Development and dissemination of deep-energy retrofit strategies through a mandatory municipal building tune-up ordinance in Seattle, Washington, USA

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Abstract. This paper describes initial implementation of a municipal-scale building-owner engagement and technical assistance process aimed at accelerating voluntary deep energy retrofits as part of a new mandatory building tune-up requirement. Leveraging building energy consumption disclosure data, a municipal ordinance mandating building tune-ups at five-year intervals, and a suite of freely-available energy simulation tools, the university-based research and deployment team seeks to develop a scalable pathway for creating custom technical and financial roadmaps for deep-energy retrofits that drive carbon-neutral operations in existing medium-sized buildings.

1. Aim of Research

This paper describes initial implementation of a municipal-scale building-owner engagement and technical assistance process aimed at accelerating voluntary deep energy retrofits (20-50% carbon emissions reductions) in the existing medium-sized (approximately 1,860-9,290m²/20,000-100,000ft²) commercial building stock in Seattle, WA, USA as part of a new mandatory building tune-up requirement. Leveraging building energy consumption disclosure data, a municipal ordinance mandating building tune-ups at five-year intervals, and a suite of freely-available energy simulation tools, the university-based research and deployment team seeks to develop a scalable pathway for creating custom technical and financial roadmaps for deep-energy retrofits that drive carbon-neutral operations.

Recognizing that buildings account for approximately one-third of energy-related greenhouse gas emissions, the City of Seattle has adopted a Climate Action Plan with a goal of net-zero emissions by 2050. This will require a 39% reduction in energy use in the commercial building sector by 2030 (2008 baseline) [1]. Consistent with the City’s climate goals, in 2016 Seattle passed a mandatory commercial building tune-up ordinance, focused on operational and maintenance improvements, that is being progressively implemented by building size. Since the current service provider market for tune-ups traditionally focuses on larger buildings, the program was designed to target the small-to-medium building sector. In 2016 the project team received funding from the United States Department of Energy’s (US DOE) Office of Energy Efficiency and Renewable Energy under Buildings Program Award #DE-RR0007556 to develop a Tune-Up Accelerator (TUA) program. This program incentivizes
building owners to complete building tune-ups roughly two years earlier than mandated by the City and includes additional support for deep-energy retrofits.

Concurrently, the Northwest Energy Efficiency Alliance (NEEA), a regional energy efficiency organization, in partnership with public universities and industry partners, developed an automated web-based parametric energy simulation and financial analysis tool known as “SPARK” [2]. This program auto-generates a technical and financial scope for deep-energy retrofits that target 30-50% energy savings in commercial building typologies.

To encourage building owners to pursue deeper retrofit options beyond the tune-up, owners are offered, at no cost to them, targeted in-depth technical assistance and utility incentives. This suite of investments is anticipated to generate an average of 20% energy savings. Seattle City Light (SCL), Seattle's publicly-owned electric power utility, will offer existing incentives for capital measures as well as innovative performance-based incentive packages currently under development. These efforts will work to achieve whole building energy efficiency through capital and operational savings.

This paper covers three streams of research and implementation: (1) deep energy retrofit project selection, (2) analytics, energy-efficiency measure development, simulation, and savings estimates; and (3) owner engagement. Finally, this project will collect and disseminate anecdotal feedback and initial observations outlining opportunities, challenges, and the current state of implementation, to guide future policy and market intervention strategies.

Figure 1. Seattle Building Tune-Up Accelerator program structure.

2. Background
Seattle’s energy benchmarking ordinance, like those in many other cities in the United States, provides local building stock energy performance data that is foundational for research, programs, and policies. The benefits of energy benchmarking and disclosure are multi-fold including tracking and documenting energy performance improvements, comparative analysis of similar building and climate typologies, inclusion of energy performance in the valuation of buildings, improving the persistence of energy savings measures, and to assist in crafting policy. These are well-documented in a publication by Cox, et al. [3].

An opportunity that emerges from benchmarking and energy disclosure is the identification of buildings with above average energy consumption, city-wide tracking of carbon emission reductions, and as a means to inform building owners and drive market uptake of energy efficiency improvements.

2.1. Establishment of a municipal tune-up ordinance
In March 2016, the City of Seattle enacted the Building Tune-Ups Ordinance (Seattle Municipal Code 22.930) along with compliance specifications that are detailed in OSE Director's Rule 2016-01 [4]. These tune-ups aim to optimize energy and water performance by identifying low- or no-cost actions related to building operations and maintenance that generate an average of 10-15% in energy savings.
Energy consumption data sorted by building typology, size, and vintage can provide valuable information. However, it may not reflect unique building characteristics that can impact energy consumption. An opportunity presented by the Seattle Building Tune-Up Ordinance, is the required collection and reporting of specific data such as envelope condition, equipment vintages, and general building system typologies. This information, in combination with historical energy use patterns, can point to building-specific energy efficiency measures.

The tune-up process offers an opportunity to identify deep-energy retrofit projects, and a point of engagement with owners to learn about future improvement plans, such as end-of-life equipment replacement or major renovations. Furthermore, this engagement provides the opportunity to present a roadmap for future improvements that is customized to specific buildings.

3. Scientific methodology

Using energy benchmarking data reported to the City of Seattle, building information collected by tune-up service providers through a US DOE supported building asset rating tool, Asset Score [5], and the SPARK technical and financial analysis web-tool, along with targeted custom EnergyPlus analysis, the project team provided direct technical assistance to building owners and tune-up service providers in support of project-specific retrofits. These were delivered at three levels of engagement depth depending on project opportunities identified: (Level 1) Automated SPARK web tool evaluation that generated a building-specific report that provided financial and technical recommendations to the building owner; (Level 2) Level 1 activities, plus building walk-through with the university-based technical team that presented specific recommendations for implementation; and, (Level 3) Level 2 activities, plus custom EnergyPlus analysis and technical recommendations for a pathway to carbon neutral operations including a building-integrated renewables plan. The process of project selection, data collection, evaluation, energy/financial analysis, and owner outreach are described in the sections below.

3.1. Building data analysis and targeting

Using municipal records and required annual energy benchmarking data, about 400 mid-size commercial buildings were identified as subject to the mandatory tune-up ordinance. Of these, 103 buildings voluntarily enrolled in the Tune-Up Accelerator program. From that sub-set, 35 were identified as potential candidates for deep-energy retrofits based on project typology, scale, and current energy consumption. These projects are selected to reflect high energy savings potential (energy use intensity (EUI) greater than 625 kWh/m²-yr (55 kBTU/ft²-yr), buildings likely to remain for the next 15 years, and that represent a cross-section of project typologies deemed informative to the City of Seattle’s future policy direction.

The Level 1 workflow for making deep energy retrofit recommendations to owners was carried out in seven key steps: (1) collect building condition and system information from Asset Score rating tool (as submitted by service providers); (2) collect corresponding energy consumption (electricity, natural gas, etc.) data from the Seattle Energy Benchmarking data set; (4) reporting building characteristics, system vintages, and energy data into the SPARK tool; (5) SPARK auto-generates an optimized energy efficiency measure, scope of work, and estimated energy and cost savings using EnergyPlus and a measure costing table; (6) SPARK auto-generates a business case for the retrofit; and (7) The SPARK report is packaged and submitted to the building owner.

3.2. Field data and public disclosure data collection

Tune-up service providers were required to submit an Asset Score report using an on-line web-form. Per the US DOE’s Asset Score website, the tool is a ‘national standardized tool for assessing the physical and structural energy efficiency of commercial and multifamily residential buildings.’ Through a set of standardized inputs, tune-up service providers enter building information about a building’s; geometry, use types, construction assemblies, lighting, heating, cooling, water heating, operations, and estimated equipment vintages.
The Seattle Energy Benchmarking website [6], contains recent utility data for most commercial buildings in the City of Seattle. The website includes three years of data pertaining to each building’s annual and space normalized greenhouse gas emissions (GHG), EUI, electricity/gas consumption (in Btu and percentage), EPA Energy Star rating, and comparison to the average of similar buildings. This data is the source of energy consumption inputs for the SPARK tool.

3.3. Project Qualification
The SPARK tool includes a “Quick-Screen” questionnaire to identify whether a building is an appropriate candidate for a deep energy retrofit. In general, suitability reflects buildings with high energy use (>625 kWh/m²-yr (>55 kBtu/ft²-yr)), that were built prior to 1996 (and the adoption of contemporary energy codes), and have poor envelope performance. Further sub-qualifications include buildings that were not likely to be demolished in the next 10-15 years, and those with opportunities for financial repositioning. Since these latter factors were generally unknown to the project team, standardized inputs were adopted.

3.4. Simulation-based energy efficiency measure development and financial analysis
For buildings that are deemed appropriate in the Quick Screen, the user is prompted to enter building address, size, primary HVAC system type (VAV, hydronic, heat-pump, etc.) and leasable area. This is followed by inputs related to energy use including the primary heating fuel, annual electrical consumption (kWh), gas consumption (therms), and instances of unique energy consuming equipment (ex. data center). Next, the user selects system descriptions including age and type of envelope/glazing, lighting and controls, plug-load management, and building-level and central plant HVAC (based on the system type). Finally metrics about business performance are collected including percent vacant, stabilized vacancy rates, 10-year lease rollover, and the capitalization rate.

3.4.1. Spark Tool automated energy efficiency measure development.
Using building input characteristics, the SPARK tool selects a pre-created EnergyPlus model adapted from US DOE reference models. Next, the tool assembles “bundles” of energy efficiency improvements using the EnergyPlus Parametric Analysis Tool (PAT) [7], SPARK then selects the best results to create an optimized measure package and reports the energy simulation data to calculate savings from the baseline (actual) energy consumption. A conceptual outline of the measures is described in the table below.

| Measures                     | Baseline                        | Upgrade                        |
|------------------------------|---------------------------------|--------------------------------|
| Wall Insulation              | U=0.96 W/mK (U=0.17)            | U=0.06 W/mK (U=0.06)           |
| New Windows                  | U=3.52 W/mK (U=0.621)           | U=1.70 W/mK (U=0.5)            |
| Envelope Sealing             | 0.5 ACH nat                     | 0.25 ACH nat                   |
| LPD Reduction                | 16 W/m² (1.5 W/ft²)             | 6.4 W/m² (0.6 W/ft²)           |
| Perimeter Daylighting        | No sensors                      | Daylight sensors added         |
| Comprehensive Lighting Control| No sensors                      | Occupancy sensors simulated through schedule changes |
| LED Task Lighting            | Plug loads defined at 16 W/m²    | Reduction in plug loads by 1W/m² |
| Occupancy Sensor Controls    | Plug loads defined at 16 W/m²    | Reduction in plug loads by 20% |
| Optimized Controls (DDC)     | Original Setpoints              | Setpoints expanded by 1oF in each direction |
| VFD on Chilled Water Loop    | Const. Speed Pump               | Var. Speed Pump                |
| VFD on Hot Water Loop        | Const. Speed Pump               | Var. Speed Pump                |
| New Boiler                   | 82% Efficient                   | 93% Efficient                  |
| Chiller Retrofit             | COP: 4 ; Min. PLR: 0.2          | COP: 5.2 ; Min. PLR: 0.2       |
| Chiller New                  | COP: 4 ; Min. PLR: 0.2          | COP: 5.8 ; Min. PLR: 0.1       |

Table 1. Overview of SPARK energy efficiency measures. (Adapted from Woods, et al. 2016)
3.4.2. Spark Tool automated financial analysis

SPARK calculates construction cost data for the measures included in each scenario on a net area basis, per measure, and combined into a total project cost that includes general conditions, contractor mark-up, and taxes. Using the estimated energy savings, projected utility conservation incentives, capitalization rate, current vacancy rate (if non-owner occupied), lease rate, and projected asset appreciation, SPARK generates a financial analysis using a methodology developed by Molly McCabe of the strategic real estate advisory firm Hayden Tanner. SPARK users have the opportunity to refine these numbers using slider-bar adjustments to further customize results, which are presented as initial capital required, net present value (NPV), and internal rate of return (IRR).

![Energy Savings Chart](image)

**Figure 2.** SPARK report partial excerpt of financial and energy analysis.

3.5. Reporting and Outreach.

The SPARK tool generates a custom report that includes a general description of deep-energy retrofits, energy savings, project scope, cost, and financial analysis data described above. This report is provided by the City to the building owner, with an offer to follow up with technical assistance to interested owners, under Level 2 support.

3.6 Analog measure cases (Level 3)

To create comparison cases and to test our methodology, the authors conducted “analog” deep energy retrofit analysis on five Level 3 buildings. These were selected because the owner proactively indicated interest in doing a deep-energy retrofit, and the type and vintage was representative of a significant portion of the Seattle building stock. This process included a conventional building audit, walk-through, and the development of a manually produced calibrated baseline energy model using the Open Studio interface to Energy Plus. Then several bundles of measures of varying depths were produced, that could be implemented over time, along with an on-site renewables plan for net-zero energy and/or carbon neutral operations. This data was presented to owners for implementation. These projects are intended to become case-study roadmaps for owners with similar buildings.

4. Results and future work

A description of the baseline/actual energy consumption, cost optimized savings, energy-optimized (enhanced) savings of Level 1 and 3 projects is detailed in the chart below.
5. Discussion

The program is targeting an initial first-year average of 20% direct reduction in energy consumption (gas and electricity) from participating buildings, collected through the utility meter, and verified via required annual energy consumption disclosure data. Further, by delivering direct technical assistance and documenting project specific services delivered, outcomes, and lessons learned, using broadly available tools and best practices, replicable implementation guidelines will be developed for jurisdictions with benchmarking information who aim to use energy transparency data to take targeted action for carbon emissions reductions.

References

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