealthy Air?*, Environment Massachusetts and Frontier Group, 6 April 2017, <http://environmentmassachusetts.org/reports/mae/our-health-risk?_ga=2.75431956.7400733.1500344662-744655483.1500344662>.

3. Ibid.

4. Gideon Weissman, Rob Sargent, and Bret Fanshaw, *Renewables on the Rise: A Decade of Progress Toward a Clean Energy Future*, Environment Massachusetts Research & Policy Center and Frontier Group, <http://environmentmassachusettscenter.org/reports/mae/renewables-rise>.

5. "Governor signs energy bill, but major issues left unaddressed", Environment Massachusetts, 8 August 2016, <http://environmentmassachusetts.org/news/mae/governor-signs-energy-bill-major-issues-left-unaddressed>.

6. *2016 Massachusetts Clean Energy Industry Report*, Massachusetts Clean Energy Center, December 2016, <http://www.masscec.com/2016-massachusetts-clean-energy-industry-report-0>.

7. Tony Dutzik et. al., *Cool Solutions: Ten Emerging Technologies and Trends that Can Help Massachusetts Meet Bold Goals for Curbing Global Warming*, Environment Massachusetts Research & Policy Center and Frontier Group, August 2015, <http://environmentmassachusettscenter.org/reports/mac/cool-solutions>.

8. Travis Madsen et al., *We Have the Power: 100% Renewable Energy for a Clean, Thriving America*, Environment Massachusetts Research & Policy Center and Frontier Group, Spring 2016, <http://www.environmentmassachusettscenter.org/sites/environment/files/reports/MA_100percent_RE_SCRN_0.pdf>.

9. "Executive Order of Mayor Thomas M. Menino: An Order Relative to Climate Action in Boston," City of Boston, 13 April 2007, <https://www.cityofboston.gov/images_documents/Clim_Action_Exec_Or_tcm3-3890.pdf>.

10. "State of the City," City of Boston, 17 January 2017, <https://www.boston.gov/departments/mayors-office/state-city>.

11. *Climate Action Plan*, City of Boston, 2014, <http://www.greenovateboston.org/climate_action_plan>.

12. Shane Levy, "U.S. Conference of Mayors Passes Landmark Resolution Supporting 100% Clean, Renewable Energy", Sierra Club, 26 June 2017, <http://content.sierraclub.org/press-releases/2017/06/us-conference-mayors-passes-landmark-resolution-supporting-100-clean>.

13. "Community-Wide Greenhouse Gas Inventory, 2005-2013," City of Boston, <https://www.cityofboston.gov/images_documents/Community%20GHG%20Inventory%202013_tcm3-49977.pdf>.

14. "Climate Change Planning," City of Cambridge Community Development Department, <http://www.cambridgema.gov/CDD/climateandenergy/climatechangeplanning>.

15. "Getting to a Net Zero Action Plan: Fiscal Year 2016 Progress Report," City of Cambridge, 5 May 2017, <http://www.cambridgema.gov/cdd/projects/climate/~/media/A21A46E0E8114CD8945EF54CCD87E413.ashx>.

16. *The Getting to Net Zero Framework*, Integral Group and Cambridge Net Zero Task Force, 29 April 2015, <https://www.cambridgema.gov/cdd/projects/climate/~/media/d74193af8dac4a57ac96e2a53946b96b.ashx>.

17. "Getting to Net Zero Task Force," Sustainable Lexington Committee, Town of Lexington, <https://www.lexingtonma.gov/sustainable-lexington-committee/getting-net-zero-task-force>.

18. Cambridge Community Electricity Program, MassPowerChoice.com, <http://www.masspowerchoice.com/cambridge>.

19. "Regular Meeting - Sullivan Chamber", City of Cambridge, 24 April 2017, <http://cambridgema.iqm2.com/Citizens/FileOpen.aspx?Type=15&ID=1690&Inline=True>.

20. "E+ Green Building Program," E+ Boston, <http://www.epositiveboston.org/>.

21. "City of Boston - Green Building Standard," DSIRE, September 2016, <http://programs.dsireusa.org/system/program/detail/5919>.

22. Boston Clean Energy Coalition, <https://bostoncleanenergycoalition.org/mission-statement/>.

23. "Pittsburgh 2030 District," 2030 Districts, <http://www.2030districts.org/pittsburgh>.

24. Ibid.

25. Ibid.

26. Ibid.

27. "Pittsburgh 2030 District," Green Building Alliance, <https://www.go-gba.org/initiatives/pittsburgh-2030-district/>.

28. Brian Conway, "Pittsburgh 2030 District is dominating North America, and growing," *Next Pittsburgh*, 1 May 2017 <http://www.nextpittsburgh.com/city-design/pittsburgh-2030-district/>.

29. Quinn Zeagler, "Local Innovation to National Leadership: Pittsburgh 2030 District Progress Report for 2016," Green Building Alliance, 26 April 2017, <https://www.go-gba.org/local-innovation-national-leadership-pittsburgh-2030-district-progress-report-2016/>.

30. Bill O'Driscoll, "What's working in the energy-conserving Pittsburgh 2030 District?" *Pittsburgh City Paper*, 27 May 2015, <https://www.pghcitypaper.com/pittsburgh/whats-working-in-the-energy-conserving-pittsburgh-2030-district/Content?oid=1828157>.

31. "Mayor's Carbon Cup," City of Boston, <http://www.greenovateboston.org/carbon_cup>.

32. "Climate Action Plan," City of Boston, 17 July 2016, <https://www.boston.gov/environment-and-energy/climate-action-plan>.

33. "Metropolitan Boston Health Care Energy & Greenhouse Gas Profile," Health Care Without Harm, 20 May 2017, <https://noharm-uscanada.org/sites/default/files/documents-files/4723/Report-Boston%20Health%20Care%20Energy%20Profile-May%202017.pdf>.

34. "Accomplishments: January - December 2016," A Better City, 2016, <http://www.abettercity.org/docs-new/A%20Better%20City's%20Accomplishments%202016.pdf>.

35. Abi Bradford et al., *Shining Cities 2017: How Smart Local Policies are Expanding Solar Power in America*, Environment Massachusetts Research & Policy Center and Frontier Group, April 2017, <http://environmentmassachusetts.org/reports/mae/shining-cities-2017>.

36. Pieter Gagnon et al., *Rooftop Solar Photovoltaic Technical Potential in the United States: A Detailed Assessment*, National Renewable Energy Laboratory, January 2016, <http://www.nrel.gov/docs/fy16osti/65298.pdf>.

37. "Resolution No. 20170202-040," City of Austin, 2 February 2017, <http://www.austintexas.gov/department/city-council/2017/20170202-reg.htm#040>.

38. Kylie McGivern, "New 'solar-ready' requirements add to Austin building costs," kxan.com, 16 June 2017 <http://kxan.com/2017/06/16/new-solar-ready-requirements-add-to-austin-building-costs/>.

39. "An ordinance amending Article 12 of City Code Chapter 25-12 to adopt a solar-ready provision to the 2015 International Energy Conservation Code," City of Austin, <http://www.austintexas.gov/edims/document.cfm?id=279788>

40. Ryan Koronowski, "Republican Mayor Leads City To First-Ever Solar Energy Mandate," *ThinkProgress*, 28 March 2013, <https://thinkprogress.org/republican-mayor-leads-city-to-first-ever-solar-energy-mandate-b9ba0241cb23>.

41. Julian Spector, "Lancaster, Calif. Requires Newly Built Houses to Fully Power Themselves with Solar," *Green Tech Media*, Feburary 2017, <https://www.greentechmedia.com/articles/read/lancaster-california-mandate-new-built-houses-solar-power-zero-net>.

42. Ethan Howland, "California city mandates solar for all new homes," *UtilityDIVE*, 27 January 2014, <http://www.utilitydive.com/news/california-city-mandates-solar-for-all-new-homes/219849/>.

43. "Multifamily New Construction - Design Requirements & Guidelines", City of Boston Department of Neighborhood Development, 12 August 2014, <https://www.boston.gov/sites/default/files/14-1_design_standards-final-august_2014_leed_rev.pdf>.

44. "MA Amendments to the Base Volume," State Board of Building Regulations and Standards, <http://www.mass.gov/ocabr/docs/dpl/dps/agendas/building-division/board-of-building-regulations-and-standards/bbrs-base-code-amendments-revised-2-14-17.pdf>. "MA Amendments to the Residential Volume," State Board of Building Regulations and Standards, <http://www.mass.gov/ocabr/docs/dpl/dps/agendas/building-division/board-of-building-regulations-and-standards/bbrs-residential-code-amendments-revised-as-of-2-14-17.pdf>.

45. Doyle Rice, "Las Vegas now runs completely on renewable energy," *USA Today*, 21 December 2016, <https://www.usatoday.com/story/news/nation/2016/12/21/las-vegas-renewable-energy/95706450/>.

46. "Mayors Climate Protection Center," The United States Conference of Mayors, <https://www.usmayors.org/mayors-climate-protection-center/>.

47. Katie Fehrenbacher, "How and Why Las Vegas Embraced Solar Energy: It's about economics," *Green Tech Media*, 11 January 2017, <https://www.greentechmedia.com/articles/read/how-and-why-las-vegas-embraced-solar-energy>.

48. Kyle Roerink, "City of Las Vegas plans to go to 100 percent renewable energy," *Las Vegas Sun*, 24 November 2015, <https://lasvegassun.com/news/2015/nov/24/city-of-las-vegas-plans-to-go-to-100-percent-renew/>.

49. Marie Solis, "Las Vegas just became the largest US city to run on 100% renewable energy," *Business Insider*, 21 December 2016, <http://www.businessinsider.com/las-vegas-just-became-the-largest-us-city-to-run-on-100-renewable-energy-2016-12>.

50. "Sustainability," City of Las Vegas, <https://www.lasvegasnevada.gov/portal/faces/wcnav_externalId/ci-sustainability?_adf.ctrl-state=4wpe2bosc_4&_afrLoop=36592768652561812>.

51. Electricity generated by municipal solar installations: Tim Boucher, "All city facilities in Las Vegas powered by 100% renewables," *Medium*, 21 December 2016 <https://medium.com/invironment/all-city-facilities-in-las-vegas-

powered-by-100-renewables-346d7886bcc2>. Total electricity consumed by municipal buildings: Las Vegas, Nevada Government, "Renewable Energy and Energy Efficiency," City of Las Vegas, <https://www.lasvegasnevada.gov/cs/groups/public/documents/document/chjk/mdmx/~edisp/prd031748.pdf>.

52. Craig A. Ruark, "Municipality headed toward net-zero energy," *Las Vegas Business Press*, 8 August 2016, <https://businesspress.vegas/special-sections/municipality-headed-toward-net-zero-energy/>.

53. Ibid.

54. "Sustainability," City of Las Vegas, <https://www.lasvegasnevada.gov/portal/faces/wcnav_externalId/ci-sustainability?_adf.ctrl-state=4wpe2bosc_4&_afrLoop=36592768652561812>.

55. "Renewable Energy and Energy Efficiency," City of Las Vegas, <https://www.lasvegasnevada.gov/cs/groups/public/documents/document/chjk/mdmx/~edisp/prd031748.pdf>.

56. Ilene Lelchuk, "S.F. complex to run on sunshine / Solar panels going up at Moscone Center," *SFGate*, 22 November 2002, <http://www.sfgate.com/bayarea/article/S-F-complex-to-run-on-sunshine-Solar-panels-2751802.php>.

57. Laurie Armstrong, "San Francisco's Moscone Center achieves LEED Gold Certification," *San Francisco Travel*, 15 October 2012, <https://www.moscone.com/uploads/award/9/pdf/Moscone%20Earns%20LEED%20Gold%20Media%20Kit.pdf>.

58. "Sustainability," Moscone Center, <http://www.moscone.com/community/sustain.html>.

59. "Largest City-Owned Solar Power System in the United States," C40 Cities, November 4, 2011, <http://www.c40.org/case_studies/largest-city-owned-solar-power-system-in-the-united-states>.

60. "Moscone Center: Solar System and Energy Efficiency Upgrade," Moscone Center, <https://www.moscone.com/uploads/news/22/pdf/Moscone%20Solar%20Factsheet.pdf>.

61. Emissions data from "Moscone Center Solar System and Energy Efficiency Upgrade," Moscone Center, <https://www.moscone.com/uploads/news/22/pdf/Moscone%20Solar%20Factsheet.pdf>. Carbon equivalent from "Greenhouse Gas Equivalencies Calculator," U.S. Environmental Protection Agency, <https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator>.

62. "Solar Installations," San Francisco Public Utilities Commission, <https://sfwater.org/index.aspx?page=403>.

63. "City of Boston achieves energy efficiency gains with capital improvements to its iconic buildings," City of Boston, 10 January 2017 <https://www.boston.gov/news/city-boston-achieves-energy-efficiency-gains-capital-improvements-its-iconic-buildings>.

64. Carbon Footprint of City Buildings Hearing #0822, Boston City Council, <https://www.cityofboston.gov/citycouncil/cc_video_library.asp?id=11245>.

65. Gillian White, "Why Should Only the Wealthy Get Solar Panels?" *The Atlantic*, 26 July 2016, <https://www.theatlantic.com/business/archive/2016/07/dc-solar-panels/493106/>.

66. Mark Jenkins, "New program helps low-income D.C. homeowners convert to solar energy," *Washington Post*, 27 May 2015, <https://www.washingtonpost.com/local/new-program-helps-low-income-dc-homeowners-convert-to-solar-energy/2015/05/26/ad0ce104-03b2-11e5-bc72-f3e16bf50bb6_story.html?utm_term=.e45c080dd376>.

67. "Solar for All," Department of Energy & Environment, District of Columbia, <https://doee.dc.gov/node/1226501>.

68. *Solar for All Implementation Plan*, Department of Energy & Environment, District of Columbia, 10 March 2017, <https://doee.dc.gov/sites/default/files/dc/sites/ddoe/service_content/attachments/DOEE-%20Report-%20Solar%20for%20All%20Implementation-%20Final%20for%20Transmittal.pdf>.

69. “DOEE and DOES Launch Solar Works DC,” DOEE DC.gov, 18 May 2017, <https://doee.dc.gov/release/doee-and-does-launch-solar-works-dc>.

70. “BCC Solar,” Boston Community Capital, <http://www.bostoncommunitycapital.org/solar-impact>.

71. “Green Real Estate Development,” Codman Square Neighborhood Development Corporation, <http://www.csndc.com/regreendev.php>.

72. “Boston Interfaith Solar Project,” Barr Foundation, <https://vimeo.com/209774037>.

73. “Newton Mayor Setti Warren Announces Groundbreaking Program Providing Solar Credits to Low-Income Newton Resi-dents,” City of Newton, 19 October 2016, <http://www.newtonma.gov/gov/building/sustainable_newton/newton_community_share_solar_initiative.asp>.

74. Pete Danko, “How Indianapolis (of All Places) Became a Solar Powerhouse,” *Breaking Energy*, 10 July 2014, <http://breakingenergy.com/2014/07/10/how-indianapolis-of-all-places-became-a-solar-powerhouse/>.

75. “Project Update”, IND Solar Farm, <http://www.indsolarfarm.com>.

76. “Greening the skies over INDy,” IND Solar Farm, <http://www.indsolarfarm.com/the-solar-farm/>.

77. Lacy Cooke, “World’s largest airport-based solar farm makes creative use of land to generate clean energy,” *Inhabitat*, 21 September 2016, <http://inhabitat.com/worlds-largest-airport-based-solar-farm-makes-creative-use-of-land-to-generate-clean-energy/>.

78. “IMS Solar Power Facility Opens,” Indianapolis Motor Speedway, 1 July 2014, <http://www.indianapolismotorspeedway.com/events/indy500/news-multimedia/news/2014/07/01/ims-solar-power-facility-opens>.

79. “Massport Takes the Wind Out of High Energy Costs; Boston Logan to Receive 20 Building-Integrated Wind Turbines,” Massport, 5 March 2008, <http://www.massport.com/massport/media/newsroom/massport-takes-the-wind-out-of-high-energy-costs-boston-logan-to-receive-20-building-integrated-wind-turbines/>.

80. “Renewable Energy at Massport,” Massport, <https://www.massport.com/environment/achievements-and-initiatives/renewable-energy/>.

81. “Using wind energy to power the city,” City of Boston, <https://www.boston.gov/departments/environment/using-wind-energy-power-city>.

82. *Innovation through Aggregation: A case study of partnership to purchase renewable energy*, A Better City, April 2017, <http://www.abettercity.org/docs-new/Innovation_Through_Aggregation.pdf>.

83. “A Better City-Facilitated Joint Solar Power Purchase Agreement,” A Better City, 19 October 2016 <http://www.abettercity.org/news-and-events/blog/a-better-city-facilitated-joint-solar-power-purchase-agreement>

84. David Chandler, “MIT to neutralize 17 percent of carbon emissions through purchase of solar energy,” MIT News, 19 October 2016, <http://news.mit.edu/2016/mit-neutralize-17-percent-carbon-emissions-through-purchase-solar-energy-1019>.

85. David L. Chandler, “MIT’s solar plant is delivering on its promises,” MIT News, 23 March 2017, <http://news.mit.edu/2017/solar-plant-delivering-promises-carbon-emissions-0323>.

86. Ibid.

87. David Chandler, “MIT to neutralize 17 percent of carbon emissions through purchase of solar energy,” MIT News, 19 October 2016, <http://news.mit.edu/2016/mit-neutralize-17-percent-carbon-emissions-through-purchase-solar-energy-1019.

88. “A Better City-Facilitated Joint Solar Power Purchase Agreement,” A Better City, 19 October 2016, <http://www.abettercity.org/news-and-events/blog/a-better-city-facilitated-joint-solar-power-purchase-agreement>.

89. David L. Chandler, “MIT’s solar plant is delivering on its promises,” MIT News, 23 March 2017, <http://news.mit.edu/2017/solar-plant-delivering-promises-carbon-emissions-0323>.

90. “City of Boston Community Greenhouse Gas Inventory, 2005-2013,” City of Boston, <https://www.cityofboston.gov/images_documents/Community%20GHG%20Inventory%202013_tcm3-49977.pdf>.

91. “Partners HealthCare signs contract with Walden’s New Hampshire wind farm,” Partners HealthCare, 13 April 2017, <http://www.partners.org/Newsroom/Press-Releases/Wind-Farm-Press-Release.aspx>.

92. Lingya Xia, "Growth and Impacts of California Community Choice Aggregation (CCA) Programs", Duke University Libraries, 28 April 2017, <https://dukespace.lib.duke.edu/dspace/handle/10161/14194>.

93. “Your Energy Choices,” Marin Clean Energy, < https://www.mcecleanenergy.org/your-energy-choices/>.

94. “MCE Reduces Rates for Second Year in a Row”, Marin Clean Energy, <https://www.mcecleanenergy.org/news/press-releases/mce-reduces-rates/>.

95. “We promised local renewables. Now we’re delivering”, Marin Clean Energy, <https://www.mcecleanenergy.org/local-projects/>.

96. “MCE Reduces Rates for Second Year in a Row”, Marin Clean Energy, 30 March 2017, <https://www.mcecleanenergy.org/news/press-releases/mce-reduces-rates/>.

97. George Foulsham, “Community choice is transforming the California energy industry,” UCLA Newsroom, 5 May 2017, <http://newsroom.ucla.edu/releases/community-choice-is-transforming-the-california-energy-industry>.

98. “Our Vision for a Local Clean Energy-Powered Bay Area”, Local Clean Energy Alliance, <http://localcleanenergy.org/about/vision>.

99. “Path Ahead: Steps Ahead for EBCE”, East Bay Community Energy, <http://ebce.org/path-ahead/>.

100. “Approved Municipal Aggregation Programs”, Massachusetts Department of Public Utilities, <http://www.mass.gov/eea/energy-utilities-clean-tech/electric-power/electric-market-info/approved-municipal-aggregation-programs.html>.

101. “Arlington Community Choice Aggregation Starts in August,” Town of Arlington, 1 June 2017, <http://www.arlingtonma.gov/home/showdocument?id=34865>. “Somerville Announces New Community Choice Electricity Program,” City of Somerville, 22 May 2017, <http://www.somervillema.gov/news/somerville-announces-new-community-choice-electricity-program>. “Community leaders band together to bring estimated $15 million in savings this winter through new regional bulk electricity buying program,” Town of Dedham, 18 November 2015, <http://www.dedham-ma.gov/departments/community-electricity-aggregation>.

102. “Brookline Green Energy,” Town of Brookline, <http://www.brooklinema.gov/1340/Brookline-Green-Electricity>.

103. “Community Choice Energy Boston,” Boston Climate Action Network, <https://communitychoiceboston.org/>.

104. *Greenovate Boston: 2014 Climate Action Plan Update*, City of Boston, <https://www.cityofboston.gov/eeos/pdfs/Greenovate%20Boston%202014%20CAP%20Update_Full.pdf>.

105. Judah Aber, “Electric Bus Analysis for New York City Transit,” Columbia University, May 2016, < http://www.columbia.edu/%7Eja3041/Electric%20Bus%20Analysis%20for%20NYC%20Transit%20by%20J%20Aber%20Columbia%20University%20-%20May%202016.pdf>.

106. Tina Casey, “Bet your EV can’t do this: Electric Garbage Truck Hauls 9 tons of trash,” *Clean Technica*, 16 September 2014, <https://cleantechnica.com/2014/09/16/first-electric-garbage-truck-in-us-hauls-9-tons-of-chicago-trash/>.

107. Adele Peters, “North America’s First Electric Garbage Truck is Silently Driving Chicago Streets,” *Fast Company*, 3 October 2014, <https://www.fastcompany.com/3036432/north-americas-first-electric-garbage-truck-is-silently-driving-chicago-streets>.

108. Motiv, “America’s First All-Electric Refuse Truck,” <https://motivps.com/portfolio/americas-first-all-electric-refuse-truck/>.

109. “Electric Bus,” Chicago Transit Authority, <http://www.transitchicago.com/electricbus/>.

110. Brianna Gurciullo, “CTA to buy more electric buses,” *Chicago Tribune*, 22 January 2016, <http://www.chicagotribune.com/news/local/breaking/ct-cta-electric-buses-met-20160122-story.html>.

111. Mark Kane, “Chicago Transit Authority Adding Electric Buses,” *Inside EVs*, 24 February 2016, <http://insideevs.com/chicago-transit-authority-adding-electric-buses/>.

112. First Priority GreenFleet, <http://www.fpgreenfleet.net>.

113. “Sacramento to Deploy 29 Electric School Buses and Charging Devices,” *Fleet News Daily*, 23 March 2017, < http://fleetnewsdaily.com/sacramento-deploy-29-electric-school-buses-charging-devices/>.

114. Ibid.

115. Nicole Schlosser, “3 California Districts Receiving Electric School Buses,” *Schoolbus Fleet*, 12 May 2017, <http://www.schoolbusfleet.com/news/722420/3-california-districts-receiving-electric-school-buses>.

116. “Indiana University researchers rank U.S. cities’ readiness for plug-in electric vehicles”, Indiana University Bloomington, 14 March 2016 <http://archive.news.indiana.edu/releases/iu/2016/03/plug-in-vehicle-city-readiness-study.shtml>.

117. “How do Residential Level 2 Charging Installation Costs Vary by Geographic Location?” The EV Project, April 2015, <https://avt.inl.gov/sites/default/files/pdf/EVProj/HowDoResidentialChargingInstallationCostsVaryByGeographicLocations.pdf>.

118. Number of charging stations: “Electric Charging Station Locations by State,“ Alternative Fuels Data Center, U.S. Department of Energy, <https://www.afdc.energy.gov/data/10366>. Number of electric vehicles sold: Gideon Weissman et al., *Renewables on the Rise: A Decade of Progress Toward a Clean Energy Future*, Environment America and Frontier Group, 20 July 2017, <http://environmentamerica.org/sites/environment/files/reports/AME%20Renewables%20on%20the%20Rise%20July%2017.pdf>.

119. “City of Portland Green Purchasing Case Study”, City of Portland, Oregon, April 2016, <https://www.portlandoregon.gov/brfs/article/474135>.

120. “Indiana University researchers rank U.S. cities’ readiness for plug-in electric vehicles”, Indiana University Bloomington, 14 March 2016 <http://archive.news.indiana.edu/releases/iu/2016/03/plug-in-vehicle-city-readiness-study.shtml>.

121. “Boston Awarded State Grant for 22 Electric Vehicle Charging Stations,” City of Boston, 25 July 2011, <https://www.cityofboston.gov/news/Default.aspx?id=5209>.

122. “Massachusetts Electric Vehicle Incentive Program (MassEVIP): Fleets,” Office of Energy and Environmental Affairs, Commonwealth of Massachusetts, <http://www.mass.gov/eea/agencies/massdep/air/grants/massevip-municipal.html>.

123. Janet Domenitz et al., *From Deceit to Transformation: How Massachusetts Can Leverage Volkswagen Settlement Funds to Accelerate Progress to a Clean Transportation System*, MASSPIRG Education Fund, 18 July 2017, <http://masspirg.org/reports/map/deceit-transformation>.

124. Minutes from July 19, 2016 meeting, State Board of Building Regulations and Standards, Commonwealth of Massachu-setts, <http://www.mass.gov/ocabr/docs/dpl/dps/meeting-minutes/building-division/board-of-building-regulations-and-standards/bbrs-meeting-minutes-07-19-2016-approved.pdf>.

125. Joe Ryan, “Cities Shop for $10 Billion of Electric Cars to Defy Trump,” Bloomberg Technology, 14 March 2017, <https://www.bloomberg.com/news/articles/2017-03-14/cities-shop-for-10-billion-of-electric-vehicles-to-defy-trump>.

126. “Public Transportation Ridership Report: Fourth Quarter 2016,” American Public Transportation Association, 3 March 2017, <http://www.apta.com/resources/statistics/Documents/Ridership/2016-q4-ridership-APTA.pdf>.

127. “Sustainability,” Bay Area Rapid Transit, < https://www.bart.gov/sustainability>.

128. Julian Spector, “Bay Area Rapid Transit Will Run Trains on 100% Renewable Energy,” Green Tech Media, May 2017, <https://www.greentechmedia.com/articles/read/bay-area-rapid-transit-will-run-on-100-renewable-energy>.

129. “Renewable Energy RFP – 2017,” Bay Area Rapid Transit, 8 May 2017, <https://www.bart.gov/sustainability/renewable-RFP/2017>.

130. “BART moves to build clean power portfolio,” Bay Area Rapid Transit, 1 May 2017, <https://www.bart.gov/news/articles/2017/news20170501-0>.

131. “Thousands attend tours of Fleet of the Future trains,” Bay Area Rapid Transit, 17 November 2016, <https://www.bart.gov/news/articles/2016/news20160921>.

132. “Sustainability,” Bay Area Rapid Transit, <http://www.bart.gov/about/projects/cars/sustainability>.

133. “Thousands attend tours of Fleet of the Future trains,” Bay Area Rapid Transit, 17 November 2016, <https://www.bart.gov/news/articles/2016/news20160921>.

134. “Case Study: Euclid Avenue BRT, Cleveland, OH,” National Association of City Transportation Officials, <https://nacto.org/case-study/euclid-avenue-brt-cleveland-oh/>.

135. “RTA’s HealthLine -- the world-class standard for BRT service,” Greater Cleveland Regional Transit Authority, <http://www.riderta.com/healthline/about>.

136. “BRT In Action - Cleveland, Ohio, USA,” Boston BRT, <http://www.bostonbrt.org/brt-in-action/>.

137. “RTA’s HealthLine -- the world-class standard for BRT service,” Greater Cleveland Regional Transit Authority, <http://www.riderta.com/healthline/about>.

138. “ITDP Celebrates Cleveland’s HealthLine as Best Practice for US BRT,” Institute for Transportation and Development Policy, 18 April 2017, <https://www.itdp.org/itdp-celebrates-clevelands-healthline-as-best-practice-for-us-brt/>.

139. Ginger Christ, “Hospitals investing in transit to provide access improve health for Clevelanders,” *cleveland.com*, 14 April 2017, <http://www.cleveland.com/healthfit/index.ssf/2017/04/hospitals_investing_in_transit.html>.

140. Ibid.

141. “Sustainability - Energy Management,” Massachusetts Bay Transportation Authority, <http://www.mbta.com/about_the_mbta/environment/default.asp?id=26014,>.

142. *Better Rapid Transit for Greater Boston: The Potential for Gold Standard Bus Rapid Transit Across the Metropolitan Area*, Boston BRT, March 2015, <http://www.bostonbrt.org/the-brt-report/>.

143. “The Gold Standard,” Boston BRT, <http://www.bostonbrt.org/the-gold-standard/>.

144. Sitka Economic Development Association, <https://www.sitka.net/>.

145. “27th Legislature (2011-2012) - Committee Minutes,” Alaska State Legislature, 7 May 2011, <http://www.legis.state.ak.us/basis/get_single_minute.asp?session=27&beg_line=00178&end_line=03146&time=1010&date=20110507&comm=RES%20%20%20%20%20%20%20&house=H>.

146. “Sitka’s Energy Situation,” Sitka Electric Department and Sitka Conservation Society, <https://sitkaenergy.wordpress.com/about/>.

147. Suzanna Caldwell, “Air source heat pumps provide energy relief in Southeast Alaska,” Alaska Dispatch News, 16 June 2014, <https://www.adn.com/alaska-news/article/air-source-heat-pumps-provide-energy-relief-southeast-alaska-0/2014/06/17/>.

148. Vanessa Stevens et al., *Air Source Heat Pump Potential in Alaska, Cold Climate Housing Research Center, December 2015*, <http://www.cchrc.org/sites/default/files/docs/EETFRound2_ASHP_Potential_in_AK_12.31.2015.pdf>.

149. Vanessa Stevens et al., *Air Source Heat Pumps in Southeast Alaska*, Cold Climate Housing Research Center, April 2013.

150. “Exploring Energy Efficiency and Conservation in Sitka, Alaska,” Sitka Electric Department and Sitka Conservation Society, <https://sitkaenergy.wordpress.com/home-heating-options/air-source-heat-pumps/>.

151. “Home Energy Rebate,” Alaska Housing Finance Corporation, <https://www.ahfc.us/efficiency/energy-programs/home-energy-rebate/>.

152. “Sitka Energy Star Program Ends”, rePOWER southeast!, 28 January 2013, <https://repowersoutheast.wordpress.com/2013/01/28/sitka-ends-energy-star-program/>.

153. “Boulder’s Climate Commitment,” City of Boulder, Colorado, <https://bouldercolorado.gov/climate>.

154. “Climate Action Tax,” City of Boulder, Colorado, <https://bouldercolorado.gov/climate/climate-action-plan-cap-tax>.

155. Ibid.

156. “Boulder’s Climate Commitment,” City of Boulder, Colorado, <https://bouldercolorado.gov/climate>.

157. *Thermal Decarbonization: First Stage Findings in Developing Renewable Heating and Cooling Alternatives for Residential and Municipal Buildings*, Carbon Neutral Cities Alliance, August 2016, <https://www.usdn.org/public/page/91/CNCA-Innovation-Fund-Products>.

158. “Climate Commitment and Energy-Related Programs: 2015 Climate Action Guide,” City of Boulder, Colorado, <https://bouldercolorado.gov/climate/climate-commitment-and-energy-related-programs-2015-climate-action-guide>.

159. Laurel Demkovich, “Northampton launches energy-saving programs,” *Daily Hampshire Gazette*, 18 July 2017, http://www.gazettenet.com/Northampton-launches-new-energy-programs-11345885.

160. “2017 Solarize Mass and Mass Solar Connect Programs Launched,” Massachusetts Clean Energy Center, 5 May 2017, <http://www.masscec.com/blog/2017/05/05/2017-solarize-mass-and-mass-solar-connect-programs-launched>.

161. “What We Do,” FortZED, <http://fortzed.com/what-is-fortzed/what-we-do/>.

162. “Fort Collins,” Microgrids at Berkeley Lab, Lawrence Berkeley National Laboratory, <https://building-microgrid.lbl.gov/fort-collins>.

163. Ibid.

164. Ibid.

165. “RDSI”, FortZED, <http://fortzed.com/case-studies-and-lessons-learned/rdsi/>.

166. Julian Spector, “New York City Set the First Citywide Energy Storage Target,” *Green Tech Media*, 27 September 2016, <https://www.greentechmedia.com/articles/read/new-york-city-becomes-first-to-set-citywide-energy-storage-target>.

167. Jeff St. John, “A Vanadium Flow Battery Brings Energy Storage to New York City’s MTA,” *Green Tech Media*, 23 April 2014, <https://www.greentechmedia.com/articles/read/A-Vanadium-Flow-Battery-Brings-Energy-Storage-to-New-York-Citys-MTA>.

168. “American Vanadium announces first CellCube vanadium flow battery installation in New York,” Gildemeister Energy Solutions, <http://energy.gildemeister.com/en/company/news/american-vanadium-partners-with-nyserda-for-cellcube/270894>.

169. Julian Spector, “New York City Set the First Citywide Energy Storage Target,” *Green Tech Media*, 27 September 2016, <https://www.greentechmedia.com/articles/read/new-york-city-becomes-first-to-set-citywide-energy-storage-target>.

170. Travis Sheehan et al., *Boston Community Energy Study*, Boston Redevelopment Authority, 2016, <http://www.bostonplans.org/planning/planning-initiatives/boston-community-energy-study>.

171. *Climate Ready Boston*, City of Boston, December 2016, <https://www.boston.gov/departments/environment/climate-ready-boston>.

172. “Request for Proposals - Moon Island Engineering Design Consultant,” Massachusetts Clean Energy Center, <http://www.masscec.com/request-proposals-moon-island-engineering-design-consultant>.