FINAL REPORT

IPRO 320
Sustainability Planning of IIT Buildings

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INTRODUCTION

Energy consumption is becoming a large problem due to increased cost, increased damage to the environment, and lack of resources. As a result of the supply of resources continuing to decrease and the cost of energy consequently increasing, IIT feels it is necessary to cut energy consumption and cost. Energy-efficient systems and practices, as well as the investment in renewable technologies can assist in achieving greater energy and operating efficiency. It is ethically our responsibility to remedy the depletion of our natural resources.

BACKGROUND

The Illinois Institute of Technology can be compared to a small city, with the campus occupying 120 acres of land. Also in comparison, IIT has an on-site electric and steam generation plant, and owns and operates all of the utility lines between and within the campus buildings. Over 100 years ago the energy using devices and the concept of the campus was conceptualized; however, current thinking and technology must be applied to the existing campus in order to create buildings for the 21st century.

PURPOSE

The objective of IPRO 320, Sustainability Planning of IIT Buildings, is to contribute to the problem solving necessary to implement energy efficiency improvements in existing buildings and to the central steam and electric systems. Alternate possibilities for energy use in context with their building type and surroundings were discovered through research of other university buildings at the University of Chicago, Loyola University, and IIT. This research was used in finding alternate forms of energy generation to secure the sustainability of the IIT campus. Also, thermal images of buildings on all three campuses were analyzed to see where the buildings are losing heat.

RESEARCH METHODOLOGY

Data Analysis / Facilities Research

- Met with facility member from each campus and discussed current systems in place
- Toured facilities to better understand the scale that utilities are produced and monitored
- Received Excel files with utilities breakdowns and costs
- Calculated electricity, gas and steam costs per square foot of building space
- Wrote about problems encountered in data analysis

University Research

- Selected universities to research
- Researched the demographics of each university, including history, campus size, number of students, and energy consumption
- Invited guest speakers to learn more about the mechanical systems of each university
- Chose three buildings at each campus to research the following, construction material, R-value, thermal images of all facades
- Obtained wall section details from original building drawings
- Analyzed findings, including where buildings lost energy and where they did well

ASSIGNMENTS

Research teams were divided into three groups to study IIT (Chrissy and Sean), University of Chicago (Melissa and Despina), and Loyola University (Joanna, Craig and Guillermo). The teams then researched their respective universities and the architectural factors that contribute to energy efficiency or the lack of energy efficiency. Another person titled Utilities and Data Engineering

Analyzing, Liz, was designated to study the numbers that were gathered for electricity on all three campuses, and draw conclusions from the findings. Alternative Methods for Sustainability was then studied by another team member, Eugene, concentrating primarily on Geothermal.

Loyola University Research Team	Joanna Ruiz Craig Lanum Guillermo Gomez
University of Chicago Research Team	Melissa Friel Despina Zouridis
Illinois Institute of Technology Research Team	Chrissy Atterberry Sean Thompson
Utilities and Data Engineering Analyzing	Elizabeth Bilitz
Alternative Methods for Sustainability – Geothermal	Eugene Gargas

The policies and grants research focused primarily on the recycling programs at IIT, Loyola, and UIC. U of C was unable to find the data necessary for an accurate comparison. The team member covering this area, Erica, was a team leader and also took on the role of preparing deliverables. The final member, Anna, also served as a team leader with the primary task of creating the IPRO's website. This member also organized the majority of the deliverables and oversaw the team's meetings.

Policies and Grants Research	Erica Kahr
Minute Taker / Agenda Maker	Erica Kahr
Master Schedule Maker	Joanna Ruiz
Web Site Designer / Document Writing	Anna Dannhausen

OBSTACLES

The main obstacles encountered in the research are a result of holes in the given data. Loyola University does not meter their steam usage per building per year, as do IIT and U of C. IIT doesn't break down the cost per pound of steam, which hindered the comparison with U of C. Since each university uses different methods of energy, its hard to compare the utilities cost per building. The electricity per building could include not only electricity used for heating and cooling, but also for computers, copiers and other equipment. The given information could also have been interpreted wrong, as someone not familiar with the system was interpreting it for this analysis. While all the universities were helpful to the team by giving tours and discussing in detail their utilities systems, there was difficulty getting some information, as is evident by some obvious holes in the data.

One of the main obstacles that the IIT team encountered was finding architectural drawings for Main Building. These drawings were needed to determine the R-values of a typical wall. Given the age of Main Building, it was nearly impossible to find a set of drawings.

Another large challenge for our team was finding a general understanding of heating and cooling systems. As our team is composed of members who are not familiar with these systems, background research was a must.

RESULTS

Universities in the Chicago area mainly rely on steam to heat their academic, dormitory and laboratory buildings. This is due to the ability to produce millions of pounds of steam in-house on an annual basis. The steam price to the university is dependent upon the cost of natural gas to run the turbines and the boilers, labor cost, maintenance, and the occasional upgrade of the system. The University of Chicago estimates their steam cost for the year 2006 around $0.01888 per pound produced. Such estimates were not available from Loyola University or IIT. Electricity is used for lighting, appliances and some heating and cooling depending on the building. The cost of electricity per kilowatt hour (KWH) is determined by the contract each university sets up with Common Wealth Edison, the Chicago area electric company. Gas is purchased for use in the production of steam, but can also be utilized for hot water boilers in areas where steam is not used. Air condition and other types of climate control come from anything from individual AC window units to complex cold water “chiller” systems.

Each university uses a mixture of old and new technology in their utilities management. All the steam plants were formerly coal-burning, but as EPA regulations and efficiency demands rose, these boilers were disabled in favor of newer, cleaner technology. IIT just replaced some of its older boilers with two brand new boilers that promise more efficient production. U of C is in the groundbreaking stages of a new chiller and steam facilities. Most buildings are monitored monthly through meter readings, which help determine changes in utilities costs per square foot of space. Saving money on energy doesn’t stop when the steam/hot or cold water leave the plant. Piping needs to be monitored regularly to make sure that they are not leaking heat. Pipes are generally insulated and sometimes buried in tunnels to prevent loss of heat as the steam travels through the system. Loyola is unique because their steam usage is monitored and regulated automatically. This means that if one building doesn’t need as much steam because its limit has been reached, that steam is passed on to another part of the system to be used. This prevents overloading the system with unwanted steam. On the reverse, U of C has such a large campus and budget that individual monitoring of buildings is not something they have chosen to do. Rather, they pump an estimated amount of steam from the steam plant and regulate at each building manually. IIT is somewhere in the middle of the other two universities. While IIT does not have the automation that Loyola does, it also does not pump out steam at the rate that U of C does. In recent years, IIT has taken far-lying buildings off the main steam line, choosing instead to heat and cool alternatively. This means that the steam does not have to travel as far, and therefore will not lose as much heat and pressure.

The amount of heat that is lost due to un-insulated pipes, which was discovered through the use of the thermal imaging camera, is one of the main findings on the IIT Campus. This is evident mainly in the northeast corner of Main Building. The un-insulated pipes have a temperature reading of around 240˚F, whereas the temperature of the insulated pipes read 100˚F less. Another location on the IIT Campus where the un-insulated pipes are an issue is in the fraternity quad. Here, even though the pipes are underground, the amount of heat that is radiated is causing the grass to die. An interesting discovery that was found was that while Crown Hall is mainly glass and steel, heat loss through the windows is minimal, compared to Main Building and Perlstein Hall.

The Loyola campus has done significant remodeling and improvements on their buildings. Due to the proximity of the lake, there is an even greater care taken to have insulated buildings. The three buildings chosen to analyze are all along-side each other moving west from the lake. What was noticed about the buildings was that a large amount of heat loss was occurring where the building meets the ground. Corners as well are releasing the most heat from the building. The closest building to the lake, Mundelein Center is currently being renovated. There was noticeable heat loss in exterior piping that was not insulated. There was also heat loss at the entrance which can be avoided with a double entry. With Chicago winds coming from the lake the double entrance can be an easy solution to avoiding heat loss when entering and exiting a building on the campus. Quinlan Life Sciences center is one of the campus' newest buildings. Sharing a side with Flanner on the west side and east of it lays Mundelein center. The Quinlan also has its weakness in the heat loss where the building meets the ground. Although most of the building is glazed there was not substantial heat loss from it. The last building which was analyzed was Flanner Hall. This building is almost completely brick so very little loss was due to glazing. A leak on the west side of the building was noticed which showed heat loss, but not substantial heat loss. As the R values of the buildings are calculated, a stronger analysis will be able to be made.

When we first began researching the three different buildings at the University of Chicago, we originally thought that the Harper Memorial Library would be the least efficient because of its Gothic design, small leaded glass windows, stone façade, etc. However, when we computed the R values for each individual building, we discovered that the Mott building was in fact the least efficient of all three buildings. We found, through the thermal imaging camera, that all three buildings shared the same characteristics for major sources of heat loss. For example, where the glazing meets the concrete/steel, and since the glazing is only single paned. The Mott building showed the greatest heat loss here (where the glazing meets the steel frame) after reviewing the thermal imaging pictures.

We ran into various obstacles while trying to compute each building's efficiency. The cross sectional drawings that we found and had to work with were less than helpful in providing us with proper dimensions of a typical wall, dimensions of materials used in the walls, and in naming the actual materials used.

Since the Mott building is the least efficient according to R values and thermal images pictures, we recommend that any leaks or cracks the building may have be reinforced. This would hopefully reduce the amount of heat lost in the building. Since leaks were found at windows and doors, and windows have the lowest R value, investing in double paned or more efficient windows as well as double entries would eradicate the major heat losses.

RECOMMENDATIONS

As large institutions, U of C, IIT and Loyola are all looking for ways to keep their annual energy costs down. U of C currently spends nearly 20 million dollars annually for their utilities and thus looks for big ways to improve efficiency. IIT and Loyola, as smaller universities, improve their efficiency through any way possible. Scheduled maintenance and monitoring of the system help cut costs in little areas. By reducing the wattage of light bulbs, taking buildings off the main system, and running large processes at night when electricity is cheaper, these two universities save money and lessen their energy footprint on the community. Studying area universities is useful to IIT since different methods can be analyzed that are already in use. For the IIT campus, automation would be the next big step for reducing energy costs, as would true alternative energy like solar power. Also, burying steam lines further into the ground would reduce the amount of escaping heat from steam, as evident by the lines of green grass in the middle of winter.

Geothermal

In the Energy Master Plan that IIT issued, it was mentioned that "the frat/sorority quad…has been in poor condition for many years…Removal of these buildings from the steam system is recommended rather than replacement of poor piping." (8) So if they are taken off, how are they going to get their heating and cooling? The answer is simple, renewable energy sources.

The buildings in the quad surround a large field basically. This field is perfect for installing a large geothermal site in order to heat and cool the frats. Also, the roofs of these buildings are empty. So if we wanted to stick an array of solar thermal panels to produce heating and cooling, then we could. These options would last for many years, eventually start saving the school money, and help to minimize mankind's impact on the environment by using energy that is already there.

In order to design any heating or cooling system, we must know the load requirements of what we are heating or cooling, and then be able to provide for the maximum load needed. Luckily for us, IIT keeps records of how much steam each building uses every month. From these records, we know that the quad uses 8,513,246 pounds of steam every year, which is the equivalent of using 119185 therms of energy per year. Now if we could eliminate what IIT spends burning those therms, IIT could save $129,754.52 per year.

The first option that we have is to put in a geothermal site. Geothermal works by the fact that the ground stays a constant temperature throughout the year under certain depths. For Chicago, this temperature is 51 degrees, and the depth is only 5-10 feet under the surface. If we drill holes deep into the ground, and then run a hot or cool liquid into it through hoses, the ground will act as a heater, or a heat sink. The way we get energy out of this is by using a heat pump, which just follows the basic gas laws, in that expansion of a substance cools it, and compression heats it. What is necessary is for us to run our 51 degree water coming out of the ground through our heat pump, and either expand it or compress it to get heating or cooling, run it through the building, and then either compress or expand it again to get it to its original pressure. The problem now though is that it will be colder or hotter than when it came in because it lost heat, or picked up heat from the building. Due to this, we simply run it back into the ground to reheat it, or rid it of the excess heat, and repeat the whole process.

Now we do have a few options of how we can implement it on IIT. The first is to use a classic glycol/water system. With this system, we will have to use rubber hosing, with bores that are 500' deep. Unfortunately though, a glycol/water system can only handle temperatures between 32 degrees and 90 degrees, so we will have to supplement the quad with heating/cooling from elsewhere during these days.

First, let's assume we are going to design a site to handle the maximum load it can, and pull the supplemental energy from the current steam system. With this system, the geothermal site will have to handle a maximum load of 2,174,107 Btuh. This means that our geothermal site will have to contain 80 bores. With 80 bores, this system will save $44,990 per year.

The payback on this system depends on the initial cost of the system. If we were to use a union company to dig our wells, the initial cost would be $2,272,427.45. This puts the payback of this system at 60.62 years. Luckily for us though, we are a private institution and can use a non-union company to drill our wells. If we do this, the initial cost lowers to $1,594,547.45, and the payback goes to 35.44 years.

These numbers are awfully high, so let's see if we can lower that number. One option we have is to not build as large of a field. Since we only need to supply more than 1,547,619 Btuh twice a year, we should instead design a field that supplies this. This would put the field at 57 bores. This would mean that a union drilled site would cost $1,953,641.67, while a non-union site would cost $1,146,464.67. These are lower, but the amount that this field would save is also lower, yielding only $39,203.20 a year. This puts the payback of a union site at 49.8 years, and a non-union site at 29.24 years.

Unfortunately though, neither of these completely removes the quad from the steam plant. However, we could use the best of these previous options, hybridized with a system that could handle what needs to be supplemented. This option would be solar thermal. Solar thermal works much like geothermal, except instead of running it through the ground, we run it through tubes that are constantly heated by the sun. This actually works perfect with our geothermal site since most of the days we can't use are in the winter, when we need heat.

The reason we can get heat during the winter when it is 0 degrees around the panels is because we are using evacuated vacuum tubes. This means that the area surrounding our glycol/water mixture will be a vacuum, which is the best insulation we have.

To make our solar site handle the full load required of it, it must be able to output a maximum load of 3,428,687 Btu/day. In our region, solar panels will put out 1000 Btu/ft^2/day. This means that we will have to have 3429 ft^2 of solar panels, or 132 panels. At a cost of $1025 per panel, and the cost of installation, our total cost comes out to be $342,868.67.

If we couple this with our best performing geothermal site, the total cost of this hybrid system comes out to be $1,489,333.34. However, now we are entitled to the full yearly savings of $129,754.52. This puts the payback of this system at an astonishing 11.48 years. This is a very quick return on an investment like this.
The problem with a hybrid site is the increased complexity it has. There is more room for error when the system is more complex. Let's finish this study by looking at a new idea on an old system that has already been implemented in a few different places.

This system was developed by Earth to Air Systems, and is a new take on geothermal. In this system, we replace the rubber hosing with copper pipe, and the glycol/water mixture with Freon 410-A. To quell your concerns, this type of Freon is completely eco-friendly, just in case there was a leak. Besides being eco-friendly, it is much more conductive than glycol/water. This, coupled with the much more conductive copper piping, makes this system increasingly more efficient than the classic geothermal site. This means that the Earth to Air system can be used year round, regardless of temperature.

A difference with this system though is that we only need to drill to a depth of 320'. This means that we will need 115 bores for this site. To drill these bores and install everything runs about $0.46 per Btuh. This means that our field is going to cost $1,571,436.76. But with our yearly savings of $129,754.52, our payback on this system is about 12.11 years.

Now we just have to figure out which choice to make. The obvious choices are between the Earth to Air system, and the hybridized geo/solar thermal site. Each has a payback of about 12 years, and each takes the quad completely off of the central steam plant. Yet each has their own advantages and disadvantages.

For instance, the Earth to Air System is said to last 100 years before it must be replaced, while the same can not be said for classic geo/solar thermal sites. Also, the Earth to Air system produces a much more comfortable humidity level than that of geo/solar thermal and conventional HVAC systems. It also won't harm the environment if its' lines were to rupture, as glycol would. Finally, this is a single system, and is not as complex as a hybridized site would be. Complexity only makes the chance of a problem greater.

On the other hand though, classic geothermal and solarthermal technologies have been around much longer than the Earth to Air system. This means that these are tried and true, and there are more people who know how to work with them. Also, the cost of refilling and repairing the site should it rupture is much less expensive than the Earth to Air system. Finally, the classic geothermal site would occupy much less space. It has half the number of bores, and they can be placed two times closer than the Earth to Air bores can. This makes the field four times smaller than the Earth to Air system.

Either way, both of these offer great improvements over our current system. They remove the problem of having to reinsulate all of the steam pipes under the quad, and give IIT a good public relations leg ecologically since we would be making a large portion of our current energy use renewable. The best improvement is the impact that it takes off our environment. By not burning the gas required to heat our quad, we are eliminating all of the pollution that it releases, and the damage it would cause on our upper atmosphere.

REFERENCES

Richard Bumsted	University of Chicago	University Planner
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