Smart Buildings Plan Project

FY 2014 Green Building Fund Grant
Technical Report

Provided for:

District Department of Environment (DDOE)

DISTRICT DEPARTMENT OF THE ENVIRONMENT

Smart Buildings Plan Project

FY 2014 Green Building Fund Grant

Technical Report

Provided by:

Roger Frechette, PE, **Interface Engineering**

Ladan Ghobad, PhD, **Interface Engineering**

Patty Rose, **Greenspace, NCR**

September 2014

INTERFACE ENGINEERING

greenspace NCR

List of Contents

Project Summary

Project Detail

Action Plan

Appendix

Project Summary

Vision

District of Columbia is a beautiful evolving and livable city. However, the energy required to sustain the life of a large modern city is massive and largely invisible. As one walks up and down the streets of our fine city, it is not apparent to the observer the amount of natural resources that are required to sustain the daily operations of our built environment. Those who own office buildings and residential property in the city may know how much electricity, gas and water their buildings consume, but currently there are no easily accessible tools to compare their buildings to those of their neighbors or, even more importantly, use that information and other data to make our use of those resources more efficient. Our vision is to have an interface that allows both professionals and resident users with the ability to understand, and as a consequence of that understanding, improve those resource flows of sources such as energy and water in the District of Columbia.

The Smart Buildings Plan is based on the simple premise that by providing a digestible and easily understood measuring stick for the District's energy consumption, profile behaviors can be altered, intervention can be designed for maximum effect, and improved performance can be achieved. The idea is to create a tool that allows building owners, policy makers and interested citizens to view the city though new lenses.

This tool will give District residents, policy makers, and the private sector the ability to understand how energy moves, and the relevant difference between buildings, neighborhoods and wards. Not only will we be able to see the city in a new light, this model will have the ability to anticipate the likely impact of future changes. The impact of code changes, policy changes, densification, height restriction changes, environmental changes, new development and technology roll-outs can be predicted beforehand, giving the decision makers from the public, private and nonprofit sectors the information they need to consider such changes, bringing some clarity to the movement of energy throughout the city.

The "City Model," similar to a computer's operating system, could have "Solution Applications" with interactive graphic user interfaces specifically designed for target audiences and a range of needs they have. We envision this tool would be equipped with several "Solution Applications," each providing a view from a different vantage point. For example, an application, providing the general public with an ability to see the flow of energy within the city may inspire those individuals to change habits, change behaviors and to become engaged in the necessary actions which are and will be required to reduce our great city's appetite for energy. In this report we will explain the initial Solution Application that meet the District Department of the Environment (DDOE) and city administration's desire to increase efficacy of policies, improve buildings performance and enhance public awareness about energy/water efficiency.

When a pharmaceutical company develops a new drug that they are certain will eliminate disease and save lives, there must be tremendous desire to offer the drug to the general population immediately. However, that would not be a responsible process. In the medical industry, a process of "Clinical

Trial" has been developed to ensure the drug will work on a smaller 'control' group before the mass distribution can take place and the greater population can benefit. In this report, we will explains a "plan of action" to identify and engage and analyze a cooperative sample of buildings to be included in the "Clinical Trial." The in depth analysis of this sample will lay the groundwork for the Smart Buildings Plan and develop the 'City Model' into an optimized tool.

The 'brain' of the tool is referred to herein as the Analytical City Modeling Engine (ACME). The ACME is similar to the Central Processing Unit (CPU) of a computer and will have the ability to assess known data from measured and modeled buildings and extrapolate that data to predict the performance of similar structures throughout the city. Data related to the building stock within the District currently exists in many forms. The intent is to create a "Reconciled Database" from buildings' "Biometric" data, manually inputted "Static" data, and to have the ability to receive "Dynamic" data, transmitted real-time, from "smart meters" installed in functioning buildings around the city (see figure 1). In addition, the aim is to create "Energy Models" for each building that participates in the "Clinical Trial," and then relate, connect, and reconcile different formats of data captured from the buildings. The data from the Clinical Trial is then extrapolated through the rest of the building stock in the city to reflect performance of the city as a whole. Once this city-wide database is established, the ACME model will then be able to predict the likely energy impact to a variety of possible changes.

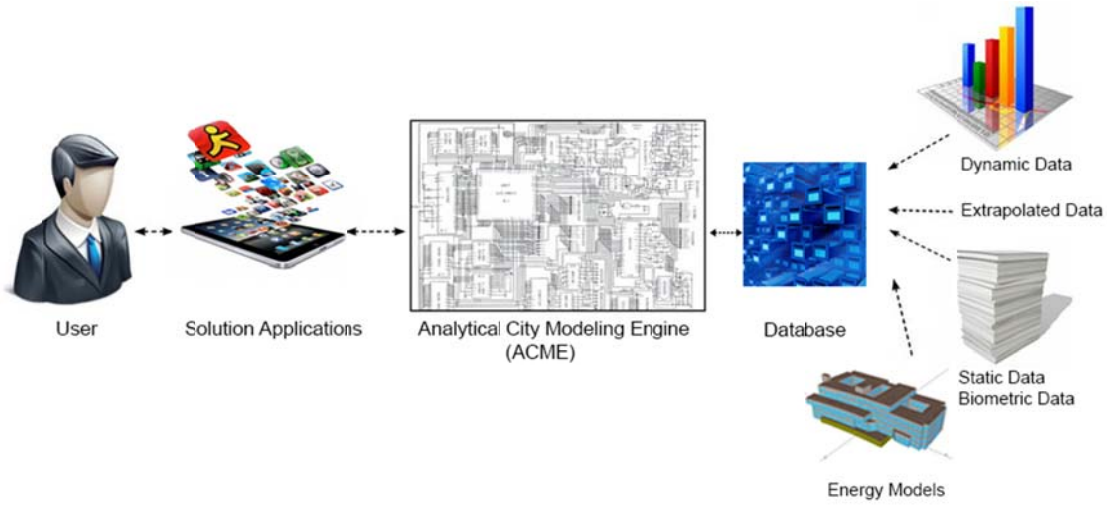


Figure 1 the District City Model

Target Audience and Mission

Policy Makers: to transform policy-making through the collection and analysis of buildings actual data and to facilitate the city administration's ability to improve energy, water, and waste outcomes and to assist them in predicting the impact changes in policies, codes, environmental resource management and adoption of new technologies can have in their rapidly changing urban environment.

The Public: to educate the citizens about the city's buildings' carbon footprint and consumption of natural resources, to build their interest in and give access to efforts to reduce buildings negative impact on the environment and encourage feelings of responsibility for the city's buildings' performance.

Goals

The goal is to develop of a dynamic, analytic, and educative platform that will support the city administration of the District of Columbia in its steps towards the goals of the 2032 Sustainable DC Plan to have the greenest, healthiest, and most livable city in the nation. This proposal suggests a plan of action for the development of smart buildings data tracking and analysis platform, called City Model; a three-dimensional, user-friendly web-based tool which is highly interactive via web applications tailored for different audiences that can address various needs and interests. The goal is to create a tool that has the following capabilities:

- Display current situation of all buildings in terms of consumption of environmental resources
- Gauge environmental impact of changes in urban scale
- Anticipate the positive and negative impacts associated with specific proposed changes
- Predict success or failure of policies to reach intended natural resource management and climate change outcomes
- Platform able to be updated and upgraded to add new features and capabilities.

Outcomes

- Data tracking over time
- Transparency of government operations and decision-making
- Stories that illustrate benefits of new approaches, policies and practices
- Testing the efficacy of policy changes
- City-wide improvements in energy efficiency and carbon footprint reductions
- More effective policies made based on analysis of data derived from the City Model, policies which are tested in advance to ensure positive environmental and economic impacts on the city
- Energy retrofits translated into economic gains
- Actions increased as a result of informed, inspired and competing building owners
- Economic gains associated with the development of new solution applications
- Green job creation in the IT, manufacturing, design and construction sectors

- Economic gains associated with the sale of telemetry components (smart grid infrastructure)
- Young residents and new businesses are attracted to Green-D.C. generating economic development advantages for the city
- Savings and reduced risks for building owners who can easily obtain reliable information without paying for exhaustive analysis

Scope

The ultimate goal of tracking data and developing a tool for analysis is the ability to support a sustainable and smart city. This plan suggests creating a fundamental framework that is an evolving tool with capabilities to evolve over time.

Development of the City Model is similar to the evolution of computer software programs such as Autodesk's AutoCAD. The first generation of AutoCAD had basic functionalities such as drawing basic 2D geometric shapes, copy, and edit. The next generations of the tool continued to develop more advanced capabilities, finally allowing for the creation of complex 3D geometric shapes.

For the City Model, we envision two versions, the Core Version and Full Version which allow for different degrees of usability.

1. Core Version (CV)
    - DDOE Edition
    - Business Edition

The Core Version of the City Model includes energy and water data for the District buildings. This version of the City Model has two editions for DDOE application and business applications. The DDOE Edition has only those core features that allow the model to be deployed as quickly and efficiently as possible by DDOE for policy making purposes. The goal is also to respond to DDOE's requests for a high functioning program that can be deployed with the minimum budget possible. The DDOE Edition of the City Model has a simple interactive graphic user interface for DDOE and city administration that allows them to view a 3D model of the city, filter, test and analyze data and view graphic reports. The database is publically accessible in this edition and it is developed with open source software that could be used by any interested individual.
The Business Edition of the City Model's Core Version targets business owners. The basic database is expanded and enhanced in the Business Edition so that it could be used by businesses for purposes such as manufacturers or vendors of building construction materials and engineering systems. The Business Edition has more detailed energy models and more accurate extrapolation engine than DDOE Version since it includes more information such as building age, last year of renovation, construction type and etc. (read more details in "Creating the Database- Energy Models" and "Analytical City Modeling Engine- Extrapolation Process)."

The increased functionality of the Business Edition could provide opportunities for income generation. Computer programmers and application developers could develop innovation applications in this

version such as an application for buildings mechanical systems. Such application would be interesting for manufacturers of buildings' mechanical equipment because the application reveals type and age of the mechanical equipment in buildings and it could highlight all the buildings with old furnace or chiller that needs replacement. This is only an example of unlimited number of applications for the City Model's platform to respond to questions related to building properties, construction materials, engineering system, and performance in terms of energy/water consumption, and its relation to the city and the environment. The solution applications would be useful for a business owner, researcher, manufacturer or a product vendor.

2. Full Version (FV)

The Full Version of the District's City Model would include a comprehensive list of sustainability outcomes:

- renewable energy
- indoor air quality
- cool roofs
- green roofs
- permeable surfaces
- water collection and reuse
- waste disposal and recycling
- building materials
- transportation

The comprehensive nature of the City Model FV should be thought of like an existing iPhone application such as RIDESCOUT which provides users with all transportation options such as car, taxi, bus, metro, bike, and walking with their estimated time, cost, and even calories consumed to get you from point A to B. The City Model FV would include sustainability data from various sources such as MapDwell, the District's Green Dashboard, USGBC's GBIG DC Map, Green Up! DC and DC Green Map and it allow for new applications to continue to add data sources, continually enriching the tool.

In addition, the City Model FV could work with economic and social data of the building owners/occupants in the District. Combining economic data (e.g. tax or income of a building owner) with social data (e.g. age and level of education of the owner) and overlaying them on top of energy/water consumption data could generate a crucial database used to predict socio-economic impact of environmental changes which could aid in city planning and development.

The Full Version could be segmented into publicly accessible components and those that are available for purchase by business owners and software developers.

Project Detail

Approach, Purpose, and Objectives

Approach: A City is a highly complex entity to replicate and study. We suggest an approach that is likened to a "Clinical Trial" process in the medical industry to create the City Model. Essentially, by conducting a comprehensive study of select and diverse collection of buildings and understanding the associated cause and effect of policy and technological changes an extrapolation method can be applied allowing us to model probable outcome of such changes on city-wide scale. The scope of the FY2014 work was largely dedicated to the organization, planning and scoping required to develop the "City Model" with the intent of beginning work on it in FY2015.

Purpose: To create a plan for creating the City Model: defining the tasks, team and estimate of the budget required.

Objectives: Develop a plan for the City Model that uses an "Analytical City Modeling Engine" (ACME), data from the "Reconciled Database" (a library of measured and modeled data from the buildings included in the "Clinical Trial") and extrapolation of this data to apply to all other buildings the "City Model" in order to test and present policy and building management results through web-based applications customized for target audiences. Figure 2 shows how the components of the District City Model are related to each other.

The City Model will start with the Core Version (CV) and a future version will upgrade to the Full Version (FV) with expansive capabilities and functionalities.

The DDOE Edition of the City Model CV aims to:

- Identify locations where energy and water usage has higher consumption levels per unit of area compared to an average building of the same occupancy type in the District of Columbia.
- Prioritize Sustainable DC Plan 2032 goals to reduce energy use by 50%, water use by 40% and waste by 15%.
- Test "what-if" scenarios and anticipate impact of changes such as policy decisions (e.g. energy codes), intensify renewable technology adoption (e.g. Photovoltaic panels), behavior or performance changes (e.g. reduce lighting power density) in buildings in the District. The City Model will define environmental implications of policy, technology, and behavior changes and it will specify how much the changes contribute to desired outcomes for environmental and economic energy impacts.
- Target buildings, neighborhoods, zip codes, and wards that will most significantly benefit from the funds invested.
- Define the impact of climate change on our energy and water consumption levels.

The Business Edition of the City Model CV will expand on the platform above and provide more detailed answers regarding energy and water consumption in the city's buildings. The Business Edition aims to:

- Prioritize strategies based on end-use energy usage (e.g. focus on space heating, cooling, lighting, or water heating)
- Define building types, building ages, construction types, and façade materials to target for reaching the maximum performance improvement.

The Full Version of the City Model, with additional layers of economic and social data, aims to:

- Test environmental implications of changes in policy, technology, behavior or operation of a building. (i.e. reductions in energy and water consumption and carbon emissions)
- Articulate economic implications of changes in policy, technology, behavior or operation of a building.
- Evaluate the cost associated with implementing changes, and specify Return on Investment, and perform life-cycle analysis.
- Identify direct economic activity and job creation brought to the city and its residents.
- Anticipate level of acceptance of a new policy, technology, behavior change by understanding the socio-economic status of building owners/occupants.
- Locate the existing and ongoing sustainability projects/measures in the city.

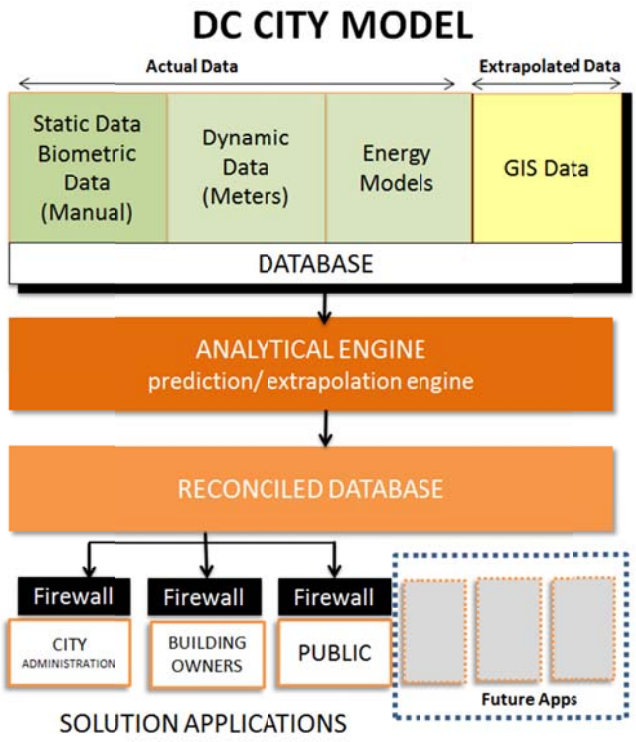


Figure 2 the District's City Model Components

Value Proposition

The DDOE Edition: In addition to its functionality, the value of the DDOE edition rests with the "reconciled database" including the biometric data of District buildings. The database is reliable as it is created by connecting, relating and comparing three types of data: static, dynamic, and energy model outputs. The database is inclusive as it uses an extrapolation engine to reflect performance of all buildings in the City. This database has the capability of prediction and testing "what-if" scenarios while others do not. Alternatives of the "reconciled database" include:

1. A national database that is not specific to the District and it is old data from 2003. ENERGY STAR Target Finder and Portfolio Manager use CBECS data as their main database.
2. *Benchmarking:* The District Benchmarking reports are limited to buildings 50,000 sf and larger and currently only data for the District's public buildings has been made publicly available. A challenge with the benchmarking data is that it is not refined and has not yet been validated. However, DDOE has ongoing projects and has executed a grant to assure the quality of the District Benchmarking data, so that this will continue to improve as a reliable data source. Furthermore, there is not a graphic user interface for users to filter and analyze benchmarking data.

The City Model's database would be the most current, relevant, accurate, connected and transparent database related to energy/water and overall sustainability in the District. Major values of the "reconciled database" of the City Model's Core Version for DDOE application include:

- Combined Building Biometrics: data about building properties and characteristics (e.g. building address, area, ownership and etc.) are extracted from various sources.
- Quality: Reconciliation of static data, transmitted dynamic data, and calculated energy models for the Clinical Trial generate a database with high quality.
- Timely: the database gets automatic updates from the buildings by accepting dynamic (real-time) data from buildings. Connectivity of the platform to the city buildings reflects supply and demand in real-time.
- Transparency: the database would be an open-source database with transparency at building-level.
- Flexibility: the platform allows expanding the Clinical Trial by adding new participants and improving the extrapolation engine by adding new types of data to match buildings in the Clinical Trial to all city buildings.
- Uniqueness: No other organization has generated similar databases as we are proposing in this plan.

The Business Edition: The expanded and comprehensive "reconciled database" in the Business Edition of the City Model, provides the most reliable data about real energy/ water consumption for buildings in The District. Major values of this database are:

- Comprehensive Building Biometrics: a comprehensive library of biometric data of the District buildings including occupancy type, last year of renovation, materials,

and engineering systems. The database is created by accepting and connecting data that is captured from various open-access sources (e.g. GIS data) of information and data that is collected via site visits or questionnaires from building owners or facility managers (e.g. building mechanical and electrical systems).

- Increased quality: detailed investigation and analysis of building performance for the Clinical Trial buildings creates a high-quality database.
- Detailed energy modeling: performance data that include buildings construction and mechanical systems that could predict future changes (i.e. building retrofits, behavior or operation change and etc.)
- Accurate Extrapolation Engine: the extrapolation engine is more accurate in the Business Edition than DDOE Version since it includes more information such as building age, last year of renovation, construction type and mechanical systems to extrapolate data from the Clinical Trial to the whole city.

The City Model Business Edition offers multiple investment opportunities. One of the crucial investment opportunities of the Business Edition is for application developers. The "reconciled database" of the City Model is comparable to a smart phone or tablet, creating a platform for new application development. Groups of computer programmers and app developers could be brought together in Hackathons, Codeathons, and technology incubators to brainstorm applications for the City Model's "reconciled database." This creates opportunities for the city to support start-up companies and the creation of green jobs. The resulting economic stimulus and financial opportunities for the city will reinforce its values as laid forth in the Sustainable DC Plan.

Future solution applications could be unlimited and applications could be designed to answer specific questions from a wide range of audiences such as

1. Product manufacturers and vendors
2. Technology Companies such as Google, Autodesk, etc.
3. Academia, Researchers, National Labs
4. Utility Companies, including:
    - Pepco
    - Washington Gas
    - DC Water
    - Federal Entities
5. Green Infrastructure suppliers and installers: smart grid, CHP (District Heating/Steam), off-site solar or wind energy
6. EcoDistricts developers and community stakeholders
7. Venture Capitalists
8. Real Estate Companies
9. Private Foundations
10. Appraisal, insurance and investment.

Literature Review

Big Data Sources

In order to become a more efficient and sustainable place, the District of Columbia needs an assessment of the building data sources that are currently available through free public data, "Big Data", sources. First, we focus on national data sources that contain information about buildings energy consumption and then we elaborate on the District's data sources in this chapter.

National Data Sources

CBECS/ RECS

Conducted by the Energy Information Association (EIA), the Commercial Buildings Energy Consumption Survey (CBECS) is a national sample survey that collects information on the stock of U.S. commercial buildings, including their energy-related building characteristics and energy usage data (consumption and expenditures). Commercial buildings include all buildings in which at least half of the floor space is used for a purpose that is not residential, industrial, or agricultural. [1]

CBECS database contains building-level data for every four years in 1999, 2003, 2007 (not published due to statistical errors), and 2011 (suspended due to budget cuts) and CBECS 2003 continues to be the most reliable source for building energy data. The 2003 CBECS estimated that there were 4.9 million commercial buildings in the US. Because it would be completely impractical and prohibitively expensive to interview all 4.9 million buildings, the Energy Information Administration (EIA) uses a statistical sample that is designed to represent the entire population. [1]

Residential Energy Consumption Surveys (RECS) contain building-level data for every four years in 2001, 2005, and 2009 when the last release occurred. CBEC and RECS Data is publicly available for nine "Census Division" in U.S. and not publicly shared at building-level due to strict confidentiality laws. [2]

EPA Portfolio Manager

Portfolio Manager was established in 1999, when Energy Star started creating a library of buildings[3]. The Portfolio Manager of EPA serves as the most common benchmarking tool for energy consumption comparisons. Portfolio Manages has also been a reporting tool used by building owners who are required to report their annual energy consumption based on the Energy Performance Benchmarking law in nine US cities including District of Columbia[4].

Currently, the EPA database includes: CBECS (1999 and 2003), plus specific building type surveys such as: EPA's data collection for Data Centers and American Water Works Association (AWWA)

[1] http://www.eia.gov/consumption/commercial/
[2] http://www.eia.gov/consumption/residential/
[3] http://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/use-portfolio-manager
[4] http://green.dc.gov/page/report-benchmarking-data

survey of Water and Wastewater Treatment Plants. In future, Portfolio Manager expects to add manual or automatic utility reports that are mandated in nine cities to its original database.

The current database includes data on approximately 300,000 buildings. However, the data base is not a representative sample of entire building stock in the country and a certain percentage of inputs are from those buildings seeking Energy Star designation that mostly have higher-than-average level of energy performance.

Currently, due to confidentiality agreements with building owners submitting to Portfolio Manager, individual buildings' data is not publicly available. Portfolio Manager only presents average consumption rates for a group of buildings filtered by size, building type, climate condition, and etc. [5]

D.C. Benchmarking Data

Benchmarking refers to the process of measuring and comparing performance metrics. In the building industry, energy benchmarking programs create standardized metrics to measure and compare energy efficiency between similar buildings just as mile-per-gallon is used to compare energy efficiency between cars. Benchmarking allows owners to assess their building's energy use and to gauge their building's performance against others in the marketplace.[6]

Washington D.C. is one of the nine states and cities thus far, that mandated benchmarking and disclosure of energy data to the public. The District Department of Environment is responsible for implementation and management of the Benchmarking in D.C. DDOE will post benchmarking information for each building to a public website upon the second annual receipt of the information. Currently, reports from fiscal years 2009 to 2012 are available online.[7]

Benchmarking data is collected through surveys that include questions regarding buildings characteristic such as the facility's name, address, year built, total floor space (gross floor area), maximum number of floors, and etc. Benchmarking report also requires building owners to report monthly consumption rate of water, and energy through Portfolio Manager.[4]

D.C. Benchmarking data is the most current and granular data about energy and water consumption in the building in the District. However, the database is not inclusive and not yet fully transparent to the public. DDOE is taking large steps towards its mission to create a highly transparent database for the public.

USGBC Building Performance Partnership (BPP) - Phase 2

Building Performance Partnership is an automated tracking and reporting energy and water platform for LEED buildings. The goals of BPP is to educate building owners and managers on the

[5] Energy Star Portfolio manager "How To" Series Quick Start Guide, Data Trends, and Technical Reference
[6] Krukowski, A. Majersik, C. (2013). Utilities' Guide to Data Access for Building Benchmarking. Institute for Market Transformation IMT Report.
[7] Green Building Report for the District of Columbia, 2007 through 2011. Written by District Department of Environment and approved by the Green Building Advisory Council.

performance of their buildings, and inform USGBC and the wider green building and real estate communities of the ongoing performance of LEED-certified buildings. [8]

Data in Building Performance Partnership is used to generate performance reports and benchmarks for each building but these reports will not be shared with anyone outside USGBC aside from partner contacts, unless express permission is given. USGBC will also compare building performance across the LEED portfolio to identify common traits among high and low performers, and share these findings in order to aid participants in improving building performance. In future, USGBC plans to share LEED building performance data with research institutions and in that case, data will be published anonymously to ensure privacy rights of building owners.[9]

Building Performance Partnership will be launched in two phases. In Phase 1, non-residential LEED-certified buildings are requested to share their energy and water performance data using Portfolio Manager tool. In the first phase, 120 buildings successfully exported monthly utility data via Portfolio Manager. In Phase two participants will report their data on a more frequent basis.

During Phase Two, USGBC will partner with several third-party data providers to offer BPP participants a variety of automated data tracking and reporting systems from which to choose. These user-friendly interfaces will facilitate the data sharing process by integrating participating buildings with the BPP database. USGBC will encourage participants to explore these third-party provided tools and make use of them whenever feasible. While data providers will offer participants the most convenient and manageable options for sending data to USGBC, the ability to share data directly with USGBC will remain as well (USGBC Website/BPP).[10]

Database for Analyzing Sustainable and High-performance Buildings (DASH)

Established in 2004, DASH is a web-based software tool supported by Green Building Alliance (GBA), a non- profit organization, and ASHRAE. Other organizations and stakeholders that support development of DASH and share their existing databases with DASH include DOE, BOMA, EIA, EPA, GSA, USGBC, IFMA.[9] DASH is expected to be the most recognized database for building data. DASH's goal is to increase the quality of information and improve ways to access information about buildings performance but it only targets green, sustainable and high performance buildings and focuses on new construction and major renovation rather than existing buildings.

Database includes:

- Operational data (energy and water)
- Real estate and financial information
- Occupant-based metrics (productivity, comfort, and performance)

DASH's current functionality includes REVIEW and REPORT building performance data in four formats: single buildings report, Portfolio Comparison Report, Global Report on Commissioning,

---

[8] USGBC Building Performance Partnership handbook. Pages 25-26 available at: http://www.usgbc.org/Docs/Archive/General/Docs9590.pdf

[9] National Institute of Building Science. (2012). Data Needs for Achieving High-Performance Buildings. NIBS with support from New Buildings Institute and the National Environmental Balancing Bureau.

[10] http://www.usgbc.org/Docs/Archive/General/Docs7743.pdf

Single Building Commissioning Report. DASH is also capable to compare buildings' performance and it allows users to discover information by dynamically filtering data based on building size, use type, geography, data year, classification, building height, number of floors, and average number of occupants. In regards to energy consumption, building- level data is not available and average rates of energy consumption or intensity is presented for group of 30 and more due to privacy issues. [11]

Building Energy Data Book

Building Energy Data Book is supported by DOE Building Technology Program in Energy Efficiency and Renewable Energy (EERE) and Energy Information Administration (EIA) in collaboration with Pacific Northwest National Lab (PNNL). Data is derived from the State Energy Data System (SEDS) Consumption Database (1080- 2009) and EIA Annual Energy Outlook, CBECS, RECS and other surveys.[12]

This database does not include building- level energy data and it only presents statistics about all buildings in the country. Some information that Building Energy Data Book provides are:

- numbers of building floors
- type of ownership
- total energy consumption
- Energy use intensities (EUI) by principal building type.
- Energy end-use split by fossil types
- energy production
- Energy consumption prices

Building types are categorized into 12 groups:

1. Health Care (Inpatient, Outpatient)
2. Food Sales
3. Lodging
4. Office
5. Mercantile (Retail and Non-Malls, Enclosed & Strip Malls)
6. Education
7. Service
8. Food Service
9. Religious Worship
10. Public Order and Safety
11. Warehouse and Storage
12. Public Assembly

[11] http://www.dashbuildings.com/(S(mhhzhn5ygvspvknxmw2nk1el))/About.aspx#WhyDash

[12] http://buildingsdatabook.eren.doe.gov/

Building Performance Database (BPD)

Building Performance Database is created by US Department of Energy to bridge the gap between building characteristics and energy performance data. The DOE Buildings Performance Database (BPD) aims to bridge this gap by compiling and cleansing a large dataset required to assess the likely performance of energy efficiency retrofit measures and services. The BPD provides access to empirical data on the actual energy performance and physical and operational characteristics of commercial and residential buildings. The database was developed to stimulate investment in energy efficiency retrofit projects and services (DOE website).[13]

In the BPD, normalized EUI is provided for a group of buildings filtered by size, building type, geography, and other building characteristics. The database includes 755,633 buildings nation-wide, from which 804 buildings are located in D.C. The database collects data from real estate companies, manufacturers, service providers, federal, state and local governments.

BOMA Experience Exchange Report (EER)

BOMA produces several resources to assist members and others in evaluating specific building related needs. The Experience Exchange Report (EER) provides market level data for more than 140 cities. The EER includes verified data on income and operating expenses from over 6,500 buildings. Data is collected via an online survey. Individual inputs are aggregated to present information in terms of averages, medians, and upper and lower quartiles. Because the data is in the form of cost, its utility for users outside the real estate or financial sectors may be limited.[9]

The captured data includes pricing for:

- Rentable area
- Office rent ($/ sf)
- Expenses/ maintenance cost
- Energy and utility cost

BOMA also implemented the 360 Program in 2009 to provide members with the capability to benchmark buildings on six major areas of building operations and management. Those buildings that achieve the required number of points are recognized as BOMA 360 Performance Buildings. As part of the submission requirements for the 360 Program, owners must submit data to the EER survey. [14]

CoStar

CoStar owns an advanced database of commercial properties both nationally and internationally. Since October 2011, their databases included nearly 80 billion sq. ft. The data largely focuses on real estate-related information, including tenant history, available space for lease and market data. [9] Recently, CoStar began including information on third-party certifications like Energy Star and LEED. The CoStar data could be of value for multiple reasons. Not only this data is valuable to identify trends within the commercial building market, but also it is useful to characterize the building stock in terms of building type, floor area, occupancy, vintage and location. Such data could also assist in identifying

[13] http://energy.gov/eere/buildings/building-performance-database

[14] BOMA 360 Performance Program available at: http://www.boma.org/awards/360-program/Documents/BOMA%20360%20FAQ.pdf

properties to include within a particular survey. [9]

ULI Greenprint Foundation

Greenprint Foundation is a worldwide alliance of real estate owners, investors, financial institutions and other industry stakeholders committed to reducing carbon emissions across the global property industry.[15] The Greenprint Foundation maintains a database and produces an annual Greenprint Performance Report covering 1,623 properties and 31 million sq. m of commercial space globally. Buildings in the database represent select assets of Greenprint members including GE Capital, Hines, Jones Lang LaSalle, Prudential and TIAA-CREF. [9] The report primarily focuses on greenhouse gas emissions associated with the reported buildings. Since the initial data collection and report in 2009, the dataset has expanded considerably in terms of properties (170% increase) and space (93% increase).[9, 16]

International Facility Management Association (IFMA)

Currently IFMA conducts annual benchmarking studies that collect annual cost and consumption for electricity, fuel oil, gas, steam, chilled water, water and sewage from building/facility management companies/personnel.[9] IFMA's online benchmarking portal, called Benchmarks Exchange (BEX), allows facility professionals to compare building data[17]. With the ability to filter information by industry, facility type and geographic region, you can access reports that target metrics unique to your facility. Data is collected through surveys through web-based survey portal of BEX.

BEX have included data from more than 1,200 buildings, contributed by facility managers from both the private and public sector. [9] Participation in IFMA studies is open to both members and non-members. The resulting data is available free to data contributors. Non-contributors pay a fee to access data from the data portal or they may purchase reports from the IFMA bookstore. These reports only share the average consumption rates and keep the information about individual organizations confidential. [9]

Build Smart DC, Honest Buildings

Build Smart DC is a program sponsored by the District Department of General Services (DGS) with the purpose of creating transparent, detailed, timely, and actionable data from the 25 million square feet of public buildings in the region. The Build Smart DC is a website that presents 15-minute electricity data provided daily for the majority of buildings in the District Department of General Services (DGS) portfolio – but this will expand to natural gas and other energy data, and it could include other buildings in the private and non-profit sectors. [18]

The District worked with local utility Pepco to get access to interval electric data, and startup Honest Buildings created the software and services that collect and organize the data.

[15] http://www.us.jll.com/united-states/en-us/greenprint-foundation
[16] http://uli.org/research/centers-initiatives/greenprint-center/
[17] http://www.ifma.org/know-base/research-benchmarks-surveys/facility-management-benchmarking
[18] http://www.buildsmartdc.com/about/energy-profiles/

In order to get electric data, smart meters at each site transmit the data through an extensive network of secure signal relays back to a central data collection server. The energy data is processed there and forwarded to DGS for creation of the charts and graphics seen on the Honest Buildings site.

Ultimately, through this tool and others, Build Smart DC enables greater accountability of government spending and performance, more information sharing among agencies and energy efficiency implementers, and a larger pool of information from which stakeholders can learn and build.[18,19]

Utility Companies

Utilities have data about their customers and the electricity, natural gas, and water they use. However, such data is rarely used in combination with building characteristics and it is not used as an informative tool to acknowledge building owners, tenants and the public about energy and water consumption of the buildings.[9] One obstacle is that the utility data generally is considered confidential unless the user authorizes sharing such data with third parties (such as for submission to Portfolio Manager) or if disclosure is required by law (such as in Washington D.C. for buildings of a certain size). Confidentiality of the utility data mostly has challenged building owners' ability to benchmark some buildings where tenants are responsible for their utility use.

Transparency of utility data has become more feasible than before with advancement of new initiatives and technologies. For instance, the Green Button[20] initiative is an industry-led effort that responds to a White House initiative to provide utility customers, such as building owners and managers and major tenants, with easy and secure access to their energy usage information in a standardized electronic format. Using Green Button Download My Data, customers are able to securely download their own detailed energy usage with a simple click of a literal "Green Button" on electric utilities' websites. In addition, new companies have developed a technology to accept "Green Button" data from customers, relate that with the building characteristics, and provide the customers with a highly-graphic analysis about the building performance[21].

Green Per Square Foot (PSF)

Green Per Square Foot, enables building owners and managers to profile their buildings, find savings opportunities, and connect to a network of qualified solutions providers. Green PSF is envisioned as tool for the Smarter Business Challenge program in D.C. to solve a number of industry pain points for commercial building owners by quantifying how much building owners can actually save and providing new insight on which service providers are best able to serve them.[22]

Summary of the existing data sources related to building's energy is illustrated in Figure 3 on the next page. Figure 4, immediately following, shows how the D.C. City Model will be connected to other data sources.

[19] https://www.honestbuildings.com/organization/#!/view/2156/dc-government
[20] http://www.greenbuttondata.org/
[21] http://energy.gov/data/green-button
[22] http://greenpsf.com/property-users/

Figure 3 Existing sources of building's energy data

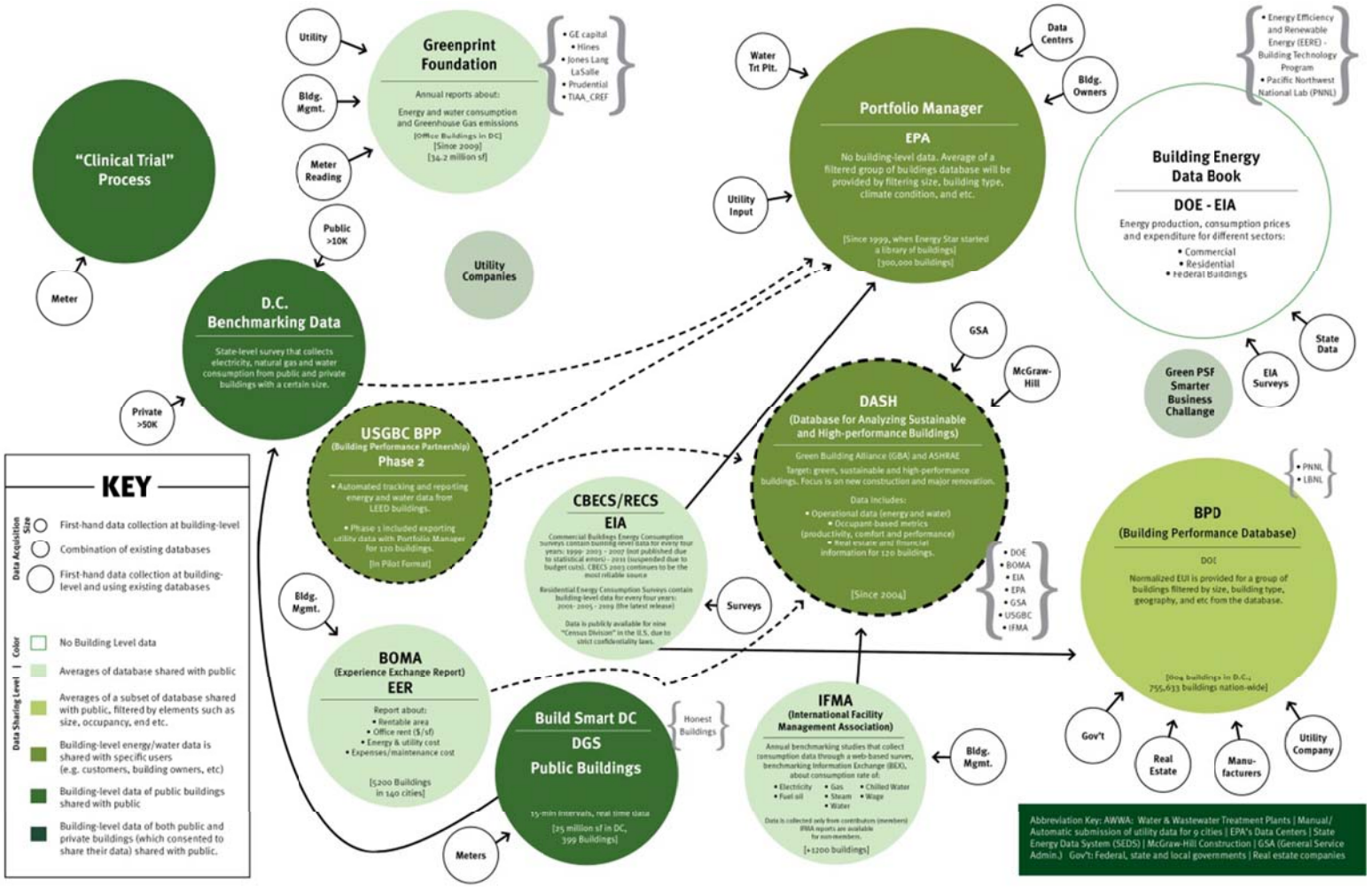
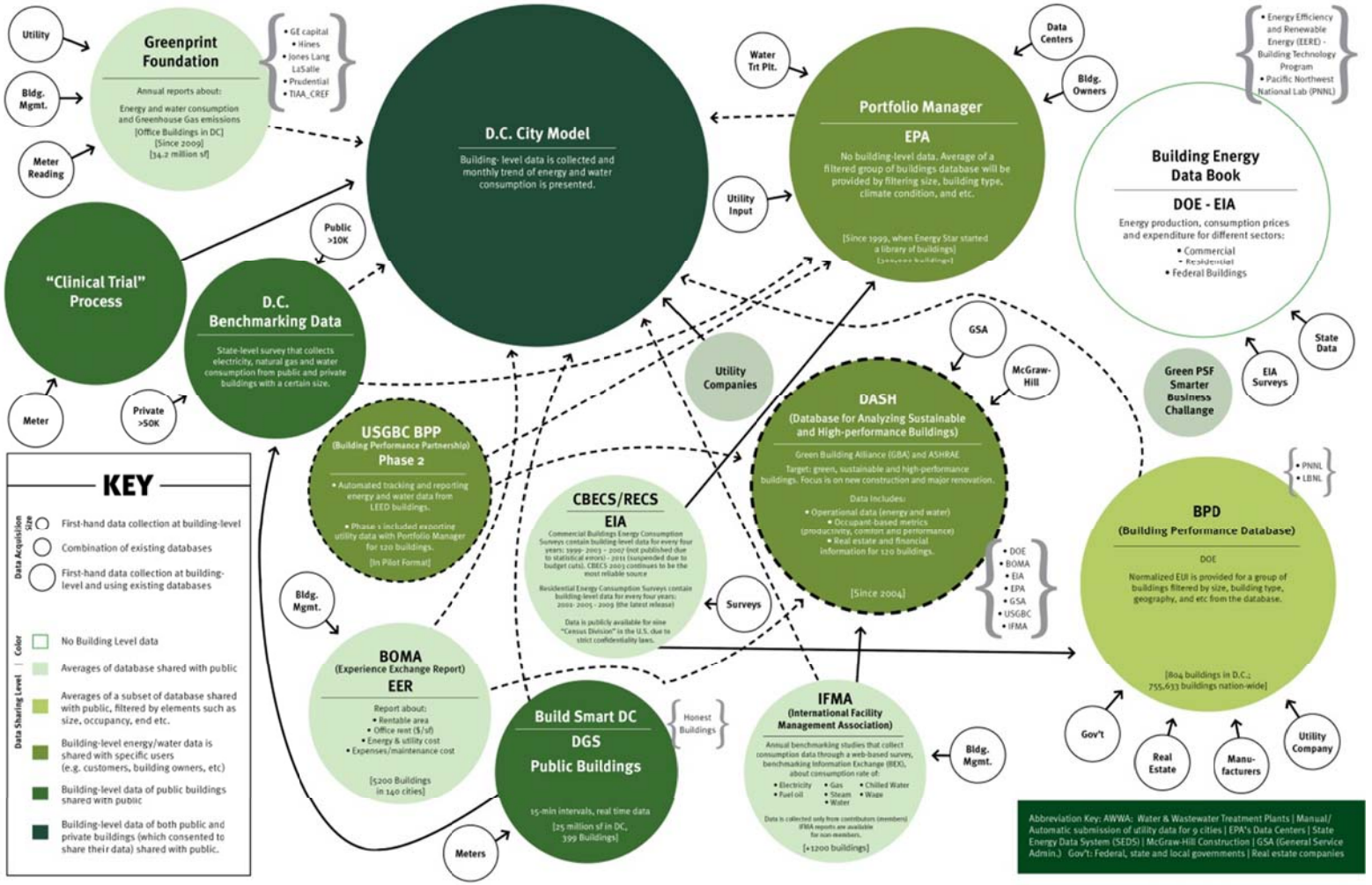


Figure 4 DC City Model within the existing data sources



Data Sources in District of Columbia

This section focuses on sustainability data beyond energy and water consumption of buildings in the District. First, we explore existing websites and online tools that map sustainability data in the city. Next, we identify the type of data required to create a comprehensive sustainable map of the District. There are three existing websites that present maps and locate "green buildings/ activities" in the districts. Green Dashboard, Green Up! DC and Green DC Map are examples of such information tools.

Green Dashboard

The Green Dashboard (Beta) is a tool designed to make sustainability data, largely environmentally sustainability data at this point, more readily available to the community, and ultimately to encourage the District to become a more environmentally, economically, and socially sustainable city.[23] Data categories are:

- Air Quality and Climate: air quality in Green Dashboard is indicating alert days that are reported by District Department of the Environment and CO2 levels that is reported 2006. No building-level information is provided in this section.
- Energy and Buildings: Energy section of the Green Dashboard presents total energy consumption in the District. Building section of the Dashboard includes charts in different categories displaying total number of the following projects:
  - ENERGY STAR Buildings
  - Green Roofs
  - Lead-safe Homes
  - LEED Buildings
  - RiverSmart Homes
  - Weatherized homes
- Nature
  - Trees: number of trees planted in the District is illustrated in a chart. Data is not up-to-data (Last updated 01/14/2013).
  - Wildlife
- Transportation: this category includes capital bikeshare, walkability, public transit and other indicators.
- Waste and Recycling: information about total waste generated in the District, number of leaking underground storage tanks, waste diverted from landfills are reported in this section. Data is limited to those control points that exist in the city. Neither total waste from all buildings, nor building-level waste data is presented.
- Water quality: Anacostia and Potomac River water quality is gauged via quantities and qualitative measures and presented in a chart on this website. Beyond these two rivers, no information about water quality in the city is provided. [23]

[23] https://greendashboard.dc.gov/

Green Up! DC

Green Up! DC is a tool that created by DDOE in collaboration with CH2MHill to display "green efforts" in the District and to act as a source to help people explore where green projects are installed.[24] The purpose is to assist the public to plan a green project and roughly estimate potential savings and costs of implementing green strategies in advance. Green Up! DC [25]displays Google map of the District, powered by DC GIS, with existing projects that use renewable energy such as PV systems, Solar Hot Water systems, stormwater remediation, and insulation and energy efficiency. However, the tool has not been updated and its information does not reflect the current situation of the District.

Green DC Map

Green DC Map is a tool sponsored by DDOE to present multiple "green projects/ activities" in the District.[26] The tool presents a Google map of DC, powered by DC GIS and specifies location of projects in three main categories; however, the data is out of date on this map. Categories of data are:

Building and Energy, such as:

- ENERGY STAR homes
- Green Buildings (LEED and Enterprise Green Communities)
- Green Roofs
- Wind Energy Sites
- Solar Energy Sites
- Geothermal Sites

Transportation, such as:

- Car share locations
- Bike locations
- Metro

Environment, such as:

- Wetlands
- Special Gardens
- Community Gardens
- Composting Demonstration Sites
- Public Recycling Sites

MapDwell

MapDwell Solar System is an interactive web-based tool that specifies energy saving potential of installing PV panels on buildings' roofs.[27] To be more specific, MapDwell Solar System shows: 1) potential electricity generated by PV panels, 2) cost of such system, 3) payback period, 4) carbon reduction, and 5) location of existing projects that have PV panels installed on their roofs.

[24] http://newsroom.ch2mhill.com/news/nation-s-capital-launches-interactive-232001
[25] http://greenup.dc.gov/
[26] http://greenmap.dcgis.dc.gov/
[27] http://www.mapdwell.com/en/dc

Green Building Information Gateway (GBIG), USGBC

GBIG has a record of green activities and buildings for both LEED and non-LEED projects in cities of the U.S., Canada and other counties such as India.[28] GBIG is in development phase and it intends to add more data about LEED projects from USGBC database. For LEED- certified buildings, GBIG 'Unpacks the LEED plaque' and shows credit achievement data in the LEED certification categories (SS, WE, AE, MR, IEQ). In addition, it presents actives that a building pursues to maintain or improve their green statues.

In the District, GBIG is a good source for Green Roof projects and it contains data about buildings that installed Green Roofs. Hypothetically, LEED scores in categories such as Material and Resources, Indoor Environmental Quality, and Energy and Atmosphere could be a good source to roughly assess buildings' environmental performance. However, LEED score cards are only limited to those buildings which were certified and also LEED scores do not guarantee a buildings' post-occupancy performance. In order to respond to this issue, USGBC is developing a "Dynamic" plaque that shows performance of certified buildings after certification and throughout its life.[29] To this end, such buildings install meters that stream data to a platform that assess building's performance based on the data received from meters. Since dynamic plaque a new project, we assume that it could contribute to the City Model at this time, but in future, it could contribute to next generations of the model.

Walk Score

Walk Score is website which maps rates the walkability for different neighborhoods and buildings based on metrics such as number of near-by public transit stations (bus and metro stations), services (restaurant, schools) and other amenities.[30] The main purpose of Walk Score was to help home buyers or renters learn about walkability of a neighborhood before they decide to live there. Interestingly, more than 10,000 websites use walk score, such as PadMapper, a map of rental buildings that is suitable for comparing rental buildings' attributes and cost of living.

Other examples that use a similar platform are Capital Bikeshare , which shows locations of bikeshares, and Recargo Plugshare that displays locations of electric car chargers on the District's map.

Additional Examples

Our team also investigated other cities' efforts regarding sustainability mapping. Some precedents of such user interactive graphic representations include:

- NYC Cool Roof Map is developed by Center for the Advanced Research of Spatial Information (CARSI).[31] Cool Roof map shows rooftop "cooling potential," defined as the relative extent to which a rooftop is likely to benefit by being painted with a reflective coating. The map also shows non-rooftop areas that could benefit from tree plantings. Other maps such as materials classification, thermal overlay, rooftop averages, and rooftop details are presented in NYC's Cool Roof Map.

[28] http://www.usgbc.org/gbig
[29] http://www.leedon.io/
[30] https://www.walkscore.com/DC/Washington_D.C.
[31] http://www.carsilab.org/coolmap/

In essence, the map is presenting how much solar energy is absorbed from horizontal surfaces. Calculations are based on deducting reflected radiation of a surface from the solar radiation that the surface receives. Solar radiation is calculated by ESRI tool, Area Solar Radiation Tool for each square meter and reflected radiation is calculated by Lidar. Lidar is a technology that uses precise timings of pulses of light emitted from a source. In addition, Lidar shows distance of nodes from the source and their 3D location.

- Urban Heat Island of Atlanta, Georgia is created by satellite imagery of Urban Atlanta NASA Goddard's Scientific Visualization Studio.[32] The satellite image shows temperatures of all horizontal surfaces including building roofs, roads, and street walkways in a two- dimensional map. By projecting the temperature map on a three- dimensional model of the city, an Urban Heat Island model of Atlanta is created. The 3D map help viewer understand the impact of buildings' density and height on temperature of urban surfaces.

Lessons Learned: City Model's Library of Green Building Attributes beyond Energy and Water

Over time, City Model will evolve and develop new versions that present sustainability information beyond water and energy consumption of buildings. Unlike some of the data warehouses described above, because the City Model gathers dynamic information, the platform will remain relevant and hopefully well utilized. Outcomes envisioned for next generation of City Model include:

- Renewable Energy
  Types of energy use other than electricity and natural gas (such as: fuel oil and renewable energy: solar PV, SHW, geothermal, biomass). Currently, fuel oil consumption data at building- level is not available. The only source is the U.S. Energy Information Administration that provides national and regional survey data of residential heating oil and propane every year.

  Among renewable energy sources, DC MapDwell has up-to-date information about solar energy projects but it is limited only to solar PV panel sites and solar hot water sites, geothermal, and biomass projects are missing. Solar hot water systems and geothermal sites have been presented in Green DC Map but as mentioned above the website is not up-to-date.

- Indoor Air Quality
  Assessment of indoor air quality could be both objective and subjective. Objective assessment is mainly based on quantities that tools and equipment measure, whereas subjective assessment is based on occupants' feedback about air quality in a space. For quantitative assessment, a building has various options such as installation of alarm systems for high internal CO_2 levels and conducting air tests based on EPA protocol. For qualitative assessment, occupants could be engaged via questionnaires and interviews to present their views, concerns, scores to a space in term of air quality.

[32] http://mynasadata.larc.nasa.gov/804-2/measuring-temperature-islands/

To map indoor air quality:

1. LEED- certified buildings that are scored in the "Indoor Environmental Quality" category by conducting air tests before occupancy, or installing of CO_2 alarm systems could be found from GBIG data library. Achievement of scores in those categories could prove that a building has an acceptable level of air quality. However, there are limitations to this data source such as limited number of LEED certified buildings that pursued those specific items for certification.

2. For qualitative assessment of a space, occupants could be asked to rate air quality in a space by responding to a questionnaire that is designed to assess level of satisfaction of occupants. The questionnaire asks them how they evaluate air quality in a space they live or work in or a space they are visiting. These questionnaires could be digitally sent to occupants' smart phones, computers and tablets and collected and reported instantly to an analysis platform or a projection board.

   USGBC is developing a tool that prompts online questionnaire on occupants' or visitors' smart phones. The questionnaire investigates quality of space in terms of daylight, air, acoustics and etc. This method could be used to map the results from questionnaires for all buildings around the city and enable comparison among them.

- Exterior Surface Temperatures would be valuable information to assess Heat Island Effect.
  - Horizontal and vertical surface temperatures could be derived from Infra-Red images captured with cameras from horizontal and vertical surfaces of buildings or it could be captured by satellites or from an airplane to capture the whole city. Examples of tools and maps created in this way are: Negawatt Harvesting (MIT) and Atlanta Heat Island Model.

- Cool roofs: Roof materials and level of light reflection from roof surfaces have an impact on Heat Island Effect and consequently, they have influence on cooling energy consumption in buildings. A map of cool roofs and building materials could be used to estimate potentials for energy savings by replacing absorbing roofs to highly reflective roofs. NYC's cool roof could be used as an example to create such map for the District.

- Permeable Surface Area Associated with properties.
  There is currently no information available regarding permeable surfaces in the District.

- Green Roofs: Green Building Information Gateway (GBIG) of USGBC provides information about green roofs in the District in a user- interactive website. Green Dashboard also provides two charts that represent number of projects with green roofs in the District and surface area of those roofs over a period of time in eight wards (since 2004). Dashboard data is relatively up to date (data last updated 07/08/2014).

- Water Collection and Reuse

    - There is currently no information available regarding water collection and reuse in the District.

- Waste Disposal and Recycling
    - The District of Columbia requires recycling in all commercial establishments. Under the District law, all commercial properties or establishments located in the District of Columbia must maintain an active commercial recycling program. The Department of Public Works collects recycling once-a-week from residential buildings with fewer than four units. Other residential buildings, mixed-use residential/commercial buildings and commercial properties must collect recycled materials through a contractor.
    - Having mandatory recycling is the first step that the city has undertaken; next step would be measuring collected recycled material and quantify waste derived from landfills.

- Transportation: information regarding public transportation systems, walkability, and access to electric car chargers are included in capital bikeshare, walkscore, and plugshare websites.

- Activity Level of Occupants – athletic fields, gyms
    - Green spaces, parks and trails are displayed in Google and GIS maps. However, building-level information such as information about the level of activity of building occupants have not been collected by any source.

- Materials
    - LEED- certified buildings that are scored in the "Material and Resources" category by using local materials, rapidly renewable, recycled materials could be found from GBIG data library. Achievement of scores in those categories could prove that a building has used sustainable materials in the building. Collecting such information from GBIC and mapping them on a map of the District would be another source of information for a sustainable city.

Digital Data Capture Methods

To create a City Model, extensive information about buildings in the city should be captured such as buildings' location, area, height, construction material. Capturing these data to generate a virtual model of the city is time consuming and laborious. This section elaborates digital methods of capturing data and recording field measures that could facilitate creation of the city's virtual model.

Laser Distance Measuring Tools known as "Electronic Tape Measures" or "Digital Measuring Devices," offer true laser light for the most accurate measuring. You simply point the laser distance measuring devices dot at a target like a wall, a house, a utility pole, nearly any object, and the device will show the distance on its LCD screen.

If you plan to capture existing conditions from the site using a laser distance meter, you can use PKNail software from PointKnown (www.pointknown.com) to export those measurements directly to Revit and use it to create a Revit model of your building. By inputting a few simple field measurements PKNail will build a Revit model of the existing structure, in the field, in real time. This approach involves trained survey personnel that walk around the perimeter of a building and measure key points on the building.[33]

Photogrammetry is surveying of objects and spaces through the use of photography and associated software. Common technique for the application of this method is convergent photogrammetry that uses multiple, oblique photographic images of an object taken at different angles. Measurements and three-dimensional models are derived by using software that traces overlapping photographic taken from different angles. It has an accuracy of about 99.95%. [33]

Satellite and Aerial Images

You can download oblique (perspective view) and orthogonal (straight down view) aerial images from Internet sites such as

- Google Earth
- Google Map
- Microsoft Bing
- Pictometry

Images from these sources could be used to capture your existing building conditions.
software from *Pictometry*[34] is an alternative source of aerial images devised with a software that enables you to extract building information that you can use for modeling such as distance and area measurements, number of windows, building height, and coordinates of the building location. [33]

Laser Scanning

Laser scanning uses medium- range pulsing laser beams, which systematically sweep over an object or space to obtain three-dimensional coordinates of points on the surface of the object or space being scanned.

LiDAR (Light Detection and Ranging) Short for Light Detection And Ranging, LiDAR. is a term used to describe the process for capturing position related data using laser or light sources. Similar to SONAR using sound waves, LiDAR uses light pulses to detect distances and measurements from a known source.

Software Developed to Process Digital data Captures

3D modeling programs from photogrammetry:

- Autodesk ImageModeler[35]
- Autodesk 123D Catch[36]
- Autodesk Photofly

[33] Autodesk. Streamlining Energy Analysis of Existing Buildings with Rapid Energy Modeling.
[34] www.pictometry.com
[35] http://usa.autodesk.com/adsk/servlet/pc/index?id=11390028&siteID=123112
[36] http://www.123dapp.com/catch

- Open source photogrammetry[37]
- ARC3d[38]
- Hypr3d[39]
- StereoScan[40]
- My3dscanner[41]
- Insight3d[42]
- Python Photogrammetry Toolbox [43]

3D modeling tools that could be used for creating or editing 3D models:

- Autodesk 3ds Max
- Rhinoceros
- Google SketchUp
- Blender
- Meshlab is an open source for the processing and editing of unstructured 3D triangular meshes.

CityScan

CityScan can scan, track and analyze everything that you see in a city. CityScan uses LiDAR to create a 3D rendering of a city that allows for measuring and analyzing every object in the city. CityScan works with clients to normalize, geolocate, and correlate data from public, private and municipal data sources. For cities, this may include zoning code or permit data; for utility companies, this could include 3rd party device agreements and any current internal GIS data[44].

For instance, CityScan is used to check code compliance in buildings and perform inspections for city constructions, roads, bill boards, and etc. One current application of CityScan is On-Premise Signage, which automates the process of signage enforcement.

GeoSim

GeoSim is an advanced 3D City Mapping technology, resulted from years of research in Israeli Air Force[45].

Its technology centerpiece is Groundscan™ which is a complete high-definition 3D City Mapping system delivering unsurpassed realism and a unique combination of powerful attributes. Groundscan™ is used to create high precision models for large scale, such as entire cities with

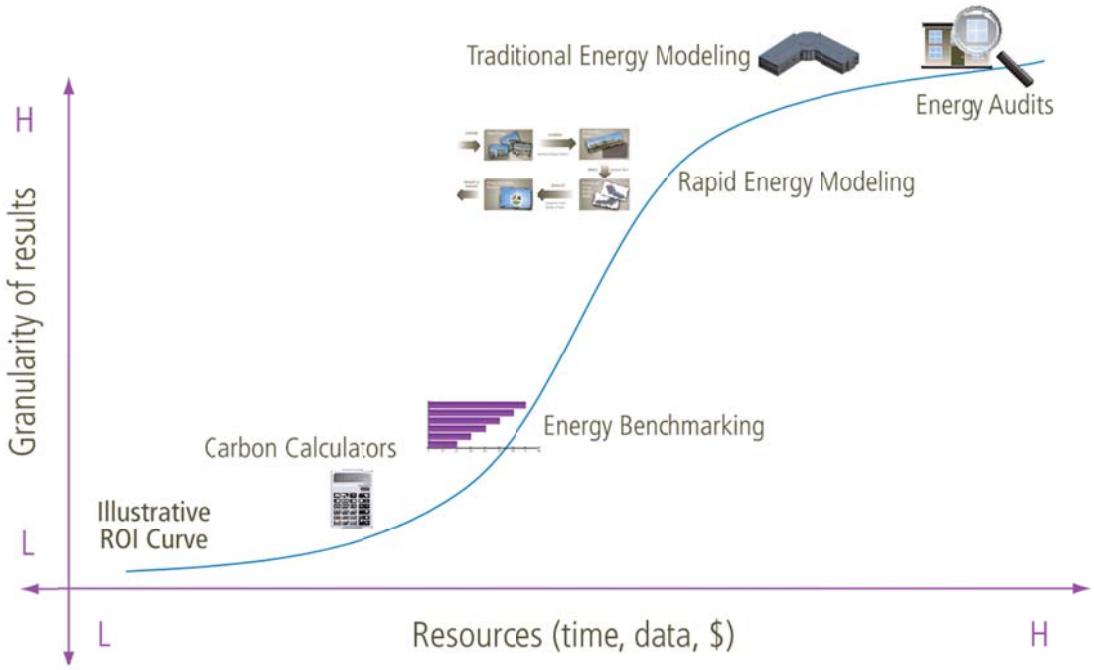
[37] http://opensourcephotogrammetry.blogspot.com/
[38] http://homes.esat.kuleuven.be/~visit3d/webservice/v2/
[39] http://hypr3d.tumblr.com/
[40] http://www.agisoft.ru/products/stereoscan
[41] http://www.my3dscanner.com/
[42] http://insight3d.sourceforge.net/
[43] http://opensourcephotogrammetry.blogspot.com/2010/09/python-photogrammetry-toolbox.html
[44] http://cityscan.com/
[45] http://www.geosimcities.com/#02

thousands of buildings with high precision, 4-6 inch spatial accuracy for outdoors and 2-3 inch spatial accuracy for indoors.

To create 3D model of a city, data is captured by Groundscan™ from both air and ground. GeoSim's mapping doesn't end at exterior walls; a proprietary indoor data collection device captures high-fidelity interiors which are fully integrated with the city exteriors.

Autodesk Rapid Energy Modeling

Rapid Energy Modeling is a "streamlined process of moving quickly and with minimal data from existing building conditions, to energy analysis, through a simplified simulation process." A typical workflow consists of three steps: *capture, model, and analyze.*[46]



- Step 1: Capturing Existing Conditions
  The first step in the rapid energy modeling process is to capture the existing conditions of your building(s). The format of the existing conditions (i.e. digital photographs, aerial or satellite images, or laser distance meter measurements) will dictate the exact steps and software needed to help capture and process those existing conditions. [33]

[46] Aniruddha Deodhar Autodesk- available at: http://autodesk.typepad.com/bpa/2013/04/streamlining-energy-analysis-of-existing-buildings-with-rapid-energy-modeling.html

Digital Photographs
Autodesk ImageModeler or Photofly are image-based modeling and photogrammetry software that create 3D Objects from 2D digital images. The 3D model could be exported as a DWG and used in energy modeling (Autodesk White Paper). Photogrammetry saves significant time dedicated to creating building geometry in energy modeling process. However, user is expected to spend some time to adjust and check the 3D model generated from images with the actual building.

Satellite and Arial Images
You can use images from Google Earth, Google Map, Microsoft Bing and Pictometry to capture data about building orientation, geometry, and neighboring conditions. To use such images, you will need to measure (at a minimum) the approximate height of the building and/or floor-to-floor height per floor as well as the approximate window-to-wall ratio (i.e. the glazing percentage) before proceeding with modeling (Autodesk White Paper). In order to do that, you could manually measure lengths and areas of building surfaces via the measuring tool in Google Earth and Pictometry. This process would have been much faster if it was automatic. Similar to Pictometry Online software outputs a KML file (Google Earth file format) that can be imported directly into Revit Architecture or Revit MEP to create a full 3D model of your building.

Laser distance meter
To create a Revit model in the field while you are using a laser meter to capture measurements, you could use PKNail software.

- Step 2: Creating a Building Model
  In next step towards rapid energy modeling, you use the captured data to create either a conceptual massing model or a more detailed model that incorporates building elements such as walls, floors, windows, roofs, and rooms/spaces. For a quick energy assessment, a conceptual massing model is often sufficient. To create the conceptual model, you can use either Revit Architecture or Revit MEP software (Autodesk White Paper).

- Step 3: Analyzing Energy Consumption and Carbon Emissions
  For energy analysis, you can use the Revit Conceptual Energy Analysis features for initial analysis and/or Green Building Studio for more detailed whole building analyses.

Autodesk InfraWorks
Autodesk InfraWorks is civil infrastructure design software. This software provides large-scale preliminary designs in context and allows you to create sketches and 3D models of infrastructure design, such as roadways, pedestrian ways, bridges, drainage, and green space to communicate with stakeholders virtually.[47] One advantage of InfraWorks is that it allows users to import data from GIS, which is one of the most important data sources for master planning and design. InfraWorks 360TM model creation includes: modeling the existing environment, and model analysis includes: dynamic

[47] http://www.autodesk.com/products/infraworks-360/overview

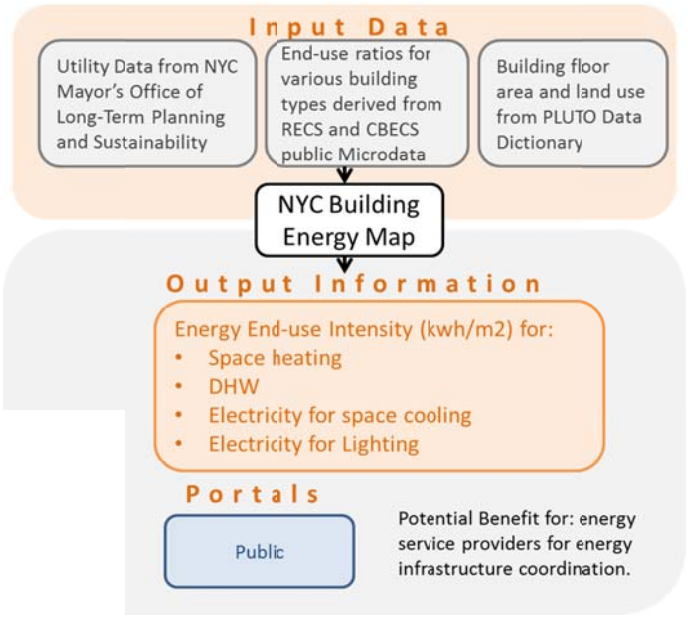
sight analysis, measure distances and areas, shadow and lighting analysis, and theme palettes. Advance design tools include: roadway design, drainage design, and bridge design[48].

Autodesk AutoCASE

Autodesk AutoCASE is a comprehensive cost-benefit analysis for evaluation of sustainability developed by Impact Infrastructure, LLC and Autodesk, Inc.[49] With this software you could estimate return on investment for sustainable infrastructure, monetize sustainability and account for risks (i.e. for wetlands, you can monetize recreational use and water quality benefits) AutoCASE is integrated to Autodesk BIM such as AutoCAD to capture information from drawings and use them for analysis. AutoCASE will serve as an economic companion tool to ENVISION™, which is planning and infrastructure rating system developed by the Institute for Sustainable Infrastructure ISI. AutoCASE is in beta version and its operation is being tested currently.

Energy Mapping Precedents

1. NYC Energy Map



Background

NYC energy map[50] is an interactive map created by researchers at the University of Columbia in 2012. Being open to the public, NYC energy map intends to educate building owners about consumption of energy resources and inform energy providers about potential locations for

[48] http://au.autodesk.com/au-online/classes-on-demand/class-catalog/2013/infrastructure-design-suite/ci1870
[49] https://beta.autodesk.com/callout/?callid=67D32ECD6AC9467B818B87BB1605BB01
[50] http://sel-columbia.github.io/nycenergy/

energy infrastructure coordination. To this end, the map displays Energy Use Intensity (EUI) at city block and building level in NYC.[51]

Utility data of account holders is derived from NYC Mayor's Office of Long-Term Planning and Sustainability. Data about land use and building floor area is derived from PLUTO Data Dictionary of the NYC Department of Planning. PLUTO contains extensive land use and geographic data at the tax lot level updated every year.

Pros

The energy map uses a model to estimate buildings' energy end-use for space heating, electricity, space cooling and hot water. The model uses end-use ratios from the Residential and Commercial Building Energy Consumption Survey (RECS and CBECS). The model assumes that end-use energy depends only on building function (residential, educational or office) rather than buildings age or construction type. After finding a building's function, the model assigns an appropriate ratio to estimate the end-use energy consumption in that building.

Cons

The engine assumes that energy use intensity only depends on *building function*. Building qualities (construction type, age, engineering systems) are not considered as influential factors on energy use level of buildings.

Building functions are simplified into eight general groups: Residential 1-4 family, Residential multi-family, office, store, education, health, warehouse, and other commercial. As a result, differences between building functions are not totally covered due to this simplification. For example, hotels and restaurants are both in "other commercial" group despite their variations in energy consumption pattern.

Web portal does not inform the user about building types; therefore, energy data of a building is provided but the user cannot relate energy data to building function.

Key Take-Away

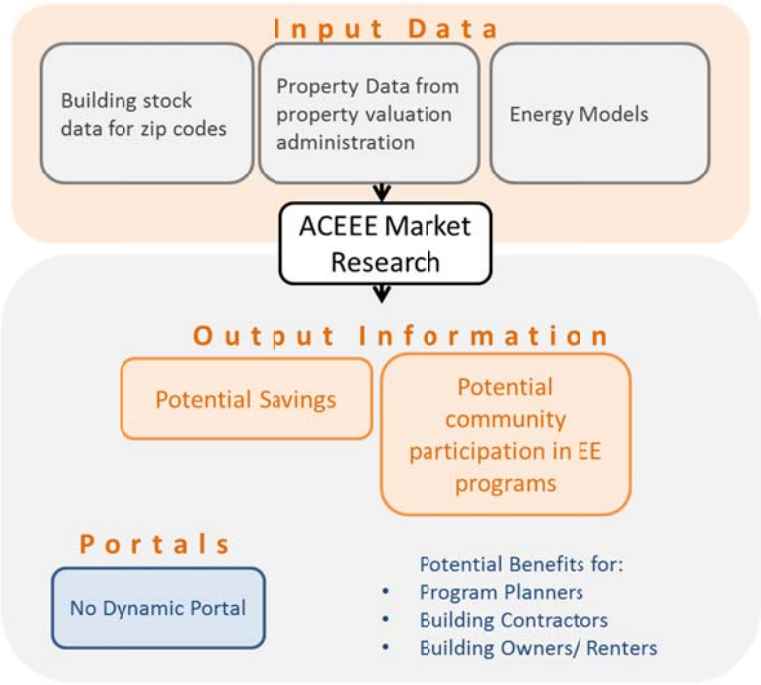
Cooperation from utility companies and city planning department paves the way for creating an energy map for a city.

In a dense city such as the District, where a building contains multiple utility accounts, it is possible to present aggregate utility data at building level without violating utility data privacy issues.

To find accurate ratios for end-use energy for building types, the model could use a validated energy simulation that represents a "typical" building of that type.

[51] Howland, A. (2012) Building an Energy Map to Encourage Retrofits in the Multi-family Housing Sector in Cambridge. MIT Energy Efficiency Strategy Project.

2. ACEEE Market Research, Cincinnati Regional Market Study



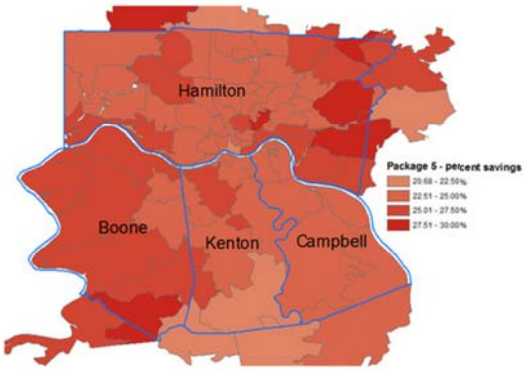
Background

ACEEE recently conducted a market study of four counties within the Cincinnati region to find homes that need energy efficiency and people who demand it. The study was performed in corporation with the University of Cincinnati Economics Center and the Greater Cincinnati Energy Alliance.[52] ACEEE prepared a map for the Greater Cincinnati Energy Alliance, which is a nonprofit local organization for energy efficiency. The map displays energy efficiency potentials in different zip codes in the region and although it is not intended to be a dynamic web portal, the map conveys invaluable information related to "supply" and "demand" of energy efficiency in Cincinnati area.[51]

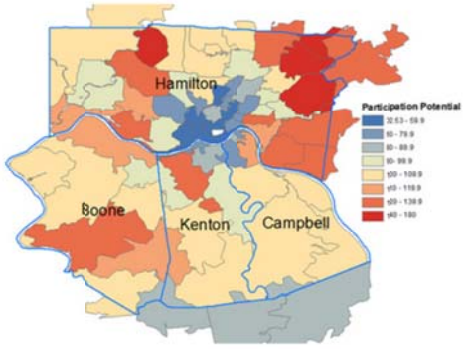
Pros

The mapping project Identifies "supply" of energy efficiency potentials, defined as energy savings potential. A map was first created to displays average percent of energy saving in a ZIP code, if home energy retrofit is implemented. An Energy Modeling Software called TREAT (Targeted Retrofit Energy Analysis Tool) was used to estimate savings from energy retrofits. A research group computed the average baseline energy use for a Cincinnati single-family home; 45 "typical" homes modeled and results extrapolated for the whole region. Savings were calculated by simulating several energy retrofit options of in form of "Retrofit Packages."

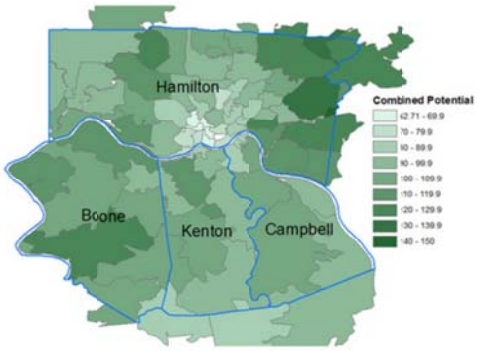
[52] http://www.aceee.org/blog/2011/12/neighborhood-outreach-energy-efficien



The mapping project identifies “demand” of energy efficiency potentials, defined as participation in energy efficiency programs. The research group Identified participation potential index based on a number of social factors which are proved to have impact on the level of participation in home retrofits. A study in Berkeley lab (*Driving Demand for Home Energy Improvement, LBNL 2010) associates demographic variables such as* type of homeownership, education, age of occupants, age of building, and income to higher rates of program participation. As a result, ACEEE’s research group extracted demographic data in those categories from Property Valuation Administration. Participation potential index with scores above 100 represent above average participation potential, whereas scores below 100 represent below average potential.



The mapping project identifies “combined” energy efficiency potential, defined by multiplying “Supply” score by “Demand” score in each zip code.



Cons

In this map, participation potential index is defined based on demographic data in Cincinnati region. However, a demographic analysis could not be an excellent substitute for on-the-ground experience. Results from field experiences by the Greater Cincinnati Energy Alliance found higher levels of interest in home energy assessments in neighborhoods with larger number of walkable areas and old historic buildings. This suggests that individual relation with the surroundings and owner's perception of their homes may play a large role in analysis.

Key Take-Away

Zip code-level information is useful for holistic assessments, when finding a regional trend is the main purpose of a project.

Energy simulation and prediction of energy savings by virtually testing home retrofits is not a new concept.

When socio-economic data is mapped and studied in combination with energy data, it will be possible to anticipate the public's feedback. In this study, the feedback was level of participation in a home retrofit program.

3. Gainesville Green

Background

Gainsville Green[53] is created by EnergyIT for property owners, renters, program planners, and building contractors. It is a dynamic and interactive web tool that displays energy data including electricity, natural gas, and water of residential buildings in Gainesville, FL in both historic and comparative ways.

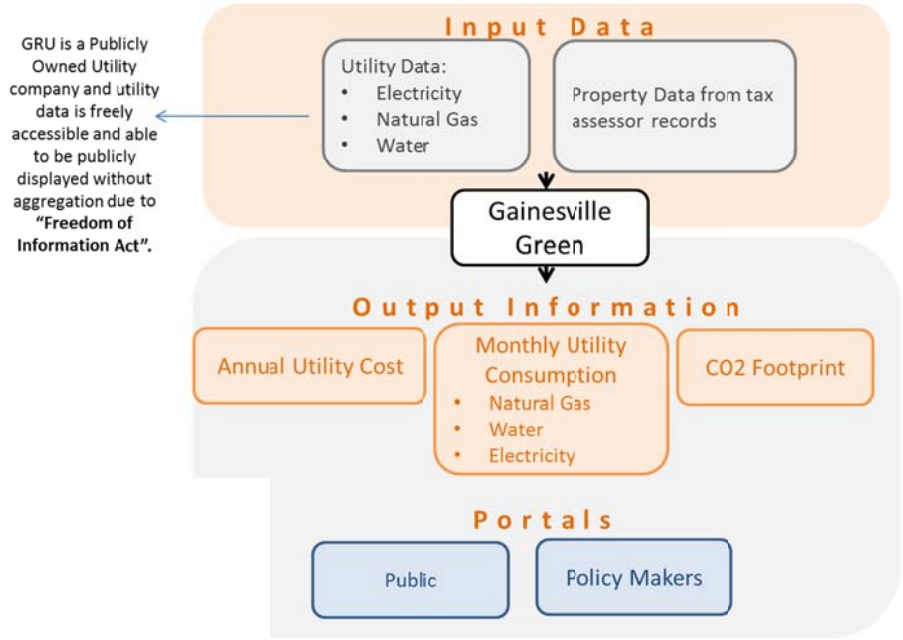
Gainsville is served by a publicly owned utility company and therefore, utility data is freely accessible and able to be publicly displayed without aggregation due to "Freedom of

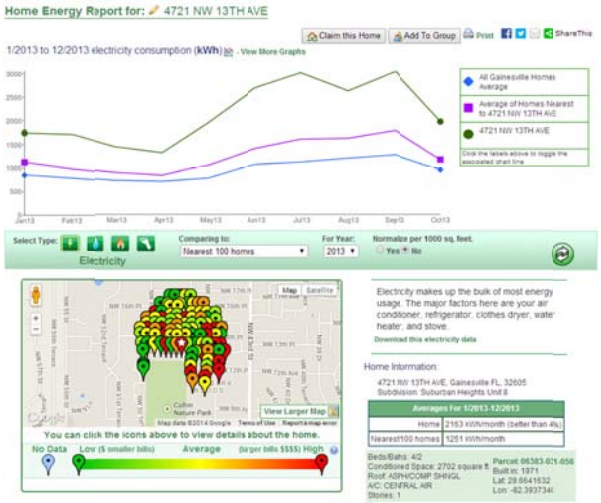
[53] http://gainesville-green.com/

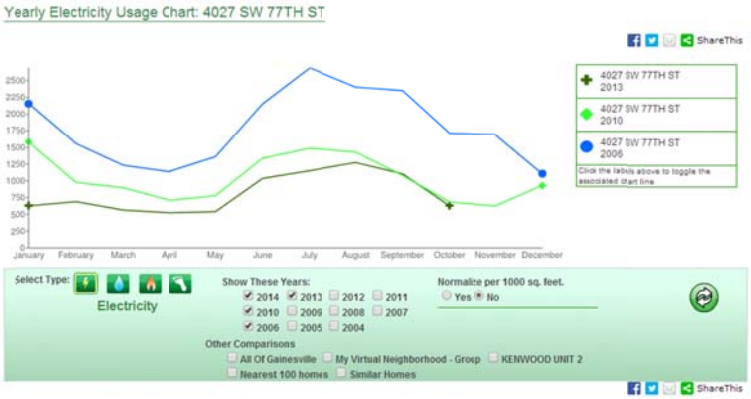
Information Act." Level of energy consumption of homes is associated with their utility bills and it is represented with colors ranging from green for low bills to red for high bills.[51]

Pros

Gainesville Green makes comparison between a select home and all homes in the city. In addition, in comparative analysis, comparison is made between a select building and the average building in the city. Furthermore, Gainsville Green illustrates historical trend of a buildings' utility data up to 10 years, starting from 2004 in the current version (accessed in August 2014).







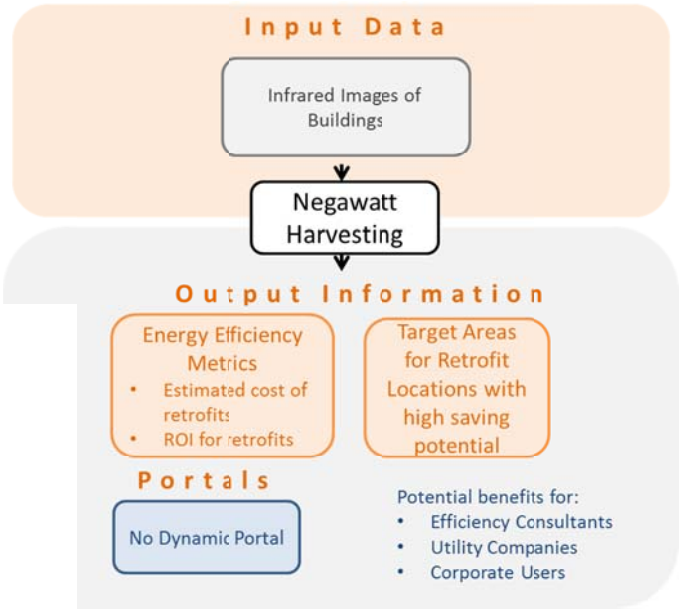
Cons

Gainsville Green does not display Energy efficiency of homes, and buildings are color-coded based on their total energy consumption. In order to represent level of energy efficiency, total consumption rates should be normalized by building area. The tool should also display other building attributes such as building construction and age, so that users could relate utilities billing data with building characteristics.

Key Take- Away

Energy data is publically available and displayed to rent payers, creating competition between building owners to reduce the level of energy consumption in their buildings.

4. Negawatt Harvesting, MIT Field Intelligence Lab (Residential Buildings)



Background

Designed by Senjay Sarma at MIT Field Intelligence Lab, Negawatt Harvesting is a map that displays areas that have high energy leaks or negative watts (Negawatts) through building envelope in city of Cambridge, MA.[54] The map could be used to find areas with high energy-saving potential. The research group captured Infra-red images with IR camera from residential buildings driving around the city; they estimated heat leaks from building units and grouped them into larger areas and communities to show Negawatt reservoirs.
IR images suggest heat leaks in a building unit and therefore they indicate energy loss from a building. These images are then translated into energy efficiency metrics, specifying cost and return of investment when efficiency measures are implemented.[51]

Pros

Representing areas within largest need for improvement in terms of energy efficiency is useful for policy makers or public organizations responsible for reducing carbon footprints of the urban environment.

The map identifies how much energy waste is due to having a loose un-insulated building envelope. Finding where those leaks are emitting from is extremely useful data for planning a retrofit.

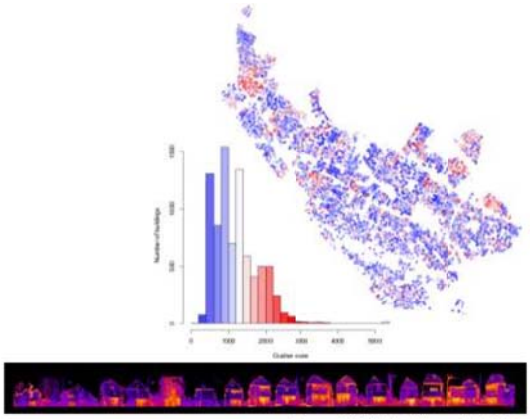
In addition to energy-savings potential, the map displays economic investment on energy efficiency by displaying cost of retrofit and return of investment in a specific area.

Cons

Pinpointing heat leaks is only one portion of energy equation, other factors such as inefficiency of mechanical and electrical systems, or above average interior setpoint temperatures are not informed in the Nagawatt Havesting map.

All IR images should be taken simultaneously or approximately in the same time frame when the temperature differences between outside and inside homes are identical and comparable. This task might be more complicated in a large urban environment. In that case, an alternative way to capture IR images of the city would be using an airplane or a satellite.

[54] http://fieldintelligence.drupalgardens.com/research_projects/negawatt-mining



Images: MIT Field Intelligence Lab, 2012

Steps towards Creation of the City Model

The “Core Version” of the City Model is intended to include water and energy data of buildings in the District. The Core Version has two editions: “DDOE Edition” that is planned to be deployed by DDOE and city administration for policy making purposes and “Business Edition” that is intended to attract various businesses and bring investment opportunities for the City Model. The model will be capable of being upgraded over time and the “Full Version” of the City Model could cover multiple pieces of “Green Building” landscape in future beyond energy and water consumption data. The table below compares the Core and Full Versions of the City Model and explains functionality of them and describes “Activities” and “Tasks” in each version.

		Functionality		
		Core Version		Full Version
		DDOE Edition	Business Edition	
Main Purpose		Policy making related to energy/water	Business Solution Applications related to energy/water	Policy making and solution applications for a wide range of sustainability measures
A. Activities				
1. Database Creation_ Data Capture Process	Static Data	Yes	Yes	Yes
	Biometric Data	Partial	Yes	Yes, extended to information about the building roof, green certificates and etc.
	Dynamic Data	Partial	Yes	In FV, buildings have more sensors to transmit data from PV panels, as an instance.
	Energy Models	Simple box energy models with no building systems	Yes, energy models that have more details	More detailed energy models
	Extrapolated Engine	Simple extrapolation based on building type and surface area	Yes, extrapolation engine based on building systems, age, construction type	Less dependence on extrapolation and more on actual real-time data streaming data from all buildings. Extrapolation may also include other sustainability measures.
2. Reconciliation process	Connect, relate, and compare static, dynamic and energy models	Automatic process	Needs human forces	More detailed process
3. Develop Solution Applications	Sustainability Solutions	No	No	Yes
	Energy Solutions	Yes	Yes	Yes
	Water Solutions	Yes	Yes	Yes
B. Investment Opportunities		Low	High	High
C. Application Developer Opportunities		Low	High	High
D. Testing “what-if” cases		Yes	Yes	Yes

Key:

	No
	Yes, Partially Performed
	Yes, Completely Performed
	Yes, Performed in Detail

Table: Comparison of the City Model Full and Core Versions

Task 1: Engagement of Clinical Trial Participants

The Clinical Trial is defined as a process where we choose a sample of buildings, study their attributes and performance, record their energy/water consumption levels, and create their energy models. This section will explain the development of a specific "plan of action" to identify candidates for the cooperative sample of buildings to be included in the "Clinical Trial" program. After reconciling measured and modeled data from the Clinical Trial the building's models are extrapolated city-wide to determine how the whole city performs in terms of its energy/water usage.

Existing energy/water data sources for the District buildings are not sufficient to create the City Model. Therefore, the Clinical Trail approach is suggested to overcome limitations of the existing data sources. These limitations include:

1. Quantity of data: The District mandatory benchmarking reports are the most current building-level data about energy consumption for the buildings in the District. However, this data is not inclusive and only covers buildings equal to or larger than 50,000 sf.
2. Quality of data: Existing data sources are neither deep enough nor high-quality enough to generate an analytical engine, Analytical City Modeling Engine (ACME), required for the City Model. Reports of electricity and gas bills from buildings would not be informative if they are not related to and connected to building attributes. A database that relates building attributes to their consumption levels does not exist for the buildings in the District.
3. Ability to test or predict "what-if" scenarios: currently no energy/water database exists that has the capability to test different policy scenarios, for example the impact of changes in building codes on consumption levels. Using the Clinical Trial approach and generating energy/water models for the city would create a database that is capable of implementing "what-if" scenarios and predict future outcomes.

We estimate that the total number of buildings that should be included in the initial Clinical Trial is one hundred. The following table shows building use types and number of buildings included in each group. Tax Codes are used to identify and coordinate building use types to standardize comparisons with other city databases, such as GIS data, that would be used in the extrapolation process. The number of Clinical Trial properties may grow as findings are derived from the preliminary phase of the Clinical Trial. It is our understanding that fewer buildings will not generate a reliable and acceptable result to be projected across the city. Over time there will be a chance to increase the number of buildings involved in the Clinical Trial and add to the data points in the City Model. Gradually, by adding the depth and breadth of data existing in the City Model, you can create a model that is an accurate representation of the city.

Adding to the number of buildings will create a model with higher resolution but it will increase the cost. Therefore, we recommend including 100 buildings in the Clinical Trial. In the future when the Full Version of the City Model is implemented the city administration can select a final number based on financial resources allocated to the Smart Buildings Project.

Clinical Trial Building Types and Number

	Tax Code	Building Use Type	Number of Buildings	
1	001	Residential- Single Family	1	
2	002	Residential- Multi Family	4	
3	015	Residential_ Mixed Use	2	10
4	016	Residential- Condo- Horizontal (less than 3 floors)	1	
5	017	Residential- Condo- Vertical (more than 3 floors)	3	
6	031	Hotel- Small	2	
7	032	Hotel- Large	4	8
8	036	Dormitory	2	
9	042	Store- Misc	4	
10	047	Store- Super Market	4	14
11	043	Store- Department	3	
12	044	Store- Shopping Center/ Mall	3	
13	034	Club- Private	1	
14	045-067	Store- Restaurant/ Commercial- Restaurant	5	8
15	045	Store- Beauty Shop	1	
16	165	Vehicle Service Station- Kiosk	1	
17	051	Commercial- Office- Small	5	
18	052	Commercial- Office- Large	8	15
19	061	Commercial- banks, Financial	2	
20	No Code	Commercial- Federal	5	9
21	No Code	Commercial- DISTRICT Gov. Office	4	
22	062	Commercial- Parking Garage	1	
23	066	Theaters, Entertainment	3	
24	072	Industrial- Heavy Manufacturing	0	
25	073	Industrial- Light Manufacturing	0	
26	081	Religious	3	
27	081	Medical	2	4
28	088	Health Care Facility	2	
29	082	Educational	11	
30	084	Public Service	2	
31	086	Embassy, Chancery, etc.	1	
32	087	Museum, Library, Gallery	8	
33	189	Special Purpose- Memorial	0	
34	No Code	Data Centers	2	
TOTAL			**100**	

To be considered in the Clinical Trial, buildings should be stand-alone or sub-metered properties. For instance, data centers should be included that are separately sub-metered.

Geographical Distribution: In an ideal case, the Clinical Trial will be composed of buildings distributed all over the eight wards of the District. Since the Clinical Trial is a volunteer sample rather than a statistical sample of buildings, we include "reward participation" to overcome problems with skewed sampling, such as finding volunteers from low-income housing through DC SEU and GreenspaceNCR. If the volunteering process for Clinical Trial did not generate a fair sample of buildings, we should plan for outreach programs to the areas without volunteers and attract building owners with reward strategies to participate in the Clinical Trial. Two strategies, voluntary and reward participation, are identified to find participants for the Clinical Trial:

1. Voluntary participation:
    a. Engage Smarter DC Challenge participants to secure needed private commercial buildings participants.
    b. Issue individual formal invitations from DDOE to engage Federal and District Government, public schools, cultural centers, healthcare centers, and data centers.
    c. Reach out through an online public invitation would be issued to those who participate in a brief survey asking building owner to participate in the Clinical Trial. The link to the survey could be posted on various District Government agencies (e.g. DDOE, DCRA) websites, online posts and emails. This method could be used to solicit participation from owners of private commercial buildings, market-rate multi-family residential buildings, and affordable housing and retail spaces.
    d. Identify those buildings that already have installed two-way metering through service providers that install and use those systems to support building efficiency to find participants who only need to agree to share the information they already have. We would look for private commercial buildings, education, healthcare, hospitality and data centers (an example of such questionnaire is prepared by Interface and is included as an Appendix to this report).
    e. Involve university campuses, public and private schools to find buildings in the educational category. Examples of such buildings in the District are Georgetown University and George Washington University. Moreover, DGS has been collecting electricity and natural gas consumption data from District Public Schools for the Build Smart DC program. These schools could be involved in the Clinical Trial process.
    f. Outreach to large portfolio property management companies to find private commercial and multi-family residential buildings. (e.g. Jones Lang Lasalle, JBG, EYA, Urban Atlantic)
    g. Involve District Housing Authority, DHCD (Department of Housing and Community Development), Enterprise Community Partners, CNHED (the Coalition of Nonprofit Housing and Economic Development), LISC (Local Initiatives Support Corporation) to find affordable housing units.

2. Reward participation
    a. Offer sub-metering, energy concierge, virtual energy audits to find multi-family residential buildings.

b. Collaborate with hardware equipment companies and consultants that install metering to provide energy management services (e.g. metering, building energy management systems) to find buildings that have that equipment installed.
c. Collaborate with DC SEU in their programs, to leverage:
    i. Financial incentives
    ii. Loans for building improvements: new boilers, thermostats, windows, and insulation
    iii. Lighting upgrade in buildings
    iv. Loans for purchasing ENERGY STAR/ energy efficient appliances

Task 2: Creating the Database

Biometric Data is information related to building characteristics to be collected from the Clinical Trial. The purpose is to use this information to identify building and to create energy models of the Clinical Trial. A list of biometric data includes the following items:

- Address
- Total Gross Floor Area
- Total Net Floor Area
- Building Footprint
- Number of Floors/ Building Height
- Ownership
- Tenant Type (Occupancy/ Use Type)
- Year of Construction
- Year of Last Major Renovation
- Building Construction
    - Façade Type: External Surface Area, Materials, Insulation, U-value
    - Glazing Type: Glazing Surface Area, U-value, SHGC, Visible transmittance
    - Window to Wall Ratio
- Engineering Systems
    - Mechanical Systems: Type, Coefficient of Performance (COP), Age
    - Electrical Systems: Type, Lighting Power Density
    - Interior equipment: Plug Loads (Computers, Printers, TVs and other)
    - Control Systems: Occupancy Sensors, Daylight Sensors, CO_2 sensors (meters)
    - Management Systems: Building Automation System (BAS)
- Number of Occupants: Residents, Staff, and Visitors
- Operation Hours (for non-residential buildings)
- Green Certification: LEED, ENERGYSTAR, and other

However, for the Core version of the City Model, which is designed for the city administration application only, building models will be created with a minimum data set required:

- Total Gross Floor Area
- Building Footprint
- Number of Floors/ Building Height
- Ownership

- Tenant Type (Occupancy/ Use Type)
- Building Envelope Material (or the overall heat transfer coefficient- U value of walls and roofs)
- Window to Wall Ratio WWR
- Glazing Material (or the overall heat transfer coefficient- U value of windows)

Table below shows data required to create the DDOE Edition versus Business Edition of the City Model. Furthermore, it presents data sources that could be used to capture the required data for creation of the City Model. Some of the building biometric data is available from existing big data sources, such as DDOE Benchmarking data/ DCRA, EPA Portfolio Manager (digitally reported version of Benchmarking reports mandated by DDOE), or the District's Geographic Information System (GIS). For example, building address and gross floor area exist in DDOE Benchmarking data, and GIS data. However, more detailed building information such as construction type does not exist in any of the data sources. Other limitation is due to the DDOE benchmarking rule that only covers buildings equal or larger than 50,000 sf, which compose only about 20% of the Clinical Trial. Information that does not exist in Benchmarking or GIS data could be captured via questionnaires. For the City Model's DDOE Edition, minimum data that needs to be collected via questionnaire, other open sources such as Google Earth, or site visit include:

- Building Envelope Material (or the overall heat transfer coefficient- U value of walls and roofs)
- Window to Wall Ratio WWR
- Glazing Material (or the overall heat transfer coefficient- U value of windows)

	City Model DDOE Edition	City Model Business Edition	**DDOE** (Benchmarking)	**DCRA/ OTR**	**DC GIS**	**Questionnaire**	Digitally-Generated Data
Address	**Yes**	**Yes**	✓	✓	✓	✓	✓
Gross floor area	**Yes**	**Yes**	✓	✓	✓	✓	
Net floor area	**No**	**Yes**				✓	
Number of floors	**Yes**	**Yes**	✓			✓	✓
Building Footprint	**Yes**	**Yes**			✓		✓
Ownership	**Yes**	**Yes**	✓	✓	✓	✓	
Tenant type (occupancy)	**Yes**	**Yes**	✓			✓	
Year of construction	**No**	**Yes**	✓	✓		✓	
Year of last major renovation	**No**	**Yes**			Building Permits	✓	
Building Material	**Yes**	**Yes**				✓	✓
Glazing Material	**Yes**	**Yes**				✓	✓
WWR	**Yes**	**Yes**			Building Mass Appraisal	✓	✓
Engineering systems	**No**	**Yes**				✓	
Interior equipment	**No**	**Yes**	✓			✓	
Number of occupants	**No**	**Yes**	✓	*Optional Input*		✓	
Operation hours	**No**	**Yes**	✓	*Optional Input*		✓	
Green Certification	**No**	**Yes**				✓	

Key	**Yes**	Data is Required	✓	Data is limited to certain buildings			
	No	Data is Not Required	✓	Includes all buildings			

The biometric data of all city buildings are generated in the City Model via extrapolation of the Clinical Trial in the Core Version. Existing biometric information is limited and it exists only for specific buildings in the city and data sources are scattered. In the City Model Core Version, you will find out if actual data or extrapolated data exists for the building by clicking on each building in the model. In future, the City Model Full Version would contain all biometric data of city buildings, rather than extrapolated data.

Static Data is an historical record of monthly utility bills including water, natural gas and electricity recorded by utility companies: DC Water, Washington Gas and PEPCO. Record of the past three years of electricity and natural gas consumption from the Clinical Trial would be required and it could be acquired from account holders (from online account profiles in digital format), from DDOE Benchmarking reports (limited to buildings larger than 50,000 in 2014 and 100,000 in 2013), or from utility companies via submission of request forms on behalf of the account holders.

Dynamic Data is real-time data about building performance that is streaming from buildings. Dynamic data will be reconciled with the modeled data from energy models of the Clinical Trial. In other words, dynamic data are crucial to validate and refine computer models. . In addition, streaming data from Clinical Trial provides accurate tracking of changes occurred in buildings' performance due to changes in code, policy, existing construction, or technology are made.

Dynamic data captured from buildings differ in the City Model's DDOE Edition and the Business Edition. The City Model's DDOE Edition use the existing infrastructure including the existing smart meters for electricity and existing meters for water and natural gas. Table below shows frequency of data. For the Business Edition of the City Model, new meters will be installed in the Clinical Trial for water and natural gas to increase the frequency of data transmitted.

	Core Version		Full Version
	DDOE Edition	Business Edition	
Dynamic Data	Using existing smart meters for electricity, existing meters for water and natural gas	Installing new meters for water and natural gas	Installing new meters for sustainability measures
Electricity	15-min	15-min	15-min
Natural Gas	Monthly	Hourly	Hourly
Water	Twice a Day	Hourly	Hourly
Renewable Energy	None	None	Yes
Indoor Air Quality	None	None	Yes
Human Health And Activity	None	None	Yes
Water Collection and Reuse	None	None	Yes
Waste Disposal and Recycle	None	None	Yes
Transportation	None	None	Yes

The Full Version of the City Model would include additional information such as building's waste disposal and recycled materials. One method to implement that is to request waste management companies weigh trash that is collected from each building. In addition, future District policies could be adopted requiring solid waste collection weight data be submitted on a reasonable basis.

Energy Models

Energy models will be used for predictions and "what-if" cases in regards to policy making. Energy simulation will be conducted for "Clinical Trial" with an energy modeling programs certified by the Department of Energy. Creating computer models of the buildings and conducting energy simulation will provide deep and clear understanding about a building behavior. Energy simulation allows studying of cause and effects on building behavior by changing multiple variables such as building materials and energy systems. It allows testing various scenarios such as different energy conservation measures and picking the most effective solution. Energy simulation is necessary in this study since there is a complex relation between building variables (building biometrics and low-impact strategies implementation) and invariables (energy /water consumption). The actual data collected from monitored building will be compared with the simulation results and energy models will be calibrated based on this comparison.

Validated energy modeling software identified by Department of Energy includes:

- EnergyPlus (free)
- OpenStuido (free)
- eQuest (free)
- DesignBuilder (about $2,000)
- IES VE (about $4,000)
- Autodesk Green Building Studio (included in Autodesk Revit/AutoCAD package)

However, for creating a large-scale energy model, such as the 100-building Clinical Trial, not all these options would be appropriate. First, the energy model does not need to be highly-detailed. Second, the software should be capable of handling a large volume of simulated thermal zones. Third, the software should have a Graphic User Interface (GUI) for easy creation of buildings' geometry and shape. Options for large-scale energy modeling include:

Autodesk: REVIT+ Green Building Studio (Rapid Energy Modeling) that has the following pros and cons:

- Pro: Capture data from open source data: satellite image, or photographs with Autodesk Recap 360
- Con: Not fully automatic to generate energy models out of captured data

Google SketchUp Model+ OpenStudio Plugin that has the following pros and cons:

- Pro: Free publically available tool
- Con: Not fully automatic, needs human intervention to create models on top of Google Earth images

IES VE Mater Planning Tool (Pilot Phase) that has the following pros and cons:

- Pro: Convenient and fast modeling with simple outputs
- Con: No direct connection to digital data sources

The Energy modeling tool selected for modeling the buildings energy use should remain consistent during the project. The energy simulation tool that the team chooses for creating the energy models outputs of the Clinical Trial will be compared with actual rates of electricity and gas usage for each of the buildings.

	Core Version		Full Version
	DDOE Edition	Business Edition	
Energy Models	Simple box energy models with no building systems	Energy models that have building systems	More detailed energy models

In the City Model Core Version developed for DDOE, energy models are simple box energy models with few thermal zones (single thermal zone per floor). These basic models are generated by the following biometric data:

- Total Gross Floor Area
- Building Footprint
- Number of Floors/ Building Height
- Ownership
- Tenant Type (Occupancy/ Use Type)
- Material (or U-value) assigned to the building envelope
- WWR
- U-value of window

In basic energy models building systems are not modeled and construction is simplified to a single number (U-value of the building envelope).
In the Business Edition of the City Model CV, energy models are more detailed as they are created based on a more expansive list of biometric data explained in previous sections.

The Full Version of the City Model would probably have one energy model related to each single building in the city, that get automatically updated as dynamic data from the building changes, when a mechanical system is replaced or the building is remodeled.

Energy modeling is not a new concept for constructions in District of Columbia. In the District, the Green Construction Code applies to all commercial projects 10,000 SF and larger (including new construction and renovations) and all residential projects both 10,000 SF and larger and 4 stories and higher. In the Green Construction Code, buildings that follow Performance Path for new construction

or major renovations are required to perform energy modeling. Buildings are required to submit inputs and outputs of energy models to DCRA for confirmation. Currently, acceptable energy modeling tools include Trane Trace, Carrier HAP, eQuest, and EnergyPro.

DDOE/DCRA could use the energy models created by buildings that seek compliance with Green Construction Code add them to the City Model's library of energy models. In that case, DDOE/DCRA need to:

1. Ask applicants to submit building energy models along with other documentation for application.
2. Define a single energy modeling tool that is used in the City Model engine. DDOE/DCRA could choose DOE's energy modeling engine, EnergyPlus, which is used as the base engine by multiple tools.
3. Define protocols for energy modeling and require applicants to use the protocols for creating energy models. Currently, buildings should comply with Section 11 (ASHRAE 90.1-2010) or chapter 407 (2012 IECC) methodology for minimum energy compliance. Further research is required to define if the existing protocols are sufficient to make all submitted energy models comparable and to define if differences between ASHRAE 90.1-2010 and 2012 IECC generate discrepancies between energy models.
4. DDOE/DCRA could accommodate assistance and support for applicants to facilitate the energy modeling process of the Green Construction Code.

Task 3: Analytical City Modeling Engine ACME

The City Model has an Analytical City Modeling Engine ACME that is a descriptive computer program/model capable of processing data, performing statistical analysis, estimating the impact of changing parameters in virtual models, and drawing conclusions.
The ACME would be a replicable engine that could be used for other cities, if a database of static, dynamic, and biometric data exists for a select number of buildings in the city.

- Extrapolation Process

The next step in creation of the City Model is to extrapolate data from the Clinical Trial to all city buildings. In the City Model CV DDOE Edition, extrapolation is a simple process based on building type and surface area. Buildings in the Clinical Trial would be matched with identical buildings that have the same use type. In the Business Edition of the City Mode CV, extrapolation engine is more complex by matching buildings based on building systems, age, last year of major renovation, construction type as well as buildings use type.

In the Core Version of the City Model there may be a significant amount of data in the City Model that is generated via extrapolation. In the Full Version of the City Model there will be less need for extrapolation since most city buildings will get connected the platform and they will transmit real-time data.

Data Source	Data Type				
	GIS ID	**SSL (Square Suffix Lot)**	**Tax Use Code**	**Building Footprint**	**Building Total Area**
DC GIS Computer Assisted Mass Appraisal (CAMA)- Commercial and Residential		✓	✓		✓
DC GIS Polygons Shape File	✓			✓	
DC GIS Tax Lots	✓	✓			

In other words, when smart meters transmit electricity, natural gas, and water data instantly from the buildings, the City Model does not need to depend on the Clinical Trial to generate data for the city buildings. By accepting streaming data from a larger number of buildings the City Model's platform will be more accurate with high-quality analysis and prediction engine for energy/water resource in the city.

In addition, in the Full Version, extrapolation process will include other sustainability measures such as renewable energy sources.

	Core Version		Full Version
	DDOE Edition	Business Edition	
Extrapolated Engine	Simple extrapolation based on building type and surface area	Extrapolation engine based on building systems, age, construction type	Less dependence on extrapolation and more on actual real-time data streaming from buildings. Extrapolation is based on additional sustainability measures

Extrapolation will be based on DC GIS data. All building blocks have a SSL (Square- Suffix- Lot) number assigned to them. SSLs are 12 characters, first 4 digits are for Square, middle 4 digits are for Suffix, and last 4 digits are for Lot). Most SSLs do not have a Suffix and you see them as 8 digit numbers in GIS files.

- If Lot is numbered 1-799 it is a Record Lot – Administered by DCRA – Office of Surveyor
- If Lot is numbered 800-1299 it is a Tax Lot – Administered by OTR – Real Property Tax Administration
- If Lot number is 2000-6999 it is a Condo Lot – Administered by OTR – Real Property Tax Administration - no geography, approved by air rights, record lot or tax lot.
- If Lot is numbered 7000 or above it is a AirRights Lot – Administered by OTR – Real Property Tax Administration

- If it begins with “PAR” (followed by parent parcel and child lot) it is a Parcel – Administered by OTR – Real Property Tax Administration Ex. PAR 01550018 (PAR 155/18)
- If it begins with “RES” it is a Reservation Ex. RES 00660000 (Reservation 66)

Since the relation between lots and buildings is “many-to-many” relationship, there is not a simple way to match them together.

- In case there is a one-to-one relation between Square (first four digits of SSL) and Lot (last four digits of SSL) numbers, use the SSL, unaltered
- In case of condos, where there are multiple Lot numbers (which has codes larger than 7000) for one Square number, use the SSR (complex number for condos created by junction table)
- In case of multiple Lots for one Square for non-residential buildings, when for example there are two address points for a corner building, use the numerically smallest Lot number, and in the long term, ask OTR to merge them if applicable.
- In case of multiple Square numbers for one Lot, where a single tax lot covers multiple buildings/properties, assign an extra alphanumeric add-on to the end of the number (e.g. 1321-0827-A, 1321-0827-B, etc.)

GIS data is split among multiple tables and shapefiles.

- The DC Polygons Shape file has GIS ID and building footprints.
- The DC Ownerpoints has SSL, the square footage, year built and tax use code.
- The DC Tax Lots has both GIS ID and SSLs that could act as a linkage between shape files and point files (use code, area, etc.)

GIS Data Source	**Data Type**				
	GIS ID	**SSL (Square Suffix Lot)**	**Tax Use Code**	**Building Footprint**	**Building Total Area**
DC Polygons Shape File	✓			✓	
DC OwnerPoint		✓	✓	✓	✓
DC GIS Tax Lots	✓	✓			

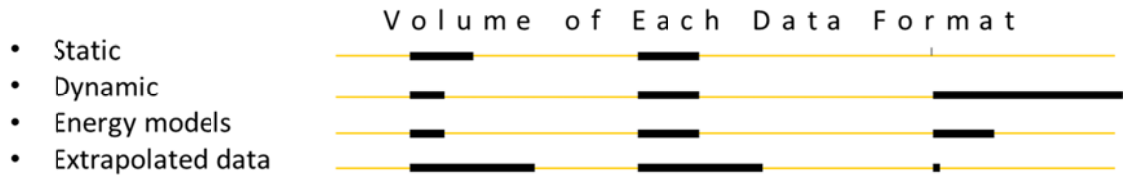
Reconciliation process

In the reconciliation process energy models of the Clinical Trial are reconciled with the actual static and dynamic data. The team will compare and study differences between 1) outputs of energy models, 2) past record of monthly electric and gas bills, 3) streaming electric and gas data from the Clinical Trial, and 4) extrapolated data. The team will connect, relate and make sense of data at this stage. In addition, they will adjust the energy models to align the outputs with the actual data captured data from those buildings.

During the reconciliation process, it is possible that the actual data collected from the “Clinical Trial” will undergo normalization and refinement before entering the Analytical City Modeling Engine ACME.

For instance, the data format might need to be changed and converted to a specific format that is readable by the Analytic Engine.

Volume of static data, dynamic data, energy model outputs, and extrapolated data differs based on the City Model's version and edition. The following graph shows this difference in the City Model CV DDOE Edition, versus Business Edition and the City Model FV. For instance, the Full Version will include more dynamic real-time data rather than static data; in addition, it will rely less on extrapolated data. However, energy model outputs would be a major part of the Full Version.



Reconciliation process depends on the software's version and its edition. In the City Model CV DDOE Edition, reconciliation process will be an automatic and simple process to create a database that is good enough for the purposes of DDOE for policy making. In the Business Edition, the purpose is to create a very accurate "database" for future investment. In order to create such a high- resolution database, the reconciliation process needs human intelligence to study and link various types of data captured from the buildings. It is obvious that the level of accuracy of the "reconciled database" has impact on the project budget.

	Core Version		Full Version
	DDOE Edition	Business Edition	
Reconciliation process	Automatic, simple process	Needs human forces	More detailed process

The establishment of a reconciled database is what can create the most valuable opportunity for the City through the development of a City Model that provides meaningful opportunities for future investment and income generation via offering the database to business owners, professionals and application developers.

Analysis and Prediction Process

The City Model CV DDOE Edition allows locating buildings that need performance improvement and allows targeting buildings, city blocks, neighborhoods, zip codes, and ward levels for implementing new policies or strategies. Energy/water benchmarks are established in the City Model for each category of building type (i.e. office, residential, healthcare buildings) by finding the average consumption rate for water, electricity and gas. Total energy and water consumption rates are normalized based on the building areas. The City Model will identify buildings with the largest EUI (Energy Use Intensity) compared to the established benchmark and locate the buildings that need retrofits or renovation to improve their energy/water performance.

The City Model CV DDOE Edition offers energy solutions and water solutions and it suggests solutions and prioritizes them based on their environmental impact. Furthermore, the City Model allows testing "what-if" cases and anticipating the environmental impact of changes in policies, codes, technology roll out (e.g. solar panels), behavior or operation change (e.g. use efficient mechanical system), or changes in the city anatomy (e.g. densification, construction of a new large development, and etc.) The City Model will define environmental implications of these changes and specify how these changes contribute reductions in energy, water, and carbon emissions. However this capability is limited in the DDOE Edition due to limitations in the extrapolated engine in this edition. In other words, the simple extrapolation process of the City Model's DDOE Edition would anticipate outcomes that are good enough for policy making but most likely not high-quality enough for other purposes. The Business Edition, on the other hand, offers high- quality results for future predictions.

	Core Version		Full Version
	DDOE Edition	Business Edition	
Sustainability Solutions	No	No	Yes
Energy Solutions (suggest and prioritize reduction strategies)	Yes	Yes	Yes
Water Solutions (suggest and prioritize reduction strategies)	Yes	Yes	Yes
Testing "What-If" Cases	Yes, Limited	Yes	Yes
Anticipate Environmental Impact	Yes, Limited	Yes	Yes
Anticipate Economic Impact	No	No	Yes
Anticipate Social Impact	No	No	Yes
Locate Buildings that Need Performance Improvement	Yes	Yes	Yes

Prediction engine is a combination of matching process, energy modeling process and extrapolation process. This is the process that the ACME follows if a certain change is aimed for a certain type of buildings in the city. For instance, the city administration would like to know how much energy consumption and carbon emissions are reduced in the city by reducing the lighting power density in office buildings larger than 50,000 sf for 10%. To answer to this question, first, the ACME picks the energy models of the office buildings larger than 50,000 amongst 100 (or more) buildings in the Clinical Trial; second, the ACME reduces lighting power density in the energy models for 10% and runs new energy simulations; third, the ACME reports outputs from the energy simulations and extrapolates the results from the Clinical Trial to the whole city; Forth, the ACME reports how much reduction in energy and carbon emissions have that change contributed to the whole city.
The City Model defines and prioritizes policy changes, technology implementations, operation changes in buildings that could result in a certain reduction percentage in the total energy and water consumption. As a result, the City Model could facilitate the city administration to track the city's water and energy flow and plan to meet the goals of Sustainable DC by 2032.

Furthermore, the ACME would predict the impact of climate change on the city's energy and water consumption. The City Model simulates the average weather condition of the National Ronald Reagan Washington national Airport in the energy modeling process. The energy models in the City Model accept Typical Meteorological Year 3 (TMY3) data that is the average weather data of the Reagan Airport from 1991 to 2005 in EnergyPlus format (available from the US Department of Energy website). By adopting the scenarios developed for future climate change, the City Model would be able to simulate future weather condition and anticipate outcomes from the whole city.

The ACME will have higher capabilities in the Business Edition of the City Model CV due to its more comprehensive and detailed database. In this edition, energy and water consumption data is aligned with building biometric data, such as age, construction type, materials, building systems, and etc.; therefore, you can filter buildings based on a specific characteristic, such as buildings' last year of renovation, and target them with higher level of refinement.

Furthermore, in the City Model's Business Edition, end-use energy types (e.g. space heating, cooling, lighting, or water heating) will be identified in the Clinical Trial buildings. If sub-metered data from the buildings are captured in the Clinical Trial, they will be used to assess proportions of end- use energy types for the whole city. In that case, the City Model could define which end-use energy usage should be the focus for policy, technology, behavior, operation change considering the climate and building profile in the District.

This task does not seem unlikely with the current sub-metering requirements of 2013 Green Construction Codes. As the Green Codes require, there will be more buildings in the city with sub-metered end-use energy consumption data in future. The District's green construction code requires sub-metering for buildings larger than 50,000 sf. For buildings that do not comply, the code requires energy distribution systems to be designed and constructed to accommodate the future installation of sub-meters.

Task 4: Development of Solution Applications

Solution applications are innovative ways to bring data analysis and prediction to a person who is not a statistician or data analyst. Solution applications are comparable to smart phone or tablet applications which made those gadgets must-have tools. The “reconciled database” of the City Model is a platform capable of hosting divergent applications related to the city’s built environment and sustainability. Today we see many applications developed that were once beyond our imagination. Many applications are developed nowadays for specific professions- apps targeted solely for airline pilots or bank tellers or pharmaceutical workers. "This is a way to enrich peoples' lives in a big way," Cook, the CEO of Apple said, "to change the way people work."

Solution applications enhance usefulness and usability of the “reconciled database” for targeted audiences. A sustainability professional can ask questions, probe database, and use graphic representations to make sense of data and find answers. By getting analytics in the hands of users, solution applications will create a widespread adoption of the “reconciled database” among businesses and professionals in the field of sustainability, energy, and water in buildings. Three solution applications are defined for the City Model that target city administration, building owners, and the public.

Policymakers: this application presents building-level information for each individual building located in the city. This portal has the highest level of granularity which is intended for the use of policy-makers and legislators.

Clinical Trial participants/ Private property owners: this portal includes building-level information about a large building portfolio. Buildings in the Clinical Trial could view building-level information of all the properties that participated in the Clinical Trial. Building owners with large building portfolio will be able to see their buildings’ performance data at building-level and compare and contrast their performance with a typical building in the city. The portal will be designed to present information that is considered of high value to building owners so we will suggest engaging building owners in facilitated conversations to help shape design their portals and identify potential ways the program’s data can benefit their businesses.

General Public: providing the public with a source of information about the performance of the District’s buildings and their impact on the sustainability of the city will be useful to individuals and organizations throughout the District and reinforce the goals and opportunities shaped by the Sustainable DC program.

These three are fundamental and primary applications for the City Model and they are comparable to the “pre-loaded” apps in a smart phone. However, many other solution applications could be developed for the City Model in future. Application developers could design and implement special apps for the “reconcile database” to help users visualize and make sense of large data sets that exist in the database.

Level of access to the information that City Model presents depends on the audience type and it ranges from full access to limited access. Three levels of transparency are possible for the model, which are listed in order of preference, but will be dependent on negotiations with the utility companies.

- Full access that has the highest level of transparency and gives permission to access full potential of the model. It enables viewing building- level information for all properties in the city.
- Granted access that gives permission to a select group of individuals, such as participants in Clinical Trial and individual building owners. Granted access allows users to view all building- level information for only one property or a group of properties. In other words, it provides deep knowledge about a limited number of buildings.
- Limited access that has the lowest level of transparency since it filters building data and poses limitation on some type of information that is presented to viewers. This limitation is intended to protect privacy of building owners and filters will be removed in case the rules of utility data sharing with the public change in future. Ideally, more transparency is desired for this level so that the public can have access to the data; however, if that level of granularity is not deemed acceptable to utilities and stakeholders, the tool will provide aggregate data at zip code or ward level. As opinions about the level of transparency changes over time, the tool should be designed to adapt and provide more granular data.

Increasing transparency of the City Model will make the tool accessible for a vast range of people and purposes. It is likely that the City Model will be used most often by people with less familiarity in energy-related topics. Therefore, the tool should provide filters and education/explanations that create a more understandable context. Likewise it should use a vocabulary suitable for this broad range of audiences.

Action Plan

Funding Plan

There are multiple opportunities for potential funding of emerging tools required in smart cities. As we can see from the recent initiatives in funding big data efforts in healthcare [55]and in basic research and scientific discovery[56], the potential for the District, in collaboration with Greenspace, NCR and Interface Engineering could pursue funding either independently or in partnership with other nonprofit organizations or academic institutions to advance the use of big data and its necessary refinement as it applies to dramatically improving the performance of our buildings from both policy and practice perspectives.

Potential Nonprofit Partners could include:

- USDN (Urban Sustainability Directors Network),
- NRDC (Natural Resources Defense Council),
- IMT (Institute for Market Transformation),
- C40 Cities Climate Leadership Group (C40), and
- The Smart Cities Council

Potential Academic Partners could include:

- Georgetown University
- George Washington University
- University of Maryland
- Carnegie Mellon University
- New York University
- University of California, Berkeley
- University of Washington

In November 2013, the Gordon and Betty Moore Foundation announced a bold new partnership to harness the potential of data scientists and big data for basic research and scientific discovery. New York University, the University of California, Berkeley and the University of Washington launched this new 5-year, $37.8 million, cross-institutional effort with support from the Gordon and Betty Moore Foundation and Alfred P. Sloan Foundation.

The potential sources include:

Local Government Grants

- Department of General Services (DGS)
- The Office of the Chief Technology Officer (OCTO)

[55] http://medcitynews.com/2014/01/7-healthcare-big-data-companies-just-got-funded-knight-foundation/
[56] Gordon and Betty Moore Foundation - http://www.moore.org/programs/science/data-driven-discovery/data-science-environments and Alfred P. Sloan Foundation - http://www.sloan.org/major-program-areas/digital-information-technology/data-and-computational-research/

- The DC Sustainability Energy Utility (DC SEU), and
- The DC Housing Authority (DCHA) if the benefits for residential buildings are highlighted

Federal Government Grants

- Environmental Protection Agency (EPA)
- US Department of Energy (DOE)
- General Services Administration (GSA)
- National laboratories including National Renewable Energy Lab (NREL), Oak Ridge National Laboratory (ORNL), and Pacific Northwest National Lab (PNNL)
- National Science Foundation (NSF)

Foundations

- Surdna Foundation
- Summit Fund
- Bloomberg Philanthropies
- Rockefeller Brothers Fund
- Gordon and Betty Moore Foundation [57]
- Alfred P. Sloan Foundation [58]
- JPB Foundation
- Gates Foundation

Corporations

- Google
- Autodesk
- Microsoft
- Amazon

Venture Capitalists

- Equilibrium Capital [59]
- Inerjys [60]
- Industrial Ecology Capital Management (IECM) [61]
- IECM is a private equity investment firm that helps create and capitalize operating firms that sustainably develop land and infrastructure assets, and provide efficient, integrated resource management services such as distributed water, wastewater, and energy utilities as well as property management.
- Natural Systems Utilities, LLC[62]
- Kleiner Perkins Caufield Byers [63]

[57] - http://www.moore.org/programs/science/data-driven-discovery/data-science-environments
[58] - http://www.sloan.org/major-program-areas/digital-information-technology/data-and-computational-research/
[59] http://www.eq-cap.com/
[60] http://inerjys.com/en/
[61] http://nsu-im-mn.wix.com/iecm#!about
[62] www.naturalsystemsutilities.com/
[63] http://www.kpcb.com/

The field of research about Big Data involves putting the staggering sums of information we are stockpiling as part of our increasingly digital activity to good use. Researchers are using data science to analyze demographics, marine biodiversity, human behavior, health records, and the financial industry, just to name a handful. And foundations large and small are getting on board. Consider a few examples:

- The Gordon and Betty Moore Foundation and the Alfred P. Sloan Foundation launched in November a $37.8 million initiative spread across the University of Washington, the University of California at Berkeley and New York University. Sloan and Moore are two of the biggest backers of data science.
- Hedge fund investor Jaffray Woodriff gave $10 million to the University of Virginia to for the school's Data Science Institute, a new interdisciplinary program at the school.
- The University of Rochester received a grant of $10 million from the Wegman Family Charitable Foundation for its Institute of Data Science, part of a $100 million commitment the university has made.
- The University of Washington just received $30 million from the Washington Research Foundation, which uses state school patent earnings to support further research. Data science is one of four fields of research the grant will benefit. The school also receives millions in support from Microsoft, Google and Amazon.
  And that's only non-government support. New York City is contributing $15 million each to data science centers at Columbia and NYU, not to mention NSF and NIH grants.

Team Players and Tasks

1. Leadership/project management has the major responsibility to ensure successful accomplishment of the project by controlling the schedule and budget and leading the team in the right direction. responsibilities of the leadership/management include:
    - define scope of work
    - define team players and assign tasks
    - coordinate between team players
    - define and manage project schedule
    - define and manage budget plan
    - perform administrative tasks
    - business development
    - make executive decisions in various stages of the project (i.e. Clinical Trial participants)
    - define security protocols for sharing data with the audiences in the solution applications

2. Content experts have the knowledge and expertise required to define and develop the contents in the City Model.
    - assist management to define the scope, tasks and schedule and help leadership to select the team players
    - identify the Clinical Trial participants

- define protocols to collect data from the Clinical Trial (e.g. format of data)
- assist data analyst to collect and analyze biometric and static data from the Clinical Trial
- collect data from all the city buildings required for creating the extrapolation engine (i.e. building type/ building area)
- define solution applications and assist graphic designers to create the features required for an interactive, useful, and informative graphic user interface

3. Cost analyst
    - create and manage the budget plan
    - assist management to define scope/team players/ schedule based on the budget

4. Energy modeler/ analyst
    - create energy models for the Clinical Trial
    - develop the evaluation engine
    - develop the prediction engine

5. Data analyst
    - collect and analyze biometric and static data from the Clinical Trial
    - work with the programmer to relate and connect data from the data sources and make sense of the data
    - generate the Reconciled Database, relate and connect data from the data sources (static, dynamic, biometric, energy model outputs, and extrapolated data)

6. Software designer
    - assist the energy modeler/analyst to create the extrapolation engine
    - assist the energy modeler/analyst to develop the prediction engine
    - create/ acquire 3D model of the city
    - assign data to 3D models
    - develop a demo of the City Model
    - implement security controls for solution applications

7. Programmer (code scripter)
    - assist the energy modeler/analyst to create the extrapolation engine
    - assist the energy modeler/analyst to develop the prediction engine
    - write programs/codes to normalize data, change format of data, and make different data sources to talk to each other

The City Model CV Business Edition requires four more roles to be added to the team mostly related to installation of new equipment in the buildings, marketing, and creating graphic user interface for users.

8. Hardware technical integration team
    - install meters and required equipment to collect dynamic data from the Clinical Trial
    - relate and connect data from different data sources

9. Web developer is responsible to create interactive web-based tool and ensure easy access for the target users.

10. Graphic designer
    - graphic design of web portals
    - graphic design for marketing purposes

11. Marketing
    - meet with stakeholders
    - seek funding options
    - marketing and outreach

The following table illustrates the tasks and responsible entities to perform them for the City Model project.

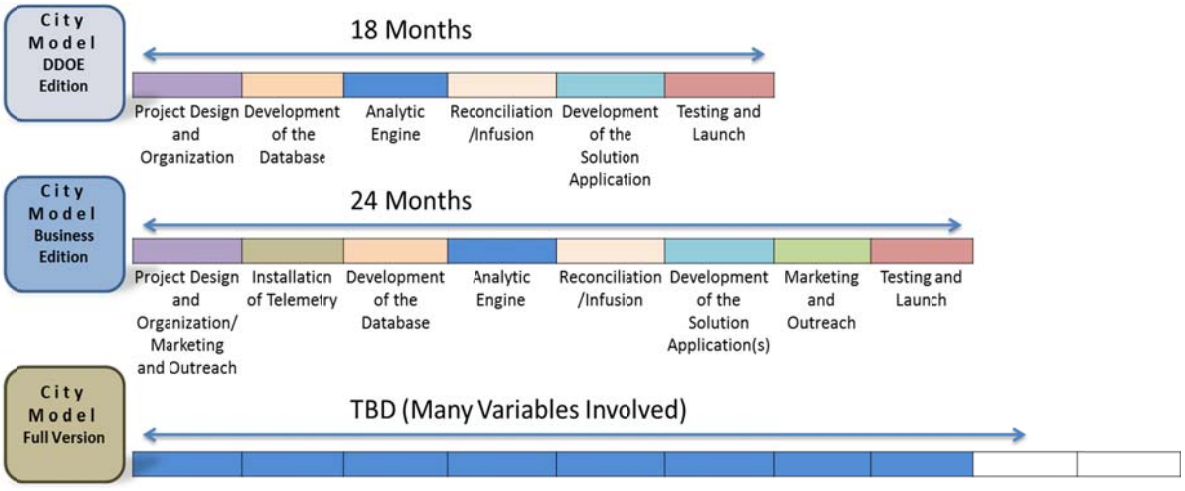
	List of Activities	Responsible Entity
	Project Design and Organization	
1	Define Scope of Work	Mngmt/ Cont Expert/ Cost Analyst
2	Define Team Players	Mngmt/ Cont Expert/ Cost Analyst
3	Define Tasks	Management/ Content Expert
4	Define Budget Plan	Mngmt/ Cont Expert/ Cost Analyst
5	Marketing and Seek Funding Options	Mngmt/ Cont Expert/ Cost Analyst
6	Negotiate with Team Players about Tasks and Budget	Mngmt/ Cont Expert/ Cost Analyst
7	Define/ Engage Clinical Trial Participants	Mngmt/ Cont Expert/ Cost Analyst
8	Define Biometric/Static/Dynamic Data to be Collected from Clinical Trial	Management/ Content Expert
9	Itemize Existing Tools/ Software for 3D Modeling, Energy Modeling and etc. and Define their Cost	Content Expert/ Cost Analyst
	Business Development	
10	Define Future Development of the City Model Beyond Energy/ Water Flow (Version 2.0: Adding Sustainability Features, Integration with Existing Tools, etc.)	Mngmt/ Cont Expert/ Cost Analyst/ Marketing
11	Meeting with application developers	Mngmt/ Cont Expert/ Marketing
12	Comments from DDOE	
13	Incorporate DDOE Comments	
	Reconciled Database	
14	Collect Biometric/Static Data from Clinical Trial	Content Expert
15	Collect Dynamic Data from Clinical Trial	Hardware Technical Integration Team
16	Create Energy Models for Clinical Trial	Energy Analyst/ Modeler
17	Relate and Connect Data from Three Data Sources	Software Designer/Energy Modeler/Hardware Team
18	Comments from DDOE	
19	Incorporate DDOE Comments	
	Analytical Engine	
17	Collect and Complete a List of Data (Building Use Type and Building Area) for all City Buildings	Content Expert
18	Develop Extrapolation Engine	Software Designer/ Content Expert
19	Develop Evaluation Engine	Energy Analyst/ Modeler
20	Develop Prediction Engine (Define Scenarios for Future Policy/ Climate Change)	Software Designer/ Energy Analyst/ Modeler
21	Develop a Demo (Proof-of-Concept)	Energy Analyst/ Modeler/ Software Designer
22	Comments from DDOE	
23	Incorporate DDOE Comments	
	Solution Applications	
22	Create/ Acquire 3D Model of the City	Software Designer/ 3D Modeler
23	Assign data to Building 3D Models	Software Designer/ 3D and Energy Modeler
24	Define Contents of Web Portals	Content Expert
25	Define and Implement Security Protocols	Management/ Software Designer/ Web Designer
26	Graphic Design of Portals	Graphic Designer
27	Create Interactive Web Interface	Web Designer
27	Comments from DDOE	
28	Incorporate DDOE Comments	
	Marketing and Outreach	
29	Meeting with Stakeholders/ Developers/ Utility Companies	Management/ Content Expert/ Marketing
30	Seek Future Options for Development of the Next Version of the City Model	Marketing
31	Marketing	Marketing

Timeline

The City Model CV (Core Version) DDOE Edition is envisioned as an 18-month effort that includes project design and organization, development of the database, creation of the analytic engine, reconciliation of data sources, and development of the solution applications. The last piece of the project would be testing and launching the City Model to find out any problems or malfunctions associated with each of the steps. Some of the project tasks are independent and therefore, they could occur simultaneously. For instance, development of the Solution Applications, development of the Analytic City Modeling Engine ACME, and development of the database could start at the same time. This fact will help reduce the total project time but we suggest the 18-month time frame to account for variances.

The City Model CV Business Edition requires more time for its accomplishment and it is anticipated to be a 2-year process with identical steps to the development of the DDOE Edition. In the Business Edition, additional time is required because of additional procedures including installation of telemetry, marketing, outreach, and business development. Additional time might also be needed for the Business Edition since some tasks such as energy modeling and creating the database are more complicated than the DDOE Edition and require more time.

The schedule for the Full Version of the City Model should be determined in future. Currently, it is unlikely to define an accurate schedule due to many unknown variables involved. However, the process would longer than 2 years for the Full Version.



Budget

The following table shows the budget required for development of the Business Edition and the DDOE Edition of the City Model assuming that the are 100 buildings participating in the Clinical Trial. Obviously, adding the number of the Clinical Trial buildings, would add to the estimated cost. The budget is divided into four major components: database, analytic engine, solution applications, and supporting services. The budget is estimated for a City Model with 100 buildings in the Clinical Trial. The higher the number of buildings in the Clinical Trial, the higher the budget would be to create the City Model. As you see in the following table, the budget required for the DDOE Edition is about $1.4 million, which is about half the price of the Business Edition at $3 million.

The most expensive component of the City Model in both DDOE and Business Editions is the database, which is significantly more expensive in the Business Edition. The reason lies in the fact that creation of the database does not require installation of new equipment in the DDOE Edition. Therefore, the will be no budget required for the labor and expenses associated with installation new water and gas meters in the buildings.

The other difference between the Business Edition and the DDOE Edition is the budget needed for development of the Solution Applications. The DDOE Edition of the City Model would only have one Graphic User Interface for policy makers or city administration, whereas in the Business Edition, there will be multiple Graphic User Interfaces to be used by various groups of audiences. In addition, the DDOE Edition and the Business Edition differ in terms of supporting services. The DDOE Edition would not have the Marketing piece since it has pre-defined users, the District administration, with no need for marketing. On the other hand, the marketing piece has a key role for the Business Edition to find additional funding sources to offset higher costs of the tool.

Cost Analysis for 100 Buildings

	Business Edition	DDOE Edition
Database		
○ **Labor**		
• Static:	1/4 [person] x 5290 [hours] x 100 [hourly payment] = $132,000	$132,000
• Dynamic:	2 [person] x100 [days] x 8 [hrs./day]x 150 [hourly payment]=$240,000	-
• Energy Models:	2 [person] x 20,000 [monthly payment] x 12 [months] = $480,000	$240,000
• Linkage	1 [person] x 20,000 [monthly payment] x 3.4 [months] = $68,000	$50,000
	Total: $920,000	**Total: $422,000**
○ **Expenses**		
• Computer Equipment:	$10,000	$10,000
• (2) Licenses for Computer Programs:	$20,000	
• Clinical Trial Equipment:	$1,000 [cost/ building] x 100 [buildings]= $ 100,000	
Equipment for One Building:		
○ *2-way meters (gas, electricity, water):*	*$800*	
○ *Transmitters, wireless receiver, and cable modem:*	*$200*	
	Total: $ 130,000	**Total: $ 10,000**
Analytical Engine		
○ **Labor**	1[person] x 20,000 [monthly payment] x 12 [months] = $280,000	$280,000
○ **Expenses**		
Computer Equipment:	$20,000	$20,000
	Total: $ 300,000	**Total: $ 300,000**
Solution Applications		
○ Graphic Designer		
○ Web Developer		
○ 3D Modeler		
○ Software Designer		Software Designer
	Total: $ 1,000,000	**Total: $ 333,000**
Supporting Services		
○ Marketing	[Labor] $200,000	-
○ Marketing	[Equipment] $150,000	-
○ Management	[Labor] $300,000	$300,000
○ Cost Estimator	[Labor] $50,000	$50,000
	Total: $ 700,000	**Total: $ 350,000**

SUMMARY	
Database	**$1,050,000**
Analytical Engine	**$300,000**
Solution Applications	**$ 1,000,000**
Supporting Services	**$ 700,000**
TOTAL COST	**$3,050,000**

SUMMARY	
Database	**$432,000**
Analytical Engine	**$300,000**
Solution Applications	**$ 333,000**
Supporting Services	**$ 350,000**
TOTAL COST	**$1,415,000**

**Disclaimer: these numbers are suggested to aid the budgeting process and the actual cost may vary.*

Appendix

Washington D.C.

Smart Buildings Plan Project

"Big Data" Survey

Be a Critical Contributor to Creating the District's Smart Building Plan!

Greenspace in collaboration with Interface Engineering is working with District Department of the Environment (DDOE) to create a plan for the energy and water "brain" of DC and transform the city into a "Smart City" by providing data-driven information to legislators, developers and building owners that inform city-wide policies and practices. The Smart Buildings Plan will address reducing citywide energy use, decreasing total potable water use and reducing greenhouse gas emissions. We need your help to identify the District's existing data sources with respect to energy and water use and performance.

Your participation in this survey is essential and we thank you in advance for taking part in this important effort to identify the District's existing energy and water data sources. This survey is expected to take approximately 15 minutes. You have the option to save your changes and return to the survey later.

Please click "Next" to begin the survey.

greenspace

DISTRICT DEPARTMENT OF THE ENVIRONMENT

INTERFACE ENGINEERING

Next

Page #2

Simple Skipping Information

- If Is your Department or Agency responsible for colle... = No then Skip to Page 8
- If Are you personally involved in, or responsible for... = No then Skip to Page 8

Please tell us about yourself

Name	_____
Agency/ Department	_____
Title	_____
Street Address	_____
State	_____
Zip Code	_____
Email	_____
Phone Number	_____

Is your Department or Agency responsible for collecting energy/water data (independent from utility companies) for the property you own, manage or have responsibility for?

- ○ Yes
- ○ No

Are you personally involved in, or responsible for, collecting data on the property(s) your department or agency owns, manages or has responsibility for?

- ○ Yes
- ○ No

If you answered "No" to the previous question, please provide us with contact information of a person who is involved in, or responsible for collecting data on the property(s) your department or agency owns or manages.

Full Name	_____
Title	_____
Email	_____
Phone Number	_____

Page #3

Please tell us about your Department/Agency

If your Department is responsible for collecting data for your property(s) is the data collection voluntary or mandatory?

- ○ Mandatory
- ○ Voluntary

If mandatory, who requires collection of data?

_____

Have you recently participated in the District Energy Benchmarking? when was your last energy and water usage report?

District Energy Benchmarking: The Clean and Affordable Energy Act of 2008 (CAEA) requires that owners of all large buildings in Washington D.C. annually report their energy and water efficiency to DDOE for public disclosure.

	2014	2013	2012	None
D.C. Benchmarking Participation	○	○	○	○

Do you collect data on all Department owned and/or managed properties?

- ○ Yes
- ○ No

In how many individual properties do you collect data ?

- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10 or more

What is the total square footage for all properties combined?

- Less than 10,000 sf
- 10,000 - 50,000 sf
- 50,000 - 100,000 sf
- 100,000 - 200,000 sf
- 200,000 - 500,000 sf
- 500,000 - 1,000,000 sf
- More than 1,000,000 sf

Please provide the addresses of buildings, from which data is collected (please ONLY include buildings located in the District of Columbia)

If the number of buildings exceeds 5, please fill out the survey twice to include other buildings.

Building 1	_____
Building 2	_____
Building 3	_____
Building 4	_____
Building 5	_____

What is the gross floor area of those buildings (in square feet)?

Building 1	_____
Building 2	_____
Building 3	_____
Building 4	_____
Building 5	_____

Please specify building(s) ownership

	Federal Government	Local Government	Private
Building 1	○	○	○
Building 2	○	○	○
Building 3	○	○	○
Building 4	○	○	○
Building 5	○	○	○

Please specify building(s) occupancy

	Federal Government	Local Government	Private	Mixed
Building 1	○	○	○	○
Building 2	○	○	○	○
Building 3	○	○	○	○
Building 4	○	○	○	○
Building 5	○	○	○	○

Please indicate the space use (type of occupancy) in building(s)

Government	• 10% • 20% • 30% • 40% • 50% • 60% • 70% • 80% • 90% • 100%
Commercial	• 10% • 20% • 30% • 40% • 50% • 60% • 70% • 80% • 90% • 100%

Residential	• 10% • 20% • 30% • 40% • 50% • 60% • 70% • 80% • 90% • 100%
Educational	• 10% • 20% • 30% • 40% • 50% • 60% • 70% • 80% • 90% • 100%
Retail	• 10% • 20% • 30% • 40% • 50% • 60% • 70% • 80% • 90% • 100%
Healthcare	• 10% • 20% • 30% • 40% • 50% • 60% • 70% • 80% • 90% • 100%
Municipal	• 10% • 20% • 30% • 40% • 50% • 60% • 70% • 80% • 90% • 100%

Other	• 10% • 20% • 30% • 40% • 50% • 60% • 70% • 80% • 90% • 100%

Please indicate if the space is separately metered?

Separately Metered	• Yes • No
Separately Metered	• Yes • No
Separately Metered	• Yes • No
Separately Metered	• Yes • No
Separately Metered	• Yes • No
Separately Metered	• Yes • No
Separately Metered	• Yes • No
Separately Metered	• Yes • No

Page #4

Let's talk about the building(s)

Does the number of buildings that your agency/ department owns or manages exceed five?

If the number of buildings exceeds 5, we will call you to discuss these questions with you directly.

- ○ Yes
- ○ No

When was the building built?

	Pre 1900	1900s	1910s	1920s	1930s	1940s	1950s	1960s	1970s	1980s	1990s	2000 and After
Building 1	○	○	○	○	○	○	○	○	○	○	○	○
Building 2	○	○	○	○	○	○	○	○	○	○	○	○
Building 3	○	○	○	○	○	○	○	○	○	○	○	○
Building 4	○	○	○	○	○	○	○	○	○	○	○	○
Building 5	○	○	○	○	○	○	○	○	○	○	○	○

When was the building last renovated/ modernized?

	Less than 1 Year Ago	1- 2 Years Ago	2- 5 Years Ago	5- 10 Years Ago	More than 10 Years Ago
Building 1	○	○	○	○	○
Building 2	○	○	○	○	○
Building 3	○	○	○	○	○
Building 4	○	○	○	○	○
Building 5	○	○	○	○	○

How many levels does the building have ABOVE grade?

Building 1

- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- More than 10

Building 2

- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- More than 10

Building 3

- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- More than 10

Building 4

- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- More than 10

Building 5

- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- More than 10

How many levels does the building have BELOW grade?

Building 1

- 2
- 3
- 4
- 5
- More than 5

Building 2	• 2 • 3 • 4 • 5 • More than 5
Building 3	• 2 • 3 • 4 • 5 • More than 5
Building 4	• 2 • 3 • 4 • 5 • More than 5
Building 5	• 2 • 3 • 4 • 5 • More than 5

Page #5

Let's talk Green Building Certification

Does the building have any green building certifications?

	LEED Certified- Building	LEED Certified- Commercial Interiors	ENERGY STAR	None
Building 1	☐	☐	☐	☐
Building 2	☐	☐	☐	☐
Building 3	☐	☐	☐	☐
Building 4	☐	☐	☐	☐
Building 5	☐	☐	☐	☐

If the building has any other green building certifications, please specify

Building 1 _____

Building 2 _____

Building 3 _____

Building 4 _____

Building 5 _____

If the building is LEED certified, what is the level of certification?

Building 1
- Certified
- Silver
- Gold
- Platinum

Building 2
- Certified
- Silver
- Gold
- Platinum

Building 3
- Certified
- Silver
- Gold
- Platinum

Building 4
- Certified
- Silver
- Gold
- Platinum

Building 5
- Certified
- Silver
- Gold
- Platinum

Page #6

Let's talk property data

Where is data collected from?

- Whole- building meter
- Whole- building meter plus sub-meters

What type of energy data do you colect? (Select all that apply)

	Electric	Gas	Water	Renewable Energy: Wind	Renewable Energy: Solar PV	Renewable Energy: Solar Thermal	Renewable Energy: Geo-thermal
Building 1	☐	☐	☐	☐	☐	☐	☐
Building 2	☐	☐	☐	☐	☐	☐	☐
Building 3	☐	☐	☐	☐	☐	☐	☐
Building 4	☐	☐	☐	☐	☐	☐	☐
Building 5	☐	☐	☐	☐	☐	☐	☐

What type of meters do you have for electricity?

Building 1
- Analog
- Digital
- I don't know

Building 2
- Analog
- Digital
- I don't know

Building 3
- Analog
- Digital
- I don't know

Building 4
- Analog
- Digital
- I don't know

Building 5
- Analog
- Digital
- I don't know

What type of meters do you have for natural gas?

Building 1
- Analog
- Digital
- I don't know

Building 2
- Analog
- Digital
- I don't know

Building 3
- Analog
- Digital
- I don't know

Building 4
- Analog
- Digital
- I don't know

Building 5	• Analog • Digital • I don't know

What type of meters do you have for water?

Building 1	• Analog • Digital • I don't know
Building 2	• Analog • Digital • I don't know
Building 3	• Analog • Digital • I don't know
Building 4	• Analog • Digital • I don't know
Building 5	• Analog • Digital • I don't know

What type of meters do you have for renewable energy?

Building 1	• Analog • Digital • I don't know
Building 2	• Analog • Digital • I don't know
Building 3	• Analog • Digital • I don't know
Building 4	• Analog • Digital • I don't know
Building 5	• Analog • Digital • I don't know

What are the units of data?

	‹Btu	kWh	therms	Gallons	Other	I don't know
Electric	○	○	○	○	○	○
Gas	○	○	○	○	○	○
Water	○	○	○	○	○	○
Renewable Energy	○	○	○	○	○	○

From question above, please specify the units if you picked other:

Electric	_____
Gas	_____

Water _____

Renewable Energy _____

What is the frequency of data collection?

	Annually	Monthly	Daily	Streaming (real-time data)
Electric	○	○	○	○
Gas	○	○	○	○
Water	○	○	○	○
Renewable Energy	○	○	○	○

Since when has data collection started?

Please indicate the year

Building 1

- 2014
- 2013
- 2012
- 2011
- 2010
- 2009
- 2008
- 2007
- 2006
- 2005

...94 additional choices hidden ...

- 1909
- 1908
- 1907
- 1906
- 1905
- 1904
- 1903
- 1902
- 1901
- 1900

Building 2	• 2014 • 2013 • 2012 • 2011 • 2010 • 2009 • 2008 • 2007 • 2006 • 2005 ... 94 additional choices hidden ... • 1909 • 1908 • 1907 • 1906 • 1905 • 1904 • 1903 • 1902 • 1901 • 1900
Building 3	• 2014 • 2013 • 2012 • 2011 • 2010 • 2009 • 2008 • 2007 • 2006 • 2005 ... 94 additional choices hidden ... • 1909 • 1908 • 1907 • 1906 • 1905 • 1904 • 1903 • 1902 • 1901 • 1900

Building 4	• 2014 • 2013 • 2012 • 2011 • 2010 • 2009 • 2008 • 2007 • 2006 • 2005 ... 94 additional choices hidden ... • 1909 • 1908 • 1907 • 1906 • 1905 • 1904 • 1903 • 1902 • 1901 • 1900
Building 5	• 2014 • 2013 • 2012 • 2011 • 2010 • 2009 • 2008 • 2007 • 2006 • 2005 ... 94 additional choices hidden ... • 1909 • 1908 • 1907 • 1906 • 1905 • 1904 • 1903 • 1902 • 1901 • 1900

Since when has data collection started?

Please indicate the month

Building 1	• 2013 • 2012 • 2011 • 2010 • 2009 • 2008 • 2007 • 2006 • 2005 • 2004 ...93 additional choices hidden ... • 1909 • 1908 • 1907 • 1906 • 1905 • 1904 • 1903 • 1902 • 1901 • 1900
Building 2	• 2013 • 2012 • 2011 • 2010 • 2009 • 2008 • 2007 • 2006 • 2005 • 2004 ...93 additional choices hidden ... • 1909 • 1908 • 1907 • 1906 • 1905 • 1904 • 1903 • 1902 • 1901 • 1900

Building 3	• 2013 • 2012 • 2011 • 2010 • 2009 • 2008 • 2007 • 2006 • 2005 • 2004 ... 93 additional choices hidden ... • 1909 • 1908 • 1907 • 1906 • 1905 • 1904 • 1903 • 1902 • 1901 • 1900
Building 4	• 2013 • 2012 • 2011 • 2010 • 2009 • 2008 • 2007 • 2006 • 2005 • 2004 ... 93 additional choices hidden ... • 1909 • 1908 • 1907 • 1906 • 1905 • 1904 • 1903 • 1902 • 1901 • 1900

Building 5	• 2013 • 2012 • 2011 • 2010 • 2009 • 2008 • 2007 • 2006 • 2005 • 2004 ...93 additional choices hidden ... • 1909 • 1908 • 1907 • 1906 • 1905 • 1904 • 1903 • 1902 • 1901 • 1900

Is data collection an on-going process in building(s)?

Building 1	• Yes • No
Building 2	• Yes • No
Building 3	• Yes • No
Building 4	• Yes • No
Building 5	• Yes • No

If you answered "No" to previous question, when did data collection end?

Building 1	• 2014 • 2013 • 2012 • 2011 • 2010 • 2009 • 2008 • 2007 • 2006 • 2005 ... 94 additional choices hidden ... • '909 • '908 • '907 • '906 • '905 • '904 • '903 • '902 • '901 • '900
Building 2	• 2014 • 2013 • 2012 • 2011 • 2010 • 2009 • 2008 • 2007 • 2006 • 2005 ... 94 additional choices hidden ... • '909 • '908 • '907 • '906 • '905 • '904 • '903 • '902 • '901 • '900

Building 3	• 2014 • 2013 • 2012 • 2011 • 2010 • 2009 • 2008 • 2007 • 2006 • 2005 .. 94 additional choices hidden ... • 1909 • 1908 • 1907 • 1906 • 1905 • 1904 • 1903 • 1902 • 1901 • 1900
Building 4	• 2014 • 2013 • 2012 • 2011 • 2010 • 2009 • 2008 • 2007 • 2006 • 2005 .. 94 additional choices hidden ... • 1909 • 1908 • 1907 • 1906 • 1905 • 1904 • 1903 • 1902 • 1901 • 1900

Building 5	• 2014 • 2013 • 2012 • 2011 • 2010 • 2009 • 2008 • 2007 • 2006 • 2005 ... 94 additional choices hidden ... • 1909 • 1908 • 1907 • 1906 • 1905 • 1904 • 1903 • 1902 • 1901 • 1900

☑ Does data exist in electronic or paper format?

	Paper Format	Electronic	I don't know
Building 1	☐	☐	☐
Building 2	☐	☐	☐
Building 3	☐	☐	☐
Building 3	☐	☐	☐
Building 4	☐	☐	☐
Building 5	☐	☐	☐

Page #7

Let's talk quality of data

Does the building have a building-wide energy management system?

	Yes	No	I don't know
Building 1	○	○	○
Building 2	○	○	○
Building 3	○	○	○
Building 3	○	○	○
Building 4	○	○	○
Building 5	○	○	○

Are the MEP (Mechanical-Electrical-Plumbing) building controls in the building(s) ...

	Manual	Digital	Analog	I don't know
Building 1	○	○	○	○
Building 2	○	○	○	○
Building 3	○	○	○	○
Building 3	○	○	○	○
Building 4	○	○	○	○
Building 5	○	○	○	○

How would you describe the quality of data?

	Excellent	Good	Fair	Poor	I don't know
Building 1	○	○	○	○	○
Building 2	○	○	○	○	○
Building 3	○	○	○	○	○
Building 3	○	○	○	○	○
Building 4	○	○	○	○	○
Building 5	○	○	○	○	○

Is the collected data currently.....

- ○ Stored
- ○ Analyzed
- ○ Both

If analyzed, has the data analysis been published?

- ○ Yes, please specify... _____
- ○ No
- ○ I don't know

Is the data publicly accessible?

- ○ Yes
- ○ No

Page #8

Let's talk about data sharing

Are you willing and/or able to share data with us?

- ◯ Yes
- ◯ No, please specify steps required steps for approval _____

Our group is preparing a project plan to collect energy and water data from a select group of buildings in Washington D.C.; the subset of buildings, called "Clinical Trial", will be evaluated and their results will be extrapolated to a greater profile of buildings in the District.

Might your department or agency be willing to participate in our "Clinical Trial"?

- ◯ Yes
- ◯ No

Can you please sign the "Energy and Water Release Authorization" form and give us authority to access your 36 months' time period consumption record for electricity, natural gas, and water?

- ◯ Yes
- ◯ No

Are you willing to share your property's data with the public?

Your data will be kept anonymous and shared with the public through a web-based portal for educating people about improving energy efficiency in buildings.

- ◯ Yes
- ◯ No, please specify any circumstances under which you would consent to share your property's data with the public

_____

If you answered "Yes" to previous questions, please sign the following documents electronically by clicking on the links below and then return to the survey by clicking "back" button on your browser's page.
"Pepco Request Form": http://bit.ly/1jzhLh0
"Natural gas and Water Release Authorization" : http://bit.ly/1qsZYzw
"Energy and Water Data Sharing Consent Form": http://bit.ly/1jzfyID