City of Lawrence

Investment Grade Audit Report

Table of Contents

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 $450,301 in annual energy savings potential. Additional maintenance savings of $127,704 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,

Joseph Hurla
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Project Overview

Summary Table of Energy Conservation Measures

Comprehensive List of Projects Identified											City Of Lawrence
Energy Efficiency Measures		Energy Savings						Other Savings			
ID #	Description	Electric Energy (kWh)	Electric Demand (kW)	Electric Cost ($)	Natural Gas (Therm)	Gas Cost ($)	Total Utility ($)	Maintenance Labor ($)	Maintenance Material ($)	Total Maintenance ($)	Total Savings ($)
1	City-Wide: Building LED Retrofits, Replacements & Controls	1,905,686	4,572	$181,126	-20,109	-$15,268	$165,858	$8,762	$27,131	$35,893	$201,751
2	City-Wide: Building Weatherization	38,677	0	$3,868	13,529	$9,200	$13,068	$0	$0	$0	$13,068
3	Parks and Rec: Parks Area Lighting	157,716	435	$16,967	0	$0	$16,967	$435	$1,954	$2,389	$19,356
4	Parks and Rec: Sports Field Lighting	44,214	510	$6,981	0	$0	$6,981	$5,230	$1,029	$6,259	$13,240
5	Parks and Rec: Advanced Timers for Tennis/Basketball Courts	6,912	0	$636	0	$0	$636	$0	$0	$0	$636
6	Public Works: Web Based Thermostats	39,114	-3	$3,163	5,546	$4,719	$7,882	$472	$492	$964	$8,846
7	Public Works: City-Wide Pole Lighting	282,322	769	$30,315	0	$0	$30,315	$553	$3,394	$3,947	$34,262
8	Public Works: DDC Upgrades and Optimization	542,986	981	$53,657	20,734	$14,591	$68,248	$901	$1,906	$2,808	$71,056
9	Airport Terminal: Split System HVAC Replacements	7,027	33	$825	170	$145	$970	$448	$616	$1,065	$2,035
10	City Hall: Replace Cabinet Heaters	51,759	39	$2,953	-4	-$4	$2,949	$43	$70	$113	$3,062
11	City Hall : Replace Windows	44,628	175	$5,556	0	$0	$5,556	$1,601	$1,921	$3,521	$9,077
12	Community Building: Replace Aging Packaged Units	22,008	126	$2,783	315	$268	$3,051	$1,565	$2,069	$3,633	$6,684
13	Community Building: Replace Roof	317	2	$39	90	$77	$116	$0	$0	$0	$116
14	Community Health: Install Electronic Air Cleaner Filtration	23,045	93	$3,121	2,898	$2,028	$5,149	$775	$29	$804	$5,953
15	Community Health: Replace Air Cooled Chiller	104,629	642	$18,883	2	$1	$18,884	$5,890	$12,607	$18,497	$37,381
16	Community Health: Replace Boillers	0	0	$0	0	$0	$0	$1,852	$3,430	$5,282	$5,282
17	Community Health: Replace Roof	762	4	$123	263	$184	$307	$0	$0	$0	$307
18	East Lawrence Rec Center: Replace Outdated Packaged Units	16,653	84	$1,974	164	$164	$2,138	$1,044	$934	$1,979	$4,117
19	Fire Station #2: Replace Outdated Rooftop Units	6,947	25	$758	-12	-$10	$748	$327	$369	$696	$1,444
20	Fire Station #3: Replace Aging Rooftop Units	6,771	24	$753	-18	-$15	$738	$587	$494	$1,081	$1,819
21	Fire Station #3: Replace Roof	879	4	$103	204	$173	$276	$312	$120	$432	$708
22	Fire Station #5: Solar Power Installation	141,928	61	$12,583	0	$0	$12,583	$0	$0	$0	$12,583
23	Holcom Rec Center: New Packaged HVAC System	51,484	211	$5,791	-602	-$512	$5,279	$544	$892	$1,436	$6,715
24	Holcom Rec Center: Sports Field Lighting and New Poles	11,410	45	$970	0	$0	$970	$0	$0	$0	$970
25	Indoor Aquatic Center: Energy & Air Quality Improvements	354,670	693	$29,033	60,053	$42,037	$71,070	$7,677	$15,128	$22,805	$93,875
26	Lawrence Arts Center: Replace Air Cooled Chiller	73,460	247	$8,230	0	$0	$8,230	$3,329	$7,126	$10,455	$18,685
27	New Hampshire Parking Garage: HVAC Replacements	16,719	41	$1,639	-1,843	-$1,567	$72	$177	$285	$462	$534
28	Outdoor Aquatic Center: Boiler Replacement	0	0	$0	0	$0	$0	$328	$853	$1,181	$1,181
29	Outdoor Aquatic Center: HVAC System Renovations	2,833	5	$285	0	$0	$285	$90	$137	$228	$513
30	Praire Park: Split System HVAC Renovation	0	0	$0	0	$0	$0	$598	$821	$1,419	$1,419
31	Solid Waste Office: Replace Packaged Unit	8,439	33	$959	17	$17	$976	$164	$193	$357	$1,333
32	Vehicle Maintenance Office: Add Ductless Mini Split	0	0	$0	0	$0	$0	$0	$0	$0	$0

Facilities in Scope

	Facility	Address	Sq. Ft.
1	Community Health Building	200 Maine St.	88,000
2	Indoor Aquatic Center	4706 Overland Dr.	44,000
3	Library	707 Vermont St.	85,000
4	Eagle Bend Clubhouse	1250 East 902 Road	3,000
5	Airport Terminal	1920 Airport Rd.	7,500
6	Airport Maintenance Facility	1920 Airport Rd.	10,500
7	Airport Community Hangar	1920 Airport Rd.	15,000
8	Fire/Med #5	1911 Stewart Ave.	26,000
9	Fire/Med #4	2121 Wakarusa Dr.	11,000
10	Fire/Med #3	3708 W. 6th St.	7,000
11	Fire and Rescue Training	1941 Haskell Ave. #5	6,500
12	Fire/Med #2	2128 Harper St.	11,000
13	Parking/AnimalControl/Transit	935 New Hampshire St.	2,300
14	Lawrence Arts Center	940 New Hampshire St.	55,000
15	City Hall	6 E. 6th St.	28,000
16	Carnegie Building	9th & Vermont	12,000
17	Union Pacific Depot	North Lawrence	5,000
18	East Lawrence Rec Center	1245 East 15th Street	18,000
19	Prairie Park Nature Center	2730 Harper St.	5,500
20	South Park Admin Office	1141 Massachusetts St.	4,800
21	Community Building	115 West 11th Street	30,000
22	Holcom Park Rec Center	2700 West 27th Street	19,500
23	Sports Pavilion	100 Rock Chalk Lane	181,000
24	Solid Waste Division	1140 Haskell	2,600
25	Street Division Office	1120 Haskell	3,200
26	YSI Sports Complex (Buildings)	W. 27th	3,300
27	27th St. Maintenance Building	W. 27th	5,000
28	Airport Hangar A	1920 Airport Rd.	12,000
29	Airport Hangar B	1920 Airport Rd.	12,000
30	Airport Hangar C	1920 Airport Rd.	12,000
31	New Hampshire Parking Garage	935 New Hampshire	128,000
32	Riverfront Parking Garage	Riverfront Plaza	136,000
33	Outdoor Aquatic Center	727 Kentucky St.	6,300
34	Vehicle Maintenance Garage	1141 Haskell	14,500
35	North Lawrence Pump Station	734 N. 2nd St	600
36	Street Division Salt Dome - Wakarusa	Wakarusa Drive	3,000
37	Street Division Salt Dome - Haskell	1128 Haskell	3,000
38	Street Division - Red Barn	1120 Haskell	7,000
39	Parks & Rec Maintenance	1050 E. 11th Street	6,900

Summary of Annual Energy Use

Consumption	Total Energy (MBtu/yr)	Electric Energy (kWh/yr)	Electric Demand (kW/yr)	Natural Gas (MBtu/yr)
Usage for Entire Site **	61049	10,876,039	33,453	23940

Cost	Total Energy Cost	Electric Cost	Natural Gas Cost
Baseline Energy Cost (In Scope)	$1,228,960	$1,069,201	$159,758.80

Notes:
MBtu = 10^6 Btu
*Annual electric demand savings (kW/yr) is the % sum of the monthly demand savings
**Usage period is the 12 month billing period of 2015
KSF = 10^3 square feet
1 MBtu = 293.3 kWh

Expected Annual Percentage Savings Expected If All Recommended ECMs Are Implemented

Consumption	Total Energy (MBtu/yr)	Electric Energy (kWh/yr)	Electric Demand (kW/yr)	Natural Gas (MBtu/yr)
Total Proposed Project Savings	21,655	3,963,995	9,851	8,140
Usage for Entire Site **	61,028	10,876,039	33,453	23,946
% Total SIte Usage Saved	35.50%	36.40%	29.40%	34.00%

	Site Area
Project Square Footage (KSF)	1,031
Total Site Square Footage (KSF)	1,031
% Total Site Area Affected	100%

Notes:
MBtu = 10^6 Btu
*Annual electric demand savings (kW/yr) is the sum of the monthly demand savings
**Usage period is the 12 month billing period of 2015
KSF = 10^3 square feet
1 MBtu = 293.3 kWh

Facility Assessments

See Facility Assessments section

ECM Descriptions

See Energy Conservation Measures section

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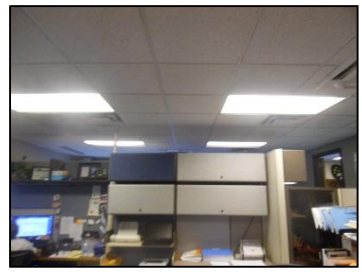
Facility Assessments

City Hall

- General: The City Hall building is a 28,000 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. A 12-watt LED will provide the same amount of light as a 32-watt fluorescent lamp, resulting in an energy savings of over 60%. City staff have installed several LED retrofit tubes and luminaires throughout City Hall. The existing LED retrofit tubes are a direct fit application meaning the costly ballast remains in place. These will be replaced and provided to the city rather than being disposed of.
- 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.
- Operating Hours: 8am to 5pm, Monday through Friday, with biweekly City Commission meetings on the 1st floor until 10pm.

Existing City Hall windows



Existing T8 Lighting

New chiller on roof

Existing EMS thermostat

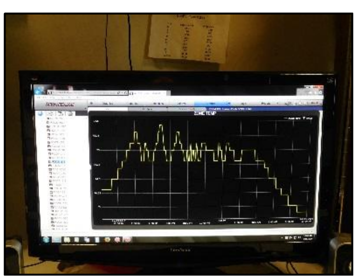
Community Health

- General: The Community Health building is an 88,000 square foot office building that includes several small private offices, 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.
- 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. A 12-watt LED will provide the same amount of light as a 32-watt fluorescent lamp, resulting in an energy savings of over 60%. 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.
- HVAC Systems: The existing HVAC system for the Community Health Center consists of a 270 ton chiller 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.
- Operating Hours: 8am to 5pm, Monday through Friday.


Brick and window envelope

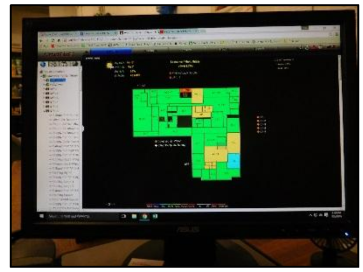

Existing building boilers


270-ton chiller


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.
- Operating Hours: 9am to 9 pm, Monday through Friday; 9 am to 9 pm on Saturday; and 12 pm to 8 pm on Sunday.



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.
- Operating Hours: 9am to 9 pm, Monday through Saturday; 9 am to 5 pm on Sunday.

Arts Center Chiller

Antiquated EMS at Arts Center

Streets Division Complex

Incandescent lighting

- General: The Streets Division Complex includes a 3,200 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. A 12-watt LED will provide the same amount of light as a 32-watt fluorescent lamp, resulting in an energy savings of over 60%.

Streets division thermostat

- 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.
- Operating Hours: 7 am to 4:30 pm Monday through Friday

Solid Waste

Existing Solid Waste T8 Lighting

- 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. A 12-watt LED will provide the same amount of light as a 32-watt fluorescent lamp, resulting in an energy savings of over 60%.

Solid Waste HVAC Unit

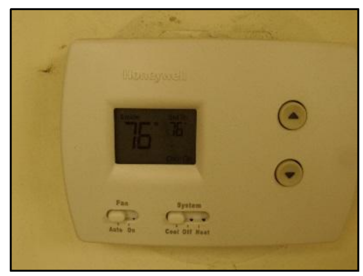
- HVAC Systems: The current HVAC for the facility consists of a single-zone packaged air handler located to the South of the facility. This packaged unit was relocated from a nearby fire station and has reached the end of its service life. The unit is ducted into the facility and provides gas heating 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.
- Operating Hours: 6 am to 5 pm Monday through Friday.

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. Fluorescent technology provides poor visibility compared to more modern lighting solutions and use significantly more energy to produce the same amount of light output. A 12-watt LED will provide the same amount of light as a 32-watt fluorescent lamp, resulting in an energy savings of over 60%. 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 located 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.
- Operating Hours: 6 am to 5 pm, Monday through Friday.

Gas-fired unit heater


Residential split system


Stand-alone thermostat

Airport Terminal

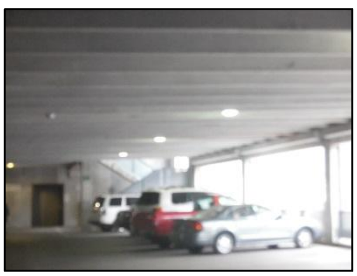
Outdated airport furnace

- 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.
- 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.

Airport Terminal T8 Lighting

- 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.
- Operating Hours: 6 am to 9 pm daily.

New Hampshire Parking Garage



Metal halide lighting at 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.
- 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 Parking Garage

Riverfront garage T5 lighting

- 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

- 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.

Highbay fluorescent lighting at Fire/Med #2

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.

Traditional thermostat at Fire/Med #3

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

Windows at Fire/Med #4

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

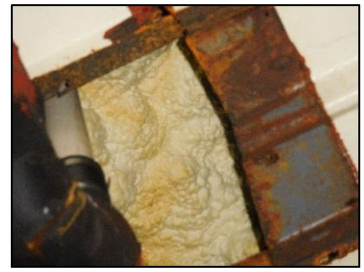
North Lawrence Pump Station

- 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. The nearby 2nd Street Underpass is illuminated by HID wallpacks with several HID ceiling mount luminaires in the walkway tunnels.
- HVAC Systems: A small unit heater protects the mechanical and electrical equipment at an operable temperature.

Pump #1 at North Lawrence Pump Station

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. A 12-watt LED will provide the same amount of light as a 32-watt fluorescent lamp, resulting in an energy savings of over 60%.
- 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.
- Operating Hours: 5:15 am to 8:45 pm, Monday through Friday; 9 am to 8:45 pm Saturday; 12 pm to 5:45 pm Sunday.



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.
- Operating Hours: 5:15 am to 8:45 pm, Monday through Friday; 9 am to 8:45 pm Sunday. Closed from September to the end of May.

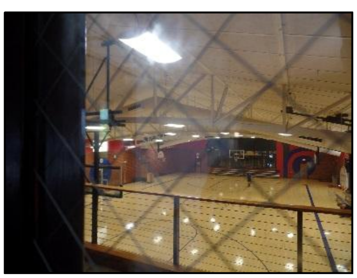
OAC Pool

OAC Exterior Lighting


Carnegie Building Lighting


Boiler at Carnegie Building


Community Building RTUs


Community Building lighting

Carnegie Building

- 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.
- Operating Hours: 8 am to 5 pm, Monday through Friday. Special events as scheduled on nights and weekends.

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.
- 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. A 12-watt LED will provide the same amount of light as a 32-watt fluorescent lamp, resulting in an energy savings of over 60%. The gymnasium is lit with high output T5 fixtures that are very costly to operate and maintain compared to lower wattage LED equivalents. 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.
- 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.

- Operating Hours: 7 am to 9 pm, Monday through Friday; 10 am – 6 pm Saturday; 1 pm to 6 pm Sunday.

Holcom Recreation Center

Holcom Center high-bay lighting

- 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 seam 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. A 12-watt LED will provide the same amount of light as a 32-watt fluorescent lamp, resulting in an energy savings of over 60%. The gymnasium is lit with high output T5 fixtures that are very costly to operate and maintain compared to lower wattage LED equivalents.

Holcom Center boiler

- 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.

Holcom Center cooling unit

- 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.
- Operating Hours: 7 am to 9 pm, Monday through Friday; 10 am to 6 pm Saturday; 1 pm to 6 pm Sunday.

East Lawrence Recreation Center

Building Entrance

- 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. A 12-watt LED will provide the same amount of light as a 32-watt fluorescent lamp, resulting in an energy savings of over 60%. The gymnasium is lit with high output T5 fixtures that are very costly to operate and maintain compared to lower wattage LED equivalents. The main recreation lobby has high wattage metal halide fixtures to illuminate the space. These fixtures use considerably more energy than an LED equivalent and produce poor light quality.

Packaged rooftop unit

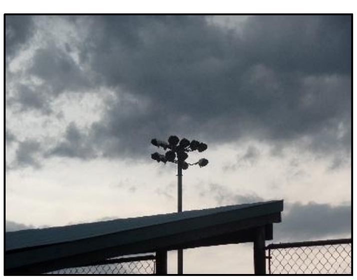
- HVAC Systems: The facility is currently conditioned with four packaged rooftop units. The gymnasium rooftop unit was recently replaced due to failure. The remaining rooftop units condition the lobby, rec room, gymnastics, and an assembly room. The three rooftops are reaching the end of their service life and need to be replaced.
- 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.

Outdated rooftop unit

- Operating Hours: 7 am to 9 pm, Monday through Friday; 10 am to 6 pm Saturday and Sunday.

Youth Sports Complex

- 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.



Existing sports field lighting

- 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.
- Energy Management Systems: The current split-systems are controlled by traditional thermostats.

27th Street Maintenance

Existing Furnace


Condensing Unit

- 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 seam 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. A 12-watt LED will provide the same amount of light as a 32-watt fluorescent lamp, resulting in an energy savings of over 60%.
- 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.
- Operating Hours: 7 am to 5 pm, Monday through Friday.

Prairie Park Nature Center

Outdated furnaces


Condensing units

- 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 seam 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.

- Operating Hours: 9 am to 5 pm, Tuesday through Saturday; 1 pm to 4 pm Sunday.

Existing DDC thermostat

Parks and Recreation Administration Office

- 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.
- 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.
- Operating Hours: 8 am to 5 pm, Monday through Friday.

P&R Admin Lighting

Union Pacific Depot

- 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 lighting throughout the facility is primarily compact fluorescent fixtures with some T8 fluorescent luminaires.
- 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.
- Operating Hours: 9 am to 5 pm, Monday through Saturday; 1 pm to 5 pm Sunday.

UP Depot thermostat

Exterior Depot Lighting

Baseline Utility Analysis

Summary of Utility Bills

Refer to the Appendix for a summary of each building's utility bills.

Base Year Energy Use by Building

The tables shown below are the baseline data calculated for each building with multiple ECMs planned. Facilities with a " - " shown may have natural gas usage but the usage was not relevant for this study.

		27th St Maint Bldg	Airport Community Hangar	Airport Hangar A	Airport Hangar B	Airport Hangar C	Airport Maintenance	Airport Terminal	Art Center	Carnegie Building	City Hall
	Area (GSF)	5,000	15,000	12,000	12,000	12,000	10,500	7,500	55,000	12,000	28,000
Electricity	Annual Cost ($)	$963	$4,111	$826	$3,924	$3,903	$5,425	$7,592	$77,900	$25,758	$95,954
	Annual Cons. (kWh)	9,584	43,129.86	8,158.43	28,056	27,915	46,786	70,681	718,599	237,078	930,955
	Annual Dem. (kW)	28	82.71	24.58	286	284	185	182	2,286	750	2,329
	$ / GSF	$0.19	$0.27	$0.07	$0.33	$0.33	$0.52	$1.01	$1.42	$2.15	$3.43
	kWh / GSF	1.9	2.9	0.7	2.3	2.3	4.5	9.4	13.1	19.8	33.2
	kBtu / GSF	6.5	9.8	2.3	8.0	7.9	15.2	32.2	44.6	67.4	113.4
Fuel	Annual Cost ($)	-	-	-	-	-	$2,576	$2,459	$15,116	$7,383	$1,149
	Annual Cons. (Therm)	-	-	-	-	-	3,440	2,938	24,060	10,946	1,322
	$ / GSF	-	-	-	-	-	$0.25	$0.33	$0.27	$0.62	$0.04
	kBtu / GSF	-	-	-	-	-	32.8	39.2	43.7	91.2	4.7
Total	Annual Cost ($)	$963	$4,111	$826	$3,924	$3,903	$8,001	$10,051	$93,016	$33,141	$97,103
	Annual Energy (kBtu)	32,701	147,165	27,838	95,731	95,250	503,640	534,974	4,857,962	1,903,544	3,308,750
	$ / GSF	$0.19	$0.27	$0.07	$0.33	$0.33	$0.76	$1.34	$1.69	$2.76	$3.47
	kBtu / GSF	6.5	9.8	2.3	8.0	7.9	48.0	71.3	88.3	158.6	118.2

		Community Building	Community Health Building	Eagle Bend Golf	East Lawrence Rec	Fire and Rescue Training	Fire/Med #2	Fire/Med #3	Fire/Med #4	Fire/Med #5	Holcom Rec Center
	Area (GSF)	30,000	88,000	3,000	18,000	6,500	11,000	7,000	11,000	26,000	19,500
Electricity	Annual Cost ($)	$32,107	$117,825	$1,103	$32,051	$3,310	$12,838	$11,398	$24,156	$78,605	$23,082
	Annual Cons. (kWh)	295,449	1,001,245	11,352	289,119	27,039	119,386	105,204	227,641	782,150	211,856
	Annual Dem. (kW)	1,001	4,396	26	1,112	131	363	320	696	1,612	727
	$ / GSF	$1.07	$1.34	$0.37	$1.78	$0.51	$1.17	$1.63	$2.20	$3.02	$1.18
	kWh / GSF	9.8	11.4	3.8	16.1	4.2	10.9	15.0	20.7	30.1	10.9
	kBtu / GSF	33.6	38.8	12.9	54.8	14.2	37.0	51.3	70.6	102.6	37.1
Fuel	Annual Cost ($)	$3,378	$14,583	-	$5,552	$2,145	$3,832	$3,150	$2,419	$2,940	$4,224
	Annual Cons. (Therm)	4,579	23,173	-	6,438	2,996	5,262	4,179	2,909	4,111	5,995
	$ / GSF	$0.11	$0.17	-	$0.31	$0.33	$0.35	$0.45	$0.22	$0.11	$0.22
	kBtu / GSF	15.3	26.3	-	35.8	46.1	47.8	59.7	26.4	15.8	30.7
Total	Annual Cost ($)	$35,485	$132,408	$1,103	$37,603	$5,455	$16,670	$14,548	$26,575	$81,545	$27,306
	Annual Energy (kBtu)	1,466,014	5,733,690	38,736	1,630,315	391,861	933,562	776,871	1,067,643	3,079,907	1,322,383
	$ / GSF	$1.18	$1.50	$0	$2	$1	$2	$2	$2	$3	$1
	kBtu / GSF	48.9	65.2	12.9	90.6	60.3	84.9	111.0	97.1	118.5	67.8

		Indoor Aquatic Center	Library	New Hampshire Parking Garage	North Lawrence Pump Station	Outdoor Aquatic Center	Parking/Animal Control	Parks & Rec Maintenance	Praire Park	Solid Waste	South Park Admin
	Area (GSF)	44,000	85,000	128,000	600	6,300	2,300	6,905	5,500	2,600	4,800
Electricity	Annual Cost ($)	$125,436	$87,687	$28,269	$1,209	$4,178	$5,224	$1,258	$8,199	$9,688	$4,121
	Annual Cons. (kWh)	1,479,704	844,567	304,854	12,602	41,159	47,361	12,524	71,599	90,481	33,279
	Annual Dem. (kW)	3728	2,980	438	26	126	180	36	285	272	165
	$ / GSF	$2.85	$1.03	$0.22	$2.01	$0.66	$2.27	$0.18	$1.49	$3.73	$0.86
	kWh / GSF	33.6	9.9	2.4	21.0	6.5	20.6	1.8	13.0	34.8	6.9
	kBtu / GSF	114.7	33.9	8.1	71.7	22.3	70.3	6.2	44.4	118.7	23.7
Fuel	Annual Cost ($)	$62,678	-	-	-	-	-	-	$845	$841	$926
	Annual Cons. (Therm)	98,523	-	-	-	-	-	-	865	851	999
	$ / GSF	$1.42	-	-	-	-	-	-	$0.15	$0.32	$0.19
	kBtu / GSF	223.9	-	-	-	-	-	-	15.7	32.7	20.8
Total	Annual Cost ($)	$188,114	$87,687	$28,269	$1,209	$4,178	$5,224	$1,258	$9,044	$10,529	$5,047
	Annual Energy (kBtu)	14,901,260	2,881,782	1,040,204	42,999	140,440	161,602	42,734	330,806	393,834	213,453
	$ / GSF	$4.28	$1.03	$0.22	$2.01	$0.66	$2.27	$0.18	$1.64	$4.05	$1.05
	kBtu / GSF	338.7	33.9	8.1	71.7	22.3	70.3	6.2	60.1	151.5	44.5

		Sports Pavilion	Street Division - Office	Union Pacific Depot	Vehicle Maintenance
	Area (GSF)	181,000	3,200	5,000	14,500
Electricity	Annual Cost ($)	$156,089	$4,069	$7,342	$19,103
	Annual Cons. (kWh)	1,745,367	34,789	64,787	161,263
	Annual Dem. (kW)	5,344	135	233	767
	$ / GSF	$0.86	$1.27	$1.47	$1.32
	kWh / GSF	9.6	10.9	13.0	11.1
	kBtu / GSF	32.9	37.1	44.2	37.9
Fuel	Annual Cost ($)	$18,351	$713	$1,636	$2,865
	Annual Cons. (Therm)	29,375	645	2,167	3,683
	$ / GSF	$0.10	$0.22	$0.33	$0.20
	kBtu / GSF	16.2	20.2	43.3	25.4
Total	Annual Cost ($)	$174,440	$4,782	$8,978	$21,968
	Annual Energy (kBtu)	8,892,939	183,205	437,762	918,552
	$ / GSF	$0.96	$1.49	$1.80	$1.52
	kBtu / GSF	49.1	57.3	87.6	63.3

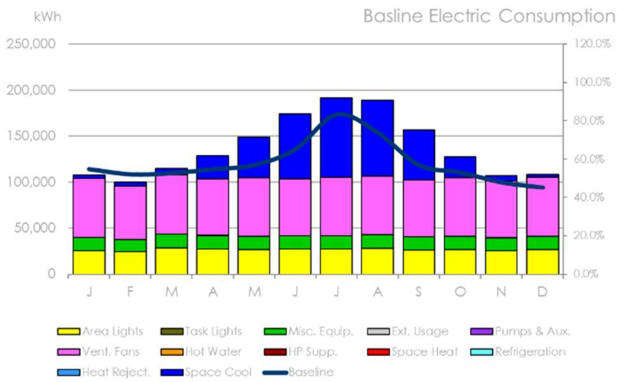
The baseline energy consumption evaluation was developed with a building-specific utility analysis. This analysis used actual reported utility consumption as defined by monthly utility bills. The data from the utility bills was normalized to typical local weather conditions using TMY3 (Typical Meteorological Year, version 3) data. 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. The baseline data is used for both bin analyses and to calibrate computer simulation building models.

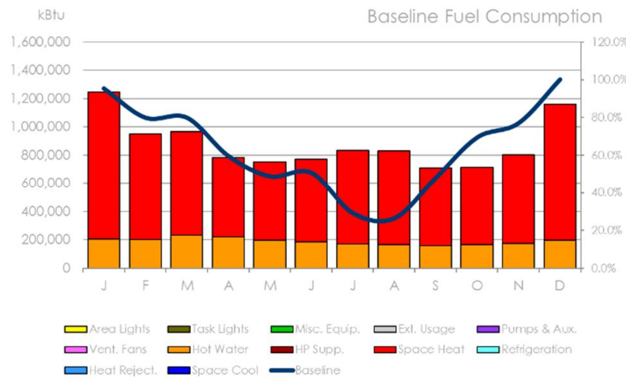
The baseline for all lighting consumption and demand was generated through a comprehensive lighting audit performed to document all fixtures, lighting controls, circuiting, and operation. Each fixture in every building was analyzed to determine: existing wattage, lumen output, ballast factor, and rated run hours. Tables showing the tabulated baseline data for the lighting project are listed in the appendix. Calculations used to determine total lighting load, consumption, and cost are also available in the appendix.

End-Use Reconciliation with Base Year

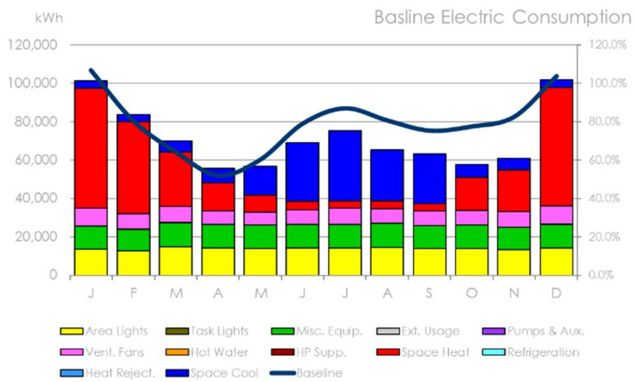
The charts below demonstrate end-use reconciliation with the base year data. The dark blue line represents the calculated baseline energy use.

Indoor Aquatic Center



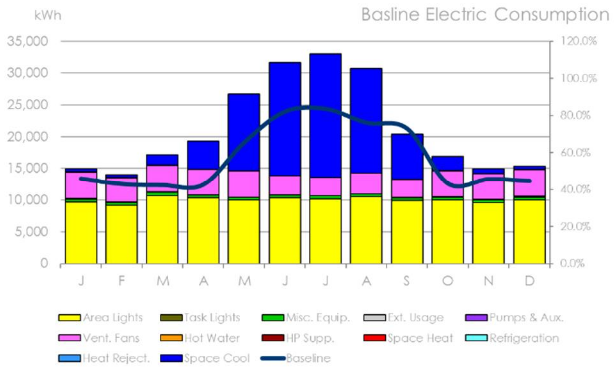


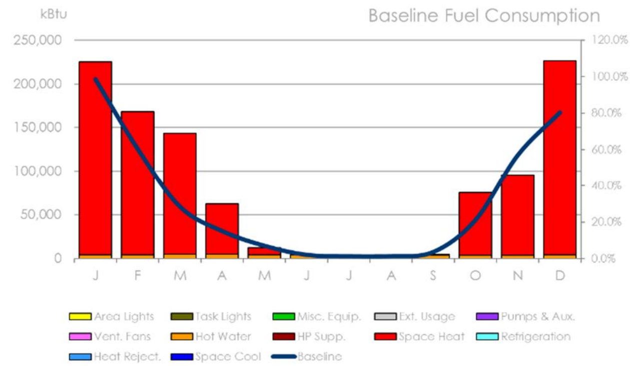
City Hall*



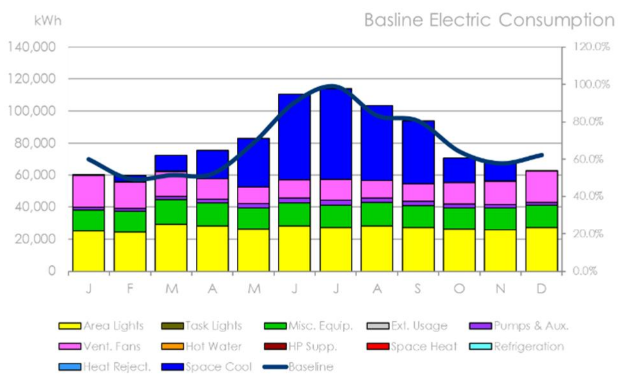
*City Hall gas usage was negligible, and not considered as part of this study.

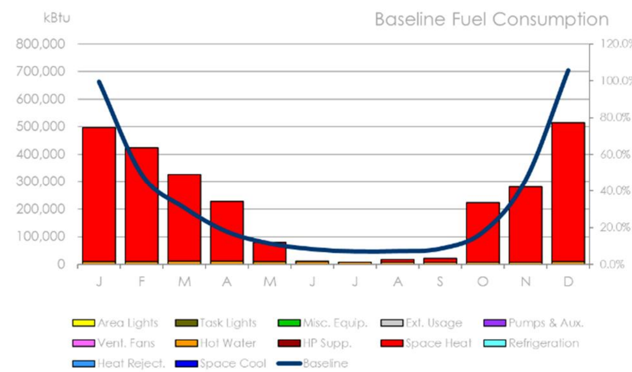
Holcom Rec Center



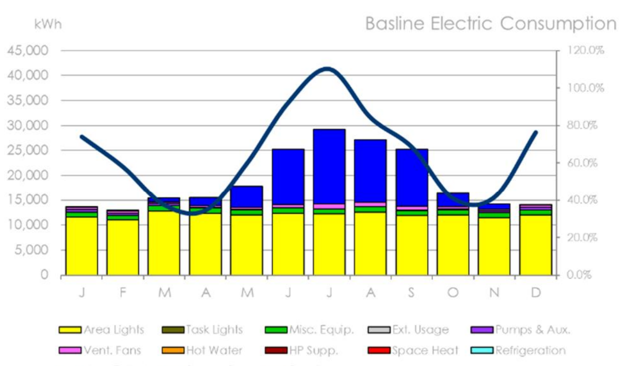


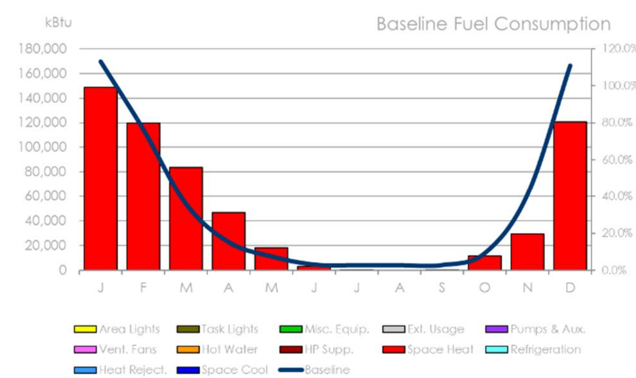
Community Health Building



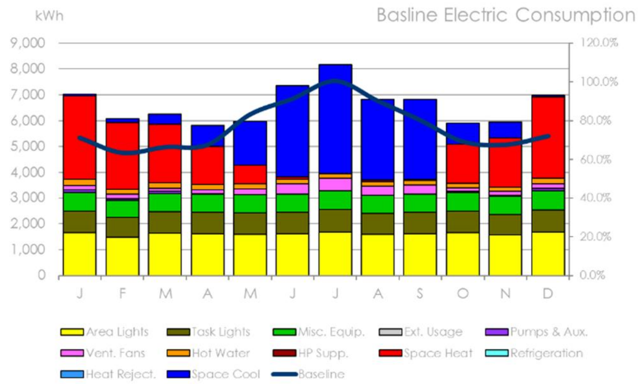


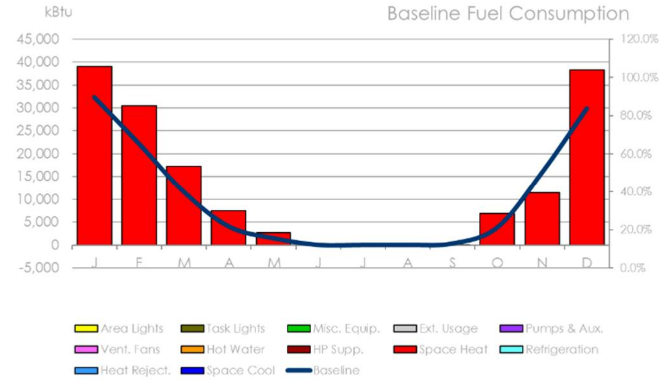
Community Building



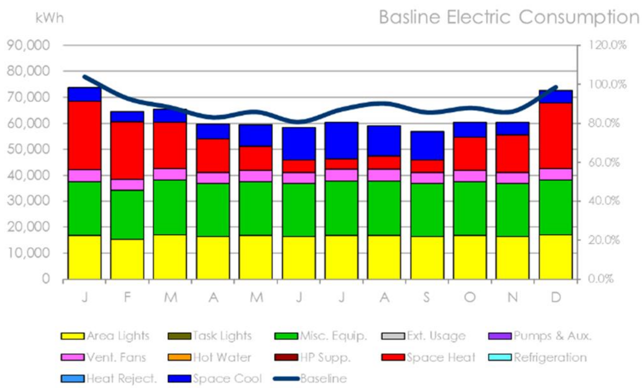


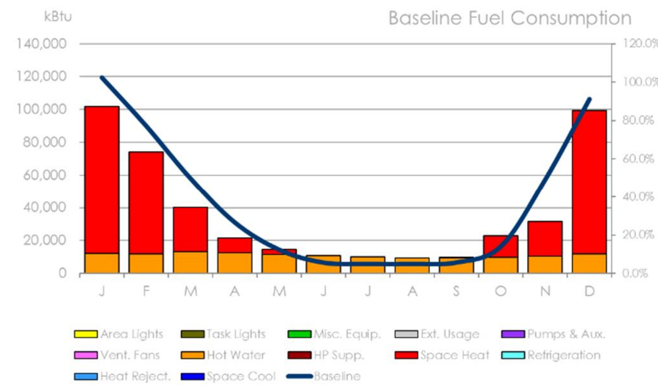
Prairie Park Nature Center





Fire/Med #5





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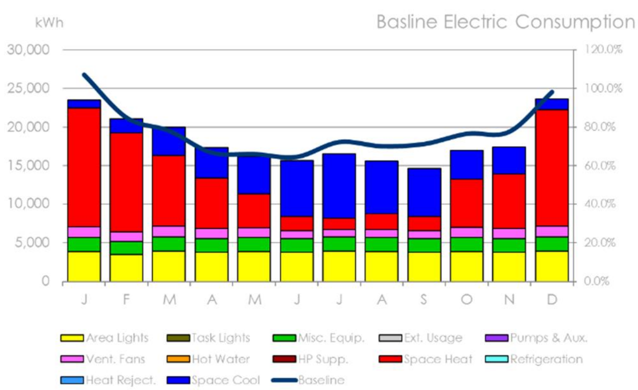

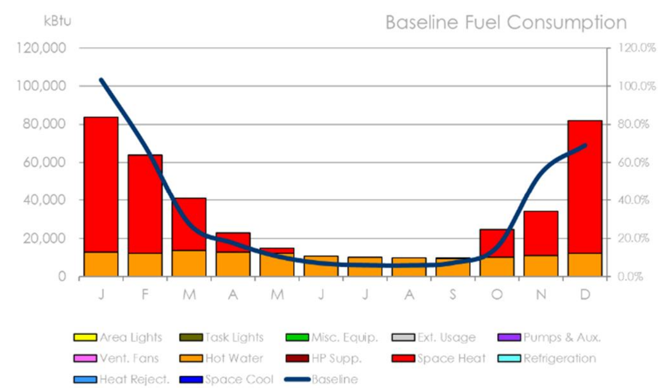

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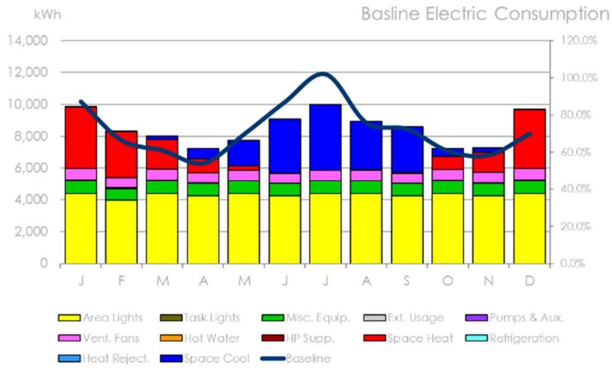

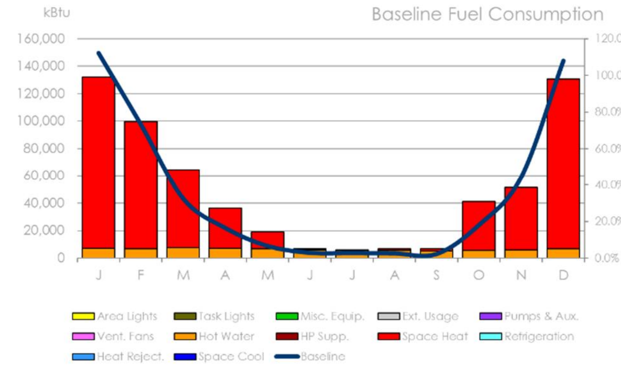

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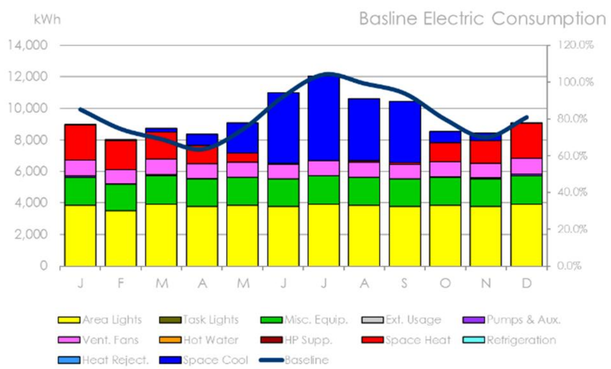

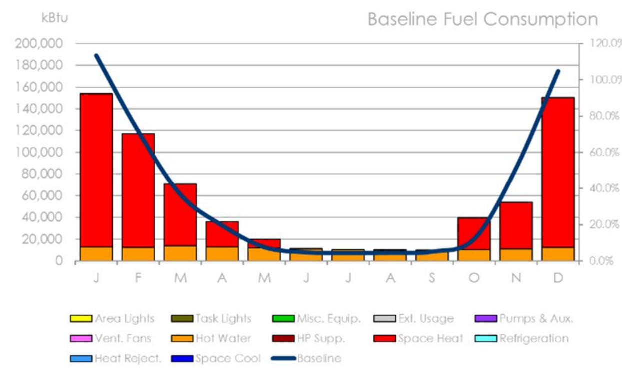

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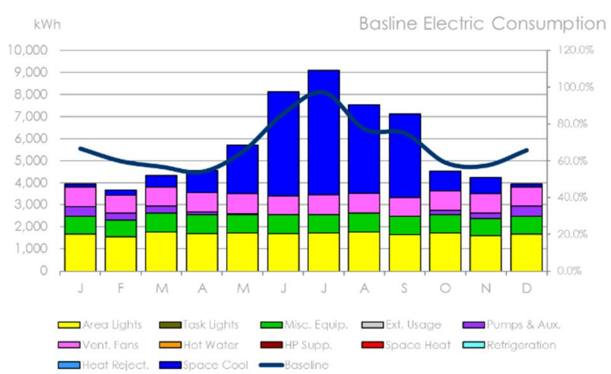

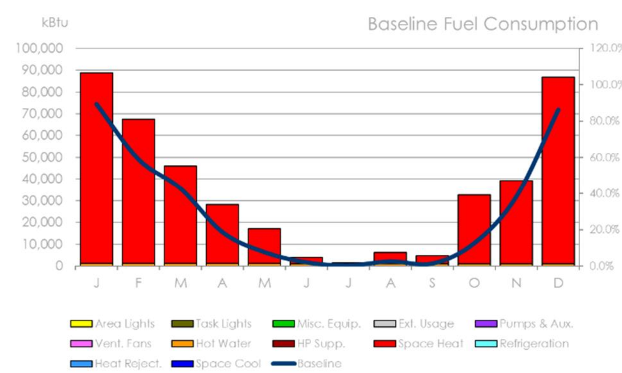

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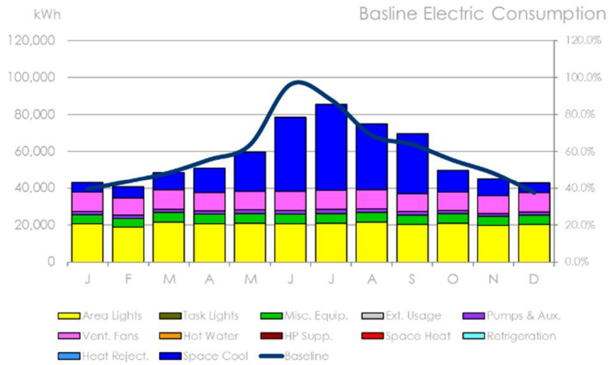
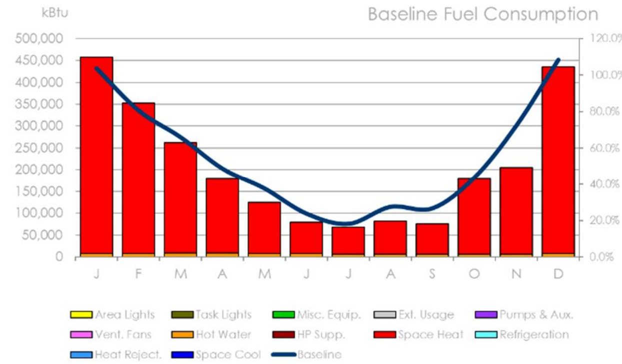
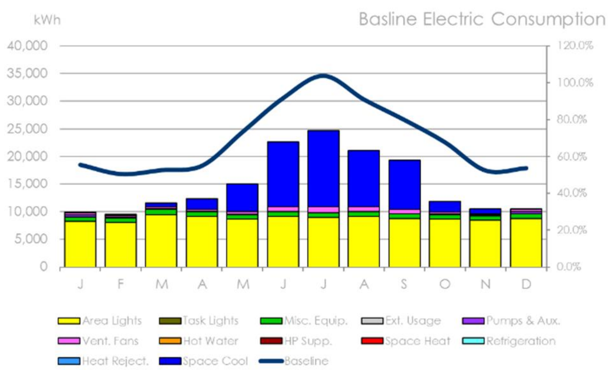
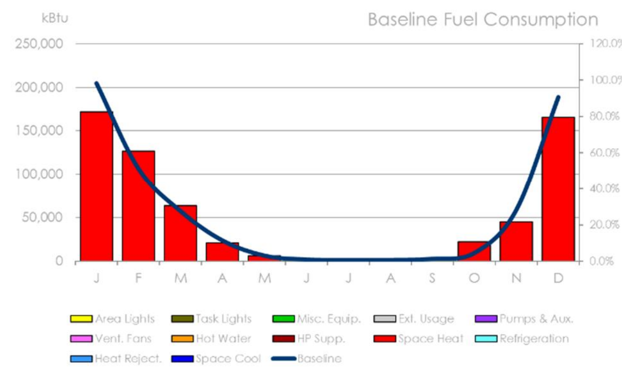


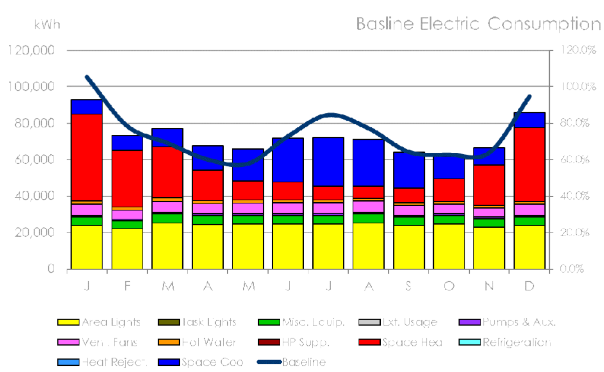


East Lawrence Recreational Center





Library*



**The library has no natural gas utility use*

Energy Conservation Measures

This section includes all of the Energy Conservation Measures analyzed for the City of Lawrence. Facility baseline consumption and cost are shown in the tables below. This section includes ECM savings methodology and estimated savings, as well as descriptions of the ECMs and the benefits they provide to the City of Lawrence.

ECM Summary Table 1, Savings by Project

Comprehensive List of Projects Identified											City Of Lawrence
Energy Efficiency Measures		Energy Savings						Other Savings			
ID #	Description	Electric Energy (kWh)	Electric Demand (kW)	Electric Cost ($)	Natural Gas (Therm)	Gas Cost ($)	Total Utility ($)	Maintenance Labor ($)	Maintenance Material ($)	Total Maintenance ($)	Total Savings ($)
1	City-Wide: Building LED Retrofits, Replacements & Controls	1,905,686	4,572	$181,126	-20,109	-$15,268	$165,858	$8,762	$27,131	$35,893	$201,751
2	City-Wide: Building Weatherization	38,677	0	$3,868	13,529	$9,200	$13,068	$0	$0	$0	$13,068
3	Parks and Rec: Parks Area Lighting	157,716	435	$16,967	0	$0	$16,967	$435	$1,954	$2,389	$19,356
4	Parks and Rec: Sports Field Lighting	44,214	510	$6,981	0	$0	$6,981	$5,230	$1,029	$6,259	$13,240
5	Parks and Rec: Advanced Timers for Tennis/Basketball Courts	6,912	0	$636	0	$0	$636	$0	$0	$0	$636
6	Public Works: Web Based Thermostats	39,114	-3	$3,163	5,546	$4,719	$7,882	$472	$492	$964	$8,846
7	Public Works: City-Wide Pole Lighting	282,322	769	$30,315	0	$0	$30,315	$553	$3,394	$3,947	$34,262
8	Public Works: DDC Upgrades and Optimization	542,986	981	$53,657	20,734	$14,591	$68,248	$901	$1,906	$2,808	$71,056
9	Airport Terminal: Split System HVAC Replacements	7,027	33	$825	170	$145	$970	$448	$616	$1,065	$2,035
10	City Hall: Replace Cabinet Heaters	51,759	39	$2,953	-4	-$4	$2,949	$43	$70	$113	$3,062
11	City Hall : Replace Windows	44,628	175	$5,556	0	$0	$5,556	$1,601	$1,921	$3,521	$9,077
12	Community Building: Replace Aging Packaged Units	22,008	126	$2,783	315	$268	$3,051	$1,565	$2,069	$3,633	$6,684
13	Community Building: Replace Roof	317	2	$39	90	$77	$116	$0	$0	$0	$116
14	Community Health: Install Electronic Air Cleaner Filtration	23,045	93	$3,121	2,898	$2,028	$5,149	$775	$29	$804	$5,953
15	Community Health: Replace Air Cooled Chiller	104,629	642	$18,883	2	$1	$18,884	$5,890	$12,607	$18,497	$37,381
16	Community Health: Replace Boillers	0	0	$0	0	$0	$0	$1,852	$3,430	$5,282	$5,282
17	Community Health: Replace Roof	762	4	$123	263	$184	$307	$0	$0	$0	$307
18	East Lawrence Rec Center: Replace Outdated Packaged Units	16,653	84	$1,974	164	$164	$2,138	$1,044	$934	$1,979	$4,117
19	Fire Station #2: Replace Outdated Rooftop Units	6,947	25	$758	-12	-$10	$748	$327	$369	$696	$1,444
20	Fire Station #3: Replace Aging Rooftop Units	6,771	24	$753	-18	-$15	$738	$587	$494	$1,081	$1,819
21	Fire Station #3: Replace Roof	879	4	$103	204	$173	$276	$312	$120	$432	$708
22	Fire Station #5: Solar Power Installation	141,928	61	$12,583	0	$0	$12,583	$0	$0	$0	$12,583
23	Holcom Rec Center: New Packaged HVAC System	51,484	211	$5,791	-602	-$512	$5,279	$544	$892	$1,436	$6,715
24	Holcom Rec Center: Sports Field Lighting and New Poles	11,410	45	$970	0	$0	$970	$0	$0	$0	$970
25	Indoor Aquatic Center: Energy & Air Quality Improvements	354,670	693	$29,033	60,053	$42,037	$71,070	$7,677	$15,128	$22,805	$93,875
26	Lawrence Arts Center: Replace Air Cooled Chiller	73,460	247	$8,230	0	$0	$8,230	$3,329	$7,126	$10,455	$18,685
27	New Hampshire Parking Garage: HVAC Replacements	16,719	41	$1,639	-1,843	-$1,567	$72	$177	$285	$462	$534
28	Outdoor Aquatic Center: Boiler Replacement	0	0	$0	0	$0	$0	$328	$853	$1,181	$1,181
29	Outdoor Aquatic Center: HVAC System Renovations	2,833	5	$285	0	$0	$285	$90	$137	$228	$513
30	Praire Park: Split System HVAC Renovation	0	0	$0	0	$0	$0	$598	$821	$1,419	$1,419
31	Solid Waste Office: Replace Packaged Unit	8,439	33	$959	17	$17	$976	$164	$193	$357	$1,333
32	Vehicle Maintenance Office: Add Ductless Mini Split	0	0	$0	0	$0	$0	$0	$0	$0	$0

ECM Summary Table 2, Savings by Building

Building	ECM Description	ECM ID	Post-Project Savings: Electric Usage (kWh)	Electric Demand (kW)	Electric Cost Savings ($)	Gas Usage (Therm)	Gas Cost Savings ($)	Total Savings ($)
27th St. Maintenance Building	Building LED Retrofits, Replacements & Controls	1	5,443	16	$589	-85	-$60	$529
Airport Community Hanger	Building LED Retrofits, Replacements & Controls	1	25,474	49	$2,478	0	$0	$2,478
Airport Hangar A	Building LED Retrofits, Replacements & Controls	1	5,491	16	$570	0	$0	$570
Airport Hangar B	Building LED Retrofits, Replacements & Controls	1	16,709	164	$2,473	0	$0	$2,473
Airport Hangar C	Building LED Retrofits, Replacements & Controls	1	16,628	163	$2,460	0	$0	$2,460
Airport Maintenance Facility	Building LED Retrofits, Replacements & Controls	1	23,839	64	$2,754	-374	-$317	$2,436
	Building Weatherization	2	1,474	0	$147	578.5	$393	$541
	Web Based Thermostats	6	752	21	$73	445	$301	$374
Airport Terminal	Building LED Retrofits, Replacements & Controls	1	15,842	36	$1,785	-248	-$211	$1,574
	Building Weatherization	2	616	0	$62	207.1	$141	$202
	Web Based Thermostats	6	7,742	6	$692	1,432	$1,217	$1,909
	HVAC System Replacements	9	7,027	33	$825	170	$145	$970
Art Center	Building LED Retrofits, Replacements & Controls	1	60,142	205	$6,603	-942	-$660	$5,943
	Building Weatherization	2	1,232	0	$123	414.1	$282	$405
	Public Works: DDC Upgrades & Optimization	8	76,517	226	$7,928	14,450	$10,115	$18,043
	Replace Air Cooled Chiller	26	73,460	247	$8,230	0	$0	$8,230
Carnegie Building	Building LED Retrofits, Replacements & Controls	1	11,221	31	$1,208	-172	-$120	$1,087
	Building Weatherization	2	319	0	$32	102.8	$70	$102
City Hall	Building LED Retrofits, Replacements & Controls	1	29,052	80	$2,933	-455	-$455	$2,478
	Building Weatherization	2	616	0	$62	207.1	$141	$202
	Public Works: DDC Upgrades & Optimization	8	20,141	183	$4,897	0	$0	$4,897
	Replace Cabinet Unit Heaters	10	51,759	39	$2,953	-4	-$4	$2,949
	Replace Windows	11	44,628	175	$5,556	0	$0	$5,556
Community Building	Building LED Retrofits, Replacements & Controls	1	57,118	148	$6,053	-890	-$756	$5,296
	Building Weatherization	2	1,040	0	$104	374.5	$255	$359
	Replace Aging Rooftop Units	12	22,008	126	$2,783	315	$268	$3,051
	Replace Roof	13	317	2	$39	90	$77	$116
Community Health Building	Building LED Retrofits, Replacements & Controls	1	172,262	622	$20,481	-2,335	-$1,635	$18,847
	Building Weatherization	2	6,526	0	$653	2194.3	$1,492	$2,145
	Public Works: DDC Upgrades & Optimization	8	97,457	475	$14,573	5767	$4,037	$18,610
	Install Electronic Air Cleaner Filtration	14	23,045	93	$3,121	2898	$2,028	$5,149
	Replace Air-Cooled Chiller	15	104,629	642	$18,883	2	$1	$18,884
	Replace Boilers	16	0	0	$0	0	$0	$0
	Replace Roof	17	762	4	$123	263	$184	$307
Eagle Bend Golf	Building LED Retrofits, Replacements & Controls	1	4,367	9	$427	-51	-$36	$392
	Building Weatherization	2	359	0	$36	120.8	$82	$118
East Lawrence Rec Center	Building LED Retrofits, Replacements & Controls	1	32,701	98	$3,757	-498	-$498	$3,259
	Building Weatherization	2	1,215	0	$121	408.4	$278	$399
	Replace RTU-2, 3, & 4	18	16,653	84	$1,974	164	$164	$2,138
Fire and Rescue Training	Building LED Retrofits, Replacements & Controls	1	14,696	40	$1,467	-230	-$196	$1,271
	Building Weatherization	2	1,208	0	$121	434.7	$296	$416
	Web Based Thermostats	6	4,986	-4	$390	1675	$1,424	$1,814
Fire/Med #2	Building LED Retrofits, Replacements & Controls	1	38,744	102	$3,948	-432	-$367	$3,581
	Building Weatherization	2	2,332	0	$233	839.9	$571	$804
	Web Based Thermostats	6	0	0	$0	0	$0	$0
	Replace Two Older Rooftop Units	19	6,947	25	$758	-12	-$10	$748
Fire/Med #3	Building LED Retrofits, Replacements & Controls	1	10,009	18	$964	-157	-$133	$831
	Building Weatherization	2	2,891	0	$289	1040.6	$708	$997
	Web Based Thermostats	6	0	0	$0	0	$0	$0
	Replace Rooftop Units	20	6,771	24	$753	-18	-$15	$738
	Replace Roof	21	879	4	$103	204	$173	$276
Fire/Med #4	Building LED Retrofits, Replacements & Controls	1	20,855	58	$2,144	-307	-$261	$1,883
	Building Weatherization	2	2,333	0	$233	839.9	$571	$804
	Public Works: DDC Upgrades & Optimization	8	61,244	-9	$5,172	517	$439	$5,611
Fire/Med #5	Building LED Retrofits, Replacements & Controls	1	67,645	209	$7,085	-971	-$825	$6,260
	Building Weatherization	2	3,099	0	$310	1115.5	$759	$1,068
	Public Works: DDC Upgrades & Optimization	8	120,207	-138	$9,617	0	$0	$9,617
	Solar Power Installation	22	141,928	61	$12,583	0	$0	$12,583

ECM Summary Table 2, Savings by Building, Continued

Building	ECM Description	ECM ID	Post-Project Savings: Electric Usage (kWh)	Electric Demand (kW)	Electric Cost Savings ($)	Gas Usage (Therm)	Gas Cost Savings ($)	Total Savings ($)
Holcom Rec Center	Building LED Retrofits, Replacements & Controls	1	33,004	106	$3,660	-486	-$414	$3,247
	Building Weatherization	2	1,194	0	$119	429.7	$292	$412
	New Packaged HVAC System	23	51,484	211	$5,791	-602	-$512	$5,279
	Sports Field Lighting	24	11,410	45	$970	0	$0	$970
Indoor Aquatic Center	Building LED Retrofits, Replacements & Controls	1	163,871	415	$16,051	-2,509	-$1,756	$14,295
	Building Weatherization	2	3,281	0	$328	1288.2	$876	$1,204
	Energy & Indoor Air Quality Improvements	25	354,670	693	$29,033	60,053	$42,037	$71,070
Library	Building LED Retrofits, Replacements & Controls	1	194,605	246	$13,575	0	$0	$13,575
	City-Wide Building Weatherization	2	984	0	$98	0	$0	$98
	Public Works: DDC Upgrades & Optimization	8	167,420	244	$11,470	0	$0	$11,470
New Hampshire Parking Garage	Building LED Retrofits, Replacements & Controls	1	214,030	306	$20,152	0	$0	$20,152
North Lawrence Pump Station	Building LED Retrofits, Replacements & Controls	1	8,959	18	$855	0	$0	$855
Outdoor Aquatic Center	Building LED Retrofits, Replacements & Controls	1	5,738	98	$924	0	$0	$924
	Replace Pool Boiler with Condensing Boiler	28	0	0	$0	0	$0	$0
	HVAC System Renovation	29	2,833	5	$285	0	$0	$285
Parking/AnimalControl/Transit	Building LED Retrofits, Replacements & Controls	1	8,521	25	$886	-134	-$113	$773
	Building Weatherization	2	1,351	0	$135	454.1	$309	$444
	Web Based Thermostats	6	5,775	-3	$468	738	$627	$1,095
	Replace Wall Pack HVAC With Gas Unit Heaters	27	16,719	41	$1,639	-1843	-$1,567	$72
Parks & Rec Maintenance	Building LED Retrofits, Replacements & Controls	1	7,305	21	$791	-123	-$86	$705
Prairie Park Nature Center	Building LED Retrofits, Replacements & Controls	1	14,478	32	$1,437	-169	-$169	$1,268
	Building Weatherization	2	736	0	$74	247.3	$168	$242
	Split System Replacements	30	0	0	$0	0	$0	$0
Riverfront Parking Garage	Building LED Retrofits, Replacements & Controls	1	42,085	69	$4,021	0	$0	$4,021
Solid Waste Division	Building LED Retrofits, Replacements & Controls	1	4,673	16	$497	-73	-$73	$424
	Building Weatherization	2	376	0	$38	126.5	$86	$124
	Web Based Thermostats	6	6,751	0	$580	250	$250	$830
	Replace Package Unit	31	8,439	33	$959	17	$17	$976
South Park Administration Office	Building LED Retrofits, Replacements & Controls	1	8,897	23	$902	-136	-$136	$766
	Building Weatherization	2	411	0	$41	138	$94	$135
Sports Pavilion	Building LED Retrofits, Replacements & Controls	1	469,209	771	$36,539	-7,351	-$5,146	$31,394
	Building Weatherization	2	4,370	0	$437	1715.6	$1,167	$1,604
Street Division - Office	Building LED Retrofits, Replacements & Controls	1	6,708	23	$791	-75	-$75	$716
	Building Weatherization	2	191	0	$19	61.7	$42	$61
	Web Based Thermostats	6	2,934	-2	$232	300	$300	$532
Street Division - Red Barn	Building LED Retrofits, Replacements & Controls	1	8,198	28	$875	0	$0	$875
Street Division - Salt Dome - Haskell	Building LED Retrofits, Replacements & Controls	1	2,894	7	$291	0	$0	$291
Street Division - Salt Dome - Wakarusa	Building LED Retrofits, Replacements & Controls	1	11,575	28	$1,165	0	$0	$1,165
Union Pacific Depot	Building LED Retrofits, Replacements & Controls	1	19,115	48	$1,934	-115	-$98	$1,837
	Building Weatherization	2	528	0	$53	189.9	$129	$182
Vehicle Maintenance	Building LED Retrofits, Replacements & Controls	1	53,583	164	$5,603	-792	-$673	$4,930
	Web Based Thermostats	6	10,174	-21	$728	706	$600	$1,328
	Add Ductless Mini Split to Server Room	32	0	0	$0	0	$0	$0
Lawrence Parks and Recreation	Parks Area Lighting	3	157,716	435.2	$16,967	0	$0	$16,967
	Sports Field Lighting	4	44,214	510.24	$6,981	0	$0	$6,981
	Sports Lighting Timers	5	6,912	0	$636	0	$0	$636
Lawrence Public Works	Public Works: Pole Lighting	7	282,322	769.32	$30,315	0	$0	$30,315

Savings Methodologies

eQUEST

The widely-accepted building energy simulation software called eQUEST (QUick Energy Simulation Tool) was used to build energy models of buildings that will receive multiple and interactive energy conservation measures. The eQUEST software uses the DOE2 (US Department of Energy) simulation engine. Each building model was calibrated to actual utility consumption as defined by monthly utility bills, normalized to typical local weather conditions provided by TMY3 data. Once the building energy model was calibrated, eQuest was used to perform parametric simulations of various system modifications to produce real-time changes in energy consumption. Changes to the model represent implementation of the proposed ECMs. When ECMs are selected for implementation, they are run simultaneously to account for the interactive energy effects of the ECM combinations. Key eQUEST input and output data are included in Appendix C – eQUEST Reports.

Lighting Tool

An excel spreadsheet was used to model the results of lighting retrofits. This analysis tool compares the energy consumption of existing fixtures in each space to the energy consumption of the fixtures 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. This estimate is based on each space's function (restroom, classroom, gymnasium, etc.) and facility operating hours. The installation of lighting controls to reduce run hours is included in the analysis. In addition, LED lighting has a positive impact on the cooling system by reducing the heat gain to the space. This effect is included in the analysis. The resulting negative impact on the heating system is also included in the analysis. Calculation equations and tabulated space data are included in Appendix D – Baseline and Proposed Lighting Tables.

Air Infiltration Calculation

A detailed on-site audit established each facility's needs. A detailed analysis of each building's specific construction, age, square footage, and utility usage was documented. A scope of work was developed to detail the control of air leakage by sealing gaps, cracks, and holes using appropriate materials such as fire retardant, polyurethane foam, caulks, and appropriate weather stripping materials. The building's insulation value, geographical wind data, and effective linear measurements of doors/windows are used to calculate infiltration at the building. The infiltration rate is used to determine available savings from a comprehensive weatherization project. Calculation equations are included in Appendix A – Savings Calculations and Equations.

ECM Descriptions

This section includes descriptions of each ECM analyzed in the project, including the resulting benefits to the City of Lawrence. Existing building descriptions are available in the Facility Assessments section.

Existing Stand-Alone, Non-Programmable Thermostat

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. The simple programmable units must be manually programmed or controlled, which often leads to inefficient set points or no control at all.

Web-Based 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:

- 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
- Vehicle Maintenance Garage Offices

Thermostat Trend Data

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.

Example Web-Based Thermostat Interface

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, analyzing system reports, conducting remote diagnostics and assessing performance, all from the web.

Interior LED Tubes to Retrofit Fluorescent Office Fixtures

Building LED Retrofits, Lighting Replacements, and Controls

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 60% 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 Lighting in Office Setting

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 existing T5HO fixtures (Community Recreation Building, Holcom Gymnasium, East Lawrence Recreation Center Gymnasium, and Sports Pavilion Lawrence) will be retrofitted with T5 LED equivalents.

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.

LED Light Fixture for Pole Lighting Near Buildings

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, 360 Energy Engineers would install automatic controls.

Automatic Occupancy Sensor

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.

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.

Aged and Distressed Pole To Be Replaced

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 LED Retrofits, Replacements, and Controls – Buildings in Scope

Facility	Address	Sq. Ft.
Community Health Building	200 Maine St.	88,000
Indoor Aquatic Center	4706 Overland Dr.	44,000
Library	707 Vermont St.	85,000
Eagle Bend Clubhouse	1250 East 902 Road	3,000
Airport Terminal	1920 Airport Rd.	7,500
Airport Maintenance Facility	1920 Airport Rd.	10,500
Fire/Med #5	1911 Stewart Ave.	26,000
Fire/Med #4	2121 Wakarusa Dr.	11,000
Fire/Med #3	3708 W. 6th St.	7,000
Fire and Rescue Training	1941 Haskell Ave. #5	6,500
Fire/Med #2	2128 Harper St.	11,000
Parking/Animal Control/Transit	935 New Hampshire St.	2,300
Lawrence Arts Center	940 New Hampshire St.	55,000
City Hall	6 E. 6th St.	28,000
Carnegie Building	9th & Vermont	12,000
Union Pacific Depot	North Lawrence	5,000
East Lawrence Rec Center	1245 East 15th Street	18,000
Prairie Park Nature Center	2730 Harper St.	5,500
South Park Admin Office	1141 Massachusetts St.	4,800
Community Building	115 West 11th Street	30,000
Holcom Park Rec Center	2700 West 27th Street	19,500
Sports Pavilion	100 Rock Chalk Lane	181,000
Solid Waste Division	1140 Haskell	2,600
Street Division Office and Red Barn	1120 Haskell	10,200
27th St. Maintenance Building	W. 27th	5,000
Airport Hangar A, B, and C	1920 Airport Rd.	36,000
New Hampshire Parking Garage	935 New Hampshire	128,000
Riverfront Parking Garage	Riverfront Plaza	136,000
Outdoor Aquatic Center	727 Kentucky St.	6,300

Weatherization Sealing of Air Gap Between Wall and Roof Deck

Vehicle Maintenance Garage	1141 Haskell	14,500
North Lawrence Pump Station and 2nd St. Underpass	734 N. 2nd St	600
Salt Domes and Wakarusa Fuel Station	Various	3,000
Parks & Rec Maintenance	1050 E. 11th Street	6,900

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.

Visible Gap Under Exterior Doors at Holcom Rec Center

Gap Between Doors Due to Worn Weather Stripping at Prairie Park Nature Center

Visible Gap Under Exterior Doors at The Sports Pavilion

Weatherization Sealing of Air Gap Between Wall and Roof Deck

Building Weatherization – Buildings in Scope

Facility	Address	Sq. Ft.
Community Health Building	200 Maine St.	88,000
Indoor Aquatic Center	4706 Overland Dr.	44,000
Eagle Bend Clubhouse	1250 East 902 Road	3,000
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Sports Pavilion	100 Rock Chalk Lane	181,000

LED Illumination of a Parking Lot

City-Wide Area Lighting

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-style area lights. The main goal of these lights is to illuminate walkways on sidewalks, paths, and some intersections across the city. Replacing the existing high wattage HID (High Intensity Discharge) Lamps with LED equivalents will increase the visibility for the public and provide increased efficiency. New LED technology consumes approximately one third of the current energy usage with significantly longer operational use. New LED fixtures will be carefully selected by 360 Energy Engineers to identify the best quality hardware for each application.

Interior spaces are often retrofitted as an economical method of installing LED lighting. The structural components of a light fixture inside of a building last for many decades. Exterior area lights are exposed to wind, rain, hail, sunlight, and vandals. The lenses and globes installed on exterior lights are often yellowed, cracked, and broken. To ensure the best exterior lighting strategy, 360 Energy Engineers replaces the light fixture at each location instead of just the lamp.

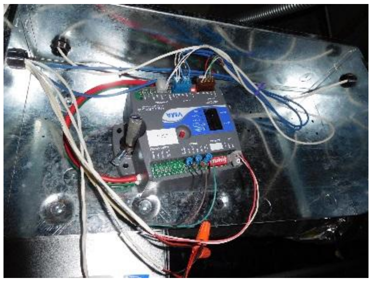
LED Cobra Head Style Luminaires

LED Replacements for Existing Shoebox Style Luminaires

LED Luminaire for Wall-Mount Illumination

City Hall Improvements

Optimize Control Strategies



New DDC Controller on VAV Box

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.

Lighting occupancy sensor used for intermediate setback control

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.

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

Zone-Setback Trend Chart

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.

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.

Replace Vestibule Cabinet Unit Heaters

The current electric heaters located at each exterior door 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 heaters will be installed with thermostats to enable heat to maintain a set temperature in the entry way.

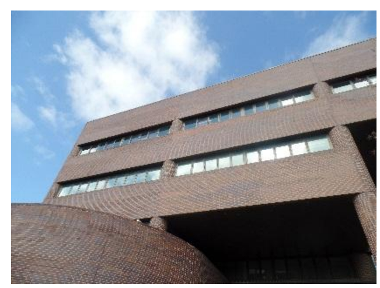
VAV Box With Electrical Reheat

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.

Electric Cabinet Heater at Main Entry

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 Improvements

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

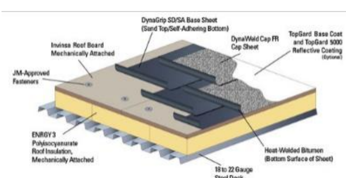
This scope will replace all of the four older rooftop units with new high efficiency rooftop units capable of improved temperature and humidity control while using less energy.

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.

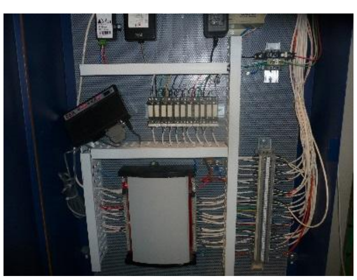
Savings will be achieved by improving the thermal resistance of the roofing system, which is the largest surface area through which heat is gained and lost contributing to energy consumption of the HVAC equipment.



Modified Bitumen Roof

Stations #3, #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 adding new building automation and controls 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. Fire Station #3 will receive new digital controls as well to control the packaged equipment and small VAV system in the sleeping quarters.

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 were installed in 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 that 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.

Station #5: Solar Power Installation

Fire Station #5 at 1911 Stewart Ave.

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 Improvements

Install Electronic Air Cleaner Filtration

Typical standard pleated air filters

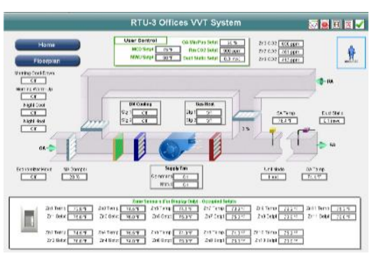
High efficiency electronic air cleaner

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.

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



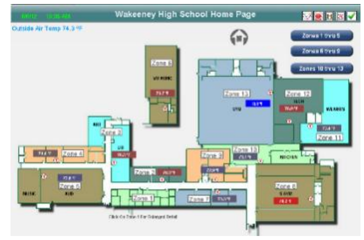
Advanced Control System Interface

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.

New Control Valve

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:

- 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

Failing Twenty Year-Old Condensing Boilers in Community Health Building

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.

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

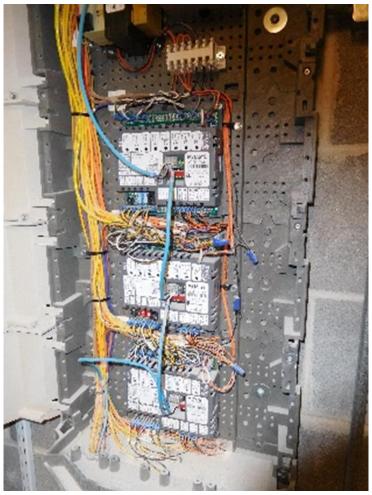
Replace Roof

Substantial De-Mineralization on Community Health Building 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.

Replace Chiller

The existing air cooled chiller is nearing the end of its recommended service life of 20 years. The existing chiller 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.



Aging Metasys Controllers

Antiquated Graphics on Windows 98 Operating System

CO_2 zone Sensor for Demand Controlled Ventilation

New DDC Controls with Optimized Control Strategies

Upgrading Existing Direct Digital Control System

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.

Zone Level Design Strategies

Optimize HVAC Operating Schedules (Space Temperature Setback and Setup)

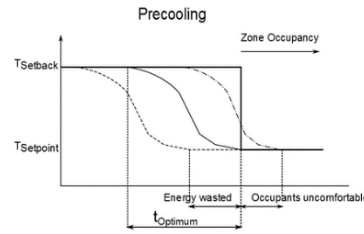
This control feature will involve implementing optimized night setup and setback temperatures using energy management controls for most of the building spaces in the Arts Center. The existing schedules and setpoints are relatively conservative with room for improvement, resulting and significant potential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

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

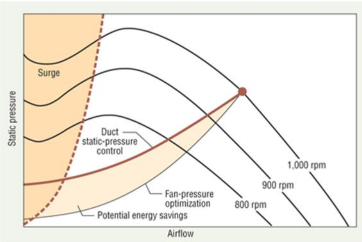
VAV systems cool only the air volume required to meet demand, rather than meeting demand by constantly heating and cooling large volumes of air. Typical VAV systems are configured to provide 55°F discharge air in response to varying cooling loads. This constant low air temperature ensures moisture is 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



Static Pressure Curve

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.

Variable Air Volume Terminals Controls Optimization

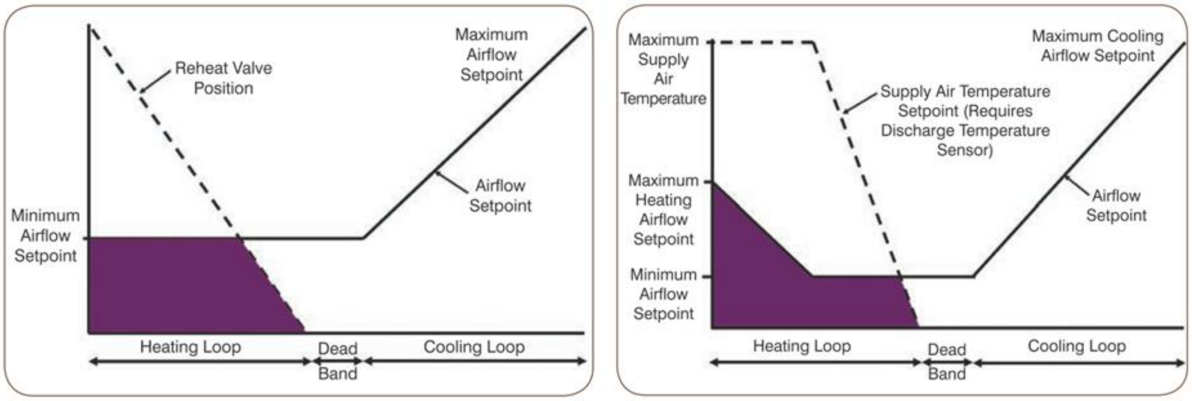
The non-auditorium spaces are conditioned by VAV boxes with hot water coils. These boxes control airflow proportional to cooling demands in the cooling mode and constant air volume in the heating mode. Although a common mode of control, this operation does not meet the requirements of ASHRAE 90.1 – Energy 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

Carrier 30RB with Greenspeed

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.

Library Improvements

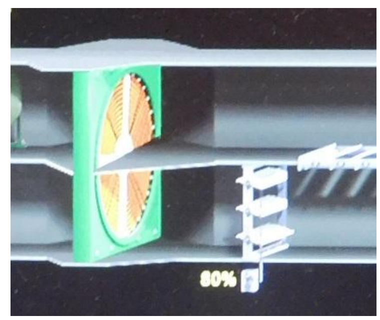
VAV Controls and Ventilation Optimization

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.

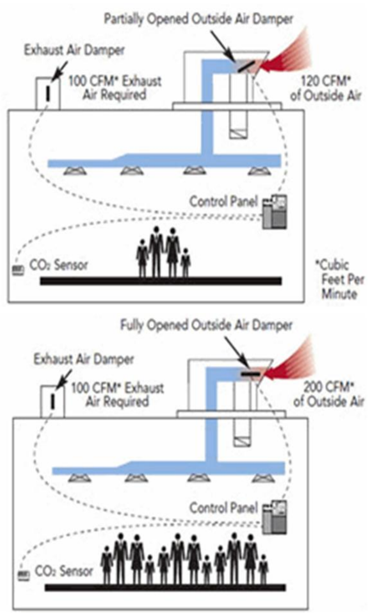

Fully open OA Damper

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

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.

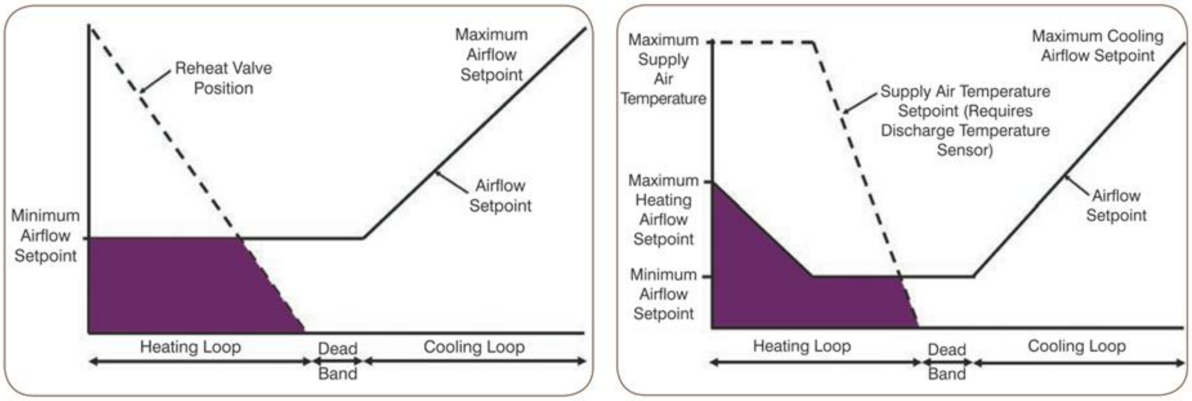
Dual-Maximum Control of VAV Boxes and Reheat

CO_2 Sensor

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.

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 Improvements

HVAC System Replacements

The existing split-system heating and cooling units at the Airport Terminal are nearing the end of their useful service life. The ASHRAE life expectancy for split-system heating and cooling units is 15-18 years. 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 95%. 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.

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

Parking Garage Office Wall Pack HVAC Unit

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.

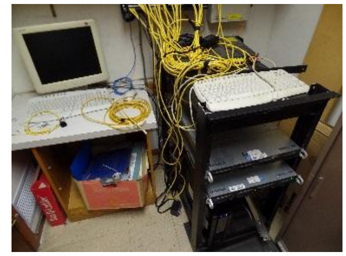
Solid Waste Office: Replace Package Unit

Existing Packaged Unit (2001) at Solid Waste Office

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.



Server Closet at Vehicle Maintenance Garage Office

Ductless Mini-Split For Server Closet at Vehicle Maintenance Garage

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.

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.

Shoebox Style Light on a Tall Pole

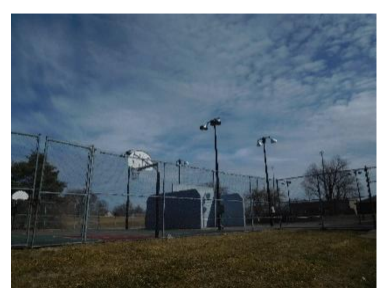
Advanced Timers for Tennis/Basketball Courts

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 will be installed at the courts of the following parks throughout the city:

- Broken Arrow Park – Horseshoe Court
- Centennial Park – Skate Ramps
- Chief Jim McSwain Park – Basketball Court
- Deerfield Park – Basketball Court and Skate Ramps
- Edgewood Park - SLKBP Hardcourt
- Hobbs Park – Basketball Court
- Holcom Park – Basketball Court
- Holcom Park – Tennis Court
- Lyons Park – Tennis and Basketball Courts



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.

1000W Metal Halide Lamp at Outdoor Tennis Court

Parks Sports Lighting

Large, 1000W HID lamps illuminate outdoor city tennis courts, basketball courts, the Centennial Park skate park, and the Horseshoe court at Broken Arrow Park. Baseball and softball fields utilize even larger 1500W HIS lamps. In most areas the lamps are still functional, but the power requirement is very high. Several fields such as the Clinton Lake Softball Complex and other various locations have begun to fail at an accelerated rate. 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. The Youth Sports Complex is not included in this project due to the age of the existing fixtures.

Map Display of Area Lights, Including Parks Sports Lighting

360 Energy Engineers identified HID Sports Lights during the audit phase of the project. A database of lighting poles, lighting technology, and GPS locations defines the city-owned area lights in each city park. The database will be used to locate each Sports Light during the conversion to LED.

Indoor Aquatic Center

Reduce After Hours Turnover & Tune Flows with VFDs


Pool Pumps

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.


Variable Speed Drives for 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

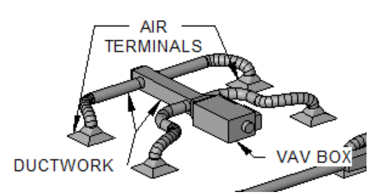
Balance Pool Pump Flows with VSDs and Eliminate Throttling Losses


Lap Pool

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.

VAV Terminal Optimization



VAV Terminal Diagram

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.

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.

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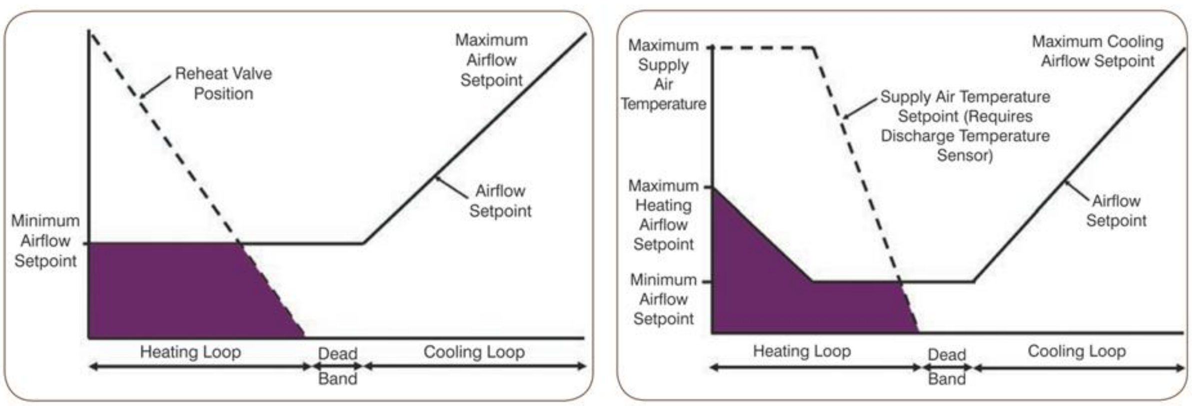

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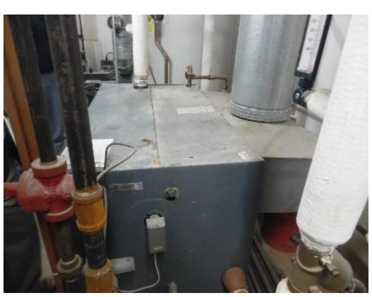
Replace Heating Water Boilers with Condensing



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 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

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.

Pool Setpoint Adjustment

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:

- 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

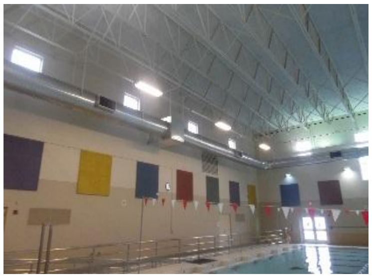
Existing Packaged Dehumidification Unit

Improved Air Distribution Design and Low Source Capture Exhaust

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.

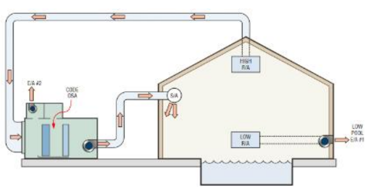
Dirty Condenser Coils

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.



Existing Supply Ductwork in Lap Pool and High Return

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.



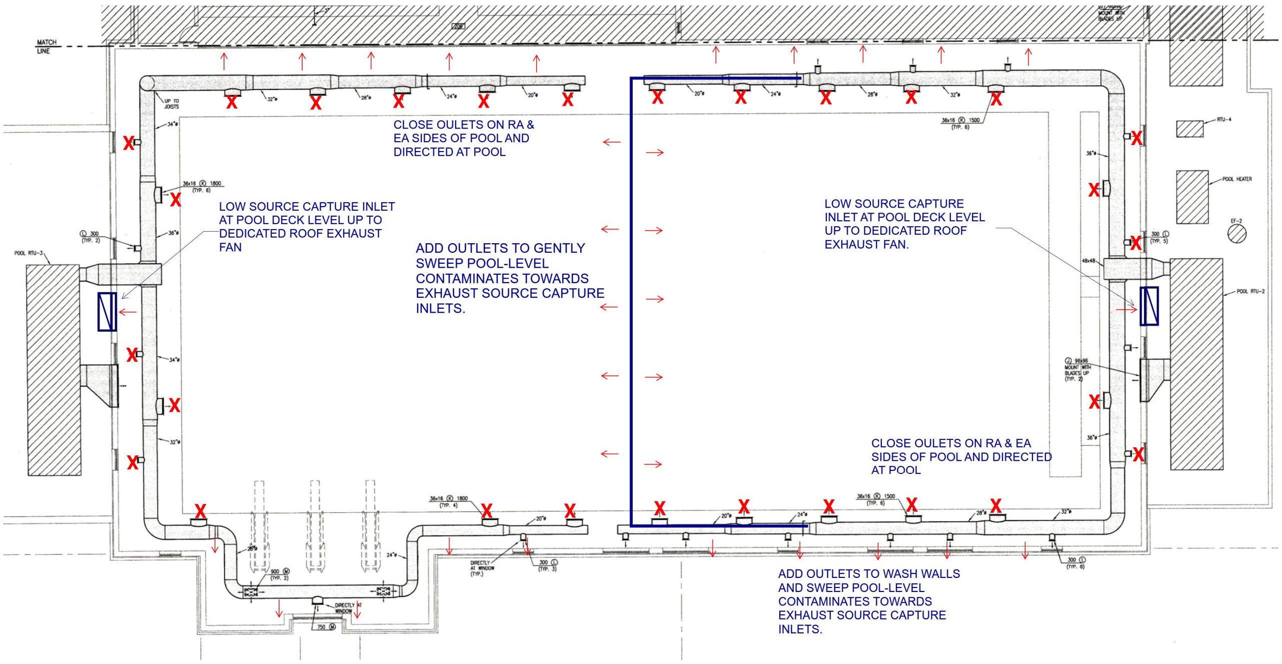
Low Source Capture Diagram

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.

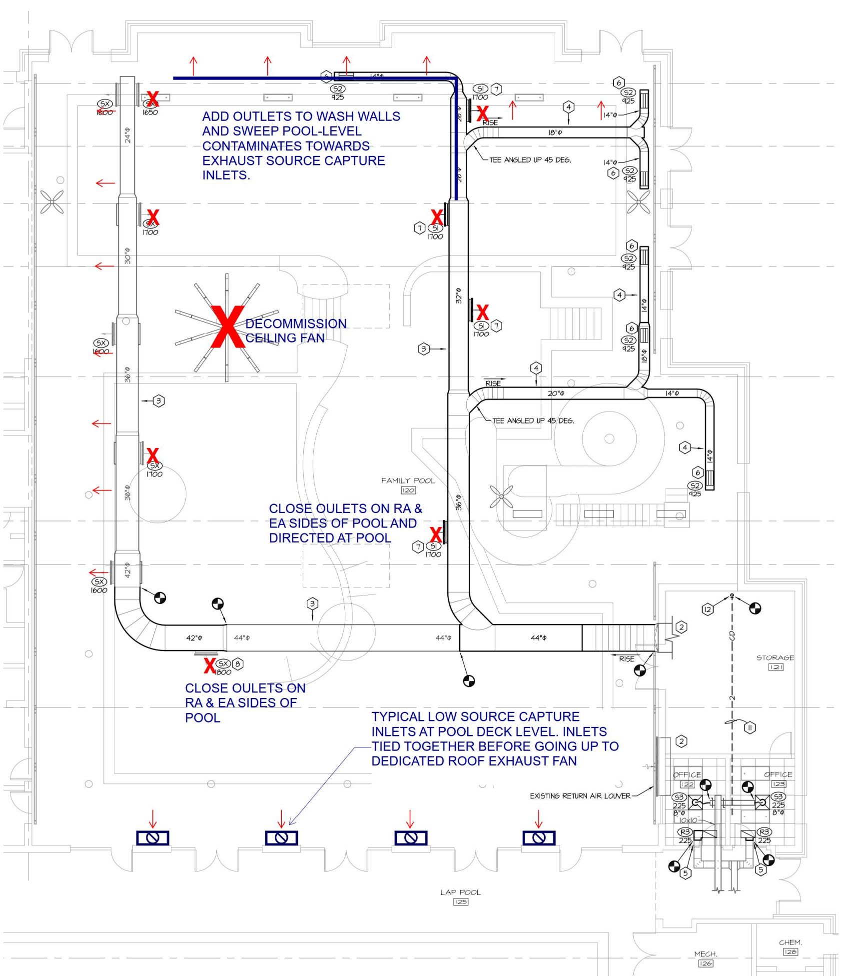
Existing Supply Ductwork in Leisure Pool

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

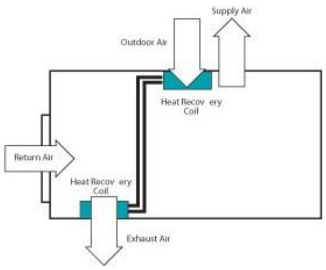
Conceptual Layout of Proposed Lap Pool Air and Exhaust Modifications



Conceptual Layout of Proposed Leisure Pool Air and Exhaust Modifications



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

Panelboard with Corrosion

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.

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.

Existing Pool Boilers

Replace Pool Water Heaters with High Efficiency 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.

New boilers with operating efficiencies in excess of 84% 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 high efficiency boiler will provide significant savings in fuel energy for pool water heating.

Holcom Recreation Center Improvements

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.

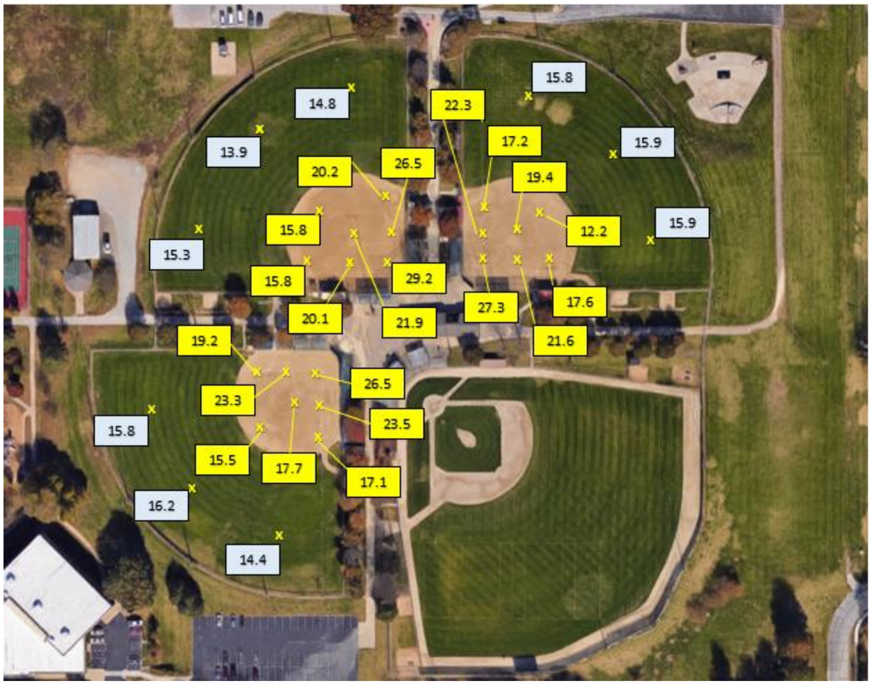
New Packaged Unit

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).

Southwest Field Illuminated by Existing Lighting

Ball Field Illuminated by LED Lights

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. LEDs will provide a cleaner, whiter light, improving the visibility of both players and fans watching the game. Additionally, LEDs turn on almost instantly, reducing the warm-up time seen in Metal Halide lamps.

Community Building Improvements

Existing Packaged Unit (1993)

Replace Aging Rooftop Units

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 of 15 years and are in need of replacement. Of the twelve units currently installed, one was replaced in 2015 and another in 2016. The remaining ten 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, including increased longevity, flexibility to prevent brittleness in cold weather, high tensile strength, and reflective mineral coatings.

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 Improvements

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.

Outdoor Aquatics Center Improvements

Stand-Alone HVAC for Concession Stand

Ductless Mint-split

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.

Split Air Handler Replacement

Outdoor Condensing Unit

The current cooling only air handler and condensing unit servicing the pool office has reached the end of its rated service life. This equipment is to be replaced with a modern unit with increased cooling efficiency. This system will also be removed from the concession stand with the addition of a standalone ductless split system decoupling these two spaces from one another and increasing the comfort for the occupants.

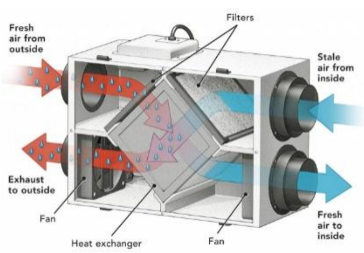
Replace Pool Boiler

Pool Water Heater

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 and will be replaced with a similar boiler.

Existing Furnaces (1997)

Air Filtration System



Energy Recovery Ventilator

Prairie Park Nature Center

Split System Replacements

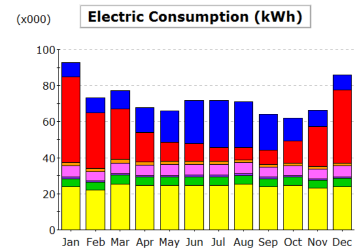
The Nature Center is currently heated and cooled by residential-style split systems with four furnaces in the mechanical room and four DX condensing units to the west of the facility. Indoor air quality has been an ongoing issue for the facility. The facilities staff did install inline canister filters 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.

To accomplish both improved indoor air quality and provide more efficient heating and cooling, new split system furnaces and condensing units will be installed with an energy recovery ventilator (ERV) to increase the outdoor air rate for the facility. An ERV mixes the exhaust and return air streams to moderate the temperature of outdoor air entering the furnace. This puts less stress on the furnace to heat the pretreated outdoor air to the desired supply temperature. This system should assist in mitigating the indoor air quality issue and improve the overall environment inside the facility.

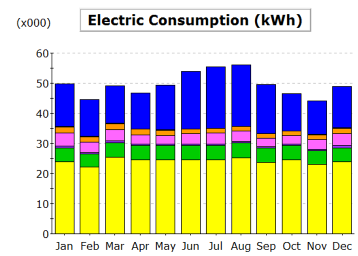
Improvements Evaluated But Not Recommended

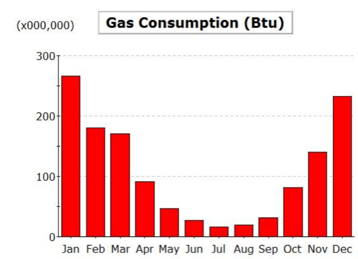
The projects described in this section were analyzed by 360 Energy Engineers. While each project has its merits, these projects are not recommended for action at this time.

Add Gas Boiler and Hot Water VAV Boxes at The Library



Current Month Electric End Use (red is heat)





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

Central Hot Water Plant

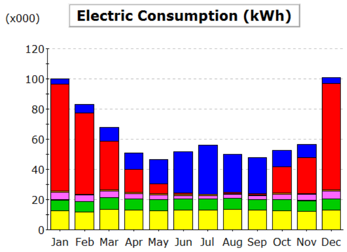
Electric resistance heat is very costly when compared to heat produced by natural gas fired equipment. While not immediately obvious from an efficiency standpoint, it is apparent when analyzed from a cost standpoint. Electricity's cost per unit of energy is 4.7 times that of natural gas' cost per unit 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.

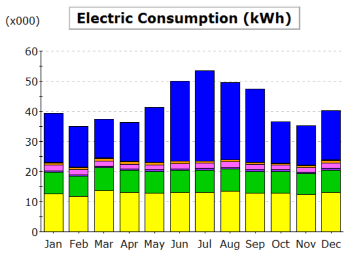
Although net energy savings is significant and future electrical costs are almost certain to continue to escalate at a rate that far out paces natural gas costs, this is a relatively capital intensive recommendation. However, when viewed over the system or building's life cycle, the city would benefit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

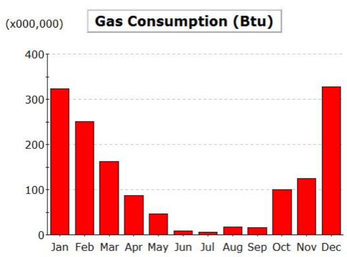
Leveraging annual utility and operational savings from other lower cost projects at the Library helps improve the financial payback of this Facility Improvement Opportunity.

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)

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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

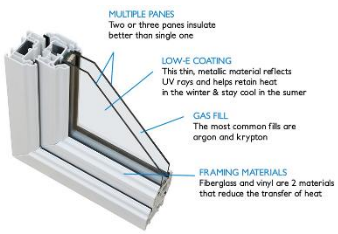
Fuel Cost Evaluation	Case Study 1	Case Study 2	Lawrence Full Fleet	Lawrence Test Fleet
CNG Fleet Size	20	30	50	5
Fueling Stations	1	2	2	1
CNG Price (DGE)	$1.78	$1.78	$1.90	$1.90
Diesel Price (Gal)	$3.90	$3.90	$2.17	$2.17
Vehicle Incremental Cost	$760,000.00	$1,100,000.00	$1,900,000.00	$190,000.00
Fueling 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 at Fire Station #3

Older window at FS#3



Example of high efficiency window

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.

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%.

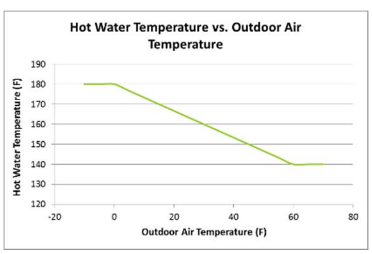
High Efficiency, Low Temperature Heating Plant Using Condensing Boilers

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.

Example High Efficiency Hot Water Plant

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 Reset Control Logic

Hot Water Temperature Reset Controls

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

Timer Control for Solid Waste Truck Block Heaters

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 the next morning.

Solid Waste Truck Parked in Front of Block Heater Receptacle

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 the electrical spend dramatically.

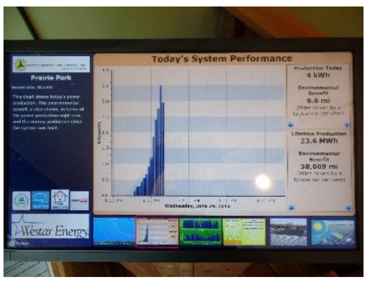
Additionally, the engine block heaters are only required when the air temperature is lower than 40 degrees. An inexpensive temperature controller can be installed to allow the heaters to run only when the air temperature requires them to do so. Surprisingly warm mornings would further reduce the electrical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

Block Heater Receptacles on Bollards

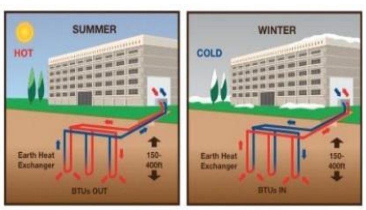
Prairie Park Nature Center Improvements

New Ground-Source HVAC System

Existing Furnaces (1997)



Solar Educational Display



Ground-Source Diagram

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.

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.

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.

Utility Rate 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: $ 0.069699 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) over 1,200 kWh.
- 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.

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: $ 0.085 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): $ 5.38 per kilowatt (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), 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 approximately 4% 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 higher than typical for the region. 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 (October through May): $ 0.0390 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): $ 0.0470 per kilowatt-hour (kWh).
- Demand charge: $ 22.22 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: $\frac{\$0.119}{kWh} \times \frac{1\text{ kWh}}{3412\,Btu} \times \frac{100{,}000\text{ Btu}}{therm} = \$\mathbf{3.49/therm}$

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: $\frac{\$0.70\backslash\text{therm}}{95\%\ efficiency} = \$\mathbf{0.74/therm}$

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

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.

THIS SECTION IS INTENTIONALLY BLANK. COMPREHENSIVE ENERGY AND MAINTENANCE SAVINGS TBD BASED ON FINAL SCOPE DEVELOPMENT, BID RESULTS, AND FINANCING TERMS.

Technical Approach

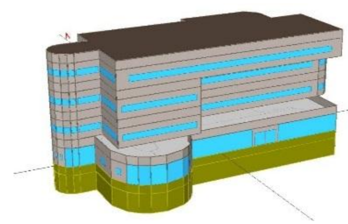
Our Philosophy

Innovative designs and customized solutions create an opportunity for the 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 the 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.

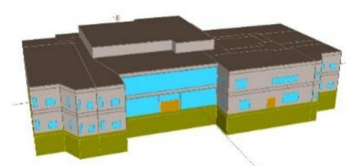
For the City of Lawrence, each aspect of the project is identified, analyzed and engineered by 360 Energy Engineers' professional engineers to produce full designs, including drawings and specifications, for each project. This allows 360 Energy Engineers to receive competitive bids from contractors without 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



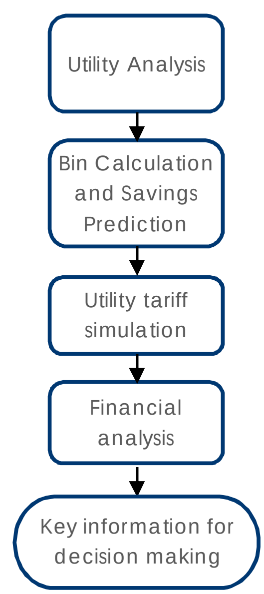
Art Center eQuest model

Energy Savings Analysis Methodology

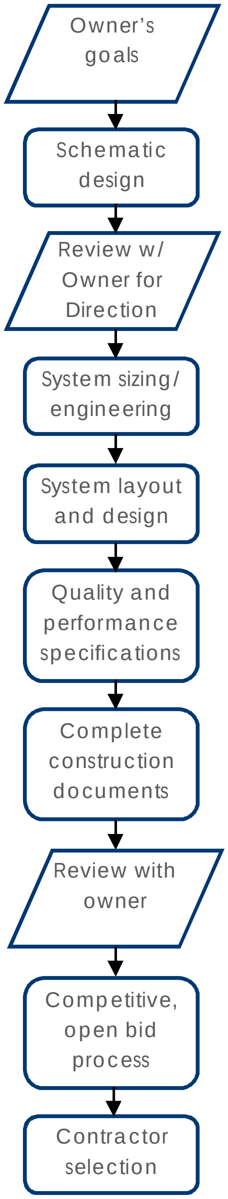
In order to evaluate how the City of Lawrence facilities use energy, formulate specific opportunities for energy conservation and accurately calculate energy savings, 360 Energy Engineers' engineers perform a detailed analysis process that encompasses:

- 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



Engineering and Design Process



Design and Engineering Methodology

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

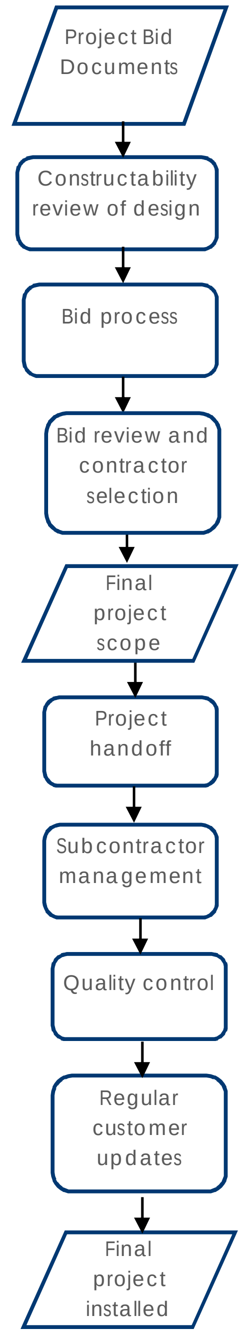
Project implementation through 360 Energy Engineers eliminates many of the hassles associated with the typical construction process. Our construction team's top priority is to ensure that the installed project meets our client's needs and the engineer's design. 360 Energy Engineers' construction manager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

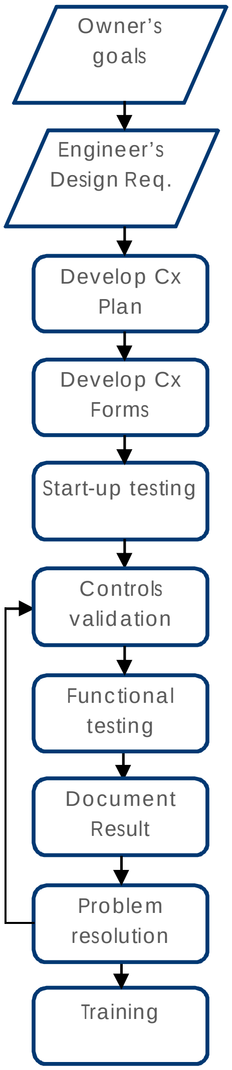
360 Energy Engineers	Traditional PC	Advantage to 360 approach
Ensure quality implementation	Verify project progress	Verifies quality defined in engineer's design and maximizes performance
Inspect all work by contractors	Contractor designed most work	Contractor meets design requirements rather than being 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.