Energy Assessment: HVAC Controls Analysis

Springfield Township
Administration/Police Building
Free Library
Wyndmoor, PA

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Executive Summary

In October 2019, Practical Energy Solutions (PES) benchmarked the whole-building energy performance of the Springfield Township Public Works, Administration/Police, and Free Library buildings. We found the Police/Administration and Free Library facilities are operating less efficiently than comparable buildings across the country (see 10/2/19 PES report).

We then conducted an assessment of these two buildings, with emphasis on the HVAC building automation system (BAS), to guide the Township in its efforts to improve energy efficiency. We focused on the BAS because both buildings are relatively new and house modern equipment and energy-efficient lighting systems; the method of HVAC system control is therefore the most obvious (and common) source of energy waste. We based most of our analysis on information gained from the Township's *enteliWEB* BAS dashboard.

We found ample opportunities to refine these controls and reduce energy consumption in both buildings. In the Administration/Police building, we identified seven measures that will *conservatively* reduce whole-building energy use by one-third, save nearly $10,000 in annual utility costs, and reduce CO_2 pollution by approximately 130,000 pounds every year. In the Free Library, we identified very similar opportunities that will *conservatively* produce a 28% energy reduction, annual utility bill savings of approximately $6,200, and CO_2 pollution reductions of more than 76,000 pounds annually. One or two measures may require minor programming by the controls contractor, but the changes are simple and most are cost-free to the Township. All told, these changes will be highly cost effective, and their implementation will have the same environmental impact as planting nearly 4,800 mature trees or removing 21 passenger cars from the road.

This report explains each measure in detail. These measures are summarized in Table 1 (next page) and include:

- Controlling airflow, heating, cooling, and ventilation based on occupants' needs, as evidenced by CO_2 levels (an indicator of air quality) and thermostat setpoints, rather than by maintaining prescribed airflow setpoints.
- Eliminating unnecessary intake of outside air into the building and preserving previously heated return air for recirculation, to decrease heating and cooling/dehumidification demands.
- Refining hot water temperature algorithms to prevent overheating of the water used to heat the two buildings.
- Modulating hot water pump speeds based on demand, rather than requiring pumps to run at unnecessarily high speeds.
- Setting back unoccupied temperature setpoints by 2-3°F.

These measures will ensure occupants' needs are met and will help control humidity, temperature, and building pressure in a more effective and energy efficient way.

Importantly, our savings estimations are intentionally conservative, because sustainable energy reductions through BAS algorithm refinements require constant watch and strict BAS control. If the Township commits to achieving these recommendations to their fullest extent, there is substantial, additional opportunity to reduce energy use even further, while saving money and further reducing the Township's environmental footprint. Specifically, we believe an *additional* energy savings of up to 20% in the Administration/Police Building and 21% in the Free Library can be achieved -- producing an *additional* $9,700 annually in utility savings ($5,200 for the Administration/Police Building and $4,500 for the Free Library). Additionally, the whole-building energy benchmark for these two buildings will fall well below the national median – 23% and 36% less than the national median, respectively – making Springfield Township a model of energy efficiency in our region. PES is available to help the Township achieve and sustain these recommendations to their fullest by performing regular BAS trending reports and assessments.

Finally, we believe a second evaluation of the BAS during cooling season may reap even more energy savings.

Table 1: Conservative Estimation of Energy Savings: Overview of Energy Conservation Measures

#	Admin/Police Building Energy Conservation Measures (ECMs)	ANNUAL SAVINGS Electricity [kWh]	Natural Gas [therm]	Total Energy [MMBtu]	% Energy Savings	Energy Cost [$]	EUI [kBtu/SF]	CO_2 [pounds]
1	VAV Minimum Airflow Control	16,870	1,669	225	10.9%	$ 3,118	90.0	40,887.3
2	Minimum Outside Air Control	3,915	1,780	191	9.3%	$ 2,039	80.6	25,863.6
3	Increased Discharge Setpoint	26,962	-	92	4.5%	$ 2,463	76.1	33,972.1
4	Hot Water Reset Sequence	-	646	65	3.1%	$ 610	72.9	7,593.0
5	Police AHU Fan Static Pressure Setpoint*	11,806	-	40	2.0%	$ 1,078	71.0	14,876.0
6	Unoccupied Thermostat Setbacks, Admin	1,330	242	29	1.4%	$ 350	69.6	4,516.2
7	Hot Water Pump Reset Sequence	1,791	-	6	0.3%	$ 164	69.3	2,256.6
	Total Savings	62,674	4,337	648	31.4%	$ 9,821	69.3	129,965

#	Public Library Energy Conservation Measures (ECMs)	ANNUAL SAVINGS Electricity [kWh]	Natural Gas [therm]	Total Energy [MMBtu]	% Energy Savings	Energy Cost [$]	EUI [kBtu/SF]	CO_2 [pounds]
8	VAV Minimum Airflow Control	12,773	1,651	209	11.0%	$ 2,921	79.0	35,509.7
9	Increased Discharge Setpoint	-	1,829	183	9.6%	$ 1,727	70.5	21,507.6
10	Hot Water Reset Sequence	-	648	65	3.4%	$ 611	67.4	7,616.4
11	Unoccupied Thermostat Setbacks	1,516	515	57	3.0%	$ 648	64.8	7,964.9
12	Hot Water Pump Reset Sequence	2,904	-	10	0.5%	$ 310	64.3	3,659.3
	Total Savings	17,193	4,643	523	27.5%	$ 6,217	64.3	76,258

**This measure was implemented by the Township after we performed our analysis. It is retained here to show the associated energy and cost savings of all measures combined.*

Project Rationale

In October 2019, Practical Energy Solutions benchmarked the whole-building energy performance of the Springfield Township Public Works, Police/Administration, and Free Library buildings. The results showed the Police/Administration and Free Library facilities operate less efficiently than comparable buildings across the country, and suggest substantial opportunities to improve energy efficiency. We therefore engaged with the Township to conduct an assessment of these two buildings, with emphasis on the HVAC control system, since the lighting system is highly efficient and the building envelope is in good condition due to the relatively young age of the buildings.

Methods

Dianne Herrin, CEM, and Ben Pressman, P.E., of Practical Energy Solutions performed a site visit of the two buildings on October 31, 2019. We evaluated actual space conditions and recorded CO_2 measurements, air temperatures, and relative humidity so we could make general presumptions about how the HVAC systems are performing and verify actual findings against Building Automation System data. We gained on-line guest access to the Township's *enteliWEB* BAS dashboard and subsequently conducted a thorough evaluation of the control system algorithm. We developed recommendations for improving energy efficiency and quantified the energy savings associated with each recommendation. Our results follow.

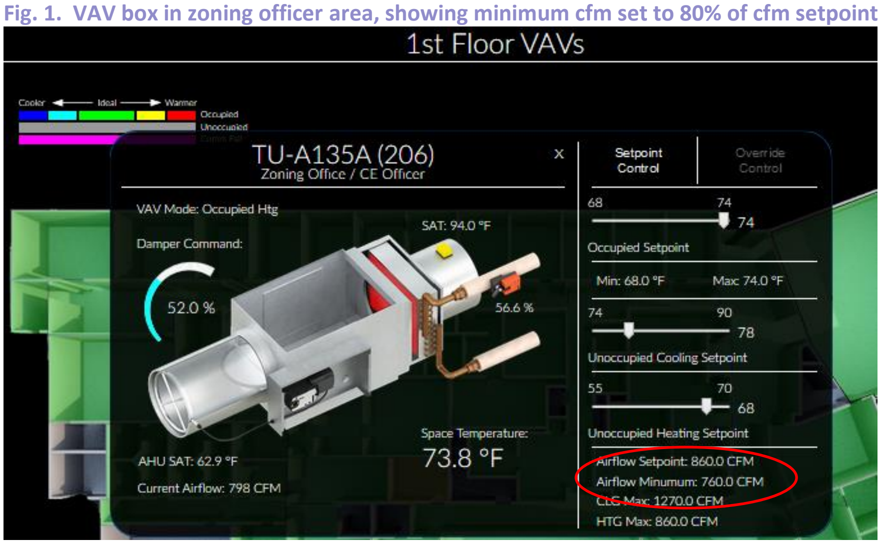
Administration/Police Building

Recommendations

Recommendation #1: VAV Minimum Airflow Control. Remove minimum airflow setpoints *or* set minimum airflow to 0 cfm for all VAVs. Allow space temperature and demand-controlled ventilation (DCV) sequence (CO_2 ppm) to dictate minimum VAV position. Increase CO_2 threshold to between 1,000 and 2,000 ppm.

Rationale: Currently, the average minimum airflow is set to ~60% of maximum airflow (Figure 1, next page). This is substantially higher than necessary and forces near-continuous airflow, heating, cooling, and ventilation even when space temperature and CO_2 concentrations are within acceptable ranges. This forces excessive reheat to occur during both heating and cooling seasons in order to maintain space temperatures.

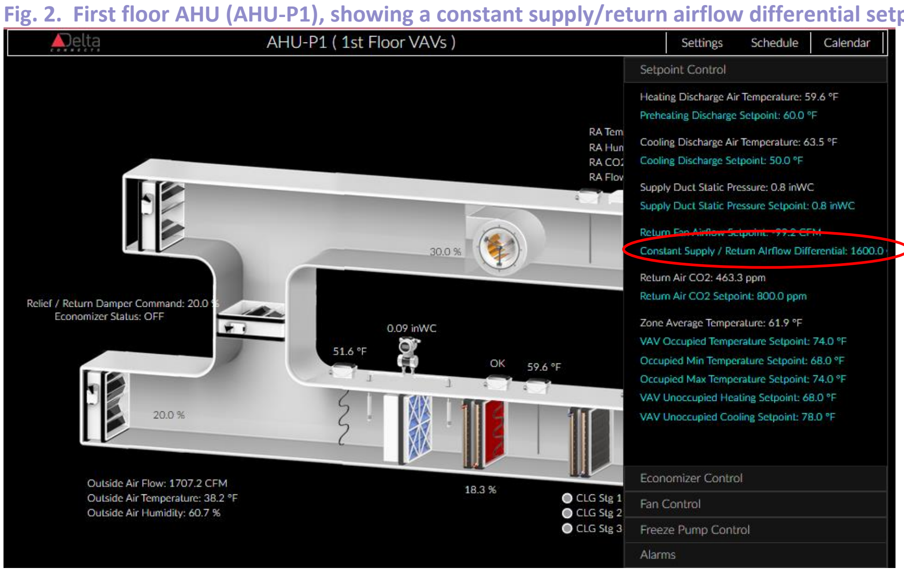
Fig. 1. VAV box in zoning officer area, showing minimum cfm set to 80% of cfm setpoint



Recommendation #2: Minimum Outside Air Control. Remove supply air/return air differential setpoint in AHU-A1 and AHU-P1. Modulate return fan speed in the AHUs to maintain static pressure setpoint *or* according to a % of supply fan speed in order to maintain target building pressure. Set minimum OA damper position between 2%-5%, and allow the DCV sequence (CO_2 ppm) and true economizer mode to control outside air damper position above this minimum value.

Rationale: AHU-A1 and AHU-P1 are set to require a minimum differential between supply air and return air of 1,500 and 1,600 cfm respectively (Figure 2). Although this is intended to control return fan speed, it forces the system to pull in excessive outside air. This increases heating and air conditioning needs. We recommend controlling return air fan speed in a more effective, energy-efficient way, via static pressure setpoint *or* % of supply fan speed. **This may require programming.**

Fig. 2. First floor AHU (AHU-P1), showing a constant supply/return airflow differential setpoint of 1,600



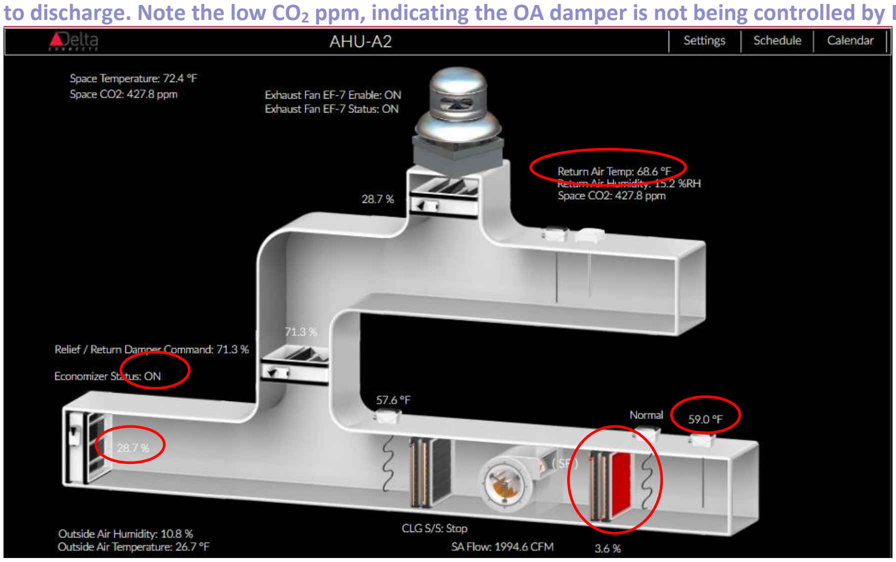
Recommendation #3: Increased Discharge Setpoint. Restore pre-heating discharge air temperature setpoint to design values (Figure 3, Table 2).

Table 2. Pre-heating discharge air temperature setpoints: Current vs. design values

	Pre-Heating Discharge Air Temperature Setpoint (F)	
Unit	*Current*	*Design*
AHU-A1	60	80
AHU-A2	_	100
AHU-P1	60	80

Rationale: Low pre-heating discharge air temperature setpoints are forcing the AHUs into economizer mode in order to cool the return air. This is causing cold outside air to enter the AHU, only to be reheated before leaving the unit and then reheated again at the VAV boxes. Increasing the pre-heating discharge air temperature setpoints will enable retention and recirculation of the warm return air and greatly reduce the need for reheating inside the AHU and VAV boxes. As stated earlier, the outside air damper position should be controlled by DCV (CO_2 at 1,000-2,000 ppm) and economizing during shoulder seasons. We understand the pre-heating discharge air is set at these low limits to address dehumidification; however, reducing outside air intake is a more effective and efficient way to control humidity.

Fig. 3. AHU-A2, showing unnecessary cooling of return air with cold outside air, and reheating prior to discharge. Note the low CO_2 ppm, indicating the OA damper is not being controlled by DCV.



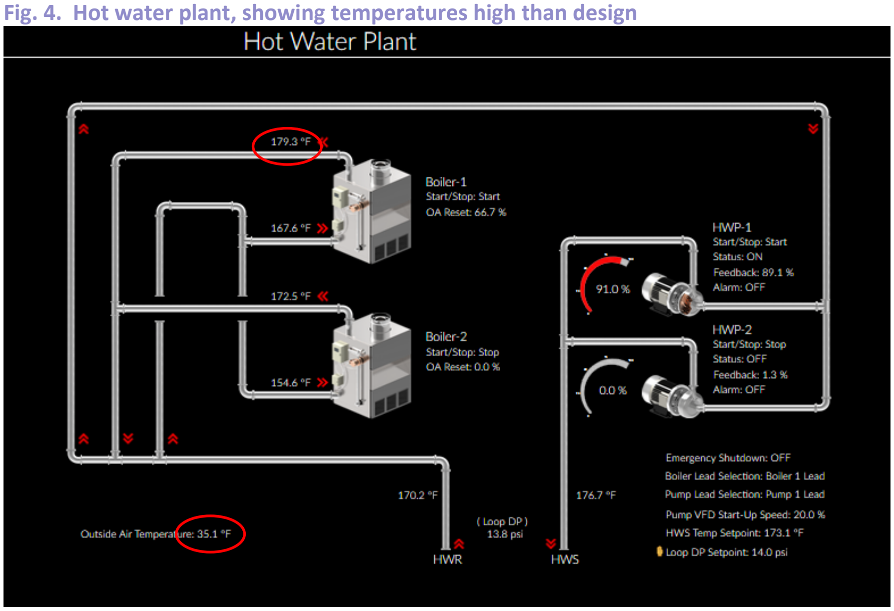
Recommendation #4: Hot Water Reset Sequence. Establish a more efficient hot water temperature sequence, preferably by implementing a hot water reset sequence based on heat load, or demand, whereby the boiler works off of return water temperature. Alternately, implement a more aggressive supply hot water reset sequence than is currently in place (as recommended in Table 3).

Table 3. Recommended supply hot water reset sequence

Recommended		Design	
Outdoor Air Temperature (°F)	Hot Water Setpoint Temperature (°F)	Outdoor Air Temperature (°F)	Hot Water Setpoint Temperature (°F)
15	150	15	180
40	130	40	160
60	110	60	140

Rationale: We observed hot water setpoint temperatures routinely hotter than prescribed in the design documents (Figure 4). The supply hot-water reset sequence in Table 3 is more aggressive than the design documents; however, we suggest trying this sequence to gain efficiencies while retaining comfort. This sequence is adjusted through the on-board boiler controllers. Ideally, however, we prefer a *load reset sequence* that sets supply water temperature based on *return* water temperature; this better ensures the boiler will respond to the actual needs of the building and maximizes energy efficiency. The load reset sequence will require additional programming in the BAS.

Fig. 4. Hot water plant, showing temperatures high than design



Recommendation #6: Unoccupied Thermostat Setbacks. Institute more aggressive unoccupied temperature setbacks as shown in Table 4.

Rationale: Currently, the unoccupied heating setpoint is 68°F and the unoccupied cooling setpoint is 78°F. Changing these setpoints by 2-3°F will save energy and operating costs.

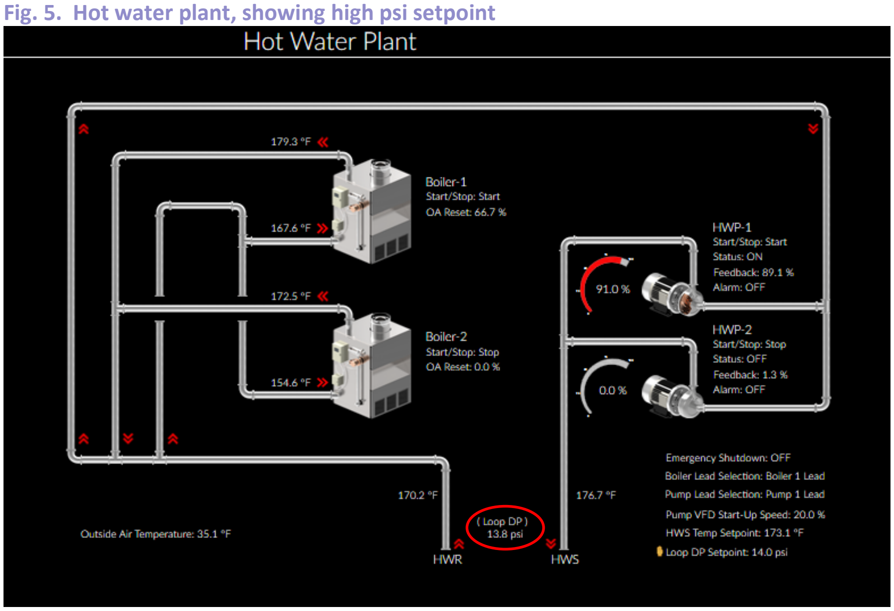
Table 4. Recommended unoccupied heating and cooling setpoints

Unoccupied Heating Setpoint		Unoccupied Cooling Setpoint	
Current	Recommended	Current	Recommended
68°F	65°F	78°F	80°F

Recommendation #7: Hot Water Pump Reset Sequence. Consider establishing a hot water pump reset sequence so hot water pump speed mirrors demand. This entails slowing the pumps when water is coming back too warm, then reducing hot water temperature if water temperature continues to remain high. Conversely, if water temperature comes back too cold, increase *temperature* first, then increase pump speed if still needed to meet heating demand. **This sequence needs review with controls contractor and BAS programming.**

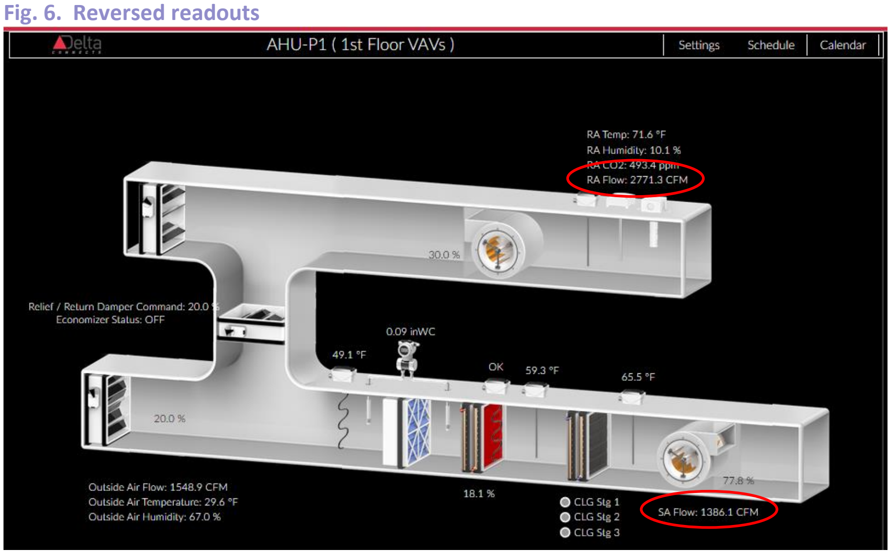
Rationale: Currently, the pumps are set to maintain ~14psi (Figure 5), requiring them to operate at higher speeds than necessary. Given the small differential between the leaving (supply) and incoming (return) hot water temperatures, the pump speeds appear higher than necessary. Controlling pump speeds will save energy due to the exponential relationship between pump speed and energy use; i.e., reducing pump speed by just 30% will reduce pumping energy by 61%. This will also enable programming of the load reset sequence suggested in Recommendation #4.

Fig. 5. Hot water plant, showing high psi setpoint



***Note*: We observed the supply and return air flow (cfm) readouts on AHU-P1 are switched and recommend correcting this in the BAS (see Figure 6).**

Fig. 6. Reversed readouts



Results

Together, these changes will conservatively reduce total energy consumption in the Administration/Police Building by approximately one-third (Table 5). The table shows the projected annual electricity, natural gas, and utility cost savings resulting from these changes.

Table 5. Conservative Scenario: Summary of Recommendations and Savings, Administration/Police Building

		ANNUAL SAVINGS						
	Admin/Police Building	Electricity	Natural Gas	Total Energy	% Energy Savings	Energy Cost	EUI	CO_2
#	Energy Conservation Measures (ECMs)	[kWh]	[therm]	[MMBtu]		[$]	[kBtu/SF]	[pounds]
1	VAV Minimum Airflow Control	16,870	1,669	225	10.9%	$ 3,118	90.0	40,887.3
2	Minimum Outside Air Control	3,915	1,780	191	9.3%	$ 2,039	80.6	25,863.6
3	Increased Discharge Setpoint	26,962	-	92	4.5%	$ 2,463	76.1	33,972.1
4	Hot Water Reset Sequence	-	646	65	3.1%	$ 610	72.9	7,593.0
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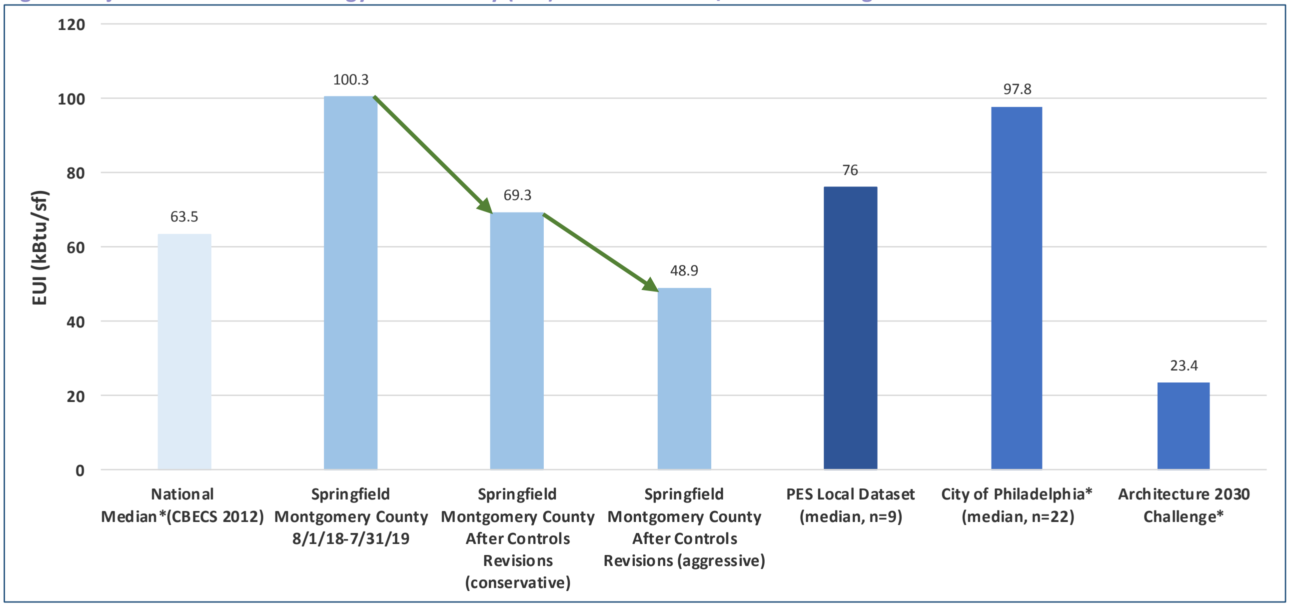
6	Unoccupied Thermostat Setbacks, Admin	1,330	242	29	1.4%	$ 350	69.6	4,516.2
7	Hot Water Pump Reset Sequence	1,791	-	6	0.3%	$ 164	69.3	2,256.6
	Total Savings	62,674	4,337	648	31.4%	$ 9,821	69.3	129,965

**This measure was implemented by the Township after we performed our analysis. It is retained here to show the associated energy and cost savings.*

These measures will bring the facility in line with the national median when it comes to whole-building energy use (Figure 7). If the measures are followed diligently and monitored over time, the Township can see up an additional 20% savings, resulting in an energy use intensity well below the national median (Figure 7).

Fig. 7. Projected reduction in energy use intensity (EUI): Administration/Police Building



Free Library

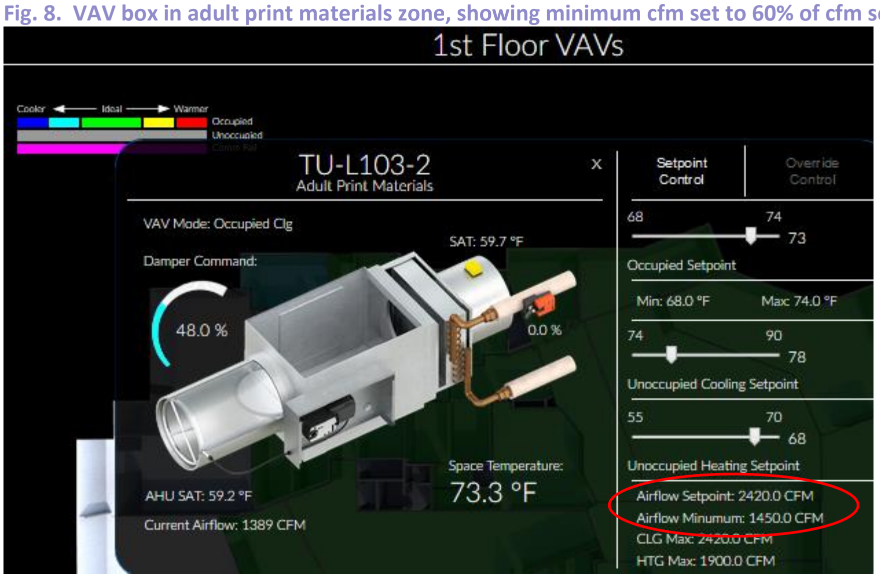
Recommendations

The recommendations for the Free Library mirror those of the Administration/Police Building. We have provided screen shots from the control system to demonstration the rationale.

Recommendation #8: VAV Minimum Airflow Control. Remove minimum airflow setpoints *or* set minimum airflow to 0 cfm for all VAVs. Allow space temperature and demand-controlled ventilation (DCV) sequence (CO_2 ppm) to dictate minimum VAV position. Increase the CO_2 threshold to between 1,000 and 2,000 ppm.

Rationale: Currently, the average minimum airflow is set to ~60% of maximum airflow (Figure 8, next page). This is substantially higher than necessary and forces near-continuous airflow, heating, cooling, and ventilation even when space temperature and CO_2 concentrations are within acceptable ranges. This forces excessive reheat to occur during both heating and cooling seasons in order to maintain space temperatures.

Fig. 8. VAV box in adult print materials zone, showing minimum cfm set to 60% of cfm setpoint



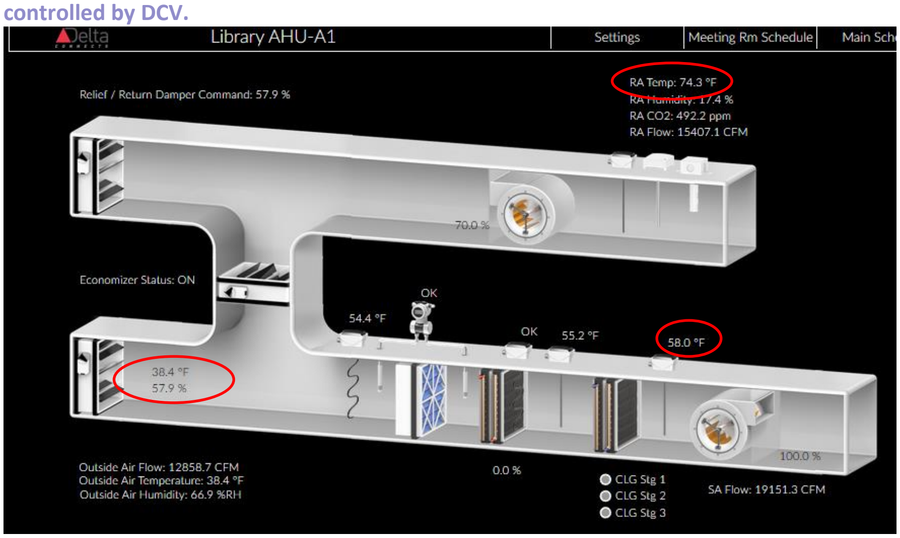
Recommendation #9: Increased Discharge Setpoint. Set pre-heating discharge air temperature setpoint to above design values (70-80 °F) (Figure 9 next page, Table 6).

Table 6. Pre-heating discharge air temperature setpoints: Current vs. design values

Unit	Pre-Heating Discharge Air Temperature Setpoint (°F)		
	Current	*Design*	*Recommended*
AHU-LIB	56.2	65	70-80

Rationale: The low pre-heating discharge air temperature setpoint is forcing the AHU into economizer mode in order to cool the return air. This is causing cold outside air to enter the AHU, only to be reheated before leaving the unit and again at the VAV boxes. Increasing the pre-heating discharge air temperature setpoints will enable retention and recirculation of the warm return air, prevent economizing during the cold winter months, and greatly reduce the need for reheating inside the AHU and VAV boxes. As stated earlier, the outside air damper position should be controlled by DCV (CO_2 set to between 1,000-2,000 ppm) and economizing during shoulder seasons.

Fig. 9. AHU-LIB, showing unnecessary cooling of return air with cold outside air, creating increased demand for reheating in VAV boxes throughout the building. Note the low CO_2 ppm, indicating the OA damper is not being controlled by DCV.



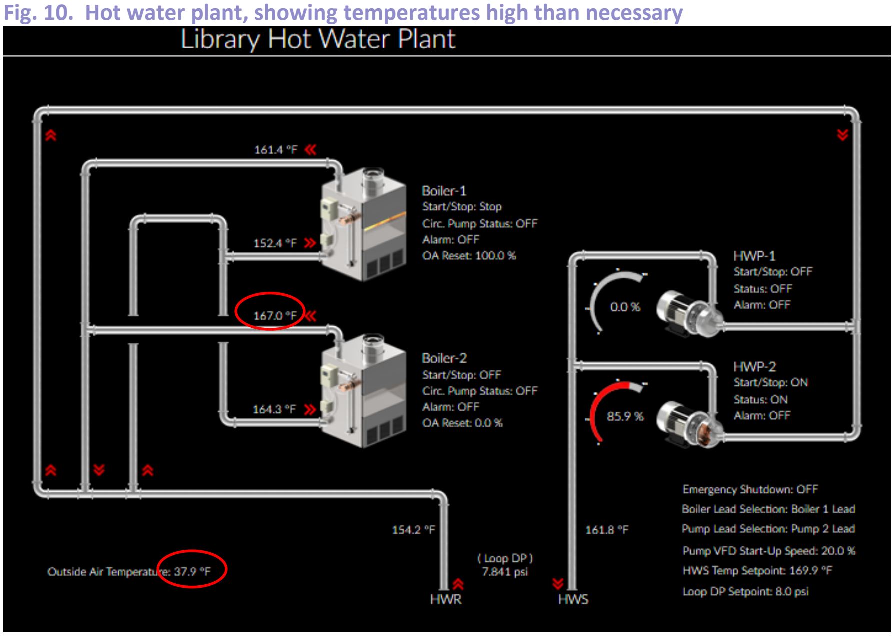
Recommendation #10: Hot Water Reset Sequence. Establish a more efficient hot water temperature sequence, preferably by implementing a hot water reset sequence based on heat load, or demand, whereby the boiler works off of return water temperature. Alternately, implement a more aggressive supply hot water reset sequence than is currently in place (as recommended in Table 7).

Table 7. Recommended supply hot water reset sequence

Recommended		Design	
Outdoor Air Temperature (°F)	Hot Water Setpoint Temperature (°F)	Outdoor Air Temperature (°F)	Hot Water Setpoint Temperature (°F)
15	150	15	180
40	130	40	160
60	110	60	140

Rationale: We observed hot water setpoint temperatures hotter than necessary (Figure 10, next page). The hot water reset sequence in Table 7 is more aggressive than the design documents; however, we suggest trying this sequence to gain efficiencies while retaining comfort. This sequence can be adjusted through the on-board boiler controller. Ideally, we prefer a *load reset sequence* that sets water temperature based on *return* water temperature; this better ensures the boiler will respond to the actual and changing needs of the building while maximizing energy efficiency. The load reset sequence will require additional programming through the BAS.

Fig. 10. Hot water plant, showing temperatures high than necessary



Recommendation #11: Unoccupied Thermostat Setpoints. Institute more aggressive unoccupied temperature setbacks as shown in Table 8.

Rationale: Currently, the unoccupied heating setpoint is 68°F and the unoccupied cooling setpoint is 78°F. Changing these setpoints by 2-3°F will save energy and operating costs.

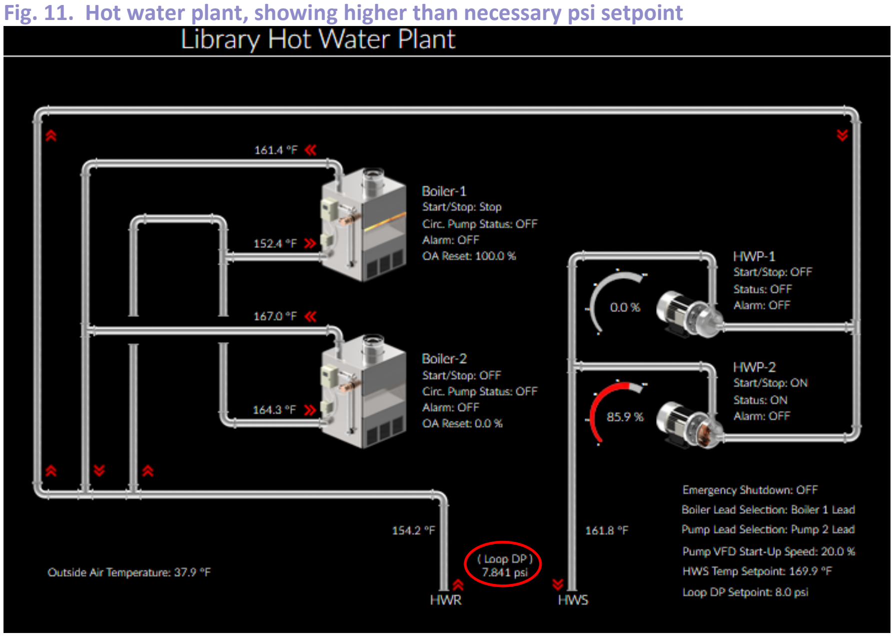
Table 8. Recommended unoccupied heating and cooling setpoints

Unoccupied Heating Setpoint		Unoccupied Cooling Setpoint	
Current	Recommended	Current	Recommended
68°F	65°F	78°F	80°F

Recommendation #12: Hot Water Pump Reset Sequence. Consider establishing a hot water pump reset sequence so hot water pump speed mirrors demand. This entails slowing the pumps when water is coming back too warm, then reducing hot water temperature if water temperature continues to remain high. Conversely, if water temperature comes back too cold, increase *temperature* first, then increase pump speed if still needed to meet heating demand. **This sequence needs review with controls contractor and BAS programming.**

Rationale: Currently, the pumps are set to maintain ~7.8 psi (Figure 11), requiring them to operate at higher speeds than necessary to meet heating demand. Given the small (<3° F) differential between the leaving (supply) and return hot water temperature, the pump speeds appear higher than necessary. This will also enable programming of the load reset sequence suggested in Recommendation 10.

Fig. 11. Hot water plant, showing higher than necessary psi setpoint



Results

Together, these changes will conservatively reduce total energy consumption in the Free Library by approximately 28% (Table 9).

Table 9. Conservative Scenario: Summary of Recommendations and Savings, Free Library

#	Public Library Energy Conservation Measures (ECMs)	ANNUAL SAVINGS Electricity [kWh]	Natural Gas [therm]	Total Energy [MMBtu]	% Energy Savings	Energy Cost [$]	EUI [kBtu/SF]	CO_2 [pounds]
8	VAV Minimum Airflow Control	12,773	1,651	209	11.0%	$ 2,921	79.0	35,509.7
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	Total Savings	17,193	4,643	523	27.5%	$ 6,217	64.3	76,258

This will bring the facility below the national median when it comes to whole-building energy use (Figure 12). If the measures are followed diligently and monitored over time, the Township can see up an additional 21% savings, resulting in an energy use intensity well below the national median (Figure 12).

Fig. 12. Projected reductions in energy use intensity (EUI): Free Library