Retro Commissioning Study of Crafton Athletic Center

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Submitted by:

Energy Resources Group, Inc.

innovation in energy and environmental design

Acknowledgements

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1 EXECUTIVE SUMMARY

This RCx Study focuses on the Coach Crafton Athletic Center on the Principia College campus, 1 Maybeck Place, Elsah, IL 62028. Retro Commissioning (RCx), or "existing building commissioning," is a systematic process for identifying and implementing operational and maintenance improvements in a building to ensure continued good performance over time. The intent of the process is to optimize the performance of building subsystems individually as well as how they function together in an integrated fashion. RCx focuses on operations and maintenance improvements and diagnostic testing and payback in less than 1 year. In the process, longer payback, capital improvement opportunities (EEMs) were identified and recommended.[1] Through detailed case studies across hundreds of RCx projects in the USA, the EPA has found RCx energy savings ranged from a minimum of 8% to over 50%, with the median being 15%.

An impetus for this RCx effort has been the Ameren Illinois Large Facility Retro Commissioning Incentive. The Ameren program divides efficiency measures into two classes: those that have expected paybacks of less than 1 year are generally part of RCx efforts; and, those having longer paybacks are candidates for their Custom Incentive program.

As a qualified participant in this effort, Principia College will submit this report to Ameren with its selected measures, receive and accept Ameren's incentives offer; implement the selected RCx Measures; and, participate in the Verification phase.

Energy Resources Group (ERG), found a number of significant opportunities to reduce energy consumption in the Coach Crafton Athletic Center with minimal investment. The suggested RCx measures are listed in Table 1.1. The suggested Energy Efficiency Measures are listed in Table 1.2.

RCxM #	Description	Potential Energy Savings				Estimated Project Cost	Potential Incentive	Return on Investment (ROI)	ROI with Incentives
		kW	kWh	Therms	$				
5.1	Schedule for AHUs 1-4		58,000	1,400	$ 4,300	$ 5,000	$ 1,600	86%	126%
5.2	Full VFDs for AHUs 1-4		160,700		$ 10,100	$ 8,500	$ 3,200	119%	191%
5.3	Correct Boiler Staging			1,000	$ 600	$ 500	$ 300	120%	300%
5.4	Schedule for Loop Pumps		42,500		$ 2,700	$ 2,500	$ 850	108%	164%
5.5	Upgrade PoolPak Controls			3,700	$ 1,750	$ 1,500	$ 3,700	117%	No Cost
5.6	Schedule for AHU5		16,700	1,500	$ 1,800	$ 750	$ 750	240%	No Cost
5.7	AHU5 DAT & CFM Opt.		17,500	2,900	$ 2,800	$ 3,500	$ 1,200	80%	122%
	Totals	0	295,400	10,500	$ 24,050	$ 22,250	$ 11,600	108%	226%

Table 1.1: Retro-Commissioning Measures

The RCx savings are largely predicated on two clear issues:

1. While the Andover system already has the capacity to control equipment "off" in the unoccupied mode, these features have, in general, not been activated.
2. Equipment is oversized for the actual loads and operating strategies appear to be based on nominal systems setpoints for supply air and chilled water temperatures and are not specifically load driven. Reworking operating strategies to respond to actual loads, with all available flows and temperature setpoints, will result in significant savings.

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[1] http://aceee.org/topics/commissioning-and-retrocommissioning

The savings in the above RCx table suggest that there can readily be savings on the order of 17% in electricity and 40% in natural gas and at this stage.

It should be noted that these opportunities are based on information that was developed from site visits, building plans, and utility data provided by College staff and from interviews with management, maintenance staff, service contractors familiar with the building, and trend logs downloaded from the Andover building automation system (BAS). The numbers in the report are based on engineering judgement and experience, at this stage of analysis, a range of 15-20% should be applied to the above numbers.

There is a lack of submetering data and the assumptions that needed to be made may result in some overlap in savings. It is recommended that the RCX measures be implemented and submetering be installed to help verify energy allocation strategies and better inform the possible savings involved.

EEM #	Description	Potential Energy Savings				Estimated Project Cost	Potential Incentive	Return on Investment (ROI)	ROI with Incentives
		kW	kWh	Therms	$				
4.1a	LED Lighting	19	34,900		$ 2,200	$ 4,600	$ 3,500	48%	200%
4.1b	LED Lighting (Natatorium)	24	76,800		$ 4,800	$ 13,440	$ 9,200	36%	113%
4.2	Condensing Boilers			3,000	$ 1,400	$ 69,700	$ 3,000	2%	2%
4.3	Cooling System Upgrade	14	34,300	1,790	$ 2,200	$ 52,200	$ 5,900	4%	5%
4.4	VFD AHU5 Fans		35,900	3,400	$ 3,900	$ 12,300	$ 5,900	32%	61%
4.5	VFD Pool Pumps		121,900		$ 7,700	$ 31,200	$ 14,600	25%	46%
4.6	VFD HCP & CHWP		99,800		$ 6,300	$ 22,000	$ 12,000	29%	63%
4.7	Solar PV		2,976,000		$ 187,000	$ 3,226,000	$ 4,491,000	No Cost	No Cost
	Totals	56	3,379,600	8,190	$ 215,500	$ 3,431,440	$ 4,545,100		

Table 1.2: Energy Efficiency Measures

Table 1.2 lists the Energy Efficiency Measures recommended for consideration. Note that they generally have longer paybacks and lower ROIs. There is a higher probability that there will be interactions among some of these measures, to the total line is included for general information purposes only. E.g., EEM 4.4 has two sets of calculations in it to show the nature of possible interactions that can occur. To the extent reasonable, ERG has tried to estimate the cascading impact of these measures. This is, of course, sensitive to the order in which the measures are implemented.

Energy efficiency is a diminishing function and the actual savings for any one item is solely a function of its sequence in line as measures are implemented. The more you save the less there is to save for the remaining items. The expected total savings from the RCxMs and EEMs will be different from the informational totals above once these cascading effects are realized in the field.

The calculations of present utility usage for Crafton produce an Energy Use Index (EUI) of 90 kBTU/SF. Using the most recent prices per unit of energy ($0.0627/kWh and $0.473/therm), the cost of this energy comes to $122,000 in electrical use and $9,600 in natural gas use each year. This equates to an energy cost of $1.37 per square foot. It should be noted that while Crafton is approximately 9% of the total campus square footage, it accounts for 15% of its energy costs.

1.1 FINANCIAL FUNDING

1.1.1 Energy Investment Policy

ERG has noticed, over its 45 years of service in the energy efficiency and renewable energy industries, that success in implementing studies has some degree of correlation to whether or not an institution has a guiding energy investment policy. ERG would suggest that one of the team's [The Principia's management, the Center for Sustainability, Principia facilities staff, and ERG] first steps would be to define the economic criteria and strategies for "project-go" funding that are reasonable and doable within the Principia's customary framework project development and implementation. With such principles in place, it is more likely that this and subsequent studies will move from paper to reality and provide a leading example of stewardship in action that also shows that there is no "sacrifice" in doing things "right". It all makes economic sense. Two examples of policies that ERG has helped formulate are attached. One is from the Missouri Botanical Garden (1995) and one is from the City of University City. Please note that staff at University City have used some of the "out" language to suppress the need to proactively implement the policy. ERG would recommend tightening up the language to minimize the opportunity to circumvent its intent. It should be more like the MBG Board Resolution, but it should address life cycle economic analyses and provide an allowance for the value of CO_2 reductions.

1.1.2 USDA Rural Energy for America Program (REAP)

The United States Department of Agriculture has the REAP program that overs some grants and loan guarantees for the investment in energy efficiency and renewable energy. The Principia College campus is in a qualifying Rural Business Services territory. Besides REAP there are multiple other programs that may be beneficial as investments in energy efficiency and renewable energy go forward on this campus. It would be an educational public service of sorts for the College to pursue such program opportunities to better publicize these benefits to the community at large.

1.1.3 Thirty Party Power Purchasing Agreement (PPA)

With all endeavors to invest in energy efficiency and renewable energy, there are potential tax benefits that not-for-profit entities leave on the table. ERG would encourage the Principia to develop a mechanism that it can use to leverage these opportunities to the extent possible.

1.1.4 Carbon Credit Markets

In addition, there are carbon credit markets that are now available that can generate $10-$25/ton of CO_2 mitigation. The above Retro-Commissioning measures (sans solar) will reduce emissions by 223 tons annually and could earn $2,200 to $5,600/year if these credits are sold. Attached is a document that discusses this expanding market opportunity. ERG is presently working with Carbon Credit Solutions, Inc.[2] to develop opportunities for our clients to participate in this growing and expanding market opportunity. Most clients, on their own, are not likely to have sufficient CO2 tonnage savings to cost effectively reach these markets. ERG is working to establish an aggregation of client CO2 savings so that it can assist our clients in reaching these markets. Attached is a brief discussion of the this market.

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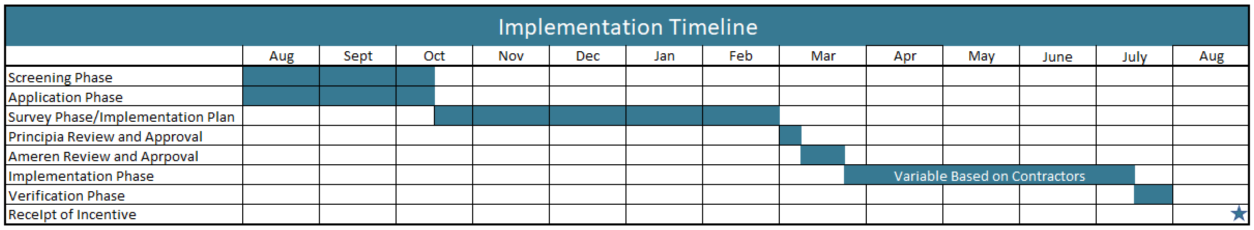
[2] https://carboncreditsolutions.ca/

1.2 NEXT STEPS

Figure 1.1 shows the timeline of this project. The time for the various tasks is shown. After Principia has an opportunity to review the RCx report it will be submitted to Ameren. Following Ameren's response to the report, there will then be an electronic submittal of the Implementation plan followed by an Implementation Plan Presentation Meeting with Principia's Ameren representative. Upon acceptance of the plan, the Survey Phase portion of the Large Facility RCx application will be completed signed and submitted to Ameren Il. Upon approval of the Survey Phase portion of the application the Implementation phase will then begin.



Implementation Timeline

	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Screening Phase	■	■	■										
Application Phase	■	■	■										
Survey Phase/Implementation Plan			■	■	■	■	■						
Principia Review and Approval								■					
Ameren Review and Arpproval								■					
Implementation Phase								■	■	■ Variable Based on Contractors	■	■	
Verification Phase												■	
Receipt of Incentive													★

Table 1.2.1 Projected Implementation Timeline

The implementation phase time frame will be largely dependent on the various contractors' availability to staff efforts. The methods of contractor implementation will be dictated by Facilities. Please note that there is an estimated one month of available unallocated time. This is not a lot of extra time, so this process needs to be carefully managed to assure that we can meet the Ameren deadlines and secure all available incentives.

The ERG team looks forward to working with Facilities and the Center for Sustainability to bring this project through implementation. With respect to future similar projects, it is recommended that extended trend logs be continued for all of the system variables that are needed to evaluate building operating parameters. Additional such trends are expected to be identified as efforts move forward.

2 BUILDING / SYSTEMS DESCRIPTION

2.1 ARCHITECTURAL

The Coach Crafton Athletic Center was built in 2007 and is located on the north end of the rural Principia College campus. The building is surrounded by woods and ravines. The building was constructed using two construction methods, a pre-engineered metal construction was used for roughly 2/3rds of the total footprint. This area contains an indoor track and gymnasium commonly called the fieldhouse. The other construction method is a tilt-up concrete building and contains the natatorium, weight rooms, locker rooms, e-sports computer room, offices, various storage rooms and mechanical rooms.

The athletic facility has three distinct zones. The fieldhouse on the north end of the building is 66% of total footprint, the natatorium, located on the south end of the building is about 19% of the footprint. Sandwiched between these two zones are the offices, weight rooms, locker/shower rooms, e-sports and mechanical rooms, accounting for about 14% of the building footprint. This central zone is split into two levels and has minimal exterior exposures. The north, south, west and second-floor east walls are all surrounded by a corridor that is open to the Indoor track area. The only exposures for this central section are the first-floor east wall, the roof, and the floor. The east exposure belongs to the mechanical room and pool equipment room. In total, the footprint of the building is 95,739 square feet.

Throughout the academic term this facility is used by many of the college's athletic teams for daily practices as well as hosting many collegiate events for track and swimming. Additionally, the building is open to the general public through the colleges "Blue and Gold" gym membership. The facility is also rented out to other local organizations for training camps and competitions. On any given day there can be as few as a handful of people using the facility to hundreds of people spectating and competing in athletic events.

2.2 MECHANICAL

Crafton Center is one of the only buildings on the Principia College campus that contains its own heating and cooling systems. The building is segmented into three distinct zones, the fieldhouse, the natatorium, and the central office area, which contains two weight rooms, showers/locker rooms, offices, mechanical 2.2.1 rooms, and offices. Each zone has a system that has been designed to meet the unique needs of that space.

Boilers

There are two Weil-McLain boilers, HWB-1 and HWB-2, used for space heating. Each of these boilers is served by a 109 GPM primary circulating pump with a 1.5 HP motor. These boilers each have a burner output of 2176 MBH with a peak efficiency of 80% and they modulate as needed. It is estimated that their Annual Fuel Utilization Efficiency (AFUE) is 70%. When active, these boilers supply hot water, through 20 HP secondary loop pumps to all 5 air handlers and both PoolPaks. The total boiler heating capacity is 4352 MBH, which serves a calculated building heating load of 2157 MBH. System heating capacity is 202% of the load, which is consistent with an n+1 redundancy approach.

HWB-3 has a boiler output of 396 MBH, also with a peak efficiency of 80% and an AFUE estimated at 70%. This smaller boiler is used only for reheat during the cooling season and serves the fifteen Air Terminal Units (VAV boxes) in the central zone on AHU-5. It uses a 16 GPM, 1 HP, constant speed pump motor.

A fourth boiler, manufactured by Laars, is for domestic hot water (DHW) and provides hot water to the shower-rooms, lavatories, and commercial washing machine. This boiler has an output of 254 MBH with an efficiency of 85% (estimated AFUE of 75%). This boiler is also coupled with a 335-gallon insulated storage tank. Two other boilers, specific to the natatorium, are discussed in the next section.

2.2.2 Natatorium

The natatorium is served by two PoolPaks which are original to the building. These units are pool specific air handling units designed to dehumidify the humid pool air. Heat that is removed from return air during the dehumidification process is either returned to the pool supply air, to the pool water, or dumped outside. Each PoolPak is tied to a 74.5-ton air-cooled condenser using R-22 refrigerant. When the recovered heat is not enough for heating the space and the pool, supplemental heat is provided to the PoolPaks by HWB-1 and HWB-2. The PoolPaks are also capable of running a variety of economizer modes, heating economizer, heating and dehumidification economizer, cooling economizer, and cooling and dehumidification economizer when the outside temperatures allow.

The pool and spa each have dedicated water heaters. The spa uses a Raypack boiler with an output of 327MBH and a peak efficiency of 82% (estimated AFUE of 72%). The Pool boiler is a Laars, with an output of 1260 MBH and a peak efficiency of 84% (estimated AFUE of 74%). These boilers are not connected to the BAS system. Since the pool area is maintained at constant space and humidity conditions that are significantly higher than normal temperatures, these boilers are likely running 24x7.

There are two exhaust fans in chemical storage rooms which should operate 24x7 but were observed in the BAS to occasionally be off.

2.2.3 Fieldhouse

The fieldhouse contains four air handlers, AHUs 1-4. Each unit is equipped with a single coil that is used for both heating and cooling. Each unit has a cooling coil capacity rated at 38.75 tons. This equates to a combined total cooling capacity of 155 tons.

The schedule lists each air handler as having a heating capacity of 388 MBH. ERG identified that this heating capacity was calculated with an incorrect ΔT. ERG estimates the actual heating capacity of each unit is 1164 MBH, for a total of 4656 MBH. Each supply air fan, equipped with a VFD, can move 15,800 CFM and is set to bring in a minimum 500 CFM of outside air (OA) for a combined air flow total of 63,200 CFM with a minimum OA of 2000 CFM.

Hot water for the coils in these air handlers is provided by boilers HWB-1 and HWB-2 through a primary/secondary two pipe pumping system.

Chilled water for the four air handlers is produced by a 155-ton chiller that is estimated to produce cooling at 1.2 kW/ton. The air-cooled compressor and condensing unit for this chiller is located on the east side of the building at grade level. The 2-pass dual-circuit evaporator for this chiller is in the second-floor mechanical room. A primary loop, 5 HP Bell and Gossett 310 GPM pump circulates water through the evaporator barrel, producing the chilled water.

Chilled/hot water in the secondary system is distributed via two Bell and Gossett 518 GPM constant speed pumps. Each pump is connected to a 20 HP motor which operates at 1750 RPM with a nominal efficiency rating of 91%.

There are two large constant speed ventilation fans that move 33,400 CFM each (EF 1&2). These exhaust fans are interlocked with motorized dampers on the fresh air louvers and barometric dampers on the exhaust louvers. When outside conditions are appropriate these units act as an economizer system for the fieldhouse.

The Cooling Setpoint for the fieldhouse is 75°F, and the Heating Setpoint is 65°F.

2.2.4 Central Offices, Weight Rooms, and Changing/Shower Rooms

The central zone of the facility is served by AHU-5. This is a 5220 CFM unit with 100% makeup air. ERG airflow testing verified this airflow rate. While there is a mixed air damper, BAS trending shows that this is always closed, making this, effectively, 100% makeup air. This unit can produce 23 tons of cooling and 188 MBH for heating. This unit is also equipped with an energy recovery wheel (ERV). There is an ERV bypass damper which allows exhaust air to bypass the ERV wheel when there is no need to recover the energy in the exhaust air stream.

According to the BAS system, the airflow at the VAV boxes is around 2800 - 2900 CFM. This is at variance with the AHU-5 specifications and the readings taken by ERG. This suggests that there are control calibration issues with the air flow sensors in these VAV boxes.

With the exception of storage and utility rooms, each room has a VAV box with a hydronic reheat coil and a supply air modulating damper. Although the dampers can modulate to meet load, they currently are programmed as constant volume. As mentioned earlier, during the cooling season HWB-3 supplies hot water to the VAV boxes. In the heating season HWB-1 and HWB-2 supply hot water to the VAV boxes and to AHU 5. This is accomplished by manually resetting change over valves. The combined heating capacity of the VAVs is 143 MBH, and AHU 5 can also supply 188 MBH, which means this system has a combined heating capacity of 331 MBH. This serves a calculated heating load for AHU-5 served spaces of 102 MBH – an excess capacity of 185%.

AHU 5 is supplied with chilled water via a 30-ton 2 pass air-cooled compressor that is paired to a remote chilled water evaporator that is estimated to produce cooling at 1.2 kW/ton. The evaporator is located in the 2nd floor mechanical room and the air-cooled compressor and condensing unit is located on the east side exterior at grade level. This unit uses R-22 Refrigerant which is being phased out of manufacture.

2.2.5 Exhaust Fans

There are seven exhaust fans in the drawing schedule. Two are used in the fieldhouse for the "economizer" cycle (see fieldhouse discussion). There are five exhaust fans in this central area. One fan is a 1500 CFM refrigerant evacuation fan for the second-floor mechanical room. At the time of inspection this unit was observed to be running. Two other fans are in chemical storage rooms for the pool area and are 100 CFM each and should run continuously. A third fan is located in the Pool Mechanical room (980 CFM). The last exhaust fan (910 CFM) is linked to the commercial dryer in the laundry room. At the time of inspection this fan was off, as was the dryer. None of these fans are under BAS control. The rest of the exhaust air from bathrooms, showers, janitors' closets (5200 CFM), etc. is exhausted through the return air on AHU-5. Exhaust fans that will run continuously account for 6580 CFM of exhaust and, consequently, 6580 CFM of outdoor air intake.

2.3 LIGHTING

The bulk of the lighting in the Crafton facility is fluorescent, using 231 compact fluorescent lamps (CFL) and 372 T8 fluorescent lamps. Other lighting includes, 32 metal halide (MH) lamps in the natatorium and 38 high-bay LED fixtures in the fieldhouse.

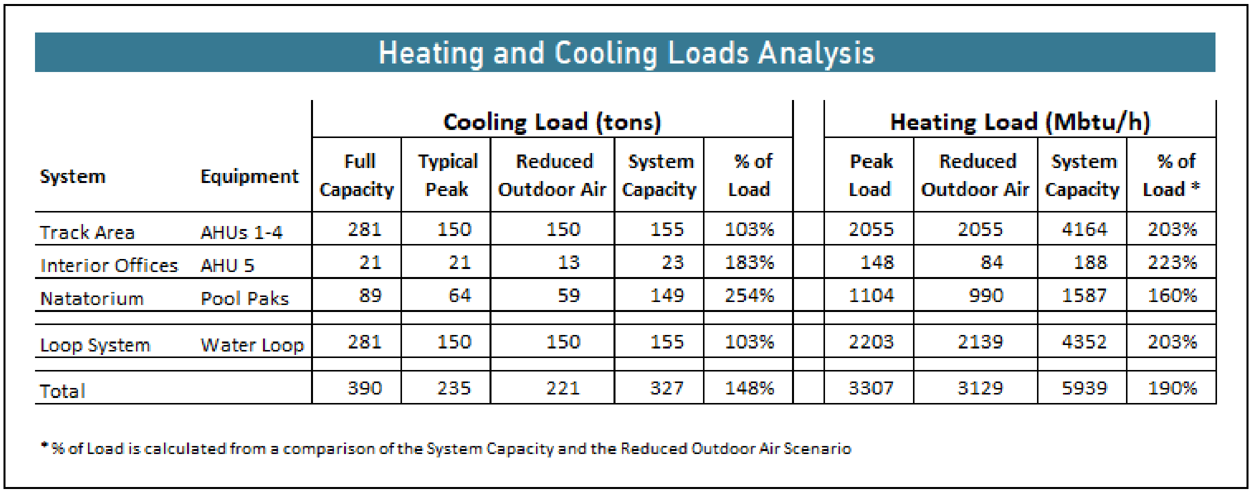
Each CFL lamp is 26 watts and the T8 fluorescent lamps are 32 watts each. The MH lamps are 1000 watts each.

The newer high-bay LED fixtures in the fieldhouse are 299 watts each and are also equipped with daylight harvesting sensors.

In the central zone, there are lighting occupancy sensors in the weight rooms, locker rooms, restrooms, and e-sports room. All offices are on a switch and lighting in the main corridors is on 24/7.

2.4 LOADS ANALYSIS

The Crafton Athletic Center has three distinct heating and cooling systems: the fieldhouse, the central offices, and the natatorium. The heating and cooling loads for each of these areas have been analyzed separately and are shown in Table 2.4.1 in various load configurations.



Heating and Cooling Loads Analysis

		Cooling Load (tons)						Heating Load (Mbtu/h)			
System	Equipment	Full Capacity	Typical Peak	Reduced Outdoor Air	System Capacity	% of Load		Peak Load	Reduced Outdoor Air	System Capacity	% of Load *
Track Area	AHUs 1-4	281	150	150	155	103%		2055	2055	4164	203%
Interior Offices	AHU 5	21	21	13	23	183%		148	84	188	223%
Natatorium	Pool Paks	89	64	59	149	254%		1104	990	1587	160%
Loop System	Water Loop	281	150	150	155	103%		2203	2139	4352	203%
Total		390	235	221	327	148%		3307	3129	5939	190%

* % of Load is calculated from a comparison of the System Capacity and the Reduced Outdoor Air Scenario

Table 2.4.1

Buildings loads were developed based on the indoor air temperature setpoints (fieldhouse is 65°F in the winter and 75°F in the summer; natatorium 82°F – 84°F depending on the swim season; and the AHU-5 areas average 72°F) and peak heating and cooling load Outside Air Temperatures (OAT) of 2°F in the winter and 95°F in the summer. Building heat loss/heat gain was developed by reviewing all exterior surface areas (the envelope) of the building and their R-Values (levels of insulation), the total areas of the construction types (windows, masonry walls, exposed concrete structure, roof decks), their associated R-Values, and the associated temperature differences at the given peak load condition. Summer heat gain calculations also include internal heat gain from lights, people, and equipment plug-loads. These room equipment loads were established through a detailed room-by-room building survey. Outdoor air loads also contribute to both the heating and cooling loads analyses and they are calculated based on current exhaust rates as well as the minimum amount of outdoor air that is required by ASHRAE Standard 62.1 (2016).

There were difficulties in calculating the occupancy-based loads. The reported peak occupancy numbers
2.4.1 are very rarely actually achieved in the space, and the building AC system was not designed to fully satisfy
the cooling loads at peak occupancy rates that have been known to occur. Therefore, for each building
system, ERG calculated "Full Capacity" and "Typical Peak" occupancy, and a reduced OA scenario at
"Typical Peak" occupancy.

Fieldhouse: AHUs 1-4

These AHUs use the chilled water/hot water piped though the secondary loop to heat and cool the space using the coil in each AHU. The design calculations in the equipment schedules for the dual-temperature-coils output capacity in heating mode was done incorrectly (discussed in Section 2.2.3) and was recalculated at 1164 MBH per unit, which far exceeds the necessary space heating capacity. This is to be expected, given the dual-temperature loop and the different ΔT across the coils in the heating and cooling states.

The system of AHUs 1-4 is well-sized for the typical peak cooling load, but unable to fully cool the space when the building is at “Full Capacity”. Since full capacity is rarely reached, the college considers this an acceptable operational state.

This system cannot currently justify a reduction in exhaust based on ASHRAE 62.1, thus the table above shows the reduced outdoor air scenario is the same as the Typical Peak scenario. ERG recommends a closer review of the defined “play areas” in order to more accurately define the required exhaust rates for this space.

Central Offices: AHU 5

AHU 5 is well sized for peak loads when effectively using the enthalpy wheel with which it is equipped. This system is currently exhausting more air than necessary. If this is reduced to required standards, the
2.4.2 AHU-5 cooling loads will drop accordingly. When this system reaches life-cycle, and trends document the actual loads under reduced exhaust, ERG recommends downsizing this equipment to better match loads.

The natatorium is kept between 82° and 84° year-round. Therefore, there is a constant 10°-12° temperature differential between these two spaces. The three mechanical rooms also tend to be warmer than the central zone by 5°-10°. As a result, AHU 5 is in cooling mode most of the year.

According to the BAS system, the cumulative airflow out of the VAV boxes is only about 2800 CFM. This is significantly below the design airflow of 5220 CFM. ERG performed a series of tests and inspections to verify the air flow of this unit. The visual inspection in early December revealed filters that were impacted and starting to cave in. According to the date on the filters they were last changed 9/26/2019. Additionally, the air intake was covered with leaves and the ERV wheel appeared to be quite dirty.

Upon testing, the pressure drop across the ERV wheel was 0.75 inches/WG. According to the manufacturers documentation, this pressure differential is a little low based on the amount of airflow flowing through the system which could indicate that the seal is due for adjustment or replacement. The airflow was also measured at AHU-5’s air intake, exhaust, and supply air duct. These measurements show that the actual airflow was around 5000 CFM. Therefore, there is a discrepancy between actual airflow and what the BAS system is reporting exiting the VAVs. TAB reports are not available to verify the initial condition of this system. As it stands now, the system may currently be out of balance. More
2.4.3 likely, the VAV box air flow sensors may not be properly calibrated. This issue will be resolved during the RCx process.

Natatorium

The natatorium has heating input throughout the year to maintain pool water and deck air temperatures. The pool and spa are heated by two boilers that total 1587 MBH capacity (shown in the table). The pool boiler alone is capable of meeting peak heating load of the natatorium water and air at 1260 MBH. In addition, the PoolPaks are also capable of drawing heat from the dual-temp loop in the heating season. The heating capacity for the natatorium far exceeds what is needed to handle the loads.

The cooling loads calculated in the table above are environmental and internal gains, but do not include the dehumidification cycle handled by the PoolPak air handlers. The pool heaters and the dehumidification trends within the PoolPak were not accessible through the BAS, so these load calculations do not take that evaporation/dehumidification cycle into account. However, the PoolPak cooling capacity and heating capacity greatly exceed the expected environmental and internal gains loads.

ERG recommends adding the pool water heating systems to the BAS in order to more fully understand the true loads on these systems. The PoolPaks are nearing life-cycle, so these added data points may help assure that Principia can successfully install smaller equipment that will meet the actual loads. Correctly sizing the equipment will save capital by reducing the initial costs of the units. Correctly sized units also typically have higher cooling/heating efficiency and improved dehumidification compared to oversized units, which will reduce operating and maintenance costs.

2.4.4 Dual-temp Loop

The heating for the fieldhouse and Central Offices comes from the dual-temp loop. If the PoolPaks managing the heating for the natatorium need additional heat, they can also draw supplemental heat from this loop during the heating season. The loop is heated by two boilers totaling 4352 MBH. This exceeds the capacity needed for the entire building, even without the heat from the natatorium's pool heaters, and exceeds the needed capacity for the fieldhouse and Central Offices. As each boiler is capable of handling the building load independently, they are considered sized in an n+1 approach to system redundancy. A more modular approach with more boilers of lower capacity would allow for downsizing when they reach life cycle.

During the cooling season, this loop is manually switched over to chilled water. This change over should be automated and controlled through the BAS. During these periods, the dual-temp loop serves only the fieldhouse. The chiller that serves the loop is properly sized for the typical peak load in the fieldhouse. A smaller 30-ton chiller serves AHU-5 cooling loads.

2.5 OCCUPANCY

The Crafton Center is open to all people associated with the college and to local community members who have purchased a Blue and Gold Gym membership. According to the College's website, the hours for the fieldhouse and weight rooms are from 6:00 am until 10:00 pm seven days a week. The natatorium hours vary by season. Currently, open swim hours are from 7:30 am – 9:00 am, 12:30 pm – 2:00pm, and 7:00 pm – 10:00 pm on weekdays and from 1:00 pm – 5:00 pm on weekends.

The hours listed on the website and the hours in the BAS system do not currently match. All calculations related to occupancy in this report were performed using the occupancy schedules established in the BAS system. ERG recommends that the BAS occupancy schedule be adjusted to reflect actual operating hours.

3 UTILITY ANALYSES

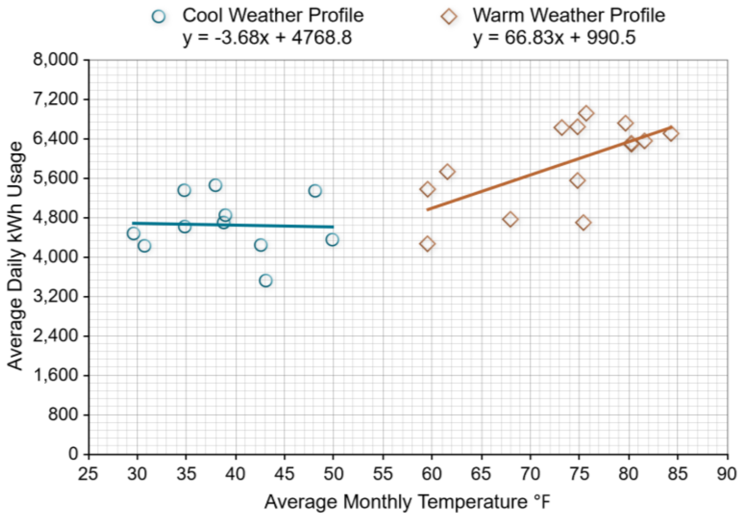
Energy usage data was provided to Energy Resources Group from utility billing sources for the campus, manual meter reads done by facilities staff, and from submetering done within the campus Building Automation System. The weather data that inform this report come from the Midwestern Regional Climate Center[3] (MRCC) for the Lambert Airport NOAA weather station (KSTL).

3.1 ENERGY USAGE – ELECTRIC

Principia College purchases its electricity from Constellation Energy on Account ID 692905 and has delivery service via Ameren Illinois on Account # 4275071008. The College is on the Ameren electric delivery DS4 rate schedule. Ameren has one meter for the entire campus. Based on this meter, The Principia College campus uses on average 10,700,000 kWh annually. The average annual price per kWh, including delivery, is $0.0627. This price will be used to estimate financial savings for the recommended retro-commissioning (RCx) and energy efficiency measures (EEMs). Principia spends an average of $673,000 on electricity annually, with a blended average annual rate of $0.063/kWh, and seasonal average rates of $0.061 (winter), and $0.067 (summer)

While the Crafton Athletic Center does not have an Ameren sub meter, it does have a building level meter that is tied into the College's Building Automation System. The Principia College Facilities department was able to provide two years of historical electrical data from this system. Based on these data, Crafton uses 1,940,000 kWh of electricity annually. The average annual electric charge for this building is $123,000. The Crafton Center makes up 18% of Principia's total electrical consumption. For comparison, Crafton, which has a footprint of 95,000 square feet, makes up about 9.5% of the total square footage of the entire campus which is just over 1,000,000 square feet.

Figure 3.1
Daily Average kWh Usage vs. Temperature
7/2017 to 7/2019, Meter:Electric, Crafton



The weather independent annual baseload energy use for Crafton is 1,670,000 kWh. This load accounts for 85.8% of the total electrical load. The weather dependent cooling load makes up 13.7% of the annual consumption at 267,000 kWh, at a cost of $14,500. The relatively flat curve during the Cool Weather Profile indicates that electricity is not used in meeting heating loads. Figure 3.1 shows the high electrical baseload and the weather dependent load used for cooling.

3.2 ENERGY USAGE – NATURAL GAS

Principia College purchases natural gas from Spire Energy [account number not available on invoices] which is delivered by Ameren on Account# 1665015829 through meter number 00413437. Principia is on

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[3] http://mrcc.isws.illinois.edu/

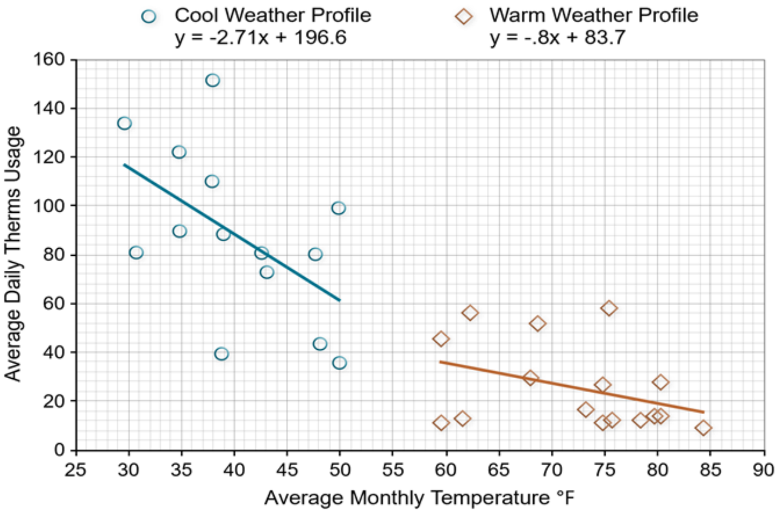
Ameren's GDS4 rate structure. There is one Ameren gas meter for the campus. Data on this usage were available from 2013, and shows that after July 2017, energy usage has become much more erratic, with large deviations - both above and below previous baselines - with average annual usage slightly higher (3.3%) than prior usage.

Analyzing all the data available from this meter, the campus uses 448,000 therms of natural gas per year. The average annual price per therm is $0.473. This price includes delivery. Based on the utility data provided, Principia spends, on average, $210,000 annually on natural gas.

The Crafton Athletic center does not have an Ameren submeter for natural gas, nor does it have a gas meter that is tied into the BAS. However, it does have a gas meter that is read and recorded manually on a monthly basis. Based on the data the Facilities Department provided, Crafton uses 19,900 Therms annually at a cost of $9,600. Crafton accounts for about 4.4% of the College's annual natural gas consumption.

Since the natatorium has a minimum setpoint of 82 degrees there is a heating load nearly the whole year. The pool boilers are turned off during the summer. Figure 3.2 shows the warm and cool weather profiles. The fieldhouse begins to need heat below 59.1°F, the intersection of the two regression lines shown in the chart. The heating load below 59°F is 12,100 therms at 61% with an annual average cost of $5500. Above 59°F, the natatorium heating loads are still somewhat weather dependent, and amount to 1,900 therms at a cost of $1050/year. The weather independent gas baseload is 16 Therms/day and 5,800 therms per year which is 29% of the total load at an annual average cost of $3200.

Figure 3.2
Daily Average Therms Usage vs. Temperature
1/2017 to 6/2019, Meter:Gas, Crafton



There is notably high variation in usage at similar temperatures. When ERG sees points that range so widely (10-60 Therms/day) at the same average daily temperatures over a wide span of temperatures, it can indicate highly variable operational practices. These data are monthly data from facility's meter 3.3.1 readings. If daily data are taken over time, they may shed light on the operational reasons for these strata of usage.

3.3 ENERGY USE SUMMARY

Projection of Usage in a Normal Year

The equations generated from the analyses depicted in Figures 3.1 (Building kWh vs. Temperature) and 3.2 (Hot Water Therms vs. Temperature) are used with "normal" year temperature data to project average annual usage for Crafton for each energy source analyzed. (Note: the "normal" year is based on NOAA published 1981-2010 thirty-year average weather data and a composite of the average year's hourly data – available from the MRCC.).

These equations establish the energy use profile. They are used to project total building energy usage at any given temperature by multiplying the equations by the number of hours in the "normal" year at all given temperatures. The sum of all of the hours of the "normal" year for each equation establishes the baseline energy usage for the building prior to the implementation of energy efficiency measures.

These equations will be used in the future to verify energy savings. For any future billing period, the equations will be exercised with respect to the temperature of that billing period and will establish what the usage would have been prior to any efficiency measures. The difference between actual energy usage and the results of the calculated "prior" usage is the savings.

The resulting energy use profiles suggests that in a statistically normal year Crafton will use 1,940,000 kWh and 19,900 Therms. This is in close agreement with actual usage figures from 2017 through 2019, well within expected annual weather variations. Using Principia's figure of 95,739 Square Feet (SF) for Crafton, it has a site Energy Use Intensity (EUI) of 90 kBtu/ft^2. According to ENERGY STAR Portfolio manager, the weather normalized mean site EUI for a *Fitness Center/ Health Club/ Gym,* is 46 kBtu/ft^2. This suggests that Crafton has nearly double the energy use footprint of comparable facilities in similar climate zones.

Normal Year Energy Usage Crafton Center

	Building kBtu
7/2017 - 7/2018	8,849,847
7/2018 - 7/2019	8,342,368
Projected Average Year	8,596,107
Site EUI (kBtu/ft^2)	90
Mean Site EUI (kBtu/ft^2)*	46

* Source: ENERGYSTAR

Table 3.3.1

Using the most recent prices per unit of energy ($0.0627/kWh and $0.473/therm), the cost of this energy comes to $122,000 in electrical use and $9,600 in natural gas use each year. This is a total of $131,600 annually and equates to an energy cost of $1.37 per square foot.

3.3.2

End Use Analysis

In order to estimate the end use of the energy consumed at Crafton, ERG used information from multiple sources, including: the utility analysis, equipment data on fan and pump horsepower, annual and daily runtimes, amperage trend logs, and the loads analysis. The estimated end use of the Electrical vs. Thermal Energy, and the breakdown of each energy type is show in the figures 3.3.2.1-3.3.2.3

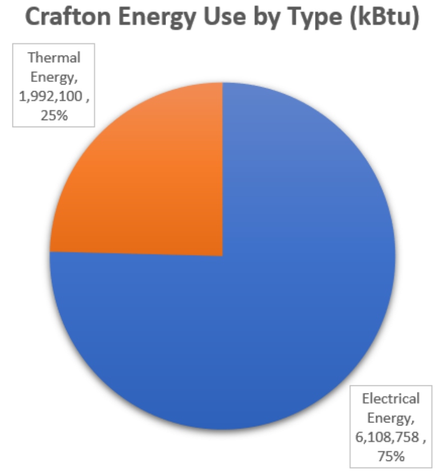


Figure 3.3.2.1

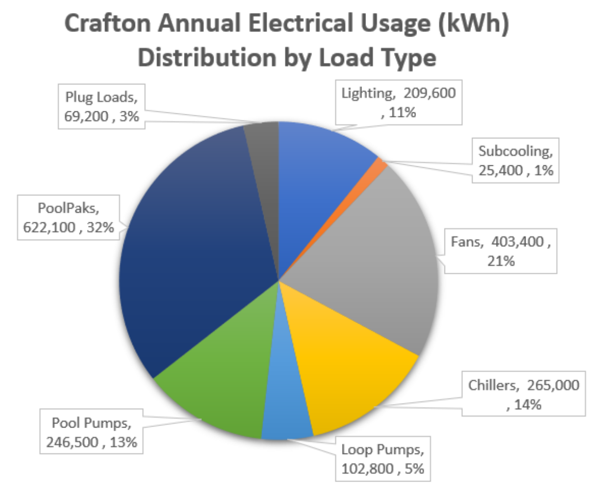


Figure 3.3.2.2

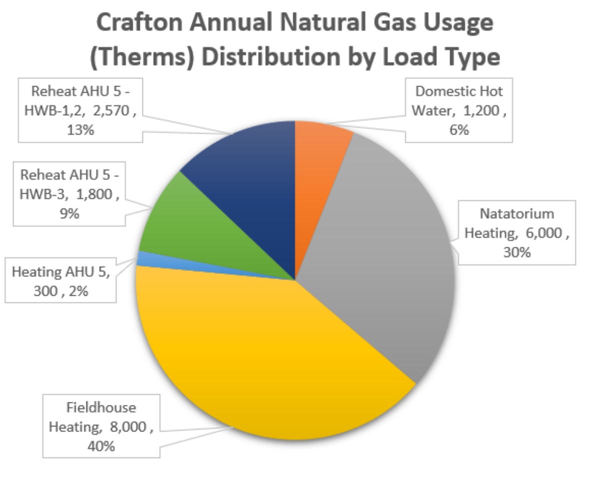
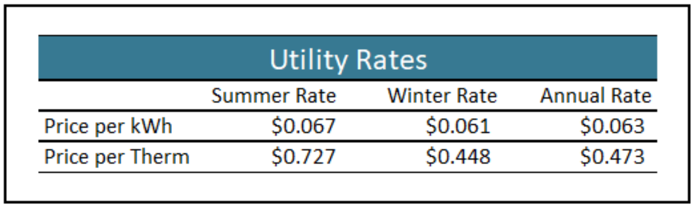


Figure 3.3.2.3

3.4 UTILITY RATES ANALYSIS

Principia College buys energy at very favorable rates. Natural gas is purchased under contracts with Spire and delivered via Ameren. Principa is on Ameren’s GDS-4 rate structure. Natural gas prices do have a seasonal variation. The annual average cost is $0.473 per Therm and the average summer and winter rates are $0.727 and $0.448 respectively. These prices include supply and delivery.

Electricity is purchased from Constellation and distributed by the Ameren Illinois DS-4 Rate. The cost for electricity also varies by season and there are separate charges for the rate of power drawn (demand kW), energy used (kWh) and energy efficiency program charges. The annual average cost of electricity is $0.0627 per kWh. The average summer and winter rates are $0.067 and $0.061 per kWh respectively.



Utility Rates			
	Summer Rate	Winter Rate	Annual Rate
Price per kWh	$0.067	$0.061	$0.063
Price per Therm	$0.727	$0.448	$0.473

Table 3.4.1

4 ENERGY EFFICIENCY MEASURES

4.1 LIGHTING

Crafton has three primary types of lighting. There are recently updated high-bay LED fixtures that are equipped with daylight harvesting in the fieldhouse.

The central area is a mixture of fluorescent lighting with two types of lamps in use, 26-watt biaxial CFLs and 32 watt 4' T8 tubes. The locker rooms, bathrooms, and weight rooms all have occupancy sensors. Individual offices, mechanical rooms, storage rooms and the e-sports room are all switched lights. The lobby and corridor areas are not switched and are all on BAS control and operate according to the schedule set in the BAS system.

Finally, the pool deck has thirty-two 1000-watt metal halide lights. These lights are all mounted to the wall above the pool deck and project the light up to the ceiling for indirect lighting to prevent glare on the pool surface. A 2015 report that the Facilities department shared with ERG explored the option to convert these lamps to LED fixtures, but it was determined to be cost prohibitive at that time. The high-bay LED light retrofit in the fieldhouse was also a part of this study. As a result of this study, the fieldhouse was upgraded from metal halide lamps to the current LED system.

Based on occupancy schedules, ERG estimates that Crafton uses 190,000 kWh/year for lighting. At the most recent calculated rate for electricity, this costs Principia about $12,000/year. T8 Fluorescent and CFLs account for 59,800 kWh (31%), High-bay LED lights account for about 34,000 kWh (18%) and the metal halides in the natatorium account for 96,000 kWh or (51%).

Principia has been changing all fluorescent T8 lamps over to LEDs and have completed over 5000 lamps on campus so far. When completed, this will reduce the load in Crafton by 19,500 kWh with a cost savings of $1,200. Principia has been purchasing LED T8 lamps from Frost electric. After Ameren Instant Incentives, the cost per lamp is currently $1.12. The cost for LEDs to re-lamp all T8 lamps in Crafton is $417. This yields a 294% ROI with a 4-month payback.

Principia Facilities department is not currently changing out the biaxial CFLs with LEDs. The price per lamp is $10.95 and is for a "hybrid" lamp that can work with or without a ballast in place. There are no other options from Frost Electric for type A or type B lamps. Therefore, the cost to replace all 231, 26-watt, biaxial lamps would be $2,530. There are two incentive options available for these lights. The first is the Ameren standard lighting incentive which reimburses $0.40 for every watt reduced or $5.60 per lamp. The second incentive option is through Ameren's custom incentive program which pays $0.12 for every kWh reduced or $8.00 per lamp. The payback for option two is 0.7 years with and ROI of 142%.

By converting all T8 and CFL lamps to LED, energy consumption would be reduced by 34,900 kWh for a total financial savings of $2,200. This project would have a payback of .5 years with an ROI of 200%. (Table 4.1.1)

Upgrade CFL and Fluorecent Lighting		
Current Energy usage (kWh)		59,800
Projected Energy Usage (kWh)		24,900
Savings (kWh)		34,900
Annual Cost Savings ($)	$	2,200
Cost of Lamps	$	4,600
Incentive	$	3,500
Cost After Incentive	$	1,100
Payback		0.50
ROI		200%

Table 4.1.1

The natatorium metal halide fixtures consume 96,000 kWh/year. ERG sourced new fixtures that would reduce the annual consumption to 25,700 kWh/year. This would save $4,400/year in operating costs. Cost estimates for this Eaton lighting fixture were $1,700. Labor to change each fixture was estimated at $510. The total cost for replacing 32 fixtures is $70,500. The available Ameren incentive is $9,400, reducing the installed cost to $61,100. Based on ERG projected energy savings and installed cost of the project, the payback is 13.9 years with an ROI of 7.2%. (Table 4.1.2)

Upgrade Metal Halide Lighting		
Current Energy usage (kWh)		96,000
Projected Energy Usage (kWh)		25,700
Savings (kWh)		70,300
Annual Cost Savings ($)	$	4,400
Cost to Replace	$	70,500
Incentive	$	9,400
Cost After Incentive	$	61,100
Payback		13.89
ROI		7.2%

Table 4.1.2

At this point, ERG does not recommend updating the natatorium lighting fixtures. However, ERG performed a further analysis of retrofitting the existing fixtures with LED lamps. The new lamps would reduce consumption to 19,200 kWh/year and would save $4800/year electrical charges. Additionally, the longer expected life on the new lamps five times longer than the existing Lamp which would further reduce operating costs. The initial lamp and labor cost to update the existing fixtures is $13,400 before the Ameren custom incentive and is $4040, after the incentive. This yields an ROI of 119% with a payback of 0.84 years. (Table 4.1.3)

Upgrade Metal Halide Lamps		
Current Energy usage (kWh)		96,000
Projected Energy Usage (kWh)		19,200
Savings (kWh)		76,800
Annual Cost Savings ($)	$	4,800
Cost of Lamps + Labor	$	13,440
Incentive	$	9,200
Cost After Incentive	$	4,240
Payback		0.88
ROI		113%

Table 4.1.3

Due to the age of the current fixtures, ERG does recommend that the condition of the current fixtures be thoroughly evaluated prior to retrofitting. If the fixtures are deemed to be at or near end-of-life, then ERG recommends reconsidering the previous option of fixture replacement.

4.2 CONDENSING BOILER

There are six combustion devices that use nearly 20,000 Therms of natural gas and 2 Pool Pak Units that use electricity to move heat around the pool system (heating pool water and supply air). This is a combined capacity of over 8.5 MMBTUh serving an estimated load of 3.5 MMBTUh for the Coach Crafton complex (Table 4.2.1).

The two 75-ton PoolPak units are highly efficient at recovering energy from the pool exhaust and directing it back into the pool. Once the pool is heated, they are expected to be able to maintain the pool most of the operating hours of a year. The hourly PoolPak input can exceed that of the pool heater. There is a lot of redundant capital infrastructure that, unfortunately, is not very efficient. In the future, when equipment fails, it is important to have a plan in place that will prevent emergency responses that replace like with like.

Mark	Serves	MBTUh Out
HWB1	Space Heat	2,176
HWB2	Space Heat	2,176
HWB3	Reheat - AHU5	396
Laars 1	Pool	1,260
Raypack	Spa	327
Laars 2	DHW	254
Pool	PoolPaks (2)	2,000
	Total	8,589

Table 4.2.1

ERG proposes that Principia begin a strategic infrastructure shift that would abandon the multiplicity of conventional boilers at Crafton and move into a modular condensing boiler approach. Part of this planning would be to instrument the existing equipment to measure usage make sure that future equipment is properly sized to loads that will exist then.

ERG suggests that step 1 is to replace HWB2 with a 1.0 or 1.5 MMBTUH modular condensing boiler that has independent 0.5 MMBTUH burner modules operating in parallel at 95% efficiency. This anticipates that there will be a significant realignment of operating strategies so that the PoolPaks handle almost all of the pool load (from ERG analyses this would be down to roughly 20°F). Supplemental heat would be provided by these heaitng boilers.

This boiler is smaller than HWB2, but according to the utility analysis, it can replace both the Laars 1.26 MMBTUh pool heater (using a heat exchanger - HX) and the 0.4 MMBTUh HWB3 boiler that supplies summer reheat. If Retro-commissioning efforts are successful in reducing the subcooling and reheat cycle in AHU-5, ERG estimates that this boiler will be still be oversized for these loads and will have much better turndown capacity and operate at high efficiency compared to the poor turndown capacity of expected of the HWB3 at an efficiency of 70%. ERG experience suggests that, lightly loaded, this boiler will operate closer to 50% efficiency for the new, very small, reheat load.

During the non-heating season, this capacity fully replaces the existing lower temperature loads, assuring that it sustains fully condensing boiler operation throughout these times. During the heating season, the condensing boiler can handle building heating requirements down to 20°F. Below that it operates in parallel with HWB1. This less efficient boiler (HWB1) would operate less than 300 hours per year and would only be on once the loop OAT reset schedule has moved out of condensing mode.

With the pool HX piped to use HWR temperatures there is the added benefit of “cascading” the available heat to make sure that the condensing boiler will always have return water temperatures – even in the winter – that keep it in a condensing mode.

With this infrastructure in place, when equipment fails in the not too distant future (spa heater), that equipment can also be replaced with a heat exchanger. When HWB1 fails, there will have been sufficient experience to know what the actual size of the new modular condensing boiler needs to be to meet the actual load of the building while providing n+1 redundancy to support resiliency. With this new modular approach, n+1 takes the form of a 0.5 MMBTUH module rather than a 2.7 MMBTUH boiler.

Condensing Boiler Upgrade		
Energy Saved (Therms)		3,800
Annual Cost Savings	$	1,800
Installed Cost	$	69,700
Estimated Incentive	$	3,800
ROI with Incentive		2.7%

Table 4.2.2

Table 4.2.2 shows the benefits and costs for taking steps to enhance the Crafton heating infrastructure. It is based on the 1.5 MMBTUh model. If the 1.0 MMBTUh model is chosen, then the cost will drop ~ $7,500. While the return on investment appears lower at this time than other measures in this report, the real benefit comes in avoiding much larger outlays when the remaining equipment reaches time for lifecycle replacement.

Table 4.2.3 illustrates the inherent benefits of working to anticipate the life cycle replacement of the less efficiency equipment. It credits the costs of the equipment being replaced. In addition, there will be lower annual equipment maintenance costs, that have not been credited in this analysis.

When it comes time to replace HWB1, it should also be replaced with a modular condensing boiler of a size to make sure that an n+1 redundancy is maintained for reliability and resilience should a module (or 2) in either unit fails.

Condensing Boiler Upgrade		
Energy Saved (Therms)		3,800
Annual Cost Savings	$	1,800
Installed Cost	$	80,000
Life Cycle HWB2	$	(47,900)
Life Cycle HBW3	$	(13,900)
Life Cycle 1.26MM	$	(35,200)
Estimated Incentive	$	3,800
ROI with Incentive		No Cost

Table 4.2.2

4.3 COOLING SYSTEM UPGRADE

The Trane TRAC 155-ton chiller is based on two screw compressors (80/75-ton splits) that can turn down to 15%. It is expected to have a 30-year life. It produces cooling in the 1.1 kW/ton range. The smaller Trane RAU-C 30-ton chiller has scroll compressors and is expected to have a 12-15-year life (approaching life cycle). It produces cooling in the 1.5 kW/ton range. This is consistent with air cooled compressors. Water cooled compressor systems are available that produce cooling with < 0.5kW/ton – less than half the energy. To put that in perspective, the current electrical usage for Crafton cooling is ~270,000 kWh/year at a cost of $14,500. Changing the technology would save 135,000 kWh and $7,250 annually.

The pool has 497,000 gallons and is in need of heat to make up what is constantly being removed in the exhaust. The pool operates between 82-84°F; the target temperature for return water from a cooling tower is 85°F. It is expected that this pool mass can be used as part of a strategy of migrating from air cooled to water cooled chillers.

ERG recommends, as part of a strategy of migrating to water cooled compressors, that Principia take a first step and retrofit the existing 30 ton chiller system (1.5 kW/ton) with a water cooled 15 ton compressor (the loads will be coming down to 14 tons) that rejects its heat to the pool. The pool has the ability to absorb 345 tons of cooling in a 1°F temperature rise. A peak day of cooling, at the rate of 14 tons, might raise the pool water temperature 0.6 °F - if there were no loses from the pool. Such an effort, while highly recommended, needs additional engineering investigation to determine how best to address issues and properly integrate the various components to optimize energy performance and minimize cost.

Another alternative would be to consider installing a ground source heat pump system to provide both heating and cooling to AHU5. Multiple institutions have indicated that there is success with this approach and its benefits of reduced maintenance and longer life cycles which are not evaluated in Table 4.3.1. Again, like the condensing boiler approach, this begins a process of upgrading the cooling infrastructure. The ROI would be much higher if it is credited with life cycle cost replacement of the existing chiller.

This would give Principia a prototypical installation that could be evaluated over time to determine if the ancillary benefits beyond energy savings and CO_2 reduction warrants further deployment on this and other campuses.

GSHP for AHU 5	
Energy Saved (kWh)	34,300
Energy Saved (Therms)	1,790
Power Saved (kW)	13.5
Annual Cost Savings	$ 2,200
Installed Cost	$ 52,200
Estimated Incentive	$ 5,900
ROI with Incentive	4.8%

Table 4.3.1

Note that the GSHP is expected to be more expensive that designing a one-off chiller system that uses the pool for condensing purposes.

4.4 Add VFD Controls to AHU-5

AHU-5 is a in a curious state. It is installed and operated as a constant volume make up air unit. However, it feeds 15 variable air volume (VAV) boxes in the spaces. These boxes, the most of the expensive costs of achieving a VAV system, are already in the building, but the air handler remains constant volume. The next step to take full advantage of these assets is to install variable frequency drives (VFDs) on the 5 HP supply fan and the 3 HP exhaust fan in the unit and add the controls needed to operate it properly. This will allow the system to reduce operating capacity to the actual load in the spaces instead of subcooling and reheating most of the air most of the time.

VFDs on AHU5 Supply and Exhaust Fans

Fan Power Savings	Supply	Exhaust
Current Annual Energy Usage (kWh)	19,500	11,700
Projected Energy Usage (kWh)	5,200	2,400
Savings (kWh)	14,300	9,300
Subcooling Savings		
Removed Subcooling (kWh)	12,300	
Removed Reheat (Therms)	3,400	
Annual Energy Savings ($)		$ 3,900
Estimated Cost		$ 12,300
Available Incentive		$ 5,900
Annual ROI w/o & w incentive	32%	61%

Table 4.4.1

AHU-5 is designed to operate as an 100% outside air system. The design CFM for this system is 5220. According to ERG's analysis and ASHRAE 62.1 standards, this zone is being over-ventilated by 46%. Adding VFDs to the system would allow the system to reduce flow to the minimum ventilation standards. Currently, the system is using 19,500 kWh for the 5 HP supply fan and 16,700 kWh for the 3 HP exhaust fan. VFD controls would allow these fans to reduce consumption by 73% and 79% respectively.

VFDs on AHU5 (Cascade)

Fan Power Savings	Supply	Exhaust
Post RCx Annual Energy Usage (kWh)	17,400	9,600
Projected Energy Usage (kWh)	10,300	4,700
Savings (kWh)	7,100	4,900
Annual Energy Savings ($)		$ 800
Estimated Cost		$ 12,300
Available Incentive		$ 4,400
Annual ROI w/o & w incentive	7%	10%

Table 4.4.2

In addition, since the unit currently delivers all of this air at 55°F; it is subcooling the space all of the time it is operating. In the winter, this air is cooled by introducing OA to reach 55°F. In the summer, the chiller is used to produce this false cooling load with mechanical power (electricity). In both cases, the VAV boxes add reheat to this excess air to bring it to a room neutral 70°F. In the summer this costs an extra 12,300 kWh of cooling energy to make subcooling happen and, throughout the year, it adds 3,400 therms (part of the large gas baseload). Table 4.4.1 shows the expected benefits and costs of this measure.

This EEM has some similar savings to RCxMs 5.6 and 5.7. Table 4.5.1, above, shows the benefits of this measure as a stand-alone measure. Table 4.5.2 shows it in a cascading mode, where savings expected from RCx items which interact with this EEM have been considered.

4.5 VFDs on Pool Pumps

There are two 20 HP pumps with a combined design flow rate of 1650 gallons (825 GPM each) that circulate the pool water. According to Illinois Title 77 Public Health Code, the 497,000-gallon pool needs to circulate the water every 6 hours. At the design flow rate, the system is turning the water over every 5 hours. Therefore, the pool is being turned over 16.6% more than required by code. The needed flowrate to satisfy the IL code, is 1380 GPM.

Based on ERGs observations, the flow rate is currently controlled via two manually adjusted 8" butterfly valves on the outlet side of each pump that are half closed. This is likely restricting the flow about 75%. The observed flow rate is around 1500 GMP, per pool flow monitoring sensors, which is 110% of needed flow, so there is an opportunity to turn it down further.

ERG estimates that by Installing VFDs on these two pumps and operating them based on current or new flow meters to maintain the required GPM flow, would allow Principia to turn down motor RPM to 75% - 85% or more. This could help automate the process by monitoring pumps speed, which can be used as an indicator of pool filter status to predict the need for backflushing operation.

Add VFDs to Pool Pumps

VFD Speed	85%	75%
Current Annual Energy Usage (kWh)	223,500	223,500
Proposed Energy Usage (kWh)	143,200	101,600
Energy Savings (kWh)	80,300	121,900
Savings (%)	36%	55%
Annual Savings ($)	$ 5,100	$ 7,700
Estimated Cost	$ 31,200	$ 31,200
Available Incentive	$ 10,400	$ 14,600
Annual ROI with Incentive	25%	46%

Table 4.5.1

Table 4.5.1 shows the benefits and costs of this measure showing a range of pump speed from 85% to 75%. Actual pump speed needed is expected to be less. Since this analysis has had to infer benefits from engineering judgement and calculations, ERG recommends a more detailed engineering study to measure actual flows that can be expected to develop actual operating impacts and savings that will result from this effort. Additional benefits will accrue from reduced pump maintenance and extended motor/pump lifecycles.

4.6 Add VFD Drives to HCP/CWP Loop Pumps

Currently there are two constant volume pumps on the Dual Temp water loop marked HCP1 and HCP2. These pumps are both 20hp with a flow rate of 518 GPM and operate lead-lag. These pumps are significantly oversized for the primary chilled water loop which has a 5hp, 310 GPM pump and the primary hot water loop which has 1.5 hp, 109 GPM flow rate. Given the difference in flow rates between the two loops, it is also likely that the chilled/heated water supply and return waters are being blended (typical of control with a 3-way valve on a constant volume pumping system) which can compromise loop water ΔT, causing the system to run less efficiently and reducing the effective capacity of the air handlers.

The pumps on the secondary loop operate approximately 300 days/year with a one-month vent mode in the fall and spring when the system is off. These 300 days of operation add up to a total annual energy usage of 93,200 kWh/year at a cost of $5,870.

The benefits and costs associated with installing a VFD on these pumps can be seen in Table 4.6.1 under HCP (Heating /Cooling Pump).

The CHWP (Cooling Water Primary) pump is a constant speed 5 HP, 310 GPM pump. This pump operates when the OAT is ≥ 54°F (~5000 Hr./year). In a constant volume mode, following the above hours of operation, this pump uses 16,000 kWh/year, which costs $1,000/year.

VFDs on Loop Pumps

	HCP	CWP
Current Annual Energy Usage (kWh)	93,200	16,000
Proposed Energy Usage (kWh)	6,000	3,400
Savings (kWh)	87,200	12,600
Savings (%)	94%	79%
Savings (kW)	6.0	0.0
Savings ($)	$ 5,500	$ 800
Estimated Cost	$ 18,900	$ 3,100
Available Incentive	$ 10,500	$ 1,500
Annual ROI with incentive	65%	50%

Table 4.6.1

The benefits and costs associated with installing a VFD on these pumps can be seen in Table 4.6.1 under CWP (Cooling Water Primary pump).

Note that the Ameren custom incentives of $0.12/kWh are available, rather than the standard VFD incentive of $125/HP.

Additional benefits will accrue from reduced pump maintenance and extended motor/pump lifecycles. The VFD would also allow the chiller to run more efficiently by increasing the temperature differential. Savings associated with the more efficient operation of the chiller are not considered in the VFD calculations.

4.7 SOLAR PHOTO VOLTAIC (PV) INSTALLATION

While this recommendation is not particularly for Crafton Athletic Facility, there is sufficient ground on the campus to suggest that the Principia install a 2 MW solar array as soon as reasonably possible – to take advantage of the current tax benefits. The Principa college has enough electrical load at 10,000 +MWh annual usage to absorb the output of a 2 MW solar photovoltaic (PV) array (~3,000 MWH/year). These systems are very cost effective in Illinois as can be seen in Table 4.7.1. There is a confluence of: federal, state and utility incentives that effectively write down the initial $3.23 million cost to $450k by the end of the first year. Over the next four years, the Illinois SREC program payments and on-going energy savings effectively “pay” the Principia $1.3 million+ for going with this solar photovoltaic. (note that the SREC program value varies over time, this is based on the current market).

Solar PV Cost/Benefit

Annual Energy Savings (kWh)	2,976,000
Installed Cost	-$3,226,000
Annual Energy Savings ($)	$187,000
26% Federal tax credit	$839,000
Depreciation (20% of 85% Basis)	$548,000
USDA REAP Grant	$484,000
Smart Inverter Rebate	$500,000
IL Solar Recs Yr 1	$246,000
Net Cost First Year	-$422,000
IL Solar Recs and Savings Yr 2-5	$1,874,000
Payment for Going Solar over 5 years	$1,452,000

Table 4.7.1

Table 4.7.1 is predicated on a "best case" scenario where The Principia would form an for-profit LLC that would attract past donors that may have a "tax shelter" appetite and, as a development department "*Thank You*" offer them some, or all, of the tax shelter available. If donors are not interested there are other third parties that would be. This LLC would own the assets as long as it takes to fully discharge the costs of the projects, selling the power generated to Principia at 75% of the current cost of electricity through a power purchase agreement (PPA). Once the debt obligation is retired and all of the RECs have been received, the PPA cost to Principia for the power produced would drop to $0.0015/kWh to maintain the LLC obligations, like system insurance, that may exist to support the SRECs (possible 15 year life). The intent will be to eliminate the LLC once it no longer has a useful purpose. Note that benefits shared with the participating "tax shelter" parties would impact the yield to the Principia. The cost to the Principia would be the legal costs necessary to form the LLC.

Solar PV Cost/Benefit

Annual Energy Savings (kWh)	484,000
Installed Cost	-$3,226,000
Annual Energy Savings ($)	$187,000
USDA REAP Grant	$484,000
Smart Inverter Rebate	$500,000
IL Solar Recs Yr 1	$246,000
Net Cost First Year	-$1,809,000
IL Solar Recs and Savings Yr 2-5	$748,000
ROI (Accelerating SRECs)	18%

Table 4.7.2

Alternatively, the Principia could forego the tax benefits. Table 4.7.2 shows the likely economics of such an approach.

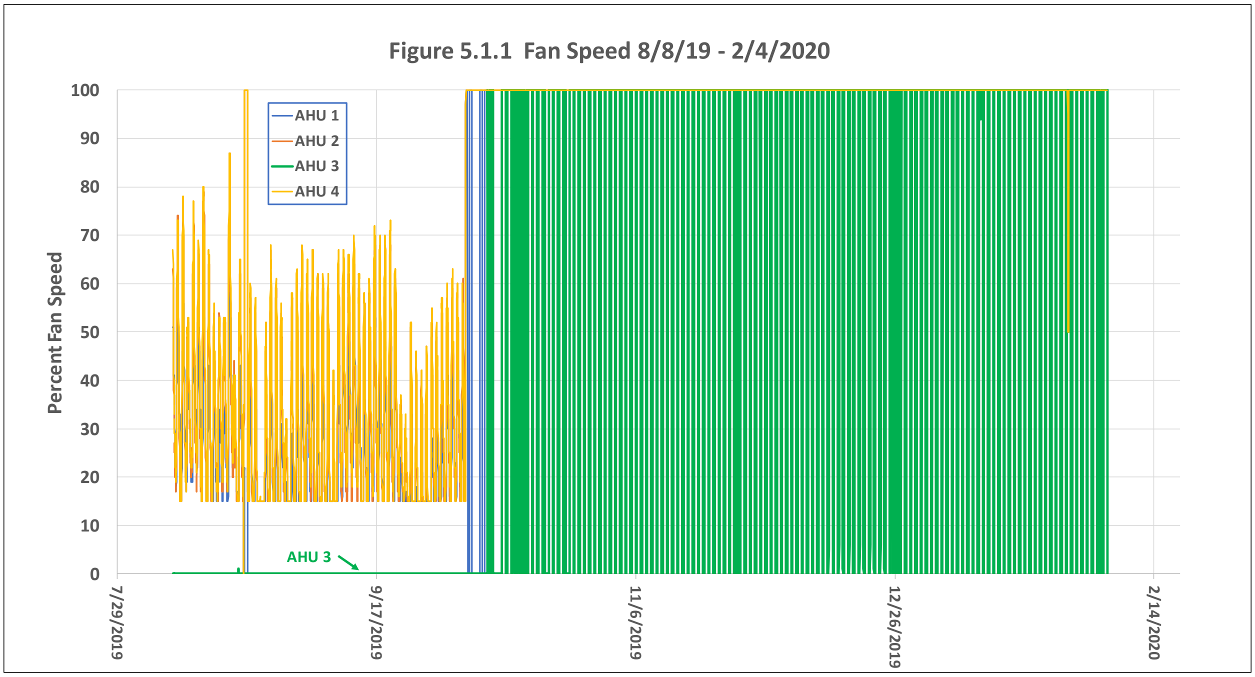
This installation will generate annual electrical savings of $187,000 that will continue to grow as electrical rates escalate over time.

5 RECOMMENDED RETRO COMMISSIONING MEASURES

This section presents the suggested Retro Commissioning Measures (RCxMs) that resulted from the investigations of BAS trends and energy usage at Crafton Athletic Center. These measures were selected because of the impact that they are expected to have on overall energy savings. Other measures have been considered but are not included here because the information available at this time is not sufficient to conclude that they would be cost-effective opportunities. The measures selected are expected to dramatically change the way energy is used in Crafton. These changes should be implemented as soon as possible. Measures that have a payback of less than one year must be initiated within 30 days after the survey presentation meeting to comply with the Ameren IL RCx incentive program. After new performance baselines have been developed, and the system response to the proposed changes is understood, additional energy efficiency measures can be evaluated.

5.1 SET OCCUPANCY SCHEDULES FOR AHUS 1, 2, 3 & 4 AND HW/CHW PUMPS

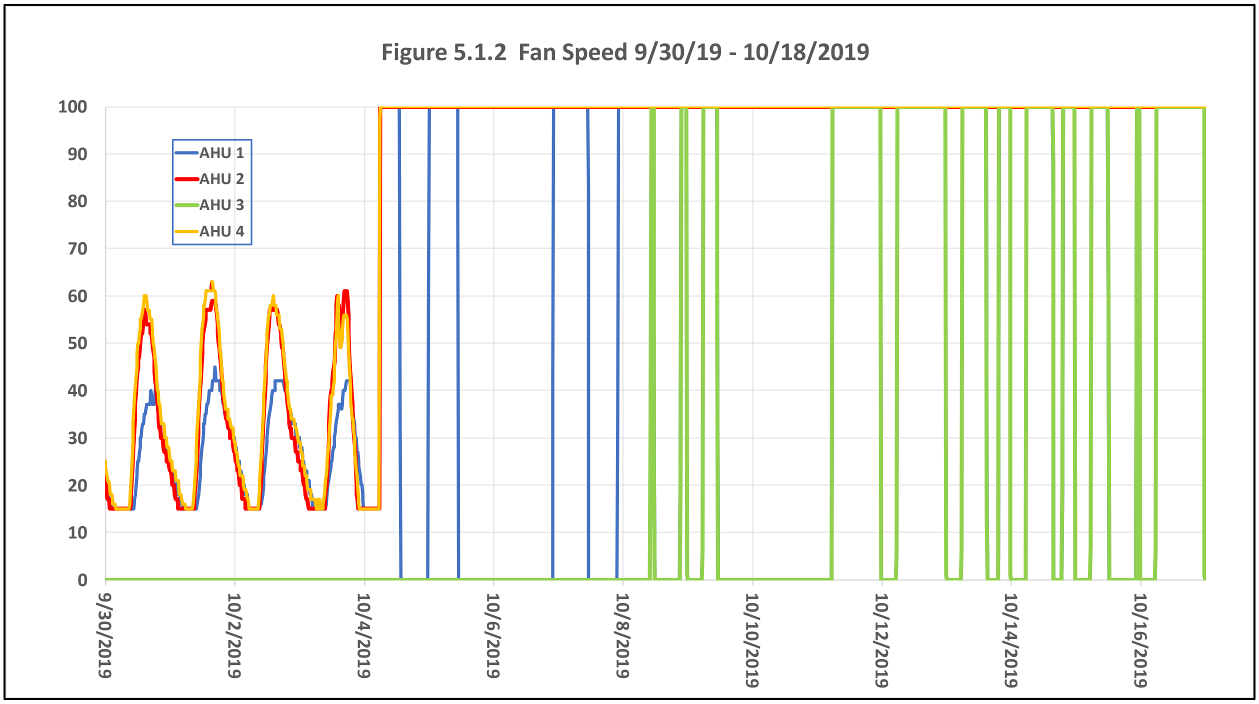
The operation of AHUs 1-4, that serve the fieldhouse, is very erratic. Figure 5.1.1 shows the fan speed for these four units from 8/8/19 through 2/4/20. There is an obvious operating change-over on 10/4/19.



Note that AHU3 is off throughout the summer operations of this unit. The highest summer usage occurred when AHUs 2&4 railed at 100% from 11 AM on 8/22 through 3 AM on 8/23 while AHUs 1&3 were off. The OAT during this time frame saw a high of 81°F and a low of 66°F, so this is unexpected based on weather and is thought to be an operator override. There was a peak weather-based excursion that can be seen on 8/19 when the OAT climbed to 95°F. Fan speeds on AHU 2&4 reached 87% while AHU1 was at 60% speed, which is normal and expected (AHU3 was off). This suggests that the peak cooling loads can be handled with just three fans operating well below maximum capacity. Note that, at this time, AHU 1 was operating at 20-30% lower speed than AHUs 2&4 and AHU1 is consistently lower than AHU 2&4. This may be a function of more exposure areas for AHU2&4 or it could be a variance in the speed calculation routines or space sensors for AHU1 causing an error. Assuming that all units are responding to similar space temperatures, all should run at roughly the same speed. During the peak event, if all four fans had been running in parallel, there would be a 45% reduction in fan power used during those peak hours.

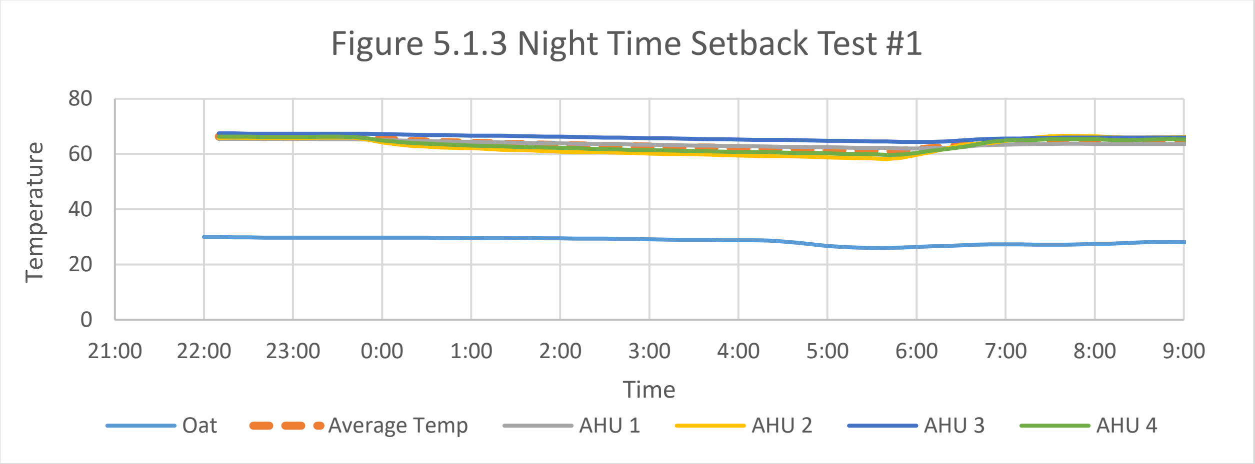
Normal cooling loads of the fieldhouse are apparently being handled by 3 units running less than 60% for most of the hours.

Figure 5.1.2 zooms in on the change-over point of 10/4/19 to try and better understand operations. At the beginning of the changeover, AHUs 1, 2, & 4 go to 100% speed and AHU 3 (green) stays off. However, AHU 1 (blue) begins to show some occupancy schedule response that turns the fan off at night. On 10/8 AHU3 comes on for 2 periods during the day of 1.5 hours and 2 hours; and on 10/9 it runs for several hours. On 10/11, AHU 1 no longer turns off at night, but AHU 3 comes on at 100% speed, like the other fans during occupied periods, but turns off from midnight to 6 AM and has several other erratic on/off profiles.

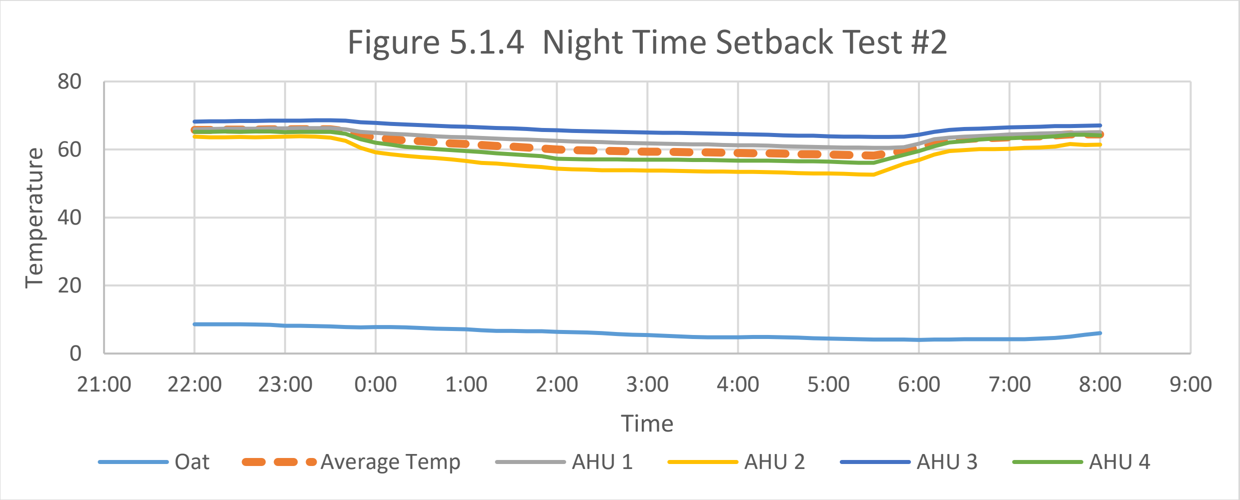


In the apparent summer mode, fans can meet cooling loads with one fan off and three fans operating at part loads. In the evening, these three fans are "railed" at 15% of fan speed (which moves very little air), suggesting that they could be off at night with little effect on the space temperature. In the winter mode, after 10/8, AHU 1 follows AHUs 2 & 4 and all three run 24/7 – the occupancy sequence of operations on these units was "disabled". AHU 1 has ocassional, inexplicable (no pattern) off periods which warrants further investigation. From 10/20 onward AHU 3 runs 100% during the occupied period. However, AHU 3 is operating on an occupancy schedule – occupancy was "enabled". ERG did note the presence of night-time set back (NsbSp) and set up (NsuSp) set points of 50° and 80° and the occupancy schedule is tied to the occupancy schedule set by security for building hours ERG verified that the occupancy trends for AHU 3 are consistent with the current operating hours of the facility.

As a test, ERG enabled occupancy on all four air handlers on two occasions and monitored the temperature loss in the space. For the first test (Figure 5.1.3), the outside air temperature for the test night was 30°F dipping down into the mid-20s°F. Over the 7-hour unoccupied period, the average temperature in the fieldhouse fell 5°F, which is significantly less than the 15°F winter setback allowed.



OAT air temperature for the second test (Figure 5.1.4) was much colder, starting at 8°F and dropping down to 4°F by the end of the unoccupied time. For this test the NsbSp was increased to 55°F. Only one of the four air handlers turned on overnight. Following the unoccupied time, the space was able to recover back to the occupied set points, despite the outside temperature remaining below 6°F, within 1.5 hours. These tests confirm that there should be no issue with running a winter-time occupancy schedule on all four air handlers in the fieldhouse, especially when people are not in the space and comfort is not an issue.



In addition to the fans, there is a 20 HP secondary loop pump that runs continuously, a 5 HP chilled water pump that runs in the summer mode and a 1.5 HP pump that runs in the heating mode. These pumps should also be off during the unoccupied period of the fieldhouse.

Additional savings that will accrue from this measure will save the energy required to heat the 1500 CFM (500 CFM per AHU based on the As Built Drawings) of outdoor air that is the minimum setting on the three fans that run all night at 100% in the winter. Note that, because the fans are typically at 15% speed during summer night unoccupied schedules, this OA in negligible and is not calculated in these savings.

It is proposed that Principia rework the fan and pump schedules to turn fieldhouse fans and pumps off each day for a minimum of six hours from 11pm to 5am. Trend logs show that many times this is a longer time. Note that extending the period of "OFF" will increase the expected savings linearly.

Table 5.1.1, to the right, lists the benefits and costs to implement this measure for the. It is estimated that the cost to implement this measure is $5,000. Since the estimated incentives available exceed the costs of this measure, there is, effectively, no cost for this effort.

Fieldhouse Occupancy Schedules	
Fan Energy Savings (kWh)	58,000
Electric Cost Savings ($)	$ 3,700
Gas Energy Savings (Therms)	1,400
Gas Cost Savings($)	$ 600
Est. Annual Energy Savings ($)	$ 4,300
Est. Implemention ($)	$ 5,000
Est. Ameren Incentive	$ 1,600
ROI After Incentive	126%

Table 5.1.1

5.2 FIELDHOUSE FULL VFD OPERATION FOR AHUS 1, 2, 3 & 4

There are three current operating modes for the fieldhouse: heating mode, cooling mode, and vent mode. These modes are switched over manually depending on the season and outside weather conditions. It appears that the heating season is from November through April, the cooling season is from June through September and vent mode is typically active in May and October.

During the cooling season the air handlers modulate fan speed on three AHUs to meet the space cooling need. During the vent mode the air handlers are turned off and the fieldhouse uses the large exhaust fans and air-intake louvers to provide an economizer cycle.

In the heating season supply air fans are on at 100% 24/7. Presumably, this is to mix the air since the hot air will collect at the ceiling. ERG would suggest that, as long as space temperatures in the occupied zone are comfortable, then the use of excess fan energy to mix the air is unnecessary.

In order to test this hypothesis, ERG performed a series of tests on the morning of January 28th, when OAT was around 32°F, with the goal of seeing at what point would there still be sufficient velocity out of the supply fans to sufficiently mix the air.

Figure 5.2.1 is a thermal image that shows the temperature differential with the fan speed at 100%, and this image is the current baseline. The temperature differential from the floor to the ceiling is 1.2° (69.4 to 70.6°F).

The first test was to reduce the fan speed to 75%. As seen in Figure 5.2.2, the temperature differential was 1.4° (74.2 to 75.6°F) after 2 hours of running at this speed. The second test reduced the fan speed to 50%. Figure 5.2.3 shows that after 2 hours the temperature differential was 2.5° (73.3 to 75.8°F). While the stratification ΔT increased 1.3°F, the overall space temperature rose 2.9°F at the floor. It appears that the hypothesis is confirmed that, while the stratification

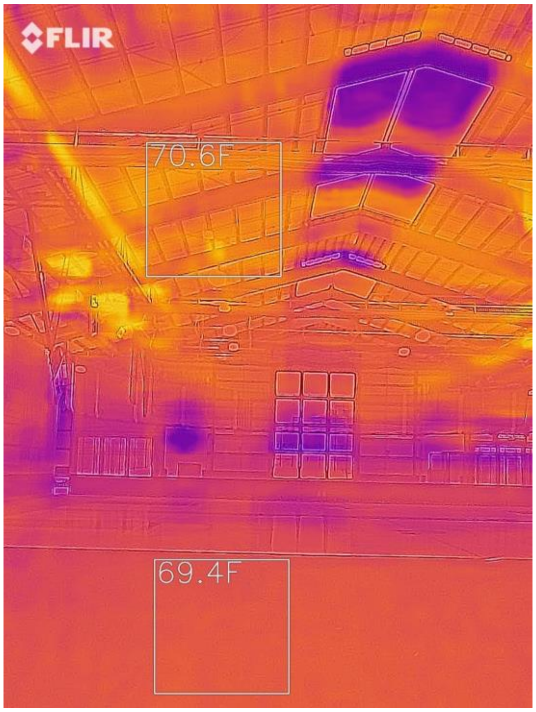


Figure 5.2.1 Thermal Image with VFD at 100%

might increase with lower air movement, the occupied space zones temperatures can be easily maintained at the floor level, which was the goal of these tests.

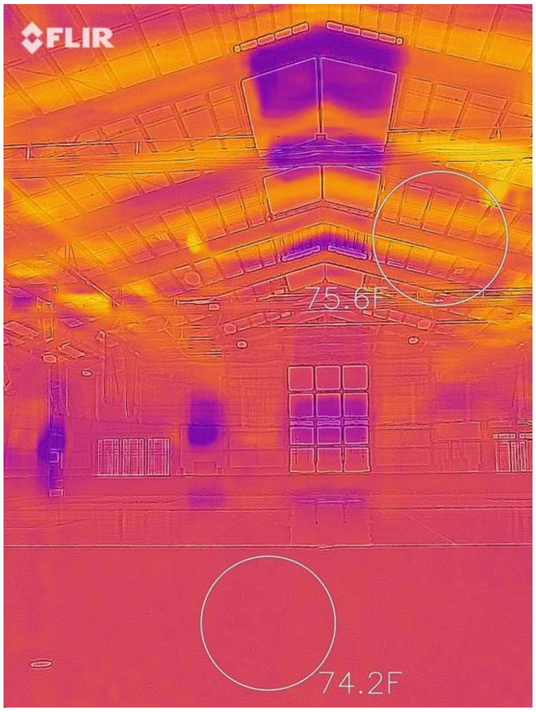


Figure 5.2.2 Thermal Images with VFD at 75% speed

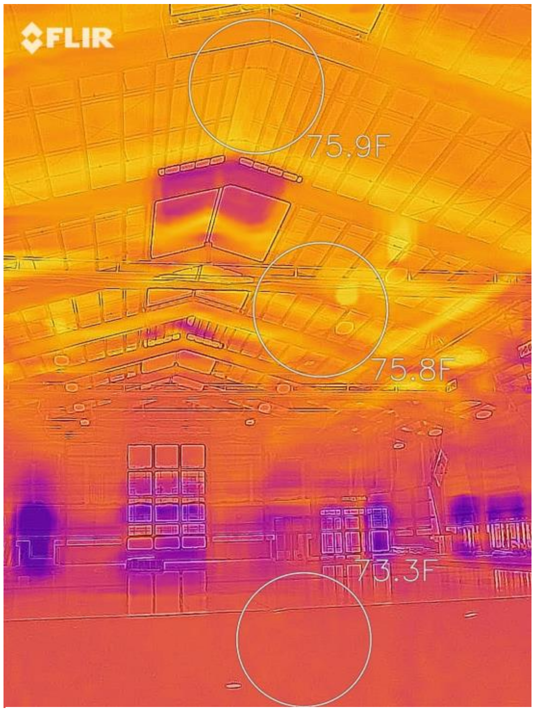


Figure 5.2.3 Thermal Images with VFD at 50% speed

In the winter mode, if all 4 fans were to operate in parallel under VFD control, not the artificially high 100%, it is the general wisdom of the industry that proper VFD operation will reduce fan power 75%.

During the summer mode, from the trend data available from last August and September, AHU3 is off all of the time. It is assumed that, with all units working, there will be better mixing and more even temperature distribution. Modeling last season's summer usage showed that running all four fans in parallel will reduce electric usage 47%.

Table 5.2.1 shows the expected benefits and costs of implementing control changes that run all four fans 18 hours a day to meet the actual heating and cooling loads in the fieldhouse. Note that these savings do not include any night setback/up savings shown in Table 5.1.1.

Fieldhouse Full VFD Operation	
Summer Fan Savings (kWh)	30,400
Winter Fan Savings (kWh)	130,300
Electrical Energy Savings (kWh)	160,700
Electric Cost Savings ($)	$ 10,100
Est. Implemention ($)	$ 8,500
Est. Ameren Incentive	$ 3,200
ROI After Incentive	191%

Table 5.2.1

5.3 CORRECT THE STAGING OF BOILERS

Presently, there is a boiler staging sequence that appears to be backwards. It calls for turning on two boilers when the OAT drops below 60°F (HWB 1 & 2 4.35 MMBtu/h combined output) and turning one boiler on once OAT drops below 22°F (2.17 MMBtu/h). The commands are in conflict and, as a result, two boilers are always on to serve a peak load of 2.16 MMBtu/h at 2 °F (St. Louis Design temperature). This means that both boilers are effectively running and are turning on/off based on maintaining the HW loop temperature.

As a result, the boilers are cycling more than is necessary, which results in excessive purge cycles reducing the overall efficiency of the boilers from the ERG original estimate of an AFUE of 70% down to an AFUE of 60%. Crafton uses, roughly, 20,000 Therms/year. A conservative estimate is that 9,000 of those therms are used by the HWB 1&2 on the dual-temp loop. Table 5.3.1 shows the benefits and expected costs to make these control changes.

Correct Boiler Staging		
Current HWB 1&2 Therms		9,000
Adjusted Therms		8,000
Saved Therms		1,000
Savings ($)	$	600
Estimated Cost	$	500
Available Incentive	$	300
Annual ROI with incentive		300%

Table 5.3.1

ERG recommends rewriting the sequence of controls to have the second boiler only come on when the first boiler is unable to maintain satisfactory loop temperatures.

5.4 OCCUPANCY SCHEDULE FOR LOOP PUMPS

On the weekdays Crafton is open from 5am until 11pm, from 7am until 11pm on Saturday, and from 5 am until 5pm on Sundays. With nighttime set back (NSB) schedules the loops pumps can be turned off at night and cycle on as needed to maintain minimum space temperatures.

At this time, the secondary loop cold/hot water pump runs all year and uses 111,500 kWh. The primary chilled loop pump runs about 5.2 months (OAT ≥ 65°F) of the year and uses 11,900 kWh, and the primary heating loop runs about 6.25 months (OAT ≤ 60°F) and uses 4,300 kWh (annual total of 127,700 kWh). Table 5.4.1 shows the estimated benefits and costs of turning off these pumps those 50 hours per week when Crafton is closed and represents a 30% savings.

Loop Pump Occupancy Schedules	
CHWP Energy Savings (kWh)	37,100
HWP Energy Savings (kWh)	1,400
CWP Energy Savings (kWh)	4,000
Total Energy Savings (kWh)	42,500
Est. Annual Energy Savings ($)	$ 2,700
Est. Implemention ($)	$ 2,500
Est. Ameren Incentive	$ 850
Return on Investment	164%

Table 5.4.1

5.5 POOLPAK CONTROLS

There are two operating valves on the auxiliary heating coil on the PoolPaks. Both show up on the BAS as always being 100% open. Each PoolPak has the ability to control its valve, but, for some reason, the PoolPaks are not doing it consistently. Communication between the PoolPak controls and Andover, or programs may not be set up, or programs don't work. Figures 5.5.1 and 5.5.2 show two operating modes over 1118 hours between Jan 10 and Feb 26/2020. Figure 5.5.1 is for 806 hours and Figure 5.5.2 is for 312 hours (28% of the time). During this time the temperature varied from 4°F and 69°F. The average discharge air temperature in Fig. 5.5.1 for PP1 was 100°F and PP2 was 74°F. In Fig 5.5.2, the PP1 average was 80°F and PP2 was 79°F. Note the overlap area is clearly from 10°F to 60°F – the temperature when boilers fire and come online.

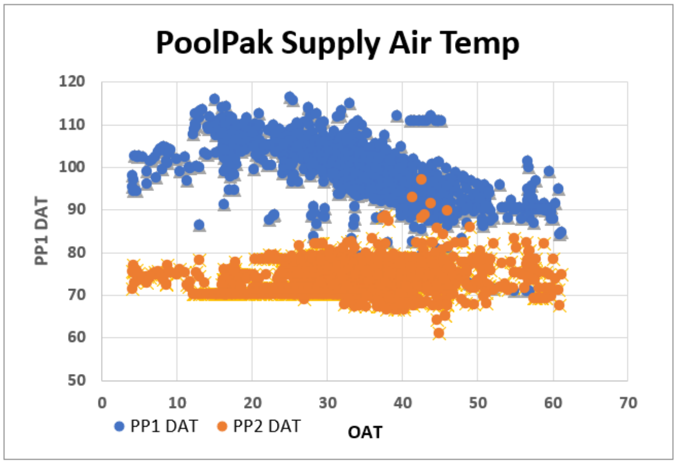


Figure 5.5.1

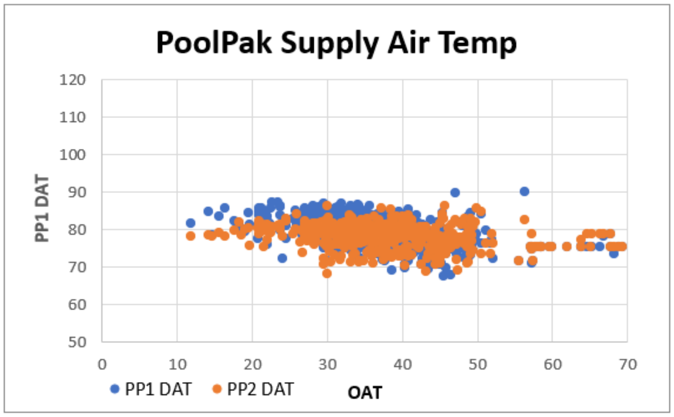


Figure 5.5.2

It is assumed that there is comfort in the pool when PP1 turns off its heat across the temperature range from 20°F through 60°F. This heat is added to the system via the auxiliary coils and is fired by HWB 1&2. This dual-temp heating loop for the PoolPak auxiliary coils (OAT ≤ 60°F) is not under control and runs wild. This is called auxiliary since it is only intended to come on if the more efficient PoolPak heat pump compressors, at a COP of 5.1, cannot keep up with the load. This is to make sure that the less efficient natural gas (COP 0.70) is used to provide additional heat only when absolutely needed. At the beginning of the heating season, with two valves open and running wild, it is likely that the pool area overheats. In response to probable overheating, staff have turned the manual isolation valve off on one of the units. Closing this one valve may have prevented overheating, but it does nothing to optimize the potential efficiency of the PoolPaks – the remaining unit, with its valve still running wild, is working erratically, not optimally; all we know is that there doesn't seem to be overheating. With one coil of auxiliary heat always available – and apparently on 72% of the time - the PoolPaks' heat recovery from the exhaust air (free energy) may often be wasted.

The PoolPaks have the ability to reject the heat associated with 150 tons of cooling to its supply air and to the pool water. Heating the supply air with the hot water from the boilers, for most of the hours of the year defeats the efficiency of the PoolPaks. The auxiliary coils should only be on in the coldest of weather, if at all.

ERG recommends that the existing PoolPak controls be reworked so that they control the valve at the auxiliary heating coil.

Automate PoolPak Aux Ht Coil	
Energy Savings (Therms)	2,600
Boiler Efficiency	70%
Therms Not Purchased	3,700
Annual Cost Savings	$ 1,750
Estimated Cost	$ 1,500
Available Incentive	3,700
Annual ROI with Incentive	No Cost

Table 5.5.1

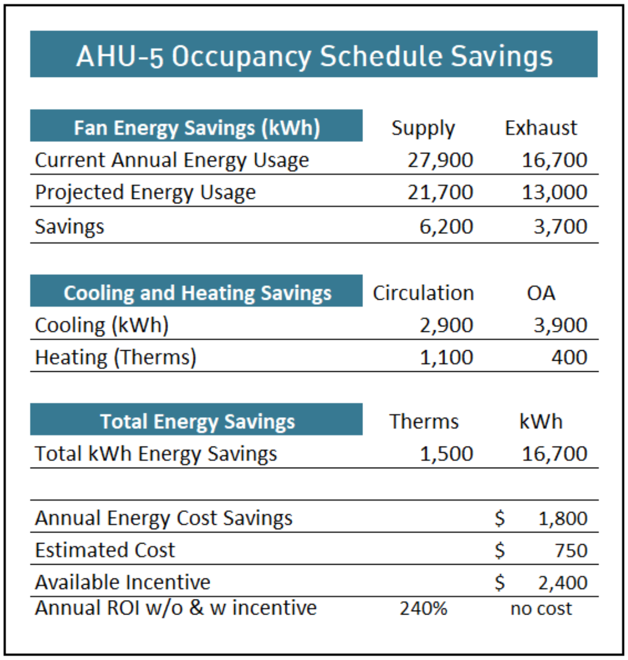
Properly operating these valves will save most of the hot water used in the auxiliary coils. Table 5.5.1 shows the benefits and costs for this effort.

5.6 RECOVER EXISTING OCCUPANCY SCHEDULE TO AHU-5

ERG's initial examination of the occupancy schedule used by AHU-5 (from 8/9/2019 to 8/17/2019) showed that the air handler was operating in over-ride of its occupancy schedule and running 24x7. During the RCx process the facilities department made some changes to the systems, and later examinations (1/6/2020 – 1/13/2020) have shown that the occupancy schedule is now effectively shutting down the fan 29% of the time.

The savings from re-implementing the existing occupancy schedule are shown in table 5.6. Additional savings are expected due to temperature setbacks which are not calculated in this measure.

ERG suggests further examination to determine the cause of the reactivation to make sure that it was not a fluke and that it will have persistence. If it was associated with the override protocol for this fan, steps need to be taken to ensure it doesn't revert to 24x7 operation again.



AHU-5 Occupancy Schedule Savings

Fan Energy Savings (kWh)	Supply	Exhaust
Current Annual Energy Usage	27,900	16,700
Projected Energy Usage	21,700	13,000
Savings	6,200	3,700
Cooling and Heating Savings	Circulation	OA
Cooling (kWh)	2,900	3,900
Heating (Therms)	1,100	400
Total Energy Savings	Therms	kWh
Total kWh Energy Savings	1,500	16,700
Annual Energy Cost Savings		$ 1,800
Estimated Cost		$ 750
Available Incentive		$ 2,400
Annual ROI w/o & w incentive	240%	no cost

Table 5.6.1

5.7 AHU 5 DAT AND AIRFLOW OPTIMIZATION

After reviewing trends and observing system performance, ERG determined that AHU-5 seldom resets discharge air temperature (DAT) during occupied operation. This results in subcooling of the supply air with a resultant excessive reheating to maintain space comfort. ERG recommends reprogramming the BAS to reset the DAT based on return air temperature and humidity. The unit currently has both sensors required to take this approach. Since this unit is currently constant volume, this would be an easy and reliable way to avoid subcooling supply air. The DAT would be reset based on a return temperature of 73°F (adjustable) with a discharge temperature range high of 67°F ramping down to a low of 55°F based on a rise in return temperature. If return humidity rises above 52%, the discharge temperature would be forced to the 55°F minimum for a period to assure space comfort.

Currently, AHU-5 is a constant volume air-handler set to flow 5200 CFM. ERG calculated the maximum necessary cooling supply airflow at 3660 CFM, and the needed ventilation (exhaust) air at 2320 CFM. Combined with the static 55°F discharge air temperature setpoint, this creates an excess 1540 CFM constant flow causing excessive subcooling and reheat.

ERG recommends re-shivving the air handler fans to reduce airflow. This will reduce the outdoor air intake and subsequent conditioning, as well as the over-supplied subcooled air and reheat. Re-shivving will also slightly reduce fan energy used.

Both of the steps above work from two directions to achieve the goal of reducing subcooling and reheat. Both are required to assure that the results will be sustained.

Table 5.7.1 shows the benefits and costs that are expected to result from this measure. Note that this has interactions with EEM 4.4. It is recommended that this be implemented first so that the potential of reducing motor horsepower might be there prior to installing VFDs

AHU-5 DAT & CFM Optimization

Reheat Savings (Therms)	2,900
Subcooling Savings (kWh)	17,500
Fan Energy Savings (kWh)	4,300
Annual Savings ($)	$ 2,800
Estimated Cost	$ 3,500
Available Incentive	$ 1,200
Annual ROI with incentive	122%

Table 5.7.1

In addition, the reduction in air flow will reduce overall maintenance costs for filters and ERV cleaning.

Note that section 7 of this report, “Issues Log,” refers to multiple opportunities to upgrade AHU 5 performance. These are in the issues log at this time because the two items in this RCxM 7 are the dominate opportunities and should be done first and would have major impact on forecasting savings from Section 7 opportunities. However, they are in the issues log so that they will be addressed at a later date.

6 ADDITIONAL ITEMS TO CONSIDER

6.1 CLEAN OR REPLACE ERV WHEEL ON AHU-5, AND IMPROVE MAINTENANCE

On inspection the ERV wheel appeared to be quite dirty. ERG tested the pressure drop across the wheel and it was 0.7” WG. According to the manufacturer documentation, this is on the low end of a typical pressure drop given the size of the wheel and the airflow through it. In addition to cleaning the wheel, the wheel gasket should be inspected and adjusted/replaced as needed.

The manufacturer documentation also provides a maintenance schedule and cleaning procedure for the wheel. Adhering to this practice will help prevent premature degradation of the unit. Proper cleaning of the wheel is especially important with the exhaust air bypass damper. When the ERV bypass damper is open, air will flow in only one direction through the wheel. This increases the likelihood that the wheel would become impacted with dirt and debris.

6.2 FIELDHOUSE MINIMUM OA AND DEMAND CONTROL VENTILATION (DCV)

Bringing OA intake in line with minimum ventilation standards set forth in ASHRAE 62.1 is not expected to generate energy savings for Principia College but deserves a mention in the report.

On AHUs 1-4, as-built drawings and the equipment schedule list a minimum OA of 500 CFM per fan, or 2000 CFM for the fieldhouse in total. In the Andover occupancy mode programming, the occupied damper setting is 5%. No Testing and Balancing (TAB) report was available, so the expected OA CFM under VFD control of the fans in unknown and is likely lower than 2000 CFM. With widely ranging VFD speeds, it would be better practice to set the damper position dynamically with an airflow calculation, which would require TAB characterization of the fans, or the addition of airflow monitoring stations.

The “Full Capacity” occupancy of the fieldhouse is rarely reached, but when it is, ASHRAE 62.1 per-person calculations (R_p) indicate that the air handlers would not be supplying sufficient ventilation air. ERG recommends implementing Demand Control Ventilation (DCV) in the fieldhouse to support compliance with ventilation standards. This would require the installation of CO_2 monitoring stations and would not result in energy savings compared to the current condition but would assist with improved ventilation during higher occupancy time periods.

If a new TAB effort is initiated, or airflow monitoring is installed, ERG suggests a review of calculations for the area-based ventilation requirement (***Ra***) of the fieldhouse to generate new minimum OA airflows based on current ventilation standards.

6.3 SUBMETERING

Many assumptions regarding the actual loads being used by different process had to be made to proceed with the analyses above. The old maxim applies that “you can’t manage what you don’t measure”. Submetering of discrete usages would allow for accurately assigning energy usage of building energy systems and provide a more thorough understanding of loads and ongoing building performance.

Submetering allows for:

- a targeted approach to identifying and reducing needless waste;
- gathering energy use data to guide future equipment design at life cycle; and,
- generating feedback to inform and improve maintenance.

ERG recommends the Principia undertake a thorough review of systems and processes to determine where such submetering would have the most benefit and include this submetering along with the upgrades that are being made. In doing this, these costs might be defrayed to some extent by including them in costs where Ameren incentive payments are maxed out.

Crafton systems that should be considered for submetering are:

- Water to the Building
- Pool, Spa, and DHW make-up water
- Condensate from the PoolPaks
- Pool pump GPM and Filter pressure drop
- BTU meter on pool heater and CHWP loop
- Others to be determined

It is important that whole buildings (or complex of buildings) energy usage be reasonably accurately measured in order to understand how the energy is being used. For instance, Figures 3.1 and 3.2 illustrate how ERG was able to regress these utility data and normalize usage based on number of days in a billing period and the average outdoor air temperature of each billing period. Not only does it provide for an actual equation of usage (above the chart – one for cooling seasons and one for heating seasons), but it also allows one to graphically review the variations in usage and begin to seeks operational reasons for why there may be large variances (e.g., why does gas usage around 38°F have such a wide range of response from 40 to 150 Therms per day – this seems to indicate operational problems, not actual building heating loads). The attached case study for the Eden Theological Seminary boiler plant replacement (steam to hot water conversion) clearly shows how ERG can use the equations from before to calculate what the usage would have been – using the prior equations – and compare that directly to current actual usage and the new equations of performance. This illustrates the DOE promulgated International Performance Measurement and Verification Protocol (IPMVP) (Option C Whole Facility Savings).

Also attached is a study done at the Donald Danforth Plant Science Center (PSC) where there were multiple measures implemented over time such that the data were able to illustrate the incremental improvements that result from various measures (Figure 2). The “red dots” represent the impact of recommissioning (reducing) the Outdoor Air Requirements (Jan 2005) and these benefits are ultimately subsumed in the “after” equations (and lines) that are primarily due to boiler changes (July 2005) from non-condensing to condensing boilers (note the building was barely 4 years old). Note that without having these data available, ERG would not have been able to generate the measured results presented in Figure 3, which impressed the board enough that they gave staff “carte blanche” authorization to pursue any and all further efficiency measures they wanted to implement, since they had already “paid it forward”.

ERG recommends that all buildings of size (to be determined) have their electric data measured and recorded in the BAS. In addition, those buildings on the central plants should have their chilled water and hot water usage measured using BTU meters to measure flow into the buildings and the resulting supply and return water temperatures. This is similar to what Washington University in St. Louis has done and the attached M&V report for the Brauer Engineering Lab building illustrates what ERG was able to do with those data – which is one of the more advanced ERG has done, primarily because we had daily data to work with – which should be the case with the submetering that is suggested here. These data could also be used for educational opportunities on campus or, at least, with the SEM team.

6.4 RAIN-WATER AND CONDENSATE CAPTURE FOR TOWER

In the effort to move from air cooled to water cooled compressors, the Crafton complex may end up with a conventional cooling tower. If this is the case, rainwater should be considered for tower water. It has the advantage of being lower cost for not having to buy it and needing less chemical treatment and blow down (lower TDS). If it were to replace water from a water treatment plant, Ameren has incentives for the energy saved in water treatment plants.

7 ISSUES LOG

1. No boiler minimum run time on boilers to prevent short cycling.
2. Set points for 2 boilers is 60° and 1 boiler is 22°
    a. This means that both boilers are effectively running and are coming on and off-line based on the loop temperature. As a result, the boilers are likely cycling more than necessary, which results in excessive purge cycles reducing the overall efficiency of the boilers.
3. Supplemental heat to PoolPaks is on whenever heating mode is on
    a. This may result in over heating of the pool space, currently the valves to PoolPak 1's auxiliary heat is manually shut off.
4. AHU 1 water valve, when the valve is off, and the fan is off the SA temp is in the 90's. this indicates water passing by the valve. The valve is not a butterfly valve and is a Belimo valve, therefore it should not leak when off.
5. AHUs 1-4 fans running concurrently with exhaust fans during "Vent Mode"
6. Discrepancy between BAS reported air flow at VAV boxes and measured airflow at AHU-5.
7. Chiller running during heating months
    a. Chiller was observed running in December with an OAT of 38°. This was communicated to Principia's Chief Engineer who manually shut down the chiller.
8. AHU-5 Occupancy Schedule
    a. Prior to December 8th AHU 5 was not operating on an occupancy schedule. When the chiller was manually shut down, AHU 5 suddenly started following a preprogramed occupancy schedule.
9. Energy Recovery Wheel:
    a. ERV bypass damper was 100% open when outside air temp was in the single digits and the freeze stat was 1° from setting off the alarm. This programing is problematic.
    b. The current programming of the energy recovery wheel of AHU-5 does not allow for an economizer mode. The wheel operates during economizer temperatures, mitigating intake air temperatures and thus requiring mechanical cooling when cooling is available from outdoor air temperatures.
    c. The programming for the wheel bypass damper is malfunctioning, it appears to be modified demand-control programming which is inappropriate for this air handler.
    d. Thus, the programming for economizer-enabling systems is working incorrectly, and "free" cooling during economizer outdoor air temperatures is unreliable or unavailable.
    e. The programming on the wheel bypass damper also causes the energy recovery wheel to be bypassed at times when it would be very beneficial – for example, the ERV bypass damper was observed 100% open when outside air temp was in the single digits. This may be caused by inappropriate manual over-ride of the damper.
    f. Without an outdoor air intake wheel bypass, which is the preferred OA bypass for ERVs, an effective economizer operation would involve shutting off the wheel when enthalpy calculations suggest that OAT can provide free cooling.
    g. The Control Heat Wheel program needs to be modified to return the heat recovery wheel to operation when outside air temperature exceeds return air temperature by a 2°F dead band. This will help to optimize utilization of the energy recovery wheel.