IPRO 337 Final Report
Spring 2008

Zero Energy Lab

Advisor: Nancy Governale-Hamill

1.0 Introduction

In today's society there is a growing need to save energy. IPRO 337: Zero Energy Lab was created in an effort to continue the research of last semester's IPRO 337: ZEL, but extending the scope beyond just that of an energy efficient Laboratory for the 4th floor of Machinery Hall on the IIT campus. The goal of this IPRO was to create a plan for the implementation of a comprehensive zero-energy solution for the same space.

2.0 Background

IPRO 337: Zero Energy Lab is an ongoing project to develop a comprehensive solution towards energy savings. The previous team concentrated on the development of a zero-energy work space for the 4th floor of Machinery Hall, and the current team is picking up where they left off. The goal of the IPRO is to create a plan for the implementation of a comprehensive zero-energy solution for the same space. Potential technologies and methodologies involved in this project included, but were not limited to, the use of photovoltaic arrays for power generation, solar-thermal heating, battery systems for energy storage, passive cooling and heating systems, and various devices native to the laboratory environment. As a team, we felt that a proper and successful implementation of these existing technologies could serve as a sort of precedent for future buildings and create a new standard for architectural engineering.

By the end of the semester, the team hoped to have a complete and comprehensive plan for the creation of the zero-energy lab. Ideally, a construction team would be able to fully install, calibrate, and prepare for use any and all recommendations for the creation of the zero-energy lab. Through research and development, the team would provide a set of documents that would enable the university to build the zero-energy lab. There will be costs to the school for the construction of the lab, but the lab should pay for itself in time, effectively costing the school nothing, by generating a teaching, research and demonstration space, as well as attracting funding from outside sources by utilizing our ZEL rating to determine if products that claim to be green actually are.

Energy saving is an important benefit from this project because wide uses of energy-efficient applications will reduce the dependence on fossil fuel and therefore minimize pollution and create a safer environment for future generations.

3.0 Purpose

The IPRO 337 team's objectives for this semester were to make further progress in updating the top floor of Machinery Hall into a lab for future energy savings technology research and for the space itself to be able to be as sustainable as possible. The team had hoped to have the space cleared so that the developed plan could be tested. However, due to time constraints (See Section *5: Objectives* of midterm report) and the lack of personnel to clear the space we weren't able to accomplish this objective that we originally set. What we intend to accomplish is as follows:

- A set of construction documents that will serve as the basis for the creation of an energy efficient space utilizing new technology as well as passive techniques inherent in all modern buildings.

- A system dedicated to 'quantify environmental friendliness' for the purposes of debunking existing green technologies and separating actual green tech from those only claiming to be. This process has been dubbed the "ZEL Rating."

- Further research into electrical and mechanical systems for the purpose of further minimizing the impact of the Zero Energy Lab.

- A web site to spread true Zero Energy ideas that will document our research, lab construction and a sample of our ZEL Rating for limited tests of truly green products.

4.0 Research Methodology

Since the beginning of the semester, a lot of reorganization has occurred within the IPRO team to allow it to function with better results. We divided into different sub-groups a few times over and the final team organization resulted in a power (electrical) team, Zero Energy Lab rating team and a construction documentation team. Within the teams we strived not to necessarily put all the engineers and architects together because we wanted to be able to learn from the knowledge within each other.

The Power Sub-Team

The electrical engineering team's main goal was to further develop the electrical system design from last semester by integrating an automated lighting system and adding a solar thermal system to provide additional heating and cooling. Given this task, the electrical engineering team decided to collectively generate ideas regarding both tasks to provide direction for the sub-team. Initial research was conducted to investigate exactly how each task could be completed. The sub-team then formed two groups to focus on the automated lighting system and the solar thermal system. Each group then investigated commercially available components that could be combined with the proposed electrical system from last semester for use in the Zero Energy Lab. The proposed electrical system consisted of a "solar hydrogen fuel cell system". Where a solar hydrogen fuel cell system is a power creation and storage system that uses a hydrogen fuel cell to charge the battery bank when the solar array is inactive. The required hydrogen fuel is produced from excess energy that is not used and unable to be stored in the battery bank. To maximize the amount of power available to the Zero Energy Lab, an efficient lighting system required. To achieve this the Zero Energy Lab was divided into nine lighting zones. Each zone is equipped with motion and photo sensors along with efficient fluorescent lighting. A computerized automation system will constantly monitor if a zone is occupied along with the intensity of sunlight. The corresponding fluorescent lights will then be dimmed to provide adequate lighting for that particular zone. When the zone is considered unoccupied the system will then extinguish the lights to conserve power. Additionally, the lighting fixtures used are attached to centrally located tracks for each zone and designed to be moved anywhere along the track to accommodate the needs of the occupants. To provide a comfortable climate for the occupants of the Zero Energy Lab, a solar thermal cooling system will collect thermal energy from the sun via solar collectors which will in turn provide hot water to an absorption chiller. The absorption chiller utilizes the hot water produce cool air similar to that of an air conditioner. The use of the solar thermal system is nearly independent of electrical energy and requires an almost negligible amount of power from the battery bank, proving to be an efficient cooling system.

Zero Energy Lab Rating Team

Initially, this team was given the task to find components such as electronic devices, finishes and furniture that were considered "green" and would be suitable for the Zero Energy Lab. After researching various products and attempting to determine the necessary criteria for "green components" the question arose: "What is green?" This led the sub-team to investigate any current rating systems used to rate products on their environmental impact. LEED (Leadership in Energy and Environmental Design) is a rating system in which points are awarded based on the construction, performance, design, and environmental friendliness of a building. This system is used specifically for buildings based on the components directly used for construction. Investigation as to

how to extend a rating rating system limited to buildings to virtually any product was conducted through internet research. It was then determined that the amount of energy used in the production, transportation and operation of a product would be a consistent basis for a rating system. Similar to LEED standards the ZEL rating is applied to products for to assess their impact on the environment. Unlike LEED, the ZEL rating focuses on how energy friendly components are. The amount of energy required to produce and transport the product to its destination, along with its yearly consumption of energy and the anticipated lifetime of the component are all factored into ZEL rating.

Construction Documentation Team

The purpose of the construction documentation team was to develop a detailed set of plans and components necessary to complete construction of the Zero Energy Lab. Initially, this sub-team assessed the current condition of the space proposed for the Zero Energy Lab. Using floor plans created from the previous semester the components and processes necessary to complete the proposed Zero Energy Lab were analyzed. A schedule of the necessary demolition, cleaning, and construction procedure required was then generated. An estimation of cost and time for demolition and cleaning based upon the labor and materials necessary for each process was then conducted by researching various companies. Using the floor plans the required materials for construction were then tabulated and research into the cost and anticipated time required for installation was conducted. Using these figures a construction schedule and components list was generated along with cost estimations for each procedure. Additionally, the placement of the proposed solar thermal chillers, collectors, lighting tracks and sensors was calculated and appropriate layouts generated.

In summary, our research methodology consisted of determining technical obstacles and then researching various solutions by using the internet, text books, experts, and the like.

5.0 Assignments

The following teams were broken up from the existing pool of members to best fit the needs of the goal of each desired sub-team.

Power Team

NAME: CHRIS MAYERS (TEAM LEADER, POWER TEAM)

- Year: 4th
- Major: EE
- Experience, Skills, Strengths: Electrical circuit design and implementation.

Electronics, electrical and computer engineering, Circuit modeling/ analysis
- Role and Responsibilities: Team Lead. Research efficient ways which may be used to provide heat and electricity to the building. Provide electrical consultation. Oversee system development.

NAME: KUNAL PATEL (TEAM MEMBER, POWER TEAM)
- Year: 3rd
- Major: Computer Engineer
- Experience, Skills, Strengths: Electronics. Computer Hardware. Operating Systems. Analyzing electronic power consumption and optimizing Operating System power plan.
- Role and Responsibilities: Testing of power consumption by electronics and computers. Research into using solar cells, and solar collectors linked to seasonal thermal stores, for space heating.

NAME: SUNI SMITH (TEAM MEMBER, POWER TEAM)
- Year: 4th
- Major: EE
- Experience, Skills, Strengths: FDTD Simulations, High performance computing, Complex networks. Java, C/C++, Pascal Matlab, FORTRAN. I have a vision about how the best website should look.
- Role and Responsibilities: Research desiccant systems, passive heating and cooling strategies for the Zero Energy Lab.

NAME: DANIEL MATHUS (TEAM MEMBER, POWER TEAM)
- Year: 3rd
- Major: Electrical & Computer Engineering
- Experience, Skills, Strengths: Zero Energy Lab team member Fall '07, CS and Electrical, Human Computer Interaction (HCI)
- Role and Responsibilities: Electrical consultant. Make circuit simulation and drawings.

ZEL Rating Team

NAME: SANDEEP SADASIVUNI (SUB TEAM LEADER, ZEL RATING TEAM)
- Year: 4th
- Major: Computer Engineering
- Experience, Skills, Strengths: Teaching Assistant for IIT's Computer Science Dept. (Aug 05-Present). Excellent communication skills, team player.
- Role and Responsibilities: Work on the new rating scale framework. Assign duties to each of the sub team members. Document the ZEL Rating ideas and make a ZEL manual. Provide examples to show how the ZEL Rating works.

NAME: LOREN BO (TEAM MEMBER, ZEL RATING TEAM)

- Year: 4th
- Major: Architecture
- Experience, Skills, Strengths: AutoCAD, Sketch-Up, Illustrator, Photoshop, Model Making
- Role and Responsibilities: Research into the main components that would make up the ZEL Rating. Come up with a formula for our rating based on the research.

NAME: KAYE PALOMO (TEAM MEMBER, ZEL RATING TEAM)

- Year: 3rd
- Major: Architectural Engineer
- Experience, Skills, Strengths: AutoCAD and MathCAD. Good with areas dealing with building systems.
- Role and Responsibilities: LEED Rating case study / compare LEED to our rating scale.

NAME: JONATHAN SIBLEY (TEAM MEMBER, ZEL RATING TEAM)

- Year: 4th
- Major: EE
- Experience, Skills, Strengths: Formula Hybrid racing, Power Electronics. Researching, coding, project management
- Role and Responsibilities: Research zero energy buildings and break down the list of building materials. Compare components made in China to the ones made in USA.

NAME: MAX IRISHFRAZIN (TEAM MEMBER, ZEL RATING TEAM)

- Year: 3rd
- Major: EE
- Experience, Skills, Strengths: Technology hunting, Electrical & Computer Engineering
- Role and Responsibilities: Work on the formula for the ZEL rating. Contact product manufacturers and talk to them about the different stages a product goes through before getting to the market.

IPRO Zero Energy Lab

Construction Documents Team

NAME: ANTHONY WACHNIAK (SUB TEAM LEADER, CONSTRUCTION DOCUMENTS TEAM)

- Year: 5th
- Major: Architecture
- Experience, Skills, Strengths: Architectural Computing & Programming, and Design Build.
- Role and Responsibilities: Prototype design-build specialist. Program the space and research the needs of similar spaces.

NAME: BRIAN ROJAS (TEAM MEMBER, CONSTRUCTION DOCUMENTS TEAM)

- Year: 2nd Year
- Major: Aerospace Engineering
- Experience, Skills, Strengths: Illinois Tech. Robotics. Analyzing data, calculating numerical data, finding information, proposing ideas, listening to others, thinking in a logical manner
- Role and Responsibilities: Program space, problem solve, find/design furniture for the studios, aid in the design of the space. Determine flooring, wall paint, and anything dealing with the renovation of the top floor of Machinery Hall. Look into pricing of building materials.

NAME: JENNIFER GAMBRELL (TEAM MEMBER, CONSTRUCTION DOCUMENTS TEAM)

- Year: Fourth year
- Major: Architecture
- Experience, Skills, Strengths: Model shop worker, Tutoring, CAD drafter, hand drafting, 3D modeling, Photoshop/Illustrator.
- Role and Responsibilities: Research new technologies; provide 3D CAD drawings of design space. Determine flooring, wall paint, furnishings of the space, and anything dealing with the renovation of the top floor of Machinery Hall. Look into pricing of building materials.

Web Team

NAME: DANIEL SIROTZKE (SUB TEAM LEADER, WEB TEAM)

- Year: 2nd Year
- Major: Computer Science
- Experience, Skills, Strengths: Previously created simple webpage's - for a Lit. class and now upkeep the site for Illinois Tech Robotics. HTML, CSS, JavaScript
- Role and Responsibilities: Create/Design Website & Website Framework. Basically make it simpler for others to upkeep in future semesters.

NAME: KYLE STACHOWIAK (TEAM MEMBER, WEB TEAM)

- Year: 2nd
- Major: Computer Science
- Experience, Skills, Strengths: programming, photoshop, webpage layout design, Illinois Tech. Robotics.
- Role and Responsibilities: General Website mapping, final content control, layout and appearance.

As far as IPRO deliverables go, the following team members were responsible for accomplishing them and turning them into the IPRO office on time:

A. Assign Meeting Roles

   a. Minute Taker: Anthony Wachniak
   b. Agenda Maker: Chris Mayers
   c. Time Keeper: Max Irishfrazin & Jennifer Gambrell

B. Assign Status Roles

   a. Weekly Timesheet Collector/Summarizer: None. As a group, we decided that we each will do out part to keep the project moving smoothly and we don't need timesheets to keep track of our work. We will keep track within our own sub teams and then update each other so that everyone is moving in the same direction and towards the same goal.
   b. Master Schedule Maker: Kunal Patel
   c. iGroups: Sandeep Sadasivuni & Jonathan Sibley
   d. Project manager: Chris Mayers
   e. Deliverables manager: Kunal Patel

6.0 Obstacles

As far as obstacles involving the entire IPRO as one team, the only obstacle we have really encountered is timeliness cleaning out the space in Machinery Hall. We did however overcome this obstacle and our advisor's company was able to donate time to clean out the space. It is clean enough that there is now an office located there which also allows the space to be supervised more often to allow more and more progress to occur. The space is now ready for future semesters to use the packet of information we have created to actually accomplish the main goal of the IPRO and finalize construction. Initially we were divided into four teams, Office Team, Finishes Team, Power Team, Web Team. The separate sub groups within the IPRO also dealt with their own individual

obstacles. During the beginning of the semester everyone had a hard time comprehending what was expected of them as most of the people were taking IPRO for the first time. It took a little more time to get a good understanding of what is to be done in the IPRO as things seemed more vague. In the future it is recommended that the tasks for small teams be more focused so that the research in the area can be more complete.

The Office Team had a hard time getting their testing environments set up as the other teams were still in their planning stages. Also, it was not practical to test all the equipment the office team had hoped for as it would prove to be expensive and very hard to get a hold of all the equipment. After scaling back the test list and the procedure was set up the team was able to finish their task. The Finishes Team had obstacles of preparing and testing products as most of the stuff was at a planning stage and since the actual work was to be done by contractors. Getting a hold of the right contractor was a bit tough. The Power Team had difficult time agreeing on a particular solar thermal system configuration and lighting system. After thorough research and discussion, appropriate systems for the Zero Energy Lab were decided upon. The website team initially had difficulty accessing the old website and the associated information. This was resolved by creating a new domain on the IIT server.

After the midterm we decided to split into new sub groups, it was decided that we needed groups to be more focused on specific tasks rather than a broad picture. This time around we divided into four sub-teams. The power team continued to focus on the development and application of the solar thermal system automated lighting systems for the lab. The Website team completed the initial site layout and began the development of a user-friendly update interface. The construction documents team dealt with creating the actual documents necessary for construction and reports. The ZEL Rating Team worked on creating a uniform rating system to rate the environmental friendliness of various components/products. Their goal was to create a rating system to more effectively measure how a particular product benefits both the environment and user compared to the LEED rating system.

The power team had a difficult time estimating exactly out how much power would be produced by the system as the weather in Chicago changes drastically from season to season and if there wasn't sufficient power stored in the system the lab would be rendered without power. Based on lighting specification, diagrams and sun light estimates, the power team was able to determine a more realistic nominal and peak load, required to determine the actual components to be employed by the system. This was taken care of by calculating how much sun light actually shines on the building on average during a given season, adjustments were made to the power profile accordingly. The web site team had minor issues in getting the website to run on all platforms but that was taken care of. Additionally, the IPRO presentations and deliverables also take up a significant amount of time which in turn lead to less time to work on the actual project.

7.0 Results

Since our IPRO wasn't necessarily able to carry out our accomplishments, our research is our results. Our research will be very useful for semesters to come when the actual execution of the goal will be taking place. The result of the power team's semesters-worth of research and development is shown in the prototype and circuit simulation model of the energy creation, storage, and distribution system. The basic system would consist of solar thermal panels on the roof and a circulating water system with a storage tank. A water pump would circulate the water heated by the solar thermal panels throughout the space and to the absorption chiller. For the desiccant dehumidification system, a basic concept of using a fan to blow air through desiccant screen was established. The hope is this concept can be developed as part of the floor layout and be connected to the environmental control system. The high thermal mass of Machinery Hall helps to keep the Zero Energy Lab warm during the winter and cool during the summer. The bricks and concrete of the structure cool overnight and then keep the space cool on hot days. This effect does not completely cool the space to comfortable temperatures nor does it dehumidify the air. A unique solution is to pair solar thermal heating and cooling with a passive heating and cooling system. The passive heating and cooling solution was developed last semester and consists of using a field bus system to continuously monitor air flow and temperatures within the lab. The field bus system implements computer automation to automatically open and close specific windows during the day and night to regulate the temperature. This also allows for the effective use of night ventilation techniques during the spring through fall. Night ventilation works by sealing the building during the day and allowing its thermal mass to absorb access heat from the air which keeps the internal building air temperature around the same as the thermal mass. Since the thermal mass, brick and concrete, has a much higher density and similar specific heat when compared to air, it requires much more energy to increase its temperature thus keeping the space cooler. At night when the outside air temperature is cooler, the building is ventilated to flush out the heat accumulated during the day. The heat absorbed by the thermal mass during the day is then removed by convection allowing the process to be repeated the next day. Solar thermal air conditioning is produced through the coupling of two main components: the absorption chiller and the evacuated tube solar thermal panel.

Absorption chilling is not a new technology. Absorption chiller air conditioners have been commercially used in the U.S. since the early 20th century. Absorption chillers were originally designed to utilize waste heat from an industrial process to drive the chilling process for tonnages typically > 50 tons. Until recently, this technology has been overlooked for application in smaller institutions. Due to the current environmental incentives, absorption chilling investment and technology has increased, thus providing absorption chillers designed for smaller tonnages (i.e. < 10 tons). In addition, current chillers are simple machines that use no harmful Chlorofluorocarbons (CFCs). Many

absorptions chillers, currently produced for small tonnage applications, are designed to use hot water as the catalyst for the chilling process (thus called “water-fired”). This hot water can be provided by evacuated tube solar thermal panels. Evacuated tubes are ideal for collecting solar energy and converting it to heat energy. Vacuums are excellent insulators, and thus they allow the solar collectors to maintain their heat. This heat is absorbed by water pumped around the collectors. Yazaki Energy Systems, Inc., among other companies, makes a water-fired absorption chiller suitable for cooling a 10 ton space. The SC-10 absorption chiller requires 210 Watts of electrical energy which can be aptly supplied by the photovoltaic array during the summer months. Apricus AP-30 evacuated tube solar thermal panels supply a nominal water temperature of 192°F making them a nice fit for the SC-10 which requires a nominal inlet temperature of 190.2°F. The combination of the solar thermal collectors, absorption chiller, and photovoltaic array provide an effective and environmentally friendly climate control system.

The current photovoltaic array and battery bank will not supply / store enough electrical energy to power the Zero Energy Lab during extended periods of little sunlight (i.e. winter). We found this out by doing calculations to find the average amount of sunlight that shines on the panels during the whole year. Those calculations clearly showed that we don’t have enough power to run the lab during winter. To make up for these shortcomings, we decided to incorporate a fuel cell instead of just solar panels (and various associated components) and a larger battery bank into the system. The addition of a fuel cell provides a longer term energy storage solution than batteries. For example, when there has been little sunlight for days or the occupants require extended hours from the Zero Energy Lab and the battery bank would become depleted, so the heavy duty would rely on it’s own solar panels rather than the solar panels that are already installed and are used to power all the office equipment and lighting etc. All of the energy consumed by the Zero Energy Lab will be produced from sunlight and water. To provide adequate lighting throughout the day a versatile daylight harvesting system utilizing a network of motion and photosensors to determine how much light to supply to a particular area. Lighting Control and Design's daylight harvesting system will be used to monitor and control lighting and power supplied to the different zones of the Zero Energy Lab. Sensors will constantly monitor daylight input from the windows and properly dim the lights in a particular zone to achieve a desired luminance. This system can be accessed by computer so timers and various settings and easily be changed when necessary. Additionally, the lights illuminating the lab are mounted on individual track systems which allow for easy movement of fixtures in the future.

Overall, the main goal of the secondary research was to provide a foundation for future IPRO teams to work off of. The development of the ZEL Rating system will provide a basis for future teams to develop a marketable business plan. The ZEL Rating is superior to the common LEED rating in that it is more practical and can be applied to virtually any product. It is the intention that a specific product can only be granted a ZEL Rating after it has been tested by the testing procedures necessary to determine its environmental

impact. The ZEL rating is a very solid foundation that future teams can work with and will lead to allow customers to examine the environmental impact of a particular product, not just knowing that the materials were/ can be recycled.

Our website is a tool to display our research and findings. Much like Google's Gmail web page, ours updates the information on the instantaneous using Ajax. Javascript and CSS are used in such a way that all the visual style is separate from the content. This provides a user-friendly method to update content and data displayed on the website. The results of the architectural/construction documents team are shown in the final design of the space. It wasn't necessarily calculations and research findings that lead to our results, rather is was painstaking efforts over and over again drawing the space, each time making it a little more functional according to the beliefs of the architects and the knowledge of what the space will be used for. We resulted in having a detailed program of the space that shows all the equipment needed in each space.

For future semesters, the design might change a bit if new technologies are discovered and used in the space. The layout might have to change to accommodate the function of these new ideas. No specific guidelines can be projected for the design, but this design created will be a very functional solution if the technologies used in this scheme are carried out to the final stage.

8.0 Recommendations

As a whole, recommendations to semesters to come would be to have weekly agendas which clearly layout the things to be done for a week. Work on short term goals on a weekly basis. It is recommended that at the start of each IPRO session, sub-team leaders make a one minute presentation explaining to the rest of the team what his/her sub team accomplished in the past 1 week. This would encourage team members to actively participate in the progress of the project. Also, since the IPRO deliverables require a lot of time and effort, it took a lot of energy away from actually making progress on our specific goal. It might be better to break up the deliverables to the bare necessities so it is easy for many multiple people to hammer them out in a quicker time period. To schedule short, concise meeting times for the areas of the deliverables wouldn't waste valuable class time that is supposed to be there to help the progress of the IPRO goal and not necessarily the deliverables.

The Power team recommends that the next IPRO familiarize themselves with the electrical energy creation, storage, and distribution system developed in this IPRO. Furthermore, we recommend that in conjunction with implementing the actual system in the Zero Energy Lab, the next IPRO should (with reference to electrical engineering) investigate and develop the previously hydrogen production system, incorporating the

newly discovered photocatalytic device and solar-thermal technology. Additionally, to complete the system window operation devices need to be designed and constructed for the lower and upper windows sections. It is also recommended the next IPRO puts greater emphasis on investigating additional passive heating and cooling methods such as an integrated desiccant systems.

The ZEL Rating team recommends talking to companies and getting building product information, to come up with more examples which illustrate the power of the ZEL Rating system. In the future, the ZEL rating team's ultimate goal should be able to compare a building of a certain size which uses only the best ZEL Rated products to a building which uses products of builder's choice. To keep it simple, we might pick out a few products (say around 5-8) from the 16 divisions in the CSI standards for building materials and give buildings a ZEL_Rating.

Best_ZEL_Building Vs Customized_Zel_Building

Basically we want to compare two buildings. One building made of products with the best ZEL ratings, and the other made with products of the owners choice. For example, the owner might want terrazzo flooring while terrazzo flooring might not have the best ZEL Rating. Cork flooring with the best ZEL rating goes into *Best_ZEL_Building* while terrazzo flooring goes into *Customized_Zel_Building.*

The Construction Documents team recommends the usage of sophisticated 3D computer simulation tools to take into account a wide range of design variables such as building orientation relative to the daily and seasonal position of the sun, window and door type and placement, insulation type and values of the building elements, as well as local climate, right from the beginning of the semester. These simulations would help rest of the group predict how the building will perform before making any renovations. As with everything in architecture, there is never really a final answer, but a temporary or simply used solution. Therefore we also challenge that their might be a better design out there that hasn't yet been discovered.

The Web Team recommends the implementation of the ZEL Rating in the zero energy lab website so that when users select a product from a drop down menu, they have the ZEL rating outputted to them. It would be nice to output similar products with a better ZEL Rating. Maintaining a database of products would help the future teams do this. Keep working on the look/feel of the site, the functionality and usability, and updating the provided product and technical information. Work on making the current website ecommerce.

9.0 References

Lighting Control

LC&D Company

http://www.lightingcontrols.com/index.asp

Company: H.E. Williams
http://www.hew.com/catalog.asp?company=williams&tab=Suspended%20XT%20System

Solar Panels

http://www.gepower.com/prod_serv/products/solar/en/index.htm
http://www.dyesol.com
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http://www.soliant-energy.com/

New hydrogen production device

http://news-info.wustl.edu/news/page/normal/9355.html
http://www.solardev.com/SEIA-makingelec.php

ZEL Rating

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http://www.greenway-battery.com/

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http://www.greensourcemag.com

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http://www.greensourcemag.com (Accessed October 30, 2007).
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http://www.aia.org/aiarchitect/thisweek07/0330/0330d_oreg.cfm

U.S. Green Building Council "Alberici Corporate Headquarters"
http://leedcasestudies.usgbc.org/process.cfm?ProjectID=662

Pricing for Building Materials

Polishing the floor - J&K Cleaning Co. (773) 769-6330

2707 W Peterson Ave, Chicago, IL

Bathrooms - Fixall Bathroom Remodeling (773) 445-6882

3008 W 109th St, Chicago, IL

10.0 Acknowledgments

See Power Point Presentation.