Cheltenham Township Energy Assessment

Township Administration Building

8230 Old York Road, Elkins Park, PA 19027

Prepared By:

Practical Energy Solutions of West Chester, PA

Prepared For:

Cheltenham Township, as part of the Delaware Valley Regional Planning Commission's *Circuit Rider for Energy Efficiency* program

APRIL 2016

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Acknowledgments

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Executive Summary

The Cheltenham Township Administration Building (21,951 ft^2) is a three-story historic stone structure comprising administrative offices, a council meeting room, and storage space. It is located on a small municipal campus that includes three other buildings and a common parking lot.

The offices on the first and second floors of the administration building are typically occupied five days per week (approximately 40 hours per week). The third floor offices have been converted to storage, and a small portion serves as an employee lounge. The rarely occupied unfinished basement is used for mechanical equipment and storage.

On March 8, 2013, Practical Energy Solutions (PES) performed an energy assessment of the Cheltenham Administration Building on behalf of the DVRPC Circuit Rider Program. The site visit revealed substantial problems with the steam heating system—including a boiler near failure, no water treatment, steam and condensate piping leaks, lack of condensate return, and insufficient zone control. As a result, temperatures fluctuate throughout the building, causing occupants to run air conditioners and space heaters throughout the winter. The result is significant, uncontrolled energy use and occupant discomfort.

However unfortunate, this situation presents an ideal opportunity for Cheltenham to fully upgrade its HVAC system. Rather than apply significant capital to fix an inefficient, outmoded system, PES recommends the township invest in a new high-efficiency HVAC system that provides heating and cooling, improved zone control, and moves the township toward its goal of energy sustainability. PES specifically recommends disabling the steam system and installing a new distributed heat pump system with variable speed drive compressor (a.k.a. variable refrigerant flow, or VRF).

VRF systems are ideal for this application. They are scalable, which may allow the township to phase in the renovation if needed and add capacity in the future. They are highly efficient and provide both cooling and heating. They are compatible with the site, as the township has an existing concrete pad to house the outdoor condensing unit. Finally, they are compatible with renewable energy. Because these systems run on electricity, the township will be able to purchase renewable energy through the grid and/or install solar photovoltaic panels in the future to power the system. Both the high efficiency of this system and this renewable sourcing capability support the Cheltenham Township Sustainability Plan energy goal, which is to:

> *Maximize energy efficiency, minimize energy demand and emissions, and shift all community electricity consumption to renewably sourced energy generated within the township and the region.*

Additional recommendations include:

- *Light level reduction*. Delamping and fixture elimination in select, overlit areas will save the township an estimated $630 per year in electricity costs, reduce CO_2 emissions by more than 8,500 pounds per year, and pay back in 2 years or less.
- *Air sealing around window frames*. Although the township is planning a window upgrade, PES recommends keeping the existing windows and performing simple air-sealing as an interim measure. The HVAC system problems are so significant that a window upgrade may lead to more windows being opened in overheated rooms, causing further energy use. Unless both the window and HVAC projects can be performed simultaneously, PES suggests directing funds to the HVAC system upgrade as an essential first step.

In summary, the failure of the existing steam system places Cheltenham Township at an important crossroads. Upgrading to a high-efficiency VRF system will provide control, efficiency, and flexibility-thereby minimizing energy use and energy costs over time, reducing environmental impacts, and enabling a transition to a cleaner energy future.

Building Description

The Cheltenham Township Administration Building (21,951 ft^2) is a three-story historic stone structure comprising administrative offices, a council meeting room, and storage space. It is located on a small municipal campus that includes three other buildings and a shared parking lot.

The offices on the first and second floors of the administration building are typically occupied five days per week (approximately 40 hours per week). The third floor offices have been converted to storage, and a small portion serves as an employee lounge. The rarely occupied unfinished basement is used for mechanical equipment and storage.

Scope of Analysis

At the time of this site visit, the steam boiler was damaged, barely functioning, and in need of replacement. This assessment therefore focuses primarily on HVAC renovations, as this is an urgent need that presents an opportunity for Cheltenham to take tangible steps toward the community's goal of lowering energy use and reducing the use of fossil fuels.

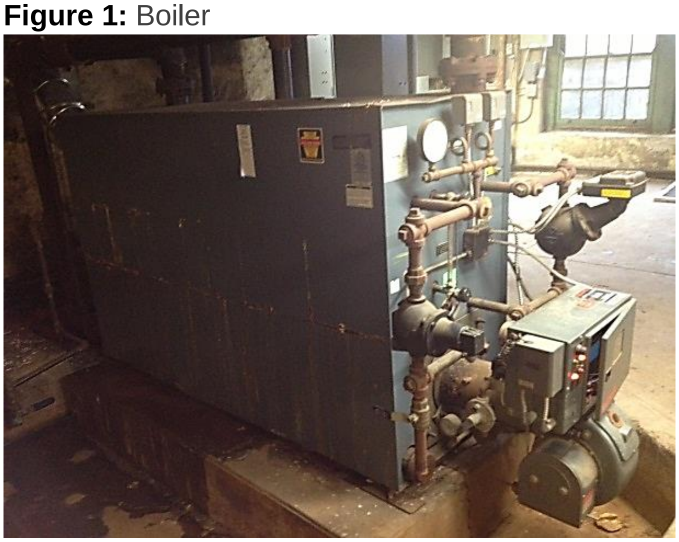
HVAC Assessment

Findings

The administration building is partially cooled by approximately 12 window-mounted air-conditioning units, two outdoor condensing units, and two mini split-systems. The building is heated by a gas-fired Weil McLain 1178 cast-iron boiler (630 MBH, 82 percent thermal efficiency, 1990 estimated manufacturing date) that provides steam to perimeter radiators. Appendix A contains an inventory of HVAC equipment.

At the time of the site visit, the boiler was damaged and leaking steam from the pressure vessel, substantially reducing steam pressure throughout the system. As a result, steam is unable to reach all of the radiators, causing significant temperature fluctuations and occupant discomfort throughout the building. The boiler is not expected to function through another winter season. An image of this boiler, captured during PES's site visit, is shown as Figure 1 below.

Figure 1: Boiler



Source: Practical Energy Solutions for DVRPC 2014

Additional problems with the steam system make it unlikely to ever operate as intended or adequately heat the building without wholesale redesign and repair. These obstacles include:

- *Lack of water treatment.* While steam systems in other Cheltenham Township facilities have water treatment components, this system does not. Without proper chemical treatment, solid deposits are left behind as steam evaporates. These deposits cause corrosion and insulate heat exchange surfaces, reducing efficiency and ultimately causing metal failure. The deposits can also clog the steam piping system components (i.e., steam valves and traps) and greatly reduce the longevity of any system repairs. The lack of water treatment has likely contributed to the boiler failure and caused piping, radiator, and steam trap damage.

- *Leaks in steam and condensate piping.* The steam system in the Cheltenham administration building is a two-pipe system. That is, one piping loop carries steam throughout the building for heat, and the second loop returns condensate water (formed as the steam cools down) back to the boiler for reheating. PES observed leaks in both piping systems. This worsens the low steam pressure problem and poses a safety hazard.

- *Lack of condensate return*. When functional, condensate return loops reduce the amount of energy needed to make steam because the condensate water that returns to the boiler is already hot, at nearly 212°F. The condensate line in the Cheltenham administration building is intended to be gravity fed, but it is not functional due to poor initial design and/or improper modifications over the years. Areas of the line turn abruptly and direct upwards, causing condensate to get “stuck” in the piping. To compensate, large amounts of fresh, cold (55°–60°F) “makeup” water are continually fed into the boiler to make new steam, requiring the boiler to use substantial amounts of energy to continually heat the cold water into steam. The maintenance staff has considered installing a condensate return pump to pull the condensate back to the boiler, but there is concern that the increased pressure may worsen piping leaks or even cause the piping to burst.

- *Lack of zone control.* A single manual thermostat located above the main stairs in the center of the building controls the steam system. Even if the system were properly functioning, this configuration would be insufficient to provide comfort. The colder (e.g., perimeter) offices cannot be consistently brought up to the setpoint temperature, because the single thermostat reads only the ambient temperature in the warmer, central area of the building.

This lack of zone control further increases energy use and energy waste. Rooms close to the thermostat and/or the boiler become overheated, and maintenance personnel report that some occupants run window air conditioners during the winter to maintain comfort. Employees in some of the more remote perimeter spaces, conversely, use energy-intensive, personal electric space heaters (which pose a fire hazard) to try to stay warm. The maintenance staff has tried to combat these problems by manually closing valves on some radiators in an effort to force steam to the perimeter units and to units that are furthest from the boiler. This has not worked, however, because steam pressure is too low due to the broken boiler and piping leaks.

HVAC Recommendations

To make the steam system operable, the township needs to invest in a new boiler, water treatment system, piping repairs, and improved thermostat/zone controls. Even when they function properly, however, steam systems are outmoded and inherently inefficient. And, with time, they rarely operate as intended due to significant and costly ongoing maintenance requirements. In addition, few service providers fully understand steam system operation and design, since it is old technology.

While unfortunate, the boiler breakdown presents an ideal opportunity for the township to invest in a modernized, energy-efficient HVAC system that will be compatible with renewable energy sources. It also offers the township the opportunity to obtain energy-efficient cooling for the summer season. Installing a system that is energy efficient and compatible with renewable energy sources is consistent with the Cheltenham Township Sustainability Plan energy goal, which is to:

> *Maximize energy efficiency, minimize energy demand and emissions, and shift all community electricity consumption to renewably sourced energy generated within the township and the region.*

Table 1 compares generally estimated project costs and benefits of four possible HVAC renovation strategies for this facility. The options include replacing the steam system with a hot water system, installing a high-efficiency distributed heat pump system with a common variable speed drive (VSD) compressor, installing high-efficiency single- and multi-zone heat pumps, or repairing the steam system.

PES recommends against any further repairs to the steam system, because this capital is better invested in a more efficient, more effective, and more serviceable HVAC system. Specifically, PES recommends retiring the steam system and installing a high-efficiency distributed heat pump system with VSD compressor.

Table 1: HVAC Renovation Options

Option	Project Cost (×1,000) [1]	Space Cooling?	Compatible with Renewable Energy Sources?	System Efficiency	Zone Control	Ongoing Maintenance Costs
Replace Steam with Hot Water System	$125[+]	No	No	Med	Fair	Med
Install Distributed Heat Pump System with VSD* Compressor	$100–$110	Yes	Yes	Very High	Excellent	Low/Med
Install Ductless Split System Heat Pumps	$75–$80	Yes	Yes	High	Good	Low
Repair Steam System	$60–$65	No	No	Low	Poor	High

Notes: *Variable speed drive. **Source:** Practical Energy Solutions for DVRPC 2014

Distributed Heat Pump Systems

Distributed heat pump systems, often referred to as variable refrigerant flow (VRF) systems, transport heat between a single outdoor condensing unit and a network of indoor units via refrigerant piping installed in the building. They offer numerous benefits in this application:

[1] *Project cost estimates are for comparison purposes only and* ***may not reflect actual project costs****. Estimates are derived from the* RSMeans 2011 Building Construction Cost Data *guide and experience with similar projects. Contractor quotations are recommended.*

1. *Scalability*. The township can continue to add indoor units until the capacity of the outdoor condensing unit is met. This scalability may allow the township to phase in this renovation if needed for budgetary and/or renovation or expansion purposes.

2. *Efficiency*. VRF systems are highly efficient, as the variable capacity feature precisely matches compressor output to actual demand. The system also has individual zones, so occupants can manage and schedule their demands for heating and cooling energy. The VRF system will also allow the township to remove the window air-conditioning units, and either seal the cavities or replace them with glazing. This will significantly reduce unwanted air infiltration and further lower HVAC energy use, thereby reducing the lifetime operational costs and environmental impacts of the HVAC system. Figure 2 below shows an infrared image captured during PES' site visit. The temperature measured by PES' infrared camera in the circle centered in the photo is 61.7°F, and the temperature toward the bottom of the AC units is closer to 50°F, indicating air infiltration through the unit.

Figure 2: Cold Air Infiltrating Through Window Air-Conditioning Units

Source: Practical Energy Solutions for DVRPC 2014

3. *Site compatibility.* Cheltenham has an existing concrete pad that could house the outdoor compressor. The single outdoor unit—a feature of the VFR system—also ensures site compatibility, whereas the split-system heat pumps require installation of numerous individual condensing units around the building exterior.

4. *Renewable energy compatibilit*y. Unlike the existing natural gas steam system, energy for the VRF can be renewably sourced. Upon installation, or in the future, the township can consider purchasing renewable electricity through the grid and/or installing solar photovoltaic panels to generate on-site renewable energy to meet the demands of the new HVAC system. Both the high efficiency of this system and this renewable sourcing capability support the Cheltenham Township Sustainability Plan energy goal.

Note: VRF systems are more expensive to purchase and install than split-system heat pumps. They are highly engineered and require advanced oil and refrigerant control components. A split-system heat pump system is PES's clear second choice, should the township choose to forego the VRF system. Like the VRF system, the split systems will enable removal of the window air-conditioning units, provide renewable energy compatibility, and offer improved efficiencies over the steam system.

Lighting

Within the last four years, the lighting system throughout Cheltenham's administration building was upgraded from T-12 fluorescent tubes to the much more efficient 32W T-8 fluorescent tubes with electronic ballasts. Lights are controlled by manual wall switches on the first and second floors, occupancy sensors on the third floor, and timers in the basement.

The majority of light fixtures are configured for two lamps, but there are about 30 fixtures in the lobby, copy room, council meeting room, and accounting office that contain four lamps. Light level measurements in these areas exceed the light level standard for this space type (30 to 50 footcandles), as shown in Table 2 below. Removing up to two lamps from each fixture will reduce energy use without compromising light levels. Table 3 shows the resultant estimated energy and cost savings.

Light levels in the tax office, second floor hallway, and second floor open office area also exceed the standard (Table 2). These areas contain two-lamp fixtures; therefore, PES suggests permanent removal of selected fixtures in these areas to reduce the light level to the recommended range and to further cut energy use (Table 3).

Table 2: Overlit Areas

	Footcandles	
Area	**Actual (range)**	**Recommended***
Accounting Office	73–114	30–50
Tax Office	75–88	30–50
Second Floor Hallway	68–80	20**
Room 206	53–72	30-50

Notes: *Energy Standard for Buildings Except Low-Rise Residential Buildings, ASHRAE/IESNA Standard 90.1 (2004), Lighting Handbook Reference and Application, 9th ed., Illuminating Engineering Society of North America. **Or not less than 1/5 the level in adjacent areas.
Source: Practical Energy Solutions for DVRPC 2014

Table 3: Lighting Level Reduction Recommendations

Item	Approx. # Fixtures	Annual Energy Savings		Energy Cost Savings [$/yr]	CO_2 Savings [lbs/yr]	Estimated Project Cost	Simple Payback [yrs]
4-lamp to 2-lamp conversion	31	4,594	kWh	$427	5,789	$ 737	1.7
Selected fixture removal	15	2,186	kWh	$203	2,754	$ 593	2.9
TOTAL	**46**	**6,780**	**kWh**	**$630**	**8,543**	**$1,330**	**2.1**

Notes: Energy savings attributed to removing fixtures is based on a 25 percent removal rate in the tax office, second floor hallway, and second floor open office area. This is meant to serve as an example only; a lighting professional should be consulted to develop a plan and to identify additional opportunities for energy conservation. Cost estimates are derived from RSMeans 2011 and PES experience with similar projects. The four-lamp to two-lamp conversion cost presumes installation of new two-lamp reflectors.
Source: Practical Energy Solutions for DVRPC 2014

Building Envelope

Windows

Windows throughout the facility are operable, double-paned units with wood frames. Windows in the council meeting room have metal frames. Employee interviews indicate that the windows are somewhat drafty; examination of the window frames confirmed this. Many have cracked sealant and signs of damage or poor installation. Figure 3 below presents two images showing window frame damage captured during PES's site visit.

Figure 3: Window Frame Damage

Source: Practical Energy Solutions for DVRPC 2014

Figure 4 below shows an infrared image captured during PES' site visit. The temperature measured by PES' infrared camera in the circle centered in the photo is 57.9°F, indicating that the thermal performance of the glazing is relatively good.

Conversations with maintenance staff revealed that a design firm is currently designing window upgrades for the facility. However, PES recommends placing the window upgrade on hold until the HVAC system is addressed or, at the minimum, performing both projects simultaneously if budget permits. Simply air sealing around the window frames as an interim measure will yield a better return on investment, while freeing funds for the much-needed HVAC upgrade. Until the HVAC system issues are addressed, a window upgrade may lead to more windows being opened in overheated rooms and additional air-conditioning units being run in the winter. Upgrading the HVAC system is an essential first step from both a financial, energy-use, and environmental perspective.

As shown earlier, the various window and through-wall air conditioners present a far greater source of cold air infiltration than the window frames. The previously described HVAC renovation plan will allow for these units to be removed and the penetrations properly sealed. The added expense of this portion of the HVAC upgrade project should be considered and prioritized above the window replacement.

Insulation

Finally, the exterior walls are heavy stone construction, and the roof is slate shingles. PES did not perform any destructive testing to determine insulation levels, but it is unlikely that installing additional insulation is a cost-effective energy efficiency measure. Heavy stone construction is, in and of itself, an excellent material for maintaining interior temperatures.

Figure 4: Window Glazing Thermal Performance

Source: Practical Energy Solutions for DVRPC 2014

Appendix A

Appendix A. Inventory of HVAC Equipment

				Cooling			Heating		
Description	Serves	Make/Model	Year	Capacity [Btu/hr]	Efficiency		Capacity [Btu/hr]	Efficiency	
Steam Boiler	Bldg	Weil McLain 1178	1990				630,000	82%	Et
Electric Space Heaters	Various	Various	n/a				25		
Window ACs (12)	Bldg	Various	2009	270,000	12.0	SEER			
Outdoor Condensing Unit	Council	Carrier	2004	60,000	10.0	SEER			
Outdoor Condensing Unit		Carrier 38TRA018	2003	18,000	12.0	SEER			
Mini Split Condensing Unit		Mitsubishi PU18EK		18,500	11.3	SEER			
Mini Split Condensing Unit		Mitsubishi MU09TW		8,500	10.2	SEER			

Source: Practical Energy Solutions for DVRPC 2014

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Energy, natural gas, electricity, energy management, heating ventilation air conditioning (HVAC), steam, boiler, lighting, air sealing, window, CO_2 emissions

Abstract:
On behalf of the DVRPC Circuit Rider Program Practical Energy Solutions (PES) performed an energy assessment of the Cheltenham Township Administration Building. PES evaluated the building's HVAC, lighting, and envelope for opportunities to save energy at this building. PES identified significant opportunities to improve and upgrade the building's steam heating system. Additional recommendations were made for reducing light levels, and installing air sealing around window frames to protect the existing windows.

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