Standardizing City Benchmarking and Reporting: Use Cases in Consolidating Building Data with SEED

Nicholas Long, Alex Swindler, National Renewable Energy Laboratory
Robin Mitchell, Lawrence Berkeley National Laboratory
Harry Bergmann, U.S. Department of Energy
Ammon Reagan, City of Berkeley
Andrew Held, D.C. Department of Energy and Environment
Jeanine Longley, Ryan McCuaig, OPEN Technologies

ABSTRACT

Market transformation in commercial building energy efficiency can be difficult due to several variables including tracking potential building upgrades and technologies, having a lack of sufficient building characteristic data, and managing disparate datasets. Nonetheless, commercial building benchmarking (and auditing) programs have expanded to over 30 cities, municipalities, and/or states in the last few years. The Standard Energy Efficiency Data (SEED) Platform is developed as a free open-source solution to address many of these challenges. Recent features have been added that have enabled users to leverage SEED for more than just tracking benchmarking data. Today, cities and municipalities have utilized SEED to improve their auditing programs, support citizen interaction, and drive significant market transformation in the building sector.

This paper will discuss the features of SEED that help drive market transformation. These features include managing complex relationships between tax lots and properties, geocoding addresses, storing building footprints, supporting GeoJSON and the Unique Building Identifier (UBID), and time-series data storage. This paper will also present three case studies demonstrating how SEED adoption and integration into programs drive market transformation for different jurisdictions. San Francisco integrated SEED with Salesforce to manage interactions with the public, the District of Columbia used the SEED application programming interface (API) connection with reporting platforms to ease the burden of reporting for building owners, and OPEN Technologies is expanding SEED to support building energy reporting at the national scale in Canada. Each of these case studies will present the data workflow and its impact on the building sector.

Introduction

The number of commercial building benchmarking and auditing programs has increased over the last several years. Presently, there are over 30 cities, municipalities, and/or states requiring the reporting of building energy consumption and building characteristics to a governing authority. (See Figure 1. Institute of Market Transformation (IMT) 2020). The ultimate goal of the collected data is to track the energy consumption and impact of energy efficiency programs deployed throughout each jurisdiction. This paper will discuss the impact in San Francisco and Washington, D.C., as well as the voluntary and mandatory programs in Canada.

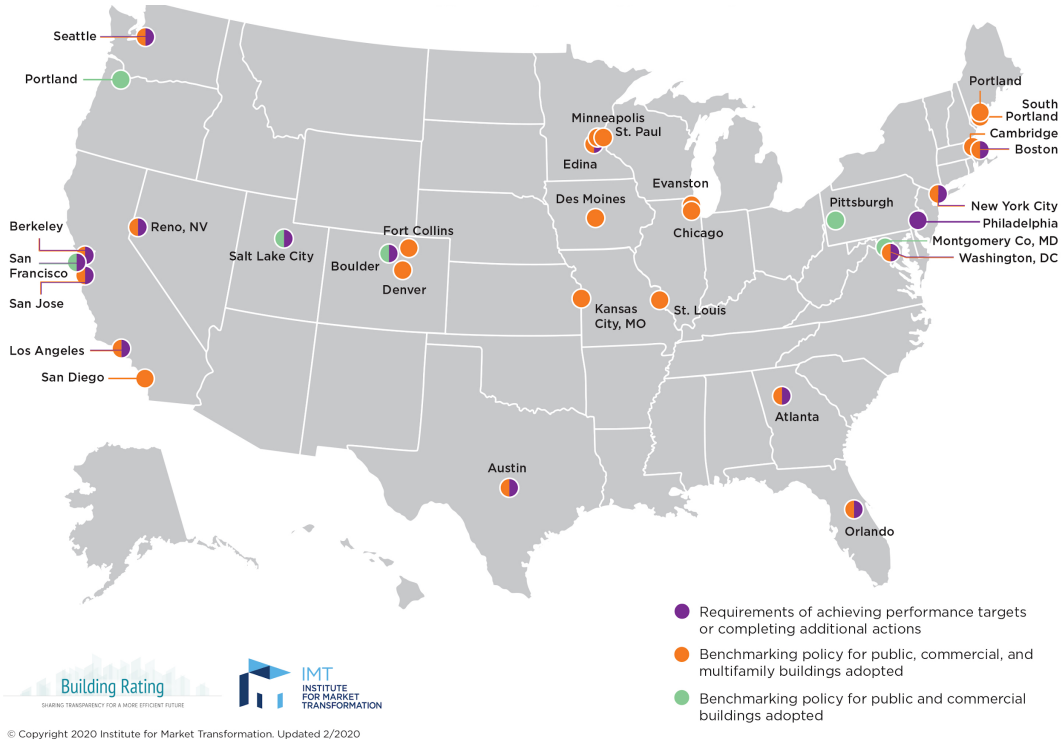

Figure 1. U.S. city and county policies supporting benchmarking and/or performance targets. *Source*: IMT 2020.

Collecting and managing the data in each jurisdiction is a non-trivial task and typically requires a dedicated staff person to manage the extract, transform, and loading (ETL) processes of the datasets. Historically, the benchmarking mandates are passed without explicit funding, causing the jurisdiction to quickly find a sustainable tracking process and staff allocations. The U.S. Department of Energy (DOE) has funded the development of the SEED Platform[1] over the last half-decade to help lower the burden on jurisdictions to engage in a benchmarking program (NREL; LBNL; DOE 2020). The goal of the SEED Platform is to provide a web application to make the ETL process simpler in terms of managing a database of buildings for tracking benchmarking compliance.

Ultimately, the goal of benchmarking and reporting programs is to drive energy savings across a large portfolio of buildings. The ability for jurisdictions to use SEED helps reduce the staff time needed to support many of the unfunded mandates from cities to manage their benchmarking programs. As presented in this paper, SEED is an open-source off-the-shelf solution to manage building data. SEED provides the ability to "tag" or "label" building records where data are missing, out of range, or missing specific monikers. Note that the use cases of SEED extend beyond commercial building benchmarking and auditing, and include use cases such as the Home Energy Labeling Information eXchange (HELIX) (NEEP 2020) and BayREN Integrated Commercial Retrofit (BRICR) project (Hooper et al. 2018). These use cases, as well as others, are not a focus of this paper.

[1] https://seed-platform.org

The Standard Energy Efficiency Data (SEED) Platform

The first open-source beta version of the SEED Platform was released in 2013 (Alschuler et al. 2014). This release was met with great enthusiasm as the promise of SEED had reached unmanageable expectations. This is not an unfortunate situation as the excitement demonstrated the overall need for such a solution. Upon release, there were usability issues and many users struggled to effectively use the program for benchmarking. In general, the initial release did not meet the hyped expectations. The program suffered from rigidity, an overly-broad scope, a lack of robust software development practices, and shifting requirements such as prioritizing reporting over data integrity. In 2016, a large effort was undertaken to revamp (not rewrite) the SEED Platform to focus on its principal use case: building benchmarking and management of building records. As a result, the program has evolved considerably over the last three years and is now successfully being deployed in several locations and includes third-party hosting providers (i.e., companies hosting SEED for a jurisdiction's use).

As described in the introduction, the SEED Platform is designed to help manage building data for cities. The program is designed as a self-deployable web application with configurable organizations and users. A SEED organization typically represents a city or jurisdiction undergoing benchmarking, and the users are the managers of the benchmarking program. The goal of SEED was to enable multiple use cases of data ingress such as tabular data (e.g., comma-separated value (CSV), Microsoft Excel, etc.), ENERGY STAR® Portfolio Manager, or BuildingSync (DeGraw et al. 2018).

Based on feedback from SEED users, the SEED Platform underwent a major software architectural shift to support the complexity of real-world data by splitting a building record into a building (or property) and its accompanying tax lot (or parcel). Figure 2 shows how SEED can establish a relationship between a building and the parcel on which it is built. In the simplest case, one building sits on one parcel, which is Case A in Figure 2. However, there are more complex relationships that exist between buildings and parcels. For example, multiple buildings can sit on one parcel, shown in Case B. In this situation, SEED can establish a "one to many" relationship between the two, (i.e., there is one parcel record that is associated with two building records). Case C shows another example where one building occupies multiple parcels. In that case, SEED can establish a "one to many" relationship between the two, such that there is one building record that is associated with all the appropriate parcel records. Case D is the most complex, where all the relationships shown in Cases A through C exist, which is generally referred to as a "campus". In this case, there is a "many to many" relationship between the campus buildings and the parcels they occupy.

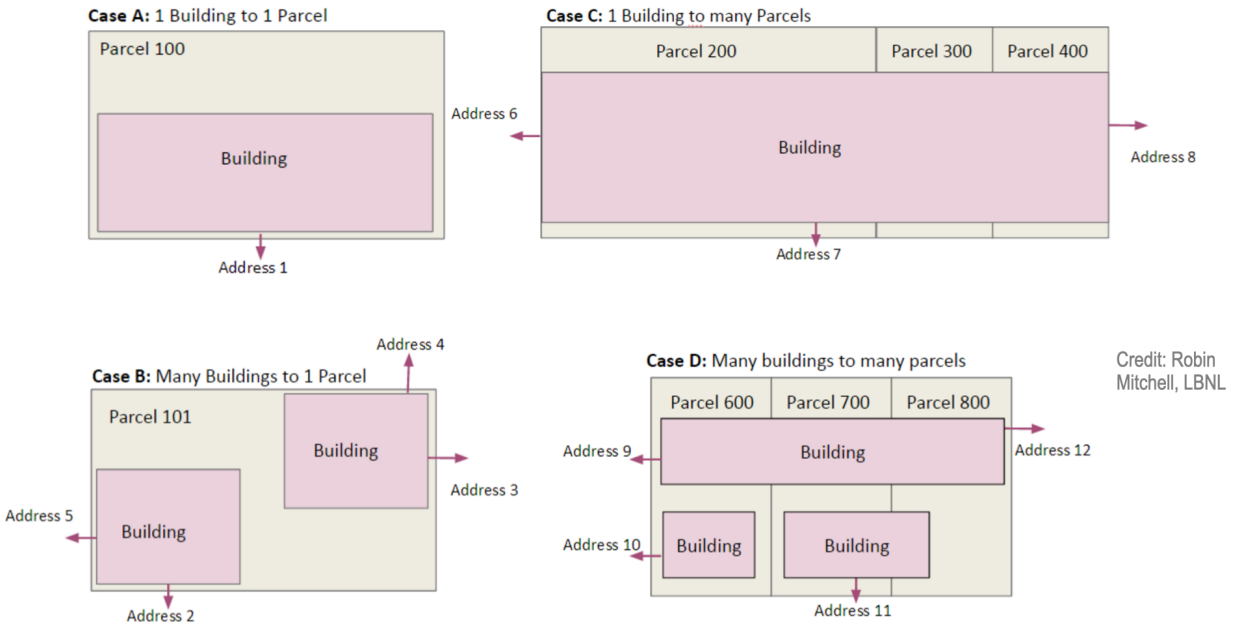

Figure 2. Four cases of how SEED manages property and tax lot relationships.

A standard SEED use case includes importing multiple datasets in which the first file contains the building addresses and energy performance data, and the second file contains the tax lot data. As the data are imported, SEED goes through the following ETL steps:

- *Save*: Each building and tax lot is saved to the SEED database for further processing; however, the records are not yet visible to the user.
- *Map*: Each column or field is mapped to SEED's list of column names. SEED provides a list of 'first-class citizen' fields such as Address, Site energy use intensity (EUI), etc., but SEED allows the user to define their column name as needed.
- *Match*: SEED searches to find if any existing records match on user-specified criteria (e.g., Portfolio Manager Property ID, Custom ID, Address Line 1, etc.).
- *Merge:* SEED merges the records that are matched. The user can specify if a column is protected or whether to favor the new/existing data.
- *Pair:* SEED runs an algorithm to pair properties with the corresponding tax lots based on fields that match in both property and tax lot records. This results in SEED having to manage many tax lots with many properties.
- *Link:* The last step is an algorithm that determines if the property or tax lot is already part of another reporting period (termed Cycle in SEED). If so, it then links the data so cycle-over-cycle reports can be generated.

One of the major focuses over the last several years is providing methods to the user to ensure their data is correct. This includes the addition of data quality rules that are run on the user's records upon import. The rules can also be run whenever requested on the full set of records or a subset of records. The data quality rules allow the user to specify a range of constraints including minimum values, maximum values, required text, required non-null values, or a specific set of enumerations. If a record is found to violate a rule, then the record is typically tagged with a label that can be easily searched later. A typical rule that is enabled is the required reporting of the site EUI. If this value is not defined, then the record is labeled as 'non-

compliant'. The benchmarking manager can then easily filter on all non-compliant records and follow up as needed.

In addition to the data quality rules, SEED installed a geographic information system (GIS)-based extension to support more advanced storage and querying of geospatial data. This extension enables SEED to geocode and store the geospatial data from imported records to better visualize an entire portfolio. Similarly, SEED implemented the ability to store building and tax lot footprints as well as the UBID (Wang et al. 2019). This feature allows the user to import a GeoJSON file (Butler et al. 2008) which is becoming readily available in many locations across the United States (Microsoft 2020). Figure 3 shows the rendering of the data out of SEED from an imported GeoJSON file from San Jose, California (CA).

Figure 3. SEED rendering of tax lots, footprints, and UBIDs.

In addition, a major code update was performed by OPEN Technologies in Canada to enable internationalization and localization. SEED now supports both English and French translations (needed for Canadian implementations) and includes the ability to switch between standard international (SI) units and U.S. customary system (USCS) units.

The last major architectural update of SEED was the inclusion of a time-series database extension called TimescaleDB (Timescale 2020). This extension allows SEED to store time-series data from data sources including Green Button (Sayogo and Pardo 2013), ENERGY STAR Portfolio Manager Meter Data, and BuildingSync Report Data. The data can be viewed as raw data or aggregated to monthly, or annual intervals.

Use Cases

The SEED Platform has been utilized in several cities and municipalities in the United States and Canada. The next three sections discuss how the Bay Area, District of Columbia, and OPEN Technologies have leveraged SEED to enable a more robust use case for compliance tracking.

The Bay Area

San Francisco adopted its benchmarking and transparency ordinance, the Existing Building Energy Performance Ordinance (EBO), in 2011 (San Francisco Environment 2020a). San Francisco's ordinance requires annual energy benchmarking and energy assessments every five years for non-residential buildings greater than 10,000 square feet (ft^2) and requires annual energy benchmarking for residential properties greater than 50,000 ft^2. The EBO covers approximately 2,700 buildings totaling 322 million ft^2.

Similar to other cities, San Francisco uses the EPA's ENERGY STAR Portfolio Manager as the tool to collect annual energy use data from their existing buildings. Over 270 fields are collected through the annual benchmark and storing this data was a challenge. San Francisco verifies each benchmark that is submitted for quality assurance; these verifications include EUI and square footage comparisons to previous years, as well as checking for temporary or default values.

Before the adoption of SEED, San Francisco implemented the EBO with various tools to store and manage the benchmark data including the continual use of Microsoft Excel as the main benchmarking database. Excel lacked the ability to effectively track benchmark resubmittals and has limited functionality. This process was inefficient, requiring significant time to manually transfer data between spreadsheets, track compliance, and issue compliance confirmations. Additionally, being a manual process created many opportunities for user error which then required additional staff time to identify and fix the errors.

In order to streamline their benchmarking process, San Francisco designed a benchmarking workflow leveraging SEED and Salesforce as a low-cost (around $1,500 per license per year), out-of-the-box solution to implement their ordinance. Each software is used for its strengths, and both software platforms were configurable by the user and did not require additional customization, making them easy to implement. SEED is used to store benchmark data, automate data quality checks, and match resubmittals, while Salesforce manages the covered buildings list and compliance information, as well as all customer interactions and emails. When San Francisco first started using the combination of both platforms, once benchmarks had been processed in SEED, the data was manually exported and then uploaded to Salesforce through a bulk import.

Building on San Francisco's work with SEED and Salesforce, the U.S. DOE-funded the Open Efficiency Platform (OEP) to help commercial energy efficiency programs become more efficient by interconnecting data through API services (Thomas et al. 2018). Through OEP, an open-source API connection was built between SEED and Salesforce to automatically transfer selected fields between the two platforms, further reducing room for user error and decreasing staff time needed to implement the EBO.

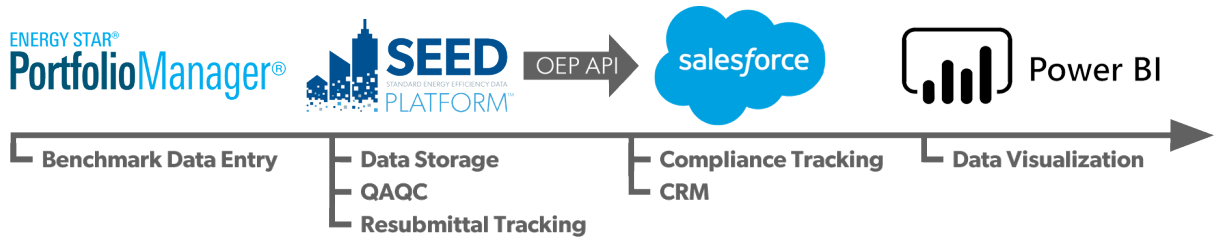

Figure 4. San Francisco's benchmarking data flow.

San Francisco's benchmark review process starts with data being uploaded from ENERGY STAR Portfolio Manager to SEED, where built-in data quality assurance checks verify specific fields based on preset inputs. San Francisco staff reviews each benchmark in SEED and labels benchmarks with the appropriate status as "ready to transfer" to salesforce. The OEP tool then transfers a subset of benchmark data and SEED labels to Salesforce. Once the data has been transferred to Salesforce, automated workflows update the building's compliance status and a custom email is generated and sent to the benchmark submitter notifying them of

compliance or to correct any errors and to resubmit. With a subset of benchmark data stored in Salesforce, San Francisco was able to develop online data visualizations using Microsoft's PowerBI (San Francisco Environment 2020b), which automatically pulls annual data directly from Salesforce and visualizes the data on a city-wide, sector-wide, and individual building level.

The data flow between ENERGY STAR Portfolio Manager, SEED, Salesforce, and PowerBI has increased the efficiency of San Francisco's benchmarking process, decreased the staff time needed to implement the ordinance, reduced the number of manual errors, sped up feedback to building owners, and allowed for the creation of real-time data visualizations.

Several other cities have adopted San Francisco's successful approach in using SEED and Salesforce as a low-cost solution to benchmark policy implementation, including the City of Berkeley, CA and the City of San Diego, CA.

District of Columbia

The District of Columbia was among the first cities in the United States to pass a benchmarking law. The Clean and Affordable Energy Act of 2008 (CAEA) requires that owners of all large private buildings (over 50,000 gross ft^2) annually benchmark their energy and water efficiency, and report the results to the District government for public disclosure (District of Columbia 2008). The District government also annually benchmarks and discloses the energy and water efficiency of District government buildings over 10,000 gross ft^2.

The District of Columbia enacted these requirements to increase the energy performance data available to owners and the market, and drive efficiency improvements. Buildings are responsible for 74% of the District's greenhouse gas emissions, and energy benchmarking is critical to improving building performance and helping District achieve its goal of becoming the healthiest, greenest, and most livable city in the nation.

Like most cities with similar requirements, the District initially managed the benchmarking requirement through an amalgamation of files and processes that spanned multiple software platforms. There was no central file management system that many users could access containing all the information and processes for running the program. There was also no standardized customer relationship management system in place to track interactions with property owners. Additionally, there was little automation in process or standard operating procedures.

Complexity was added when the District passed the CleanEnergy D.C. Omnibus Amendment Act of 2018 in December 2018, which expands the number of buildings covered by the CAEA, and requires building owners to meet specific Building Energy Performance Standards (BEPS) for their properties (District of Columbia 2018). As a result, the current system in place for collecting, processing and disclosing building energy data is not adequate for large amounts of data that will need to be processed.

To begin to address these data concerns, in 2019 the District moved program management and tracking of the benchmarking requirement and data into SEED and began using ENERGY STAR Portfolio Manager Web Services. The combination of the API functionality of SEED and Portfolio Manager allowed the District to develop scripts (programmed in the Python programming language) to fully automate the reporting, tracking, data quality checking, and disclosure of benchmarking.

Currently, a building owner can complete the one-time process of enrolling in the automatic reporting of benchmarking data. The reporter shares their account and relevant

properties through Portfolio Manager, which the District accepts using a scheduled script that runs every hour. The reporter is then sent an email confirmation that they are enrolled via an automatic report.

Every morning a scheduled script pulls all relevant information out of Portfolio Manager, uploads, and maps the data to SEED. The data is quality checked by a separate script that applies SEED data quality labels to the property record based on predetermined data quality criteria. District staff pairs property reports to tax lots in SEED to help track enforcement activities. Because the District also has access to the properties in Portfolio Manager, staff members can provide highly-specific manual data quality checks for property owners on request via email or when they call into the District's Benchmarking Help Center[2]. This kind of assistance has contributed to a major improvement in data quality and building owner/manager satisfaction with the benchmarking program.

At the end of the day, all new and resubmitted reports are sent automated emails based on those data quality labels. This is the first point of contact with reporters, after which District staff converse with reporters to resolve all data quality issues and provide additional instructions. Once issues are resolved, District Staff mark the property and paired tax lot as compliant in SEED and notify the reporter. All email interactions are tracked using the notes and label functions in SEED. While this is not a perfect customer management solution, as running analytics on this data is difficult, SEED allows the District to have a centralized record of all written communication regarding a property.

Once a week, the District pulls the latest benchmarking data out of SEED and updates its public disclosure[3] and benchmarking map[4]. By standardizing and automating the disclosure of benchmarking data, the District drastically reduces what used to be a week-long process of creating the annual disclosure to no staff time at all. Additionally, any new reports that come in after the deadline are automatically incorporated into the following week's disclosure, eliminating the even more tedious task of updating an existing disclosure.

The open-source and API capabilities of SEED also allows the District to better support efficiency program implementers in the District. The DC Sustainable Energy Utility (DCSEU) runs all of the energy efficiency incentives in the District. The District has given DCSEU access to SEED and allowed them to pull the data into their tracking software through an API. This way the DCSEU can plan their activities and focus on certain buildings based on the latest benchmarking data. DCSEU account managers now have a picture of the building's energy performance and can tailor incentives to a specific building before they even talk to the building owner.

The District's move to SEED has enabled staff to efficiently streamline the reporting process for the benchmarking program well in advance of the new benchmarking and energy performance requirements. Because more buildings are enrolling in automated reporting the District can effectively count properties in compliance before the reporting deadline and focus on properties that have had compliance issues in the past. Due to SEED, the District experienced a 96% compliance rate in 2019 (for the 2018 calendar year data), and a month before the reporting

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[2] https://doee.dc.gov/node/572222

[3] https://opendata.dc.gov/datasets/building-energy-benchmarks

[4] http://energybenchmarkingdc.org

deadline in 2020, the District already had a compliance rate up to 40%. To help other cities follow in its footsteps the District published all relevant custom scripts to its GitHub page[5].

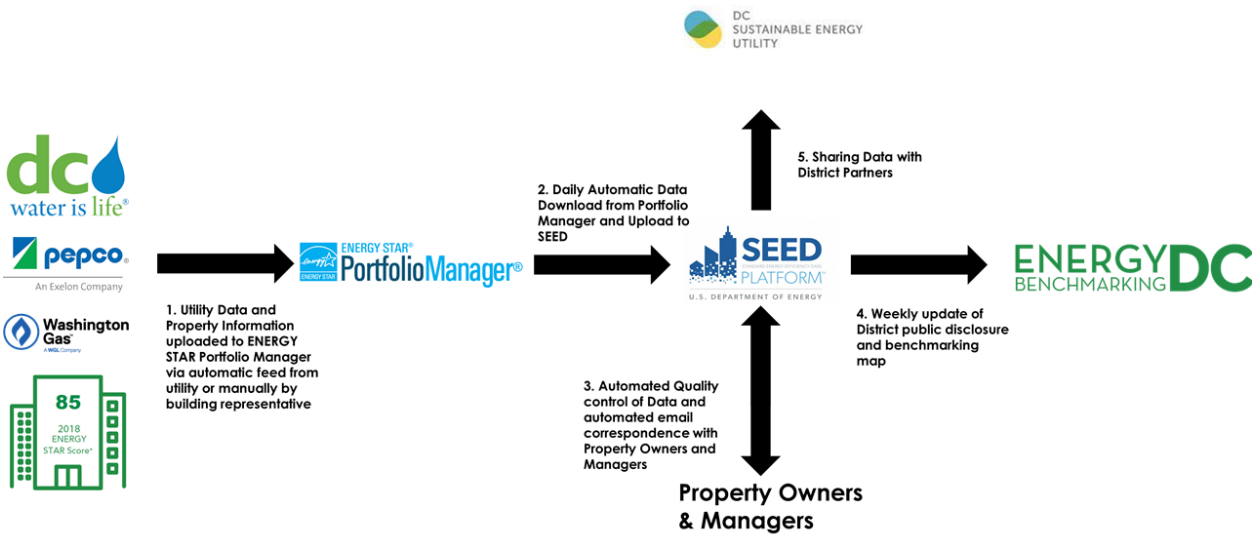

Figure 5. Data flow for Washington, DC benchmarking ordinance.

Benchmarking in Canada

Energy Benchmarking is less widespread in Canada than the United States, but traction has started at a provincial and municipal government level. In the Province of Ontario, under the Reporting of Energy Consumption and Water Use regulation (Ontario 2019), building owners need to report their building's energy and water use once a year to the Ministry of Energy, Northern Development and Mines (ENDM). As of July 1, 2019, all buildings in the province 100,000 ft^2 and larger are required to report building information and usage data through ENERGY STAR Portfolio Manager, with professional third-party verification of submitted data every fifth year.

In Provinces without benchmarking regulations, some cities have initiated voluntary programs as a test. The City of Edmonton was the first to launch a voluntary city Building Energy Benchmarking Program in 2017, which is moving into its third year. In the second year of the program, 184 buildings across Edmonton participated (City of Edmonton 2019), representing 2,763,000 square meters (m^2) of gross floor area.

Building Benchmark BC[6], a pilot energy benchmarking program that was made possible due to funding from Natural Resources Canada and BC Hydro (a crown corporation providing electricity in British Columbia) is the primary Canadian use case described in this section. It brings together a variety of municipalities and community partners and centralizes the program design and management for efficiency.

Building owners and managers are encouraged to set up ENERGY STAR Portfolio Manager as the first goal of Building Benchmark BC. All registrants of the voluntary program

[5] https://github.com/BenchmarkDC/ENERGY-STAR-Web-Services

[6] https://buildingbenchmarkbc.ca/

receive information on how to create an account, add properties, and sync with utility providers for automated data pushes with utility information as per the client's billing cycle. BC Hydro – the primary electricity provider in the regions participating in this program – has the capability to do aggregate datasets for multi-unit residential buildings, which means all buildings are eligible for the program (commercial, residential, or industrial) so long as they are over 20,000 ft^2.

SEED was localized for the Canadian market by OPEN Technologies, with adjustments to accommodate both national languages (English and French), options for selection of Canadian metric units, and allowances for a Postal Code in replacement of a Zip Code. Funding to make SEED available within Canada via these needed adjustments was the first initiative where Natural Resources Canada supported the use of SEED. This was followed by funding to build a tool called GRID (made by OPEN Technologies) that is now available for free to any Canadian jurisdiction that wishes to run an energy benchmarking program. There is a paid premium version available for those who want additional functionality, or who are not eligible to use the free version.

GRID uses the SEED database, introduces data visualizations, adds functionality for managing relationships with building owners and managers, and tracks status in a voluntary or mandatory program. GRID allows a program manager to send each participating property manager an Energy Scorecard that uses histograms to show how their performance ranks against their peers. Within GRID, properties can be noted as *ready for public disclosure*, and will then appear on a public-facing map with clickable pins for each property. A viewer of the public disclosure map can select a property and see details on the energy use of that property. Figure 4 shows an example of the Energy Scorecard and the Data Visualization Map.

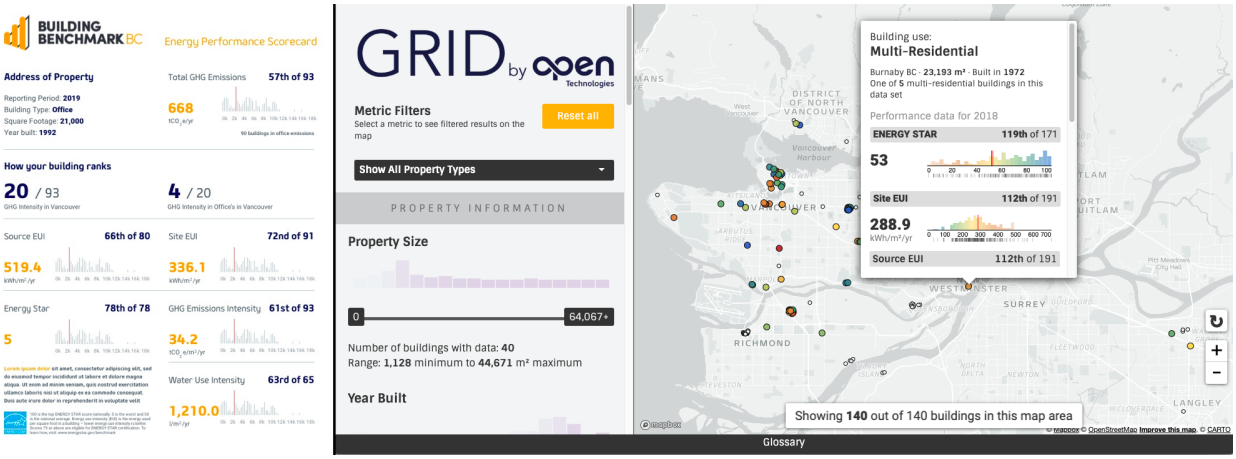

Figure 6. Left: Scorecard, Right: Disclosure map with property pins.

Discussion and Conclusions

The SEED Platform has been in use for several municipalities to drastically reduce the staff cost of operating benchmarking and compliance ordinances. As cities and municipalities pass transparency laws, it is also imperative that they provide adequate funding to manage the transparency (and benchmarking) programs. The SEED Platform was developed specifically for the use case where funds and staff time are limited and enables a city to quickly ramp up quality data collection and interpretation. The community of SEED users continues to grow and has

further reduced the cost of onboarding new cities and municipalities as the knowledge base has grown.

Demonstrated above in the three use cases, SEED has had a significant market impact through open solutions. It is important to note that SEED is only one part of the entire infrastructure for benchmarking and transparency. There exists a need to ingest data from ENERGY STAR Portfolio Manager and potentially integrate with Salesforce. Salesforce is not a free solution. However, as demonstrated in the Bay Area use case above, it is possible to purchase a minimal set of Salesforce packages at a reasonable price. Since SEED itself is open source, a city or municipality can host their own instance using the installation instructions provided with SEED. The advantages and disadvantages should be carefully weighed before deciding to self-host SEED.

Future Work

SEED is still a work in progress, and the road map extends out several years. As more cities and municipalities adopt SEED, there is an ongoing list of features and bugs that need to be addressed. The objective is to build a larger open-source community that will be able to maintain SEED in the long term. However, for now, this is still planned to occur as part of a U.S. DOE project. As more and more cities pass audit requirements, it is logical to extend SEED to store both benchmarking and audit results. This connection will leverage the BuildingSync schema exchange as a method to ingest the data. In addition to audit data through the Audit Template Tool, it is a desire to import Asset Score related results into SEED. Both of these features could benefit from UBID.

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