Boston Building Energy Reporting and Disclosure Ordinance

Data Analysis and Recommendations

Submitted to the City of Boston Environment Department

Submitted by Peregrine Energy Group, Empower Efficiency, OptiMiser, and Harvey Michaels

DRAFT February 21, 2015

PEREGRINE ENERGY GROUP

Table of Contents

Introduction

Boston's Building Energy Reporting and Disclosure Ordinance (BERDO) is providing new insight into the energy use and greenhouse gas (GHG) emissions associated with Boston's largest buildings. The data reported under BERDO will inform the design of the City's initiatives to reduce emissions and enable the City to track the progress of those initiatives over time. This data will also show building owners how the energy performance of their buildings compares to that of their peers, and in the future when building data is publically reported, it will enable Boston's businesses and residents to consider building energy performance when deciding where to work and live. Prior to BERDO, building energy use was largely invisible; BERDO brings it into full view.

This report presents an analysis of the first year of BERDO data, the 2013 energy use data for the largest non-residential[1] buildings – individual buildings over 50,000 square feet and sets of buildings totaling over 100,000 square feet on a single tax lot. The purpose is to better understand these largest users of energy, and as well, to test the manageability and value creation of the current BERDO process before it is extended to the residential and smaller commercial facilities covered by the ordinance. We look at the rate of compliance with the ordinance, GHG emissions and energy use by sector and property type, and building benchmarks such as energy use intensity and ENERGY STAR Score. We also offer suggestions to make the BERDO data more actionable and, in appendices, describe the data quality issues we encountered, making recommendations designed to enhance compliance and data quality for future reporting cycles.

[1] "Non-residential" is defined as any building or set of buildings on one tax lot in which over fifty percent of the floor area, apart from parking, is used for non-residential purposes.

Compliance with the Ordinance

Shown in Table 1, as of February 6, 2015, 562 (71%) of the 790 parcels required to report had submitted BERDO reports. These parcels represented 718 (73%) of 984 buildings encompassed by the 790 parcels.[2] The parcels reporting represent over 84% of the total square footage covered by parcels required to report.[3] In addition, another 204 parcels not required to report, representing 221 buildings, submitted data voluntarily.

	Required to Report	Submitted Reports	Compliance Rate
Total buildings (based on number of buildings identified in Portfolio Manager)	984	718	73%
Total parcels (based on unique tax assessor IDs)*	790	562	71%
Total square footage (based on tax assessor data)*	189,191,367	159,225,789	84%

*From City of Boston's 2013 Tax Assessor Database. Gross square footage is not calculated for commercial condo buildings, and was estimated in GIS for the purpose of analysis using building footprint and number of floors. The gross square footage for two additional parcels required to report without GROSS_AREA available in tax assessor data was pulled from their PM submissions.

Table 1: BERDO Compliance by Number of Buildings, Parcels, and Square Footage

In general, larger parcels (greater than 300,000 ft^2 in gross floor area) were more compliant, with compliance rates between 82% and 100% by size category when divided into categories by 100,000 ft^2, as shown in Table 2, and overall compliance of 91%, as shown in Table 3. Parcels between 50,000 and 300,000 ft^2 had compliance rates between 61% and 74% (Table 2) and an overall compliance of 66% (Table 3). As also shown in Table 3, this smaller parcel category accounted for the greater number of reporting parcels (419 out of 562, or 75%).

[2] The number of buildings used throughout compliance analysis is as reported in tax assessor data. Number of buildings is also a reported metric in Portfolio Manager submissions, and 791 buildings were reported in the 562 submissions received by February 6 for parcels required to report. These submissions included additional parcels and buildings that entities were not required to report. An additional 90 Portfolio Manager submissions were received that included only voluntary parcels, and reported encompassing 101 buildings submitting data voluntarily.

[3] For the compliance analysis, we did not include Boston's municipal buildings. However, those buildings are included in the energy use and GHG emissions analysis presented in the next section.

Gross Square Footage*	Parcels Required to Report	Parcels Submitted Reports	Compliance Rate
50,000 to 100,000	351	215	61%
100,001 to 200,000	210	155	74%
200,001 to 300,000	71	49	69%
300,001 to 400,000	39	32	82%
400,001 to 500,000	22	18	82%
500,001 to 600,000	19	19	100%
600,001 to 700,000	16	18	89%
700,0001 and Greater	60	58	97%
Grand Total	**790**	**562**	**71%**

*From City of Boston's 2013 Tax Assessor Database. Gross square footage is not calculated for commercial condo buildings, and was estimated in GIS for the purpose of analysis using building footprint and number of floors. The gross square footage was pulled from Portfolio Manager submissions for two additional parcels without GROSS_AREA available in tax assessor data.

Table 2: BERDO Compliance by Parcel Size Groups (100,000 ft^2 intervals)

Gross Square Footage*	Parcels Required to Report	Parcels Submitted Reports	Percent of Total Submitted Reports	Compliance Rate
300,000 and below	632	419	75%	66%
Above 300,000	158	143	25%	91%
Grand Total	**790**	**562**	**100%**	**71%**

*From City of Boston's 2013 Tax Assessor Database. Gross square footage is not calculated for commercial condo buildings, and was estimated in GIS for the purpose of analysis using building footprint and number of floors. The gross square footage was pulled from Portfolio Manager submissions for two additional parcels without GROSS_AREA available in tax assessor data.

Table 3: BERDO Compliance by Parcel Size Groups (Below and Above 300,000 ft^2)

Property types identified in the tax assessor data for parcels required to report were matched to 16 distinct sectors (and "Other") for compliance analysis, as shown in Table 4. Buildings identified as Office, Higher Ed, Health Care, Storage, Other, and Manufacturing/Industrial encompassed the highest volume of buildings required to report, together accounting for 714 or 73% of the total. The top three sectors by volume required to report – Office, Higher Ed, and Health Care – submitted the most reports, with compliance rates of 80%, 94%, and 86%, respectively. Laboratories had the highest compliance rate, with 25 of 25 (100%) buildings reporting, and Pre K-12 Education had

the lowest at 41% with 7 of 17 buildings reporting, followed by Other at 43% and Commercial at 47%.

Sector*	Buildings Required to Report	Buildings Submitted Reports	Compliance Rate
Office	260	207	80%
Higher Ed	161	152	94%
Health Care	113	97	86%
Storage	64	33	52%
Manufacturing/Industrial	57	34	60%
Commercial	47	22	47%
Hotel	40	26	65%
Residential	28	19	68%
Laboratory	25	25	100%
Nonprofit	24	18	75%
Parking	21	17	81%
K-12 Education	17	7	41%
Sports/Entertainment	15	10	67%
Supermarket	12	7	59%
Mixed Use Property	11	6	55%
Other	89	38	43%
Grand Total	**984**	**718**	**73%**

*Sector estimates determined to best correspond to each parcel's "P-Type," or property type code, as identified in the City of Boston's Tax Assessor Database

Table 4: BERDO Compliance by Sector

Of the 221 buildings encompassed by parcels submitting reports voluntarily, Higher Ed, Office, Commercial, and Other accounted for the most submissions, together submitting reports for 131 buildings, or 59% of the total. Buildings classified as Pre K-12 Education, Laboratory, Hotel, Restaurant, Supermarket, and Sports/Entertainment submitted reports voluntarily for the lowest volume of buildings, together accounting for 11 buildings, or 5% of the total.

Sector*	Buildings Submitted Reports	Percent of Total Voluntary Submissions

Higher Ed	60	27%
Office	30	14%
Commercial	20	9%
Nonprofit	15	7%
Health Care	14	6%
Residential	13	6%
Parking	11	5%
Mixed Use Property	10	5%
Manufacturing/Industrial	9	4%
Storage	7	3%
Sports/Entertainment	3	1%
Supermarket	3	1%
Restaurant	3	1%
Hotel	1	1%
Laboratory	1	1%
Pre K-12 Education	0	0%
Other	21	10%
Grand Total	**221**	**100%**

*Sector estimates determined to best correspond to each parcel's "P-Type," or property type code, as identified in the City of Boston's Tax Assessor Database. The sectors identified for voluntary submissions are identical to the 16 identified for required reports, except Restaurant. No restaurants were required to report but parcels identified as restaurants submitted reports voluntarily.

Table 5: Sector Analysis of Buildings Submitting Reports Voluntarily

Building Characteristics

Boston received 642 BERDO reports, covering 870 buildings and 175 million square feet. Office buildings are the most prevalent property type, accounting for 42% of the floor area and 28% of the buildings. Hospitals, university buildings, hotels are the next largest groups. Sixteen percent of the space, grouped as "Other" in Figure 1 below, is spread across over 30 different space types, including recreational facilities, storage, malls, and houses of worship.

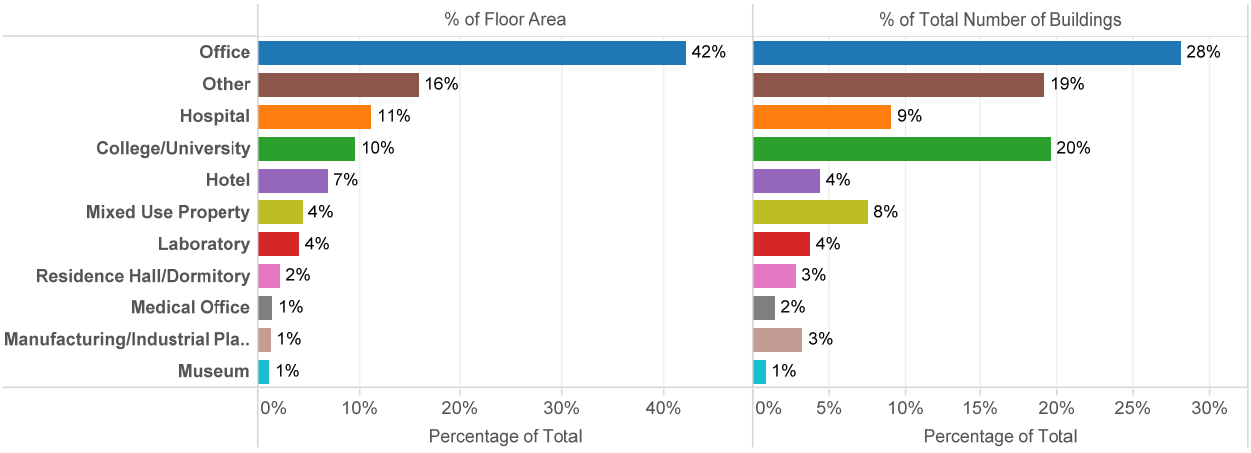


Figure 1: Floor area and number of buildings by property type

The reports reflect primarily newer buildings. As shown in Figure 2, over two thirds of the square footage reported was built after the 1950s.

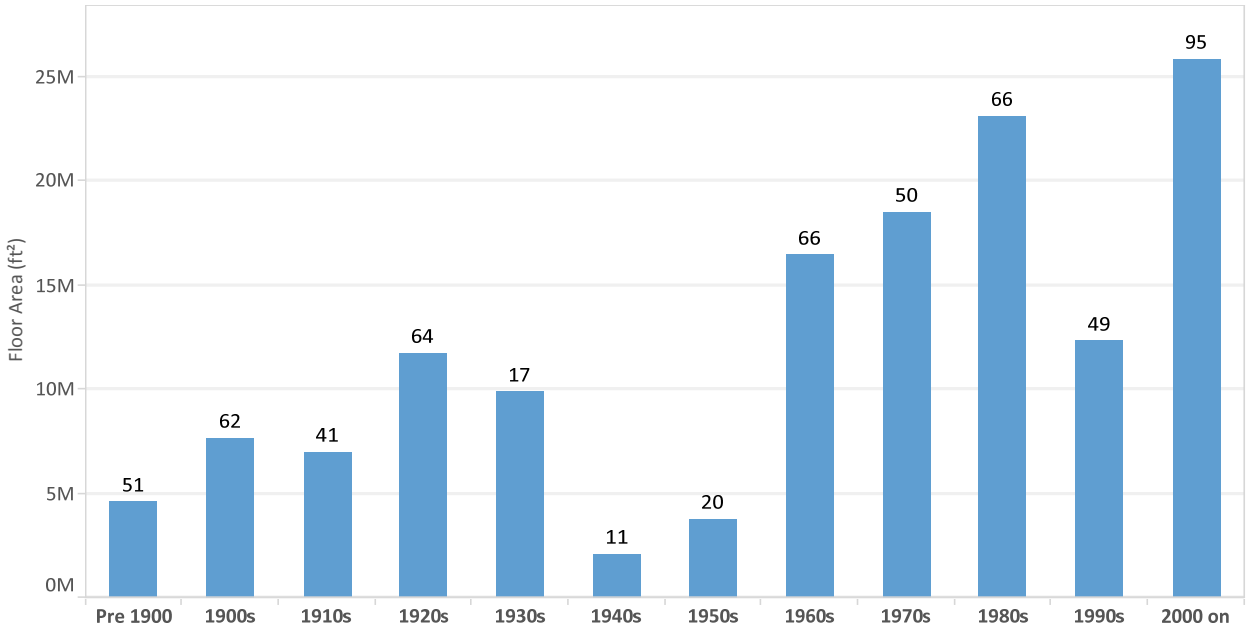


Figure 2: Floor area and number of buildings by decade built

Shown in Figure 3, the square footage reported is fairly evenly distributed by size of building. For example, there is approximately the same amount of square footage in buildings up to 500,000 square feet as in buildings of over 1,000,000 square feet.

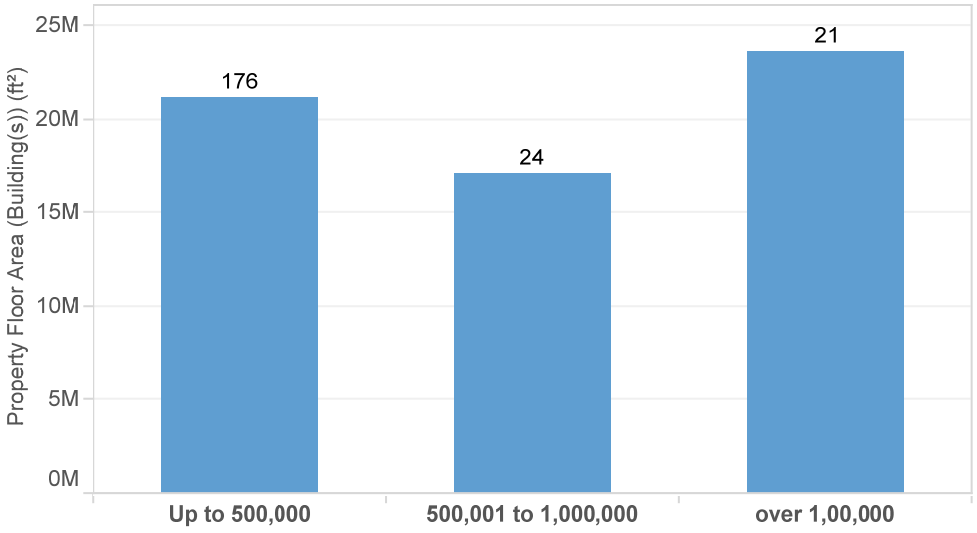


Figure 3: Floor area and number of buildings by building size

What the BERDO Data Reveals about Boston's Largest Buildings

GHG Emissions and Energy Use

By Fuel

For the properties submitting BERDO reports, electricity is the largest contributor to both GHG emissions and energy use, accounting for 54% of GHG emissions and 45% of site energy use (Figure 4). With its low emissions intensity, natural gas accounts for only 16% of GHG emissions but 25% of energy use. District steam represents 25% of GHG emissions and 23% of site energy use, and district chilled water represents 4% of GHG emissions and 6% of site energy use. Oil is not a significant contributor to either emissions or energy use.

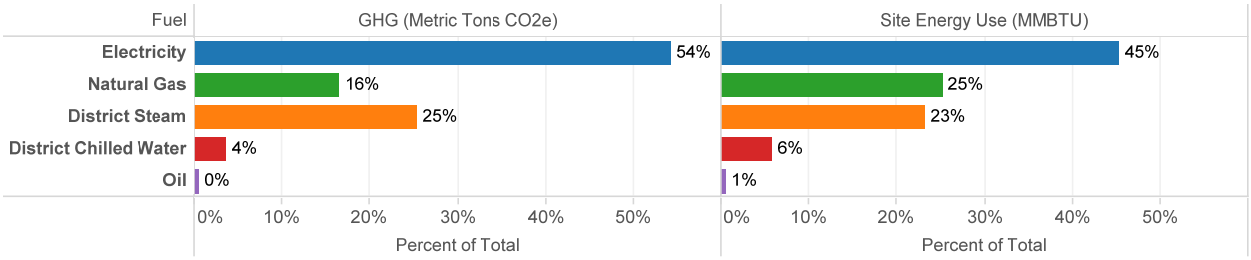


Figure 4: GHG Emissions and Site Energy Use by Fuel

Table 4 includes the number of reporting properties by fuel type, where electricity is the most common reported fuel type, followed by natural gas and district steam. A few buildings reported district chilled water (n=32) and fuel oil (n=62).

	Number of Properties Reporting Use
Electricity	570
Natural Gas	397
District Steam	119
District Chilled Water	32
Oil	62

Table 3: Number of Properties Reporting Use by Fuel

By Property Type

Shown in Figure 5, reporting office buildings and hospitals are the primary contributors to GHG emissions at 30% and 25% of the total, followed by university buildings and labs (9% and 8%, respectively). A collection of property types characterized as "other" accounts for 7% of the total. This category includes a diverse mix of buildings, including sports arenas, distribution centers, retail stores, and parking. Several other building types emit less than 5% of the total GHG emissions each, including hotels (5%), mixed-use properties (5%), manufacturing/industrial plants (4%), medical offices (2%), residence halls/dormitories (2%), museums (1%), and supermarkets (1%).

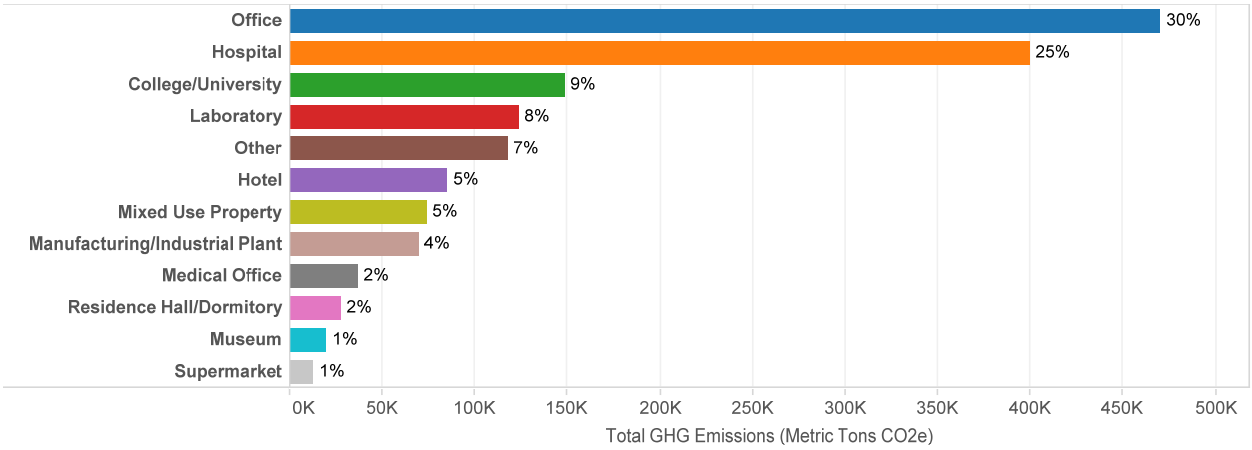


Figure 5: GHG Emissions by Property Type

By Sector

In addition to characterizing buildings by property type, we also characterized them by sector.[4] Property type relates to the nature of the building itself and is useful for comparing like buildings to each other. Sector, on the other hand, refers to the ownership entity. For example, Harvard Stadium has a property type of "outdoor arena", and would be compared to Fenway Park. However, it belongs to the sector "higher education" and would be grouped with other university-owned buildings, such as dormitories, classrooms, and laboratories. Sectors are useful for assessing the overall contribution of different types of entities to energy use and emissions, as well as for designing programs targeting those entities. Both the City of Boston and its Green Ribbon Commission have initiatives targeting the major sectors.

Illustrated by Figure 6, health care and commercial real estate are the two largest sectors, responsible for approximately 30% and 29%, respectively, of the total GHG emissions. Higher education is the next largest sector, at 20%, followed by hotels (5%), manufacturing (4%), government (2%), and non-profits (2%). As with property type, there is a catchall "other" sector (6%) that includes a diverse mix of other entities, including supermarkets and distribution centers.

[4] Sector assignments were made primarily on the name of the property owner. Where the owner's name did not indicate the sector, the property type was used to make the sector assignment.

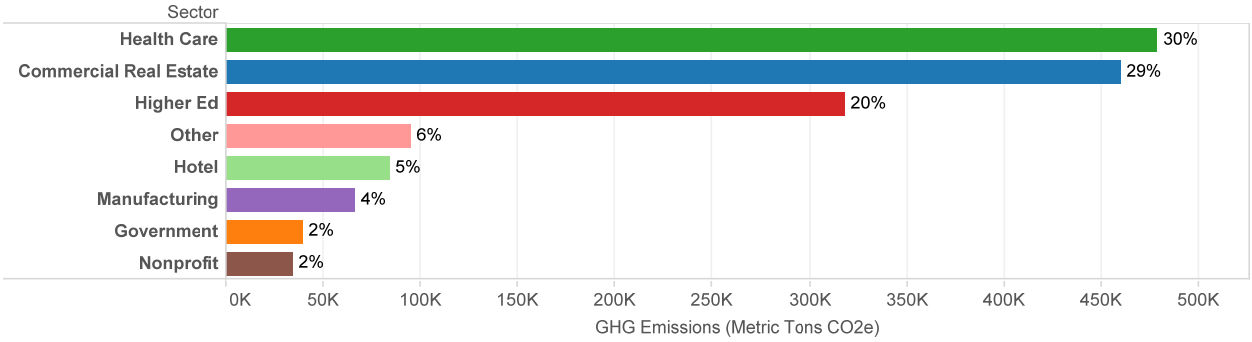


Figure 6: GHG Emissions by Sector

We also looked at the property types of the buildings within each sector. Whereas some sectors, such as hotels, have buildings all of one type, other sectors, such as higher education, include a variety of different building types. The property type breakdown for sectors with the greatest variety of property types is shown in the figures that follow (Figures 7 and 8). The size of the boxes indicates the percentage of that sector's GHG emissions that are attributable to the property type. The numbers indicate the number of buildings.

Figure 7: Commercial Real Estate Sector GHG Emissions by Property Type

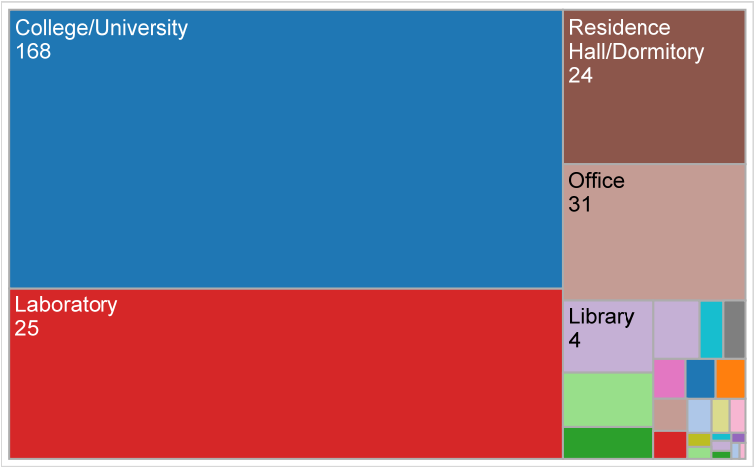


Figure 8: Higher Education Sector GHG Emissions by Property Type

By Quartile

To examine the size distributions of contributors to GHG emissions, we organized the properties into GHG emissions quartiles. We ranked the properties by emissions and then divided them into four equal groups (by total emissions, not number of properties). Quartile 1 contains the largest properties that make up 25%, Quartile 2 the next largest, and so forth. Table 4 shows the number of properties by quartile. The table indicates that a very small number of properties makes up the top 25% (n=6), while 8 times that many make up the lower 25% (n=481).

	Number of Properties
Quartile 1	6
Quartile 2	26
Quartile 3	69
Quartile 4	481

Table 4: Emissions Quartiles

Figure 9 displays the properties in each quartile. The color indicates the sector, and the size of each box indicates the property's GHG emissions. The figure shows, for example, that four of the six properties in Quartile 1 are in the health care sector, with the remaining two properties from manufacturing and higher education. While there are no commercial real estate properties in Quartile 1, that sector accounts for a significant

share of Quartile 2 (12 of the 26 properties). Hotels, on the other hand, appear only in Quartile 3 and Quartile 4. There are health care and higher education properties in all four Quartiles.

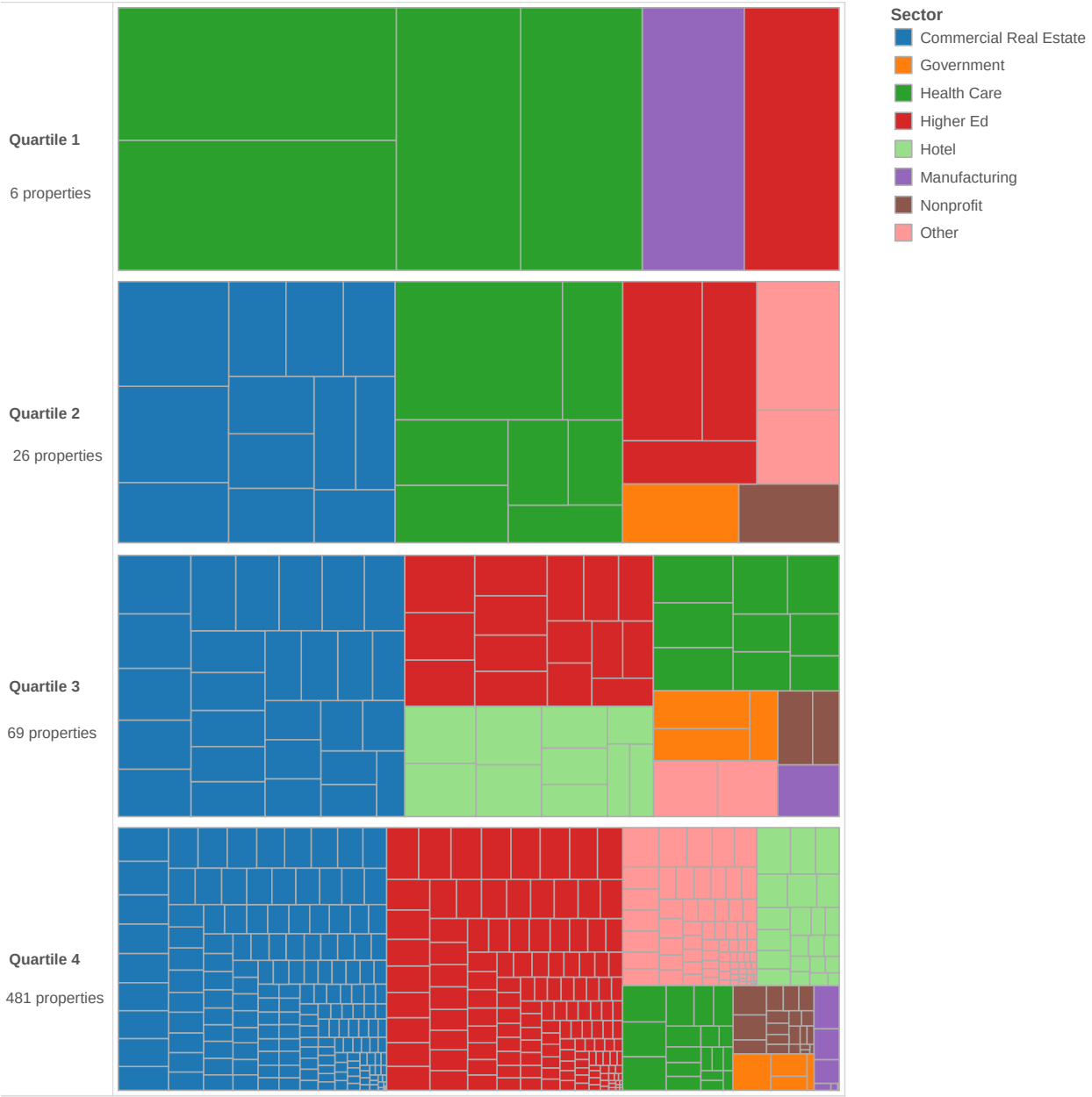


Figure 9: GHG Quartiles by Sector

By Building Year Built and Building Size

Looking for patterns in energy use, we examined intensity (EUI) (energy use per ft^2)[5] by year of construction and by size category.

EUI is a common metric of building energy performance; it reports the building's annual energy use as a function of its size. Within buildings of the same type, lower EUIs generally indicate better energy performance. However, different types of buildings have different energy use intensities. For example, as discussed below, hospitals use more energy per square foot, and so have higher EUIs, than office buildings.

Figure 10 shows EUI for Boston's office buildings by decade of construction, revealing that buildings constructed in the 1950s through 1970s have the highest median EUIs and buildings constructed in the 1940s and earlier have the lowest. This result is contrary to the expectation of many who assumed that older buildings would fare poorly when BERDO data is reported.

[5] EUI can be reported using either site or source energy. Site energy is the energy consumed at the building site; it is what is reflected on utility bills. Source energy reflects the energy content of the raw fuel that, for example, is burned at power plants to generate electricity that is then transmitted to the building site. Source energy also reflects the losses that occur during transmission. In this report we use site EUI.

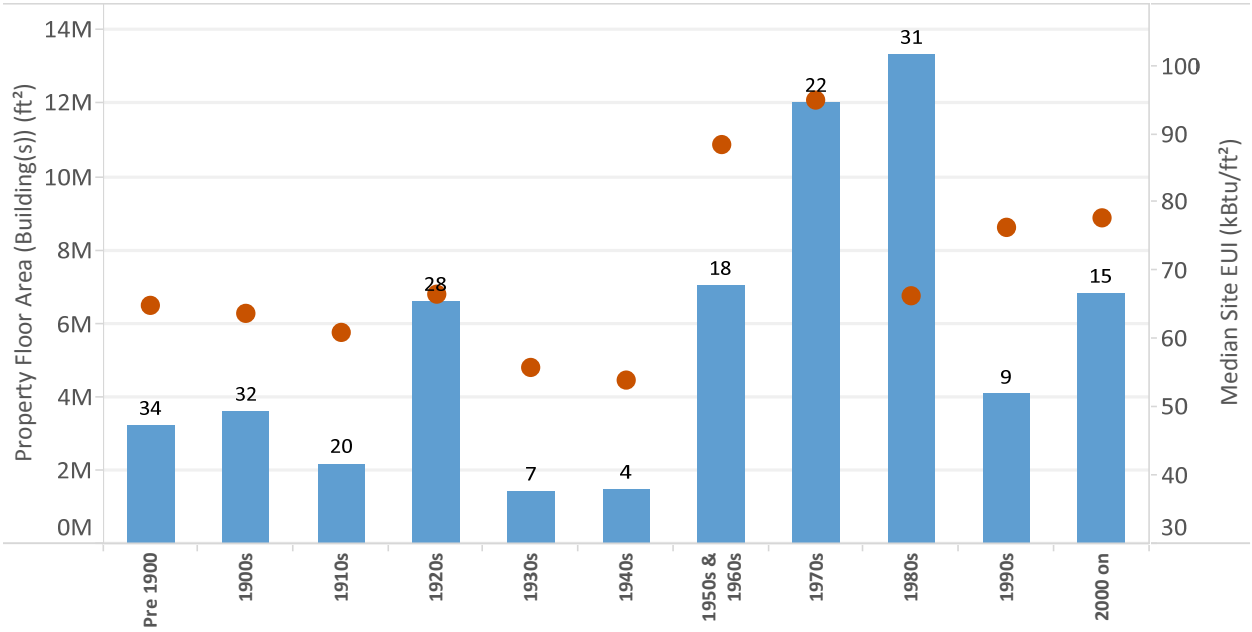


Figure 10: Energy Use Intensity by Year Built

The blue bars indicate floor area and the orange circles indicate the median EUI. The numbers are the number of properties.

The pattern of EUI by year of construction may create opportunities for targeted energy efficiency initiatives. The variation in EUI is due in large part to changes over time in construction materials and building systems. As a result, buildings of similar age have similar materials and systems and may present similar energy efficiency opportunities.

Figure 11 looks at median EUI by building size. The figure shows that buildings over 1,000,000 square feet have a slightly higher median EUI than smaller buildings.

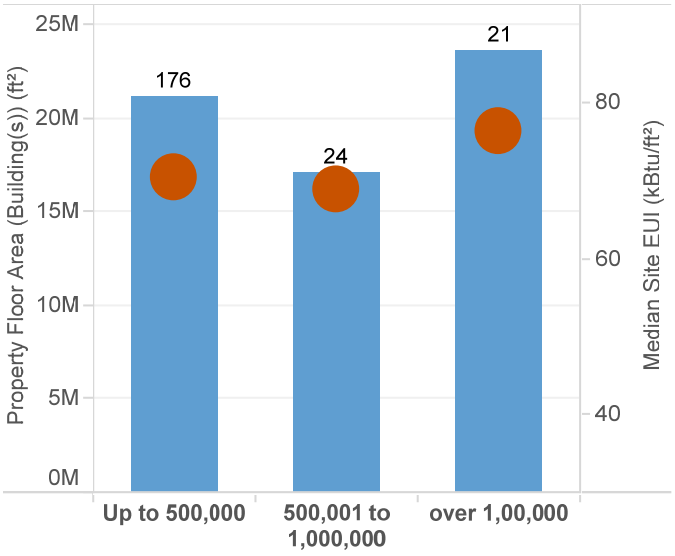


Figure 11: Energy Use Intensity by Building Size

The blue bars indicate floor area and the orange circles indicate the median EUI. The numbers above the bars show the number of properties.

Benchmarking Buildings

Energy Use Intensity

Energy Use Intensity (EUI) (energy use per ft^2) can be used to reveal differences between different types of properties and also across properties within a type. A review of EUIs for Boston's major property types shows that laboratories, hospitals, and medical office buildings have the highest median EUIs (Figure 12). Laboratories also have the widest range of EUIs within the property type. Office buildings have the most outliers.

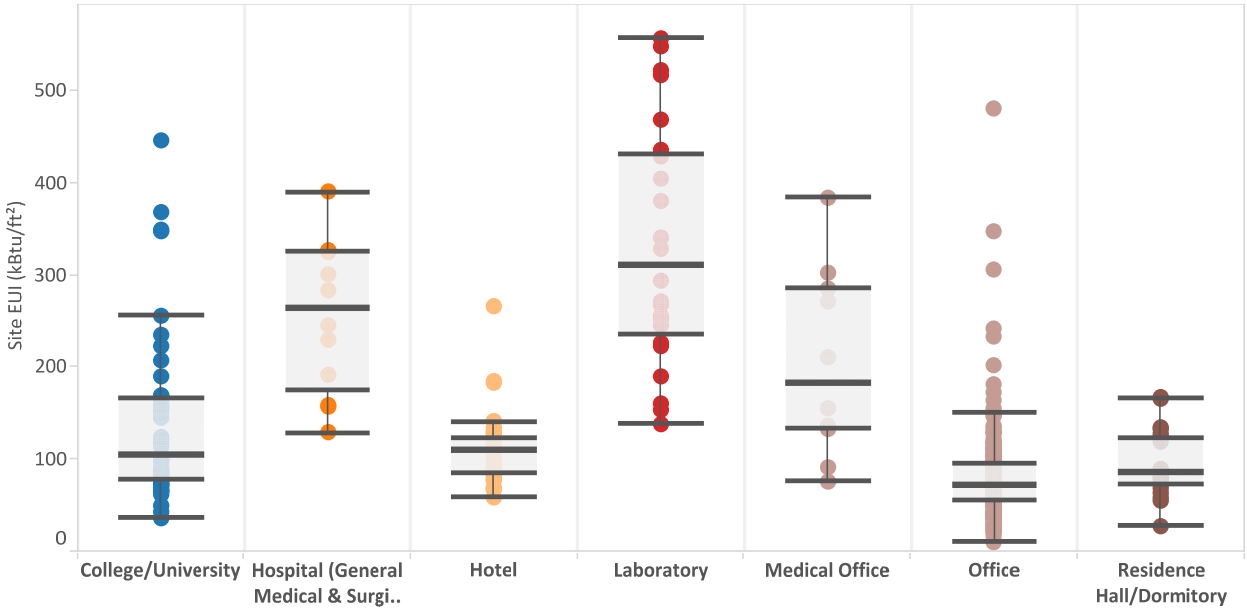


Figure 12: Energy Use Intensity by Property Type

The colored dots represent individual properties. The solid bars in the center of the boxes are the median; the top and bottom of the boxes are the 25% quartile and the 75% quartile. The whiskers mark the nearest data point with 1.5 times interquartile range, i.e., 1.5 times the distance between the upper and lower quartiles.

Buildings with high EUIs for their property type may offer the greatest opportunities for energy efficiency improvements. The BERDO data enables the City to identify and target those buildings.

Energy Star Scores

The Environmental Protection Agency (EPA) Portfolio Manager® generates ENERGY STAR scores for certain building types. These scores enable us to compare Boston's buildings not only to each other but also to similar buildings across the country. Nationally, a score of 50 represents median energy performance; a score of 75 or above means that a building may be eligible for ENERGY STAR certification.

For several property types, the median ENERGY STAR score of Boston's buildings is above the national median of 50; these include office buildings, financial offices, and dormitories (Figure 13). Boston is at the median for hotels, and well below the median in hospitals and medical office buildings. Boston's buildings show quite a wide range of ENERGY STAR scores, particularly the office buildings. As an objective standard for setting a priority for a city efficiency outreach campaign, buildings with low ENERGY STAR scores may present good targets for Boston energy efficiency programs.

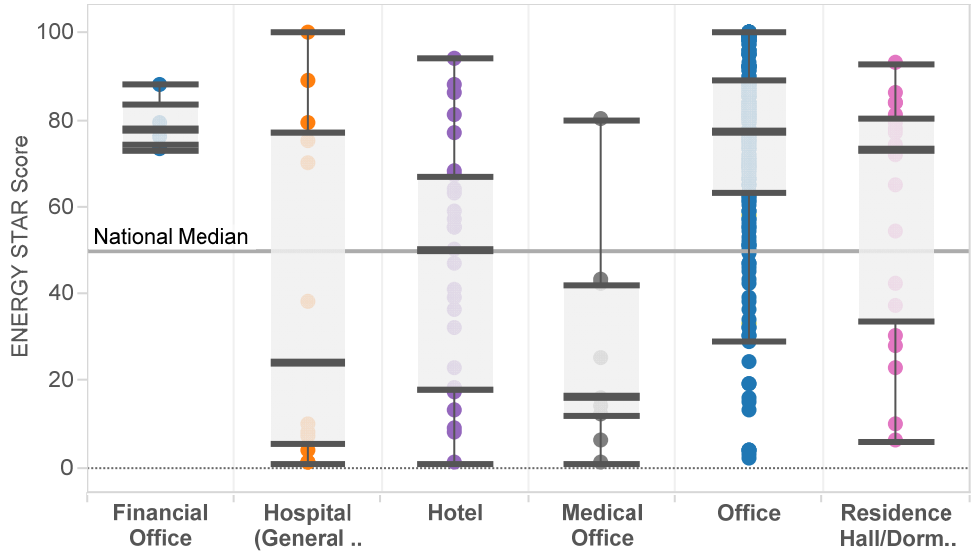


Figure 13: ENERGY STAR Score by Property Type

The solid bars in the center of the boxes are the median; the top and bottom of the boxes are the 25% quartile and the 75% quartile. The whiskers mark the nearest data point with 1.5 times interquartile range, i.e., 1.5 times the distance between the upper and lower quartiles.

Figure 13 shows the median ENERGY STAR score for Boston's office buildings by decade of construction. It shows that in in every decade the majority of Boston's office buildings have scores above the national median of 50.

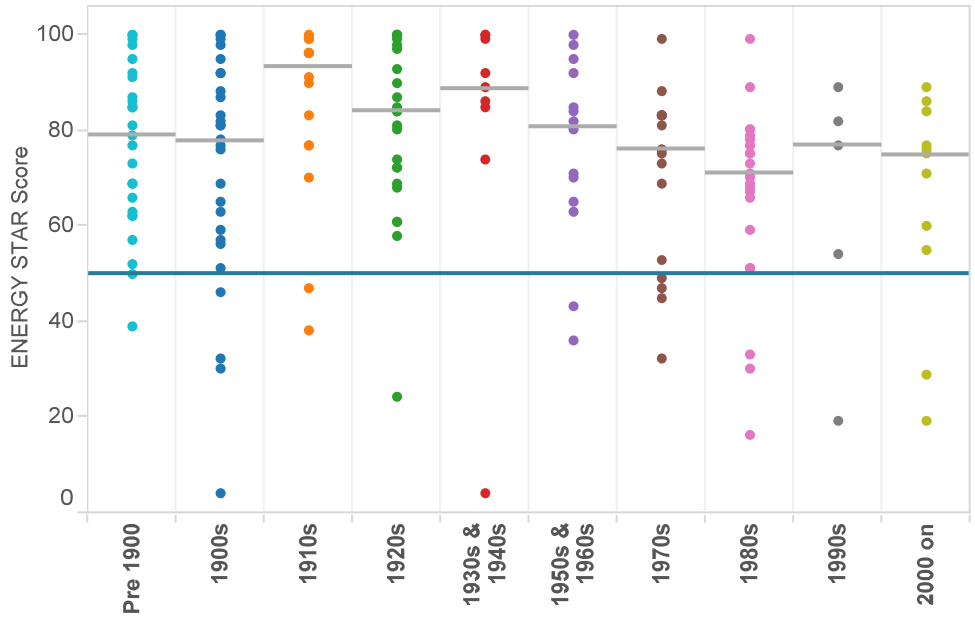


Figure 14: Office Buildings: ENERGY STAR Scores by Decade Built

The grey lines show the median ENERGY STAR score for each decade.

Water Use

While BERDO requires reporting of water use data, less than half of the properties in the data set provided it. Given the incompleteness of the data, it is difficult to assess overall water use, or the contributions of the individual sectors to that total. However, it is possible to look at the water use intensities of the buildings that did report it and to view the variances between and within property types. Not surprisingly, property types that include housing (hotels, dormitories, hospitals) and industrial processes have higher water use intensities than property types that do not include those uses (offices and non-residential university buildings).

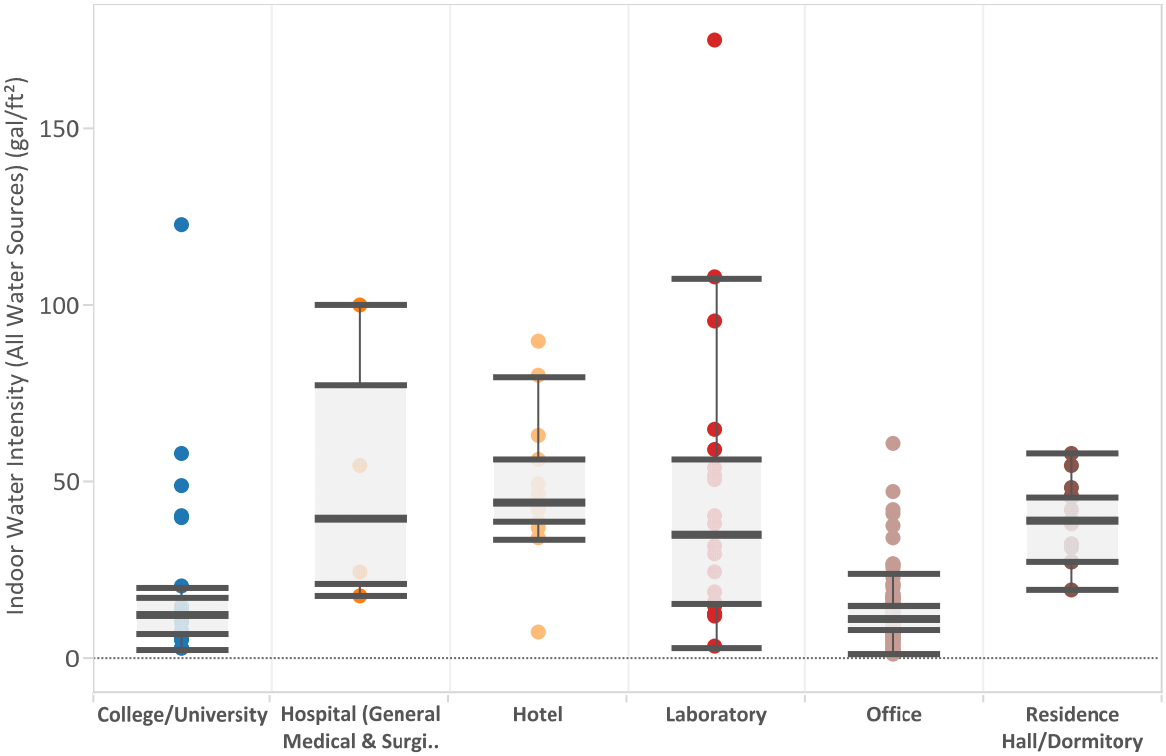


Figure 15: Water Use Intensity by Property Type

Municipal Buildings

In addition to receiving BERDO reports from buildings owned by others, the City of Boston reported BERDO data for its own municipal buildings. The City's reports cover 321 buildings and nearly 17 million square feet.

The City's BERDO reports reveal that schools are by far the dominant property type for municipal buildings, accounting for 67% of the square footage and 58% of the GHG emissions. Office buildings are the next largest category, followed by libraries and police stations. A collection of 18 property types characterized as "others" in Figure 16 together account for 8% of the square footage and 4% of emissions.

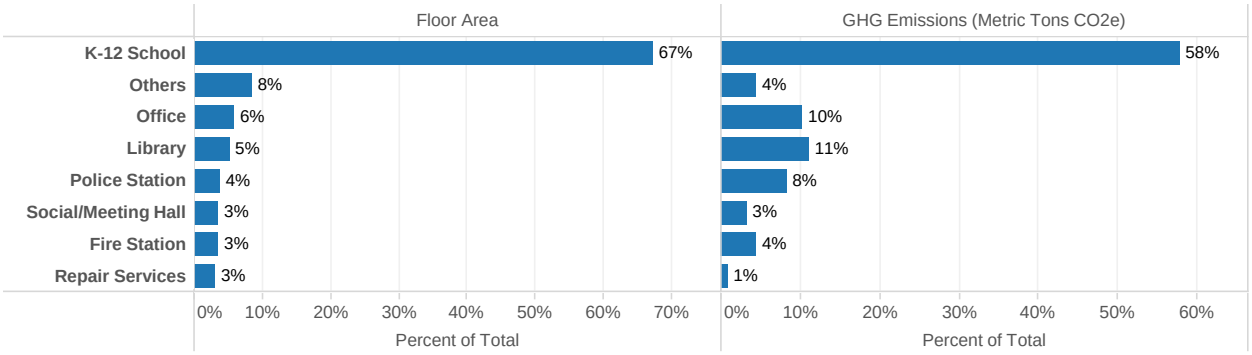
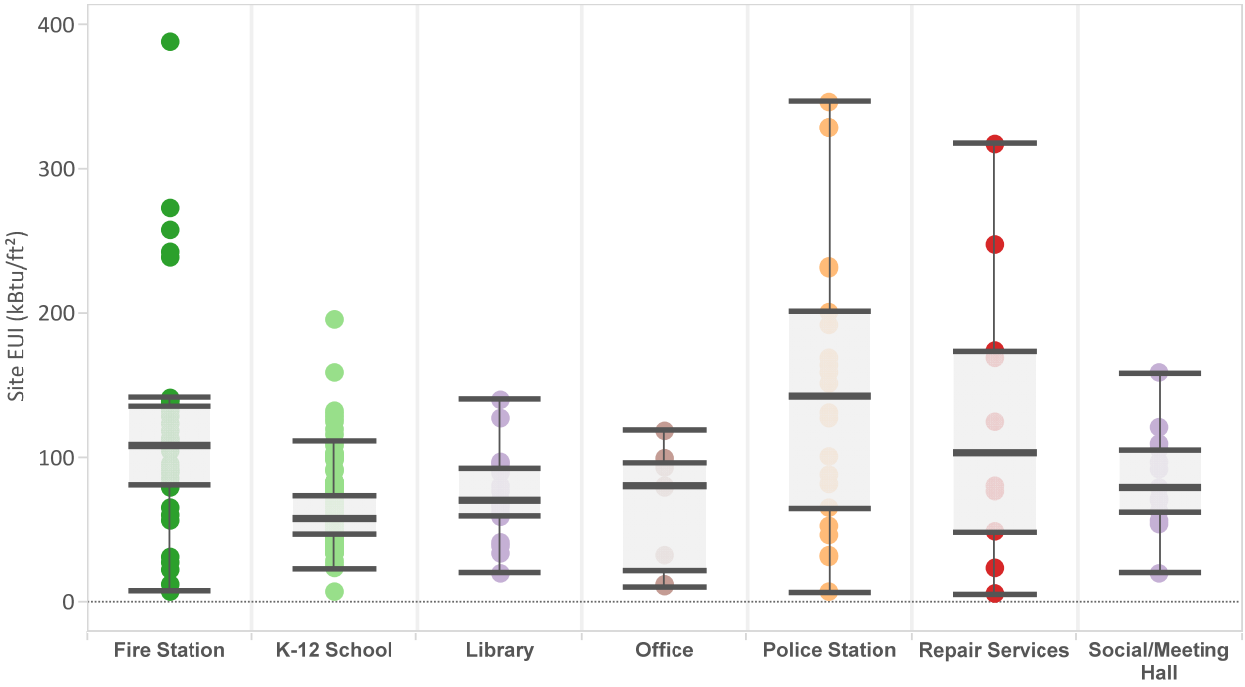


Figure 16: Floor area and GHG emissions of municipal buildings

As with the non-municipal buildings, examining energy use intensities shows differences between different types of properties and also across properties within a type. For Boston's municipal buildings, police and fire stations have the highest median EUIs and the widest range of EUIs.



Conclusions regarding the 2013 BERDO Data

The 2013 BERDO data offers valuable insights regarding the sectors, property types, and properties that drive energy use and GHG emissions in Boston. Although information regarding individual buildings is not publically reported this year, the data enables the City to see which buildings within each property type have the highest energy use intensities. The data will help the City to know which types of buildings and which specific buildings to target for energy efficiency outreach. The BERDO data should improve the efficiency and the effectiveness of the City's energy efficiency initiatives.

The 2014 BERDO data, which will be reported in May 2015, will be even more valuable. That data will include the large residential buildings, and so will provide insight into the energy use and GHG emissions in that sector. The 2014 reports will also include a second year of data for the large non-residential buildings, so that the City will begin to see changes in use and emissions over time. Finally, 2014 data will be publically reported, enabling Boston's businesses and residents to see the energy performance of the City's buildings.

As discussed in more detail in Appendix 1, there were limitations in the 2013 data that restricted the scope and depth of the analysis. Most significantly, over 10% of the properties that submitted data had to be excluded from the energy use and GHG emissions analysis because the reports for those properties generated by Portfolio Manager did not include GHG emissions or EUIs. With greater clarity about what is required by Portfolio Manager in order to generate those values and better error flagging being developed, it can be expected that this problem will be reduced in the 2014 data. Also, although the property owners enter monthly energy use data into Portfolio Manager, that system provides only annual totals to the City. Having access to the monthly data would enable deeper and richer analysis.

Making BERDO More Actionable

In this initial BERDO cycle, the ordinance wasn't fully implemented, in that the information was not made public, and some of the buildings covered by the ordinance were exempt, including non-residential buildings between 35,000 and 50,000 sq. ft. and all residential buildings (over 35 units). Boston chose to begin its energy disclosure program in 2014 with a focus on the largest non-residential buildings, to better understand these largest users of energy, and as well, to test the manageability and value creation of the current BERDO process before extending to the remaining facilities covered by the ordinance.

In this section, we consider possible directions for future cycles of the BERDO initiative, within the bounds of the current ordinance.

Context – Revisiting the opportunity of BERDO

Considering how to make BERDO more actionable, it is valuable to reflect on why Boston is pursuing BERDO as part of the Greenovate and Renew Boston initiatives, and how these may create benefits for its citizens.

Economic: The benefits include affordability, economic growth, and jobs. More efficient buildings have lower energy costs, and thereby are more affordable for tenants and profitable for owners, while creating more economic growth and jobs. Energy benchmarks on EPA Portfolio Manager®, by themselves, correlate with a 7% average savings through feedback and awareness. Typically, 30% savings are found in energy audits that can be achieved through building improvements that pay for themselves entirely through the value of the energy saved.[6]

Further, *making efficiency visible* is a target for local Boston businesses developing their companies in the *innovation economy,* as new leading players in efficiency technology and financial services, digital energy information, and control technologies; thereby adding to Boston's leadership in these important and emerging fields.

Livability: Tenants (particularly residential but commercial as well) have little control of how buildings are maintained and operated, and owners often have little incentive to improve the building's comfort, light, and hot water systems. More efficient buildings with upgraded systems not only save energy and money, but have fewer system failures in the dead of winter. As a result of insulation and air sealing, efficient buildings are quieter and have less problems with pest infestation. In addition, public areas upgraded with LEDs may be more brightly and safely lit.

Climate: Boston seeks to lead by example by demonstrating that reasonable paths exist to reduce GHG emissions adequately to sustain a livable Earth. An aggressive plan, like those put forward at the 2014 United Nations Framework Convention on Climate Change in Lima, Peru require the developed world to reduce carbon emissions by 5% per year until 2050 to stabilize climate. Efficiency opportunities that pay for themselves

[6] Institute of Market Transformation, "EPA Analysis Shows Big Benchmarking Savings", October 2012 http://www.imt.org/news/the-current/epa-analysis-shows-big-benchmarking-savings

with energy savings can easily address over half of what we need to do between now and 2050. Between now and 2020, building energy efficiency is in fact the bulk of what we can do to reduce emissions as more expensive technologies become more cost effective, such as solar and wind energy, electric vehicles, and technologies to sequester carbon from fossil electric plants.[7]

Potential Actionable Directions – from *Disclosure* to *Transparency*

Energy efficiency's most persistent market barrier is its lack of transparency: turning the abstraction of energy efficiency into something real and actionable is the key to unlocking its potential. Certainly, the development of analytics that provide greater transparency are being broadly pursued by academia, industry, and new ventures, and these seek to develop their value proposition in case study environments such as Boston. As a result, Boston doesn't need to develop the analytics, but the City does need to be clear and consistent in its objectives, as well as providing assistance by simplifying the legal and regulatory environment.

If Boston chooses therefore, the BERDO program can progress in future cycles to be not only about *disclosure of energy use,* but increasingly about greater *transparency for efficiency,* providing:

1) Greater benefits for the building owner, and
2) Additional benefits from increasing public access.

In this section, we offer an initial consideration of how energy data reporting could be made more effective with advanced analytics and greater accessibility:

- What if our measurements could not only report normalized energy use, but also report efficiency potential, as well as the efficiency achieved over time, for every building in Boston?

- What if there were an "efficiency meter" that told each building owner not only how much energy was savable and saved, but also how much money, GHG emissions, and other economic and livability benefits could be achieved?

[7] Richard. K. Lester and David M. Hart Unlocking Energy Innovation: How America Can Build a Low-Cost, Low-Carbon Energy System, MIT Press, November 2011.

- What if this information was not only available to the building owner, but also accessible with reasonable and necessary privacy protections to the public in manner to effectively spur action?

A path for BERDO that gradually encourages greater ***disclosure of energy use*** and ***transparency for efficiency,*** over time, may create these potential benefits:

Building owner benefits

- Behavior/operating savings – EPA Portfolio Manager®'s 7% savings provides a compelling case for building owners to support and review the data. System improvements, such as those being pursued by SEED (Standard Energy Efficiency Data Platform), should increase the usability and results.

- Voluntary Upgrades – Development of Building "EKG" analytics increasingly identify physical improvement options with a minimum of audit expense, at least initially. Local companies such as Retroficiency and Essess produce automated "no touch audits" with only energy data, infrared drive by photos, and publically available databases; First Fuel supports an efficient process with a minimum of onsite data; while companies like KGS Buildings and Cimetrics add supplemental data monitors to "retrocommission" buildings to operate as designed.

- Certifications – Buildings benefit from receipt of certifications such as ENERGY STAR and LEED. Buildings acquiring these will improve their marketing and public relations campaigns, but as well, the City of Boston can assist spotlighting these buildings in some manner.

- Economics – Data systems of these types can show building owners their lost profitability that result from exceeding average energy use on a normalized basis, their shortfall from best practices, and how much their efforts have achieved to date. In addition, these systems could identify the financial from utility and climate incentive programs that might be available to them.

- Livability – These data systems can potentially show stronger indicators of the comfort performance of the buildings, including more granular temperature monitoring, hot water levels, etc.

Benefits from increasing public access

In time, more energy and normalized efficiency meter information could be made available on *maps* and *apps* of various kinds: these may allow prospective tenants and buyers, public interest groups, and potential vendors the ability to assess the performance and availability of efficiency opportunities.

Utilities do currently use some advanced information tools of this type to target and support their customers. Our suggestion is for the City of Boston to democratize this process in a manner that allows for the City and its efficiency service providers to more effectively address the BERDO goals somewhat independently of the utilities – Renew Boston is in fact such an initiative. Specific benefits from increasing public access include:

- Selection - Prospective tenants when selecting apartments and commercial space could use the public data to better understand the total cost of renting the space, the likely livability, and as well be able to act on their preferences for environmentally conscious buildings.
- Social norms - Interest groups and civil society could use the public data to identify and create public pressure on building owners to participate in efficiency and climate goals. In addition, transparent benchmarks may begin to create a culture where efficiency is the norm, not the outlier: norms are social levers that get people to take action.
- Vendors – Available profile data can help efficiency vendors effectively target qualified leads for their products and services.
- City Energy Management – Boston can apply these systems to improve its targeting and direction of resources, as a potential path forward for the Renew Boston program.

Potential Steps Towards More Actionable Transparency

Below are some initial suggestions on ways to expand BERDO's impact, developing pathways to 1) improved efficiency analytic systems, and 2) greater transparency.

1. Developing a pathway to improved efficiency analytic systems:

Our work shows some early steps in applying EPA Portfolio Manager®, ENERGY STAR buildings ratings, and the DOE Standard Energy Efficiency Data Platform (SEED) initiative. Boston could adopt a long-term strategy to be an active and demanding customer for these systems, and lobby to improve the systems in the direction of the

City's needs. Annually, Boston should assess the effectiveness of these systems and establish its strategy to influence EPA and DOE to make improvements by:

- Supporting trials of these and other new/improved systems on an ongoing basis, with evaluations, and seeking funds from utilities, State, and Federal levels to support test and evaluation in Boston.

- Lobbying for utilities to achieve their commitment to *Green Button Connect,* allowing buildings to assign monthly energy bill information access to a third parties of their choice. The monthly data stream is an important element of improved analytic system capabilities. Once hourly energy use information is collected by advanced meters, the capabilities will again dramatically increase. Hourly meter implementation is a goal of the Grid Modernization plans that utilities are developing, and due for filing with the Massachusetts Department of Public Utilities next summer,

- Expanding analytic systems to become incentive application systems as well, to assist building owners in collecting incentives for efficiency actions. Achieving a more efficient building creates a number of potential revenue streams for building owners, in addition to the value of energy saved.

    - Saved kwh and therms of gas are of system benefit value to utility distribution companies, and these companies now pay their customers to save energy.

    - Saving peak demand energy when needed by the electric grid system, such as during hot summer day air conditioning peaks, has a value called *demand response,* and utilities pay customers who can reduce energy during these times.

    - And soon very possibly, as utilities develop strategies to meet their carbon saving obligations under new EPA Clean Air Act rule 111(d), there will be another revenue stream for efficiency.

- As a result, there is a powerful opportunity for an analytic system that provides a measurement tool through which to distribute utility efficiency, demand response (DR), and potential carbon offset incentives, based on measured building performance.

2. Developing a pathway to greater transparency:

As the benefits from increasing public access to building data are potentially large, a gradual strategy to bring more data and more buildings to the public domain should be strongly considered. Again, utilities have access to very granular energy data now, which they are beginning to apply to their efficiency marketing as they choose. Limiting data access for use only by the utility company limits results to that utilities program designs and preferences. Boston's BERDO system can support building stakeholders that may have differing need and agenda – some are therefore hiring third-party vendors to improve their own data visibility and take action. The following approaches could contribute to a pathway to greater transparency:

- *Gradually extend the amount of data made available.* Relative energy scores such as ENERGY STAR ratings currently have higher awareness and acceptance among building stakeholders, and are the first step towards actual building energy scores. The next step is to extend the efficiency scoring to more granular indicators over time. This approach allows for a step-wise introduction of disclosure requirements, with increasing public familiarity and decreasing concerns over time. This approach could allow for medium-term progression to broad data disclosure, which should lead to increased building efficiencies as the corrected social norms and cultural factors are established.

- *Extend BERDO to more buildings:* As mentioned above, while commercial efficiency is important, the opportunity for improvement in residential buildings might be higher. Tenants have little control of how buildings are maintained and operated, and landlords often have little incentive to improve the building's comfort, light, and hot water systems. The result is often tremendous waste – with apartments that are drafty, with steam and hot water leaks, and tenants with no choice but to open windows in winter to keep their units from overheating. So, continuing the program to all covered facilities including residential is an important step. In addition, extending the program to cover all of the commercial buildings above 35,000 sq. ft. expands the potential of the program.

- *Add voluntary reporting:* More granular information might be voluntarily reported, especially when the building scores well, and receives recognition, or doesn't score well but receives the benefit of more funding for efficiency, better financing, or appropriate targeted marketing. Voluntary participation of smaller buildings and voluntary reporting of addition data collection "fields" should be supported and encouraged.

- Encourage *Maps* and *Apps:* With broader public accessibility to transparent efficiency data, there are great opportunities to improve the effectiveness of systems for individuals, groups, and crowdsourced public norm systems. Processes being tested, such as the Mapdwell Solar Map project, may suggest how geographic display of information may increase public awareness. *New urban mechanics* conceptually illustrate great opportunities to extend what can be done with available data applied to creative Apps. A recent MIT research and thesis project examined a number of strategies for encouraging efficiency with Energy Maps.[8]

Leveraging the BERDO towards a more impactful system of energy transparency and removing the most significant market barrier to energy efficiency is a goal worthy of Boston, the #1 city for energy efficiency.[9]

[8] *The Residential Energy Map: Catalyzing Energy Efficiency Through Remote Energy Assessments and Improved Data Access*, MIT. Energy Efficiency Strategy Project, Howland, Alexis et. al.; July 2013. http://web.mit.edu/energy-efficiency/docs/EESP_Howland_ResidentialEnergyMap.pdf

[9] *ACEEE 2013 City Efficiency Scorecard*, September 2013 http://aceee.org/local-policy/city-scorecard

Appendix 1: Data Quality, Compliance Determination Process and Recommendations for Future Reporting Cycles

Data Quality

We encountered several data quality problems that required us to exclude properties from most of the analysis. Shown in Table 5, these problems included the following:

- Excessive district steam use. This appears to have been caused by a confusion about units. For district steam, Portfolio Manager® allows users to choose from among several different units for data entry, including "MLbs (million pounds)" and "kLbs (thousand pounds)." However, Boston's district steam provider bills customers in "mlbs", but uses that to mean "thousand pounds." Many customers apparently entered usage from their bills that was reported in thousand pounds into Portfolio Manager® as million pounds, causing the steam use to be greatly overstated.
- Zero or missing GHG emissions as reported by Portfolio Manager®. This includes many properties that reported energy use. However, to generate GHG emissions, Portfolio Manager® requires a full 12 calendar months of data for every meter. Given utility billing cycles, it is often necessary to enter 13 months of utility bill data to cover a full 12 calendar months. Properties that did not do so did not have reported GHG emissions.
- Zero or missing square footage.
- Zero or missing EUI as reported by Portfolio Manager®. As with GHG emissions, Portfolio Manager® requires a full 12 calendar months of data in order to generate an EUI. In the great majority of cases, where Portfolio Manager® did not generate EUI, it also did not generate GHG emissions. However, there is a handful of properties where Portfolio Manager® generated GHG emissions but not EUI; we were not able to determine what distinguishes those properties.
- EUIs outside of the expected range, either below 5 or above 1,000 kBtu per square foot. Some of the high EUIs appear to be caused by errors in square footage (e.g., 125 square feet entered for a building of 125,000 square feet).

	Removed	Properties Remaining	Percent of Initial Total
Properties submitting reports		642	100%
District steam use > 750,000,000	8	634	99%

No GHG emissions reported	81	553	86%
No square footage	25	528	82%
No EUI	8	520	81%
Site EUI < 5 or > 1,000 kBtu per ft^2	13	507	79%

Table 5: Energy Data Clean-up Report

For the analysis of energy use, we excluded the properties with excessive steam use. For the analysis of GHG emissions, we also excluded properties with no reported emissions. For the analysis of intensities, we excluded all properties with any of the issues listed above.

The data problems were not concentrated in buildings of a particular size. Table 6 shows, by size group, the percentage of total properties and the percentage of properties for which Portfolio Manager® did not report GHG emissions. The percentages are nearly identical.

Property Floor Area	% of Total Number of Properties	% of Properties with No Reported GHG Emissions
Up to 500,000	81.2	81.5
500,001 to 1,000,000	7.9	7.4
Over 1,000,000	10.9	11.1

Table 6: Data Errors by Building Size

Water Data

While the energy and GHG emissions data was not perfect, the water data was much worse. Shown in Table 6, of the 642 total properties, 344 did not report water use. Of those that did report water use, 11 had no water intensity and a handful had unreasonably high usage or intensities, suggesting possible data errors.

	Removed	Properties Remaining	Percent of Initial Total
Properties submitting reports		642	100%
No water use	344	298	46%
No water intensity	11	287	45%

Water use > 300,000 kgal	2	285	44%
Water intensity > 400 gal per ft^2	3	282	44%

Table 7: Water Data Clean-up

Square Footage

We found a high variance between building square footage as reported through BERDO and square footage as listed in the assessor database, even when limiting the analysis to the most comparable parcels. Detailed in Table 8, total square footage (Property Floor Area (Buildings and Parking) (ft^2)) submitted for the 442 parcels we compared differed from the total square footage listed in the tax assessor database by an absolute value of 84,083,118 ft^2, with an average difference of 131,909 ft^2 and a standard deviation of 491,439 ft^2. Thirty-four submissions (8 percent) reported square footage identical to the tax assessor database, and 391 submissions (88 percent) fell within one standard deviation of the mean.

	Total Submissions	Percent of Submissions Analyzed
Single-parcel submissions with both Property Floor Area and tax assessor square footage	442	100%
Identical Property Floor Area and tax assessor square footage	34	8%
Difference between Property Floor Area and tax assessor square footage within one standard deviation of the mean*	391	88%
Average difference between Property Floor Area and tax assessor square footage (ft^2)	131,909	
*Standard deviation between property Floor Area and tax assessor square footage (ft^2)	491,439	

Table 8: Square Footage Analysis

The variance in reported square footage does not necessarily indicate errors in either the BERDO reports or the assessor database. We heard anecdotally from some BERDO reporters that they do not think of their buildings in the same configurations that

appear in the assessor data. A structure that the tax records may show as multiple buildings may be treated by the owner as a single structure, and vice versa. The BERDO reporters submitted square footage and energy use for the buildings as they understand them. Differences between those reports and the assessor data may reflect differences in how the lines are drawn rather than different understandings of the size of the buildings.

Compliance Determination Process

We used the following process to assess compliance with the BERDO ordinance.

1. Buildings submitted usage data through ENERGY STAR's Portfolio Manager®.
2. Submissions were compiled in an aggregate report and matched to the list of buildings required to report by tax assessor ID. Common issues that made an initial match by tax assessor ID unsuccessful included:

    - Tax assessor ID entered incorrectly (including multiple, duplicate, or incorrect numerals),
    - Tax assessor ID abbreviated to exclude first two digits (the district identifiers), and
    - Tax assessor ID not entered.

3. When the tax assessor ID was incorrect or unavailable, a secondary matching process was performed based on street address, and the tax assessor ID for the submission was corrected. Street address matches failed in cases where:

    - The street address was formatted differently ("One Boston Street" instead of "1 Boston St"). These were easily identified and the correct tax assessor ID located through a visual scan of the failed matches.
    - The street number identified in the Portfolio Manager® report was a singular value ("20 Boston St"), where the address in the Assessing Database was a range of street numbers ("10-30 Boston St").
    - The street address identified in the Portfolio Manager® report corresponded with an adjacent street or proprietary drive.

- Discrepancies in street numbers were resolved by searching the building address in Google Maps, and then using the City of Boston Assessing Map to identify the relevant parcel (www.cityofboston.gov/assessing/search).
- Where reports were filed without all tax assessor IDs included, and the list of buildings required to report included adjacent parcels or even disparate parcels owned by the same entity, assumptions had to be made as to whether the report included all parcels, some segment of them, or an individual parcel. The best way to resolve this was by comparing reported square footage to square footage listed in the tax assessor database, but identical totals were seldom produced.

4. When multiple tax assessor IDs were entered, additional clean up was required.

    - By far, the biggest hindrance to matching was that buildings were allowed to submit single Portfolio Manager® reports spanning multiple parcels. Of the buildings reported this way (i.e., part of large campuses or industrial parks), some entered all included tax assessor IDs in the appropriate field, and these were then parsed out and matched. Others entered additional parcel numbers in a notes field, which were also parsed out appropriately. Common issues encountered with these multi-parcel reports included:

5. Voluntary submissions occurred because they were adjacent or owned by the same entity. Identification by square footage was especially difficult in these cases, as tax assessor data for these parcels was not included in the list of buildings required to report, and had to be located in the full assessor database. Besides the difficulty with compliance analysis, these reports were likely to have less accurate building data, because master responses had to be selected for fields that could not be summed, such as “Year Built”.
6. After generating the list of compliant buildings, a mailing was sent by the City of Boston to all non-compliant buildings to solicit late submissions. The late submissions through November 24, 2014 were collected and rolled into the report using the previous five steps before beginning analysis.

Recommendations

The top reporting errors or inconsistencies in Portfolio Manager® submissions affecting analysis were:

- Incorrect, missing, or partial tax assessor IDs;
- Inconsistently formatted addresses or addresses that did not correspond to the tax assessor database;
- Energy usage data for multiple buildings and/or parcels submitted in a single report;
- Failure to submit 12 calendar months of data, which resulted in Portfolio Manager® not reporting GHG emissions or EUI;
- Submission of data greater than 120 days old, which resulted in Portfolio Manager® not reporting GHG emissions or EUI; and errors in energy and water units

We recommend the following revisions to regulations and reporting resources to mitigate these issues:

1. Where possible, separate Portfolio Manager® reports should be submitted for each unique tax assessor ID.
    a. At a minimum, multiple buildings in one tax lot (with one tax assessor ID) should be combined in the list of buildings required to report. The number of buildings present on the lot should be included and square footage summed. Fields that cannot be summed should be pulled from the building with the greatest square footage to generate a master record.
    b. Preferred is to examine these buildings individually, which requires that an unique identifier alternative to the tax assessor ID must be selected as a unique identifier.
2. Tax assessor IDs of all buildings required to report should be provided to owners, with clear instructions to only include those buildings in submissions.
    a. Parcel maps from the tax assessor database should be provided to support identification of the appropriate parcel.
    b. In cases where the tax assessor data is incorrect or accurate usage data for that parcel alone cannot be provided, the City should be contacted, or at the very least a clear flag or note with an explanation must be provided in the submitted report.
3. The instructions for reporters should specify that reporters provide the data that is needed for Portfolio Manager® to report GHG emissions and EUIs, including that the data cover the full calendar year and (apparently) not be more than 120 days old.

4. The instructions for reporters should highlight the importance of using the correct units with particular attention to where this was a problem in the 2013 reporting: district steam and water.

Improvements to EPA Portfolio Manager®

We recommend the following revisions:

- Required entry of a tax assessor ID for all submissions:
    - Instant validation of the ID
    - Geolocation (Google maps matching, etc.),
    - Help with lookup tied to the City of Boston Assessing Map (www.cityofboston.gov/assessing/search).
- The option to submit distinct usage data for different buildings in a single report would maintain a level of convenience for entities required to report usage for multiple buildings, while contributing to a more robust and granular data set for analysis.
- If, as appears to be the case, Portfolio Manager® does not report GHG emissions or EUI for properties that report energy use data that is more than 120 days old, consider modifying that requirement for data reported in connection with city disclosure ordinances. For the purpose of a reporting ordinance, all that matters is whether the data covers the full reporting period; it does not matter whether the data is more than 120 days old.
- Portfolio Manager® should report monthly energy use data to the City. Although the building owners enter monthly data into Portfolio Manager®, that system currently provides only annual totals to the City. Having monthly data would greatly increase the utility of the data set. With monthly data, it is possible to distinguish heating use from baseload use, to see how the building responds to temperature, and to identify potential energy efficiency opportunities. Having monthly data would make BERDO much more actionable.

Appendix 2: The Use of SEED in Compliance Reporting

Parallel to the compliance analysis performed in Microsoft Excel, the Standard Energy Efficiency Data (SEED) Platform™ was used to support the process of determining building compliance. SEED is an open-source software platform created through a U.S. Department of Energy initiative. Its development was primarily driven by a desire to allow cities and other entities to clean and standardize, merge, map, and share large building energy datasets from multiple sources, making it ideal in supporting BERDO compliance analysis.

For the purposes of this analysis, SEED was used as follows:

1. The full list of reporting buildings was uploaded, including notes about exemption and contact information.
2. Fields were mapped to standard Building Energy Data Exchange Specification (BEDES) fields, where possible, or given explicit, descriptive names when unique to the report (e.g., “Exempted?” was changed to “Notes on Exemption from Reporting Ordinance”). The fields mapped to the standard fields “PM (Portfolio Manager®) ID”, “Tax Assessor ID”, “Address Line 1”, and “Address Line 2” were used to auto-match buildings between reports, so it was important to ensure these fields were mapped appropriately.
3. The submitted ENERGY STAR Portfolio Manager® output was uploaded and fields were mapped to BEDES fields, where possible.
4. SEED then proceeded with an automated matching process between data sets based on Portfolio Manager® ID, Tax Assessor ID, and street address. The results were returned with an associated “Match Confidence” score, and could be sorted low to high for review of approximate matches.
5. Unmatched buildings from either dataset were reviewed, edited, and linked to a match, where possible.
6. Both data sets were then “merged” into a single building data set when a match was established. Where no match was established correctly (either because the building was on the required reporting list and had not submitted a report or those had submitted a report voluntarily but were not on the required list), the building record would exist with the supplementary data fields supplied by either Portfolio Manager® or blank tax assessor reports.
7. Filters were then applied to identify buildings with identical reported data, or numerical data in a range between a selected minimum and maximum. This subset

of buildings from the search were then “labeled” with custom labels or bucketed into a “project” containing only those selected buildings.

The “manual matching” process for buildings with discrepancies in tax assessor IDs or street addresses remained the same as in Excel, although the easy filtering and record search functionality made the lookup process somewhat easier than searching through an Excel sheet for partial matches.

The biggest SEED limitation was that the multi-parcel reports could not be parsed out once uploaded, and separating them out for the purpose of compliance reporting would create building records with blank or duplicate usage data.

Recommendations for Using SEED as a Compliance Reporting Tool

At the time of this reporting cycle, SEED was undergoing extensive revisions, with a full v1.1 available on October 29, 2014. During this development phase, software bugs made upload, mapping, and matching difficult and unreliable, making Excel the better alternative for cleanup, organization, and compliance analysis. SEED’s current functionality does not support reporting and analysis, so while buildings can be sub-grouped in projects to generate totals in various categories, more extensive analysis can only be performed by exporting the report from SEED and importing it into an external program.

There are plans for expanding the core reporting and analysis capabilities, and the source code for SEED is publicly available to encourage third-party developers to create plug-ins or applications that extend the core functionality. DOE would like to see the creation of a SEED “marketplace” for such third-party applications, for purchase of unique instances of the platform.

Benefits of the SEED platform include:

- Automated matching with an associated confidence rating so fuzzy matches can be reviewed and revised.
- Updated reports and new submissions can be easily incorporated. This is where SEED provides the best advantage over Excel, because merging reports in Excel can be time-intensive and manual, leading to room for error.
- An intuitive interface for users unfamiliar with Excel matching, sorting, and filtering functions.

- The ability to share a single account with multiple users who can access data securely and remotely without sending out different iterations of workbooks and spreadsheets. User licenses can be created by any designated account owner, and granted different levels of privilege to access, modify, and manage data by need.
- A responsive support team that helps resolve errors and facilitates incorporation of user feedback into future revisions (which occur frequently).
- Documentation of proper data cleaning, organization, and field-matching processes applicable to a range of report types, and specific support materials for working with Portfolio Manager® output.
- While users can choose to host their own instance of SEED, the Lawrence Berkeley National Lab has committed to providing free hosting services for at least a year for interested users. The accounts hosted here are unique and specific to each organization.
- Building data can be easily shared with the DOE's Building Performance Database, supporting the effort to aggregate building energy use data nationally and making it publicly available in one standardized repository.

Current SEED issues include:

- Building records correspond singularly to a row on an Excel sheet. This means parsing out of individual tax assessor IDs needs to happen prior to upload, and additional IDs need to be included in the Portfolio Manager® record, as usage data has been summed across parcels. In short, compliance analysis and energy use analysis cannot be conducted using the same report, but must happen separately – one must include all reported PIDs in a single column, and one must include them listed side-by-side for a single Portfolio Manager® report. This also makes any analysis using tax assessor data (building age, square footage, cost, etc.) difficult, as that data may span multiple parcels and need to be combined (or a master number identified) to compare with single Portfolio Manager® reports. For these reasons, the platform may lend itself better to compliance reporting than energy usage analysis, which is best conducted using a more flexible tool to organize reports.
- Frequent revisions during this reporting cycle interrupted user workflow, introducing software bugs, new features, and process changes that had to be mastered before continuing work on a dataset, and occasionally wiping clean all existing data, requiring extensive work to be reproduced.

While SEED in its current iteration is not sufficient to perform the full scope of analysis required for BERDO projects, extensive developments have resulted in vast

improvements since the beginning of use for this reporting cycle. SEED is a useful tool for:

- Initial matching efforts in compliance analysis,
- Standardizing field names for subsequent matching and merging efforts,
- Bucketing buildings according to different criteria for further analysis in another program, and
- Sharing reports between users to enable collaborative analysis.

For future reporting cycles, the following process is recommended for compliance analysis:

- The full list of buildings required to report is uploaded into SEED, and buildings later exempted or granted exemptions are flagged in the database.
- As Portfolio Manager® submissions roll in, successive output reports are uploaded into SEED and matched with existing data.
- Incorrect or partial matches are reviewed and corrected individually, using the same process performed this year in Excel.
- Reports determined to contain multiple parcels are grouped in a project, exported, and parsed out into separate rows in Excel, with all energy usage fields left blank besides those contained in the "master" record.
    - The Portfolio Manager® report ID should also be removed from the "duplicate" records, and an additional field added flagging these buildings as included in the same report. This will prevent re-association of these buildings with a single building record in SEED, but allow them to be easily linked with the report for later usage analysis.
    - The revised multi-parcel records are then re-uploaded to SEED.
- All supplemental datasets (i.e., Top 50 owners, alternate sector data, full tax assessor database records for expanded analysis of buildings reporting voluntarily, etc.) are uploaded into SEED and matched with existing records.
- Reports of unmatched tax assessor records are generated in SEED and exported periodically to act as the list of buildings to receive compliance reminders.
- Once the deadline for submission has passed, a master report of building data is exported for further manipulation and analysis of usage and ownership data in an external program.

As SEED is explicitly intended for use in BERDO compliance analysis, it is likely that programs will be developed in the coming year(s) that integrate ENERGY STAR Portfolio

Manager® reporting with SEED, simplifying the submission process and creating a potential for some of the recommended improvements to be incorporated directly into the reporting software. Such a tool could be extremely powerful in improving compliance rates and reducing the manual cleanup efforts involved in generating the final list of compliant buildings.