Ohio Lean Building and Workforce Development Project Provides Students with Real-World Experience

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Introduction

Energy efficiency measures with respect to buildings, both commercial and residential, can result in a significant reduction in the building's energy use. Many energy efficient measures offer a short investment payback time. Therefore, energy efficiency measures offer a solution to both diminishing fossil fuel resources and global warming effects from burning fossil fuel. It is important to teach students in colleges and universities how to conduct energy assessments and to prepare reports outlining energy efficiency measures. This project is such a program; it teaches students how to conduct commercial energy assessments, from performing a utility analysis, to performing the actual field assessment, to writing the energy efficiency measures and the final report. It also demonstrates how a partnership can be formed between several colleges and universities and describes how funding can be obtained to support student tuition and internships. Assessment tools like reporting formats, energy efficiency assessment software relevant to commercial building assessments, can be obtained from established industrial assessment programs. This paper demonstrates how the assessment procedures can be developed to focus on no-cost or low-cost energy efficiency measures that companies can implement.

Obtaining Funding

The Ohio Department Services Agency solicited a Request for Proposal (RFP) for energy efficiency projects. Under the leadership of Dr. Kelly Kissock of the University of Dayton, the University of Dayton and Sinclair College partnered on a proposal titled "Ohio Lean Building and Workforce Development." The purpose of the proposed project was to train university and college students to conduct ASHRAE Level II commercial energy assessments. It was proposed that two additional university and college partners from different geographic locations within the State of Ohio be included. The proposed deliverables of the project included performing a total of 49 commercial energy assessments and training a minimum of thirty-six students. Priority was to be given to government and educational facilities for the assessments. The proposal for this grant was awarded.

Program Organization

The proposal for this grant was submitted by the University of Dayton Research Institute. Therefore, the University of Dayton was responsible for submitting all progress, financial, and final reports. Sinclair was responsible for obtaining and training two additional partners. The assessment tools, as described above, were obtained from the University of Dayton Industrial Assessment Center's "Energy Efficiency Guidebook" which is available free of charge at http://academic.udayton.edu/kissock/http/research/EnergySoftware.htm. The University of Dayton Industrial Assessment Center is one of twenty-six Department of Energy funded Centers. It has been in operation since the early 1980's and has completed over 950 industrial assessments. In the years of operation, the Center has developed many spreadsheets, software programs, and report formats which it made available to the Ohio Lean Building Project (OLBP). Colleges and universities wishing to replicate such a program would also have access to the "Energy Efficiency Guidebook."

Formal Program Goals

The program's goals:

1. Train the next generation of energy engineers and technicians in building energy efficiency.
2. Make Ohio's buildings more energy efficient by providing actionable information about cutting edge energy-efficiency technologies and techniques.
3. Improve the practice of energy efficiency by disseminating best practices through seminars, conferences and papers.

Student Requirements, Expectations and Learning Assessment Rubric

The students selected to participate in the program were required to have a background in heating, ventilation, and air conditioning (HVAC) either by experience or field of study. They also were required to have excellent math, computer and communication skills, both written and verbal, as well as being proficient with Excel. Throughout the program the students were required to:

- Develop skills to communicate with building operators to collect building and utility information and to schedule assessments.
- Develop the ability to calculate the unit cost of natural gas and both unit and demand cost of electricity
- Develop the ability to perform a complete utility analysis using linear regression analysis to determine the:
  - Heating slope
  - Natural gas base load
  - Cooling slope
  - Electric base load
- Develop the skills to locate data loggers and sensors and launch such equipment
- Develop the ability to calculate the estimated energy, cost and CO_2 saving associated with an energy efficiency measure
- Develop the ability to write the energy efficiency measure
- Develop the ability to write a complete, format report.

The students were assessed on their ability to perform these activities.

Energy Assessment Procedure

The energy assessment format initiated consisted of:

1. Utility analysis
   a. Linear regression analysis of natural gas and electric use
2. Building specification collection
   a. Building construction data and square footage

3. Site data collection and logging
    a. Occupancy times
    b. Data logging of HVAC system
    c. Lighting type and number
4. Identification of no-cost and low-cost energy efficient measures (EEM)
    a. Install demand ventilation control to reduce outdoor air
    b. Schedule equipment operation with occupancy
    c. Reduce reheat by reducing minimum air flow in VAV system
    d. Install VFD control on constant speed pumps and fans
    e. Relocate VFD pressure sensor to improve variable speed pump and fan flow control

Examples of Assessment Procedures

Utility Analysis

A minimum of one full year of natural gas and electric bills was obtained for the building before the on-site assessment was conducted. A linear regression analysis was performed by the students on the utility usage. An example of a linear regression analysis of natural gas usage for a facility is shown below in Figure 1.

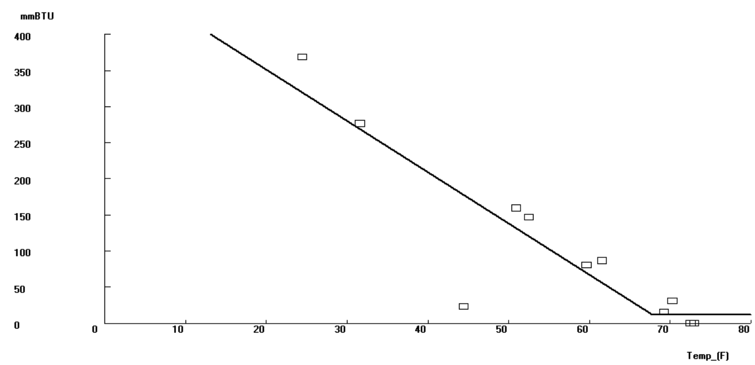


Figure 1. Linear Regression Analysis of Facility Natural Gas Use

From this analysis it was determined the "heating Slope" was 7.10 $mmBtu/mo$-^oF, the change point temperature, the temperature at which the heating system turns on, is 67.8^oF, and the temperature independent natural gas use was 11.50 $mmBtu/mo$. Natural gas use per month is shown in Figure 2 below.

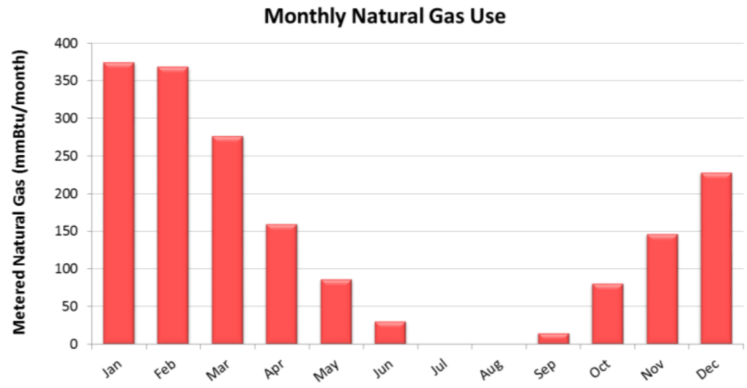


Figure 2. Natural Gas Use per Month

The linear regression for the electric use of this facility is shown below in Figure 3.

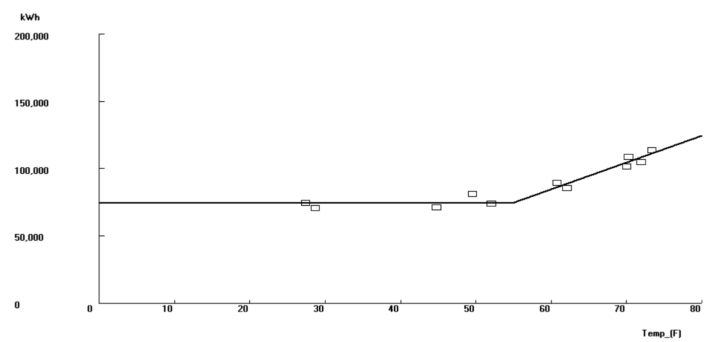


Figure 3. Linear Regression Analysis of Facility Electric Use

From this analysis the students determined that the "cooling slope" was 1,986, $kWh/mo\text{-}^{\circ}F$, the change point temperature, the temperature at which the cooling system turns on, is $54.8^{o}F$, and the temperature independent electric use was 74,391 kWh/mo. Electric use per month is shown in Figure 4 below.

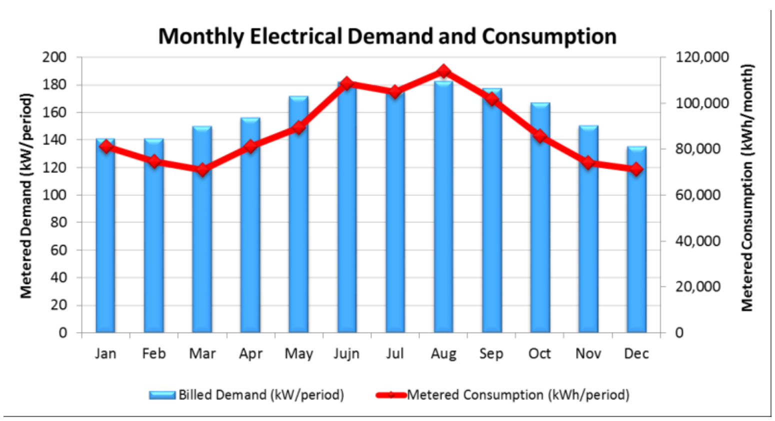


Figure 4. Electric Use per Month

Building Specification Collection and Site Data Collection and Logging

The site visit consisted of collecting building specifications, counting lighting and determining the lighting schedule, collecting HVAC equipment specifications and schedule, HVAC equipment data logging and trending, and occupancy schedule.

Below in Figure 5, students are collecting information from a roof-top unit. They determine if the roof top unit has both heating and cooling, the capacity of each, mmBtu/hour heating and tons cooling. Care is given to determine if the unit has a functioning economizer. If the facility has the capability for trending, that data is obtained; outdoor, return, mixed and supply air temperatures are recorded to determine the functionality of the economizer. The return and outdoor $CO_2\ ppm$ is also measured to determine if the outdoor air percentage could be reduced. If trending was not available, data loggers were installed to collect the desired data

Figure 5. Student Gathering Information from Roof-Top Unit

Figure 6 below shows screen copies of a building automation system from which trending was obtained.

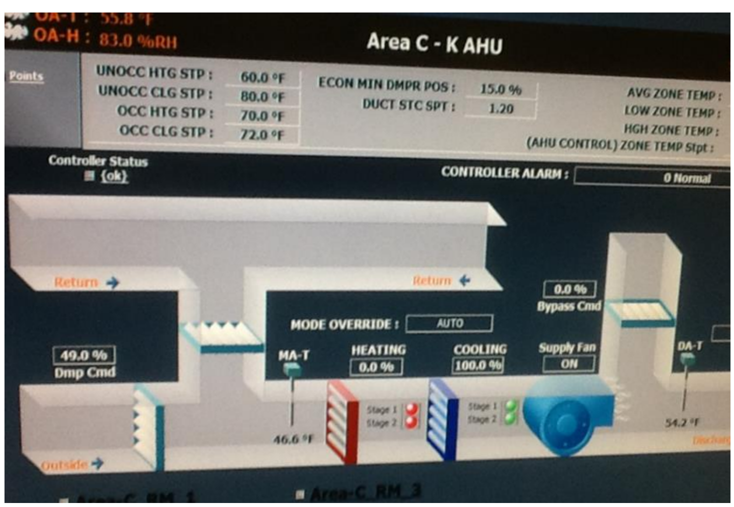


Figure 6. Screen Copy of Building Automation System

Figure 7, 8, 9 and 10 below demonstrates analysis of the above data with respect to the economizer operation.

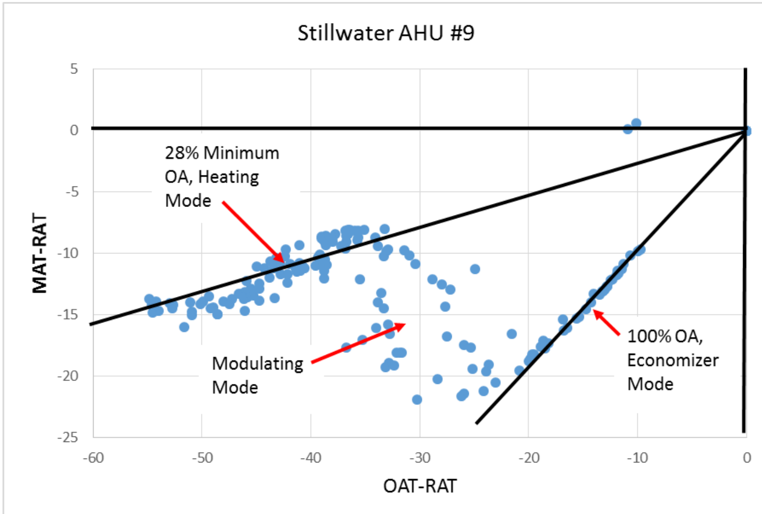


Figure 7. Mixed Air Temperature – Return Air Temperature Plotted over Outdoor Air Temperature – Return Air Temperature

Figure 7 above shows the economizer is correctly using 100% outdoor air in the economizer mode and then modulates to minimum outdoor air in the heating mode. However, the current percentage outdoor air of 28% can be reduced to 10%, providing energy, cost and CO_2 savings. The student's calculations for determining the minimum outdoor air are given below. The equation for minimum outdoor air:

$$Minimum\ Outdoor\ Air = \frac{CO_2\ ppm\ in\ Return\ Air - CO_2\ ppm\ Mixed\ Air}{Target\ Maximum\ CO_2\ ppm - CO_2\ ppm\ Outdoor\ Air} \qquad Eq.1$$

The $CO_2\ ppm$ in the mixed air is determined by the following equation:

$$CO_2\ ppm\ Mixed\ Air = \%\ OA \times CO_2\ ppm\ OA + (1 - \%\ OA) \times CO_2\ ppm\ RA \qquad Eq.2$$

With an upper limit of $800\ ppm\ CO_2$ in the return air, $248\ ppm\ CO_2$ in the outdoor air and $479\ ppm\ CO_2$ in the return air, the minimum outdoor air of 12% is determined. The savings which will result by reducing the outdoor air from 28% to 12%, or 16% during the heating season is then calculated. Figure 8 below indicates the heating season is 50^oF and below.

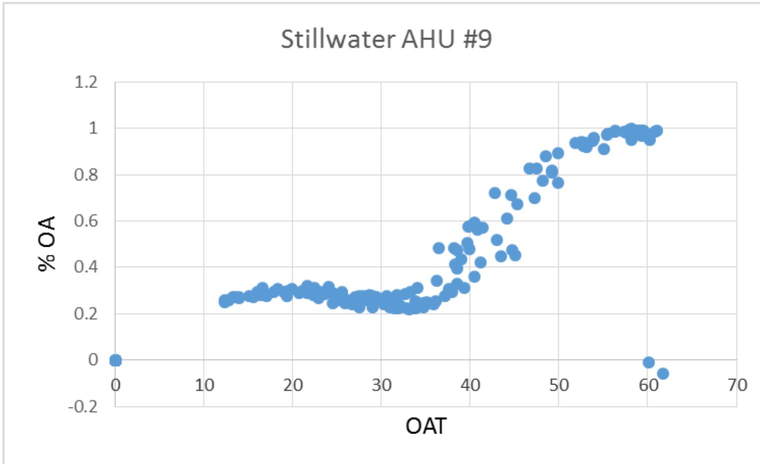


Figure 8. Percentage Outdoor Air over Outdoor Air Temperature

Figure 9 below plots the percentage outdoor air against the enthalpy.

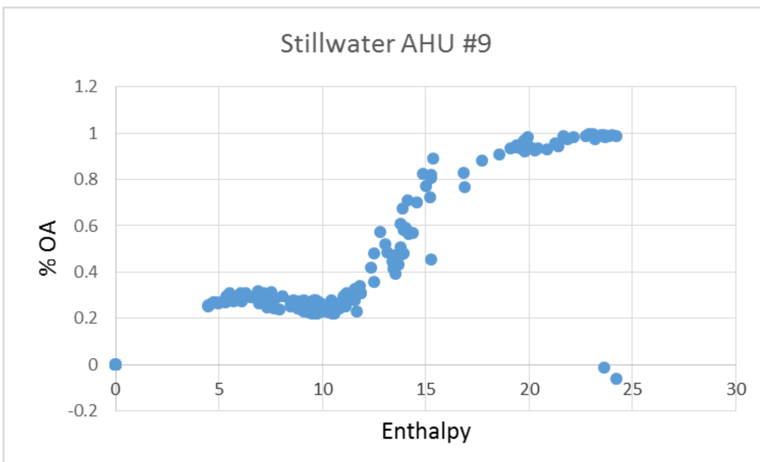


Figure 9. Percentage Outdoor Air over Enthalpy

Figure 10 below shows hot and cold water temperatures. A transition in hot water temperature can be seen between $40^{o}F\ and\ 50^{o}F$. Therefore, the students used a heating outdoor temperature change point of 50^{o}F.

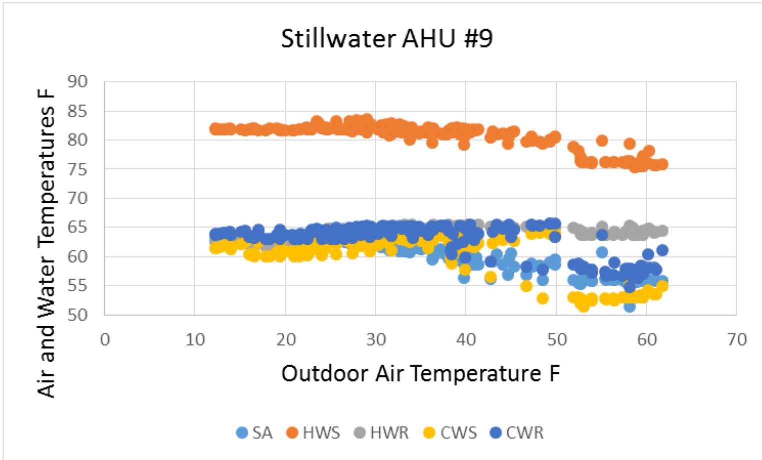


Figure 10. Supply Air Temperature, Hot and Cold Supply and Return Water Temperatures,

Example of Analysis of HVAC Data Logging

AHU #9 delivers 6,000 cfm. A TMY3 weather file, available at http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/ was used to calculate the energy, cost and CO_2 savings. The equation is:

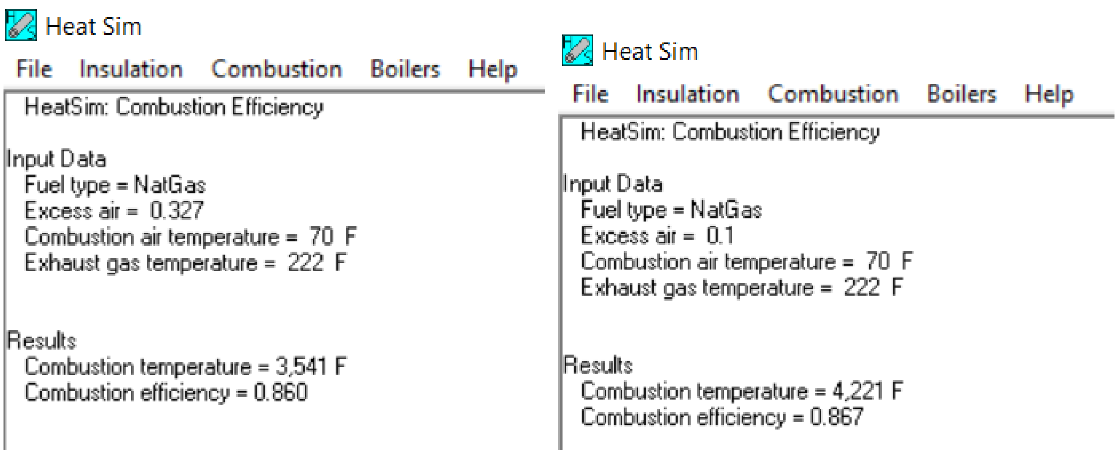
$$Savings = TOA \leq 50^oF \sum_{hr=1}^{hr=8760} \rho_{air} \times C_{p\ air} \frac{60\ min}{hr} \times cfm \times \%\ reduction \times \frac{\$}{Btu} \qquad Eq.3$$

The annual savings are 71 MMBtu, $350 and 3.8 $tonnes\ of\ CO_2$.

Data Collection and Combustion Analysis of Boiler

Figure 11 below shows a student collecting data such as MMBtu/hour from a boiler. The students performed a combustion analysis on all boilers to determine the combustion efficiency, the CO ppm in the undiluted flue gas, and the percent of excess combustion air. If the CO exceeded 25 ppm, it was recommended to have the boiler serviced. If the excess combustion air was greater than 10%, the percentage recommended by the Department of Energy, calculations were performed to determine the estimated savings from adjusting the excess air to the recommended percentage. Figure 12 below is the printout from HeatSim indication a 0.7% increase in efficiency by reducing the excess combustion air form 32.7% to 10%.

Figure 11. Students Recording Specifications from a Boiler



Heat Sim
File Insulation Combustion Boilers Help
HeatSim: Combustion Efficiency

Input Data
Fuel type = NatGas
Excess air = 0.327
Combustion air temperature = 70 F
Exhaust gas temperature = 222 F

Results
Combustion temperature = 3,541 F
Combustion efficiency = 0.860

Heat Sim
File Insulation Combustion Boilers Help
HeatSim: Combustion Efficiency

Input Data
Fuel type = NatGas
Excess air = 0.1
Combustion air temperature = 70 F
Exhaust gas temperature = 222 F

Results
Combustion temperature = 4,221 F
Combustion efficiency = 0.867

Figure 12. Printout for HeatSim, Available Free at
http://academic.udayton.edu/kissock/http/research/EnergySoftware.htm

Figure 13 below shows a student obtaining specifications from a chiller. Trending or data logging was also an important part of the analysis of the chilled water systems.

Figure 13. Students Recording Specifications from a Chiller

Sharing of Knowledge Gained

As knowledge was obtained about increasing the efficiency of mechanical systems, training sessions were conducted to share that knowledge with all the partners in the project. The Figure 14 below shows one of the training sessions.

Figure 14. Training University Faculty and Students in Energy Efficiency

Partners

Figure 15 below lists the four schools who participated in the Ohio Lean Building and Workforce Development Project.

UNIVERSITY of DAYTON | SINCLAIR COLLEGE | CLEVELAND STATE UNIVERSITY 1964 | ZANE STATE COLLEGE ZSC

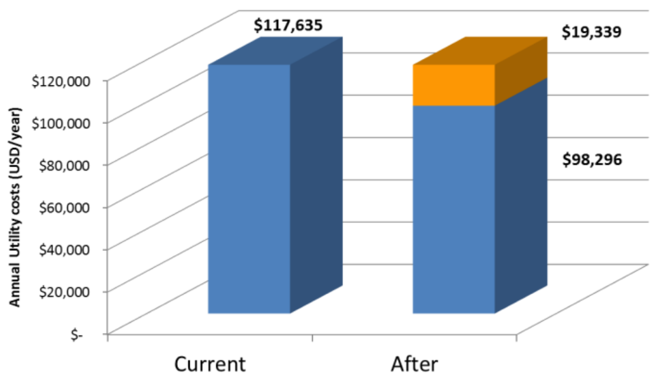
Figure 15. The Four Participating Schools: University of Dayton, Sinclair College, University of Cleveland and Zane State College

Examples of Building and Assessment Results

Below are some examples of the 49 assessments conducted. The EEM's, energy efficient measures and the annual percent savings for cost, energy and CO_2 are given.

Goodwill Easter Seals Miami Valley by the University of Dayton

Figure 16. Goodwill Easter Seals Miami Valley



16.4% Cost Savings

Figure 17. Original Utility Cost and Estimated Savings for Goodwill Easter Seals

Recommended Energy Efficiency Measures	Annual Savings			Implementation cost	10-year Internal Rate of Return
	Electric (kWh)	Gas/Fuel (mmBTU)	Cost (USD)		
1. LED retrofit from T8	155,394	-	$ 15,852	$ 49,639	30%
2. Computer Scheduling (community and office computers)	2,432	-	$ 246	$ -	Infinite
3. Control Set Points for ERV Natural Gas Heating	(21,756)	490	$ 1,555	$ -	Infinite
4. Scheduling of Heat Pumps and ERVs	827	225	$ 1,686	$ -	Infinite
Total	**136,896**	**715**	**$ 19,339**	**$ 49,639**	**37%**

16.4% Cost Savings

Figure 18. List of EEM's for Goodwill Easter Seals

Montgomery County Animal Resource Center by Sinclair Community College

Figure 19. Montgomery County Animal Resource Center

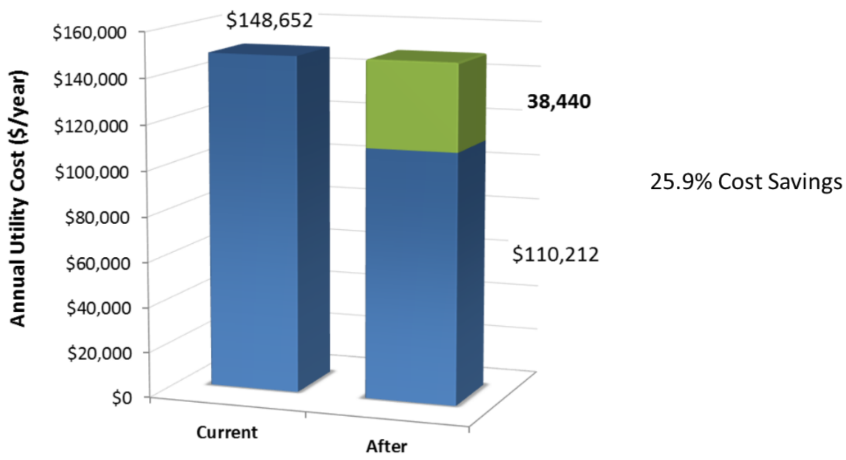


Figure 20. Original Utility Cost and Estimated Savings for Montgomery County Animal Resource Center

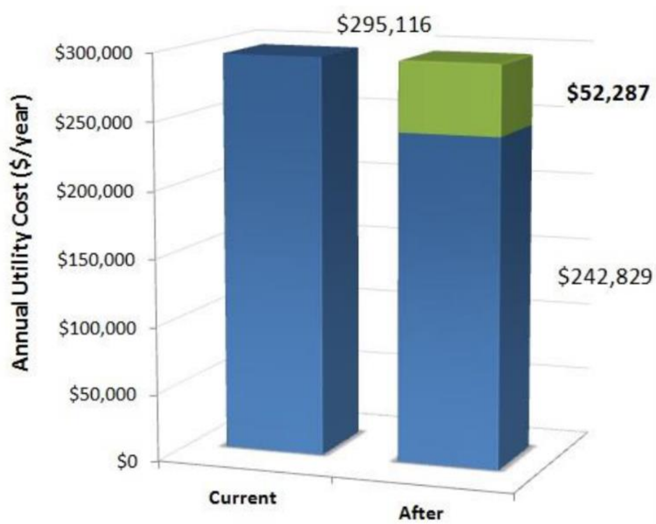
	Assessment Recommendations	Annual Savings		Project Cost	Simple Payback	10 year Internal Rate of Return
		CO_2 (Tonnes)	Dollars			
Lighting						
1	Replace Metal Halide Bulbs with LED Bulbs	50	$8,227	$17,149	26 months	50%
2	Replace Fluorescent Bulbs with LED Bulbs	39	$5,796	$11,515	24 months	53%
	Total	89	$14,023	$28,664	25 months	51%
HVAC						
3	Install ERV to Reduce Outdoor Air	98	$12,082	$57,800	58 months	19%
4	Reprogram AHU 1-4 to Preheat to 32F Only	94	$11,675	$5,000	6 months	237%
	Total	192	$23,757	$62,800	32 months	39%
Process Heating						
5	Reduce Excess Combustion Air to 10% on Boiler	5	$660	$400	8 months	168%
	Total	5	$660	$400	8 months	168%
Assessment Recommendations Total		**286**	**38,440**	**91,864**	**29 months**	**42%**

25.9% Cost Savings

Figure 21. List of EEM’s for Montgomery County Animal Resource Center

Cleveland State University Plant Services by Cleveland State University

Figure 22. Cleveland State University Plant Services



17.7% Cost Savings

Figure 23. Original Utility Cost and Estimated Savings for Cleveland State University Plant Services

	Assessment Recommendations	Annual Savings CO_2 (Tonnes)	Annual Savings Dollars	Project Cost	Simple Payback	10 year Internal Rate of Return
Motors						
1	Replace Smooth drives to Notched belt drives	3	$438	$0	< 1 month	Infinite
	Total	3	$438	$0	< 1 month	Infinite
HVAC						
2	Install Demand Ventilation	107	$44,277	$3,000	1month	1479%
3	VFD on Chill water pumps	19	$1,964	$5,150	32 months	40%
4	VFD on Cooling Tower Fan motors	9	$968	$5,150	104months	16%
	Total	135	$47,209	$13,300	4 months	358%
Lighting						
5	Replace Fluorescent Bulbs with LEDs	40	$4,640	$26,190	68 months	15%
	Total	40	$4,640	$26,190	68 months	15%
Assessment Recommendations Total		**210**	**$52,287**	**$39,490**	**10 months**	136%

17.7% Cost Savings

Figure 24. List of EEM's Cleveland State University Plant Services

Muskingum County Library by Zane State College

Figure 25. Muskingum County Library

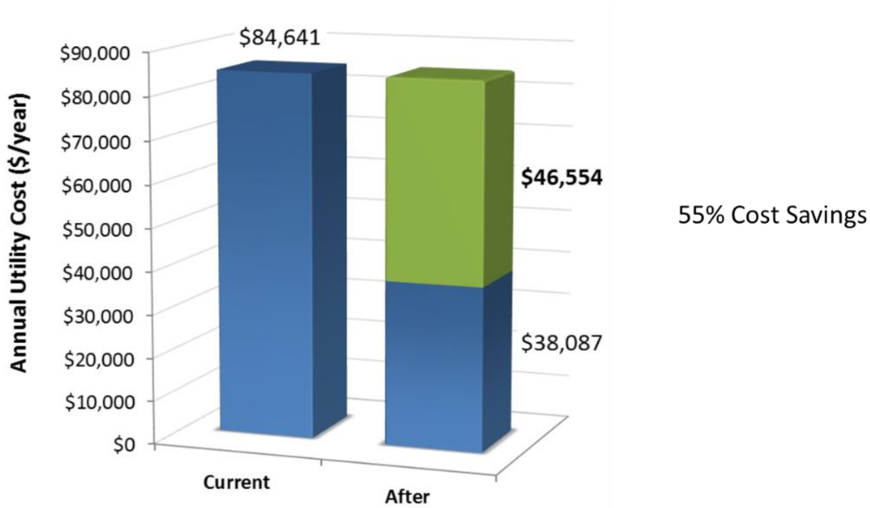


Figure 26. Original Utility Cost and Estimated Savings for Muskingum County Library

	Assessment Recommendations	Annual Savings: CO_2 (Tonnes)	Annual Savings: Dollars	Project Cost	Simple Payback	10 year Internal Rate of Return
Motors						
1	Install VFD's on Air Handling Units	145	$24,698	$23,025	12 months	110%
2	Install VFD's on Hot and Chilled Water Pumps	14	$2,406	$3,700	19 months	68%
3	Replace Smooth Belt with Notched Belts	5	$931	$0	< 1 month	Infinite
	Total	164	$28,035	$26,725	12 months	108%
Lighting						
4	Replace All Existing lamps with LED Lamps	73	$13,038	$32,731	31 months	41%
	Total	73	$13,038	$32,731	31 months	41%
HVAC						
5	Adjust Economizer Controls	20	$3,363	$3,000	11 months	115%
6	Install Demand Ventilation	13	$2,118	$15,000	8 years	10%
	Total	33	$5,481	$18,000	40 months	31%
Assessment Recommendations Total		**270**	**$46,554**	**$77,456**	**20 months**	**63%**

55% Cost Savings

Figure 27. List of EEM's for Muskingum County Library

Conclusion

The students participating in the program were required to have good communication, organization, math, computer, and writing skills. Particular attention was given to Excel skills. Students were also required to have some background in HVAC systems. Very few students had experience or particular knowledge in commercial HVAC systems. The students were assessed at the completion of the program on their ability to:

- Communicate well
- Collect building data
- Perform a utility analysis
- Organize and schedule assessments
- Estimate energy, cost and CO_2 savings
- Write energy efficiency measures and final reports

Upon completing the program, students demonstrated organization and communication skills, an in-depth knowledge of commercial HVAC systems, data logging, and data analysis procedures. Students also demonstrated good energy efficiency measure recommendation and final report writing skills. The students who participated in the project gained real-world skills which they are taking with them in their future employment.

The participating schools of the Ohio Lean Building and Workforce Development Project conducted 49 commercial energy assessments and trained 36 students in a one year timeline. As the project progressed, expertise was gained with respect to data collection and analysis procedures. A continuing training program with all partners facilitated the sharing of acquired knowledge and skills. The project was structured such that it could be repeated with other colleges and universities in the state and the country. The program will continue for another year with 50% shared cost of the assessment coming from or on behalf of the customer, and 50% of the cost coming from a State grant.