



MONITORING & VERIFICATION (M&V) REPORT

City of Seattle Tune-Up Accelerator

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Executive Summary

Background

In addition to utility led project measurement and verification, per Subtask 7.4 of the sub-recipient grant agreement between the City of Seattle Office of Sustainability & Environment (OSE) and the Smart Buildings Center (SBC) for the Building Tune-Up Accelerator (TUA) Project, the Smart Buildings Center was tasked with providing additional Measurement and Verification (M&V) services on up to 10% of the participating buildings population. Ten buildings were selected to undergo this additional analysis, which included onsite verification and data analysis. The goal of the site visits and analysis was to evaluate the energy and cost savings resulting from energy measures implemented. This analysis can help inform OSE's ongoing administration of the Seattle Building Tune-Ups as well as give the participating building's operational staff additional knowledge about the energy-consumption characteristics of their facilities, with the potential of further improved operations and maintenance (O&M). The following report summarizes the activities and findings stemming from this analysis; it begins with a summary of the overall methodology and analytical framing of the analysis and then provides a building by building level summary of observations and findings.

Approach

The process for conducting the M&V analysis included sample selection, site visits and energy savings analysis. For each building in the sample, the SBC conducted a whole building analysis, which included onsite verification and functional testing of a sample of the building equipment using temperature and power loggers to document operating conditions of equipment within the scope of the tune-up and energy conservation measures (ECM's) coupled with a comparison of pre- and post-implementation non-normalized and weather normalized energy use. The following section describes each of these steps in greater detail.

Sample Building Selection

The SBC team worked with OSE to identify a set of criteria that would adequately cover the breadth of unique building types, service providers (Tune-Up Specialists) and other characteristics that might shape or influence the building performance and subsequent energy savings. The following methodology was used for selecting the sub-set of buildings for M&V:

- ***Include a diverse set of primary use building types.***¹ The team assessed the spread of building types in the population and agreed to the following:
 - Mixed Use (1)
 - Hotel (1)
 - K-12 School (2)
 - Office (3)
 - Medical Office (1)
 - College/University (1)
 - Non-Refrigerated Warehouse (1)

¹ Primary use type was obtained from the building's ENERGY STAR Portfolio Manager benchmarking report. For buildings with more than one space use, EPA determines use type based on the space that is greater than 50% of the building. If no one space is greater than 50%, the building is classified as mixed use.



- **Select buildings where corrective actions were found and implemented.** Since this analysis is interested in understanding the impact of the corrective actions, the sample should only include buildings that had taken corrective actions.
- **Include a diverse group of service providers in the sample set.** Include at least one of each type of service provider: in-house personnel, maintenance/controls contractors, and building commissioning providers.
- **Include buildings with and without building automation systems (BAS).** Include in the data set buildings with and without building automation systems to evaluate any potential differences in corrective actions and energy savings.

Site Visits

For each building in the sample, the SBC conducted a preliminary interview with the building representative(s) and the Tune Up Specialist(s) who completed the initial assessment and signed off on the final TUA Summary Report to the City of Seattle. The SBC then visited each building at least once to provide visual verification and gather contextual information that might be helpful in the analysis. The site visit was largely guided by the completed building's TUA Summary Report (and other documents as available such as the Asset Score, Seattle City Light Operating Hours worksheet, and any documentation obtained from Tune Up Specialists) and included the following tasks:

1. The SBC team visually observed corrective actions to better understand persistence of the Tune Up measures (i.e., repairs to dampers, equipment, control settings, etc.).
2. Installed data loggers or leveraged BAS trend data to verify that any corrective actions requiring control changes were still in place (set points, scheduling, resets, etc.) for at least each major HVAC system component; for example, one VAV multiple zone air-handler plus one VAV terminal box. In instances where an equipment sampling methodology was applied to the verification, the SBC requested that the Tune-Up Specialist identify at least one piece of equipment in each sample group that was included in the tune-up services.

Energy Consumption Analysis Methodology

The energy consumption analysis of utility data included a building level pre- and post-tune-up energy data analysis and a regression analysis for weather normalized data where applicable. This was informed by an analysis of other data collected through the on-site verification process. The following describes the methodology of the overall M&V energy consumption analysis, while the analysis of the data collected on-site to verify persistence of tune-up actions is provided under each building's summary section.

- **Data sources:** The energy data analysis relied upon monthly utility (electric and gas) data collected from ENERGY STAR Portfolio Manager.
- **Data analysis tools:** The team built an Excel dashboard of the building's energy consumption trends over time for each building to determine pre- vs. post-tune-up energy consumption savings. The dashboards helped visualize energy use patterns across different years and highlighted data gaps and unusual dips or spikes in energy consumption. Dips or gaps that could not be explained were cleaned to match the trend. Seattle City Light's "regress-o-matic" Excel tool was used to run a baseline regression to obtain weather-normalized savings if applicable.
- **Pre- and post-tune-up timeframe:** Pre- and post-tune-up energy use was compared for both a 1-year (2018 baseline) and 2-year (2017 baseline) data gap keeping the months used in the comparison constant. For all buildings, January 1 through October 31 monthly energy consumption was used. This allowed SBC to observe the difference in energy consumption before



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the implementation period (year 2017) and during implementation period (2018) compared with post-implementation period (2019). For calculating the energy savings, SBC selected the 2-year gap because this wider range accommodated the fact that most buildings started their tune-up assessment (and may have started making corrections) in early 2018 and finished implementation between October 2018 and June 2019. As an O&M program, OSE's experience has been that individual tune-up measures have a range of implementation timing. Some measures, such as HVAC scheduling corrections, may be implemented early in the tune-up at the time of the assessment, whereas other measures, such as sensor repairs, are implemented later due to the need to order new equipment or schedule a specialist to do the repair. Therefore, having a wide window for implementation is important, however, for the buildings in this sample that completed their tune-up later in 2019, some possible energy savings may not yet be detectable in the monthly data that was available at the time of this report. A future update of the monthly data to include months after 2019 to have full year of post implementation data is recommended.

- **Assumptions/limitations:** The data analysis relied on energy use data provided by the utilities and uploaded to Portfolio Manager. It is assumed that the occupancy, hours of operation, and equipment (apart from implemented tune-up measures) using energy, as well as other building operations remain reasonably constant in the pre and post periods, unless noted on the individual reports. The GHG emissions values reported in this analysis use custom factors provided by Seattle City Light. Natural gas consumption was converted into kWh to be used in SCL regression tool for weather normalization. Seattle City Light (SCL) secures carbon offsets equal to the greenhouse gas emissions resulting from all aspects of SCL's operations, including those created by the generation of electricity the utility buys, employees' travel, and the trucks and other equipment used in its operations.

Final Sample and Overall Results

Table 1: Building Sample Characteristics

| Building # | Use Type | Required Actions Completed/ Persisted | Voluntary Actions Found/ Completed | BAS? | M&V Notes (Completed actions showed persistence unless otherwise noted.) |
|------------|--------------------|--|---------------------------------------|------|---|
| 1 | Hotel | 5/5 | 3/1 | No | Updated maintenance plan still phasing in. |
| 2 | Office | 3/3 | 1/0 | Yes | Legacy BAS was upgraded, as per tune-up recommendation. |
| 3 | Non-ref. warehouse | 2/2 | 5/2 | No | |
| 4 | K-12 school | 7/7 | 2/1 | Yes | |
| 5 | Mixed Use | 7/6 | 5/1 | Yes | One completed required action did not show persistence. |



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| | | | | | |
|----|---------------------|-----|-----|-----|--|
| 6 | Medical Office | 2/2 | 1/0 | Yes | |
| 7 | K-12 school | 8/8 | 7/3 | Yes | One voluntary action completed did not persist. |
| 8 | Office | 5/5 | 5/0 | Yes | |
| 9 | College/ University | 8/8 | 3/2 | Yes | |
| 10 | Office | 3/3 | 4/0 | Yes | One of the required actions was 75% complete & scheduled for immediate completion. |

Table 2: Building Energy Consumption & Emissions - Percent Change Post-Tune-Up - 2017 vs. 2019 Non-Normalized

| Building # | Electric | Natural Gas | Total Energy Use | GHG Emissions |
|-----------------|----------|-------------|------------------|---------------|
| 1 | (3.81%) | 0.51% | (1.84%) | 0.14% |
| 2 | 12.69% | 7.45% | 12.32% | 10.08% |
| 3 ² | 4.92% | - | 4.92% | 4.87% |
| 4 ³ | (7.13%) | - | (7.13%) | (7.09 %) |
| 5 | (3.16%) | 17.57% | 11.65% | 16.95% |
| 6 ⁴ | (1.18%) | - | (1.18%) | (1.24%) |
| 7 | 20.38% | 31.67% | 27.17% | 31.11% |
| 8 | 16.73% | 0.47% | 14.42% | 5.65% |
| 9 | 5.65% | 12.55% | 8.59% | 11.89% |
| 10 ⁵ | 11.31% | - | 11.31% | 11.33% |

² This building's gas use wasn't analyzed because the tenant using gas left and the gas service stopped on 6/30/18

³ The gas consumption was not analyzed for this building because the meter was malfunctioning, and the management didn't realize it until much later.

⁴ This building is electric only with no natural gas use.

⁵ Gas analysis was excluded for this building due to unexplained high variability in usage trends.



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Table 3: Building Energy Consumption & Emission - Percent Change Post-Tune-Up - 2017 vs. 2019 - Weather Normalized

| Building # | Electric | Natural Gas | Total Energy Use | GHG Emissions |
|------------|----------|-------------|------------------|---------------|
| 1 | 1.58% | 0.94% | 1.28% | 1.00% |
| 2 | 0.74% | 0.93% | 0.75% | 0.84% |
| 3 | 0.05% | - | 0.05% | 0.12% |
| 4 | (0.11%) | - | (0.11%) | (0.17%) |
| 5 | 0.82% | 6.55% | 5.15% | 6.41% |
| 6 | 0.19% | - | 0.19% | 0.14% |
| 7 | 0.20% | 5.04% | 3.29% | 4.84% |
| 8 | 0.16% | 8.88% | 1.51% | 6.28% |
| 9 | 0.45% | 6.47% | 3.11% | 5.93% |
| 10 | 2.42% | - | 2.42% | 2.41% |

Building Level Reports

The following sections provide a detailed description of each of the ten buildings included in this analysis. Each report contains four sections: (1) a description of the building, (2) a description of the corrective actions including required, recommended and additional actions taken, (3) an energy consumption comparison, and (4) a conclusion.

Building 1

Description

Building 1 is a five-story, approximately 50,000-60,000 square foot (SF) hotel building constructed in the 1970s, with an additional approximately 20,000 SF parking garage. The walls are concrete with furring and approximately three inches of fiberglass insulation for a total insulation value of R-11, consistent with the period of construction. The built-up roof has roughly five inches of rigid insulation for an estimated insulation value of R-19. The ventilation system for the building is mechanical exhaust only with passive make-up air from the automatic entrance doors in the lobby, double-paned operable windows in the guest rooms and staff spaces, and the elevator shaft, which ventilates the corridors. The parking garage uses natural ventilation. The guest and staff rooms are heated and cooled by packaged terminal heat pumps (PTHPs). The corridors are not heated nor cooled. Domestic hot water (DHW) is provided by a central natural gas boiler. There is no building automation system (BAS).

Table 4: Building 1 Characteristics

| | | | |
|----------------------|-------|----------------------|--------------|
| Decade Built: | 1970s | Tune-Up Path: | Tune-Up Plus |
|----------------------|-------|----------------------|--------------|



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| | | | |
|---------------------|-----------|------------------------|---------------|
| GFA: | 50-60K SF | Fuel Sources: | Electric, Gas |
| Primary Use: | Hotel | Secondary Uses: | Parking |

Findings, Corrective Actions, and Verification

Initial Assessment (Pre-Action)

The Tune-Up Specialist inspected and tested equipment in 14 guest rooms (12% of total rooms).

M&V Site Visits (Post-Action)

The initial M&V site visit at Building 1 (including data logger deployment) was performed by SBC on 5/31/19; data loggers were retrieved on 7/12/19. Verification methods included visual observation, verbal and written confirmation from building management and/or the Tune-Up Specialist, and data capture using the following instruments:

- HOBO U12 temperature/humidity/light logger
- HOBO UX90 motor runtime logger
- HOBO UX120 4-channel analog logger with external TMC-HD air/water/soil temperature sensor
- Fluke 63 infrared thermometer

Required Actions

Based on the Tune Up Accelerator Summary Report for this building, the following required actions were identified (these are listed by category and assessment element ID):

HVAC

- **G5:** Several PTHP temperature sensors in the guest rooms were malfunctioning.
Requirement: Repair or replace the faulty sensors.
M&V: Property manager stated that faulty PTHP sensors had been replaced. Of the list of rooms with the updated annual maintenance completed at the time of the M&V inspection, only two were vacant and thus available for testing. In both cases the sensors appeared to be functioning correctly, as tested by changing the set points.
- **G7:** Two heat pumps in the lobby, one near the retail coffee vending stand (a heat-producing area) and one closer to the entry (an area prone to heat loss), were controlled separately via on-unit controls. Guests had access to change temperature settings, resulting in instances of simultaneous heating and cooling. Set points observed were 60° F on one and 70° F on the other.
Requirement: Install one thermostat to control both units; restrict guest access to control.
M&V: A single wireless thermostat controlling both heat pumps in the lobby was observed (see picture below). Its location is more challenging for guests to access, resulting in a more consistent temperature range. Hobo U12 Temperature data loggers and UX90 motor runtime loggers were deployed for over 5 weeks to verify heat pump operation. The data shows minimal instances of simultaneous heating and cooling, though occasionally this still occurs, which can be explained by the varying microclimates that exist in the lobby. (See graph in Figure 1 below). When it becomes necessary to replace either of the heat pumps, a suggested strategy would be to replace both with one unit that can serve the whole area.



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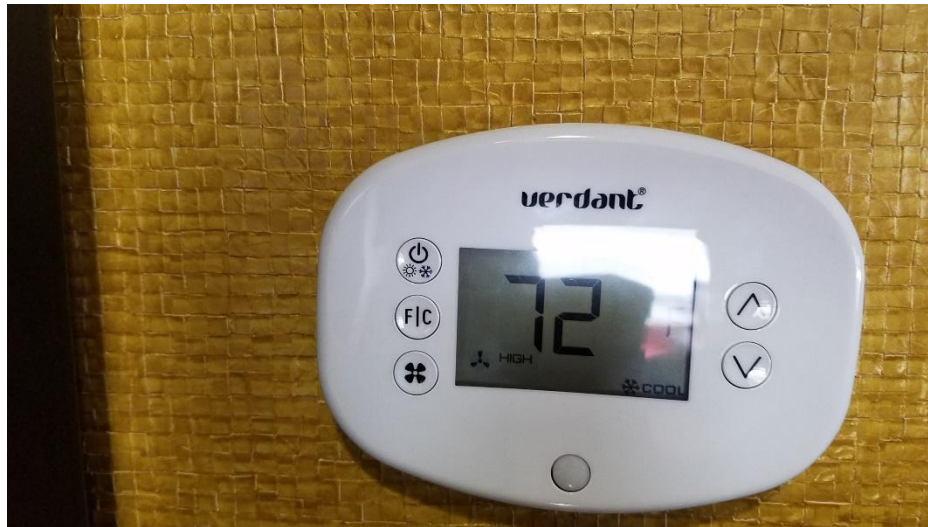


Photo 1. G7: Single wireless thermostat to control both lobby heat pumps.

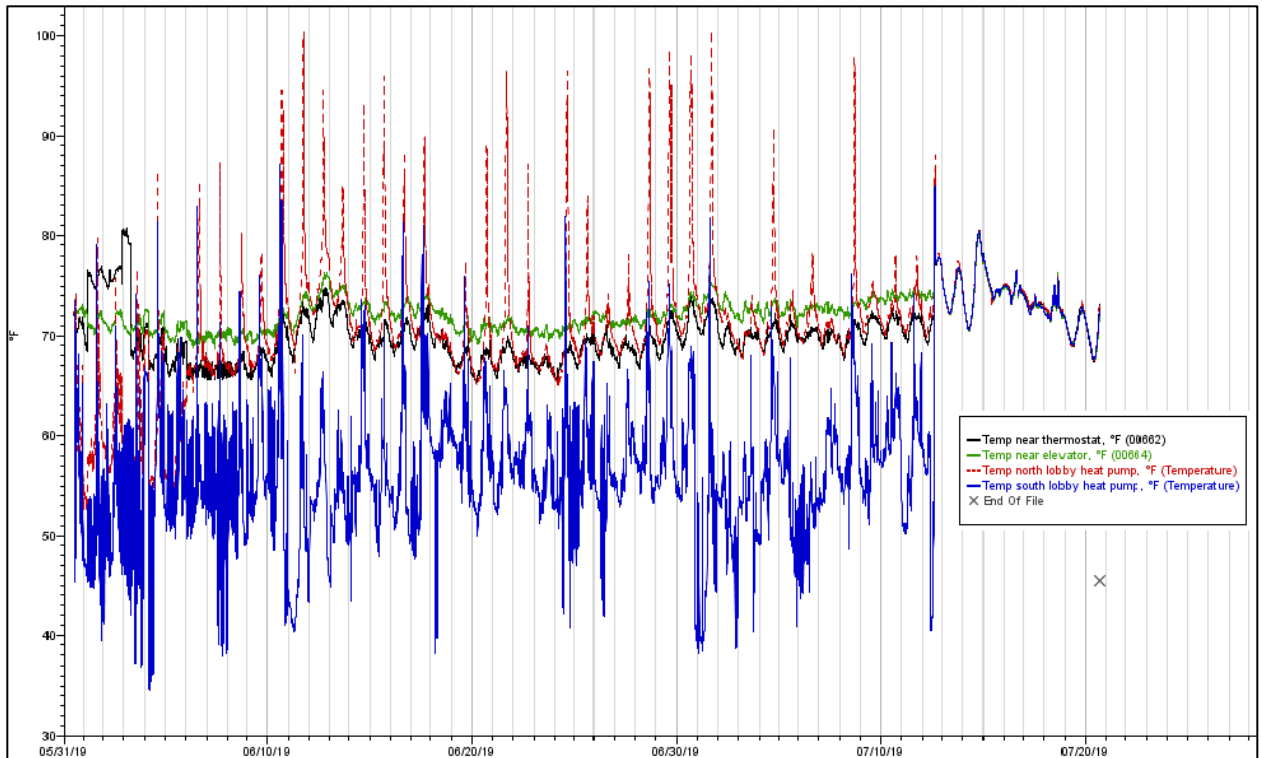


Figure 1. Graph of temps in lobby show minimal instances of simultaneous heating and cooling.

- **G11:** 12 out of 14 units (86% of sample) were found with either dirty coils, dirty filters, water in the condensate pan, or temperature sensors out of calibration.
Required action: Perform annual maintenance on each guest room in the following areas:
 - PTHP (following ASHRAE Standard 180, Table 5-20), including:
 - Clean condensate pan
 - Brush/clean coils
 - Verify temperature calibration; repair/replace sensors as necessary



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M&V: Guest room maintenance is performed on a rolling basis as vacancies allow, and the updated maintenance policy (per ASHRAE Standard 180, Table 5-20) was implemented starting around Feb. 2019; estimated completion rate is about one room/week. Management has developed their own checklists for this. Of the list of rooms with completed maintenance at the time of the M&V inspection, only two were vacant and thus available for testing. In both rooms, it was observed that maintenance on the PTHPs had been recently performed.

Domestic Hot Water (DHW)

- **L1:** Hot water tank temperature set point was observed at 138 ° F.
Required action: Reduce set point to 130 ° F.
M&V: As per visual observation, tank temperature was set to approx. 128 ° F, verified at inlet with infrared thermometer. The recommendation to lower the temperature was followed, but this may be too low. In order to prevent bacteria growth, the tank temperature should be maintained at 135 ° F, as recommended in the Tune Up Specialist's assessment report. Water temperatures in two guest rooms, as tested with Hobo TMC-HD water temperature sensor were between 105-112 ° F.



Photo 2. DHW boiler thermostat showing tank temperature.

Water Usage

- **J9:** Within the 12% assessment sample, 2 showers and 1 toilet were leaking.
Required action: Inspect shower, faucet, and toilet during annual guest room maintenance; repair any leaks.
M&V: Property manager stated that leaking faucet heads observed in three rooms during the initial assessment had been repaired. These rooms were not vacant on the dates of the M&V site visits and therefore could not be verified. Of the list of rooms having the updated annual maintenance completed at the time of the M&V inspection, only two were vacant and thus available for testing. In both cases testing showed faucet heads to be working properly and not leaking.

Recommended Actions (Voluntary Implementation)

Based on the Tune Up Accelerator Summary Report for this building, the following recommended actions were identified (these are listed by category and assessment element ID):

HVAC

- **G9:** All outside air dampers were closed, and it was apparent that they had been installed that way as shipped from the factory.
Recommendation: Open outdoor vent if closed when performing annual maintenance (refer to required action for assessment element G11 above).
M&V: Of the list of rooms with completed maintenance at the time of the M&V inspection, only two were vacant and thus available for testing. In both rooms, it was observed that



maintenance on the PTHPs had been recently performed and that the dampers had been opened.

Lighting

- **H2:** Lighting in 5 staff areas is controlled by manual switches.
Recommendation: Replace manual switches with occupancy sensors.
M&V: Staff area lighting was still controlled by manual switches. Management has a 3rd-party bid for a lighting upgrade that would include installing occupancy sensors and retrofitting the lighting to LED. According to the manager at the time of the M&V site visit, the bid was being considered but there were no immediate plans to move forward with the upgrade.
- **H4:** Parking garage is lit with T8 linear fluorescents.
Recommendation: Re-lamp the parking garage with tubular LEDs. According to the Tune Up Specialist, if the replacement TLED is 18 watts, this project will save ~5,500 kWh per year.
M&V: Hotel management has a 3rd-party bid for a lighting upgrade that would retrofit all lighting to LED. According to the manager at the time of the M&V site visit, the bid was being considered but there were no immediate plans to move forward with the upgrade.

Additional Measures

Based on the Tune Up Accelerator Summary Report, these actions were included as recommended actions by the Tune Up Specialist, but do not have corresponding element IDs within the Tune Up Accelerator Summary Report.

- Hot water boiler room smells of gas indicating incomplete combustion and inadequate airflow. According to Tune Up Specialist, only 100 sq. in. of ventilation airspace was available into the room (50 sq. in. from door undercut, 50 sq. in. from vent in wall). 200 sq. in. is the minimum required by law to fire both heaters simultaneously (1,320 sq. in. recommended).
Recommendation: Increase combustion openings directly to boiler room from garage to at least 200 sq. in.
M&V: As per visual observation, combustion openings for the boiler room have been increased to meet the minimum requirement for air volume. The door undercut was doubled and the wall vent was enlarged.
- Boiler circulation pumps are operating even when the boilers are not firing, which results in heat loss via the flue, reducing system efficiency. This is not the intended operation, according to the installation manual for these units.
Recommendation: Change control wiring to prevent circulation pump operation when boilers are not firing. When future replacement of either boiler is required, replace it with a heat pump water heater to perform the base load of heating, re-piping the system so that the gas heater only operates to supplement when there is a high demand for heat.
M&V: New wiring and plumbing indicated that water heater controls had been recently changed to prevent circulation pump operation when boilers are not firing. Boilers were not firing during M&V visit, nor were the circulation pumps operating, meeting the intention of the retrofit.



Photo 3. New wiring and plumbing to prevent circulation pump operation when boilers are not firing.

Energy Consumption Comparison

Table 5: Building 1 Timeline

| | | | |
|------------------------------|-------------------|------------------------------|------------------|
| Baseline: Pre-period | 1/1/17 – 10/31/17 | Implementation Period | 7/1/18 – 4/30/19 |
| Timeline: Post-period | 1/1/19 – 10/31/19 | Post TU Energy Data | 6 months |

Data Analysis

- **Data gaps or spikes/dips:** For this building, significant dips in natural gas consumption were observed for the months of May, June and July 2018. As per discussion with management, the restaurant kitchen was closed for renovation starting in May and reopened in July.
- **Data cleaning:** To address the usage dips that were likely from the restaurant closure, the data values for those months were adjusted based on previous years' trends to normalize the pattern.
- **Pre and post timeframe:** For this building, 4 months of the implementation period (1/1/19 – 4/30/19) overlapped with the post-period, therefore it is possible that some energy savings may not yet be seen in the data available at the time of this report.

Energy Use Analysis Results

- For this building, we observed non-normalized electricity use increase of 7.37%, and natural gas use was increased by 16.47%. The building's total GHG emissions were increased by 15.61% (12.77 MT CO₂) when comparing 2018 vs. 2019.
- For the 2-year comparison, we observed energy increases of 1.84% and a GHG emissions increase of 0.14% between 2017 and 2019.
- We observed weather normalized energy savings of 1.28% for 2-year comparison. Also, the weather normalized GHG emissions were reduced by 1% in 2-year comparison.
- The below table provides pre- and post-energy use numbers for electricity, natural gas, total energy and GHG reduction.



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Table 6: Building 1 - Pre- vs. Post-period (2017 vs 2019) Energy Use & Emissions – Non-Normalized

| | % Change | kWh | therms | kBtu |
|----------------------|----------|-------------|----------|-------------|
| <i>Electric</i> | (3.81%) | (21,774.49) | (743.12) | (74,294.56) |
| <i>Natural Gas</i> | 0.51% | 2,453.10 | 83.72 | 8,369.99 |
| <i>Total Energy</i> | (1.84%) | (19,321.49) | (659.41) | (65,924.91) |
| <i>GHG Emissions</i> | (0.14%) | | | |

Conclusion

This building did see weather-normalized energy savings post tune-up, despite the limited opportunities for corrective measures inherent from the use type (24/7 hotel) and the primary heating system used in the building (PTHPs controlled by guests). The minor gas savings in the 2-year analysis likely result from the adjustments to the hot water heating system. The electricity savings likely resulted from the controls retrofit for the two heat pumps in the lobby which reduced the occurrence of simultaneous heating and cooling.

The on-site manager expressed support for the Tune-Up program, stating that it got them more focused on thinking about sustainability in energy use. Unfortunately, they are somewhat limited in their ability to implement changes because of certain policies set by the larger hospitality group that runs this and other hotels. The manager would like to see the lighting upgrade implemented, which would very likely result in substantial energy savings. This will depend on decision-making from upper management, which will also likely be influenced by the real estate market in the area, where the current trend is marked by a construction boom of high-rise buildings.

Building 2

Description

Building 2 is a five-story, approx. 50,000-60,000 SF office building constructed in the 1890s. The walls are brick with no furring or cladding. According to the Tune-up Summary Report, the walls and roof are insulated, but R-value is unknown. The primary building use is office space, with retail on the ground floor consisting of a pub/restaurant and a salon. Ventilation and cooling for the building is served by two packaged rooftop units (RTU) with fixed outside air dampers. Heating throughout the building is accomplished through electric-reheat variable air volume (VAV) boxes. Building pressure control is accomplished by relief fans. The ground floor is served by the smaller of the two air handling units (AHU), which runs nearly 24/7 as the pub is open 11am-2am, seven days/week. The 20-year-old direct digital control (DDC) BAS was upgraded in Oct 2018, a decision prompted by the tune-up recommendations. Since the upgrade, the system is now equipped with duct static pressure reset and discharge air temperature reset functionality. VAV set points are typically between 74-76° F for cooling and 70-73° F for heating. DHW is served primarily by natural gas tank heaters, with some additional electric point-of-use water heaters in certain tenant spaces.

Table 7: Building 2 Characteristics

| | | | |
|---------------------|-----------|---------------------|---------------|
| Decade Built | 1890s | Tune-up Path | Tune-Up Plus |
| GFA | 50-60K SF | Fuel Sources | Electric, Gas |



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| | | | |
|-------------|--------|----------------|-------------------|
| Primary Use | Office | Secondary Uses | Other, Restaurant |
|-------------|--------|----------------|-------------------|

Findings, Corrective Actions, and Verification

Initial Assessment (Pre-Action)

Every piece of equipment connected to the current DDC System was evaluated from front end by the Tune-Up Specialist. Suspect devices were flagged for the owner for further evaluation.

M&V Site Visits (Post-Action)

An M&V site visit at Building 2 was performed by SBC on 8/6/19. Verification methods included visual observation of BAS interface and verbal and written confirmation from building management and the Tune-Up Specialist.

Required Actions

Based on the Tune Up Accelerator Summary Report for this building, the following required actions were identified (these are listed by category and assessment element ID):

HVAC

- **G1:** Sunday operating schedule was in place for upper office floors (2-5), even though these spaces are not typically occupied on this day.

Requirement: Change operating schedule to reduce or eliminate Sunday runtime.

M&V: Runtime schedule as observed in BAS interface was set for 12-hour operation M-F, reduced to 4-hour schedule on Saturday, and not operating on Sunday.

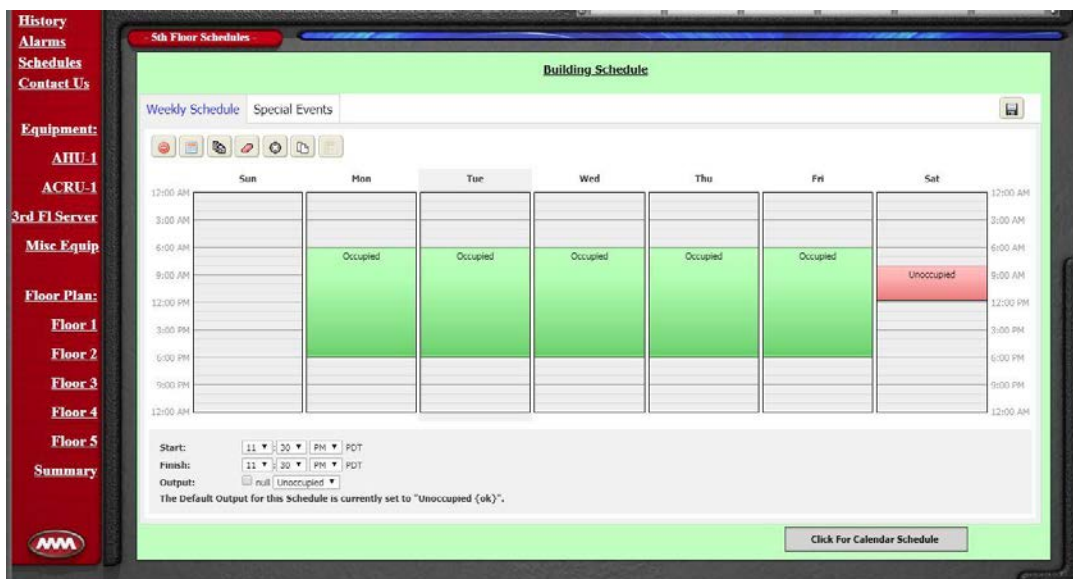


Photo 4. Screenshot from Bldg. 2 BAS showing operation Mon-Sat and no operation on Sunday.

- **G5:** Temperature sensor(s) for AHU-1 were not working properly.
Requirement: Repair or replace sensor(s).
M&V: According to building management, these sensors were replaced as part of the



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controls upgrade in Oct. 2018. Observation of temperature readings from BAS on date of M&V site visit indicated normal operation.

- **G6:** Several VAV Box Controllers appeared to be out of calibration or tubes not connected properly, requiring further investigation.

Required action: Investigate VAV box controllers and repair/replace as necessary.

M&V: According to building management, all controllers were inspected as part of the controls upgrade in Oct. 2018, and faulty controllers were replaced. Random spot check of VAV readings in BAS interface indicated normal operation.

| GraphicTag | EffOcc | EffVavCode | SpaceTemp | EffSPT | Boxflow | EffFlowSPT | DamperPos | CldDmd | HtgDmd | AirStarved | Comm |
|------------|------------|------------|-----------|---------|---------|------------|-----------|--------|--------|------------|--------|
| VAV-101 | Unoccupied | InvacCool | 70.4 °F | 78.0 °F | 0 cfm | 0 cfm | 0 % | 0 % | 0 % | Satisfied | Normal |
| VAV-102 | Unoccupied | InvacCool | 71.0 °F | 78.0 °F | 0 cfm | 0 cfm | 0 % | 0 % | 0 % | Satisfied | Normal |
| VAV-103 | Unoccupied | InvacHeat | 68.6 °F | 62.0 °F | 112 cfm | 0 cfm | 0 % | 0 % | 0 % | Satisfied | Normal |
| VAV-104 | Occupied | InvacCool | 69.0 °F | 72.0 °F | 201 cfm | 108 cfm | 0 % | 0 % | 0 % | Satisfied | Normal |
| VAV-105 | Occupied | InvacHeat | 68.8 °F | 68.6 °F | 210 cfm | 199 cfm | 17 % | 0 % | 9 % | Satisfied | Normal |
| VAV-106 | Occupied | InvacCool | 68.6 °F | 72.0 °F | 233 cfm | 199 cfm | 11 % | 0 % | 0 % | Satisfied | Normal |
| VAV-110 | Occupied | InvacHeat | 67.6 °F | 67.6 °F | 364 cfm | 350 cfm | 35 % | 0 % | 76 % | Satisfied | Normal |
| VAV-201 | Occupied | InvacHeat | 70.2 °F | 74.1 °F | 515 cfm | 498 cfm | 30 % | 0 % | 100 % | Satisfied | Normal |
| VAV-202 | Occupied | InvacHeat | 71.5 °F | 71.6 °F | 562 cfm | 498 cfm | 29 % | 0 % | 0 % | Satisfied | Normal |
| VAV-203 | Occupied | InvacCool | 74.3 °F | 75.0 °F | 422 cfm | 390 cfm | 22 % | 0 % | 0 % | Satisfied | Normal |
| VAV-204 | Occupied | InvacCool | 73.7 °F | 75.0 °F | 182 cfm | 178 cfm | 27 % | 0 % | 0 % | Satisfied | Normal |
| VAV-205 | Occupied | InvacHeat | 73.7 °F | 73.1 °F | 466 cfm | 487 cfm | 26 % | 0 % | 55 % | Satisfied | Normal |
| VAV-206 | Occupied | InvacHeat | 71.8 °F | 71.6 °F | 176 cfm | 178 cfm | 32 % | 0 % | 0 % | Satisfied | Normal |
| VAV-301 | Occupied | InvacHeat | 71.8 °F | 72.6 °F | 850 cfm | 850 cfm | 53 % | 0 % | 100 % | Satisfied | Normal |
| VAV-302 | Occupied | InvacHeat | 72.3 °F | 71.6 °F | 488 cfm | 487 cfm | 38 % | 0 % | 0 % | Satisfied | Normal |
| VAV-303 | Occupied | InvacCool | 74.3 °F | 75.0 °F | 229 cfm | 240 cfm | 29 % | 0 % | 0 % | Satisfied | Normal |
| VAV-304 | Occupied | InvacHeat | 74.0 °F | 73.6 °F | 386 cfm | 330 cfm | 69 % | 0 % | 49 % | Satisfied | Normal |
| VAV-305 | Occupied | InvacHeat | 74.1 °F | 72.6 °F | 513 cfm | 487 cfm | 29 % | 0 % | 0 % | Satisfied | Normal |
| VAV-306 | Occupied | InvacHeat | 72.4 °F | 71.6 °F | 229 cfm | 195 cfm | 21 % | 0 % | 3 % | Satisfied | Normal |
| VAV-401 | Occupied | InvacHeat | 69.8 °F | 70.6 °F | 201 cfm | 199 cfm | 18 % | 0 % | 100 % | Satisfied | Normal |
| VAV-402 | Occupied | InvacCool | 70.4 °F | 72.3 °F | 500 cfm | 487 cfm | 25 % | 0 % | 0 % | Satisfied | Normal |
| VAV-403 | Occupied | InvacHeat | 73.0 °F | 72.6 °F | 182 cfm | 178 cfm | 26 % | 0 % | 25 % | Satisfied | Normal |
| VAV-404 | Occupied | InvacHeat | 72.3 °F | 71.6 °F | 208 cfm | 248 cfm | 30 % | 0 % | 0 % | Satisfied | Normal |
| VAV-405 | Occupied | InvacHeat | 71.4 °F | 71.6 °F | 265 cfm | 248 cfm | 41 % | 0 % | 12 % | Satisfied | Normal |
| VAV-406 | Occupied | InvacCool | 72.9 °F | 74.0 °F | 106 cfm | 100 cfm | 19 % | 0 % | 0 % | Satisfied | Normal |
| VAV-407 | Occupied | InvacHeat | 70.0 °F | 69.6 °F | 186 cfm | 199 cfm | 33 % | 0 % | 0 % | Satisfied | Normal |
| VAV-501 | Occupied | InvacHeat | 70.6 °F | 70.6 °F | 237 cfm | 248 cfm | 26 % | 0 % | 0 % | Satisfied | Normal |

Photo 5. Screenshot of Bldg. 2 BAS interface showing VAV summary page.

Recommended Actions (Voluntary Implementation)

Based on the Tune Up Accelerator Summary Report for this building, the following recommended actions were identified (these are listed by category and assessment element ID):

HVAC

- **G8:** Evidence of air balancing issues was observed.

Recommendation: Test and Balance (TAB) / commissioning should be performed as part of the planned control system upgrade.

M&V: According to building management, TAB was completed as part of the controls upgrade in Oct. 2018. No indications of a deficiency were evident on the date of the site visit.

Additional Measures

Based on the Tune Up Accelerator Summary Report, these actions were included as recommended actions by the Tune Up Specialist, but do not have corresponding element IDs within the Tune Up Accelerator Summary Report.

- **Recommendation:** Upgrade legacy building automation system to enhance efficiency.

M&V: According to building management, a full upgrade to a Honeywell system with Spyder controllers was completed in Oct. 2018. BAS interface was observed, including reset functionality for duct static pressure and discharge air temperature.



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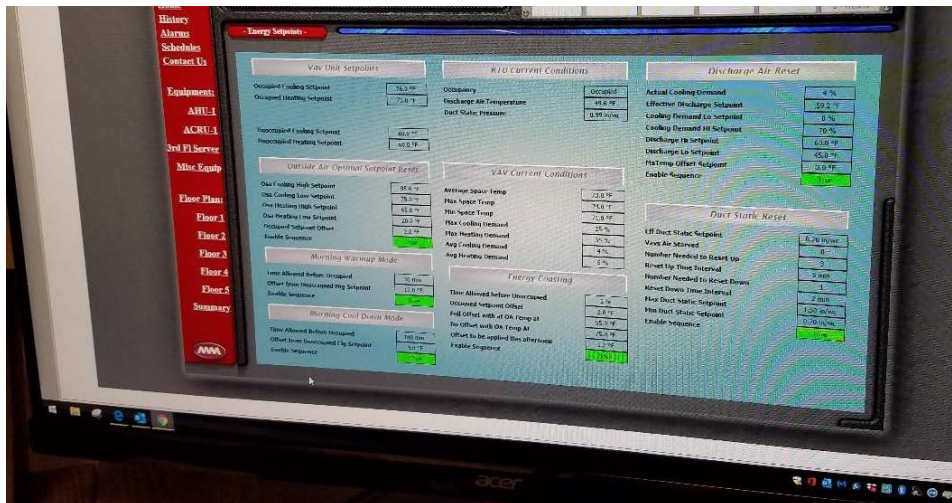


Photo 6. Bldg. 2 BAS interface screenshot.

Energy Consumption Comparison

Table 8: Building 2 Timeline

| | | | |
|------------------------------|-------------------|------------------------------|-------------------|
| Baseline: Pre-period | 1/1/17 – 10/31/17 | Implementation Period | 6/6/18 – 10/31/18 |
| Timeline: Post-period | 1/1/19 – 10/31/19 | Post TU Energy Data | 10 months |

Data Analysis

- **Data gaps or spikes/dips:** For this building, significant dips in electric energy consumption were observed for the months of October and November 2018. When discussed with building management, they couldn't find anything out of the ordinary per their records, therefore we assumed the dips were a metering or reporting error.
- **Data cleaning:** To address the unexplained usage dips, the data values for those months were adjusted based on previous years trends to normalize the pattern.
- **Pre and post timeframe:** This building completed the tune-up just prior to the post-period.

Savings Results

- For this building, we observed total non-normalized energy use savings of 12.58% and GHG emissions reduction of 8.26% when comparing 2018 vs. 2019.
- For the 2-year comparison, we observed energy savings of 12.32% and GHG reduction of 10.08% between 2017 and 2019.
- For weather normalized energy analysis, we noticed negligible increase in energy use of 0.04% in 1 year analysis and energy savings of 0.75% in the 2 year analysis.
- Below table provides saving numbers for electricity, natural gas, total energy and GHG reduction.

Table 9: Building 2 - Pre- vs. Post-period (2017 vs 2019) Energy Use & Emissions – Non-normalized

| | % Change | kWh | therms | kBtu |
|--------------------|----------|-----------|----------|------------|
| <i>Electric</i> | 12.69% | 96,657.59 | 3,298.75 | 329,795.70 |
| <i>Natural Gas</i> | 7.45% | 4,264.17 | 145.53 | 14,549.36 |



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| | | | | |
|----------------------|--------|------------|----------|------------|
| <i>Total Energy</i> | 12.32% | 100,921.59 | 3,444.27 | 344,344.47 |
| <i>GHG Emissions</i> | 12.34% | | | |

Conclusion

Building 2 saw energy savings in both natural gas and electricity; these savings likely resulted from the tune-up measures in this building addressing HVAC improvements, especially upgrading the BAS including TAB and re-commissioning, replacing faulty VAV controllers and temperature sensors, and adjusting the Sunday runtime. These measures would have affected both natural gas as the fuel for the RTUs as well as electricity running the fans. The building manager stated that the tune-up assessment helped with achieving buy-in for the controls upgrade, and the utility incentives greatly contributed to that decision. He also indicated that while he appreciates the benefits of tuning up for efficiency, he would prefer to do so from a market-driven perspective rather than because of regulatory requirements. They are also completing a tune-up in another vintage building in their portfolio.

Building 3

Description

Building 3 is a five-story, approx. 100,000-110,000 SF warehouse constructed in the 1950s. The walls are tilt-up concrete with no furring, cladding, or insulation and the open-framed roof is insulated with R-15 between the decking and roof membrane. The building was purchased by the current owners around the year 2000, when they renovated it to create office and retail space in a small portion of the building, and most of the mechanical equipment is of that vintage. There is no BAS. The space type is roughly 70% non-refrigerated warehouse, 15% refrigerated warehouse, 10% office space, and 5% retail. The non-refrigerated portion is not heated nor cooled. The refrigerated portion includes a walk-in freezer inside a walk-in cooler, both cooled by a packaged RTU. The offices are heated and cooled by a heat pump split system in fair condition, controlled via programmable thermostats. These are turned down manually by staff for holidays. There are also some electric resistance strip heaters. Ventilation is provided by a single-zone AHU with a fixed outside air damper. Two electric tank water heaters mounted above the office space serve DHW in the office portion (for a small staff kitchen and the restrooms). HVAC for the retail portion, on the north end of the building, is served by single-zone packaged RTUs with fixed outside air dampers, using electricity for cooling and natural gas for heating. DHW is provided by a gas water heater. The space was unoccupied at the time of the M&V site visit and the HVAC systems had been shut off since the previous tenant moved out in Nov. 2018. This was the only portion of the building that used gas, so gas was therefore excluded from the energy analysis.

Table 10: Building 3 Characteristics

| | | | |
|---------------------|---|-----------------------|----------------|
| Decade Built | 1950s | Tune-Up Path | Tune-Up Plus |
| GFA | 110-110K SF | Fuel Sources | Electric, Gas |
| Primary Uses | Refrigerated and Non-refrigerated warehouse | Secondary Uses | Office, Retail |



Findings, Corrective Actions, and Verification

Initial Assessment (Pre-Action)

Every piece of equipment was evaluated from front end by the Tune-Up Specialist. Suspect devices were flagged for the owner for further evaluation.

M&V Site Visits (Post-Action)

Initial M&V site visit at Building 3 was performed by SBC on 7/12/19. Verification methods included visual observation, verbal and written confirmation from building management and/or the Tune-Up Specialist, and data capture using a Fluke 63 infrared thermometer.

Required Actions

Based on the Tune Up Accelerator Summary Report for this building, the following required actions were identified (these are listed by category and assessment element ID):

HVAC

- **G2:** Thermostats in office area had a small occupied dead band that should be increased, and unoccupied dead band was the same as in occupied mode.
Requirement: Adjust the set points to widen the dead band and reduce heating temperature set point for unoccupied mode.
M&V: Thermostats in office area were observed to be set at 75° F for cooling and 70° F for heating in occupied mode. In unoccupied mode the heating set point was observed at 60° F.

DHW

- **I1:** The DHW heaters serving the kitchens were set too high.
Requirement: Reduce set point temperatures for DHW to 120° F.
M&V: Thermostats on water heaters were observed to be set at 120° F. Temperature readings at outlet and inlet pipe taken with infrared thermometer averaged at 90° F and 82.5° F respectively, indicating standby operation at the time.

Recommended Actions

Based on the Tune Up Accelerator Summary Report for this building, the following recommended actions were identified (these are listed by category and assessment element ID):

HVAC

- **G9:** Manual dampers that regulate flow of outside air to the mezzanine office do not meet ASHRAE 62.1 standards.
Recommendation: Manual dampers that regulate flow of outside air to the mezzanine office spaces could be rebalanced to meet ASHRAE 62.1 standards. Another option that would save energy is to add motorized dampers that close when building is unoccupied; currently they stay open.
M&V: As per building management, dampers had not been adjusted, and there were no plans to do so given the age of the equipment since it will likely need to be replaced soon anyway.
- **G15:** Rooftop units serving the retail space had faulty economizer function due to various issues related to stuck damper linkage, so that the dampers were either locked or could not fully stroke.
Recommendation: Repair stuck damper linkages to restore proper economizer operation.



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- M&V:** According to building management, the gas-packs are now de-commissioned and will be replaced before another tenant moves in, so linkage repair is no longer required.
- **G18:** The heat pumps are coming to the end of their useful life (20+ years old).
Recommendation: Replace all the heat pump units with high efficiency units, making sure to adjust dampers to ASHRAE 62.1 standards.
M&V: According to building management, there is no immediate plan to replace the heat pumps. They will be replaced when they are no longer functional.

Lighting

- **H4:** Some lighting has been changed to LED, but there are several areas in the building that haven't been upgraded.
Recommendation: Upgrade lighting to LED with occupancy sensors throughout the building.
M&V: According to building management, a lighting upgrade to LED with occupancy sensors was completed in Nov. 2018, including all of the retail space, warehouse, and loading docks. LED fixtures were observed in these areas, and occupancy sensors appeared to work properly, staying lit for 60 seconds after motion has stopped. They were planning another round of upgrades to LED in fall 2019, including the offices, exterior lighting (replacing 400w metal halide fixtures), and a sign (replacing five 8 ft T-12s).

Domestic Hot Water (DHW)

- **I1:** The DHW heaters serving the kitchens were set too high.
Requirement: Reduce set point temperatures for DHW to 120° F.
M&V: Thermostats on water heaters were observed to be set at 120° F. Temperature readings at outlet and inlet pipe taken with infrared thermometer averaged at 90° F and 82.5° F respectively, indicating standby operation at the time.

Additional Measures

Based on the Tune Up Accelerator Summary Report, these actions were included as recommended actions by the Tune Up Specialist, but do not have corresponding element IDs within the Tune Up Accelerator Summary Report.

HVAC

- DHW piping above offices in unconditioned warehouse space was uninsulated.
Recommendation: Insulate DHW piping in unconditioned areas.
M&V: Pipe insulation was observed on all hot water pipes leaving the water heaters.



Photo 7. DHW pipe insulation installed March 2019.

- **Recommendation:** Upgrade to electronically commutated motors (ECM) for evaporator fans in the walk-in cooler and freezer.
M&V: According to building management, they are considering this recommendation but have no immediate plans to implement it.
- **Recommendation:** Install smart thermostats in office spaces to limit the amount of electric resistance strip heat.
M&V: According to building management, they are working on a larger plan for smart controls, integrating other systems such as security cameras. There is no planned timeline for this upgrade.
- **Recommendation:** Install new insulation for the refrigerant piping for the walk-in cooler and freezer to replace damaged insulation.
M&V: Insulation was installed on the refrigerant piping on the roof, and most sections had been covered with metal roofing panels to prevent birds from further damaging the insulation



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as had happened previously (a common problem with rooftop insulation). Areas not covered had sustained further damage.



Photo 8. Refrigerant piping on roof was installed, with portions covered to prevent damage from birds.



Photo 9. Uncovered insulation had sustained more damage from birds.

- **Recommendation:** Drop the floor freeze protection boiler set point for the walk-in freezer.
M&V: According to building management, the set point for the frost heave prevention boiler had been reduced by 3° (to 76° F). As observed, boiler temperature on gauge read 90° F, but



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readings taken with infrared thermometer showed 76.5° F at the outlet and 74° F at the inlet, indicating that the gauge may be faulty.



Photo 10. Electric boiler temperature gauge may be faulty.

Energy Consumption Comparison

Table 11: Building 3 Timeline

| | | | |
|------------------------------|-------------------|------------------------------|-----------------|
| Baseline: Pre-period | 1/1/17- 10/31/17 | Implementation Period | 3/1/18 – 3/1/19 |
| Timeline: Post-period | 1/1/17 – 10/31/19 | Post TU Energy Data | 7 Months |

Data Analysis

- *Data gaps or spikes/dips:* This building didn't have any natural gas use after 06/2018, and the gas meter is now inactive. As per discussion with management, only electric usage is analyzed for energy use analysis.
- *Data cleaning:* There had been a pretty consistent trend in electric usage for this building since 2013. Therefore, no adjustments were needed to clean data.
- *Pre and post timeframe:* This building had 3 months of overlapping in implementation period and post timeframe from 1/1/19 – 3/1/19. Therefore, some energy savings for this building were not factored in.

Energy Use Analysis Results

- For this building, we observed energy savings (which includes only electric) of 8.47%. The building's total GHG emissions were reduced 8.38% when comparing 2018 vs. 2019.
- For the 2-year comparison, we observed energy savings of 4.92% and GHG emissions reduction of 4.87% between 2017 and 2019.
- For weather normalized analysis, 0.05% energy savings were observed comparing 2017 vs 2019.
- Below table provides pre and post energy use numbers for electricity, total energy and GHG reduction.



Table 12: Building 3 - Pre- vs. Post-period (2017 vs. 2019) Energy Use & Emissions – Non-normalized

| | % Change | kWh | therms | kBtu |
|----------------------|----------|-----------|----------|------------|
| <i>Electric</i> | 4.92% | 30,047.13 | 1,025.45 | 102,520.81 |
| <i>Total Energy</i> | 4.92% | 30,047.13 | 1,025.45 | 102,520.81 |
| <i>GHG Emissions</i> | 4.87% | | | |

Conclusion

In this building, energy savings likely resulted from the tune-up measures performed, especially the lighting upgrade, replacing insulation for the refrigerant piping on the roof for the walk-in cooler and freezer, insulating the DHW piping in the unconditioned warehouse, adjusting the thermostat schedule, and reducing the DHW and floor freeze protection boiler set points. The building manager indicated that the tune-up recommendations brought awareness to several potential savings opportunities and helped influence the decision to implement many voluntary measures, including influencing the expedited timing of the lighting upgrade that was completed for the tune-up and the future upgrade that had been planned for late 2019.

Building 4

Description

Building 4 is a two-story, approx. 60,000-70,000 SF public K-12 school building constructed in the 1910s. The envelope's masonry curtain wall is insulated with approx. R-13. The attic is insulated with about R-24. A renovation including an addition was completed around the year 2000. Heating is generated by two natural gas boilers, one condensing and one fire-tube. Before the tune-up, the fire-tube was the primary boiler, but that has been changed to utilize the condensing boiler as the main source. Cooling is generated by a chiller plant. Air distribution is supplied by a constant volume single-zone VAV system with economizing. It is controlled by a DDC BAS with set points at 68° F for heating and 76° F for cooling. There is no pressurization control for the building. DHW is supplied by natural gas water heaters. Lighting is controlled by occupancy sensors in the common areas as well as being controlled by the BAS on the same schedule as the HVAC. Exterior lighting is on a schedule as well as controlled by a photo sensor.

Table 13: Building 4 Characteristics

| | | | |
|---------------------|-------------|-----------------------|----------------|
| Decade Built | 1910s | Tune-Up Path | Tune-Up Plus |
| GFA | 60-70K SF | Fuel Sources | Electric, Gas |
| Primary Uses | K-12 School | Secondary Uses | Office, Retail |

Findings, Corrective Actions, and Verification

Initial Assessment (Pre-Action)

Every piece of equipment was evaluated by the Tune-Up Specialist in summer of 2018. Where possible, suspect devices were repaired or replaced right away; all repairs were completed by autumn 2018.



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M&V Site Visits (Post-Action)

An M&V site visit at Building 4 was performed by SBC on 8/15/19. Though summer, the school was partially occupied by a summer program. Verification methods included visual observation of equipment, the BAS interface and verbal and written confirmation from the Tune-Up Specialist.

Required Actions

Based on the Tune Up Accelerator Summary Report for this building, the following required actions were identified (these are listed by category and assessment element ID):

HVAC

- **G3:** Boiler supply temperature reset was configured to respond to outside air temperature (OAT). Also, the less efficient fire-tube boiler was set as the primary boiler.
Requirement: Modify the reset schedule to look at zone demand instead of OAT. Make the condensing boiler the lead boiler over the fire-tube one.
M&V: The site visit occurred in the summer when the boilers were turned off. According to the Tune-Up Specialist, who is also a Retro-commissioning Specialist (RCx) for the school district, at the time of the assessment (autumn 2018) he changed the BAS configuration to make the condensing boiler the lead boiler over the fire-tube and modified the reset schedule to look at a sample of zone demand instead of OSA. He also lowered the HWS temp for the condensing boiler.



Photo 11. The less efficient non-condensing boiler was carrying the primary load.



Photo 12. Settings were changed so that the more efficient condensing boiler carries the primary load.



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- **G6:** Several faulty terminal controllers were diagnosed with either the input or output not working properly.
Requirement: Repair or replace faulty terminal controllers.
M&V: As per the RCx, all faulty controllers were replaced. During a random spot check, terminal controllers appeared to be working properly.
- **G11:** Around 40 fan coil units had very dirty coils and plenums, reducing air flow and temperature control.
Requirement: Clean dirty coils and plenums.
M&V: According to RCx, all fan coil units and plenums were cleaned. A spot check of several units indicated they had been cleaned.
- **G12:** Several filters were very dirty, reducing air flow and coil operation.
Requirement: Replace dirty filters.
M&V: According to RCx, all filters were replaced. New filters were observed during a spot check of several units.
- **G14:** Several broken fan belts and loose sheaves causing belt slippage were found.
Requirement: Replace broken belts and adjust loose sheaves and belt tension.
M&V: According to the RCx, all belts and sheaves were inspected, broken belts were replaced, sheaves that were loose and causing belt slippage were adjusted, and belt tension was also adjusted. During a random spot check, no broken or loose belts were observed.
- **G17:** About a half-dozen non-functioning damper actuators and two faulty valve actuators were found.
Requirement: Repair or replace non-functioning actuators.
M&V: According to the RCx, all non-functioning damper actuators and valve actuators were replaced. During a random spot check, new damper actuators were observed and functioning properly.



Photo 13. New damper actuator.



Photo 14. Random inspection of several units indicated filters had been replaced, and coils and plenums had been cleaned.



Lighting

- **H2:** Outdoor daylight sensor was found to be malfunctioning.
Requirement: Repair or replace outdoor daylight sensor.
M&V: According to the RCx, the daylight sensor had been replaced. Sensor was located and all exterior lighting was off during the daytime site visit, as intended.

Recommended Actions

Based on the Tune Up Accelerator Summary Report for this building, the following recommended actions were identified (these are listed by category and assessment element ID):

Lighting

- **H4:** Outdoor lighting is inefficient high intensity discharge (HID) type. Gymnasium has been updated to LED, but classroom lighting is fluorescent in 2x4 parabolic fixtures. Entry areas and the library have access to daylight but no daylighting sensors.
Recommendation: Upgrade all lighting to LED. Install daylighting sensors in the entry areas and library to take advantage of daylight harvesting opportunities. Install occupancy sensors in storage rooms and custodial closets.
M&V: According to RCx, there were no immediate plans to implement further lighting upgrades.

Water Usage

- **J11:** Some automatic faucets stay on longer than necessary.
Recommendation: Adjust automatic faucet “on” time.
M&V: According to the RCx, all faucets were evaluated and “on” time settings were adjusted where possible. A random spot check found that faucets stayed on an appropriate amount of time for washing hands and then turned off.

Energy Consumption Comparison

Table 14: Building 4 Timeline

| | | | |
|------------------------------|-------------------|------------------------------|------------------|
| Baseline: Pre-period | 1/1/17 - 10/31/17 | Implementation Period | 8/1/18 – 11/1/18 |
| Timeline: Post-period | 1/1/19 – 10/31/19 | Post TU Energy Data | 10 Months |

Data Analysis

- *Data gaps or spikes/dips:* The work to evaluate this building highlighted the gas metering problem explained below, however, the facility staff had noted that this building has had high variability in gas consumption over the last 5 years from their perspective. The electricity usage, however, seems to be in a stable trend over the years.
- *Data cleaning:* There had been a pretty consistent trend in electric usage for this building since 2013. Therefore, no adjustments were needed to clean electric data. However, for natural gas data with inconsistent use patterns and unexplained outliers, it was impossible to adjust the trend and values. When the monthly data was pulled and the school conservation staff was contacted, they informed us that the gas meter had malfunctioned and that they noticed this only after we asked



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them about the unusual data variability. (The school district had a gap in conservation staff due to a person leaving, so they were getting caught up in 2019.) Due to lack of reliable data for natural gas use, we decided to only do electric use data analysis and removed gas use from the analysis.

- *Pre and post timeframe:* This building completed the tune-up just prior to the post period.

Energy Use Analysis Results

- For this building, we observed energy increase of 7.13%. The building's total GHG emissions were also increased by 7.09% when comparing 2017 vs. 2019.
- For the 1-year comparison, we observed energy increase of 8.87% and GHG emissions increase of 8.83% between 2017 and 2019.
- For weather normalized analysis, 0.11% energy increase were observed comparing 2017 vs 2019.
- The table below provides pre and post energy use numbers for electricity, total energy and GHG reduction.

Table 15: Building 4 - Pre- vs. Post-period (2017 vs. 2019) Energy Use & Emissions – Non-normalized.

| | % Change | kWh | therms | kBtu |
|----------------------|----------|-------------|----------|-------------|
| <i>Electric</i> | (7.13%) | (28,492.58) | (972.40) | (97,216.68) |
| <i>Total Energy</i> | (7.13%) | (28,492.58) | (972.40) | (97,216.68) |
| <i>GHG Emissions</i> | (7.09%) | | | |

Conclusion

The electrical consumption increase is not necessarily surprising, since many of the actions taken would have potentially increased energy use due to increased fan motor operation, such as replacing broken fan belts, dampers, and faulty VAV controllers. Occupancy changes year to year could have also affected electrical use, such as an increase of the use of portable classrooms as well as summer school programs.

Building 5

Description

Building 5 is a two-story, approximately 80,000-90,000 SF brick multi-use City-owned building originally constructed in the 1930s as an airplane hangar. About a third to a half of the glazing is single pane. A new hangar roof with R-38 insulation was installed around the year 2000. Lighting is primarily fluorescent, with dimmable fixtures, occupancy sensors, and/or daylight sensors in about two thirds of the building. Some tenants use supplemental plug load lighting, primarily in a portion of the building designated for artist studios.

The building is divided into three distinct sections, each with its own heating plant. There is no mechanical cooling in the building. The east portion of the building, roughly 35% of the total space, is steel framed with brick infill walls (mostly uninsulated) and has vintage steel framed windows as well as a large single-pane glazed hangar door on the north side with an uninsulated vestibule. It contains two separate sections of two-story offices and meeting space, separated by an unconditioned high-bay mechanical space. It is heated by a recently upgraded natural gas



condensing boiler, with radiators in the northeast offices and a constant volume multi-zone AHU serving the southeast offices. It is controlled by a DDC BAS. Hot water is provided by a natural gas water heater.

The central portion of the building (roughly 30% of the total space) is a high-bay hangar space with a 30-foot ceiling and single-pane glazed hangar doors on both the north and south sides that are very poorly sealed. It is heated by four natural gas hanging units controlled by two thermostats that are accessible to the public. No mechanical ventilation is provided for the space, which is poorly sealed from the exterior providing plenty of natural air flow. This space is used intermittently for large special events, primarily in the summertime.

The west portion of the building (roughly 35% of the total space) was renovated in 2013 to create several artist studios. The walls and roof were insulated at that time with R-31 and R-38, respectively. Glazing was replaced with double-paned, wood-framed windows. The HVAC systems were also replaced at that time. Heat is provided by two condensing boilers using the vintage radiator system with non-electric thermostatic valves. Circulation pumps are equipped with variable frequency drives (VFD). Operable windows provide natural ventilation except for four interior rooms that are equipped with ducted fan coils with an economizer. The renovation in this area included a new DHW recirculation system with digital controls; the pumps are left on at night for artists who work odd hours.

Table 16: Building 5 Characteristics

| | | | |
|---------------------|-------------------|-----------------------|---------------|
| Decade Built | 1930s | Tune-Up Path | Tune-Up Plus |
| GFA | 80,000-90,000K SF | Fuel Sources | Electric, Gas |
| Primary Uses | Office | Secondary Uses | Events |

Findings, Corrective Actions, and Verification

Initial Assessment (Pre-Action)

Every piece of heating, ventilation, lighting, and water use equipment was evaluated by the Tune-Up Specialist in May 2018.

M&V Site Visits (Post-Action)

An M&V site visit at Building 5 was performed by SBC on 10/24/19, with a subsequent visit to retrieve the data loggers on 11/15/19. Verification methods included visual observation of equipment; verbal and written confirmation from the Tune-Up Specialist, building management, and the Resource Conservation Manager (RCM) for the building; and data capture using the following instruments:

- HOBO U12 temperature/humidity/light logger
- Fluke 63 infrared thermometer

Required Actions

Based on the Tune Up Accelerator Summary Report for this building, the following required actions were identified (these are listed by category and assessment element ID):



HVAC

- **G1:** East boiler supply temperature and hangar space thermostat set points were the same during both occupied and unoccupied schedules, and circulating pumps were operating even with no load. Boilers and pumps were set to operate even when unnecessary in the summer months.

Requirement: Set back boiler supply temperature at night in radiator zones and disable circulation pumps when there is no load. Set back hangar set points at night or during unoccupied periods. Disable boilers and boiler pumps seasonally.

M&V: The BAS was inaccessible during site visit, but as per building management night set back functionality for the boiler temperature had been enabled. Temperature had previously been set to 160° F even in unoccupied times and is now set to 100° F during unoccupied periods, based on an occupancy schedule of 8am to 5pm M-F. Management provided a work order showing this included as a line item. All boilers and circulating pumps were disabled for the summer months, and they had recently been turned back on for winter. The two thermostats for the hangar space gas-fired units had been upgraded to include set back capability. Upon observation, they were each incorrectly set at different set points, and according to the manager at the time of the site visit, these had changed since they last had been observed. Though the requirement to enable unoccupied temperature set back was completed, the intended outcome did not show persistence. The manager then again changed both thermostats to 64° F for occupied periods and 55° F for unoccupied periods, on a schedule of 9am to 8pm. But because fluctuating nature of the event activity in the space and the public has access to these controls, maintaining consistent settings will continue to pose a challenge unless they are locked down.

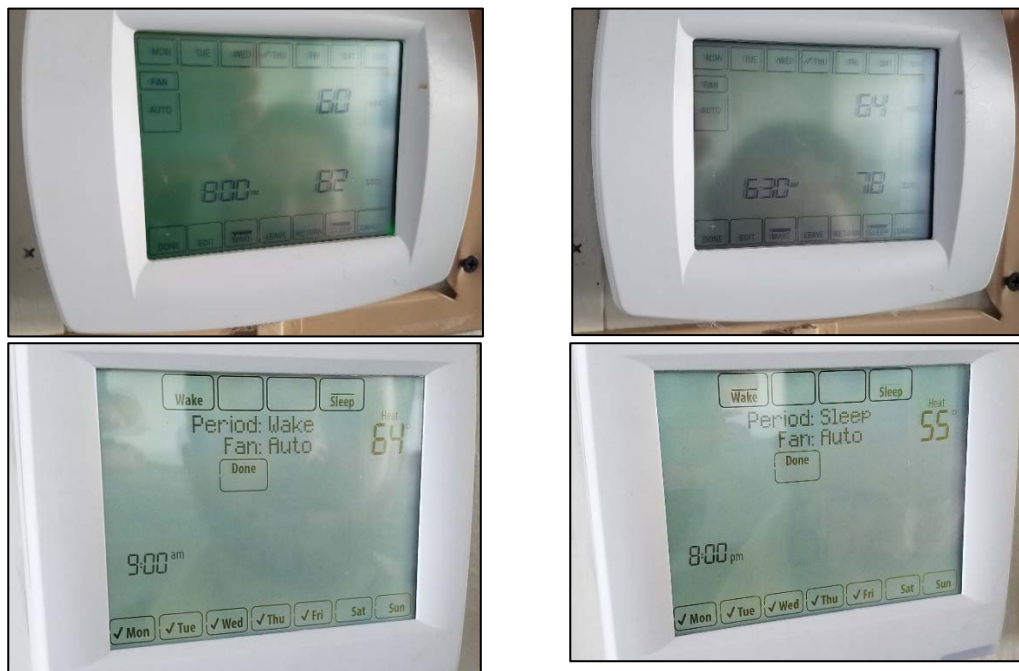


Photo 15. Top photos show that thermostats were set incorrectly. Bottom photos show corrected settings for occupied and unoccupied periods.



- **G2:** Because the artist studios have 24/7 access and some tenants on the lower floors of the artist studios leave their radiators turned up even when unoccupied, the upstairs artist studios in the western wing often overheat in the winter time, leading to open windows.
Requirement: Review options to avoid wasted heat due to open windows in wintertime and correct if possible.
M&V: As observed, no setback is possible on the radiator controls. As per building management, the boiler hot water loop temperature reset schedule was verified, and the range was extended to reduce over-heating in swing seasons. Efforts to influence tenants to turn down radiator controls during unoccupied periods could be made, but without behavior changes or a major retrofit, further potential for improvement is limited.
- **G3:** Boiler hot water loop temperature reset functionality was not enabled.
Requirement: Enable hot water temperature to be reset based on OAT.
M&V: The BAS was inaccessible during site visit, but as per building management, boiler temperature reset had been enabled. Management provided a work order showing this included as a line item, to be enabled according to the following schedule: 100° F at 60° F OAT, and 160° F at 45° F OAT. At the time of the site visit, the outside temperature was about 60° F, and an infrared thermometer reading on the supply pipe showed a temperature of 100.6, indicating that the reset function was working as intended.
- **G4:** Optimum start functionality was not enabled for the AHU serving the southeast office spaces or for the hydronic heating loop serving the west offices/studios.
Requirement: Enable optimum start for the east AHU and west heating loop.
M&V: The BAS was inaccessible during site visit, but as per building management, optimum start had been enabled for both the east AHU and west heating loop. Management provided a work order showing this included as a line item, implemented based on a schedule of 8am-5pm Monday through Friday.
- **G6:** Space heating hot water distribution pumps were enabled even when zones were at setpoint. Also, the east AHU outside air (OA) damper remained open during morning warm-up.
Requirement: Disable boiler distribution pumps when zones are at setpoint. Reconfigure OA damper to close during morning warm-up sequence.
M&V: The BAS was inaccessible during site visit. Distribution pumps were running. According to Tune-Up Specialist, maintenance staff won't allow pumps to shut off due to potential thermal shock on the cast iron heat exchanger. This is deemed to be insignificant to overall energy use. Building management indicated that OA damper controls had been enabled to stay closed during morning warm-up, and provided a work order showing this included as a line item.

Lighting

- **H2:** LED lights installed at west entrance were controlled by switches and were observed on during the day.
Requirement: LED lights installed at west entrance should be placed on a daylight sensor or timeclock control to keep them disabled during daylight hours.
M&V: The entry lights were observed to be off during the day as intended, and timeclock control was visually verified.
- **H3:** Occupancy and/or daylight sensors in several artist studios had been disabled by tenants with tape or paper covers.



Requirement: Return daylight and occupancy sensors to a functional state.

M&V: The artist studios were inaccessible during the site visit. According to building management, tape and paper covers had been removed. For additional context, the lighting configuration in these studios were originally supposed to have two zones controlled by the photo sensors, but were wired incorrectly for single-zone functionality, resulting in problematic dark areas away from the windows. Because of the nature of the work conducted in the artist studios, specific lighting qualities are especially important, which is why tenants want to manipulate the controls. Opportunities for improvement in this scenario are limited, but management did retro-commission the daylighting system to provide 10% dimming savings.

Recommended Actions

Based on the Tune Up Accelerator Summary Report for this building, the following recommended actions were identified (these are listed by category and assessment element ID):

HVAC

- **G16:** The insulation on the ductwork from the air handler serving the southeast offices is severely degraded and should be replaced.
Recommendation: Replace ductwork insulation from air handler serving southeast offices to reduce heat loss due to location of uninsulated, leaky ducting in unconditioned space.
M&V: Upon visual inspection, insulation appeared old and was degraded in some places. According to building management, there are no immediate plans to replace the insulation.
- **G18:** The AHU and ductwork serving the SE office spaces is at the end of its usable life.
Recommendation: Plan to replace AHU and ductwork serving southeast offices with energy recovery ventilation (ERV) and a variable refrigerant flow (VRF) heat pump.
M&V: According to building management, there are no immediate plans to replace AHU and/or ductwork.

Lighting

- **H2:** Some areas lack occupancy sensors.
Recommendation: Occupancy sensors would provide savings in restrooms, nonprofit storage and staging areas, and office workrooms. Daylight dimming controls could provide savings in the atrium event space (dimmable lights would be required). Consider retrofitting daylighting system in artist studios for dual zone functionality as originally intended.
M&V: According to building management, there are no immediate plans to upgrade lighting controls.

Water Use

- **J12:** A wide variety of fixture vintages are present. Most toilets are 3.5 gallons per flush (gpf), with some newer low flow toilets at 1.28gpf. Most sink faucets are 1.25 gpm. One shower in artist space was not accessible.
Recommendation: Replace vintage toilets and faucets with modern low flow fixtures.
M&V: According to building management, there are no immediate plans to upgrade any of the water fixtures.

Envelope

- **K1:** There is a hole in the ceiling on the second floor of the northeast office space that is open to the outdoors. Throughout the northeast office space, several windows don't fully close, and there are large areas of uninsulated envelope and areas with old steel framed single-pane windows.
Recommendation: Closing and sealing the hole in the ceiling on the second floor will



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improve energy performance, as will repairing the windows so they close properly, insulating exterior walls and upgrading the windows throughout.

M&V: As visibly observed, some areas of the ceiling and walls had visible insulation that appeared to be recently installed. Some windows had been insulated and filled in with sheetrock. According to the RCM, upgraded walls were insulated to R-19 and the upgraded ceiling areas were insulated to R-38. Some windows still did not seal well when closed. The second floor of the northeast office space was inaccessible at the time of the site visit, but building management indicated that the hole in the ceiling had been sealed.



Photo 16. Part of the ceiling was insulated. Note the ductwork to the right that has not been insulated.



Photo 17. Some windows were filled in and insulated.



Energy Consumption Comparison

Table 17: Building 5 Timeline

| | | | |
|------------------------------|-------------------|------------------------------|-----------------|
| Baseline: Pre-period | 1/1/17 - 10/31/17 | Implementation Period | 5/1/18 – 8/1/19 |
| Timeline: Post-period | 1/1/19 – 10/31/19 | Post TU Energy Data | 10 Months |

Data Analysis

- *Data gaps or spikes/dips:* There weren't any major spikes or dips noticed for energy consumption from 2014-2018 for this building.
- *Data cleaning:* There had been a pretty consistent trend in electric and gas usage for this building since 2014. Therefore, no adjustments were needed to clean data.
- *Pre and post timeframe:* Tune-up completed several months before post period.

Energy Use Analysis Results

- For this building, we observed 11.65% energy savings and high GHG emission reduction (16%) when comparing 2017 vs. 2019.
- For the 1-year comparison, we observed about 2.5% of increase in energy use and a 2.7% increase in GHG emissions between 2018 and 2019.
- For weather normalized analysis, we noticed relatively significant energy savings 5.15% along with about 6.41% GHG emissions reduction when comparing 2017 vs. 2019.
- Below table provides pre and post energy use numbers for electricity, natural gas, total energy and GHG reduction.

Table 18: Building 5 - Pre- vs. Post-period (2017 vs. 2019) Energy Use & Emissions

| | % Change | kWh | therms | kBtu |
|----------------------|-----------------|------------|---------------|-------------|
| <i>Electric</i> | (3.16%) | (6,234.84) | (212.78) | (21,273.27) |
| <i>Natural Gas</i> | 17.57% | 86,713.65 | 2,959.38 | 295,866.97 |
| <i>Total Energy</i> | 11.65% | 80,475.29 | 2,746.48 | 274,581.69 |
| <i>GHG Emissions</i> | 16.95% | | | |

Conclusion

Although this building's overall electricity use did not see savings, it saw sizeable natural gas savings resulting from the tune-up. This is likely a result of disabling the boilers seasonally, and optimizing the control functionality for the heating, including enabling unoccupied setbacks for the boilers and the gas-fired heaters, temperature reset based on OA, optimum start, and shutting the AHU outside air damper during morning warm up. Sealing air gaps and adding insulation likely contributed as well, although there is still quite a bit of non- or under-insulated space resulting in appreciable heat loss, so that work should be continued. Another measure that would likely result in savings is to install controls that will shut off the gas unit heaters in when the hangar space is unoccupied, since it is used sporadically. An alternative would be to install thermostats that could be controlled remotely, so that the event coordinator who works offsite can warm the space up for anticipated events ahead of time without requiring travel to the site.



Replacing the aging AHU in the east portion with more efficient ERV and VRF heat pumps is also recommended for both gas and electricity savings, but this will be most effective if the envelope issues are addressed.

Building 6

Description

Building 6 is a five-story, approximately 90,000-100,000 SF medical center and office building constructed in the 2010s and is divided into two portions with separate electrical meters. Floors 1-2 are metered together with the ground floor housing a 24-hour emergency room, and imaging services on the second floor. Floors 3-5, used for medical offices, are metered together and are the focus of this analysis, as the Tune-Up had not yet been completed for floors 1-2 at the time of the M&V site visit. There is no natural gas use. The walls are constructed with metal studs and approx. R-19 of insulation. The built-up roof has about R-30 of insulation. HVAC is provided by packaged RTU with electric reheat VAVs, controlled by a DDC BAS. DHW is provided by electric tank water heaters. Lighting is primarily linear T-5 fluorescent and controlled by timeclock controls (occupancy from 7am-7pm M-F, Sat 8-1), occupancy sensors (with occupant override switches in offices), and photo sensors.

Table 19: Building 6 Characteristics

| | | | |
|---------------------|-------------------|-----------------------|---------------|
| Decade Built | 2010s | Tune-Up Path | Basic Tune-Up |
| GFA | 90,000-100,000 SF | Fuel Sources | Electric |
| Primary Use | Medical Office | Secondary Uses | |

Findings, Corrective Actions, and Verification

Initial Assessment (Pre-Action)

The Tune-Up Specialist conducted a physical inspection of all major equipment in 80% of the floor area of all five floors of the building with exception of the terminal units (a sample of 16% was physically inspected). 100% of the terminal units were investigated through the BAS, as were the sequence of operations and schedules. An interview of building personnel was also conducted. This initial assessment was completed in December 2018.

M&V Site Visits (Post-Action)

An M&V site visit at Building 6 was performed by SBC on 10/23/19. Verification methods included visual observation of equipment and BAS interface; verbal and written confirmation from the Tune-Up Specialist and building management; and data capture using HOBO UX90-006 room occupancy and light loggers. SBC conducted a subsequent site visit to retrieve the data loggers on 11/20/19.



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Required Actions

Based on the Tune Up Accelerator Summary Report for this building, the following required actions were identified in the medical office part of the building (these are listed by category and assessment element ID):

HVAC

- **G6:** Several supply terminal units (STU) and exhaust terminal units (ETU) showed substantial flow variance from set points (either over-ventilating or under-ventilating).
Requirement: Investigate control settings and/or equipment and return to proper operation.
M&V: According to building management, most of the suspect units had been set to manual override with dampers at 100%. The settings on these units were subsequently changed to remove the manual override and return them to intended operation. Two units had filters that were blown out. These filters were replaced, and the units were rebalanced. Several units had dampers that were mechanically stuck (open, shut, or somewhere in between); management physically corrected these. One unit was found to have a broken damper that was replaced. Visual observation of the BAS interface confirmed all units listed as suspect had been restored to intended operation.

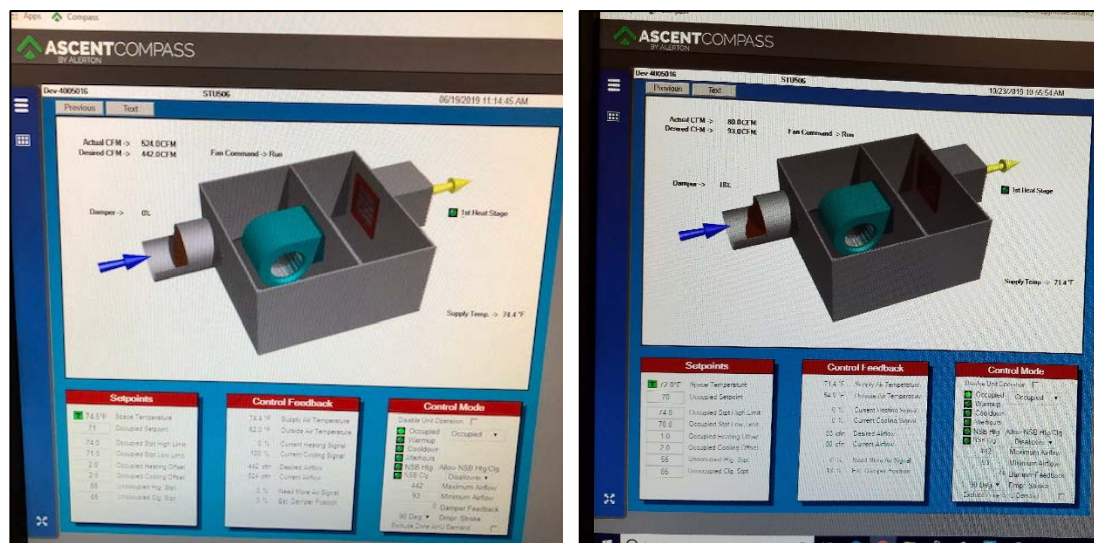


Photo 18. Before and after BAS settings for VAV box.

Lighting

- **H3:** Custodial staff were overriding lighting control system and leaving all the lights on throughout the entire 3rd floor at night.
Requirement: Change lighting control settings or occupant behavior to avoid leaving lights on during unoccupied hours.
M&V: According to building management, custodial staff were educated about the importance of turning the lights off. Data from lighting loggers indicates that behavior has changed and the lights are being turned off after custodial work is completed (see graph below). Visual observation of the third floor from the exterior on 10/30/19 at 6am indicated common area with lights on but office lights off (see photo below).



Photo 19. Photo taken at 6am shows common space on third floor lights on, but office lights (right side) off.

Recommended Actions

Based on the Tune Up Accelerator Summary Report for this building, the following recommended actions were identified (these are listed by category and assessment element ID):

Lighting

- **H1:** Daylighting controls appear to be working properly, but elevator lobby area is very bright at night and levels could be lowered.
Recommendation: Evaluate lighting levels and adjust if possible.
M&V: According to building management, no action had been taken on this recommendation, but it was still being considered.

Energy Consumption Comparison

Table 20: Building 6 Timeline

| | | | |
|------------------------------|-------------------|------------------------------|------------------|
| Baseline: Pre-period | 1/1/17 - 10/31/17 | Implementation Period | 1/1/19 – 6/24/19 |
| Timeline: Post-period | 1/1/19 – 10/31/19 | Post TU Energy Data | 4 Months |



Data Analysis

- *Data gaps or spikes/dips:* This building has 2 electric meters and no gas meter. We did an evaluation with just 1 meter since we are only evaluating floors 3-5 served by that meter. The other meter is for the medical center on floors 1-2.
- *Data cleaning:* There had been a pretty consistent trend in electric usage for this building since 2014. Therefore, no adjustments were needed to clean data.
- *Pre and post timeframe:* There was an overlap of 6 months for implementation and post period from 1/1/19 – 6/24/19. It is highly likely that the data analysis has not captured energy reductions from first 2 quarters of 2019.

Energy Use Analysis Results

- For this building, we observed a slight increase in energy use and GHG emission, 1.18% and 1.24% respectively, when comparing 2017 vs. 2019.
- For the 1-year comparison, we observed a negligible increase of less than 1% in GHG emissions and energy consumption between 2018 and 2019.
- For weather normalized analysis, we noticed slight energy savings 0.19% along with about 0.14% GHG emissions reduction when comparing 2017 vs. 2019.
- The table below provides pre and post energy use numbers for electricity, total energy and GHG reduction.

Table 21: Building 6 - Pre- vs. Post-period (2017 vs. 2019) Energy Use & Emissions

| | % Change | kWh | therms | kBtu |
|----------------------|----------|------------|----------|-------------|
| <i>Electric</i> | (1.18%) | (6,753.00) | (230.47) | (23,041.24) |
| <i>Total Energy</i> | (1.18%) | (6,753.00) | (230.47) | (23,041.24) |
| <i>GHG Emissions</i> | (1.24%) | | | |

Conclusion

Building 6 saw a small increase in energy use stemming from floors 3-5. This was not unexpected though, since many of the measures for floors 3-5 involved increasing air flow by correcting stuck dampers or removing manual overrides of the controls, which may have slightly increased energy use (though addressing the important concern of indoor air quality), negating energy savings from other measures such as lighting schedule improvements. The tune-up summary reported more corrections for the medical center on floors 1-2 and the Tune-Up Specialist expressed confidence that those would result in energy savings once implemented. We recommend that OSE update the analysis after those are implemented, if possible.

Building 7

Description

Building 7 is a two-story (plus basement and attic), approximately 60,000-70,000 SF wood-framed private K-12 school building constructed in the 1900s, with mechanical and electrical upgrades in 2006 that came along with construction of a 12,000 SF addition on the north side. The walls are estimated to be insulated to R-6, and the attic is estimated to be insulated to R-4. Most of the glazing is original single-pane windows. The basement contains mechanical equipment and facility staff offices, with the rest of the building used as classrooms, offices and



library space. Heating is generated by two hot water boilers and distributed by constant volume single-zone AHUs with zone heating coils. The heating and ventilation are controlled by a DDC BAS. Supplemental heat is provided by a steam boiler and radiator system that is manually engaged when OA temperature drops below 45° F. Building pressure is primarily controlled through operable windows. There is no mechanical cooling except in a small portion of the building (about 3% of the total floor space) which is served by a packaged RTU. This portion of the building is also equipped with demand-controlled ventilation (DCV). DHW is provided by electric tank water heaters. Lighting is controlled by manual switches and some occupancy sensors in classrooms. A partial LED upgrade was completed in 2018.

Table 22: Building 7 Characteristics

| | | | |
|---------------------|-------------|-----------------------|---------------|
| Decade Built | 1900s | Tune-Up Path | Tune-Up Plus |
| GFA | 60-70K SF | Fuel Sources | Electric, Gas |
| Primary Use | K-12 School | Secondary Uses | N/A |

Findings, Corrective Actions, and Verification

Initial Assessment (Pre-Action)

The Tune-Up Specialist assessed HVAC equipment by reviewing trends for all units using BAS, analytic program and thermal imaging. Lighting was visually observed in occupied spaces. Water fixtures in several restrooms, break rooms, and labs were inspected, and flow rates were verified. This assessment took place in May 2018.

M&V Site Visits (Post-Action)

An M&V site visit at Building 7 was performed by SBC on 10/28/19, with a subsequent visit to remove data loggers on 11/15/19. Verification methods included visual observation of equipment and BAS interface; verbal and written confirmation from the Tune-Up Specialist and building management; and data capture using the following instruments:

- HOBO U12 temperature/humidity/light logger
- HOBO UX120 4-channel analog logger with external TMC-HD air/water/soil temperature sensor
- Fluke 63 infrared thermometer

Required Actions

Based on the Tune Up Accelerator Summary Report for this building, the following required actions were identified (these are listed by category and assessment element ID):

HVAC

- **G1:** All AHUs run on same schedule with optimal start.
Requirement: Separate AHU schedules with start time about one hour prior to student arrival. Stop time should be at final bell with afterhours timer utilized for after-school activities.
M&V: Visual observation of the BAS interface confirmed that all three AHU optimum schedules had been separated with stop time adjusted, based on weekday schedule of 7am-4pm.



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- **G4:** Optimal start control functionality not enabled for individual zones.
Requirement: Enable optimal start for zones.
M&V: Visual observation of the BAS interface confirmed that optimal start was added for zones.
- **G6:** Multiple units' heating valves were open during unoccupied hours even though the units were not in afterhours heating mode. Additionally, heating lockouts were not being utilized for either boiler system.
Requirement: Correct control settings causing heating valves to stay open during unoccupied hours.
M&V: As per building management, issue with heating valves staying open was caused by a night setback setting which caused unoccupied heating, which was corrected. Guidance was given to space occupants on the proper use of overrides for afterhours use. Additionally, heating lockouts were enabled for both systems. Visual observation of the BAS interface confirmed these corrections had been completed.
- **G11:** Basement AHUs were difficult to reach because area is being used for storage.
Requirement: Remove storage items to facilitate access to air handlers.
M&V: As per building management, the mechanical space is no longer used as a storage location, and visual inspection confirmed this.
- **G14:** AHU-4 filter frame is taped on and therefore ineffective.
Requirement: Repair or replace filter frame.
M&V: As per building management, a bracket on the filter frame was repaired to restore it to full functionality; visual inspection confirmed this (see photo below).



Photo 21. A bracket on the non-functioning filter frame was repaired.

Water Use

- **J5:** Irrigation system does not have rain sensors.
Requirement: Install rain sensor for irrigation.
M&V: As per building management and visual inspection, a rain sensor controlling the irrigation was installed (see photo below).



Photo 22. A rain sensor was added to the irrigation system.

Recommended Actions

Based on the Tune Up Accelerator Summary Report for this building, the following recommended actions were identified (these are listed by category and assessment element ID):

HVAC

- **G9:** Some spaces have high CO₂ levels when occupied. The only ventilation option is through operable windows.
Recommendation: Provide CO₂ control on AHU-3 and AHU-4.
M&V: As per building management, this recommendation is being considered, but there are no immediate plans for implementation.
- **G15:** Two steam radiators appear to have reduced flow and may be clogged.
Recommendation: Repair or replace steam traps and/or clear blockages
M&V: Steam boiler was turned off at the time of the site visit because OA temperature was above 45° F, so testing with ultrasonic leak detector was not possible. According to building management, steam traps had been replaced and blockages were cleared.



- **G16:** Multiple pipes in the penthouse area require insulation repair.
Recommendation: Repair or replace pipe insulation in penthouse area.
M&V: As per visual inspection, piping in the penthouse area had new insulation installed.
- **G18:** Zone cabinet heaters and wall convectors are beyond service life and have difficulty maintaining comfort in the zones.
Recommendation: Replace zone heaters.
M&V: According to building management, this recommendation is being considered but there are no immediate plans for replacement.

Lighting

- **H1:** Classrooms have a large amount of access to daylight.
Recommendation: De-lamp or install a daylighting control system to take advantage of daylight harvesting potential.
M&V: As per building management, this recommendation is being considered, but there are no immediate plans for implementation.
- **H4:** Lighting in commons area is primarily incandescent.
Recommendation: Upgrade lighting to LED. Large usage of incandescent lighting in commons area-Recently upgraded lighting to LEDs
M&V: According to building management, a partial lighting upgrade to LED was completed, and visual inspection verified this. There are plans pending to upgrade the rest of the building to LED.



Photo 23. New insulation on piping in penthouse area.

Envelope

- **K1:** A possible roof leak at a penetration was observed.
Recommendation: Investigate possible roof leak and repair if necessary.
M&V: As per building management, investigation found no issues. No further action was taken.

Additional Measures

HVAC

- Basement boiler is kept running at 180°F during warm weather.
Recommendation: Disable boilers during summer.
M&V: As per building management, this recommendation was followed for the summer of 2018, but when the boilers were enabled for autumn, they had multiple issues including leaks, which they attributed to turning off the boilers for summer. To avoid these issues, the facility



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team made the decision to not shut off the boilers for summer 2019, and instead they were kept set at very low temperatures (90-100 °F).

Energy Consumption Comparison

Table 23: Building 7 Timeline

| | | | |
|--------------------------------------|-------------------|------------------------------|----------------|
| M&V Baseline: Pre-period | 1/1/17 - 10/31/17 | Implementation Period | 6/1/18 -6/1/19 |
| M&V Timeline: Post-period | 1/1/19 – 10/31/19 | Post TU Energy Data | 5 Months |

Data Analysis

- *Data gaps or spikes/dips:* There weren't any major spikes or dips noticed for energy consumption from 2014-2018 for this building. However, it is noticed that there was decreasing electricity usage in 2017 -2018 but consistent trend.
- *Data cleaning:* There had been a pretty consistent trend in electric and gas usage for this building since 2014. Therefore, no adjustments were needed to clean data.
- *Pre and post timeframe:* The implementation period partially overlapped the post period. Therefore, there are some potential energy savings that may not be factored in the analysis.

Energy Use Analysis Results

- For this building, we observed significant energy savings and GHG emission reduction when comparing 2017 vs. 2019. The numbers are 27.17% and 31.11% respectively.
- For the 1-year comparison, we observed about 2.7% of increase in energy use and 5.36% increase in GHG emissions between 2018 and 2019.
- For weather normalized analysis, we noticed relatively high energy savings 3.29% along with about 4.84% GHG emissions reduction when comparing 2017 vs. 2019.
- The table below provides pre and post energy use numbers for electricity, natural gas, total energy and GHG reduction.

Table 24: Building 7 - Pre- vs. Post-period (2017 vs. 2019) Energy Use & Emissions

| | % Change | kWh | therms | kBtu |
|----------------------|-----------------|------------|---------------|-------------|
| <i>Electric</i> | 20.38% | 65,598.83 | 2,238.77 | 223,823.21 |
| <i>Natural Gas</i> | 31.67% | 154,020.18 | 5,256.43 | 525,516.85 |
| <i>Total Energy</i> | 27.17% | 219,612.75 | 7,494.99 | 749,318.72 |
| <i>GHG Emissions</i> | 31.11% | | | |

Conclusion

The energy savings for Building 7 are likely partially a result of the tune-up measures enacted such as the BAS control changes for the boiler systems (which would affect both the natural gas use as boiler fuel source and electricity for fan use) and the LED lighting retrofit. Additionally, the boilers were turned off for the summer of 2018 but not for the summer of 2019, so it was expected that gas use would increase from the previous year. (The boilers were turned off for the summer of 2018 as per the Tune-Up recommendation, but when the boilers were enabled for autumn, facilities staff observed multiple issues including leaks, which they attributed to turning off the boilers for



summer. To avoid these issues, the facility team made the decision to keep the boilers running for summer 2019, but at very low temperatures.)

The building management is supportive of the city’s sustainability initiatives; they commented that the tune-up was surprisingly low-cost and that they appreciated the generous amount of time to complete the requirements. They also mentioned that they see a general need for controls and mechanical industries to work a little more closely together because it is helpful to have all the players there to help with the process of making efficiency upgrades.

Building 8

Description

Building 8 is a four-story, approx. 60,000-70,000 SF office building constructed in the 1980s, with an additional approx. 20,000 SF parking garage. The walls are concrete with furring and are insulated, probably to at least R-13 given the vintage. HVAC for most of the building is served by a multi-zone dual-duct AHU with fan powered VAVs. Heating is provided by a hot water boiler plant and cooling is provided by a chiller plant. The backup chiller failed and was replaced in August of 2019 (the old primary chiller is now the backup unit). A small data center (less than 1% of total floor space) is cooled by a Liebert air conditioning system; no heating is provided for the data center. Ventilation is demand controlled. The parking garage utilizes natural ventilation. DHW for most of the building is provided by natural gas water heating tanks, with an electric tank heater in the data center. The building has both DDC and legacy pneumatic control systems. Lighting is primarily T-8 fluorescent with some T-12s, controlled by a timeclock set to a 6am-6pm weekday schedule.

Table 25: Building 8 Characteristics

| | | | |
|----------------------------|-----------|------------------------------|---------------|
| <i>Decade Built</i> | 1980s | <i>Tune-Up Path</i> | Basic Tune-Up |
| <i>GFA</i> | 60-70K SF | <i>Fuel Sources</i> | Electric, Gas |
| <i>Primary Use</i> | Office | <i>Secondary Uses</i> | Parking |

Findings, Corrective Actions, and Verification

Initial Assessment (Pre-Action)

Assessment sampling method: In May 2018, the Tune-Up Specialist inspected and tested 12% of the dual duct VAV units, as per OSE director’s rule.

M&V Site Visits (Post-Action)

An M&V site visit at Building 8 was performed by SBC on 10/29/19. Verification methods included visual observation and verbal and written confirmation from building management, the Tune-Up Specialist and the controls contractor.

Because the open-plan office space was occupied at the time of the M&V site visit and building management wanted to avoid disrupting occupants, they did not want functional testing of equipment performed, as testing had already been performed by the controls



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contractor on 11/12/18 and the Tune-Up Specialist on 1/25/19. They were also under a time constraint so as an alternate to physical testing, management provided a detailed log from the Tune-Up Specialist of all equipment issues that had been addressed. See below.

| Issue No. | Required or Recommended | Issue Date | Initiator | Equipment Tag | Description | SBT Form ID Number | Issue Status | Corrective Action Performed/Owner Response | Confirmed Corrective Action is Complete |
|-----------|-------------------------|------------|-----------|---------------|---|--------------------|--------------|--|---|
| 1 | Required | 4/5/18 | KBA | South HWV | SOUTH HWV serving hot duct when commanded fully closed at 0% from the BAS appears to be leaking by as indicated by hot duct temperature significantly above return temper (-30 Degrees). Troubleshoot, repair and replace as necessary. | Table 1-1-G | Resolved | 10/15/18 - PacAir checked the south zone hot water regulating valve, found that the valve is ok, the transducer is bad, does not bleed down the pneumatic air completely at a no heat call. 11/12/18 - Zach with PacAir replaced transducer and the valve now closes completely. | 1/25/19 |
| 2 | Required | 4/5/18 | KBA | Cold Duct DSP | Cold duct static pressure sensor indicates 1.25" vice 2.00" at magnehelic gauge. Recalibrate as necessary. | Table 1-1-E | Resolved | 10/15/18 - PacAir checked the cold deck static pressure. The pressure is at 2.0" w.c. and the magnehelic reads 2.0". The setpoint and the static pressure reading on the DDC are 1.25" w.c. The sensor needs to be calibrated and the setpoint raised to 2.0" w.c. 11/12/18 - Zach with PacAir checked sensor and it will need to be replaced. Will get us pricing to replace the sensor. 1/15/19 - Zach with PacAir removed failed transducer and install new transducer and checked operations and calibrations with duct static. | 1/25/19 |
| 3 | Recommended | 4/5/18 | KBA | West HWV | BAS feedback percentage does not appear to match actual valve position. Recommend recalibration of valve feedback input. | Table 2-1-C | Resolved | 10/15/18 - PacAir checked the west zone hot water regulating valve, found that the valve has a bad diaphragm in the actuator, and the output card in the controller is bad. The card should be putting out 4-20 MA and is putting out 45 MA. Picked up and installed a new diaphragm for the west hot water zone. Now the valve opens completely. | 1/25/19 |
| 4 | Required | 4/5/18 | KBA | VAV-102 | Hot Duct air volume unable to achieve heating CFM set point, unit appear to be several hundred CFM from set point. Troubleshoot, repair and replace damper as necessary. | Table 1-1-F | Resolved | (By Reception Area) 10/15/18 - PacAir checked VAV 102, the hot deck damper is completely open, but there is not much air presenting on the hot deck side. The hot deck static could be raised and then the CFM may be sufficient. Also found that the cold deck damper is opening on a call for heat. Controller needs to be checked. Obtained the information from the chilled water return sensor, and forwarded on to Rick for a replacement sensor. 11/12/18 - Found cold deck damper set in manual to 200cfm and program set to open cold damper with a call for heat. Reprogrammed damper and now cold damper closes 100% and heat duct getting 350cfm of heat, which, when tested is more than adequate to heat space. | 01/25/2019 400cfm was reached |
| 5 | Required | 4/5/18 | KBA | VAV-203 | When floor occupancy was commanded to unoccupied mode the unit Supply Fan continued to operate and dampers continued to modulate. Incorporate unit to occupancy schedule to reduce energy use in occupied mode. | Table 1-1-F | Resolved | 2nd floor 11/12/18 - Zach with PacAir, VAV-203 found occupied set to manual. Changed to auto, now it will shut down with the bldg. schedule. | 1/25/19 |
| 6 | Required | 4/5/18 | KBA | VAV-207 | When floor occupancy was commanded to unoccupied mode the unit Supply Fan continued to operate and dampers continued to modulate. Incorporate unit to occupancy schedule to reduce energy use in occupied mode. | Table 1-1-F | Resolved | 2nd floor 11/12/18 - Zach with PacAir - VAV not following bldg schedule. Reprogrammed VAV to follow global schedule. VAV will now Shutdown when Bldg. is unoccupied. | 1/25/19 |
| 7 | Required | 4/5/18 | KBA | VAV-107 | When floor occupancy was commanded to unoccupied mode the unit Supply Fan continued to operate and dampers continued to modulate. Incorporate unit to occupancy schedule to reduce energy use in occupied mode. | Table 1-1-F | Resolved | Mainroom 1st Floor (retrofitted to reliable?) 11/12/18 - Zach with PacAir - VAV not following bldg schedule. Reprogrammed VAV to follow global schedule. VAV will now Shutdown when Bldg. is unoccupied. | 1/25/19 |
| 8 | Required | 4/5/18 | KBA | VAV-111 | When floor occupancy was commanded to unoccupied mode the unit Supply Fan continued to operate and dampers continued to modulate. Incorporate unit to occupancy schedule to reduce energy use in occupied mode. | Table 1-1-F | Resolved | Kitchen 1st Floor (retrofitted to reliable?) 11/12/18 - Zach with PacAir - VAV not following bldg schedule. Reprogrammed VAV to follow global schedule. VAV will now Shutdown when Bldg. is unoccupied. | 1/25/19 |
| 9 | Required | 4/5/18 | KBA | VAV-109 | When floor occupancy was commanded to unoccupied mode the unit Supply Fan continued to operate and dampers continued to modulate. Incorporate unit to occupancy schedule to reduce energy use in occupied mode. | Table 1-1-F | Resolved | Assembly Room (retrofitted to reliable?) 11/12/18 - Zach with PacAir - VAV not following bldg schedule. Reprogrammed VAV to follow global schedule. VAV will now Shutdown when Bldg. is unoccupied. | 1/25/19 |
| 10 | Required | 4/5/18 | KBA | VAV-311 | When floor occupancy was commanded to unoccupied mode the unit Supply Fan continued to operate and dampers continued to modulate. Incorporate unit to occupancy schedule to reduce energy use in occupied mode. | Table 1-1-F | Resolved | By Freight Elevator 3rd floor 11/12/18 - Zach with PacAir - VAV not following bldg schedule. Reprogrammed VAV to follow global schedule. VAV will now Shutdown when Bldg. is unoccupied. | 1/25/19 |
| 11 | Required | 4/5/18 | KBA | VAV-310 | When floor occupancy was commanded to unoccupied mode the unit Supply Fan continued to operate and dampers continued to modulate. Incorporate unit to occupancy schedule to reduce energy use in occupied mode. | Table 1-1-F | Resolved | 3rd floor 11/12/18 - Zach with PacAir - VAV not following bldg schedule. Reprogrammed VAV to follow global schedule. VAV will now Shutdown when Bldg. is unoccupied. | 1/25/19 |
| 12 | Required | 4/5/18 | KBA | VAV-309 | When floor occupancy was commanded to unoccupied mode the unit Supply Fan continued to operate and dampers continued to modulate. Incorporate unit to occupancy schedule to reduce energy use in occupied mode. | Table 1-1-F | Resolved | Wall by AED 3rd floor 11/12/18 - Zach with PacAir - VAV not following bldg schedule. Reprogrammed VAV to follow global schedule. VAV will now Shutdown when Bldg. is unoccupied. | 1/25/19 |
| 13 | Required | 4/5/18 | KBA | CHILLER | Chillwater supply temperature and chillwater return temperature readings off by more than 8 degrees F with unit in recirc and no flow. Recalibrate, replaced as necessary. | Table 1-1-E | Resolved | 10/15/18 - PacAir - Sensor needs to be replaced. Obtained the information from the chilled water return sensor and forwarded on to Rick for a replacement sensor. 11/12/18 - Per Zach, Bob installed the new sensor and this is now reading correctly | 1/25/19 |

Photo 24. Detailed log of issues and correction/testing dates.

Required Actions

Based on the Tune Up Accelerator Summary Report for this building, the following required actions were identified (these are listed by category and assessment element ID):

HVAC

- G1:** When floor occupancy was commanded to unoccupied mode, eight terminal unit supply fans continued to operate and dampers continued to modulate.
Requirement: Change control settings so that supply fans are disabled in unoccupied mode.
M&V: The supply fans had all either been set to manual or were not following the building schedule at all. These settings have all since been changed and each unit tested to confirm proper functionality, as detailed in the log.
- G5:** Several sensors were malfunctioning, including the chilled water return temperature sensor, which was off calibration by 8°F.
Requirement: Adjust, repair, or replace faulty sensors.
M&V: The faulty sensor has since been replaced and tested to confirm proper functionality, as detailed in the log.
- G6:** Cold duct static pressure sensor indicated 1.25" versus 2.00" at Magnehelic gauge.
Requirement: Recalibrate or replace as necessary.
M&V: Upon further investigation, the controls contractor found that the duct static pressure



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- transducer was faulty, which has since been replaced and tested to confirm proper functionality, as detailed in the log.
- **G7:** South valve serving hot duct when commanded fully closed at 0% from the BAS appeared to be leaking, as indicated by significant delta between hot duct temperature and return temperature (>30 °F higher).
Requirement: Repair or replace valve as necessary.
M&V: Upon further investigation, controls contractor found faulty transducer (electric-pneumatic), which has since been replaced and tested to confirm proper functionality, as detailed in the log.
 - **G17:** Hot Duct air volume was unable to achieve heating cubic feet per minute (cfm) set point (appeared to be several hundred cfm lower than set point). Also, the cold deck damper was opening on a call for heat.
Requirement: Troubleshoot, repair, or replace the damper as necessary.
M&V: Upon further investigation, the cold deck damper had been set in manual to 200cfm and the programming set to open the cold deck damper on a call for heat, which was also causing the reduction in hot deck cfm. This has since been reprogrammed and tested to confirm proper functionality of maintaining heating cfm, as detailed in the log.

Recommended Actions

Based on the Tune Up Accelerator Summary Report for this building, the following recommended actions were identified (these are listed by category and assessment element ID):

HVAC

- **G18:** Both the boiler and the pneumatic control system are approaching end of life.
Recommendation: Upgrade to high-efficiency boiler and upgrade the leaky pneumatic control system to DDC.
M&V: According to management, they are considering these recommendations but there are no immediate plans for replacing this equipment.

Lighting

- **H2:** Lighting in restrooms, lounges/break rooms, storage closets, printing/copying rooms and conference rooms is controlled by manual switches. Exterior offices have access to daylight.
Recommendation: Install occupancy sensors in these areas. Install daylighting controls in exterior offices.
M&V: Building management is averse to occupancy sensors because of negative experience with occupancy sensors in these types of spaces. There are no plans to install any sensors.
- **H4:** Most of the lighting is T-8 fluorescent, but there are some T-12 fixtures in the basement file rooms, mechanical rooms, stairwells, and elevators.
Recommendation: Replace T-12s with T-8 fixtures; upgrade to LED for greatest savings.
M&V: Building management is considering this recommendation, but there are no immediate plans to implement it.

Water Use

- **J4:** Over 1000 SF is irrigated, and there is no rain sensor.
Recommendation: Recommended a rain sensor be installed to prevent watering on rainy days.
M&V: According to building management, irrigation is only enabled for a short period in the summertime when there is very little rain, and doesn't feel it would be worth the investment.



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- **J12:** Water fixtures appear to be original vintage from period of construction.
Recommendation: Replace with low-flow fixtures.
M&V: Building management plans to replace fixtures only as they wear out.

Energy Consumption Comparison

Table 26: Building 8 Timeline

| | | | |
|--------------------------------------|-------------------|------------------------------|-------------------|
| M&V Baseline: Pre-period | 1/1/17 - 10/31/17 | Implementation Period | 4/5/18 – 11/12/18 |
| M&V Timeline: Post-period | 1/1/19 – 10/31/19 | Post TU Energy Data | 10 months |

Data Analysis

- *Data gaps or spikes/dips:* There weren't any major spikes or dips noticed for energy consumption from 2013-2018 for this building.
- *Data cleaning:* There had been a pretty consistent trend in electric and gas usage for this building since 2013. Therefore, no adjustments were needed to clean data.
- *Pre and post timeframe:* The tune-up was completed just prior to the post period..

Energy Use Analysis Results

- For this building, we observed substantial energy savings and GHG emission reduction when comparing 2017 vs. 2019. The numbers are 14.42% and 5.65% respectively.
- For the 1-year comparison, we observed slight energy savings of 1.25%, but, a significant increase in GHG emissions at about 23.94% between 2018 and 2019.
- For weather normalized analysis, we noticed relatively more energy savings 1.51% along with about 6.28% GHG emissions reduction when comparing 2017 vs. 2019.
- Below table provides pre and post energy use numbers for electricity, natural gas, total energy and GHG reduction.

Table 27: Building 8 - Pre- vs. Post-period (2017 vs. 2019) Energy Use & Emissions – Non-normalized

| | % Change | kWh | therms | kBtu |
|----------------------|-----------------|------------|---------------|-------------|
| <i>Electric</i> | 16.73% | 174,423.06 | 5,952.74 | 595,131.48 |
| <i>Natural Gas</i> | 0.47% | 802.27 | 27.38 | 2,737.34 |
| <i>Total Energy</i> | 14.42% | 175,225.30 | 5,980.12 | 597,868.71 |
| <i>GHG Emissions</i> | 5.65% | | | |

Conclusion

Much of the electrical savings can likely be attributed to several of the tune-up measures that address electricity-consuming equipment, most notably replacing the chilled water return sensor and cold deck duct static pressure transducer (which was likely wasting a substantial amount of fan energy), and changing the VAV schedule control settings (which were also likely wasting fan energy).



The building manager said they weren't looking forward to the tune-up but it ended up being a better experience than anticipated in terms of the support from the city. They did mention that most of the proposals they received to do the tune-up work were too expensive and suggested that education be provided so that building owners realize they have many options for tune-up providers.

Building 9

Description

Building 9 is a two-story, approx. 60,000-70,000 SF trades education building with several large lab/classroom spaces, constructed in the 2010s. The walls and roof are steel framed and insulated, probably at least to R-19 and R-38 given the period, according to Washington State Energy Code. HVAC for most of the building (about 75% of the floor space) is served by single-zone constant volume AHUs, with the other 25% using VAVs (also equipped with DCV), all heated by two boilers. The building is ventilated with 100% outside air because of the need for dust control. Building pressure is controlled by relief air dampers. This is the only area of the building that is mechanically cooled. The first floor has radiant heating on the same boiler loop that serves the AHUs and VAVs. DHW for the building is provided by natural gas water heating tanks. The building has a DDC BAS. Lighting is primarily T-8 fluorescent, with some LED upgrades. The lighting is controlled on the same schedule as the HVAC, with some daylighting controls.

Table 28: Building 9 Characteristics

| | | | |
|---------------------|--------------------|-----------------------|---------------|
| <i>Decade Built</i> | 2010s | <i>Tune-Up Path</i> | Basic Tune-Up |
| <i>GFA</i> | 60-70K SF | <i>Fuel Sources</i> | Electric, Gas |
| <i>Primary Use</i> | College/University | <i>Secondary Uses</i> | N/A |

Findings, Corrective Actions, and Verification

Initial Assessment (Pre-Action)

Assessment sampling method: In October 2018, the Tune-Up Specialist inspected all heating and cooling systems; lighting in labs, classrooms, and select offices; and sampled 10% of the DHW fixtures.

M&V Site Visits (Post-Action)

An M&V site visit at Building 9 was performed by SBC on 11/14/19, with a follow-up visit on 12/16/19. Verification methods included visual observation, verbal and written confirmation from building management and the Tune-Up Specialist, and data capture using the following instruments:

- HOBO U12 temperature/humidity/light logger



- HOBO UX90-006 light/occupancy logger

Required Actions

HVAC

- **G1:** HVAC schedule follows classroom/lab schedule. However, holiday HVAC schedule is not configured.
Requirement: Configure holiday schedule for HVAC.
M&V: The BAS interface is accessed offsite at the college district facility office, so visual confirmation was not available at time of site visit. Building manager and Tune-Up Specialist confirmed that the holiday schedules were restored on 12/20/18.
- **G2:** Spray booths were going positive when exhaust fans shut down; it's possible the damper was closing before fan fully stopped.
Requirement: Inspect damper and troubleshoot/correct the sequence of operation so exhaust fan turns on before the make-up air unit (MAU).
M&V: A failed fan was found, causing the damper to not open. This has been corrected and was confirmed with testing during the site visit. Booth pressure is monitored closely with visual gauges and logged regularly.
- **G4:** Operator was manually adjusting lab occupancy schedule to start lab HVAC early on hot summer days.
Requirement: Automate using optimal start control function and include a night flush sequence if possible.
M&V: Optimal start function was enabled and performs satisfactorily, as confirmed with testing on 4/12/19, according to building management. The BAS interface is accessed offsite at the college district facility office, so visual confirmation was not available at time of site visit.
- **G5:** AHU outside air temperature sensor was showing much lower than expected temperatures. AHU-1: 54.2°F OAT vs bldg. OAT 57°F. AHU-4: 43°F. Another was reading 28 °F.
Requirement: Troubleshoot and repair/replace sensors as necessary.
M&V: Per building management, faulty sensors were replaced and tested on 4/12/19. The BAS interface is accessed offsite at the college district facility office, so visual confirmation was not available at time of site visit.

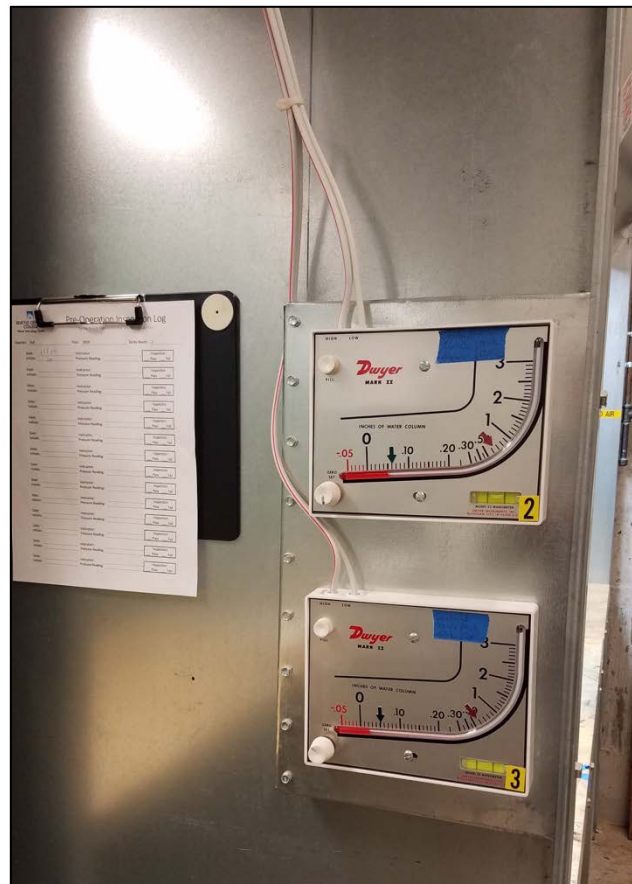


Photo25. Spray booth pressure is monitored and logged regularly.



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- **G6:** Operator overrides were only lasting for 30 minutes before the BAS reset to default settings.
Requirement: Adjust control settings to extend override period.
M&V: As per building management, the main reasons for overrides are environmental or for equipment failure (i.e. bad heating valve). The control sequence was adjusted and verified on 4/12/19. The BAS interface is accessed offsite at the college district facility office, so visual confirmation was not available at time of site visit.
- **G7:** Radiant floors observed to be in heating while the AHU was in cooling mode.
Requirement: Troubleshoot or refine control sequences.
M&V: Per building management, the set point for the radiant floors was adjusted on 12/20/18, and radiant floor now operates as expected. Cooling not enabled during time of the site visit so physical confirmation wasn't possible.
- **G17:** AHU-1 heating coil was staying at supply temperature set point even when heating valve commanded off.
Requirement: Inspect valve for possible leak or faulty operation.
M&V: As per building management, the actuator was adjusted on 4/12/19 and valve now fully closes, operating as expected. The BAS interface is accessed offsite at the college district facility office, so visual confirmation was not available at time of site visit.

Lighting

- **H3:** Lighting stays on past occupancy schedule.
Requirement: Configure lighting to same schedule as HVAC.
M&V: Building manager and Tune-Up Specialist confirmed that the lighting was set to follow HVAC schedule on 12/20/18. Lighting loggers were deployed, with data confirming these schedule settings (off at 21:00). See graph in Figure 4 below.

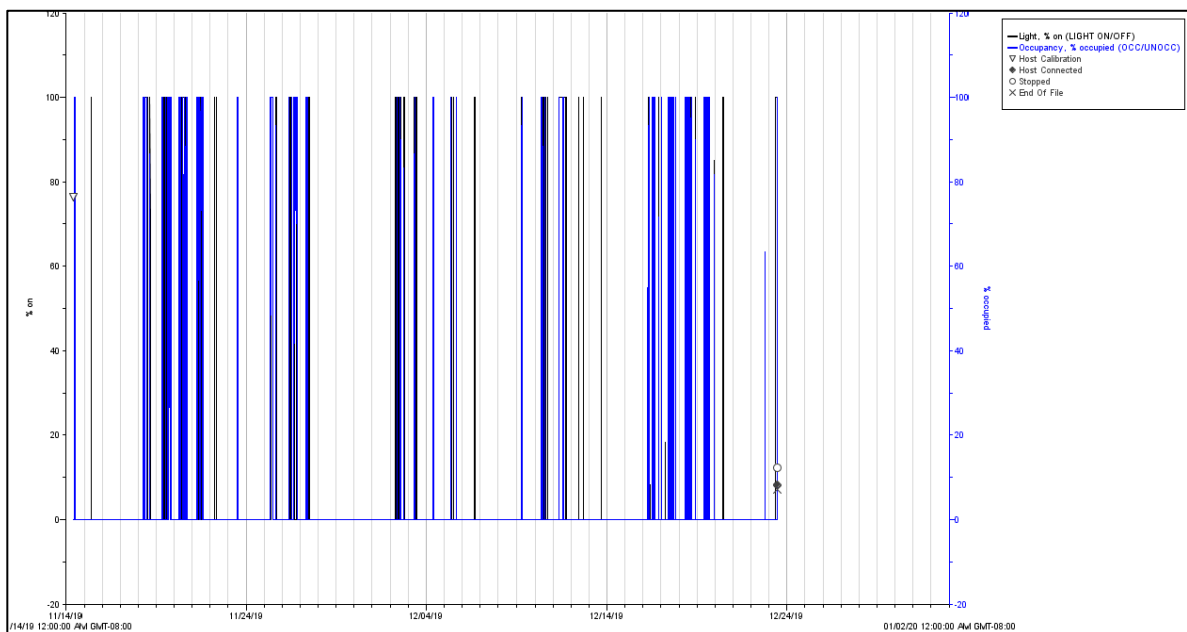


Figure 3. Lighting/occupancy logger data shows correct schedule.



Recommended Actions

HVAC

- **G8:** After hours, building pressure is high, mostly in section C (labs).
Recommendation: Have a TAB professional investigate.
M&V: According to management, TAB was not undertaken, but sequence adjustments seem to have resolved this issue, as confirmed on 4/12/19. The BAS interface is accessed offsite at the college district facility office, so visual confirmation was not available at time of site visit.

Lighting

- **H4:** Most of the lighting is T-8 fluorescent.
Recommendation: Continue upgrading to LED for greatest savings.
M&V: Building management's strategy is to continue upgrading hard-to-reach fixtures to LED, and to replace faulty fixtures with LED when possible.

Envelope

- **K1:** Rooftop drain above west wall of auditorium was dripping, and evidence of water infiltration was present in wood storage room. Water was running in from outdoors at entrance floors.
- **Recommendation:** Correct water intrusion issues.
- **M&V:** Building management confirmed that concrete at entrances were modified to prevent water run-in. Visual inspection confirmed that this had been addressed, as well as the rooftop drain and storage room issues.

Energy Consumption Comparison

Table 29: Building 9 Timeline

| | | | |
|--------------------------------------|-------------------|------------------------------|-------------------|
| M&V Baseline: Pre-period | 1/1/17 - 10/31/17 | Implementation Period | 11/1/18 – 4/12/19 |
| M&V Timeline: Post-period | 1/1/19 – 10/31/19 | Post TU Energy Data | 7 months |

Data Analysis

- **Data gaps or spikes/dips:** There weren't any major spikes or dips noticed for energy consumption from 2013-2018 for this building.
- **Data cleaning:** There had been a pretty consistent trend in electric and gas usage for this building since 2013. Therefore, no adjustments were needed to clean data.
- **Pre- and post- timeframe:** The tune-up was completed a couple months into the post period so it is possible that some energy savings may not yet be reflected in the available data.

Energy Use Analysis Results

- For this building, we observed substantial energy savings and GHG emission reduction when comparing 2017 vs. 2019. The numbers are 8.59% and 11.89% respectively.



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- For the 1-year comparison, we observed some energy savings of 2.79%, and GHG emission reductions 2.88% between 2018 and 2019.
- For weather normalized analysis, we noticed energy savings of 3.11% along with 5.93% GHG emissions reduction when comparing 2017 vs. 2019.
- Below table provides pre and post energy use numbers for electricity, natural gas, total energy and GHG reduction.

Table 30: Building 9 - Pre- vs. Post-period (2017 vs. 2019) Energy Use & Emissions

| | % Change | kWh | therms | kBtu |
|----------------------|----------|-----------|----------|------------|
| <i>Electric</i> | 5.65% | 31,275.03 | 1,067.36 | 106,710.40 |
| <i>Natural Gas</i> | 12.55% | 51,649.38 | 1,762.70 | 176,227.70 |
| <i>Total Energy</i> | 8.59% | 82,922.32 | 2,829.99 | 282,930.94 |
| <i>GHG Emissions</i> | 11.89% | | | |

Conclusion

Building 9 saw substantial savings, likely resulting from the tune-up measures performed, primarily in HVAC. The most notable measures were the schedule adjustments, building pressure control sequence adjustments, adjusting the actuator for the AHU hot water supply valve, and eliminating the simultaneous heating/cooling issue with the radiant floors. It is also important to note that these savings have occurred despite increasing building occupancy over the implementation and M&V periods, as classes have been added to the schedule.

Building management is very supportive of the city's sustainability efforts and as often as possible implements no or low-cost improvements when opportunities arise.

Building 10

Description

Building 10 is six-story, approximately 80,000-90,000 SF brick office building, constructed in the 1910s. An addition of two floors was completed in the 1990s, insulated to R-15 in the walls and R-35 in the roof. There is no insulation in levels 1-4, but the south wall is adjacent to another building. The building also has an approx. 10,000 SF parking garage with exhaust fans for ventilation. Floors 1-4 has single-pane, wood framed windows and floors 5-6 have double-pane, wood framed windows. HVAC is served by two packaged RTUs; one serves 75% of each floor and the other serves 25% of each floor. One is about 10 years old and the other is reaching its end of life. Both units stay on 24/7 to accommodate a call center on level 5. VAVs with electric



reheat serve the zones. The building has a DDC BAS that was recently upgraded from a legacy system. Controls have been upgraded on four floors, with the remaining two floors to be upgraded in early 2020. DHW is provided by natural gas tank heaters. Lighting is T-8 fluorescent throughout the building, with manual switches.

Table 31: Building 10 Characteristics

| | | | |
|---------------------|-----------|-----------------------|----------------|
| Decade Built | 1910s | Tune-Up Path | Basic Tune-Up |
| GFA | 80-90K SF | Fuel Sources | Electric, Gas |
| Primary Use | Office | Secondary Uses | Parking Garage |

Findings, Corrective Actions, and Verification

Initial Assessment (Pre-Action)

Assessment sampling method: In August 2018, the Tune-Up Specialist Walked each floor to review operations, temperature conditions, and layouts and physically inspected approximately three boxes per floor. In addition, setpoints and operating conditions were reviewed for all VAV boxes at the BMS.

M&V Site Visits (Post-Action)

An M&V site visit at Building 10 was performed by SBC on 11/15/19, with a follow-up visit on 12/16/19. Verification methods included visual observation, verbal and written confirmation from building management and the Tune-Up Specialist, and data capture using a HOBO UX90 motor runtime data logger.

Required Actions

HVAC

- **G1:** Parking garage exhaust was operating continuously from 6am to 9pm. The general occupancy schedule for the building is Monday through Friday, but both AHUs were always on because of 24/7 call center on level 5 (typically 4-5 occupants). VAVs on levels 1-4 and 6 are on from 6am-6pm M-F; VAVs on level 5 stay on 24/7.
Requirement: Reduce operating hour of garage exhaust fans to high-traffic hours only. Confirm AHU-1 satisfies 24/7 call-center operation on Level 5, and if so, schedule AHU-2 off at night.
M&V: Building management observed movement in garage to identify high-traffic periods, then changed the garage exhaust schedule to 7-9 and 4:30-6pm. Additionally, AHU-1 is set to serve the call center at night, with AHU-2 turned off, except during warm weather. Schedules were observed visually through the BAS interface, and motor data logger confirmed intended operation.



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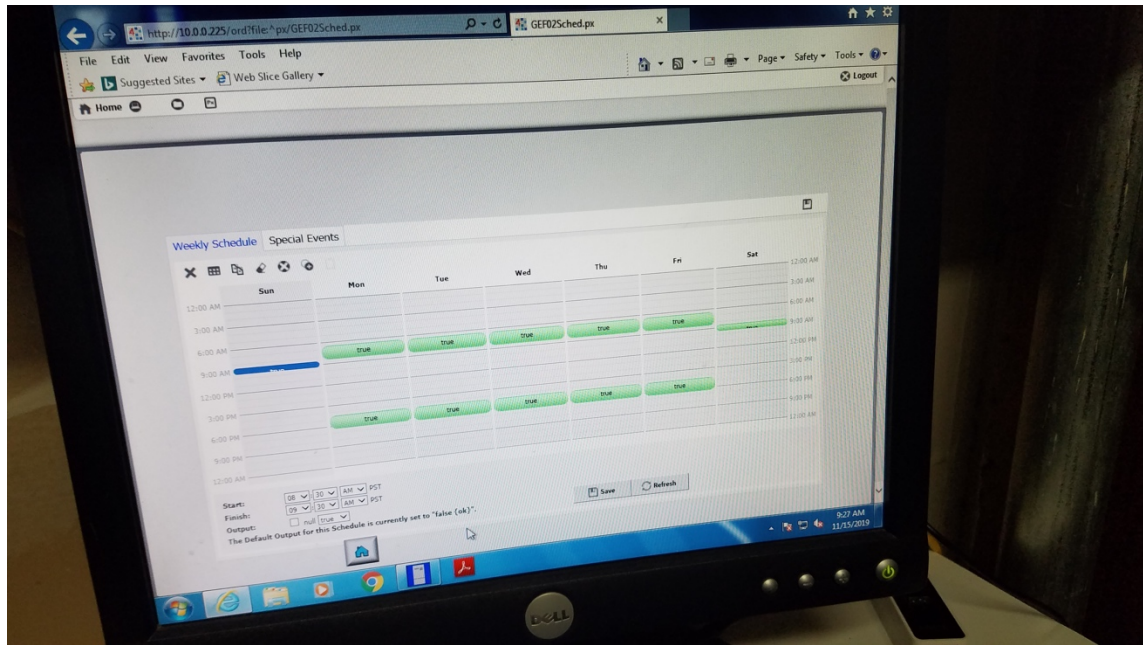


Photo 26. Reduced parking garage exhaust fan schedule.

- **G2:** HVAC set-point and set-back temperatures could be lowered.
Requirement: Review HVAC set-point and set-back temperatures and update as appropriate (e.g. 68°F /62°F in heating, and 75°F /80°F in cooling).
M&V: VAV settings were observed through BAS interface, and occupied set points were 72°F for heating and 75°F for cooling. Night set backs were 60°F for heating and 75°F for cooling.

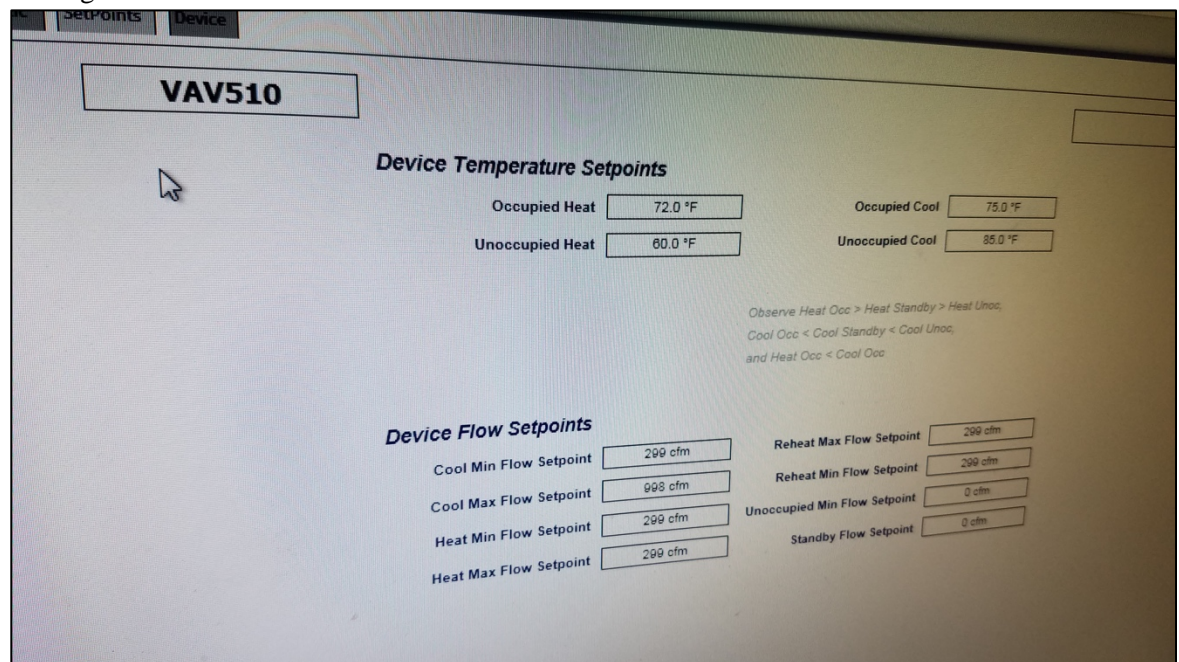


Photo 27. VAV set points and set backs.

- **G5:** Thermostats in office spaces are located near the ceiling.



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Requirement: Move thermostats from ceiling to wall according to ASHRAE guidelines where possible.

M&V: As per building management, this had been completed on 4 of 6 floors, with the other two floors scheduled to be completed as part of the remaining controls upgrade in early 2020. This was confirmed by visual observation.



Photo 28. Thermostats were previously located near the ceiling (left) but have been moved to a more accurate location further down the wall (right).

Recommended Actions

HVAC

- **G16:** Insulation on condensing water for AHU-1 damaged and missing in some places.
Recommendation: Consider replacing and covering to protect from degradation from sun damage.
M&V: This action had not completed per visual inspection during the site visit.
- **G18:** AHU-1 8 years old and still fully operational. AHU-2 age unknown, however, it looks older and may be nearing the end of its useful life. Original VAV boxes approaching 30 years old, and end of useful life.
Recommendation: Consider replacing aging equipment soon.
M&V: This action had not completed as per visual inspection during the site visit. According to building management, there were no immediate plans to replace the AHU, and VAV boxes will be replaced as they fail.

Lighting

- **H2:** All lighting is controlled by manual switches. Exterior offices have access to daylight.
Recommendation: Install occupancy sensors in conference rooms, storage rooms, and restrooms that are often not occupied. Install daylighting controls in perimeter areas.
M&V: According to building management, there are no immediate plans to upgrade the lighting controls.

Water Use

- **H2:** Various lavatory faucet flow rates observed throughout the building.
- **Recommendation:** Consider installing low flow fixture or aerators on lavatory and kitchenette faucets: 1.0-1.5 gpm lavatory faucets, 1.75 gpm showerhead, and 1.5 gpm kitchen faucet. Consider motion sensor lavatory faucet controls.



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- **M&V:** According to building management, there are no immediate plans to upgrade the water fixtures.

Energy Consumption Comparison

Table 32: Building 10 Timeline

| | | | |
|--------------------------------------|-------------------|------------------------------|------------------|
| M&V Baseline: Pre-period | 1/1/17 - 10/31/17 | Implementation Period | 8/9/18 – 4/12/19 |
| M&V Timeline: Post-period | 1/1/19 – 10/31/19 | Post TU Energy Data | 7 months |

Data Analysis

- **Data gaps or spikes/dips:** This building had consistent electric usage except for April 2014, which was normalized with average values from previous 3 years consumption. For natural gas, variable gas usage was noticed across different months for different years, which was unexplained.
- **Data cleaning:** Electric usage for April 2014 outlier was adjusted based on previous 3 years average consumption. Gas was not analyzed due to unexplained variability.
- **Pre and post timeframe:** The tune-up was completed a couple months into the post period so it is possible that some energy savings may not yet be reflected in the available data.

Energy Use Analysis Results

- For this building, we observed energy savings of 11.31%, and GHG emissions increase of 11.33% when comparing 2017 vs. 2019.
- For the 1-year comparison, we observed energy savings of 9.24%, and GHG emission increase of 9.26% between 2018 and 2019.
- For weather normalized analysis, we noticed energy savings of 2.42% along with 2.41% of GHG emissions reduction when comparing 2017 vs. 2019.
- Below table provides pre and post energy use numbers for electricity, total energy and GHG reduction.

Table 33: Building 10 - Pre- vs. Post-period (2017 vs. 2019) Energy Use & Emissions

| | % Change | kWh | therms | kBtu |
|----------------------|----------|------------|----------|------------|
| <i>Electric</i> | 11.31% | 108,921.33 | 3,717.29 | 371,639.58 |
| <i>Total Energy</i> | 11.31% | 108,921.33 | 3,717.29 | 371,639.58 |
| <i>GHG Emissions</i> | 11.33% | | | |



Conclusion

This building's electric savings are likely a result of the tune-up measures implemented, especially reducing the parking garage runtime by more than 75%, adjusting the VAV setpoint and setback schedules, repositioning the thermostats for more accurate readings at occupant level, and reducing the AHU runtime schedules during the unoccupied hours (while still maintaining operation for 24/7 call center). The variability in natural gas consumption could be a result of the controls upgrade; management had stated they were still getting used to the control system so it's possible further adjustments could be made.

M&V Conclusions

The M&V analysis examined a 10% sample (n=10) of the total population of Tune-Up buildings (n=102). In most all cases, the SBC team was working with limited post-tune-up utility data making it difficult to draw definitive conclusions regarding the impact on energy consumption. Likewise, the diversity of building types in the sample coupled with the limited post-tune-up utility data make it a challenge to apply perceived energy consumption impacts observations across the entire population. That said, the M&V process did provide relevant and informative insights about the function of the overall Tune-Up Accelerator program; on-site observations confirmed that actions were being accurately reported by the participants, providing assurance that this is likely consistently reflected throughout the overall cohort.

Overwhelmingly, the most common required and voluntary actions completed in both the sample and the total population were in HVAC. This is not surprising, as HVAC equipment is varied and complex with many possible combinations of systems and components, and thus presents the most opportunity for improvement.

The most frequently required actions in the sample were in HVAC schedules and HVAC controls (70% each). Overall, the most frequently required action for the whole Tune-Up population was HVAC schedules (58%), followed by set points (49%) and then controls (41%). These results also provide assurance that the sample is somewhat reflective of the overall cohort.

Efficiency loss due to schedule, set point, and controls issues are typical in any building that has been operating for an appreciable amount of time, for various reasons such as occupants changing settings, manual overrides for temporary situations that aren't changed back afterward, accidental changes in control settings by facility staff or contractors, occupancy changes that don't get changed in HVAC schedules, etc. Fortunately, these are usually the easiest situations to both identify and rectify, and this is reflected in the M&V results. All required actions in the sample were completed, with all but one action persisting (the thermostat settings in the hangar at Building 5), for a 98% persistence rate.

Sixty percent of the voluntary actions recommended in both the sample and the overall cohort were related to HVAC, with 20% in lighting and 10% each in water use and envelope. Fluorescent lighting is still more common than LED, and many buildings don't use efficient lighting controls. The relative ease of implementation and favorable paybacks associated with lighting upgrades make them "low hanging fruit" in terms of efficiency upgrades, so it is



reasonable to expect that lighting would be the next largest category of voluntary measures recommended and corrected.

From the weather normalized analysis, nine out of the ten buildings sampled showed some total energy savings, ranging from .05% to 2.42%. For the one building that saw a very modest increase in energy use (.11%), only electricity use was considered because the natural gas data was missing.

Only one of the buildings in the sample did not have any kind of BAS, but the remaining nine buildings varied widely in sophistication and level of control, from pneumatics to legacy DDC systems to recently upgraded, state of the art DDC systems. There was no observed correlation between amount of energy savings and the type of BAS system in use.

For a more comprehensive and conclusive M&V evaluation on similar programs in the future, it is recommended that at least a year of post-implementation utility data is obtained. The team originally planned for a longer post period, but many participating buildings didn't complete their required actions in time, which was an unforeseen challenge. A longer period for M&V would have helped to avoid overlapping between implementation period and post period for data analysis. Ideally, we would have compared 2017 vs 2020 as pre vs post to ensure that corrective measures were implemented thoroughly and changes in systems would have started to kick in. Another recommendation that would be helpful from an M&V standpoint is to require participants to report completion dates for each action implemented.

Most of the building representatives indicated that the Tune-Up had motivated them to take beneficial action, whether in terms of expected energy savings, improved maintenance processes and efficiencies, or influencing decisions that were already on the table. They were also generally happy with the support provided by the program in achieving compliance.