The Ohio State University
Campus as a Living Laboratory

Energy Audit: Reducing the Carbon Footprint of the Olentangy Wetlands Reserve Building

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Executive Summary

Our research project attempts to address potential methods of carbon reduction for implementation at the Olentangy River Wetland Research Park. Through the use of various technologies such as smart grid innovation, efficient lighting, and solar power, Team Energy has developed a comprehensive approach to effectively reduce the carbon emissions of the wetlands building. Team Energy first became interested in carbon reduction at the wetlands building after Lynn McCready, the interim director of the wetlands center, expressed an interest in reducing the carbon footprint of the center.

Team Energy has investigated several carbon reduction methods that are capable of producing measurable energy savings at the wetland center. These methods include energy saving LED light bulbs and innovative smart grid technology to monitor and control the electricity usage at the building. These methods are inexpensive, have a fast payback, and can be easily implemented at the wetlands center.

In addition to these methods, Team Energy discusses the role of solar power at the wetlands building. Ohio has a fantastic solar resource considering its distance from the equator, and solar energy is clean, green, and renewable. The potential utilization of solar power at the wetlands building offers management a viable option to reduce carbon emissions.

As with any project proposal, Team Energy realizes the importance of adequate funding and stakeholder interest. Team energy believes that our micro approach to carbon reduction can gain favorability among benefactors and shareholders through education. Above all, Team Energy desires that our research and solar project be used as a tool for education.

Finally, as the third largest public university in the nation, Team Energy is committed to promote sustainable stewardship here at the Ohio State University. Through education, Team Energy hopes to raise awareness about the benefits of carbon reduction and alternative energy, while helping to facilitate Ohio State's long term goal of carbon neutrality. If not us, who?

Introduction

Over the past several decades, climate change, and the effects associated with it, has emerged as global issue. Societies are dependent on fossil fuels, and this dependence grows daily. To address these issues, Nation States and NGO's (Non-Government Organizations) have begun to address climate change at the macro level. Their primary focus has been to reduce carbon emissions through policy and technology. While Team Energy is in agreement with these strategies, we propose that a micro approach to carbon reduction is needed as well. This approach considers how individual actions and small scale projects can collectively address the large scale issues associated with climate change. Team Energy has constructed a comprehensive micro approach solution to reduce the carbon footprint of the Olentangy wetlands building.

The Olentangy River Wetland Research Park is one of the most comprehensive wetland research and education facilities in the nation. The wetlands reserve is located on a 30-acre site just north of Ohio State's Columbus campus. The engineered reserve was constructed in two main phases: Phase 1 featured the construction of two 2.5-acre marshes and a river water delivery system that was completed in 1994. Phase 2 involved the construction of the wetlands building itself for research and educational purposes, and this phase was completed in 1999 (The Ohio State University 2013).

While the design of the wetlands themselves was carefully scrutinized and evaluated, the design of the building appears to be an afterthought. Because of this, the poor design of the building, along with a poor choice of building materials, has created an energy hog. The result is the construction of a world class wetlands reserve that has added to carbon emissions, instead of reducing them. In an effort to reverse this trend, Team Energy has developed the following solutions that can correct this.

Our research has focused on an array of methods to achieve carbon reduction. More specifically, Team Energy has investigated the components of the building itself to create a checklist of possible solutions. This checklist includes the possible implementation of an updated smart control system to efficiently manage electricity usage, the conversion from fluorescent light bulbs to more energy efficient LED (light emitting diode) lighting, as well as a small scale solar grid. Team Energy has been directly challenged by Lynn McCready, the acting interim director of the wetlands, to reduce the carbon footprint of the wetlands building. In response, Team Energy has developed the following comprehensive approach to accomplish this task. Our micro approach to carbon reduction is based on affordable solutions, and the potential use of green energy and technology to reduce carbon emissions, while simultaneously promoting energy conservation education.

It is our intention to create a model of sustainability at the Olentangy Wetlands Reserve that can be used as a template for existing Ohio State campus buildings to follow. Team Energy understands that retrofitting any building is expensive, and that is why we are promoting simple/ efficient methods for existing buildings to implement to reduce their carbon footprint. In an attempt to help accomplish Ohio State's long term goal of reaching carbon neutrality, Team Energy realizes that educating the student body and general public on everyday methods that reduce carbon emissions is our desired goals. We consider our research and project a starting point, and above all, an educational opportunity to discuss the benefits of a micro approach to carbon reduction. Finally, we wish to stress how our research corresponds with Ohio State's future sustainability expectations of "[creating] a living laboratory that will involve all members of the university," and to ". . . lead Ohio State in achieving sustainability in all areas of university operations, including responsible resource use and energy management (UESS 2006)."

Smart Controls and Energy Efficiency

The Olentangy Wetlands Reserve, as we have come to discover, embodies a vast amount of energy inefficiency. The first major issue is the HVAC (heating, ventilating, & air conditioning) system and its flawed design. The air used to cool the building is chilled to 55 degrees Fahrenheit in an outside compressor unit, and then pumped into the wetlands building. This air is already too cold to be used comfortably for air conditioning purposes. So if occupants desire the interior of the building to have an internal air temperature of 65 degrees Fahrenheit, the cooled air needs to be reheated by 10 degrees via the buildings boiler system before it can be distributed to a given location. This extra step requires unnecessary energy consumption, and adds to carbon emissions of the wetlands building. Secondly, much of the lighting inside of the building remains on all night for security reasons, and utilizes environmentally unfriendly fluorescent lighting. In addition, the amount of lighting that is left on in the building in comparison to the average number of people who occupy the building on any given day is additionally inefficient. According to Team Energy's private/random observations of building occupancy, there are usually only five or six people occupying the building at any given time. The amount of lighting that is left on in the building is disproportional to the occupancy rates, and represents yet another example of the degree of energy inefficiency at the wetlands building.

Fortunately for the building and the occupants, there are a few basic upgrades that can be implemented at the building that will save a measurable amount of energy, and these upgrades are fairly easy to install. Thanks to Tracy Willcoxon, the senior energy manager at the McCracken Power plant, and Benjamin Musci a student intern from energy services and sustainability, Team Energy was able to conduct a professional energy audit of the building’s electrical components that focused on lighting, and HVAC controls. The audit revealed inefficiencies in operating systems that when corrected would reduce energy use. In regards to the flawed HVAC design, installing high efficiency motors and variable frequency drives on the fans that pump the air throughout the building would be recommended. In particular, installing a VFD (variable frequency drive) on Air Handler 1's supply fan motor would be recommend, as it has an excellent payback (1.45 yrs), and setting back Air Handler 2’s load from 9 a.m. to 5 a.m. would result in a $1409 savings per year. This gives a payback of .29 years, and all that needs to be done is for an FOD (frequency operation drive) technician to change the controls, no new equipment needs to be installed. This is pretty good because any payback under 4 years is generally recommend. Variable frequency drives change fan power based on the real-time load. For most buildings, HVAC systems are designed for peak load operation, even though peak load conditions only occur less than 5% of the time annually. This means that the fans are using excess energy 95% of the time. The installation of variable frequency drives on the control room fans, and on the external chiller fan would save a measurable amount of energy. For example, a 50% reduction in fan speed will lead to a 90% reduction in energy usage (Piper 2013). In addition, Team Energy would suggest the installation of a nighttime setback program for the HVAC system. A nighttime setback system will automatically shut down the HVAC unit at night, and turn it back on before the arrival of faculty and staff.

The audit also revealed that the most cost effective place to replace existing lights with LED lighting would be in the main corridor. Another solution that our audit revealed is the process of delamping. Delamping is the process of setting the

Figure 1: Light Bulb Comparison Chart

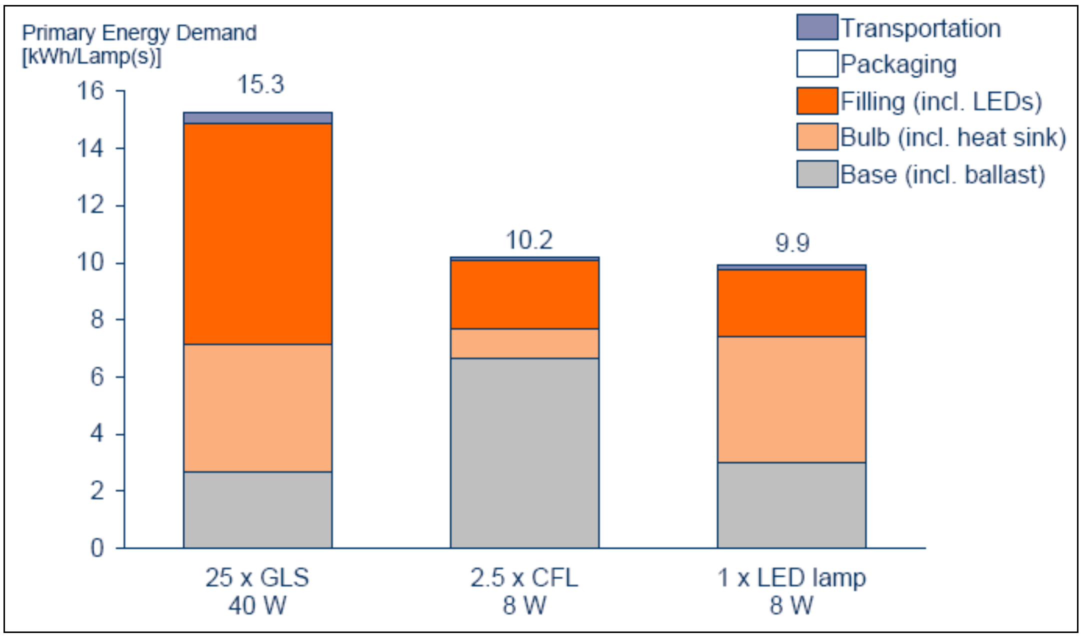

Figure 1 shows the total amount of energy needed to create different bulbs, although the difference between LED's and CFL's is small, the savings add up, as discussed below (EarthEasy 2012).

lights in a particular room to the optimal brightness based on the natural sunlight that a given room receives. Based on the abundance of large bay windows throughout the building, this process could result in significant energy savings. To address lighting issues related to the wetlands building, Team Energy suggests the installation of LED lights where feasible. Because the building currently utilizes fluorescent lights, LED bulbs seem to be the most viable option for lighting, not only because of their low energy use and cost efficiency, but also because of their technological capabilities. Energy savings between typical lighting sources can be seen below in Figure 1.

When considering energy efficiency only, LED's and compact fluorescents look very similar in energy consumption, only having a 0.3 kilowatt difference between them. However, when we consider the 120 lights inside of the wetlands building, this 0.3 kilowatt difference adds up to a 36 kilowatt annual difference, which over the lifespan of a building saves a considerable amount of energy, and perhaps just as importantly, is environmentally friendly. Unlike fluorescents lights, LED's contain no mercury. The toxicity of mercury is well known and creates serious long term health problems such as brain, kidney, and lung damage, and contributes to reproductive problems (EPA 2012).

In addition to utilizing LED lighting, the use of strategically placed daylight sensors can automatically shut off or dim lighting once the sun rises, which will save energy and reduce emissions. Dimming is effective because it reduces the total amount of electricity that is flowing through a circuit, thus saving more energy than switching to LED's alone. With the minimal traffic throughout the wetlands building on any given day, occupancy sensors should be implemented to shut the lights off when someone walks out of a bathroom, office, or classroom, saving up to an additional 20% on lighting energy (LECI 2011).

Another energy saving implementation that has potential at the wetlands building are plug-in appliance modules. These modules can work cohesively with occupancy sensors to control appliance use when someone enters or leaves a room. There are several rooms in the wetlands building, and there are many appliances in these separate rooms that are plugged in or on stand-by. Appliances on stand-by use as much as 10% of their total electricity use just by being plugged in (LECI 2011). Team Energy recommends a combination of these implementations, and outlines the potential savings they would produce in Table 1 of the attached appendix (Page 18).

Finally, Team Energy recommends that all of these electrical upgrades be controlled in unison by a system such as the Lutron Smart Grid. A system such as this offers direct control of lighting, shades, HVAC, and other appliances. This is important because most commercial buildings pay for electricity during peak demand times when it is most expensive. To reduce peak consumption, managers must understand rates, building controls, weather, and building occupancy. Research suggests that an automated approach to demand side response is significantly more efficient than the traditional manual responses that make up the majority of U.S. buildings (Kiliccote et al. 2011). A smart grid system has the ability to adjust and control individual electronic components based on the real-time price of electricity and pre-programmed energy saving strategies. A computer with Internet access, combined with a smart meter obtains real-time energy usage, as well as demand responses, and forwards this information to the smart grid system which interprets the data and self-adjusts based on pre-programmed settings. Team Energy is confident that the above recommendations will produce measurable energy savings, thus reducing the carbon footprint of the wetlands building.

Solar Options

The Olentangy Wetlands Reserve building offers a favorable venue for the installation of a solar array. In spite of Ohio's northern geographic location, the state's potential for solar capacity is promising. According to greenenergyohio.org, Ohio averages about 340 kilowatt-hours of solar energy per square meter during daylight hours. With all this free energy easily obtainable, it makes sense to investigate whether or not this resource can be captured and applied toward a beneficial use at the wetlands building.

In the world of small-scale solar operations, there are two basic approaches to capture and store the sun's energy. The first approach uses a photovoltaic system to generate electricity from sunlight. The electricity that is generated from this process is then used to power on site electronic devices. The second approach involves using sunlight to generate heat. The energy from the sun is directly used to heat an object, or to heat a liquid to be used as a radiant heat source.

Team Energy has chosen to investigate the implementation of the first approach, which can further be broken down into various options for the wetlands building. The first option would be to use the power generated from the solar panels to directly power electronic devices at the wetlands building. While some electronic devices such as light emitting diodes (LED's) can run on direct current (DC), the majority of electronic devices use alternating current (AC). Since the power generated from solar is DC, an inverter will be needed for this system to power everyday electronics. A key advantage to this approach is it's potential to operate completely independently of the electrical grid.

The second option would be to divert the power that the solar display creates back into the main electrical grid. An inverter and a smart meter would be needed for this process to convert current and measure energy flow. The idea behind sending power back into the grid is that the electric utility, in this case AEP, would purchase the electricity in the form of credits. These credits could then be applied toward a portion of the buildings monthly electric bill. Although this type of system is being implemented in Ohio, given the current state of Ohio legislation regarding these issues, Team Energy believes option one appears to be our most viable. The main goal of our project and the installation of solar panels is to reduce the carbon emissions of the wetlands building, not to reduce the building's cost of electricity. Thus, to construct a proper cost-benefit analysis, these reductions must be accounted for. Rather than comparing the cost and benefit of our proposal in purely monetary values, it is important that our suggested methods of carbon reduction are put in a numerical form for comparison as well.

Table 1: Cost Benefit Analysis of Solar Power

	Kilowatt Hours (Solar)	Carbon Emissions Remaining (Metric Tons)	Carbon Emissions Reduced/Month (Metric Tons)	Area Solar Panels with Average Efficiency (m^2)	Cost ($)
Reduce Grid Power 25%	6,224.3	13.2	10.4	395.2	79,038.85
Reduce Grid Power 50%	12,448.6	8.8	14.8	790.4	158,077.69
Reduce Grid Power 75%	18,672.9	4.4	19.1	1185.6	237,116.54
Reduce Grid Power 100%	24,897.2	0.0	23.5	1580.8	316,155.38

Table 1 represents four different levels of solar integration.

To construct an accurate cost benefit analysis, Team Energy has collected data from Patrick Smith with the Facilities Operations and Development department here at

Ohio State. This data includes the monthly electricity consumption for the wetlands building dating back to 2003, and on average, the building uses approximately 25,000 kilowatt hours per month. Kilowatt hours can be converted into metric tons of carbon emissions using a simple conversion factor from the Environmental Protection agency: 7.0555×10^{-4} metric tons CO_2 / kWh (EPA 2013). Using this conversion factor, the building's average use of 25,000 kilowatt hours equates to roughly 17.6 metric tons of carbon emissions as shown in **Table 1**. In addition, the amount of carbon emissions is directly proportionate to the amount of energy being used, meaning every bit of energy saved produces a reduction in carbon emissions.

To demonstrate the ranges of reduction associated with different levels of solar production, four levels of reduction are shown above. Analyzing a range of carbon reduction levels allows management to consider an appropriate option for the wetlands building. Team Energy recommends the 25% solar power production level from the above table. However, the table additionally represents a long-term approach to carbon reduction that could eventually lead the wetlands building to energy independence.

In order to calculate the number of solar panels needed to meet the levels of energy specified, a few equations and figures are needed. First, we need to define how much energy can be collected per square meter on a daily basis. In Ohio, every square meter of solar panel can collect roughly 0.45 to 0.6 kilowatt hours of energy per day (USDOE 2013). This range is based on seasonal changes and solar panel efficiency. To provide an estimate for the number of solar panels needed, the amount of energy collected per day is averaged to 0.525 kilowatt hours, as reflected in **Table 1**. Due to the fact that the collection of energy is measured in square meters, the 0.525 kilowatt hours per square meter is then multiplied by the kilowatt hours desired to be harvested from solar energy. This provides an accurate estimate for the total amount of solar panels needed. Finally, every square meter of panel costs roughly $200, (these values were used in Table 1) and were determined from prices set by Xunlight, an instate solar panel manufacturer.

Finances and Stakeholder Interest

One key issue that any project faces is how it will be funded. Our project presents us with a particular set of problems related to securing sources of outside funding. The first problem addresses the method in which Ohio State purchases electricity from American Electric Power (AEP). As opposed to paying for actual kilowatt consumption, Ohio State purchases electricity on a flat rate based on the number of buildings that the campus owns and the square footage of those buildings. When we consider the market share of energy that Ohio State purchases, we can conclude that this flat rate package is cheaper for the university than actually paying for kilowatts consumed. This system offers no incentive for the university to reduce energy consumption because they would still pay the same flat rate. This compounds our problem of reducing the carbon footprint of the wetlands building because we are now forced to solicit outside funds without the capability of being able to show benefactors how their contributions helped the university's bottom line. This narrows our potential revenue sources to groups and individuals who are content with seeing gains in carbon reduction alone.

In addition to soliciting for resources and funding, our project is eligible for the American Taxpayer Relief Act of 2012, H.R. 8, which provides commercial buildings the opportunity to take advantage of federal credits (112th Congress 2013). The Business Energy Investment Tax Credit (as it is known) will cover up to 30% of expenditures, with no maximum limit. Eligible solar projects include equipment that uses solar energy to generate electricity, to heat or cool buildings, and hybrid solar lighting systems. These credits have been extended until December of 2016, and would help reduce the in-house costs of our recommendations.

Finally, Team Energy has secured enough project material to create an actual working example of a micro carbon reduction unit that we have donated to the wetlands building. The unit consists of a 70 watt flexible solar panel that is connected to a charge controller, which keeps the battery from overheating. The controller is then connected to a twelve-volt deep cycle battery that is ultimately connected to a 400 watt inverter that turns direct current into alternating current. The inverter is equipped with three standard outlets and two USB ports. This unit is capable of producing enough electricity to easily charge laptop computers or cell phones, and is available for student use in the wetlands building lobby. Team Energy believes that this accomplishment will solidify our project's credibility, and can be used as a working example to educate and generate shareholder interest in an attempt to cover additional costs not associated with the above-mentioned funding sources. In addition, Team Energy desires that future students build upon the foundation that our model has created, and develop a student sustainability group related to these issues, which would in turn create another avenue for possible funding.

The above-mentioned project is an example of a micro approach to carbon reduction that is based on clean/renewable solar energy. Team Energy's portable charging unit exemplifies the ideas of a micro approach to carbon reduction. Having said this, our project would not have been possible without corporate sponsorship (interested stakeholders). Thanks to our sponsors, (Xunlight, Advanced Auto Parts, O'Reilly's Auto Parts, Lowe's, and Sandy Hill Fruit Farm), Team Energy was able to respond to Lynn McCready's challenge, and actually accomplish the goal of reducing the carbon footprint of the wetlands building. Although our contribution is small, the idea is to expand these types of projects to promote real solutions for emission reductions. Team Energy is confident that with student involvement, corporate sponsorship, federal funding, and stakeholder interest, our educational approach to the reduction of carbon emissions through micro solutions can be successfully implemented one solution at a time.

We feel that our micro solutions offer more than just a casual learning experience. Team Energy believes that the portable charging station mentioned above is a product that is capable of being produced by the engineering department here at Ohio State. In this example, engineering students will be able to utilize lab time to build the individual components of the system, and test them for durability. Meanwhile, earth science students can locate and identify locations on campus where these installations would be most productive, and social science students can identify places where they are most needed. Through this comprehensive approach, education is shared, and products are distributed according to data. This gives students real, hands on experience, while promoting carbon neutralization on campus.

Education and Sustainability

Ohio State is a leader in the collegiate community. From our athletics to our world class medical center, Ohio State sets standards for others to follow. Among these standards is the university's commitment to sustainability. One initiative that Ohio State has implemented is the zero-waste program at Ohio Stadium. The goal of this initiative is to compost 90% of the trash being generated at the stadium. On October 20th 2012, Ohio Stadium achieved its goal of zero waste. This has caused other universities with large stadiums to rethink how they are dealing with their trash, and the quantity of non-compostable trash being generated at these locations. In addition to academics and recycling, Ohio State is a leader in the coal industry. Currently, Ohio State is researching and developing a coal technology that prevents carbon emissions from entering the atmosphere. This process chemically breaks down the coal in a sealed chamber, and captures the carbon. Ohio State is the only university in the country working on this type of coal technology (Ohio State Develops Clean Coal Technology 2013). These are just a few examples of what Ohio State is working on to promote sustainability, and our approach to carbon reduction reflects these "lead by example" values of innovation and education.

In regards to education, one benefit of a solar project is the aspect of having such a project on university property. Ohio State is an institution for learning, and a building such as the wetlands has the capacity to provide a large range of educational benefits to students and people of all ages. Implementation of a working solar unit at the wetlands building grants Ohio State the opportunity to educate visitors on the importance of sustainable energy. Team Energy realizes that people who are unfamiliar with both green and alternative sources of energy may be wary of adopting them. This is due to the various unknowns that are associated with this type of change. People are often hesitant to consider new ideas for a number of reasons. Recognition of these factors only strengthens Team Energy's case for education. We recommend using signage and pamphlets at the Olentangy Wetlands, along with local city and school newspaper articles that promote green energy and alternative energy sources. This broadens the audience and allows the community as a whole to learn from the example set at the wetlands. Additionally, Ohio State could utilize the newly formed EEDS

(Environment, Economy, Development & Sustainability) program to fulfill some of the criteria for the new program by promoting sustainability. The EEDS program was established in 2012, and already has an enrollment of 100 students. Encouraging students to participate in the new major and get involved with projects such as ours offers educational opportunities that benefit students through hands on experience.

In addition to promoting education, a micro approach to carbon reduction requires flexibility. When evaluating the sustainability of other buildings on campus, it is important to remember that there is no fix- all solution, and that every building is unique, and comes with its own unique set of challenges. Not every building will be able to incorporate solar panels alternatives. Efficient lighting or window treatments may set the standard for other buildings across the university. It only takes one building to be a catalyst for change on campus, and our approach to carbon reduction at the wetlands building can be used as a template for other campus facilities to use to evaluate their own energy inefficiencies.

In the realm of public education and transparency, Ohio State has designed a website that is available for public viewing that measures and monitors energy use and consumption for fifteen popular buildings across campus. This data distinguishes energy consumption in terms of use, such as heating and cooling, and gives data on CO_2 emissions. This information is broken down into weekly and monthly observations, and notes use changes from previous years. This allows students to see the benefits of energy saving implementations, such as the installation of energy efficient lighting. For example, if one decides to replace existing lighting in a building with energy efficient LED lighting, students can then see changes in energy consumption on the websites graphs. Team Energy believes that this type of visual awareness is an important aspect in promoting energy conservation because the gains in conservation are both visible and measurable.

In past years, sustainability has always been a cost to a business. What makes Ohio State unique from other colleges is that the university has embraced the benefits of committing to sustainability. Ohio State has started what they believe to be the “business case” for sustainability. The business case for sustainability describes the benefits that come from the implementation of sustainable initiatives. OSU has laid out their business case for sustainability with the appropriate title: Leadership Expectations and Responsible Stewardship. The leadership expectation aspects of the initiative are focused on building campus and community support programs that encourage and embrace sustainable practices. What Ohio State hopes to accomplish in building these communities is for the students to be aware of the importance of OSU's sustainable initiatives, and to bring in people from outside of the university to connect with university sustainability programs.

The Responsible Stewardship part of Ohio State's commitment to sustainability results from the sheer size of the university. The university realizes the importance of a conscious approach to energy and waste management. Ohio State has committed to purchasing 50 megawatts of wind energy, which will directly reduce the amount fossil fuel that the university is using and help build external relationships within the community. This aligns with what Ohio State has labeled the One University approach, and this multifaceted approach to sustainability is reflected in Team Energy's micro approach to carbon reduction by promoting multidisciplinary interaction and education.

Conclusion

The above research and suggestions embrace the idea of a micro approach to carbon reduction. Through our integrated approach to energy savings, Team Energy has accomplished our original objective of promoting education by completing a working model of a micro carbon reduction unit via our portable charging system. In addition to this, if the wetlands management acts upon our suggestions, the carbon footprint of the wetlands building will be reduced significantly. When Team Energy decided to address this problem, we focused on solutions that had a high likelihood of being incorporated, as opposed to some lofty unreal expectations of what we could accomplish in a limited time frame and on zero budget.

As our research and data began to come together, certain solutions to address energy consumption at the wetlands building became more relevant than others. Among these solutions was the installation of a smart grid system to control the buildings demand for electricity. A smart grid system has the ability to adjust and control individual electronic components based on the real-time price of electricity and pre-programmed energy saving strategies. To maximize the efficiency of the smart grid system, Team Energy also recommends replacing all fluorescent lighting with more energy efficient and environmentally friendly LED lighting. These upgrades, along with day lighting techniques, delamping, variable frequency drive updates, and plug-in appliance modules offer a comprehensive approach to carbon reduction that result in measurable energy conservation. These suggestions are based on data collected from our energy audit of the building, and a more detailed account of the technical aspects of these recommended changes can be seen in the attached appendix.

In addition, the idea of integrating a solar display that could reduce the electricity consumption of the wetlands building is an attractive option that Team Energy has thoroughly investigated. Realizing that a complete retrofit to solar power at the wetlands building was an unachievable aspiration, Team Energy focused on a manageable integration that could be used to supply partial power to the wetlands facility. This scaled down approach still offers considerable savings because this integration has the potential to reduce electricity consumption of the facility by as much as 25%. This idea is attractive because it utilizes renewable green energy, and meets the requirements for federal tax credits under the American Taxpayers Relief Act of 2012. Team Energy is confident that with student involvement, corporate sponsorship, federal funding, and stakeholder interest, that our micro approach to carbon reduction can be successfully implemented.

A reoccurring theme that is present in our research and project is the larger idea that Team Energy is passionate about the educational opportunities that are associated with our research and project, and how these themes correspond with Ohio States existing sustainability goals. As the nation's third largest public university, Team Energy feels obligated to ensure that Ohio State leads by example. For this reason, we feel that educating the student body and the general public about the benefits of carbon reduction and alternative energy is our greatest tool. It is our desire to see our micro solutions to carbon reduction embraced at the university level, and perhaps that our model eventually become curriculum for Ohio State students of different disciplines to collectively build and distribute. Our vision is in line with Ohio State's long term sustainability goal of becoming a carbon neutral facility by 2050, and Team Energy is confident that our micro approach to carbon reduction can help to accomplish this goal.

Appendix

LED Lighting

Room	# LED Lamp Retrofitts	LED Cost/Room	Sensor Cost	Total Cost	Payback (Yrs)
0100	4	$ 145.52	$0	$ 145.52	55.2
0100A	8	$ 291.04	$0	$ 291.04	18.4
0101	12	$ 436.56	$0	$ 436.56	55.2
0103 (sensor)	8	$ 291.04	$93	$ 383.54	17.9
0104	36	$ 1,309.68	$0	$ 1,309.68	25.1
0105	2	$ 72.76	$0	$ 72.76	33.9
0105J	2	$ 72.76	$0	$ 72.76	13.6
0107	8	$ 291.04	$0	$ 291.04	5.5
0107A	8	$ 291.04	$0	$ 291.04	7.5
0108	27	$ 982.26	$0	$ 982.26	12.4
0109 (sensor)	8	$ 291.04	$93	$ 383.54	23.9
0113T (sensor)	3	$ 109.14	$93	$ 201.64	11.3
0115T (sensor)	3	$ 109.14	$93	$ 201.64	11.3
0120M	32	$ 1,164.16	$0	$ 1,164.16	46.0
0125	8	$ 291.04	$0	$ 291.04	34.5
0127	8	$ 291.04	$0	$ 291.04	34.5
0128	48	$ 1,746.24	$0	$ 1,746.24	46.0
0129	8	$ 291.04	$0	$ 291.04	55.2
X0100L	14	$ 509.32	$0	$ 509.32	5.5
X0105C	38	$ 1,382.44	$0	$ 1,382.44	2.5
TOTALS	**285**	**$ 10,368.30**	**$ 370.00**	**$ 10,738.30**	10.1

Table 2. Savings Associated with LED retrofitting

This table shows the cost/benefit of retrofitting the listed rooms with LED lighting and occupancy sensors as designated in the table. It lists the number of LED lamps that will be required for each room, the cost of the LED lamps and the occupancy sensors, along with the projected amount of years it will take to pay for itself.

Table 3: Variable Frequency Drive Updates

Annual Energy Savings Estimate for VFD addition and Electric motor efficiency upgrades

Compares VFD capacity control versus other types capacity control.

Location/Use: **AH2 SAF**

To make Comparisons and Estimate Savings, need to know following:

a. Motor horsepower (Total HP that use xx% efficient motors)
b. Cost of Kwh of electricity.
c. Total hours of operation per year.
d. Present method of capacity control (guide vanes, fan curves, discharge vanes, cv's, etc.) That VFD will replace

Efficency Upgrade:

OLD:	**92%**	**eff motors**
	71,265	kwh/yr
	$6,086	per yr
NEW:	**95%**	**eff motors**
	68,789	kwh/yr
	$5,875	per yr
Savings:	**2,476**	kwh/yr
	$211	per yr

Step 1: Converting motor Horsepower to Kw

10 HP x .746 = 7.46 Kw_A

Step 2: Multiply the Adjustable Frequency Drive Power Ratio (from table below) times Kw_A from Step 1.

0.28 Ratio x 7.46 Kw_A = 2.0888 Kw_B (using VFD)

Step 3: Multiply the Power Ratio of the presently employed control (see below) times Kw_A from Step 1.

0.28 Ratio x 7.46 Kw_A = 2.0888 Kw_C (method now employed)

Step 4: Subtract Step 2 Kw_B from Step 3 Kw_C.

2.089 Kw_C − 2.089 Kw_B = 0 Kw_D (savings using VFD)

Step 5: Multiply Step 4 KW_D savings, times hours per year of operation, times cost of electricity per KwH.

0 Kw_D x 8760 Hrs x $ $0.0854 $/Kwh = **$ -** | **0** VFD Annual calculated savings kwh/yr

Ratios For Above Calculations:	
Fans at 60% of maximum flow	
Ratio	**Flow Control Method**
0.28	Variable

Ratios For Above Calculations:	
Pumps at 70% of maximum flow	
Ratio	**Flow Control Method**
0.40	Variable

0.28	Variable Frequency Drive	0.40	Variable Frequency Drive
0.62	Inlet Guide Vane	0.94	Discharge Valve
0.88	Outlet Damper	1.00	Bypass Valve
0.88	Fan	1.00	No control

Above, Table 3 shows the estimated annual energy savings for the variable frequency drivers and motor efficiency upgrades. Included in the table are the calculations for the current kWh/yr energy usage of the motors and the monetary and energy savings that would result from the implementation of variable frequency drives.

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