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# City of Lawrence

## Investment Grade Audit Report

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# Executive Summary

The Investment Grade Engineering Audit conducted by 360 Energy Engineers has identified a number of opportunities for the City of Lawrence to improve its energy efficiency and facility performance through the implementation of an energy conservation project. Through comprehensive energy calculations based on actual utility rates, 360 Energy Engineers has identified $**512,333 in annual energy savings** potential. Additional **maintenance savings of $93,998 annually** has also been calculated.

360 Energy Engineers conducted a detailed evaluation of many Public Works and Parks and Recreation facilities for the City of Lawrence. A description of the facilities existing construction – as well as its mechanical, electrical, controls and other systems – can be found in the Facility Analysis section of this report. Dozens of opportunities were identified by 360 Energy Engineers' Professional Engineers and Certified Energy Managers as they conducted this detailed study for the City. This information is intended to provide accurate projections of energy savings potential, detailed data regarding potential upgrades to building systems, and the resources to aid the City of Lawrence in implementing building improvements that represent ideal long-term solutions.

Following final design and subcontractor procurement, the next step will be to perform the installation of the Energy Conservation Measures identified. During the construction phase of the project, 360 Energy Engineers' team will work diligently to ensure that the project is installed as designed, maximizing energy and maintenance performance for decades to come. During the construction period – and beyond – 360 Energy Engineers hopes to demonstrate its commitment to providing Lawrence with incomparable experience, expertise and value.

- Continued oversight and involvement of licensed Professional Engineers to ensure that the project is installed per their design details and intent.
- On-site construction management to oversee project installation by selected contractors, coordinate scheduling and minimize disruptions to occupied spaces.
- Effective commissioning of all functional systems, verifying correct installation and performance.
- Ongoing performance maximization to continuously commission all systems and ensure efficient, low-maintenance operation with maximum comfort.
- Decades of experience and a flexible approach mean the project developed for your facilities will yield the maximum benefits to your budget and buildings.
- Through efficient operation and an independent structure, 360 Energy Engineers delivers higher quality at a lower cost than any competition in the industry.

360 Energy Engineers feels strongly that our industry experience, engineering and energy conservation expertise, and superior value will make us the clear choice for your energy conservation or facility improvement projects. We hope to continue to serve you as you move forward to address your energy and facility needs.

Sincerely,

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Vice President of Business Development
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# Technical Approach

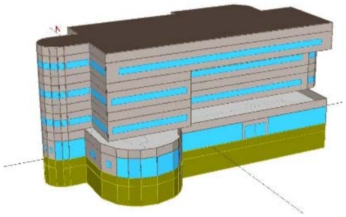
## Our Philosophy

Innovative designs and customized solutions create an opportunity for your project to be successful, but the detailed analysis and planning that goes into our solutions ensure that success. Our team completes its energy analysis and project design in-house, refusing to leave the success of your project in the hands of unconcerned third parties. Our in-house engineering team commits the time, effort, and expertise necessary to properly design every facet of your customized solution.

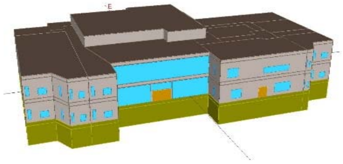
For the City of Lawrence, each aspect of the project is identified, analyzed and engineered by 360 Energy Engineers' professional engineers to produce full designs, including drawings and specifications, for each project. This allows 360 Energy Engineers to receive competitive bids from contractors without jeopardizing the performance or quality of the project. This competition, coupled with solutions engineered for maximum value, results in the lowest costs possible for the City of Lawrence.

This approach is uncommon for most performance contracting projects, where broad, undefined concepts are usually passed to contractors to price a turn-key solution. Not knowing details such as sizing, routing, equipment features, etc., the contractors have no other option but to make grossly conservative assumptions and price accordingly to make sure there is money to cover unknown issues during installation.

Preliminary building energy models examples:



City Hall eQuest model



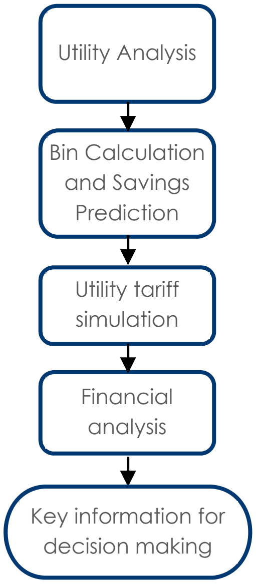
Art Center eQuest model

## Energy Savings Analysis Methodology

In order to evaluate how the City of Lawrence facilities use energy, formulate specific opportunities for energy conservation and accurately calculate energy savings, 360 Energy Engineers' engineers perform a detailed analysis process that encompasses:

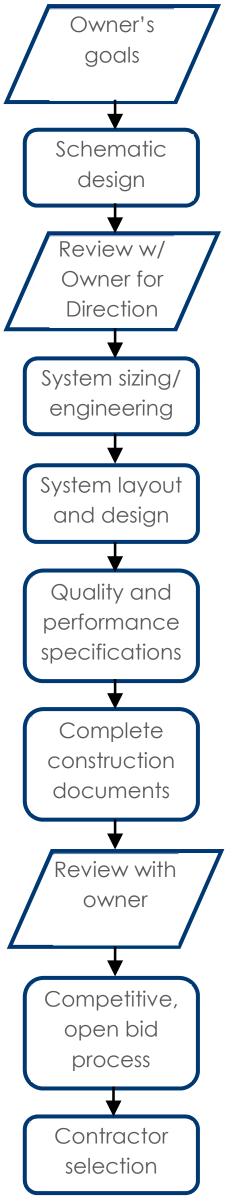
- Investigating facilities to gain a deep understanding of the energy consuming systems' operation and efficiency.
- Utilizing a combination of mathematically accurate bin calculations and detailed lighting and water consumption analysis to calculate energy savings in terms of kilowatt hours (kWh), kilowatts (kW), and Therms (Th).
- Building a detailed simulation of each facility's utility tariff to obtain an accurate annual dollar savings
- Performing a comprehensive financial analysis of each conservation measure being considered to provide owner/decision makers with the data needed to make informed decisions.

***Energy analysis process***



# Design and Engineering Methodology

***Engineering and Design Process***



360 Energy Engineer's approach to project design and engineering is what differentiates us from our competition. 360 Energy Engineers prides itself on being a true engineering company, contrasting most performance contracting companies that broker most aspects of the project, including engineering and design, to subcontractors. We develop a complete set of construction documents detailing our innovative designs and customized solutions. These documents are used to solicit competitive, consistent bids from contractors, and they are ultimately the roadmap for the contractors to use to ensure a successful project. Once the project is designed, our engineers remain heavily involved in the construction management process, guaranteeing that the intent and details of each design are properly installed, preventing contractors from omitting, neglecting, or modifying essential components of the original design. Through this constant and focused attention to detail, we deliver on the promise of our customized solutions and innovative designs – providing you a project of incomparable value.

Comprehensive and competent design and implementation not only create a high quality project, they create a smaller project price tag. In traditional performance contracting projects, clients pay significant premiums to fund the exorbitant risk for the performance contractor and its subcontractors. This risk results from the limited clarity and detail provided before the performance contractor commits to a guaranteed price. Establishing pricing on conceptual designs and estimates results in both the performance contractor and subcontractors hedging prices with hefty risk premiums. It also prevents the ability to attain competitive bids of equal scope from contractors, further confusing what the owner is actually getting for their money.

The table below compares and contrasts 360 Energy Engineers' engineering approach to traditional performance contracting:

| 360 Energy Engineers | Traditional PC | Advantage to 360 approach |
|---|---|---|
| Identify root of issues | Identify old equipment | Search for **underlying cause** of problems |
| Develop holistic solutions | Select new equipment | Diagnose problems not symptoms |
| Complete project design | Equipment replacement | **Provide value** of professional design |
| Create complete bidding documents | Identify basic project components for bidding | Competitive, **low-cost bids** instead of high pricing to cover risk of PC's vague scope |
| Detailed drawings and specifications | Favored contractors fill in the blanks | Eliminates risk to contractors, leading to lower pricing and superior quality |
| Product independence | Proprietary products | **Best products** to address your specific needs |
| On-staff design engineers | Contractors do design | **Qualified engineers** fully develop solutions |

# Construction Management Methodology

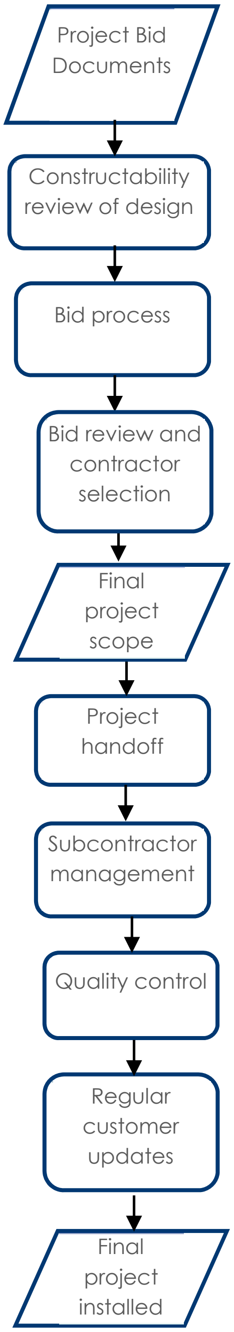
Project implementation through 360 Energy Engineers eliminates many of the hassles associated with the typical construction process. Our construction team's top priority is to ensure that the installed project meets our client's needs and the engineer's design. 360 Energy Engineers' construction manager oversees every aspect of the project's implementation and ensures that the project is built as designed.

360 Energy Engineers' construction management coordinates the contracting efforts with the owner and engineer. This careful coordination is essential to ensure the project is completed with minimal disruption to the owner's operations, is installed in a timely manner, is delivered on budget, and performs as the engineer intended. By acting as the sole source of accountability for your project, 360 Energy Engineers' construction team ensures that you receive the highest-quality, most cost-effective project installed in your facilities.

The table below compares and contrasts 360 Energy Engineers construction management approach to the traditional performance contracting approach:

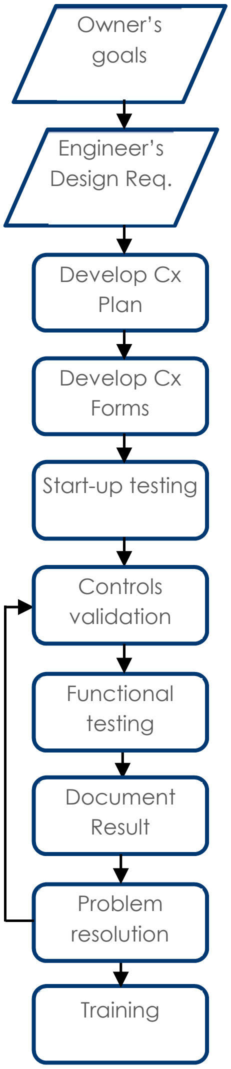
| 360 Energy Engineers | Traditional PC | Advantage to 360 approach |
|---|---|---|
| Ensure quality implementation | Verify project progress | Verifies quality defined in engineer's design and maximizes performance |
| Inspect all work by contractors | Contractor designed most work | Contractor **meets design requirements** rather than being given free reign |
| Verify compliance with engineer's design | Ask contractor if work is per design | Maximizes performance through system life and reduces total operating costs |
| Pay contractors when work complete per design | Pay contractors upon receiving invoice | **Your money** is protected until contractor has completed **quality installation** |
| Professional engineer who designed project performs final inspection | Contractor who designed and installed project gives approval | You ultimately get what you pay for with 360EE, contractor is free to cut corners with PC. |
| Complete system commissioning | Control system validation | Assurance that all systems perform as designed with 360EE, validation that controls appear to manipulate system properly with PC. |

***Construction Management Process***



# Commissioning Methodology

360 Energy Engineers' Commissioning Plan



360 Energy Engineers' primary goal on each project is to transform the owner's goals and requirements into the function of their building systems. In order to achieve this goal, 360 Energy Engineers' utilizes a systematic commissioning process that eliminates the common disconnects between the owner's goals, 360EE's engineering and design, contractor installation and final operation of each building system. Our polished commissioning process is just one of several reason why, project after project, we stand out from our competition.

360 Energy Engineers' commissioning is predominantly a quality assurance function – a verification of system performance, relying on enhanced field testing upon completion of construction. As with all quality assurance activities, simply testing the end product does not guarantee performance and may only serve to highlight performance deficiencies to be corrected.  In order to gain the greatest possible benefit from the commissioning process, 360 Energy Engineers' commissioning process contains all of the following elements:

- Continual Quality Assurance. 360EE's engineers and construction team make concerted efforts to continually build quality into all phases of the project, not just at the final performance testing.  They carefully monitor construction progress and verify compliance with contract documents and overall standards of quality.
- The Commissioning Plan.  This document is developed by 360 Energy Engineers engineering and construction teams to define the scope and format of the commissioning process and the responsibilities of all involved parties.  The Commissioning Plan is provided to all commissioning team members to inform them of the intent and scope of the commissioning work, to ensure inclusion in the project scope, and to expedite the commissioning process.
- Preparation for Testing.  To prepare for the system performance testing, 360 Energy Engineer's construction team and the contractors carefully examine the construction documents, submittals and contract revision documents.  The contractors develop and provide signed start-up forms (and/or Pre-functional Test Checklists) to 360EE's construction team for review and approval prior to beginning test and balance (TAB) and functional test activities. Using these forms, each contractor must verify that the systems are installed in compliance with the construction documents, are clean and properly prepared for operation, are fully functional for test and balance, and ready for functional testing. 360's engineers write all Functional Test Procedures, which identify the specific functional tests to be performed.
- Functional Testing. Functional testing is performed by experienced and qualified technicians of the contractor(s) responsible for installation as facilitated witnessed and documented by 360 Energy Engineers.  Functional testing verifies proper sequencing, operation and performance of installed equipment and systems under realistic operating conditions.  The functional testing follow the written Functional Test Procedures with test results documented for permanent record.
- Documentation.  Startup forms, TAB forms, and Functional Test Procedures are developed to guide the commissioning process.  Specific written documentation is maintained for all other commissioning activities.  Commissioning reports are generated by 360EE's construction team to document project issues, deficiencies and status of

construction and/or testing. Reports and resolution are tracked for the duration of the project. At the end of the commissioning process, all documentation is assembled and summarized in the final commissioning report.

- Problem Resolution. When a report is issued to address an identified deficiency, 360EE's construction manager forwards it to the appropriate parties to initiate corrective action in an expeditious manner. 360EE's engineers are relied on for design modification and issuance of final design details and the contractors are relied on for implementation of that design.

# Measurement and Verification Methodology

The measurement and verification (M&V) process is often the most confusing part of a performance contract. 360 Energy Engineers' approach is designed to provide a clear path to measurable energy savings. For the types of projects recommended for the City of Lawrence and their inherent energy impact, IPMVP Option A for Lighting as well as Option D for HVAC measurements offer the most cost effective, accurate method for quantifying the utility consumption reduction. Details of the measurements and calculations will be listed in the Measurement and Verification Plan.

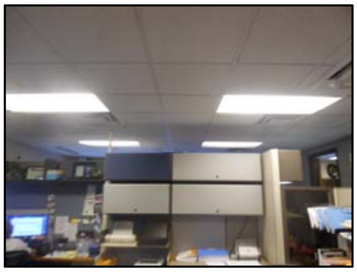
# Facility Assessments

## Public Works

### City Hall

- **General:** The City Hall building is a 27,828 square foot office building that includes several small private offices, an open lobby, and several large meeting rooms. This facility includes offices for several City departments including Public Works, Planning, Utilities, the City Manager, and the City Commission Chambers. City Hall has a basement floor with four additional floors. This facility is open during normal business hours with some extended hours for the City Commission chambers.
- **Building Envelope:** The facility has a brick finish with a flat roof. Large windows cover much of the north and south walls. The modified bitumen roof is displaying some degradation of the mineral layer.
- **Lighting Systems:** The lighting throughout the facility is primarily standard-efficiency T8 fluorescent fixtures with solid state ballasts. These lamps are rated at 32 watts. Fluorescent technology provides poor visibility compared to more modern lighting solutions and use significantly more energy to produce the same amount of light output. City staff has installed several LED retrofit tubes and luminaires throughout City Hall.
- **HVAC Systems:** The existing HVAC system for City Hall consists of a rooftop packaged unit with electric reheat VAV boxes. Some areas in the building are served by a VRF system. Electric cabinet unit heaters serve the stairwells and vestibules, although the temperature controls for these units no longer function correctly.
- **Energy Management Systems:** The existing HVAC system is controlled by a Johnson Controls BAS.


Existing City Hall windows


Existing T8 Lighting


New chiller on roof


Existing EMS thermostat

## Community Health

Brick and window envelope

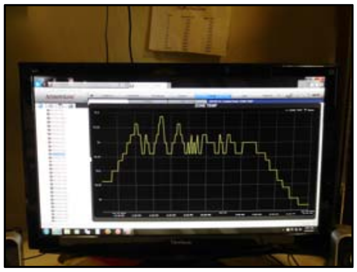
- **General:** The Community Health building is an 88,000 square foot office building that includes several small private offices, an a shared corridor on each floor, and several large meeting rooms. This facility includes offices for the Douglas County Health Department, the Visiting Nurses Association, and the Bert Nash Community Mental Health Center. This facility operates during normal business hours with varying occupancy levels. The Community Health Building was constructed in 1999, and it has not had any major renovations or additions.
- **Building Envelope:** The facility has a brick finish with a large, flat roof. The perimeter offices include large windows. The modified bitumen roof is displaying some degradation of the mineral layer.

Existing building boilers

- **Lighting Systems:** The lighting throughout the facility is primarily standard-efficiency T8 fluorescent fixtures with solid state ballasts. These lamps are rated at 32 watts. Fluorescent technology provides poor visibility compared to more modern lighting solutions and use significantly more energy to produce the same amount of light output. City staff has installed several LED retrofit lamps in the pendant fixtures installed in the large conference rooms. City staff has replaced many special Cold Cathode Tubes that were originally installed above soffits throughout much of the building. These Cold Cathode Tubes were replaced with T8 fluorescent luminaires.

100-ton chiller

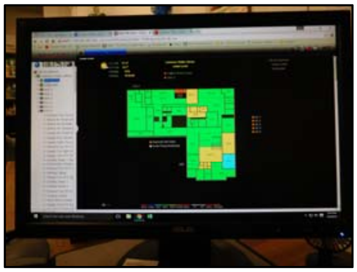
- **HVAC Systems:** The existing HVAC system for the Community Health Center consists of a 100 ton chilller on the roof, ten condensing boilers in the central mechanical room, multiple large air handlers, and many VAV boxes.
- **Energy Management Systems:** The existing HVAC system is controlled by an Automated Logic BAS.



Automated Logic interface

# Library

- General: The Library is an 85,000 square foot building that was completely reconstructed in 2014. This facility includes large, open spaces; several small offices; and an auditorium. This facility is open to the public from 9am to 9pm on weekdays with reduced hours on the weekends.
- Building Envelope: The facility is constructed of mixed materials, including pre-cast panels and large window walls. The flat roof was installed in 2014 and shows no signs of wear or degradation.
- Lighting Systems: The lighting throughout the facility is primarily standard-efficiency T5 fluorescent fixtures with solid state ballasts. These lamps are rated at 25 watts. Fluorescent technology provides poor visibility compared to more modern lighting solutions and use significantly more energy to produce the same amount of light output.
- HVAC Systems: The existing HVAC system for the Library consists of rooftop packaged units with VAV boxes. The VAV boxes use electric reheat.
- Energy Management Systems: The existing HVAC system is controlled by a full DDC system.



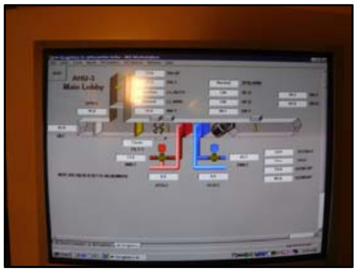
Library DDC Controls Interface

Library building lighting

# Arts Center

- General: The Lawrence Arts Center is a 55,000 square foot building that was constructed in 2000. This facility includes large, open studios; several small offices; a large auditorium; and a two-story atrium. This facility is open from 9am to 9pm with reduced hours on Sundays.
- Building Envelope: The facility is constructed of mixed materials, including brick, metal, and glass.
- Lighting Systems: The lighting throughout the facility is primarily standard-efficiency T8 fluorescent fixtures with solid state ballasts. These lamps are rated at 32 watts. Fluorescent technology provides poor visibility compared to more modern lighting solutions and use significantly more energy to produce the same amount of light output. Several CFL and Metal Halide recessed cans are installed throughout the building.
- HVAC Systems: The existing HVAC system for the Arts Center consists of a large rooftop chiller, two boilers, and multiple air handlers.
- Energy Management Systems: The existing HVAC system is controlled by an antiquated BAS.

Arts Center Chiller



Antiquated EMS at Arts Center

## Streets Division Complex

Incandescent lighting

Streets division thermostat

- General: The Streets Division Complex includes a 3,152 square foot office building, the "Red Barn", storage sheds, large parking lots for city-owned vehicles and maintenance. The Streets Division Complex operated during normal business hours except during harsh weather events when the sand trucks and plows are deployed.
- Building Envelope: The office building is a wood-frame structure with residential-style siding and a sloped, shingled roof. The doors, windows, and siding appear to be in adequate condition. The Red Barn is a metal building with large bay doors that are typically open during operating hours.
- Lighting Systems: The lighting throughout the facility is primarily standard-efficiency T8 fluorescent fixtures with solid state ballasts. These lamps are rated at 32 watts. Fluorescent technology provides poor visibility compared to more modern lighting solutions and use significantly more energy to produce the same amount of light output.
- HVAC Systems: The existing HVAC system for the office building is a residential style split system.
- Energy Management Systems: The existing HVAC system is controlled by traditional stand-alone thermostats.

## Solid Waste

Existing Solid Waste T8 Lighting

Solid Waste HVAC Unit

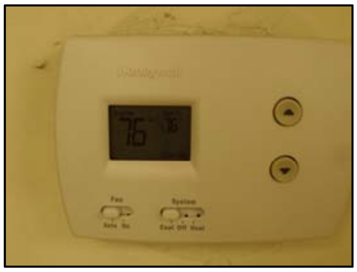
- General: The solid waste facility is a 2,600 square foot office building including several small private offices, open lobby, and employee locker rooms. This facility is the central hub for the solid waste division workers coming and going throughout the day making trips from residential neighborhoods to the waste dump.
- Building Envelope: The facility has a brick finish with an asphalt shingle roof. Visible moisture between window panes are an indicator of window failure.
- Lighting Systems: The lighting throughout the facility is primarily standard-efficiency T8 fluorescent fixtures with solid state ballasts. These lamps are rated at 32 watts. Fluorescent technology provides poor visibility compared to more modern lighting solutions and use significantly more energy to produce the same amount of light output.
- HVAC Systems: The current HVAC for the facility consists of a single-zone packaged air handler located to the South of the facility. This packaged unit was relocated from a nearby fire station and has reached the end of its service life. The unit is ducted into the facility and provides gas heating and dx cooling for the spaces. With an uncertain future for the facility moving forward, a simple unit replacement will ensure proper heating and cooling for the facility regardless of the function.
- Energy Management Systems: The current packaged unit is controlled by a traditional thermostat.

# Vehicle Maintenance

- General: The Vehicle Maintenance Garage is a 14,500 square foot facility including several large garage bays, open office space, conference room, and parts storage. This facility is responsible for maintaining operation of all the city vehicles including fire and medical, solid waste, and other public works automobiles.
- Building Envelope: The facility has a brick exterior with several large overhead roll up doors surrounding the building.
- Lighting Systems: The lighting throughout the facility is primarily standard-efficiency T8 fluorescent fixtures with solid state ballasts. These lamps are rated at 32 watts each. Fluorescent technology provides poor visibility compared to more modern lighting solutions and use significantly more energy to produce the same amount of light output. The shop bays have 400 watt metal halide luminaires which are very maintenance intensive and use more than twice as much energy than a comparable LED.
- HVAC Systems: With a large open shop environment it is very difficult to heat and cool the facility. The garage bays are heated with gas unit heaters hung from the ceiling of the facility. There are also several small evaporative coolers to help moderate the temperature in the summer. To ventilate the space, a large exhaust system is located in the shop mezzanine and provides fresh air to the spaces to limit the carbon monoxide levels. The office space and parts storage area are conditioned by a single split-system located in a mechanical closet. A small conference room is locate on the second floor along with some small offices that have now been converted to storage areas. To condition this portion of the building, a single-zone packaged unit is located on the roof. In the conference room, there is a small server room closet that must be cooled to prevent the equipment from over-heating. Having a server on this second floor, the packaged unit must maintain operation even while the conference room is unoccupied to continuously cool the server. De-coupling these two spaces would enable the existing unit to be able to setback its zone temperature, saving the current wasted energy.
- Energy Management Systems: The current packaged unit and split-system is controlled by a traditional thermostat. The shop heaters are controlled by unitary thermostats as well. The ventilation system has a central controller to monitor air quality and ventilate the space appropriately.

Gas-fired unit heater

Residential split system



Stand-alone thermostat

## Airport Terminal

- General: The Airport Terminal is a 7,500 square foot facility including office space, occupant lounge, and large front lobby.
- Building Envelope: The facility has a stone façade and wood siding exterior with large windows surrounding the exterior. Skylights and large windows facing the tarmac allow large amounts of natural light into the occupied space.


Outdated airport furnace

- Lighting Systems: The lighting throughout the facility is primarily standard-efficiency T8 fluorescent fixtures with solid state ballasts. The facility also has a large amount of CFL lamps lighting many of the spaces. Fluorescent technology provides poor visibility compared to more modern lighting solutions and use significantly more energy to produce the same amount of light output.
- HVAC Systems: Three split systems condition the facility. The current units are reaching the end of their service life and are in need of replacement. The mismatched outdoor condensing units are coupled to three Trane furnaces located in mechanical closets.
- Energy Management Systems: The current split-systems are controlled by traditional thermostats.


Airport T8 Lighting

## New Hampshire Parking Garage

- General: The New Hampshire Parking Garage is one of three large parking facilities located in downtown Lawrence. This facility includes the City’s Transit, Parking Division, and Animal Control Office. These spaces are located on the first floor of the facility.


Metal halide lighting at New Hampshire parking garage

- Lighting Systems: The lighting throughout the garage is primarily high output 250 watt and 175 watt metal halide fixtures. Several original metal halide luminaires in the stairwells have recently been replaced with LED wall packs. Some building wall packs still remain metal halide and are in need of replacement.
- HVAC Systems: The transit office, parking and animal control, and the maintenance shop in the basement are conditioned by three wall-hung Bard packaged units. These units use electric heat during the winter and are quite costly to operate.
- Energy Management Systems: The current packaged units are controlled by traditional thermostats.


Riverfront garage T5 lighting

## Riverfront Parking Garage

- General: The Riverfront Parking Garage is a two-level concrete parking structure.
- Lighting Systems: The ground level of the parking garage has a mix of 30ft area lights and decorative globes mounted on the adjoining building as well as entry gates and columns. Both types of luminaires are metal halide technology, and can be replaced with equivalent LED luminaires. The lower level of the parking garage has a large number of HE Williams Model 96 T5 Fluorescent fixtures. These fully-enclosed, low-profile, wrap-around fixtures are well suited for garage lighting, but replacements with LED fixtures will ultimately lower utility bills and reduce maintenance.

## Fire/Med #2

Highbay fluorescent lighting at Fire/Med #2

- General: The Fire/Med #2 building is a single-story firehouse built in 2002. This facility includes a large truck bay, sleeping dorms, a meeting room, a kitchen, and a living room. This facility is generally occupied every hour of every day.
- Building Envelope: The facility was constructed with mixed materials.
- Lighting Systems: The lighting throughout the facility is primarily standard-efficiency T8 fluorescent fixtures with solid state ballasts. The facility also has a large amount of CFL lamps lighting many of the spaces. Fluorescent technology provides poor visibility compared to more modern lighting solutions and use significantly more energy to produce the same amount of light output.
- HVAC Systems: Rooftop packaged units provide both heating and cooling to this facility.
- Energy Management Systems: The current systems are controlled by traditional thermostats.

## Fire/Med #3

Traditional thermostat at Fire/Med #3

- General: The Fire/Med #3 building is a single-story firehouse built in 1968 with a major renovation in 2003. This facility includes a large truck bay, sleeping dorms, a meeting room, and a kitchen space. This facility is generally occupied every hour of every day.
- Building Envelope: Ground-level windows were replaced as part of the 2003 renovation. However, several clerestory windows are original to the building and do not provide an adequate thermal barrier or protection against heat infiltration. The roof is in poor condition and should be replaced soon.
- Lighting Systems: The lighting throughout the facility is primarily standard-efficiency T8 fluorescent fixtures with solid state ballasts. Fluorescent technology provides poor visibility compared to more modern lighting solutions and use significantly more energy to produce the same amount of light output.
- HVAC Systems: Rooftop packaged units provide both heating and cooling to this facility.
- Energy Management Systems: The current systems are controlled by traditional thermostats.

## Fire/Med #4

Windows at Fire/Med #4

- General: The Fire/Med #4 building is a single-story firehouse built in 2006. This facility includes a large truck bay, sleeping dorms, a meeting room, a kitchen space, and a living room. This facility is generally occupied every hour of every day.
- Building Envelope: The facility was constructed with mixed materials.
- Lighting Systems: The lighting throughout the facility is primarily standard-efficiency T8 fluorescent fixtures with solid state ballasts. The facility also has a large amount of CFL lamps lighting many of the spaces. Fluorescent technology provides poor

visibility compared to more modern lighting solutions and use significantly more energy to produce the same amount of light output.

- HVAC Systems: Rooftop packaged units provide both heating and cooling to this facility. Electric reheat allows for individual control in each sleeping dorm at an increased utility cost.
- Energy Management Systems: The current systems are controlled by a BAS.

Lighting at Fire/Med #4

## Fire and Rescue Training Center

- General: The Fire and Rescue Training Center building is a single-story building constructed in 1968. This facility is has an identical floorplan as Fire/Med #3 before that facility's renovation. This facility includes a large truck bay, a meeting room, a kitchen space, and small storage areas. This facility is relatively unoccupied except for scheduled training sessions.
- Building Envelope: The facility is constructed of primarily brick with some cast-in-place concrete.
- Lighting Systems: The lighting throughout the facility is primarily standard-efficiency T8 fluorescent fixtures with solid state ballasts. Fluorescent technology provides poor visibility compared to more modern lighting solutions and use significantly more energy to produce the same amount of light output.
- HVAC Systems: Rooftop packaged units provide both heating and cooling to this facility.
- Energy Management Systems: The current systems are controlled by standard thermostats.

Fire & Rescue Training Center HVAC

Pump #1 at North Lawrence Pump Station

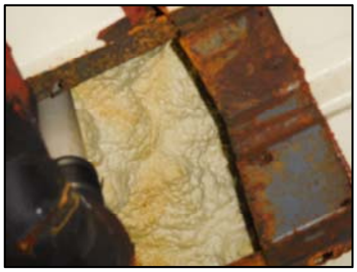
## North Lawrence Pump Station

- General: The North Lawrence Pump Station is a small building that protects two large pumps, a smaller sump pump, and all related controls. This building is unoccupied.
- Building Envelope: The building is constructed of brick and siding with a sloped, shingled roof.
- Lighting Systems: This facility has some fluorescent luminaires with very low run hours. A few metal halide wallpacks are mounted to the building exterior for security.
- HVAC Systems: A small unit heater protects the mechanical and electrical equipment at an operable temperature.

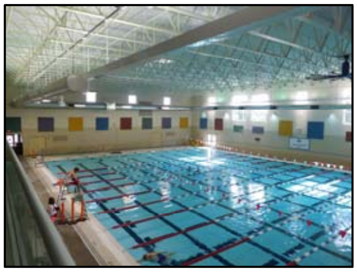
# Parks and Recreation

## Indoor Aquatic Center

- General: The Indoor Aquatic Center is a 44,000 square foot building that was constructed in 2001. This facility includes two large pool areas, locker rooms, an event room, storage areas, and an office area. The facility operates from 5:15 am to 8:45 pm with reduced hours on the weekends.
- Building Envelope: The facility is constructed of brick and concrete panel.
- Lighting Systems: The lighting throughout the facility is primarily standard-efficiency T8 fluorescent fixtures with solid state ballasts. These lamps are rated at 32 watts. Fluorescent technology provides poor visibility compared to more modern lighting solutions and use significantly more energy to produce the same amount of light output.
- HVAC Systems: The Indoor Aquatic Center HVAC system includes rooftop package units, specially-designed duct paths, and a heating water boiler.
- Energy Management Systems: The current systems are controlled by a DDC system.



IAC rust from poor ventilation



Lighting at IAC

## Outdoor Aquatic Center

- General: The Outdoor Aquatic Center main building (6300 square feet) includes a pump room, a meeting room, a lounge, locker rooms, and storage areas. A concession stand shares a roof with the main building and is connected via attic space. The Outdoor Aquatic Center operates from 5:15am to 8:45pm with reduced hours on Sundays. The Aquatic Center only operates during summer months.
- Building Envelope: The building is built primarily of stone and concrete with a sloped, shingled roof.
- Lighting Systems: The lighting throughout the facility is primarily standard-efficiency T8 fluorescent fixtures with solid state ballasts. Fluorescent technology provides poor visibility compared to more modern lighting solutions and use significantly more energy to produce the same amount of light output. Metal Halide area lights provide both full illumination of the pool area and security lighting at night.
- HVAC Systems: A single air handler provides conditioned air to the building.

OAC Pool

OAC Exterior Lighting

## Carnegie Building


Carnagie Lighting

- **General:** The Carnegie Building is a 12,000 square foot facility built in 1904 with an addition constructed in the 1930s. The most recent building renovation was completed in 2011. This facility includes a large event space, meeting rooms, and several office areas.
- **Building Envelope:** The building is constructed of brick and stone with a flat roof. Recent renovations and repairs have kept the building in adequate condition.
- **Lighting Systems:** The lighting throughout the facility is primarily standard-efficiency T5 fluorescent fixtures with solid state ballasts. These lamps are rated at 25 watts. Fluorescent technology provides poor visibility compared to more modern lighting solutions and use significantly more energy to produce the same amount of light output.
- **HVAC Systems:** The Carnegie Building is conditioned with a hydronic system utilizing a small boiler and dx condensing units. The air handler for the HVAC system is located in an attic space above a storage room.

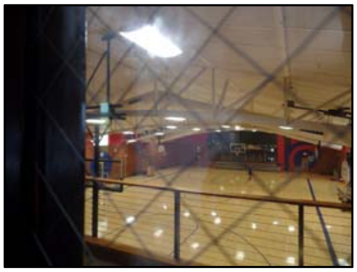

Boiler at Carnegie

## Community Building

- **General:** The Community Building is a 30,000 square foot facility located in downtown Lawrence. This recreation center includes a basketball court, cardio room, weights room, ballet dance hall, and other common assembly spaces used for various functions. The facility is operated daily as the downtown rec building from 7 a.m. to 9 p.m. throughout the week with reduced hours on the weekend.
- **Building Envelope:** The facility is comprised of a brick exterior with a rubber EPDM membrane roof.


Community Building RTUs

- **Lighting Systems:** The lighting throughout the facility is primarily standard-efficiency T8 fluorescent fixtures with solid state ballasts. These lamps are rated at 32 watts. Fluorescent technology provides poor visibility compared to more modern lighting solutions and use significantly more energy to produce the same amount of light output. The gymnasium lights were replaced recently with high output T5 fixtures that are doing a fantastic job of lighting the court. When these eventually lamps fail, it is recommended to convert the lighting systems to an LED alternative to lower the operating and maintenance costs.
- **HVAC Systems:** Twelve single-zone packaged rooftop units heat and cool the facility. During a previous renovation, the old racquetball room was repurposed as a cardio room. When this change was made, a new RTU was placed above this room to meet the new space needs. The remaining eleven RTUs are in need of replacement. Many of the units are over 20 years old and starting to cause issues for the maintenance staff. Several units on the facility walkthrough were noted to have persistent issues.


Community Building lighting

- **Energy Management Systems:** The existing rooftop units are controlled by a central control system accessible to the Parks and Recreation Administration from the maintenance office. This enables the system to be controlled with more advanced control sequences and can enable the system to run in a more efficient manner.

## Holcom Recreation Center

- General: The Holcom Recreation Center is a 19,500 square foot facility located in the central part of Lawrence. This recreation center includes a basketball court, workout room, rec room, and other common assembly spaces used for various functions. The facility is operated daily from 8 a.m. to 6:30 p.m. throughout the week and reduced hours on Saturday.
- Building Envelope: The facility is comprised of a concrete block exterior with a standing seem metal siding.
- Lighting Systems: The lighting throughout the facility is primarily standard-efficiency T8 fluorescent fixtures with solid state ballasts. These lamps are rated at 32 watts. Fluorescent technology provides poor visibility compared to more modern lighting solutions and use significantly more energy to produce the same amount of light output. The gymnasium lights were replaced recently with high output T5 fixtures that are doing a fantastic job of lighting the court. When these eventually lamps fail, it is recommended to convert the lighting systems to an LED alternative to lower the operating and maintenance costs.
- HVAC Systems: The facility is currently conditioned with four air handling units with DX cooling coils and hot water heat. Two of the air handlers were recently rebuilt and received a new condensing unit. The remaining air handlers are located in the gymnasium and are very difficult to maintain, requiring a lift to access the equipment for service. The condensing unit for the gym air handlers is past its expected service life and in need of replacement. Additionally, the current Ajax boiler has many issues. The steel tube design is very inefficient and provides poor heating at part-load conditions. With poor efficiency and aging equipment, a new heating source is required for the facility.
- Energy Management Systems: The existing HVAC equipment is controlled by a central control system accessible to the Parks and Recreation Administration from the maintenance office. This enables the system to be controlled with more advanced control sequences and can enable the system to run in a more efficient manner.

Holcom high-bay lighting

Holcom boiler

Holcom cooling unit

## East Lawrence Recreation Center

Packaged rooftop unit

Outdated rooftop unit

- General: The East Lawrence Recreation Center is an 18,000 square foot facility located in East Lawrence. This recreation center includes a basketball court, workout room, rec room, gymnastics room, and assembly spaces used for various functions. The facility is operated daily from 8 a.m. to 6:30 p.m. throughout the week and reduced hours on Saturday.
- Building Envelope: The facility is comprised of a concrete block exterior, brick façade, and a rock-ballasted roof.
- Lighting Systems: The lighting throughout the facility is primarily standard-efficiency T8 fluorescent fixtures with solid state ballasts. These lamps are rated at 32 watts. Fluorescent technology provides poor visibility compared to more modern lighting solutions and use significantly more energy to produce the same amount of light output. The gymnasium lights were replaced recently with high output T5 fixtures that are doing a fantastic job of lighting the court. When these eventually lamps fail, it is recommended to convert the lighting systems to an LED alternative to lower the operating and maintenance costs. The main recreation lobby has high wattage metal halide fixtures to illuminate the space. These fixtures use considerably more light than an LED equivalent and produce poor light quality.
- HVAC Systems: The facility is currently conditioned with four packaged rooftop units. The gymnasium rooftop unit was recently replaced due to failure. The remaining rooftop units condition the lobby, rec room, gymnastics, and an assembly room. The three rooftop units are reaching the end of their expected service life and in need of replacement.
- Energy Management Systems: The existing rooftop units are controlled by a central control system accessible to the Parks and Recreation Administration from the maintenance office. This enables the system to be controlled with advanced control sequences and can enable the system to run in an efficient manner.

## Youth Sports Complex

Existing sports field lighting

- General: The Youth Sports Complex is a 55-acre sporting complex, including 23 soccer fields, 5 football fields, and 8 baseball diamonds. These fields are used by Parks and Recreation for the city youth sports leagues. Along with the sports fields, there are several small restrooms and a concession stand facility.
- Building Envelope: The concession stand is made of concrete block exterior.
- Lighting Systems: All of the lighting in this complex is metal halide antiquated technology. Sports field lighting provides safety for the players and is a crucial component to the daily operation of these facilities. While these lights have significantly lower run hours compared to an office building, clear lighting, safety, and system maintenance are compelling reasons to replace these aging systems.
- HVAC Systems: The concession stand has a split-system to condition the space during operation.
- Energy Management Systems: The current split-systems are controlled by traditional thermostats.

## 27th Street Maintenance

- **General:** The 27th Street Maintenance shop is a 5,000 square foot facility near the Youth Sports Complex. This facility houses all of the necessary equipment to maintain and operate the Youth Sports Complex fields as well as the Clinton Lake Softball Complex. There are a few offices in the facility that are occupied by Parks and Recreation staff and maintenance personnel.
- **Building Envelope:** The shop is constructed with vertical metal siding with a standing seem metal roof.
- **Lighting Systems:** The lighting throughout the facility is primarily standard-efficiency T8 fluorescent fixtures with solid state ballasts. These lamps are rated at 32 watts. Fluorescent technology provides  poor visibility compared to more modern lighting solutions and use significantly more energy to produce the same amount of light output.
- **HVAC Systems:** The office space has a split-system and personal terminal air conditioners. These units do an adequate job of conditioning the spaces and are not recommended for replacement. Once the units do fail, a one-for-one replacement would ensure continued operation of the facility. The shop area has a make-up air system to ventilate the space.

## Prairie Park Nature Center

- **General:** The Prairie Park Nature Center is a 5,500 square foot interactive and educational facility. This facility houses a wide variety of animals and educational material showing off wildlife found in Kansas. This facility is open from 9 a.m. to 5 p.m. Tuesday through Saturday with reduced hours on Sunday.
- **Building Envelope:** The facility is constructed with a stucco finish and a standing seem metal roof. The facility has a large amount of window area facing the prairie to the East of the facility.
- **Lighting Systems:** The lighting throughout the facility is primarily standard-efficiency T8 fluorescent fixtures with solid state ballasts. These lamps are rated at 32 watts. Fluorescent technology provides poor visibility compared to more modern lighting solutions and use significantly more energy to produce the same amount of light output. The facility also has a large amount of compact fluorescent lamps lighting some areas of the exhibit.
- **HVAC Systems:** Currently there are four split-systems conditioning the exhibit, office area, and educational learning classroom. These units are unable to provide proper amounts of ventilation air to the space in order to supply improved air quality. An air filtration system was installed to filter out some of the particulates from the air and make the facility more enjoyable for the occupants.  Although some improvement was reported, a strong odor from the animals is still present in the facility.
- **Energy Management Systems:** The existing split-systems are controlled by a central control system accessible to the Parks and Recreation Administration from the maintenance office. This enables the system to be controlled and scheduled remotely.

Outdated furnaces

Condensing units

## Parks and Recreation Administration Office

Existing DDC thermostat

- General: The Park and Recreation Administration Office is a 4,800 square foot office building that includes several small private offices, an open lobby, and a large conference room. This facility is the main office for the Parks and Rec administrators.
- Building Envelope: The Park and Recreation Administration Office is a single-story brick building with aluminum-framed windows.
- Lighting Systems: The lighting throughout the facility is primarily T5 fluorescent fixtures. These lamps are rated at 28 watts and are marginally more efficient than the more common T8 lamps. Fluorescent technology provides relatively poor visibility compared to more modern lighting solutions and use significantly more energy to produce the same amount of light output.

P&R Admin Lighting

- HVAC Systems: The Park and Recreation Administration Office is serviced by residential-style split systems that are appropriate for a facility of this size and type.
- Energy Management Systems: The existing split-systems are controlled by a central control system accessible to the Parks and Recreation Administration from the maintenance office. This enables the system to be controlled and scheduled remotely.

## Union Pacific Depot

UP Depot thermostat

- General: The Union Pacific Depot is a 5,000 square foot facility built in 1889. The most recent building renovation was completed in 1996. This facility includes a large community room and a small theater for events. A reception area is used as the Lawrence Visitors Center, which is open during normal business hours.
- Building Envelope: The building is constructed of brick and stone with a multi-faceted shingled roof. Recent renovations and repairs have kept the building in adequate condition.
- Lighting Systems: The lipghting throughout the facility is primarily compact fluorescent fixtures with some T8 fluorescent luminaires.

Exterior Depot Lighting

- HVAC Systems: The Union Pacific Depot is conditioned with a hydronic system utilizing a small boiler and dx condensing units. The air handler for the HVAC system is located in an attic space above a storage room.
- Energy Management Systems: The existing system is controlled by a central control system accessible to the Parks and Recreation Administration from the maintenance office. This enables the system to be controlled and scheduled remotely.

# Energy Conservation Measures

## City Wide Improvements

### Web-Based Thermostats

Several city buildings have advanced Building Automation Systems or Direct Digital Controls that manage the heating, cooling, ventilation, and scheduling of the facility. Other buildings use simple programmable or non-programmable thermostats. These units must be manually programmed or controlled, which often leads to inefficient set points or no control at all.

Existing Stand-Alone, Non-Programmable Thermostat

In an effort to reduce energy consumption and costs, as well as ease the time burden associated with maintaining individual thermostat settings at most city buildings, web-based energy management thermostats will be connected to a single, web-accessible graphical user interface (GUI) to allow for centralized schedule management, reporting, and troubleshooting of all major heating and cooling equipment across all buildings in the following list:

Web-Based Thermostat

- Fire/Medical #2
- Fire/Medical #3
- Fire/Training Center
- New Hampshire Parking Garage - Maintenance
- New Hampshire Parking Garage - Parking Office
- New Hampshire Parking Garage - Transit Office
- Solid Waste Office
- Streets Division Office
- Airport Terminal
- Maintenance Hangar Office
- GUTS Hangar
- Vehicle Maintenance Garage Offices
- Outdoor Aquatic Center Building
- Eagle Bend Clubhouse

Thermostat Trend Data

Example Web-Based Thermostat Interface

This system would maximize the City's buildings efficiencies, reduce energy consumption, and deliver significant cost savings. Energy management thermostats are perfect for situations where a full-scale building automation system would be too costly and overly complex. This system is the newest WiFi enabled technology offered for the commercial market that addresses all of the basic energy management needs of small commercial buildings.

Interior LED Tubes to Retrofit Fluorescent Office Fixtures

In addition to energy management features, the system will also send maintenance personnel regular maintenance reminders and alerts based on your system's performance. Furthermore, the system's reports feature allows for tracking the performance of multiple locations, analyze system reports, conduct remote diagnostics and assess performance, all from the web.

## Building LED Retrofits, Lighting Replacements, and Controls

LED Lighting in Office Setting

All fluorescent, incandescent, and HID lamps installed inside or directly to the exterior of city buildings will be replaced with LED lighting technology.  LED lamps are 40% more efficient than the very common T8 fluorescent lamp.  A single 60 watt incandescent light bulb can be replaced with a 7 watt LED. These energy efficiency changes will make a dramatic effect on the monthly electric utility charge.

LED lamps also have an extremely long life. The average life of an interior 4' LED lamp is 50,000 hours, compared to typical T8 fluorescent lamps, which are rated at 20,000 or 25,000 hours. The performance of the LED lamp is also guaranteed by the manufacturer for five years, whereas T8 fluorescent lamps have only a one year warranty.

Exterior Security Lighting Attached to Building

For interior building spaces, most fixtures will be retrofitted with LED lamps.  This means that the fluorescent lamps and ballasts will be removed, but the metal fixture will stay in place.  Installers will re-wire the fixture to insure it satisfies current electrical safety codes and requirements.  LED lamps will then be installed. Gymnasiums that have recently been upgraded to T5HO fixtures (Community Recreation Building, Holcom Gymnasium, East Lawrence Recreation Center Gymnasium, and SPL) will not be retrofitted or replaced.  Although LEDs use less energy than T5HO technology, the most prudent action is to continue using the high quality T5HO lamps in the gymnasiums mentioned above.

LED Light Fixture for Pole Lighting Near Buildings

For exterior spaces like security lighting and nearby pole lights, the fixtures will be completely replaced.  Exterior light fixtures are exposed to severe weather and harsh sunlight.  Retrofits are nearly as expensive as complete replacements, and the existing lenses are often dulled and yellow.  All wall packs, security lights, and nearby pole lights will be replaced with LED fixtures.  Some existing fixtures have already been replaced with LEDs.  Those will remain in place where they have been professionally selected and installed.

Reducing the connected load of the lighting system represents only one part of the potential for maximizing energy savings. The other part is minimizing the use of that load through automatic controls. Automatic controls switch lighting based on occupancy. In situations where lighting may be on longer than needed, left on in unoccupied areas, or used when sufficient daylight exists for daylight harvesting, 360 Energy Engineers would install automatic controls.

Automatic Occupancy Sensor

In large, complex buildings with many individually controlled spaces, a more advanced lighting control system will be installed. In the Community Health Building, City Hall, and the Library, an advanced lighting control system will be centrally controlled. This means that a facilities manager can remotely operate and schedule lighting. This can insure that lights do not stay on overnight or on weekends and holidays. An advanced lighting control system can accurately measure and track the amount of energy saved through occupancy sensing, daylight harvesting, and scheduling.

Exterior bollards with integrated lights will be replaced at Prairie Park Nature Center and the Japanese Friendship Garden. The metal halide light fixtures in those bollards are inefficient and should be replaced. Since the light fixtures are integral to the bollard, the entire assembly will be replaced.

Aged and Distressed Pole To Be Replaced

City Parking Lot #3 and City Parking Lot #5 both have aging decorative light poles. The metal poles and fixtures are faded, dented, and show signs of corrosion. The poles will be replaced with new LED light poles to provide security lighting in the parking lots.

The canopy that covers the sidewalk next to Parking Lot #3 (800 Block) is equipped with 24 flood lights in poor condition. These floodlights once used incandescent lamps, but have since been retrofitted with CFL lamps. We will replace these fixtures and all exposed conduit with LED equivalents that will efficiently provide illumination to the sidewalk.

Parking Lot #3 Canopy Lighting and Conduit To Be Replaced

## Building Weatherization

Building weatherization drives down energy consumption by sealing gaps in the building that are allowing uncontrolled flow of air through cracks, holes and gaps in the exterior of the building. This air infiltration leads to excess HVAC equipment use and occupant discomfort. The gaps will be filled with appropriate building materials, and door sweeps will be applied where needed.

Although sealing gaps sounds simple, it is a complex improvement project. Selecting appropriate fire retardant materials, polyurethane foams, and long-lasting door sweeps requires experience and a scientific understanding of both air infiltration and building materials. Additionally, local building and energy codes must be considered when applying these materials to a facility.

Implementation of building envelope measures assist with over all building performance including energy savings and carbon reduction. Building envelope measures also provide benefits in the health and safety of the people utilizing the facility.

Weatherization Sealing of Air Gap Between Wall and Roof Deck

# Public Works Improvements

## Timer Control for Solid Waste Truck Block Heaters

Solid Waste Truck Parked in Front of Block Heater Receptacle

During cold winter nights, the City of Lawrence Solid Waste truck operators use GFCI receptacles on dedicated circuits to run engine block heaters. When the forecasted temperature is near or below freezing, the operators plug their trucks in at the end of shift. These 1500W block heaters keep the engine warm throughout the night to ensure the truck will start in freezing conditions for the next morning.

Currently, these engine block heaters are drawing electricity throughout the night (at least 14 hours) when only 3 hours is needed to adequately warm up an engine block before starting. Time controls on the dedicated receptacles can reduce that electrical spend dramatically.

Block Heater Receptacles on Bollards

Additionally, the engine block heaters are only required when the air temperature is lower than 40 degrees. An inexpensive temperature controller can be installed to allow the heaters to run only when the air temperature requires them to do so. Surprisingly warm mornings would further reduce the electrical draw of these engine block heaters if temperature controls are added to the electrical circuits.

The above-mentioned controls can be equipped with override controls in case of unanticipated schedule changes. The controls will not be added to the circuits that power block heaters for salt trucks or other vehicles that do not follow strict schedules.

## City-Wide Pole Lighting

Decorative Pole Light

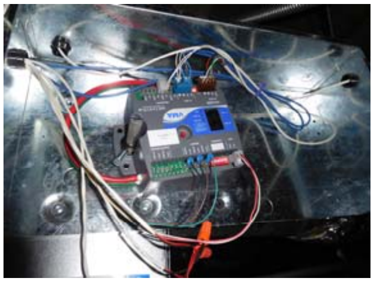
Area lighting is a crucial component to a city's overall appearance as well as safety at night. The existing pole lights in the city include pole top, cobra head, and shoebox area lights. The main goal of these lights is to light up walkways on sidewalks, paths, and some intersections across the city. Replacing these high wattage HID (High Intensity Discharge) Lamps with LED equivalents will increase the visibility for the public and provide increased efficiency utilizing one third of the existing wattage with significantly longer operational use. New LED fixtures will be carefully selected by 360 Energy Engineers to identify the best quality fixture for each application.

# City Hall

## Optimize Control Strategies

### Optimize HVAC Operating Schedules

This control feature will involve marginally improving night setup and setback temperatures using the existing energy management controls in City Hall. The current HVAC systems are scheduled effectively; however, some opportunities exist on holidays and area-specific scheduling needs.



New DDC Controller on VAV Box

### Optimal Start of HVAC Systems Based On Outdoor Air Conditions

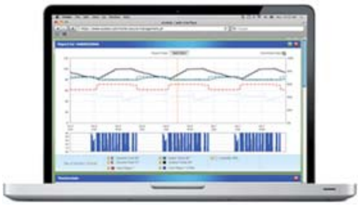
Equipment start times are normally set earlier than necessary to ensure proper comfort is maintained even during hot or cold weather. An optimal start feature incorporated into 360EE's design would automatically compensate building start times for changes in weather. If weather is extreme, then equipment is started early enough to properly condition the building before it is occupied. During mild weather, equipment start times can be delayed to obtain more energy savings.

Lighting occupancy sensor used for intermediate setback control

A complimentary feature, Optimal Stop, is used to save energy at the end of each day. This feature takes advantage of a building's "flywheel" effect. In mild weather, equipment can stop earlier than usual without adversely effecting indoor temperatures.

### Zone-Level Intermediate Setback Control

This energy conservation opportunity includes integrating the new lighting occupancy controls with the controls on the VAV boxes in order to automatically adjust the temperature setpoint and ventilation rates in each room based on occupancy. With so many spaces in City Hall having variable occupancy patterns, these controls provide a much more manageable and effective means to manage energy use than laboriously entering time schedules in a control system for each space.



Zone-Setback Trend Chart

When occupancy is sensed by the occupancy sensor, the thermostat goes into an occupied mode (i.e. programmed setpoints) and full ventilation is provided. If a unit is scheduled on and no occupancy is sensed during that time, the thermostat goes into an unoccupied mode (e.g., intermediate setback setpoint) and ventilation air is shut off until occupancy is sensed again. This setback temperature would be between the scheduled occupied and unoccupied setpoints, such that when occupancy is again sensed, the space can quickly return to the occupied setpoint. For example, if the design occupied and unoccupied cooling season temperatures setpoints were 74°F and 85°F for a space, the intermittent setback temperature might be 78°F, allowing the unit to more quickly respond to an occupied signal than it would if cooling down from 85°F. During scheduled unoccupied periods, the occupancy control functionality of the unit could be turned off, forcing the space to remain at the unoccupied temperature setpoint even if occupancy was detected.

### Disable reheat systems in summer months

For the VAV reheat systems, 360EE will identify zones that do not require significant reheat during the summer months and disable these. Many facilities with electric reheat systems have successfully shut off the reheat coils at the breaker during the cooling season, leading to significant energy savings. In conjunction with this change, it may be necessary to adjust the supply-air temperature to avoid overcooling certain spaces, and it may be necessary to leave the reheat coil breakers active in certain spaces (such as interior zones) in order to maintain comfort.

VAV Box With Electrical Reheat

## Replace Vestibule and Stairwell Cabinet Unit Heaters

The current electric heaters located at each exterior door and in each stairwell are original to the building's 1980 construction and do not function properly. These units, when enabled to heat in the cooler months, operate at 100% capacity, making the vestibules stifling hot during the winter. This expensive heat that is generated with costly electricity is wasted each time someone enters or leaves the building.

New cabinet unit heaters with functioning controls will save a significant amount of electricity by limiting the temperatures to reasonable levels at building entries.

Electric Cabinet Heater at Main Entry

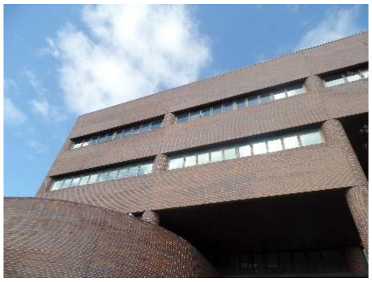
## Replace Windows

The existing windows at City Hall represent the largest source of unwanted heat loss and heat gain. This is primarily due to the current windows having poor seals, thus being a common source of air leakage. Additionally, the window or glazing systems throughout City Hall are beginning to fail. Specifically, the glazing seals on many windows have broken causing glass discoloration. Considering the condition of many of the windows throughout City Hall, installation of new windows with the latest in advanced window design will provide energy savings and comfort.

Options for new window products include:

- Spectrally selective glass. This type of glass can maximize or minimize solar gain and shading depending on the chosen selectivity.
- Double-glazed, low-e systems. Layers of low-e film are stretched across the interior air space between glass panes, and windows with this feature offer R-values as high as 8.
- Gas filled windows. Using argon or krypton gas between glass panes, this technology minimizes the convection currents and conduction through the gas-filled space, reducing overall heat transfer through the window.

360 Energy Engineers recommends that all non-atrium windows be replaced with a proper window system that meets stringent energy performance requirements and satisfies aesthetic concerns.



City Hall South Facing Windows

Efficient Window Section

# Fire/Medical Buildings

## Station #3: Replace Rooftop Units


Older RTU at FS#3

Fire Station #3 has four rooftop units providing heating and cooling. Three are original from 2003. One of the units was installed in 2000. This older unit originally served much more area through underfloor ductwork than it currently serves. Most rooms were removed from this rooftop unit and placed on to the 2003 rooftop units. Likely, there is air escaping through this unused underfloor duct network, which is wasteful.


Newer High Efficiency Rooftop Unit

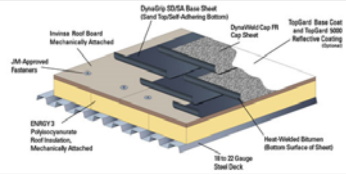
This scope will replace all of the four older rooftop units with new high efficiency rooftop units capable of improved temperature and humidity control while using less energy. For the oldest unit at Fire Station #3 serving the underfloor system no longer used, a new, properly sized and selected high efficiency rooftop unit will be located over the dining area in which it serves. New ductwork will be installed and the underfloor ductwork will no longer be used.

## Station #3: Replace Roof


Roof deterioration at FS#3

The existing roof is a built-up roof with rock ballast covering. This roof is beginning to fail in some spots. During our facility audit, we witnessed visible water damage in the main corridor. In order to prevent more water infiltration which can lead to mold and potential equipment damage, the roof is in need of replacement. This scope will include a complete tear off of the existing roofing system down to the deck and replacement with a new high-performing modified bitumen roofing system and appropriate insulation thickness and slope.

Savings will be achieved by improving the thermal resistance of the roofing system, which is the largest surface area through which heat is gained and lost contributing to energy consumption of the HVAC equipment.



Modified Bitumen Roof

## Stations #4 and #5: Uniform HVAC DDC Controls Installation

Fire Station #2 and the Fire Training Center both operate HVAC equipment through standard thermostats with no front-end graphic and automation systems. Fire Station #3 also runs most of its equipment through standard thermostats, except for the sleeping quarters which use a simple digital control system for the variable air volume HVAC system. These buildings will be improved with web-enabled thermostats as described earlier in this report. Fire Station #4 and Fire Station #5 have variable air volume systems that utilize a digital control system for temperature control.


Digital HVAC controls at FS#4

This scope of work will include expanding the system in the Community Health building over to Fire Stations #4 and #5 to create a uniform energy management and automation system to effectively control temperature, energy, and receive proactive maintenance alerts to improve operations.

Digital HVAC controls at FS#5

Savings will be achieved by improving the operating control strategies for the equipment and scheduling areas of the buildings. One example is the office area in Station #5. This space can be setup with temperature setbacks outside of business hours.

## Station #2: Replace Two Older RTUs

Older RTU at FS#2

The three rooftop units installed at Fire Station #2 are original from 2001, putting them beyond their expected 15 year service life. The unit serving the sleeping quarters was recently replaced with a new, smaller unit, to correct humidity issues. This leaves two units, which are less efficient than today's standards and in need of replacement.

This scope will replace the two older rooftop units with new high efficiency rooftop units capable of improved temperature and humidity control while using less energy.

Fire Station #5 at 1911 Stewart Ave.

## Station #5: Solar Power Installation

Fire Station #5 was designed with a south-facing, angled roof that is naturally suited for photovoltaic panels. The standing-seam metal roof will last for decades, further proving that this is a perfect site for solar power. An approximately 100W photovoltaic power system will produce over 137,000kWh annually, greatly reducing the City's energy spend and environmental impact. An internet-based monitoring system will allow all users the ability to quickly and effectively see the performance of the photovoltaic system. The construction of a solar power system for Fire Station #5 will be a high profile success for the City of Lawrence.

Computer Rendering of a 100kW PV Array on the roof of Fire Station #5.

# Community Health Building

## Install Electronic Air Cleaner Filtration

Typical standard pleated air filters

The six large air handlers in the Community Health Building feature standard, pleated air filters to filter out large particles from the air that is used to condition and ventilate spaces. In order to provide clean air for the occupants of the building, large amounts of outdoor air are introduced into the building to dilute the contaminants in the circulated air.

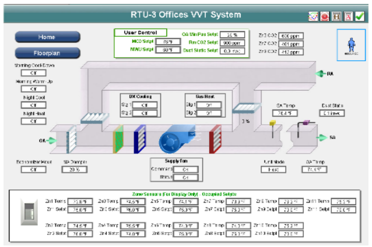
Polarized-media air filters offer several advantages over the standard filters. Standard filters are designed to capture large particles in the air in order to protect the HVAC equipment in which they are used. Polarized-media air filters not only capture large particles to protect equipment, they also capture much smaller particles that can affect the quality of the air and health of the occupants. Not only does it improve the quality of the air, less outdoor air is required to dilute the circulating air because this outdoor air is now cleaner. Polarized-media air filters also require less maintenance due to the longer life of the individual filters.

High efficiency electronic air cleaner

Savings will be achieved by replacing standard air filters with polarized-media air filters. The electrostatic air filters will improve indoor air quality and will require less outdoor air, thus decreasing the amount of energy used to heat and cool ventilation air.

## Upgrade HVAC Control System

This energy conservation opportunity will include recommissioning the control system in the Community Health Building. The building is currently being operated by an Automated Logic DDC control system. This system was installed and originally commissioned in 1998, and while it utilizes some energy efficient strategies, there is room for improvement as technology has advanced a large measure over the past twenty years. In addition, some of the system's hardware, such as the controllers and reheat valves, have been failing as of late and need to be replaced as part of the upgrade.

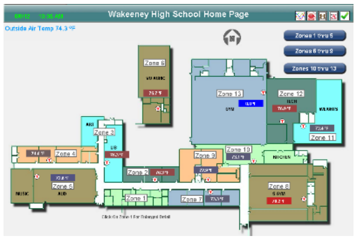


Advanced Control System Interface

The existing Automated Logic control system will be re-commissioned so they operate more efficiently. The operation and setpoints of all the systems, including all energy recovery units, will be adjusted so that the systems are operating correctly and as efficiently as possible. Control sequences will be redesigned and implemented when deemed necessary. This will lower the runtime of the equipment as well as the amount of cooling or heating produced during part-load conditions. This will also decrease energy spent wastefully cooling or heating the spaces during periods when no one is occupying the building. Failed or aging controllers, valves, and other hardware will be evaluated and replaced as needed. The following individual strategy improvements will be implemented and commissioned into the system:

New Control Valve

- Optimize HVAC operating schedules (space temperature setback and setup)
- Optimal start of HVAC systems based on outdoor air conditions
- Zone-level intermediate setback control with occupancy sensors
- Differential enthalpy economizer control of air handling units
- Air handler static pressure setpoint trim-and-respond reset based on demand
- Dual maximum VAV control to reduce overcooling and reheat swing waste
- Widen zone temperature dead-band
- Lower VAV minimum box flow setpoints in conjunction with new electronic air cleaners
- Variable speed pumping of heating water
- Chilled water temperature setpoint reset
- Boiler sequencing control for optimal energy performance



Building Control System Layout

## Replace Boilers

The heating water system at the Community Health Building consists of ten, small, single stage condensing hot water boilers. These boilers have been in operation for nearly twenty years, which is roughly the expected life of the equipment. End of life is evident by persistent failures and repairs. Based on condition and age, these boilers are due for replacement.

Failing Twenty Year-Old Condensing Boilers in Community Health Building

In lieu of a direct replacement of the ten single stage condensing boilers, four-to-six larger modulating condensing hot water boilers will be installed. These boilers will have higher turndown to match the load, which will improve energy efficiency. By having fewer pieces of equipment installed, there will be fewer to maintain. The boilers installed will also be more robust and more reliable than the currently failing boilers. The existing boiler models, which were a failed first generation of condensing boilers, are known for their heat exchanger failure.

Modern Condensing Boiler With Higher turndown

## Replace Roof

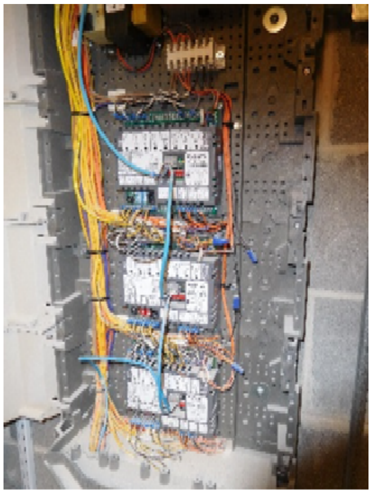
The Community Health Building's roof is a modified bituminous system that is original to the building's construction in 1999. The roof shows substantial de-mineralization. De-mineralization of cap-sheets occurs when weather, over time, washes away the aggregate minerals and rocks from the underlying felt. Bare felt areas can cause exposure of the membrane to direct sunlight and UV radiation, which causes rapid membrane deterioration. Some deterioration has likely already occurred, and, if left untreated, will lead to premature roof failure. The top sheet can be re-impregnated with additional minerals to extend the life of the roof a few more years. However, the roof would still need to be replaced soon, so 360EE recommends a full roof replacement.

Substantial De-Mineralization on Community Health Building Roof

# Lawrence Arts Center

## New DDC Controls with Optimized Control Strategies

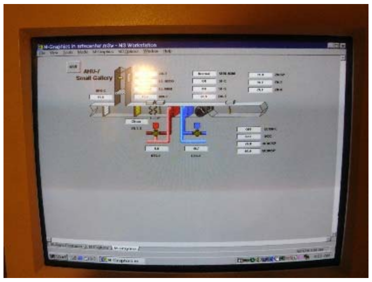
### Upgrading Existing Direct Digital Control System



Aging Metasys Controllers

This project includes upgrading antiquated hardware, programming and graphics on the existing Johnson Metasys control system. The existing control system is over 15 years old, and relies on an antiquated computer running old software on a slow operating system. All air handling units, VAV terminals, and central plant equipment are currently controlled by this system. The system is difficult to manage and does not allow for effective remote control or monitoring, making it less effective at performing energy conservation strategies.

A new, comprehensive DDC system will be installed on all equipment along with an upgraded workstation that will ultimately provide a much better interface for the user, making energy management and troubleshooting much easier. Remote management and monitoring of the system will allow facilities staff to identify problems and receive error alerts without even being in the facility. Furthermore, improved control sequences will be implemented as described below in this section to improve energy performance and comfort.



Antiquated Graphics on Windows 98 Operating System

### Zone Level Design Strategies

**Optimize HVAC Operating Schedules (Space Temperature Setback and Setup)**

This control feature will involve implementing optimized night setup and setback temperatures using energy management controls for most of the building spaces in the Arts Center. The existing schedules and setpoints are relatively conservative with room for improvement, resulting and significant potential energy savings. The setup and setback temperatures will be 60°F during the heating mode and 85°F during the cooling mode. The typical occupied setpoints will be maintained to ensure the comfort for all visitors and performers in the facility.

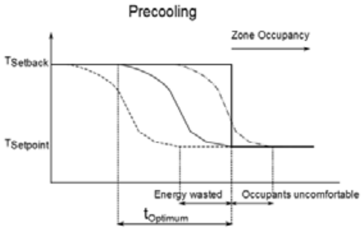
$CO_2$ zone Sensor for Demand Controlled Ventilation

**Utilize Demand-Based Ventilation Control**

360EE's design of a new DDC system in the Arts Center will include the installation of carbon dioxide ($CO_2$) sensors in spaces with high variances in occupancy such as the auditoriums. In these spaces, large quantities of ventilation air are provided at a constant rate to satisfy the ventilation requirements at a worse-case scenario – full occupancy. Typically, these spaces are not fully occupied, so they are not required to receive the large ventilation rate which requires significant additional heating and cooling. This control strategy will determine the minimum amount of ventilation needed to provide acceptable indoor air quality at all times. This will be accomplished through dynamically controlling the ventilation rate to each space to maintain $CO_2$ levels that correspond to acceptable air quality for each space. This significantly lowers the amount of energy needed to temper the outdoor air to maintain comfortable conditions in the spaces.

### Optimal Start/Stop of HVAC Systems Based On Outdoor Air Conditions

Equipment start times are normally set earlier than necessary to ensure proper comfort is maintained even during hot or cold weather. An optimal start feature incorporated into 360EE's design would automatically compensate building start times for changes in weather. In extreme weather, equipment would be started early enough to properly condition the building before it is occupied. During mild weather, equipment start times can be delayed to obtain more energy savings.



Smart Control Strategy

### Conversion from Constant Air Volume (CAV) Variable Temperature to Variable Air Volume (VAV) Constant Temperature

Retrofits involving conversion from CAV to VAV are perhaps the most widely employed energy-saving retrofit to commercial HVAC systems. Many of the large air handling units currently serving the Lawrence Arts Center operate with constant airflow, modulating the discharge air temperature in response to changing heating and cooling loads. While this does effectively control temperature in the space, these systems use significantly more energy and result in high space humidity in cooling mode (leading to occupant discomfort) when compared to systems with modulating airflow.

Single Zone Constant Volume Air Handling Unit

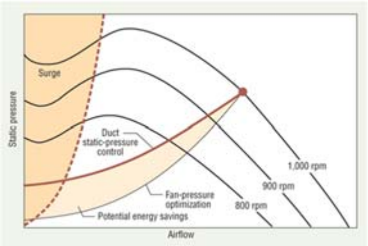
VAV systems cool only the air volume required to meet demand, rather than meeting demand by constantly heating and cooling large volumes of air. Typical VAV systems are configured to provide 55°F discharge air in response to varying cooling loads. This constant low air temperature ensures moisture is consistently removed from the air, dehumidifying the space very effectively. Implementation of this conversion will require the addition of Variable Frequency Drives (VFDs) to the motors, allowing the fan to slow down and speed up. Fan energy consumption is proportional to the cube of the fan speed, meaning a 50% reduction in fan speed results in a power reduction of 88%.

### Variable-Air-Volume Static Pressure Reset

This control strategy involves implementing a static pressure reset control strategy for the VAV air handling units in the Arts Center. The existing air handling units currently operate under an industry-standard, constant static pressure setpoint. The VAV zone box dampers are then modulated and hot water reheat coils enabled to control space temperature. This type of sequence has been the accepted or "standard" type of sequence in the past, but as energy consumption has become more of a concern, more efficient control sequences have been developed and should be implemented.

Variable Speed Fan Drive

A static pressure reset control strategy will operate the fan more efficiently, while maintaining the same level of comfort control. Instead of controlling fan speed to a constant static pressure setpoint, the fan speed will be controlled by VAV box need, to ensure that at least one of the system's VAV box dampers is fully open. This will make the static pressure of the system dynamic and will allow the fan speed to decrease more during part-load conditions than under the current operation. The new sequence should control the supply fan speed off of zone damper positions. High limit and low limit setpoints for duct static pressure would also be implemented to ensure that no damage occurs to the existing duct work.



Static Pressure Curve

### Variable Air Volume Terminals Controls Optimization

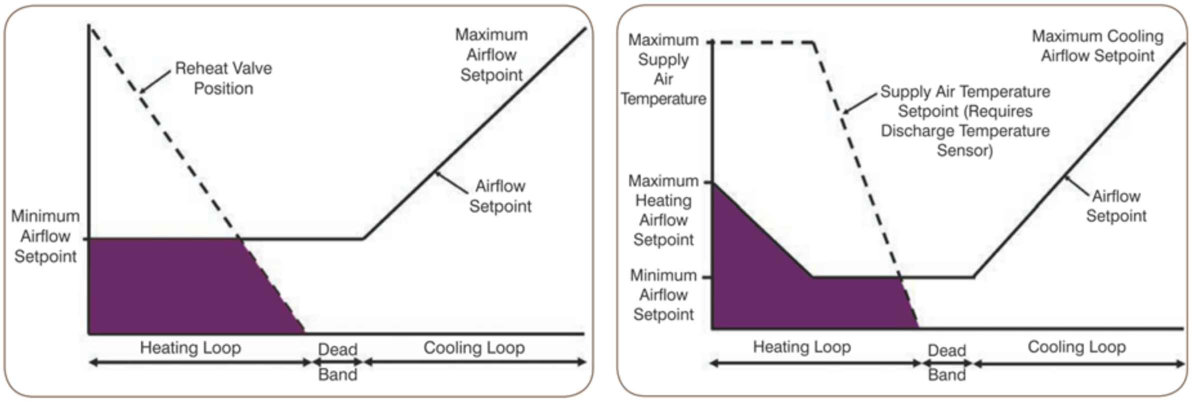
The non-auditorium spaces are conditioned by VAV boxes with hot water coils. These boxes control airflow proportional to cooling demands in the cooling mode and constant air volume in the heating mode. Although a common mode of control, this operation does not meet the requirements of ASHRAE 90.1 – Energy Standard for Buildings due to its inefficient operation during part-load heating. A dual-maximum or reverse-acting control on these boxes yield much improved energy performance over the current box control.

VAV Terminal Boxes

360 Energy Engineers recommends reprogramming all VAV controllers to implement dual-maximum airflow control. Currently, the VAV box modulates the volume damper down from the zone maximum airflow setpoint (when the space is at full cooling) to the zone minimum (when no cooling is required). This minimum airflow rate is then maintained as the space temperature falls through the dead-band into heating mode. As the VAV box transitions into heating mode, the hot water heating coil simultaneously opens while the minimum airflow jumps to the heating minimum setpoint. The hot water reheat coil then modulates up to maintain the space at the heating setpoint until the control valve is fully open. This logic, shown in the figure below, is effective at maintaining comfort in spaces, but results in large amounts of wasted reheat energy. As an alternative, more modern control strategies very often use Dual Maximum logic, where a separate maximum heating airflow setpoint is calculated, independent from the maximum cooling airflow setpoint. Heating elements are still modulated to provide adequate heating to spaces, but the lower supply airflow in heating means less reheat is required, and can save significant fan energy at the air handling units supplying VAV boxes. This strategy is shown on the second image on the following page.

VAV Zone Controller

**Conventional VAV Reheat Control (Left) vs. Dual Maximum VAV Reheat Control (Right)**



Benefits of dual maximum logic over traditional VAV reheat logic include lower fan energy, lower cooling energy use, lower reheat energy use, improved thermal comfort by not pushing zone temperature to heating setpoints during the cooling season, and reduced stratification due to supply air temperature control. Moreover, systems which utilize dual maximum control are better able to respond to varying weather conditions, and utilize less gas and electricity during both heating and cooling seasons. 360 Energy Engineers recommends to integrate these control strategies into the new DDC control system installed in this building.

## Replace Air Cooled Chiller with Premium Efficiency Unit

The existing Trane air cooled chiller is nearing the end of its rated service life, and is quite inefficient compared to newer units with the latest available technology. Many options are available for air cooled chillers, with each manufacturer touting the "most efficient" or "best" equipment. 360 Energy Engineers' product independence and engineering expertise allows for an unbiased analysis of available equipment, ultimately leading to a specific recommendation given the needs of the specific facility where the unit will be installed. A high-efficiency scroll chiller with variable speed condenser fans is available for a lower first cost than some alternatives, but still provides the performance and efficiency of a higher cost unit. The following sections outline some of the ideal features of a new air cooled chiller to be installed at the Arts Center.

Existing 124 Ton Trane Chiller

### Variable Speed Condenser Fans

Chillers with variable speed condenser fans, such as the Carrier 30RB chiller with Greenspeed technology, feature a high-efficiency, variable-speed condenser fan along with finely-tuned controls, which together provide premium part-load efficiency to reduce utility costs over the lifespan of the chiller. Additionally, the lower sound levels achieved at part-load conditions can be very beneficial for sensitive acoustic applications.

Existing Helical Rotary Screw Compressor

### Scroll Compressors

Although relatively new to HVAC applications, the use of scroll compressors for HVAC and refrigeration has been widespread since the mid-1980s. Scroll compressors have a successful history in HVAC applications. Acceptance has been quick, creating a demand for millions of units over the past 20 years. Scroll compressors proved their reliability in that time to be as good as or better than other technologies. Since their introduction, millions of scroll compressors have seen successful service worldwide in food and grocery refrigeration, truck transportation, marine containers, and residential and light commercial air-conditioning.

Although their full-load efficiency is generally slightly below that of a screw machine, scroll chillers' part-load efficiency (IPLV) is generally better than that of a rotary screw machine, which ultimately results in lower annual energy costs. Scroll compressors have many distinctly appealing qualities including efficiency, low sound levels, and reliability.

Carrier 30RB with Greenspeed

# Library

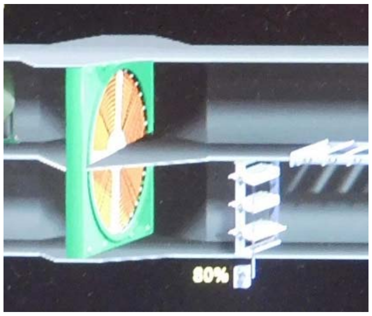
## VAV Controls and Ventilation Optimization

### Reset Outdoor Air Rates to Appropriate, Code Compliant Levels

When reviewing the design mechanical plans and during our field investigation, 360 Energy Engineers noticed that all variable air volume rooftop units were bringing in an exorbitant amount of ventilation air relative to a reasonable quantity for a library. For context, a reasonable amount of outdoor air for a variable volume air handler serving a library is 25% of the total supply airflow. The VAV rooftop units in the library are bringing in 40% to 80% outdoor air, much higher than what is normal for a library building. In fact, RTU-3, which was at 80% outdoor air, was not even close to providing enough cooling to cool this amount of outdoor air. This issue prevents the unit from fully cooling and dehumidifying the spaces served. Consequently, the building often suffers high humidity and temperatures on hot and humid days.

Typical VAV Rooftop Unit

After searching for the reasoning behind these higher-than-normal outdoor air rates, 360 Energy Engineers' team performed a thorough review of the design documents and discovered that very high density occupancy spaces such as the auditorium and meeting/activity rooms were served by the same air handlers that serve the stacks, circulation and other lower-occupant density spaces. This is generally poor design practice because it results in the primary air handing units bringing in a percentage of outdoor air to meet the ventilation requirements of the assembly spaces while significantly over ventilating other spaces. Consequently, these systems currently consume an excessive amount of cooling and heating energy.



Controls-3 with OA damper 80% Open

360 Energy Engineers proposes to set outdoor air rates at code-required minimums based on the 2015 International Mechanical Code. We have performed these calculations, and from making some minor adjustments to VAV box minimums, we are able to reduce outdoor air rates from 15,000 CFM as designed to 9,260 CFM, saving a significant amount of energy and greatly improving indoor environmental quality by allowing the equipment to more effectively cool and dehumidify the building.

Fully open OA Damper

Below is a table that compares the designed outdoor air flow rates with 360EE's Code Calculations:

| Rooftop Unit Tag | Design OA Rate (CFM) | Proposed OA Rate (CFM) |
|---|---|---|
| **RTU-1** | 3,000 | 1,390 |
| **RTU-2** | 3,000 | 1,140 |
| **RTU-3** | 4,500 | 2,370 |
| **RTU-4** | 4,500 | 4,360 |
|  | **15,000** | **9,260** |

### Add Dedicated Ventilation System to Auditorium

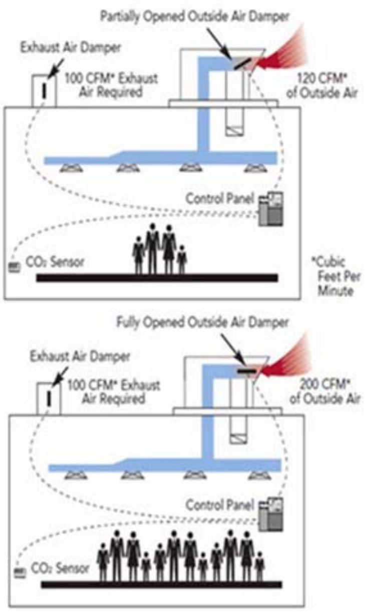
To reduce outdoor airflow rates based on code minimums, the HVAC system design included serving very high density occupancy spaces, such as the auditorium, with the same unit as the main entry lobby and circulation areas, which have a much lower occupant density. Proper design practice involves providing a dedicated unit to handle ventilation air only for this space while allowing the VAV system to provide space heating and cooling. This would eliminate the need for the primary VAV air handler to bring in a percentage of outdoor air to meet the ventilation requirements of the assembly spaces while significantly over-ventilating the lower density spaces.

Roof-Mounted Energy Recovery Ventilator for Auditorium

360 Energy Engineers recommends installing a simple roof-mounted energy recovery ventilator (ERV) to provide 775 CFM of ventilation air to the main auditorium. This will allow the primary air handler's (RTU-4) outdoor air rate to be reduced from 4,500 CFM to 1,090 CFM, saving a significant amount of energy. Furthermore, the ERV can be controlled by a $CO_2$ or occupancy sensor to minimize outdoor air when the room is not being used.

### Dynamic Control of VAV Box Minimums and Air Handler Ventilation based on $CO_2$

This conservation opportunity includes the installation of carbon dioxide ($CO_2$) sensors in select spaces with high variances in occupancy such as general circulation, meeting rooms, the auditorium and offices. In these spaces, large quantities of ventilation air are provided at a constant rate to satisfy the ventilation requirements at a worse-case scenario: full occupancy. Typically, these spaces are not fully occupied, and are therefore not required to receive the large ventilation rate which requires significant heating and cooling.



$CO_2$ Control of Ventilation

This control strategy will determine the minimum amount of ventilation needed to provide acceptable indoor air quality at all times. This will be accomplished by dynamically controlling the ventilation rate at each air handler to maintain $CO_2$ levels in each zone that correspond to acceptable air quality for each space. Additionally, VAV terminal minimum airflow setpoints will be dynamically reset based on the ventilation requirements in the space it serves. This change significantly lowers the amount of energy needed to temper the outdoor air. This strategy will also reduce costly electric reheat energy by lowering VAV box minimums.

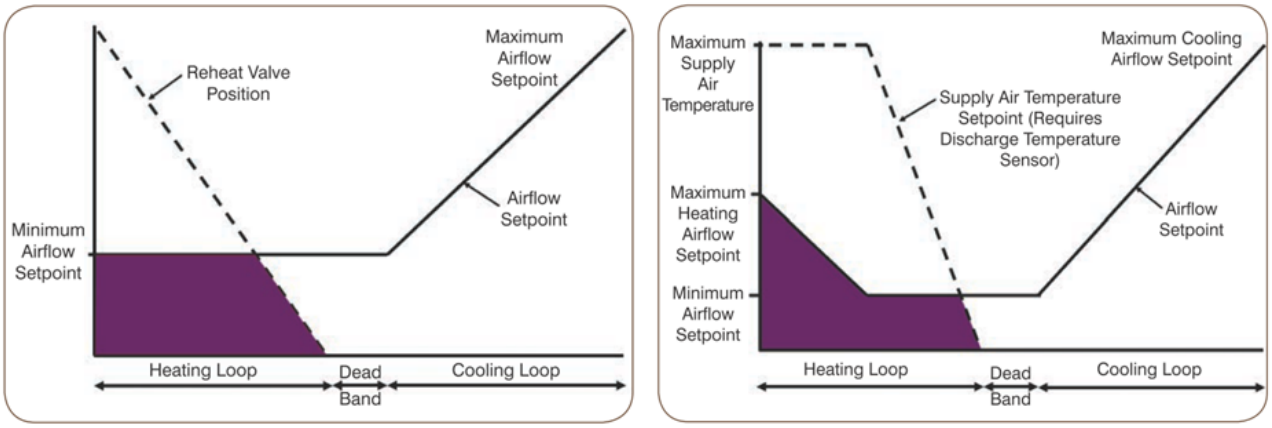
### Dual-Maximum Control of VAV Boxes and Reheat

The Library's VAV boxes control airflow proportional to cooling demands in the cooling mode and constant air volume in the heating mode. Although a common mode of control, this operation does not meet the requirements of ASHRAE 90.1 – Energy Standard for Buildings, due to its inefficient operation during part-load heating. A dual-maximum or reverse-acting control on these boxes will yield improved energy performance. This benefit is compounded at the library due to its use of very costly electric heat at the VAV terminal box.

$CO_2$ Sensor

360 Energy Engineers recommends reprogramming all VAV controllers to implement dual-maximum airflow control. Currently, the VAV box modulates the volume damper down from the zone maximum airflow setpoint (when the space is at full cooling) to the zone minimum (when no cooling is required). This minimum airflow rate is then maintained as the space temperature falls through the dead-band into heating mode. As the VAV box transitions into heating mode, the electric heating coil simultaneously activates while the minimum airflow jumps to the heating minimum setpoint. The electric reheat coil then modulates up to maintain the space at the heating setpoint until all electric heating stages are on. This logic, shown in the figure below, is effective at maintaining comfort in spaces, but results in large amounts of wasted reheat energy. As an alternative, more modern control strategies very often use Dual Maximum logic, where a separate maximum heating airflow setpoint is calculated, independent from the maximum cooling airflow setpoint. Heating elements are still modulated to provide adequate heating to spaces, but the lower supply airflow in heating means less reheat is required, and can save significant fan energy at the air handling units supplying VAV boxes. This strategy is shown on the second image below.

**Conventional VAV Reheat Control (Left) vs. Dual Maximum VAV Reheat Control (Right)**



Benefits of dual maximum logic over traditional VAV reheat logic include lower fan energy and lower cooling energy use, improved thermal comfort by not pushing zone temperature to heating setpoints during the cooling season, and reduced stratification due to supply air temperature control. Moreover, systems which utilize dual maximum control are better able to respond to varying weather conditions, and utilize less power during both heating and cooling seasons.  360 Energy Engineers recommends to integrate these control strategies into the current Automated Logic control system.

# Airport Terminal

## HVAC System Replacements

The existing split-system heating and cooling units at the Airport Terminal are nearing the end of their useful service life. With the typically inconsistent loads of an airport terminal waiting area, the building's HVAC load varies dramatically. Multi-stage DX air conditioners will run more efficiently during part-load conditions than the older models currently installed. Higher efficiency condensing furnaces will improve heating efficiency up to 98%. One of the reasons that a condensing furnace improves efficiency so much is that it uses the exhaust heat to warm up the return air before it re-enters the main heat exchanger of the furnace. Instead of venting all of that energy out into the environment, it can be used to lower utility expenses.

Parking Garage Office Wall Pack HVAC Unit

# New Hampshire Parking Garage

## Replace Wall Pack HVAC Units With Gas Heat

The New Hampshire Parking Garage offices (Transit, Parking, and Maintenance) each use Bard wall pack heating and cooling units. These small packaged units work well for small office spaces that do not have a wildly varying HVAC load. The currently installed units use electric heat. Although electric heaters are less expensive to install, they are much more costly over time due to the relatively high cost of electricity. Gas heat is much less expensive over time. A gas utility line is available in the alley behind the parking garage. The installation of natural gas to the office areas will make the long term utility bills much lower.

Existing Packaged Unit (2001) at Solid Waste Office

# Solid Waste Office

## Replace Package Unit

The existing packaged unit is in poor condition and in need of replacement. Several building occupants notified 360EE of private offices that do not adequately heat and cool during extreme outdoor conditions. A new packaged unit would provide increased efficiency and be able to modulate air flow to the building as necessary to meet the unique internal load conditions. These conditions vary dramatically as the occupancy of the building changes throughout the day (approximately 90 people visit the office daily). To control the new packaged gas heat and DX cooling unit, an internet-based thermostat would be installed to allow for remote access and control. This would allow for more advanced scheduling similar to what the city has in other buildings currently.

# Vehicle Maintenance Office

## Add Ductless Mini-Split for Server Room

The second floor of the Maintenance Garage is conditioned by a single zone packaged rooftop unit. This unit is responsible for heating and cooling several small offices on the second floor that are currently being utilized as storage and a small conference room that rarely gets used. The most important aspect of the load on the second floor is the server closet adjacent to the conference room. This closet accounts for almost all the load that the existing packaged unit must condition. To minimize wasted heating and cooling when the second floor is unoccupied, a ductless mini-split HVAC system will be installed in this closet to handle the load of the server. This would allow the packaged unit to be set to an unoccupied mode by an internet based thermostat controlled remotely.  During nights, weekends, and holidays, the small, efficient ductless mini-split will keep the server cool without wasting energy on the rest of the second floor.

Existing Window System Showing Condensation Between Glass Panes

Server Closet at Vehicle Maintenance Garage Office

Ductless Mini-Split For Server Closet at Vehicle Maintenance Garage

Twin 50HP Pump Motors at a Venture Park Holding Tank

# Parks and Recreation Improvements

## Parks Area Lighting

Lawrence City Parks are currently lit by a combination of both metal halide and high pressure sodium HID lights. With significant run hours, and being vastly spread throughout the town, this is a perfect opportunity to install modern LED lighting solutions. All existing HID fixtures will be replaced with new LED equivalents producing increased visibility, longevity, efficiency, and overall appearance. Any existing LED fixtures already installed by the city staff will remain in place. LED technology lasts four times as long as a comparable HID lamp. This means that the maintenance staff will have fewer service calls to replace failed lamps and ballasts.


Decorative 10' Light Pole

In addition to the energy savings and long lamp life, LED technology produces a much whiter light than other commercially available lighting technologies. The whiter color of the LED has many benefits, including scientifically-proven lighting response in the human eye. Scotopic Response refers to the way the human eye responds to low light levels, and it's been proven that LED light sources provide better Scotopic lighting. This is very important in area lighting, where objects and movement on the edges of the illuminated areas may quickly become obstacles in streets and sidewalks.


Shoebox Style Light on a Tall Pole

With a holistic replacement of all the city parks lighting, the city will eliminate wasted energy while maintaining a safe and visually attractive environment for the public.

## Advanced Timers for Tennis/Basketball Courts

Basketball, Tennis, Handball, and Horseshoe courts all have high wattage sports lights for night play. The Centennial Park Skate Park also has several of these high wattage lights. These lights are currently operated by park users. When playing at night, these court lights can be turned on. At midnight, the court lights automatically turn off.


Walkway Area Light

There are often times when park users turn on the lights to use the courts, then leave long before the timer turns the lights off. Veteran's Park utilizes a system that turns the lights off an hour after they have been activated to prevent lighting vacant courts. A similar system can be installed at the courts of the following parks throughout the city:

- Broken Arrow Park
- Centennial Park
- Chief Jim McSwain Park
- Deerfield Park
- Edgewood Park
- Hobbs Park
- Holcom Park
- Lyons Park


Basketball Court With High Powered Lighting

The new timer system would still be active at the currently prescribed times. After a park user activates the lights, the lights will remain on for one hour. At that time, a buzzer will sound repeatedly for 45 seconds. This allows the park user to re-start the lights. If the park user is no longer at the court, the lights will turn off, reducing the electrical load from these high wattage lights. Clear instructions will be printed on weather-resistant labels at each set of lighting controls.

## Parks Sports Lighting

1000W Metal Halide Lamp at Outdoor Tennis Court

Large, 1000W HID lamps illuminate outdoor city tennis courts, basketball courts, the Centennial Park skate park, and the Horseshoe court at Broken Arrow Park. The lamps are still fully functional, but the power requirement is very high. Replacement of these lights with low-power LEDs will provide long term savings. In addition to energy savings, LED lights last longer and provide a cleaner, whiter light with less light spillage.

# Indoor Aquatic Center

## Reduce After Hours Turnover & Tune Flows with VFDs

The turnover rate (turnovers per day) refers to the time it takes to move a quantity of water, equal to the total gallons in the pool and surge vessel, through the filtration system. Minimum turnover rates for various types of pools are determined by code and professional practice. Typically, shallow areas with a lot of activity, such as play areas, require more turnovers per day than deeper lap pools. The leisure pool, for instance, is designed for a full turnover to occur every 2.4 hours. The lap pool is appropriately designed for a full turnover every 6.2 hours.

Pool Pumps

360 Energy Engineers is proposing to install variable speed drives on the pool pumps so during unoccupied periods when no activity is present, the recirculation pumps for both pools could be reset up to 8 hours. This will reduce the leisure pool flow from 755 gpm to 221 gpm and the lap pool recirculation would reduce from 1,790 gpm to 1,386 gpm. According to pump affinity laws, the energy savings would be proportional to the reduction in speed to the third power. A summary of current and proposed pump power requirements is below:

| Pump | Current After-Hours Pump Horsepower | Proposed After-Hours Horsepower | Power Savings |
|---|---|---|---|
| **Lap Pool** | 34 HP | 16 HP | 13 kW |
| **Leisure Pool** | 14.5 HP | <1 HP | 12 kW |

Variable Speed Drives for Pumps

### Balance Pool Pump Flows with VSDs and Eliminate Throttling Losses

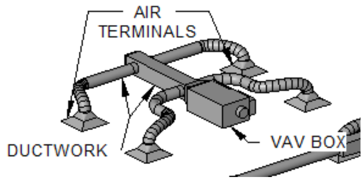
The current pool recirculation and play area feature pumps do not have flow balancing devices. Given that the design head (pressure lift) requirements of these are inherently conservative, these pumps are over pumping, providing more flow than precisely engineered design flow values. This wastes energy with no real benefit.

360 Energy Engineers will properly balance recirculation pump flows to design values by changing their speed with variable speed drives. We also propose to tune the pool feature and water slide pump with variable speed drives to provide only the appropriate flow needed.

Lap Pool

## VAV Terminal Optimization

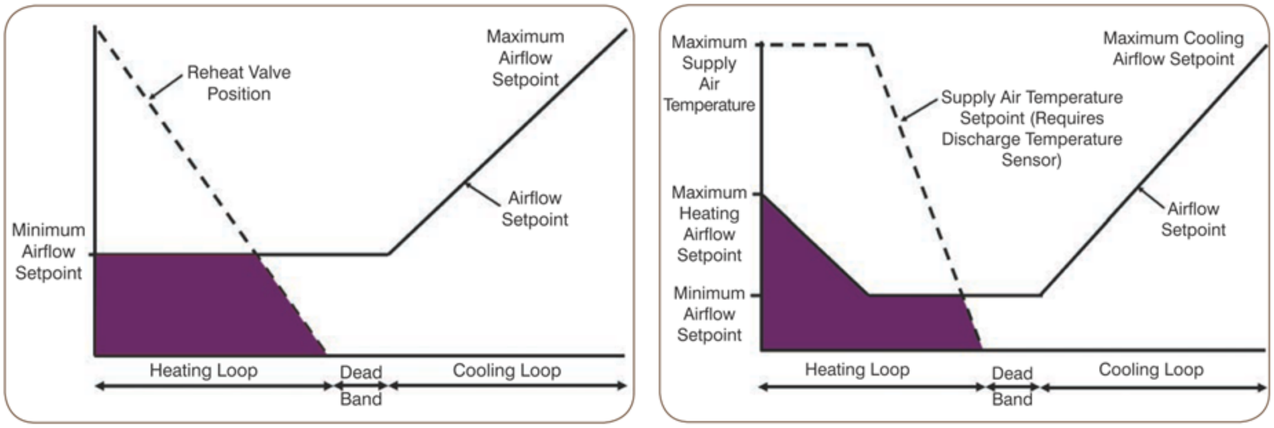
The non-natatorium spaces are conditioned by VAV boxes with hot water coils. These boxes control airflow proportional to cooling demands in the cooling mode and constant air volume in the heating mode. Although a common mode of control, this operation does not meet the requirements of ASHRAE 90.1 – Energy Standard for Buildings due to its inefficient operation during part-load heating. A dual-maximum or reverse-acting control on these boxes yield much improved energy performance over the current box control.



VAV Terminal Diagram

360 Energy Engineers recommends reprogramming all VAV controllers to implement dual-maximum airflow control. In the dual-maximum strategy, the VAV box modulates the volume damper down as a supply airflow setpoint is reset from the zone maximum airflow setpoint (when the space is at full cooling) proportionally down to the zone minimum (when no cooling is required). This minimum airflow rate is then maintained as the space temperature falls through the dead-band into heating mode. As the VAV box transitions into heating mode, the hot water heating coil simultaneously opens while the minimum airflow jumps to the heating minimum setpoint. The hot water reheat coil then modulates up to maintain the space at the heating setpoint until the control valve is fully open. This logic, shown in the figure below, is effective at maintaining comfort in spaces, but results in large amounts of wasted reheat energy. As an alternative, more modern control strategies very often use Dual Maximum logic, where a separate maximum heating airflow setpoint is calculated, independent from the maximum cooling airflow setpoint. Heating elements are still modulated to provide adequate heating to spaces, but the lower supply airflow in heating means less reheat is required, and can save significant fan energy at the air handling units supplying VAV boxes. This strategy is shown on the second image below.

**Conventional VAV Reheat Control (Left) vs. Dual Maximum VAV Reheat Control (Right)**



Benefits of dual maximum logic over traditional VAV reheat logic include lower fan energy, lower cooling energy use, lower reheat energy use, improved thermal comfort by not pushing zone temperature to heating setpoints during the cooling season, and reduced stratification due to supply air temperature control. Moreover, systems which utilize dual maximum control are better able to respond to varying weather conditions, and utilize less gas and electricity during both heating and cooling seasons. 360 Energy Engineers recommends integrating these control strategies into the current Automated Logic control system.

## Replace Heating Water Boilers with Condensing


Existing Heating Water Boiler

This energy conservation opportunity includes the replacement of the existing hot-water boiler for HVAC service at the Indoor Aquatic Center. The existing hot-water boiler at this facility is original to the building's construction and is nearing the end of its useful life. The boiler has been estimated to operate at 75% peak efficiency with decreased efficiency at part-load conditions, resulting in an average efficiency closer to 60%.

The existing hot-water boiler will be replaced with a smaller, natural-gas fired, condensing boiler. The installation of the smaller condensing boiler will allow for the heating system to operate at efficiencies well above 90%. The ability of the boiler to modulate down provides an increase in system efficiency at part-load conditions, which is where a vast majority of boiler operation occurs. This increase in boiler efficiency will decrease the amount of fuel used by the boiler, both during part and full-load conditions.


Condensing Boiler Plant

## Change Pool Temperature and Environmental Setpoints

Currently, the pool water temperatures are set at 86°F and 82°F for the leisure and lap pools respectively. Original design documentation indicates the basis of design for pool water temperatures were 82°F and 78°F for the leisure and lap pools respectively. Although these design values are a little low for comfort, reducing the pool water temperature setpoint by only a degree or two would yield significant energy savings from reduced pool heating requirements and lower load on the dehumidification system.


Pool Setpoint Adjustment

## Replace Dehumidification Units and Mitigate IAQ Issues

Harmful chloramine gasses and air with high moisture content are largely to blame for the significant corrosion on surfaces of all three air handling units serving the pools at the Indoor Aquatic Center. The Leisure Pool unit is planned for immediate replacement due to corrosion and major component failures, and the other two units serving the Lap Pool are in similar need of major repair or replacement in the next year or two.

Modern pool dehumidifiers for large capacity applications allow exceptional moisture control in high humidity locations such as natatoriums. Units would be designed to efficiently remove moisture from the air and provide well-conditioned, comfortable air to occupants. Energy efficiency features for pool dehumidification units can include:


Existing Packaged Dehumidification Unit

- Hot-gas reheat dehumidification methods where refrigeration processes remove latent heat, preserving sensible heat by recovering it from exhaust air
- Exhaust air energy recovery used for reheat
- Economizer use for dehumidification, when outside air conditions are ideal, that uses dry outside air to directly dehumidify, reducing the need for mechanical dehumidification
- Refrigerant hot-gas heat recovery for use in pool heating

### Improved Air Distribution Design and Low Source Capture Exhaust

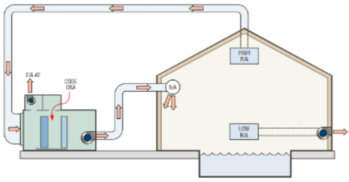

Dirty Condenser Coils

The air distribution design for both the lap pool and leisure pool, including the new design in the leisure pool promote high air velocities at the pool surfaces by aiming large amounts of air directly at the pool. Furthermore, the large ceiling fans installed in each natatorium compounds this issue. Thoroughly mixing the air in the auditorium, as is currently done, appears to address acute chloramine vapor issues at the pool surface. However, this design promotes excessive evaporation rates (up to 66% higher than normal) that result in poorer overall indoor air quality and higher dehumidification load on the HVAC units. This results in increased chemical use and increased energy consumption. It also reduces the dehumidification units' ability to maintain reasonable environmental conditions. 360 Energy Engineers recommends a much more effective air distribution design to improve indoor air quality and minimize evaporation and energy consumption. This design strategy is described below.

Existing Supply Ductwork in Lap Pool and High Return

Modern natatorium design has moved away from designing ductwork to have grilles aimed at the pool water surface as is currently the case in both pools. It is more effective to pull air across the pool water surface at very low velocity (less than 30 feet per minute). Consequently, all of the air supply should be aimed at exterior walls and windows and not at the pool. Directing air away from the pool water surface reduces water evaporation by approximately 40%, reducing energy consumption. It also promotes more effective capture control of chloramine vapors when coupled with a source capture exhaust system installed at deck level.

360 Energy Engineers recommends modifying the current supply duct layouts to generally form a "U" around three sides of each pool to provide 100% of the airflow that travels across or "washes" windows and outside walls with dry supply air. In addition to improving indoor air quality, this ductwork configuration also raises the temperature of the inside surface while flushing it with the lowest dew point air in the facility, minimizing condensation on windows and doors.



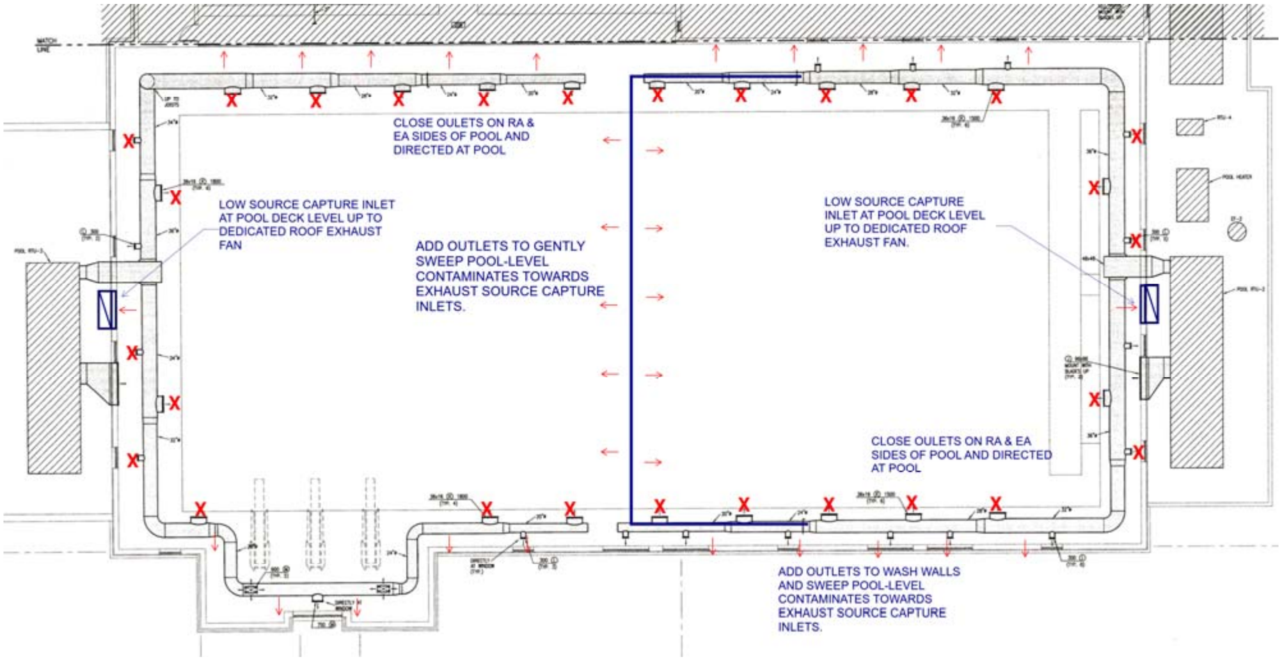
Low Source Capture Diagram

To more effectively dispose of chloramine vapors from the pool water surface, 360 Energy Engineers recommends source capture strategies in each pool to evacuate high-chloramine-concentration vapors directly from the pool surface. This source capture strategy would employ floor-level dedicated exhaust intakes on the same side of the spaces as the HVAC return air inlets. Consequently, supply air is pulled over the water surface at a low velocity so that contaminated air is moved toward a low exhaust point and exhausted directly outdoors. This low exhaust source capture strategy minimizes and prevent the recirculation of chloramines and other airborne pollutants, helping maintain the quality of supply air to the breathing zone in the pool and deck area. The absence of chloramines and corrosive pollutants also helps protect natatorium equipment and other HVAC system components.

Existing Supply Ductwork in Leisure Pool

Energy is saved by significantly lowering pool water evaporation rates, this decreasing dehumidification and pool heating requirements.

## Conceptual Layout of Proposed Lap Pool Air and Exhaust Modifications


CLOSE OULETS ON RA & EA SIDES OF POOL AND DIRECTED AT POOL

LOW SOURCE CAPTURE INLET AT POOL DECK LEVEL UP TO DEDICATED ROOF EXHAUST FAN

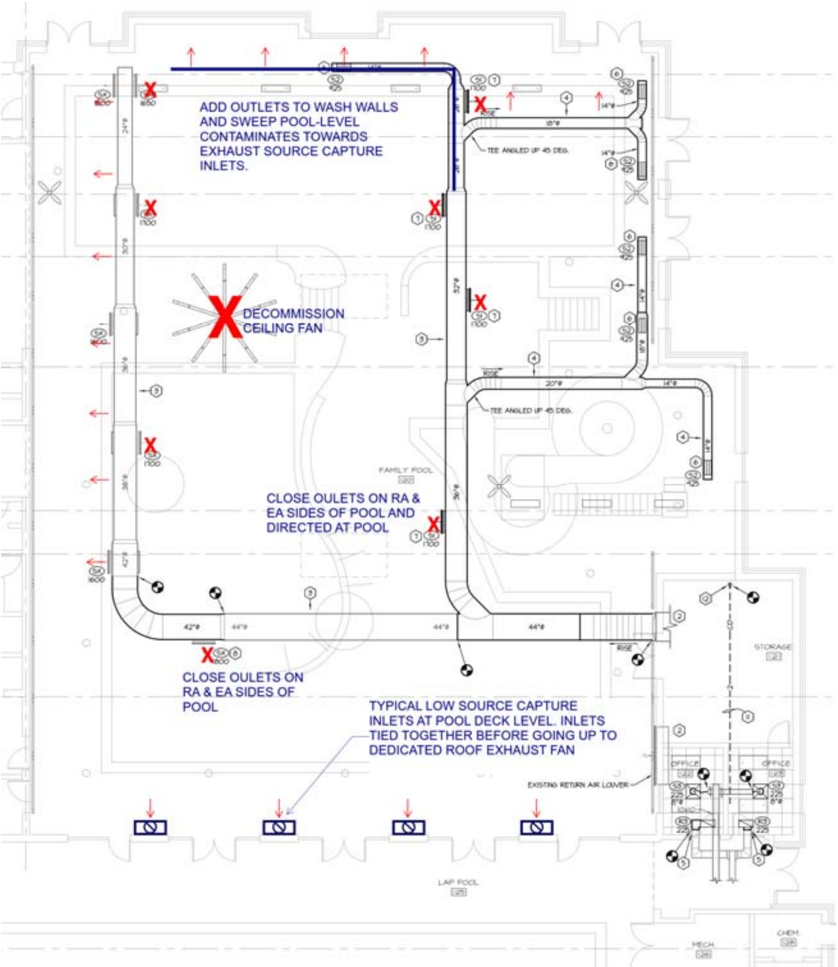
ADD OUTLETS TO GENTLY SWEEP POOL-LEVEL CONTAMINATES TOWARDS EXHAUST SOURCE CAPTURE INLETS.

LOW SOURCE CAPTURE INLET AT POOL DECK LEVEL UP TO DEDICATED ROOF EXHAUST FAN.

CLOSE OULETS ON RA & EA SIDES OF POOL AND DIRECTED AT POOL

ADD OUTLETS TO WASH WALLS AND SWEEP POOL-LEVEL CONTAMINATES TOWARDS EXHAUST SOURCE CAPTURE INLETS.

## Conceptual Layout of Proposed Leisure Pool Air and Exhaust Modifications


ADD OUTLETS TO WASH WALLS AND SWEEP POOL-LEVEL CONTAMINATES TOWARDS EXHAUST SOURCE CAPTURE INLETS.

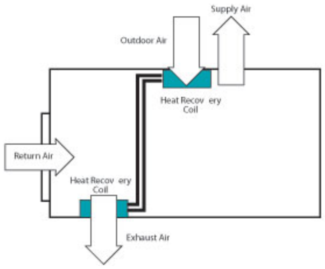
DECOMMISSION CEILING FAN

CLOSE OULETS ON RA & EA SIDES OF POOL AND DIRECTED AT POOL

CLOSE OULETS ON RA & EA SIDES OF POOL

TYPICAL LOW SOURCE CAPTURE INLETS AT POOL DECK LEVEL. INLETS TIED TOGETHER BEFORE GOING UP TO DEDICATED ROOF EXHAUST FAN

### Optimized Ventilation and Exhaust Control based on Activity



Exhaust Schematic

Optimized control strategies for the pool ventilation and exhaust systems would be implemented, including the installation of some new control hardware, to modulate outdoor air and exhaust airflow rates based on pool activity and contaminant levels (VOCs) measured in the natatoriums. A description of the modes of operation and corresponding control of ventilation and exhaust are described below:

**Unoccupied Mode**: Outdoor air volume is controlled as a reduced volume (generally one-half of the code required level per ASHRAE 62.1). The low source capture exhaust air will operate at 100% of its capacity, removing surface-level contaminates. The new dehumidification unit will be in recirculation mode with the dehumidifier exhaust air fan running at low volume to maintain a small negative air balance in the pool room.

Decommissioned Exhaust Fan

**Occupied Mode**: Under normal pool use, outdoor air volume is controlled to the code required level (per ASHRAE 62.1). The low source capture exhaust air will operate at 100% of its capacity, removing surface-level contaminates. The new dehumidification unit's exhaust air fan will be running at medium volume to maintain a small negative air balance in the pool room.

**Event Mode**: Under high activity, such as swim meets or fully occupied leisure pool use, outdoor air volume is controlled to approximately 120% of the code required level (per ASHRAE 62.1). The low source capture exhaust air will operate at 100% of its capacity, removing surface-level contaminates. The new dehumidification unit's exhaust air fan will be running at high volume to maintain a small negative air balance in the pool room.

Decommissioned Exhaust Duct

**VOC-Based Control of Source Capture Exhaust System:** VOC sensors with the ability detect when interior levels chloramines are present would be installed in the natatoriums, and the low source capture exhaust speed based on these levels of contaminants (VOCs). This would provide the ability to optimize the volume of exhaust air required with the energy cost of doing so and ensures a suitable pool environment for the occupants.

## Replace Corroded Electrical Gear and Recommission Mechanical Room Exhaust

The Indoor Aquatic Center is served by relatively new electrical distribution equipment. Accelerated corrosion, caused by excessively warm and humid air, is visible on the equipment. The presence of corrosion of this magnitude indicates that internal circuit breakers may suffer from the same rust and corrosion issues. Circuit breakers in poor condition are less likely to effectively trip during a fault condition. A high risk of injury or property damage exists if a system disconnect cannot adequately open a circuit in an emergency situation. 360 Energy Engineers will replace damaged and corroded electrical panels, breakers, motor starters, and a wireway.

Panelboard with Corrosion

To protect new electrical equipment and retard future corrosion, 360 Energy Engineers also recommends to recommission some general exhaust and fresh air makeup in these spaces. The pool equipment room was recently retrofitted with a dedicated exhaust system isolated to the surge chamber. The general equipment room exhaust was decommissioned at that time. This greatly improved the overall air quality throughout the equipment room. However, maintaining some general exhaust is recommended due to the storage of corrosive chemicals in the room, particularly in the electrical and chemical feed rooms. These rooms currently store corrosive chemicals, and exhaust will minimize corrosion and other issues within these spaces.

## Replace Pool Water Heaters with Condensing Boilers

Existing Pool Boilers

Due to heat losses to the ambient air, through the pool surfaces to the earth, and indirectly through walls, pool water must consistently be heated to maintain comfortable and desired temperatures. Currently, an atmospheric gas fired boiler operates on the roof to supply hot water to maintain 82°F-86°F water for the lap pool and recreational pool, respectively.  This atmospheric combustion design yields varying operating conditions that adversely affect the performance of the boiler, especially when considering the boiler's exposure to extreme cold during winter months. The existing boiler operates between an estimated 65%-70% efficiency, which is very low for today's standards.

Modern Condensing Pool Boiler

New boilers with operating efficiencies in excess of 93% have greater turndown capability and operate better at low load conditions than the existing equipment. Relocating the boiler inside the mechanical room would help protect it from environmental elements. The new unit would be equipped with a sealed combustion chamber for protection from chemicals stored in the mechanical room.  The dramatic efficiency gains from the antiquated atmospheric boiler to a condensing boiler with 10:1 turndown will provide significant savings in fuel energy for pool water heating.

# Holcom Recreation Center

## New Packaged HVAC Systems


Gymnasium Air Handler

Holcom Recreation Center is conditioned by four air handlers, two for the gym and two for the remainder of the facility. These air handlers utilize hot water for heating and have DX condensing units for cooling. The hot water is generated by an Ajax boiler that is beginning to fail and is in need of replacement. Two of the air handlers were recently rebuilt, receiving new internal components and outdoor condensing units. These two units serve the front portion of the building including the weight room, rec room, lockers, and front lobby. The other two units are mounted to the gymnasium ceiling. These units have experienced many issues recently and are a concern with very difficult access to service the units during failure.


Aging AJAX Boiler

To improve the HVAC strategy, new packaged units will be installed to the North of the facility near the existing condensing units. Commercial outdoor packaged systems contain all components needed for heating, cooling and ventilation in one factory-fabricated, weather-tight unit. Heating is provided by low-cost natural gas while cooling is provided by direct expansion of refrigerant. Recent advancements in compressor technology, such as variable speed and digital scroll, have allowed for much better cooling part-load performance than the existing DX systems serving the Holcomb Recreation Center.

With the gymnasium air handlers removed, the remaining two air handlers will be fitted with gas furnace duct heaters. These duct heaters will provide heating for the two air handlers, eliminating the need for a new boiler to be installed. The complex and costly boiler maintenance, as well as the required annual boiler inspections, will no longer be required for this facility.

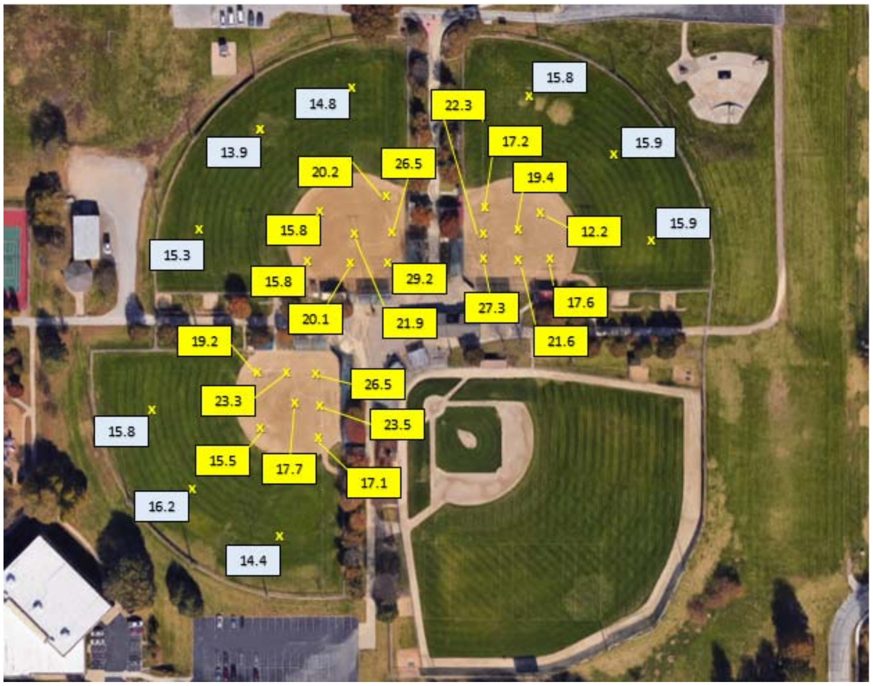

New Packaged Unit

## Sports Field Lighting

The four baseball fields at Holcom Sports Complex (Red, Gold, Blue, and Ice Fields) are illuminated by 1500 watt metal halide lamps mounted on 80 foot wooden poles installed in 1970. The wooden poles are in poor condition, showing visual splits and cracks. They are warped and at least one has been removed due to safety concerns.


Ice Field with Existing 1500W Metal Halide Lighting

The existing metal halide lights are past their recommended useful life, and they do not adequately light the playing surface.  According to Little League© International's 2015 Lighting Standards and Safety Audit, the required average lighting level is 50 foot-candles in the infield and 30 foot-candles in the outfield.  The diagram below shows that the current light levels are well below the standard:



*Blue boxes indicate outfield measurements, Yellow boxes indicate infield measurements. All measurements taken on a clear night. All measurements shown are in foot-candles (fc).*

The replacement lights can potentially be either Metal Halide or LED. As a newer technology, LED lamps have a slightly higher initial cost. However, the total energy usage of LEDs is much lower than Metal Halides, resulting in a lower lifetime cost. Additionally, LEDs will provide a cleaner, whiter light, improving the visibility of both players and fans watching the game.

Southwest Field Illuminated by Existing Lighting

Ball Field Illuminated by LED Lights

# Community Recreation Center

## Replace Aging Rooftop Units


Existing Packaged Unit (1993)

The community center has twelve packaged gas/DX rooftop units that provide heating and cooling for all spaces in the facility. Most of these units are well past their rated service life and are in need of replacement. Of the twelve units currently installed, one was replaced in 2015 and will remain in place. The remaining rooftop units will all be replaced with new packaged units.

The new units will include high efficiency digital scroll compressors and variable speed fans to modulate air flow in the facility as needed throughout the day. These new units will also have increased cooling efficiency providing additional utility savings during operation. The units will be controlled by digital controllers, so they can be added to the existing control system interface used by the Parks and Recreation facilities staff.


Rooftop Hail Damage

## Replace Roof

The existing EPDM rubber membrane roof is beginning to fail. Many soft spots were noted on the facilities walkthrough indicating saturated and damaged roof insulation which can cause moisture to enter the facility. A new modified bitumen roofing system will be installed after tearing off the existing membrane and damaged insulation. A modified bitumen roof has many advantages over membrane roofing systems and provides increased longevity compared to lower cost alternatives.


Rubber Membrane Roof

Savings will be achieved by improving the thermal resistance of the roofing system, which is the largest surface area through which heat is gained and lost contributing to energy consumption of the HVAC equipment.

# East Lawrence Recreation Center

## Replace Rooftop Units 2, 3, & 4


Packaged Rooftop Unit (1996)

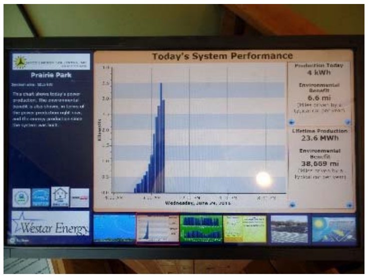
The East Lawrence Recreation Center is conditioned by four packaged rooftop units. One unit has been recently replaced due to failure and will be excluded from the scope of this project. The remaining three units are in need of replacement as they are nearly 20 years in age and have reached the end of their rated service life. With increased efficiencies due to technological advancement such as variable speed and digital scroll compressors, the facility will not only have lower operating costs but provide increased comfort for the occupants. The existing units are controlled by a central digital control system by Parks and Recreation. The new units would be fitted with digital controllers and be able to be accessed remotely similar to the current system.

# Nature Center

## New Ground-Source HVAC System

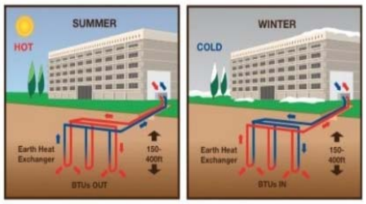
Existing Furnaces (1997)

The Nature Center is currently heated and cooled by residential-style split systems with four furnaces in the mechanical room and four DX condensing units to the west of the facility. Indoor air quality has been an ongoing issue for the facility. The facilities staff did install inline canister filters and active UV filters to eliminate some stale air and particle issues but this did not entirely eliminate the indoor air quality issues.  Outdoor air ventilation would be a significant improvement, but the current heating and cooling system is not designed to allow adequate outdoor ventilation air into the facility. Additionally, the existing units are due for replacement as they are near the end of their recommended service life.



Solar Educational Display

To accomplish both improved indoor air quality and provide more efficient heating and cooling, a ground-source (also known as geothermal) HVAC system will be installed, replacing the residential split systems. Four new water source heat pumps will be installed in place of the furnaces. A geothermal hydronic loop will be installed to extract heat from the ground during the winter.  This same water loop will take heat out of the building during the summer, transferring this heat to the ground. By utilizing heating and cooling from the ground, this system provides the building some "free energy" and a reduction in the overall utility consumption. This system can also incorporate outdoor ventilation air to the spaces, which is something currently missing from the existing system.



Ground-Source Diagram

As an educational tool for the facility, a solar PV display was installed to provide an interactive learning experience for the visitors. A ground-source, or geothermal, heating and cooling system is a great opportunity to educate visitors on this modern, high-efficiency heating and cooling system.  An addition to the solar PV display will educate and inform visitors on the benefits of a ground-source HVAC system.

# Outdoor Aquatics Center

## Stand-Alone HVAC for Concession Stand

The concession stand area is detached from the main building at the outdoor aquatic center. However, these areas are served by a common HVAC system. This causes ineffective cooling in the concession area due to the very long duct run from the air handler to the concession stand. 360EE recommends installing a dedicated cooling-only mini split system to solve comfort issues in the concession areas.


Ductless Mint-split

## Replace Pool Boiler with Condensing Boilers

To prepare the pool for swimming in June, pool water must be heated in the spring. Currently, an atmospheric gas fired boiler operates on the roof to supply hot water for pool heating. This atmospheric burner design yields varying operating conditions that adversely affect the performance of the boiler. The existing boiler operates just over 80% efficient; low for today's standards and considering constantly increasing energy costs.

The dramatic efficiency gains from the antiquated atmospheric boiler to a condensing boiler with 10:1 turndown will provide significant savings in fuel energy for pool water heating. However, this project will yield a poor payback due to the low annual operating hours of the boiler. This boiler typically operates for only two months annually.

Outdoor Condensing Unit


Pool Water Heater

# Improvements Not Recommended

The projects described in this section were analyzed by 360 Energy Engineers. While each project has its merits, these projects are not recommended for action at this time.

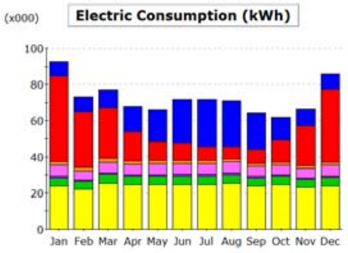
## Add Gas Boiler and Hot Water VAV Boxes at The Library

Electric resistance heat is very costly when compared to heat produced by natural gas fired equipment. While not immediately obvious from an efficiency standpoint, it is apparent when analyzed from a cost standpoint. Electricity's cost per unit of energy is 4.7 times that of natural gas' cost per unit of energy for the City of Lawrence. This simply means that the building, if heated with natural gas, would cost 21% of the current cost to heat. Unfortunately, converting to natural gas as a retrofit project is expensive. Natural gas heating could have been incorporated in the design of the building renovation much more cost effectively, resulting in a much lower life cycle cost for the facility. 360 Energy Engineers has evaluated the energy savings and implementation cost of converting the Library's electrical resistance VAV terminal reheat to hot water terminal reheat.

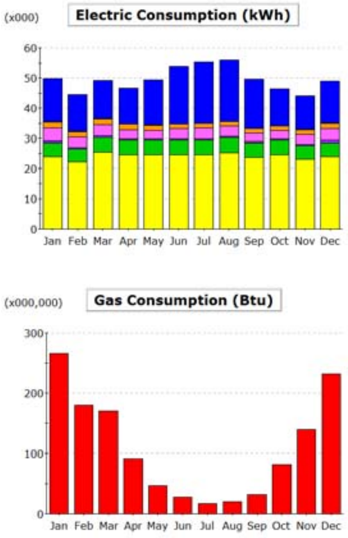
This concept is based on heating hot water generated by new high-efficiency condensing boilers capable of operating at efficiencies up to 95%. Hot water distribution piping would be installed throughout the building, and connected to existing VAV terminal boxes equipped with new hot water reheat coils. Because the existing terminal box controllers are new, they would simply require minor reprogramming to send an analog heating signal to a newly installed hot water valve instead of a digital heating signal to an electric coil. One of the primary design challenges would be determining a location for the new, small central hot water plant, which would mean sacrificing some (although minor) storage space. 360 Energy Engineers would work with facility staff to allocate space for the new hot water plant.

Although net energy savings is significant and future electrical costs are almost certain to continue to escalate at a rate that far out paces natural gas costs, this is a relatively capital intensive recommendation. However, when viewed over the system or building's life cycle, the city would benefit economically in the long term from converting this building to natural gas.

Leveraging annual utility and operational savings from other lower cost projects at the Library helps improve the financial payback of this Facility Improvement Opportunity.



Current Month Electric End Use (red is heat)

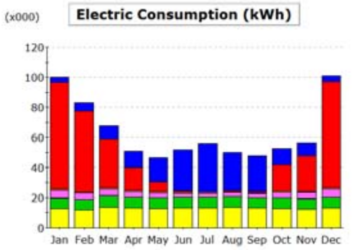


Month Elec & Gas End Use with HW Boiler (red is heat)

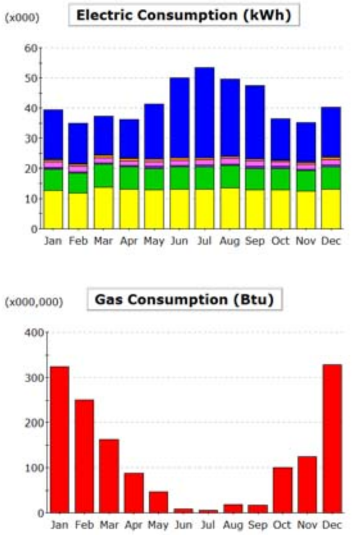
🟨 Area Lighting
🟫 Task Lighting
🟩 Misc. Equipment
⬜ Exterior Usage
🟪 Pumps & Aux.
🟪 Ventilation Fans
🟧 Water Heating
🟫 Ht Pump Supp.
🟥 Space Heating
🟦 Refrigeration
🟦 Heat Rejection
🟦 Space Cooling

Central Hot Water Plant

# Add Gas Boiler and Hot Water Reheat to VAV Boxes at City Hall



Current Monthly Electric End Use (red is heat)



Monthly Elec & Gas End Use with HW Boiler (red is heat)

🟨 Area Lighting
🟫 Task Lighting
🟩 Misc. Equipment
⬜ Exterior Usage
🟪 Pumps & Aux.
🟪 Ventilation Fans
🟧 Water Heating
🟥 Ht Pump Supp.
🟥 Space Heating
🟦 Refrigeration
🟦 Heat Rejection
🟦 Space Cooling

Electric resistance heat is very costly when compared to heat produced by natural gas fired equipment. While not immediately obvious from an efficiency standpoint, it is apparent when analyzed from a cost standpoint. Electricity's cost per unit of energy is 4.7 times that of natural gas' cost per unit of energy for the City of Lawrence. This simply means that the building, if heated with natural gas, would cost 21% of the current cost to heat. Unfortunately, converting to natural gas as a retrofit project is expensive. Natural gas heating could have been incorporated in the design of the building renovation much more cost effectively, resulting in a much lower life cycle cost for the facility. 360 Energy Engineers has evaluated the energy savings and implementation cost of converting City Hall's electrical resistance VAV terminal reheat to hot water terminal reheat.

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Leveraging annual utility and operational savings from other lower cost projects at City Hall helps improve the financial payback of this Facility Improvement Opportunity

# Solar PV for Pumping on Tanks 5 and 6 at Venture Park

Water Storage Tanks #5 and #6 at Venture Park each have twin 50HP electric pump motors. Although these motors run infrequently, the billed electrical demand creates significant cost. A solar-powered pumping system can provide most of the power required to run these large pumps. A small array of photovoltaic panels will be installed near each pump. These panels will be ground-installed due to the abundance of space available near the tanks. Each array of photovoltaic panels will charge an array of batteries. When pumping power is required, these batteries will power the 50HP pump motors through an AC inverter.

Remote Photovoltaic Array Used for Solar-Powered Water Pumping

The smaller sump and transfer pumps at Venture Park could use small-scale solar pumping methods, but their relatively small power requirement and inconsistent use pattern make it impossible to develop an estimated financial benefit.

The City of Lawrence's improvements at the Venture Park site are a wonderful example of environmental stewardship. Using solar-powered means of removing water from the site is yet another mechanism to improve that process even further.

Pump Station at Venture Park Holding tank

## Compressed Natural Gas (CNG) Solid Waste Truck Fleet Replacement

The current solid waste truck fleet is comprised of over 50 trucks, including roll-off, rear load, hook and auto side loaders (ASL). All of these vehicles are diesel powered machines with the exception of one roll-off test truck. This test truck was part of a pilot to test the effectiveness of CNG fleet vehicles. The CNG roll-off truck does not have a constant routine, making data acquisition difficult. It makes several runs a day, but is used much less than an ASL, picking up residential refuse throughout the week. The other component to the test was a filling station. The filling station installed does not have individual hose reading, which makes tracking fuel economy and operating costs much more difficult.

Existing Diesel Truck

When looking at the change from all diesel to all CNG trucks there are several factors to consider. The incremental costs of the CNG truck, fueling costs, maintenance costs, and fueling station solutions, are just some of the necessary factors needed to evaluate a potential conversion. Many case studies have been conducted to quantify the opportunity. While it was favorable for some tests, current economics are not advantageous for a fleet conversion. Currently, the city pays $2.17/Gal of diesel. The cost for a Diesel Gallon Equivalent (DGE) of CNG is $1.90. This means that the differential in fueling costs equates to $0.27/gal. For the evaluation, an incremental cost of $38,000/truck was used for the added expense. To cover the cost of a filling station, $1.1 million dollars was included per station. A fleet requires one station for every 15-25 vehicles in use.

Existing Diesel Truck

| Fuel Cost Evaluation | Case Study 1 | Case Study 2 | Lawrence Full Fleet | Lawrence Test Fleet |
|---|---|---|---|---|
| CNG Fleet Size | 20 | 30 | 50 | 5 |
| Fueling Stations | 1 | 2 | 2 | 1 |
| CNG Price (DGE) | $1.78 | $1.78 | $1.90 | $1.90 |
| Diesel Price (Gal) | $3.90 | $3.90 | $2.17 | $2.17 |
| Vehicle Incremental Cost | $760,000.00 | $1,100,000.00 | $1,900,000.00 | $190,000.00 |
| Fueling Stations Cost | $1,100,000.00 | $2,200,000.00 | $2,200,000.00 | $1,100,000.00 |
| Total Capital Cost | $1,860,000.00 | $3,300,000.00 | $4,100,000.00 | $1,290,000.00 |
| Miles/Year/Truck | 7000 | 7000 | 7000 | 7000 |
| Yearly Fuel Savings | $300,000.00 | $445,000.00 | $202,500.00 | $20,250.00 |
| SPB of Fuel | 6 | 7 | 20 | 64 |

Example CNG Fueling Station

As shown in the figure above, the cost benefit for the City of Lawrence is not as evident as for other markets that have higher fuel rates. The majority of these studies were conducted several years ago, when diesel was much more expensive than it is now. While fuel is a large portion of the quantifiable savings, there are other factors to consider. Maintenance costs on diesel fueled trucks is quite intensive and can lead to an excessive amount of down time. The maintenance for a CNG truck is much less than that of diesel. At this time, 360 Energy Engineers does not recommend the City of Lawrence to move forward with a solid waste fleet conversion from diesel to CNG.

## Replace Windows and Doors at Solid Waste Office

The facility's current glass doors and windows are contributing to the high level of discomfort in the facility. High levels of condensation are visible between the panes of glass in multiple windows of the Solid Waste Office. This condensation is an indicator of broken seals between the panes. When the insulating gas escapes the window, it no longer provides adequate insulation to the interior of the building. Additionally, broken seals are a good indicator of air infiltration which makes occupant discomfort even worse.

The existing door and window systems will be replaced with new thermally broken aluminum framed double-pane glass. These will improve the heating and cooling in the facility while lowering energy use.

Existing Window System Showing Condensation Between Glass Panes

## Replace Windows at Fire Station #3

Older window at FS#3

When Fire Station #3 was architecturally renovated and expanded in 2003, several windows around the top perimeter of the facility were not replaced. These windows have poor thermal performance and should be replaced with high efficiency, low emissivity, double-paned windows. The large bay doors in the garage area appear to be in relatively good condition, but re-sealing and replacement of glazing would help improve thermal performance and make the space more comfortable.

Example of high efficiency window

The remaining original window systems will be removed and replaced with new double-paned, thermally broken, aluminum-framed systems. In addition, a low-emissivity coating on the window system will reduce radiative heat gains and losses to further improve efficiency.

Savings will be achieved by improving the thermal resistance of these window systems, which cover a large percentage of the building. This will allow for the HVAC equipment to operate at lower loads reducing utility consumption.

## Photovoltaic School Beacons

The City of Lawrence recently replaced several AC-powered school zone flasher beacons with solar-powered flashers. A complete replacement of existing AC-powered beacons will take this part of the City's electrical load off of the electrical utility. Additionally, a complete replacement will develop a consistent signage throughout the City. Lastly, a complete replacement will reduce maintenance complexity and expense as the older, AC-powered beacons will all be removed.

The newest solar-powered school zone flasher system can be seen on Harper St., just south of Kennedy School. This signage is clear, easily readable, and 100% powered by the small photovoltaic array above the flasher. Replacing the older, AC-powered beacons in the city with this technology will promote safety, reduce maintenance, and improve the appearance of the City of Lawrence.


Existing School Zone Beacon
Powered by Electric Utility


Solar-Powered School Beacon
Uses No Utility Electrical Power

# Replace Condensing Boilers at Lawrence Arts Center

Existing Atmospheric Boilers

The existing hot-water boilers at this facility are original to the building's construction and are nearing the end of their useful life. The boilers have been estimated to operate at 80% peak efficiency with decreased efficiency at part-load conditions, resulting in an average efficiency of around 70%.

## High Efficiency, Low Temperature Heating Plant Using Condensing Boilers

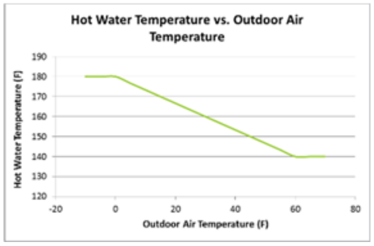
Example High Efficiency Hot Water Plant

The new heating water system would likely involve the use of three natural-gas fired, condensing boilers each sized at 50% of the building's heating load. This would provide full redundancy, so if one boiler was to fail, the building would still receive all of the heat it demands. Furthermore, the boilers would be specified with fully modulating burners that provide an increase in system efficiency at part-load conditions, which is where a vast majority of boiler operation occurs. This increase in boiler efficiency will decrease the amount of fuel used by the boilers.

## Boiler Sequencing Control for Optimal Energy Performance

The new boiler plant would come equipped with sequencing controls programmed to operate multiple boilers for optimal system efficiency. This optimally efficient operation would include staging the boilers to maximize the number of boilers operating while minimizing their firing rates. Energy is saved by maximizing the time each boiler operates in its peak efficiency range.

## Hot Water Temperature Reset Controls



Hot Water Reset Control Logic

A hot water boiler's operating efficiency is proportional to its return water temperature. As the return water temperature decreases the boiler efficiency increases. For this reason, operating a boiler at a constant year-round temperature, as is currently the case at the Arts Center, is wasteful when cooler water temperatures will suffice. The hot water reset feature reduces hot water temperature as heating demand decreases. Building and system conditions are monitored to insure that the zone or coil needing the most heating is always satisfied. As a result, heating energy is saved during part-load conditions due to increased boiler efficiency.

# Reduce After Hours Turnover & Tune Flows with VFDs at Outdoor Aquatic Center

The turnover rate (turnovers per day) refers to the time it takes to move a quantity of water, equal to the total gallons in the pool and surge vessel, through the filtration system. Minimum turnover rates for various types of pools are determined by code and professional practice. Typically, shallow areas with a lot of activity, such as play areas, require more turnovers per day than deeper lap pools. The outdoor pool, for instance, is designed for a full turnover to occur every 6 hours, which is customary for this type of pool.

Pool Recirculation Pump

360 Energy Engineers evaluated installing a variable speed drive on the pool recirculation pump so that during unoccupied periods, when no activity is present, the recirculation pump for the pool could be reset for up to 8 hours of turnover. This will reduce the leisure pool flow from 755 gpm to 221 gpm and the lap pool recirculation would reduce from approximately 1,400 gpm to 1,106 gpm. According to pump affinity laws, the energy savings would be proportional to the reduction in speed to the third power. A summary of current and proposed pump power requirements is below:

| Pump | Current After-Hours Pump Horsepower | Proposed After-Hours Horsepower | Power Savings |
|---|---|---|---|
| **Pool Recirc.** | 41 HP | 21 HP | 17.5 kW |

# Replace Damaged Skylight at East Lawrence Recreation Center

Failing Skylight

Gymnasium Skylights

On the roof of the East Lawrence Recreation Center, there are eight large skylights providing natural light for the gymnasium. One of the skylights was repaired after is caused a water leak in the gymnasium. Another skylight is in poor condition and needs to be replaced to eliminate moisture from entering the building and causing issues with the gymnasium flooring.

# Consumption & Savings Analysis

## Rate Analysis

### Electricity

The facilities owned by the City of Lawrence are serviced with electrical power by Westar Energy. Most facilities are billed at the Small General Service rate as follows:

- Customer charge: $ 22.50 per monthly billing.
- Energy charge: $ 0.09699 per kilowatt-hour (kWh) for the first 1,200 kWh, where kWh is the metered amount of electrical energy consumed between the monthly read dates.
- Energy charge: $ 0.050723 per kilowatt-hour (kWh), where kWh is the metered amount of electrical energy consumed between the monthly read dates.
- Winter demand charge (October through May): $ 4.38 per kilowatt (kW) over 5 kW, where kW is the metered peak electrical demand registered between the monthly read dates.
- Summer demand charge (October through May): $ 8.47 per kilowatt (kW) over 5 kW, where kW is the metered peak electrical demand registered between the monthly read dates.

Small General Service also has charges for Transmission, Power Generation, Efficiency, and other surcharges and taxes. These rates are not published and change over time. During the evaluation period, a sample of recent bills was evaluated and a blended rate was calculated for the actual charge paid by the facilities. The blended rates are listed below:

- Energy charge: $ 0.0917658 per kilowatt-hour (kWh), where kWh is the metered amount of electrical energy consumed between the monthly read dates.
- Winter demand charge (October through May): $ 4.38 per kilowatt (kW) over 5 kW, where kW is the metered peak electrical demand registered between the monthly read dates.
- Summer demand charge (June through September): $ 8.47 per kilowatt (kW) over 5 kW, where kW is the metered peak electrical demand registered between the monthly read dates.

When evaluating the blended utility rate paid by the City of Lawrence, it is around11% higher than the regional average. The retail price of electricity in the commercial sector of the west north central region, which includes the states of Iowa, Kansas, Minnesota, Missouri, Nebraska, and South Dakota, is $ 0.0823 per kWh (Energy Information Administration, Electric Power Monthly).  This also does not take into account the demand charge which is rather high for the City of Lawrence Small General Service. Accounting for those additional charges, the city pays well above the regional average, amplifying the effects and savings from energy conservation measures and energy related facility improvement opportunities.

Larger buildings and meters are billed at the Medium General Service, which is as follows:

- Customer charge: $ 100.00 per monthly billing.
- Winter Energy charge (October through May): $ 0.014627 per kilowatt-hour (kWh), where kWh is the metered amount of electrical energy consumed between the monthly read dates.
- Summer Energy charge (June through September): $ 0.019261 per kilowatt-hour (kWh).
- Demand charge: $ 15.615204 per kilowatt (kW), where kW is the metered peak electrical demand registered between the monthly read dates.

Medium General Service also has charges for Transmission, Power Generation, Efficiency, and other surcharges and taxes. The blended rates are listed below:

- Winter Energy charge: $ 0.038813 per kilowatt-hour (kWh), where kWh is the metered amount of electrical energy consumed between the monthly read dates.
- Summer Energy charge: $ 0.044646 per kilowatt-hour (kWh).
- Demand charge: $ 20.214 per kilowatt (kW), where kW is the metered peak electrical demand registered between the monthly read dates.

When evaluating the blended utility rate paid by the City of Lawrence, it is around 50% lower than the regional average of $ 0.0823 per kWh (Energy Information Administration, Electric Power Monthly). This however does not take into account the demand charge which is very high for the City of Lawrence Medium General Service. Accounting for those additional charges, the city pays substantially more than the regional average, amplifying the effects and savings from energy conservation measures and energy related facility improvement opportunities.

## Cost of Heating with Electricity vs. Gas:

When comparing the cost of heating with electricity and natural gas, the delivered cost of the energy from the utility supplier and the efficiency to convert that utility into useful heat must be considered.

### Cost of Electric Heat:

Blended Electric Rate (Westar MGS): $0.119/kWh

Converting kWh to therms: $\frac{\$0.119}{kWh} \times \frac{1\text{ kWh}}{3412\ Btu} \times \frac{100{,}000\text{ Btu}}{therm} = \$\boldsymbol{3.49/therm}$

*Note: the blended $/kWh electric rate includes all costs associated with demand (kW) and consumption (kWh) divided by the total consumption (kWh).*

### Cost of Natural Gas Heat:

Current natural gas cost: $0.70/therm

Cost to generate one therm of heat through a high-efficiency condensing boiler: $\frac{\$0.70\backslash\text{therm}}{95\%\ efficiency} = \$\boldsymbol{0.74/therm}$

Therefore, electricity costs nearly **5 times** more than natural gas to provide space heating at current electric and gas rates.

# ECM Analysis

This section describes each ECM analysis. Engineering notes, schematics, bin data, and mathematical calculations are excluded for clarity. A narrative description of each ECM is available in the Energy Conservation Measures section. More detailed calculations and results are available in the Appendix.

# City-Wide Web Based Thermostats

## Baseline Energy Consumption & Cost

A detailed bin analysis calculation tool was developed specifically to calculate the baseline energy consumption of the existing HVAC equipment that is currently controlled via a traditional thermostat. This tool utilizes Typical Meteorological Year (TMY3) local weather data to determine the number of hours in each temperature "bin", where each bin has a two degree range. A baseline schedule, determined by site audits, observations, and conversations with facility personnel, was applied to the equipment. For each hourly bin, including both occupied and unoccupied hours, heating and cooling runtimes proportional to a deviation from a balance point of 55°F were applied to the equipment. Fan, heating, and cooling energy are all then calculated for each of the hourly bins given the baseline schedules and temperature setpoints to establish the baseline cost of operating HVAC equipment as it currently runs. Equations used in the bin analysis are listed in the Appendix.

## Savings Estimates

The same bin analysis tool was used to calculate post-project consumption of the new and remaining HVAC equipment given modified equipment schedules, and temperature setpoints controlled by the new web based thermostats. Allowing unoccupied space conditions for areas such as the administrative offices creates a smaller temperature difference between the outdoor air and the indoor space, reducing the heating and cooling loads of the space. While the temperature floats to these unoccupied setpoints, the equipment can turn completely off, saving significant energy. The consumption associated with the increased equipment efficiencies, revised schedules, and modified setpoints was compared with the baseline consumption to determine the projected annual savings. Equations associated with this calculation are listed in the Appendix. The resulting savings from the installation of this equipment is as follows:

- Post - Annual Electrical Consumption Saved: 148,234 kWh
- Post - Annual Natural Gas Consumption Saved: 19,482 Therms
- Post - Annual Savings Projected: $ 27,275
- Post - Annual Maintenance Savings Projected: $250

# Public Works: Timer Control for Solid Waste Truck Block Heaters

## Baseline Heater Consumption & Cost

A detailed hourly analysis calculation tool was developed specifically to calculate the baseline energy consumption of the existing block heaters used by the Solid Waste Trucks. This tool utilizes Typical Meteorological Year (TMY3) local weather data to determine the dry bulb temperature at each hour of a calendar year. A baseline use, determined by site audits, observations, and conversations with facility personnel, was applied to the analysis. For nights where the temperature reached freezing or below, the total energy consumption of block heaters was calculated for the off-shift hours in a day.

## Savings Estimates

The same analysis tool was used to calculate post-project consumption given temperature controls and timers. For each night that resulted in freezing (or lower) temperatures, the full electrical load of the block heaters was calculated for a period of four hours before the start of the early morning shift. The resulting savings from the installation of this equipment is as follows:

- Pre – Annual Electrical Consumption: 68,062 kWh
- Post - Annual Electrical Consumption Saved: 39,812 kWh
- Post - Annual Savings Projected: $3,662.75

# City-Wide Building – LED Retrofits, Replacements, & Controls

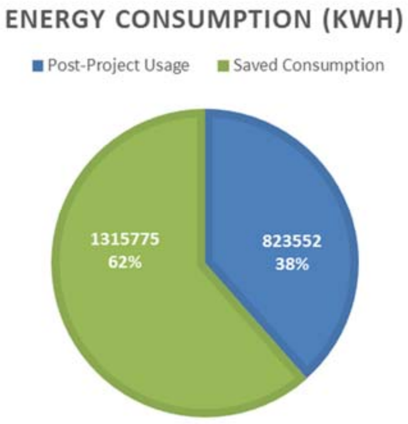
## Baseline Facilities Consumption & Cost

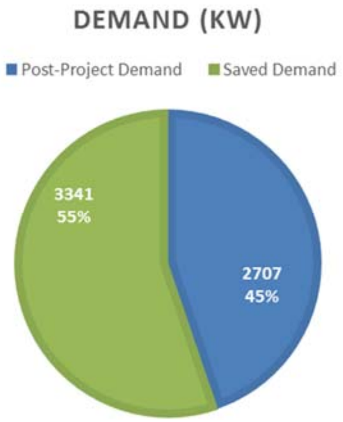
The baseline for all lighting consumption and demand was generated through a comprehensive lighting audit documenting all fixtures, lighting controls, circuiting, and operation input in to a proprietary tool. Each fixture in every building was analyzed in terms of many design components including, but not limited to: existing wattage, lumen output, ballast factor, and rated run hours. Tables showing the tabulated baseline data for the lighting project are listed in the appendix.

## Savings Estimates

A proprietary calculation tool was utilized to model lighting retrofits. This tool compares the energy consumption of existing fixtures versus the energy consumption of the fixtures after installation of retrofits and replacements along with all associated lighting controls. An estimated number of run hours is applied to each fixture on an annual basis to calculate the total power consumption saved. This estimate is based on each space's function (restroom, classroom, gymnasium, etc.) and facility operating hours. In addition, there is a positive impact on the cooling system by reducing the heat gain to the space with LED lighting post-installation. The resulting savings impact from all lighting retrofits and replacement fixtures from this measure is as follows:

- Pre - Annual Electrical Consumption: 2,139,327 kWh
- Post - Annual Electrical Consumption Saved: 1,315,774 kWh
- Pre - Annual Electrical Demand: 6,048 kW
- Post - Annual Electrical Demand Saved: 3341 kW
- Post - Annual Savings Projected: $138,451
- Post - Annual Maintenance Savings Projected: $31,211





# Public Works: DDC Upgrades and Optimization

## Baseline Energy Consumption & Cost

A detailed bin analysis calculation tool was developed specifically to calculate the baseline energy consumption of the existing HVAC equipment that is currently controlled by a digital control system. This tool utilizes Typical Meteorological Year (TMY3) local weather data to determine the number of hours in each temperature "bin", where each bin has a two degree range. A baseline schedule, determined by site audits, observations, and conversations with facility personnel, was applied to the equipment. For each hourly bin, including both occupied and unoccupied hours, heating and cooling runtimes proportional to a deviation from a balance point of 55°F were applied to the equipment. Fan, heating, and cooling energy are all then calculated for each of the hourly bins given the baseline schedules and temperature setpoints to establish the baseline cost of operating HVAC equipment as it currently runs. Equations used in the bin analysis are listed in the Appendix.

## Savings Estimates

The same bin analysis tool was used to calculate post-project consumption of the new and remaining HVAC equipment given modified equipment control sequences, new system components, and setpoint changes. Allowing unoccupied space conditions for areas such as the administrative offices creates a smaller temperature difference between the outdoor air and the indoor space, reducing the heating and cooling loads of the space. While the temperature floats to these unoccupied setpoints, the equipment can turn completely off, saving significant energy. The consumption associated with modified controls sequences, revised schedules, and modified setpoints was compared with the baseline consumption to determine the projected annual savings. Equations associated with this calculation are listed in the Appendix. The resulting savings from the installation of this equipment is as follows:

- Post - Annual Electrical Consumption Saved: 810,236 kWh
- Post - Annual Electrical Demand Saved: 8 kW
- Post - Annual  Natural Gas Consumption Saved: 13132 Therms
- Post - Annual Savings Projected: $67,282
- Post - Annual Maintenance Savings Projected: $5,570

# City Hall: Replace Vestibule and Stairwell Cabinet Heaters

## Baseline Energy Consumption & Cost

A detailed bin analysis calculation tool was developed specifically to calculate the baseline energy consumption of the existing Vestibule and Stairwell Cabinet Heaters. This tool utilizes Typical Meteorological Year (TMY3) local weather data to determine the number of hours in each temperature "bin", where each bin has a two degree range. A baseline schedule, determined by site audits, observations, and conversations with facility personnel, was applied to the equipment. For each hourly bin, including both occupied and unoccupied hours, heating and cooling runtimes proportional to a deviation from a balance point of 55°F were applied to the equipment. Fan, heating, and cooling energy are all then calculated for each of the hourly bins given the baseline schedules and temperature setpoints to establish the baseline cost of operating HVAC equipment as it currently runs. Equations used in the bin analysis are listed in the Appendix.

## Savings Estimates

The same bin analysis tool was used to calculate post-project consumption of the Vestibule and Stairwell Cabinet Heaters given the new heaters with modified equipment control sequences and setpoints. Being able to control the units properly greatly improves utility savings. Having the existing unit controls not functioning properly makes a considerable difference in the overall impact of the new units. Equations associated with this calculation are listed in the Appendix. The resulting savings from the installation of this equipment is as follows:

- Post - Annual Electrical Consumption Saved: 30,000 kWh
- Post - Annual Electrical Demand Saved: 20 kW
- Post - Annual Savings Projected: $1,162
- Post - Annual Maintenance Savings Projected: $100

# City-Wide: Building Weatherization

## Baseline Facilities Consumption & Cost

A detailed analysis of each building's specific construction, age, square footage, and utility history was documented and shared with Building Energy Solutions, who specializes in building weatherization for energy savings.

## Savings Estimates

Building Energy Solutions used detailed information about each facility to develop the following savings calculations results:

- Post - Annual Electrical Consumption Saved: 36,851 kWh
- Post - Annual  Natural Gas Consumption Saved: 13,130 Therms
- Post - Annual Savings Projected: $12,482

# Public Works: City-Wide Pole Lighting (Downtown, Parking, Etc.)

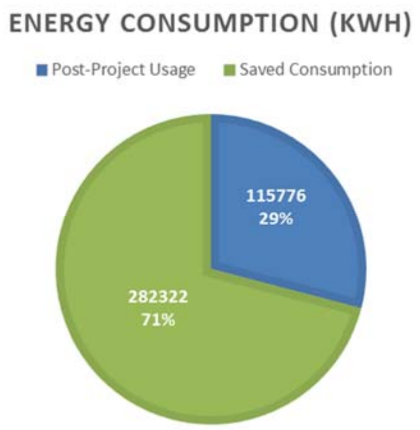
## Baseline Lighting Consumption & Cost

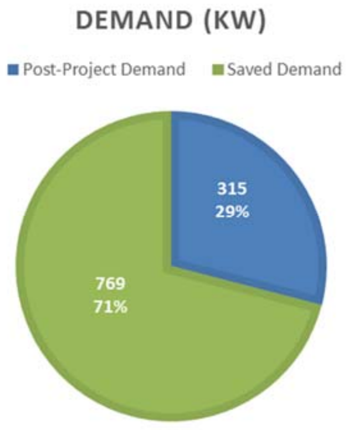
The baseline for all lighting consumption and demand was generated through a comprehensive lighting audit documenting all fixtures, lighting controls, circuiting, and operation input in to a proprietary tool. Each fixture in every building was analyzed in terms of many design components including, but not limited to: existing wattage, lumen output, ballast factor, and rated run hours. Tables showing the tabulated baseline data for the lighting project are listed in the appendix.

## Savings Estimates

Designed lighting retrofits were modeled with a proprietary calculation tool. This tool calculates the difference between the energy usage of existing fixtures and the energy usage of each fixture after installation of retrofits and replacements. An estimated number of run hours is applied to each fixture on an annual basis to calculate the total power consumption saved. The resulting savings impact from all lighting retrofits and replacement fixtures from this measure is as follows:

- Pre - Annual Electrical Consumption: 398,098 kWh
- Post - Annual Electrical Consumption Saved: 282,322 kWh
- Pre - Annual Electrical Demand: 1,084 kW
- Post - Annual Electrical Demand Saved: 769 kW
- Post - Annual Savings Projected: $30,836
- Post - Annual Maintenance Savings Projected: $4,221





# Parks and Rec: Parks Area Lighting

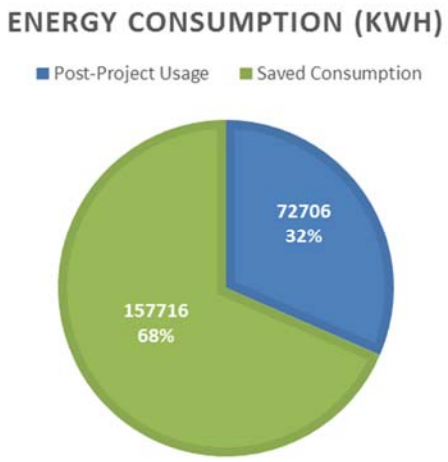
## Baseline Lighting Consumption & Cost

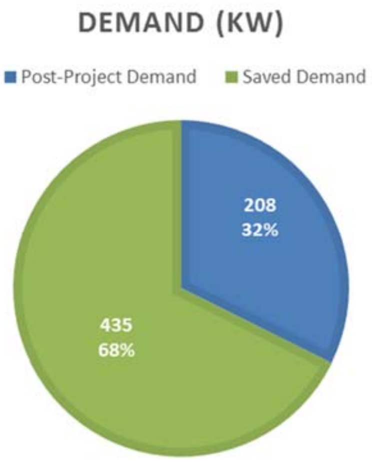
The baseline for all lighting consumption and demand was generated through a comprehensive lighting audit documenting all fixtures, lighting controls, circuiting, and operation input in to a proprietary tool. Each fixture in every building was analyzed in terms of many design components including, but not limited to: existing wattage, lumen output, ballast factor, and rated run hours. Tables showing the tabulated baseline data for the lighting project are listed in the appendix.

## Savings Estimates

Designed lighting retrofits were modeled with a proprietary calculation tool. This tool calculates the difference between the energy usage of existing fixtures and the energy usage of each fixture after installation of retrofits and replacements. An estimated number of run hours is applied to each fixture on an annual basis to calculate the total power consumption saved. The resulting savings impact from all lighting retrofits and replacement fixtures from this measure is as follows:

- Pre - Annual Electrical Consumption: 230,422 kWh
- Post - Annual Electrical Consumption Saved: 157,716 kWh
- Pre - Annual Electrical Demand: 643 kW
- Post - Annual Electrical Demand Saved: 435 kW
- Post - Annual Savings Projected: $16,967
- Post - Annual Maintenance Savings Projected: $2,389





# Community Health: Install Electronic Air Cleaner Filtration

## Baseline Facility Consumption & Cost

A detailed bin analysis calculation tool was developed specifically to calculate the baseline energy consumption of the existing HVAC equipment with the current filters installed. This tool utilizes Typical Meteorological Year (TMY3) local weather data to determine the number of hours in each temperature “bin”, where each bin has a two degree range. A baseline schedule, determined by site audits, observations, and conversations with facility personnel, was applied to the equipment. For each hourly bin, including both occupied and unoccupied hours, heating and cooling runtimes proportional to a deviation from a balance point of 55°F were applied to the equipment. Fan, heating, and cooling energy are all then calculated for each of the hourly bins given the baseline schedules and temperature setpoints to establish the baseline cost of operating HVAC equipment as it currently runs. Equations used in the bin analysis are listed in the Appendix.

## Savings Estimates

The same bin analysis tool was used to calculate post-project consumption of the new and remaining HVAC equipment given modified filtration air cleaners. The consumption associated with modified controls sequences, revised schedules, and modified setpoints was compared with the baseline consumption to determine the projected annual savings. Equations associated with this calculation are listed in the Appendix. The resulting savings from the installation of this equipment is as follows:

- Pre - Annual Electrical Consumption: 956,922 kWh
- Post - Annual Electrical Consumption Saved: 23,385 kWh
- Pre - Annual Electrical Demand: 4,240 kW
- Post - Annual Electrical Demand Saved: 91 kW
- Pre - Annual Natural Gas Consumption: 27,262 Therms
- Post - Annual Natural Gas Consumption Saved: 3,171 Therms
- Post - Annual Savings Projected: $4,856
- Post - Annual Maintenance Savings Projected: $2,000

# Solid Waste Office: Replace Packaged Unit

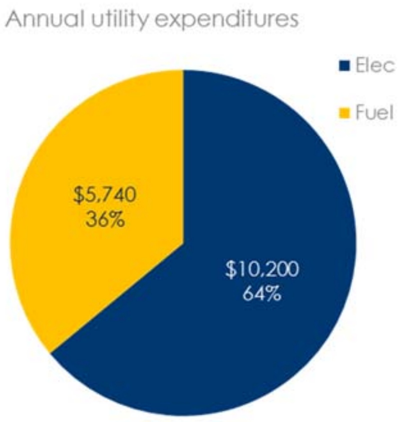
## Baseline Energy Consumption & Cost

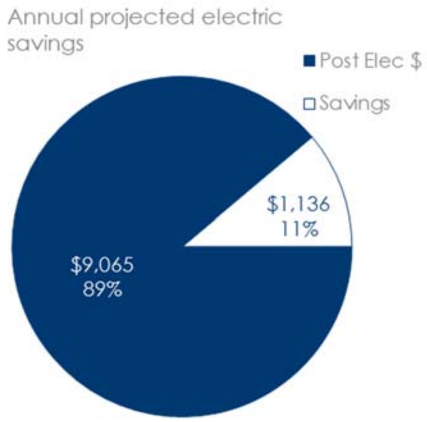
A detailed bin analysis calculation tool was developed specifically to calculate the baseline energy consumption of the existing packaged unit located to the South of the facility. This tool utilizes Typical Meteorological Year (TMY3) local weather data to determine the number of hours in each temperature “bin”, where each bin has a two degree range. A baseline schedule, determined by site audits, observations, and conversations with facility personnel, was applied to the equipment. Actual equipment characteristics were recorded and are listed in the Equipment Inventory section of this report. For each hourly bin, including both occupied and unoccupied hours, heating and cooling runtimes proportional to a deviation from a balance point of 55°F were applied to the equipment. Fan, heating, and cooling energy are all then calculated for each of the hourly bins given the baseline schedules and temperature setpoints to establish the baseline cost of operating HVAC equipment as it currently runs. Equations used in the bin analysis are listed in the Appendix.

## Savings Estimates

The same bin analysis tool was used to calculate post-project consumption of the new HVAC equipment given the new packaged unit. The consumption associated with the increased equipment efficiencies, revised schedules, and modified setpoints was compared with the baseline consumption to determine the projected annual savings. Equations associated with this calculation are listed in the Appendix. The resulting savings from the installation of this equipment is as follows:

- Pre - Annual Electrical Consumption: 90,481 kWh
- Post - Annual Electrical Consumption Saved: 23,300 kWh
- Pre - Annual Natural Gas Consumption: 1,105 Therms
- Post - Annual Natural Gas Consumption Saved: 300 Therms
- Post - Annual Savings Projected: $1,240
- Post - Annual Maintenance Savings Projected: $800





# Vehicle Maintenance: Add Ductless Mini-Split for Server Room

## Baseline Facility Consumption & Cost

A detailed bin analysis calculation tool was developed specifically to calculate the baseline energy consumption of the existing HVAC equipment that is currently conditioning the second floor conference room and small storage areas. This tool utilizes Typical Meteorological Year (TMY3) local weather data to determine the number of hours in each temperature “bin”, where each bin has a two degree range. A baseline schedule, determined by site audits, observations, and conversations with facility personnel, was applied to the equipment. For each hourly bin, including both occupied and unoccupied hours, heating and cooling runtimes proportional to a deviation from a balance point of 55°F were applied to the equipment. Fan, heating, and cooling energy are all then calculated for each of the hourly bins given the baseline schedules and temperature setpoints to establish the baseline cost of operating HVAC equipment as it currently runs. Equations used in the bin analysis are listed in the Appendix.

## Savings Estimates

The same bin analysis tool was used to calculate post-project consumption of the new and remaining HVAC equipment given the new equipment installed in the server closet. Allowing unoccupied space conditions for all other areas including the conference room creates a smaller temperature difference between the outdoor air and the indoor space, reducing the heating and cooling loads of the space. Having a decoupled system allows the server closet to maintain temperature without having a large impact on the overall utility usage wasting energy to cool the adjacent spaces. While the temperature floats to these unoccupied setpoints, the equipment can turn completely off, saving significant energy. The consumption associated with the increased equipment efficiencies, revised schedules, and modified setpoints was compared with the baseline consumption to determine the projected annual savings. Equations associated with this calculation are listed in the Appendix. The resulting savings from the installation of this equipment is as follows:

- Pre - Annual Electrical Consumption: 18,059 kWh
- Post - Annual Electrical Consumption Saved: 4001 kWh
- Pre - Annual  Natural Gas Consumption: 7,172 Therms
- Post - Annual  Natural Gas Consumption Saved: 199 Therms
- Post - Annual Savings Projected: $352
- Post - Annual Maintenance Savings Projected: $250

# Indoor Aquatic Center: Energy & Indoor Air Quality Improvements

## Baseline Facility Consumption & Cost

A detailed bin analysis calculation tool was developed specifically to calculate the baseline energy consumption of the existing packaged unit located to the South of the facility. This tool utilizes Typical Meteorological Year (TMY3) local weather data to determine the number of hours in each temperature "bin", where each bin has a two degree range. A baseline schedule, determined by site audits, observations, and conversations with facility personnel, was applied to the equipment. Actual equipment characteristics were recorded and are listed in the Equipment Inventory section of this report. For each hourly bin, including both occupied and unoccupied hours, heating and cooling runtimes proportional to a deviation from a balance point of 55°F were applied to the equipment. Fan, heating, and cooling energy are all then calculated for each of the hourly bins given the baseline schedules and temperature setpoints to establish the baseline cost of operating HVAC equipment as it currently runs. Equations used in the bin analysis are listed in the Appendix.

## Savings Estimates

The same bin analysis tool was used to calculate post-project consumption of the new HVAC equipment given the new packaged unit. The consumption associated with the increased equipment efficiencies, revised schedules, and modified setpoints was compared with the baseline consumption to determine the projected annual savings. Equations associated with this calculation are listed in the Appendix. The resulting savings from the installation of this equipment is as follows:

- Pre - Annual Electrical Consumption: 1,450,318 kWh
- Post - Annual Electrical Consumption Saved: 97,463 kWh
- Pre - Annual Electrical Demand: 3,880 kW
- Post - Annual Electrical Demand Saved: 86 kW
- Pre - Annual Natural Gas Consumption: 102,037 Therms
- Post - Annual Natural Gas Consumption Saved: 71,591 Therms
- Post - Annual Savings Projected: $85,940
- Post - Annual Maintenance Savings Projected: $5,150

# Lawrence Art Center: Replace Air Cooled Chiller with Premium Efficiency Unit

## Baseline Facility Consumption & Cost

A detailed bin analysis calculation tool was developed specifically to calculate the baseline energy consumption of the existing HVAC equipment with the current air cooled chiller. This tool utilizes Typical Meteorological Year (TMY3) local weather data to determine the number of hours in each temperature "bin", where each bin has a two degree range. A baseline schedule, determined by site audits, observations, and conversations with facility personnel, was applied to the equipment. For each hourly bin, including both occupied and unoccupied hours, heating and cooling runtimes proportional to a deviation from a balance point of 55°F were applied to the equipment. Fan, heating, and cooling energy are all then calculated for each of the hourly bins given the baseline schedules and temperature setpoints to establish the baseline cost of operating HVAC equipment as it currently runs. Equations used in the bin analysis are listed in the Appendix.

## Savings Estimates

The same bin analysis tool was used to calculate post-project consumption of the remaining HVAC equipment given the new air cooled chiller. The consumption associated with the increased efficiency was compared with the baseline consumption to determine the projected annual savings. Equations associated with this calculation are listed in the Appendix. The resulting savings from the installation of this equipment is as follows:

- Pre - Annual Electrical Consumption: 708,386 kWh
- Post - Annual Electrical Consumption Saved: 73,215 kWh
- Pre - Annual Electrical Demand: 2,249 kW
- Post - Annual Electrical Demand Saved: 74.6 kW
- Post - Annual Savings Projected: $8,213

# New Hampshire Parking Garage: Replace Wall Pack HVAC Units with Gas Heat

## Baseline Facility Consumption & Cost

A detailed bin analysis calculation tool was developed specifically to calculate the baseline energy consumption of the existing HVAC equipment, which includes three Bard wallpack units with electric heat. This tool utilizes Typical Meteorological Year (TMY3) local weather data to determine the number of hours in each temperature "bin", where each bin has a two degree range. A baseline schedule, determined by site audits, observations, and conversations with facility personnel, was applied to the equipment. For each hourly bin, including both occupied and unoccupied hours, heating and cooling runtimes proportional to a deviation from a balance point of 55°F were applied to the equipment. Fan, heating, and cooling energy are all then calculated for each of the hourly bins given the baseline schedules and temperature setpoints to establish the baseline cost of operating HVAC equipment as it currently runs. Equations used in the bin analysis are listed in the Appendix.

## Savings Estimates

The same bin analysis tool was used to calculate post-project consumption of the new HVAC equipment given the new packaged unit. The consumption associated with the increased equipment efficiencies, revised schedules, and modified setpoints was compared with the baseline consumption to determine the projected annual savings. Equations associated with this calculation are listed in the Appendix. The resulting savings from the installation of this equipment is as follows:

- Pre - Annual Electrical Consumption: 406,226 kWh
- Post - Annual Electrical Consumption Saved: 45,725 kWh
- Pre - Annual Electrical Demand: 895 kW
- Post - Annual Electrical Demand Saved: 23 kW
- Pre - Annual  Natural Gas Consumption: 0 Therms
- Post - Annual  Natural Gas Consumption Saved: -1559 Therms
- Post - Annual Savings Projected: $1,967
- Post - Annual Maintenance Savings Projected: $250

# Fire Station #5: Solar Power Installation

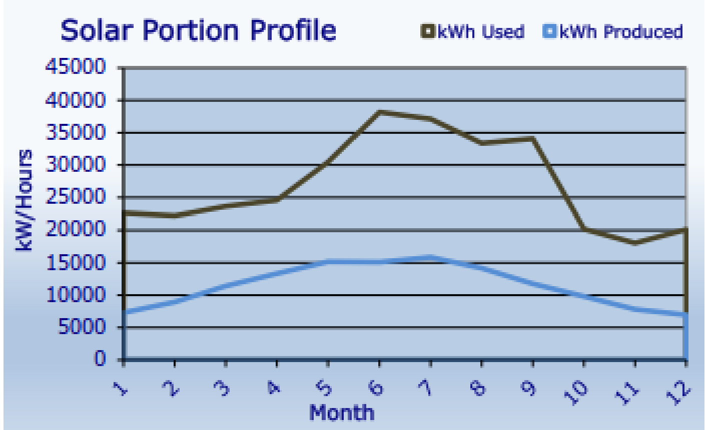
## Baseline Facility Consumption & Cost

Historical usage and billing data were used to determine the facility consumption and cost.

## Savings Estimates

Cromwell Solar of Lawrence, Kansas, used the baseline facility consumption, utility cost, geographic location, building structure, roof orientation, and pitch to calculate available solar energy using their tools and expertise. The size of the truck bay roof, as well as its pitch and orientation, results in a potential array size of approximately 100kW. Using solar analysis tools and methodology, Crowmwell Solar calculated the potential energy availability from an array of this size. The resulting savings impact from this measure is as follows:

- Pre - Annual Electrical Consumption: 801,687 kWh
- Post - Annual Electrical Consumption Saved: 137,662 kWh
- Pre - Annual Electrical Demand: 1,581kW
- Post - Annual Electrical Demand Saved: 100 kW
- Post - Annual Savings Projected: $13,217



# East Lawrence Rec Center: Replace RTU-2, 3, & 4

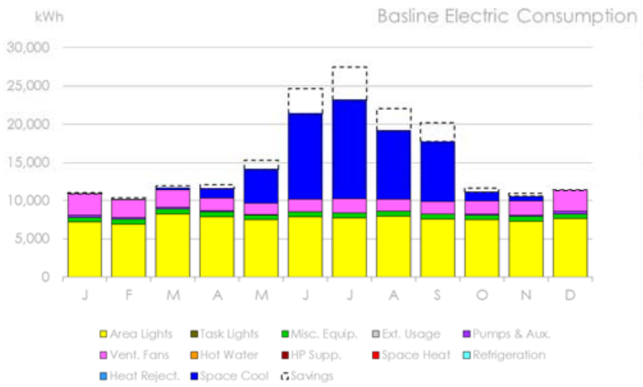
## Baseline Energy Consumption & Cost

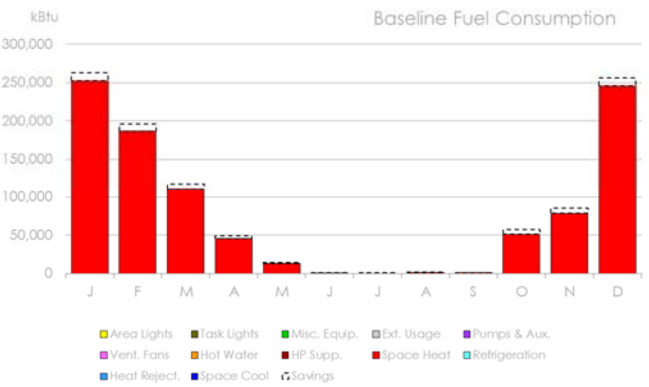
A detailed bin analysis calculation tool was developed specifically to calculate the baseline and post energy consumption of all of the existing HVAC equipment that is currently conditioning the facility. This tool utilizes Typical Meteorological Year (TMY3) local weather data to determine the number of hours in each temperature "bin", where each bin has a two degree range. A baseline schedule, determined by site audits, observations, and conversations with facility personnel, was applied to the equipment. Actual equipment characteristics were recorded and are listed in the Equipment Inventory section of this report. For each hourly bin, including both occupied and unoccupied hours, heating and cooling runtimes proportional to a deviation from a balance point of 55°F were applied to the equipment. Fan, heating, and cooling energy are all then calculated for each of the hourly bins given the baseline schedules and temperature setpoints to establish the baseline cost of operating HVAC equipment as it currently runs. Equations used in the bin analysis are listed in the Appendix.

## Savings Estimates

The same bin analysis tool was used to calculate post-project consumption of the new and remaining HVAC equipment given the three new packaged RTUs. The consumption associated with the increased equipment efficiencies, revised schedules, and modified setpoints was compared with the baseline consumption to determine the projected annual savings. Equations associated with this calculation are listed in the Appendix. The resulting savings from the installation of this equipment is as follows:

- Pre - Annual Electrical Consumption: 275,667 kWh
- Post - Annual Electrical Consumption Saved: 22,155 kWh
- Pre - Annual Electrical Demand: 1076 kW
- Post - Annual Electrical Demand Saved: 110 kW
- Pre - Annual  Natural Gas Consumption: 6,665 Therms
- Post - Annual  Natural Gas Consumption Saved: 339 Therms
- Post - Annual Savings Projected: $3,061
- Post - Annual Maintenance Savings Projected: $2,500





# Community Building: Replace Aging Rooftop Units

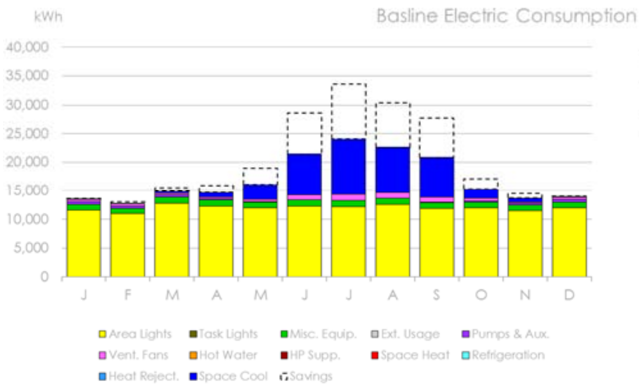
## Baseline Facility Consumption & Cost

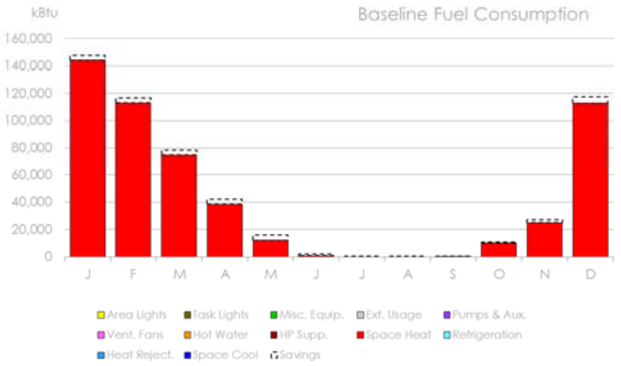
A detailed bin analysis calculation tool was developed specifically to calculate the baseline and post energy consumption of all of the existing HVAC equipment that is currently conditioning the facility. This tool utilizes Typical Meteorological Year (TMY3) local weather data to determine the number of hours in each temperature "bin", where each bin has a two degree range. A baseline schedule, determined by site audits, observations, and conversations with facility personnel, was applied to the equipment. Actual equipment characteristics were recorded and are listed in the Equipment Inventory section of this report. For each hourly bin, including both occupied and unoccupied hours, heating and cooling runtimes proportional to a deviation from a balance point of 55°F were applied to the equipment. Fan, heating, and cooling energy are all then calculated for each of the hourly bins given the baseline schedules and temperature setpoints to establish the baseline cost of operating HVAC equipment as it currently runs. Equations used in the bin analysis are listed in the Appendix.

## Savings Estimates

The same bin analysis tool was used to calculate post-project consumption of the new and remaining HVAC equipment given the eleven new packaged RTUs and the one newly replaced RTU. The consumption associated with the increased equipment efficiencies, revised schedules, and modified setpoints was compared with the baseline consumption to determine the projected annual savings. Equations associated with this calculation are listed in the Appendix. The resulting savings from the installation of this equipment is as follows:

- Pre - Annual Electrical Consumption: 291,809 kWh
- Post - Annual Electrical Consumption Saved: 43,193 kWh
- Pre - Annual Electrical Demand: 904 kW
- Post - Annual Electrical Demand Saved: 229 kW
- Pre - Annual Natural Gas Consumption: 6,298 Therms
- Post - Annual Natural Gas Consumption Saved: 408 Therms
- Post - Annual Savings Projected: $5,791
- Post - Annual Maintenance Savings Projected: $2,750





# Parks & Rec: Sports Field Lighting

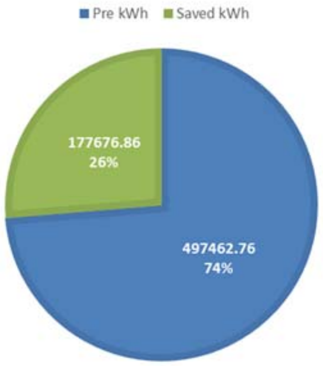
## Baseline Lighting Consumption & Cost

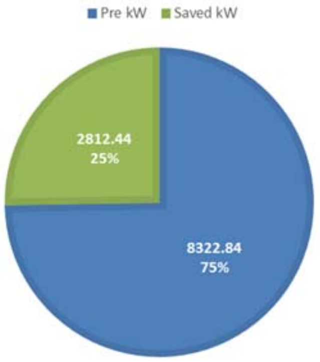
The baseline for all lighting consumption was generated through a comprehensive lighting audit documenting all fixtures, lighting controls, circuiting, and operation input in to a proprietary tool. Each fixture in every building was analyzed in terms of many design components including, but not limited to: existing wattage, lumen output, ballast factor, and rated run hours. Tables showing the tabulated baseline data for the lighting project are listed in the appendix.

## Savings Estimates

A proprietary calculation tool was utilized to model lighting retrofits. This tool accounts for the power draw of existing fixtures versus the power draw of the fixture after installation of retrofits and replacements. An estimated number of run hours is applied to each fixture on an annual basis to calculate the total power consumption saved. The resulting savings impact from all lighting retrofits and replacement fixtures from this measure is as follows:

- Pre - Annual Electrical Consumption: 497,463 kWh
- Post - Annual Electrical Consumption Saved: 177,676 kWh
- Post - Annual Savings Projected: $32,419
- Post - Annual Maintenance Savings Projected: $27,094





# Prairie Park: New Ground-Source HVAC System

## Baseline Facility Consumption & Cost

A detailed bin analysis calculation tool was developed specifically to calculate the baseline and post energy consumption of all of the existing HVAC equipment that is currently conditioning the facility. This tool utilizes Typical Meteorological Year (TMY3) local weather data to determine the number of hours in each temperature "bin", where each bin has a two degree range. A baseline schedule, determined by site audits, observations, and conversations with facility personnel, was applied to the equipment. Actual equipment characteristics were recorded and are listed in the Equipment Inventory section of this report. For each hourly bin, including both occupied and unoccupied hours, heating and cooling runtimes proportional to a deviation from a balance point of 55°F were applied to the equipment. Fan, heating, and cooling energy are all then calculated for each of the hourly bins given the baseline schedules and temperature setpoints to establish the baseline cost of operating HVAC equipment as it currently runs. Equations used in the bin analysis are listed in the Appendix.

## Savings Estimates

The same bin analysis tool was used to calculate post-project consumption of the new HVAC system given the ground source heat pumps. The consumption associated with the increased equipment efficiencies, ground-source heating and cooling, revised schedules, and modified setpoints was compared with the baseline consumption to determine the projected annual savings. Equations associated with this calculation are listed in the Appendix. The resulting savings from the installation of this equipment is as follows:

- Pre - Annual Electrical Consumption: 70,153 kWh
- Post - Annual Electrical Consumption Saved: 1,512 kWh
- Pre - Annual Natural Gas Consumption: 1178 Therms
- Post - Annual Natural Gas Consumption Saved: 1161 Therms
- Post - Annual Savings Projected: $1,295
- Post - Annual Maintenance Savings Projected: $2,000

# Holcom Rec Center: New Packaged HVAC System

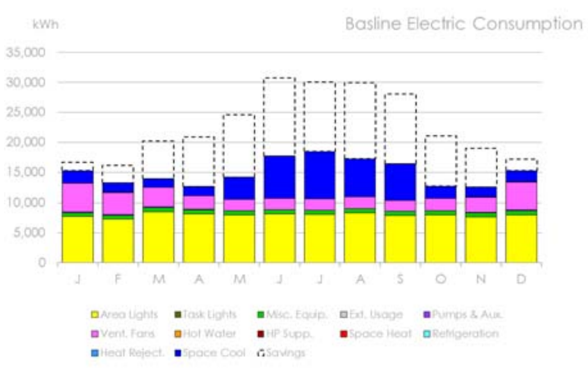
## Baseline Facility Consumption & Cost

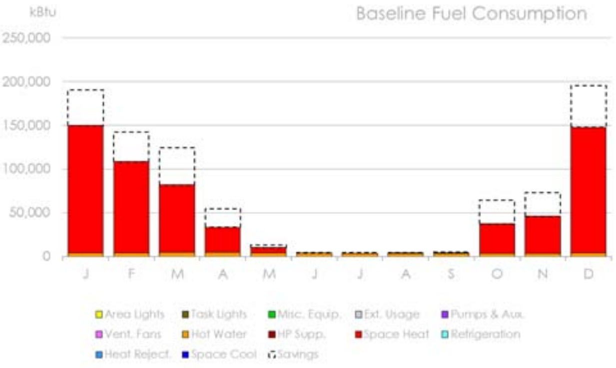
A detailed bin analysis calculation tool was developed specifically to calculate the baseline energy consumption of the existing HVAC equipment that is currently conditioning the facility. This tool utilizes Typical Meteorological Year (TMY3) local weather data to determine the number of hours in each temperature “bin”, where each bin has a two degree range. A baseline schedule, determined by site audits, observations, and conversations with facility personnel, was applied to the equipment. Actual equipment characteristics were recorded and are listed in the Equipment Inventory section of this report. For each hourly bin, including both occupied and unoccupied hours, heating and cooling runtimes proportional to a deviation from a balance point of 55°F were applied to the equipment. Fan, heating, and cooling energy are all then calculated for each of the hourly bins given the baseline schedules and temperature setpoints to establish the baseline cost of operating HVAC equipment as it currently runs. Equations used in the bin analysis are listed in the Appendix.

## Savings Estimates

The same bin analysis tool was used to calculate post-project consumption of the new and remaining HVAC equipment given the two new packaged units. The consumption associated with the new system design, increased equipment efficiencies, revised schedules, and modified setpoints was compared with the baseline consumption to determine the projected annual savings. Equations associated with this calculation are listed in the Appendix. The resulting savings from the installation of this equipment is as follows:

- Pre - Annual Electrical Consumption: 200,692 kWh
- Post - Annual Electrical Consumption Saved: 82,000 kWh
- Pre - Annual Natural Gas Consumption: 7,824 Therms
- Post - Annual Natural Gas Consumption Saved: 600 Therms
- Post - Annual Savings Projected: $4,019
- Post - Annual Maintenance Savings Projected: $3,500





# Community Health: Replace Air Cooled Chiller with Premium Efficiency Unit

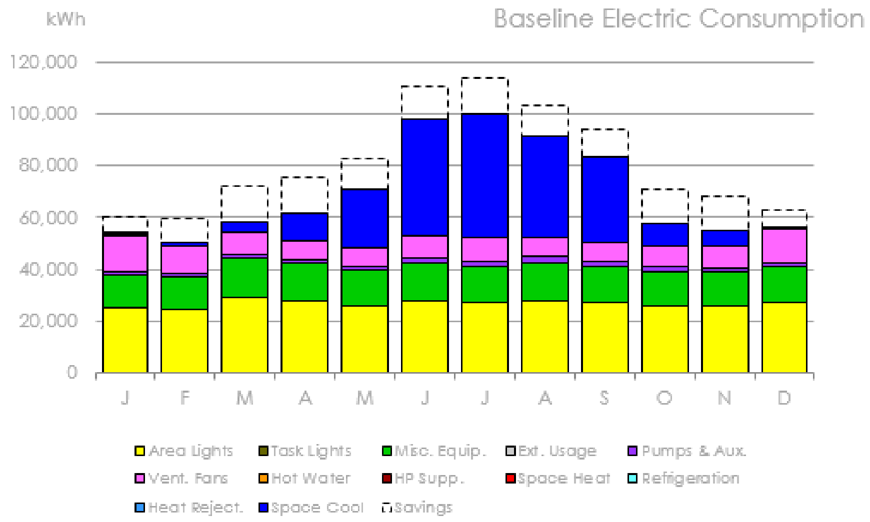
## Baseline Facility Consumption & Cost

A detailed bin analysis calculation tool was developed specifically to calculate the baseline energy consumption of the existing HVAC equipment, which includes a chiller at the end of its rated service life. This tool utilizes Typical Meteorological Year (TMY3) local weather data to determine the number of hours in each temperature "bin", where each bin has a two degree range. A baseline schedule, determined by site audits, observations, and conversations with facility personnel, was applied to the equipment. For each hourly bin, including both occupied and unoccupied hours, heating and cooling runtimes proportional to a deviation from a balance point of 55°F were applied to the equipment. Fan, heating, and cooling energy are all then calculated for each of the hourly bins given the baseline schedules and temperature setpoints to establish the baseline cost of operating HVAC equipment as it currently runs. Equations used in the bin analysis are listed in the Appendix.

## Savings Estimates

The same bin analysis tool was used to calculate post-project consumption of the remaining HVAC equipment, including the new chiller. The consumption associated with the increased efficiency was compared with the baseline consumption to determine the projected annual savings. Equations associated with this calculation are listed in the Appendix. The resulting savings from the installation of this equipment is as follows:

- Pre - Annual Electrical Consumption: 956,922 kWh
- Post - Annual Electrical Consumption Saved: 87,184 kWh
- Pre - Annual Electrical Demand: 4,240 kW
- Post - Annual Electrical Demand Saved: 26 kW
- Post - Annual Savings Projected: $9,780
- Post - Annual Maintenance Savings Projected: $1,400



# Airport Terminal: HVAC System Replacements

## Baseline Facility Consumption & Cost

A detailed bin analysis calculation tool was developed specifically to calculate the baseline energy consumption of the existing HVAC equipment that is currently conditioning the facility. This tool utilizes Typical Meteorological Year (TMY3) local weather data to determine the number of hours in each temperature "bin", where each bin has a two degree range. A baseline schedule, determined by site audits, observations, and conversations with facility personnel, was applied to the equipment. Actual equipment characteristics were recorded and are listed in the Equipment Inventory section of this report. For each hourly bin, including both occupied and unoccupied hours, heating and cooling runtimes proportional to a deviation from a balance point of 55°F were applied to the equipment. Fan, heating, and cooling energy are all then calculated for each of the hourly bins given the baseline schedules and temperature setpoints to establish the baseline cost of operating HVAC equipment as it currently runs. Equations used in the bin analysis are listed in the Appendix.

## Savings Estimates

The same bin analysis tool was used to calculate post-project consumption of the new HVAC split-system equipment given the four furnaces and condensing units. The consumption associated with the increased equipment efficiencies, revised schedules, and modified setpoints was compared with the baseline consumption to determine the projected annual savings. Equations associated with this calculation are listed in the Appendix. The resulting savings from the installation of this equipment is as follows:

- Pre - Annual Electrical Consumption: 73,184 kWh
- Post - Annual Electrical Consumption Saved: 5,178 kWh
- Pre - Annual Natural Gas Consumption: 3,682Therms
- Post - Annual Natural Gas Consumption Saved: 500 Therms
- Post - Annual Savings Projected: $826
- Post - Annual Maintenance Savings Projected: $850

# Fire Station #2: Replace Outdated RTUs

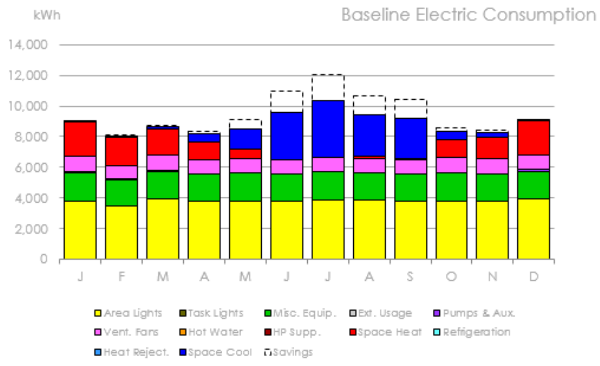
## Baseline Facility Consumption & Cost

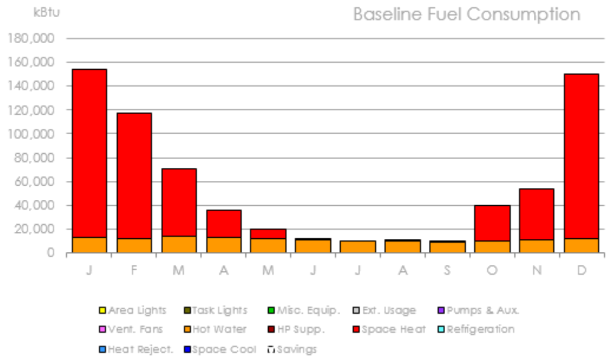
A detailed bin analysis calculation tool was developed specifically to calculate the baseline and post energy consumption of the existing HVAC equipment that is currently conditioning the facility. This tool utilizes Typical Meteorological Year (TMY3) local weather data to determine the number of hours in each temperature “bin”, where each bin has a two degree range. A baseline schedule, determined by site audits, observations, and conversations with facility personnel, was applied to the equipment. Actual equipment characteristics were recorded and are listed in the Equipment Inventory section of this report. For each hourly bin, including both occupied and unoccupied hours, heating and cooling runtimes proportional to a deviation from a balance point of 65°F were applied to the equipment. Fan, heating, and cooling energy are all then calculated for each of the hourly bins given the baseline schedules and temperature setpoints to establish the baseline cost of operating HVAC equipment as it currently runs. Equations used in the bin analysis are listed in the Appendix.

## Savings Estimates

The same bin analysis tool was used to calculate post-project consumption of the new and existing HVAC packaged equipment. The consumption associated with the increased equipment efficiencies, revised schedules, and modified setpoints was compared with the baseline consumption to determine the projected annual savings. Equations associated with this calculation are listed in the Appendix. The resulting savings from the installation of this equipment is as follows:

- Pre - Annual Electrical Consumption: 115,039 kWh
- Post - Annual Electrical Consumption Saved: 6,956 kWh
- Pre - Annual Electrical Demand: 360 kW
- Post - Annual Electrical Demand Saved: 32 kW
- Post - Annual Savings Projected: $812
- Post - Annual Maintenance Savings Projected: $500





# Fire Station #3: Replace Rooftop Units, Relocate One

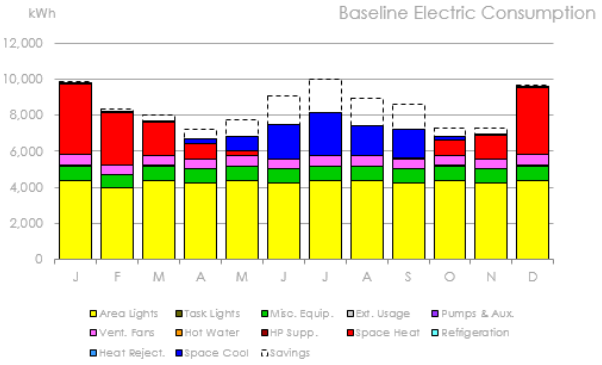
## Baseline Facility Consumption & Cost

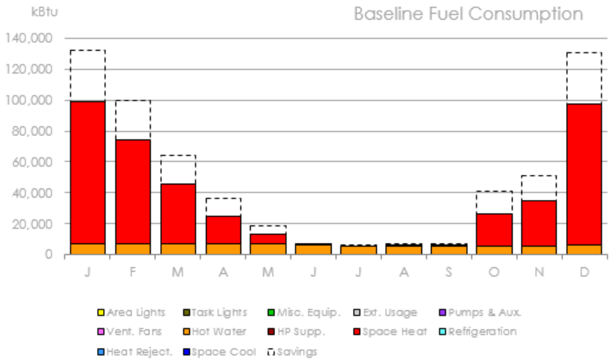
A detailed bin analysis calculation tool was developed specifically to calculate the baseline and post energy consumption of all of the existing HVAC equipment that is currently conditioning the facility. This tool utilizes Typical Meteorological Year (TMY3) local weather data to determine the number of hours in each temperature "bin", where each bin has a two degree range. A baseline schedule, determined by site audits, observations, and conversations with facility personnel, was applied to the equipment. Actual equipment characteristics were recorded and are listed in the Equipment Inventory section of this report. For each hourly bin, including both occupied and unoccupied hours, heating and cooling runtimes proportional to a deviation from a balance point of 55°F were applied to the equipment. Fan, heating, and cooling energy are all then calculated for each of the hourly bins given the baseline schedules and temperature setpoints to establish the baseline cost of operating HVAC equipment as it currently runs. Equations used in the bin analysis are listed in the Appendix.

## Savings Estimates

The same bin analysis tool was used to calculate post-project consumption of the new HVAC packaged equipment. The consumption associated with the increased equipment efficiencies, new unit locations, revised schedules, and modified setpoints was compared with the baseline consumption to determine the projected annual savings. Equations associated with this calculation are listed in the Appendix. The resulting savings from the installation of this equipment is as follows:

- Pre - Annual Electrical Consumption: 103,624 kWh
- Post - Annual Electrical Consumption Saved: 5,498 kWh
- Pre - Annual Electrical Demand: 311 kW
- Post - Annual Electrical Demand Saved: 22 kW
- Post - Annual Savings Projected: $630
- Post - Annual Maintenance Savings Projected: $250





# Holcom Recreation Center: Sports Field Lighting

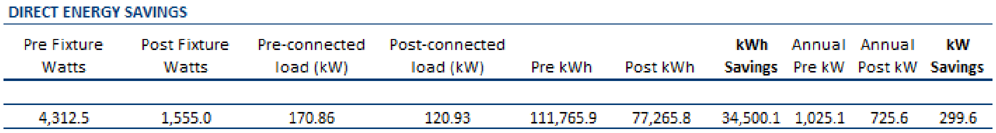
## Baseline Facility Consumption & Cost

The baseline for all lighting consumption was generated through a comprehensive lighting audit documenting all fixtures, lighting controls, circuiting, and operation input in to a proprietary tool. Each fixture at every ball diamond was analyzed in terms of many design components including, but not limited to: existing wattage, lumen output, ballast factor, and rated run hours. Tables showing the tabulated baseline data for the lighting project are listed in the appendix.

## Savings Estimates

A proprietary calculation tool was utilized to model lighting retrofits. This tool accounts for the energy consumption of existing luminaires versus the energy consumption of the luminaires after installation of retrofits and replacements. An estimated number of run hours is applied to each luminaire on an annual basis to calculate the total energy consumption saved. The resulting savings impact from all lighting retrofits and replacement fixtures from this measure is as follows:

- Pre - Annual Electrical Consumption: 111,765kWh
- Post - Annual Electrical Consumption Saved: 34,500 kWh
- Pre - Annual Electrical Demand: 1,025 kW
- Post - Annual Electrical Demand Saved: 300 kW
- Post - Annual Savings Projected: $4,883
- Post - Annual Maintenance Savings Projected: $6,225



**DIRECT ENERGY SAVINGS**

| Pre Fixture Watts | Post Fixture Watts | Pre-connected load (kW) | Post-connected load (kW) | Pre kWh | Post kWh | **kWh Savings** | Annual Pre kW | Annual Post kW | **kW Savings** |
|---|---|---|---|---|---|---|---|---|---|
| 4,312.5 | 1,555.0 | 170.86 | 120.93 | 111,765.9 | 77,265.8 | 34,500.1 | 1,025.1 | 725.6 | 299.6 |

# Community Health: Replace Boilers

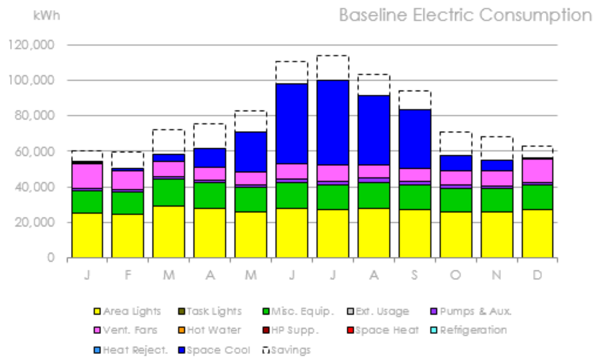
## Baseline Facility Consumption & Cost

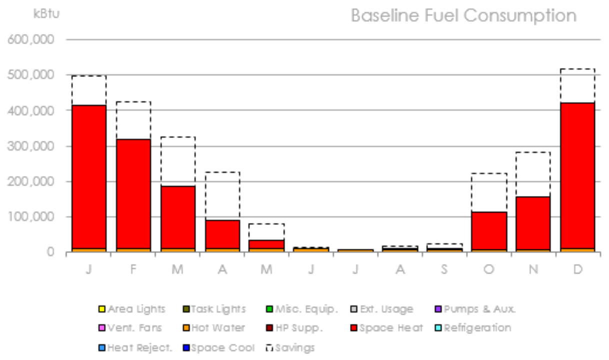
A detailed bin analysis calculation tool was developed specifically to calculate the baseline energy consumption of the existing HVAC equipment with the existing boilers. This tool utilizes Typical Meteorological Year (TMY3) local weather data to determine the number of hours in each temperature “bin”, where each bin has a two degree range. A baseline schedule, determined by site audits, observations, and conversations with facility personnel, was applied to the equipment. For each hourly bin, including both occupied and unoccupied hours, heating and cooling runtimes proportional to a deviation from a balance point of 55°F were applied to the equipment. Fan, heating, and cooling energy are all then calculated for each of the hourly bins given the baseline schedules and temperature setpoints to establish the baseline cost of operating HVAC equipment as it currently runs. Equations used in the bin analysis are listed in the Appendix.

## Savings Estimates

The same bin analysis tool was used to calculate post-project consumption of the remaining HVAC equipment given the new air cooled chiller. The consumption associated with the increased efficiency was compared with the baseline consumption to determine the projected annual savings. Equations associated with this calculation are listed in the Appendix. The resulting savings from the installation of this equipment is as follows:

- Pre - Annual Natural Gas Consumption: 27,262 Therms
- Post - Annual Natural Gas Consumption Saved: 1363 Therms
- Post - Annual Savings Projected: $927
- Post - Annual Maintenance Savings Projected: $1000





# Community Health: Replace Roof

## Baseline Facility Consumption & Cost

A detailed bin analysis calculation tool was developed specifically to calculate the baseline and post energy consumption of all of the facilities existing HVAC equipment with the existing roof. This tool utilizes Typical Meteorological Year (TMY3) local weather data to determine the number of hours in each temperature "bin", where each bin has a two degree range. A baseline schedule, determined by site audits, observations, and conversations with facility personnel, was applied to the equipment. For each hourly bin, including both occupied and unoccupied hours, heating and cooling runtimes proportional to a deviation from a balance point of 55°F were applied to the equipment. Fan, heating, and cooling energy are all then calculated for each of the hourly bins given the baseline schedules and temperature setpoints to establish the baseline cost of operating HVAC equipment as it currently runs. Equations used in the bin analysis are listed in the Appendix.

## Savings Estimates

The same bin analysis tool was used to calculate post-project consumption of the remaining HVAC equipment given the new air cooled chiller. The consumption associated with the increased roof insulation was compared with the baseline consumption to determine the projected annual savings. Equations associated with this calculation are listed in the Appendix. The resulting savings from the installation of this equipment is as follows:

- Pre - Annual Electrical Consumption: 956,922kWh
- Post - Annual Electrical Consumption Saved: 9,900 kWh
- Pre - Annual  Natural Gas Consumption: 27,262Therms
- Post - Annual  Natural Gas Consumption Saved: 700 Therms
- Post - Annual Savings Projected: $882
- Post - Annual Maintenance Savings Projected: $650

# Fire Station #3: Replace Roof

## Baseline Facility Consumption & Cost

A detailed bin analysis calculation tool was developed specifically to calculate the baseline and post energy consumption of all of the facilities existing HVAC equipment with the existing roof. This tool utilizes Typical Meteorological Year (TMY3) local weather data to determine the number of hours in each temperature "bin", where each bin has a two degree range. A baseline schedule, determined by site audits, observations, and conversations with facility personnel, was applied to the equipment. For each hourly bin, including both occupied and unoccupied hours, heating and cooling runtimes proportional to a deviation from a balance point of 55°F were applied to the equipment. Fan, heating, and cooling energy are all then calculated for each of the hourly bins given the baseline schedules and temperature setpoints to establish the baseline cost of operating HVAC equipment as it currently runs. Equations used in the bin analysis are listed in the Appendix.

## Savings Estimates

The same bin analysis tool was used to calculate post-project consumption of the remaining HVAC equipment given the new air cooled chiller. The consumption associated with the increased roof insulation was compared with the baseline consumption to determine the projected annual savings. Equations associated with this calculation are listed in the Appendix. The resulting savings from the installation of this equipment is as follows:

- Pre - Annual Electrical Consumption: 103,624 kWh
- Post - Annual Electrical Consumption Saved: 244 kWh
- Pre - Annual Electrical Demand: 311 kW
- Post - Annual Electrical Demand Saved: 1 kW
- Post - Annual  Natural Gas Consumption Saved: 110 Therms
- Post - Annual Savings Projected: $118

# Financial Analysis

## Summary of Project Financials

The following pages outline the costs, annual energy, maintenance, and total budget savings and financial performance from a simple payback perspective of the project analyzed and developed by 360 Energy Engineers during the Investment Grade Engineering Audit.

These improvements analyzed were selected based on observations by our engineering team as well as conversations with City of Lawrence administration, facilities staff, and building occupants. Our goal is to work closely with the City of Lawrence in an effort to provide the City with the information to make educated decisions potential energy-conservation and infrastructure-improvement projects.

## Comprehensive List of Projects Identified

City of Lawrence

| | Project Components | Turn-Key Cost Estimate | Utility Savings | Maint. Savings | Total Savings | Payback |
|---|---|---|---|---|---|---|
| Neutral Cash Flow Beginning in Year 1 - 20 Year Financing @ 3.25% | 1. City-Wide: Web Based Thermostats | $60,000 | $27,275 | $250 | $27,525 | 2.2 |
| | 2. Public Works: Timer Control for Solid Waste Truck Block Heaters | $35,000 | $3,663 | $0 | $3,663 | 9.6 |
| | 3. City-Wide: Building LED Retrofits, Replacements & Controls | $1,400,000 | $107,294 | $24,219 | $131,513 | 10.6 |
| | 4. Public Works: DDC Upgrades and Optimization | $870,000 | $67,282 | $5,750 | $73,032 | 11.8 |
| | 5. City Hall: Replace Vestibule and Stairwell Cabinet Heaters | $15,000 | $1,162 | $100 | $1,262 | 11.9 |
| | 6. City-Wide: Building Weatherization | $150,000 | $12,482 | $0 | $12,482 | 12.0 |
| | 7. Public Works: City-Wide Pole Lighting (Downtown, Parking Lots, etc.) | $480,000 | $30,836 | $4,221 | $35,057 | 13.7 |
| | 8. Parks and Rec: Parks Area Lighting | $270,000 | $16,967 | $2,389 | $19,356 | 13.9 |
| | 9. Community Health: Install Electronic Air Cleaner Filtration | $100,000 | $4,856 | $2,000 | $6,856 | 14.6 |
| | 10. Solid Waste Office: Replace Package Unit | $30,000 | $1,240 | $800 | $2,040 | 14.7 |
| | 11. Vehicle Maintenance Office: Add Ductless Mini Split for Server Room | $10,000 | $352 | $250 | $602 | 16.6 |
| | 12. Indoor Aquatic Center: Energy & Indoor Air Quality Improvements | $1,600,000 | $85,940 | $5,150 | $91,090 | 17.6 |
| | 13. Lawrence Arts Center: Replace Air Cooled Chiller with Premium Efficiency Unit | $160,000 | $8,213 | $0 | $8,213 | 19.5 |
| | 14. Parks and Rec: Advanced Timers for Tennis/Basketball Courts | $30,000 | $1,214 | $0 | $1,214 | 24.7 |
| | 15. New Hampshire Parking Garage: Replace Wall Pack HVAC Units with Gas Heat | $60,000 | $1,967 | $250 | $2,217 | 27.1 |
| | 16. Fire Station #5: Solar Power Installation | $400,000 | $13,217 | $0 | $13,217 | 30.3 |
| | 17. East Lawrence Recreation Center: Replace RTU-2, 3 & 4 | $180,000 | $3,061 | $2,500 | $5,561 | 32.4 |
| | 18. Community Building: Replace Aging Roooftop Units | $300,000 | $5,791 | $2,750 | $8,541 | 35.1 |
| | 19. Parks & Rec: Sports Field Lighting | $2,400,000 | $32,419 | $27,094 | $59,513 | 40.3 |
| | 20. Prairie Park: New Ground-Source HVAC System | $150,000 | $1,295 | $2,000 | $3,295 | 45.5 |
| | 21. City Hall: Replace Windows | $500,000 | $3,527 | $250 | $3,777 | - |
| | 22. Outdoor Aquatic Center: Condensing Boilers and Concession Stand HVAC | $170,000 | $737 | $300 | $1,037 | - |
| | **SUBTOTAL - All Projects Above this Line** | **$9,370,000** | **$430,790** | **$80,273** | **$511,063** | **18.3** |
| CIP Projects | 23. Holcom Recreation Center: New Packaged HVAC Systems | $170,000 | $4,019 | $3,500 | $7,519 | 22.6 |
| | 24. Community Health: Replace Air Cooled Chiller with Premium Efficiency Unit | $300,000 | $9,780 | $1,400 | $11,180 | 26.8 |
| | 25. Airport Terminal: HVAC System Replacements | $50,000 | $826 | $850 | $1,676 | 29.8 |
| | 26. Fire Station #2: Replace Outdated RTUs | $50,000 | $812 | $500 | $1,312 | 38.1 |
| | 27. Fire Station #3: Replace Rooftop Units, Relocate One | $75,000 | $630 | $250 | $880 | - |
| | 28. Holcom Recreation Center: Sports Field Lighting | $1,050,000 | $4,883 | $6,225 | $11,108 | - |
| | 29. Community Health: Replace Boilers | $240,000 | $927 | $1,000 | $1,927 | - |
| | 30. Community Health: Replace Roof | $640,000 | $882 | $650 | $1,532 | - |
| | 31. Fire Station #3: Replace Roof | $130,000 | $118 | $0 | $118 | - |
| | **SUBTOTAL - All Projects Above this Line** | **$12,075,000** | **$407,895** | **$62,904** | **$548,315** | **22.0** |
| Priority Tier II | 32. City Hall: Add Gas Boiler and Hot Water Reheat to VAV Boxes | $560,000 | $18,721 | -$600 | $18,121 | 30.9 |
| | 33. Library: Add Gas Boiler & Hot Water VAV Boxes | $970,000 | $29,400 | -$500 | $28,900 | 33.6 |
| | 34. Venture Park: Solar PV for Pumping on Tanks 5 and 6 | $150,000 | $3,400 | $0 | $3,400 | 44.1 |
| | 35. Lawrence Arts Center: Replace Condensing Boilers | $150,000 | $2,533 | $0 | $2,533 | 59.2 |
| | 36. Community Building: Replace Roof | $300,000 | $445 | $250 | $695 | - |
| | 37. Solid Waste: Replace Windows & Doors | $30,000 | $205 | $100 | $305 | 98.4 |
| | 38. East Lawrence Recreation Center: Replace Damaged Skylight | $20,000 | $0 | $100 | $100 | - |
| | 39. Outdoor Aquatic Center: Reduce After-Hour Turnover & Tune Flows with VFDs | $25,000 | $967 | $0 | $967 | - |
| | 40. Fire Station #3: Replace Windows | $90,000 | $474 | $0 | $474 | - |
| | 41. Public Works: PV School Beacons | $390,000 | $2,520 | $0 | $2,520 | - |
| | **SUBTOTAL - All Projects Above this Line** | **$14,760,000** | **$512,333** | **$93,998** | **$606,330** | **24.3** |

**Projects Listed as "CIP Projects" have a component included on City's CIP List for 2017, 2018, 2019 & 2020**

**City of Lawrence**

Lawrence, Kansas

Facility & Energy Infrastructure Improvement Project

2017 Implementation

**Project: Neutral Cash Flow - Year 1**

***Anticipated* Project Payment Schedule**

| Date | Energy Savings | Maintenance Savings | Total Savings | Principal & Interest | Net Savings |
|---|---|---|---|---|---|
| FY 2017 | $430,790 | $80,273 | $511,063 | $0 | $511,063 |
| FY 2018 | $443,714 | $82,681 | $526,395 | ($528,700) | -$2,306 |
| FY 2019 | $457,026 | $85,161 | $542,187 | ($540,935) | $1,252 |
| FY 2020 | $470,736 | $87,716 | $558,452 | ($553,452) | $5,001 |
| FY 2021 | $484,858 | $90,348 | $575,206 | ($566,259) | $8,947 |
| FY 2022 | $499,404 | $93,058 | $592,462 | ($579,362) | $13,100 |
| FY 2023 | $514,386 | $95,850 | $610,236 | ($592,768) | $17,468 |
| FY 2024 | $529,818 | $98,725 | $628,543 | ($606,485) | $22,058 |
| FY 2025 | $545,712 | $101,687 | $647,399 | ($620,519) | $26,880 |
| FY 2026 | $562,084 | $104,738 | $666,821 | ($634,878) | $31,943 |
| FY 2027 | $578,946 | $107,880 | $686,826 | ($649,569) | $37,257 |
| FY 2028 | $596,315 | $111,116 | $707,431 | ($664,600) | $42,831 |
| FY 2029 | $614,204 | $114,450 | $728,654 | ($679,979) | $48,675 |
| FY 2030 | $632,630 | $117,883 | $750,513 | ($695,714) | $54,800 |
| FY 2031 | $651,609 | $121,420 | $773,029 | ($711,812) | $61,216 |
| FY 2032 | $671,157 | $125,062 | $796,220 | ($728,284) | $67,936 |
| FY 2033 | $691,292 | $128,814 | $820,106 | ($745,136) | $74,970 |
| FY 2034 | $712,031 | $132,678 | $844,709 | ($762,379) | $82,331 |
| FY 2035 | $733,392 | $136,659 | $870,051 | ($780,020) | $90,030 |
| FY 2036 | $755,394 | $140,759 | $896,152 | ($798,070) | $98,082 |
| FY 2037 | $778,055 | $144,981 | $923,037 | ($816,537) | $106,500 |
| **Total** | **$12,353,555** | **$2,301,936** | **$14,655,492** | **($13,255,458)** | **$1,400,034** |

**Financing Asuumptions**

| | |
|---|---|
| Total Project Cost | $9,370,000 |
| FCIP Fee | $87,850 |
| Total Financed | $9,457,850 |
| Financing Term | 20 Years |
| Interest Rate | 3.25% |
| Inflation Rate Demonstrated | 3.00% |
| Payment Escalation | 2.30% |

**City Statistics**

| | |
|---|---|
| Total Value of Infrastructure & Energy Projects Completed | $9,370,000 |
| Percentage of Project Funded by Savings (Excluding CIP Value) | 110.56% |

**City of Lawrence**

Lawrence, Kansas

Facility & Energy Infrastructure Improvement Project

2017 Implementation

**Project: Comprehensive**

***Anticipated* Project Payment Schedule**

| Date | Energy Savings | Maintenance Savings | Total Savings | Principal & Interest | Net Savings |
|---|---|---|---|---|---|
| FY 2017 | $453,668 | $67,804 | $521,471 | $0 | $521,471 |
| FY 2018 | $467,278 | $69,838 | $537,115 | ($680,668) | -$143,553 |
| FY 2019 | $481,296 | $71,933 | $553,229 | ($696,419) | -$143,190 |
| FY 2020 | $495,735 | $74,091 | $569,826 | ($712,534) | -$142,708 |
| FY 2021 | $510,607 | $76,314 | $586,920 | ($729,022) | -$142,101 |
| FY 2022 | $525,925 | $78,603 | $604,528 | ($745,891) | -$141,363 |
| FY 2023 | $541,703 | $80,961 | $622,664 | ($763,151) | -$140,487 |
| FY 2024 | $557,954 | $83,390 | $641,344 | ($780,811) | -$139,467 |
| FY 2025 | $574,692 | $85,892 | $660,584 | ($798,879) | -$138,294 |
| FY 2026 | $591,933 | $88,468 | $680,402 | ($817,365) | -$136,963 |
| FY 2027 | $609,691 | $91,122 | $700,814 | ($836,278) | -$135,465 |
| FY 2028 | $627,982 | $93,856 | $721,838 | ($855,630) | -$133,792 |
| FY 2029 | $646,821 | $96,672 | $743,493 | ($875,429) | -$131,936 |
| FY 2030 | $666,226 | $99,572 | $765,798 | ($895,687) | -$129,889 |
| FY 2031 | $686,213 | $102,559 | $788,772 | ($916,413) | -$127,641 |
| FY 2032 | $706,799 | $105,636 | $812,435 | ($937,619) | -$125,183 |
| FY 2033 | $728,003 | $108,805 | $836,808 | ($959,315) | -$122,507 |
| FY 2034 | $749,843 | $112,069 | $861,912 | ($981,514) | -$119,601 |
| FY 2035 | $772,339 | $115,431 | $887,770 | ($1,004,226) | -$116,456 |
| FY 2036 | $795,509 | $118,894 | $914,403 | ($1,027,464) | -$113,061 |
| FY 2037 | $819,374 | $122,461 | $941,835 | ($1,051,239) | -$109,404 |
| **Total** | **$13,009,591** | **$1,944,369** | **$14,953,961** | **($17,065,551)** | **-$2,111,590** |

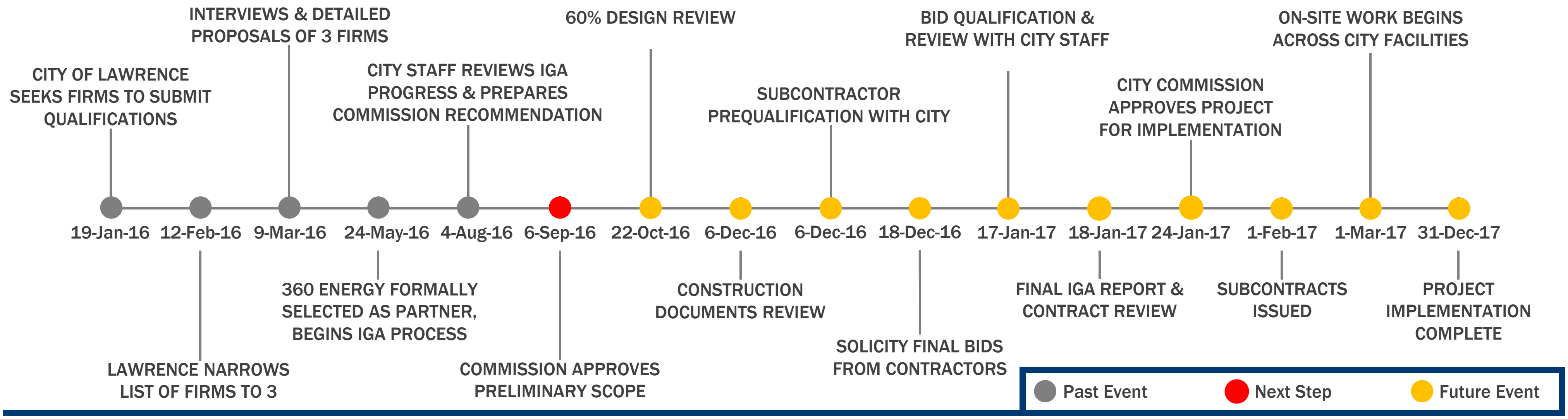
**Financing Asuumptions**

| | |
|---|---|
| Total Project Cost | $12,075,000 |
| FCIP Fee | $101,375 |
| Total Financed | $12,176,375 |
| Financing Term | 20 Years |
| Interest Rate | 3.25% |
| Inflation Rate Demonstrated | 3.00% |
| Payment Escalation | 2.30% |

**City Statistics**

| | |
|---|---|
| Total Value of Infrastructure & Energy Projects Completed | $12,075,000 |
| Percentage of Project Funded by Savings (Excluding CIP Value) | 87.63% |
| Value of CIP Projects Completed without Additional Allocations | $2,905,000 |

# CITY OF LAWRENCE – ANTICIPATED PROJECT TIMELINE



CITY OF LAWRENCE SEEKS FIRMS TO SUBMIT QUALIFICATIONS

INTERVIEWS & DETAILED PROPOSALS OF 3 FIRMS

CITY STAFF REVIEWS IGA PROGRESS & PREPARES COMMISSION RECOMMENDATION

60% DESIGN REVIEW

SUBCONTRACTOR PREQUALIFICATION WITH CITY

BID QUALIFICATION & REVIEW WITH CITY STAFF

CITY COMMISSION APPROVES PROJECT FOR IMPLEMENTATION

ON-SITE WORK BEGINS ACROSS CITY FACILITIES

19-Jan-16 12-Feb-16 9-Mar-16 24-May-16 4-Aug-16 6-Sep-16 22-Oct-16 6-Dec-16 6-Dec-16 18-Dec-16 17-Jan-17 18-Jan-17 24-Jan-17 1-Feb-17 1-Mar-17 31-Dec-17

LAWRENCE NARROWS LIST OF FIRMS TO 3

360 ENERGY FORMALLY SELECTED AS PARTNER, BEGINS IGA PROCESS

COMMISSION APPROVES PRELIMINARY SCOPE

CONSTRUCTION DOCUMENTS REVIEW

SOLICITY FINAL BIDS FROM CONTRACTORS

FINAL IGA REPORT & CONTRACT REVIEW

SUBCONTRACTS ISSUED

PROJECT IMPLEMENTATION COMPLETE

● Past Event ● Next Step ● Future Event

## SCHEDULE DETAILS

| DATE | MILESTONE |
|---|---|
| 19-Jan-16 | City of Lawrence notifies FCIP firms of interest in project |
| 12-Feb-16 | Lawrence creates short list of 3 firms to interview |
| 9-Mar-16 | Short listed firms present detailed proposals, interview |
| 24-May-16 | Commission formally selects 360 Energy Engineers |
| 4-Aug-16 | City staff reviews IGA progress, prepares recommendation |
| 6-Sep-16 | City commission approves preliminary project scope |
| 22-Oct-16 | 60% Design Development review with City staff |
| 6-Dec-16 | Construction Documents review and approval for bidding |
| 6-Dec-16 | Collaborative subcontractor pre-qualification process |
| 18-Dec-16 | Solicit final pricing from pre-qualified subcontractors |
| 17-Jan-17 | Bid qualification and review with City staff before approval |
| 18-Jan-17 | Final IGA Report and Contract submitted for staff review |
| 24-Jan-17 | Project approved for implementation by Commission |
| 1-Feb-17 | Equipment ordered and subcontracts issued for project |
| 1-Mar-17 | On-site work begins across City buildings, managed by 360 |
| 31-Dec-17 | Project implementation and commissioning complete |
| 1-Jul-19 | Performance Maximization and Tracking finalized by 360 |

**Next Step – Commission Approval of City Staff Recommendation for Project Scope**
The Lawrence City Commission has already authorized 360 Energy Engineers to conduct an Investment Grade Energy Audit; this report has been completed and is pending final approval by the Facilities Conservation Improvement Program (FCIP). The objective of all parties is to implement measures identified through that program and, in order to do so, 360 Energy Engineers continues in its turnkey role by developing all measures further for competitive pricing procurement. While no additional financial commitment is requested – and thus no legal requirement exists for the undertaking of this step – Lawrence City Staff, 360 Energy Engineers, and the FCIP all request that the City Commission provide preliminary approval of the identified scope of work that will be developed for bidding and implementation.

# Appendix

## Energy and Maintenance Savings

Comprehensive energy and maintenance savings TBD based on final design analysis, bid results, and financing terms.

## Savings Calculations and Methodology

### Lighting Retrofits and Replacements

The lighting usage baseline operation was modeled in detail using our proprietary lighting analysis tool. The lighting analysis tool was then utilized to model lighting retrofits, new fixture installation, controls strategies, and other lighting opportunities. Lighting technology upgrades affect utility costs by reducing electrical consumption and demand of the lighting system. Utility costs related to heating and cooling are also affected because the upgraded lighting system reduces heat gain from lamps and ballasts adding/subtracting additional load from the HVAC system. 360 Energy Engineers energy savings calculations account for all of these effects.

Consumption Savings:
(Fixture Quantity) x ((Watts/Existing Fixture) - (Watts/Upgraded Fixture)) x (Annual Hours) (1000 Watts/kW)

Where:

Fixture Quantity - Quantity of fixtures of a particular type to be upgraded.

Watts/Existing Fixture - Observed wattage of each fixture before the upgrade (including lamps and ballasts and accounting for burned out fixtures).

Watts/Upgraded Fixture - Wattage of each fixture after the upgrade both retrofitted and replaced.

Annual Hours - Annual fixture burn hours. This represents the actual hours the fixture is expected to be in use during the year. The hours vary with the type of space served and the habits of the occupants. Automated occupancy loggers are used to assist in the development of annual operation hours for each type of space.

A second calculation is used to determine the energy savings that can be expected from reduced cooling loads. These are termed “A/C Savings” and are calculated as follows:

A/C Savings:
Electrical Savings x Number of Cooling Months (12 Months/Year) x COP

Where:

COP - Coefficient of Performance of the cooling system

The third calculation is used to determine extra heating that must be done to compensate for the reduction in heat gains in the building because of the upgrades in lamps and ballasts. This is referred to as “Heating Penalty” and is expressed in units of MCF.

Heating Penalty:
(Electrical Savings) x (Number of Heating Months) x (3413 Btu/kWh)
(12 Months/Year) x (1,030,000 Btu/MCF) x (Heating Efficiency)

Where:

Heating Efficiency - Efficiency of the heating system

Once Electrical Savings, A/C Savings, and Heating Penalty are calculated for each lighting upgrade, utility rates can be applied to these energy consumption values to determine the net effect of the lighting upgrades on utility costs.

Total Savings:
= ((Electrical Consumption Savings + A/C Consumption Savings) x ($/kWh))
+ ((Demand Savings + A/C Demand Savings) x ($/kW))
- ((Heating Penalty) x ($/MCF))

## HVAC Replacements and Renovations

The baseline operation for each building receiving new HVAC equipment and/or building controls was modeled in detail using eQUEST (Quick Energy Simulation Tool), a powerful energy simulation program. Once an accurate computer model was made of these buildings' current systems and modes of operation, the replacement components were then simulated in eQUEST to quantify the effects of adding new equipment.

The energy reduction resulting from the installation of new, more efficient equipment, as well as properly sizing the equipment to match the facilities load and ventilation requirements, was determined by exporting hourly baseline energy end use components from eQUEST for the systems being analyzed. This information was processed in an Excel-based system model developed to simulate the operation of these systems. This was performed outside of eQUEST in a custom-developed modeling tool called BUAT or Building Utility Analysis Tool which is not constrained by some savings calculation limitations in the eQUEST program.

## Energy Modeling and Savings Methodology

### Utility Analysis

In order to accurately quantify the potential savings of energy conservation opportunities, the buildings' present state of energy consumption is determined. The baseline energy consumption of the building is calculated from actual utility information provided by a process of prorating and weather normalization. The process of prorating and weather normalization and their significance towards the baseline energy modeling is described below.

#### Prorating Utility Data

Utility companies typically read their customer's meters during the middle of each month, and therefore, a given monthly utility bill contains consumption information from two different months. To find its relationship to weather patterns, which are reported on a monthly basis, the consumption reported on a utility bill was distributed between the two months it covers. This process is referred to as prorating the utility data. For more accuracy, 26 months of utility bills are generally requested and used, if available.

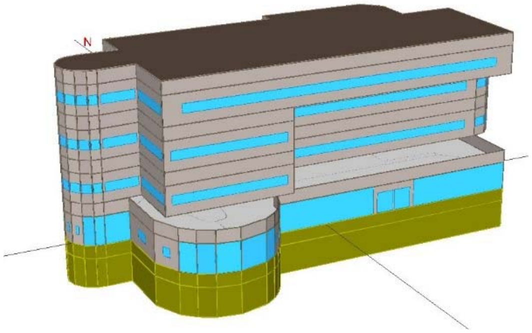
#### Weather Normalization

Once the utility consumption data was placed in its appropriate month, the consumption was normalized using actual and typical meteorological year (TMY3), 30-year average year's weather. This was done to eliminate any extraordinarily high or low energy use due to untypical mild or extreme weather conditions. This normalization used the variables of heating degree-days and cooling degree-days to relate weather to weather-dependent energy use. Heating degree-days (HDD) and cooling degree-days (CDD) are quantitative indices that indicate the demand for energy needed to heat or cool a building.

In order to correlate energy consumption to weather conditions, a linear regression analysis was performed to generate the relationship between energy use and actual degree-days. A typical year's degree-days are then applied into this correlation to obtain a typical year's utility usage. In the case of natural gas, only heating degree-days were used because it assumed that temperature-dependent consumption gas only applies to the heating months. Cooling degree-days were used to correlate electrical demand (kW) and consumption (kWh) for space cooling.

# Building Energy Simulation

Example eQUEST computer energy model



The foundation of this process is performing detailed Department of Energy DOE-2.2 energy simulation – also known as a building energy model – of each building to accurately quantify the potential savings opportunities and develop precise cost estimates. 360 Energy Engineers utilizes eQUEST (QUick Energy Simulation Tool) to analyze the energy use in each building, particularly for major mechanical systems and controls systems. Accurate energy modeling provides reliable cost and savings projections that in turn provide a solid basis for making energy improvement decisions.

To evaluate the facilities use energy, formulate specific opportunities for energy conservation, and accurately calculate energy savings, 360 Energy Engineers' engineers perform a detailed analysis process that encompasses:

- The building energy model is constructed and calibrated to replicate, at a reasonable level, the energy and demand use profiles of the current baseline building operation. This is accomplished by first running the model as first constructed. These results are then compared to the baseline energy consumption derived in the utility analysis and weather normalization process to assess how closely the model matches the building's current operation. After examining the results, it is apparent where energy or demand is too high or too low, and adjustments are made. The key is getting all parameters, including electric energy, electric demand, and fuel use, to align simultaneously while maintaining the validity of the inputs into the model. The calibration process requires numerous iterations in order to achieve a satisfactorily calibrated model.
- After the model is calibrated, changes are made to the models which represent implementation of proposed energy conservation opportunities (ECOs). ECOs are implemented as parametric runs, or groups of component changes to the baseline inputs, to assess the energy savings of each ECO individually. When ECOs are selected for implementation, they are run simultaneously to account for the interactive energy effects of the ECO combinations.
- Building a detailed simulation of each facility's utility tariff to obtain an accurate annual dollar savings
- Performing a comprehensive financial analysis of each conservation measure being considered to provide owner/decision-makers with the data needed to make informed decisions.

360 Energy Engineers takes great pride in its unique approach to completing detailed utility analysis during the audit phase and complete building energy simulations, to understand the impact of system changes, ensure sound design solutions, ensure accurate energy savings projections and maximize value to our clients. Other companies complete this process as a formality and a sales tool. Our approach provides clients a transparent understanding of utility use and energy conservation recommendations, and lays the foundation for our rigorous IPMVP Measurement and Verification plan.

# Savings Reporting and Reconciliation

No more than 18 months following Project Completion, 360EE will provide to Customer a savings report identifying the Actual Energy Savings through retrofit isolation measurements.

# Utility Rates Used to Calculate Savings

The utility rates listed in the table below will be used to determine the amount of dollar savings achieved each year for purposes of measuring the program's performance relative to the Energy Savings Post-project and Baseline.

| | Electric Rates | | Natural Gas Rates |
|---|---|---|---|
| | **Consumption** | **Demand** | **Consumption** |
| **Small General Summer** | $0.0917658 / kWh | $8.47 / kW | $0.68/ Therm |
| **Small General Winter** | $0.0917658 / kWh | $ 4.38 / kW | $0.68/ Therm |
| **Medium General Summer** | $0.044646 / kWh | $20.214 / kW | $0.68/ Therm |
| **Medium General Winter** | $0.038813 / kWh | $20.214 / kW | $0.68/ Therm |

# Measurement and Verification Plan

## Lighting Retrofits and Replacements M&V Plan

Lighting energy savings (kWh) are based on the difference between the baseline and post-retrofit power (Watts), the fixture quantities, and the hours of operation. For this M&V plan, it is assumed that the operating hours remain constant during the performance period.

M&V Option: IPMVP Option A – Partially Measured Retrofit Isolation Definition of Baseline

International Performance Measurement and Verification Protocol Option A verification techniques will be utilized to verify annual energy savings of $5,301 annually for lighting Renovations. This method will assist in measuring savings at a system level where key performance factors (e.g., lighting fixture power) or operational factors (e.g., lighting fixture utilization) can be measured during the baseline and post-installation periods. Any factor not measured is estimated based on assumptions, analysis of historical data, or manufacturer's data.

Lighting Energy Savings: The proposed lighting energy savings are calculated using the equations below:

ES = EB – EP

Where:

ES = Electrical kWh Saved

EB = Baseline Electrical Consumption (Includes interior and exterior lighting)

EP = Proposed Electrical Consumption (Includes interior and exterior lighting)

For Light Fixtures:

EP = ∑( EPIL(1)+EPIL(2)+…+EPIL(n*)) + ∑ (EPEX(1)+EPEX(2)+…+EPEX(p*))

*Where n represents the total number of interior retrofits and p is the total number of exterior retrofits

Where:

EPIL(n) = LMP(n) x HRS(n) x PWR(n)= Interior Lighting Proposed Consumption

EPEX(p) = LMP(p) x HRS (p) x PWR (p) = Exterior Lighting Proposed Consumption

LMP(n) = Number of lamps of fixture type "n" – (stipulated values)

HRS(n) = Average annual hours* of use for fixture of type "n" – (stipulated values)

PWR(n) = Proposed watts per fixture of type "n" – (measured parameter)

*Where a given fixture retrofit type is utilized in multiple spaces with different run hours, the fixtures will be divided into distinct categories such that the appropriate number of run hours is assigned to each fixture.

EB = ∑( EBIL(1)+EBIL(2)+…+EBIL(n*)) + ∑ (EBEX(1)+EBEX(2)+…+EBEX(p*))

*Where n represents the total number of interior retrofits and p is the total number of exterior retrofits

Where:

EBIL(n) = LMP(n) x HRS(n) x PWR(n)= Interior Lighting Baseline Consumption

EBEX(p) = LMP(p) x HRS (p) x PWR (p) = Exterior Lighting Baseline Consumption

LMP(n) = Number of lamps of fixture type "n" – (stipulated values)

HRS(n) = Average annual hours* of use for fixture of type "n" – (stipulated values)

PWR(n) = Proposed watts per fixture of type "n" – (measured parameter)

Operations And Maintenance and Other Cost Savings: O&M savings were estimated using manufacturer's published life data for lamps and ballasts and readily available costs. It is assumed the new system will need negligible maintenance.

Post-Installation M&V Activities and Sample Sizes: Upon completion, an as-built inventory of post-installation lighting fixtures will be supplied, including the lighting lamps actually installed, and lighting illumination levels (foot–candles). Lighting level measurements will be made in the same fashion as baseline measurements. Savings predictions will be corrected based on as-built data and will be reported in the M&V Report. Immediately following installation, fixture power consumption will be measured in a manner identical to that for the baseline fixtures. Quantities and locations of measurements will be determined utilizing the IPMVP Guidelines for Partially Measured Retrofit Isolation. Sample sizes shall meet a confidence of at least 80% and a precision of 20%.

## HVAC Replacements and Renovations M&V Plan

Savings in both electric (kWh) and gas (therms) are based on the difference between the baseline and post-project power energy consumed for a particular system. For this M&V plan, it is assumed that the operating hours remain constant during the performance period.

M&V Option: IPMVP Option D – Calibrated Energy Model

Customer and 360 Energy Engineers agree that Option D, Calibrated Simulation, of the International Performance Measurement and Verification Protocol (IPMVP) will be utilized to verify annual energy savings of *TBD* annually for HVAC Renovations. Modeled energy consumption in the city of Lawrence's Premises to reflect the baseline period and post project Scope of Work were compared using a calibrated energy model taking into account both building parameters, building geometry, envelope and HVAC system components.

Simulation Program: The software that will be utilized to develop a calibrated simulation of the Customer's Premises during the baseline as well as simulating the effect of the Energy Conservation Measures (ECMs) implemented by 360 Energy Engineers will be eQUEST (Quick Energy Simulation Tool), a Department of Energy (DOE) supported program common in the industry.

HVAC Energy Savings: The proposed HVAC renovation energy savings are calculated using the equations below:

Energy Savings = Modeled Baseline Energy Usage (Calibrated Simulation) – Guarantee Period Energy Model

Where:

Guaranteed Period Model = Modeled Baseline Energy modified to reflect Energy Conservation Opportunities implemented by 360 Energy Engineers.

Modeled Baseline Energy Usage = Modeled energy usage of the Calibrated Simulation that reflect the Baseline building and its operation.

Energy Simulation Process:

Build Baseline Model: Baseline building parameters, including building geometry, envelope, HVAC systems, etc. are input into the modeling software and documented.

Parameters were gathered from facility walkthroughs, interviews with facilities staff and administration, and building blueprints.

Calibrate Baseline Model: Calibration of the baseline is achieved by verifying that the simulation model reasonably predicts the energy use of the facility during the Baseline Period. This is performed by comparing model results that reflect the building(s) to a set of utility bills for the Baseline Period, including consumption and demand. Main steps in the calibration process are listed below:

Energy and demand results are compared with baseline metered data, on a monthly basis. Baseline metered usage is weather normalized to TMY3 data (provided by DOE) to aid in the comparison between modeled baseline usage and actual metered baseline usage. Weather normalization involves developing linear regressions between consumption and weather. Patterns and correlations are graphically generated to help aid in their assessment and identification and analysis.

Input data is revised and additional simulations are performed until the simulation closely matches the facility's baseline.

More details about the modeling methodology can be found in Energy Modeling and Savings Methodology.

Energy Conservation Measure (ECM) Simulation: Once an accurate baseline simulation is developed, changes that will be made to the facilities as part of each ECM are modeled in the Simulation Program. Simulated usage of the post ECM buildings is compared with the baseline simulation to determine energy savings.

Where more than one ECM is to be simulated for a building, ECM simulations are based off each other creating a stacking effect which more closely models the actual building's predicted performance; not all ECM simulations are compared with the baseline. Building simulation outputs can be found in the Appendix Savings Documents under the Baseline and ECM Output.

Operations And Maintenance and Other Cost Savings: O&M savings were estimated based on labor and materials required to maintain old system.

Pre-Installation M&V Activities and Sample Sizes: All M&V activities for this measure were performed prior to the installation of the new systems. Building and HVAC equipment information was collected during the Investment Grade Audit. These observations and measurements were used in developing the baseline energy model. Furthermore, post-installation about new systems and equipment were taken from engineered project plans and equipment cut sheets to develop the Energy Conservation Measure Simulation.

Post-Installation M&V Activities and Sample Sizes: No post installation M&V measurements will be performed to greatly simplify the M&V efforts. All post-installation operational variables (e.g., run hours, temperature setpoints) was assumed to be equal to the baseline conditions. Post-installation system performance was obtained from engineered project plans and equipment cut sheets.

# Baseline and Proposed Lighting Tables

--To be added at a later date.

# Equest Output Files

--To be added at a later date.