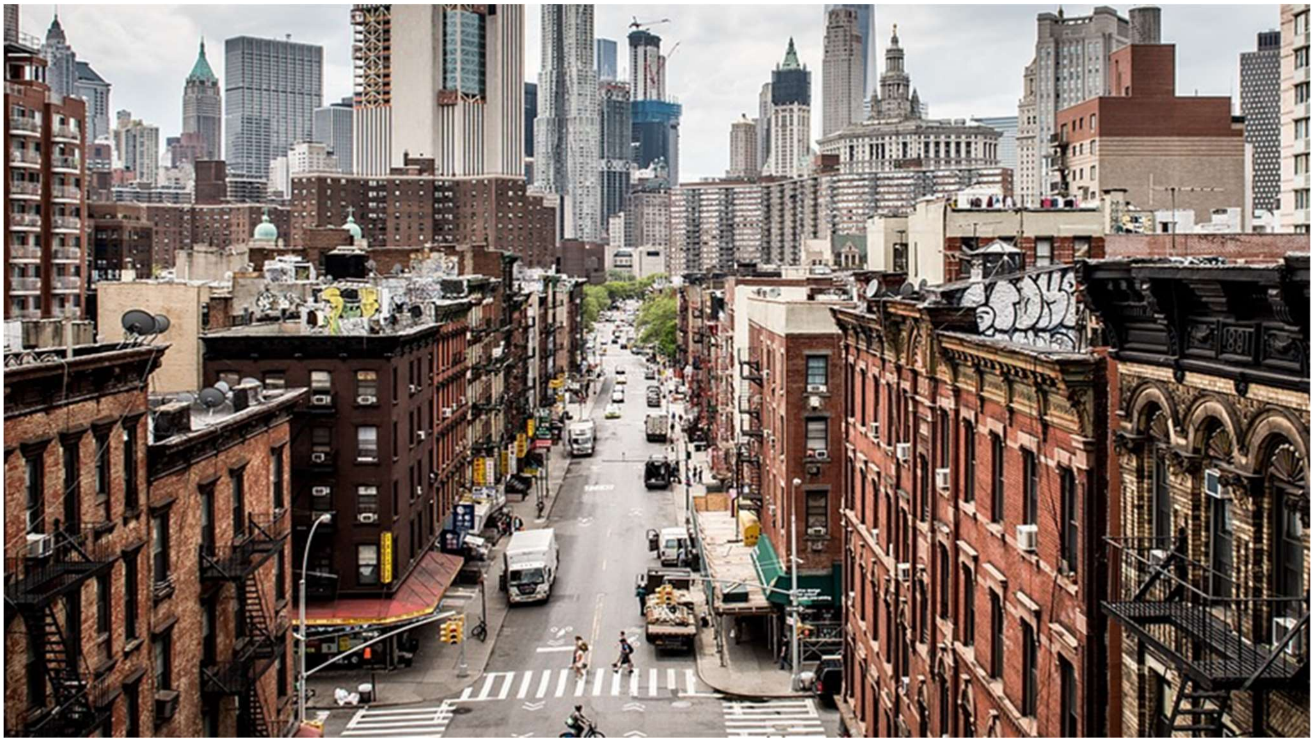

# Innovations in Urban Sustainability

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**Master of Science in Sustainability Management**

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# Executive Summary:

According to the 2010 United States census, urban residents account for 80% of the population.[1] In the face of climate change, cities will be central to moving towards a sustainable future. Cities leaders are taking action towards transforming their policy, infrastructure, and built environments to meet this challenge. At the U.S. Conference of Mayors this year, heads of cities from across the country vowed to build partnerships for a low carbon future and a sustainable economy.[2] The push for cities to lead on climate change makes the evaluation of the success of sustainable innovations more important than ever.

How far have sustainable innovations come? This report provides an assessment of the current state of sustainability innovations across and within American cities. It aims to answer the question: what is the level of penetration of sustainable innovations nationally and what support or barriers exist that might explain the current state of maturity?

## Sustainable Innovations

The research was conducted on ten innovations across a range of essential city services including energy (community solar), transportation (bike share), buildings (building retrofits, energy benchmarking, cool roofs), water (green stormwater infrastructure and stormwater charges), municipal operations (LED street-lighting), and waste (pay-as-you-throw policies, biogas energy use at wastewater treatment facilities).

## Scoring Framework

In order to get at these questions, a scoring framework was designed to provide urban leaders with information regarding the reality behind the aspirations. Eight indicators were determined to reveal successes and barriers each innovation has faced. These indicators were divided along two broad categories of 'within cities' and 'across cities.'

# Findings:

Having looked at the ten innovations across the eight indicators, a standard scoring rubric was applied to see how the innovations compared against each other. The results are charted below.

In Figure 1, the x-axis is composed of the four indicators which describe how an innovation has penetrated within cities: scale within cities, pace of adoption within cities, regulatory needs and the extent of private marketplace. The y-axis is composed of innovations which describe how an innovation has scaled across the eight-three cities under review: scale of adoption across cities, pace of adoption across cities, ease of replicability and the level of federal or state support available.

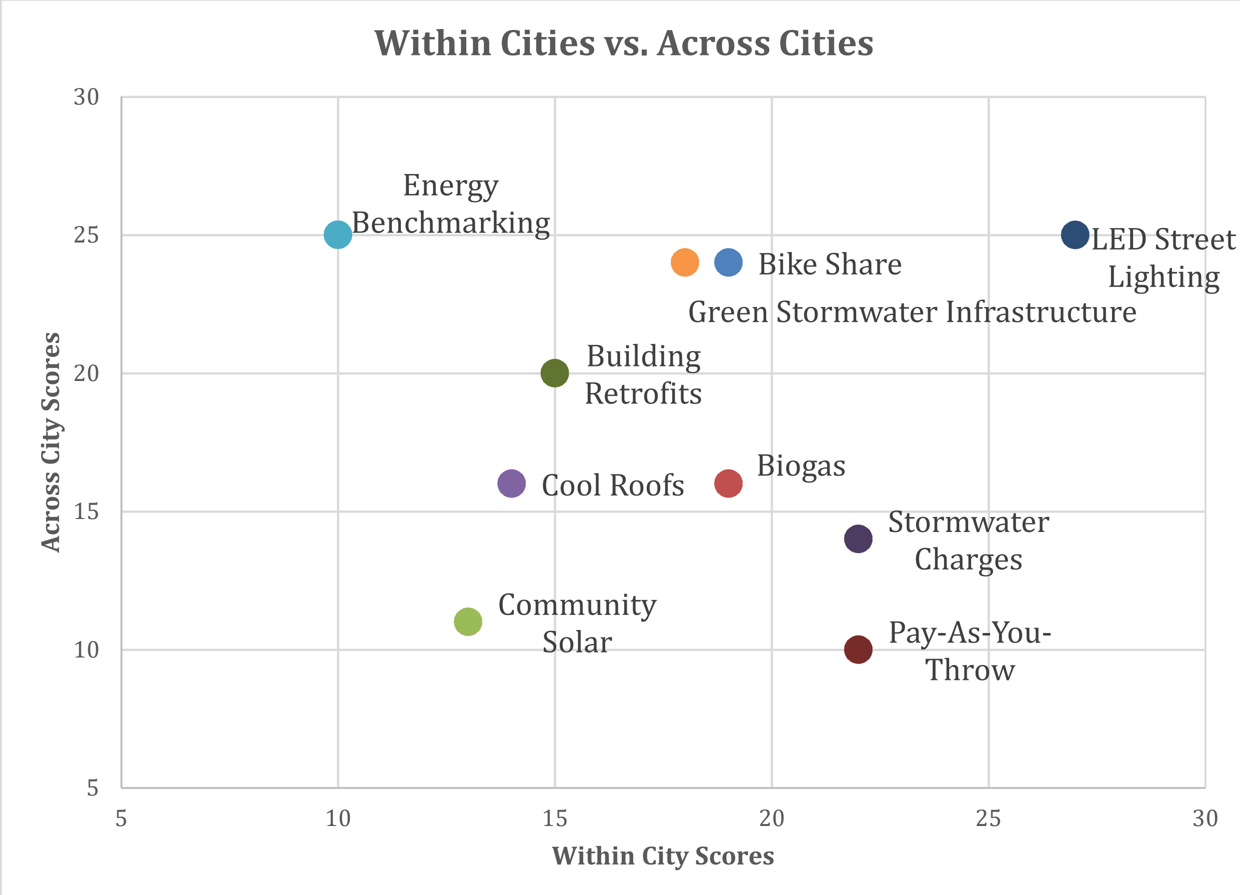



Figure 1: Innovation Matrix

Figure 1 reveals only LED street lighting scores well within and across cities. This innovation is clearly outpacing the rest of the innovations under review. Finally, community solar has the lowest score for both sets of indicators as shown in the graph. When the score for all eight indicators is summed, LED street lighting indeed occupies the top rank with community solar in the tenth position, as can be seen in Figure 2.

LED street lighting, biogas energy, stormwater charges, and pay-as-you-throw policies have scaled the best within cities. They can be seen laying furthest to the right of the graph. Close inspection of the individual indicator scores shows that each of these innovations has achieved 80% or greater scale within at least eight cities. No significant barriers exist in the form of regulation. A private marketplace is present to support their adoption.

Innovations which have best scaled across cities nationally include bike share, green stormwater infrastructure, energy benchmarking and LED street lighting. Each has been implemented in a high percentage of cities and do not need extensive tailoring for adoption. They enjoy enough federal and state support to smooth the way for adoption.

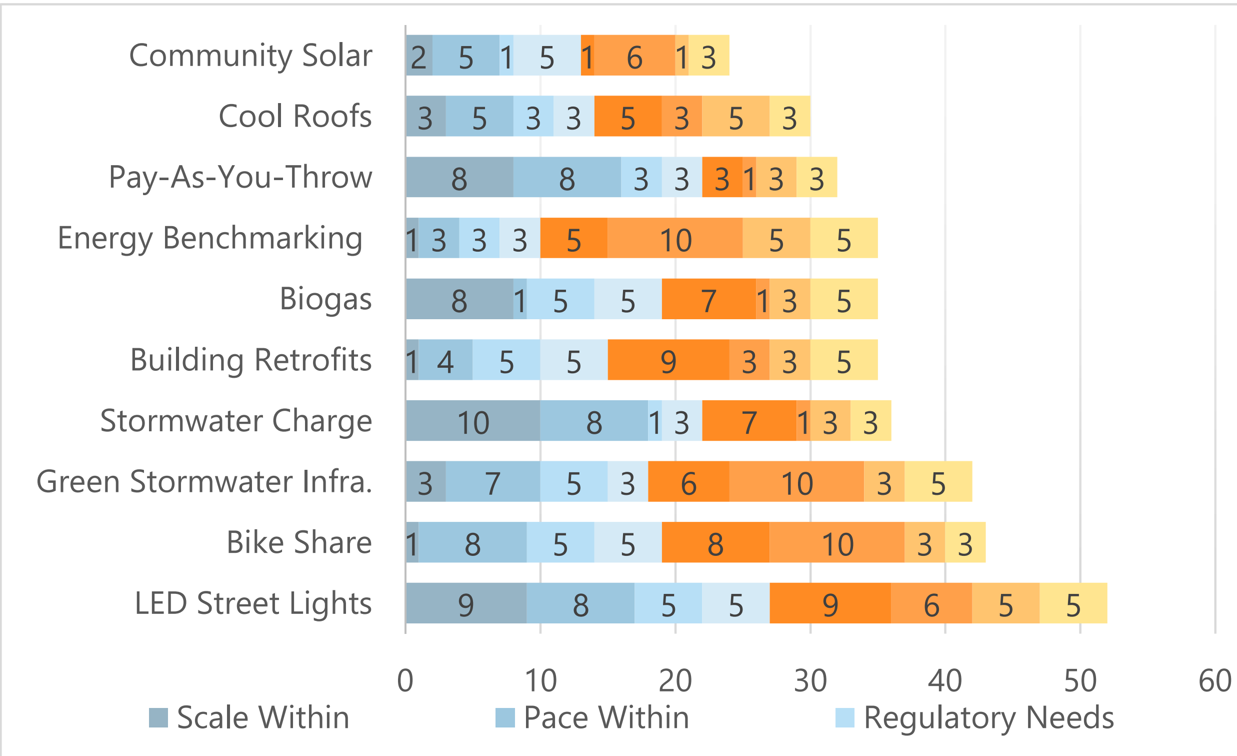



Figure 2: Ranking of Innovations

## Observations

Several observations emerged from an in-depth look at the research:

- When the choice of adoption rests with the individual user, innovations struggle to scale within cities. The need for individual residents to  choose to retrofit their building or to opt into a community solar project, for example, has prevented building retrofits and community solar from gaining traction in American cities. Cities can pave the way for adoption by providing the option for a resident to opt into a sustainable innovation, but this does not provide enough incentive for rapid adoption. In contrast, system-wide programs like pay-as-you-throw, green stormwater infrastructure, LED street lighting, stormwater charges and biogas energy avoid the need for customer education and/or behavior changes because the innovation can be applied by city managers without need for consumer adoption.
- Tackling energy efficiency seems to be a driving force behind a city's adoption of an innovation. Even though they affect different city services, biogas energy, cool roofs, energy benchmarking, LED street lighting, and building retrofits all offer cities a means to reduce the energy needs of a city. A more data driven approach might help sync these efforts and drive further adoption.

- Rapid pace of growth--the rate cities have implemented the innovation in the last three years--does not always mean deep penetration of an innovation within a city. For example, green stormwater infrastructure and energy benchmarking have scaled across cities but not within cities. In the case of green stormwater, many cities have attempted implementation, but city space that can be converted into green stormwater infrastructure is limited thereby preventing it from scaling within cities. Cities have chosen to implement energy benchmarking and continue to do so but the design of the programs capture a very low percent of buildings within a city.
- The expense of an innovation does not seem to prohibit an innovation's adoption. Bike share can be an expensive proposition for a city, but public-private partnerships have enabled its adoption. In the case of biogas energy production at wastewater treatment plants, upgrading to biogas use takes capital upfront but the existence of funding mechanisms, federal and state technical support, and money saved through energy efficiency has allowed cities to adopt this innovation. In both cases, once the value proposition of the innovation is proven, external support whether in the form of government funding or private partnerships fills the necessary funding gap to support adoption of these innovations.

## Final Thoughts:

How well have sustainable innovations scaled in American cities? Graphing the innovations against each other gives a snapshot of their relative successes to date. The good news is that the majority of innovations--eight out of ten--have been adopted by at least 50% of cities under review. This demonstrates the willingness of American cities to embrace sustainable innovations.

When all four qualitative indicators receive high scores, the lack of barriers works in tandem to encourage adoption. The research confirms that LED street lighting has scaled well across most large U.S. cities and has been extensively adopted within these cities. LED street lighting scores well across all qualitative indicators because this innovation lacks barriers and has therefore reach scale.

When more than one barrier exists, the cumulative effect is poor scaling. Community solar has two low scores for qualitative indicators. Community solar faces the greatest number of barriers and as a result lags behind all other innovations under review.

Because of the defined scope of the project, there are several features not captured by the selected indicators. As currently defined, the scoring framework seeks only to describe the current scale of innovations and identify barriers to each innovation's adoption.

To extend the research, additional indicators could be added to the scoring rubric. In particular, the sustainability benefits a city might receive from any given innovation could be compared. A possible indicator could be the amount of greenhouse gas reductions a city might accrue from adoption of an innovation.

Additional research might further develop a cost comparison. While cost was considered as part of the replicability indicator—asking simply 'was cost a substantial barrier to adoption?'--no attempt was made to assign a relative dollar value to any innovation. The return on investment was not addressed.

Finally, because of the choice to focus on cities with populations greater than two hundred fifty thousand, the extent of scaling in smaller municipalities has not been captured. Including municipalities with smaller populations would change the relative scoring of the innovations under review and allow for analysis of how the size of a city impacts the adoption of certain innovations.

Each of these areas represents fertile areas for additional research.

# Methodology

## Purpose of the study

A scoring rubric allows for a better understanding of how innovations have done in comparison to each other. By normalizing the innovations against each other, the report separates impressions of an innovation's success from its actual application. The scoring framework can be used as a tool for benchmarking today's progress and for identifying barriers.

Of the eight indicators, four were designed as quantitative indicators aimed at revealing the current state of an innovation's scale. These include measuring the extent of scale within cities, pace of scale within cities, extent of scale across cities, and pace of scale across cities. Four qualitative indicators were chosen to shed light on the different conditions necessary for scaling: need for regulatory changes, existence of private sector, ease of replicability, and extent of federal and state support.

The report applied a scoring rubric to innovations so they could be compared against each other. It did not seek to rank cities. The choice to rank innovations was done to reveal common features among successful innovations, features independent of any specific city context.

## Project Scope

The study researched innovations across American cities with a population greater than 250,000. (See Appendix 2 for a list of these cities.)

For each of these eight-three cities, the presence of the innovation and start date were determined. This allowed for the calculation of the percentage of cities across the United States possessing the innovation and an assessment of the pace of adoption across cities.

In order to analyze the extent an innovation has scaled within cities, eight to ten cities with mature innovations were identified for in-depth research to understand how they achieved maturity. These 'lead cities' were analyzed to determine the percentage of the larger system the sustainable innovation has displaced. From this research, it was also able to assess how quickly each city adopted the innovation.

When applicable, outlier cities were included for comparison purposes. For example, if an innovation had failed in a city, attention was paid to why this had occurred.

## Innovations

The research started with an extensive list of innovations resulting from a team-wide conversation. The list was generated in order to show coverage of all main city systems. They included:

- Energy: community solar, 100% renewable energy commitments, microgrids.
- Transportation: electric vehicles, bike share, rideshare/carpooling, reduced parking minimums, dynamic parking charges, transit oriented development, autonomous vehicles, complete streets.
- Buildings: residential retrofits, near-zero energy building codes, building energy systems, cool roofs, energy benchmarking, district energy.
- Water: green stormwater infrastructure, leak reduction strategies, conservation pricing, watershed protection, stormwater charges, water recycling.
- Municipal operations: LED street lighting, EV/AFV for public transit.
- Air: congestion pricing, street-level air quality monitoring.
- Waste: pay-as-you-throw policies, biogas production at wastewater treatment facilities, organic collection, waste-to-energy.
- Finance: PACE/retrofit funds, green bonds/green banks.

The list was narrowed as research revealed the extent of information available to address the indicators. Some innovations such as PACE financing was subsumed under the broader innovation of building retrofits. Others such as rideshare/carpooling were taken off the final list due to the lack of data available for analysis. Stationary air quality monitoring was also excluded once it was known that very few cities had engaged in air quality monitoring above and beyond federal mandates. In air quality monitoring, New York City is an outlier based on its extensive program. No other city has developed a similar system.

The final list of innovations selected for review are shown in the table below:

| **Innovation** | **Definition** |
|---|---|
| Bike share | Bike share is defined as a non-motorized transportation program for point-to-point trips. The program provides bikes and bike-stations within a service area. Bike share programs provide on-demand bikes for rental by any individual for a short trip. The bike can be left at any program stations installed throughout by the cities in the covered service area. |
| Biogas Use at Wastewater Treatment Facilities | At wastewater treatment facilities, biosolids are fed into anaerobic digesters. The anaerobic digestion process generates biogas, a renewable energy. Biogas can be harnessed to power the plant while also providing heat for the anaerobic digestion process. |
| Building Retrofits | Building retrofits can include upgrades made to heating and cooling systems, installation of efficient lighting and windows, and improvements to the building envelope to reduce energy |

| | |
|---|---|
| | demand and improve energy efficiency of a building. |
| Community Solar | Community solar is a program where power generating photovoltaic panels are either owned by a community or a third-party and provide shared electricity to city residents through solar energy. Cities can implement the program by installing solar gardens and providing electricity through them to urban residents through a voluntary buy-in into renewable energy units. |
| Cool Roofs | A cool roof is a roof or roofing system that is designed to reflect sunlight and reduce heat absorption. It can be implemented as reflective paint, tiles, sheet coverings, or shingles. By reflecting light, a cool roof reduces local air temperatures, energy use in buildings, and peak load demand. |
| Energy Benchmarking | Benchmarking measures the energy use of a building over time, and assess' this use relative to similar buildings. Cities require buildings of a certain size or type to Benchmark, which allows officials to track the city's overall energy consumption, identify high energy consuming buildings or communities, and determine energy saving measures to be implemented across a city. |
| Green Stormwater Infrastructure | Strategies that use natural mitigation methods to reduce the volume of stormwater runoff entering treatment plants. These include downspout disconnection, rainwater harvesting, rain gardens, swales, green roofs, permeable pavements, revitalization of vacant lots, parks, riparian buffers, and natural or constructed wetlands. |
| LED Street Lighting | Cities around the US are increasingly upgrading their street-lights from out old, High Pressure Sodium (HPS) technology to LED technology. LED street lights provide better lighting, are highly energy efficient, and last longer – thereby reducing greenhouse gas emissions and saving cities considerable energy and maintenance costs. |
| Pay-As-You-Throw Policies | PAYT is a trash metering scheme that creates a direct economic incentive to generate less waste. Residents or commercial businesses are charged a fee based on the volume of municipal solid waste they dispose. PAYT is commonly accompanied by a free recycling scheme, thereby encouraging a higher recycling rate, which diverts municipal solid waste from landfills. |
| Stormwater Charges | A stormwater charge is a funding mechanism used to effectively manage and operate the infrastructure associated with the stormwater system. Property owners are levied a fee based on the size of impervious surface. Most widely used fee structure is using the average impervious area of all property assessed such as the Equivalent Residential Units. |

## Definition of indicators:

In order to assess how and why individual innovations have reached maturity, it was necessary to develop a framework for assessing relative scale.

### Within Cities:

1. **Scale of adoption within cities**: For each innovation, the extent of the innovations maturity was assessed by comparing the size of the sustainable innovation to the size of the traditional system it replaced. This was defined specifically to each innovation. The percentage of the traditional system that was replaced was then used to determine the score for scaling within cities. This was important for understanding the degree to which the sustainable innovation had overtaken the traditional system.
2. **Pace of adoption within cities**: How quickly has the innovation expanded within the cities once adopted? This indicator noted how the innovation has grown or expanded since the date it was taken up by the city. An effort was made to determine how many years it took a city to go from initial adoption to maturity. This was important in understanding
3. **Regulatory needs**: The research addressed the question, does a law or regulation need to be changed or passed to make way for the innovation? This was important for identifying any potential regulatory barriers to adoption of the innovation.
4. **Extent of private marketplace**: Is there a robust private market in place to support adoption of this innovation? This could include the existence of private companies that produce the technology needed or a contractor base available to install or support implementation of the innovation. This was important for understanding how much support is available to cities for adoption of the innovation.

### Across Cities

5. **Scale of adoption across cities**: Scale of adoption across cities was defined as the percentage of the eighty-three cities that currently have implemented the innovation. This is important for understanding how extensively the innovation has been implemented across the country.
6. **Pace of adoption across cities**: The pace of adoption was defined as the expansion rate over the last three years. Defining the period of growth from 2014-2017 was important for understanding the recent growth trends at play and thus is a better predictor of the adoption rate of the innovation in the near future.
7. **Replicability**: The research addressed how easily the innovation could be repeated across cities. Does the innovation need tailoring to each city or is it ‘out-of-the box’? Replicability also addressed the expense of the innovation and whether or not expense presented a barrier for adoption of the innovation. This was important for understanding how easy it would be for other cities to adopt the innovation.

8. **Level of federal or state support**: The research looked at how much federal or state support exists. Support was interpreted broadly to include both grant support or technical support. This was important for noting how much support a city could draw upon in adopting the innovation.

# Innovation Scorecards

| **Bike Share**: Bike share is defined as a non-motorized transportation program for point-to-point trips. The program provides bikes and bike-stations within a service area. Bike share programs provide on-demand bikes for rental by any individual for a short trip. The bike can be left at any program stations installed throughout by the cities in the covered service area.<br>● Bike share programs utilized public-private partnerships to raise the funding required to achieve scale.<br>● Bike share programs have grown quickly in the past 3 years due to minimal regulation impeding bike share adoption. The exception is Seattle, where bike share system was shut down due to lack of use. | | **TOTAL SCORE**<br>**43** |
|---|---|---|
| **Within Cities** | | |
| **Indicators** | **Score** | **Rationale** |
| Scale within cities | 1 | Bike (all bikes) represent 1 % of entire mode share in cities under review. This includes personal bikes as well as bike-share bikes indicating an estimate of how much of a city's transportation system, bike share programs comprise of. . |
| Pace of adoption within cities | 8 | Total number bike share stations in select cities has a compound annual growth rate (CAGR) of 20% from year launched compared with year-to-date. This shows how bike share systems are scaling within a city based on the number of stations at launch and at present (2017). |
| Regulatory needs | 5 | Based on the cities reviewed there is not a strict nor a soft regulatory change required for bike share to be launched/implemented. Bike share programs are launched under a city's jurisdiction with private partnerships, but there are no regulatory changes needed for the implementation. |
| Extent of private marketplace | 5 | There are numerous companies to assist with planning, implementing, and operating bike share systems. Motivate Company operates over 66% of bike share systems. Another company of similar nature is Decobike. |
| **TOTAL WITHIN CITIES SCORE: 19** | | |
| **Across Cities** | | |
| **Indicators** | **Score** | **Rationale** |
| Scale across cities | 8 | 70% of cities under review have a bike-share system operating within their boundaries. |
| Pace of adoption across cities | 10 | Since 2014, the number of cities with bike share programs have gone from 29 to 58, resulting with a 100% growth rate |
| Level of federal or state support | 3 | 9 federal financial programs are available nationally for bike share (capital and equipment). |
| Replicability | 3 | Bike share is not easy to replicate given the high financial costs associated with implementation and maintenance, although many cities have used public-private partnerships to overcome these costs. Additionally, a city's infrastructure poses as a barrier to replicating bike share system when considering placement of bike stations. |
| **TOTAL ACROSS CITIES SCORE: 24** | | |

| **Biogas Energy from Anaerobic Digestion at Wastewater Treatment Facilities:** At wastewater treatment facilities, biosolids are fed into anaerobic digesters. The anaerobic digestion process generates biogas, a renewable energy. Biogas can be harnessed to power the plant while also providing heat for the anaerobic digestion process.<br>● Anaerobic digestion at wastewater treatment plants is a proven innovation which has seen slow but steady growth since the 1970s.<br>● Despite high capital costs, a large array of grants and other funding mechanisms along with a high return on investment have led to its continued adoption. | | **TOTAL SCORE**<br>**35** |
|---|---|---|
| **Within Cities** | | |
| **Indicators** | **Score** | **Rationale** |
| Scale within cities | 8 | All of the eight cities researched cover more than 50% of the wastewater treatment facility energy needs with biogas. Four have reached 100% of their energy needs, resulting in an average of 84%. |
| Pace of adoption within cities | 1 | It takes between seven and ten years for a wastewater treatment facility to achieve net zero after an upgrade. |
| Regulatory needs | 5 | Installing biogas generation capacity in wastewater treatment facilities does not require any regulatory changes. |
| Extent of private marketplace | 5 | A robust private marketplace exists to build, upgrade and run facilities. Over 200 companies operate in this market. |
| **TOTAL WITHIN CITIES SCORE: 19** | | |
| **Across Cities** | | |
| **Indicators** | **Score** | **Rationale** |
| Scale across cities | 7 | 66% of cities under review use biogas produced from anaerobic digestion to generate power in at least one wastewater treatment plant. |
| Pace of adoption across cities | 1 | Wastewater treatment plants have been utilized to produce biogas for decades, with slow and steady growth since the 1970s. From 2014 to 2017, the growth rate was 10%. |
| Level of federal or state support | 5 | Extensive federal and state support exists in the form of grant and technical assistance. This includes clean water funds, EPA methane programs, biofuel programs, and green bonds to support renewable energy efforts. The EPA also provides feasibility analysis and technical support for facility upgrades a through its Methane to Market program. |
| Replicability | 3 | While use of biogas from anaerobic digestion is a well-known technology, adoption does require a feasibility study for an existing upgrade or new facility. Capital costs for these programs can also be significant. |
| **TOTAL ACROSS CITIES SCORE: 16** | | |

| **Building Retrofits:** Building energy accounts for 40% of the total US energy consumption. Building retrofits can include upgrades made to heating and cooling systems, installation of efficient lighting and windows, and improvements to the building envelope to reduce energy demand and improve energy efficiency of a building.<br>• The pace of adoption of retrofits within a city is increasing slowly. This is likely due to the upfront capital costs borne by building owners.<br>• The pace of adoption of retrofits across cities increased since 2011 as many cities started adopting retrofit or energy efficiency programs | | **TOTAL SCORE**<br>**35** |
|---|---|---|
| **Within Cities** | | |
| **Indicators** | **Score** | **Rationale** |
| Scale within cities | 1 | Most cities have retrofitted only less than 3% of the total buildings in the city. The highest number of buildings retrofitted so far was in Houston which is 271. |
| Pace of adoption within cities | 4 | Retrofits take at least 5-6 years to reach 3-5% scale within a city. |
| Regulatory needs | 5 | No regulatory changes are required for implementing a retrofit program but a regulatory change can drive the adoption of retrofits at a greater pace as not many building owners make use of the retrofit programs offered by their city. |
| Extent of private marketplace | 5 | A robust private marketplace where several NGOs and private organizations offer either grants or financing options to homeowners for retrofitting their homes. Many electrical appliance companies now manufacture high efficiency appliances and also offer installation and consulting services. |
| **TOTAL WITHIN CITIES SCORE: 15** | | |
| **Across Cities** | | |
| **Indicators** | **Score** | **Rationale** |
| Scale across cities | 9 | 89% of cities have retrofit programs. |
| Pace of adoption across cities | 3 | Building retrofit programs have seen a 30% growth rate over the last three years as many cities are realizing the environmental and monetary benefits that come from retrofits. |
| Level of federal or state support | 5 | Extensive federal or state support exists in the form of grants, rebates and PACE financing. Good technical assistance is available in the form of free or discounted energy audits or consultations for energy improvements in a building. |
| Replicability | 3 | Retrofit programs are easy to replicate but take time to scale as they are time consuming and capital intensive. |
| **TOTAL ACROSS CITIES SCORE: 20** | | |

| **Community Solar:** Community solar is a program where power generating photovoltaic panels are either owned by a community or a third-party and provide shared electricity to city residents through solar energy. Cities can implement the program by installing solar gardens and providing electricity through them to urban residents through a voluntary buy-in into renewable energy units.<br>● Most current community solar projects are located in smaller towns and do not fall within the research scope.<br>● State legislation regarding virtual net metering caps and program size limits plays a pivotal role in scaling. | **TOTAL SCORE**<br>**24** |
|---|---|

| **Within Cities** | | |
|---|---|---|
| **Indicators** | **Score** | **Rationale** |
| Scale within cities | 2 | Most cities are achieving less than 20% of their solar power from community solar. Sacramento is an exception, which receives 75% of its solar energy from community solar. |
| Pace of adoption within cities | 5 | Adoption to maturity of projects within cities varies from 2-4 years. |
| Regulatory needs | 1 | Cities will need to work with their utilities and public service commission to establish regulations related to virtual net metering, subscription limit and energy bill credits for customers. |
| Extent of private marketplace | 5 | There are numerous partnerships between utilities and solar contractors in the market. Leaders include Xcel Energy, NRG and Tuscon Electric Power. |
| **TOTAL WITHIN CITIES SCORE: 13** | | |
| **Across Cities** | | |
| **Indicators** | **Score** | **Rationale** |
| Scale across cities | 1 | 9.63% of the cities under review have developed at least one community solar project. |
| Pace of adoption across cities | 6 | Cities have been increasingly launching community solar programs. The number of cities with at least one community solar project has grown 60% in the last three years. |
| Level of federal or state support | 3 | Virtual net metering legislation available in the states of 27 cities under review. States include: California, Colorado, Delaware, Illinois, Maine, Maryland, Massachusetts, New York, Oregon, Pennsylvania, Rhode Island, Utah, Vermont, Washington and West Virginia. |
| Replicability | 1 | Dependent on existing state legislation regarding virtual net metering and renewable energy credits which causes the electricity billing model to be tailored per state. |
| **TOTAL ACROSS CITIES SCORE: 11** | | |

**Cool Roofs:** A cool roof is a roof or roofing system that is designed to reflect sunlight and reduce heat absorption. It can be implemented as reflective paint, tiles, sheet coverings, or shingles. By reflecting light, a cool roof reduces local air temperatures, energy use in buildings, and peak load demand.

- Cool roofs continue to scale within cities as energy costs and energy demands increase.
- Cool roofs continue to scale as they provide a lower cost and maintenance solution to mechanical cooling systems.

**TOTAL SCORE**
**30**

| Within Cities | | |
|---|---|---|
| **Indicators** | **Score** | **Rationale** |
| Scale within cities | 3 | Cool Roof programs are typically implemented as an addendum to a City Building Code. They are typically required for all new construction, roof replacements, or when roofs are altered. This impacts all new or remodeled buildings compared to the larger system of all buildings within a city. |
| Pace of adoption within cities | 5 | These building code changes typically apply to 100% of new and altered buildings in a city. |
| Regulatory needs | 3 | Cool roof programs are reliant on building code legislation to scale. However, once that legislation is in place there are few barriers to adoption. |
| Extent of private marketplace | 3 | There are numerous contractors and construction firms that can perform cool roof installations in any major city. |
| **TOTAL WITHIN CITIES SCORE: 14** | | |

| Across Cities | | |
|---|---|---|
| **Indicators** | **Score** | **Rationale** |
| Scale across cities | 5 | 40 of our 83 researched cities (48%) have adopted Cool Roof policies. |
| Pace of adoption across cities | 3 | Between 2014 and 2017, the growth of Cool Roof policies adopted by cities was 21%. |
| Level of federal or state support | 3 | Some grant support is available to private building owners; technical support available via not-for-profit organization Cool Roof Rating Council (CRRC). |
| Replicability | 5 | Cool Roofs can be installed using several methods (paint, tiles, sheet coverings, or shingles) and accommodates all roof types, making it easily replicable. |
| **TOTAL ACROSS CITIES SCORE: 16** | | |

| | |
|---|---|
| **Energy Benchmarking**: Benchmarking measures the energy use of a building over time, and assess this use relative to similar buildings. Cities require buildings of a certain size or type to Benchmark, which allows officials to track the city's overall energy consumption, identify high energy consuming buildings or communities, and determine energy saving measures to be implemented across a city.<br>● Despite easy adoption and support, existing Energy Benchmarking programs have scaled slowly within cities.<br>● Energy Benchmarking programs are expected to capture smaller buildings within cities with existing programs, and across cities as energy costs continue to rise. | **TOTAL SCORE**<br>**35** |

| Within Cities | | |
|---|---|---|
| **Indicators** | **Score** | **Rationale** |
| Scale within cities | 1 | Energy Benchmarking Policies capture less than 20% of the size of the larger system (all buildings within a city). |
| Pace of adoption within cities | 3 | Energy Benchmarking typically captures additional building types/sizes on an annual basis for the following 3-4 years after the implementation of its policy. |
| Regulatory needs | 3 | Energy Benchmarking programs are reliant on regulatory changes to scale. However, once that legislation is in place there are few barriers to adoption. |
| Extent of private marketplace | 3 | Private utilities readily available to provide a building's energy usage to a building owner. ENERGY STAR® Portfolio Manager (developed in partnership with the EPA) serves as the standard for Energy Benchmarking software. |
| **TOTAL WITHIN CITIES SCORE: 10** | | |

| Across Cities | | |
|---|---|---|
| **Indicators** | **Score** | **Rationale** |
| Scale across cities | 5 | 40 of our 83 researched cities (48%) have adopted Energy Benchmarking policies. |
| Pace of adoption across cities | 10 | The number of cities adopting Energy Benchmarking policies has grown 122% between 2014 and 2017. |
| Level of federal or state support | 5 | State governments provide financial support to buildings owners for Energy Benchmarking software and energy efficiency projects. . Substantial technical support is available through federal government (DOE). |
| Replicability | 5 | Private utilities already monitor a building's energy usage, and ENERGY STAR® Portfolio Manager is a cloud-based software easily accessible to building owners and operators. |
| **TOTAL ACROSS CITIES SCORE: 25** | | |

| **Green Stormwater Infrastructure (GSI)**: Strategies that use natural mitigation methods to reduce the volume of stormwater runoff entering treatment plants. These include downspout disconnection, rainwater harvesting, rain gardens, swales, green roofs, permeable pavements, revitalization of vacant lots, parks, riparian buffers, and natural or constructed wetlands.<br>● GSI has seen rapid adoption based on demonstrated results, extensive financial and technical assistance, the National Pollution Discharge Elimination Systems (NPDES) permit program, and EPA consent decrees.<br>● Only a small portion of land can be managed by GSI, limiting its ability to scale within a city. | | **TOTAL SCORE**<br>**42** |
|---|---|---|
| **Within Cities** | | |
| **Indicators** | **Score** | **Rationale** |
| Scale within cities | 3 | The ten cities have managed with green stormwater infrastructure an average of 23% stormwater runoff on city impervious cover. |
| Pace of adoption within cities | 7 | Completion of pilot projects usually takes two to three years. Cities generally add more projects right after pilot projects were completed. |
| Regulatory needs | 5 | Building green stormwater infrastructure does not need any regulatory changes. A review of local codes helps cities see opportunities and remove barriers on incorporating GSI to existing gray infrastructure. Cities have been following BMPs included at their NPDES permit program and long-term control plan for stormwater consent decrees issued by EPA. |
| Extent of private marketplace | 3 | There is a growing number of private contractors and landscapers that partner with cities building on green stormwater infrastructure projects. Private developers include Tetra-Tech, Sustainable Business Network(SBN) and Environmental Consulting Technology, Inc. |
| **TOTAL WITHIN CITIES SCORE: 18** | | |
| **Across Cities** | | |
| **Indicators** | **Score** | **Rationale** |
| Scale across cities | 6 | 51% of cities under review have completed at least one green stormwater infrastructure project. |
| Pace of adoption across cities | 10 | The number of cities developing green stormwater infrastructure has steadily increased since 2008. The growth rate was 100% between 2014 and 2017. |
| Level of federal or state support | 5 | There is extensive federal financial support from a range of agencies, including EPA, FEMA, HUD, DOT, DOE, and the State Water resources Control Board. EPA also has a technical assistance program that helps cities evaluate urban soil as well as monitor and compare the effectiveness of GSI projects,and share lessons learned shared through its website. |
| Replicability | 3 | Capital costs can be lower than gray infrastructure for a similar volume of stormwater, helping make the case for investment. GSI projects are easily replicable if supporting infrastructure (e.g. space and technical staff) is in place. |
| **TOTAL ACROSS CITIES SCORE: 24** | | |

| **LED Street Lighting**: Cities around the US are increasingly upgrading their street-lights from out old, High Pressure Sodium (HPS) technology to LED technology. LED street lights provide better lighting, are highly energy efficient, and last longer – thereby reducing greenhouse gas emissions and saving cities considerable energy and maintenance costs.<br>● Because of the clear and measurable reduction in energy consumption, this is a low hanging fruit for most cities evaluating opportunities to save costs and lower greenhouse gas emissions.<br>● Continued innovation from the private sector is further increasing the attractiveness of LED lighting. | **TOTAL SCORE**<br>**52** |
|---|---|

| **Within Cities** | | |
|---|---|---|
| **Indicators** | **Score** | **Rationale** |
| Scale within cities | 9 | All eight cities covered have converted 80% to 100% of their traditional HPS street lights to LED. |
| Pace of adoption within cities | 8 | LED programs are typically quickly scaled throughout a city. Within two years, most cities have converted 80% of their street lighting to LED. |
| Regulatory needs | 5 | While there are no regulatory changes required, city may find it more challenging to implement LED street-lighting program if the electric utility owns the city's street lights. |
| Extent of private marketplace | 5 | Several private companies are involved in manufacturing LED street lights and in helping finance LED streetlight programs. Cities are increasingly exploring Public Private Partnerships to facilitate these programs. |
| **TOTAL WITHIN CITIES SCORE: 28** | | |
| **Across Cities** | | |
| **Indicators** | **Score** | **Rationale** |
| Scale across cities | 9 | 83% of cities under review have installed LED street lights for at least some portion of their streetlights. |
| Pace of adoption across cities | 6 | In 2014, 43 cities had adopted LED street lighting. This went up to 69 cities by 2017 – a growth rate of 60% |
| Level of federal or state support | 5 | To accelerate technological development and implementation of LEDs, the Department of Energy offers technical assistance and facilitates ongoing dialogue and collaboration with key standards setting organizations. |
| Replicability | 5 | This innovation is easily replicable. |
| **TOTAL ACROSS CITIES SCORE: 25** | | |

| **Pay-As-You-Throw (PAYT)**: PAYT is a trash metering scheme that creates a direct economic incentive to generate less waste. Residents or commercial businesses are charged a fee based on the volume of municipal solid waste they dispose. PAYT is commonly accompanied by a free recycling scheme, thereby encouraging a higher recycling rate, which diverts municipal solid waste from landfills.<br>● PAYT is easily replicable and scalable; the average duration from pilot to citywide adoption is 1 to 3 years<br>● PAYT is less effective in cities with a large number of multi-family residential properties, where it can be more challenging to determine who produced what waste. | **TOTAL SCORE**<br>**32** |
|---|---|

| **Within Cities** | | |
|---|---|---|
| **Indicators** | **Score** | **Rationale** |
| Scale within cities | 8 | Cities reviewed had PAYT schemes that covered an average of 71% of households. |
| Pace of adoption within cities | 8 | PAYT programs implemented since 2000 have reached full adoption an average of 1-3 years after program launch . |
| Regulatory needs | 3 | Legislation must be passed at the county or city level to put a PAYT framework in place. State level change might be required to support a new PAYT framework. |
| Extent of private marketplace | 3 | PAYT has not created any notable private marketplace. However, a private marketplace is not needed to adopt PAYT;existing private haulers typically adjust their services to incorporate the program. |
| **TOTAL WITHIN CITIES SCORE: 22** | | |
| **Across Cities** | | |
| **Indicators** | **Score** | **Rationale** |
| Scale across cities | 3 | 22% (18 out of 83 cities) of cities have adopted a PAYT program. |
| Pace of adoption across cities | 1 | Growth rate in top 83 cities between 2014 to 2017 is relatively slow at 7%. However, growth rate across all of U.S. between 2006 to 2011 (latest data available) is 27%. |
| Level of federal or state support | 3 | Some financial support for education and materials (i.e. trash carts) is available, mostly at the state level. Significant technical support is available from the EPA |
| Replicability | 3 | Easy to replicate. Most cities first identify a pilot community before launching a citywide program, which can add some complexity. |
| **TOTAL ACROSS CITIES SCORE: 10** | | |

| **Stormwater Charges**: A stormwater charge is a funding mechanism used to effectively manage and operate the infrastructure associated with the stormwater system. Property owners are levied a fee based on the size of impervious surface. Most widely used fee structure is using the average impervious area of all property assessed such as the Equivalent Residential Units.<br>● While 53 cities have already adopted this innovation, no new cities have done so in the last three years. This may be due to issues related to their regulatory authority. Enacting a city ordinance is a major barrier in implementing stormwater charges. | | | **TOTAL SCORE**<br>**36** |
|---|---|---|---|
| **Within Cities** | | | |
| **Indicators** | **Score** | **Rationale** | |
| Scale within cities | 10 | By definition, stormwater charges apply to nearly all properties within a city. Some explicit exemptions are often offered to federal and state agencies, school districts and higher institution of education, as well as undeveloped lots and agricultural land. | |
| Pace of adoption within cities | 8 | Implementation of a stormwater fees typically takes about one year. This includes enacting city ordinances to enable the program, developing the fee structure, developing the collection system, and communicating the changes to the public. | |
| Regulatory needs | 1 | No state regulatory change is needed. However, a clearly defined authority for stormwater is needed for cities to adopt these programs. An enactment of city ordinance for stormwater charge is typically required before the implementing the program. | |
| Extent of private marketplace | 3 | Only few private firms available, primarily to advise cities as they structure these programs. This includes FCS Group, Raftelis Financial Consultant, Stormwater Maintenance & Consulting, and Geosyntec Consultants. A private contractor base has developed to help property owners reduce their fees through green infrastructure and other mechanisms. | |
| **TOTAL WITHIN CITIES SCORE: 22** | | | |
| **Across Cities** | | | |
| **Indicators** | **Score** | **Rationale** | |
| Scale across cities | 7 | 65% of, 53 out of, 83 cities reviewed have adopted a stormwater charge. | |
| Pace of adoption across cities | 1 | Zero growth across the 83 cities assessed in the past three years. Cities not implementing stormwater charge typically allocate city budget to funding their stormwater operations. This may be due to issues related to their regulatory authority. | |
| Level of federal or state support | 3 | Some technical support programs do exist, such as EPA's NPDES Stormwater Program which provides guidance for funding and planning stormwater programs. | |
| Replicability | 3 | Stormwater charges are easily replicable, as long as there is a clear framework for municipalities to establish these programs. | |
| **TOTAL ACROSS CITIES SCORE: 14** | | | |

## Indicator Findings

It is also possible to draw conclusions about scalability by looking at how the innovations rank along each individual indicator.

### Scale within cities:

| Rank | Scale within cities | Score |
|---|---|---|
| 1 | LED street lighting | 10 |
| 2 | Stormwater charges | 10 |
| 3 | Biogas at wastewater treatment facilities | 8 |
| 4 | Pay-as-you-throw | 8 |
| 5 | Green stormwater infrastructure | 3 |
| 6 | Cool roofs | 3 |
| 7 | Community solar | 2 |
| 8 | Bike share | 1 |
| 9 | Building retrofits | 1 |
| 10 | Energy benchmarking | 1 |

The innovations were scored from one to ten on the 'scale within cities' indicator. There is a large disparity between the top four innovations which have matured to replace 80% of traditional system and the bottom four innovations that have struggled to break 30%. The top four—LED street lighting, stormwater charges, biogas at wastewater treatment facilities, and pay-as-you-throw policies can all be applied across the city system by city planners.

### Pace within cities:

| Rank | Pace within cities | Score |
|---|---|---|
| 1 | Bike share | 8 |
| 2 | LED street lighting | 8 |
| 3 | Pay-as-you-throw | 8 |
| 4 | Stormwater charges | 8 |
| 5 | Green stormwater infrastructure | 7 |
| 6 | Community solar | 5 |
| 7 | Cool roofs | 5 |
| 8 | Building retrofits | 4 |
| 9 | Energy benchmarking | 3 |
| 10 | Biogas at wastewater treatment facilities | 1 |

The innovations were scored from one to ten on the 'pace within cities' indicator. The top five innovations include bike share, LED street lighting, pay-as-you-throw, stormwater charges, and green stormwater infrastructure. In the case of LED street lighting, pay-as-you-throw, and stormwater charges, the pace it takes an innovation to scale within a city goes hand and hand their success at scaling within the city. In the case of bike share and green stormwater infrastructure, however, there is no relationship between the length of time it takes a city to scale these innovations to reach maturity within a city and the success the innovation has had in scaling within cities. In contrast, biogas has done relatively well at scale within cities despite the longer time it has taken the innovation to achieve maturity.

## Regulatory needs:

| Rank | Regulatory needs | Score |
|---|---|---|
| 1 | Bike share | 5 |
| 2 | Biogas at wastewater treatment facilities | 5 |
| 3 | Green stormwater infrastructure | 5 |
| 4 | LED street lighting | 5 |
| 5 | Building retrofits | 5 |
| 6 | Cool roofs | 3 |
| 7 | Energy benchmarking | 3 |
| 8 | Pay-as-you-throw | 3 |
| 9 | Stormwater charges | 1 |
| 10 | Community solar | 1 |

The innovations were scored from one to five on the 'regulatory needs' indicator. Most of the innovations that were evaluated do not face significant regulatory hurdles. It is only community solar and stormwater charges for which a regulatory change presents a hurdle to adoption.

## Extent of private marketplace:

| Rank | Extent of private sector | Score |
|---|---|---|
| 1 | Bike share | 5 |
| 2 | Biogas at wastewater treatment facilities | 5 |
| 3 | Building retrofits | 5 |
| 4 | Community solar | 5 |
| 5 | LED street lighting | 5 |
| 6 | Cool roofs | 3 |
| 7 | Energy benchmarking | 3 |
| 8 | Pay-as-you-throw | 3 |
| 9 | Green stormwater infrastructure | 3 |
| 10 | Stormwater charges | 3 |

The innovations were scored from one to five on the extent of a private marketplace indicator. A sufficient private sector exists to assist with the adoption of any of the innovations under review or no private marketplace is needed for adoption.

## Scale across cities:

| Rank | Scale across cities | Score |
|---|---|---|
| 1 | Building retrofits | 9 |
| 2 | LED street lighting | 9 |
| 3 | Bike share | 8 |
| 4 | Biogas at wastewater treatment facilities | 7 |
| 5 | Stormwater charges | 7 |
| 6 | Green stormwater infrastructure | 6 |
| 7 | Cool roofs | 5 |
| 8 | Energy benchmarking | 5 |
| 9 | Pay-as-you-throw | 3 |
| 10 | Community solar | 1 |

The innovations were scored from one to ten on the 'scale across cities' indicator. Three innovations—building retrofits, LED street lighting and bike share—have been implemented in at least 80% of the cities under review. Despite extensive adoption across cities, bike share and building retrofits have not scaled well within cities. LED street lighting stands out as scaling well both across and within cities.

Only two innovations-- pay-as-you-throw and community solar—have lagged significantly behind. In the case of pay-as-you-throw, this low score results from defining the scope of cities under review. Pay-as-you-throw does well in smaller municipalities than in cities with a larger percentage of multi-family buildings. Regional differences hamper community solar. Community solar is dependent upon state virtual net metering laws which do not exist in every state. Like pay-as-you-throw, community solar has seen more widespread adoption in small municipalities with more open space to host solar installations.

## Pace across cities:

| Rank | Pace across cities | Score |
|---|---|---|
| 1 | Bike share | 10 |
| 2 | Energy benchmarking | 10 |
| 3 | Green stormwater infrastructure | 10 |
| 4 | Community solar | 6 |
| 5 | LED street lighting | 6 |
| 6 | Cool roofs | 3 |
| 7 | Building retrofits | 3 |
| 8 | Biogas at wastewater treatment facilities | 1 |
| 9 | Pay-as-you-throw | 1 |
| 10 | Stormwater charges | 1 |

The innovations were scored from one to ten on the 'pace within cities' indicator. Three innovations have experienced rapid growth over the last three years: bike share, energy benchmarking, and green stormwater infrastructure. It is interesting to note that despite this quick uptake in the last few years, these innovations have not succeeded in scaling extensively within cities. In the case of pay-as-you-throw, the pace of adoption across cities may be skewed by the scope of the research on large cities. Pay-as-you-throw experiences challenges in implementation in larger cities. Biogas at wastewater treatment facilities has experienced slow but steady growth over a longer time frame. In this case, slow pace of adoption across cities has not hampered its scale across cities because it has had many more years to achieve its scale across cities.

## Replicability:

| Rank | Replicability | Score |
|---|---|---|
| 1 | Cool roofs | 5 |
| 2 | Energy benchmarking | 5 |
| 3 | LED street lighting | 5 |
| 4 | Bike share | 3 |
| 5 | Biogas at wastewater treatment facilities | 3 |
| 6 | Green stormwater infrastructure | 3 |
| 7 | Pay-as-you-throw | 3 |
| 8 | Building retrofits | 3 |
| 9 | Stormwater charges | 3 |
| 10 | Community solar | 1 |

The innovations were scored from one to five on the 'replicability' indicator. Community solar is the only innovation for which replicability is a major barrier. Because state's vary according to how their electricity bills are metered, community solar programs must be customized for adoption.

## Level of federal and state support:

| Rank | Federal and State Support | Score |
|---|---|---|
| 1 | Biogas at wastewater treatment | 5 |
| 2 | Building retrofits | 5 |
| 3 | Energy benchmarking | 5 |
| 4 | Green stormwater infrastructure | 5 |
| 5 | LED street lighting | 5 |
| 6 | Bike share | 3 |
| 7 | Community solar | 3 |
| 8 | Cool roofs | 3 |
| 9 | Pay-as-you-throw | 3 |
| 10 | Stormwater charges | 3 |

The innovations were scored from one to five on the 'level of federal and state support' indicator. The existence of federal and state support is not enough to explain why an innovation has scaled well within or across cities. For example, building retrofits have scaled well across cities but the existence of federal and state funding has not spurred much uptake among residents within cities. For biogas, federal and state support has been important for scaling as it has covered some of the upfront capital costs of upgrades.

# Innovation Analysis

## Bike Share

### Innovation:

Bike share is defined as a non-motorized transportation program for point-to-point trips, the program provides bikes and bike-stations within a service area. Trips on average range from 0.5-3.0 miles[1]. It is a sustainability innovation as it provides a mode of transportation that does not contribute CO2e emissions. It aims to reduce congestion by providing an alternate means of transportation. It also allows cities to lower their carbon footprint along with giving citizens with health benefits of biking. Furthermore, it allows for a convenient transportation system for residents and tourists. [2]

### Scale within cities:

On average in US Cities, bicycle trips represent 1%[3] of all commuting to work trips. This statistic represents all bikes in in a city and is not specific to bike-share programs.

**Travel mode share to work by city in 2014:**

| Cities | Public Transport Use | Bikes | Walking | Carpool | Car-commute |
|---|---|---|---|---|---|
| New York | 32% | 1% | 6% | 7% | 49% |
| Chicago | 12% | 1% | 3% | 8% | 70% |
| San Diego | 4% | 1% | 3% | 9% | 75% |
| Washington DC | 16% | 1% | 4% | 10% | 64% |
| Boston | 13% | 1% | 6% | 7% | 67% |
| Minneapolis | 6% | 1% | 2% | 8% | 77% |
| Philadelphia | 10% | 1% | 4% | 8% | 72% |
| San Francisco | 18% | 2% | 5% | 10% | 57% |
| Indianapolis | 2% | 0% | 2% | 10% | 82% |

(Data taken from U.S. Census and The Transport Politic)[4]

[1] Bike Sharing in the United States: State of the Practice and Guide to Implementation. (2012, September). Retrieved November 2, 2017, from http://www.pedbikeinfo.org/pdf/Programs_Promote_bikeshareintheus.pdf
This source is provided by Daniel Goodman (FHWA). It contains the overall bike-share process and different examples.

[2] Lee , J. (2015, March 14). Why Cities are Supporting Bike Sharing Programs. Retrieved November 14, 2017, from https://www.triplepundit.com/special/business-of-biking/cities-supporting-bike-sharing-programs/

[3] Freemark, Y. (2016, September 01). Travel mode shares in the U.S. Retrieved October 19, 2017, from https://www.thetransportpolitic.com/databook/travel-mode-shares-in-the-u-s/
Data has been compiled using census ACS data for 2014. Table titled "Travel to work by city in 2014: 15 largest cities and all cities with more than 30,000 commuters" is used primarily.

## Pace of adoption within cities:

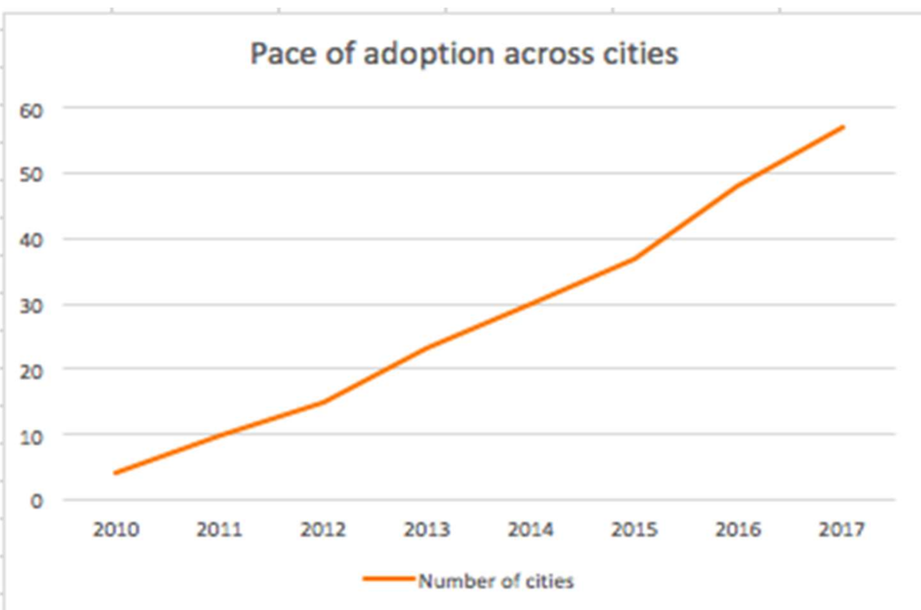
In order to analyze the pace of adoption within cities, number of stations at launch and at present will be researched and recorded. Following, a Compound Annual Growth Rate (CAGR) will be calculated for each of the cities and then averaged to observe the growth. Based on analysis using data from launch year number of station data and ytd number of station, the average pace of adoption is 20% (See Appendix).

## Scale across cities:

Currently there are over 119[5] cities in the United States with bike-share programs, however, only 58 cities out of the 83 cities under review have bike share programs. The percentage is 69.9%.

## Pace of adoption across cities:

There are 57 cities out of the 83 currently under review with a bike-share system. The graph below indicates the pace of adoption. The X-axis represents the year and the Y-axis the total number of cities with bike-share systems.




| | # of cities with innovation in 2014 | # of cities with Innovation in 2017 | Growth Rate |
|---|---|---|---|
| **Bike Share** | 29 | 58 | 100% |

[4] Freemark, Y. (2016, September 01). Travel mode shares in the U.S. Retrieved October 19, 2017, from https://www.thetransportpolitic.com/databook/travel-mode-shares-in-the-u-s/
Data has been compiled using census ACS data for 2014. Table titled "Travel to work by city in 2014: 15 largest cities and all cities with more than 30,000 commuters" is used primarily.

## Regulatory needs:

Bike-share does not require any changes in regulation or legislation to allow for its adoption. Bike-share is driven by public-private partnerships, so some government support is necessary.

## Extent of private marketplace:

There are private partnerships in place to support the innovation. There are private companies that provide bikes, docks, and the technology to support the innovation. An example is Motivate, which partners with governments and brands assisting with the planning, launching, all the way to the actual managing. Motivate operates in over 66%[6] of the U.S. bike share fleet. A recent innovation is dock-less bike share which poses as an uprising competition and is in the process of being launched. It has recently (2017) been launched in Washington D.C.[7] and is in its early stages.

## Replicability:

This innovation is difficult to replicate given the intricacy of the bike-share model in terms of financial and infrastructure. Expense is a barrier to adoption as implementing a bike-share service can cost up to $5,000 per bike for capital and $100-$200 operating expense per year[8]. Without public-private partnership bearing expenses, bike-share is difficult to implement. Even though there are many cities with a bike-share program, in terms of concept it is not out-of-box, but in terms of implementation it can be considered as out-of-box. For instance, the physical infrastructure to implement the bike-share stations is a concerning factor that requires capital investment and tailoring to each city's geography, culture and needs. Another challenge for implementation is determining ownership while establishing a public-private partnership.

## Level of federal or state support:

There are several ways[9] for the innovation to funded as listed below:

- Federal and local grants
- Donations
- Sponsorships
- Private Investment

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[6] Motivate: What We Do. (n.d.). Retrieved October 15, 2017, from https://www.motivateco.com/what-we-do/
The company website includes data on fleet ownership and operations

[7] FTA Program & Bicycle Related Funding Opportunities. (2016, March 16). Retrieved November 02, 2017, from https://www.transit.dot.gov/regulations-and-guidance/environmental-programs/livable-sustainable-communities/fta-program-bicycle

[8] DeMaio, P. (2011, February 15). Five Things Every Mayor Should Know Before Starting a Bike Sharing Program. Retrieved October 20, 2017, from https://www.shareable.net/blog/five-things-every-mayor-should-know-before-starting-a-bike-sharing-program
This article includes an estimate for the cost of bike-share program implementation

[9] Funding. (n.d.). Retrieved October 21, 2017, from http://bikeshare.com/marketplace/funding/
Bikeshare.com was created by Cyclehop, LLC, a bike share consulting and operations company, for the purpose of connecting and developing the bike share industry.

- User fees and advertising

Through a conversation with Daniel Goodman at The Federal Highway Administration (FHWA), the following information was gathered. According to the Department of Transportation, multiple Federal Transit Administration grant programs are able to help cities, towns and rural areas invest in bicycle infrastructure, which improves personal mobility and helps more people access public transportation. FHWA also provides funding for bicycling (including bike share programs). [10] There are 9 different federal programs, specifically for bike share, that are available for cities to apply to. These programs are very competitive and do not guarantee funding. [11]

In terms of technical support, there is a guide published by D.O.T and FHWA outlining the various steps in planning and implementing a bike-share system. This is to the extent of technical support provided.

[10] FTA Program & Bicycle Related Funding Opportunities. (2016, March 16). Retrieved November 04, 2017, from https://www.transit.dot.gov/regulations-and-guidance/environmental-programs/livable-sustainable-communities/fta-program-bicycle

[11] Pedestrian and Bicycle Funding Opportunities U.S. Department of Transportation Transit, Highway, and Safety Funds. (2016, August 12). Retrieved November 2, 2017, from https://www.fhwa.dot.gov/environment/bicycle_pedestrian/funding/funding_opportunities.pdf
This link was provided by Daniel Goodman who works at Federal Highway Administration. It includes a list of programs available

# Biogas Energy from Anaerobic Digestion at Wastewater Treatment Plants

## Innovation:

Anaerobic digestion is the process by which microorganisms break down organic waste and produce biogas in the form of methane. Biogas can be harnessed to power vehicles, produce electricity, or provide heat. At wastewater treatment facilities, biogas is applied to power the plant while also providing heat for the anaerobic digestion process.[12] Additional biogas can be used to produce excess electricity that can be sold back to the grid. Biogas can also be fed into a natural gas system but it must first be purified. A current trend is for wastewater facilities to move towards co-digestion, mixing food waste with biosolids to boost biogas production. Co-digestion can utilize extra capacity at a wastewater facility while diverting organic matter from landfills.

## Extent of scale within cities:

For the eight cities investigated in-depth, 100% of the city's wastewater is treated by a biogas-enabled facility. In addition, biogas use covers at least 50% of its facility's energy needs. Four of these cities have reached net-zero energy. In three of these cities, this was done with the addition of organic material to the feedstock at the wastewater treatment plant. Using the percentage of energy needs provided by biogas, the average scale within these cities is 84%.

## Pace of adoption within cities:

Biogas production within each of the eight cities went through several stages of scaling. All started with anaerobic digestion at a wastewater treatment plant. Most of these facilities engaged in early use of biogas to run a portion of the treatment facility's needs (prior to 2000). Biogas production was increased through upgrades or inclusion of organic material. For those facilities which have reached net zero energy, initial upgrades are done in about four years; net zero energy is reached as feedstock is boosted. This takes between seven to ten years.

| Cities | % of city wastewater treated by biogas enabled facilities | % of facility's energy | Co-digestion | Stages of adoption |
|---|---|---|---|---|
| Oakland, CA | 100% | 100% | Yes | 1985: Biogas in use.<br>2002: co-digestion.<br>2012: net zero. |

[12] EPA. (October 2011). Combined Heat and Power Partnership: Opportunities for Combined Heat and Power at Wastewater Treatment Facilities: Market Analysis and Lessons from the Field. Retrieved from https://www.epa.gov/chp/opportunities-combined-heat-and-power-wastewater-treatment-facilities-market-analysis-and

| | | | | |
|---|---|---|---|---|
| | | | | Sells excess electricity to the grid. |
| San Diego, CA | 100% | 100% | No | 1996: biogas in use.<br>1998: constructed Metro Biosolids Center, co-located with landfill<br>Sells excess electricity to the grid. |
| Stockton, CA | 100% | 100% | No | Legacy biogas use.<br>2004: upgraded facility<br>Currently covers energy needs of facility. |
| Chicago, IL | 100% | 100% | Yes | Legacy biogas use.<br>2015: added organics to feedstock.<br>2017: reached net zero. |
| San Jose, CA | 100% | 75% | No | Legacy biogas use.<br>2013: opened stand-alone facility co-located with wastewater treatment plant. |
| Fresno, CA | 100% | 75% | No | Legacy biogas use since 1970s.<br>2004: upgraded facility |
| Albuquerque, NM | 100% | 70% | No | 1986: biogas in use.<br>1994: plant upgrades |
| Fort Worth, TX | 100% | >50% | Yes | Early 1960s: biogas use.<br>2001: reached 50% energy covered.<br>2008: stated goal of moving towards net zero. |

## Regulatory needs:

Biogas energy derived from anaerobic digestion does not need any change in regulation to allow for production of biogas at a wastewater treatment facility. Motivation for adopting anaerobic digesters, upgrading existing digesters for biogas production, or co-digestion at wastewater facilities increases in states with renewable energy standards or in cities with waste reduction goals aimed to divert organic matter from landfills.[13]

## Scale across cities:

Of the 83 cities under review, 54 cities have anaerobic digesters facilities producing biogas. This is 65% of the cities under review.[14] It is worth noting that many cities deploying anaerobic digesters fall below the population cut-off for the scope of this project. The prevalence of biogas use at wastewater treatment

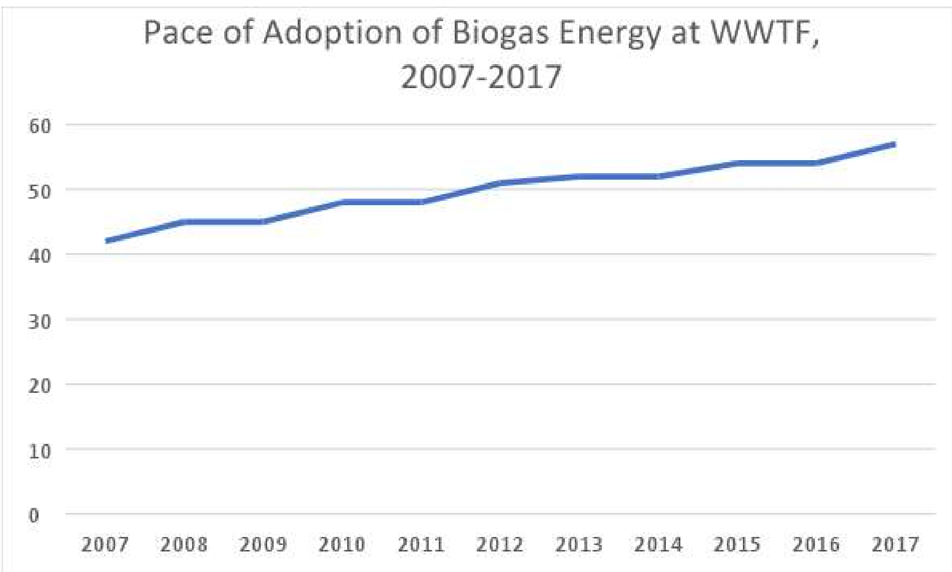
[13] Fitzgerald, Lily.(2013) *Anaerobic Digestion of Food Waste in New England Summer 2013 Report.* Retrieved from http://www.ct.gov/deep/lib/deep/compost/compost_pdf/ad_of_food_waste_in_new_england.pdf

[14] See the accompanying excel spreadsheet. This is consistent with the national statistic provided by the American Biogas Council: 68% of wastewater treatment plants using anaerobic digestion also produce biogas. American Biogas Council. (2017) *What Is a Biogas System?* Retrieved from https://www.americanbiogascouncil.org/pdf/ABC%20Biogas%20101%20Handout%20NEW.pdf

facilities across cities of varying size indicates the appropriateness of the technology independent of population levels.

## Pace of adoption across cities:

Pace of adoption across the country can be characterized as steady growth. Since anaerobic digestion is a common feature of wastewater facilities, there have always been some facilities utilizing biogas to produce energy to run their facility. Since 2000, an increasing number of facilities have upgraded to allow greater utilization of biogas. Wastewater treatment plants might upgrade to a combined heat and power system to take advantage of biogas already being produced from anaerobic digestion or increase the amount of biogas produced through addition of organic matter to the feedstock. Oakland is a leader in this, starting co-digestion in 2002.




| | # of cities with innovation in 2014 | # of cities with Innovation in 2017 | Growth Rate |
|---|---|---|---|
| **Biogas Energy** | 52 | 57 | 10% |

## Extent of private marketplace:

There is an extensive private marketplace of contractors and private companies to build new systems or to provide technical enhancements to support improved biogas production. Anaerobic digestion also enjoys robust support from industry advocacy groups including the American Biogas Council (ABC), the Water Environment Research Foundation (WERF), National Association for Clean Water Agencies, Water Environment Foundation (WEF), and the Air and Waste Management Association (A&WMA).

## Replicability:

Biogas energy production from anaerobic digestion is a well-known technology. The EPA has identified combined heat and power additions to anaerobic digestion as reliable and cost-effective.[15] While upgrading a wastewater treatment plant does require capital upfront for planning and construction, multiple funding options are available. The cost of operating the facility is partially offset by production of biogas and the sale of land application material. The cost of generating electricity is below the typical retail rates making it a cost-effective option.[16] The wastewater treatment facility serving Seattle, Washington, described biogas as "our most cost-effective and reliable energy source."[17]

## Level of federal and state support:

Funding sources exist at both the federal and state level to support the construction or upgrade of wastewater treatment facilities. Support can come from federal or state clean water funds, EPA methane programs, biofuel programs, and green bonds to support renewable energy efforts. The EPA maintains a combined heat and power funding database listing state and federal funding options.[18]

Biogas burned for electricity and fed into the grid as well as biogas purified and fed into natural gas lines are both considered renewable energy and accepted under Renewable Portfolio Standards and other state and city green power programs. Biogas-producing facilities can benefit from the sale of Renewable Energy Credits (RECs) and carbon offsets.[19]

The EPA also provides feasibility analysis and technical support for wastewater treatment facilities looking to upgrade digesters for combined heat and power capabilities.[20] Through the Methane to Market program, the EPA offers project development support and market development both domestically and with partner countries.[21] In order to encourage food waste digestion, the EPA also provides a mapping tool connecting food waste producers with facilities that co-digest.[22]

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[15] EPA. (October 2011). *U.S. Environmental Protection Agency Combined Heat and Power Partnership.* Retrieved from https://www.epa.gov/sites/production/files/2015-07/documents/opportunities_for_combined_heat_and_power_at_wastewater_treatment_facilities_market_analysis_and_lessons_from_the_field.pdf

[16] EPA. (October 2011). *Combined Heat and Power Partnership: Opportunities for Combined Heat and Power at Wastewater Treatment Facilities: Market Analysis and Lessons from the Field*. Retrieved from https://www.epa.gov/chp/opportunities-combined-heat-and-power-wastewater-treatment-facilities-market-analysis-and

[17] King Count. Washington State. (2017). *Energy Use: Factors Driving Energy Use and Costs.* Retrieved from http://www.kingcounty.gov/services/environment/wastewater/resource-recovery/Energy/energy-use/factors.aspx

[18] See database located at https://www.epa.gov/chp/dchpp-chp-policies-and-incentives-database

[19] EPA. (May 2012). *Technology Market Summit: Study Primer for Participation Discussion, Biodigesters and Biogas.* Retrieved from https://www.americanbiogascouncil.org/pdf/biogas_primer_EPA.pdf

[20] EPA. (October 2011). *U.S. Environmental Protection Agency Combined Heat and Power Partnership.* Retrieved from https://www.epa.gov/sites/production/files/2015-07/documents/opportunities_for_combined_heat_and_power_at_wastewater_treatment_facilities_market_analysis_and_lessons_from_the_field.pdf

[21] EPA. (November 2010). *U.S. Governments Methane to Markets Partnership Accomplishments Fifth Annual Report.* Retrieved from https://www.epa.gov/sites/production/files/2016-01/documents/usg_2010_accomplishments.pdf

[22] EPA. Pacific Southwest, Region 9. (2017) *Waste to Biogas Mapping Tool*. Retrieved from https://www3.epa.gov/region9/biogas/purpose.html

# Building Retrofits

## Innovation:

Building energy consumption accounts for almost 40% of the total US energy consumption[23] and hence there is a dire need to reduce energy consumption in buildings. Retrofits are upgrades made to the existing building components to reduce energy consumption. Retrofits are usually lighting fixtures, HVAC system upgrades, window fixtures and envelope insulation. City governments are realizing the significant energy reduction opportunities that come with retrofits and have introduced and are introducing retrofit programs that provide incentives to homeowners/building owners. This innovation was analyzed by researching all the existing retrofit programs and energy efficiency programs in place in all the top 83 US cities.

## Scale within cities:

To determine the scale of the innovation the number of buildings or the total square footage area covered in the retrofit program was divided to the total number of buildings in city. On an average 3% of the total buildings have been retrofitted. This does not include single family homes as most city government website do not adequately disclose this data.[24]
Example:

| | |
|---|---|
| Chicago retrofitted 72 buildings | Total number of buildings are 3,296 |
| Houston retrofitted 271 buildings | Total number of buildings are 3,505 |
| New York retrofitted 190 buildings | Total number of buildings in NYC are 727,565 |
| Los Angeles Has retrofitted 10 buildings | Total number of buildings in LA are 1,961 |
| Seattle retrofitted 19 buildings | Total number of buildings are 847 |

## Pace of adoption within cities:

The pace of adoption within cities was determined by the number of buildings or square footage area it covered since the retrofit program has been in place. Example: For Chicago the pace of adoption of the retrofit program was:

| | |
|---|---|
| June 2012 | 14 buildings participating |
| March 2013 | 32 buildings retrofitted in total |
| June 2014 | 48 buildings retrofitted in total |
| July 2016 | 60 buildings retrofitted |
| April 2017 | 72 buildings retrofitted in total |

[23] US Energy Information Administration. Frequently asked questions. Retrieved from https://www.eia.gov/tools/faqs/faq.php?id=86&t=1. Accessed Dec 1 2017

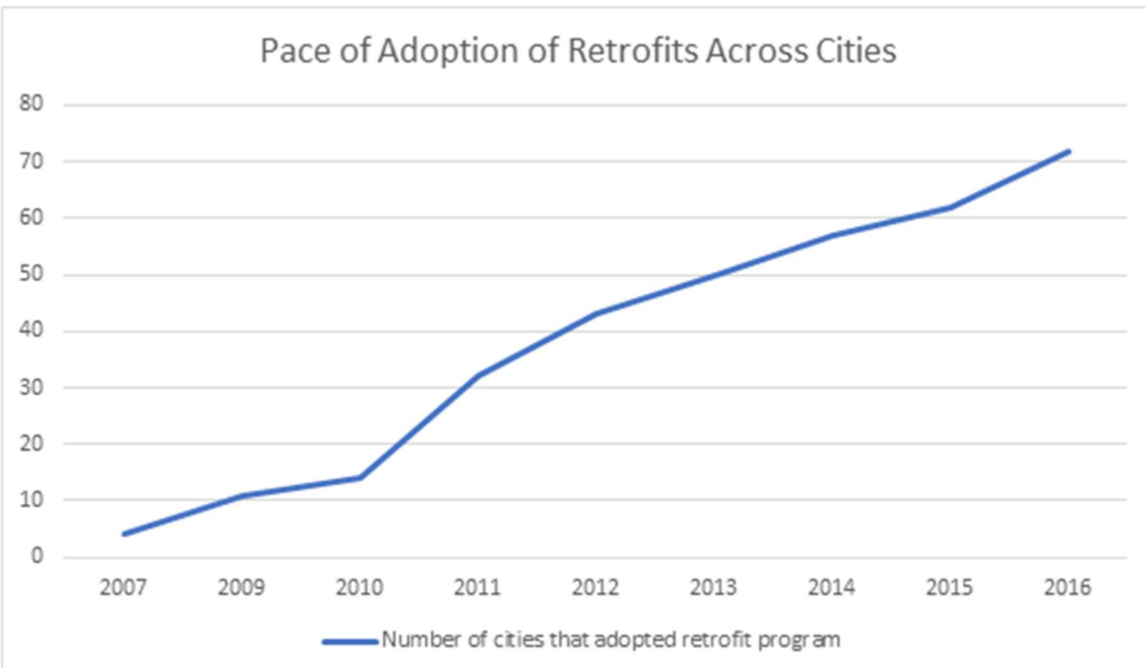
[24] City of Chicago (2017).*Office of Mayor,City of Chicago*.Retrived from https://www.cityofchicago.org/content/dam/city/depts/mayor/Press%20Room/Press%20Releases/2017/April/041417_Retrofit50MSF.pdf
American council of energy efficient economy.New York.Retrieved from https://database.aceee.org/city/new-york-city-ny.
C40Cities. (2014). *Houston Building Retrofit Program*.Retrived from http://www.c40.org/case_studies/houston-building-retrofit-program-tranche-2-results.Accessed October 2 2017.Emporis. *Houston*. Retrieved from https://www.emporis.com/city/101031/houston-tx-usa.Accessed October 31 2017

## Scale across cities:

Almost 89% of the cities (74/83) have adopted retrofit programs in one form or the other either as energy efficiency programs on lighting retrofits, HVAC system upgrades etc.[25]

## Pace of adoption across cities:

Some of the most successful retrofit programs started in 2007 but on an average most successful retrofit programs started around 2011.Most cities take around 1-2 years to reach around 2 million square footage coverage in retrofits.




| | # of cities with innovation in 2014 | # of cities with Innovation in 2017 | Growth Rate |
|---|---|---|---|
| **Retrofits** | 57 | 74 | 30% |

## Regulatory needs:

25 Google sheets.Retrofit.Capstone 3 folder.

Regulatory changes are not required to adopt retrofit programs but a regulatory change will drive retrofit program implementation at a greater pace as most homeowners do not make use of the city's retrofit program initiatives to retrofit their home either because they are not aware of the long term benefits of retrofits or do not want to pay out of pocket to retrofit their homes.

## Extent of private marketplace:

Many private contractors offer energy retrofit financing and retrofitting services. Example: The PACE Commercial Consortium, spearheaded by the Carbon War Room and backed by Lockheed Martin, Barclays Capital, and Ygrene Energy Fund, announced, in September 2011, its intent to fund $550 million worth of energy retrofits in Miami-Dade County, Florida, and $100 million more in Sacramento, California. (Gerdes, n.d.)There are several private contractors in various cities that offer retrofit services.[26]

## Replicability:

The innovation will be slightly difficult to replicate given that a retrofit program needs good funding and technical support to implement retrofit programs in cities.

## Level of federal or state support:

The innovation does enjoy federal and state support mostly in the form of grants. Many states allot a budget for energy efficiency measures in their annual budget. Example : Chicago received $25 million of federal support for its Chicago ramp up retrofit program from the US Department of Energy. Austin received $10 million of federal grant for its retrofit program from the Department of Energy for its Austin Climate Retrofit Program. Cincinnati received 17 million for its Greater Cincinnati Retrofit Ramp-up program.[27] Technical assistance in form of free or subsidized energy audits or energy advisory services are available. Example: The NYC Retrofit Accelerator offers free, personalized advisory services that streamline the process of making energy efficiency improvements to buildings that will reduce operating costs, enhance tenant comfort, and improve the environment.[28]

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[26] Renew Energy Partners. *About.* http://renewep.com.Accessed October 12 2017.
We manage properties.Energy retrofits. Retrieved from http://www.wemanageproperties.com/energy-retrofits/

[27] U.S.Department of Energy. *Retrofit Ramp-up selected projects*.Retrived from https://energy.gov/sites/prod/files/edg/media/Retrofit_Ramp-Up_Project_List.pdf Accessed October 20 2017.

[28] New York City retrofit Accelarator. Frequently asked questions.Retrieved from https://retrofitaccelerator.cityofnewyork.us/faqs. Accessed November 30 2017

# Community Solar

## Innovation:

A program consisting of power generating photovoltaic panels that is either owned by a community or a third-party and provides shared electricity to a community is referred to as community solar. The main aim of community solar to allow multi-family units and homeowners without enough rooftop space to host solar panels to share the benefit of solar power.

Participants in the program subscribe to a fixed amount of MW from the installation and pay a different price for it per KW than they would to the utility for the same amount of power coming from the grid.[29] Community solar limits the maximum MW subscription per house for each installation with the aim of evenly distributing the sustainability benefits of renewable energy across all levels of society in the country. For this analysis, community solar is only defined as Photovoltaic (PV) Systems that allocate electricity from a jointly owned or a third party owned system to offset electricity consumption by individual businesses and residences. [30]

## Scale within cities:

Community solar provides not only provides access to renewable energy but also a unique set of benefits in the form of market opportunities and economies of scale. From the 83 cities under review, Tucson and Sacramento are the frontrunners in implementation of community solar with Sacramento getting 75%[31] of its total PV energy from community solar. Lead cities were determined by finding the major community solar projects in the country and the utilities they were served by.

Community Solar Table 1 shows the scaling of community solar in cities under review.

| **City** | **Utility** | **MW** | **Total Solar MW** | **% of installed Solar in the city** | **Phase** |
|---|---|---|---|---|---|
| New York | ConEdison | 3.00 | 33 | 9.09% | Development |
| Denver | Xcel | 4.00 | 25 | 16.00% | Expansion |
| Tucson | Tuscon Electric | 22.3 | 254 | 8.78% | Mature |
| Sacramento | SUD | 12.0 | 16 | 75.00% | Mature |

[29] Feldman, David, et al. *Shared Solar: Current Landscape, Market Potential, and the Impact of Federal Securities Regulation*. National Renewable Energy Laboratory, Apr. 2015, www.nrel.gov/docs/fy15osti/63892.pdf.

[30] Feldman, David, et al. *Shared Solar: Current Landscape, Market Potential, and the Impact of Federal Securities Regulation*. National Renewable Energy Laboratory, Apr. 2015, www.nrel.gov/docs/fy15osti/63892.pdf

[31] Carey, B., Gerstel, D., & Jang, S. (2017, April). Community solar Share the sun rooflessly. Retrieved September, 2017, from https://www.strategyand.pwc.com/media/file/Community-solar.pdf

| | | | | | |
|---|---|---|---|---|---|
| Colorado Springs | CSU | 4.8 | Not Found | NA | Mature |
| Minneapolis | Xcel | 2.05 | 447 | 0.46% | Development |
| Saint Paul | Xcel | 1.30 | 8 | 16.25% | Development |
| Buffalo | NRG | 0.86 | 3 | 28.67% | Pilot |

## Pace of adoption within cities:

On average, community solar projects take 2 years from adoption to completion.[32] Full subscription for the program varies with the size and accessibility of the solar panels. Detailed data on the scale and timing of individual projects is not available through the utilities websites or on research reports since most cities have small-scale projects near by and have multiple stakeholders involved therefore utilities cannot provide the required data. For analysis, Sacramento has been used as an example. The city started its Bright Tucson Community Solar Program in 2011 with a 1.6MW capacity and then after its success, it scaled up to 22.3 MW in 2017, making it one of the most robust community solar programs in the country. These attributes of the Sacramento program along with small period required for adoption to completion of community solar programs, the innovation scores high for this indicator. [33] [34]

## Scale across cities:

8 out of 83 cities have adopted the innovation. 9.63%

The percentage of cities adopting community solar within the scope of this project is low at this stage because our analysis involves cities with a population of 200, 000 or higher. Most current community solar projects are located in smaller towns with open fields in order to facilitate the installation of large solar arrays. The number of cities are expected increase in the coming years with subscription from nearby cities for the current projects and legislation in states such as Colorado, California and Minnesota mandating utilities to have community solar incorporated within their distribution system.

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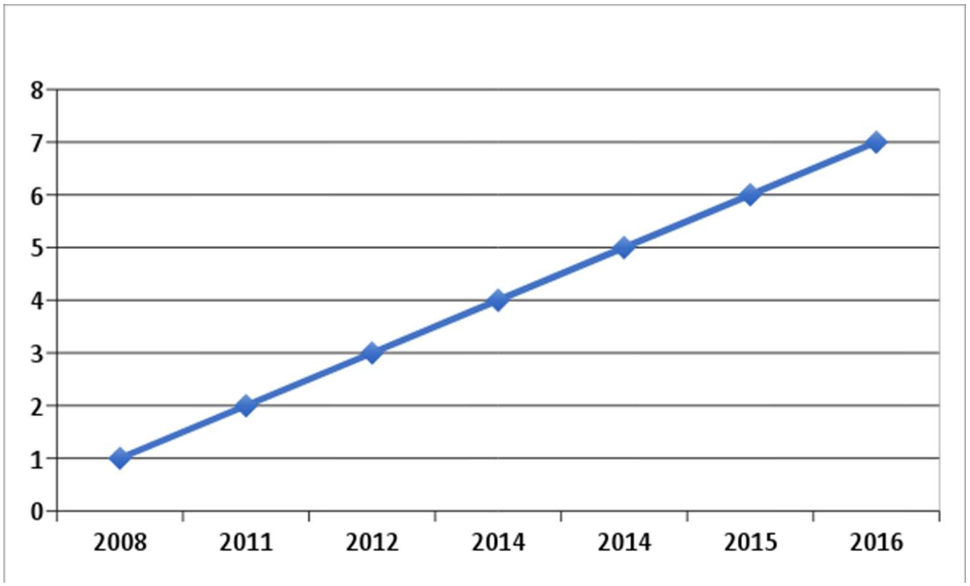
[32] Solar Rewards Community. (n.d.). Retrieved November 15, 2017, from https://www.xcelenergy.com/programs_and_rebates/residential_programs_and_rebates/renewable_energy_options_residential/solar/available_solar_options/community-based_solar

[33] Challenges and Successes on the Path toward a Solar-Powered Community. (2011, Oct. & nov.). Retrieved from https://www.nrel.gov/docs/fy12osti/51057.pdf

[34] Feldman, David, et al. *Shared Solar: Current Landscape, Market Potential, and the Impact of Federal Securities Regulation*. National Renewable Energy Laboratory, Apr. 2015, www.nrel.gov/docs/fy15osti/63892.pdf.

## Pace of adoption across cities:

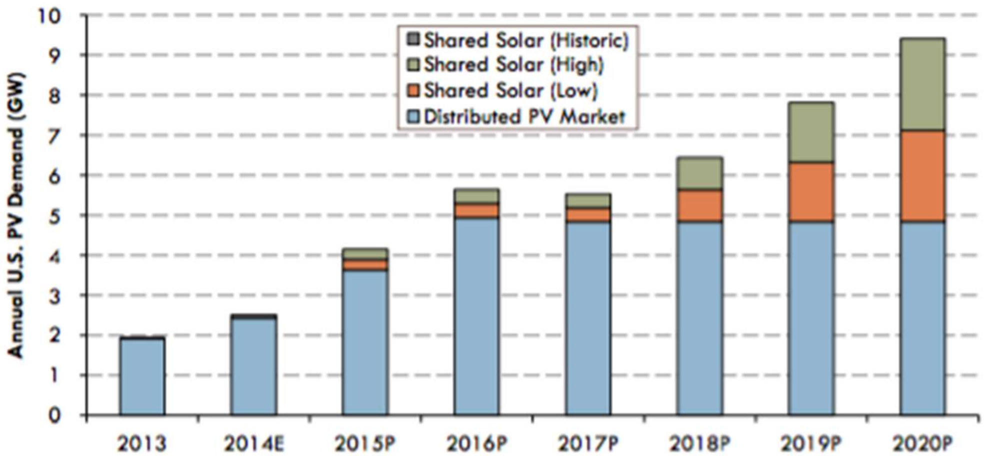



Community Solar Figure 1: Starting Years of Community Solar Programs Year vs. No. of Cities

| | # of cities with innovation in 2014 | # of cities with Innovation in 2017 | Growth Rate |
|---|---|---|---|
| **Community Solar** | 5 | 8 | 60% |

Community solar began in 2006 in Ellensburg WA and the market capacity ever since has increased 2500 times over 180 projects throughout the U.S.[35] Table 2 shows that for the cities within the scope of this report, community solar started off in Sacramento in 2008 and has since expanded across Tucson, Colorado Springs and the rest of the cities mentioned above. This shows that the innovation is within its nascent stage of development (less than 10 years for cities under evaluation) and is expected to escalate across the U.S. in the coming five years as analyzed below.

[35] Carey, B., Gerstel, D., & Jang, S. (2017, April). Community solar Share the sun rooflessly. Retrieved September, 2017, from https://www.strategyand.pwc.com/media/file/Community-solar.pdf




Community Solar Figure 2: Estimated PV market potential of onsite and community solar in the U.S. [36]

Since community solar is in its early stages of development, it is important to analyze the forecasted increase in its adoption throughout the U.S. According to NREL, 49% of households and 48% of business do not have space to host a solar panel on their rooftops which will assist in the expansion of community solar.[37] Figure 2 shows the expected increase in the number of community solar projects in the coming 3 years, NREL estimates that by expanding the market to the above mentioned customers, community solar could represent 32%–49% of the distributed solar market in 2020, thus leading to a growth in the total solar deployment from 2015–2020 by 5.5–11.0 GW and representing $8.2–$16.3 billion of cumulative investment.[38] The estimates by the NREL take into account the over calculation of multifamily buildings that could potentially deploy single PV systems and the scalability of community solar assisted by added competition and reduction in upfront capital cost.[39]

## Regulatory needs:

The energy sector is dependent on utilities for distribution which are regulated at a state level, hence, community solar developers must take into account a large number of state specific regulatory regimes before implementing a project. Various states have adopted comprehensive shared energy program legislation such as virtual net metering (VNM) to support and guide community solar programs. Virtual net metering enables a customer to virtually get electricity credits from off-site electricity generating installations. In order to execute such an initiative, legislation from the state regarding subscription limits, utility mandates, and virtual net metering caps and credits is required.[40]

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[36] Carey, B., Gerstel, D., & Jang, S. (2017, April). Community solar Share the sun rooflessly. Retrieved September, 2017, from https://www.strategyand.pwc.com/media/file/Community-solar.pdf

[37] Feldman, David, et al. *Shared Solar: Current Landscape, Market Potential, and the Impact of Federal Securities Regulation*. National Renewable Energy Laboratory, Apr. 2015, www.nrel.gov/docs/fy15osti/63892.pdf.

[38] NY-Sun. (n.d.). Retrieved November 15, 2017, from https://www.nyserda.ny.gov/All-Programs/Programs/NY-Sun/Customers/Solar-Options/Community-Solar

[39] Feldman, David, et al. *Shared Solar: Current Landscape, Market Potential, and the Impact of Federal Securities Regulation*. National Renewable Energy Laboratory, Apr. 2015, www.nrel.gov/docs/fy15osti/63892.pdf.

[40] Carey, B., Gerstel, D., & Jang, S. (2017, April). Community solar Share the sun rooflessly. Retrieved September, 2017, from https://www.strategyand.pwc.com/media/file/Community-solar.pdf

As of early 2017, at least 21 states had adopted or proposed legislation providing mandates for both virtual net metering and shared energy programs which played an important role in spurring the growth of community solar in cities such as Denver, Minneapolis, Sacramento and New York.[41]

## Extent of private marketplace:

According to PwC, at least 110 utilities across the country have partnered with program administrators and private developers to offer community solar programs. Major utilities in Minnesota, Massachusetts, and Arizona represent nearly 67 percent of the total community solar capacity in the country with Xcel Energy leading the marketplace with approximately 96MW in community solar projects.[42] [43] Apart from Xcel, the following solar developers are currently leading the market: NRG, Sunshare, Blackhills Energy, NREL, Posada, Vote Solar GRID Alternatives, Solar City.[44]

## Replicability:

The innovation can be easily replicated in cities which are in states with existing virtual net metering policies: California, Colorado, Delaware, Illinois, Maine, Maryland, Massachusetts, New York, Oregon, Pennsylvania, Rhode Island, Utah, Vermont, Washington, West Virginia.

Since community solar is in its nascent stage, further work on legislation and an understanding of variation in state securities laws with jurisdiction would assist in lowering the barriers to the adoption of the innovation and escalating its impact and total share in Photovoltaic Solar across the U.S. [45]

## Level of federal or state support*:*

The innovation enjoys state support in the form of Renewable Energy Credits and Federal Support in the form of Investment Tax Credits which apply to all photovoltaic (PV) projects. Community Solar installations qualify for a 30% rebate of installation costs for a tax paying owner which can assist in an immediate payback and incentive for the innovation. Analysis of reports done by NREL reveals that since community solar is a region centric innovation, legislation required to ease its integration in the form of virtual net metering laws and bill credit mechanisms are contingent on state level legislation and not city level regulations. [46]

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[41] Carey, B., Gerstel, D., & Jang, S. (2017, April). Community solar Share the sun rooflessly. Retrieved September, 2017, from https://www.strategyand.pwc.com/media/file/Community-solar.pdf

[42] Carey, B., Gerstel, D., & Jang, S. (2017, April). Community solar Share the sun rooflessly. Retrieved September, 2017, from https://www.strategyand.pwc.com/media/file/Community-solar.pdf

[43] Hannah, L. (2016, December 21). A Checkup on Xcel's 2-Year-Old Community Solar Program. Retrieved November 15, 2017, from https://www.greentechmedia.com/articles/read/xcels-community-solar-program-turns-two

[44] 'The 4 Ps of Community Solar. (n.d.). Retrieved October 15, 2017, from https://3degreesinc.com/wp-content/uploads/2016/02/3Degrees_4PsCommSolar_WhitePaper_Aug2015.pdf

[45] Feldman, David, et al. *Shared Solar: Current Landscape, Market Potential, and the Impact of Federal Securities Regulation*. National Renewable Energy Laboratory, Apr. 2015, www.nrel.gov/docs/fy15osti/63892.pdf.

[46] Feldman, David, et al. *Shared Solar: Current Landscape, Market Potential, and the Impact of Federal Securities Regulation*. National Renewable Energy Laboratory, Apr. 2015, www.nrel.gov/docs/fy15osti/63892.pdf.

Examples of state level legislation include:

- Minnesota: The Solar Energy Jobs Act: The act requires the state's largest utilities to submit proposals for including a community solar program of 1MW or less within their generation capacity. Each program is required to have a minimum of 5 customers at the utility retail rate with an option for an alternative solar or renewable energy rate.[47]
- Colorado: The Community Solar Gardens Act: The legislation requires community solar programs to have a capacity of 2MW or less, a minimum of 10 customers, and subscriptions capped at 120% of a customer's average annual electricity demand. It also requires all billing credits to be the same as retail rates, unless there is a justifiable fee for electricity transmission, integration, and program administration.[48]
- California: The Green Tariff Shared Renewables Program: The program requires the state to install 600 MW of community solar by 2019, which is expected to immensely impact the national size of the community solar market. The aim is to enable renewable energy access to residents currently unable to host onsite PV generation. [49][50]

[47] Haugen, D. (2014, March 13). Minnesota's new solar law: Looking beyond percentages. Retrieved November 10, 2017, from http://midwestenergynews.com/2013/05/24/minnesotas-new-solar-law-looking-beyond-percentages/

[48] Colorado Community Solar Gardens Act «. (n.d.). Retrieved October 15, 2017, from http://www.solargardens.org/legislation-news-2/colorado-community-solar-gardens-act/

[49] 'Community Solar in California', *Centre for Sustainable Energy*, June 2015

[50] Norm, Kim, and Rob Sargent. "How Smart Local Policies Are Expanding Solar Power in America." *Shining Cities 2016*, Apr. 2016, environmentamerica.org/sites/environment/files/reports/EA_shiningcities2016_scrn.pdf.

# Cool Roofs

## Innovation:

A cool roof is a roof or roofing system that is designed to reflect sunlight and reduce its heat absorption. A cool roof can be made up of any type of reflective paint, tiles, sheet coverings, or shingles. [51]

A cool roof benefits both the urban landscape and environment by reducing local air temperatures, and reducing cooling energy use in buildings. By reducing a building's energy usage, cool roofs also work to reduce peak electricity demands, and power plant emissions.[52]

## Scale within cities:

Cool roof programs are typically implemented within cities as part of an amendment to Building Code requirements, an Energy Code Requirement, or a mandatory policy. Once the innovation has been implemented, impacting all new and remodeled construction, it is considered fully scaled .[53] Lead cities were chosen depending on the amount of data available, if that city had a city-specific Cool Roof Policy (as opposed to a State level requirement, only), and whether that city or region offers incentives for adoption (example: rebate programs).

## Pace of adoption within cities:

The pace of adoption has been defined as how many years a program has been in place, and how many roofs have been coated within that timeframe.

| City | Regulation | Installed Cool Roofs | Total Cool Roofs | Implementation Year |
|---|---|---|---|---|
| New York City[54] | NYC CoolRoofs Program aims to coat 1 million square feet of rooftop annually, with a goal of 10 million square feet covered. | 5.7 Million SF | 10 Million SF | 2009 |
| Los Angeles[55] | LA Green Building Code requires roofing material on all residential buildings to meet minimum values for 3-year aged solar | | | 2014 |

[51] Cool Roofs. (n.d.). Retrieved October 23, 2017, from https://energy.gov/energysaver/energy-efficient-home-design/cool-roofs

[52] Cool Roofs. (n.d.). Retrieved October 23, 2017, from https://energy.gov/energysaver/energy-efficient-home-design/cool-roofs

[53] Cool Roof Rating Council Resources. (2017, September 26). Retrieved October 23, 2017, from http://coolroofs.org/resources/rebates-and-codes

[54] Furman, A. (2015, January 14). NYC CoolRoofs. Retrieved October 23, 2017, from http://www.c40.org/case_studies/nyc-coolroofs

[55] California's Title 24 For Low-Slope Roofs. (2017, March). Retrieved from https://www.gaf.com/Other_Documents/Green_Roof_Central/GAF_Title_24_Handbook_Low_Slope.pdf

| | | | | |
|---|---|---|---|---|
| | reflectance and thermal emittance.[56] State program Title 24 (2005) requires cool roofs (new construction, additions, or reroofing) on applicable non-residential low-slope buildings. | | | |
| Chicago[57] | Chicago Energy Conservation Code: Section 18-13--101.5.4.1 through 18-13-101.5.4.3 of the Chicago Energy Conservation Code requires cool roofs on all low and medium pitched roofs. | | | 2016 |
| Houston[58] | Houston Commercial Energy Conservation Code: The 2015 Houston Commercial Energy Conservation Code contains mandatory cool roofing provisions for new commercial buildings and alterations to existing commercial buildings. The provisions of this code do not apply to single-family houses, multi-family structures of three stories or fewer above grade, and manufactured houses. | | | 2016 |
| Philadelphia[59] | Philadelphia cool-roof Law: Law mandating energy-efficient reflective roofs or green roofs on all new commercial and residential buildings with no or low slopes. | | | 2010 |
| Dallas[60] | Dallas Green Building Ordinance: Mandatory Green building standard that all new residential or commercial construction must | | | 2013 |

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[56] Cool Roof Rating Council Resources. (2017, September 26). Retrieved October 23, 2017, from http://coolroofs.org/resources/rebates-and-codes

[57] Cool Roof Rating Council Resources. (2017, September 26). Retrieved October 23, 2017, from http://coolroofs.org/resources/rebates-and-codes

[58] The 2015 Houston Commercial Energy Conservation Code. (2017, July 19). Retrieved from https://edocs.publicworks.houstontx.gov/documents/divisions/planning/enforcement/1209_cool_roof_guidelines.pdf

[59] Maynard, N. F. (2010, May 20). PHILADELPHIA ADOPTS COOL-ROOF LAW. Retrieved from http://www.builderonline.com/building/building-science/philadelphia-adopts-cool-roof-law_o

[60] Kaplow, S. (2013, October 17). Green Building is Now the Law in Dallas. Retrieved from https://www.greenbuildinglawupdate.com/2013/10/articles/leed/green-building-is-now-the-law-in-dallas/

| | | | | |
|---|---|---|---|---|
| | either meet the minimum requirements of the Dallas Green Construction Code or be LEED certifiable or be Green Built Texas certifiable or be certifiable under an equivalent green building standard. | | | |
| Austin[61] | Austin Urban Heat Island Initiative: Adoption of the International Energy Conservation Code (IECC) mandates that all new and remodeled commercial buildings require a cool roof. | | | 2001 |

## Scale across cities:

Of our 83 cities, 40 have adopted a cool roof program, or 48%.[62]

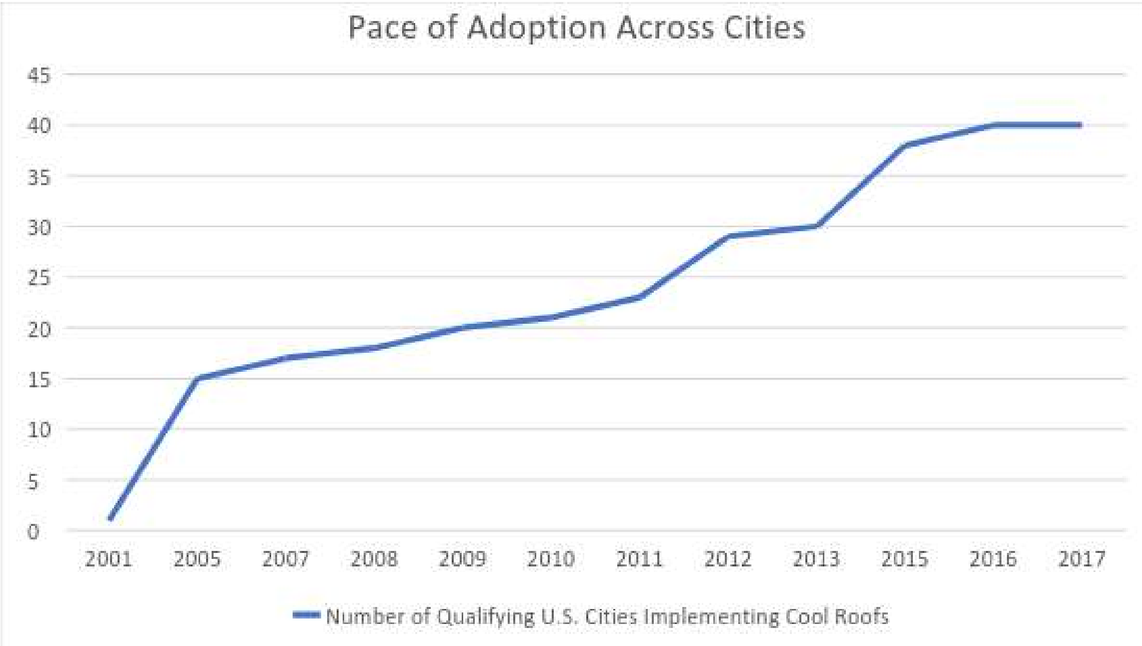
## Pace of adoption across cities:

The pace of adoption across cities data has been derived implementation year as provided by the Department of Energy's (DOE) Energy Codes site.[63] The Y-axis is the number of cities that have adopted the innovation and the X-axis is the year that the innovation was adopted.

[61] City of Austin | Urban Heat Island Initiatives . (2015, August 5). Retrieved from https://www.austintexas.gov/sites/default/files/files/Planning/City_Arborist/2015_08_05_City_of_Austin_UHI_Programs.pdf

[62] Cool Roof Rating Council Resources. (2017, September 26). Retrieved October 23, 2017, from http://coolroofs.org/resources/rebates-and-codes

[63] Status of State Energy Code Adoption. (2016, September). Retrieved from https://www.energycodes.gov/status-state-energy-code-adoption




| | # of cities with innovation in 2014 | # of cities with Innovation in 2017 | Growth Rate |
|---|---|---|---|
| **Cool Roofs** | 33 | 40 | 21% |

## Regulatory needs:

This innovation has been implemented as a Building Code Requirement, Energy Code Requirement, or a mandatory policy. Its success is contingent upon regulation that mandates adoption.[64]

## Extent of private marketplace:

Private Marketplace support for Cool Roofs is limited to Contractors or construction companies that perform the work and installation. For some policies, building owners must choose from a pre-approved list of contracting companies to perform the installation to qualify for a rebate or tax incentive program.[65]

## Replicability:

As cool roofs can be made of reflective paint or roofing material, they are easily applied to nearly all types of roofing systems. Its ease of application makes Cool Roofs an easily replicable innovation within

[64] Cool Roof Rating Council Resources. (2017, September 26). Retrieved October 23, 2017, from http://coolroofs.org/resources/rebates-and-codes
[65] Cool Roofs. (n.d.). Retrieved October 23, 2017, from https://energy.gov/energysaver/energy-efficient-home-design/cool-roofs

all cities. Applicable Building Code Requirements, Energy Code Requirements, and/or policies need to be implemented to promote adoption. [66]

## Level of federal or state support:

Approximately six Cool Roof policies have been implemented at a state level. Cool Roof programs also enjoy federal rebate and tax incentives[67], as well as educational and support outreach from non-profit educational organizations such as the Cool Roof Rating Council (CRRC).[68]

[66] Cool Roofs. (n.d.). Retrieved October 23, 2017, from https://energy.gov/energysaver/energy-efficient-home-design/cool-roofs
[67] Cool Roofs. (n.d.). Retrieved October 23, 2017, from https://energy.gov/energysaver/energy-efficient-home-design/cool-roofs
[68] Cool Roof Rating Council Resources. (2017, September 26). Retrieved October 23, 2017, from http://coolroofs.org/resources/rebates-and-codes

# Energy Benchmarking

## Innovation:

Benchmarking is a software that uses data from the utility to measure the energy use of a building over time, and assesses this energy use relative to similar buildings, or a building of reference that has been built to a standard such as LEED.

Benchmarking is a valuable tool to government properties, building owners and managers, and designers, as it allows them to compare and identify opportunities to reduce their Building's energy consumption.[69]

## Scaled within cities:

To determine the scale of adoption, the current number of buildings required to comply has been compared to the total number of buildings within a city. As the number of buildings required to comply changes annually, depending on City Ordinance requirements, only the most recent number of buildings required have been compared. The conclusion of this analysis can be observed in the table below. Lead cities were chosen depending on the amount of data available, how long the policy has been in place (varied), and the size and type of buildings required to comply.

## Pace of adoption within cities:

Pace has been assessed as the year the Energy Benchmarking Ordinance was implemented, compared to the number of buildings required to benchmark annually. The size and type of buildings required to comply varies by city. Pace of Adoption is determined by when benchmarking was initiated, and over how many years it has taken to expand.

Size of the System

| City | Benchmarked Buildings | Total Buildings | Benchmarked of Total Buildings (%) | Timeframe | Annual Pace of Adoption (%) |
|---|---|---|---|---|---|
| New York City[70] | 182,884 | 1,002,579 | 18.2% | 2009-2017 | 2.27% |
| Chicago[71] | 3,593 | ~360,000 | .99% | 2013-2017 | .24% |
| Philadelphia[72] | 2,800 | ~500,000 | .56% | 2012-2017 | .11% |
| San Francisco[73] | 2,312 | 200,198 | 1.1% | 2010-2017 | .16% |
| Seattle[74] | 3,340 | 194,244 | 1.71% | 2010-2017 | .25% |
| Washington DC[75] | 3,246 | ~180,000 | 1.8% | 2008-2017 | .20% |

[69] Building Energy Use Benchmarking. (n.d.). Retrieved October 23, 2017, from https://energy.gov/eere/slsc/building-energy-use-benchmarking

[70] NEW YORK CITY LOCAL LAW 84 BENCHMARKING REPORT. (2012, August). Retrieved from http://www.nyc.gov/html/gbee/downloads/pdf/nyc_ll84_benchmarking_report_2012.pdf

[71] Chicago Energy Benchmarking Report. (2016). Retrieved from https://www.cityofchicago.org/content/dam/city/progs/env/EnergyBenchmark/2016_Chicago_Energy_Benchmarking_Report.pdf

[72] Philadelphia's Energy Benchmarking and Disclosure Law (Philadelphia Code section 9-3402) . (2017). Retrieved from http://www.phillybuildingbenchmarking.com/about/#about-ordinance-anchor

[73] SAN FRANCISCO EXISTING COMMERCIAL BUILDINGS PERFORMANCE REPORT 2010-2014. (2014). Retrieved from https://sfenvironment.org/sites/default/files/fliers/files/sfe_gb_ecb_performancereport.pdf

[74] Seattle Building Energy Benchmarking Analysis Report. (2013). Retrieved from http://www.seattle.gov/Documents/Departments/OSE/EBR-2013-report.pdf

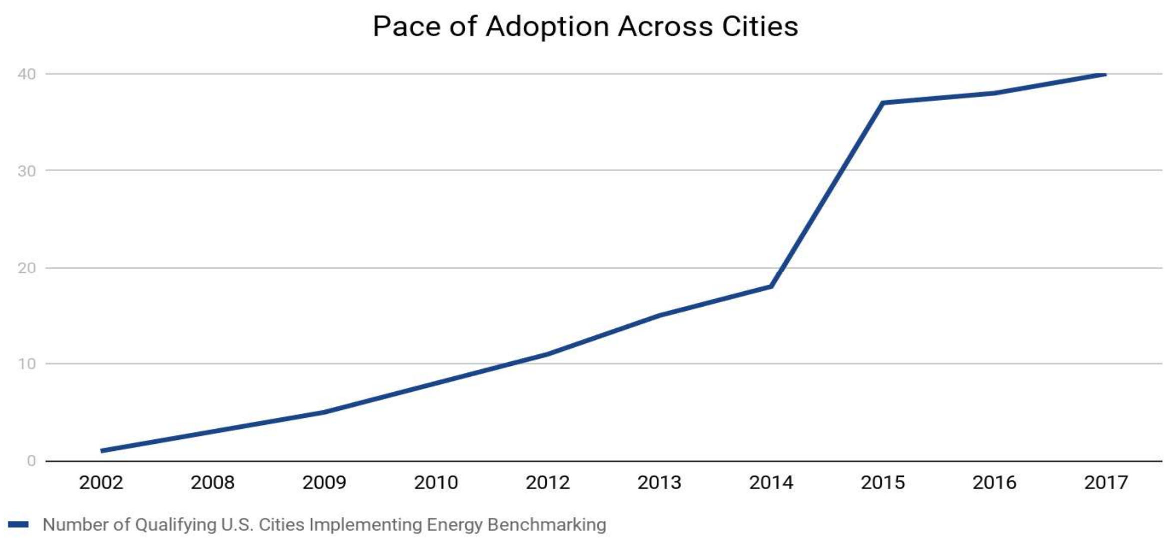
| | | | | | |
|---|---|---|---|---|---|
| Minneapolis[76] | 420 | 129,114 | .325% | 2013-2017 | .08% |

## Scale across cities:

Of the 83 cities under review, 40 have adopted an Energy Benchmarking program, or 48.2%

## Pace of adoption across cities:

In this graph the X-axis represents the year the innovation was adopted and the Y-axis represent the number of cities under review that had adopted the innovation. The pace of adoption across cities increased substantially between the years 2010 and 2015 due to a state mandated ordinance in California. As observed in the pace within cities, adoption begins to slow around 2015-2016.




| | # of cities with innovation in 2014 | # of cities with Innovation in 2017 | Growth Rate |
|---|---|---|---|
| **Energy Benchmarking** | 18 | 40 | 122% |

## Regulatory needs:

This innovation is implemented by a State or Local Government as a Benchmarking Ordinance or mandatory policy. Its success is contingent upon regulation that mandates adoption.[77]

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[75] Department of Energy & Environment Energy Benchmarking. (n.d.). Retrieved 2017, from https://doee.dc.gov/energybenchmarking

[76] Energy Benchmarking Results for Public and Large Commercial Buildings . (2016). Retrieved 2017, from http://www.ci.minneapolis.mn.us/environment/energy/WCMS1P-116916

[77] BENCHMARKING PROGRAMS AND POLICIES LEVERAGING ENERGY STAR. (2017, September). Retrieved from https://www.energystar.gov/sites/default/files/tools/ES_Government-Factsheet_09292017.pdf

## Extent of private marketplace:

Private Marketplace support is limited to privately-owned utilities providing whole building energy data to building owners to comply with City Benchmarking requirement[78] ENERGY STAR® Portfolio Manager serves as the standard for Energy Benchmarking software (developed by the EPA).

## Replicability:

Energy Benchmarking is easily implemented, so long as there are applicable ordinances, and/or mandatory policies implemented to promote adoption.

## Level of federal or state support:

Approximately ten Energy Benchmarking policies have been implemented at a state level.[79] Energy Benchmarking programs also have guides, toolkits, databases, directories, and step-by-step planning programs and support made available by the Department of Energy (DOE).[80]

[78] BENCHMARKING PROGRAMS AND POLICIES LEVERAGING ENERGY STAR. (2017, September). Retrieved from https://www.energystar.gov/sites/default/files/tools/ES_Government-Factsheet_09292017.pdf

[79] BENCHMARKING PROGRAMS AND POLICIES LEVERAGING ENERGY STAR. (2017, September). Retrieved from https://www.energystar.gov/sites/default/files/tools/ES_Government-Factsheet_09292017.pdf

[80] Building Energy Use Benchmarking. (n.d.). Retrieved October 23, 2017, from https://energy.gov/eere/slsc/building-energy-use-benchmarking

# Green Stormwater Infrastructure

## Innovation:

According to the EPA, "green infrastructure is a cost-effective, resilient approach to managing wet weather impacts by using vegetation, soil, and other elements and practices to restore some of the natural processes required to manage water and create healthier urban environments."[81] Green stormwater infrastructure (GSI) reduces the amount of water entering sewer and stormwater treatment plants and protect the quality of receiving water bodies such as rivers, streams and lakes. For this research, the term green stormwater infrastructure (GSI) will include GSI or low impact development (LID) systems. EPA defines low impact development as "an approach to land development (or re-development) that works with nature to manage storm-water as close to its source as possible."[82] GSI and LID systems include downspout disconnection, rainwater harvesting, bioretention (rain garden and bioswale), vegetated roofs, permeable pavements, urban trees, parks, riparian buffers, and natural or constructed wetlands.

## Scale within cities:

All cities are using gray infrastructure (traditional underground pipe system drainage) to manage sewer and storm water either as municipal separate storm sewer system (MS4) or as combined sewer system (CSS). Gray infrastructure, unlike green infrastructure, is a network of pipes, tunnels and ditches for stormwater management. To date, the construction and maintenance of gray infrastructure have cost billions of dollars to US cities.[83] Still, many cities have sewage systems that overflow with pollutants into water bodies during strong rainy days. The high cost of construction and maintenance of gray infrastructure has made some cities turn into using green infrastructure for managing their stormwater. Green infrastructure is a good alternative to gray infrastructure because aside its lower capital costs, it reduces sewer overflows and water pollutants from runoff and recharge ground water through infiltration process in the soil. Although some cities have not completely adopted GSI, many of them have been implementing this innovation in some ways through education and incentives for residents to construct systems such as rain gardens and downspout disconnections, or by charging stormwater fees equivalent to impervious surface area of property owners and using the collected money to fund green stormwater infrastructure projects.  However, many large cities have plans or ordinances in place and have budget for GSI projects. The National Resource Defense Council (NRDC) conducted in 2011 a research titled "Rooftops to Rivers II", which featured twelve large US cities with GSI program.[84]

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[81] United States Environmental Protection Agency. (2017) Retrieved from https://www.epa.gov/green-infrastructure/what-green-infrastructure

[82] US Environmental Protection Agency. (2017) Retrieved from https://www.epa.gov/sites/production/files/2015-09/documents/bbfs2terms.pdf

[83] Water Environment Federation. (2014, September 3). Innovative Financing Accelerates Stormwater Management. Retrieved from http://stormwater.wef.org/2014/09/innovative-financing/

[84] Hobbs, Karen. (2015, February 17). Rooftops to Rivers II: Green Strategies for Controlling Stormwater and Combined Sewer Overflows Retrieved from https://www.nrdc.org/resources/rooftops-rivers-ii-green-strategies-controlling-stormwater-and-combined-sewer-overflows

This research assumes that green infrastructure systems manage one inch of runoff from surface systems and that soil stores 20% of runoff volume from contributing impervious surface.[85] The size of the system managed by green stormwater infrastructure is equal to the acres of green stormwater infrastructure built plus 20% of the city impervious cover.[86,87,88] The percent of the larger system is the ratio of the size managed by green stormwater infrastructure to the total impervious cover in the city. Table 1 shows the percent of the larger system for the ten cities analyzed in this research.

| City | Total Green Infrastructure Built (acres) | Total City Impervious Cover (acres) | Size of the System managed by GSI (acres) | Percent of Larger System |
|---|---|---|---|---|
| New York[89] | 1,101 | 118,329 | 24,767 | 20.9% |
| Chicago[90] | 135 | 85,213 | 17,178 | 20.2% |
| Philadelphia[91] | 1000 | 55,922 | 12,184 | 21.8% |
| San Francisco[92] | 430 | 18,366 | 4,103 | 22.3% |
| Seattle[93],[94] | 208 | 31,358 | 6,480 | 20.7% |
| Detroit[95] | 3,141 | 42,373 | 11,616 | 27.4% |
| Nashville[96] | 1,168 | 51,387 | 11,445 | 22.3% |
| Portland[97],[98] | 4,948 | 38,163 | 12,581 | 33.0% |

[85] Philadelphia Water. (September 2016). *Green Stormwater Infrastructure Planning and Design Manual Version 1.0.* Retrieved from http://documents.philadelphiawater.org/gsi/GSI_Planning_and_Design_Manual.pdf

[86] Nowak, David J., and Greenfield, Eric J. (2012). Trees and Impervious Cover Change in U.S. Cities. *Urban Forestry and Urban Greening*, 11, 21-30. doi:10.1016/j.ufug.2011.11.005

[87] The Trust for Public Land's Center for City Park Excellence. (June 2008*) How Much Value Does the City of Philadelphia Receive from its Park and Recreation System?* Retrieved from http://cloud.tpl.org/pubs/ccpe_PhilaParkValueReport.pdf. p.4

[88] San Francisco Department of Public Health. *Impervious Ground Surfaces*. Retrieved from http://www.sfindicatorproject.org/indicators/view/26

[89] New York Department of Environmental Protection. (2016). *NYC Green Infrastructure 2015 Annual Report*. Retrieved from http://www.nyc.gov/html/dep/pdf/green_infrastructure/gi_annual_report_2016.pdf

[90] City of Chicago. (April 2014). *City of Chicago Green Stormwater Infrastructure Strategy.* Retrieved from https://www.cityofchicago.org/content/dam/city/progs/env/ChicagoGreenStormwaterInfrastructureStrategy.pdf p.26

[91] Philadelphia Water Department. (2017, October 30). Greened Acres. Retrieved from http://www.phillywatersheds.org/category/blog-tags/greened-acres

[92] San Francisco Water Utilities Commission. (2016, June 21). *Update on Flood Resilience Study and Stormwater Management Efforts.* Retrieved from http://sfwater.org/Modules/ShowDocument.aspx?documentid=9332. p. 9

[93] City of Seattle. (2015, November). *Green Stormwater Infrastructure in Seattle Implementation Strategy 2015-2020*. https://www.seattle.gov/Documents/Departments/OSE/GSI_Strategy_Nov_2015.pdf. p. 25

[94] Seattle Public Utilities. (2015, May 29). Integrated Plan In *Protecting Seattle's Waterways* (Volume 3). Retrieved from http://www.seattle.gov/util/cs/groups/public/@spu/@drainsew/documents/webcontent/01_030099.pdf. p.17

[95] Detroit Water and Sewerage Department. (2017). Green Infrastructure Projects Retrieved from http://www.detroitmi.gov/Government/Departments-and-Agencies/Water-and-Sewerage-Department/Green-Infrastructure-Projects

[96] Metro Nashville/Davidson County Planning Department. (2016). 2016 Annual Report NashvilleNext: AGeneral Plan for Nashville and Davidson County. Retrieved from http://www.nashville.gov/Portals/0/SiteContent/Planning/docs/NashvilleNext/AnnualReports/2016AnnualReport-Final_v6_web.pdf

[97] Garrison, Noah, Hobbs Karen. (2011) Portland, Oregon, A case Study of How Green Infrastructure is Helping Manage Urban Stormwater Challenges. In *Natural Resources Defense Council: Rooftop to Rivers II: Green Strategies for Controlling Stormwater and combined Sewer Overflows.* Retrieved from https://www.nrdc.org/sites/default/files/RooftopstoRivers_Portland.pdf. p.2

[98] Under2MOU, City of Portland Bureau of Planning and Sustainability. (December 2016*). City of Portland Under 2 MOU Appendix*. Retrieved from http://under2mou.org/wp-content/uploads/2015/05/Portland-Appendix.pdf

| | | | | |
|---|---|---|---|---|
| Louisville[99] | 424 | 64,520 | 13,328 | 20.7% |
| Kansas, MO[100] | 744 | 40,723 | 8,889 | 21.8% |

GSI Table 1. Size of Green Stormwater Infrastructure System within Cities

## Pace of adoption within cities:

The pace of adoption within cities refers to the number of years it takes for cities full adoption of green stormwater infrastructure. Full adoption takes place when cities create more projects after pilot project were built. It takes about two to three years to complete green infrastructure projects. Cities get the benefits once projects are completed.

Table 2 shows the increase in acres of green stormwater infrastructure built by the ten cities analyzed in this report recently. Except for Chicago, years closer to 2017 were chosen. Chicago's green roof is more mature than its green alleys program, which is under Chicago's green stormwater infrastructure strategy launched in 2014.[101] Chicago is the leader on installations of green roofs in the United States. Hence, the focus here is on green roof. The size of green roofs in Chicago has more than doubled from 2006 to 2010. However, there is no data found on significant increase in Chicago's green roof construction from 2010 to 2017. Philadelphia has been very rapidly adopting this innovation with 908 acres of green infrastructure added in a span of only three years. Seattle is at the bottom of the rank with forty-three (43) acres of projects added from 2011 to 2016.

| City | Year 1 | GSI built by Year 1 (acres) | Year 2 | GSI Built by Year 2 (acres) | Increase in Acres |
|---|---|---|---|---|---|
| New York[102,103] | 2013 | 50.0 | 2016 | 457.0 | 135.7 |
| Chicago[104, 105] | 2007 | 68.9 | 2010 | 126.5 | 19.2 |

[99] City of Louisville. (2017) Goal 15: Expand Green Infrastructure Incentives Citywide by 2018. In *Sustain Louisville.* Retrieved from https://louisvilleky.gov/government/sustain-louisville/goal-15-expand-green-infrastructure-incentives-citywide-2018

[100] Garrison, Noah, Hobbs Karen. (2011) Kansas, Missouri: A case Study of How Green Infrastructure is Helping Manage Urban Stormwater Challenges. In *Natural Resources Defense Council: Rooftop to Rivers II: Green Strategies for Controlling Stormwater and combined Sewer Overflows.* Retrieved from https://www.nrdc.org/sites/default/files/RooftopstoRivers_KansasCity.pdf

[101] Adaptation Clearinghouse. (April 2014). *City of Chicago Green Stormwater Infrastructure Strategy.* Retried from http://www.adaptationclearinghouse.org/resources/city-of-chicago-green-stormwater-infrastructure-strategy.html

[102] New York Department of Environmental Protection (2014). *NYC Green Infrastructure 2013 Annual Report*. Retrieved from (http://www.nyc.gov/html/dep/pdf/green_infrastructure/gi_annual_report_2014.pdf

[103] New York Department of Environmental Protection (2017). *NYC Green Infrastructure 2016 Annual Report*. http://www.nyc.gov/html/dep/pdf/green_infrastructure/gi_annual_report_2017.pdf

[104] Taylor, David A. (2007). Growing Green Roofs, City by City. *Environmental Health Perspectives, 115 (6),* A306-A311. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1892107/

[105] City of Chicago Department of Planning and Development. *Chicago Green Roofs*. Retrieved from https://www.cityofchicago.org/city/en/depts/dcd/supp_info/chicago_green_roofs.html

| | | | | | |
|---|---|---|---|---|---|
| Philadelphia[106,107] | 2014 | 92.0 | 2017 | 1000.0 | 302.7 |
| San Francisco[108, 109] | 2013 | 0.1 | 2016 | 430.0 | 143.3 |
| Seattle[110,111] | 2011 | 0.2 | 2016 | 43.2 | 8.6 |
| Detroit[112, 113] | 2013 | 1349.0 | 2017 | 1482.90 | 66.95 |
| Nashville[114] | 2013 | 600.0 | 2016 | 1168.0 | 189.3 |
| Portland[115,116] | 2012 | 14.6 | 2014 | 485.0 | 235.2 |
| Louisville[117,118] | 2013 | 0.1 | 2016 | 250.0 | 83.3 |
| Kansas, MO[119,120] | 2012 | 100.0 | 2017 | 744.0 | 128.8 |

GSI Table 2. Pace of Adoption of Green Stormwater Infrastructure within Cities

## Scale across cities:

Out of the 83 large cities under review for the adaptation of green infrastructure for managing stormwater, 42 cities or 51% have green infrastructure projects.

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106 Philadelphia Water Department. (2015, January 6). *Greened Acre Retrofit Program*. Retrieved from http://www.phillywatersheds.org/category/blog-tags/greened-acre-retrofit-program

107 Philadelphia Water Department. (2015, January 6). *Greened Acre Retrofit Program*. Retrieved from http://www.phillywatersheds.org/category/blog-tags/greened-acres

108 San Francisco Public Utilities Commission (2014, March 18). *San Francisco Public Utilities Departmental Climate Action Annual Report Fiscal Year 2012-2013*. Retrieved from https://sfenvironment.org/sites/default/files/fliers/files/sfe_cc_2014_sfpuc_cap_fy1213.pdf

109 San Francisco Public Utilities Commission (2016, June 21). *Update on Flood Resilience Study and Stormwater Management Efforts* [PowerPoint slides]. Retrieved from http://sfwater.org/Modules/ShowDocument.aspx?documentid=9332

110 Garrison, Noah, Hobbs Karen. (2011) Seattle, Washington, A Case Study of How Green Infrastructure is Helping Manage Urban Stormwater Challenges. In *Natural Resources Defense Council: Rooftop to Rivers II: Green Strategies for Controlling Stormwater and combined Sewer Overflows.* Retrieved from https://www.nrdc.org/sites/default/files/RooftopstoRivers_Seattle.pdf

111 Seattle Public Utilities, King County Department of Natural Resources and Parks Wastewater Treatment Division. (2017*). 2016 Overview and Accomplishment Report Green Stormwater Infrastructure*. Retrieved from http://www.700milliongallons.org/wp-content/uploads/2017/02/1702_8095m_2016-GSI-accomplishment-Report-pages.pdf

112 Tetra Tech (2015, August 1). *Detroit Water and Sewerage Department Green Infrastructure Progress Report 2015*. Retrieved from http://www.detroitmi.gov/Portals/0/docs/DWSD/GI_StormWater/gi_progress2015.pdf

113 Tetra Tech. (2017). *Detroit Water and Sewerage Department Green Infrastructure Progress Report 2017*. Retrieved from http://www.detroitmi.gov/Portals/0/docs/DWSD/2017-09-25%20DWSD%20GI%20Annual%20Report%20FY%202017%20WEB%20VERSION.pdf?ver=2017-10-23-080710-217

114 Chen, Janie and Hobbs, Karen. (2013, October). *Rooftops to Rivers II: Green Strategies for Controlling Stormwater and combined Sewer Overflows. Update 2013*. Retrieved from https://www.nrdc.org/sites/default/files/rooftopstoriversII-update.pdf

115 City of Portland Environmental Services. (2012). *Green Infrastructure Tour.* Retrieved from *https://www.portlandoregon.gov/bes/article/439734*

116 City of Portland Bureau of Planning and Sustainability. (2016, December). *Under 2 MOU – Appendix*. Retrieved from http://under2mou.org/wp-content/uploads/2015/05/Portland-Appendix.pdf

117 City of Louisville. (June 2014). Sustain Louisville 2013 Progress Report. Retrieved from https://louisvilleky.gov/sites/default/files/sustainability/pdf_files/2013_progress_report_final.pdf

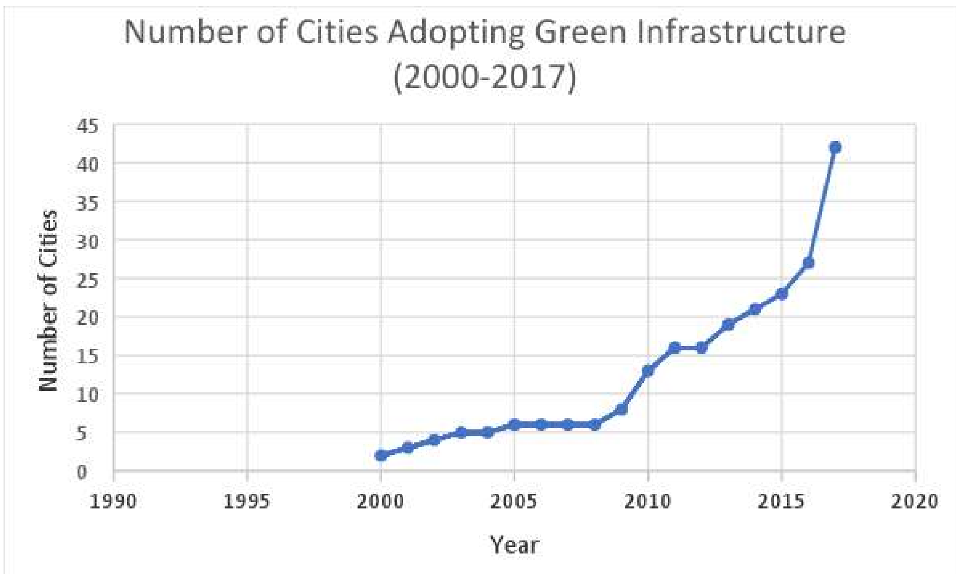
118 City of Louisville. (2017). Sustain Louisville 2016 Progress Report. Retrieved from https://louisvilleky.gov/sites/default/files/sustainability/sustain_louisville_2016_progress_report.pdf;

119 Kansas City Water Services, Missouri. (2016). *Middle Blue River Basin Green Solutions Pilot Project*. Retrieved from http://kcmo.gov/wp-content/uploads/2016/02/MiddleBlueRiverFinalReportExecSummary030514FINAL.pdf

120 American Society of Civil Engineers (2016, October 13). *Kansas City's Middle Blue River Green Infrastructure Earns Envision Platinum.* Retrieved from http://news.asce.org/kansas-citys-middle-blue-river-green-infrastructure-earns-envision-platinum/

## Pace of adoption across cities:

Figure 1 shows the pace of adoption of green infrastructure across the nation. It shows that from 2000 to 2008, there was a gradual adoption of the innovation, followed by a faster implementation from 2009 to 2015. There had been a dramatic increase in the pace of adoption across cities from 2014 to 2017, when additional twenty-one (21) cities had adopted the innovation in a span of three years. This may be due to the increasing number of pilot projects that have proved the environmental, social and economic benefits of this innovation. More publications have been released to disseminate the quantified benefits of adopting green infrastructure.[121, 122] As well, EPA's campaign shows case studies on these benefits.[123] This research also found out that more than twenty (20) cities that have not yet implemented any green infrastructure projects are in planning, designing, or public education stage.




GSI Figure 1. Pace of Adoption of Green Stormwater Infrastructure across Cities

| | # of cities with innovation in 2014 | # of cities with Innovation in 2017 | Growth Rate |
|---|---|---|---|
| **Green Stormwater** | 21 | 42 | 100% |

## Regulatory needs:

There is no regulatory change needed for cities to implement green infrastructure. NPDES permit under the Clean Water Act authorizes state governments to regulate pollution discharge to water bodies in cities. In 1987, Congress added Stormwater Rules, which have driven cities to implement best stormwater

[121] Center for Neighborhood Technology, American Rivers. (2010). *The Value of Green Infrastructure: A Guide to Recognizing Its Economic, Environmental and Social Benefits*. Retrieved from http://www.cnt.org/sites/default/files/publications/CNT_Value-of-Green-Infrastructure.pdf

[122] U.S. Environmental Protection Agency (2017, March 22). *Benefits of Green Infrastructure*. Retrieved from https://www.epa.gov/green-infrastructure/benefits-green-infrastructure

[123] U.S. Environmental Agency. (2015). *Case Studies Analyzing the Economic Benefits of Low Impact Development and Green Infrastructure Programs*. Retrieved from https://www.epa.gov/sites/production/files/2015-10/documents/lid-gi-programs_report_8-6-13_combined.pdf

management practices to reduce the volume of runoff entering sewer systems.[124] EPA has required cities under federal consent decree to reduce their pollution runoffs through BMPs. However, like Washington, DC which aims to reduce its overflows by 96% using underground storage tunnels, cities may choose to manage their stormwater mainly with gray infrastructure.[125] Building gray infrastructure such as deep storage tunnels take a big portion of city budget and many years to complete.[126] NPDES, a tight budget, and the additional economic, environmental and social benefits of green infrastructure lead cities to launch green infrastructure plan and ordinance. City stormwater ordinance has helped cities increase the participation of constituents in the adoption of green infrastructure through new development and redevelopment projects.

## Extent of private marketplace:

Currently, there is a growing number of private developers and contractors working with city governments on green stormwater infrastructure projects. These include Tetra-Tech, Sustainable Business Network (SBN in Philadelphia), Storm and Streams Solutions, LLC, and Williamette Partnership. To help city decision-makers and private investors, NatLab (Natural Infrastructure Financing Laboratory), an alliance by The Natural Resource Development Council, The Nature Conservancy, and EKO Assets Management, created a report titled "Creating Clean Water Cash Flows".[127] This report aims to encourage cities and private investors to embrace implementation of GSI.

## Replicability:

Building green stormwater infrastructure is easy as long as there are supporting infrastructure in place. The presence of financial and technical assistance from the federal and state government helps cities replicate GSI in their communities. As well, the result of EPA's case studies on the economic benefits of GSI to communities should encourage cities to replicate this innovation.[128] Additionally, there are federal and state grants available to cities to fund this endeavor.

## Level of federal or state support:

There is both financial and technical assistance for GSI lead by the EPA. The major grant program is Clean Water State Revolving Fund. Cities can avail for federal and state funding through several US Departments as suggested by the EPA.[129]

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[124] Environmental Protection Agency. (September 2010). Regulatory Framework and Program Areas of the NPDES Program. In *NPDES Permit Writer's Manual* (Chapter2). Retrieved from https://www.epa.gov/sites/production/files/2015-09/documents/pwm_chapt_02.pdf

[125] District of Columbia Water and Sewer Authority. (2017). *Clean Rivers Project*. Retrieved from https://www.dcwater.com/clean-rivers-project

[126] Kloss, Christopher, Calarusse, Crystal. (June 2006). Rooftops to Rivers: Green Strategies for Controlling Stormwater and Combined Sewer Overflows, 7. Retrieved from https://www.nrdc.org/sites/default/files/rooftops.pdf

[127] Valderama, Alisa. (2013, March 7). NatLab Report Highlights Strategies for Green Infrastructure Finance. Retrieved from https://www.nrdc.org/experts/alisa-valderrama/natlab-report-highlights-strategies-green-infrastructure-finance

[128] U.S. Environmental Agency. (2015). *Case Studies Analyzing the Economic Benefits of Low Impact Development and Green Infrastructure Programs*. Retrieved from https://www.epa.gov/sites/production/files/2015-10/documents/lid-gi-programs_report_8-6-13_combined.pdf

[129] U.S. Environmental Protection Agency (2017, October 25). *Green Infrastructure Funding Opportunities*. Retrieved from https://www.epa.gov/green-infrastructure/green-infrastructure-funding-opportunities

A. Environmental Protection Agency (EPA)
B. US Housing and Urban Development (HUD)
C. Department of Homeland Security – Federal Emergency Management Administration (FEMA)
D. Department of Transportation
E. Department of Agriculture
F. Department of Energy
G. U.S. Department of Commerce
H. State Water Resources Control Board

Furthermore, EPA has been actively giving technical assistance on EPA website, wherein EPA describes case studies on technical assistance projects with some cities. [130,131]

[130] U.S. Environmental Protection Agency (2017, July 31). *Technical Assistance with Green Infrastructure*. Retrieved from https://www.epa.gov/water-research/technical-assistance-green-infrastructure

[131] U.S. Environmental Protection Agency. Technical Guidance on Implementing the Stormwater Runoff Requirements for Federal Projects under Section 438 of the Energy Independence and Security Act. Retrieved from https://www.epa.gov/sites/production/files/2015-08/documents/epa_swm_guidance.pdf

# LED Street Lighting

## Innovation:

LED street lights provide better lighting than traditional HPS (High-pressure Sodium) street lights and offers better distribution of light. LED street lights are highly energy efficient and last long – thereby reducing greenhouse gas emissions and saving cities considerable amount of energy and maintenance cost.

## Scale within cities:

On average, it takes two years to study the feasibility plan for converting traditional HAS lights to LED lights. Once the plan is accepted, cities convert 80% of street lights to LED within first two years.

| | Year of Adoption | Year of Completion | No. of HPS Lights ('000) | No. of LED Lights ('000) | Conversion % |
|---|---|---|---|---|---|
| New York, NY | 2013 | 2018 | 250 | 200 | 80 |
| Los Angeles, CA | 2011 | 2016 | 170 | 170 | 100 |
| San Antonio, TX | 2012 | 2013 | 25 | 25 | 100 |
| San Diego, CA | 2012 | 2013 | 40 | 35 | 88 |
| San Francisco, CA | 2014 | 2016 | 25 | 20 | 80 |
| Boston, MA | 2010 | 2016 | 64 | 64 | 100 |
| Portland, OR | 2009 | 2016 | 55 | 55 | 100 |
| Las Vegas, NV | 2011 | 2013 | 52 | 42 | 81 |

## Pace of adoption within cities:

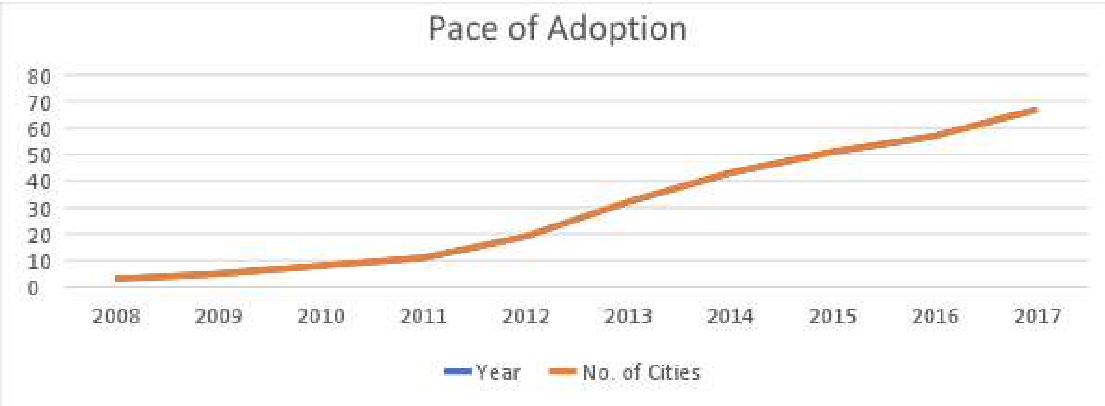
From seven cities reviewed, most cities completed installing over 80% of LED street lights within first two years of implementation. Cities like New York, Chicago, San Francisco, Portland, LA, San Diego and Las Vegas have installed LED lights between 80% to 100%.

## Scale across cities:

83% - 69 of the 83 cities reviewed, have adopted the innovation. This is the easiest and low hanging fruit for any city to adopt energy efficiency measures, mostly because cities can clearly measure energy use reduction and savings in dollars.

## Pace of adoption across cities:

Adoption of LED Street Lights increased by 60% from 43 cities in 2014 to 69 cities in 2017.




The Y-axis shows the number of cities that have adopted the innovation, while the X-axis shows the year that the innovation was adopted.

| | # of cities with innovation in 2014 | # of cities with Innovation in 2017 | Growth Rate |
|---|---|---|---|
| **LED street lighting** | 43 | 69 | 60% |

## Regulatory needs:

No change in regulation or legislation is required. Having said this, in cities where utility owns street lights, city municipality does not have a direct control in changing street lights to LED. Utility may not want to let go the control of street lights, invest in upfront cost of technology and replacement of street lights[132]. Under such circumstances, city municipality may find it difficult to adopt LED street lights and receive any environmental or economic benefit from doing so[133].

## Extent of private marketplace:

Yes, several private companies are involved in manufacturing LED lights, including for street lighting and also in refining and further developing the technology.

## Replicability:

This innovation can be easily replicated.

## Level of federal or state support:

[132] Greensboro News & Record, (2014, April) Greensboro pushes for better rates on LED streetlights. Retrieved from: http://www.greensboro.com/news/greensboro-pushes-for-better-rates-on-led-streetlights/article_985e0250-ced0-11e3-bb85-0017a43b2370.html

[133] Northeast Energy Efficiency Partnerships, (2015, January) *LED Street Lighting Assessment and Strategies for the Northeast and Mid-Atlantic*. Retrieved from: http://www.neep.org/sites/default/files/resources/DOE_LED%20Street%20Lighting%20Assessment%20and%20Strategies%20for%20the%20Northeast%20and%20Mid-Atlantic_1-27-15.pdf

LED differs fundamentally from traditional lighting technologies in terms of materials, drivers, system architecture, controls, and photometric properties. To accommodate these differences, new test procedures and industry standards have been developed yet more are needed. To accelerate their development, DOE is offering technical assistance and facilitating ongoing dialogue and collaboration with key standards setting organizations to support the new ENERGY STAR SSL Program.[134]

[134] US Department of Energy, *DOE Municipal Solid-State Street Lighting Consortium.* Retrieved from: **https://energy.gov/eere/ssl/doe-municipal-solid-state-street-lighting-consortium**

# Pay-As-You-Throw

## Innovation:

Pay-As-You-Throw (PAYT) is a trash metering scheme that creates a direct economic incentive to generate less waste. Residents or commercial businesses are charged for the municipal solid waste they dispose. The concept is similar to paying a water or electricity bill – though exact unit metering is less common. Instead the scheme is usually implemented with fees based on standard trash cart sizes, supplemented by purchase of special trash bags or stickers for additional trash. Standard trash carts are mostly available in 3 sizes – ranging from 32, 64, to 96 gallons. Most pricing models are based on variable rates – different trash cart sizes have different rates. PAYT is commonly accompanied by a free recycling scheme, thereby encouraging a higher recycling rate, which diverts municipal solid waste from landfills.

## Scale within cities:

For PAYT to scale up within a city, it needs to reach the residential households. Most cities start with pilot programs before scaling up. The reference time period is defined from pilot to citywide implementation. See Table 1 for the size of system and pace of adoption within 8 selected cities. Lead cities have been determined based on data availability, in particular the time period from pilot to citywide implementation, as that has proved to be very challenging to identify.

Pay-As-You-Throw Table 1. Size of the System and Pace of Adoption Within Cities

| City | # of households[135] | % of household covered | Pilot to Citywide | Pace of Adoption (%/year) |
|---|---|---|---|---|
| Anchorage[136] | 105,175 | 77.4 | 2008-2014 | 11.06 |
| Austin[137] | 265,649* | 59.3 | 1997-2000 | 14.83 |
| Fort Worth[138] | 195,078* | 77.2 | 1996-2003 | 9.65 |
| Minneapolis[139] [140] | 162,352* | 61.6 | 1989-1995 | 8.80 |
| Sacramento[141] | 154,581* | 75.7 | 1998-1999 | 37.85 |
| San Antonio[142] | 488,645 | 72.5 | 2015-2017 | 24.17 |
| San Jose[143] | 276,598* | 71.8 | 1991-1993 | 23.93 |
| Tulsa[144] | 164,471 | 72.5 | 2011-2012 | 36.25 |

*Based on 2000 Census

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135 https://www.census.gov

136 https://www.muni.org/departments/sws/curbside/Pages/default.aspx

137 https://archive.epa.gov/wastes/conserve/tools/payt/web/html/summer99.html

138 https://archive.epa.gov/wastes/conserve/tools/payt/web/html/spring-04.html#1

139 http://www.ci.minneapolis.mn.us/solid-waste/about/solid-waste_aboutus-history

140 https://archive.epa.gov/wastes/conserve/tools/payt/web/pdf/sera06.pdf

141 https://archive.epa.gov/wastes/conserve/tools/payt/web/html/ca.html#sacramento

142 http://sanantonio.gov/Portals/0/Files/budget/FY16BudgetPolicyIssuesCouncilConsideration.pdf

143 https://archive.epa.gov/wastes/conserve/tools/payt/web/html/ssanjose.html

144 http://www.kjrh.com/news/local-news/investigations/city-of-tulsa-spent-nearly-1-million-on-know-your-trash-campaign-to-educate-tulsans-on-new-service

Commercial businesses have been excluded from the size of the system, as PAYT tends to pilot with residential households, and scale based on its success. PAYT outreach and education have also mainly targeted residential households.

Despite citywide implementation, PAYT currently does not reach 100% adoption because most multi-family units, defined as housing with 5+ units, are exempt from PAYT due to difficulties in confirming waste ownership. Separately, households based in mobile homes, boats, and recreation vehicles, are also excluded.[145]

## Pace of adoption within cities:

For the 8 selected cities, the average duration from pilot to citywide adoption is 4.5 years. The average pace of adoption, or percentage of PAYT households reached annually, is 20.82%. See Table 1 for details by city.

It should be noted that PAYT programs implemented after 2000 have shorter durations due to existing expertise. On average, pilot to citywide adoption is 1 to 3 years.

Separately, cities have measured PAYT systems impact based on increased recycling and diversion of municipal solid waste sent to landfills.[146]

## Scale across cities:

18 out of 83 cities reviewed have adopted the innovation. (22%)

Pay-As-You-Throw Table 2. Cities from Top 83 U.S. Cities that Adopted PAYT and Year Implemented

| **City** | **State** | **Population** | **Year Implemented**[147] |
|---|---|---|---|
| Los Angeles | California | 3,976,322 | 1996 |
| San Antonio | Texas | 1,492,510 | 2015[148] |
| San Jose | California | 1,025,350 | 1993 |
| Austin | Texas | 947,890 | 1997 |
| San Francisco | California | 870,887 | 1999 |
| Fort Worth | Texas | 854,113 | 1996 |
| Seattle | Washington | 704,352 | 1981 |
| Portland | Oregon | 639,863 | 1992 |
| Oklahoma City | Oklahoma | 638,367 | 1997 |
| Albuquerque | New Mexico | 559,277 | 1995 |
| Sacramento | California | 495,234 | 1999 |
| Long Beach | California | 470,130 | N/A |
| Colorado Springs | Colorado | 465,101 | N/A |

[145] https://archive.epa.gov/wastes/conserve/tools/payt/web/html/top11.html

[146] https://www.epa.gov/sites/production/files/2015-09/documents/skumatz.pdf

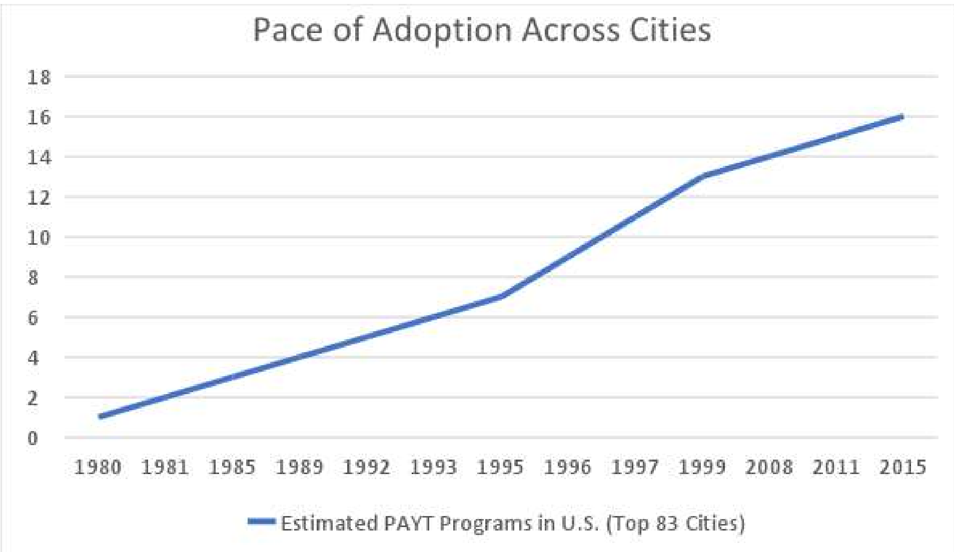
[147] https://archive.epa.gov/wastes/conserve/tools/payt/web/html/comm-2.html

[148] http://www.sanantoniocitymanager.com/2016/02/pay-as-you-throw/

| | | | |
|---|---|---|---|
| Oakland | California | 420,005 | 1985 |
| Minneapolis | Minnesota | 413,651 | 1989 |
| Tulsa | Oklahoma | 403,090 | 2011[149] |
| Stockton | California | 307,072 | 1980 |
| Anchorage | Alaska | 298,192 | 2008 |

## Pace of adoption across cities:

See below to see how PAYT programs have scaled across in scope cities based on available data (see Table 2 for details).




| | # of cities with innovation in 2014 | # of cities with Innovation in 2017 | Growth Rate |
|---|---|---|---|
| **Pay-as-you-throw*** | 15 | 16 | 7% |

*Excludes Long Beach and Colorado Springs, year implemented not available

It is worthwhile to note that the trend above is not indicative of how PAYT have scaled in all of U.S. This is because PAYT programs have steadily scaled in smaller communities and smaller cities for past two decades, and therefore excluded from the top 83 cities in scope. See Table 3 for details.

Pay-As-You-Throw Table 3. Estimated PAYT Programs across all U.S. from 1980 to 2011

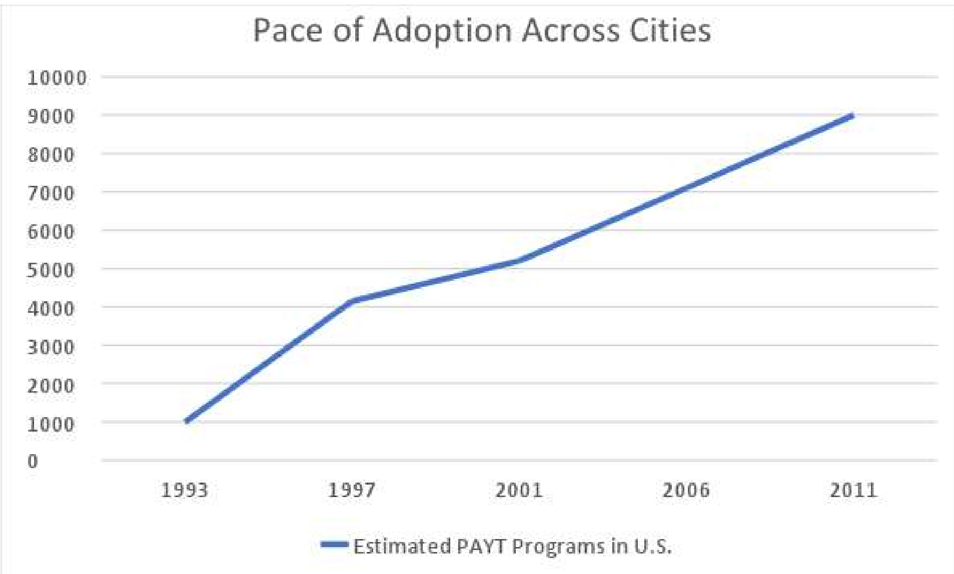
| **Year** | **Estimated PAYT Programs in U.S.**[150] |
|---|---|
| 1980 | 100 (excluded from graph) |
| 1993 | 1000 |
| 1997 | 4150 |

[149] https://www.cityoftulsa.org/trash

[150] https://archive.epa.gov/wastes/conserve/tools/payt/web/pdf/sera06.pdf (except for 2011)

| | |
|---|---|
| 2001 | 5200 |
| 2006 | 7100 |
| 2011 | 9000[151] |

See below to see how PAYT programs have scaled from 1993 to 2011. This data is inclusive of all U.S. cities. While there was an estimated 100 PAYT across the U.S. as of 1980 – there is a lack of data between 1980 and 1993 to assess pace of adoption during that time period. Instead, the starting point is baselined in 1993, with interval data points every 4 to 5 years. PAYT growth rate across all of U.S. between 2006 to 2011 (latest data available) is 26.8% - more than 3 times compared to that of top 83 U.S. cities.




## Regulatory needs:

Regulatory and legislation changes are required to adopt PAYT programs.

## Extent of private marketplace:

Yes, existing private haulers can easily integrate PAYT programs into their current collection services. However, municipalities often implement and execute PAYT programs on their own. Out of the 18 cities, only Colorado Springs rely exclusively on private haulers for waste management.

## Replicability:

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[151] https://www.epa.gov/sites/production/files/2015-09/documents/skumatz.pdf

PAYT is easily replicated – it is quick to implement and demonstrated reduction in municipal solid waste in cities regardless of population size, average income, age, education level.  Effort is required though, to identify pilot community before scaling up citywide.

## Extent of federal or state support:

PAYT programs varied at state support level – they ranged from statewide requirement (Vermont) to widespread adoption (i.e. Rhode Island, Massachusetts, Maine).  Some financial support is available at the state level.

At the federal level, U.S. EPA has an extensive PAYT website that includes toolkits and case studies for city manager.  However, they were last updated on February 21st, 2016 and moved to the archival section. It is unclear what type of federal technical support is available outside of already published information.

# Stormwater Charges

## Innovation:

Stormwater utility is a funding mechanism to effectively manage and operate the infrastructure associated with the stormwater system.

The Clean Water Act mandates cities with population of over 100,000 to comply with the EPA's storm-water regulation in regard to stormwater runoffs flowing into municipal separate storm sewer system (MS4).[152] This causes cities to update their storm-water infrastructure in accordance to the EPA's regulation. Since this is an unfunded mandate, many cities face financial challenges for the operation and maintenance of their storm-water infrastructure and programs. In light of this, many states established a clear statutory authority for local municipal governments to enact and implement storm-water utilities as a funding mechanism for storm-water infrastructure. Storm-water utilities can financially ensure a governing body to provide continuous and sufficient controls, to prevent pollutants caused by storm-water runoffs from discharging into water resources through MS4.[153] Since stormwater utility is dedicated to directly supporting the ongoing operation of stormwater infrastructure, it should be considered as a sustainability innovation.

Fee systems also play an essential part of enacting and implementing storm-water utilities since developing a fair and reasonable fee for all property owners is key to effectively generating revenue for the operation of storm-water systems. There are two major types of fee systems being used for storm-water utilities, the Equivalent Residential Units (ERU), and Tier system. An ERU is usually the average impervious area on a single family residential parcel. Fees for nonresidential properties are proportional to the ratio of the parcel's impervious area to the ERU. A Tier system usually consists of three tiers of parcel size with the largest bearing the highest storm-water charges.[154] The final objective of these two systems is to levy equitable fee to all MS4 users.

## Scale within cities:

The charges are assessed in proportion to a property's contribution to stormwater runoffs. Once a stormwater utility is implemented, all real property with impervious surface will be assessed for the stormwater fee. Stormwater utility has scaled nearly to 100% within cities. Cities from the 83 largest cities that enacted and implemented the storm-water utilities within the past ten years, according to Western Kentucky University Stormwater Utility (WKU-SWU) Survey 2016,[155] are selected for current level of scalability assessment. Subsequently, six cities are identified for assessment on scalability within cities. The assessment indicated that all six identified cities charge storm-water service fees to both residential and non-residential properties. This finding suggested that storm-water charge has scaled near to full capacity within cities. This aligns with the mechanism of storm-water utility in which it ensure each property owners contribute their fair share of money to funding the needed operation of managing

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[152] U.S. Environmental Protection Agency. Storm-water Rules and Notice. https://www.epa.gov/npdes/storm-water-rules-and-notices

[153] NACWA. Navigating Litigation Floodwaters: Legal Considerations for Funding Municipal Storm-water Programs.

[154] Campbell, C. W., Dymond, R. L., and Dritschel, A. Western Kentucky University Storm-water Utility Survey 2016.

[155] Campbell, C. W., Dymond, R. L., and Dritschel, A. Western Kentucky University Storm-water Utility Survey 2016.

and treating storm-water runoffs caused by building's impervious surface. Among the six cities assessed, only the city of El Paso provides an explicit exemption to buildings owned by the federal and state agencies, public institutions of higher education, the Housing Authority of the City of El Paso and independent school districts are exempt, as well as undeveloped lots and agricultural land. Since exemption is granted based on type of ownerships rather than type of buildings, and was found only in one of the six cities assessed; it is not factored in the assessment of the innovation scale within cities.

## Pace of adoption within cities:

Pace of adoption within cities is determined by comparing the types of property assessed at start of implementation and types of property assessed today or most recently. Types of property are categorized into two groups, residential and nonresidential. Cities from the 83 under review that enacted and implemented the storm-water utilities within the past ten years (according to WKU-SWU Survey 2016) are selected for pace of adoption evaluation. Subsequently, six cities are identified to assess the pace of adoption from year of implementation to current level of scale. The subsequent finding indicated that all six cities charge storm-water fees, at the beginning of implementation, to all property types (residential and non residential) connected to MS4 that have an impervious surface area. The innovation will reach near full scale within a year once a city has adopted it, since the storm-water charge is assessed based on usage of storm-water service and tied to property ownership. The table below shows the findings of the six cities assessed.

| Pace of Adoption Assessment | | | | Adoption by Property Type | |
|---|---|---|---|---|---|
| City | State | Fee System | Year Created | Residential* | **Non Residential |
| Baltimore | MD | ERU | 2013 | Yes | Yes |
| Houston | TX | ERU | 2010 | Yes | Yes |
| Nashville | TN | Tier System | 2009 | Yes | Yes |
| St. Louis | MO | Parcel Area | 2008 | Yes | Yes |
| Jacksonville | FL | Tier System | 2007 | Yes | Yes |
| El Paso | TX | Tier System | 2007 | Yes | Yes *** |

*Any property upon which two or fewer single-family residential units have or had been constructed or placed, including manufactured homes.
**All parcels within the City that do not meet the definition of residential. This includes, but is not limited to, commercial parcels, industrial parcels, and parcels owned by non-profit organizations, religious institutions, apartments, and condominiums.
*** Explicit exemption to Federal and state agencies, public institutions of higher education, the Housing Authority of the City of El Paso and independent school districts are exempt, as well as undeveloped lots and agricultural land.

## Scale across cities:

The data obtained from WKU-SWU survey year 2016 were used for identifying cities with adoption. As a result, sixty-five percent of, or 53 out of, 83 cities reviewed were identified adopting the innovation. Among the 53 cities, there are two types of fee systems that are most commonly used; they are the ERU and Tier system. The ERU accounted for 42% of 53 cities reviewed while the Tier system accounted for 38%. This also aligns with the most popular fee system identified in the WKU-SWU Survey 2016. See below tables for comparison.

| **83 Cities Assessed** | | | |
|---|---|---|---|
| **Fee Systems** | **SU** | **%** | |
| ERU | 22 | 42% | Most popular |
| Fixed Rate | 3 | 6% | |
| Tier System | 20 | 38% | Second most popular |
| Residential Equivalence Factor (or similar) | 3 | 6% | |
| Two Level System (Residential/Commercial) | 1 | 2% | |
| Existence of Utility/Fee Verified | 1 | 2% | |
| Fee per Parcel Area | 1 | 2% | |
| Water Meter | 1 | 2% | |
| By Water Usage | 1 | 2% | |
| Cities with SU among 83 cities | 53 | | |
| % Cities with SU among 83 cities | 65% | | |

| **WKU-SWU Survey 2016** | | | |
|---|---|---|---|
| **Fee System** | **SU** | **%** | |
| ERU | 739 | 47% | Most popular |
| Flat | 231 | 15% | Second most popular |
| Tier | 228 | 14% | Second most popular |
| REF | 138 | 9% | |
| Dual | 105 | 7% | |
| Others | 142 | 9% | |
| Total Identified SU | 1583 | | |

## Pace of adoption across cities:

Pace of adoption across cities is determined by identifying the number of cities adopted the innovation for year 2014 and year 2017, or most recent data available. The data obtained from WKU-SWU survey years of 2014 and 2016 were used for identifying cities with adoption. The percentage change (Number of Year 2016/Number of Year 2014 - 1) is used as a growth rate to measure the pace of adoption across cities. The result indicated that sStorm-water utility has experienced zero growth for the past three years from 2014 through 2017 among the 83 cities under review. Fifty-three of the 83 cities have adopted this innovation; the remaining cities not implementing storm-water charge could be due to a lack of clear authority from the state level.

| | # of cities with innovation in 2014 | # of cities with Innovation in 2017 | Growth Rate |
|---|---|---|---|
| **Stormwater Charges** | 54 | 54 | 0% |

## Regulatory needs:

This innovation does not need regulatory change. However, a clearly defined authority for stormwater utility is needed to help city municipalities to enacting stormwater utility.

The Natural Resources Defense Council (NRDC) conducted a survey of all 50 states and found that nearly all states provide municipalities with the legal authority to establish utilities. If authority is unclear, local governments can request an opinion from the state Attorney General for a determination of authority. Once authority is established, the utility will need to enact city ordinances to enable the program and fee. [156]

## Extent of private marketplace:

FCS GROUP, a private consulting firm, provides supports to municipal storm-water utility by developing sustainable, level-of-service-focused funding solutions that support engineering team innovations, green infrastructure goals and stakeholder demands.[157] There are more firms available in the private market such as, Raftelis Financial Consultant, Stormwater Maintenance & Consulting, and Geosyntec Consultants.

## Replicability:

This innovation can be easily replicated if the state has clearly established authority for municipalities to implement storm-water utilities.

## Level of federal or state support:

This innovation enjoys federal (EPA) support in technical and legal aspect.[158] [159] [160] No significant monetary support from the federal or state level, since storm-water charges are meant to be the funding mechanism for storm-water operations.

[156] NACWA. Navigating Litigation Floodwaters: Legal Considerations for Funding Municipal Storm-water Programs.

[157] FCS Group. Storm-water. http://www.fcsgroup.com/sectors/storm-water/

[158] National Association of Flood and Storm-water Management Agencies. Guidance For Municipal Storm-water Funding.

[159] U.S. Environmental Protection Agency. Funding Storm-water Programs.

[160] U.S. Environmental Protection Agency. Storm-water Planning.

# Addendum: District Energy

| | |
|---|---|
| **District Energy System (DES)**: A utility infrastructure where a single energy source serves more than one building. Steam, hot water, or chilled water is produced centrally at a thermal-energy-generating plant and distributed through underground pipes to buildings connected to the system. Many DES have been in operations for decades, and are well suited to meet high density of heat and cooling demand. As a result, they can be found in downtown business districts and college campuses across the U.S.<br>● High capital costs, lack of federal or state mandate, and lack of investment innovation have led to slow adoption<br>● DES upgrade opportunity includes transition to renewable from fossil fuel use, potential benefits included reduced primary energy consumption, GHG emissions, and air pollutions | **TOTAL SCORE**<br>**28** |

| Within Cities | | |
|---|---|---|
| **Indicators** | **Score** | **Rationale** |
| Scale within cities | 4 | DES covered an average of 40% of heating and cooling needs in downtown business districts of the 8 lead cities. |
| Pace of adoption within cities | 1 | It takes from 7-19 years to build a new system or upgrade an existing system. Once the DES built and or upgrade has been implemented, the benefits are immediate. |
| Regulatory needs | 3 | Local ordinance with city council is required to implement a new DES. No state or federal legislation is required. |
| Extent of private marketplace | 5 | A robust private marketplace exists to build, upgrade and run facilities. Over 5 companies operate in this market. Leaders include ConEdison, Enwave, Veolia North America, and NRG Energy. |
| **TOTAL WITHIN CITIES SCORE: 13** | | |

| Across Cities | | |
|---|---|---|
| **Indicators** | **Score** | **Rationale** |
| Scale across cities | 5 | 44.6% of top 83 U.S. cities adopted DES in downtown business districts to generate heating, cooling, or power (when combined with the CHP). |
| Pace of adoption across cities | 4 | DES is a mature innovation. From 2014 to 2017, the growth rate was 4%. |
| Level of federal or state support | 5 | Extensive federal and state support exists in the form of grant and technical assistance. These include within EPA and US Department of Energy. |
| Replicability | 1 | Although district heating and cooling is a well-known legacy technologies, adoption does require high capital costs and state legislation. |
| **TOTAL ACROSS CITIES SCORE: 15** | | |

# District Energy

District energy system (DES) refers to a utility infrastructure where a single energy source serves more than one building. Steam, hot water, or chilled water is produced centrally at a thermal-energy-generating plant and distributed through underground pipes to buildings connected to the system. DES is well suited to meet high density of heat and cooling demand, and as a result has been implemented in downtown business districts and on college campuses across the U.S. DES can also be found serving airports, hospitals, and military sites.

While DES has been operational in the U.S. for more than a century, recent interests have emerged to optimize their energy efficiency by upgrades such as combined heat and power (CHP) – where production of electricity and thermal energy (heating and/or cooling) comes from a single energy source.[161] There is also an opportunity for DES to transition from fossil fuel use to renewable energy source, which can reduce primary energy consumption by 30-50%.[162] Reduction in GHG emissions and air pollutions are also potential benefits.[163]

## Scale within Cities:

For DES to scale up within a city, it needs to increase the number of buildings served. Downtown business district is selected as the larger system because it is 1) commonly found across top cities and 2) preferred location for DES. See Table 1 for the size of system and scale within 8 selected cities.

DES Table 1. Size of the System and Scale Within Cities

| City | Type | # of Buildings (2017 DES) | # of Buildings (2017 Downtown)[164] | % of Buildings (DES) |
|---|---|---|---|---|
| **Boston**[165] | CPH | 152 | 270 | 56.30% |
| **Chicago**[166] | Cooling | 100 | 1,531 | 6.53% |
| **Philadelphia**[167] | CPH | 500 | 666 | 75.08% |
| **Phoenix**[168] | Cooling | 43 | 361 | 11.91% |
| **Pittsburgh**[169] | Cooling,Heating | 59 | 550 | 10.73% |
| **San Diego**[170] | Cooling | 17 | 146 | 11.64% |
| **Seattle**[171] | Heating | 200 | 552 | 36.23% |

161 https://www.energy.gov/eere/amo/combined-heat-and-power-basics

162 http://www.rapidshift.net/district-energy-in-cities/

163 http://staging.unep.org/energy/districtenergyincities

164 https://www.emporis.com/

165 https://www.cityofboston.gov/images_documents/BERDO_rprt_webfinal_tcm3-52025.pdf

166 http://enwavechicago.com/files/enwavechicago/ckfinder/files/DistrictEnergyMagThermalChicago2Q12%20Cover%20Story.pdf

167 http://philadelphia.cbslocal.com/2015/02/18/inside-philadelphia-steam-plant-the-third-largest-utility-in-the-city/

168 http://www.nrg.com/business/large-business/thermal/projects/phoenix/

169 http://apps.pittsburghpa.gov/mayorpeduto/District_Energy_in_Pittsburgh_DOE_Power_Point_AL.pdf

170 http://www.nrg.com/business/large-business/thermal/projects/san-diego/

171 http://enwaveseattle.com/documents/SeattleSteamFAQ.pdf

| | | | | |
|---|---|---|---|---|
| **St. Paul**[172] | CHP,Cooling | 200 | 276 | 72.50% |

The number of buildings served is constrained by the DES capacity; major upgrades are often tied increased capacity. An urban DES typically serves over 50% of the Class A commercial office space in the downtown business district.[173] Philadelphia and St. Paul have scaled the most, with over 70% of buildings in their respective downtown business districts being served by DES.

Once the larger system (the number of buildings) was identified, data was collected to determine two reference point in the DES lifecycle in order to calculate pace of adoption within cities.

## Pace of adoption within cities:

As noted previously, many DES have been in operations for decades. To assess pace of adoption within cities, two reference points were selected to normalize data. The first is Start Year, defined as when DES started to operate regularly, as some of the older DES used to only operate to meet high demand. Second is Recent Upgrade Year, defined as when DES were upgraded to increase capacity. The annualized difference of buildings served between Start Year and Recent Upgrade Year provides the pace of adoption within cities. See Table 2 for details.

DES Table 2. Pace of Adoption Within Cities

| City | Type | Start Year | # of Buildings (Start Year DES) | Recent Upgrade Year | # of Buildings in (Current DES) | # of Buildings (Difference) | # of Buildings/ Year (Difference) |
|---|---|---|---|---|---|---|---|
| Boston | CPH | 2003 | n/a | 2016 | 152 | n/a | n/a |
| Chicago | Cooling | 1995 | 12 | 2002 | 100 | 88 | 12.57 |
| Philadelphia | CPH | 1990 | 400 | 2012 | 500 | 100 | 4.55 |
| Phoenix | Cooling | 2001 | 1 | 2005 | 43 | 42 | 10.50 |
| Pittsburgh | Cooling, Heating | 1983 | 125 | - | 59 | -66 | -1.94 |
| San Diego | Cooling | 1971 | 10 | 1999 | 17 | 7 | 0.25 |
| Seattle | Heating | 1986 | n/a | 2009 | 200 | n/a | n/a |
| St. Paul | CHP Cooling | 1983 | 40 | 2011 | 200 | 160 | 5.71 |

Due to data constraint, analysis for Boston and Seattle cannot be completed. All other cities, except Pittsburgh, have updated their DES in past two decades to increase capacity. The pace in which DES has

[172] http://www.ever-greenenergy.com/project/district-energy-st-paul/

[173] Robert P. Thornton, (August 5 2017) IDEA Report: The District Energy Industry", International District Energy Association, http://www.saclafco.org/Meetings/Documents/2009/september/sac_019986.pdf

been adopted within cities ranged from 0.25 to 12.57 buildings per year. There is no correlation between time of upgrade and pace of adoption.

Pittsburgh Allegheny County Thermal (PACT), serving Pittsburgh's downtown, is the only DES from selected cities without an upgrade since its implementation in 1983.[174] Its capacity is engineered to support 300 users, or buildings. At time of implementation, it served 125 buildings. That number has steadily dropped to 59 as building owners choose to install newer technologies during renovations.[175]

## Scale across cities:

44.6% (37 cities) of the cities under review have adopted DES in downtown business districts. Implemented systems included either heating, cooling, both, or CHP.

DES Table 3. Cities from Top 83 Cities that Adopted DES and Start Year

| City | Population | Start Year | City | Population | Start Year |
|---|---|---|---|---|---|
| New York | 8175133 | 1882 | Las Vegas | 632,912 | 2000 |
| Los Angeles | 3,976,322 | N/A | Baltimore | 614,664 | 1996 |
| Chicago | 2,704,958 | 1995 | Milwaukee | 595,047 | N/A |
| Houston | 2,303,482 | 1999 | Tucson | 530,706 | 2004 |
| Phoenix | 1,615,017 | 2001 | Kansas City | 481,420 | N/A |
| Philadelphia | 1,567,872 | 2012 | Atlanta | 472,522 | N/A |
| San Antonio | 1,492,510 | N/A | Miami | 453,579 | 1984 |
| San Diego | 1,406,630 | 1999 | Omaha | 446,970 | 2003 |
| Jacksonville | 880,619 | 2005 | Minneapolis | 413,651 | 1972 |
| San Francisco | 870,887 | N/A | Tulsa | 403,090 | N/A |
| Indianapolis | 855,164 | 2011 | New Orleans | 391,495 | 1999 |
| Seattle | 704,352 | 1986 | Cleveland | 385,809 | 1894 |
| Denver | 693,060 | N/A | St. Louis | 311,404 | 1904 |
| Washington | 681,170 | 1934 | Pittsburgh | 303,625 | 1999 |
| Boston | 673,184 | 2006 | Saint Paul | 302,398 | 1983 |
| Detroit | 672,795 | 1903 | Henderson | 292,969 | N/A |
| Nashville | 660,388 | 1974 | Lincoln | 280,364 | 1989 |

[174] http://apps.pittsburghpa.gov/mayorpeduto/District_Energy_in_Pittsburgh_DOE_Power_Point_AL.pdf
[175] http://www.post-gazette.com/business/businessnews/2013/02/14/Is-Downtown-Pittsburgh-heat-system-losing-steam/stories/201302140473

| | | | | | |
|---|---|---|---|---|---|
| Portland | 639,863 | 2017 | Orlando | 277,173 | 1997 |
| Oklahoma City | 638,367 | N/A | | | |

## Pace of adoption across cities:

Figure 1 shows how DES have scaled across downtown business districts in top 83 U.S. Cities, where X-axis represents decade and Y-axis represents number of DES, based on available data (see DES Table 3 for details).

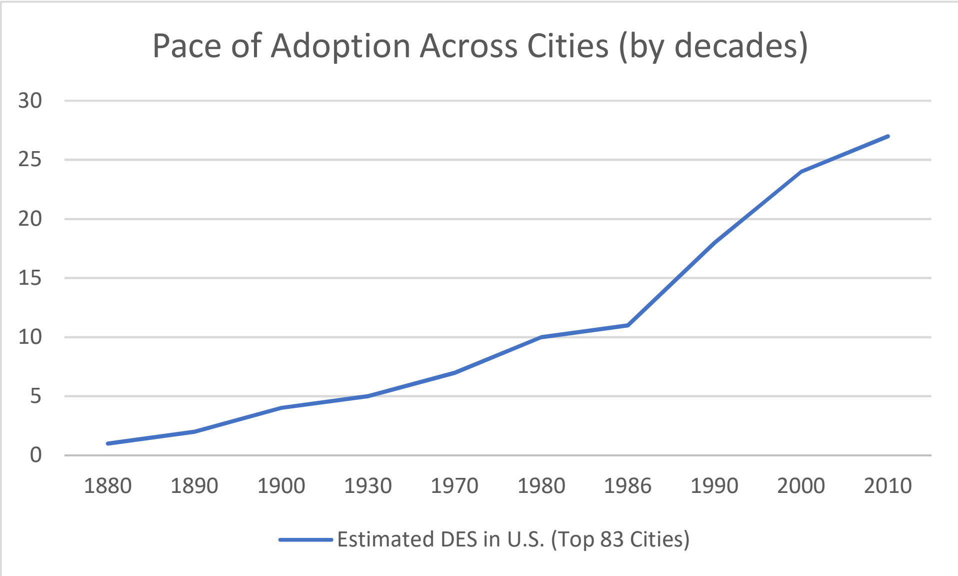


Figure 1: DES Pace of Adoption Across Cities (by decade)

Throughout the years, upgrades to the older DES have been made to improve their energy efficiencies. In recent years, upgrades also included transition of energy source from fossil fuel to renewable. Its centralized maintenance and potential utilization of renewable energy resources are recognized as more sustainable than individual building systems. Because DES upgrades increase its capacity to serve the larger system, they have been included in the pace of adoption along with new DES implementations.

| | # of cities with innovation in 2014 | # of cities with Innovation in 2017 | Growth Rate |
|---|---|---|---|
| District Energy System (DES) | 26 | 27 | 4% |

*Excludes 10 cities, start year not available (see Table 3 for details)

However, the growth rate in the past twenty years are relatively slow. See below how DES (including upgrades) have scaled across downtown business districts of in scope cities by year based on available data from 1997 to 2017 (see Table 3 for details)

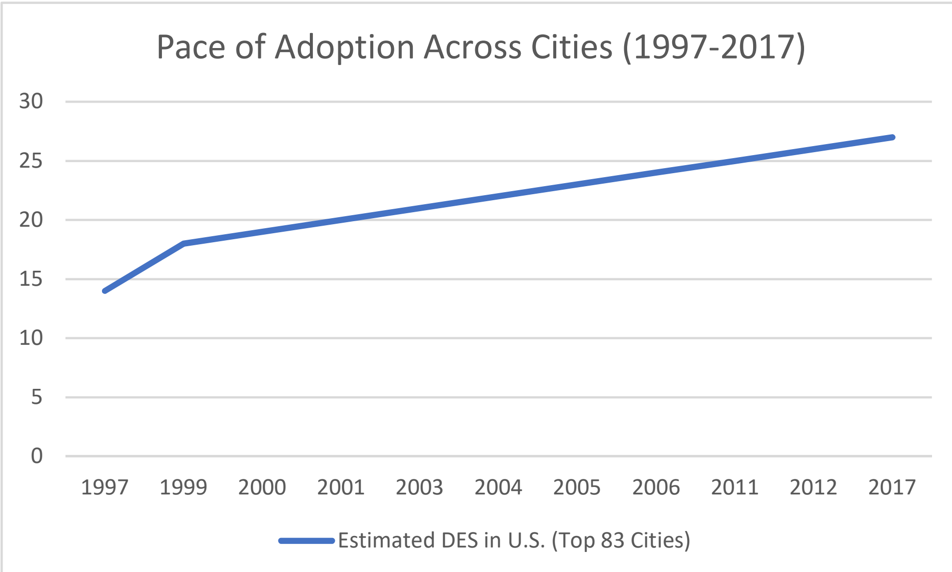


Figure 2: DES Pace of Adoption Across Cities from 1997 to 2017

DES are scaling very slowly because upfront capital is high at the initial stages. Besides construction of thermal-energy-generating plant and distribution network, additional costs are expected for business development, design, and contract work. The payback period is significantly longer compared to most real estate investments. In addition, there is a knowledge gap on how to compare DES to existing individual systems; this has impeded decision makers to fully understand the potential value of DES on energy efficiency, building square footage saved, positive environmental impact, and financial benefits. Finally, there is little to no incentives from the U.S. government to develop DES.[176]

To achieve scale, stakeholders such as federal & state agencies, local municipalities, real estate developers, and building owners need to be educated on DES benefits. Because U.S. building codes and design protocols for energy use are for single buildings, architects and developers have not been encouraged to think about surrounding communities. This institutionalized approach can be updated in professional studies such as architecture schools or LEED training programs.[177]

[176] Steve Tredinnick, Syska Hennessy Group; Madison, Wis. (Jun 07, 2013). Why District Energy is Not More Prevalent in the USA? http://www.hpac.com/heating/why-district-energy-not-more-prevalent-us

[177] Steve Tredinnick, David Wade, Garry Phetteplace "District Energy Enters The 21st Century" Ashrae Journal, July 2015

## Regulatory needs:

Yes, local ordinance with city council is required to implement a new DES.[178] No state or federal legislation is required. However, industry leaders have considered the benefits of state energy policy that 1) provides authority to city leaders to mandate DES for building owners or 2) provide financial incentives for DES development.[179]

## Extent of private marketplace:

Yes, a handful of companies have been in the market for decade and have continuously developed their DES solutions. The leading companies are Enwave, Veolia North America, NRG Energy, and DE St. Paul Inc. For instance, Veolia North America has developed Green Steam, where old systems are retrofitted to produce "green steam" using clean fuels and saved waste heat. DE St. Paul Inc., which operates in St. Paul, successfully transitioned its DES to renewable energy sources (i.e. biomasses, solar) from fossil fuel.

## Replicability

DES is not easy to replicate. First, it is a capital-intensive innovation. Capital costs vary depending on type of energy provided, system capacity, fuel sources, and size of distribution network – which can range from millions to billions of U.S. dollars.

Second, return on investment is somewhere between twenty to fifty years, depending on scope. Financial institutions and real estate developers are likely looking for faster returns.

## Level of federal or state support:

While federal or state funding is not directly available for DES, it qualifies for a number of funds that supports energy efficiency. They are as follows: Emerging CDFI fund, Department of Energy's State Energy Program EERE fund, EPA's Clean Energy Financing Program.[180]

At the city level, DES qualifies for: Funds TIF for redevelopment areas, City Appropriations Community Development Block (CDBD) Grants, qualified energy efficiency bond (OEBCB)[181]

Technical support on how to develop DES is also provided by EPA.

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[178] https://chicago.legistar.com/ViewReport.ashx?M=R&N=Text&GID=106&ID=1736035&GUID=ABDBAB88-EDDB-41DF-A65D-9D5693FF064E&Title=Legislation+Text

[179] https://www.ashrae.org/File%20Library/docLib/eNewsletters/Tredinnick--072015--6012017Feature.pdf

[180] EPA Office of Sustainable Communities Smart Growth Program "District-Scale Energy Planning: Smart Growth Implementation Assistance to the City of San Francisco" https://www.epa.gov/sites/production/files/2015-06/documents/sf_district_energy_planning.pdf

[181] Karl F. Seidman and Drew Pierson, "Financing Urban District Energy Systems, Trends and Policy Implications for Portland" Page 16, January, 2013 http://web.mit.edu/colab/gedi/pdf/Financing%20District%20Energy/DES_report.pdf

# Appendix 1: Scoring

Each indicator was scored. Scoring allowed innovations to be ranked against each other based on their current state of scalability and adoption hurdles. Each quantitative indicator was scored from one to ten. Each qualitative indicator was scored from one to five. The indicator scores were then summed resulting in a final score for each innovation. An innovation can earn a maximum score of sixty. The highest score indicates that the innovation has been adopted widely across the United States, has reach maturity in at least eight cities, and currently enjoys enough support to allow for easy adoption.

## 1. Scale of adoption within cities:

| Score | Scale of adoption within cities |
|---|---|
| 10 | 91-100% |
| 9 | 81-90% |
| 8 | 71-80% |
| 7 | 61-70% |
| 6 | 51-60% |
| 5 | 41-50% |
| 4 | 31-40% |
| 3 | 21-30% |
| 2 | 11-20% |
| 1 | 0-10% |

## 2. Pace of adoption within cities:

| Score | Pace of adoption within cities |
|---|---|
| 10 | Immediate |
| 9 | |
| 8 | 1-2 years |
| 7 | |
| 6 | 3-4 years |
| 5 | |
| 4 | 5-6 |
| 3 | |
| 2 | |
| 1 | 7+ years |

## 3. Scale of adoption across cities:

| Score | Scale of adoption across cities |
|---|---|
| 10 | 91-100% |
| 9 | 81-90% |
| 8 | 71-80% |
| 7 | 61-70% |
| 6 | 51-60% |
| 5 | 41-50% |
| 4 | 31-40% |
| 3 | 21-30% |
| 2 | 11-20% |
| 1 | 0-10% |

## 4. Pace of adoption across cities:

If an innovation had already received a 10 for scale of adoption across cities, then it was given a 10 for pace of adoption across cities. For all other innovations, scores were assigned according to the following table:

| Score | Pace of adoption across cities |
|---|---|
| 10 | 91-100% |
| 9 | 81-90% |
| 8 | 71-80% |
| 7 | 61-70% |
| 6 | 51-60% |
| 5 | 41-50% |
| 4 | 31-40% |
| 3 | 21-30% |
| 2 | 11-20% |
| 1 | 0-10% |

## 5. Regulatory needs:

| Score | Regulatory needs |
|---|---|
| 5 | None needed. |
| 4 | |
| 3 | Yes, but easy to pass. |
| 2 | |
| 1 | Yes, multiple policy changes needed; significant barrier. |

## 6. Extent of private marketplace:

| Score | Extent of private marketplace |
|---|---|
| 5 | Yes, significant grant and technical support is easily accessible. |
| 4 | |
| 3 | Yes, private marketplace exists but not fully developed. |
| 2 | |
| 1 | Non-existent. |

## 7. Replicability:

| Score | Replicability |
|---|---|
| 5 | Easy 'out-of-the-box' adoption possible. |
| 4 | |
| 3 | Some tailoring needed but not significant barrier. |
| 2 | |
| 1 | Requires significant adaptation to each environment. |

## 8. Level of federal or state support:

| Score | Level of federal and state support |
|---|---|
| 5 | Yes, significant financial and technical support. |
| 4 | |
| 3 | Yes, some support but not substantial |
| 2 | |
| 1 | None. Cities must act independently. |

# Appendix 2: List of Cities Within Scope of Study

| 2016 Rank | City | State | 2016 Estimate |
|---|---|---|---|
| **1** | New York | New York | 8,537,673 |
| **2** | Los Angeles | California | 3,976,322 |
| **3** | Chicago | Illinois | 2,704,958 |
| **4** | Houston | Texas | 2,303,482 |
| **5** | Phoenix | Arizona | 1,615,017 |
| **6** | Philadelphia | Pennsylvania | 1,567,872 |
| **7** | San Antonio | Texas | 1,492,510 |
| **8** | San Diego | California | 1,406,630 |
| **9** | Dallas | Texas | 1,317,929 |
| **10** | San Jose | California | 1,025,350 |
| **11** | Austin | Texas | 947,890 |
| **12** | Jacksonville | Florida | 880,619 |
| **13** | San Francisco | California | 870,887 |
| **14** | Columbus | Ohio | 860,090 |

| | | | |
|---|---|---|---|
| **15** | Indianapolis | Indiana | 855,164 |
| **16** | Fort Worth | Texas | 854,113 |
| **17** | Charlotte | North Carolina | 842,051 |
| **18** | Seattle | Washington | 704,352 |
| **19** | Denver | Colorado | 693,060 |
| **20** | El Paso | Texas | 683,080 |
| **21** | Washington | District of Columbia | 681,170 |
| **22** | Boston | Massachusetts | 673,184 |
| **23** | Detroit | Michigan | 672,795 |
| **24** | Nashville | Tennessee | 660,388 |
| **25** | Memphis | Tennessee | 652,717 |
| **26** | Portland | Oregon | 639,863 |
| **27** | Oklahoma City | Oklahoma | 638,367 |
| **28** | Las Vegas | Nevada | 632,912 |
| **29** | Louisville | Kentucky | 616,261 |
| **30** | Baltimore | Maryland | 614,664 |

| | | | |
|---|---|---|---|
| **31** | Milwaukee | Wisconsin | 595,047 |
| **32** | Albuquerque | New Mexico | 559,277 |
| **33** | Tucson | Arizona | 530,706 |
| **34** | Fresno | California | 522,053 |
| **35** | Sacramento | California | 495,234 |
| **36** | Mesa | Arizona | 484,587 |
| **37** | Kansas City | Missouri | 481,420 |
| **38** | Atlanta | Georgia | 472,522 |
| **39** | Long Beach | California | 470,130 |
| **40** | Colorado Springs | Colorado | 465,101 |
| **41** | Raleigh | North Carolina | 458,880 |
| **42** | Miami | Florida | 453,579 |
| **43** | Virginia Beach | Virginia | 452,602 |
| **44** | Omaha | Nebraska | 446,970 |
| **45** | Oakland | California | 420,005 |
| **46** | Minneapolis | Minnesota | 413,651 |
| **47** | Tulsa | Oklahoma | 403,090 |

| | | | |
|---|---|---|---|
| **48** | Arlington | Texas | 392,772 |
| **49** | New Orleans | Louisiana | 391,495 |
| **50** | Wichita | Kansas | 389,902 |
| **51** | Cleveland | Ohio | 385,809 |
| **52** | Tampa | Florida | 377,165 |
| **53** | Bakersfield | California | 376,380 |
| **54** | Aurora | Colorado | 361,710 |
| **55** | Honolulu | Hawaii | 351,792 |
| **56** | Anaheim | California | 351,043 |
| **57** | Santa Ana | California | 334,217 |
| **58** | Corpus Christi | Texas | 325,733 |
| **59** | Riverside | California | 324,722 |
| **60** | Lexington | Kentucky | 318,449 |
| **61** | St. Louis | Missouri | 311,404 |
| **62** | Stockton | California | 307,072 |
| **63** | Pittsburgh | Pennsylvania | 303,625 |
| **64** | Saint Paul | Minnesota | 302,398 |

| | | | |
|---|---|---|---|
| **65** | Cincinnati | Ohio | 298,800 |
| **66** | Anchorage | Alaska | 298,192 |
| **67** | Henderson | Nevada | 292,969 |
| **68** | Greensboro | North Carolina | 287,027 |
| **69** | Plano | Texas | 286,057 |
| **70** | Newark | New Jersey | 281,764 |
| **71** | Lincoln | Nebraska | 280,364 |
| **72** | Toledo | Ohio | 278,508 |
| **73** | Orlando | Florida | 277,173 |
| **74** | Chula Vista | California | 267,172 |
| **75** | Irvine | California | 266,122 |
| **76** | Fort Wayne | Indiana | 264,488 |
| **77** | Jersey City | New Jersey | 264,152 |
| **78** | Durham | North Carolina | 263,016 |
| **79** | St. Petersburg | Florida | 260,999 |
| **80** | Laredo | Texas | 257,156 |
| **81** | Buffalo | New York | 256,902 |

| | | | |
|---|---|---|---|
| **82** | Madison | Wisconsin | 252,551 |
| **83** | Lubbock | Texas | 252,506 |

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